

JILL LIVETT JACINTA O'LEARY MARK TORY

# TECH *by* DESIGN

FOR THE  
VICTORIAN  
CURRICULUM





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JILL LIVETT JACINTA O'LEARY MARK TORY



**Tech by Design Student Book**

1st Edition

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*Recycle*  
**A PAIR OF  
 JEANS**  
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istock.com/diacosims

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**Design challenges**  
Provide a consistent framework for creating design solutions that integrate the required technologies and society content and address achievement standards

## DESIGN CHALLENGES

All the challenges that follow are project ideas – each challenge leads you through the design process and will help you to design, make, and evaluate products that effectively store and hold. The tasks within each challenge will help you to develop some great ideas and make creative and useful solutions.



Some general products that store or hold

## STORE-IT

### Design situation or problem

You probably have many things that clutter your bedroom or other parts of your house – things that need to be organised. Or, you may be very organised but want to put some special things on display. Each situation needs an individual solution.

### Focus for assessment

- When checking whether you've designed and made a great product, your teacher will assess how well you have addressed the following questions.
- Have you identified the needs of the person you are making the product for?
  - Is your research clear and detailed?
  - Are your design drawings accurate and creative, and do they have all the required information (measurements, joints, list drawing, etc)?
  - Is your cutting, shaping and assembly accurate?
  - Is your decorative design interesting and creative (in both the use of colour and shape)?
  - Have you tested and evaluated/assessed to a smooth finish?
  - Have you tested safely in a planned and productive way?
  - Is your evaluation clear, detailed and honest?

Think about your needs and the needs of others around you. Decide whether to design and make your storage product for yourself or for someone else.

### STORE-IT DESIGN CHALLENGE

You are to design and produce a shelf or container that holds items such as DVDs, game discs, jewellery, trophies, collections and phones/chargers.

### REQUIREMENTS (LIMITS OR CONSTRAINTS)

- Your product should be no larger than the size set by your teacher.
- Choose from the joining methods specified by your teacher.
- Use the materials available in your school (or provide special materials from home).
- If you are designing and making a shelf, **no simple box shapes are allowed**.
- Your design must have some **form of decoration**, such as shaping, painting or metal crumpling.
- Use at least two different materials (such as wood, metal, plastic and/or fabric).
- Any division between items should not be too complex – don't create separate slots or lots of divisions.

### DESIGN CHOICES

- You will need to make decisions regarding:
  - the shape of your storage solution (within the size limits)
  - materials you will use
  - jobs you will use to construct your design (within the teacher's set requirements)
  - decorative design.

### Investigating

#### USK 1 Mind map

- Think about all the aspects that might be related to your design task.
  - Start a mind map by writing the heading 'Store-it solution' in a box in the centre of the page.
  - Think of 5–6 categories that you will need to make decisions about. Categories could include **materials, shape and colour, position, things to hold, types of decoration and themes.**

- On the mind map, list things that relate to each category and that are also relevant to designing and planning your storage solution.
- Highlight the ideas you think will work best.



Template of a mind map

Your mind map needs to be clear, use colour effectively, and include at least 4–5 ideas for each category. Use a full page.

### USK 2 Thinking about your design: web diagram

- Complete a web diagram (see page 8) for your storage solution. Each section of the spider's web should cover one of the areas below. This will help you to make decisions about what your storage solution will be for and how it might work.
- Who – who will the product be for?
  - What – what will it contain?
  - Where – where is it going to go?
  - How – how does it need to go?
  - When – when will it be used and how often?
  - Wow – what styling, themes do you like and what will give it impact?

### DESIGN BRIEF

Use the information in your web to write your design brief – a paragraph explaining your individual design situation. Start with the following words: 'I need to design and make a storage solution that ...'.

### USK 3 Criteria for success

We all have an idea of what a good product is like. Criteria for success define our expectations or standards in areas such as function (how the product

works), construction (how well it has been made) and appearance (how good it looks). Your criteria need to be specific, and relate to your situation.

- Write a set of four criteria questions that you can use to judge whether your finished product meets your expectations. Make sure your questions cover the areas of function, construction and appearance.
- Remember to think about these criteria when you are developing and choosing your designs.

### Design research

Ask your teacher which of these tasks you need to complete.

#### TASK 1A Design analysis

Find four images of existing storage designs that are relevant and that you like. For each storage design, write a comment or analysis (2–3 sentences) that discusses:

- what the product is for
  - its visual design (colour, shape and line) and style
  - the use of materials
  - how it works.
- This research could be done in a group and your design analysis could be presented to your class.

#### TASK 2 Situation research

Answer the following questions to think about what your storage solution will need.

- Explain where will the holder go. In which room will it be on the floor, the wall, a bench, a desk or a shelf? Draw a map of the room and mark the likely position of the storage solution.
- What colours and shapes would suit the chosen position/room?
- Describe the style of things you like, or the themes/areas (for example, cartoons, sport or music) you are interested in that could be reflected in your design.
- Draw small diagrams of the items you want to store in your storage solution. Next to each item, write how many items will need to be stored or displayed. Measure the items and write the measurements on the diagrams. You will refer to this later, so it's important to be accurate.

**Matrix of materials**  
A simple and easy-to-understand guide to suitable materials for each design challenge

DESIGN CHALLENGES		Wood	Metal	Plastic	Fabric	Systems	Moulding & prototyping
5 Design to hold and store	Store-it, page 140						
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9 Human-centred design	Clean water solution, page 191						
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10 Sustainable solutions	Recycle a pot/kit, page 205						
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11 Travelling to the future	Mow-it, page 228						
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## NelsonNet

Complimentary access to NelsonNet is available to teachers who use the accompanying student book as a core resource in their classroom. Contact your education consultant for access codes and conditions.



## NelsonNet resources

Resources available to teachers include teacher plans, assessment rubrics, syllabus maps, chapter PDFs and weblinks.

## Weblinks

Students and teachers can link directly to external websites referred to in *Tech by Design* via the free, unprotected weblinks site.

# ABOUT THE AUTHORS

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# GLOSSARY

**acrylic cement** a self curing polymer that doesn't need heat to set

**acrylic** material made from synthetic resins

**alloy** a metal made by combining two or more elements to make it stronger

**alternating current** electric current that reverses direction at regular intervals, used in power supplies

**analysing** looking at positives and negatives from many aspects

**annealed** heating to reform the metal's structure, to soften it

**annotations** comments made on drawings (or text) to aid clarity

**battery** stores electric energy to power something (such as a car)

**bevel gears** gears with axes where the shafts intersect and the gears are conical. Generally mounted on an angle.

**blockboard** building material made by sandwiching a core of wooded strips between layers of plywood

**brainstorming** putting forward ideas

**built environment** structures made by humans e.g. buildings and roads

**cam** rotating or sliding part in a machine

**capacitor** passive electronic component that stores energy

**carbonisation** the conversion of an organic substance into carbon

**carborundum** sandpaper with grid made from silicon carbide

**caster wheel** a wheel that can swivel freely to roll in any direction; like the wheels on a shopping trolley

**chain drives** a driving mechanism that transmits power from one place to another via an endless chain

**chassis** the solid base of a car

**circuit** complete path of an electric current

**complementary** adds to, completes or makes up the whole

**components** the part of a whole; part of a machine or electrical system

**compound gear** the number of gears fixed together

**compression** a squashing force

**conductor** a material through which electric current can pass

**constraints** limits or boundaries to work within

**consumers** people who buy products

**convergent thinking** thoughts that converge, which means come together or join to become one thing

**crank** an arm attached to an axle

**criteria for success** standards expected of the finished product

**current** the flow of electrons in a circuit

**design** noun – a work that has had creative input; verb – to create and combine interesting ideas into a product

**design elements** the building blocks of design – point, line, shape, form, texture, tone.

**design principles** ways to arrange design elements, such as balance, contrast, allot proportions, use of space, symmetry/asymmetry, etc.

**design process** a set of steps to follow to arrive at a designed solution for a need, opportunity or problem

**design thinking** takes full account of the user's need, researches and puts forward many possible solutions and uses feedback to select and complete the best one

**differential steering** steering with only two driven wheels (one on either side of a robot)

**diode** only allows current to flow in one direction

**direct current** current that flows around a circuit in one direction

**divergent thinking** thoughts that diverge, which means go in different directions to create a solution to a problem or need

**DPDT switches** a switch containing two SPST switches that move together; can be used to reverse a motor

**effort** a machine's input force

**electric motor** changes the electrical energy from the batteries to movement of the shaft

**electricity** form of energy that causes the movement of tiny particles called electrons that are too small to see.

**electromagnets** magnets that work if electricity is passed through a coil, creating a magnetic field

**embossing** pressing patterns into material

**engraving** forming a design by cutting on the surface of a hard material, such as timber or acrylic

**enterprise** putting in effort to achieve something

**entrepreneurship** taking financial risk to bring something to market

**epoxy resin** type of glue used with acrylic to glue it to other materials

**ergonomics** the science of creating products to suit humans and reduce fatigue, strain, injury

**evaluation criteria** standards used to judge a finished product

**extraction** a process where usable metal is removed from ore

**fabrics** thread or yarn woven, knitted or bonded together

**feasible** possible, doable, worthwhile

**felted or bonded** heat, agitation or bonding chemicals are applied to fibres to create a matted material

**fibres** hair-like threads that can be spun together to make thread or yarn

**fixed magnets** magnet that stays magnetic after being removed from an external magnetic field

**flat drawings** an outline or silhouette of a textile product, considered a working drawing that gives information for construction

**force advantage** when a machine makes it easier to move a heavy object, but at a slower speed

**forces** the push or pull on an object

**fossil fuels** fuel such as oil, coal or gas, formed by the remains of living organisms over millions of years

**fulcrum** a pivot point for a lever to rotate around

**function** how something works

**gearbox** a set of gears meshed to change the speed and torque of the motor shaft

**gears** wheels with teeth that interlock or slot into others to create motion

**generating** starting, creating, bring into being

**grain direction** the direction of grain in fabric (selvedge edge) or timber (mostly length), which can usually be seen

**graphic organiser** a diagram or placement of text visually to aid communication and sort out ideas

**grit count/grade** classification of sandpaper according to how many pieces of grit there are in each square inch

**hardwood** trees with nuts, broad fleshy leaves and flowers; can be evergreen or deciduous

**harmonious** blends nicely and gives a feeling of peace and harmony

**hazards** actions, things, situations or behaviour that could be dangerous

**human-centred design** focuses more on the people and what they need rather than adapting an existing product

**humanitarian design** design for people in dire need who don't have access to necessary resources

**idler gear** gear placed between the input and output gears to make them turn in the same direction

**inclined plane** a sloping ramp that makes it easier to raise an object

**input-process-output diagrams** method of showing the important features of a product

**inspire** give rise to other ideas

**insulator** stops or hinders the flow of electricity.

**jeopardise** to put in danger

**juxtaposition** placed beside another thing as contrast or to blend

**knitted** threads or yarns create interlocking loops

**lamine bending** joining very thin strips of timber together in a curved form with jigs

**laminating** joining strips of differently coloured material together

**lamp** device for giving off light

**laser engraving and cutting** cutting a design into the surface of timber with a laser cutter/engraver

**lateral thinking** thinking sideways or beyond the normal or immediate response to create new and different ideas

**lever** a rigid bar that rotates around a fulcrum

**lifting pulley** a set of wheels and a rope that makes it easier to lift a load

**light-emitting diodes (LEDs)** semiconductor diode which glows when voltage is applied; energy efficient

**linear motion** an object moving in a straight line

**load** the machine's output force

**longwall mining** mining process where the side of a tunnel is mechanically excavated and, as the tunnel moves sideways, the roof of the original tunnel space is collapsed and closed.

**manipulating** changing by handling, bending, flattening, melting, etc.

**manufactured boards** made from logs which are chipped or finely crushed, mixed with glue and pressed into boards

**manufactured fibres** synthetic or regenerated fibres

**marketing** the actions needed to bring a product to market

**marquetry** embedding a design in the surface of timber with differently coloured veneers

**materials** what something is made of  
**mechanical advantage** how machines trade force for speed, or speed for force

**medium-density fibreboard (MDF)** made from very fine wood fibres and glue. Large sheets or boards are made using pressure and heat.

**microcontrollers** a small computer chip that can be programmed to monitor inputs and control outputs

**mode of transport** ways to move around over land, sea and air

**moral right** the right of a creator of a 'work' to be made clear to any viewer of the 'work'

**motors** a machine powered by electricity; involve magnets

**multimeter** contains many meters in one package

**natural fibres** fibres that are grown or come from plants or animals

**need** something considered of importance; a feeling that one lacks something

**on-off-on switch** is 'on' when the toggle is pushed to one side position, is 'off' with the toggle in the middle position, and is 'on' again when the toggle is pushed to the other side position

**open-cut mining** mining process where all surface material is blasted and removed, leaving an open hole that can be kilometres wide

**opportunity** a favourable or timely chance or possibility

**ore** rocks containing metal

**orthogonal drawings** 2D technical drawings showing several views that are aligned

**oscillating motion** backward and forward motion in an arc

**parallel circuits** circuits where the current from the battery splits into more than one pathway

**particle board** made from large chips and particles of timber pulp mixed with glue, and pressed to form a large flat sheet.

**partnership** working with others

**planks** long thin pieces of timber

**plywood** manufactured timber product made by gluing layers of veneer placed so that the grain of each layer runs at right angles to the layers above and below.

**polarity** direction of magnetic forces

**polypropylene** type of plastic

**polystyrene** a synthetic resin; can be solid or foamed

**PPE** personal protective equipment

**process** a set of steps as in the design process or affecting a change on a material during production

**producing** making something

**product** a good or service created as a result of processes and serving a need

**production line** a group of machines laid out one after the other to construct a part in a factory

**production** the making, construction or manufacturing of a product

**proximity** close to

**purpose** the reason for doing something or for which something exists

**pushrod** a rod operated by cams that opens and closes valves

**pyrography** burning a design into the surface of the timber

**quality** the nature of something or a standard of workmanship

**rack and pinion gear** device for converting rotary motion into linear motion

**ratio** something in relation to another thing, expressed in numbers

**reciprocal motion** backward and forward motion in a straight line

**reclaim** another term for re-use, usually referring to timber

**recyclable** material (or product) that can be recycled

**recycle** can mean the same as re-use but often implies that a process or system has been involved

**recycled** a material that has gone through a process or system making it suitable for use in a new product

**reduce** to use materials carefully and to cut back when possible

**refraction** a bending force

**regenerated fibres** fibre created by dissolving cellulose area of plant fibre in chemicals and making it into fibre again

**rendered** tone applied to a drawing; but has many other meanings

**repair** to take action on existing products to make them last longer

**requirements** things needed

**researching** looking, observing, reading, etc. for information and ideas

**resistance** the force that opposes current in a circuit

**resistor** a component that limits current in a circuit

**resources** supplies or sources

**rethink** to consider if a product can have less of a negative impact

**re-use** to use the materials or the product for another new or different use

**risk assessment** assessing risks that lie ahead

**risk management** managing risks with a set of procedures

**risk** the chance of something negative happening

**robot** a machine that can do complicated tasks automatically

**rotary force** a force that causes rotation

**rotary motion** an object moving in a circle or part of a circle

**Safety Data Sheet (SDS)** provides information needed to deal with hazards of a product or substance.

**sanding direction** the ideal direction in which to sand wood

**sanding order** the order in which you use sandpaper

**sense** detect the environment; detect properties such as heat, sound and light

**series circuits** a circuit where components are arranged one after the other

**service** providing assistance for another person; a system to supply needs to the public

**sewing machines** machine with a mechanically driven needle for sewing cloth

**shear** two forces pushing inwards but past each other

**simulate** pretend or provide a virtual or substitute conditions /situation to 'test' or try something

**softwood** evergreen trees with needles or cones, such as pine or cedar trees

**solder** a metal with a low melting point

**specialist paper** paper with grit made from silicon carbide

**speed advantage** when a machine makes the load go faster, but with a weaker force

**SPST switches** a simple on-off switch that can be used to turn a motor on or off

**standard sizes** sizes of materials that do not need to be cut to size

**strategic** important, well thought out

**switch** connects or disconnects a circuit

**synthetic fibres** fibres such as polyester, nylon and acrylic

**system** a product designed to perform a task

**tactile** the sensation of touch, or the look of how it would feel.

**technology** comes from the Greek *tekhнологia* meaning art or craft combined with language

**tension** a stretching force

**thermoplastic** plastics that will soften and can be easily shaped and moulded

**thermoset** a chemical reaction for forming plastics

**thinking critically** thinking about situations and their existing solutions

**tools** device to help you complete a task

**torque** a rotary force; a force that causes rotation

**torsion** a twisting force

**transistors** the building block of electronics; used as an electronic switch

**underground mining** an access tunnel is excavated into the side of a mountain or a deep shaft is dug into the ground, and then tunnels are cut to follow the ore body.

**upcycle** use material for another product in a way that doesn't degrade the material

**upcycling** reusing material from an existing product to create something new

**variables** a factor that is likely to change; data item that may take on more than one value during a program

**veneer** timber rolled and sliced into thin layers; used for plywood layers

**viable** capable of working successfully

**void loop** continuously loops, allowing the robot to check inputs and respond

**void set-up** only runs once in Arduino; tells the Arduino which pins will be inputs and outputs

**voltage** the force that pushes electrons around a circuit

**worm gear** gear with many teeth

**worm** a special gear with only one spiral tooth

**woven** threads are interwoven with alternating under/over pattern

# DESIGN CHALLENGES

CHAPTER	CHALLENGE	Wood	Metal	Plastic	Fabric	Systems	Modelling & prototyping
5 Design to hold and store	Store-it, page 140	■	■	■	■		
	Carry-it, page 144				■		
	Show-it, page 148	■	■	■			
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SECTION ONE

# GETTING STARTED

- 1 Design basics
- 2 Materials
- 3 Tools and processes
- 4 Engineering basics





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# 1

## DESIGN BASICS

### KEY KNOWLEDGE

In this chapter, students will gain knowledge and understanding of:

- ▶ the design process
- ▶ investigating
  - ▶ defining the need
  - ▶ the design brief
  - ▶ criteria for success
- ▶ generating
- ▶ producing
- ▶ evaluating
- ▶ planning and managing
- ▶ sustainability
- ▶ design elements and principles
- ▶ design styles.

# WHAT IS DESIGN?

**Design** can be considered as both a noun and a verb. As a noun, design defines a sphere of study (for example, 'she works in design') or the physical thing we see (for example, 'this piece of design here'). As a verb, design defines the act of creating a design. However, design is not the same as art. Design requires a function – it has a result to achieve, whereas art can follow an imaginative thread to express something. Designers use their imagination but must apply it in a logical manner to suit a purpose. This includes not only thinking about how beautiful something is, but also the function, the quality, the cost and its sustainability (see more on page xx).

Design plays an important part in our daily lives and is all around us. All constructed or created objects, places and systems involve aspects of design – the seat you are sitting on, the earphones you use to listen to music with, the clothes you wear, the transport you move around in, the network of storage, pipes and taps that bring water into your house, and the implements you eat with. Someone has spent effort, time and money in designing, creating and producing all of these things.

What do you think of when you hear the word 'design'? There are lots of ideas that may come to mind, but most of them boil down to this concept:

**Design is focused on creating solutions for people's needs, their situations and their problems.**

Design is about making our daily lives easier and our experiences more pleasing. It makes the services we rely on dependable and efficient. It determines the look, feel and function of the products we use and wear. If you have ever rearranged your room or desk, created a garden in specific arrangements, carefully selected what you will wear, or worked out how to make something work and look good, then you are actively involved in the major aspect of design – **solving problems**.



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**These people are involved in design – what do you think they are doing?**

## Design activities

Design is a broad field of work that involves lots of different types of activities, and people with a wide variety of skills. Some of these activities might include:

- **researching** – finding out about materials, places, systems and technologies, and finding out about people and how they interact with other people, objects and the world around them
- **generating** – coming up with ideas, drawing, modelling, testing, trying things out, creating and making things
- **producing** – knowing about materials and how things are made; making products/solutions

- **thinking critically** – thinking about situations and their existing solutions; questioning ideas
- **analysing** – considering the impact of existing and new ideas on our lives.

Design involves:

- thinking
- asking questions, listening to people and observing
- being creative – coming up with ideas, trialling and experimenting
- organising and making
- testing, analysing and evaluating, learning from mistakes.

## WHAT IS TECHNOLOGY?

The word **technology** comes from the Greek *tekhnologia* meaning art or craft combined with language. Early technology consisted of tools and implements for survival tasks such as eating, sleeping and keeping warm. During the era of the Roman Empire, some inventions were developed that formed the basis of modern machines and materials. These inventions made life easier and more enjoyable for most people.

Over the centuries, technology has grown increasingly more sophisticated. The Industrial Revolution during the 1700s introduced powered machinery and mass production in factories to replace old methods, making production faster and easier. Before then, people worked mostly from home and made things by hand.

Since the late 1900s, the information and technological revolution has helped us control these machines, manage information, communicate quickly and easily, improve medical care, replace dangerous dirty work, and access research and new knowledge easily – all of which have changed the nature of work and play immensely. These changes have come with many positive and negative consequences that have affected us socially, economically and environmentally. You can read more about this under Sustainability on page 10.

In the meantime, we need to remember that the word ‘technology’ still describes the most basic tools and techniques through to the most sophisticated products and systems of our time.

In Product Design and Technology you will use available technology as you work through the design process to create solutions for problems and to meet needs. You can read more about this in Chapter 2.

## The history of design

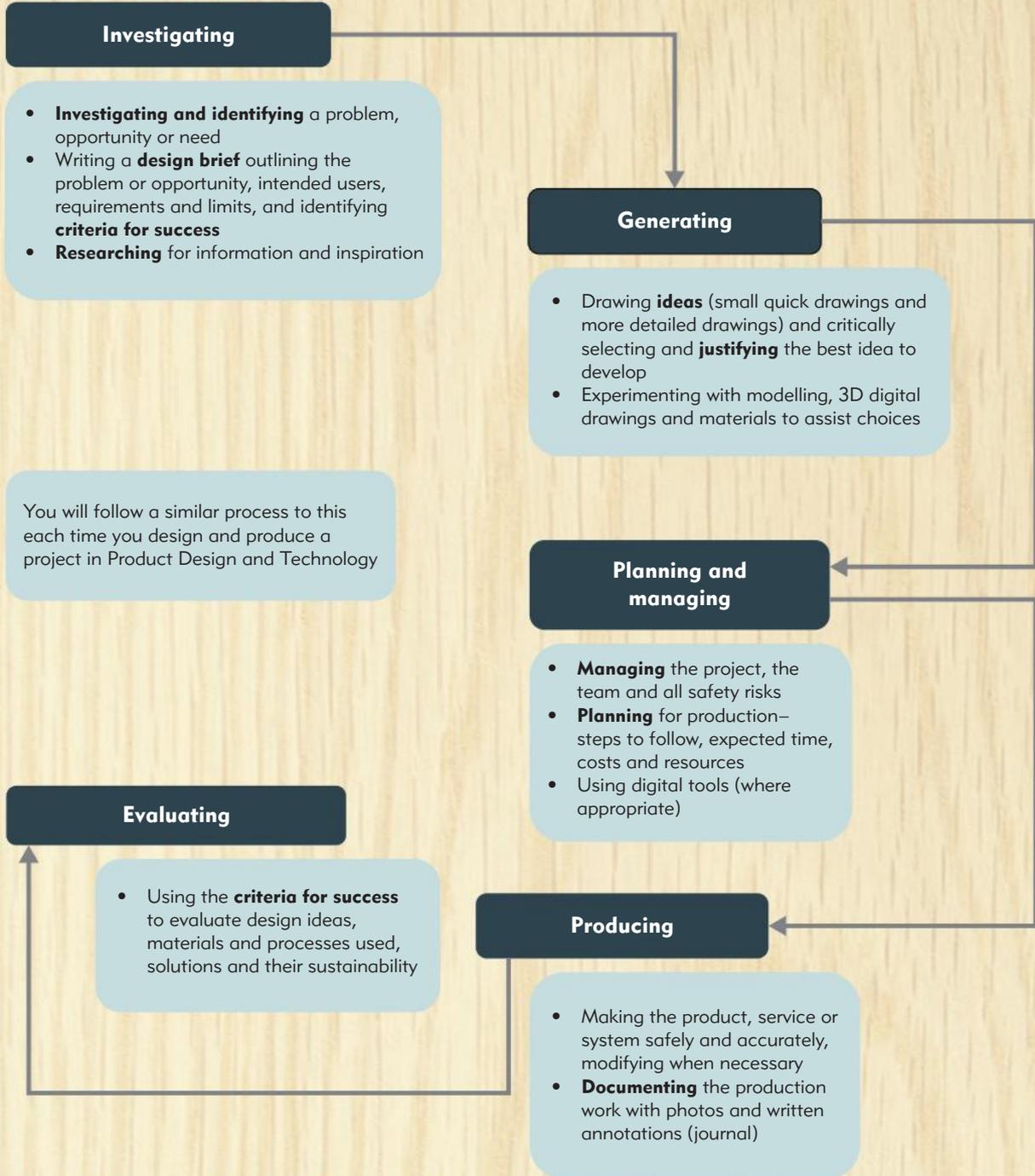
- 1 Archimedes is accredited with devising the screw, the pulley and the lever. Who was Archimedes? Find some drawings of his inventions, copy the drawings, and then draw modern-day equivalents that you might find in your school or around your house. How is each item used and how useful is it? What else did Archimedes invent?
- 2 Ctesibius and Hero are accredited with inventing pumps, wind and hydraulic organs, compressed-air engines and screw-cutting machines. Who were Ctesibius and Hero? Find a drawing of their inventions and draw or find an image of a modern-day equivalent that exists.
- 3 Before mass production, many garments were fastened by tying and lacing, or by using a buckle or clasp made of thorn, bones or wood. Draw an example of each of these and alongside draw a type of fastener that would be commonly used today. Explain the technology that has been developed to enable mass production of the modern version.
- 4 Think of a product that a primitive human may have used. Draw up a table with four columns and draw a series of diagrams of this product as it developed throughout any four stages of history (such as primitive times, the Roman Era, the Middle Ages, the Industrial Age, the Information and Technological Age and a future age).

## WHAT IS THE ‘DESIGN PROCESS’?

Designers work in all sorts of ways, and perform a range of tasks to design and create things. However, most people working in design use some form of **design process**. This process works through the steps from identifying a problem or need to realising or creating the product (or service) that ‘solves’ the problem. Along the way, many factors are considered. Understanding the nature of the problem is important, as is exploring many alternatives. If the solution is a physical product, it needs to be made of suitable materials that are safe, economic and constructed appropriately. If the solution is a service, it needs to take human behaviour into account and be efficient, flexible, safe and reliable.

The details and the order in which design activities are carried out will differ, but no matter what the design problem or need is, the steps that are followed are similar. We can learn from some of the patterns in the way designers work.

## The Design Process



The design process can differ in the number of steps and doesn't always happen in this set order. Steps can be repeated or re-visited in any order, particularly the investigating and research steps. Depending on the problem, some steps may require more time and effort than others.

## Note

For the purposes of this text, stages and steps are interchangeable, although they may be separated and distinct in senior secondary studies.

The common stages of the design process are:

- investigating
- generating
- producing
- evaluating
- planning and managing.

We usually think of the design process as a cycle – we go through each stage, evaluate, and then go back to the beginning again because solutions can always be redesigned and improved in the future.

**Planning and managing** takes place throughout the whole process; from the conception of an idea to its realisation (the solution).

Each of these design process stages can involve a wide range of activities or tasks, but not all of them need to be carried out in every design process. Designers choose the activities or ‘design tools’ that will be the most useful for their situation – they use them in a **strategic** way to come up with the best solution. When you are using the design process, you will need to use a range of design tools to develop the best solutions. This is what is known as **design thinking**.

The next section will explain some of the activities that you might undertake in your design journey.

## FOCUS ACTIVITY

### Using the design process

To consolidate your understanding of the stages of the design process, discuss the following questions.

- 1 Why do we use the design process? What do you think could go wrong if you make a product without following the design process?
- 2 With a classmate, complete this sentence: ‘*Product Design and Technology means to use ...*’
- 3 Is the first idea always the best idea?

# INVESTIGATING

This stage includes activities such as **identifying, considering, researching, experimenting, examining, testing, evaluating** and **selecting**.

Before you set your mind to designing, you will need to carry out some of these activities to determine what it is you are going to design, what purpose it needs to fulfil and who will be using it. Sometimes this is called a **need**, opportunity or problem to be solved.

## What is a design problem?

Problems can be anything from solving global and environmental issues, to personal problems such as how you might keep your house organised or improve communication with a friend or relative. In this subject, when it comes to solving problems by using design, we are referring to ‘problems’ that can be solved by a well-designed **product, service, built environment** or **system**. Problems in a design sense can also be thought of as needs, requirements or opportunities.

An **opportunity** means a timely event or situation that makes it possible to do something. In the design and technology sense, it often refers to an area where nothing has existed before, or where the solution that currently exists needs a lot of improvement. In a business sense, opportunity is a chance to provide a product that satisfies a niche or gap in the market.

Look at some common products and items and identify the problem or need behind why these designs were produced. Often they are simple and everyday issues that we all struggle with.

### Examples of common problems and the design solution

PROBLEM	DESIGN SOLUTION
Keeping your hands clean while cutting an avocado	An avocado slicer
Street lights shining in your window	Curtains or outdoor shutters
Feeling isolated in a big block of flats	A central community garden
Books on the floor	A bookshelf
Pedestrians crossing a road with traffic	Timed and coloured traffic lights
Keeping food fresh	A sleek new refrigerator (or a fresh food delivery service)
Feeling like your clothes are old-fashioned	Fashionable new clothes

## Products as solutions

- 1 Draw up a table with the column headings 'Product as solution' and 'Problem' as shown in the example. For each of the everyday products given below, list the product in the left column and explain the problem that this product solves in the right column. Remember, you need to describe the problem that existed before the product was designed or made.

- |              |                  |                         |                             |
|--------------|------------------|-------------------------|-----------------------------|
| ▪ Spoon      | ▪ Remote control | ▪ Sticky-tape dispenser | ▪ Shower nozzle             |
| ▪ Web camera | ▪ Beanie         | ▪ Raincoat              | ▪ Ladder                    |
| ▪ Sunglasses | ▪ Wedding ring   | ▪ Security safe         | ▪ Doorbell                  |
| ▪ Torch      | ▪ Cheese grater  | ▪ Car alarm             | ▪ Electric car (or bicycle) |

### Example of everyday products as solutions

PRODUCT AS SOLUTION	PROBLEM
Wire basket to fit my bike	When I ride my bike to school, my shoulder bag always twists around to the front and knocks my knees.
Stroller	Parents are physically unable to carry their infants and toddlers around with them everywhere they walk.

- 2 Create another table using the same headings, but switch them so 'Problem' is in the left column and 'Product as solution' is in the right column. Add the list of 'problems' below to the left column and write the name of a product that could be designed and made as a solution in the right column.
- An eight-year-old has nowhere to put her books and they end up spread all over the floor.
  - A student's tools are kept in a plastic bag.
  - An adult cooking a meal wants to keep his office clothes clean without having to change.
  - Precious photographs keep getting blown off the mantelpiece.
  - When a person is cooking, the recipe book always flips shut and she gets annoyed because she has wet hands and doesn't want to touch the pages.
  - Items stored on a high shelf can't be reached by standing on the floor.
  - A grandmother needs to bend down all the time to reach her magazines, and this is difficult and painful for her.
  - You have nothing to wear to your friend's 18th birthday party.

## Where do I start?

Conducting research to find out what kinds of products you can make with available resources is a good start to investigating a design problem. Ask your teacher what materials are available and what processes can be or must be included. Keep in mind your current skills and what new skills you could learn. Think about whether you can get the information you need while in the classroom, or whether you need to conduct some research out of the classroom.

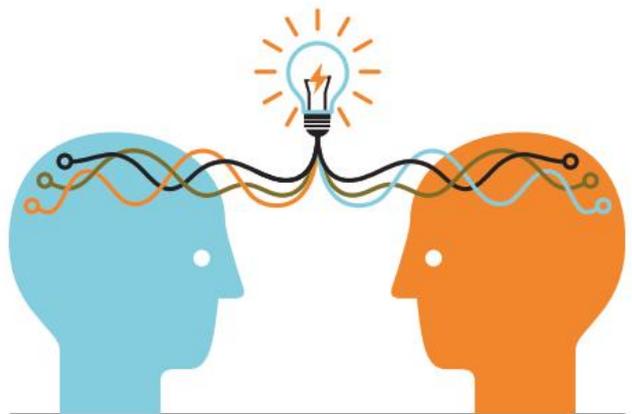
In general, design begins with the thought: *'I think something is needed here to improve the situation'*.

## Brainstorming

**Brainstorming** is an excellent activity for generating ideas. Brainstorming is useful in a group and involves coming up with many ideas as quickly as possible, no matter how silly or 'undoable' they seem at first. Brainstorming is mostly done with words and phrases, but drawings can help too.

Brainstorming can help decide what to investigate, where to start and what to put your mind to. It can be done at any stage that requires input of ideas. Questions to guide you include: *'What if ...?'*, *'What else ...?'* and *'What about ...?'*

If you brainstorm with another person or a group, they can often help you come up with new ideas. It's important to write down or draw everything that is thought of. After brainstorming, you can eliminate ideas that aren't suitable, combine and improve the best ideas, and then select the most suitable idea to develop.

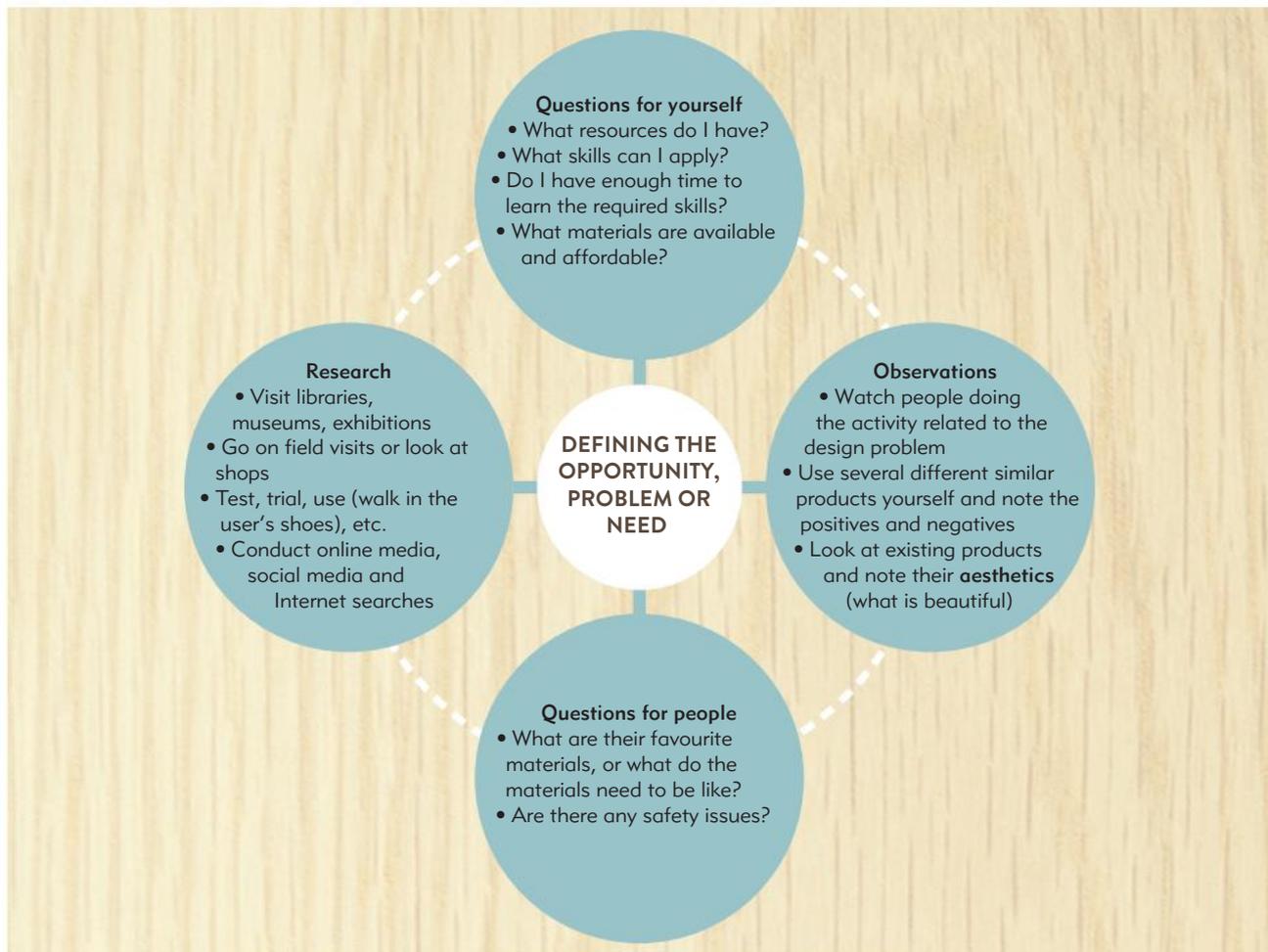


**Create some sentence starters that will help with brainstorming for a project.**

## Defining the opportunity, problem or need

Once an opportunity, problem or need has been selected, it needs to be narrowed down or further defined. You need your design challenge to be reasonably clear, yet not too broad and not too

narrow. It needs limits, while also allowing for a variety of solutions and enough room for your creative input. This helps to make creating a solution an achievable feat. The process of defining can be helped by research, observation and questions.

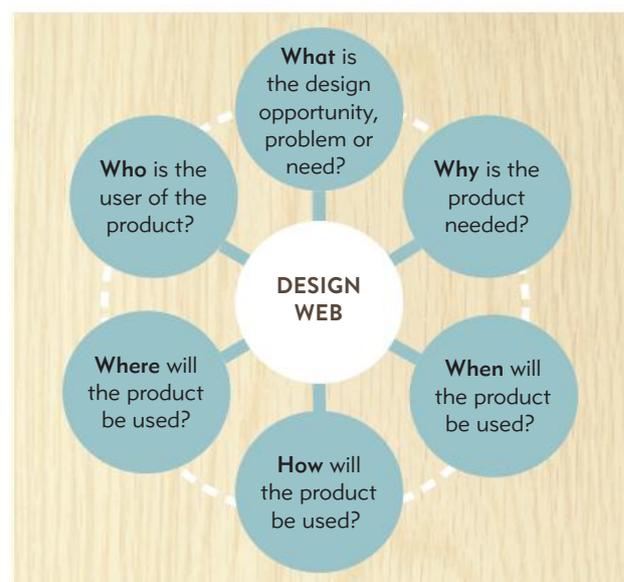


### Defining the opportunity, problem or need

By asking questions, you can start to clarify and identify what is required. Notes, diagrams, photos, tables, charts and lists can be used to record this information.

### Using a design web

A design web, or web diagram, may help define the problem so you can write a design brief. It reminds you of the areas to be covered. Completing a design web diagram by filling out the radial arms of the spider's web can help you to make some decisions about your project.



A design web

Next, you must gather details about the **constraints** related to both the product and your **resources**. You can make another type of web diagram to show this. These questions may help you.

- What are the restrictions?
- What do the materials need to do?
- What materials can I use?
- What are the size limits?
- What type of joins are required?
- What aesthetics will appeal to the user? (What will they find beautiful?)
- When does it need to be finished?
- How much is the budget?

The answers to these questions will help you list the **requirements**. Both sets of information form the basis of your design brief.

## What is a design brief?

A design brief is a statement that outlines the **opportunity, need** or **problem to be solved**, the situation, the user (or users) and the requirements. It is the starting point for the process of designing and making. The design brief clarifies and defines the task and gives a guideline for design by giving the designer goals and expectations to fulfil, including a budget and a date for completion. Often, it also takes the place of an agreement between the designer and the client.

A design brief is often written in two parts. The first part outlines the design problem and gives a picture of the situation around the problem. The second part outlines the constraints or requirements. In some cases, your teacher may suggest you write these constraints as 'criteria for success'.

The design problem or need for a design brief can arise through many situations. For example, a special occasion such as a birthday party or a wedding, a house renovation, a sporting event, a decline in health, impairments of sight and hearing, movement of large numbers of people, dangerous behaviour, and the importance of connecting people in a community.

A design brief includes the answers to the questions you included in your design web: *Why?*, *What?*, *Who?*, *Where?* and *When?*. It also considers the available resources and skill level of the designer. This is particularly important when designing in the classroom.

## Criteria for success

Included in a design brief are **criteria for success**. This might sound confusing, but they are simply criteria or standards for what is expected in the finished product that you write *before* you make the product. They help you at the end of the project to decide whether the product you designed and made was successful. The criteria for success also help to keep you focused when designing and to think about what you are aiming for.

Criteria are standards or levels of expectation that can be somehow measured. The criteria for success emphasise the main requirements of the design brief. They may also be called **evaluation criteria**, in which case they are written as questions. In some cases, you may call the 'requirements' the 'criteria for success', and vice versa. Your teacher will advise you on this.

### Note

A **criterion** is a single point or requirement to be met for a situation.

The **criteria** are the points or requirements to be met for a situation.

One criterion (singular); many criteria (plural).

The criteria for success cover aspects such as aesthetics, functionality, sustainability and the suitability of the materials.

### ■ Aesthetics

Aesthetics is about beauty, which is dependent on individual taste, experience, education and culture. It is the aspect of something that is seen, felt, heard or smelled, all of which we judge by our senses. We all have a different sense of aesthetics. In Product Design and Technology, it is the senses of sight and touch that most applies to what we design and make. Aesthetics are important because the products we use every day affect our feelings and our wellbeing.

You can read more about aesthetics later in the chapter on page 37 under the heading 'Design elements and principles'.

### ■ Functionality

Functionality is about how a product fulfils its primary function or purpose – does it do what it is meant to do? Some associated words are added in brackets (see page 30)., performance, safety, reliability,

operation, durability and quality. You can also consider secondary functions, which are functional parts of a product that support its primary function. For example, the primary function of a bag is to carry or hold things; a secondary function could be a strap or handle to help you carry the bag and therefore support your use of the bag.

In some product designs, a mechanical movement or an electronic system may be included. These should work as expected. In service designs, people's interaction should be clear and comfortable. In a built environment, movement, noise, light, temperature and any controls need to function suitably.

### ■ Sustainability

Sustainability is about the economic, environmental and social issues that need to be considered when designing and making any product. It is about making 'good' choices so that we don't reduce the ability of future generations to live their life well. Sustainability in design is about making balanced design choices – considering the product's usefulness, how long it will last, its quality, how much waste it will create and what can be done with it when it is no longer required. Sustainable design is important for our environment – it allows us to conserve resources and reduce waste throughout the lifecycle of the product. Service design should consider people's behaviour, and any destruction of resources or creation of waste that occurs because of this behaviour.

You can read more about sustainability later in this chapter on page 37.

### ■ Suitability of materials – characteristics and properties

Materials will be selected based on what is required. This can be expressed as their characteristics or properties, which are things such as strength, stretch, flexibility, ability to transmit electricity (conductive or non-conductive), or whether they are insulating (against heat, electricity or noise), rust-prone, corrosive, rust-resistant. Characteristics or properties are generally thought of as something special about the way a material looks, or the way it behaves/reacts in different circumstances such as pressure, heat or water.

Materials are categorised into two major groups – resistant and non-resistant. Resistant materials are usually rigid or solid. Wood, plastics and metal are all called resistant, even though some materials in these categories are flexible or liquid-like (for example, mercury). They are considered resistant because they do not move when we touch or push them. Most textiles are called non-resistant, because they are flexible, and move or give way when we touch or push them. You can read more about materials in Chapter 2.

### Using criteria for success

You will be using criteria for success to make sure you have included all the necessary requirements when designing and later when you have finished your product. You will be using them to judge how well your designed product met the requirements of the design brief. This will occur in the evaluation stage of the design process.

#### Constraints (or criteria for success) using the example of a CD container

AREAS TO COVER AND QUESTIONS TO GUIDE YOU	EXAMPLE CRITERIA (FOR A CD CONTAINER)
<b>Size</b> – What are the specific measurements? Is there a certain space into which the product must fit? Does it have to contain/store objects of a certain size?	<ul style="list-style-type: none"> <li>• It must fit 10 CDs</li> <li>• It must fit into the top cupboard in our kitchen</li> </ul>
<b>Weight</b> – Is the weight of any relevance? Does it need to be lightweight for easy lifting, or heavy for stability?	<ul style="list-style-type: none"> <li>• It can't be too heavy as Mum needs to take it in and out of the top cupboard</li> </ul>
<b>Performance</b> – What must the product do? What major function must it perform? Are there any other functional aspects that are also important?	<ul style="list-style-type: none"> <li>• It must hold the CDs neatly and the titles must be easily seen</li> <li>• It must work so that one CD can be taken out without disturbing the others</li> </ul>
<b>Safety</b> – Is the product safe for the user?	<ul style="list-style-type: none"> <li>• It must not have sharp edges or break easily</li> </ul>
<b>Quality</b> – To what degree of quality should the product be made?	<ul style="list-style-type: none"> <li>• The joins must not have any gaps and must be strong enough so they don't split</li> <li>• Any components must be securely attached</li> </ul>

<b>Materials</b> – What is required from the materials? Do they need to be strong, flexible, elastic, rigid, waterproof, etc.? What materials are available? Must the product be made from specific material?	<ul style="list-style-type: none"> <li>The materials need to provide a waterproof surface, and they need to be rigid and easy to clean</li> </ul>
<b>Aesthetics</b> – How should the product look? What shapes and proportions should it have? What type of lines, colours or colour schemes and textures should it have? What will appeal to your user?	<ul style="list-style-type: none"> <li>Mum likes monochrome colour schemes and she likes green, so it should be various shades of green</li> <li>Mum likes simple designs, but include lines near the edges to add interest</li> <li>Mum likes bold simple shapes in large proportions, not complicated and busy</li> </ul>
<b>Cost</b> – What is the budget? Can you afford the most expensive materials or do cheaper versions need to be used?	<ul style="list-style-type: none"> <li>It must be made for less than \$20</li> </ul>
<b>Time</b> – When does the product need to be finished?	<ul style="list-style-type: none"> <li>Finish date is 25 May</li> </ul>

## Evaluation criteria

Your teacher might ask you to write the criteria for success as questions. These questions are called evaluation criteria and will help you judge later whether the product functions or looks as it needs to.

For example, evaluation criteria for a library bag might be:

- Is the library bag big enough to carry three A4-sized books comfortably?
- Is the bag strong enough to carry three heavy books?
- Are the handles securely attached and in a good position?
- Is the recycled material suitable?
- Does the recycled material look good to me?
- Does the design show my interest in dogs?

Once the design brief has defined the problem or need, the next stages of the design process can begin.

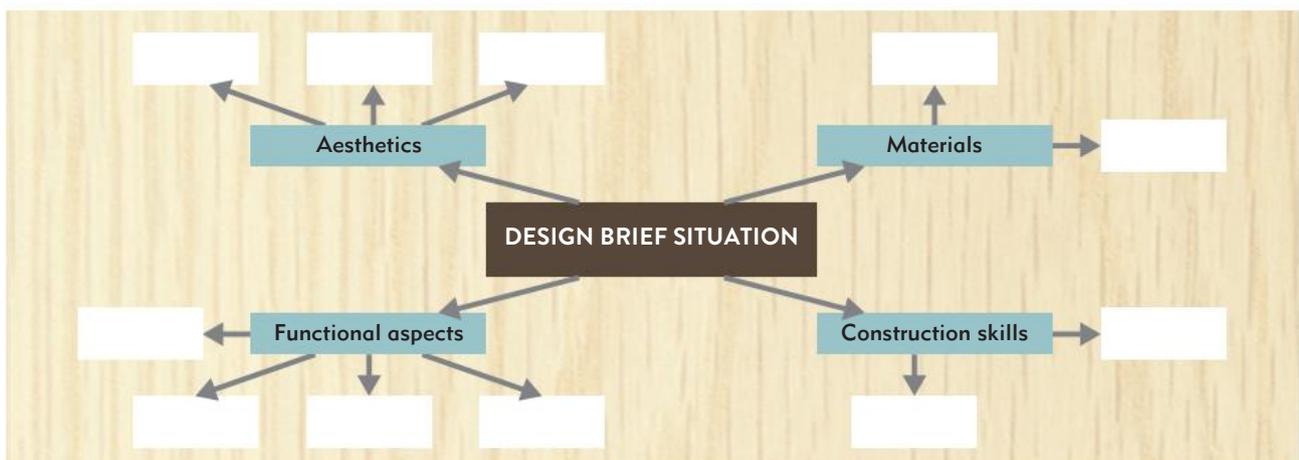
## FURTHER INVESTIGATIONS

You have already completed initial investigations to decide on what problem or need you will solve and the situation around it, but you will now need to conduct further investigations. At this stage, you will need to research specific information and research for inspiration (ideas to inspire you). Use your design brief to identify the areas of research that are important to you. What do you need to find out?

### Using graphic methods to organise ideas

A **graphic organiser** is any visual method that shows thinking and/or connections. It can be a rigid diagram or a hand-drawn and free-flowing diagram. It may follow specific rules or it may not!

Select a graphic organiser that is suitable for organising your ideas or research such as a mind map (sometimes called a concept map), a fishbone diagram, a lotus diagram or a Venn diagram. Many graphic organisers can be created digitally with software such as *Inspiration* or *SpicyNodes* (which is more interactive).



Example of a mind map structure

## ■ Creating a mind map

Write your project name or an idea in the centre. Next, add new and related ideas radiating out with connecting lines from the centre, like rays from the sun.

Add branches and connection lines between the ideas that are related. Use lines, colours and arrows to show connections. Add your own symbols, cartoons or diagrams that will assist in your recall and understanding. Focus on the key ideas from your design brief and what you need to find out, learn or do, and the ideas that you need to explore. You can write phrases that begin with verbs such as:

- 'I will measure ...'
- 'I will count ...'
- 'I will collect ...'
- 'I will test ...'
- 'I will practise ...'
- 'I will find out ...'
- 'I will experiment with ...'
- 'I will draw ...'
- 'I will compare ...'
- 'I will ask ...'
- 'I will learn how to ...'
- 'I will explore ...'
- 'I will try ...'

There are many templates for mind maps, but drawing up your own gives you much more control.

## ■ Creating a fishbone diagram

Create a heading that names the problem or need. Next, draw a horizontal line that represents the

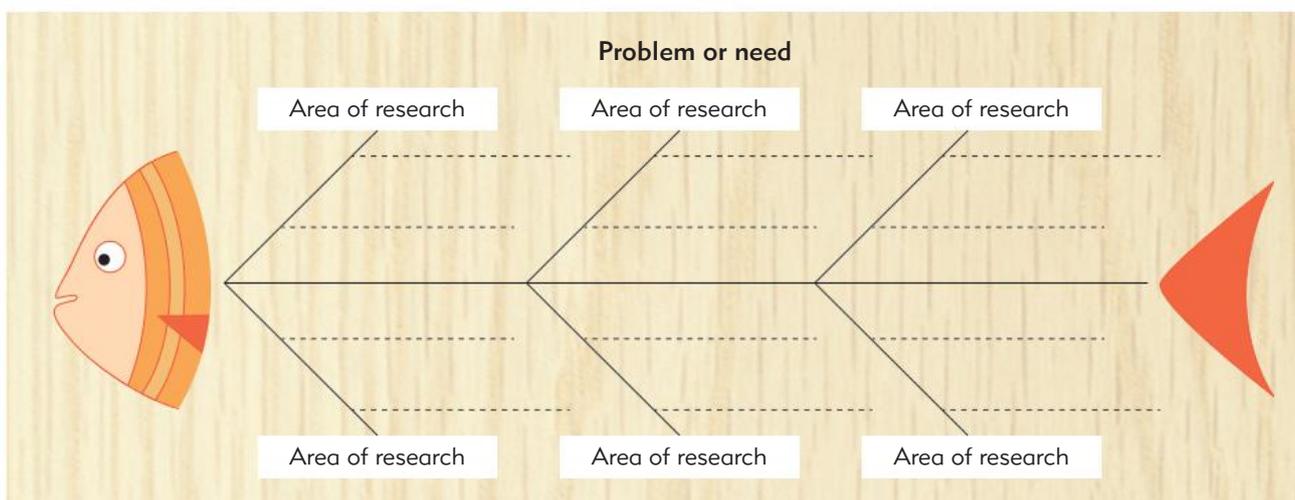
backbone of the fish, and draw a tail on the opposite end. Draw at least four angular lines from the spine to represent the fish ribs – these will identify the four main areas of research or activities required. From each of these lines, draw more horizontal lines to list the details of research or activities using the same sentence starters as for the mind map.

## ■ Creating a lotus diagram

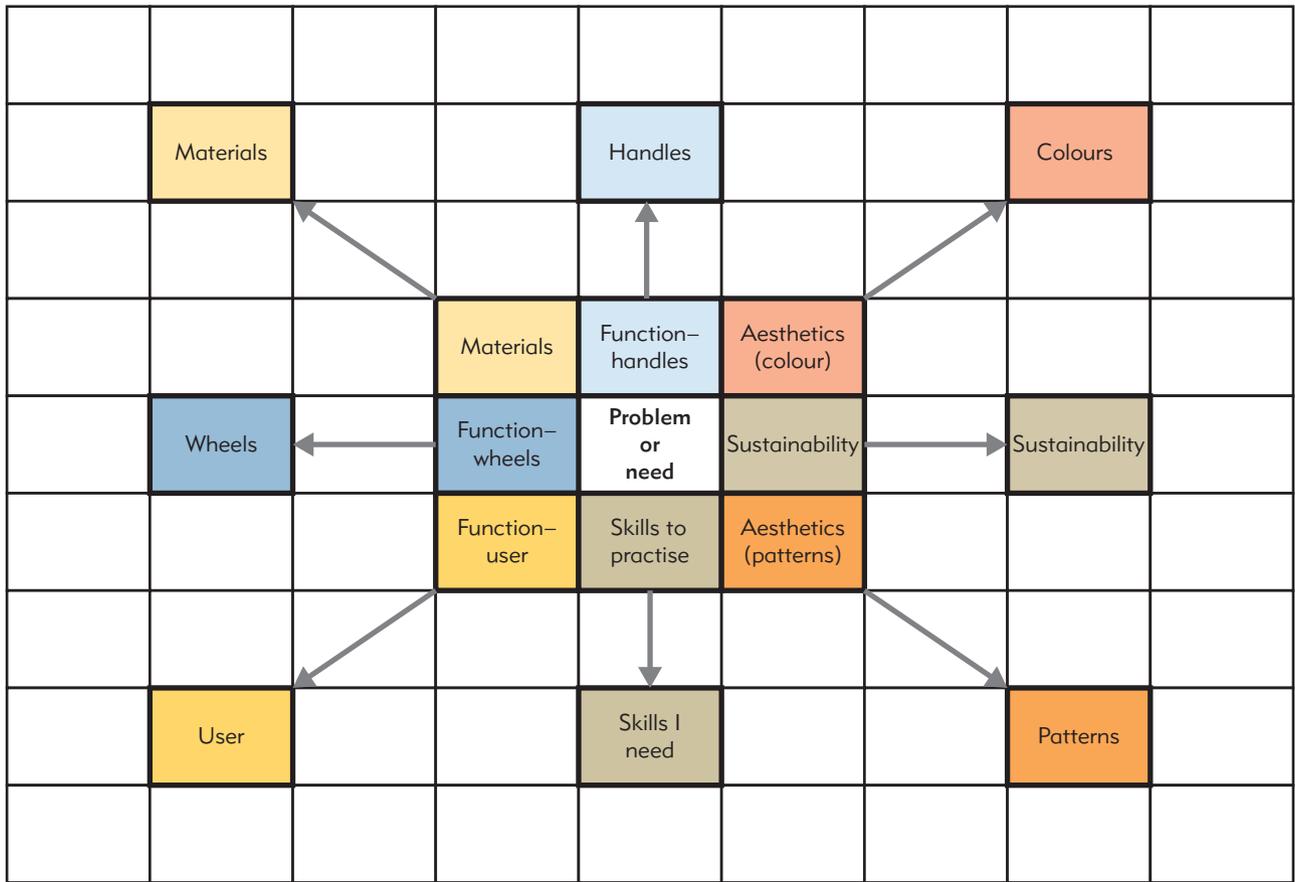
A lotus diagram resembles an eight-leaved lotus flower, with each petal unfolding into a new blossom. It is a large grid consisting of 81 boxes (or lotus blossom petals), each large enough to write in a phrase. The problem or need is written in the central box. Each of the eight boxes surrounding the centre identifies an area for research, and each of these has their own blossom or grid for more details. Not all boxes need to be filled in. The grid can be hand-drawn allowing some boxes to be larger than others or to be a different shape.

## Giving your graphic organiser a title

No matter which form of graphic organiser you use, or at what stage of the design process you are at, give your graphic organiser a title to show why you are using it; for example, 'Mind map to research playgrounds', or 'Mind map of ideas for playgrounds'. No matter which form of graphic organiser you use, make it interesting by adding colour and little diagrams that will help the viewer to see and understand your design thinking.



**Example of a fishbone diagram structure**



Example of a lotus diagram structure

## Researching for information

Conduct some research to gain information about your design product. Your research could include:

- taking photos of the intended environment of your product
- seeing what suitable (or new) materials are available and looking at their characteristics and properties (for example, flame-retardant fabrics; differences between natural hardwood and plantation softwood timbers)
- finding out the costs and size availability of your materials
- finding out what tools, equipment or machinery you will be permitted to use
- noting the skills you already have and the skills you will need to learn or improve
- measuring any items to be fitted into your product or the spaces where the product must fit
- finding out about ergonomics (page 30)
- researching sustainability issues around intended materials or products

- testing existing products, discussing their sustainability and noting how they could be improved
- creating questionnaires about product requirements, appearance, etc.
- gathering feedback and opinions from users of the product you are designing
- searching for consumer feedback on similar existing products.

## Researching for inspiration

**Inspire** means to give thought, feeling, reason or suggestion. 'To be inspired' means to take thought or reason from something or someone. 'Inspiration' is something that influences your thoughts or feelings, or arouses effort to do well.

Your research for inspiration could include:

- your own photos of nature or environments
- objects with aspects you like (for example, proportion, appearance of lightness or weight)
- products that solve a similar problem to your design brief

- products with aspects you like and could perhaps use in your designs (for example, a handle, a specific component, a clever mechanism)
- colours, lines, shapes and textures from nature or other products
- samples of materials that could be used.

Include research that will help you create the best design in terms of aesthetics. Read more about this on page 37. under the heading ‘Design elements and principles’.

### Acknowledging intellectual property – moral rights

Intellectual property (IP), is the property of your mind. However, IP is not just ideas that float around in your head – they must be shown somehow in text, as an image or in a product. In other words, your ideas need to be tangible (which means real).

When you use the work of others, the creator of that work has a **moral right** to be attributed. The creator’s

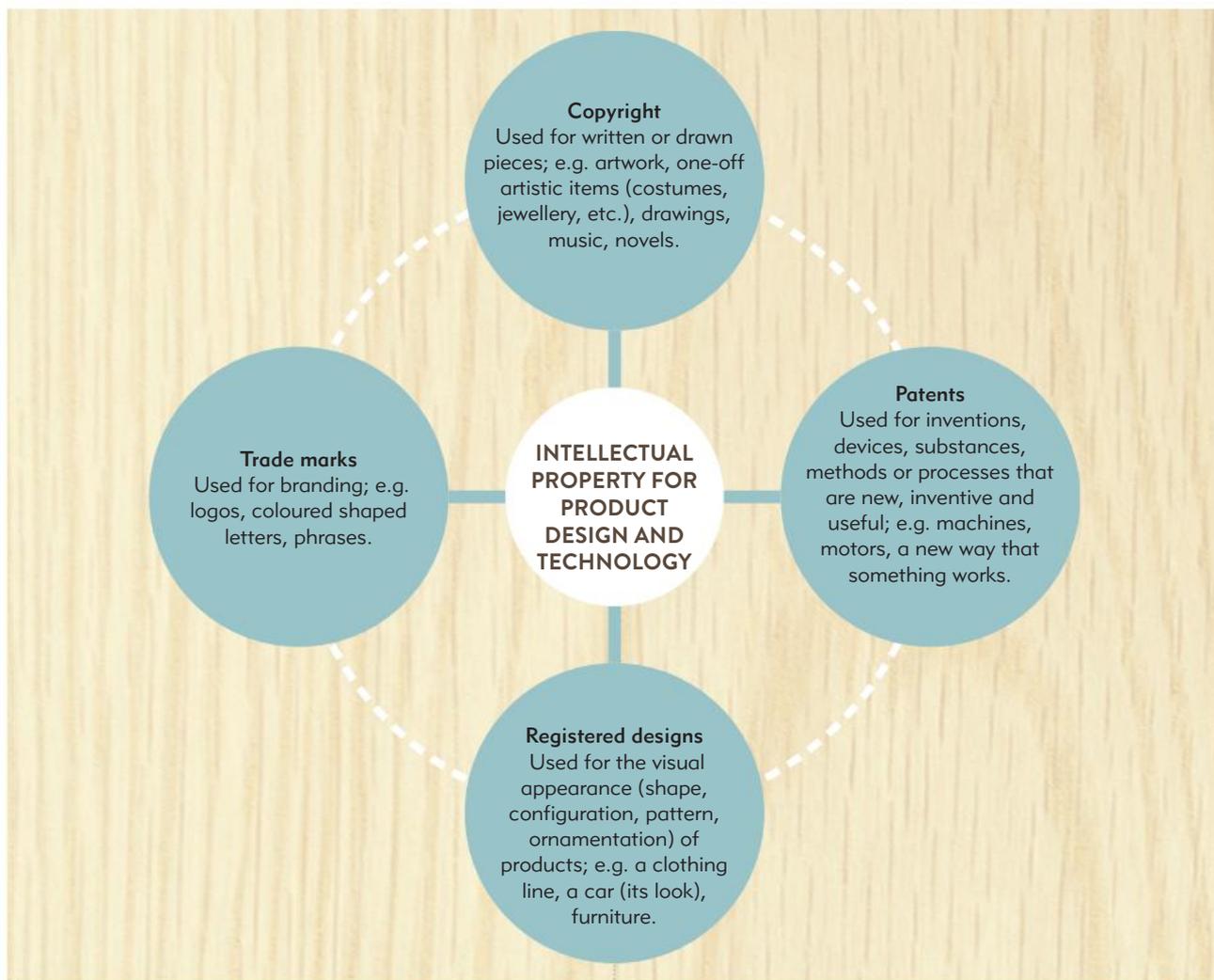
name must appear near the image (or words) so that it is obvious to the viewer who the creator is. You can do this in your folio by writing the name of the creator clearly next to any images you have collected.

If you were to protect your own IP, you may need several types of IP rights depending on your product. IP is a complicated legal area. There are other forms of IP rights that are not so relevant to Product Design and Technology. For more detailed information, visit the websites of IP Australia or Australian Copyright Council.

 IP AUSTRALIA  
AUSTRALIAN COPYRIGHT COUNCIL

## GENERATING

Generate means to produce, create, kick off or trigger a process. The generating stage can be thought of as investigating and recording multiple ideas. You can start this by looking at your collection from your



### Intellectual property for Product Design and Technology

further investigations or research. Again, you can use graphic organisers to help become more focused and to link any ideas from your research into what you might design and make.

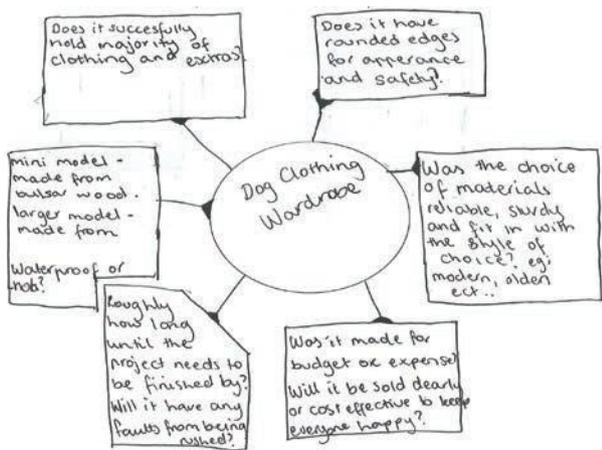
### Idea sketches

Generation starts with idea sketches – quick thumbnail drawings of ideas. The sketches are drawn loosely with little detail, and are used to roughly indicate what an object, system or environment could look like. They can show the whole product or idea, or they can show parts. Many designers use lead pencil for idea sketches, while others prefer pen, fine-liners and markers. Some designers work in a methodical way, producing ideas based on one aspect (such as geometric forms) before moving onto another aspect.

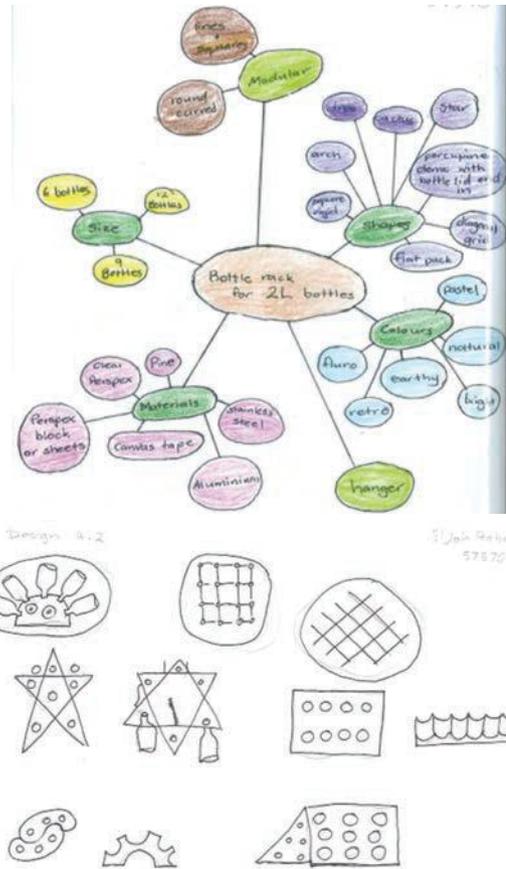
Ideas can be anything such as:

- colours you want to use or combine
- themes to explore
- materials to use or combine
- lines, shapes and textures that would look good
- how components will look
- placement of components, controls or decorative features
- ways to join or attach items
- any functional aspects of the product.

As mentioned earlier, there are many visualisation software tools to help in the planning and recording of ideas.



Breana's ideas for her design brief

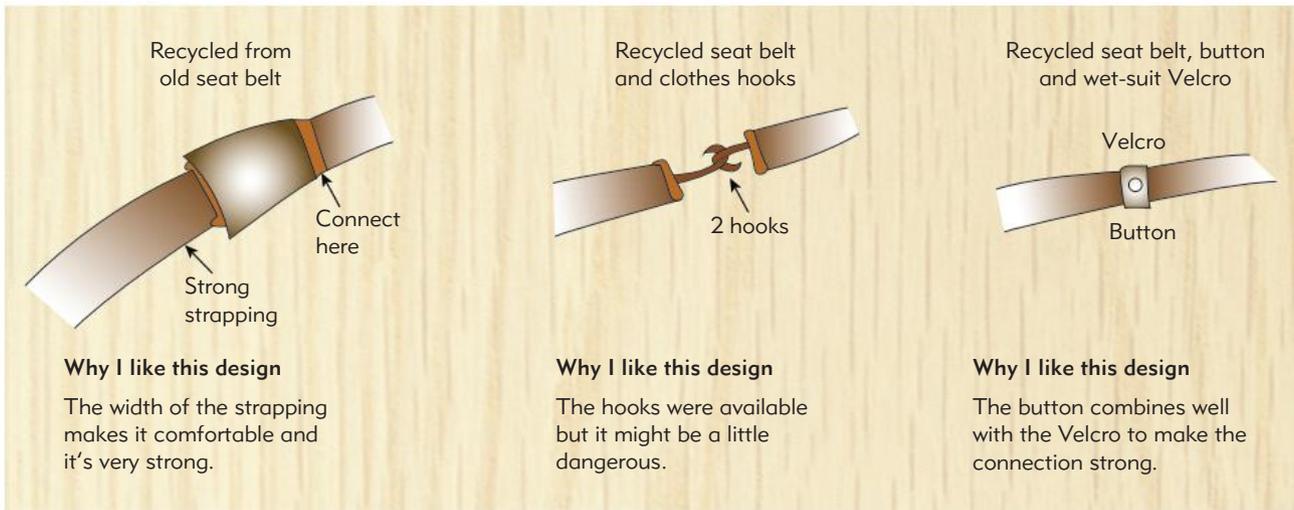


Elijah's brainstorming and idea sketches for storage of 2L bottles



Sara Hussain's concept map and idea sketches for a purse

The aim of these sketches is to explore many ideas. Think of idea sketching as a visual form of mind mapping. Instead of writing down lots of ideas, you are drawing them. Use annotations to help clarify and communicate what the ideas are or what you are trying to work out. A black pen for outlining and a splash of colour here and there can bring life and interest to your page.



### Design ideas for a belt buckle on a bag

#### Creativity – stretching your ideas

To be truly innovative and creative, we need to come up with ideas that are new and different. We need to push ourselves to create things that aren't the same as everything else. This is not always easy to do, which is why we research – to bring other ideas into our head. We look at ideas from other people, nature, different objects and the built world, and try to combine them in unusual ways. It's extremely difficult to start from nothing when aiming to be original, but borrowing other ideas and changing them to suit our situation is a good way to start. Making connections between seemingly unrelated ideas can help us to be creative.

Although many of us think we are not creative, there are techniques and practices that can be learnt to improve this. It is important to be open to the process – to put in some effort and not to worry about looking bad or making 'mistakes'. You may hate creating something that 'isn't good enough', but keep going. Great ideas don't pop out of nowhere in the first drawing – they usually come from a big collection of not-so-great ideas. Creativity is a process; not a one-off. You must work through things and practise, and you may create a little garbage along the way. A big part of your design journey requires you to strip away layers of self-doubt, embarrassment and self-criticism. Dive in and take a risk.

#### Being creative and inventive

**Lateral thinking** (a term coined by scholar Edward de Bono) is a method for solving problems using an indirect and creative approach. It is not about a logical

step-by-step approach, but rather letting ideas flow and connect on any level. 'Thinking outside the box' (or square) means thinking outside the ordinary or looking beyond the obvious and logical, stretching your ideas and taking a risk. You can use creative techniques to make your design something special and different.

Try to avoid thinking that there is only one way of doing things. A visit to the kitchen section of the supermarket will show you how many versions there are of some products; for example, colanders and bread-boards. Most existing items can be improved in function and appearance; however, don't try to achieve too many changes at once. You need only apply a few creative techniques to one or two of your ideas.

At this stage of the design process you are free to explore and not to worry about the quality of your drawing. Later you will create drawings of the whole product that can be improved and show more detail.



A word cloud diagram of verbs related to being creative

## Being creative

### Some techniques for being creative

Add	take a feature or part of another idea and add it to yours
Combine	join two ideas that are similar or completely different
Crossover	join unexpected concepts
Curl	turn straight edges and shapes into curlier ones
Hybridise	blend two or more things to make something new
Fragment	break the original idea down into smaller pieces and separate
Change the scale	make your idea (or part of your idea) bigger or smaller
Contract	make it smaller, or shrink portions or aspects of the idea
Contradict	go in the opposite direction; turn something inside out
Distort	take the whole or part/s and change by making longer, bigger, rounder, more abstract, etc.
Disguise	hide or camouflage aspects within the design idea
Divide	split aspects into parts (halves, thirds, quarters, etc.), then re-join them
Empathise	take on the feelings of something and overlay an emotional aspect
Emphasise	add an extra line around the border to emphasise some parts
Exaggerate	make parts or proportions oversized or undersized
Parody	make fun of product aspects with a play on words
Improve	make one little part or the whole more suitable for the user
Isolate	focus on one aspect of an idea and make it a whole
Transfer	take the idea and put it into a new context
Twist	spiral, bend or twist the whole idea or part of it
Repeat	use the idea more than once, or use parts more than once
Rearrange	move components or pattern segments to create a new arrangement
Straighten	make the edges and shapes more geometric
Subtract	take something away and simplify the idea

Substitute	change one aspect with an aspect from elsewhere, or replace a component with something else
Zigzag	turn straight edges into jagged edges

- 1 Write out four techniques for being creative from the table and draw an example of each in your current design project.
- 2 Gather the following items: leaf, stick, flower, coloured paper, fabric. Combine these items to create an animal or a human. Create two new living things by drawing these elements in different silly ways. Take the best drawing and, on a new page, turn it into a motif (a decorative shape, either simple or intricate, to be used repeatedly in a pattern). Think about how you could incorporate this pattern into your project.
- 3 Lightly draw four squares. Choose two to four activities from the table and apply them to the squares to make three new shapes. Incorporate these new shapes into a product.

### Tip

There are many apps for mobile devices that will be useful in your creative journey. Many have a free 30-day trial period so you can try before you purchase them.

### Critical thinking – questioning your ideas

In general, the two hemispheres of our brains are geared towards different kinds of thinking. The right side is attributed as being in control of spatial awareness and to being artistic and creative, while the left side is where more logical, mathematical and analytical processes occur. Of course, the brain is much more complex and, although each side may work independently, there is a lot of crossover in all kinds of thinking.

We need to use both sides of our brain to achieve good quality solutions in design – not just the creative, non-linear, sensing side, but also the logical, rational, linear, judging side. If we only use our creativity to produce novel and practical ideas, then we may not produce **viable**, quality solutions.

Asking questions is one critical thinking technique that can assist us to make quality decisions in design.

## Critical thinking questions

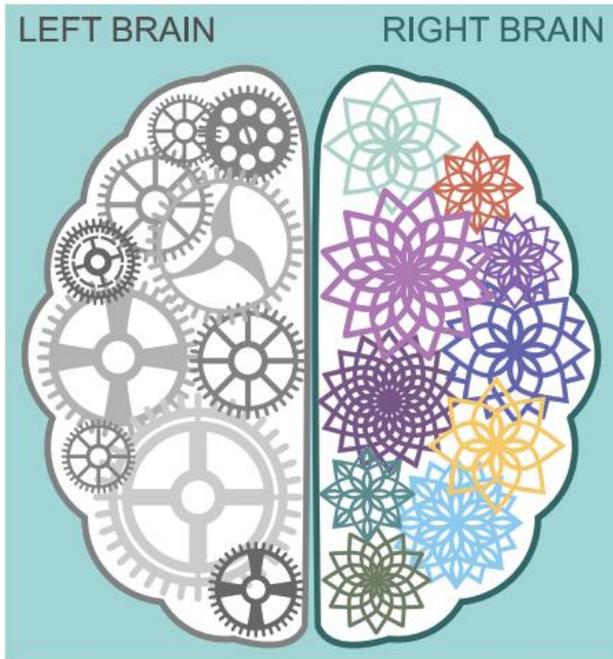
AREA	QUESTIONS
Function and construction	<p>Will this work? What are the problems?</p> <p>Where are the weak points in this design or in its construction?</p> <p>Are the strong points in the right places?</p> <p>What would happen if I put pressure or force to each part of the design?</p> <p>Are the handles, straps, levers or buttons in an easy-to-reach place?</p>
Available time	<p>How long will it take to finalise and produce this idea?</p> <p>How much time will I need to learn and practise new skills?</p> <p>Can I make this design into a product in the given time?</p>
Aesthetics	<p>Will the end-user like this colour?</p> <p>Do the colours clash? Can I put more thought into the colours?</p> <p>Have I considered the most appropriate texture?</p> <p>Can I change something to make my design more aesthetic?</p> <p>Are the shapes and proportions balanced?</p> <p>Are the colours in my design available in the materials I will use?</p> <p>Can I add lines to emphasise edges or to improve the aesthetic?</p> <p>Could the surface have texture, colour or pattern added to look more aesthetic?</p> <p>Can I hide parts (joins or mechanisms) to improve the aesthetics?</p> <p>Can I expose parts for a different aesthetic?</p>

Material and processes	<p>Is the material available in the length, thickness or form that I need for this design?</p> <p>Can I afford this material?</p> <p>What skills do I need to construct this design?</p> <p>What skills do I have already to construct this design?</p> <p>Do I know how to join these parts?</p> <p>Can I find out or learn how to join these parts?</p> <p>Do I have the tools, equipment or machinery available to complete the processes in my design?</p>
Experience	<p>Is my design too ambitious for my experience?</p> <p>Do I have the experience to know how to construct this design?</p> <p>Do I know beforehand what I need to learn and practise?</p> <p>Do I know enough to make judgements on whether my construction is good quality?</p>
Design brief constraints	<p>How does this design meet the constraints?</p> <p>Does this design suit the user in all aspects?</p>

Once you have asked the relevant questions, you are ready to proceed to the next step. Keep in mind that the above questions can be applied to your design ideas at any stage, such as the beginning when you have a lot of ideas or later when you refine your work into a single idea.



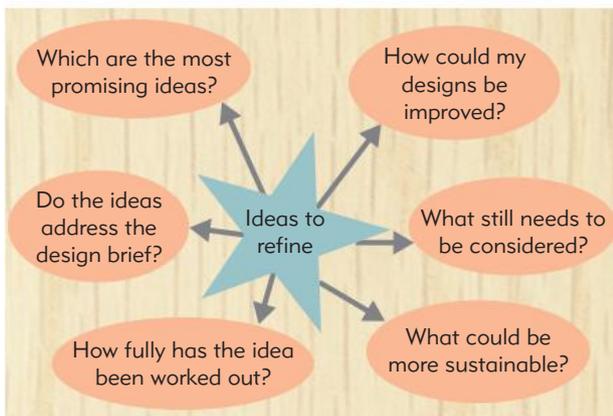
**Critical thinking is applied to idea/thumbnailed sketches (a), from which ideas are refined (b), until one central idea shines through (c), which is also 'critiqued'.**



**The left and right brain**

### Refining ideas

Refining means to improve, add detail, clarify or narrow down. After applying your critical thinking, you will have narrowed down and identified the most suitable ideas to refine. You can now produce some more detailed drawings that show what the whole product could look like. Your teacher may ask for one refined design or several design options.



**General questions to ask when evaluating ideas**

### Exploring the design elements and principles

Before you start your design options, it's important to become familiar with the design elements and principles (see page 37). On one or two pages of your sketchbook, spend some time exploring the design elements and principles – think about how you can incorporate them into your ideas before creating design options.

### Using a mood board

A mood board is a physical or digital board that shows a mood. We are talking about a visual 'style', not an emotional mood; however, colours, textures and text can elicit an emotional reaction (see more about this on page 39 under the heading 'Colour').

A physical mood board is a collage of material samples, textures, components, colour swatches and other objects that are pinned or glued to a board. These boards can be made of cork for easy pinning, or made of plywood and covered in fabric to add double-sided Velcro. They can also be magnetic, with a small magnet glued or sewn into each item to be attached. A physical mood board is suitable for team work and can be displayed in the classroom. It can be quite large for a strong impact.

A digital board can be made using software such as Microsoft PowerPoint or a collage app, with images and blocks of colour inserted on a digital page. Unless it is printed, a digital board can only be viewed on a screen, which may make it more suitable for an individual or to be shared with a small group.

 [PINTEREST.COM](https://www.pinterest.com)

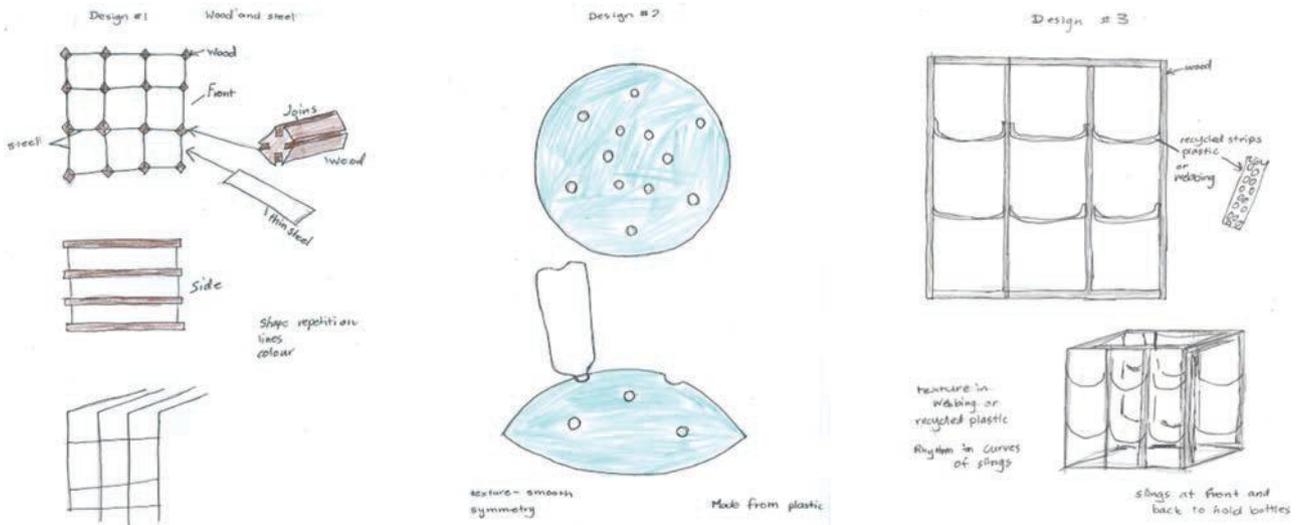
### Tip

Pinterest has a large variety of mood boards for various purposes. Once registered, you can also save and share your own mood boards.

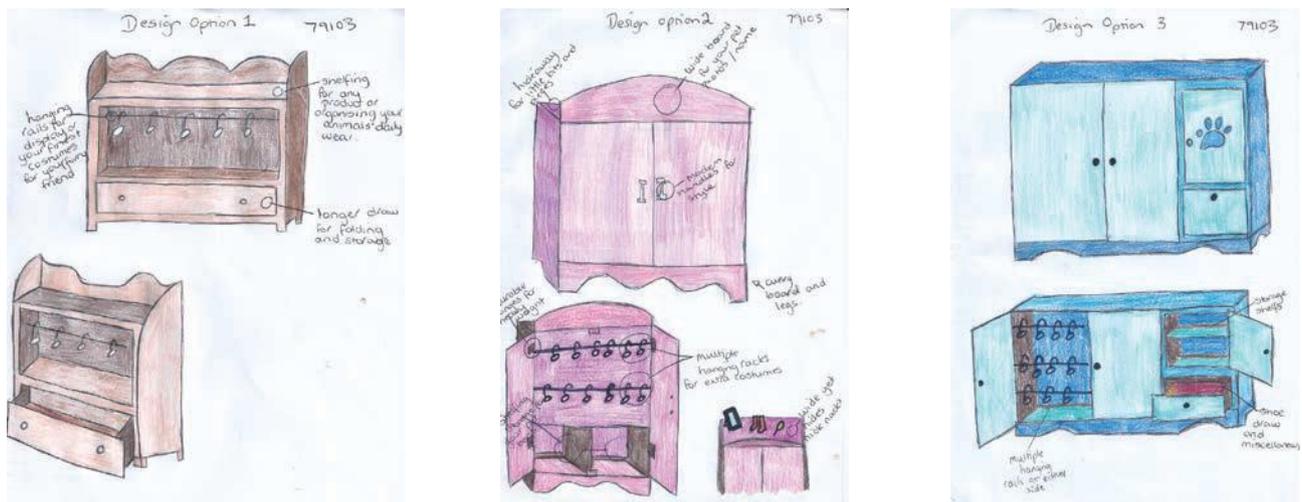
A mood board is like a reference for a visual style. If created before the design options, it can be a checklist of colours, shapes, textures, lines or components to include in your design. It can remind you of how your product design should be aesthetically. A mood board is a good reference for group work.

### Design options

Design options are drawings that each show a different idea for a design solution, from which the most suitable is selected (often by a client). They are drawn in a presentation style – three-dimensional, showing more detail than your idea sketches, and coloured or **rendered** to show what the whole product will look like. You may need to draw different views such as front, side and back. You may also need to enlarge some details, which could be done in an exploded aspect (or close-up detailed drawing) of part of the design. Each drawing should be large and presented on an A4 page.



Elijah's three design options for storing 2L bottles



Breana's three design options for a 'pawdrobe' to store dog accessories

Design options include written comments or **annotations** that address the requirements outlined in the design brief. Annotations may relate to:

- sizes
- materials
- components
- reasons for certain colour/texture
- construction techniques such as joins or how components will be attached
- function – how it works.

Your design options should be visibly different from each other, not just the same object with some parts in different positions. Each option should also be a viable solution for your design brief.

### Modelling

Modelling can be done physically or virtually. A physical model is made of material such as paper,

cardboard, clay, tin or cotton. It is a representation of a design made to full scale (1:1), or to a smaller scale to show structure or workings. A physical model can be used to see if the final design works. See more about scale on pages 24 and 25.

A virtual model is created digitally with a computer program. Digital models are often used to **simulate** different uses or situations, such as flying an aeroplane, traffic networks, crowd movement patterns or extreme weather effects.

Ask your teacher if you can present a model as a design option, or whether it would be more useful as a way of checking your final design further along your design process.

In garment design, a toile is a version of a garment made to check the fit or to test a pattern. Toile (pronounced 'twal') is a French term meaning linen cloth or canvas. It is usually made of cheap



**Paper from old books can be folded to resemble garments**

material, such as calico, so that it can be marked, cut and roughly sewn in the process of perfecting a design or getting the fit right. Preferably, the calico is the same weight or thickness as the garment's intended fabric. Toile is a form of modelling, but it is most often done once the final design has been selected. Modelling of garment designs earlier in your design journey can be done with folded paper to resemble a drawing.

### Manipulating materials

At this stage, you may need to explore your materials to help decide if your designs (or at least one of them) are **feasible** (doable). See more on page xx under the heading 'Manipulating materials – tests and/or trials'.

### Computer-aided drawing

Computer-aided drawing (CAD) is another useful visualisation tool. Although it is good to start your design journey with pencil and paper (a fast method to get a lot of ideas down), it can be helpful to create your designs digitally as you progress.

CAD allows us to design objects quickly and efficiently, as well as accurately and effectively. Once an idea has been conceived (usually through idea sketches), it can be accurately recreated on the computer and subsequently repeated in a matter of hours. Before CAD, any change in a design would require a whole new drawing. CAD allows any adjustments to be made quickly and easily.

CAD is also a great way to show ideas clearly and efficiently to a group so that everyone can understand the structure. It also allows complicated, difficult-to-describe designs to be presented in an easily understood way.

If using CAD to produce your design options, be sure they are three-dimensional and rendered.

### 3D Three-dimensional printing

If your school has a 3D printer, or you intend to use an outside source to print your design as a three-dimensional image, then you will need a CAD drawing. The file must be saved in .STL, .OBJ or .WRL format, which will require specialised software. 3D Warehouse converts Google SketchUp files into print-ready STL files. There are also many online services available to print your emailed file.

 3D WAREHOUSE

### Selecting the best design

One method to select the best design is to draw up a grid with the criteria for success listed on the left and the design options listed across the top. Give each option a score out of five for how well it fulfilled the criteria. For example, a student developed criteria for evaluating designs for a backpack and developed three design options. From the grid, the student is likely to select design option 2 as the 'best' option, as it scores high for most requirements.

## Using the criteria of success to select the best backpack design (which can be highlighted in the table)

CRITERIA FOR SUCCESS FOR EVALUATING DESIGN OPTIONS AND SELECTING THE BEST		DESIGN OPTION 1	DESIGN OPTION 2	DESIGN OPTION 3
Functionality	Will my belongings fit easily into the backpack? Is it the right size?	High 5/5	High 5/5	Low 1/5
	Are there pockets to hold smaller items? Are the straps in a good position?	Low 1/5	High 5/5	Med 3/5
	Is there allowance for padding inside to stop items protruding into my back?	Med 2/5	Med 2/5	Med 2/5
Materials	Is the material the backpack will be made of weatherproof? Is it strong? Is it sustainable?	Low 1/5	High 5/5	High 5/5
		Med 3/5	Med 2/5	Med 3/5
Construction	Will the processes indicated be strong enough and give reinforcement on the stress points?	Med 2/5	Med 3/5	Low 1/5
Aesthetics	Am I happy with the way the backpack will look? Does it suit my school situation?	High 5/5	High 5/5	High 5/5
Totals (if using numeric scores)		19/35	27/35	20/35

A score out of five or a rating system can be used to select the best option. For example,

- High (fulfils the criteria extremely well) – if scored would be 5/5
- Medium (fulfils the criteria somewhat) – if scored could be either 2/5 or 3/5
- Low (barely meets the criteria) – if scored would be 1/5.

### Justifying the selection

Justifying means to explain why or to give reasons. You will need to explain how the selected option (or idea) fulfilled the criteria better than the other options. Start with a sentence that clearly states which option came out as the best, and then explain why the selected or best design was chosen.

*Example: I like the backpack design with buttons rather than a zip as the buttons won't catch the pages of my school books. Also, I can make the buttons bigger and in interesting colours. The material suggested is recycled tent material, so I know it will be strong. I have not yet decided on all the processes, but I know I will need to reinforce the*

*sections where the straps are connected to the bag by using extra material and stitching. I will add the pocket arrangement from design option 1 as I think it's bigger.*

### Drawing for construction

Now that you have chosen the best idea or option, you need to get down to the practical details of how to make it. A working drawing is needed, which will give you all the information you need to go ahead and make your design. It's a good idea to write down all your measurements before you start the drawing.

A working drawing is usually two-dimensional. It shows all the flat pieces of material that are needed for the product. Some of these will be like a pattern or template to show any shapes that need to be cut for your project. Working drawings are drawn to scale and in correct proportion. You may not be confident to accurately work this out, but it's important to attempt it at this stage. It will help you to work independently from your teacher.

## Types of working drawings

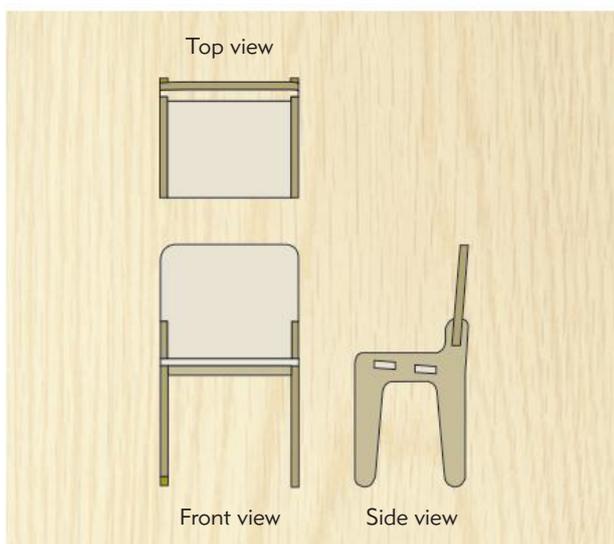
- **Orthogonal drawings** are suitable for wood, metal and plastic products. They are two-dimensional and show several aligned views of the product.
- **Flat drawings** (often called 'flats' or trade sketches) are suitable for garments and other textile products. They show a front and back view of the garment (or product) as if it were laid out flat.

Creating your working drawings on lightly gridded paper can help to align all the views. Extra views are only needed if they are different (for example, if the left side is different to the right side, or the front and back are different).

Whatever type of working drawing you choose to use, you must:

- draw to scale
- align the views
- include all measurements
- show all views necessary (for example, left and right side if they are different)
- label the views
- label the parts
- show the placement of all components or parts
- name the joins or processes to be used
- indicate the materials.

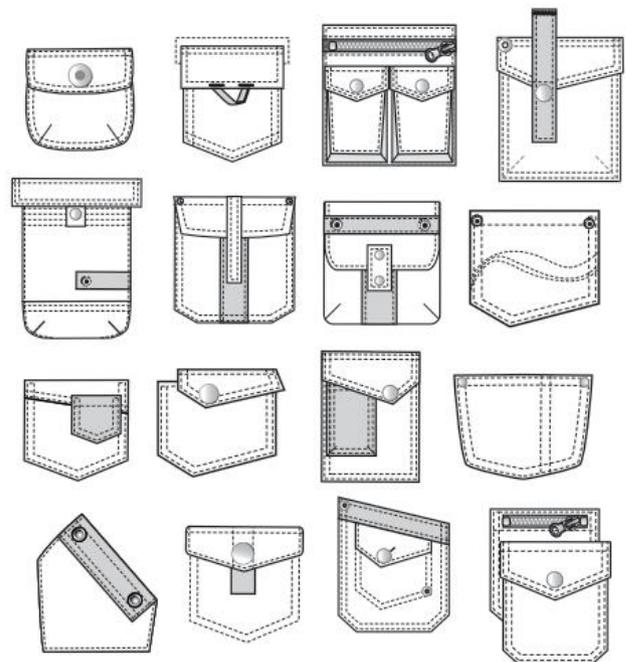
For some products, a separate drawing for a component or part might be necessary such as shown in the pocket 'flats' image. From your working drawings, you will then be able to compile a list of the materials you require.



**Orthogonal drawing of a chair – note that the views are aligned and the drawing is yet to be dimensioned**



**Flat drawing of a pair of shorts with four views**



**Pockets may require their own 'flat' drawing**

## Tips for creating your working drawing

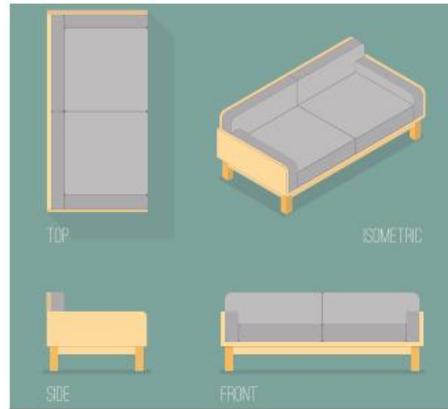
To create your working drawing, start by taking your preferred option design drawing and visually breaking it into the pieces that it will be made from.

## EXAMPLE OF ORTHOGONAL DRAWING FOR WOOD PRODUCTS

For a small wooden stool, take the design option drawing and visually separate the different parts of the stool such as the legs, the seat and any rails. If you have a three-dimensional model, you could take it apart. Each of these parts will need to be made in a particular shape and to a particular size, and they must fit together. Imagine you are looking directly down on the product for the 'top view' (also called the 'plan view'), directly in front for the 'front view' and directly from one side for a 'side view'. An orthogonal drawing needs to show the shape, position and measurements of product parts. For wood products, your drawing must also include the thickness of the material as this will determine the measurements for joins.

## EXAMPLE OF FLAT DRAWING FOR TEXTILES PRODUCTS

If you are designing with textiles, take the design option drawing and imagine you are laying the garment (or product) design flat on the page. Visually separate the parts such as the front, back, sleeves and pockets. You will need to work out their shape, position and size. Use a grid or a ruler to align the tops and bottoms of both views. Notice the alignment in the two views of the backpack drawing.

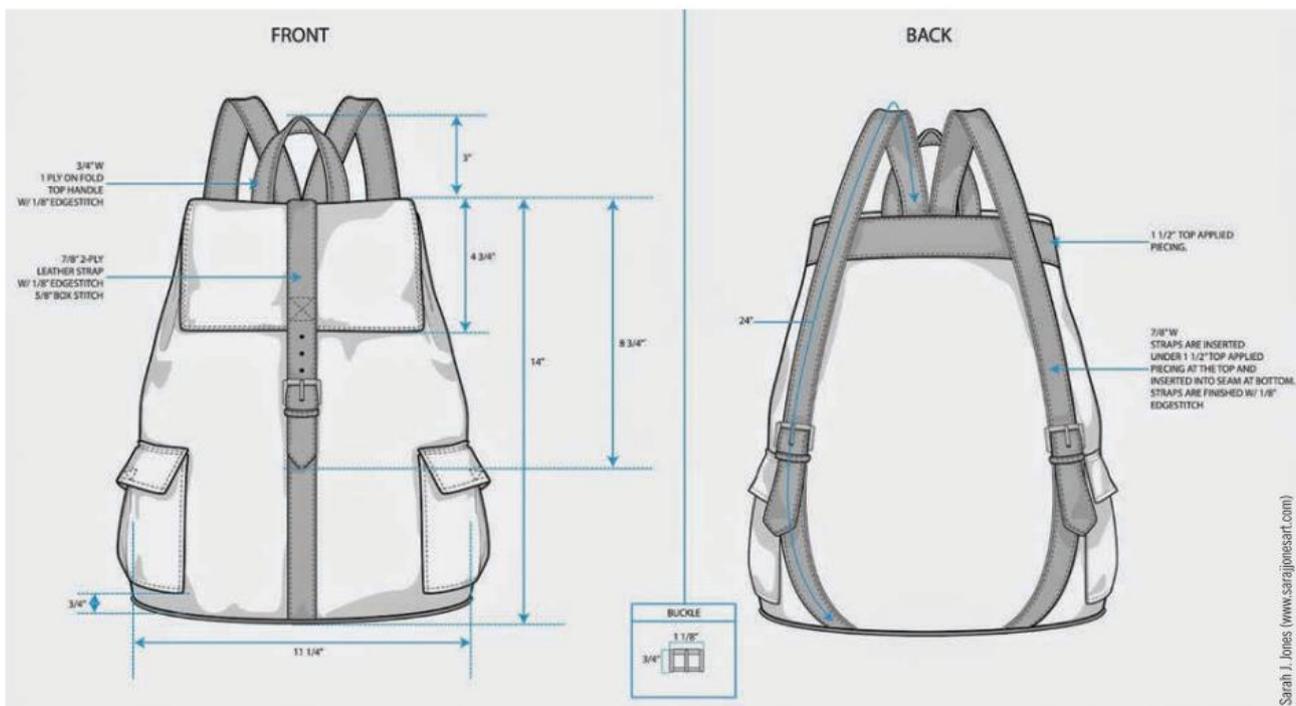


**Orthogonal drawing (with an isometric drawing) of a couch showing the thickness of the timber – note that the drawing is yet to be dimensioned**

## Scale in working drawings

Remember that your working drawing needs to be drawn to scale – a drawing of a large product in its true size won't fit on a sheet of paper. Working to scale makes the drawing more manageable, and the actual size of your product will be represented on paper as a **ratio**. For example, in a 1:10 drawing, 200 millimetres of actual size would be represented on paper by 20 millimetres.

The Australian Standard for technical drawings AS1100 (and the International Standard ISO 5455) recommend the scales to be used are 1:2, 1:5, 1:10, 1:20, 1:50 and 1:100, and larger for buildings. In each of these ratios, the '1' represents the actual



**Flat drawing of a backpack**

measurement and the other number represents the amount it is divided by on the paper. Where the object is very small, enlarged ratios are used. These scales start at 2:1, 5:1, etc.

It is helpful to convert all your measurements into the required ratio before you start your working drawing. This chart of values for four ratios with the most relevant measurements may help you.

**Conversion table for scale drawings (all values are in millimetres)**

ACTUAL SIZE = 1 (OR 1:1)	1:2	1:5	1:10	1:20
10	5			
15	7			
20	10			
30	15	6		
40	20	8		
50	25	10	5	
100	50	20	10	5
200	100	40	20	10
300	150	60	30	15
400	200	80	40	20
500		100	50	25
600		120	60	30
700		140	70	35
800		160	80	40
900		180	90	45
1000		200	100	50

Note: Some table entries are blank as it would not make sense to use these conversions.

You must indicate the scale and the units of measurement on your drawing. This is usually written under the drawing. For example, for a full-sized

drawing with measurements in millimetres, write 'SCALE 1:1 (all dimensions in mm)'. If the drawing is not in correct proportions, write 'NOT TO SCALE' under the drawing.

### Materials and components list

Using your working drawings of your preferred option, you will need to make a materials and components list.

- Materials – what the product will be made of; for example, plastic, wood, metal, paper/card or fabric.
- Components – other items needed to construct your project; for example, zippers, Velcro, nails, screws, buttons, rivets or staples. (In dressmaking, these items are called 'notions'.)

The following section outlines how to create a materials and components list for wood and textile projects. For other materials such as plastic, metal or paper/card, your teacher will tell you how to work out the materials and components lists.

#### EXAMPLE OF MATERIALS AND COMPONENTS LIST FOR WOOD PROJECTS

From an orthogonal drawing, you can create a cutting list for all wood, metal and plastic parts. Look at the pieces of material that are the same thickness and width, and determine how many pieces in your design are like this and how long they need to be.

Possible components to include in your list are items such as nails, screws, bolts, nuts, hinges, latches, magnets, handles, brackets, dowel, 'biscuits' and any metal, plastic or glass additions.

#### EXAMPLE OF MATERIALS AND COMPONENTS LIST FOR TEXTILES PROJECTS

From a flat drawing, you can draft a pattern or create pattern pieces from which you can calculate the amount of material and notions needed. Pattern

### Example of a cutting list for a small stool with a slatted top

#### CUTTING LIST FOR A STOOL

PART	AMOUNT	THICKNESS	WIDTH	LENGTH	COST
Legs	4	18 mm	25 mm	360 mm	\$18.50
Rails	4	18 mm	25 mm	340 mm	\$17.60
Slats on top	6	12 mm	25 mm	380 mm	\$15.80
Total cost					\$51.90

drafting is skill that requires years of learning and experience. Pattern drafting is important in industry as it includes 'grading', which includes a series of lines for several sizes. In your case, use a commercial pattern that is similar to your design and adjust it to suit your measurements. Alternatively, take another garment that is the correct size, pull it apart and trace the pieces. This is where making a toile is useful (see page 20).

You should be able to create your own patterns for simple fashion accessories such as purses, bags or added pockets. Remember to include seam allowances. Stitching occurs approximately 5 mm from the edge of fabric, so this must be considered when marking out the pattern pieces.



Alamy Stock Photo/Panther Media GmbH

### Top stitching

Once you have all the pattern pieces marked out, set them out flat on a table and determine how much fabric you need in total by placing the pieces in a rectangular space. Remember to consider the **grain direction**, as this is important for products being made of woven or knitted fabrics. Grain direction may not be a concern if using felted fabric or leather. To be sustainable, avoid wasting fabric by placing your pattern pieces as close to each other as possible.

Possible notions (components) to include in your list are items such as zippers, Velcro, buttons, hook-and-eye closures, press studs, rivets and magnets.

## Working drawings

- 1 Refer to the orthogonal drawings of a chair (page 23) and a toolbox (page 24). With your ruler, trace the alignment of the views. How are they aligned?
- 2 Refer to the flat drawing of the pair of shorts (page 23). With your ruler, trace the alignment of the front and back view, and the left-side and right-side view. How are the views aligned?
- 3 Discuss the purpose of a working drawing and what it should show.

## PLANNING AND MANAGING

Although planning and managing takes place throughout the design process, it is of most value and importance for the production stage.

### Planning the processes

Once you have the measurements, the shapes and the position of pieces for your project, you can start to plan the actual construction steps – the sequence of steps to be followed. This is the order in which *processes* are followed (this is not to be confused with the design process). A **process** is a construction technique or anything that causes a change to the material.

You will need to think about the best order of processes involved and determine which ones should go first.

### Tips

#### Wood products

In many wood projects, it is not a good idea to finely sand (a finishing process) all the parts before cutting them as the wood often gets scratched during these earlier processes. Usually it is best to wait until the product is finished so that all scuff marks can be sanded away at the end.

#### Textiles products

It is important to iron fabric before cutting out the garment pieces that will be joined to make clothing. It is also important to repeat the ironing process throughout the garment construction and on the finished project to remove all creases created during construction.

Common basic processes are involved in producing any physical product. The most basic processes are:

- preparing the material (this could be as simple as checking for flaws)
- measuring and marking the material
- cutting (and possibly shaping) the pieces out of the material
- joining the pieces
- assembling the pieces of the product
- finishing the product.

For each project there will be a different number of processes, and some of the basic processes will require several procedures to prepare or set them up. For example, some products will need a lot of working at the shaping stage, while other products may

have several different joins that each require a set of processes or steps.

Your task is to predict the order and number of steps in constructing your project, equipment needed for each step, and how long each step will take. Write the steps as instructions to yourself.

Although you may not feel confident creating a production plan, it is important to attempt one as it will help you to work independently from your teacher. Your plan may not be accurate, but don't worry at this stage. The goal of the plan is to think about what is required – to think ahead and be organised. If the order changes or you need help in places, you will record this in your journal and you will have learnt something. An account of this learning can be included in your evaluation at the end of the project.

#### Example of a production plan for a skirt

STEP	DETAILED DESCRIPTION OF THE STEP	RESOURCES AND EQUIPMENT REQUIRED	TIME REQUIRED
1	<b>Preparation</b> Prepare fabric by washing and ironing it to allow for shrinkage	Washing machine Iron	15 min (to wash) allow time to dry 30 min (to iron)
2	<b>Measuring and marking material</b> Measure and check pattern pieces Lay out fabric so that grain is straight Pin pattern pieces to fabric, use chalk if needed	Tape measure Pins Tailor's chalk	1–2 h
3	<b>Cutting</b> Cut fabric carefully around the edge of all pattern pieces.	Scissors	30 min
4	<b>Joining fabric</b> • Overlock edges of the skirt piece	Overlocker	45 min
5	• Tack zip to skirt, iron, sew in place; Even up fabric edges either side of zip	Sewing machine	10 min
6	• Tack top of skirt to be gathered; Pull these threads and even out gathers	Needle and thread	60 min
7	• Sew top of skirt to bottom edge of waistband	Iron	30 min
8	• Iron waistband over and hand-stitch other edge to inside of skirt	Sewing machine with buttonhole stitch	20 min
9	• Mark buttonholes on waistband; Sew buttonholes, and cut open; Sew buttons in correct position.		5 min
10	<b>Finishing</b> Cut all loose threads or sew them in; iron!	Scissors Iron	60 min
<b>Approximate time expected</b>			6–7 hours

The following table gives you some guiding questions to help create your own sequence plan for a wood, metal or plastics project.

Your own production plan table will need additional columns for the safety procedures and the estimated time for each step. If the same safety

procedures are repeated for each step (especially in a sewing project), you can omit the safety column and include an overall paragraph under the table.

For a garment, use the commercial pattern instructions as the basis for your sequence of steps.

### Guiding questions for a production plan

## PRODUCTION STEPS

NAME OF PRODUCT: FOR EXAMPLE, WOODEN COFFEE TABLE		
STEP	DESCRIPTION OF STEP/PROCESSES (INCLUDE MATERIALS)	EQUIPMENT, TOOLS AND/OR MACHINERY
1	<b>Preparing the material</b> <ul style="list-style-type: none"> <li>Name the material.</li> <li>Does it need to be washed or cleaned? Straightened? Checked for squareness, defects, etc.</li> </ul>	What will you use to do this?
2	<b>Measuring</b> <ul style="list-style-type: none"> <li>What will you be measuring? Name the pieces and parts. <i>e.g. Measure dressed timber for leg lengths, rails and top.</i></li> </ul>	What will you use to measure accurately?
3	<b>Marking</b> (or placing pattern pieces on material) <ul style="list-style-type: none"> <li>What pieces will be marked? Name them. <i>e.g. Mark out the mortise and tenon joints; mark centre of dowel joints on planks for table top.</i></li> </ul>	What will you use to mark out the material accurately?
4	<b>Cutting</b> material <ul style="list-style-type: none"> <li>What pieces will be cut? Name them. <i>e.g. Cut all legs to 300 mm; cut rails and planks for the table top to 250 mm.</i></li> </ul>	What will you use to cut and what will help you cut accurately?
5	<b>Shaping</b> (relevant to resistant materials) <ul style="list-style-type: none"> <li>Do any pieces need to be shaped? <i>e.g. Shape the curve on the legs; gouge out the recess; cut decorative edge to table top.</i></li> </ul>	What will you use to shape and what will help you shape accurately?
6	<b>Joining</b> (you will need to break into the number of steps needed) <ul style="list-style-type: none"> <li>Which pieces will be joined first and with what type of join? How will you set up for this? <i>e.g. Secure work, drill holes for dowels, pare back mortises in legs; cut dowels for holes (slightly shorter than hole depth); cut out the tenons on the rails; dry-fit rails to legs; check squareness; join planks; clean up glue.</i></li> </ul> Joining or attaching components <ul style="list-style-type: none"> <li>Which components will be attached and how? <i>e.g. Mark out hinge position.</i></li> </ul>	List each step for your project in its own row and the equipment needed.
7		
8		
9	<b>Assembling</b> <ul style="list-style-type: none"> <li>What needs to be assembled and when? Name the pieces. <i>e.g. Attach table top to legs with brackets.</i></li> </ul>	What will you use to do this?
10	<b>Finishing</b> <ul style="list-style-type: none"> <li>What needs to be done to finish the product? Include more steps if necessary. <i>e.g. Plane and sand table top surface and ends; sand complete table using gradually finer grades of sandpaper; Apply two coats of finish (sanding between each).</i></li> </ul>	What will you use to do this?

Note: change the order of the steps or add additional processes (such as a decorative process) where needed.

## Planning for service designs

For a service design, you could include:

- maps or building plans to show people movement and directions
- list and costs of equipment needed
- plans to show placement of equipment
- timeframes for implementation and availability of the service
- safety analyses for the equipment, staff and the users of the service
- photos, drawings or mood boards to show aesthetic aspects of the place where the service will occur; for example, colours, aromas, lighting, noise, temperature, privacy, space and comfort
- list of perceived benefits of the service, both physical and psychological.

## Planning the available time

Once the sequence or order of steps is planned in detail, you can create a timeline of the dates that each step is expected to be completed. Again, don't worry that it may not go exactly as planned – it's just a plan.

The timeline should match the number of steps in your sequence plan. In the example for making a

skirt (see page 27) there are 10 steps. An example timeline for that sequence is given in the following table. This timeline assumes that the practical work is being completed in class sessions of 2 hours. It also allows for preparation and cleaning up time. The shaded area marks the date that each step is expected to be completed. Your teacher will help you with the dates.

From this timeline, you can see that the student expects to finish steps 2 and 3 on 20 April, and steps 8 and 9 on 4 May. Work out which steps can be combined in one session. If you are unsure, you can always complete trials of processes and document how long they take.

Timelines can be created digitally as a Microsoft Word table, an Excel spreadsheet, or by using many other software programs and apps.

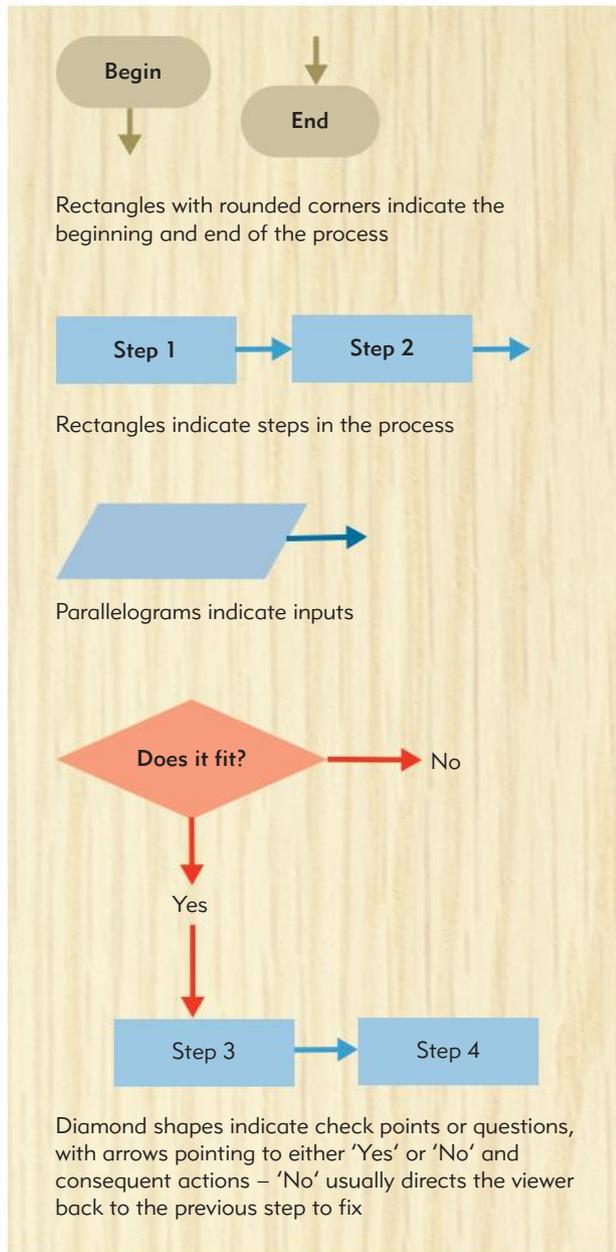
## Using flowcharts

A flowchart can also be used to show your planning as a timeline. A flowchart is made of certain shapes and lines to show step-by-step processes and indicate where checks need to be made. It is very useful for products with mechanical or electronic parts.

### Example of a timeline for a skirt

STEP	DATES							
	10 APRIL	13 APRIL	20 APRIL	23 APRIL	29 APRIL	2 MAY	4 MAY	10 MAY
1 Preparation								
2 Measure/ mark								
3 Cutting								
4 Gathering								
5 Join skirt to waist								
6 Finish waistband								
7 Insert zipper								
8 Buttonholes								
9 Buttons								
10 Loose threads/iron								

The following diagram shows the shapes used in a basic flowchart. There are more shapes involved in complicated flowchart. Once again, it is far more useful to attempt to create your own flowchart by yourself. Use all your previous planning to help you.



**The components of a flowchart**

## Planning for safety

Safety is crucial during production. It is important to follow safe practices whenever you are carrying out processes, but it is also important to ensure that your product is safe for any user. To do this, we think ahead for possible safety problems and plan for them. We create a **risk assessment** and use **risk management** throughout production.

### Risk assessment

Risk assessment involves looking at the processes we plan to use and identifying the **hazards**, the **risk** of them causing a problem, the likelihood of this happening, and the safety guidelines, controls or precautions to prevent any problems.

### Note

A **hazard** is a dangerous object, action, situation or behaviour.

A **risk** is the chance, possibility or potential of the hazard causing harm, a problem or a negative outcome. In a risk assessment document, risk refers to the chance of something happening that will have a negative impact on the health or safety of a person.

### Risk management

Risk management involves creating a risk assessment, and referring to it as you work through production. Your teacher will also be checking classroom controls, analysing the approach, reporting any 'incidents' (near-accidents), having a response plan, and amending safety plans. You must follow all safety instructions and plans.

If you are unable to keep the risk to an acceptable level, or you are unable to implement any control or precautions (or if your teacher thinks so), then you should exclude or eliminate that process from the activity.

Your risk assessment will outline the practical activities, the likelihood or possibility of injury, and then the precautions needed.

### Example of a risk assessment for a textiles project

PROCESS OR ACTIVITY	HAZARD	POSSIBLE INJURY	RISK (1-5)	CONTROL OR ELIMINATE BY:
Moving around the workshop	<ul style="list-style-type: none"> <li>Cords or equipment that may be laying around, especially on the floor or across walkways</li> <li>Sharp pins</li> </ul>	<ul style="list-style-type: none"> <li>Could cause tripping or other injuries</li> <li>Could pierce hands or feet</li> </ul>	3	<ul style="list-style-type: none"> <li>Keep the sewing area neat and tidy. Make sure all power cords are in a position where they will not be tripped over.</li> <li>Keep scissors in a sensible place, such as on the desk.</li> <li>Make sure all pins are kept in a container and returned once they are no longer in use.</li> </ul>
Cutting procedures	<ul style="list-style-type: none"> <li>Sharp blades on scissors</li> </ul>	<ul style="list-style-type: none"> <li>Could cut hands or pierce foot if dropped</li> </ul>	2	<ul style="list-style-type: none"> <li>When cutting, make sure it is done on a flat surface rather than on your lap or by holding material in your hand.</li> <li>Keep scissors closed when moving around.</li> </ul>
Sewing	<ul style="list-style-type: none"> <li>Sharp machine-powered needles</li> <li>Insufficient lighting</li> <li>Bad ergonomic set-up (such as desk too low or machine too far away)</li> </ul>	<ul style="list-style-type: none"> <li>Could pierce the skin</li> <li>Could strain eyesight</li> <li>Could induce bad posture, which could lead to neck and spine problems</li> </ul>	2	<ul style="list-style-type: none"> <li>Make sure fingers are at a reasonable distance from the foot of the machine.</li> <li>Set up a lamp in the working area if extra light is required.</li> <li>Check seating and table are at the correct height. Sit up straight with ears in line with shoulders, and take regular breaks to stretch.</li> </ul>

### Note

**Ergonomics** is the science of designing machines, products and workspaces to fit the people using them to avoid fatigue, strain, accidents and injury.

For example, a sewing workstation should have the height of the chair and table adjusted to suit the user, which will ensure correct and safe posture.



**Good ergonomic set-up and straight posture while sewing are important for your spine.**

### General safety

The following are some general safety considerations.

- **Workspace** – Keep it clear with everything in its place. Clear the floor of all obstacles so that you don't trip over anything while concentrating on your work.
- **Lifting and moving materials** – Use suitable lifting equipment whenever possible. Learn and use the correct method for lifting.
- **Lighting** – Be sure the lighting is adequate to avoid eyestrain or making dangerous mistakes because you can't see properly.
- **Ventilation** – It is important to remove toxic dust, gases and vapours prior to them reaching dangerous levels.
- **Personal protection equipment (PPE)** – Always wear any protective gear recommended for hazardous processes. Some are outlined below.
  - **Eye and face protection** – Available for varying purposes, from flexible goggles to welding masks. Normal eyeglasses are not considered as a satisfactory substitute for safety glasses.
  - **Footwear** – Most work-related foot injuries are caused by falling objects. In a wood or metal workshop, wear reinforced, impact-resistant shoes or boots. Do not wear sandals.

- Ear protection – Exposure to consistently high noise levels has been shown to cause fatigue, stress, and emotional disturbance in workers. Use earplugs or earmuffs depending on the volume.
- Respiratory protection – Dust and particles of any type can cause serious respiratory problems. Masks may be of a disposable paper-type, or consist of a more substantial rubber nose and mouthpiece with interchangeable cartridges to filter the air.
- **Product safety** – It is a legal requirement that all products for sale in Australia are safe for the user, so it's important to keep this in mind when you are designing and making a product.
- **Materials** – Find out about the materials you are using and any toxicity that may affect your health or a user's health. Obtain a **Safety Data Sheet (SDS)**, previously called a Materials Safety Data Sheet, and follow all precautions.

### Safety

A Safety Data Sheet (SDS) provides information about substances and their associated hazards. If you are working with a hazardous substance (for example, mineral turpentine), you should have its current SDS. It describes the properties and uses of a substance, health-hazard information, precautions for use, and safe handling requirements. An SDS for most hazardous substances will be available online.

### Planning for quality in production

**Quality** has many definitions. When it comes to products, quality can be defined as 'fit for purpose' or suitable for the situation. It also means a degree or standard of excellence. When we say something is 'good quality', we usually mean that it works as expected – it is well-designed, well-made and of good quality material.

You can improve the quality of your work by:

- being clear about the purpose of your product and the problem it solves
- exploring materials so that you recognise which materials are the most suitable for different situations
- listening to advice and choosing the best methods for cutting, joining and finishing
- trialling processes on scrap materials and repeating them

- using equipment correctly so that it helps you to be accurate
- checking measurements before each process
- asking for help when unsure
- analysing your work at all stages to check it is going to fit its purpose.

## PRODUCING

The hard work of resolving your design, planning your procedures, and then preparing, testing and trialling materials means you are now ready to make your product. There will probably be aspects that still need to be tweaked, such as some of the steps in the production plan, but sometimes you won't know what you need until you are at that point.

The term **production** refers to the making of the product. All productions have the same major processes. Processes are the changes that you put your material through. Their main processes are marking out, cutting and shaping, joining and finishing. You can read more about materials, processes and production in Chapter 2.

As mentioned earlier on page 31, follow your risk assessment throughout production.

### Documenting progress

As you work on your production, you will need to document each step of the process. The best way is to take photos and present these with labels and explanations. This will be called your log or journal. One journal method is to insert photos and relevant log entries into a digital document after each session. Your teacher will probably also ask for a collection of all your journals as one large story showing the production stages of your design process.

### Naming processes and equipment

In your journal, name all the processes and equipment you use. You will need to learn these from your teacher, this textbook or the internet. It is important to do this so your communication and documentation is very clear.

### Recording changes during design and production

You will need to show any changes (modifications) that you made to your designs, material choices and production processes. List the types of changes



Date: 20/03/16

Time spent: 20 minutes

Equipment used: Overlocker, long-handled tweezers  
(for threading), reading light

Process: I spent most of this time re-threading the overlocker with a different coloured thread. This was very difficult and I had to do it several times before the overlocker would sew how I wanted to. By then, I got so frustrated I decided to pack up for the day.

Date: 22/03/16

Time spent: 3 hours

Equipment used: Overlocker, reading light, iron

Process: Mum helped me set up the overlocker to do a rolled hem. I hemmed the edge of the skirt but missed some of the edge, so I had to do it again. This made the length a little shorter than planned.

Example of log entries

that were made and why they were made (see the example of log entries). Keep notes of any discussions you had with your teacher – what suggestions they made and what you did because of their advice. Add this information to your log near the relevant photos.

### Planning ahead

When it's time to pack up, make a note of where you are up to and what you will need for next session. This can save a lot of time and prevent minutes of wondering, 'What was I up to?'

#### FOCUS ACTIVITY

### Processes and planning

- 1 What processes have you completed in your current project? Name the processes and all the equipment needed.
- 2 What is a modification? Explain a modification that could occur if you realised you did not cut a piece of your product big enough. Your explanation could include an annotated diagram.
- 3 In a small group, discuss why it is a good idea to write notes for your next production session.
- 4 What is risk management? Name some risk management activities you will need to complete for your project.

## EVALUATING

We analyse and evaluate our efforts to see whether or not we have achieved what we set out to do. In the design process, evaluation involves thinking critically about our designs (are they a good solution to the design brief?) and the finished product (does it measure up to our expectations?). We also look to see what improvements could be made for the future.

When evaluating finished products, we look at:

- the **solution** (finished product, service or built environment) and how suitable it is for its intended purpose – how it satisfies the design brief and/or the previously developed criteria for success (or evaluation criteria)
- the **designing activities** that led to the solution and how they could be improved

- the **processes** – the way it was created and what improvements could be made
- any **materials and equipment** used and consider whether they were the most suitable
- the **sustainability** of the solution.

Each of these can be checked or ‘tested’ on the finished project to see if they were satisfied.

### Testing/checking the product

To decide if the product has satisfied the criteria for success, the product must be put through some simple ‘tests’ or checks.

#### Examples of criteria and suitable tests

PRODUCT	CRITERIA	CHECK OR TEST
Furniture or household items	Does the container hold 10 CDs as required?	Get 10 CDs and place them into the container to see how easily they fit.
	Does the chair sit stably without rocking?	Sit on the chair and rock back and forth to judge how much it wobbles or stays stable.
	Does the storage unit stay square and not skew?	Push the unit from the side to see that it remains square.
	Does the sensor work effectively?	Wave a hand across the sensor and see if it reacts.
Clothing or textile products	Is the product strong?	Push and pull to see if it is strong.
	Are the seams straight with no gaps?	Inspect the seams and tug and pull them.
	Do the buttons match the buttonholes?	Do all the buttonholes up and check for evenness.
	Has suitable thread been used on all seams?	Inspect the thread used on the garment for suitable thickness and colour.
Services	Do the users feel comfortable being in the space?	Ask a few potential users to be in the space and get their feedback.
	Were the users kept waiting too long?	Do a trial run and ask some of the users for their feedback.

Once you have tested/checked the solution, write an explanation of how well the criteria for success have been addressed. Your responses require more than a ‘Yes’ or ‘No’ answer. Each response should be an explanation.

#### More questions to guide you in evaluating your product

<b>Functional aspects</b>	<ul style="list-style-type: none"> <li>• Does it fulfil its function (perform) as expected? (Write the expected function and the name of your product and explain how well it works.)</li> <li>• Was the product the right size? Does it fit? (Explain the size it needed to be and its actual size.)</li> <li>• Does it hold what it was meant to hold? (Explain what it needed to hold and how many or how the contents fit into it.)</li> <li>• Do the fastenings work effectively? (Describe the fasteners used, what they need to do and how well they work.)</li> </ul>
<b>Aesthetic aspects</b>	<ul style="list-style-type: none"> <li>• Were the colours as expected? (Describe the colours expected and the actual colours of your project.)</li> <li>• How might the design be improved aesthetically? (Suggest some shapes, proportions, textures or colours that could make your product more aesthetic.)</li> <li>• What do I like or dislike about the look of the product?</li> </ul>
<b>Suitability of the materials</b>	<ul style="list-style-type: none"> <li>• Is the fabric or material/s suitable? Why? (Name the material and explain why it is suitable.)</li> </ul>
<b>Quality of production processes</b>	<ul style="list-style-type: none"> <li>• Were the processes completed accurately? (Name the processes and explain the degree of accuracy and how it could be improved.)</li> <li>• Were the processes completed efficiently with minimal waste of time and materials? (Outline the time you took and where time was wasted. Outline the waste material you created and how it could have been minimised.)</li> </ul>

## Evaluating the design process

### Questions to guide you in evaluating your process

<b>Designing</b>	<ul style="list-style-type: none"><li>• Did I research and explore a lot of ideas for this project?</li><li>• Was I able to draft a working drawing with enough information to follow?</li></ul>
<b>Organisation</b>	<ul style="list-style-type: none"><li>• Was it finished on time? Did I need to plan my time better?</li><li>• Did it take as long or longer than I expected? What took longer than expected?</li><li>• Did I follow the steps in my plans? Why or why not?</li><li>• What problems did I have and how did I manage them?</li></ul>
<b>Skills</b>	<ul style="list-style-type: none"><li>• What did I set out to learn and how did it go? Explain the easy parts and the harder parts.</li><li>• What safety precautions did I take?</li><li>• What could have been improved in any of the cutting, shaping, joining and finishing processes?</li></ul>

### FOCUS ACTIVITY

## Presenting an evaluation report

You can present your evaluation in front of the class or in written form as a report. The evaluation has two parts.

### Part 1

List your criteria for success. Explain how you checked or tested your product for each criterion. Explain how well the product met this criterion in both your own opinion and (where possible) from another person.

### Part 2

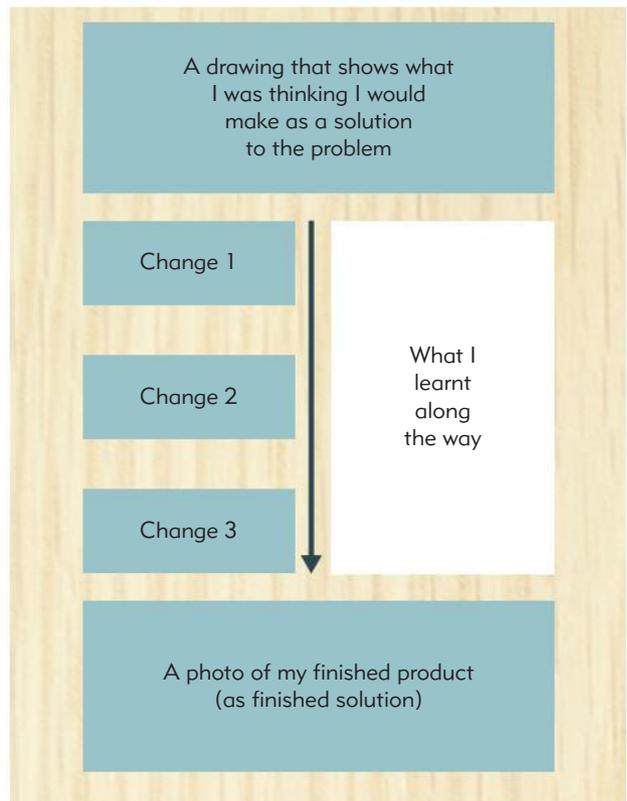
Write a paragraph for each of the areas 'Designing', 'Organisation' and 'Skills' using the guiding questions from the table (but only respond to the questions that are relevant to you).

### FOCUS ACTIVITY

## Visual evaluation of your design journey

Choose one of these visual methods of evaluation:

- 1 Create your own graphic organiser as below with two big shapes at the top and the bottom of the page. Between the two shapes, create several smaller shapes. In the large shape at the top, draw what you were thinking about as a solution to the problem. In the shape at the bottom, insert a photo of your finished solution. Fill the smaller shapes with any changes or mistakes you made and all the things you learnt along the way.
- 2 Insert a copy of your final design drawing and a photograph of your finished solution. Annotate the aspects that are the same and those that are different.



# TYPICAL TASKS FOR A PROJECT FOLLOWING THE DESIGN PROCESS

## TASK 1 – RESEARCHING, INVESTIGATING AND MAKING DECISIONS

- Show evidence of your research and investigation that led to your choice of design problem, opportunity or need.
- Write a design brief with criteria for success.

## TASK 2 – RESEARCHING FURTHER

- Present information regarding the design problem, the situation and the possible materials and processes that could be used.
- Present images that inspire you.

## TASK 3 – DESIGNING

- Present idea sketches or design ideas.
- Write annotations to explain the ideas that could be developed further and those that should be rejected.
- Present two or more numbered and annotated design options that show use of the design elements and principles, or construct a scale model or a digital image.
- Write a justification (a statement that explains the final design).

## TASK 4 – PLANNING

- Create two-dimensional working drawings (for example, pattern pieces).
- Write a sequence plan (5–10 steps), a timeline and a materials list for making the product.
- Write a list of all the processes involved in a risk assessment

## TASK 5 – TESTS AND TRIALS

- Identify and correctly name the materials and equipment that you intend to work with. Document this with samples, photos (your own or others') and/or diagrams.
- Carry out some skills tests and trials with the materials and equipment. Document with photos and/or diagrams and captions.

## TASK 6 – PRODUCING

- Manage risks to make your product, safely and accurately.
- Document your work with photographs and captions.

## TASK 7 – EVALUATING

- Write an evaluation report on how your product turned out and whether it met the aesthetic, functionality and sustainability expectations, as outlined in your criteria for success in the design brief.

Flowchart of design process – tasks could be presented in a design folio to show your design journey

# FACTORS INFLUENCING DESIGN DECISIONS

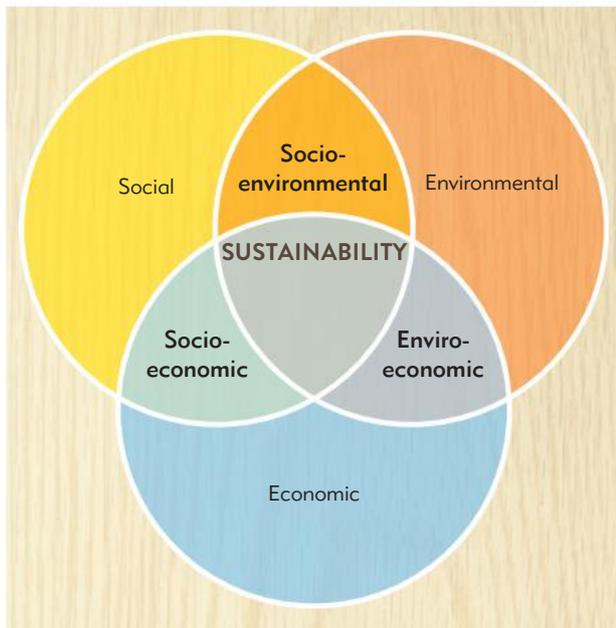
Throughout the design process you will be applying knowledge, practical skills and processes. You will need to consider:

- what technologies and resources are available
- how to create innovative solutions
- current and future needs
- sustainability – with its three overlapping and intertwining areas of environmental, social and economic factors
- aesthetic and functional requirements
- the suitability of enterprise and marketing for the designed solution.

# SUSTAINABILITY

Sustainability is about being long-lasting. Sustainable design means using natural and human resources in a way that does not **jeopardise** or put at risk the opportunities of future generations.

Sustainability can be considered as a stool with three legs – the legs represent environmental, social and economic impacts. If either of the legs becomes weak or wobbly, the seat is not truly supported.



**Venn diagram showing how the three areas of sustainability are interconnected**

Sustainability can also be thought of as:

- happy people
- healthy planet
- financial fairness.

All products have environmental, social and economic impacts. These impacts come from the sourcing and extracting of materials, and from the manufacturing of products. The impacts may also come about during the use of products and when products are discarded.

‘Designers should define their role broadly as agents of good in the world, and limit their work to “legitimate” products: those that are needed, and those that can be made without damage to nature or – through the unethical actions of manufacturers and investors – damage to people.’

Philippe Starck, renowned French designer

# DESIGN ELEMENTS AND PRINCIPLES

The **design elements** and **design principles** are what we use when creating any design. They are used in communication design, product design and design of environments. They are the visual and creative tools for well-designed and aesthetically pleasing products.

## Design elements

The design elements are the building blocks of designs.

### The six design elements

<b>Line</b>	<b>Shape</b>	<b>Form</b>
<b>Tone</b>	<b>Texture</b>	<b>Colour</b>

## Line

A line goes from one point to another. Lines can be described as thick, thin, uniform, straight, curved, broken, zig-zagged, spiralled, freeform, hatched or cross-hatched, and they can be interrupted or flow through a product. Lines can be seen in edges of a design (such as the intersection of walls and roofs in buildings) or in a line of stitching (such as the hem of a skirt). They can be varied to create patterns on the surface of products or to emphasise the area of a surface. Lines can also be described as vertical, horizontal, perpendicular, parallel, diverging or random.



Thick yellow lines are used on footpaths to mark boundaries



Lines of various thickness, colour and nature can be used to create patterns

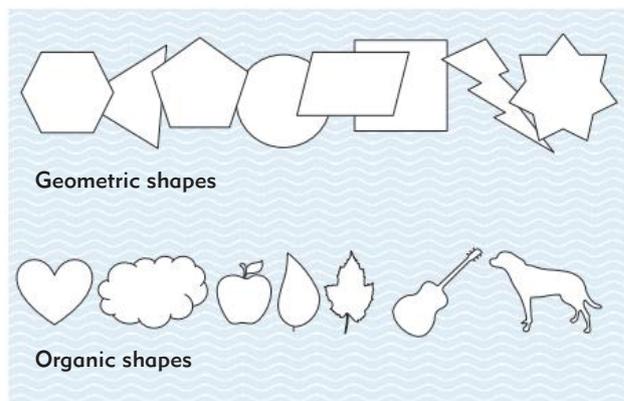
## Shape

Shape is two-dimensional – created by a line meeting itself. It is flat and fits into an area of space determined by two dimensions: length and width. Shapes can be described as geometric or organic. Geometric shapes include triangles, circles (including half-moon, pie slices, etc.), squares, rectangles and other parallelograms, and unusual shapes with straight edges and sharp corners. Mathematical rules govern many geometric shapes. Organic shapes tend to be ‘softer’, curvier or freeform, as they don’t appear to follow rules. They may have names such as love-hearts, clouds or leaves.

You can see a combination of both geometric and organic forms in many products. Shapes can be used not only to dictate a plane or a surface of a product, but also to create patterns on the surface of products. A silhouette is a shape.



Silhouettes of people on the outer edge of a building in St Kilda add colour and interest

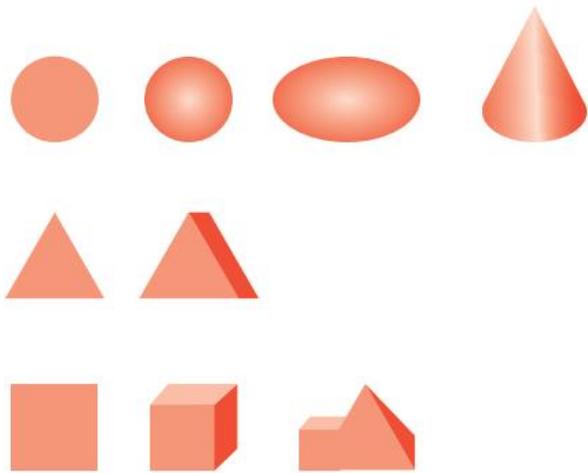


Geometric and organic shapes

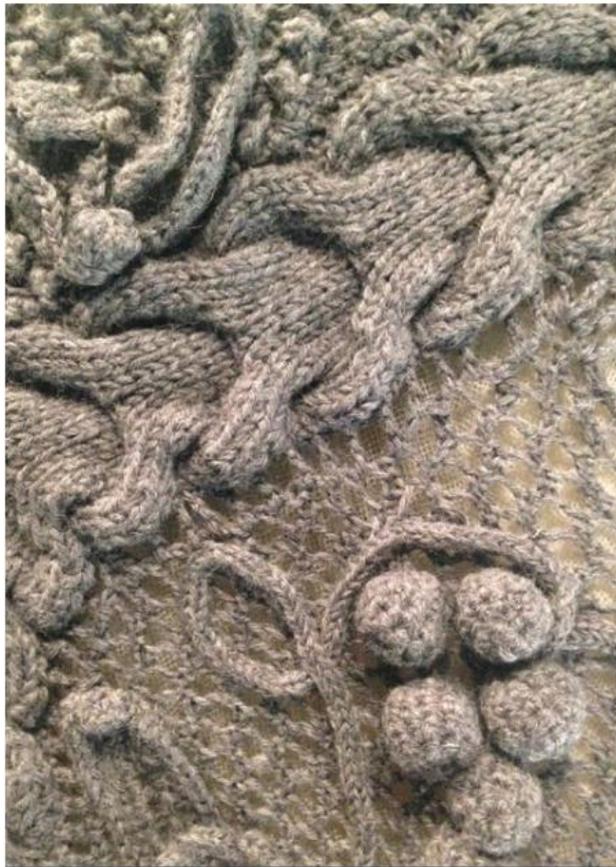
## Form

Form is three-dimensional, not flat. It fits into an area of space determined by three dimensions: length, width and height (or depth). Shape is the basis of form. Similar to shape, form can be described as geometric or organic. Geometric forms are uniform and governed by specific mathematical rules.

Forms are also described as bulky, light, monolithic (large and rock-like), fragile, showing rhythm or tension, being balanced, and being or appearing stable.



**Different three-dimensional forms for circles, triangles, and rectangles**



**Detail of organic forms and texture in a Jean-Paul Gaultier knitted garment**

## Texture

Texture is the surface or feel of materials. It is felt by our sense of touch and seen with our sense of sight. The word **tactile** is used to explain the sensation of touch, or the look of how it would feel. Texture invites us to judge the comfort or discomfort, warmth or coolness, roughness or smoothness of a surface, or the heaviness or lightness of an object. Texture can separate parts or components in a design and provide contrast. Textures are described as rough, smooth, shiny, corrugated, rippled, matte, sticky, soft, furry, bumpy, scratchy, cold or warm.



**Objects with very different textures**

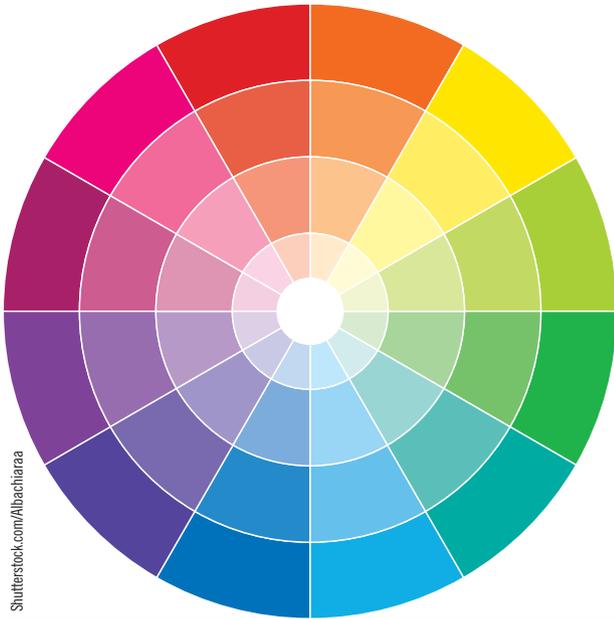
## Colour

Colour comes to us as light reflected or transmitted off surfaces. All colours are called 'hues', except for black and white. Colour changes according to where the light is reflected from and what is nearby.

Colour is used to attract or focus attention, to suggest a feeling, emotion or mood, or to emphasise shape or form. It can be used in unexpected ways to excite or add interest. Colour is also used to beautify things or to make them more aesthetic.

Colours are organised in groups, as shown on a colour wheel.

- Primary colours are red, yellow and blue.
- Secondary colours are a mix of primary colours: red + blue = purple; red + yellow = orange; blue + yellow = green.
- Tertiary colours are secondary colours mixed with one of its primary colours, such as purple + red, or purple + blue.



**A colour wheel**

A secondary colour is **complementary** to the primary colour it is opposite to on the colour wheel (yellow vs purple, red vs green, blue vs orange). Complementary colours provide strong contrast – they stand out against each other, which can be of practical use in products with safety issues. For example, life rafts are often orange to provide visible contrast against ‘blue’ water. Safety vests for construction workers are yellow or lime-green to stand out against the darker colours of building materials and roads.



**Orange stands out as it complementary to the surrounding colours**

Other colours are **harmonious** colours that work well together. There is a lot of theory on how to use colours for certain effects, but the best way for you to decide is to experiment and explore combinations.

There are many words to describe the feelings that colour evokes, such as warm (red/yellow), cool (blue tints), angry, soothing, bright, happy, energetic, playful, summery, wintery, autumnal and dangerous.

### Tone

Tone can refer to the shade of colour applied, the feeling of a colour scheme, the degree of colour applied according to the amount of black or white added, or the spread of a colour from a dark shade to a lighter shade. Tone is easily identified in a two-dimensional shape or drawing, but is sometimes harder to see in three-dimensional form as there may be some confusion for the viewer depending on the angle or the light. The word ‘tonal’ is used to describe colour when the grading of tone is obvious and when there are various shades or tints of the one colour.



**Tone is used in design drawings to show form**

### Transparency, translucency and opacity

Transparency, translucency and opacity are words used to describe colours and materials.

Transparent describes materials such as glass, plastic or fine fabric that allow light to pass through them and objects to be seen through them. Some transparent materials also have a colour, such as tinted glass and plastic or fine-coloured fabric

Translucent describes materials that allow some light to pass through them but objects cannot be distinguished through them, such as frosted glass for bathroom windows and acrylic shower curtains.

Opaque describes materials that light does not pass through – we cannot see any objects through them.



Examples of transparent, translucent and opaque objects

FOCUS ACTIVITY

## Identifying design elements

- 1 There are many visual examples given for each design element in the images on pages 38–41, yet many of the examples also include other design elements. List each example and describe two other design elements you can see.
- 2 Pick out three moods or feelings listed under the colour wheel and choose a colour that you relate to this mood.
- 3 Describe four design elements of a project you have recently worked on and draw examples of each element. Use some of the suggestions for creative thinking on page 17 and add to your own design drawings to create new ideas.
- 5 Look at the following image of glasses cases and outline four design elements by describing the shapes, forms, colours, lines and textures you can see. There are useful words in the chapter for each design element under the relevant headings that will help you describe them.



Handmade glasses cases

## Design principles

Design principles can be thought of as the ways in which design elements (the building blocks of design) have been arranged or used.

### Examples of some design principles

Space – positive and negative	Balance	Harmony/unity
Pattern and repetition	Proportion	Movement/rhythm
Symmetry or asymmetry	Contrast/emphasis	Scale

There are other words to name design principles such as emphasis, variety, proximity, visual hierarchy, visual weight, alignment, tension, focal point and surface qualities. In this text, we will concentrate on the design principles given in the table. It's important to learn language to describe design principles so that you can communicate how they have been used to arrange the design elements in a work.

### Space – positive and negative

Space is the area in, around and between something. Designing involves arranging the elements in and around space. Three-dimensional designs (forms) have length, width, height and occupy a 'space'. They also have a close relationship with their surrounding space; for example, interior design, buildings, gardens and furniture. Space can be considered as positive or negative. Positive space is the space the object takes up or occupies. Negative space is the area around the object or spaces within the object, such as windows in a building, the space inside a handle, 'cut-away' parts on clothing, or between the slats of a backrest on a chair.



**Close-up of detail of 'cut-away' from a Jean Paul Gaultier garment**

### Balance

Balance is the distribution of visual weight by the placement of lines, colours, texture and forms. This can be achieved by symmetry (elements on one side of the design being similar to those on the other side), or by asymmetry (the sides are different but still look balanced). For example, a large pale-coloured form that is off-centre can be balanced by a small, brightly coloured form on its opposite side. A balanced design has a feeling of stability – it doesn't appear to tip over or look 'uncomfortable'. Balance can be achieved by **manipulating** any other of the design principles.

### Harmony/unity

Unity in a design gives a feeling of harmony. Unity is sometimes achieved by repeating aspects of a design in **proximity** or within the design itself.

### Pattern and repetition

Pattern refers to a repeated feature such as a line, a colour, a shape or a texture. Patterns are often used as surface decoration on materials. In fabric, a pattern is usually printed, but a repeated process of the fabric

(such as a twisted pleat) can also create a physical pattern. Some patterns may alternate, be slightly irregular or slowly change (for example, get bigger or smaller). Patterns in nature are usually irregular, such as the grain of wood or veins in a leaf. The parts do not always repeat in an identical way, but they often echo each other. Some of these patterns in nature are called fractals.

Although repetition is an important part of creating patterns, it also works with aspects of a design to create a feeling of unity or rhythm (two other design principles) – for either the object as a whole or for the object and its surrounds. One repeating line or shape in different products can tie them together. For example, a piece of furniture can repeat certain symbols or lines from the building it will be placed in. This can add a soothing feeling.

### Note

The word 'pattern' also means template, which is a single shape.



**Pattern and repetition in construction**

### Proportion

Proportion refers to the relation of parts within a design – their size and the space between. For example, we expect the backrest of a child's chair to be in proportion to the size of the seat. The human body is a measure by which we judge the appropriateness and proportions of objects.

Designers sometimes deliberately exaggerate and distort proportions to create deliberate tension or interest. For example, a sofa in the form of a giant hand attracts the viewer as the proportion we

expect is distorted. Public or corporate spaces are often of huge proportions to create feelings of awe in those who enter. The proportions of our homes are more in scale with human measurements, and feel friendlier, more comfortable and less intimidating.

### Movement/rhythm

Movement is dependent on the lines, edges, shape, and colour within a design. These elements can be arranged to direct the path of the viewer's eye to focal areas. They also contribute to the feeling of 'aliveness' in the design. The elements may make the viewer feel as though the piece is heading somewhere, as if it is 'on the move'. When one or more elements of design are repeated, it creates a feeling of rhythm.

### Symmetry or asymmetry

When an object is symmetrical, you can place a line through the centre and one side is a mirror image of the other. Some objects or shapes have more than one line of symmetry. Symmetry lines can be vertical, horizontal and/or diagonal. Symmetry is a common way to achieve balance in a design.

An object that is asymmetrical has no lines of symmetry. The two sides of an imaginary central line are not the same. The object can still be balanced – the designer can use other design elements (such as colour) to provide balance and unity.

### Contrast and emphasis

Contrast is the **juxtaposition** of opposites, (putting different things next to each other) such as complementary colours (see page 40), light and dark, thick and thin, and furry and metallic. Contrast can also be a direction, such as horizontal and vertical.

Our eyes are naturally drawn to any area of visual contrast. Contrast is used to separate parts or create interest. It can be achieved with textures and colours of materials, and by combining geometric and organic shapes and forms. This method is often used to emphasise part of the design.



**Contrast in construction**

### Scale

Scale refers to the relation between something real and a model or representation of it. You will probably be familiar with scale on maps, but in design we mostly use scale in diagrams and drawings – particularly when making models (such as a miniature cardboard model for a chair design). Read more about scale in relation to working drawings on page 24.

When used as a design principle, the scale refers to the size of an object compared with what is expected or usual, or compared with other objects. Scale within a design can be played with, and can be exaggerated or reduced for effect. Some examples of this effect are a giant handle on a product, very thin legs on a table, large buttons, and elongated thick stitching on a garment. The scale might also be suggested; for example, a shell or covering makes part of a product appear larger than it is.

Part of an object can be scaled down and repeated to create a pattern or a feeling of movement (two other design principles). For example, a circular shape could be repeated in gradually reduced sizes to create not only a pattern, but also a feeling of upward movement.

## DESIGN STYLES

In design, a style is made up of certain design elements and principles that are grouped and arranged in a recognisable way. This is most easily seen in furniture, architecture and clothing. Styles are often named for the era in which they occurred, or by a philosophical movement.

Older historical styles include medieval, Tudor, Gothic, Renaissance and baroque.

There are many styles of the 1900s named by the era:

- 1920s – flapper-style of dress, Art Deco and Art Nouveau styles of building and furniture, Bauhaus style of building and furniture (emphasised function by using straight lines and with little decorative elements)
- 1950s – rockabilly dress style
- 1960s – hippy style
- 1980s – power-dressing style.

Some styles are named after a branch of philosophy or an artistic movement.

- Shaker – a religious group that believed in simplicity and hated dust, so all interiors were designed to be easily cleaned.
- Art Nouveau – a style of paintings, buildings and furniture in which craftsmanship and natural forms are embraced.
- Zen – a minimalist style with clean lines, simple shapes and no clutter.

Many styles are named after the country they are associated with:

- Japanese – minimalist and clean lines
- Indian – lots of bright colours, silver and gold, and intricate detail
- Moroccan – use of coloured, tiled patterns contrasting with desert colours.

Many designers are known for their individual style. Canadian architect Frank Gehry has his own distinct style. Many of his buildings stem from his life-long love of fish – how they move and how their scales move. His style is evident in the Guggenheim Museum Bilbao, in northern Spain. In Australia, he designed the business school for the University of Technology Sydney, which opened in 2015. Gehry said he was inspired by folds in skin and clothing, although many critics said the building looked like a squashed paper bag.

Jean-Paul Gaultier is a French fashion designer who also has his own distinct style. He uses a combination of elements that might be considered out of the ordinary, such as unexpected textures in garments. His haute couture outfits are usually extremely detailed and take hundreds of hours to construct.

### Note

**Haute couture** is a French term that means 'high sewing'. It refers to the time, skill and effort that goes into creating a well-designed, handmade gown from the highest-quality fabric. Garments are custom-made – designed and sewn to fit a specific person. For a fashion house to call itself 'haute couture', it must comply with some strict regulations. You can research this online.



Frank Gehry designed the Guggenheim Museum Bilbao in Spain (left) and the Dr Chau Chak Wing Building at University of Technology Sydney (right).



**Jean-Paul Gaultier garments with obvious textures**

Alessi is an industrial arts factory, founded near Milan in Italy. It is renowned for producing objects that are not only usable, but also look good. Aesthetics is an important aspect of the designs. Alessi sources designers from all over the world and has put the work of many Australian designers into production. In recent years, Australians have made up a big contingent of foreigner designers. Some of these Australian designers are: Marc Newson, Adam Cornish, Susan Cohn, Abi Alice, Adam Goodrum, Lisa Vincitorio, Jim Hannon-Tan and Helen Kontouris.



**'Piccantino' chilli scruncher by Jim Hannon-Tan for Alessi**

Looking at design styles can be useful in your design journey. It helps you to decide what you like and to trigger ideas. Styles can be chosen from history or from contemporary situations. You can invent your own style by combining design elements and principles in your own way.

### Note

This section has only covered a handful of design styles, and they have only been described briefly. To find out more, ask your parents or older friends about other styles and conduct your own research.

## ANALYSING DESIGNS

Analysing means looking for and seeing particular things. We may be analysing why something appeals to us aesthetically, why it functions well, or how it was made. We can analyse for faults or for success.

The diagram on the following page sums up the benefits of analysing products.



**Mind map – analysing designs**

# ENTERPRISE AND MARKETING

**Marketing** is about getting your product or service known to **consumers**. **Enterprise** is about taking action and commitment to bring an idea to fruition. It is sometimes confused with **entrepreneurship**, which is about taking financial risks in bringing ideas to the market. Enterprise is often used as another word for ‘business’ – it implies hard and consistent work.

Enterprise and marketing are activities that you can take into consideration with your projects. You can start small, test your product on classmates or the community, work out how to promote your product,

and follow up with the require hard work. This could be applied to any of the solutions you devise in the design challenges later in this book.

When marketing, you can use any of the work you completed during your design journey to help sell your idea. You can show the research you conducted, the ideas you developed, and how the finished solution was made. You can use images of the finished solution and point out their advantages for the situation. You can use any of the visualisation software available commercially (or with free 30-day trial periods) to help you.

- How many processes have been mentioned in this chapter? Draw up a table and explain their differences with a diagram for each process to help you remember. Create a poster, chart or wall map that could be used by the whole class, such as:
  - a colourful wall map of the design process to show the main stages
  - a diagram to show the place of 'processes' in a system
  - an annotated image to show the thinking processes attributed to each side of our brains
  - a chart of processes for production suitable to the material category in your school workshop
  - a simple flowchart of the steps involved in one production process.

**ANALYSING A PRODUCT**

- Find a commercial product to analyse. Choose a product that has been well designed, well made and you would love to use, and with the information needed to address at least four of the following:
  - what the product is and its function
  - the designer's name or the name of the company or brand
  - the material it is made from and why it is suitable
  - special things that this product does or has
  - how you think it is constructed (how bits are joined or attached)
  - a description of the design elements used and an explanation of two design principles (refer to pages 37–43)
  - a comment on how sustainable it is.

Present your analysis with an image of the product and annotations to explain your four points.

- Look at the images of the different styles of letterboxes. Discuss:
  - the different functional aspects and how they would suit different users – what sort of people or situations do you think they each suit?
  - the different materials used for each letterbox
  - the design elements and principles you can see
  - which you think is the most aesthetic.

**TRIALLING A PROCESS**

- Ask your teacher for the name of two processes you will be learning. Conduct an internet search for any information, images, or videos of instructions or tutorials on these processes. Present your research in a document and include the following:
  - a big heading that states the name of the two processes
  - URLs of the two most useful websites for each process (four in total)
  - a very brief description of what is being explained on each website or video
  - one to three images as a visual reference.

The purpose of this activity is to share information with classmates. This will help to save time, to give the class a bank of useful instructional resources, to prepare everyone for the teacher's instructions, and to help all students complete the processes to a high quality. Class results could be assembled in a booklet.



Letterboxes to analyse



# 2

## MATERIALS

### KEY KNOWLEDGE

In this chapter, students will gain knowledge and understanding of:

- ▶ a range of materials commonly used in product and system design
- ▶ sustainability issues related to sourcing and use.

# SELECTING MATERIALS

We live in a complex environment with lots of products and a wide range of **materials** supporting our everyday life. Look around you – what materials do you see? All these materials have been carefully chosen to form the products and the built environment around you.

The materials used in products and in our built environment are selected for specific reasons, usually based on the following factors:

- properties and characteristics – the in-built qualities of each material and how they respond in different situations
- cost
- availability – how easy they are to find and buy
- appearance – what they look and feel like
- workability and ease of use
- sustainability.

Designers and manufacturers carefully research different materials, and may gather technical information from other people such as material scientists and engineers. This information helps them to select the most suitable material for a specific product or situation.

The material choices that designers make will change depending on the needs of the people using the product, the requirements of the situation and environment, and the level of quality expected of the product. Sometimes designers can't select the 'best' material for their designs (as it might be too costly or

it might not be available locally), so compromises may be made and an alternative material chosen.

## Material categories

There are many categories that we use to divide and group materials. The major categories are mainly based on where the materials come from, and their characteristics and properties.

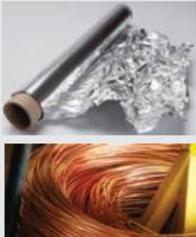
There are other materials that we sometimes use that don't fit into these main categories, or that cross over more than one category; for example, stone and concrete.

## Integrating materials

This chapter separates materials into different groups, explains their different forms, and the tools and machinery used to work with each group. You are encouraged to mix and integrate materials from different categories, and to choose the specific material that best suits the needs and requirements of your product and the situation. Some of the most interesting and innovative designs come out of trying new combinations – mixing things up in ways that haven't been tried before.

When you integrate different materials in your design and production work, it is important to consider the following questions.

- Where and how will the materials be joined together? Will the joining method work for both/all materials?
- Will the materials be durable when used together, or will one wear out the other?

METALS	TIMBER AND TIMBER PRODUCTS	PLASTICS	PAPER AND PAPER PRODUCTS	TEXTILES	GLASS AND CERAMICS
Minerals that are usually mined from the ground	Sourced from trees, and cut into planks or formed into sheets	A combination of chemicals that create a polymer	Plant-based fibres that are bonded together	Fabric and yarns, usually made from fibres (natural or synthetic) or thin sheet material (e.g. animal skin, rubber)	Rigid materials made from sand or clay that change structure at high temperatures
					
<small>Shutterstock.com/Lorena Fernandez</small>	<small>Dreamstime.com/Herbert Quick</small>	<small>Shutterstock.com/photka</small>	<small>Dreamstime.com/Tatyana Vychezhanina</small>	<small>Dreamstime.com/Kontoja</small>	<small>Shutterstock.com/Africa Studio</small>

- How will the different characteristics of each material work together to make the product function well?

- How will the materials be finished? Will this need to be done before or after assembly?
- How will the visual aspect of the product be improved by combining materials?

## Materials around you

- 1 Look at the photo of a furnished room. Identify and list as many materials as possible. If you know the specific names of the materials, include these too.



Shutterstock.com/Breadmaker

- 2 In an information table similar to the one shown, list all the general characteristics and properties (qualities) of the materials from question 1 in each category (you may need to generalise). Think about qualities such as strength, flexibility, durability, elasticity, weight, appearance (colour, sheen, etc.), conductivity, insulation and resistance to water.

CATEGORY	GENERAL CHARACTERISTICS
Metals	
Timber and timber products	
Plastics	
Paper and paper products	
Textiles	
Glass and ceramics	

- 3 Look at the photos of the three chairs. Identify all the materials in these chairs (don't forget the ones that are hidden). Why do you think those specific materials have been used for each chair? What would happen to the chairs if you changed the materials? How would it change how they work and what they can be used for?



Shutterstock.com/Sarah2

Shutterstock.com/Aleksandr Kur ganov

Dreamstime.com/Regoarts

- 4 Look at the photos of children in different settings. Discuss where you think these children are. What sort of hat might each child need, and what would be the purpose of each hat? If you were designing and making hats for these children, what sort of qualities would the materials for each hat need to have? Can you suggest a good type of fabric for each hat?



Getty Images/Sally Anscombe



Shutterstock.com/Alena Uzerova



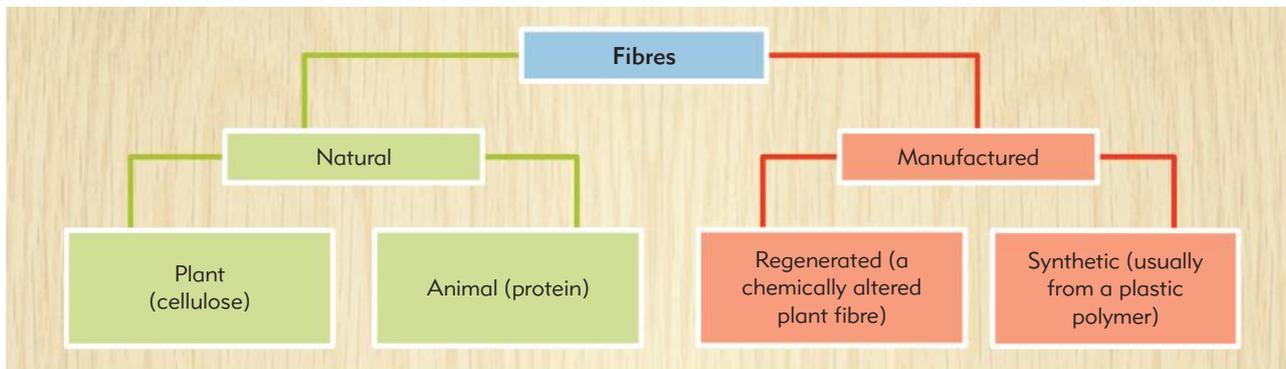
iStock.com/skynesher

- 5 Explore the articles about innovative materials on the Materia website and select a material you find interesting. Describe what sort of material it is and what is special about it. Explain a way it might be used in a product or place, and discuss the impact it will have on the way we do things.

## TEXTILES – FIBRES AND FABRIC

**Fibres** are the starting point for most **fabrics** – the hair-like threads that can be spun together to make a thread or yard, and then woven, knitted or bonded together to create a length of fabric. Fibres come from a wide range of sources, some of which are natural and some are created by people (manufactured).

The diagram shows how fibres are grouped together.



## Natural fibres

**Natural fibres** are grown, and come from either plants or animals.

Fibres that are sourced from plants come from the seed pods (such as cotton fibres surrounding the seed), from the structural fibres within grass-like fronds (such as flax fibres, which are used to make linen), or from the fruit (such as coir from coconuts). Plant fibres include cotton, flax/linen, bamboo, hemp, jute and raffia.



Cotton seed pod



Flax grass

Fibres from animals are usually taken from their hair or fleece. They can be sourced from a range of different animals such as sheep, goats, alpacas, llamas, rabbits and camels. Silk is created differently – it is the thread created by the silkworm to make its cocoon.



Wool fleece from a sheep



Silk from silkworms

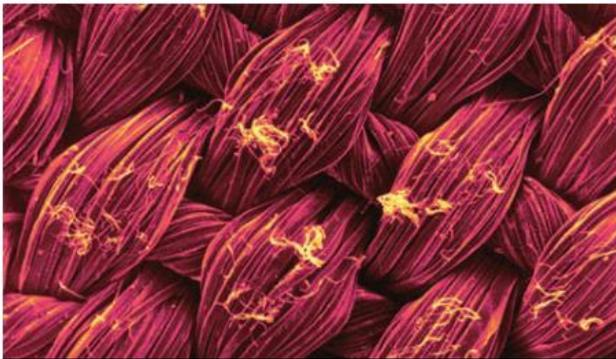
When viewed under a microscope, natural fibres are often uneven and irregular (a characteristic). This characteristic can give natural fibres particular qualities (properties).

Woollen fibres are formed like interlocked scales and 'snag' on each other and grip together. Pockets of air trapped by the fibres provide insulation, which means woollen clothing keeps you warm. The interlocking nature of the fibres is also useful to form felt (where heat, soap and agitation locks the fibres together in a stiff, matted fabric).

Cotton and hemp fibres are uneven and rough when viewed under a microscope, compared with silk fibres that are quite smooth. For this reason, fabric made from hemp is usually dull but silk fabric is shiny and lustrous because it reflects light better.



Science Photo Library/POSNER AND SYRED



Science Photo Library/Dennis Kunkel Microscopy

**Characteristics of different natural fibres give different properties**

### Processing natural fibres

Natural fibres go through the following stages.

- growth – animals or plants are grown to produce the fibre
- harvesting/collecting – fibres are separated from the animal or plant
- cleaning – unwanted materials are removed from the fibres (by shaking, brushing and washing to remove dirt, vegetable matter and oils/grease)

- carding – fibres are brushed to line them up
- bleaching and dyeing – colours of the fibres are changed
- spinning – fibres are twisted together to make a thread or yarn.

**GROWING**

**COLLECTING/HARVESTING**

**SCOURING**

**CARDING**

**DYEING**

**SPINNING**

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Alamy Stock Photo/jan suttile

Alamy Stock Photo/Paul Felix Photography

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## Commonly used natural fibres

### Cotton

The seed of the cotton plant has furry fibres that help in the distribution of the cotton seeds. These fibres are harvested, separated from other plant matter, cleaned and bleached, carded, and then spun into a thread or yarn.

#### WHAT IS COTTON LIKE?

Cotton usually has a soft, cool feel and is comfortable to wear next to the skin. Cotton allows heat to escape from the body and absorbs moisture easily, but becomes heavy when wet and doesn't dry quickly. It is reasonably hard-wearing, depending on the type of fabric it is turned into. Cotton drapes reasonably well and has some stretch, but wrinkles easily (these wrinkles can be removed with a hot iron). Cotton can be dyed easily (it also holds stains), but colours fade quickly. Cotton fabric is comparatively cheap and readily available.

#### USES

Cotton is used for clothing (such as jeans and T-shirts) and bedding, particularly where keeping cool is important. The moisture absorbency of cotton makes it a good fibre for use in towels. Cotton can also be used for curtaining and furnishing fabrics. Cotton can be blended with other fibres so that its negative qualities are lessened (for example, cotton is often blended with polyester so that it wrinkles less and is more hard-wearing).



Cool, comfortable clothes are often made of cotton

### Sustainability issues for cotton fibres/fabric

	Cotton is a renewable resource – it can be grown repeatedly.
	A large amount of pesticides and insecticides are used to help cotton plants grow – this can contaminate the soil and water, and may affect the health of people in the farming area.
	Organic cotton, which is grown without the use of chemicals, is becoming a popular choice (but it is expensive).
	Cotton needs large quantities of water to grow (over 20 000 L of water is needed to grow 1 kg of cotton) and often requires large-scale irrigation – this damages and removes water from natural ecosystems.
	Some of the bleaching and dyeing chemicals used to colour cotton are toxic – the chemicals can cause problems when they are finished with and thrown away.
	Cotton products are reasonably durable and last well.
	Cotton colours fade, but for some products (such as jeans) this isn't a problem.
	Cotton products can be washed in cold water and don't require dry-cleaning (therefore avoiding the use of chemicals that are very harmful to the environment).
	When a cotton product is no longer useful, it breaks down quickly and easily in landfill without leaving any harmful waste.

iStock.com/Pngebat

### Wool

Wool usually comes from the fleece of sheep, though it can be made from the fleece or hair of many other animals. After shearing, vegetable matter and dirt is removed from the fleece by shaking and brushing, and then the fleece is scoured (washed with detergents to remove dirt and natural oils and grease, such as lanolin). The clean fleece is combed and carded to align the fibres, and then the fibres are dyed and spun into thread or yarn. Two or more thin yarns are often spun or plied together to give the wool greater strength. Woollen fibres can also be felted together to make a thick water-resistant fabric that insulates from heat – felt is created by agitating the fibres together until they interlock.

#### WHAT IS WOOL LIKE?

Wool feels warm to touch, but is usually a bit prickly and uncomfortable to have against the skin (unless it is a very fine merino wool fabric). Wool is a great

insulator and protects from both heat and cold. Wool can also absorb a lot of moisture without feeling heavy or cold.

Alamy Stock Photo/PhotosStock-Israel



**Wool is sometimes used in high-fashion clothing**

### USES

Wool is used for clothing and some bedding products for cold conditions. Very fine woollen fabrics are often selected for high-quality fashion clothing. Specially treated wool can be used as insulation in houses, or layered with other materials to make protective clothing and products for extreme heat situations. Wool can be used in floor coverings (such as rugs and carpets) as it is fairly tough and warm to touch.

### Sustainability issues for wool fibres/fabric

	Wool is a renewable resource.
	Sheep need to be treated with pesticides while growing their fleece – pesticides are often harmful to farmers and can run into waterways if not carefully handled. Sheep can also damage fragile environments by removing vegetation, which encourages soil erosion.
	Harsh chemicals are used in the scouring of fleece and the dyes used to colour wool are sometimes toxic – these can be damaging if not disposed of properly after use.
	Sheep farming practices such as mulesing are considered cruel and unethical.
	Woollen clothing and bedding don't require washing frequently and are washed at a moderate temperature (therefore using less water and energy than items that are washed frequently at high temperatures).
	Some high-end specialty wool fabrics require dry-cleaning (using toxic chemicals).
	Wool takes up dyes effectively and colours don't fade quickly.
	Woollen products last well if looked after properly (although they can be attacked and eaten by insects).

iStock.com/Pingebat



Woollen products are well suited to recycling and remaking into new products.



When woollen products are finished with and thrown away, they break down easily in landfill.

## Manufactured fibres

**Manufactured fibres** are categorised into two main groups: **regenerated fibres** and **synthetic fibres**.

### Regenerated fibres

Production of regenerated fibres starts with the collection of natural plant-based fibres from trees and grasses. These fibres are chemically treated to create a flexible, usable fibre that can be spun and turned into thread, yarn and fabric. Rayon is the common name for all fibres/fabric made from a cellulose source (wood and bamboo), and 'viscose' indicates a particular method of processing the fibres. Common regenerated fabrics include tencel, lyocell, modal and bamboo.



Getty Images/Wsturlan

**Bamboo can be made into a regenerated fibre and used for clothing**

### WHAT ARE REGENERATED FIBRES AND FABRICS LIKE?

Like most manufactured fibres, regenerated fibres have a sheen or lustre because the fibres at a microscopic level are uniform and regular. Fabrics from regenerated fibres are usually soft to touch, don't irritate and drape/flow well. These fabrics 'wick' or draw moisture away from the body so the wearer feels comfortable in hot climates, and there is some evidence that the fibres have antibacterial qualities. Regenerated fabrics tend to crease easily.

## USES

Fabric from regenerated fibres is mostly used in clothing. Bamboo-based fabric has become popular for babies' and children's clothing because of its antibacterial properties and it doesn't irritate skin. Regenerated fibres and fabrics are reasonably cheap, and they are often used instead of more expensive silk fabrics because of their similar sheen.

### Sustainability issues for regenerated fibres/fabric

	Sourcing the original fibres for regenerated fabrics may cause some environmental impacts. Some efforts have been made to reduce these impacts by sourcing fibres from bamboo (a fast-growing, comparatively low-impact material), soy processing waste, and sensitively sourced wood material.
	Some methods of processing fibres use damaging chemicals that can be harmful to workers, and damaging when disposed of, whereas other processes are much less harmful (such as the method used to make tencel and some bamboo fibres/fabric).
	Regenerated fabrics are not very durable, strong or elastic, so clothing made from these fabrics does not last long.
	Most of these fabrics require ironing after washing (using energy), and some require dry-cleaning using toxic chemicals.
	Due to their cellulose source, regenerated fabrics break down easily in the environment when thrown away.

iStock.com/Pingebat

## Synthetic fibres

**Synthetic fibres** are usually sourced from a combination of chemicals (either coal-based or petroleum-based) that create a polymer. The chemicals are combined and melted, and the thick liquid is then forced through very small holes called spinnerets. The thin streams that come out of the spinnerets are either air-blown or chemically treated to form a continuous fibre or filament. Common forms of these fibres are polyester, nylon and acrylic.



Nylon at a microscopic level

Science Photo Library/EYE OF SCIENCE



Alamy Stock Photo/Porky Pies Photography

### Waterproof clothing is often made of nylon

### What are synthetic fabrics like?

Similar to regenerated fibres and fabrics, synthetic fibres are shiny. They reflect light because they are smooth and even. However, some synthetic fibres are 'delustered' (made less shiny) during the production process to make them look more natural. Some synthetic fibres are stretchy and elastic (such as elastane and lycra), and some are extremely strong (such as nylon and polyester). Some synthetic fabrics have a slightly harsh feel, but this depends on how the fibres and fabrics are made. Most synthetic fibres are good insulators (protect from heat and cold), do not crease easily, and resist water. Polyester polar fleece mimics wool. It is light, insulating and warm (even when wet), and doesn't irritate those who might be sensitive to wool. Synthetic fabrics can be washed easily in cold water, don't stain easily, and will hold their colour well through washing and wearing. These fabrics are also very tough and hard-wearing.

### USES

Synthetic fibres are used in many types of clothing and accessories, including footwear. Some synthetic fibres are used for industrial purposes, such as ropes, protective materials, cleaning products and structural parts.

### MICROFIBRES

Manufacturers can now create extremely fine synthetic fibres called microfibrils (about 1/100th the diameter of a human hair), which changes some of the usual characteristics of synthetic fibres. Microfibrils are silky and soft to feel, are more breathable, and are still resistant to moisture and rain (and therefore often used for sportswear). These fabrics are lighter in weight, and drape and flow well. Microfibre fabrics are frequently used for cleaning products – combinations of very fine fibres

attract and trap dirt particles, and then release them easily when washed. This reduces the need for chemical cleaners. Microfibre cloths are also much softer on surfaces than conventional cleaning cloths.



Microscopic view of the microfibrils in a cleaning cloth

### Sustainability issues for synthetic fibres/fabrics

	Many of the materials used to create synthetic fibres come from non-renewable resources such as coal and petroleum.
	Production of synthetic fibres uses lots of energy (compared with other fibres), and creates more greenhouse gases than other fibres.
	Producing synthetic fibres uses the smallest amount of water (compared with other fibres).
	A few synthetic fibres can be sourced from recycled materials (for example, a small amount of polyester polar fleece is sourced from recycled PET bottles).
	Products made from synthetic fibres are easily washed, don't lose their colour, and rarely need ironing.
	Products made from synthetic fibres are durable, hard-wearing, and last well.
	When washed, synthetic fibres break down into nanoparticles that get washed into our waterways and are absorbed by wildlife.
	When products made from synthetic fibres are thrown away, they don't break down easily in the natural environment.

### Note

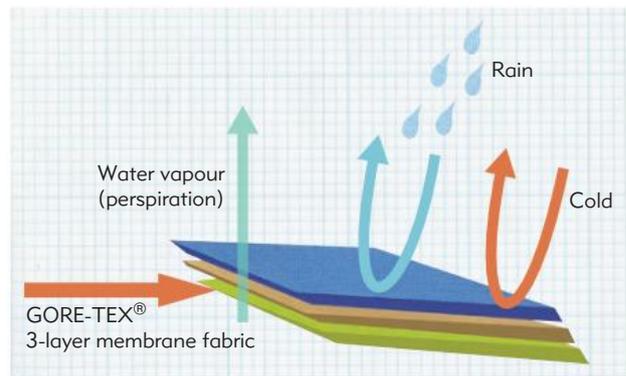
**Renewable resources** are those that can be grown, harvested, used, and grown again. **Non-renewable resources** are those that cannot be easily replaced by nature. There may only be a certain amount of that resource in the world – it is called a **finite resource**. We reduce the total amount of these resources every time they are used, and they may eventually run out. Renewable resources are generally more sustainable to use in products than non-renewable resources.

### Fabrics using a blend of fibres

Some fabrics blend together two types of fibre. This provides the fabric with the desired qualities of both fibres in the one fabric. For example, polyester and cotton are often blended to create poly-cotton, which has the comfort, soft feel and water absorbency of cotton, and the resistance to creasing and durability of polyester. Poly-cotton is often used in T-shirts, business shirts and bed linen.

### Laminated fabrics

Specialty fabrics can be made by bonding layers of different fabrics together. This layered or laminated fabric will give the qualities of each fabric/fibre, but in the desired place. For example, Sportwool™ clothing has a layer of superfine merino next to the skin to absorb moisture and reduce chill after exercise, and has a layer of hard-wearing, fast-drying polyester on the outside. Laminated raincoat fabrics (such as GORE-TEX®) have three layers to allow the very fine water vapour condensing from the body to escape through the fabric, but doesn't allow larger rain drops to pass through the fabric in the other direction.



The structure of the synthetic fabric GORE-TEX®

### Skins and sheet materials (membranes)

Materials such as leather, sheepskin, rubber and neoprene are not created from fibres, but are instead formed as a sheet material. Some sheet materials are formed naturally and are then treated (for example, skins are removed from dead animals and tanned to make them last). Others are formed using natural or synthetic polymers that are cast, and then rolled or extruded as a sheet. These materials usually have some water resistance, are insulating, flexible and have some stretch (a few of these materials are very stretchy). Some sheet materials become stiffer and more brittle with age and sunlight.

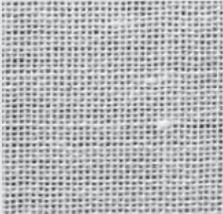
OVERVIEW OF FIBRES, THEIR QUALITIES AND USES				
FIBRE	CHARACTERISTICS – APPEARANCE AND FEEL	PROPERTIES	USES	
Natural	Wool	<ul style="list-style-type: none"> <li>Fine to thick fibre</li> <li>Usually soft</li> <li>Warm to touch</li> <li>Weak</li> </ul>	<ul style="list-style-type: none"> <li>Insulating (doesn't allow heat to escape)</li> <li>Absorbs water</li> <li>Resists flame</li> <li>Moderate cost</li> </ul>	<ul style="list-style-type: none"> <li>Clothing</li> <li>Outer wear</li> <li>Blankets</li> </ul>
	Silk	<ul style="list-style-type: none"> <li>Fine/thin</li> <li>Usually soft</li> <li>Warm to touch</li> <li>Shiny</li> <li>Weak</li> </ul>	<ul style="list-style-type: none"> <li>Insulating</li> <li>Absorbs water</li> <li>Resists flame</li> <li>Creases easily</li> <li>Expensive</li> </ul>	<ul style="list-style-type: none"> <li>Expensive clothing and accessories</li> </ul>
	Cotton	<ul style="list-style-type: none"> <li>Soft</li> <li>Fine</li> <li>Cool to touch</li> <li>Strong</li> </ul>	<ul style="list-style-type: none"> <li>Allows heat to escape (conducting)</li> <li>Absorbs water</li> <li>Creases</li> <li>Low cost</li> <li>Colour fades</li> </ul>	<ul style="list-style-type: none"> <li>Clothing</li> <li>Sheets and towels</li> <li>Packaging</li> <li>Medical uses</li> </ul>
Regenerated	Bamboo	<ul style="list-style-type: none"> <li>Silky</li> <li>Soft shine</li> </ul>	<ul style="list-style-type: none"> <li>Absorbent (draws moisture from the skin)</li> <li>Antibacterial</li> <li>Durable and strong</li> <li>Dyes easily</li> </ul>	<ul style="list-style-type: none"> <li>Clothing</li> <li>Underwear</li> <li>Knitwear</li> <li>Un-woven nappies</li> </ul>
	Rayon	<ul style="list-style-type: none"> <li>Fine</li> <li>Medium to soft feel</li> <li>Shiny</li> <li>Weak</li> </ul>	<ul style="list-style-type: none"> <li>Absorbs some water</li> <li>Creases easily</li> <li>Burns and melts with heat</li> <li>Low cost</li> </ul>	<ul style="list-style-type: none"> <li>Clothing</li> <li>Linings for dresses and jackets</li> </ul>
Synthetic	Nylon	<ul style="list-style-type: none"> <li>Can be made fine or thick</li> <li>Medium to harsh/rough feel</li> <li>Very strong</li> </ul>	<ul style="list-style-type: none"> <li>Insulating</li> <li>Crease resistant</li> <li>Resists water</li> <li>Burns and melts with heat</li> <li>Colour doesn't fade</li> </ul>	<ul style="list-style-type: none"> <li>Clothing</li> <li>Waterproof clothing and covers</li> <li>Bags</li> <li>Industrial uses</li> </ul>
	Lycra	<ul style="list-style-type: none"> <li>Can be made fine or thick</li> <li>Always blended with other fibres</li> <li>Strong</li> </ul>	<ul style="list-style-type: none"> <li>Lightweight</li> <li>Durable (resists breaking down)</li> <li>Very elastic</li> <li>Returns to original shape after being stretched</li> </ul>	<ul style="list-style-type: none"> <li>Clothing</li> <li>Swimwear</li> <li>Underwear</li> </ul>

## Fabric construction

Fabric construction has a significant effect on the qualities of a fabric. The way the fibres or yarn are put together to make fabric will contribute to its properties such as flexibility or stiffness, the amount of stretch it has, how insulating it is, and how well it protects from moisture.

The three main forms of fabric construction are:

- **woven** – threads are interwoven, with alternating an under/over pattern (warp is the threads running through the fabric; weft is the threads running side to side across the fabric)
- **knitted** – threads or yarn create interlocking loops
- **felted or bonded** – heat, agitation or bonding chemicals are applied to fibres to create a matted material.

FABRIC CONSTRUCTION	WOVEN	KNITTED	BONDED OR FELTED
Appearance	Usually an even, grid-like appearance with under/over pattern of threads	Looped threads; can have a smooth, rough or ribbed texture	No thread, uniform construction, matted appearance
Properties	Tightly woven fabrics are firm and strong Loosely woven fabrics are flexible and drape well	Stretchy, flexible, firmness dependent on the tightness of the knit and weight of thread	Thick – very firm and inflexible, not stretchy, insulating and water resistant Thin – flexible and absorbent
Forms and uses	Basic weaves: <ul style="list-style-type: none"> <li>• Plain – a simple alternating woven pattern (e.g. shirt fabric and sheets)</li> <li>• Twill – strong diagonal pattern in the weave (e.g. jeans)</li> <li>• Satin – has a shiny surface and a dull, wrong side (e.g. formal clothing and curtains)</li> </ul>	Basic – plain, purl and ribbed stitches (e.g. clothing and craft) Double – interlock, double-knit (e.g. sportswear and hosiery) Tricot – used for satin-finished swimwear	Wool – can be felted together using pressure and detergent (e.g. warm clothing and floor coverings) Synthetics – chemically or heat bonded (e.g. medical uses, filters, and cleaning and disposable cloths)
Examples	 <p>Plain weave – organza</p>  <p>Twill – denim</p>	 <p>Single-knit</p>  <p>Knitted terry cloth</p>	 <p>Felt</p>  <p>Thermo-bonded fabric (interfacing)</p>

FOCUS ACTIVITY

## Everyday fibres and fabrics

- Consider the clothes you are currently wearing.
  - Draw a quick sketch and describe each item of clothing.
  - Find out what fibres they are made from – all clothing should have a tag on it that identifies the fibre content of the fabric.
  - What fabric construction is used for each item?
  - Read the characteristic/properties of these fibres and fabric listed in the charts on pages 57–8. Why do you think these fabrics were chosen for your items of clothing?
- Choose **four** of the following fabric products.
  - T-shirt
  - shoes
  - rug for a children's playroom

- backpack
- stretch pants
- oven mitts
- umbrella

What fabric qualities or characteristics are needed for each product? Which fibre/fabric would be the best choice? The example in the following table shows what you could discuss.

FABRIC PRODUCT	CHARACTERISTICS/ PROPERTIES NEEDED	CHOICE
Woollen hat, scarf and mittens	The fibre/fabric needs to be warm, stretchy, comfortable against the skin, and fairly light to wear	Either wool or acrylic

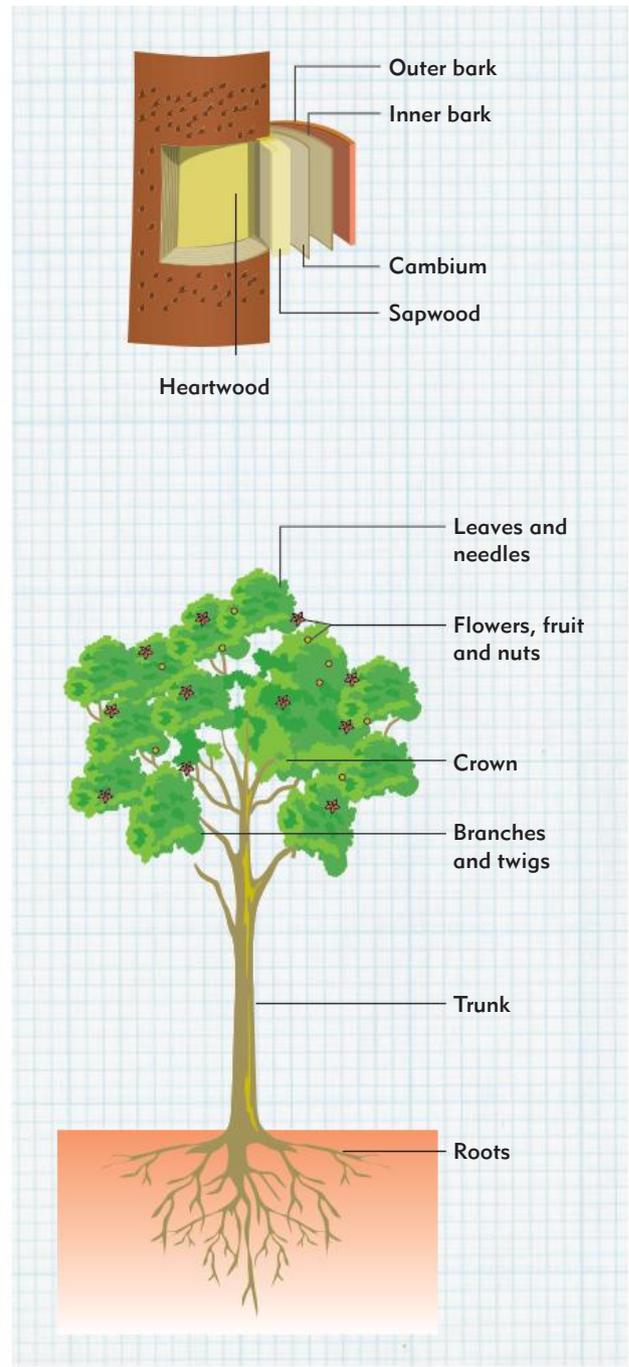
# WOOD AND TIMBER PRODUCTS

Trees are wonderful living things that provide us with a great range of benefits. Trees:

- produce the oxygen that we need to breathe (it is a by-product of the process that converts sunlight energy and carbon dioxide from the atmosphere into sugars)
- provide a living environment for birds, animals and insects
- provide us with food (mainly fruit)
- provide shade and shelter, and cool the air
- stabilise ground surface and stop erosion
- filter impurities from water and air
- provide us with timber for building and products, cellulose material for paper and fabric, and gums/resins for other uses.

## Parts of a tree

- Roots – absorb water and nutrients from the soil, and also stabilise the tree
- Trunk – supports and provides a strong structure for the tree; made from a number of layers
- Bark – a strong outer layer that protects the tree
- Heartwood – the centre section of the tree; made from layers of cells that are no longer active but are stiff and hardened, and provide structure to the tree
- Sapwood – one of the active layers of the trunk; made of narrow tubes that transport water and nutrients around the tree; as sapwood becomes inactive, it turns into heartwood
- Cambium layer – the narrow growing layer of the trunk that adds its 'rings'; when a ring is fully developed, it becomes a sapwood layer and a new cambium layer is started
- Crown – the upper part of the tree that contains lots of branches and leaves
- Branches and twigs – the narrower structural parts of a tree that support leaves/needles, flowers and fruit, or cones
- Leaves/needles – the small fleshy parts of the tree that use chlorophyll to convert sunlight and water into sugars, and emit oxygen
- Flowers/fruit/cones – the parts of the tree that help it to reproduce (to create more trees) through the development and distribution of seeds.



## Softwood and hardwood

**Softwood** and **hardwood** identify two different groups of trees and describe their botanical characteristics. The names do not describe the soft or hard qualities of the timber from those trees.

## SOFTWOODS

- Called **gymnosperms**, which means their seeds fall to the ground uncovered
- Have needles and cones
- Evergreen (do not lose their foliage in autumn)
- Examples include pines, cedars, cypress, fir, spruce and yew



## HARDWOODS

- Called **angiosperms**, which means their seeds are covered by a hard shell (nuts) or contained in fruit
- Have broad fleshy leaves and flowers
- Can be evergreen or deciduous (lose their leaves in autumn)
- Examples include eucalypts, oaks, ash, blackwood, balsa, teak, mahogany and willow



Some Australian hardwoods may be mistaken for softwoods. For example, Australian red cedar isn't a real cedar – it is a type of mahogany (hardwood). The she-oak looks like it has needles and cones, but it is an angiosperm (hardwood) because it has branchlets with tiny leaves, flowers and woody fruit.

## Growing and harvesting trees

Trees for timber production are sourced from forests or from plantations.

- **Forests** – where trees grow naturally in mixed species, with lots of other types of vegetation (small bushes and grasses).
- **Rainforests** – a complex and rich ecosystem of trees, plants and wildlife that develop in areas of

high rainfall. There are two forms of rainforest, determined by where they occur – tropical rainforest (found in hot, tropical regions) and temperate rainforest (found in cooler regions). These forests have high levels of biodiversity (a very wide range of plants and animals co-exist in the area).

- **Old-growth forests** – forests that have developed over centuries and haven't been disturbed much by humans. The forests include mixed-aged trees and vegetation, and also have a high level of biodiversity.
- **Regrowth forest** – forests that have regrown from a significant event (natural or caused by humans) such as bushfire or logging. The trees are usually more uniform in age, and plants have less diversity.
- **Plantations** – tree farms. Plantations are usually a 'monoculture', where a single type of tree is grown. The trees are planted methodically in rows for harvesting after 15–60 years. Often, the trees are not native to the area and do not provide a good living environment for local animals, birds and insects. Australia has many radiata pine plantations, which are native to California and Mexico.

There are two types of tree harvesting.

- **Clear-fell logging** – all vegetation from an area is removed, and the useful tree trunks are converted into timber.
- **Selective logging** – the best trees for timber production are identified, individually cut down and removed.



Australian rainforests have a complex and rich ecosystem of trees plants and wildlife



Shutterstock.com/Janelle Luggie

Plantations are tree farms usually where one type of tree is grown in uniform rows

## Converting trees into timber

After trees have been cut down, they are transported to a mill where they are converted into useful products for manufacturing and construction. Some wood is cut into timber **planks** of different sizes. Other logs are rolled and sliced into continuous thin layers, called **veneer**, that are used for plywood layers and for surfacing manufactured boards. Other material from logs are chipped or finely crushed, mixed with glue and pressed into **manufactured boards**.

## Cutting timber from a log

A round log must be cut into sections to create useful timber planks. There are two main methods of cutting a log into timber sections.

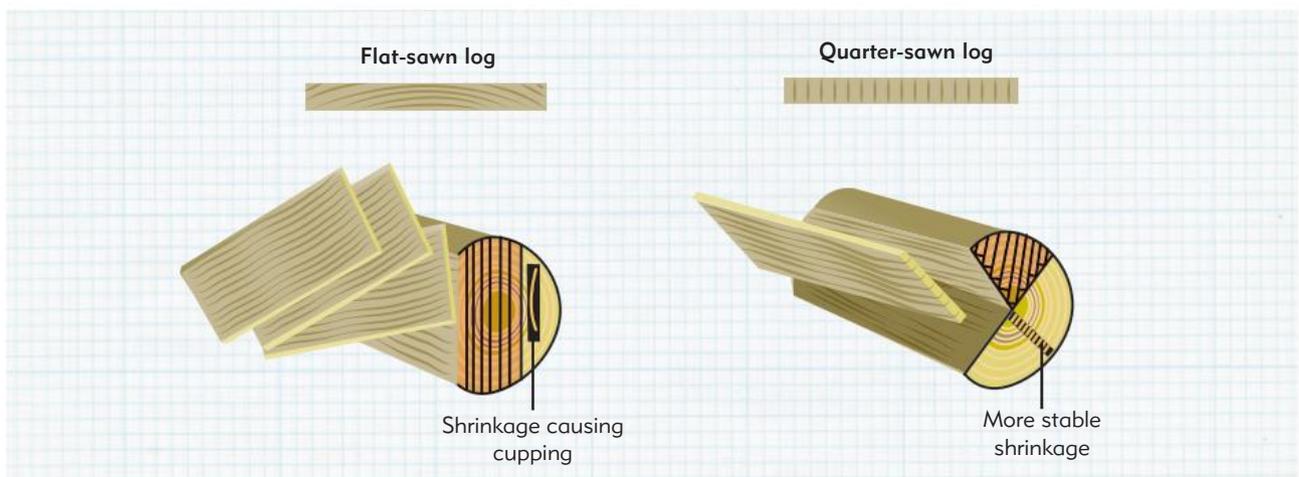
- **Quarter-sawn** – as many of the boards as possible point towards the centre of the log, producing narrow boards.

- **Flat-sawn** – where parallel cuts slice through the log, producing wide boards (this is also called ‘through and through’ sawn, plain-, live-, regular- or back-sawn).

When timber is first cut from a log, it contains a lot of moisture. The outside parts of the log contain the most moisture. After a log is cut into boards or planks, it is seasoned (the process of drying the timber to remove its moisture). As the timber dries out, it shrinks – the parts of the timber that were on the outside of the log shrink the most. Quarter-sawn boards shrink more evenly and with more stability during the seasoning process than plain-sawn boards, which are likely to cup or curve as they dry out.

## Timber grain

What is timber grain? **Grain direction** describes the direction of the fibres in a piece of timber. Timber fibres were once hollow cells that transported water



and nutrients around the tree. The fibres are usually lined up and point in the same direction (up and down the trunk of the tree). Occasionally the grain changes direction to go around or along a branch. In a timber board, you can sometimes see the cross-section of a branch that has been sliced through, and the grain forms a tight circular pattern – this is called a knot.

Grain markings (light and dark grain lines) can be very indistinct and hard to see in some timbers, whereas other timbers have very clear and distinct grain lines that show the different stages of a tree's growth. In some timbers, such as blackheart sassafras, the heartwood (at the centre of the tree) has a very different grain colour to the timber in the outer layers of the tree. Grain markings that are very uneven and decorative are called figured grain.



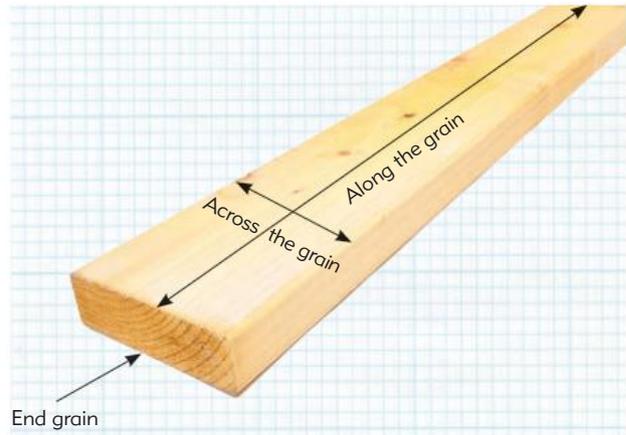
Shutterstock.com/Reinhold Leitner

**Figured grain – wood grain that is decorative and/or unusual, such as bird's eye grain**

When cutting or sanding timber, the direction of the grain must be considered.

- **With the grain** – when you cut or sand in the same direction as the grain lines.
- **Across the grain** – when timber is cut at right angles to the grain lines.

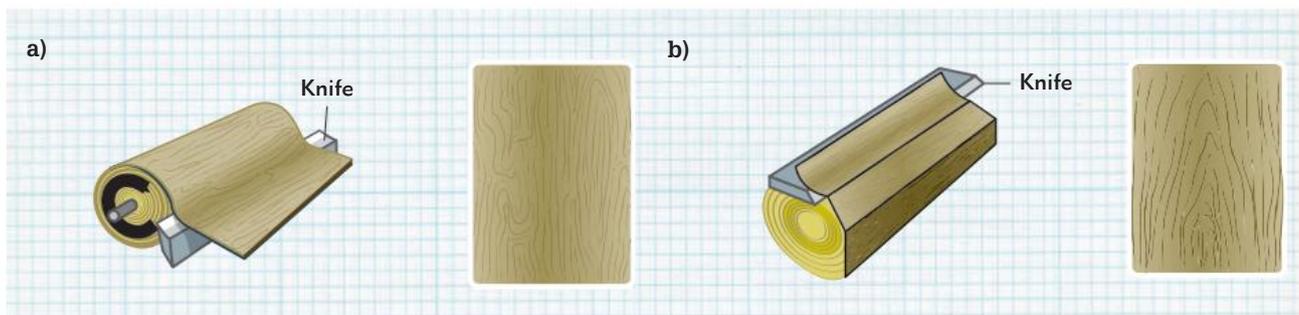
- **End grain** – when timber is cut across the grain, the section that shows the cut ends of the fibres is called the end grain.



**Woodgrain direction**

**Sustainability issues for solid timber**

	Requires trees to be cut down.
	Causes irreversible environmental damage if trees are cut from rainforest or old-growth forest.
	Causes fewer problems if trees are cut from regrowth forests.
	Logging removes wildlife habitat.
	Causes fewer environmental problems if trees are cut from plantations.
	Processing timber from trees creates waste, and not all the tree can be used.
	Products made from solid timber usually last longer.

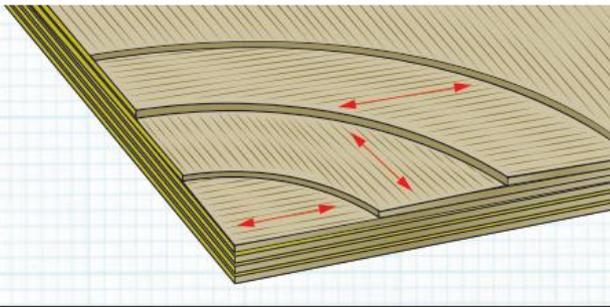


**Rotary-cut veneer (a) and flat-cut veneer (b)**

## Veneers and plywood

A veneer is a very thin piece of wood that is either rotary-cut or flat-cut from a log. Rotary-cutting veneer creates large sheets that are used for the layers in plywood. Flat-cut veneers are used for decorative work, such as marquetry. Because veneers are sliced from a log with a knife rather than cut with a saw, very little of the log is wasted.

**Plywood** is a form of manufactured timber product. It is made by gluing together layers of veneer that are placed so that the grain of each layer runs at right angles to the layers above and below. Crossing the grain in this way makes plywood very strong, but also light. Plywood is produced in large sheets, usually 2400 mm by 1200 mm. It is made with an odd number of layers (for example, 3 layers = 3 ply, and 5 layers = 5 ply) so that the grain runs in the same direction on the outside faces of the sheet. The thickness of the layers in different sheets can vary, and the total sheet thickness can be as little as 1.5 mm or as thick as 50 mm. Some plywood is suitable for wet environments, as the layers are glued together using water-resistant glue. Flat sheets of plywood can be used to form furniture and building structures – it is often used for the back of cabinets, and for the base of boxes and drawers. Plywood is also flexible and can also be used to form curved shapes.



Layering of veneer in hardwood

### Sustainability issues for plywood

	Requires trees to be cut down.
	Level of environmental impact is partly determined by where the trees are sourced (rainforest/old-growth, regrowth or plantation).

	Processing from a log doesn't create very much waste.
	Plywood is a very strong and light material (therefore, less material is needed in products for the same level of strength, and less fuel is needed when products are transported).
	Lesser-quality timber can be used for inner layers and outer unseen surfaces.
	Products made from plywood last reasonably well, unless the type of plywood glue doesn't suit the product's environment.

## Manufactured boards

**Blockboard** is made by joining long strips of solid wood together with an outer facing of veneer. This means lesser-quality solid timber can be used to form a strong, wide sheet. Blockboards are used in a wide range of building situations.

**Particle board** is made from large chips and particles of timber pulp that are mixed with glue, and pressed to form a large flat sheet.

**Medium-density fibreboard (MDF)** is made from very fine wood fibres and glue. Large sheets or boards are made using pressure and heat. MDF is denser and stronger than particle board. It is commonly used to make kitchen cabinets and inexpensive furniture.

### Safety

The glue used in sheets of MDF is usually formaldehyde-based, and the fibres in the boards are so small they can lodge in the lungs. Both aspects make MDF a significant health risk – it should not be cut, drilled or sanded in schools.

Particle board and fibreboards are very heavy, and are usually structurally stable (they don't twist and warp like solid timber). A layer of timber veneer can be glued to the outside surface of a board to make it look like solid timber, or it can be surfaced with plastic laminate such as melamine or laminex. Different boards can be used in dry or damp situations, depending on the type of glue used to bind the board material. If an unsuitable board is put into a damp situation, it will swell and become damaged quickly.

### Sustainability issues for manufactured boards

	Requires trees to be cut down.
	Most MDF made in Australia comes from plantation timber.
	Can use lesser-quality timber, and may use more of the timber waste/offcuts.
	Can be a health risk for workers when used in manufacturing.
	Products made from MDF may not last as well as those made from solid timber.
	Products made from MDF are heavy and require more fuel to transport.

### Bamboo

The use of bamboo in building and furniture construction has become more popular in recent years. Bamboo is classified a grass and grows extremely fast. Some species can grow up to 90 cm in a day, but the most commonly grown bamboo will increase by 5–10 cm per day. Bamboo can be harvested for use in 3–5 years, whereas plantation timber needs to grow for a lot longer before it is ready for harvesting (hardwoods need 20–120 years of growth). For many centuries, bamboo has been cut, dried and used in building construction and scaffolding in Asian countries because it is very strong and flexes rather than breaks when put under pressure. This is particularly useful in areas where earthquakes occur.



**Bamboo is a strong and flexible building material**

More recently, bamboo has been turned into a manufactured board or sheet for use in flooring, building and furniture construction. Bamboo fibre can also be turned into yarn or fabric (see page 54 for more information). Only the strong outside ring of woody bamboo material is useful for converting into boards. To make the boards, the bamboo is harvested and then either cut lengthwise into narrow strips, or grooved and flattened. It is then steamed to remove insects and impurities – this process is called **carbonisation**. The longer the bamboo is carbonised or steamed, the darker it gets and the weaker it becomes. After carbonisation, the bamboo strips are glued, heat pressed and the sheet surfaces are planed flat. The resulting flat sheet can be used as is, or it can be layered to make blockboard or bamboo plywood. Sometimes bamboo material is shredded, and then glued and pressed to make a random, decorative pattern – this technique can utilise much of the offcut waste material.

When bamboo is used as simple poles in construction, it is a very sustainable material – it doesn't require much processing and most of the plant is used, producing minimal waste. Although bamboo boards require much more processing, they are more appealing and longer lasting. Bamboo boards are a tough material that resists water damage much better than other manufactured boards.

### Sustainability issues for bamboo

	Bamboo grows much faster than trees. It can be harvested after 3–5 years, and is harvested without killing the plant.
	Plantations can cause environmental damage if a forest is removed to plant bamboo, or if the bamboo plants invade surrounding forest.
	Bamboo is a very dense, strong, tough and durable material – much more durable than other manufactured boards and as tough as most hardwoods.
	There is very little waste in the production of bamboo boards.
	Bamboo boards are mostly produced overseas, and require fuel to transport to Australia for use. Boards are very heavy, requiring more fuel to move.
	The carbonisation process weakens bamboo – so strength isn't consistent.
	Some of the glues used in the production of bamboo boards can be harmful to workers (although the process is less harmful than for other manufactured boards).

OVERVIEW OF DIFFERENT TIMBER MATERIALS, THEIR QUALITIES AND USES

TIMBER	APPEARANCE	PROPERTIES	USES	
Hardwood	Tasmanian oak (kiln-dried hardwood) Eucalyptus ( <i>Australia</i> )	Pale-pinkish colour, very even grain, sap pockets	Medium weight and density	Building
	Blackwood ( <i>Australia</i> )	Mid-brown colour	Medium weight and density	High-quality furniture
	Jarrah ( <i>Australia</i> )	Dark-red colour	Very dense/solid and heavy	High-quality furniture, building, flooring
	Teak ( <i>South-East Asia</i> )	Mid-brown colour	High oil content, weather resistant, resists insect attack	Furniture and storage
Softwood	Radiata pine ( <i>California</i> )	Pale-yellow colour, obvious knots	Soft, easily dented	Inexpensive furniture, building
	Hoop pine ( <i>Australia</i> )	Pale-yellow colour, straight even grain	Soft, easily dented	Mouldings and flooring, cabinets, plywood
	White cypress pine ( <i>Australia</i> )	Pale-yellow/orange, variations in colour, pleasant smell	High resin content, resists rotting	Fence posts, house frames, flooring
	Western red cedar (NOT Australian red cedar) ( <i>North America</i> )	Mid-reddish-brown colour	Very soft, resistant to decay and borers	Window and door frames
Manufactured boards	Plywood	Obvious layers, colour determined by timber	Strong, light, flexible (if thin)	Structural, boats, cabinets, flooring, furniture
	Blockboard	Layers and blocks, colour determined by timber	Strong, lighter than MDF/particle board, stable	Solid doors, shelving
	Particle board and MDF	Light- to mid-brown colour, may have a veneer surface	Strong, heavy, stable	Inexpensive furniture, under-flooring, panelling, cabinets, mouldings, moulded doors
	Bamboo board	Light to dark colour (depending on carbonised treatment), even grain	Very strong, behaves more like solid hardwood, heavy	Flooring, building construction and panelling, benchtops, furniture

FOCUS ACTIVITY

Using timber

- Consider the different forests you have seen (including plantations).
    - Can you remember where you saw them? What types of forests were they?
    - Do you think these forests had a diverse range of vegetation and wildlife?
    - Which types of forests do you think we should source our timber and timber products from? Give reasons for your answer.
    - Which type of tree growth and harvesting is more sustainable?
  - Explain the difference between solid timber and a manufactured timber product.
  - List three timber products that you use regularly.
    - Find out what type of timber or timber product was used to make each product.
    - Do you know where the timber material came from?
  - Why do you think these materials were used for these products? (Think about the appearance and properties of the different materials.)
  - Choose three products from the following list.
    - kitchen cabinet
    - fence post
    - durable and high-quality chair
    - flooring
    - window frame
    - musical instrument
    - outdoor set of table and chairs
    - benchtop
- Which timber or manufactured timber product would you select to make each of your chosen products? Explain the reasons for your choice. To explore other timbers, investigate the Australian Timber Database or the Australian Hardwood Network.

 MORE IN YOUR WORKBOOK

# METAL

Metals come in many forms – they are usually hard and durable, and are extremely useful in many situations and applications. Metals also have other useful characteristics – they conduct heat and electricity, they are opaque (solid and don't allow light to pass through them), they can be shaped and joined when heated, and most can be polished to produce a shiny, reflective surface. Metals occur frequently within the list of chemical elements (called the Periodic Table) – about 91 of the 118 recognised elements are metals of some sort.

## Sourcing metals

### Mining

Metals are usually found as minerals in the earth's crust – in rocks on or under the earth's surface. The rocks containing metal is called **ore**, and it is usually taken from the earth through mining. Mining companies put a lot of effort into survey areas to find mineral deposits. When minerals are found, there are two main forms of mining them.

- **Open-cut mining** – all surface material is blasted and removed, leaving a large open hole that is sometimes kilometres wide.
- **Underground mining** – an access tunnel is excavated into the side of a mountain or a deep shaft is dug into the ground, and then access tunnels are cut horizontally or on a decline to follow the ore body.



Open-cut mining

**Longwall mining** is a new development in mining, often used for bulk removal of coal. The side of a tunnel is mechanically excavated and, as the



Longwall underground mining

tunnel moves sideways, the roof of the original tunnel space is collapsed and closed.

Some gold and copper mines use a 'block cave' underground mining method. An access tunnel is excavated to the base of the ore body. Material is mined from the base, and then the rest of the ore body is gradually blasted and removed through an access tunnel to the surface. Underground mining, particularly longwall and block cave mining, can cause significant surface motion (the surface soil collapses into the mine) and may create large sinkholes.

The world's deepest underground mines are gold mines in South Africa. They are almost 4 km deep. The deepest mines in Australia are the copper and zinc mines in Mount Isa, which are 1.8 km deep. The Bingham Canyon copper mine near Salt Lake City, Utah, USA is the largest open-cut mine. It is almost 4 km across and 1.2 km deep.

### Extracting metal from the ore

Usable metal taken from the ground needs to be removed from the ore – this is called **extraction**. A few metals occur in the earth in a reasonably pure form and require little treatment to be usable (for example, gold), but most mined ore needs to be treated to extract the pure or base metal. The ore is crushed and treated in different ways to remove the metal from unwanted rocky material.

- **Froth flotation** – crushed ore is treated with a chemical that binds with the metal particles. It is then placed in a bath of water and detergent. Air is pumped through the bath, causing it to foam, and the chemically bound metal particles float to the top of the foam and are skimmed off.

- **Smelting** – heat is used to melt metal from the ore, and to create a chemical reaction that removes oxygen and other impurities, leaving the pure metal.
- **Chemical extraction** – ore is placed in a bath of a chemical that reacts with the metal, which removes the metal particles from the ore. The chemicals are drained off and the metals are removed.
- **Electrolysis** – an electrical current is passed through a liquid bath containing metal particles. These particles collect at the negative electrode (the cathode).

Most metals will go through several of these processing stages during the extraction process. These processes use energy and create waste in the form of gases, waste chemicals, contaminated water and slag (the left-over, non-metal parts of the mined ore).

### Note

The science that explores the chemical and physical nature of metals and how they are produced is called metallurgy.

### Alloys

Different metals can be combined to create an **alloy**. This gives the alloyed metal different characteristics and properties to those of the original individual metals. For example, gold in its pure form is very soft, so it is usually alloyed with metals such as copper, silver or nickel to make it harder and more durable. 'Carats' indicate how pure the gold is – pure gold is 24 carat, 18 carat is an alloy that contains 75% gold, and so on.



Alamy Stock Photo/David Gee 2

**Gold jewellery with carat markings to show how pure the gold is**

Other alloys include:

- bronze – one of the earliest alloys to be used; it is a mixture of copper and tin that has greater strength when combined than either of its base metals
- steel – adding carbon to iron increases its toughness and strength
- stainless steel – adding chromium to steel makes it resistant to rust.

### Forming metal into usable materials

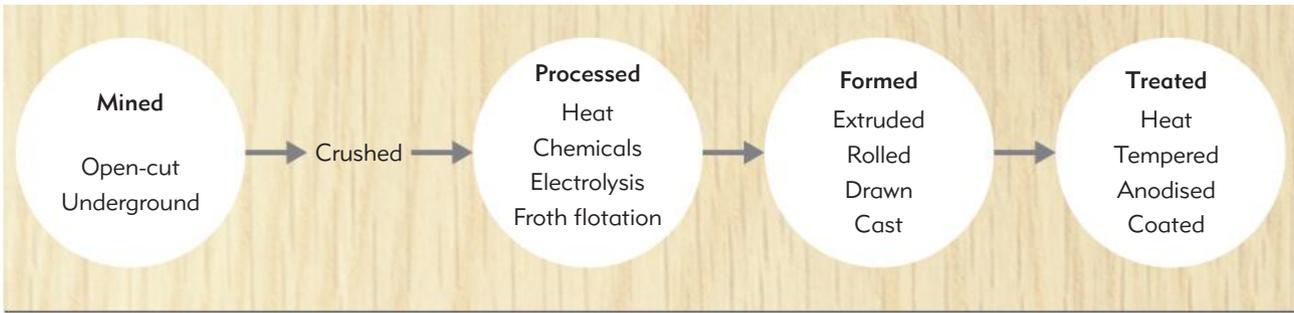
After extraction, metal is shaped into different forms ready for manufacturing products. Metal can be:

- large sheets of various thickness, either smooth or textured
- rods and bars in different widths and thicknesses
- tubing
- angles and shapes
- different shaping of rolled sheets (such as for roofing)



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**Metal can be turned into many different shapes**



## Processing metal

- wire (drawn)
- mesh or expanded sheet
- moulded shapes (using a cast).

Metals may also be treated to give certain properties.

Treatments include:

- tempering – heat-treating and dipping metal into oil to make it tougher and less brittle
- annealing – heat-treating metal to make it less brittle and softer, and easier to shape
- anodising – colouring some metals with heat, electricity and/or acid (for example, titanium, steel and aluminium)
- galvanising or coating – coating a metal with another metal, plastic or paint to prevent rusting.

## Note

Some metals have unusual properties. For example, the hazardous metal mercury is a liquid at room temperature. Gallium, a metal that isn't well known but is used in electronic components, has a low melting temperature of 30°C (it can melt in your hand), and can attack the structure of other metals and make them weak.

FERROUS METALS (CONTAIN IRON)	NON-FERROUS METALS (DO NOT CONTAIN IRON)
<b>Examples:</b> <ul style="list-style-type: none"> <li>• iron, cast iron and wrought iron</li> <li>• mild steel, carbon steel and stainless steel.</li> </ul>	<b>Examples:</b> <ul style="list-style-type: none"> <li>• precious metals – gold and silver, platinum and palladium</li> <li>• copper, brass, tin, aluminium, nickel, lead and zinc.</li> </ul>
<b>Characteristics:</b> <ul style="list-style-type: none"> <li>• usually magnetic</li> <li>• usually prone to rust (apart from wrought iron and stainless steel).</li> </ul>	<b>Characteristics:</b> <ul style="list-style-type: none"> <li>• less likely to rust (useful in outdoor or wet environments)</li> <li>• usually lighter than ferrous metal (useful for aeroplane construction or food/drink containers)</li> <li>• more malleable and easier to shape</li> <li>• not magnetic (useful in electronics).</li> </ul>

## Ferrous and non-ferrous metals

Metals are usually grouped into two categories: ferrous and non-ferrous metals. 'Ferrous' means containing iron.

## Commonly used metals

### Mild steel

Mild steel is a ferrous metal commonly used to make simple products as it is easy to shape, form and join.

Mild steel:

- is made from iron, with a small carbon content
- has a dull, dark blue-grey appearance
- rusts easily
- is very cheap and easy to purchase
- is fairly tough, and can be annealed (heat-treated) to make it more malleable
- isn't very strong
- is easy to weld.

Because mild steel is a ferrous metal, it conducts electrical current effectively and is magnetic.

### Sustainability issues related to mild steel

	Requires iron ore to be mined, from either open-cut or underground mines, causing damage to the mine site.
	Iron is a non-renewable resource.
	Mild steel is a comparatively heavy metal, requiring more fuel to transport.
	Mild steel rusts easily and isn't very durable.
	Comparatively low levels of energy are used to process mild steel.
	Mild steel can be easily recycled and re-formed into new products.

## Stainless steel

Stainless steel is a ferrous metal that is deep silvery grey in colour, and is very shiny and reflective. Stainless steel is an alloy – iron is usually combined with at least 10.5% chromium and some carbon. It is sometimes alloyed with other metals to give it specific qualities.

Stainless steel is very strong and resists rusting (corrosion) and staining, and is therefore a good material to use in wet areas or for products that contain liquids. Because it is tougher, stainless steel is much harder to work with than mild steel – it is very difficult to cut, drill into and weld (cutting and drilling processes work better at slow speed with the use of cutting compounds). Stainless steel also hardens as it is worked.



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**Stainless steel makes an excellent work surface**

### Sustainability issues related to stainless steel

	Requires iron ore and other metals to be mined, from either open-cut or underground mines, causing damage to the mine site.
	Iron (the main material in stainless steel) is a non-renewable resource.
	Stainless steel is a comparatively heavy metal, but because it is strong, less is needed in a product.
	Doesn't rust (particularly in saltwater areas), and is very durable and strong.
	Comparatively low levels of energy are used to process stainless steel.

	Food and water can be carried in stainless steel without contamination, therefore it is healthier.
	Stainless steel can be easily recycled and re-formed into new products. Currently, approximately 60% of stainless steel is made from recycled material.

## Aluminium

Aluminium is a non-ferrous metal that is very light, is silvery grey in colour, and has a high sheen. Bauxite is mined to create aluminium. Australia has five bauxite mines – three in Western Australia, one in the Northern Territory and one in Queensland. Bauxite is removed from a mine and then sent to a processing plant where it is treated with chemicals, heated, and put in a bath with high levels of electricity to convert and remove the pure aluminium.

Aluminium is very light and strong, is easy to cut and shape, and conducts heat and electricity effectively. Its strength decreases in hot situations (above 100°C), but it increases in low temperatures. Aluminium is easily machined, so drilling, cutting and shaping processes can be done without special equipment. Aluminium can be welded with a tungsten inert gas (TIG) welder. Surfaces should be cleaned and pre-heated before welding to make welding easier and the join stronger.

Because aluminium is easily formed, it is often used for products that need to be extruded (pushed through a defined shape) or rolled. It is commonly formed into tubing that is made into lightweight furniture. Aluminium is also hygienic and doesn't contaminate food and drinks, so it is often used in canning, and for food containers and drink bottles. It resists rusting and is often used in outdoor environments, such as for window frames and shelters.



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**This foil baking tray is made from aluminium**

Aluminium is easily recycled and doesn't lose any quality through the process – recycled aluminium is just as good as new aluminium. Processing recycled aluminium only uses 5% of the energy needed to make new aluminium, so using recycled aluminium is much better for the environment. Around 35% of aluminium material comes from recycled sources.

### Note

In North America, aluminium is called 'aluminum' (without a second i).

### Sustainability issues related to aluminium

	Requires bauxite to be mined from open-cut mines, which causes significant, permanent damage to the mine site.
	Bauxite (the main material in aluminium) is a non-renewable resource, but it is one of the most abundant minerals on the earth's surface.
	Mining bauxite and processing aluminium produces significant waste and pollution.
	Aluminium is a very light, strong metal, therefore products made from aluminium don't require as much fuel to transport.
	Aluminium is mined and processed in Australia, therefore it requires less fuel in transportation.
	Aluminium doesn't rust and is very durable.
	High levels of energy are used to process aluminium.
	Food and water can be carried in aluminium without contamination, therefore it is healthier.
	Aluminium can be easily recycled and re-formed into new products. Currently, approximately 35% of aluminium is made from recycled material.

### Silver

Silver is a very shiny metal, is lustrous pale grey in colour, and is prized as a precious metal. Silver can be mined in a pure nugget form, but is mostly found mixed with other minerals that need to be separated and removed in the refining process. Mexico is the world's largest producer of silver, but it is also mined in other countries in the Americas, Europe and Australia. Silver can also be sourced as a by-product of other mining in Africa.



AAP Photo/Broken Hill Regional Tourist Association

### Cannington silver and lead mine in Queensland

Silver is relatively rare and expensive (although not as expensive as gold), and is commonly used in jewellery and coins. Silver doesn't rust and is easily shaped, formed and drawn into wire. Because it is fairly soft, it is usually alloyed with other metals to increase its toughness. In sterling silver, silver is alloyed with copper to reduce tarnishing (discolouring of silver due to contact with air and chemicals). Silver is very reflective and has been used for many years in mirrors (a thin film of silver behind glass provides a reflection). Silver-coated tiles are also used to protect spacecraft from the sun.

Silver is the best thermal and electrical conductor of all metals, which makes it very useful for industrial and electrical products, and also in solar panels. Silver is used in machinery to reduce friction in moving parts – bearings are often plated with a thin layer of silver. It is also antimicrobial (this limits and fights the growth of microbes, mostly bacteria) and is used in medical applications, such as in bandages. Silver has also been widely used in the photographic industry. Although digital photography has removed the need for photographic film, silver is still used in the production of X-ray films.



iStock.com/Ben-Schnewille

### Silver is used in photovoltaic solar panels

## Sustainability issues related to silver

	Requires ore to be mined, mostly from underground mines.
	Silver mining doesn't have a good history of environmental and ethical practices – recent changes to mining and production processes have improved safety and environmental outcomes.
	Silver mining creates toxic waste – arsenic is usually present in tailings dams.
	Silver is often found in ore that also contains other metals, including lead. The safety of mine workers is not always protected.
	Silver requires a very high level of energy to be processed (much more than aluminium).
	Silver products are usually long-lasting – silver does tarnish and rust (very slowly), but this can be removed easily.
	There has been a lot of concern about the welfare of workers in the silver jewellery industry, leading to some manufacturers certifying that their products are ethically produced.
	Silver is effectively recycled – recycled silver is often used in industrial applications.

## FOCUS ACTIVITY

### Using metals

- Research a mine in Australia that produces ore used to make metal.
  - Where is the mine?
  - What type of mine is it – open-cut or underground?
  - What type of ore is mined and what metal/s is made from this ore?
  - Is the ore processed and turned into metal in Australia or overseas?
- List the main categories of metals. Find other metals for each category that can be added to the chart above. Find out information about these additional metals. As a class, develop an extended chart.
- Discuss the main sustainability issues related to the production and use of metal. What are the problems and benefits of using metal to make products and in construction?
- Select three of the following products.
 

▪ outdoor seating	▪ earrings
▪ letterbox	▪ boat
▪ surgical tools	▪ down pipes for a roof
▪ structural house beam	▪ cutlery (knives, forks and spoons)
▪ aeroplane panels	▪ electrical wiring
▪ saucepan	
▪ fence	

Which metal would you choose to make each product from, and why would this be a good choice?

## OVERVIEW OF DIFFERENT METALS, THEIR QUALITIES AND USES

METAL	APPEARANCE	PROPERTIES	USES	
Ferrous	Mild steel	Dark, dull blue-grey	Fairly strong, hard and ductile, rusts easily, not very durable, inexpensive	General structural and construction, coated furniture and products
	Stainless steel	Reflective, mid-silver-grey	Difficult to work, hygienic, durable and tough, non-rusting	Cutting tools, kitchen surfaces, food and drink containers, medical tools
Non-ferrous	Aluminium	Light silver-grey	Easy to work, non-corrosive, lightweight	Lightweight construction, outdoor products, furniture, boats, food and drink containers, foil
	Copper	Red-gold, shiny	Easy to work, solders well, tarnishes, conducts heat and electricity	Pipes and sheet products, plumbing, electronics
	Silver	Light silver-grey, lustrous	Easy to form and work, soft, conducts heat and electricity, tarnishes, expensive	Jewellery, electronics, machine bearings, solar cells, photographic film, medical
Alloys	Brass	Golden yellow	Harder than copper, solders well	Bar, rod, cast and sheet products, tapware and plumbing, instruments
Plated	Galvanised iron (zinc coating)	Dull to bright grey, patterned surface	Non-rusting, tough, inexpensive	Roofing, nails, fencing, pipes

# PLASTICS

Plastics are such a part of our lives that it's hard to believe they've only been used to make products for just over 100 years. Plastics replaced the use of more traditional materials, such as metal, wood and glass, in the production of many of the items we use every day. Think about the products you have used today – how many of them have at least some part made from plastic? Cars, toothbrushes, chairs, phones and even your clothes are partly or completely made from some type of plastic.

We use the term 'plastics' to refer to a synthetic or human-made material where a polymer (a substance with a chain molecular structure) is formed by the mixture of chemicals. Early plastics were made from natural substances (such as rubber, milk protein and shellac) that were chemically treated. In the early 20th century, the exploration, development and use of synthetic plastics rapidly expanded.

The use of plastics has many benefits.

- Plastics give us cheaper, more abundant, easily formed and reproduced, and more lightweight and colourful products.
- Some products made of plastics are stronger and more hard-wearing than those made from older, traditional materials.

However, the use of plastics also creates significant problems.

- Production of plastics uses many non-renewable resources.
- Plastics create waste and pollution when made.
- The use of some plastics is linked with health issues in workers and in the community.
- Plastics are often used for short-lived or single-use products that are quickly thrown away, creating significant landfill problems.
- Plastics enter waterways and the sea, and endanger wildlife.
- Plastics can take up to 1000 years to break down in the environment.

Fortunately, many plastics can be recycled and re-used, lessening the negative impacts of their use.



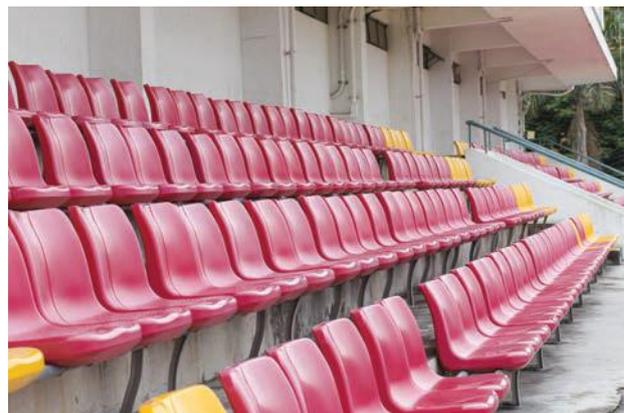
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## Plastic products used every day

### Note

One-third of the world's plastic is used to make packaging (such as bags, bottles and food containers). One-third is used in building and construction (such as pipes, cladding and frames), and the final third is used to make a wide range of other products.

## Types of plastics

Plastics are usually classified into two main categories – **thermoplastic** and **thermoset** plastics. This refers to a plastic's structure and whether it can be re-formed repeatedly when heated and reheated.

### Thermoplastics

Thermoplastics will soften and be easily shaped and moulded when heated. They can also be reheated and reshaped many times. They are easy to recycle, as products made from these plastics can be collected after use, melted and then re-formed into new products.

#### PLASTIC MEMORY

Plastic memory is a term used for most thermoplastics that return to their original shape or form after heating. For example, plastic that is stretched to produce thin packaging for savoury snacks will, when heated, shrink and return to its thicker form. Acrylic sheet that has been twisted, bent or pressed while hot will return to its flat state when reheated.

#### POLYETHYLENE TEREPHTHALATE (PET)

Polyethylene is the most commonly used plastic worldwide. It is made from petroleum materials, and is mainly used in packaging to make bags and thin films, and to make drink bottles. Polyethylene is also used to make a fibre that can be spun and used in clothing. Polyethylene has low softening and melting points, so it cannot be used for products that might get hot. It is generally not very strong, but it does resist impacts. Polyethylene is a good electrical insulator.

Polyethylene is versatile as changes to its density and chemical content give it different properties. A variation in chemicals can produce high-density polyethylene (HDPE), which is used to make detergent bottles, rubbish bins and some water pipes.



**Bottles made from PET**



**Clothing made from recycled PET plastic bottles**

#### ACRYLIC (PMMA)

Acrylic is often used as a replacement for glass because it can be made in a highly transparent form. Acrylic (sometimes called Perspex) is hard and reasonably impact-resistant. It can also be coloured, and is available in translucent and opaque forms. Acrylic is inexpensive, lightweight and easy to work with. Acrylic can be heated and formed onto shapes by slumping, blowing or strip heating, although it does scratch and crack when put under pressure.

Other uses for acrylic include eye glasses, marine tanks, windows and skylights, furniture, signs, optical fibres (cheap alternative to glass fibres) and light coverings for cars.



**Frames for glasses are often made from acrylic**

### Thermoset plastics

Thermoset plastics are formed through a chemical reaction. Once formed, they cannot be changed or re-formed without damaging the plastic. Currently, thermoset plastics cannot be recycled, although scientists are working on a new range of thermoset plastics that can be broken down with acid and re-used.

#### EPOXY RESIN

Epoxy is a two-part resin made from a basic component and a hardener or catalyst. When the parts are mixed together, a chemical reaction starts and the

resin ‘cures’ or hardens. Epoxy resin is a thermoset plastic as it can’t be melted, re-formed or reshaped once it has cured. Epoxy resins can be poured into cast shapes, or they can be used in combination with fibre matting to create a hard thin shell (for example, it can be used with fibreglass to make the hull of boats and the outer surface of surfboards). Epoxy resin can also be used as an effective two-part glue that gives a high-strength bond.

### Safety

Epoxy resins produce strong fumes, and should only be used in fume cupboards or with a respirator and good ventilation. Take care when mixing resins, and always wear gloves when handling these resins. Dispose of unused resins carefully after they have cured.

### Recycling plastic

To reduce the negative impacts of plastics on the environment, it is important to reduce the amount of plastic we use and throw away. We are all encouraged to use the six Rs of sustainability: *Rethink, Recycle, Re-use, Repair, Reduce and Refuse*.

Recycling plastic is something practical we can all do to lessen the amount of new plastic being made, and to reduce the amount of plastic that goes to landfill or into waterways. In Australia during 2014–15, we recycled 28% of the plastic packaging that was thrown away. This level is increasing every year, but there is still much room for improvement.

To be recycled effectively, plastics need to be identified and separated – firstly into plastics that can and can’t be recycled, and then into the different types of recyclable plastics. The purity of plastics being recycled is determined by how much contamination (from other plastics) is allowed through the recycling system. High-quality plastics have little or no contamination – pure plastics can be formed and shaped easily and are more consistent, reliable and durable. Recycling plants have highly developed sorting machines that identify and separate all the plastic material they receive.

Plastics have a numbering system for easy identification. The number in a triangle tells us what type of plastic an object is made from and whether it can be recycled.

Currently, most thermoplastics can be recycled as they can easily be melted down and re-formed into new products. Most recycling collection services collect

### The numbering system for plastics

SYMBOL	ACRONYM	FULL NAME AND USES
 PET	PET	Polyethylene terephthalate – soft drink bottles and food packaging
 HDPE	HDPE	High-density polyethylene – milk bottles and washing-up liquid bottles
 PVC	PVC	Polyvinyl chloride – food trays, cling wrap and shampoo bottles
 LDPE	LDPE	Low-density polyethylene – carrier bags and bin liners
 PP	PP	Polypropylene – margarine tubs and microwavable meal trays
 PS	PS	Polystyrene – foam meat trays, plastic cutlery and packaging for electronic goods and toys
 OTHER	Other	Any other plastic that does not fall into the categories above; includes acrylic, melamine, polycarbonate, nylon and fibreglass

plastics numbered 1–5, and 6 (except expanded polystyrene, which is often used in packaging to protect fragile goods).

### Bioplastics

Bioplastics are made from naturally sourced, biological materials such as vegetable material (corn, sugar cane, plant cellulose), fats and oils. Different bioplastics are used for various situations and products. Many of these behave in a similar way to petroleum-based plastics, and can be used as a more environmentally friendly alternative.

Bioplastics are better for the environment because:

- they are made from waste materials or renewable resources
- the production of bioplastics produces less greenhouse gases than petrochemical plastic alternatives
- they break down more quickly in the environment and leave a biological or natural residue.

The polylactide (PLA) plastic filament used in many 3D printers is a bioplastic made from corn or dextrose (a starch-based sugar). PLA is also used to make the mesh for pyramid-shaped tea bags.



Dreamstime.com/Laurentiu Iordache

**Pyramid tea bags are made from PLA bioplastic to keep their structure**

### Sustainability issues related to plastics

	Uses mainly non-renewable resources to make (often petroleum-based).
	More manufacturers are designing products so that the plastic content can be recycled.
	Some plastics are harmful to workers during the manufacturing process. Extra care needs to be taken to ensure their welfare.
	To make plastics, it requires about half the amount of energy as aluminium, but about twice the energy needed for mild steel.
	Most thermoplastics can be recycled, and there are developments in new thermoset plastics to make them recyclable.
	Plastics that are thrown into landfill take hundreds of years to break down.
	Many plastics that are thrown away end up in waterways and the sea, where they are harmful to wildlife.
	When some plastics break down in the environment, they don't disappear – they turn into fine plastic particles or dust that can also be harmful.
	Bioplastics (made from organic material) break down much better in the environment. They are constantly being improved and are used more for everyday products and packaging.
	Only 28% of the plastic we consume is currently recycled – this could be improved.

### OVERVIEW OF DIFFERENT PLASTICS, THEIR QUALITIES AND USES

PLASTIC	APPEARANCE	PROPERTIES	USES	
Thermoplastic	Acrylic (PMMA, Perspex)	Transparent (glass-like), translucent or opaque, can be coloured, highly reflective surface	Hard, smooth and lightweight, brittle, easily scratched, easy to work	General purpose as a replacement for glass
	Polystyrene	Slightly dull	Soft, flexible, easily shaped	Vacuum forming
	Expanded polystyrene	Light, soft 'pressed balls', or slightly solid foam	Good insulation, absorbs shock, burns with poisonous gas	Packaging, and heat and sound insulation
	Polyethylene (PET)	Transparent, glass-like, can be tinted	Easy to mould	Bottles, food containers and fabric for clothing
	Polypropylene (PP)	Dull surface, can be coloured, translucent or opaque	Flexible, doesn't weaken when bent, inexpensive	Bubble wrap, light shades, bottle tops and hinges, medical tools, thermal underwear, ropes, stationery folders and butter containers
Thermoset	Epoxy resins	White and clear two-part viscous liquids	Bonds well, waterproof, tough when used with glass matting	Two-part glues, boat building, water tanks, swimming pools and surfboard outer layer; used to make fibreglass
	Melamine	Opaque, thin material with smooth or textured surface	Very tough surface, brittle	Laminate for cabinets and panelling, children's plates and cutlery, and picnicware

## Safety

Be very careful when working with plastics, as many of them can produce fumes that are dangerous to breathe in. The glues used for plastics can be harmful too.

- » Always use the safest plastic for your product.
- » Do not heat your plastic unless you know it is safe to do so – never burn plastic.
- » Choose plastic glues with care – some are not appropriate to use in schools.
- » Plastic glues must be used in a fume cupboard (or with effective masks and good ventilation) – check the specific safety requirements for the glue you are using.
- » Wear gloves when using plastic glues.
- » Wear eye protection and dust masks when working with plastics.
- » Take care when sanding plastics as some are dangerous to inhale – wet sanding is preferable.

### FOCUS ACTIVITY

## Using plastics

- 1 In a group, develop a mind map that explores one type of plastic. Include:
  - its recycle code
  - what the plastic is like – its characteristics and properties
  - what it is made from
  - the different forms it might be available in (such as flat sheet, film or rods).
  - the different products, packaging or parts it is used to make (find pictures of these items).
- 2 As a class, collect examples of different products/objects made from plastic. Sort the plastic products into groups (use recycle codes to help – if the object doesn't have a code, try to determine the type from its characteristics). Create a display of plastics in your classroom.
- 3 List all the plastic products/objects you use in a day – remember to include items such as a car (which contains lots of different types of plastic) and food packaging. Why do you think we use plastics for these products? Are there alternative products

made from different materials available for any of the items you used during the day?

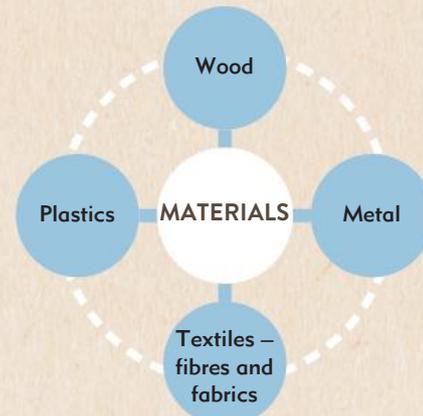
- 4 Discuss the sustainability issues related to the use of plastics. What are the main problems and their consequences? (Hint: investigate the Pacific trash vortex.) Develop a list of five things that you could do in your everyday life to reduce the impact of your plastic use.

## THINKING SKILLS

## THINKING ABOUT MATERIALS

Choose one of the following tasks.

- 1 In groups, develop and display a mind map (or other graphic method) that explains the classification of materials. Make sure you show all the material categories (textiles, wood, metal and plastics), and the sub-grouping within each material category. Make your display visually appealing.



### Example of a simple mind map for the classification of materials

- 2 Research a specific material (for example, silk, Tasmanian oak, copper, nylon) and explain how it goes from its source (where it is grown, mined, etc.) through its processing stage, to become a product (or part of a product). Consider the different types of products that might be made from this material. Present this information in a visual way to your class, using diagrams and photos.

**3** Choose a product, and visually show its journey from material source to the end of its life. Use pictures to show what happens at each stage of the product's life – sourcing and processing materials, making the product, transporting and selling it, using the product (including how long it might last for), and then what happens when it isn't useful anymore.

Possible products:



**Woolen jumper**



**Wooden stool**



**Copper light shade**



**Nylon tent**

iStock.com/evermilla; Shutterstock.com/BEPictured

Shutterstock.com/dandesign86; iStock.com/REMINC1980



# SELECTING TOOLS AND PROCESSES

When making a product, the choice of tools and processes have a big impact on how the product looks and how well it performs (does its 'job'). Selecting the right tools and process for production is a vital part of the planning and managing process, and leads to successful production work and a well-made product.

If you choose the correct **tools**, your work will be:

- easier to complete
- more accurate and precise
- finished faster.

If you choose the correct **processes**, your production work will:

- be stronger and will last longer
- usually look better
- improve the way the product performs and suits its environment.

When choosing tools and processes, you need to ask yourself the following questions:

- Which tools and processes will give me the best result? (Best means most accurate, strongest, suits the use, etc.)
- Which are available or easy to access?
- Which are the safest to use?
- Which are appropriate for my skill level?

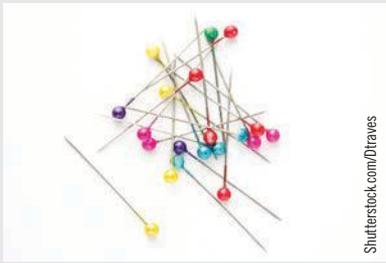
## TOOLS AND PROCESSES FOR TEXTILES

### Textiles tools and equipment

A variety of small tools are used when making products from fabric, fibre and yarn.

#### Tools and equipment for textiles

TOOLS		USE	CARE AND SAFETY
Cutting	Scissors – fabric 	To cut fabric (only use for fabric – paper blunts the blades)	<ul style="list-style-type: none"> <li>• Pay attention when cutting</li> <li>• Beware of pins when cutting</li> <li>• Keep fingers away from the blades</li> </ul>
	Scissors – paper 	To cut paper patterns and yarn	<ul style="list-style-type: none"> <li>• As above</li> </ul>
	Un-picker (or quick-unpick) 	To cut through stitches easily	<ul style="list-style-type: none"> <li>• The point is very sharp</li> </ul>

Holding	Pins		To hold fabric pieces together; to hold pattern onto fabric	<ul style="list-style-type: none"> <li>• The tips are very sharp – be careful that you don't press them into your fingers</li> <li>• Collect and safely store all pins after use</li> </ul>
	Embroidery hoop		To hold work steady while stitching	<ul style="list-style-type: none"> <li>• Low risk – don't pinch skin between hoops</li> </ul>
	Needles		To stitch with when hand-sewing fabric (shown with a needle threader)	<ul style="list-style-type: none"> <li>• As above</li> </ul>
Stitching	Knitting needles		Loops yarn to create a knitted fabric	<ul style="list-style-type: none"> <li>• Be careful the ends don't poke people</li> <li>• Safely store after use</li> </ul>
	Crochet hooks		Loops yarn to create a crocheted fabric	<ul style="list-style-type: none"> <li>• Reasonably safe to use</li> </ul>

Pressing and ironing	<p>Iron</p>  <p style="font-size: small; text-align: right;">Shutterstock.com/indigolditas</p>	<p>Applies heat and steam to remove creases and press folds</p>	<ul style="list-style-type: none"> <li>• Very hot – keep hands away from hot surface</li> <li>• Pay attention while ironing</li> <li>• <b>Electrical safety</b> – check cords before use; do not use near water (apart from steam chamber)</li> </ul>
	<p>Steam press</p>  <p style="font-size: small; text-align: right;">ImageReflex/Alamy Images/Alamy</p>	<p>As above</p>	<ul style="list-style-type: none"> <li>• <b>Be trained before you use a steam press</b> – steam burns are very serious</li> <li>• <b>Electrical safety</b> – check cords before use</li> </ul>

### Sewing machines

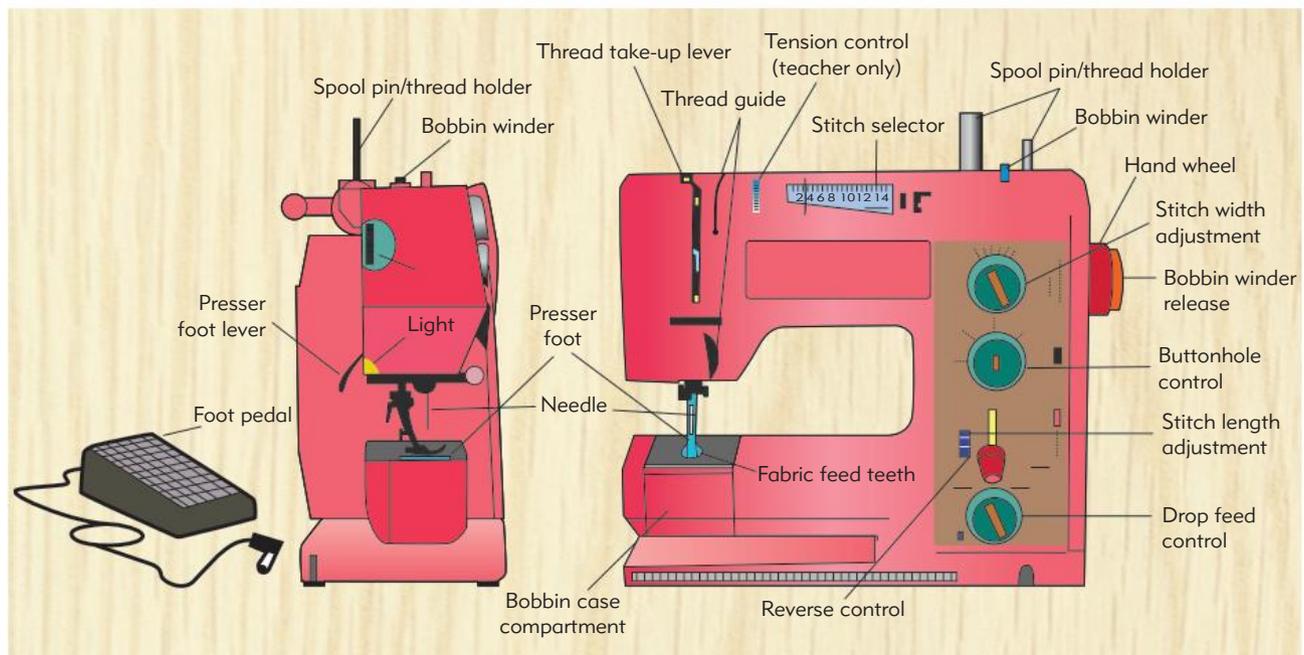
**Sewing machines** are one of the basic ‘tools of the trade’ in textiles. Most sewing machines sew:

- a basic seam
- a zigzag or finishing edge
- decorative and patterned stitches
- buttonholes.

Some advanced machines have computer programming that can complete a digital design in stitches. These require some training to prepare and

upload a digital design, and to set up the sewing machine to complete this design on fabric.

A wide range of sewing machines are available, and they all have slightly different threading arrangements and placement of controls. Before you use a sewing machine, you’ll need to learn about those used at your school and complete a sewing machine licence (if your teacher requires it) to show you are competent. Many machines follow a basic set-up and have the same controls as shown in the following image.



## THREADING YOUR MACHINE

Threading a sewing machine correctly is important – if it is threaded incorrectly, the thread will break or tangle and the machine won't sew. Your teacher will demonstrate how to thread your sewing machine, but there are also simple tutorials on the internet. You will need to know how to fill a bobbin and place it correctly in its compartment. You will also need to choose the correct machine needle for the fabric you are sewing, and learn how to change needles.

### Safety

There are many safety issues that must be considered when using a sewing machine.

- » A sewing machine is an electrical machine – check that all cords are in good condition before plugging it in.
- » Don't drape the cords across an area where people walk – it will be tripping hazard.
- » Don't use a sewing machine without proper training.
- » Set up the sewing machine at a suitable height, and ensure your chair is well positioned so you aren't slouching or straining your back.
- » Always focus while sewing – make sure that your fingers never go near a moving needle.
- » A sewing machine is not a racing car – start off slowly and increase your speed as you become more experienced.
- » Sew in a well-lit area.
- » Put your machine away safely after use.

## OVERLOCKERS

Overlockers are useful machines suitable for more advanced sewing tasks. Overlockers cut the edge neatly and sew an overlocked seam with three or four threads at the same time. It is a great machine for sewing knit fabric, as the seam usually has some stretch and the edges of the fabric don't unravel. Overlockers can also be used to create neat rolled edges and hems, particularly on fine fabrics that are difficult to sew.

Learning how to set up and use an overlocker requires skill and patience. It is important to keep the machine threaded for the next user, as threading an overlocker takes 10–20 mins for an experienced user.

### Safety

All safety rules for sewing machines apply to the overlocker, but there are some additional safety concerns.

- » An overlocker has a sharp blade near multiple sewing needles – it is crucial to focus and keep your fingers away from the dangerous sewing areas of the machine.
- » Make sure you remove all pins when sewing.



## Processes in textiles

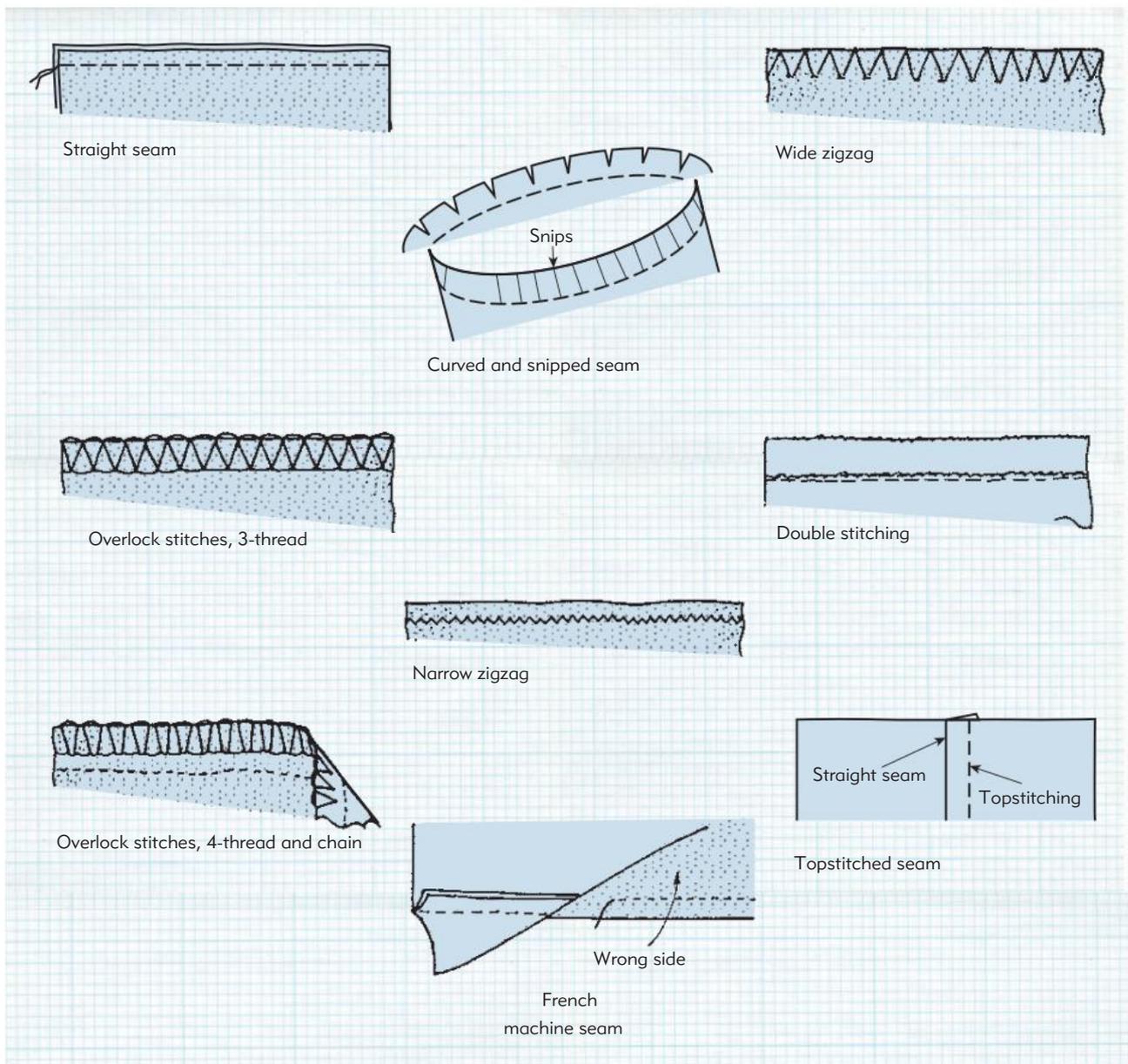
### Seams

There are many seams options when sewing fabric together. What seam you choose will depend on the strength you need, the purpose of the seam, how heavy your fabric is, and whether your fabric will fray and unravel easily.

#### SEAMS THAT JOIN

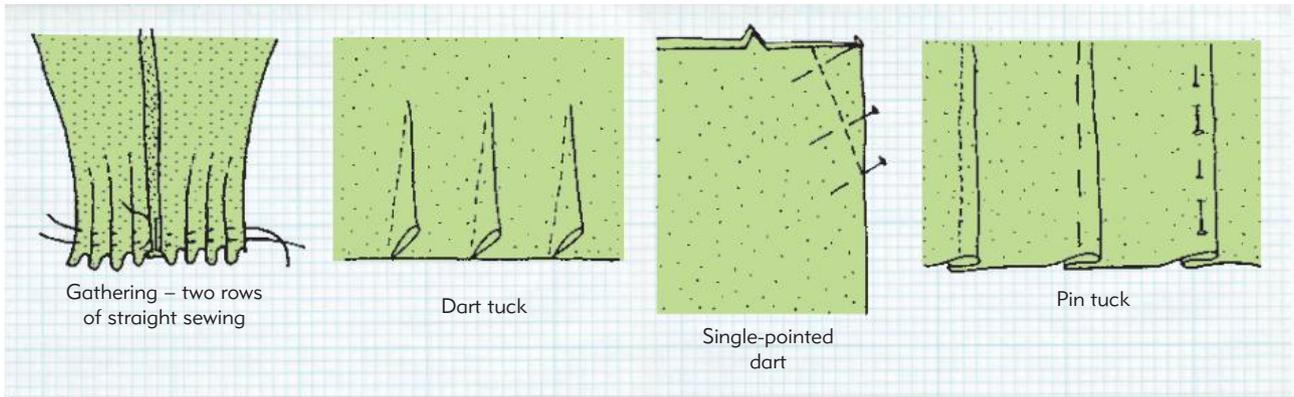
■ A straight or curved seam is most commonly used for simple joining tasks. Curved seams often need to be snipped, but don't cut through the threads of the seam.

- Zigzag is used to 'finish' the seam (sewn between the joining seam and the edge of the fabric) – it stops the fabric fraying. Overlocked seams also provide a strong 'finish'.
- Topstitching provides extra strength and gives a professional-looking flat seam.
- Double stitching is used in sections that need added strength.
- French seams give a smooth finish, and are often used when sewing fine fabric.



#### Seams that join

## SEAMS TO CREATE SHAPE

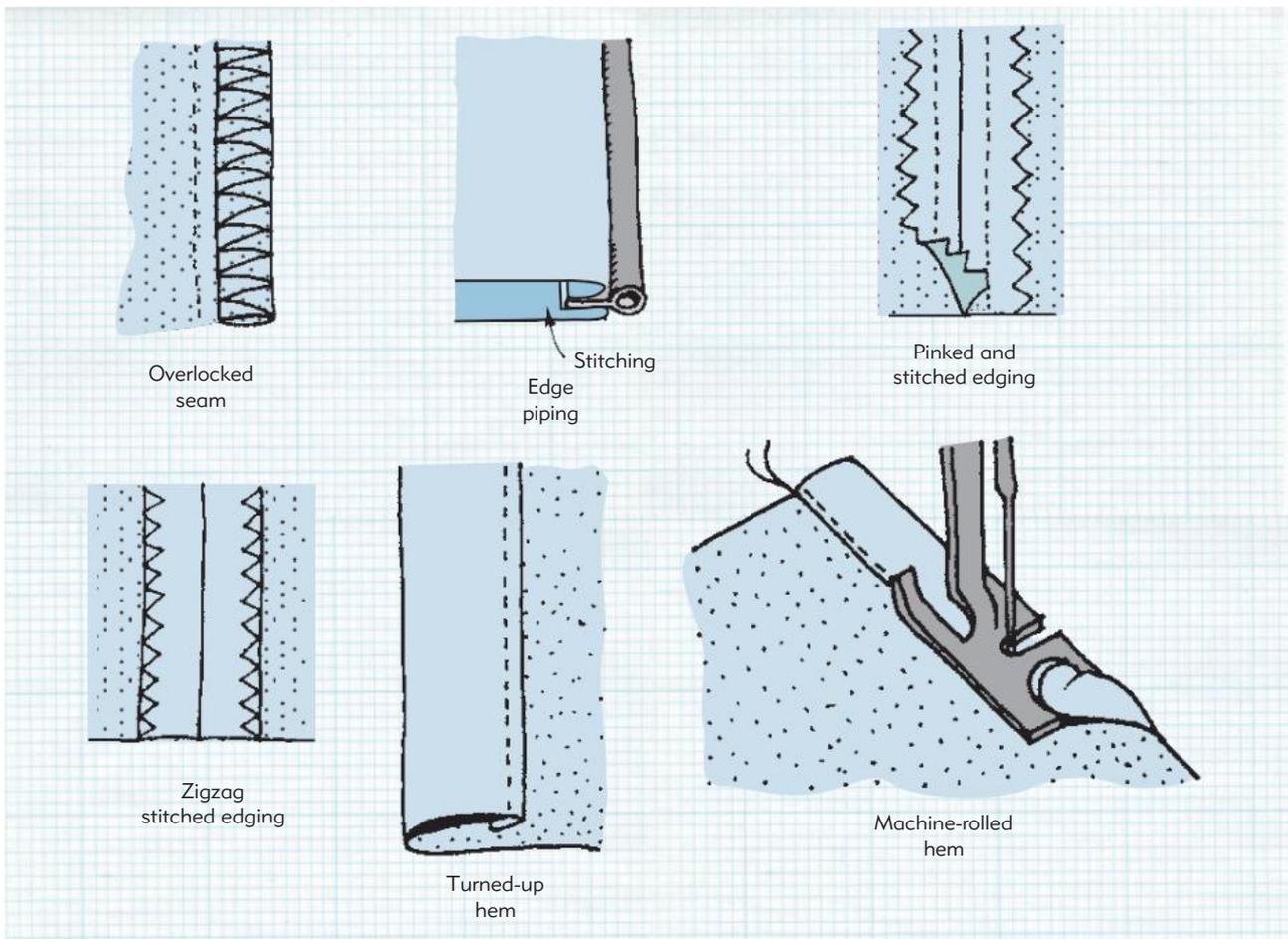


### Seams to create shape

## SEAM NEATENING OR FINISHING

There are many methods to neaten and finish seams. This sometimes needs to be done to make the inside of the sewn object smoother and more comfortable,

to stop the fabric fraying, or to give extra strength. Choose the seam finish that best suits the weight of the fabric and the use of the sewn object.



### Seam neatening or finishing

## Creative and decorative processes

The following creative and decorative processes are fun to work with. Exploring these processes and techniques helps you to develop creative and innovative designs.

### FELTING

Felting is a process that uses the scaly structure of wool fibres to create a strong, matted fabric. Felted fabric is fuzzy, thick, stiff and water resistant.

To felt wool, vigorously apply pressure (scrubbing and rubbing), hot water and soap until the fibres interlock. Patterns can be felted onto the surface by placing different-coloured woollen 'tops' in a pattern, and by layering fine fabric pieces with woollen fibres (the woollen fibres attach through the fine fabric). You can also felt knitted fabric and old woollen jumpers (the yarn used in the knitting must be wool, and not machine washable). Either throw the knitted pieces into a washing machine on a hot cycle with detergent, or manually scrub with hot water and soap. The knitted fabric will shrink a lot during this process. Once fabric is felted, it can be cut and sewn into a product.



Shutterstock.com/Denis Churin

### Hand-felted slippers

### WEAVING

Handweaving is an ancient craft – it is a very early form of technology. Fabric is created for a purpose by interweaving threads or yarns, grasses or strips of skin, alternating in an under-and-over pattern, usually at right angles. Handweaving is still practised in many communities and settings.

- Many Australian Indigenous nations have their own distinct forms of weaving. A combination of locally sourced grasses and commercial threads and yarns are used to make beautiful baskets and carrying containers, and other practical and decorative objects.

- With the rise in popularity of crafting skills, many people are rediscovery weaving as a way of exploring texture and colour of wools and yarns to make simple products.



Alamy Stock Photo/Elli Bachman

**Traditional Indigenous Australian weaving of the Wurrumiyanga community**

### FOCUS ACTIVITY

## Exploring weaving

- 1 Investigate the different forms of traditional and contemporary Australian Indigenous weaving. Who does the weaving? How is it done? What materials are used? How do these objects fit into traditional and contemporary life? You could visit Melbourne Museum and research some of the objects in the Bunjilaka Aboriginal Cultural Centre. Perhaps someone from a local Aboriginal community could talk to your class about why and how they weave.
- 2 Look at the natural materials in your local area – your school, local parks and bushland. Think about how they could be used to make something woven. Create a useful handwoven object that combines locally found and commercial materials.

## CREATING FABRIC WITH STITCH-ON 'WASH-AWAY' MESH

'Wash-away' is a water-soluble mesh, sometimes called fabric stabiliser. Items such as pieces of fine transparent fabrics, threads and yarn, ribbon and braid can be sewn together, and then attached to the mesh with lines of machine sewing. Once all the layers are connected with the sewn lines, the piece can be submerged in water to dissolve the mesh. This leaves behind the sewing and fabric layers. Other elements such as buttons and beads can be added by hand after the mesh has been dissolved.



Pam Martin - Somerset Stitch - England

## DYEING

Fabric can be dyed a single colour, or a pattern can be created during the dyeing process. Techniques to dye fabric include natural dyeing, Shibori, Batik and tie-dyeing.

### FOCUS ACTIVITY

#### Exploring dyeing

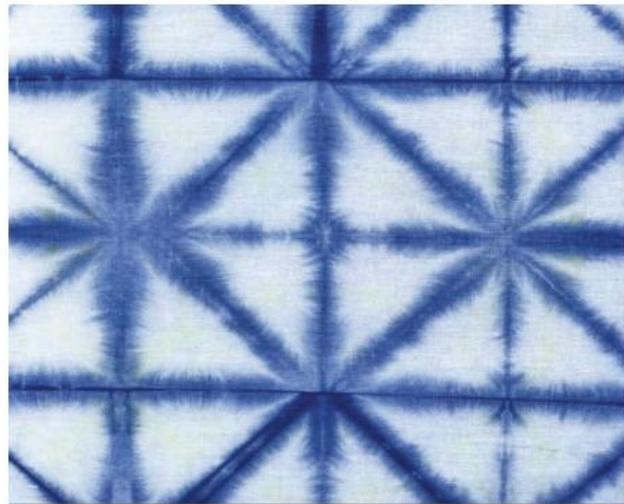
- 1 Try dyeing fabric with natural, everyday materials such as onion skins, leaves, flowers, rusty metal. What is a mordant and what does it do? What commonly found chemical can be used as mordants?
- 2 Find out about the Japanese art of Shibori (folding and dyeing). Why is Shibori fabric often blue? What dyes are traditionally used? How do different folds, stitching and gathering create patterns (experiment)?
- 3 Explore the art of Batik or wax-resist dyeing. Who traditionally created Batik fabric? How did they get different layers of colour? How can you try this out safely using hot wax?
- 4 What is tie-dyeing? When did it become popular in contemporary culture? Why? What item of clothing was usually tie-dyed?

Instruction videos for many of these techniques can be found on the internet.



Naturally dyed wool

istock.com/Ken Wiedemann



Shibori

Shutterstock.com/vetre



Wax is applied to create a Batik design

Shutterstock.com/Ismaail Senung



A tie-dyed pattern

Shutterstock.com/mark higgins

## PRINTING

There are many different techniques to print onto fabric. Most fabric paints and dyes need to be ironed after the print has dried to colour-set the print (so it doesn't wash away).

- Silk-screen printing – a stencil is attached to a silk screen, and fabric paint is then pushed through the screen with a squeegee (the paint can only move through the holes or negative spaces of the stencil).
- Digital printing – a digital design or image is printed onto fabric transfer paper, and then ironed onto fabric.
- Block printing – a block or stamp is created (such as simple potato stamps, cord glued onto a wooden block in the form of a pattern, or foam cut and glued to a backing), and then dipped into fabric paint and applied to the fabric.
- Organic fabric print – natural objects such as leaves and flowers are used to create a print.

Shutterstock.com/Pierr Lerch



**Silk-screen printing**

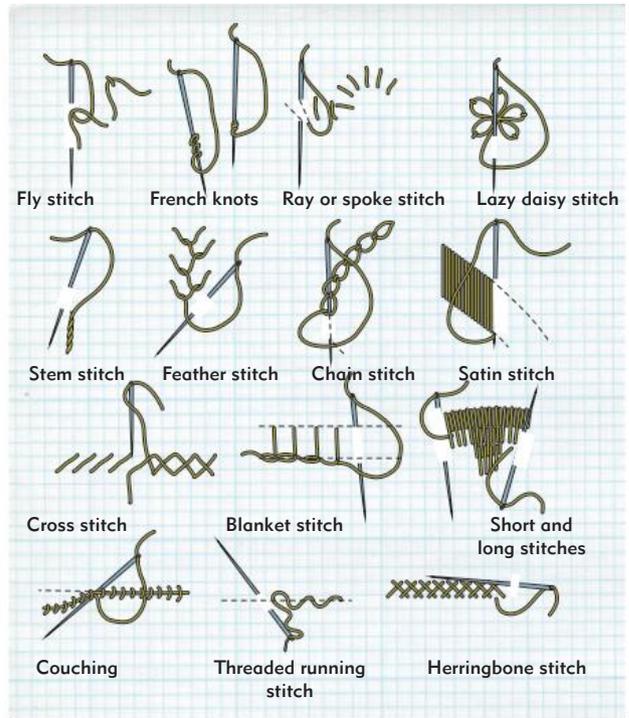
Shutterstock.com/BKivveander



**Traditional Indian block printing**

## DECORATIVE STITCHING

Embroidery stitching can be used to add visual interest and colour to a fabric product.

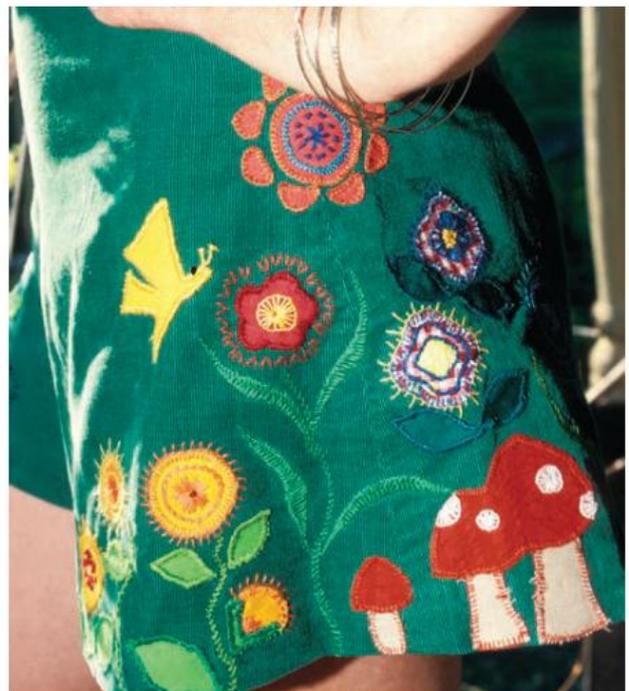


**Decorative embroidery stitches**

## ADDITIVE DECORATION

Different items can be added to the surface of fabric to add interest and impact, such as:

- sequins, beads and buttons
- ribbons and braids
- appliqué – layers of contrasting fabric are sewed onto a base fabric to create a design (attaching with iron-on fusible web helps).



**Appliqué**

Imagefolk/Howard Birnstihl

## Textiles tools and processes

- 1 Can you remember all the parts of a sewing machine? With a partner, take turns testing your knowledge.
- 2 Select and draw three items of clothing. Label each drawing with all joining and decorative processes used to make the clothing item.
- 3 If you were making clothing for a small child, which types of decorative processes wouldn't be suitable? Explain your answer.
- 4 Choose one joining or decorative processes. Create a step-by-step written explanation of how that process should be completed. Use diagrams to help illustrate the steps, and remember to include any safety rules.

## TOOLS AND PROCESSES FOR WOOD

### Woodworking tools

HAND TOOLS FOR WOOD	USE	CARE AND SAFETY
<p>Steel rule and tape measure</p>  <p>Measuring and marking</p>	To measure in cm and mm	<ul style="list-style-type: none"> <li>• Protect the edges from wear</li> <li>• Keep from bending so that ruling and measuring is easier</li> </ul>
<p>Try square</p> 	To measure and accurately mark 90° and 45°	<ul style="list-style-type: none"> <li>• Corners might be sharp – handle with care</li> </ul>
<p>Marking gauge</p> 	To mark a line that is parallel to the edge	<ul style="list-style-type: none"> <li>• Beware of fine marking point</li> </ul>

Vernier caliper

Shutterstock.com/0100



To accurately measure the internal and external dimensions of an object

- Points and end might be sharp – handle with care

SAWS

Tenon saw

Shutterstock.com/stuart.ford



To cut accurate joints

- Ensure material is secured in a vice or with clamps before cutting
- Keep fingers away from sharp teeth of saw
- Make sure the teeth don't hit anything metal

Coping saw

Shutterstock.com/froy



To cut curves in thin to medium thickness materials

Piercing saw

iStock.com/vosmanius



To cut detailed curves and angles in thin material

Rip saw

Shutterstock.com/Maryna.Mandarinika



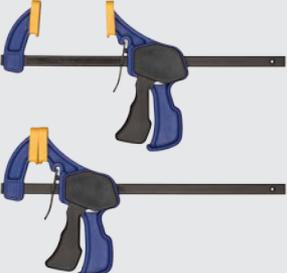
To cut (fairly roughly) along the grain

Specialist and Japanese saws

Shutterstock.com/donatas.1205



For very fine, accurate cutting, and special tasks

Cutting tools	<p>Chisel</p>  <p>Shutterstock.com/pyzmat</p>	<p>To accurately remove timber and shape joints</p>	<ul style="list-style-type: none"> <li>• Keep fingers away from sharp blade of the chisel</li> <li>• Never place hands in front of the chisel</li> <li>• Make sure material is secured in a vice or with clamps before using</li> <li>• Make sure the blade doesn't hit anything metal</li> <li>• Don't use chisels for other tasks</li> </ul>
	<p>Gouge</p>  <p>Shutterstock.com/Paolo Cremonesi</p>	<p>Curved blade to carve and remove timber, to create hollow forms</p>	<ul style="list-style-type: none"> <li>• As above</li> </ul>
	<p>Plane</p>  <p>Shutterstock.com/vilorejo</p>	<p>To shave a thin slice of timber off and to smooth the surface</p>	<ul style="list-style-type: none"> <li>• The blade can be very sharp – keep fingers away</li> <li>• Make sure timber is secure</li> <li>• Ask for help to set the plane up correctly</li> </ul>
<b>CLAMPS</b>			
Holding	<p>G clamp</p>  <p>Shutterstock.com/jasni</p>	<p>To hold work steady</p>	<ul style="list-style-type: none"> <li>• Very heavy – don't drop onto your feet</li> </ul>
	<p>Quick-action clamp</p>  <p>Shutterstock.com/donatas_1205</p>	<p>Also to hold work steady; can be applied and removed quickly</p>	

Sash cramp/clamp



Shutterstock.com/pyzmat

For gluing larger flat surfaces and frames (sash cramp)

Spring clamp



Shutterstock.com/Ariphoto

For holding smaller pieces in place

Bench vice



Shutterstock.com/Nomad\_Soul

Attached to the bench and used for holding things firmly while working; wooden jaw surfaces limit damage to work

File



Shutterstock.com/Luisa Fumi

To shape and smooth timber and metal (available in different levels of smoothness)

- Files are brittle – they can snap easily if hit
- Always secure timber when filing

Rasp



Shutterstock.com/pjuzl47

Removes timber and shapes quickly (can be rough)

Surform rasp or plane (microplane)



Shutterstock.com/MR Gao

Striking	<p>Hammer</p>  <p><small>iStock.com/xmxxx</small></p>	To strike nails (and to remove nails using the claw)	<ul style="list-style-type: none"> <li>• Only use a hammer for striking metal</li> <li>• Keep fingers and thumb out of the way when striking</li> </ul>
	<p>Mallet</p>  <p><small>iStock.com/gymane</small></p>	To strike chisel handles and to knock timber into place	<ul style="list-style-type: none"> <li>• Only use for striking timber and plastic</li> <li>• Keep hands out of the way when striking</li> </ul>
Joining	<p>Screwdriver set (including flat, Phillips, Pozidriv and square)</p>  <p><small>Shutterstock.com/except_else</small></p>	To insert screws	<ul style="list-style-type: none"> <li>• Beware of points when applying pressure – a screwdriver can bruise or cut if it slips</li> </ul>
	<p>Spanners (ring, open-ended and combination)</p>  <p><small>Shutterstock.com/Robert_Neal</small></p> <p>Shifting spanner</p>  <p><small>Shutterstock.com/Pincarel</small></p>	To move and tighten nuts and bolts	<ul style="list-style-type: none"> <li>• Make sure the spanner fits the nut correctly and doesn't slip off under pressure</li> </ul>

# Woodworking machinery

PORTABLE POWER TOOLS		USE	CARE AND SAFETY
Drilling	Portable drill (cordless or with a cord) 	To drill holes and insert/remove screws	<ul style="list-style-type: none"> <li>• Always wear safety glasses</li> <li>• Secure the material you are drilling into</li> <li>• Tie long hair back</li> <li>• <b>Electrical safety</b> – Make sure the charging station is set up correctly</li> </ul>
	Engraver (Dremel tool) 	For engraving, and for fine sanding with sanding heads (uses either vibrating or spinning mechanism)	<ul style="list-style-type: none"> <li>• <b>Electrical safety</b> – Check cords before use; make sure tool end never makes contact with the cord</li> </ul>
Cutting	Jigsaw 	To cut curves through thin to thick material <b>Hazardous – requires extra training</b>	<ul style="list-style-type: none"> <li>• Always wear safety glasses</li> <li>• Secure the material you are cutting</li> <li>• Tie long hair back</li> <li>• Keep fingers away from the moving blade</li> <li>• <b>Electrical safety</b> – check cords before use; never let the blade get close to the electrical cord</li> <li>• <b>Be trained before use</b></li> </ul>
	Scroll saw 	To cut curves through thin material	<ul style="list-style-type: none"> <li>• Always wear safety glasses</li> <li>• Tie long hair back</li> <li>• Keep fingers away from the moving blade</li> <li>• <b>Electrical safety</b> – check cords before use, never let the blade get close to the electrical cord</li> <li>• <b>Be trained before use</b></li> </ul>
	Multitool 	Uses vibrating cutting action, and has detachable tools for different cutting and sanding tasks	<ul style="list-style-type: none"> <li>• Always wear safety glasses</li> <li>• Tie long hair back</li> <li>• Keep fingers away from the moving blade</li> <li>• <b>Electrical safety</b> – check cords before use, never let the blade get close to the electrical cord</li> <li>• <b>Be trained before use</b></li> </ul>

Experienced students only

Sanding	Laminate cutter (small router)	 <p style="font-size: small; text-align: right;">Shutterstock.com/Brilliant Eye</p>	<p>Lightweight router that cuts and shapes edges and forms (with a template)</p> <p><b>Hazardous – requires extra training</b></p>	<ul style="list-style-type: none"> <li>• Only use with a roller guide or template</li> <li>• <b>Electrical safety</b> – check cords before use; never let the cutting bits get close to the electrical cord</li> <li>• <b>Be trained before use</b></li> </ul>	Experienced students only
	Biscuit or domino joiner	 <p style="font-size: small; text-align: right;">Shutterstock.com/OlegSam</p>	<p>Cuts or drills special grooves for joining</p> <p><b>Hazardous – requires extra training</b></p>	<ul style="list-style-type: none"> <li>• Plunge tool – cutting parts should never be exposed while turned on</li> <li>• <b>Electrical safety</b> – check cords before use; never let the belt get close to the electrical cord</li> <li>• <b>Be trained before use</b></li> </ul>	Experienced students only
	Orbital sander (1/3 sheet)	 <p style="font-size: small; text-align: right;">Shutterstock.com/OlegSam</p>	<p>To sand and smooth large sections of work (result depends on the grade of sandpaper used)</p>	<ul style="list-style-type: none"> <li>• Collect dust in a dust catcher</li> <li>• <b>Electrical safety</b> – check cords before use; make sure the cords aren't a tripping hazard</li> </ul>	
	Random orbital sander	 <p style="font-size: small; text-align: right;">iStock.com/dial-a-view</p>	<p>Same as orbital sander but more flexible due to sanding pad; uses disposal round sanding discs</p>	<ul style="list-style-type: none"> <li>• As above</li> </ul>	
	Palm sander	 <p style="font-size: small; text-align: right;">Shutterstock.com/Norman Pogson</p>	<p>Has very small shaped pads that can sand in tight corners</p>	<ul style="list-style-type: none"> <li>• As above</li> </ul>	
	Belt sander	 <p style="font-size: small; text-align: right;">Alamy Stock Photo/Stock-Industrial</p>	<p>Fast-moving belt roughly removes timber material</p> <p><b>Hazardous – requires extra training</b></p>	<ul style="list-style-type: none"> <li>• Requires skilled handling for a good result</li> <li>• <b>Electrical safety</b> – check cords before use; never let the belt get close to the electrical cord</li> <li>• <b>Be trained before use</b></li> </ul>	Experienced students only

## Large woodworking machines

Most of the larger machines at a school in the wood/metal areas are only for teachers to use as they are very dangerous. However, there are some machines that are useful and reasonably safe for students to use. One such machine is the pedestal drill.

PEDESTAL DRILL/ DRILL PRESS	USE	CARE AND SAFETY
	<p>To drill holes vertically (used for a range of materials)</p>	<p>Listen carefully to your teacher's instructions about safe use, and ask permission before using.</p> <ul style="list-style-type: none"> <li>• Wear protective glasses</li> <li>• Tie long hair back</li> <li>• No loose clothing</li> <li>• Always clamp down material</li> <li>• Don't get distracted</li> <li>• Make sure your hands are never near a spinning drill bit</li> <li>• Cover the chuck with the chuck cover, and always remove the chuck key before use</li> </ul>

Note: your teacher may add to safety guidelines to fully cover each machine's individual safety requirements.

Other woodworking machines that you may use at school include:

- spindle sander – for sanding curved and shaped pieces of timber
- finisher (belt-and-disc sander) – for sanding specific angles and flat surfaces quickly
- horizontal borer – for drilling holes horizontally.

Your teacher will have some form of written and/or practical test for you to complete before you can use these machines.

## Sandpaper

Sandpaper is used to remove unwanted material, and to make the finished surface smooth. You will need to be familiar with sandpaper terminology.

- **Grit** – Sandpaper is made from fine pieces of grit/stone that are attached to a paper or fabric

backing. Different papers are named according to the material the grit is made from; for example, garnet paper is made from crushed garnet stone.

- **Grit count/grade** – Sandpaper is classified or graded according to how many pieces of grit there are in each square inch (25 mm). The fewer the pieces of grit in an inch, the larger the individual pieces of grit are and the rougher the sandpaper is. Any sandpaper with a count of 40–80 grit is very rough and is used to remove material quickly. A grit count of 120–180 is reasonably smooth. Above 220 is for very fine smoothing of timber.
- **Specialist paper** – paper with grit made from silicon carbide is called **carborundum** paper (or 'wet and dry' paper). It is used for a range of materials, often for sanding and polishing plastic and metal. The grit level of carborundum is usually a lot higher than regular sandpaper: 240–1200 grit counts are commonly used, and are called microgrits.
- **Sanding order** – when using sandpaper, use the rough grade first and then work through a number of grades until you finish with a very smooth sandpaper (that is, start with a low number grit and end with a high).
- **Sanding direction** – always sand in the same direction as the grain. If you sand across the grain, you will add scratches to your surface. When sanding end grain, you can sand in any direction (for information about timber grain, see page xx).

### Tip

The smaller the sandpaper grit count number, the rougher it is.

### Safety

Sanding can be hazardous, as it creates very fine particles that can be breathed in. Wear dust masks and glasses when using sanding machines, and a higher level of protection when sanding more dangerous materials (some plastics, timbers and manufactured boards).

## Fastenings

Fastenings are the objects we use join things together. They include nails and screws (rivets can also be used to join parts of a product – see the Metal section on page 66).

## Nails

### Nails and their uses

NAIL TYPE	USES	ILLUSTRATION
Bullet head	General construction	 Andrew Kay Photography
Bullet head: galvanised	For use outside, or where rusting is likely	 iStock.com/qhrome27
Flat head	Nailing thin timbers, packing crates	 Andrew Kay Photography
Clout	Fixing sheet metal and soft materials to timber	 Andrew Kay Photography
Twisted	Increased holding power, very secure	 Andrew Kay Photography
Cut tack	Used to attach upholstery fabric	 Andrew Kay Photography
Corrugated fastener	Reinforces a weak joint, rough work and construction	 Andrew Kay Photography
Staple	Attaching wires and cables to timber	 Andrew Kay Photography

When nailing, choose a nail that is long enough to give a strong connection. Some nailing situations require pre-drilling a pilot hole to prevent timber splitting. Nails can be driven in straight or on an angle (skew nailed, which creates a stronger joint). A nail punch can be used to drive a bullet head nail below the surface, and the hole can be filled with putty for a neater joint.

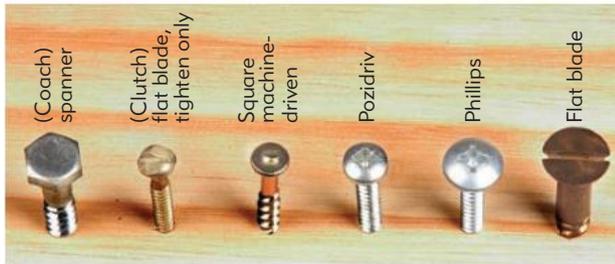
### Screws

Screws are harder to use than nails, but they give a stronger joint. Screws are chosen if a product is likely to receive lots of heavy use, and for specific tasks, such as attaching a hinge.

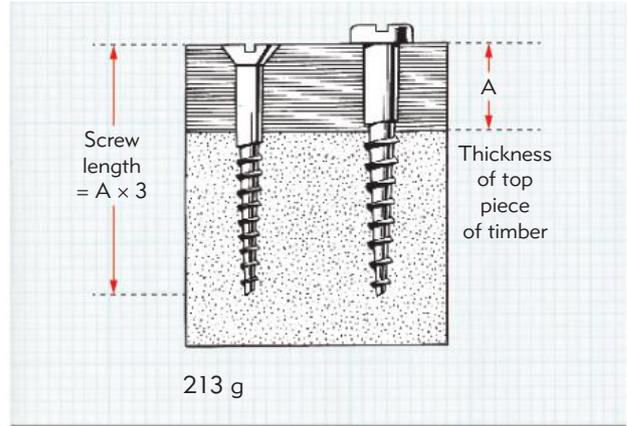
## Screws and their uses

SCREW TYPE	USES	MEASUREMENT
Countersunk head	Hinges and general work (where the screw must be flush with the surface)	Screws usually have two measurements: <ul style="list-style-type: none"> <li>• One measurement describes the diameter of the screw shank</li> <li>• The other measurement describes the length of the screw that sits below the surface</li> </ul>
Round head	Fixing thin metal or plastic, or metal fittings	
Coach screw	Securing heavy timber, machinery, vices and gates	
Self-tapping screws	Securing particle board (they have a drilling point and don't require pre-drilling)	

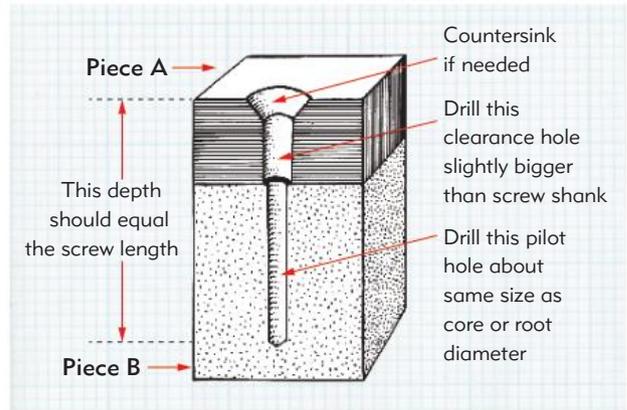
Screws can be made from different materials such as stainless steel, brass, galvanised metal, zinc plated and coated. If a product is being made for a harsh environment (such as outdoors where it is exposed to weather conditions), screws need to be carefully selected. The correct type of metal and finish need to be chosen for the situation.



A variety of screw-tightening methods



Selecting screw length



Pre-drilling for a screw

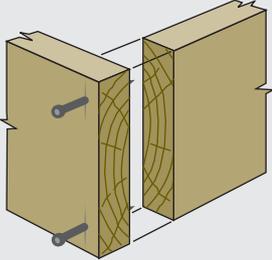
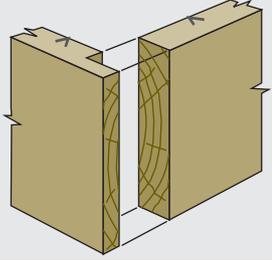
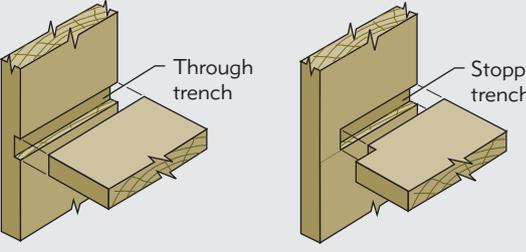
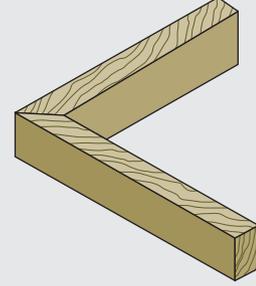
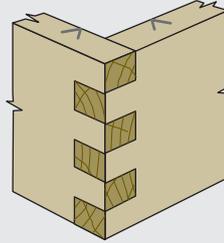
## Glues

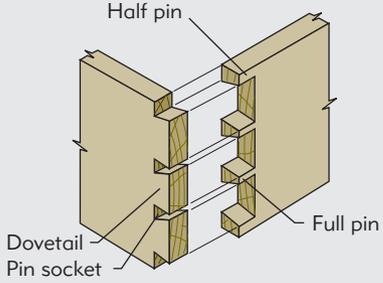
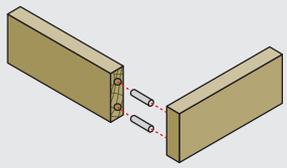
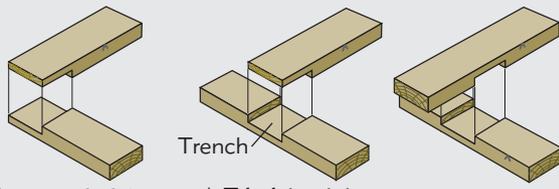
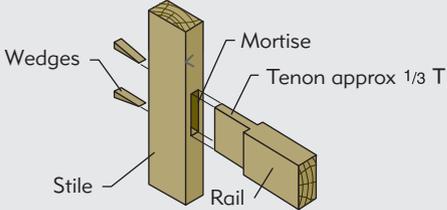
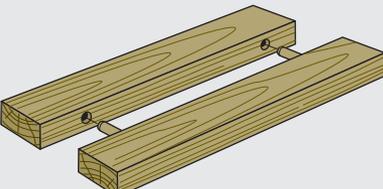
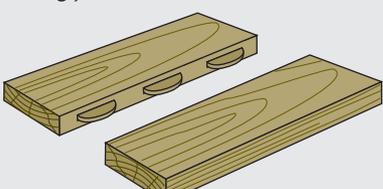
There are lots of different glues available for joining materials. For each joining situation, the most appropriate glue needs to be selected to suit the materials and the use of the product.

## A guide to glues

GLUE	AVAILABLE TIME FOR ASSEMBLY	CLAMPING/DRYING TIME	USE	CHARACTERISTICS
PVA white or yellow glue	7–10 minutes	8–24 hours	<ul style="list-style-type: none"> <li>• Indoor products</li> <li>• Timber</li> <li>• Low-stress joints</li> </ul>	<ul style="list-style-type: none"> <li>• Dries clear and colourless</li> <li>• Water-soluble</li> </ul>
Contact adhesive	Can be moved while liquid (10–20 minutes) Is applied to both sides – sticks on contact when touch-dry	5 minutes	<ul style="list-style-type: none"> <li>• To join most materials</li> </ul>	<ul style="list-style-type: none"> <li>• Sticky, creamy liquid</li> <li>• Flexible</li> </ul>
Epoxy (two-part) glue – resin and hardener/catalyst mixed together	Different forms are available (see instructions)	5 minutes to 12 hours, depending on type of resin	<ul style="list-style-type: none"> <li>• To glue different types of materials together</li> </ul>	<ul style="list-style-type: none"> <li>• Toxic – requires safety precautions</li> <li>• Sets clear</li> </ul>
Polyurethane	45–60 mins	2–3 hours	<ul style="list-style-type: none"> <li>• Boat building, interior and exterior joinery</li> <li>• Timber and other materials</li> </ul>	<ul style="list-style-type: none"> <li>• Slightly foaming, gap filler</li> <li>• Stains hands (wear gloves)</li> </ul>

## Common woodworking joints

JOINT	DESCRIPTION	USES
<p>Butt joint</p> 	<ul style="list-style-type: none"> <li>• Simple joint</li> <li>• Weak, not very durable, quick to make</li> </ul>	<ul style="list-style-type: none"> <li>• Rough carpentry and inexpensive furniture</li> </ul>
<p>Rebate joint</p> 	<ul style="list-style-type: none"> <li>• Corner joint</li> <li>• One side is cut to receive the other</li> <li>• Medium-strength joint</li> <li>• Reasonably simple to make</li> </ul>	<ul style="list-style-type: none"> <li>• Cabinets and drawers</li> </ul>
<p>Trench/housing joint</p> 	<ul style="list-style-type: none"> <li>• One side is cut to receive the other</li> <li>• Medium-strength joint</li> <li>• Reasonably simple to make by hand or machine</li> </ul>	<ul style="list-style-type: none"> <li>• Shelves, supports and dividers</li> </ul>
<p>Mitre joint</p> 	<ul style="list-style-type: none"> <li>• Framing joint</li> <li>• Both sides are cut at a 45° angle</li> <li>• Weak and difficult to glue (can be strengthened with a spline or dowel)</li> <li>• Clean-looking joint</li> </ul>	<ul style="list-style-type: none"> <li>• Frames, and edging around a cabinet or tabletop</li> </ul>
<p>Finger or box joint</p> 	<ul style="list-style-type: none"> <li>• Decorative joint</li> <li>• Interlocking/alternating fingers</li> <li>• Very strong joint</li> <li>• Time-consuming and difficult to make</li> </ul>	<ul style="list-style-type: none"> <li>• Boxes and solid frames</li> </ul>

<p>Dovetail joint</p> 	<ul style="list-style-type: none"> <li>• As above</li> </ul>	<ul style="list-style-type: none"> <li>• As above</li> </ul>
<p>Dowel joint</p> 	<ul style="list-style-type: none"> <li>• Holes are drilled into both pieces of timber to receive a short dowel plug</li> <li>• Medium- to high-strength joint</li> <li>• Accuracy required for the placement of holes</li> </ul>	<ul style="list-style-type: none"> <li>• Furniture and cabinet frames, including tables and chairs</li> </ul>
<p>Halving joints</p>  <p>A corner halving joint      A T halving joint      A cross halving joint</p>	<ul style="list-style-type: none"> <li>• Both narrow pieces of timber are cut to slot into each other</li> <li>• Medium-strength joint</li> </ul>	<ul style="list-style-type: none"> <li>• Furniture and cabinet frames, doors,</li> </ul>
<p>Mortice and tenon joint</p> 	<ul style="list-style-type: none"> <li>• A hole is drilled and chiselled into one side and a post that fits the hole is cut in the other</li> <li>• Very strong joint</li> <li>• Wedges can be used to tighten and strengthen the joint further</li> </ul>	<ul style="list-style-type: none"> <li>• Furniture and cabinet frames</li> </ul>
<p>Dowelled widening joint</p> 	<ul style="list-style-type: none"> <li>• Used to join timber together to make a wider board</li> <li>• Requires accuracy in the placement of holes for dowels</li> </ul>	<ul style="list-style-type: none"> <li>• Tabletops, benches and wide cabinets</li> </ul>
<p>Biscuit widening joint</p> 	<ul style="list-style-type: none"> <li>• As above</li> <li>• Requires less accuracy, although there is some room for movement when gluing</li> </ul>	<ul style="list-style-type: none"> <li>• As above</li> </ul>

## Note

- » **Joint** is a noun and refers to the result of joining pieces together.
- » **Join** is a verb and describes the action of putting the pieces together.

For example, 'I am going to join these pieces to make this joint.'

## Decorative processes

Products made from timber must function well, and also be interesting and visually appealing. Decorative processes are used to add visual interest to product (they make it look great) and they sometimes help the product to function well; for example, the laser-cut design in a candle holder allows the light to pass through.

DECORATIVE PROCESS	EXAMPLE
<b>Laminating</b> – joining strips of differently coloured timber together	
<b>Laminate bending</b> – joining very thin strips of timber together in a curved form with jigs	
<b>Marquetry</b> – embedding a design in the surface of timber with differently coloured veneers	
<b>Laser engraving and cutting</b> – cutting a design into the surface of timber with a laser cutter/engraver	
<b>Pyrography</b> – burning a design into the surface of the timber	

Getty Images/Bloomberg

iStock.com/Eptavi

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Shutterstock.com/Alexandru Nika

## Using woodworking tools and processes

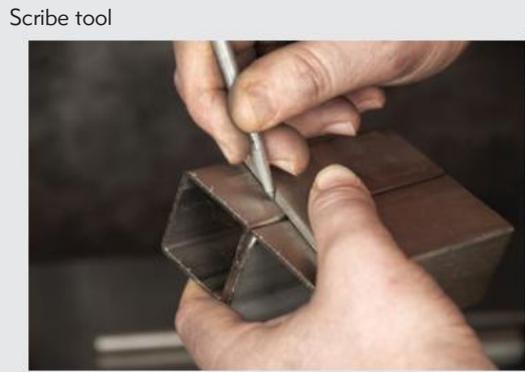
- 1 The hand tools on page 88 are divided into groups based on what they are used for – measuring and marking, cutting, shaping and joining. For each of these four purposes, list one hand tool that you have used. Describe when you used each tool (for what type of product), and what you used them to do (the specific task in production).
- 2 With a partner, write an explanation of how to choose the correct sandpaper for your current project (material type and grade), and describe how it should be used.
- 3 Identify a specific part of a product that requires a joint. Choose three alternative joints that could be used for this situation. Describe the advantages and disadvantages of each joint, and then identify which one you would choose and explain why.

## TOOLS AND PROCESSES FOR METAL

Many of the tools and equipment explained in the Wood section of this chapter can also be used for metal. The following table shows some of the hand tools specifically used on metal.

### Hand tools

HAND TOOLS FOR METAL		USE	CARE AND SAFETY
Measuring and marking	Calipers 	To measure the external dimensions of an object	<ul style="list-style-type: none"> <li>• Make sure the ends are not bent or twisted</li> </ul>
	Micrometer 	For very fine and accurate measurement of the external dimensions of an object	<ul style="list-style-type: none"> <li>• Low risk</li> </ul>
	Centre punch 	To mark points	<ul style="list-style-type: none"> <li>• Hold tool at right angles to the surface to avoid it slipping, avoid hitting fingers with striking tool</li> </ul>



Scribe tool

Shutterstock.com/delek

To mark lines

- Has sharp points – handle with care



Engineer's vice

Shutterstock.com/donatas.1205

To hold work steady

- If portable, they need to be firmly attached to the bench (very heavy)



Pliers

Shutterstock.com/homoo

To hold and manipulate work; some can cut wires

- Be careful not to pinch or cut yourself

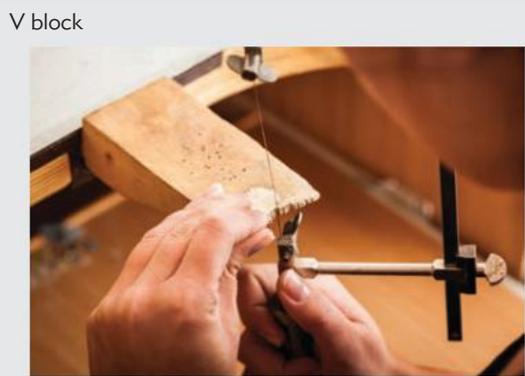


Vice grip pliers

iStock.com/ppjohnson1

To hold and lock onto a piece of work

- Release pressure after use

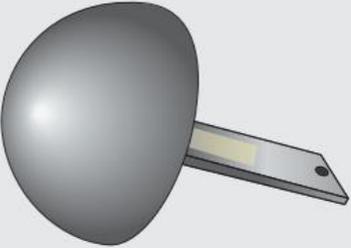


V block

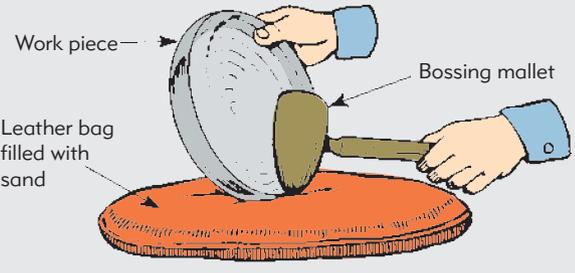
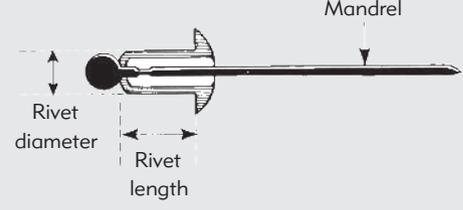
iStock.com/Opia

To rest small pieces of work against while cutting and filing

- Low risk, replace when damaged from use

Cutting	Hack saw  <small>Shutterstock.com/Bigdoug2005</small>	To cut thin metal and tubing	<ul style="list-style-type: none"> <li>Beware of the very sharp edges of cut material</li> </ul>
	Tin snips  <small>Shutterstock.com/Chere</small>	To cut thin metal sheet material	<ul style="list-style-type: none"> <li>Cut edges are very sharp</li> </ul>
	Cold chisel  <small>Shutterstock.com/Mohammad Sajid Safi</small>	To cut metal by striking	<ul style="list-style-type: none"> <li>Avoid hitting fingers with striking tool</li> </ul>
Hitting	Ball-peen hammer  <small>Shutterstock.com/Winai Tepsuttinun</small>	To strike and shape metal – has two heads (one flat, the other domed)	<ul style="list-style-type: none"> <li>Keep hands away from the striking area</li> </ul>
	Bossing mallet (wooden or nylon)  <small>Shutterstock.com/vee</small>	To strike and shape metal	<ul style="list-style-type: none"> <li>Keep hands away from the striking area</li> </ul>
	Dolly 	To shape and create forms when beating metal	<ul style="list-style-type: none"> <li>Avoid hitting fingers with striking tool</li> </ul>
Joining	Soldering iron  <small>Stock.com/jojoapphoto</small>	Used hot to apply melted solder to a metal surface	<ul style="list-style-type: none"> <li>Tip needs to be heated to a high temperature – handle with extreme care when hot</li> </ul>

## Forming and joining processes

PROCESS	DESCRIPTION	USES
<p>Beating</p>  <p>Work piece</p> <p>Leather bag filled with sand</p> <p>Bossing mallet</p>	<p>Using a hammer and leather sand bag or form to create a curved shape – because metal becomes more brittle when beaten, this process requires the metal to be <b>annealed</b> (heating to reform the metal's structure, to soften it)</p>	<ul style="list-style-type: none"> <li>Decorative bowls, spoons and jewellery</li> </ul>
<p>Casting</p>  <p style="writing-mode: vertical-rl; transform: rotate(180deg); font-size: small;">Shutterstock.com/Arsel Ozgurdaal</p>	<p>Melted metal is poured into a hollow form or mould to create a shape (moulds can be made from different materials)</p>	<ul style="list-style-type: none"> <li>Jewellery and decorative forms</li> <li>Parts that aren't commercially available</li> <li><b>Safety</b> – this process can be very hazardous as it uses molten metal; take extreme care</li> </ul>
RIVETING		
<p>Solid rivet</p>  <p>Round head    Truss head    Countersunk head    Flat head    Pan head</p>	<p>Joining with a shaped metal plug – can be hammered and fixed by hand with a hammer</p>	<ul style="list-style-type: none"> <li>Joining most types of sheet metal and thin materials together</li> <li>Decorative features</li> </ul>
<p>Pop rivet</p>  <p>Rivet diameter</p> <p>Rivet length</p> <p>Mandrel</p> <p>The rivet is placed in a pre-drilled hole and 'popped' using rivet pliers</p>	<p>As above – pop rivets can also be attached with a pop rivet tool</p>	<ul style="list-style-type: none"> <li>As above</li> </ul>

## JOINING WITH BOLTS AND NUTS

### Nuts



Wing nut



Hexagon nut



Nylon nut

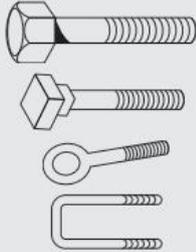


Dome nut

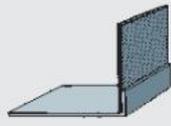
Internal thread of the nut helps it to slide on and grip the thread of the bolt; a range of different bolts and nuts are available

- Fastening and securing in a wide range of situations

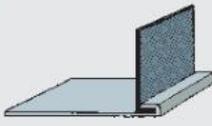
### Bolts



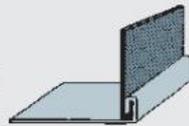
### Folding and bending



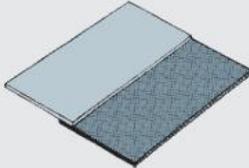
A lap seam (right angles)



A peined-down seam



A knocked-up seam



A lap seam (flat); this can be soldered and/or riveted

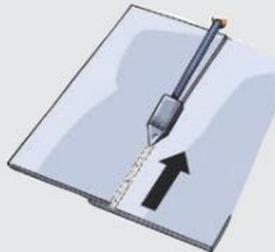


A groove seam

Edges of sheet metal are folded, and soldered or interlocked to form a join

- Box construction
- More accurate with the use of a folding bar or press

### Soldering – soft and hard



Soft and hard soldering refers to the melt temperature of the solder material

- solder can be melted into the tip of the soldering iron, then it flows between two cleaned metal surfaces to make a join
- solder can be placed onto a cleaned joint, then it is heated and the solder flows into the joint as it melts

- Sheet metal, box construction and jewellery
- **Safety** – heat and molten metal is used in this process; take extreme care.
- **Safety** – some solders contain toxic metals; choose the safest solder available and always wash hands after use

### Brazing and welding



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Welding rod has an electric current that is passed through, which melts on contact with another metal and joins; used to create a raised join

- Metal fabrication
- **Safety** – always wear full personal protective equipment (PPE): face guard, gloves, full clothing
- **Be trained before use**

Experienced students only

## Decorative treatments

Decorative treatments add interest to the surface of metal. It can also add a softer, more organic appeal to a material that is otherwise hard and cold to look at. Some decorative treatments also protect the surface underneath. These processes usually involve applying colour, altering the surface,

or cutting through the metal. Specific instructions describing how these processes are carried out can be found on many websites (but always check with your teacher that the process is safe to do in class). Some of these processes can only be carried out with specialist equipment and need to be done in a commercial setting.

DECORATIVE TREATMENT FOR METAL	DESCRIPTION	CARE AND SAFETY
<p>Anodising</p>  <p>Alamy Stock Photo/David J. Green</p>	<p>Creates surface colour on aluminium and titanium. Electrodes are attached to the metal, which is then placed in an acid bath. An electric current is then passed through the bath.</p>	<ul style="list-style-type: none"> <li>• Process uses acids and electrical currents, and should only be carried out by a teacher (or commercially outsourced)</li> </ul>
<p>Heat colouring</p>  <p>Alamy Stock Photo/E.R. Deaginger</p>	<p>As steel is heated, the surface colour changes as the temperature of the steel increases. The colour will be uniform if the piece is heated to the same temperature. Heating different sections to different temperatures gives interesting colour variations. The piece of steel can be cooled gradually or quenched in water. The finished piece can be varnished or rubbed with beeswax to give a glossy finish.</p>	<ul style="list-style-type: none"> <li>• High temperatures are involved; work in a heat-proofed area with good ventilation</li> <li>• Always use gloves when handling heated metal</li> </ul>
<p>Patina</p>  <p>istock.com/ginton</p>	<p>The surface of copper and bronze can be given an aged look by applying chemicals. For a green 'verdigris' finish, apple cider vinegar and salt can be mixed (3:1 ratio), applied to the surface and left to sit for 1–24 hours. This surface can also be protected with varnish or wax.</p>	<ul style="list-style-type: none"> <li>• Mixes for coloured patinas use chemicals such as ammonia that need to be handled with care (wear gloves and safety glasses) and should be used in a fume cupboard</li> </ul>
<p>Brushed metal</p>  <p>Shutterstock.com/Andrey_Kuzmin</p>	<p>The surface of sheet metal can be sanded to create a surface pattern.</p>	

### Piercing



iStock.com/bulentozder

Using a fine piercing saw, designs are cut into the metal. Some designs require holes to be drilled and the saw blade threaded through the hole to cut an internal shape.

### Etching

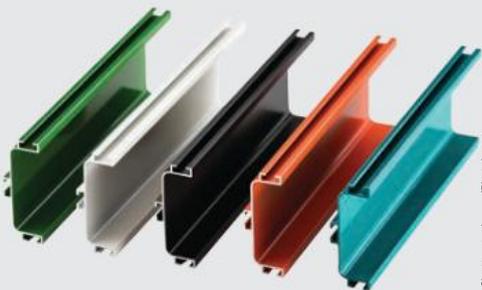


Shutterstock.com/yelbuke

Creates a relief design (below the surface) into metal by using the corrosive action of acid on the surface. A design is applied to the surface with a solution that resists acid. The piece is then placed in the acid bath until the rest of the surface is eaten away to the desired depth. Permanent markers (such as Sharpies) work well to create an acid-resist layer.

- Process uses acid, and must be carried out in a fume cupboard under close supervision of a teacher

### Spray or powder coating



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A layer of paint or plastic is sprayed over the metal surface to add colour and protect the metal from rusting and weathering. When an object is spray-coated, a thin layer of paint is sprayed onto the surface and allowed to dry. When an object is powder-coated, a thin layer of plastic powder is applied to the surface, and then the object is heated and the powder melts to create a thin plastic film over the surface.

- Spray coating can be done in a spray booth at school, but powder coating is usually done commercially.

### Electroplating



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A very thin layer of metal (usually precious metal) is attached to a metal object, and then the object is placed in a chemical bath containing metal ions. An electrical current is passed through the bath, which attracts the metal ions to the surface of the charged object. Electroplating is usually done as a cheaper alternative to making the object out of solid precious metal. The surface also has all the desired characteristics of the plated metal.

## Using metalworking tools and processes

FOCUS ACTIVITY

- 1 Look through the woodworking tools on page 88 and list all the tools that could also be used in the metalworking area. Explain how they might be used differently with metal.
- 2 Find three objects that are made from metal. Try to identify the metal they are made from and list some of the production processes that would have been used to make them (remember to consider any decorative treatments).
- 3 In a group, list the main hazards and safety concerns you might face when working with metal, metal hand tools and machinery. Choose one main safety area and design a poster that informs students about being safe when working with metal.

# TOOLS AND PROCESSES FOR PLASTIC

Many of the tools and processes that have already been covered in this chapter (particularly in the 'Tools for wood' section) can also be used for plastic. This section will focus on how to modify the use of these tools, and on the additional equipment you might require.

The main types of plastic used in schools are **acrylic** and **polypropylene**. These plastics use different equipment and processes, so they are covered below in separate sections.

## Working with acrylic

Acrylic sheet and rod is easy and safe to use, and is available in a range of brilliant colours and levels of transparency. The form of acrylic most commonly found in schools is a 3 mm acrylic sheet.

## Tools and equipment

TOOLS FOR ACRYLIC		USE	CARE AND SAFETY
Measuring and marking	Pencil	To mark on the protective paper surface	
	Chinograph pencil (waxy pencil)	To mark on the glossy acrylic surface	<ul style="list-style-type: none"> <li>• Can be removed with methylated spirits</li> </ul>
	Steel rule, try square	To accurately measure and mark	
	Scribe tool	To mark lines	<ul style="list-style-type: none"> <li>• Has sharp points – handle with care</li> </ul>
Cutting	Piercing or coping saw (with a fine-tooth blade)	To cut curves	<ul style="list-style-type: none"> <li>• Your teacher can use most of the cutting machinery used for timber (for example, bandsaw and radial arm saw)</li> </ul>
	Scroll saw	To cut intricate curves	
	Score-and-snap knife	To scribe and snap a straight cut	<ul style="list-style-type: none"> <li>• Lots of pressure is needed to snap after scribing; do this with care</li> </ul>



Shutterstock.com/Mike Golubev

	<p>Laser cutting</p>  <p>Shutterstock.com/9photos</p>	<p>A digital file is uploaded to the laser cutter, which then accurately cuts (and engraves) the acrylic</p>	<ul style="list-style-type: none"> <li>• Must be used in a well-ventilated area, and all fumes and dust should be extracted</li> <li>• Follow the machine's operating instructions closely</li> </ul>
Drilling	<p>Pedestal drill</p>	<p>To drill holes in acrylic</p>	<ul style="list-style-type: none"> <li>• Always wear safety glasses</li> <li>• Secure the material you are drilling into</li> <li>• Tie long hair back</li> <li>• <b>Electrical safety</b> – Make sure the charging station is set up correctly</li> </ul>
	<p>Portable power drill</p>		
	<p>Hand drill</p>		
<p>Forstner drill bit</p>  <p>123RF/Mertz Hirth</p>	<p>To cut larger holes in acrylic with a scraping action</p>	<ul style="list-style-type: none"> <li>• Used in a pedestal drill – follow all safety guidelines for this machine</li> </ul>	
Heating and shaping	<p>Strip bender</p> 	<p>Heats a small strip of the acrylic; allows the acrylic to be bent on a line when hot</p>	<ul style="list-style-type: none"> <li>• The heating element gets very hot, don't allow hands to get close to it, or any material (other than the acrylic) to lay over it</li> <li>• Don't touch the heated part of the acrylic</li> <li>• <b>Electrical safety</b> – Check cords regularly</li> </ul>
	<p>Small oven</p>  <p>Shutterstock.com/9photos</p>	<p>To heat whole pieces of acrylic; good for twisting, pressing and slumping acrylic</p>	<ul style="list-style-type: none"> <li>• Use oven mitts or heatproof gloves when extracting hot items from the oven</li> <li>• <b>Electrical safety</b> – Check cords regularly</li> </ul>

Smoothing	Steel rule	To scrape straight edges and to remove cutting marks	<ul style="list-style-type: none"> <li>• Corners may be sharp; avoid bending the rule – if bent, it loses accuracy</li> </ul>
	File	To sand and smooth (use the smoother grades)	<ul style="list-style-type: none"> <li>• Use a brush to clean; don't knock on a bench – files may shatter.</li> </ul>
	Carborundum paper	To sand and polish (use wet to reduce clogging of the grit)	<ul style="list-style-type: none"> <li>• Keep slightly used paper – can be used repeatedly until worn out</li> </ul>
	Polishing medium (such as Brasso)	To make sanded edges glossy	<ul style="list-style-type: none"> <li>• Follow the safety guidelines on the bottle; clean surface and hands after use</li> </ul>
	Glass cleaner	For the final polish	<ul style="list-style-type: none"> <li>• Follow the safety guidelines on the bottle; clean surface and hands after use</li> </ul>

### Note

When drilling into acrylic, normal drill bits over 3 mm in size will 'grab' the acrylic and crack or shatter it. The angle of the drill bit's cutting edge needs to be less pointy. Your teacher can grind back drill bits to a flatter angle on a grinder. Drill bits such as spade bits and **Forstner bits** scrape rather than cut, and work well on acrylic for drilling large-sized holes.

### Glues

There are various glues that can be used with acrylic, depending on the situation.

- **Acrylic cement** (for example, Weldon 16 and Acrifix 192) – is reasonably safe to use if safety guidelines are followed. Cements are most effective when joining two flat surfaces together. These glues don't work well when joining an end to a flat, or two ends together.
- Two-part **epoxy resin** (for example, Araldite) – can be used to glue acrylic to other materials, but is not always successful or permanent.
- Glues that 'melt' or dissolve acrylic – these cannot be used in schools as they produce fumes that are dangerous to inhale.

### Safety

Glues used with acrylic have strong fumes. They must be used in a well-ventilated area (preferably a fume cabinet) and you should always wear gloves.

### Joining to other materials

To join acrylic to other materials, it can be:

- screwed onto timber (using round-headed screws that don't crack the acrylic when tightened)
- pop-riveted to other thin materials

- slotted into a groove
- used with normal glass door hinges in the place of glass for doors.

### Decorative processes

There are many ways to decorate acrylic.

- **Laminating** – layers of acrylic sheet can be glued together (using acrylic cement) to make a thicker block. You can experiment with different colour combinations – fluorescent acrylics work well with this technique. Small blocks or shapes can be cut from these layered sheets, which can then be used in brightly coloured jewellery or for highlight details on products. If you are using transparent layers, try embedding paint powders or fine glitter between the layers.



Laminated acrylic

- **Embossing** – when sheet acrylic is heated, shapes (such as keys, pendants, coins, stamps or a laser cut pattern) can be very firmly pressed into the surface to create a pattern.



**Embossed acrylic**

- **Engraving** – the surface of acrylic sheet can be hand-engraved using an engraving tool (see page xx). This takes planning and a high level of drawing skill and control.
- **Laser engraving** – acrylic is perfect to engrave using a laser cutter/engraver. Digital photos or drawn designs can be converted into a file that is read by the laser cutter and cut into the acrylic sheet. The laser can cut into the acrylic to different depths, which gives photographs or drawings a three-dimensional effect. Alternatively, the laser engraver can create an all-over two-dimensional pattern.



**Laser-engraved acrylic**

## Working with polypropylene

The form of polypropylene most commonly used in schools is a 1.5 mm thick sheet. It can be bought in large sheets in a variety of colours and textures. It usually has a dull surface and is translucent, which makes it a great material for creating light shades. It is

also flexible, so it can be twisted and bent into many shapes and forms.

Polypropylene sheets can be treated like heavy cardboard. It can be:

- **cut** with scissors or a craft knife (take extreme care)
- **scored** with a pointed tool or blunt knife to create a sharp fold
- **punched** with a craft punch or heavy paper punch to create even holes.

## Joining polypropylene

Polypropylene sheets can be joined using rivets or glue.

- **Rivets** – small, nylon two-part rivets are useful for joining overlapping sections of polypropylene sheets. Holes are punched into both sections, the rivet is placed through the holes, and then the back capping is snapped on. Rivets can form a decorative feature. Metal pop rivets can also be used, but the back of these aren't as flat as the nylon rivets, and they can rip through the plastic if punched too firmly or if the hole is too large.



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**Two-part nylon rivets are suitable for joining overlapping polypropylene sheets**

- **Gluing** – polypropylene is difficult to glue. Specialist hot-melt glue is available (high temperature is required, so a large glue gun is needed) and a two-part epoxy resin has been developed specifically for polypropylene.

## Vacuum forming

Vacuum forming is another way of using plastics and heat to create a form. It is used in industry to make many products and forms of packaging. The plastic used for this process is usually **polystyrene** (the rigid form, not the expanded foam form). Vacuum-forming machines allow plastic to be moulded onto a preformed solid shape (the mould). A vacuum former

allows moulded plastic shapes to be made many times to the same form.

Vacuum forming machines have:

- a heating element that heats the plastic sheet
- a compartment with a well-sealed window or door
- a vacuum that sucks out all the air in the compartment – this draws the softened plastic firmly onto the mould
- a platform on which the mould is placed – this has many holes to allow the air to flow through when it is being removed.



**A vacuum former**

It is important to make a good mould or former to shape the heated soft plastic. The sides of the mould need to be shaped on an angle so that it can be removed from the plastic form after it is vacuumed and cooled. The mould or former also needs to be finished smoothly. Moulds can be made from materials such as plaster, clay, resin and timber but do NOT work with MDF due to safety concerns (see page 63).



**Form moulded with a vacuum former**

## SAFETY

Whatever materials, tools, machinery and processes we use to make a product, it is vitally important to think about **safety**. Safety is a factor that should be considered during the design stage – products should be designed so they can be made safely and are safe to use. Designers need to choose the safest materials, the safest construction processes, the safest tools and equipment, and the safest decorative and finishing processes that are possible without lessening the quality of the product.

In the early stages of your experiences as a student designing and making products, your teacher will make a lot of decisions about the materials, tools and processes you will use – and their decisions will be based on what is safe for you. However, as you gain more experience, you will need to make more decisions. *'Is this safe?'* should be one of your first questions when making design choices. The section on risk assessment in chapter 1 (see page 30) will give you guidance about how to identify hazards, assess risks, and develop and put into practice safe working procedures (safety controls).

### Safe work practices

When thinking about being safe, there are some common guidelines that can be followed in most situations.

Be prepared	<ul style="list-style-type: none"> <li>• Wear clothing appropriate for the work environment – solid, leather shoes, hair tie for long hair, protective clothing for specific tasks</li> </ul>
Choose your materials carefully	<ul style="list-style-type: none"> <li>• Always choose the safest material that is appropriate for the product and situation</li> <li>• Be careful when moving materials</li> <li>• If the pieces of material are large, make sure you don't strain your body when moving them (manual handling) – ask for help</li> <li>• When moving long or pointy materials, make sure no one is in the way or might be hit</li> </ul>
Work in an appropriate environment	<ul style="list-style-type: none"> <li>• Make sure lighting and ventilation is good</li> <li>• Clear away any obstacles or things people could trip over</li> <li>• Don't enter restricted areas without permission</li> <li>• Move around the classroom sensibly (don't run)</li> </ul>

Be careful when using hand tools	<ul style="list-style-type: none"> <li>• Know what tools are for (be trained) before you use them, and always use them for the correct task</li> <li>• Report any broken or damaged tools to your teacher</li> <li>• Carry and pass tools to others carefully</li> </ul>
Be careful when using machines	<ul style="list-style-type: none"> <li>• <b>Complete all informal and formal training and testing before you use any machinery</b></li> <li>• Always ask permission and be properly supervised while using a machine</li> <li>• Wear the correct <b>PPE</b> (personal protective equipment) for the machine you are using – this may include safety glasses, ear protection, dust mask, face shield, solid shoes and apron</li> <li>• Set up and use a machine so that using it doesn't strain your body</li> <li>• Focus and don't get distracted</li> <li>• Keep body parts, especially hands, away from any moving or sharp areas of a machine</li> <li>• Never leave a machine turned on or running</li> <li>• Ask for help if a machine doesn't seem to be working correctly, or you are unsure</li> </ul>
Be safe around electricity	<ul style="list-style-type: none"> <li>• Always check cords for damage before you turn on a machine</li> <li>• Never work with electricity in a wet area</li> <li>• Check that cords don't trail across an area where people walk</li> <li>• Always turn off a machine before checking, adjusting or changing parts</li> <li>• Make sure that any sharp part of an electrical machine never gets close to the power cord</li> <li>• Never leave an electrical machine that is turned on unattended</li> </ul>
Take care when using glues	<ul style="list-style-type: none"> <li>• Use the safest glue or solder possible</li> <li>• Follow the instructions for use</li> <li>• Use in a well-ventilated area (a fume cupboard, if necessary)</li> <li>• Wear gloves when needed</li> </ul>

### Note

Thinking about safety is not only important to your well-being, but it also keeps other students and your teacher safe. **Knowledge** (about materials, tools and machinery), **awareness** (of what is going on in the classroom environment) and **good decision-making** (choosing to do the safest thing) are critical to keeping you and those around you safe.

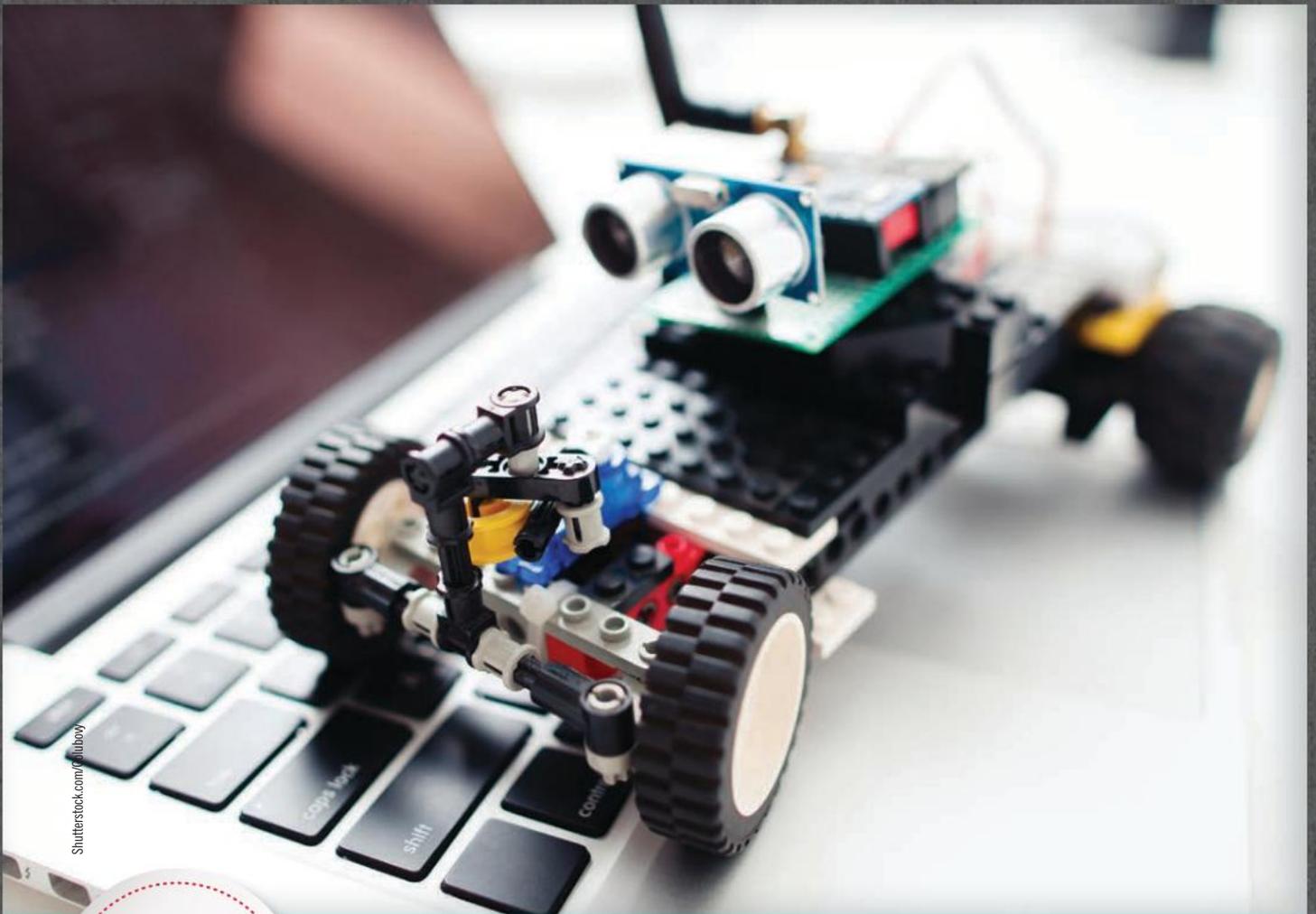
## THINKING SKILLS

### THINKING ABOUT PROCESSES, TOOLS AND SAFETY

Choose one of the following tasks.

- 1 Select a machine and write step-by-step instructions of how to use the machine for someone who hasn't used it before. Use diagrams in your instructions and remember to include all the safety guidelines. Alternatively, select a difficult process (for example, a joint or decorative technique) and explain how it is completed safely.
- 2 Draw a detailed picture of a classroom situation showing students working unsafely. Think of all the things they could do that goes against the safety rules you have learnt. Under your drawing, list the unsafe work practices and explain why they are unsafe and what students and teachers should be doing.
- 3 Draw a map of your classroom and identify all the machines and safety equipment (for example, fire extinguishers and emergency stop buttons). Make a note of restricted areas and areas that might be hazardous (such as around machines).





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# 4

## ENGINEERING BASICS

### KEY KNOWLEDGE

In this chapter, students will gain knowledge and understanding of:

- ▶ motions
- ▶ simple machines
- ▶ mechanical advantage
- ▶ force
- ▶ energy
- ▶ structures
- ▶ electronics
- ▶ electrical principles
- ▶ electronic components
- ▶ creating circuits
- ▶ input–process–output diagrams.

# FORCES

**Forces** are a push or pull on an object. We feel the force of gravity pulling us to the ground. Two bar magnets push each other apart if you try to bring the two south poles together or the two north poles together and pull each other together if you bring a north pole near a south pole.

A force is anything that causes an object (mass) to start moving, accelerate, or slow down and stop. Some examples of forces in action are:

- thrust force – increases the speed of an object; for example, the wind blowing into the sail of a yacht sends it skimming across the water
- drag force – reduces speed; for example, the drag of the water on the hull of a yacht reduces its speed
- torque – a rotational force; for example, a spanner loosening a nut
- pressure – a force applied to an object that can cause the object to change its shape (deform).

## Note

**Newton** is the unit used to measure force, and is named in Sir Isaac Newton's honour. He is famous for explaining forces and most particularly for explaining the laws of gravity.

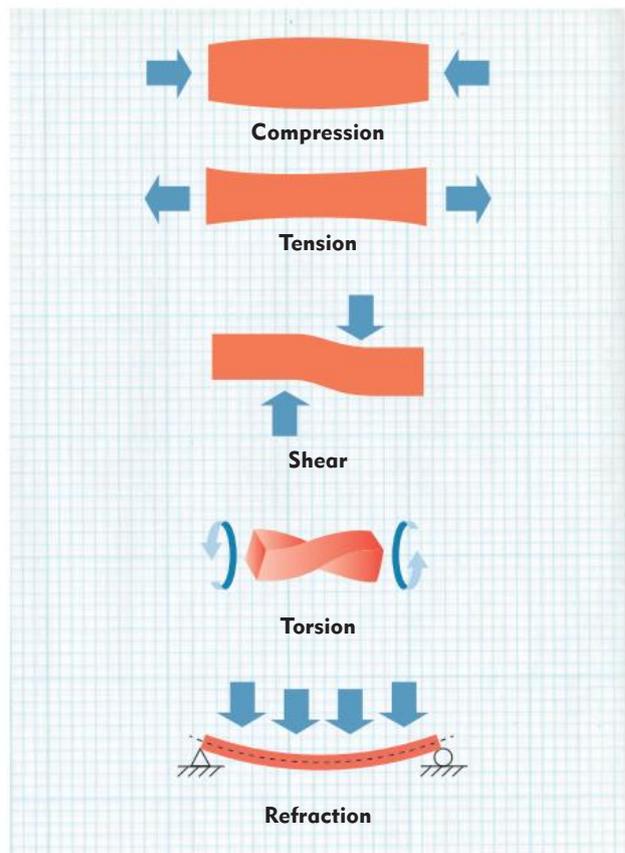


A wrecking ball is an example of a large force

## Types of force

There are five types of forces that directly affect objects. These forces are important to consider when designing structures. If the structure cannot handle the forces applied, it will break or be damaged.

- **Compression** – a squashing force
- **Tension** – a stretching force
- **Shear** – two forces pushing inwards but past each other
- **Torsion** – a twisting force
- **Refraction** – a bending force



The five types of forces



Refraction force

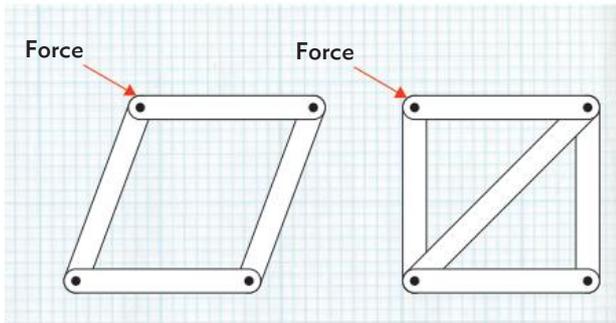
## Forces

- 1 Draw an object being shaped by each of the five forces (compression, tension, torsion, shear and refraction).
- 2 Which two of the five forces push into an object?
- 3 What is the difference between compression forces and shear forces?

## STRUCTURES

### Shapes for structures

The strongest shape for structures is the triangle. A rectangle is a weak structure that can be easily deformed. Adding a triangle brace to a rectangle makes it much stronger and able to withstand forces.



**Adding a triangle support makes a weak rectangle into a strong structure**

### Cylinders and domes

A dome is a strong structure that resists compression. Domes are not often used in building construction because it is hard to make the dome and hard to fit our furniture into it. A cylinder is often used for a soft drink can because of its strength against compression – if soft drink cans were rectangular prisms, they would squash much more easily.

### Bridges

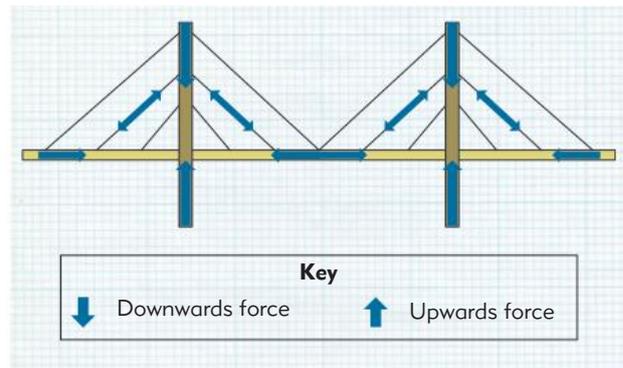
A bridge is one example of how we need to design structures to withstand forces. Imagine a road and rail bridge that crosses a harbour. It must be very high so that ships can sail under it. Consider all the forces exerted on that structure – cars and trucks pushing down, wind pushing on the sides, and earthquakes shaking the whole bridge. A bridge must withstand all these forces.

A bridge can be a simple beam or have a support structure to help to overcome the applied forces.



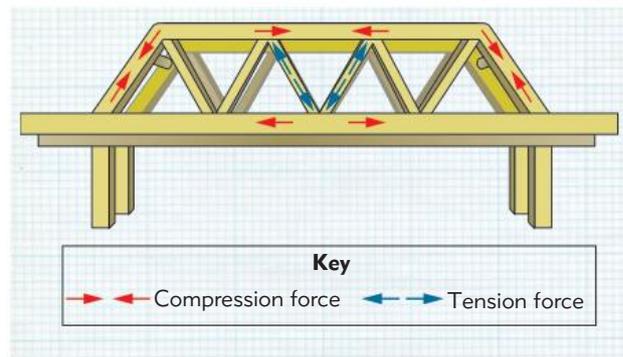
**ANZAC Bridge in Sydney is a cable-stayed bridge**

The main forces acting on the cable-stayed ANZAC Bridge are the forces of gravity pushing down on the bridge itself, and the vehicles passing over the bridge. Each stay (cable) is under tension, transferring that force to the towers. The towers are under a compression force being pulled down by the stays but being pushed up by the ground.



**Forces acting on a cable-stayed bridge**

A truss bridge is an example of using triangles to distribute the force on a bridge. Each part of the triangle is under either compression force or tension force.



**Truss bridge showing compression forces (red arrows) and tension forces (blue arrows)**

## Straw bridges

### Aim

To design and create the strongest possible bridge to span a gap of 21 cm using drinking straws and pins.

### Materials

- A packet of drinking straws
- Pins
- White tack (to cover the pin ends)
- Ruler
- 2 shoe boxes
- Weights (or objects of known masses)

### Method

- 1 Build your bridge using straws and pins. Cover any exposed pin ends with white tack for safety.
- 2 Place your bridge between the two shoe boxes turned upside down or with the lid on. The gap should be 21 cm.
- 3 Test the bridge to destruction by placing larger and larger weights on the bridge until it collapses.

### Analysis

- 1 How much weight did your bridge take? Compare your result with your classmates.
- 2 Discuss why some bridge designs were stronger than others

### Extension – Paper bridges

Surprisingly strong structures can be constructed with pages of paper by creatively folding, rolling and joining the paper. Try the straw bridge activity using A4 sheets of paper.

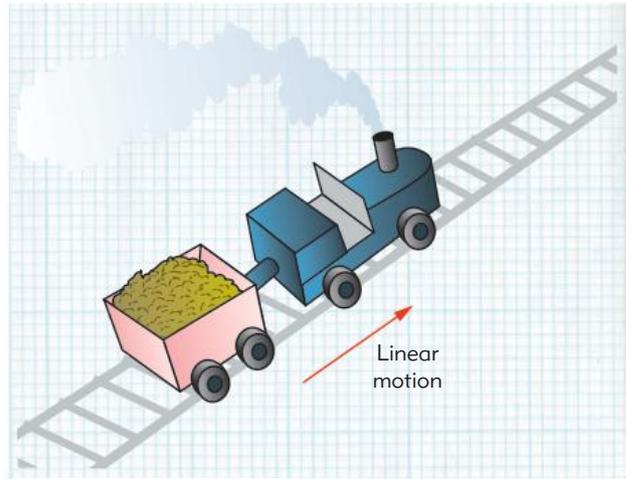
## MACHINES

Over time, people have developed machines to help move ourselves and large objects. Machines make it easier for us to do work. For example, it is hard to lift a heavy rock but with a crowbar it is easier. The first simple machines amplified the force that humans had available, and enabled the building of amazing structures such as the Great Pyramid of Giza in Egypt. Modern complex machines, such as cars, are still constructed from the same simple machines used throughout history.

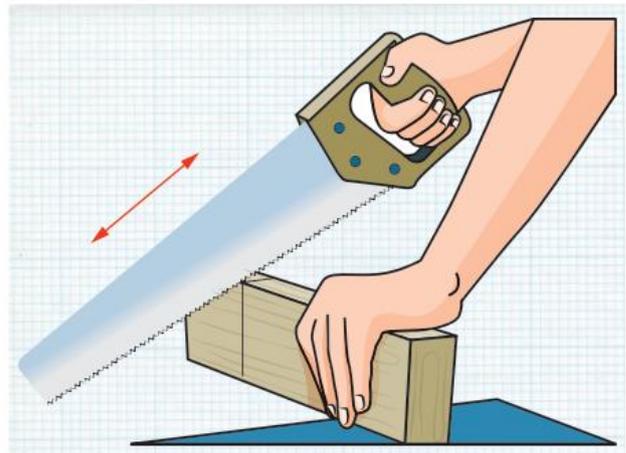
### Motions

There are four types of motion.

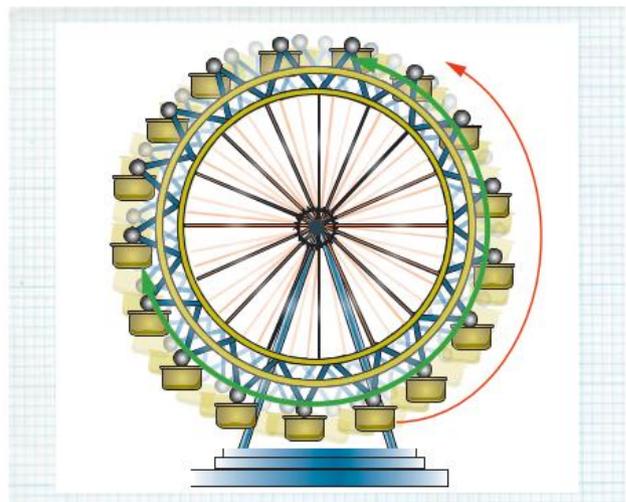
- **Linear motion** – an object moving in a straight line
- **Rotary motion** – an object moving in a circle or part of a circle (an arc)
- **Reciprocal motion** – backward and forward motion in a straight line
- **Oscillating motion** – backward and forward motion in an arc.



Linear motion



Reciprocal motion



Rotary motion



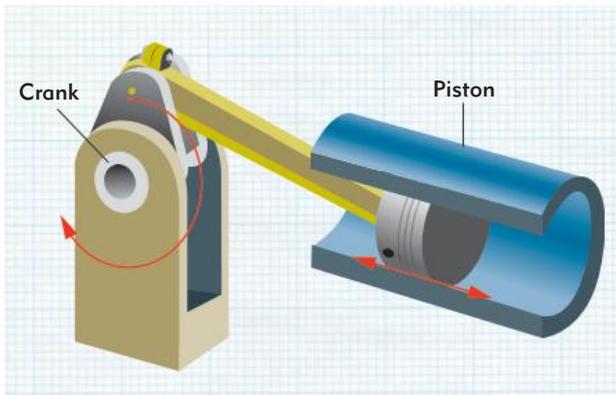
### Oscillating motion

#### Tip

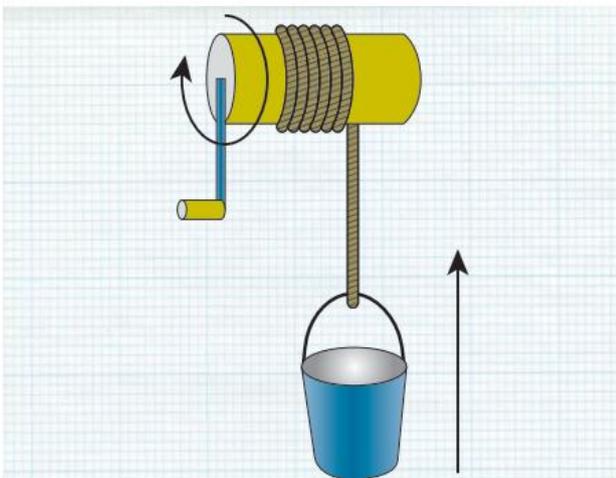
'Reciprocal' is pronounced *ree-sip-ree-cal*.  
'Oscillating' is pronounced *oss-sill-ate-ing*.

### Changing motion types

Many machines change one type of motion to another type. Two examples of mechanisms that change the type of motion are cranks with pistons, and winches.



Rotating a crank makes the piston go back and forth in a reciprocating motion



Rotating the handle of the winch lifts the bucket out of the water in a linear motion.

## Motion

- 1 Show the person beside you the four motion types with your hands.
- 2 Name an example of each of the four motion types that can be seen in your school. For example, swings oscillate back and forth.
- 3 Research a machine that changes one type of motion to another. Name the mechanism that changes the type of motion.

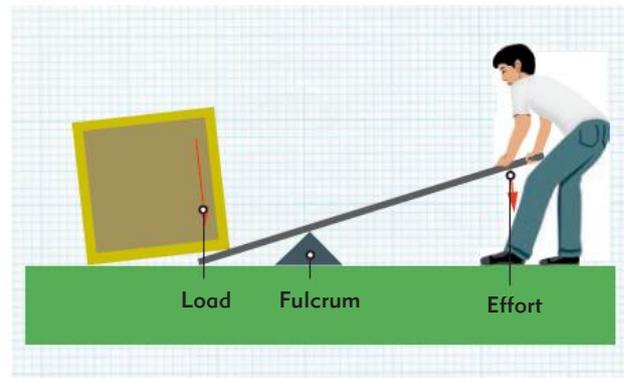
## SIMPLE MACHINES

The input (what drives the movement) and output (the result of the movement) forces of a machine each have a special name.

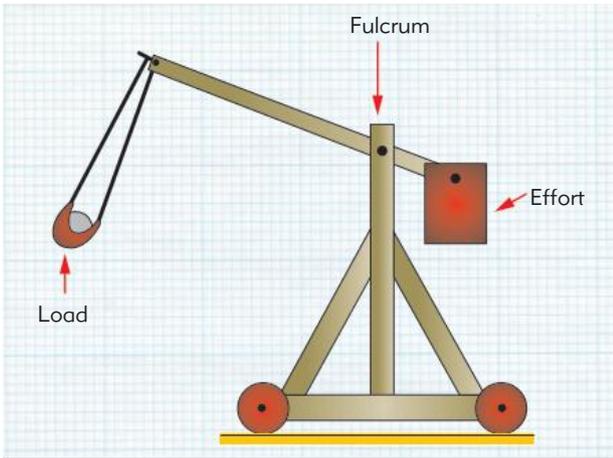
- **Effort** – the name of a machine's input force.
- **Load** – the name of a machine's output force.
- **Mechanical advantage** – describes how machines trade force for speed, or speed for force.
- **Force advantage** – when a machine makes it easier to move a heavy object, but at a slower speed.
- **Speed advantage** – when a machine makes the load go faster, but with a weaker force.

### Levers

A **lever** is a rigid bar that rotates around a **fulcrum**. A fulcrum is also known as a pivot. Depending on the location of the fulcrum, levers can give you a force advantage or a speed advantage.



**Lever with force advantage** – if the load is closer to the fulcrum than the effort is to the fulcrum, the lever has a force advantage and makes it easier to lift the load



**Catapult lever with speed advantage – if the effort is closer to the fulcrum than the load, the lever has a speed advantage and makes the load go faster**

### Lever class

Levers can be grouped into three classes depending on the arrangement of the load, effort and fulcrum. First-class levers have the fulcrum between the effort and load. Second-class levers have the load between the effort and fulcrum. Third-class levers have the effort between the load and fulcrum.

### Lifting pulleys

A **lifting pulley** is a set of wheels and a rope that makes it easier to lift a load. Three examples of

lifting a pulley, showing the force advantage of using different wheel combinations, can be seen in the diagram. In each example, the blocks of the upper pulleys are fixed in space. When there is more than one pulley or wheel, lower pulleys move up when the rope is pulled and are called moving pulleys.

#### FOCUS ACTIVITY

### Levers

- 1 Create a simple second-class lever with a beam from a length of timber, a fulcrum from another block of timber, and a weight. Show that moving the weights closer to the fulcrum makes it easier to lift the weight with the beam.
- 2 Use a 10 kg weight, 2 m beam and large spring balance (weighing scale) to complete the table below. The fulcrum should be at one end of the beam and the spring balance at the other.

The distance from the fulcrum to the weight	0.5 m	1 m	1.5 m	2.0 m
---	-------	-----	-------	-------

Weight shown on spring balance	
--------------------------------	--

- 3 Does the second-class lever give a speed or force advantage?

**One fixed pulley wheel** changes the direction of the force you apply, allowing you to pull down with all your weight. 100 kg lifts 100 kg load. No force advantage.

**Two pulley wheels** (one fixed and one moving) are arranged to lift double the force that you apply. 50 kg lifts a 100 kg load. The two ropes share the 100 kg load equally. 2 × force advantage.

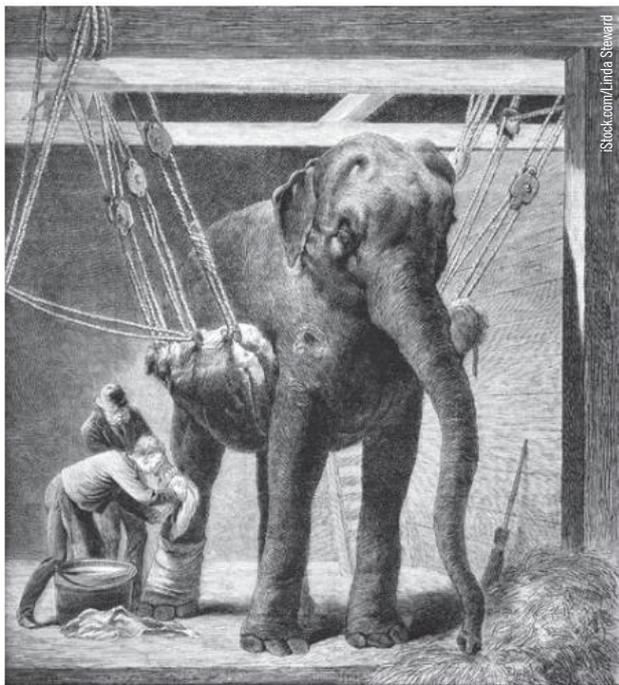
**Four pulley wheels** (two pulleys on the fixed block and two pulleys on the movable block) are arranged to lift quadruple the force that you apply. 25 kg lifts 100 kg load. The four ropes share the 100 kg load equally. 4 × force advantage.

**The force advantage of three different lifting pulleys**

## Pulley force advantage

Each lifting pulley makes it easier to lift large weights – the more moving pulleys, the easier it is to lift. Two moving pulleys allows you to double the input force, meaning you can lift twice as much as your own weight. Three moving pulleys means you can lift triple your own weight, and so on.

Although one pulley doesn't increase the input force, it can still make it easier to lift an object because you can pull down with all your weight and the object is lifted up.



Lifting a heavy elephant with a lifting pulley

### FOCUS ACTIVITY

## Pulleys

- 1 Try the four different lifting pulleys to lift a 1 kg weight (refer to the previous diagrams to help set up the pulleys). Use a spring balance as the effort. Record your results in a table.

Number of pulleys	1	2	3	4
Weight shown on spring balance				

- 2 Describe how adding pulleys changes the speed or force advantage.

## Gears

Have you ever tried to ride a bike up a steep hill in top gear? A **gear** is a wheel with teeth that interlocks or slots into others to create motion. Gears can give

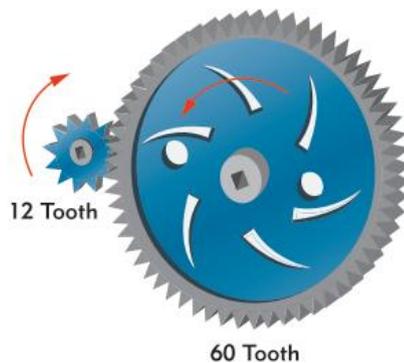
a torque or a speed advantage. **Torque** is a **rotary force**. Forces used in this chapter so far cause a push or a pull in a straight line. Torque is a force that causes rotation. When describing gears and wheels that rotate, we use the term torque rather than force.



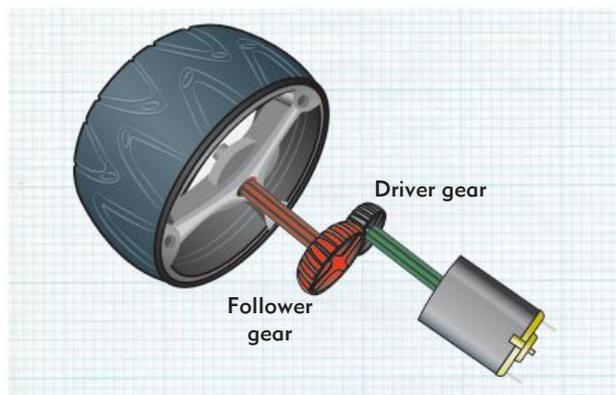
Complex clockwork gears

When a small gear turns a larger gear, there is a torque as it requires less force to create motion.

When a larger gear turns a small gear, there is a speed advantage as it turns the smaller wheel multiple times for the effort involved. When a larger gear turns a small gear, there a speed advantage.



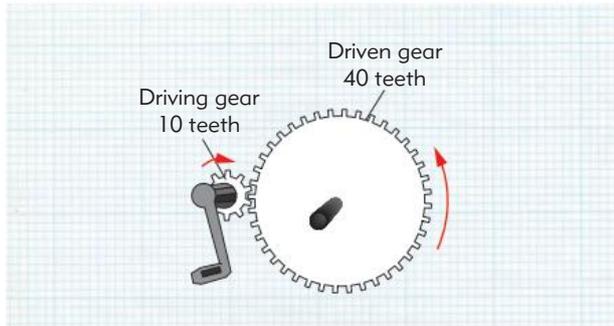
The small gear spins five times faster than the large gear



Gears are creating a torque advantage to make it easier for the motor to drive the wheel

## Meshed gears

When two gears mesh together, they turn in opposite directions to each other (one clockwise and the other anticlockwise). Sometimes a handle can be used to turn the driving gear.



Meshed gears

### MECHANICAL ADVANTAGE FOR MESHED GEARS

Gears give a speed or torque advantage depending on the gear ratio. The gear ratio is found by dividing the number of **driven** teeth by the number of **driving** teeth (sometimes called drive or driver teeth). A gear ratio greater than 1 gives a torque advantage, and a gear ratio less than 1 gives a speed advantage.

$$\text{Gear ratio} = \frac{\text{number of teeth on driven gear}}{\text{number of teeth on driving gear}}$$

In the meshed gear diagram, the driven gear has 40 teeth and the driving gear has 10 teeth.

$$\begin{aligned}\text{Gear ratio} &= \frac{\text{number of teeth on driven gear}}{\text{number of teeth on driving gear}} \\ &= \frac{40}{10} \\ &= \frac{4}{1}\end{aligned}$$

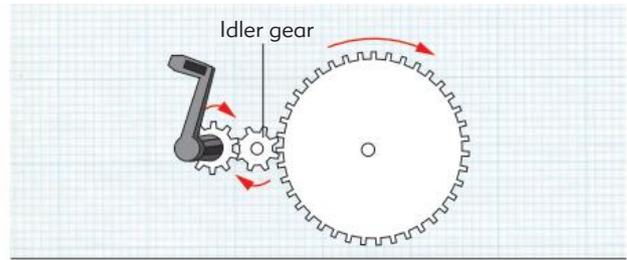
Therefore, the gear ratio is 4 (also expressed as 4:1).

The gear ratio of 4 means the driven gear rotates with 4-times the torque but 4-times slower than the driving gear.

## Special gear types

### Idler gear

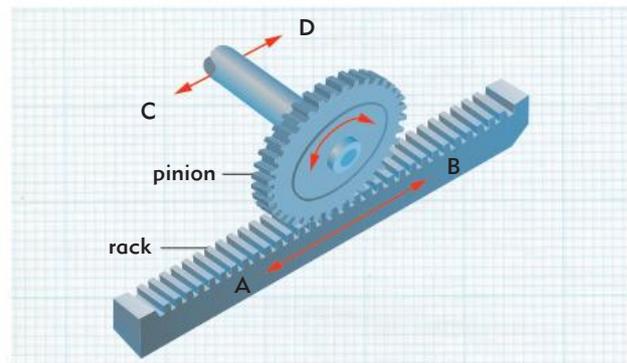
When two gears mesh together they turn in opposite directions, but sometimes you need both gears to turn in the same direction. Using an **idler gear** between the input and output gears causes the input and output to turn in the same direction.



Idler gear

### Rack and pinion gear

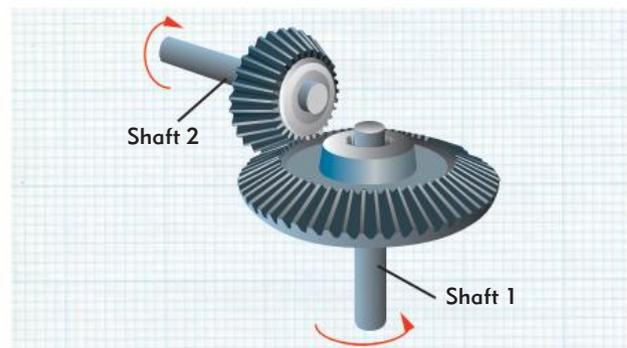
A **rack and pinion gear** is used to change rotary motion of the pinion gear to linear motion of the rack. Alternatively, linear motion of the rack can cause rotary motion of the pinion gear.



Rack and pinion gear

### Bevel gears

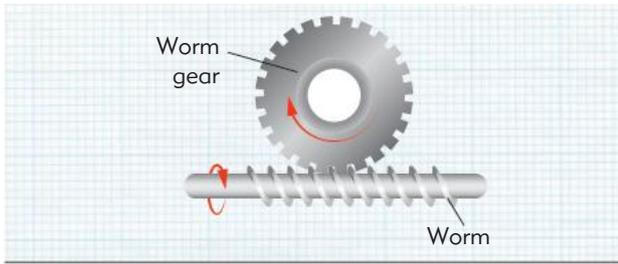
**Bevel gears** are used when shafts need to turn at an angle to each other, normally a right angle. This may be useful in a design challenge when shafts need to be at an angle to each other.



Bevel gears turning shafts at 90° to each other

### Worm and worm gear

A **worm** is a special gear with only one spiral tooth (similar to a screw). The **worm gear** (sometimes called the worm wheel or gear wheel) has many teeth. Because the worm is always the input and it only has one tooth, there is always a large torque advantage.



**Worm and worm gear – the worm has 1 tooth and the worm gear has 24 teeth**

### MECHANICAL ADVANTAGE FOR WORM AND WORM GEARS

In the worm and worm gear diagram, the worm has 1 tooth (the driving gear) and the worm gear has 24 teeth (the driven gear).

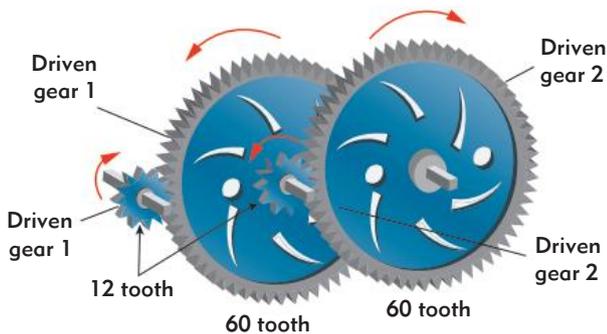
$$\begin{aligned} \text{Gear ratio} &= \frac{\text{number of teeth on driven gear}}{\text{number of teeth on driving gear}} \\ &= \frac{24}{1} \end{aligned}$$

Therefore, the gear ratio is 24 (also expressed as 24:1).

The gear ratio of 24 means the driven gear (worm gear) rotates with 24-times the torque but 24-times slower than the driving gear (worm).

### Compound gear

A **compound gear** has multiple gears on the same shaft. There are two driving gears and two driven gears, which allows a large speed or torque advantage.



**Compound gear**

### MECHANICAL ADVANTAGE FOR COMPOUND GEARS

When compound gears are used, the gear ratios multiply to create a very large advantage. In the compound gear diagram, both driving gears have 12 teeth and both driven gears have 60 teeth.

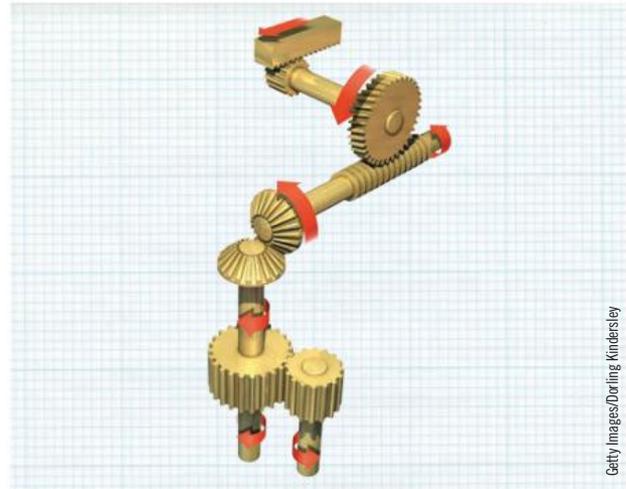
$$\text{Gear ratio} = \frac{\text{number of teeth on driven gear 1}}{\text{number of teeth on driving gear 1}} \times \frac{\text{number of teeth on driven gear 2}}{\text{number of teeth on driving gear 2}}$$

$$\begin{aligned} &= \frac{60}{12} \times \frac{60}{12} \\ &= \frac{5}{1} \times \frac{5}{1} \\ &= \frac{25}{1} \end{aligned}$$

Therefore, the gear ratio is 25 (or 25:1).

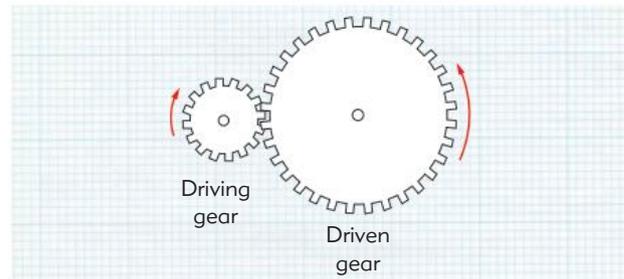
## Gears

1 Name the gear types shown in the following diagram.



Getty Images/Dorling Kindersley

- 2 If the rack was the input, would the meshed spur gears give a torque advantage or a speed advantage?
- 3 Count the teeth of the gears in the following diagram.



a Calculate the gear ratio.

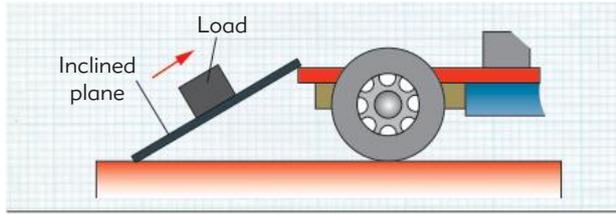
$$\text{Gear ratio} = \frac{\text{number of teeth on driven gear}}{\text{number of teeth on driving gear}}$$

- b Does this gear system rotary force?
- c Does this gear system increase rotary speed?

### Inclined plane

An **inclined plane** is a sloping ramp that makes it easier to raise an object – an inclined plane always gives a force advantage. The more gradual the slope, the easier it is to lift the load. It is believed that ancient

Egyptians used inclined planes to lift huge stones when making the pyramids.



**Inclined plane**

## Crank

A **crank** is an arm attached to an axle. Turning a crank rotates a shaft. The longer the crank, the easier it is to turn the shaft.

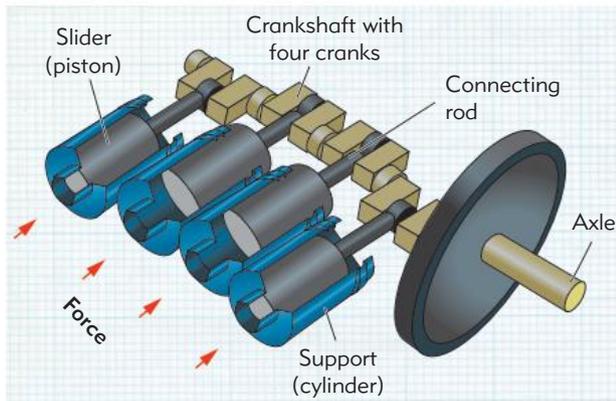


Getty Images/Science & Society Picture Library

**Cranks have many practical applications, such as lifting a bucket of water out of a well**

## Crank and slider

A crank and slider changes reciprocal (backward and forward) motion to rotary motion. A car engine uses a crank and slider to make the force from the burning fuel in the cylinder rotate an axle. The piston slides back and forth causing the crank to rotate the axle.



**Four cranks on a crankshaft attached to sliders (pistons) change reciprocal to rotary motion to power a car**

Crank and sliders can also be used in reverse, where rotating the crank causes the slider to reciprocate back and forth.

## FOCUS ACTIVITY

### Model crank and slider

#### Aim

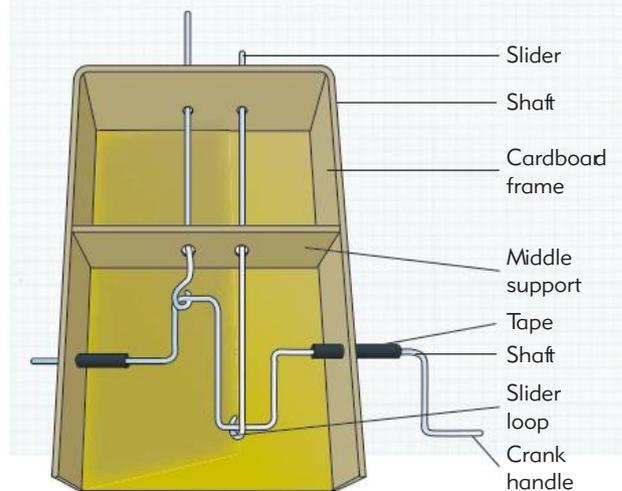
To learn how a crank works by building your own model.

#### Materials

- Cardboard (you could use a shoebox)
- Tape (masking, electrical or sticky tape)
- Stiff wire
- Scissors
- Pencil

#### Method

- 1 Create a frame for a wire crank using the cardboard and tape.
- 2 Using the pencil, punch holes in the cardboard frame for the wires. Refer to the diagram as a guide.

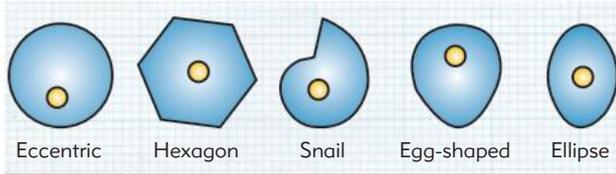


#### Model crank and slider set-up

- 3 Cut a cardboard middle support that fits inside the frame. Slot the middle support in line with the cranks.
- 4 Bend the stiff wire to form a shaft with a crank handle and crank. Add tape to stop the crank shaft from travelling left and right.
- 5 Bend the end of the two wire sliders into a closed loop around the cranks.
- 6 Turn the crank handle to move the sliders up and down. You could add small figures on top of the wires to make a puppet show.

## Cam and pushrod

A **cam** is shaped so that it pushes a rod up and down as it rotates. There are many cam shapes – each shape causes a different movement of the **pushrod**. If you change the shape of the cam wheel, you can change the way that the pushrod moves.



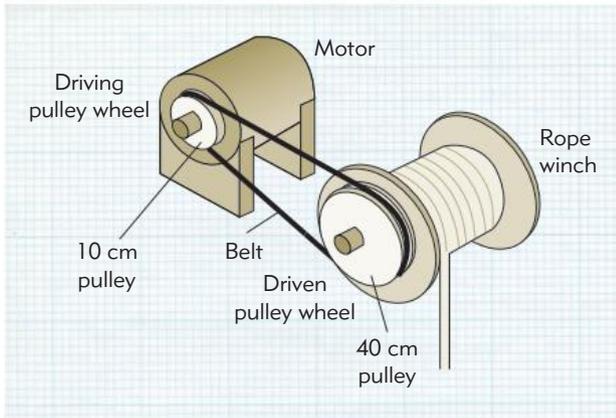
### Cam shapes

#### Note

Cam and pushrod mechanisms will be very important in the robotics design challenges. See page 156 for more information about pushrods.

## Belt and pulley

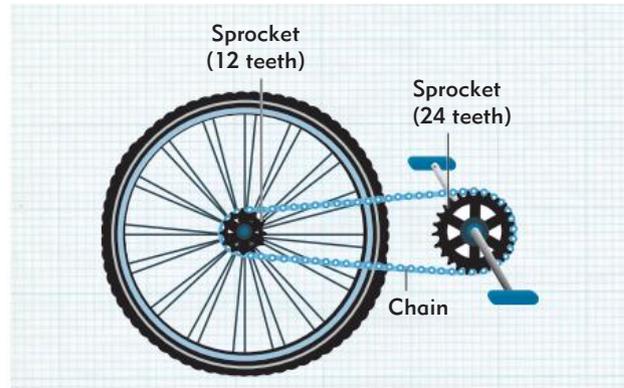
Belt and pulley drives can give either a torque or speed advantage. Similar to gears, a large pulley turning a small pulley gives a speed advantage, whereas a small pulley driving a large pulley gives a torque advantage. Belts can vary in length, which allows the driving pulley to be placed as far from the driven pulley as needed.



### Motorised belt and pulley, connected to a winch

## Chain and sprocket

Bicycles are the machine that most people think of when talking about **chain drives**. Chain drives are used to gain a torque or speed advantage. Chain and sprockets have an advantage over belt drives as the chain does not slip.



### Chain and sprocket drive for a bicycle

## Comparing pulley drives with chain drives

Pulley drives and chain drives are quite similar, but with some key differences. Pulley drives are usually quieter, cheaper and require less maintenance than chain drives. However, pulley drives can transmit less torque before they slip, so a chain drive is used when transmitting high torque without slip.

Sometimes a machine needs the pulley to slip if something goes wrong to save the machine from damaging itself. Most school pedestal drills use belt drives between the motor and drill. The belt drive will slip if the drill bit gets caught, saving the motor from burning out or the drill bit from breaking and hitting a student.

### MECHANICAL ADVANTAGE FOR PULLEY DRIVES

Mechanical advantage can be calculated using the diameter measurements of the pulleys. A mechanical advantage greater than 1 gives a torque advantage, and a mechanical advantage under 1 gives a speed advantage.

$$\text{Mechanical advantage} = \frac{\text{diameter of driven pulley}}{\text{diameter of driving pulley}}$$

In the diagram of the motorised belt and pulley, the driving pulley diameter is 10 cm and the driven pulley diameter is 40 cm.

$$\begin{aligned} \text{Mechanical advantage} &= \frac{\text{diameter of driven pulley}}{\text{diameter of driving pulley}} \\ &= \frac{40 \text{ cm}}{10 \text{ cm}} \\ &= 4 \\ &= \frac{4}{1} \end{aligned}$$

Therefore, the mechanical advantage is 4 (or 4:1).

A mechanical advantage of 4 is a torque advantage – the rotary force is increased 4-times.

### MECHANICAL ADVANTAGE FOR CHAIN DRIVES

In the diagram of the bicycle chain and sprockets, the large sprocket is attached to the pedals and the small sprocket is attached to the rear wheel. This large sprocket driving a small sprocket means that the rear wheel spins faster than the pedals, giving a speed advantage.

The mechanical advantage for chain and sprockets is determined in the same way as for gears.

$$\text{Mechanical advantage} = \frac{\text{number of teeth on driven sprocket}}{\text{number of teeth on driving sprocket}}$$

In the bicycle example, the driving sprocket has 24 teeth and the driven sprocket 12 teeth.

$$\begin{aligned}\text{Mechanical advantage} &= \frac{\text{number of teeth on driven sprocket}}{\text{number of teeth on driving sprocket}} \\ &= \frac{12}{24} \\ &= \frac{1}{2} = 0.5\end{aligned}$$

Therefore, the mechanical advantage is 0.5 (or 1:2).

A mechanical advantage of 0.5 is a speed advantage. The gears lower the torque by half, but double the speed of rotation.

### FOCUS ACTIVITY

## Bicycle gearing

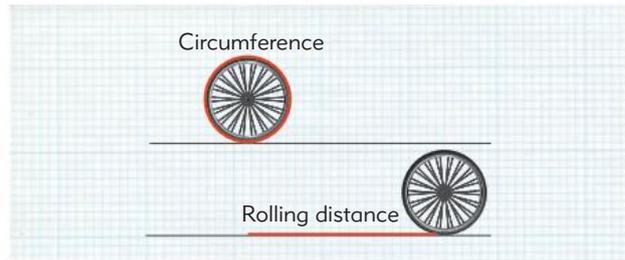
Without gears, old penny-farthing bicycles used to turn the drive wheel once for every one turn of the pedal. This means the bicycle moved forward by the length of the circumference of the driving wheel once for each pedal.



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**Penny-farthing – the front wheel is much larger than the back wheel**

With modern gears, you can change how far the bicycle moves forward with each pedal to create a speed or torque advantage.



**Distance traveled forward for one rotation of the wheel**

### Aim

To demonstrate the effect gears have on how far a bicycle moves forward with each rotation of the pedals.

### Materials

- Bicycle (with gears)
- Tape measure
- Chalk
- Safe, flat surface (such as a basketball court)

### Method

- 1 Mark a starting point with chalk.
- 2 Place the bicycle on the starting point with the tyre valve exactly above the chalk mark.
- 3 Roll the bicycle forward until the bicycle has rolled once (the valve will be above the chalk mark again).
- 4 Mark the end point with chalk.
- 5 Measure and record the distance that the bicycle rolled – this is the distance the bicycle moves without gearing.





- 6 Select 1st gear and place the bicycle over the starting point as before. Pedal exactly once (so the pedal starts and stops in the same position) and record the finish position of the bicycle.
- 7 Repeat for all the bicycle gears.

Bicycle gear	None (one tyre circumference)	1st gear	2nd gear	3rd gear	4th gear	5th gear
Distance travelled						

### Analysis

Compare the distance moved when a gear is selected with the circumference of the wheel.

- 1 Which gear gives the greatest speed advantage?
- 2 Which gear gives the greatest torque advantage?

## ELECTRICITY

**Electricity** is one of the main energy sources we use to power our lives. We store and play music, call people across the globe, monitor our heartbeats, secure our houses and power our concerts all with electricity. Electricity is a form of energy that causes the movement of tiny particles called electrons that are *far* too small to see. Electricity flows in wires in a similar way to water flowing through pipes.



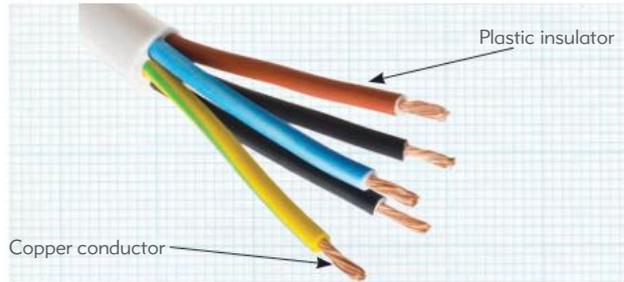
Shutterstock.com/Raoud Morijn Photographer

### Power lines transfer electrical energy

You will need to be familiar with the following electrical terms.

- **Conductor** – All electricity requires a conductor to flow through. Conductors are usually made from copper because it is a good conductor with low electrical resistance.
- **Insulator** – An insulator stops or hinders the flow of electricity. Plastic and rubber are two good insulators. Wires are wrapped in plastic to stop the electricity leaving the wire. High-voltage wires are always insulated to keep you safe.

- **Resistance** – Resistance is the force that opposes current in a circuit. Every component has some resistance. The symbol for resistance is  $\Omega$  (the Greek letter omega).
- **Current** – Current is the flow of electrons in a circuit. Current is measured in amperes or amps. In electronics, we use very small currents. A light-emitting diode (LED) typically uses 7 milliamps (which is seven-thousandths of one amp).
- **Voltage** – Voltage is the force that pushes electrons around a circuit. The unit of voltage is volts.



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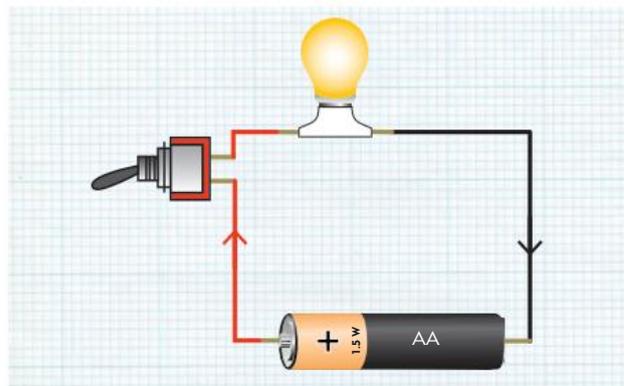
### Mains cable showing conductors and insulators

### Circuits

Electricity flows around a **circuit** to make something work; for example, the electricity may power a lamp or turn a motor. All circuits must have three parts: a closed path, a power supply and a load.

- **Closed path**– an unbroken circuit that electricity can flow around.
- **Power supply** – the energy source, usually batteries or a plug pack.
- **Load** – the component that uses the power, such as a lamp or heater.

In the lamp circuit shown in the diagram, the electricity flows out of the battery, through the switch and into the lamp. When the switch is in the on position, the electrons give energy to the lamp and then return to the battery.



### Lamp circuit with switch and continuous loop

## Conventional current

Current is the flow of charge in a circuit. Conventional current describes positive charges flowing from the positive terminal of a power source to the negative terminal. In reality, current in circuits is the flow of negatively charged electrons in the opposite direction. In technology, we ignore the fact that electrons are negatively charged and use conventional current flow from positive to negative.



## Safety

Electricity is very useful, and this book teaches you about electricity and electronics. However, electricity can be very dangerous. If misused, mains power from power points can lead to death.

It is generally safe to use the battery-powered circuits listed in this book. However, even batteries can be dangerous if mistreated.

## FOCUS ACTIVITY

### Electricity

- 1 What is the difference between an insulator and a conductor?
- 2 What is moving in an electric current flow?
- 3 What is the unit of current?
- 4 What is the unit of voltage?
- 5 What three parts are needed for a circuit?
- 6 What is resistance?

## Circuit types

There are two main types of electrical circuits: **series circuits** and **parallel circuits**.

### Series circuits

In a series circuit, **components** are arranged one after the other. The same current flows through each component, but the voltage is split between the load.

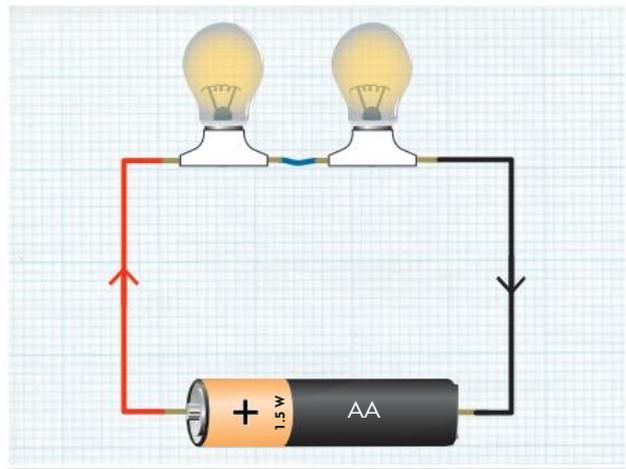
## FOCUS ACTIVITY

### Series circuits

Imagine you are part of the current flowing in the series circuit shown in the diagram. You start your journey in the battery, go out into the red wire, through the first lamp (give the lamp half of the energy you are carrying), into the blue wire, through the last lamp (give that lamp half of the energy you are carrying), into the black wire, and finally back into the battery to get more energy and go around the circuit again. Keep this journey in mind as you complete this activity.

### Aim

To investigate what happens to the light levels of lamps in a series circuit when more lamps are added.



Lamp circuit with continuous loop and two lamps.

### Materials

- Low-voltage lamps
- Battery packs
- Crocodile clips and wire

### Method

- 1 Create the series circuit shown in the diagram. Start with just one lamp in your circuit.
- 2 Create the same series circuit but add an additional lamp.
- 3 Create the same series circuit again and add a third lamp.

### Safety

Do not short-circuit the battery. At least one lamp must be wired between the positive and negative end of the battery pack.

### Analysis

Observe what happens to the light levels as more lamps are added.

## Parallel circuits

In parallel circuits, (see bottom of page) the current from the battery splits into more than one pathway. Although each pathway gets the whole voltage, the battery will run flat more quickly than in a series circuit because the battery is powering more lamps, each with the same voltage and current.

## Current

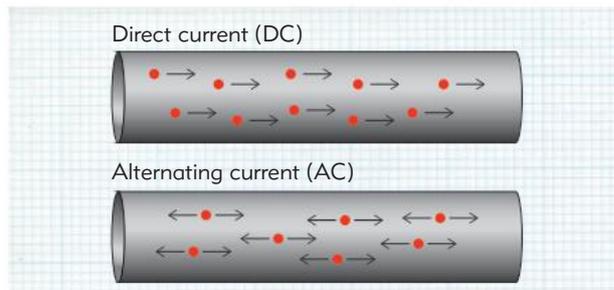
### Direct current

**Direct current** flows around a circuit in one direction only. All batteries provide direct current to power a circuit. In the circuits shown below, the current flows out of the positive end of the battery, through the circuit, and back into the negative end of the battery.

### Alternating current

**Alternating current** flows in one direction for a short time and then back the other way for a short time, repeating continuously. Look closely at a speaker when it is in use and you will see it moving in and out. Speakers must be powered by alternating current – if

speakers were powered by direct current, they would stay pushed out and produce no sound.



**Electrons in a wire moving one direction (DC) and electrons in a wire moving back and forth (AC)**

## Ohm's law

Ohm's law is the relationship between voltage ( $V$ ), current ( $I$ ) and resistance ( $R$ ) in a circuit, which can be expressed as an equation.

$$\text{Current} = \frac{\text{Voltage}}{\text{Resistance}}$$
$$I = \frac{V}{R}$$

FOCUS ACTIVITY

## Parallel circuits

### Aim

To investigate what happens to the light levels of lamps in a parallel circuit when more lamps are added.

### Materials

- Low-voltage lamps
- Battery packs
- Crocodile clips and wire

### Method

- 1 Create the first parallel circuit shown in the diagram.
- 2 Add an additional lamp in parallel as shown in the second image.

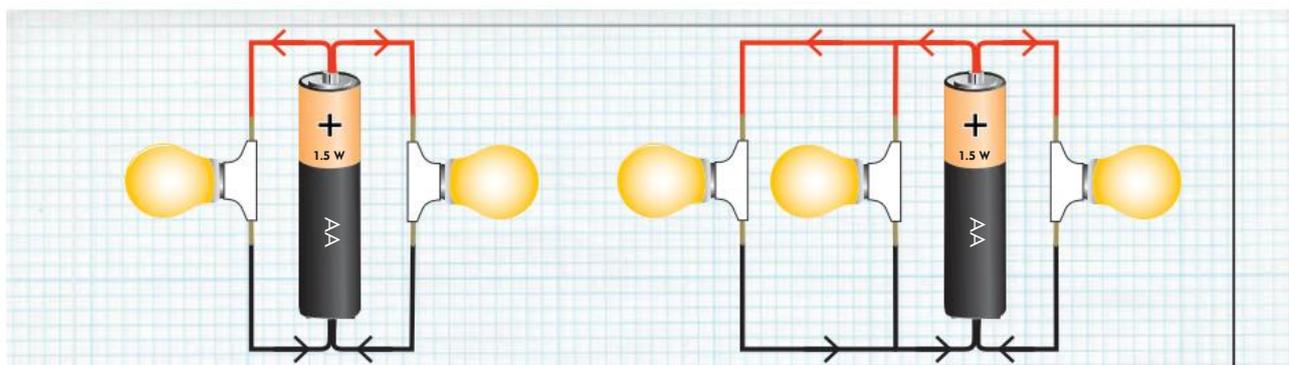
- 3 Add a third lamp in parallel.

### Safety

Do not short-circuit the battery. At least one lamp must be wired between the positive and negative end of the battery pack.

### Analysis

Observe what happens to the light levels as more lamps are added. What is the difference between a series and parallel circuit?



**Two lamps in parallel.**

**Three lamps in parallel.**

The amount of current that flows depends on the voltage pushing the electrons and the resistance opposing the flow of electrons. A typical current draw ( $I$ ) for a car headlight can be calculated. A car has a 12 V battery ( $V$ ) and a 4  $\Omega$  lamp ( $R$ ).

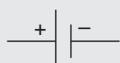
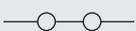
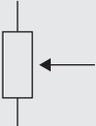
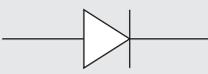
$$I = \frac{V}{R}$$

$$= \frac{12}{4} = 3$$

Therefore, the current draw is 3 A (that is, 3 amps).

## COMPONENTS

A standard set of technical symbols are used for the components in circuit diagrams.

COMPONENT	SYMBOL
Battery	 single-cell battery
Switch	  Closed (on)      Open (off)
Resistor	
Potentiometer	
Lamp	
LED	
Diode	
Capacitor	  Non-polar      Polar
Motor	
Transistor	

### Batteries

A **battery** is an energy source that generates a flow of electrons to power circuits. The flow of electrons can only take place in a closed electrical circuit. The previous lightbulb diagrams show closed circuits. If the battery is disconnected from a circuit, no current

flows. Batteries provide direct current (DC). Batteries have a positive and negative terminal.

### Battery types

Disposable AAA and AA batteries are used in remote controls and many school projects. They have 1.5 volts per battery. 12 V lead-acid batteries are

used in most cars. Lithium batteries are used in most phones and remote-controlled toys. They have 3.6 volts per battery.



istock.com/omegarevision

### AA batteries



imagefolk/Mark Boulton/istock.com/imagefolk

### 12 V battery



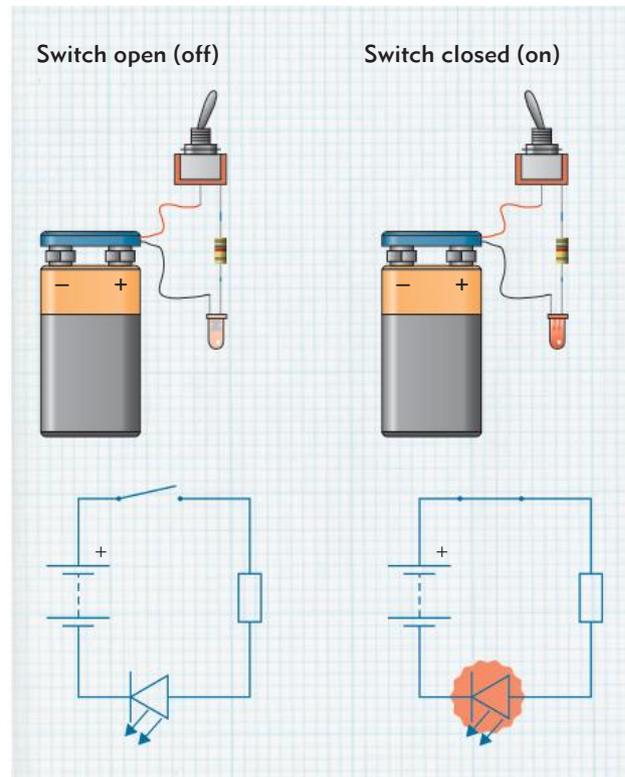
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### Lithium battery

Most devices can use rechargeable batteries. These are a more sustainable choice – using rechargeable batteries saves many batteries being thrown out as landfill.

## Switches

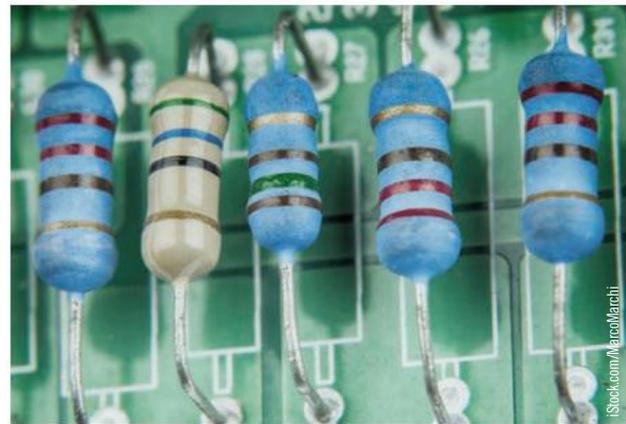
A **switch** connects or disconnects a circuit. When you turn on a switch, the circuit is closed and current flows. When you turn the switch off, the circuit is open and the current cannot flow. Pictured is an LED circuit with an open and closed switch. Below each picture is the same circuit drawn using the appropriate technical symbols.



Switching an LED circuit open (off) and closed (on), shown with illustrations and circuit symbols

## Resistors

A **resistor** is a component that limits current in a circuit. Resistors are often used to protect components that would be broken by too much current, such as an LED. The coloured bands printed on a resistor indicate the resistor value.



istock.com/MarcoMarchi

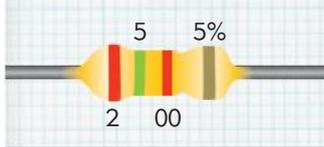
### Resistors (4-band)

### Resistor colour codes

Resistor values are shown using colour codes – usually four coloured bands but sometimes five coloured bands. With a four-band resistor, the first two bands represent the digits from 0–9. The third band represents the number of zeros, and the fourth band

shows the tolerance (how accurate the resistor is, as a percentage). Resistors have the first three bands close together and a slight gap before the fourth band.

Colour	First band	Second band	Third band	Fourth band (tolerance)
Black	0	0	–	
Brown	1	1	0	1%
Red	2	2	00	2%
Orange	3	3	000	
Yellow	4	4	0000	
Green	5	5	00000	
Blue	6	6	000000	
Violet	7	7		
Grey	8	8		
White	9	9		
Gold				5%
Silver				10%



Resistor with a value of 2500  $\Omega$  with 5% tolerance

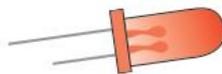
## Potentiometers

Potentiometers are variable resistors that allow you to change their resistance by turning a dial. Similar to a normal resistor, a potentiometer limits the current flow in a circuit. Potentiometers can be used to change the volume of a radio or to dim a light.

## Incandescent lamps

An incandescent **lamp** has a resistive wire that heats up so hot that it emits light. Unfortunately, lamps waste most of the energy from the power supply as heat, and only some of the energy is used to produce light.

## LEDs



**Light-emitting diodes (LEDs)** are a common light source. They are available in many colours and are very efficient. Nearly all the energy used to power an LED comes out as light, and very little energy is wasted as heat. Many houses, cars and trucks are changing to LED lighting to save money and lower greenhouse gas emissions.

When wiring LEDs in your own circuit, an LED will require a resistor to set the current and voltage. Note that LEDs have an anode and cathode leg – the anode (A) is the longer leg and the cathode (K) is the shorter leg.

## Tip

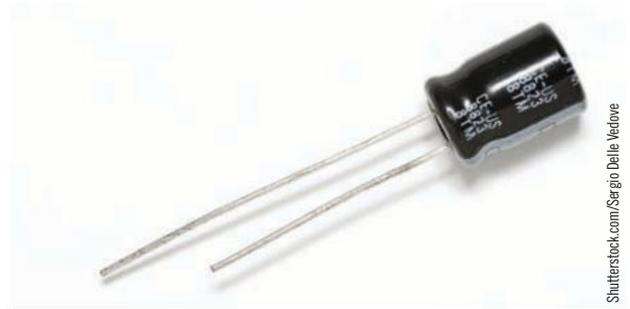
Memory aid for LEDs – current flows from A to K, in the same way that the alphabet flows.

## Diodes

A **diode** only allows current to flow in one direction. It creates a 'one-way street' for current. The diode allows the current into the anode leg and out of the cathode leg, but never the other way around. Diodes are often used to protect a circuit from being accidentally connected with the battery the wrong way around (which would break sensitive components with reverse current).

## Capacitor

A **capacitor** is a small component that can store and release electricity like a rechargeable battery. Capacitors are used in camera flashes because they can release their energy in one quick burst. The amount of energy a capacitor can store is measured in farads.

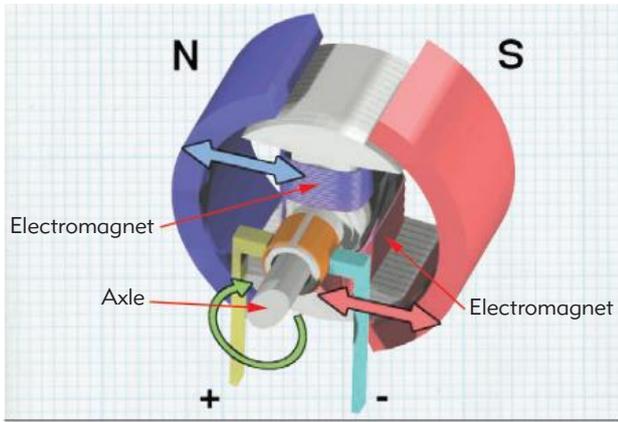


Capacitor

## Motors

**Motors** involve magnets. There are two kinds of magnets in motors: **fixed magnets** (the magnets you will be familiar with) and **electromagnets**. Electromagnets work due to one of the fundamental forces of nature – if electricity is passed through a coil, it creates a magnetic field with a north and a south pole.

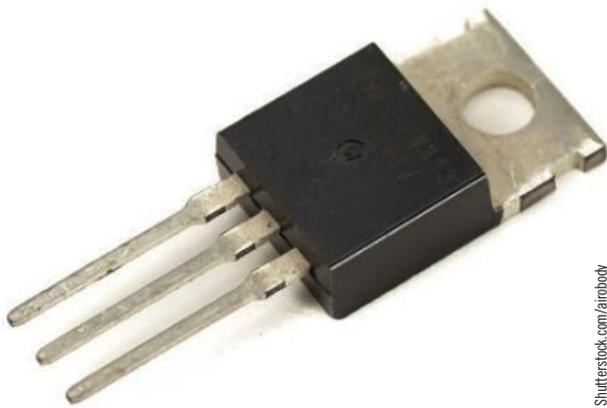
Motors turn by two magnets opposing each other. If you hold two magnets together, they will attract if the opposite poles are close to each other, or push apart if the same poles are close to each other. The electromagnets are connected so that they change **polarity** to always oppose the nearest fixed magnets and push away from the fixed magnet spinning the motor around.



Inside a simple motor

## Transistors

**Transistors** are the most common building block of modern electronics. Transistors have three legs and are used as an electronic switch. The transistor is turned on by passing a small current from the base to the emitter. When switched on, the transistor allows a larger current into the collector and out of the emitter.

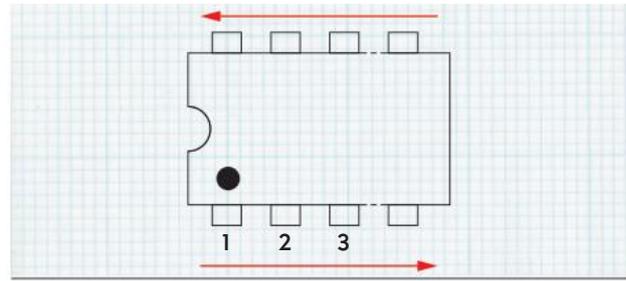


Typical three-legged transistor

## Integrated circuits

An integrated circuit contains an entire circuit all in one package. Because electronic components have been miniaturised, integrated circuits may have anywhere from hundreds to billions of components in the one package. A transistor may be just a few nanometres wide.

When working with integrated circuits, it is important to know the pin numbers. Pin number 1 is anticlockwise from the notch at the end of the integrated circuit, and sometimes has a dot indicating pin 1. The pins are then numbered in an anticlockwise direction around the chip.



Integrated circuit chip

# CREATING CIRCUITS

## Joining wires with clips

The simplest way to create a circuit is to join individual components with crocodile clips. The diagram shows a switched LED circuit. This method is useful for simple circuits, but it becomes messy and confusing for more complicated circuits.



Simple LED switch circuit with crocodile clips

## Printed circuit boards

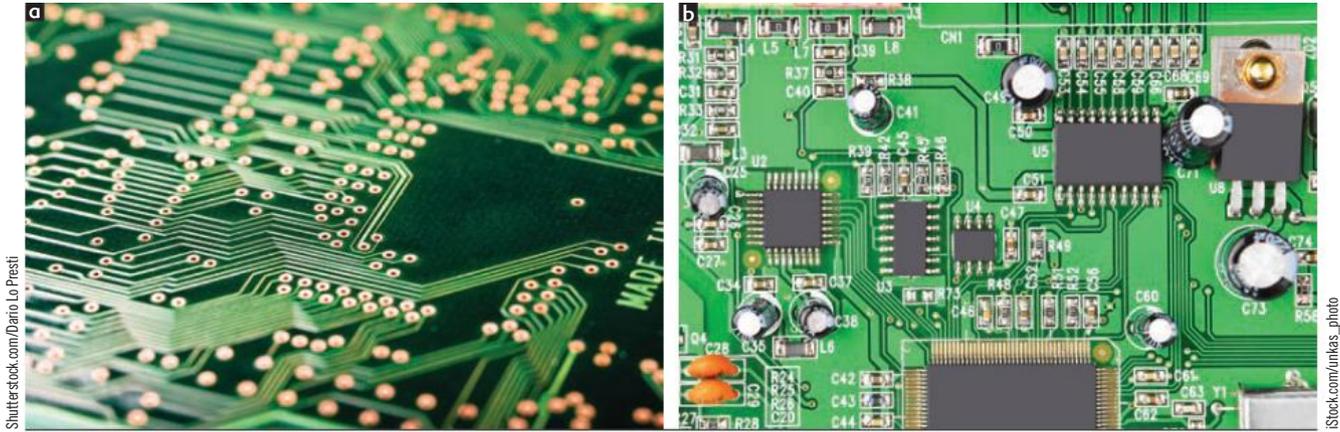
Printed circuit boards allow you to neatly create complicated electrical circuits. Printed circuit boards have copper tracks laid out on a strong fibreglass board. Pads are used to join the components to the track.

## Placing components

While resistors and some capacitors may be placed either way around, most components are polar and must be placed in the correct orientation.

Some components have markings to help with orientation.

- Diodes have a stripe to show the cathode.
- Transistors can be tricky, so check the board carefully.



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**a) Circuit board with tracks and pads b) Circuit board with components soldered to the pads on the tracks**

- Polar capacitors commonly have a plus or minus marked above one of the legs.
- Integrated circuits have a notch at one end.

### Soldering

Soldering is the most important skill for electronic circuit building. A well-soldered circuit should last a lifetime.

**Solder** is a metal with a low melting point – you melt it with a hot soldering iron and use it to join components.

### Safety

Take care when soldering as a soldering iron is very hot, often around 350° Celsius. This can cause a nasty burn. Protective glasses must be worn as hot solder can spatter. Take care not to burn high-voltage leads with the iron.

To solder a printed circuit board, the following steps must be followed.

- 1 Ensure the soldering iron has reached the required temperature.
- 2 Check the pad and lead (component leg) are clean.
- 3 Clean the tip of the soldering iron.
- 4 'Tin' the tip of the soldering iron by adding a small amount of solder.
- 5 Heat both the pad and lead until hot enough to melt the solder.
- 6 Apply solder to the heated junction of the pad and lead (not the soldering iron).
- 7 As soon as the solder flows around the lead, remove the soldering iron and solder.

### Multimeter

A **multimeter** contains many meters in one package. Commonly, a multimeter can measure voltage, current, resistance, continuity and capacitance. Check resistor and capacitor values with a multimeter before soldering

components in your circuit – misplacing just one resistor can ruin your circuit. When the circuit is complete, the voltmeter is useful for locating any possible faults.

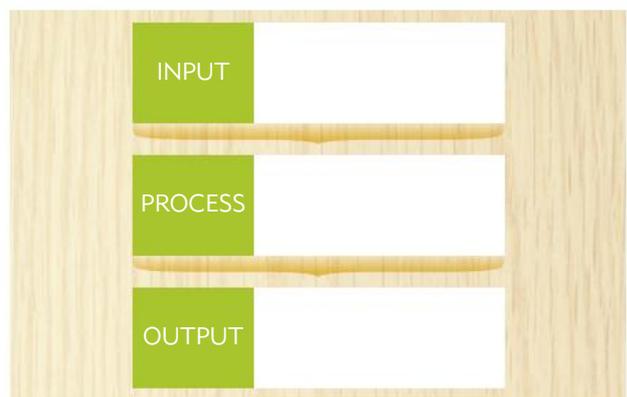
## SYSTEMS

A system is a product designed to perform a task. For example, a kettle is a system designed to boil water. A system can be mechanical or electrical, or both.

### Input–process–output diagrams

**Input–process–output diagrams** are a method of showing the important features of a product. A simple example is the kettle diagram shown. Later in this book when you are planning your project, you will use input–process–output diagrams to explain how your project will work.

In an input–process–output diagram, the inputs are stated first and list everything required to go into the system. The process describes how the system works, and the outputs describe everything that comes out of the system.



**Input–process–output diagram**

## Input–process–output for a kettle

When we boil water in a kettle, the system involves the following:

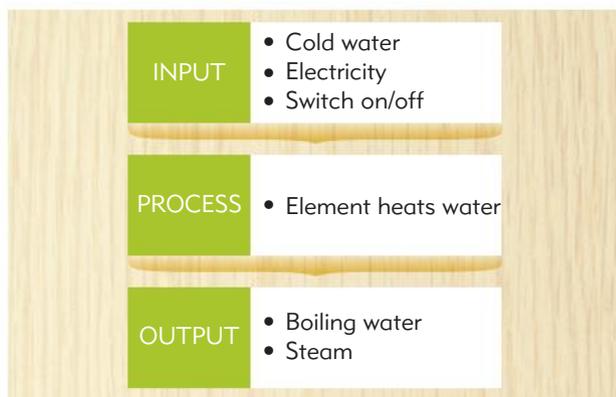
- **input** – cold water, electricity and the user turning the switch
- **process** – electrical energy into the heating element heats the water
- **output** – boiling water and steam

When you are creating an input–process–output diagram, first list the inputs (all the energy, data and material going into the product). Then list the outputs (all the energy, materials and data coming out of the product). Finally, list all processes.

INPUTS	PROCESSES	OUTPUTS
What is required to make the system work	What happens to make the system work	What the system creates

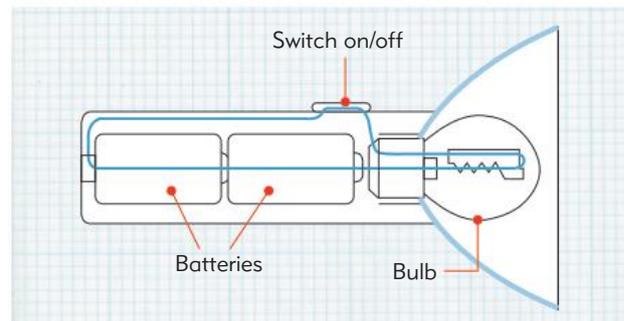


**Outputs of a kettle system are boiling water and steam**



**Kettle input–process–output diagram**

## Input–process–output for a torch



Consider the torch diagram above.

- 1 Name the input(s) to this torch.
- 2 Name the output(s) from this torch.
- 3 Name the process(s) of this torch.
- 4 Create an input–process–output diagram for the torch.

## Control and robotics systems

### Switching control

The simplest way to control an electrical circuit is with a switch. Switches can be used to turn circuits on or off, such as controlling the lights in your house. More complicated switches can change the direction that a motor spins.

### Sensor control

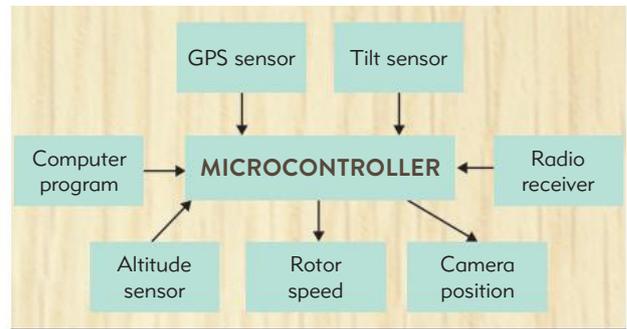
Some electrical circuits can sense their surroundings and automatically turn on and off. For example, many street lights sense when they need to be on or off. They turn on when it is dark at night, and turn off when it is light in the morning – the sensors detect the amount of light. Heaters can sense the temperature in a room and turn on and off to maintain a steady temperature. Sensors can be used to detect many conditions such as tilt, smoke, position, acceleration, wind speed, current and sound level. All these sensors are used in electronic control circuits to engineer the environment that we live in.

### Microcontroller

Using **microcontrollers** allows us to control more complicated machines. A microcontroller is a small computer chip that can be programmed to monitor inputs and control outputs. Any type of sensor can be attached to a microcontroller to monitor inputs and

outputs, and they can be programmed to perform however you wish.

A quadcopter drone is one example of a micro-controlled robot. There are many sensors on the drone including a radio receiver to receive signals from the operator, a GPS for position, tilt sensors and altitude sensors. The microcontroller uses the information from the sensors to control the speed of the rotors and the movement of a camera.



**Quadcopter drone block diagram**

You will learn more about controls in the challenges in Chapter 7 on page 173.

## THINKING SKILLS

### SIMPLE MACHINES

- 1 Choose four simple machines and draw them clearly and accurately. Annotate each drawing, and show the input and output motions with arrows. Choose one simple machine and research the oldest use of the machine in history.

### ANALYSING A PRODUCT

- 2 Find a simple mechanical product, such as a stapler. Describe what the product is and its function (what is it for?). Identify the main simple mechanism in the product (lever, gears, pulley, etc.) and draw an annotated diagram of the machine. Name any other simple mechanisms in the product. How could you change the machine to make it easier to use?

### ANALYSING STAPLERS

- 3 Consider the staplers in the image below. Discuss the difference between the staplers and when each stapler would be used. Draw the lever from each stapler and label the effort, load and fulcrum. Identify the lever class of each stapler. Which stapler would be stronger?



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### DESIGNING A MACHINE

- 4 Design a machine that combines many simple mechanisms to perform a function. The machine can be silly and fun, or it can be serious and solve a real problem. If you need some inspiration, research Rube Goldberg machines on the internet.
  - Give your machine a suitable name.
  - Draw your machine to show how the simple mechanisms are combined.
  - Annotate your design, naming each mechanism.

 RUBE GOLDBERG MACHINES



Getty Images/Jeffrey Coolidge

**Combining simple machines**

## SECTION TWO

# DESIGN CHALLENGES

- 5 Design to hold and store
- 6 Mechanical moves
- 7 Electrifying robots
- 8 Design to shelter and protect
- 9 Human-centred design
- 10 Sustainable solutions
- 11 Travelling to the future





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# 5

## DESIGN TO HOLD AND STORE

### KEY KNOWLEDGE

In this chapter, students focus on what it means to store and hold. They use the design process to:

- ▶ identify and define people's storage needs
- ▶ develop a range of storage solutions for a specific situation
- ▶ make and evaluate one of these solutions.

### DESIGN CHALLENGES

- ▶ Store-it – design and make a storage shelf or box
- ▶ Carry-it – design and make a carry bag
- ▶ Show-it – design and make a photo display stand
- ▶ Mini storage – design and make a USB drive casing

# FOCUS ON STORAGE

Storage is a common need – we all have different things that we need to hold or store. There are many reasons, **functions** or **purposes** of/for storage/holding products.

- **Protection, safety and security** – Objects need to be protected from damage caused by weather and temperature changes, light, dirt, and general wear and tear. Some objects are important, precious or fragile, and need to be kept safe from other people (such as small children) or kept from being taken and used inappropriately. Some objects are dangerous and need to be kept out of reach.
- **Displaying** – Sometimes we have special things we want to show to others. We want to keep them all in the one place and to display these things in a way that makes them look good, but

that doesn't put them in danger of being handled or damaged. We may also want to display often-used objects so we can find them easily.

- **Moving** – When objects need to be moved around, they may be difficult to carry or we may want to carry many things at a time. We need a way of holding these items safely while they are being carried.
- **Organising and containing** – It can be helpful to have some way of holding objects in an organised way, such as putting things that are similar or related together, or separating different groups of objects so we know where to find them. Storage can also help us to organise and use space efficiently. Sometimes we want to contain or group things together for use at another time, or because we might lose them easily if they weren't contained.

FOCUS ACTIVITY

## Holding and storing

- 1 Think of a real-life situation for each of the purposes listed above. Identify the people involved, the things that need to be stored, and current solutions/products.
- 2 Are there any other reasons why we might design products that store or hold things?
- 3 The products in the following list are designed to store and hold specific things.
  - USB flash drive
  - printer's type case
  - bookcase
  - backpack
  - factory storage
  - refrigerator
  - dam
  - artist's case
  - make-up stand
  - collection display
  - Svalbard seed vault in Norway
  - a What is the main purpose for each storage solution? (Some may need to be researched.)
  - b Discuss why some of these products are very important in our lives, or why they are no longer needed.
  - c Discuss the function of each type of storage (such as protection and security, displaying or organising).



Refrigerator

Shutterstock.com/focanimages



Backpack



Printer's type case



Svalbard seed storage



Artist's box



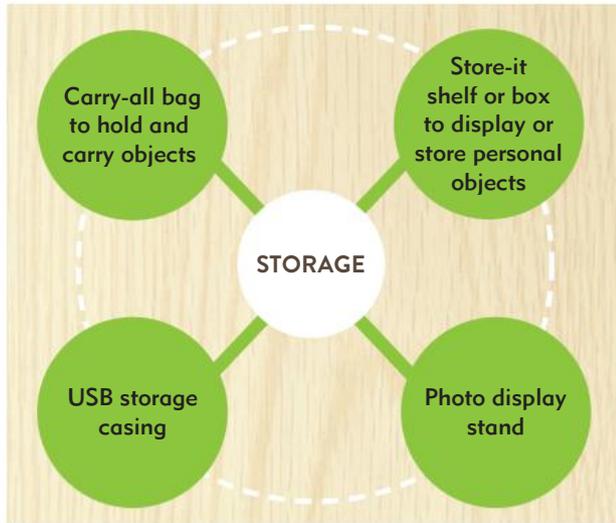
USB flash drive

- 4 Think of the following groups of people.
  - Librarians
  - Childcare workers
  - Scientists
  - Defence force personnel
  - Artists
  - Chefs
  - a What specific items might these people want to store or hold?
  - b Products designed to store or hold these items usually focus on one purpose more than others. Identify the main purpose each of these groups of people would look for in a storage product.
- 5 List the items you need to store and hold. If you were to design a product for these items, what would its main purpose be? Do some products have more than one purpose? An example has been provided to get you started.

OBJECTS/ THINGS	DESIGN PRODUCT	MAIN PURPOSE	OTHER PURPOSES
Example: Money	Wallet	<ul style="list-style-type: none"> <li>• To keep money safe and secure</li> </ul>	<ul style="list-style-type: none"> <li>• To carry money from one place to another</li> <li>• To protect money from being damaged</li> </ul>

# DESIGN CHALLENGES

All the challenges that follow are project ideas – each challenge leads you through the design process and will help you to design, make, and evaluate products that effectively store and hold. The tasks within each challenge will help you to develop some great ideas and make creative and useful solutions.



Some general products that store or hold

## STORE-IT

### Design situation or problem

You probably have many things that clutter your bedroom or other parts of your house – things that need to be organised. Or, you may be very organised but want to put some special things on display. Each situation needs an individual solution.

### Focus for assessment

When checking whether you've designed and made a great product, your teacher will assess how well you have addressed the following questions.

- » Have you identified the needs of the person you are making the product for?
- » Is your research clear and detailed?
- » Are your design drawings accurate and creative, and do they have all the required information (measurements, joins, lid drawing, etc.)?
- » Is your cutting, shaping and assembly accurate?
- » Is your decorative design interesting and creative (in both the use of colour and shaping)?
- » Have you sanded and varnished/painted to a smooth finish?
- » Have you worked safely in a planned and productive way?
- » Is your evaluation clear, detailed and honest?

Think about your needs and the needs of others around you. Decide whether to design and make your storage product for yourself or for someone else.

### STORE-IT DESIGN CHALLENGE

You are to design and produce a shelf or container that holds items such as DVDs, game discs, jewellery, trophies, collections and phones/chargers.

#### REQUIREMENTS (LIMITS OR CONSTRAINTS)

- Your product should be no larger than the size set by your teacher.
- Choose from the joining methods specified by your teacher.
- Use the materials available in your school (or provide special materials from home).
- If you are designing and making a shelf, **no simple box shapes are allowed** – think of other shapes or ways to use rectangles.
- Your design must have some **form of decoration**, such as shapes, painting or metal scrolling.
- Use at least two different materials (such as wood, metal, plastics and /or fabric).
- Any division between items should not be too complex – don't create separate slots or lots of divisions.

#### DESIGN CHOICES

You will need to make decisions regarding:

- the shape of your storage solution (within the size limits)
- materials you will use
- joins you will use to construct your design (within the teacher's set requirements)
- decorative design.

## Investigating

### TASK 1 Mind map

Think about all the aspects that might be related to your design task.

- Start a mind map by writing the heading 'Store-it solution' in a box in the centre of the page.
- Think of 5–6 categories that you will need to make decisions about. Categories could include **materials, shape and colour, position, things to hold, types of decoration and themes.**

- On the mind map, list things that relate to each category and that are also relevant to designing and planning your storage solution.
- Highlight the ideas you think will work best.



**Template of a mind map**

Your mind map needs to be clear, use colour effectively, and include at least 4–5 ideas for each category. Use a full page.

### **TASK 2** Thinking about your design: web diagram

Complete a web diagram (see page 8) for your storage solution. Each section of the spider's web should cover one of the areas below. This will help you to make decisions about what your storage solution will be for and how it might work.

- Who – who will the product be for?
- What – what will it contain?
- Where – where is it going to go?
- How – how does it need to work?
- When – when will it be used and how often?
- Wow – what styling, themes do you like and what will give it impact?

### **DESIGN BRIEF**

Use the information in your web to write your design brief – a paragraph explaining your individual design situation. Start with the following words: *'I need to design and make a storage solution that ...'*

### **TASK 3** Criteria for success

We all have an idea of what a good product is like. Criteria for success define our expectations or standards in areas such as function (how the product

works), construction (how well it has been made) and appearance (how good it looks). Your criteria need to be specific, and relate to your situation.

- Write a set of four criteria questions that you can use to judge whether your finished product meets your expectations. Make sure your questions cover the areas of function, construction and appearance.
- Remember to think about these criteria when you are developing and choosing your designs.

## **Design research**

Ask your teacher which of these tasks you need to complete.

### **TASK 4A** Design analysis

Find four images of existing storage designs that are relevant and that you like. For each storage design, write a comment or analysis (2–3 sentences) that discusses:

- what the product is for
- its visual design (colour, shape and line) and style
- the use of materials
- how it works.

This research could be done in a group and your design analysis could be presented to your class.

### **TASK 4B** Situation research

Answer the following questions to think about what your storage solution will need.

- 1 Explain where will the holder go. In which room will it belong? Will it be on the floor, the wall, a bench, a desk or a shelf? Draw a map of the room and mark the likely position of the storage solution.
- 2 What colours and shapes would suit the chosen position/room?
- 3 Describe the style of things you like, or the themes/ areas (for example, cartoons, sport or music) you are interested in that could be reflected in your design.
- 4 Draw small diagrams of the items you want to store in your storage solution. Next to each item, write how many items will need to be stored or displayed. Measure the items and write the measurements on the diagrams. You will refer to this later, so it's important to be accurate.

#### TASK 4C Joins research

Select and research three different types of joins that could be used in constructing your storage solution. For each join:

- find a clear picture
- describe where it might be used in a storage product
- explain the advantages and disadvantages of the join.

### Materials

There are many different materials you could use for this design challenge, but not all of them will be available in your school.

#### TIMBER

Although there are many timbers that might be suitable for a storage shelf or container, the most commonly available is radiata pine. Standard sizes are 140 mm x 12 mm, and 190 mm x 19 mm. Other timbers might be used in small amounts as a highlight or feature. Also, consider using plywood – it is made from layers of thin veneer, which makes it light and strong. Plywood is a sheet material (supplied in large sheets, usually 1200 mm x 2400 mm). Thin plywood is also flexible and can be made to curve. Dowel or shaped mouldings can also be used as a structural part of your design, or for decoration.

#### METAL

Commonly used metal materials include threaded rod (a useful structural material that can connect parts using the rod and hex nuts), mild steel (in flat, square or angle form), sheet aluminium (chequer plate has an interesting textured surface that can be used decoratively) and aluminium or steel tubing.

#### PLASTIC

The most useful type of plastic for this challenge is acrylic sheet or rod. It can be easily cut and bent, and is available in a wide range of colours, levels of transparency, and textures. Acrylic can also be easily cut and engraved using a laser cutter, if you have access to this technology. A 3D printer can also form other plastics into decorative and useful components of your design (such as connectors, handles or hooks).

#### FABRICS

Fabrics can be used in combination with other materials in this challenge to create soft forms and

divisions. Make sure you choose a strong fabric that will cope with wear and tear.

### Generating

#### TASK 5 Design development

##### SKETCHES AND OPTIONS

Brainstorm some ideas for your situation/design brief – develop four ideas as sketches, each taking up half an A4 page. Try to show your ideas from different angles, and label some of the materials and features of each design. Think about each sketched idea. What is good or interesting about each one? What does/doesn't look appealing? What might be hard to make? Write at least three comments for each idea explaining your thoughts.

##### ORTHOGONAL DRAWING OF YOUR CHOSEN DESIGN

Develop and draw your chosen storage solution design, based on your initial sketches and thinking.

Draw your design using the orthogonal drawing method – you must show the front, side view and top view. Information about **orthogonal** drawing can be found in the section on drawing products on pages 23–4. When drawing, use a ruler and be accurate. You will need to show thicknesses of the materials, the design's measurements, and details of the joins on your drawing.

- Use a full page for your design drawing.
- Show details – include information that explains the joins, measurements, materials, etc.
- Write comments – explain how your design will work, its features, etc.
- Colour – show the colours of all parts of your design (such as wood and metal texture, and the colour of acrylic).

#### TASK 6 Materials cutting list

Create a table to list each part of your design. Include how many of each part is needed, their size (length, width and thickness), and what material each part will be cut from (some sizes might be determined by **standard sizes** that are supplied). Remember to allow for any joins when calculating the part sizes.

#### Materials cutting list

PART	NO.	LENGTH	WIDTH	THICK	MATERIAL (INDICATE STANDARD SIZE)

## Note

Most materials are processed and supplied in **standard sizes**. You need to know what these standard sizes are, as it is easier and less wasteful to match your product measurements to these sizes. For example, radiata pine is usually supplied in lengths that are either 140 mm wide × 12 mm thick, or 190 mm wide × 19 mm thick. If you are making a storage shelf from pine, it would make sense to make the width of your shelf either 140 mm or 190 mm to match the width of the timber.

## Planning and managing

### TASK 7 Production plan

Develop a production plan to help guide you while you are making your storage product. Use the following table headings to structure your plan. Try to be as detailed as possible. You could discuss this as a class, but remember that different designs might need a different work plan.

#### Production plan

PRODUCTION STEP	TOOLS AND EQUIPMENT	SAFETY

### TASK 8 Joins practice

Watch a demonstration of the joins you plan to use. If necessary, make a practice join so that you feel confident and able to do these joins to make your storage solution.

## Safety

If you are using any machinery during production, make sure you complete any school safety tasks or tests, and that you are **competent** before you start work. Competent means you know what you are doing and have practised the skills needed. Tasks and tests may include:

- » a machine safety test
  - » a competency test (where you demonstrate to the teacher that you know how to use the machine)
  - » a completed entry in your machine safety passbook.
- Remember to always ask permission from your teacher before you use a machine

## Producing

### JOURNAL DURING PRODUCTION

Keep a journal while you are making your product to record your progress, and to reflect on the things

that go well and what could be improved. Briefly summarise what you completed during each step (this will probably match your plan), and record how long this took (either in minutes or periods). For each entry, write in your reflections – explaining the things you’ve done well, what you had problems with, and what you could improve. Use photos to visually record your production.

### Production journal

JOURNAL <i>What you completed in each stage</i>	TIME*	REFLECTION <i>What went well? What could be improved? What did you learn?</i>

\*Time – how long did it take to complete?

### TASK 9 Making your product

You need to construct your product. This will involve:

- marking out your materials
- cutting your pieces, checking, and adjusting length
- marking out your joins
- cutting and shaping joins
- pre-join sanding or decorative processes (if needed)
- a dry check and adjusting (if needed)
- assembly
- completing any decorative processes
- final sanding and varnishing/painting/finishing.

## Evaluating

### TASK 10 Evaluation of your finished product

Evaluate your work – make judgements about your finished product using the criteria for success you wrote in Task 3.

#### Evaluation

EVALUATION CRITERIA	HOW DID YOU CHECK THIS?	HOW WELL DID YOUR FINISHED PRODUCT PERFORM IN THIS AREA?

As part of your evaluation, answer the following questions or points:

- Which stage of design and production did you enjoy the most?
- How you could improve a stage of design and/or production?
- Give an example of when you showed persistence during the design and production process.

## CARRY-IT

### Design situation or problem

It is hard to juggle all the things you need to carry from one place to another in your hands. Different forms of bags and packs have been developed to make holding and moving objects easier. When you are travelling from place to place, what do you need to carry? Do you need different carrying solutions for different times of the day, to carry different objects for different circumstances?



People use carrying solutions in many different situations

## Mind-mapping in a group

In groups, discuss when and how you carry objects. Complete a mind map of your discussion.



## CARRY-IT DESIGN CHALLENGE

You are to design and make a fabric carrier for holding and moving objects of your choice. The carrier can be designed and made for you, or for someone else. It should be comfortable to wear and keep its content secure while being moved. You also need to think about the specific needs of the person who will use the carrier.

### REQUIREMENTS (LIMITS OR CONSTRAINTS)

- Your product should be no larger than the size set by your teacher.
- Use at least two different types of fabric, one of which needs to be **recycled**.
- Include a method of keeping the contents **secure** (such as a fastening or flap).
- Include a feature that will make it **comfortable** to wear or hold.
- Incorporate some **form of decoration** to make it individual and easily recognisable.
- Use at least two forms of stitching or joins.

### DESIGN CHOICES

You will need to make decisions regarding:

- what your carrier will hold
- the form, shape and size of your carrier (within the limits set by your teacher)
- how it will work
- decorative design and techniques (a range of these will be shown to you by your teacher).

## Focus for assessment

For the assessment of your design work, your teacher will be looking for:

- » relevant, detailed and interesting research into different forms of carriers, fabrics, and decorative techniques
- » clear and perceptive thinking when defining what you need
- » creative and innovative design ideas that are clearly and accurately drawn
- » logical and detailed planning for making
- » skill in a range of construction and decorative processes, and accuracy when making
- » an honest evaluation of your finished product.

## Investigating

### TASK 1 Researching different bags and packs

Collect images of different bags, packs and carriers that are different or unique in some way, and that you think have been well designed. Consider:

- the materials used
- the purpose of the bags
- their visual appearance
- any special features.

### TASK 2 Design brief

Write a design brief for your carrying solution that discusses:

- who your carrier will be for and their needs
- what objects need to be carried
- any special qualities the carrier needs to have
- how it might work
- where it might be used and where it will be stored when not in use
- what visual style would work well.

### TASK 3 Criteria for success

Write a set of four criteria questions that you can use to judge whether your finished product meets your expectations and the needs explained in your design brief. Make sure your questions cover the areas of function, construction and appearance.

## Materials

### WHY DO WE USE RECYCLED MATERIALS?

Being environmentally sustainable is important – we don't want to cause long-term damage to the environment by the way we use and consume products. Read more about sustainability on pages 10, 37, the textiles section of Chapter 2, and page 204.

When designing and making products, we need to think about where the materials in the products come from, and what happens to those materials when the product isn't useful anymore and is thrown away.

The decisions you make when choosing your fabrics for your carrying solution make a difference, and are one of the factors that determines whether your product will be sustainable or not. You want to choose fabrics that have few or no negative impacts on the environment when they are created, but this is usually hard to judge when buying new fabrics.

Choosing a recycled fabric will have a positive impact on the environment – you are saving materials from becoming landfill or rubbish, and you are giving them a new life. This is called **upcycling** – instead of a product being thrown away, the materials are recycled into a new, useful product that is usually of more worth than the old product.

### TASK 4 Fibres and fabric construction (group research and presentation)

Choose and find samples of three fabrics that could be used to make your products. In groups, research the fabrics and present your information to your class. In your presentation, you will need to:

- explain what the fibres are
- explain where each fibre comes from and how it is processed
- identify each type of fibre classification (for example, natural, synthetic – refer to Chapter 2)
- describe the fabric construction
- describe the characteristics and qualities of each sample – from observations, and from further research
- if you can, make a judgement about how sustainable each fabric is.

## Design research

### EXAMPLES OF DECORATIVE TECHNIQUES

Choose a form of decoration that will suit your design ideas. You may want to combine more than one technique. Your teacher will give you some direction and will show you examples of some of these techniques.

- Decorative stitching and embroidery
- Beading and sequins
- Silk-screen printing or block printing
- Appliqué



- Machine embroidery
- Digital printing
- Padding and quilting
- Attaching braids, ribbons and cords
- Attaching fastenings in a decorative way (such as buttons, buckles and toggles).

#### TASK 5 Trialling decorative techniques and ideas

Complete small samples of several different decorative techniques and ideas.

### Generating

#### TASK 6 Design development

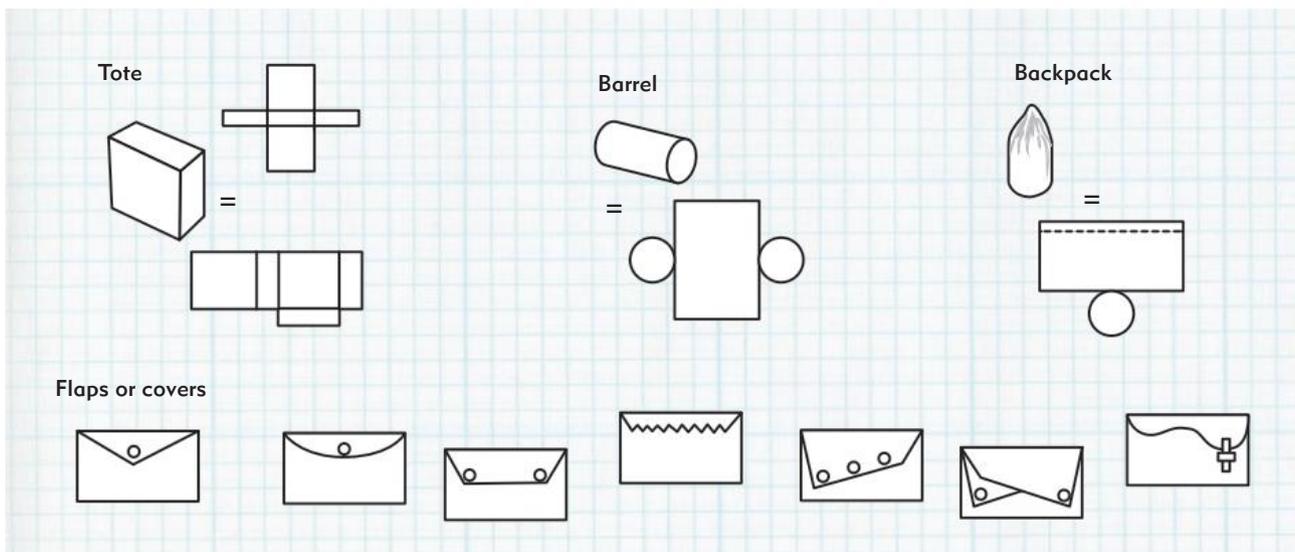
##### CARRIER SHAPES AND DECORATIONS

Sketch 3–4 bag shape ideas that would suit your needs. Explore:

- different basic geometric shapes
- different proportions
- how you might hold the carrier, or how it would attach to the body.

Write comments on each sketch to explain its features and its good/bad points. Refer back to your design brief and choose the design that best suits your needs. Explain your choice.

Next, develop ideas for the decorative aspect of your carrier. Brainstorm a range of ideas as sketches, and then create two different ideas that explore different techniques. Your design could be abstract and made from patterns, or it could look like something recognisable (for example, objects or words). Write comments that explain your thoughts about each idea.



Basic carrier shapes and templates, and flap fastenings

## Tip

Carriers come in a wide variety of shapes and forms, but there are some basic forms that you can work with and adapt to create your carrier pattern. Some different forms of flaps or covers are also shown.

## YOUR FINAL DESIGN

Accurately draw your final design, showing:

- the form of the finished carrier, and the shape of the pattern pieces needed
- the measurement of parts
- the method of holding objects in the bag safely
- the materials used, indicating the recycled material
- the decoration design, indicating the techniques involved.

## Planning and managing

### TASK 7 Flowchart for making your product

List the steps you need to follow to make your carrier, and then draw a flowchart that puts those steps in order. Indicate 'quality checks' (where you ask your teacher to check your work to make sure the quality of your work is satisfactory). Refer to page 30 about drawing a flowchart.

## Producing

### TASK 8 Making your product

Use your flowchart to guide you while making your product. The main stages involve:

- drawing and cutting your pattern
- cutting your fabric
- sewing your main carrier pieces (and your lining, if you have one)
- sewing your straps or handles and attaching them to your carrier body
- completing your decorative design (this may be completed before putting your carrier together, depending on the technique).

Make sure you think about quality and safety while you are making.

Keep a visual and written journal during production. Record what you did at each stage, what you learnt, and what you could improve.

## Tip

Some of the following points might help you to improve the quality of your production work.

- » Draw your pattern accurately, and make sure you allow for seams when you cut your fabric.
- » Select the best fabric available, and make sure it is suitable for what you are making.
- » Before sewing a seam, pin or tack your pieces together to make sure they fit and are being joined in the correct place.
- » After sewing a seam, check that it is straight (or correctly curved), that you have secured the ends by reverse stitching, and that both sides have been sewn and are attached.
- » Snip curves and corners in seam allowances so they don't gather or pucker when turned out the right way.
- » Iron seams after sewing so they sit flat.
- » Snip off your ends as you go to keep your work neat.
- » Make sure all topstitching is even and accurate.
- » Practise your decoration techniques and complete them with care and accuracy.

## Safety

Remember to follow safety guidelines while you work (refer to pages 79–82 for information on tools and equipment safety). You will need to:

- » consider your machine set-up and seated position
- » take care when using sharp tools
- » concentrate while you work
- » consider electrical safety and safe use of an iron.

Make sure you are well trained before using any equipment, and have passed any safety and skills tests that are required by your school.

## Evaluating

### TASK 9 Evaluation of your finished work

- 1 Take a photo of your finished product.
- 2 Use the criteria for success that you wrote in Task 3 to judge whether your carrying solution functions well, is constructed well, and looks good.

### Evaluation

CRITERIA	HOW DID YOU CHECK THIS?	HOW WELL DID YOUR FINISHED PRODUCT PERFORM IN THIS AREA?

- 3 Summarise how well you think your carrying solution suits your needs or the needs of the person you made it for. Discuss one or two areas where the design or construction of your carrying solution could be improved

4 What new things did you learn while designing and making your product?

5 How did you show persistence during the designing and making process?

## CASE STUDY

### Crumpler – developed from tough experience

Crumpler bags were born out of a simple need. Stuart (Stu) Crumpler wanted to be able to carry a heavy load home on his bicycle, but he couldn't find a bag that was tough enough. Stu decided to make his own bag out of the strongest materials, threads, straps and buckles he could find, constructing it using his grandmother's sewing machine.

Later, while Stu was working for a bicycle courier company, the owners saw and loved his bag and ordered enough for the rest of their couriers. The company had so many enquiries from the public about the bags that the owners sold their courier business and set up the Crumpler company with Stu.

Over the past 20 years, Crumpler have developed a reputation for making tough bags, tested by experience. Crumpler now have a range of carrying products for different purposes that are sold worldwide. The company has a team of designers who observe and consider the needs of people who might use their products, and then develop, trial and prototype new ideas.

Did you know ...

- Crumpler is a Melbourne-based company.
- The Crumpler logo was an early marketing image sprayed on the laneways of Melbourne to promote the company.

- Crumpler designed and made the luggage for Australian competitors at the Rio 2016 Olympics.
- Crumpler believes their bags are so strong and well-made, they guarantee them for life.



**Crumpler bags embody the Crumpler motto:  
Built for Purpose & Made to Last**

## SHOW-IT

### Design situation or problem

Most of us store our photos on a device – a computer, a phone, on apps or in the cloud. Sometimes we click on them to remember different experiences and people, but there are some photos that are special and we want to see them all the time. They remind us of important moments, places and people.

## FOCUS ACTIVITY

### Photo display stands – discussion

- 1 What are some of the special things we want to be reminded of through photos?
- 2 What do you or your family currently use to display photos?
- 3 Special photo display stands are used to hold photos – why? What function does a photo frame/stand have?
- 4 Discuss and list the features, requirements or qualities that you think a photo display stand should have.

## SHOW-IT DESIGN CHALLENGE

You are to design and make a display solution for holding, protecting and displaying a favourite photo. This product could be for your use, or for your family or friends.

### REQUIREMENTS (LIMITS OR CONSTRAINTS)

- Your product needs to hold a standard sized photo (either 7.5 cm × 12.5 cm, or 10 cm × 15 cm).
- The photo needs to be **easy to see**.
- The photo needs to be **protected**.
- You must be able to **change the photo easily**.

- The display product needs to be able to **stand on a flat surface**.
- Include at least two different materials and two acrylic colours in your design.

### DESIGN CHOICES

You will need to make decisions regarding:

- the shape and size of your display solution, and what sized photo it will be made for
- how you will include materials and colour
- the stand method/structure you will use
- the method used for holding and changing photos.

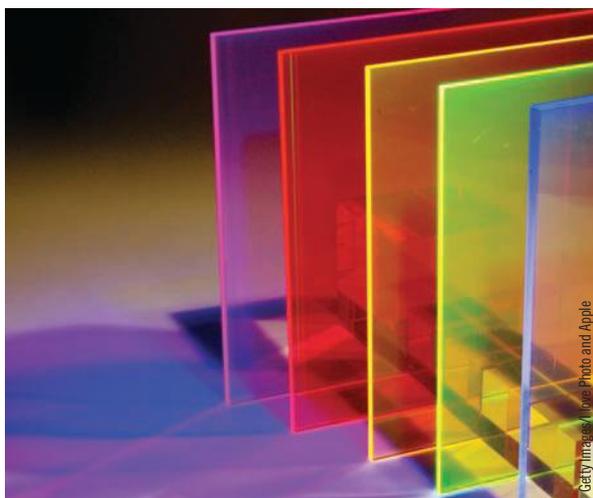
## Focus for assessment

For the assessment of your design work, your teacher will be looking for:

- » clear and interesting research
- » a detailed design brief that describes the situation you are designing for
- » design ideas that suit the purpose and are creative
- » accurate drawings that show your ideas clearly
- » careful planning
- » an honest evaluation of your finished product.

## Acrylic – a versatile material

The main material to be used for this design challenge is 3mm sheet acrylic. It has some great characteristics and properties that make it useful for this type of product – it comes in a variety of colours, it can be **transparent, translucent or opaque**, it can be cut easily and it can be shaped and formed when heated. However, the surface of acrylic is easily scratched, it can snap and break easily while being worked. Always keep the protective paper on during production. See Chapter 3 for more information about acrylic sheet.



## Investigating

### TASK 1 Researching sheet acrylic

Find out more about sheet acrylic.

- What is its scientific name? What other names are commonly used for acrylic?
- Is acrylic a 'thermoset' or 'thermoplastic' plastic? What does this mean?
- Does acrylic have a plastic identifying number (in a triangle)?
- How is sheet acrylic made?
- List at least four products that are commonly made from sheet acrylic.

Note: when you search for information on acrylic, details about acrylic paint or acrylic fibre may not be very useful so be careful to specify sheet acrylic in your searches.

As a group, find out about another type of plastic using the same questions. Present your information to your class.

### TASK 2 Design brief

Write a design brief for your display solution that discusses:

- who you are designing the photo display stand for
- what sort of photo might be displayed (for example, holiday, people or landscape)
- what size the photo is
- where it might be placed
- how often the photos might be changed
- what style and colours might suit the person and the position.

Start with the following words: *'I need to design and make a display solution that ...'*

### TASK 3 Criteria for success

To write criteria for success, look at the requirements in your design challenge. They describe some of the features of a 'good', well-designed photo stand. Turn three of these dot points into criteria questions, and develop another criterion from the design choices section of the design challenge.

## Generating

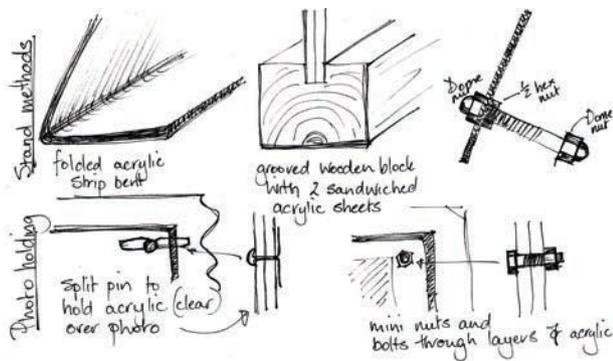
### TASK 4 Design ideas

#### SKETCHING

Sketch at least four ideas for your display solution, exploring:

- standing methods
- ways to hold the photo
- shapes and colours for the main part of the stand
- additional parts that can be cut from acrylic (or other materials) and attached to the main stand.

Draw your ideas from the front and the side, and write comments to explain how they work.



#### Practical options for holding the photo and the standing method

#### STANDING METHODS OR STRUCTURES

Examples of standing methods or structures for your display solution include:

- using nuts and bolts
- bending the acrylic sheet
- using a slotted timber block.

#### HOLDING THE PHOTO

Consider how your display solution is going to hold the photo. Example of photo-holding methods include:

- folded acrylic
- clips, pins and bolts.



#### Photo-holding method

#### DRAWING YOUR CHOSEN IDEA

Choose the design sketch that you think will work best and draw this design accurately.

- Use a ruler when drawing.
- Show the thickness of the materials.
- Show the front and side view (orthogonal drawing technique).
- Draw to scale – either full size or half size.
- Include comments to indicate materials, methods of standing and holding photos, etc.
- Show the colours of all parts of your design.

## Planning and managing

### TASK 5 Planning for production

Develop a production plan for making your display product. Use the table format on page 27 to plan your steps, tools and safety considerations.

#### Note

An acrylic sheet will have a paper or plastic surface covering to protect it from being scratched. It is virtually impossible to remove a scratch from sheet acrylic, so make sure you keep the covering in place until the last possible moment.

For information about cutting, drilling, filing, sanding and polishing acrylic, see Chapter 3.

## Producing

### TASK 6 Making your product

Follow your plan and make your stand. Make sure that you follow any of the safety guidelines you mentioned in your plan, and that you are fully trained before you use any new equipment or machines.

### JOURNAL

Take photos of each stage while making your product and reflect on your experiences. Ask yourself the following questions: What did you do? What could you do better? What did you complete well? What did you learn?

## Evaluating

### TASK 7 Feedback from others

Turn your criteria for success questions (Task 3) into a questionnaire. Ask five people to look at your product, carefully test and use it, and then answer your questionnaire.

Take a photo of the finished product. In a report, include your photo and summarise the feedback of your testers. In your report:

- comment on the areas where the feedback indicated that your stand worked well
- identify aspects of your product that your testers thought weren't great
- suggest one or two ways you could improve your product.

## MINI STORAGE

### Design situation or problem

USB flash drives are useful tools to store and move digital data, but sometimes it is difficult to identify your drive. The commercial products look very plain and similar to each other. Can you make a USB flash drive casing that is more imaginative?

## MINI STORAGE DESIGN CHALLENGE

You need to design and make a casing for a USB flash drive that is individual and easy to recognise.

### REQUIREMENTS (LIMITS OR CONSTRAINTS)

- Your product needs to **stand out** and have features that make it **easily recognised**.
- The casing must **fit tightly** onto the USB flash drive inner component.
- Your product must be **comfortable** to hold and easy to grab when inserting and removing the USB flash drive from a device.
- Use materials available in your school (this might include sheet plastic, 3D printing plastic or bamboo plywood).

### DESIGN CHOICES

You will need to make design decisions regarding:

- the shape and colour of USB flash drive casing
- whether your design will be abstract (based on simple shapes and patterns) or will have recognisable features (based on letters or an object)
- how it will be constructed
- the materials you will use.

## Focus for assessment

For the assessment of your design work, your teacher will be looking for:

- » clear and relevant research that has been presented well
- » creative and interesting sketches that show your ideas in colour and explain some construction details
- » detailed working drawings that are accurate (orthogonal), or well-prepared CAD drawings that can be successfully converted into a 3D printing file
- » a clear flowchart that explains how you will make your product
- » precise cutting, joining and finishing during construction (or effective 3D printing)
- » an honest evaluation of your design and production work.

## Investigating

### TASK 1 Mind map and design brief

Brainstorm a range of ideas and present these as a mind map. In your brainstorming, you will need to consider:

- who you are making this product for (and if they have any special needs)
- where the USB flash drive will be stored when not in use, and how it will be carried when moving files from one place to another
- the size of the inner component (be accurate), and the size limits for the casing

- your material choices
- colours suitable for the person, the theme or the style, or colours that stand out
- themes or style that relate to the person using the casing, or that might be interesting to explore.

Highlight one idea from each category that you want to use as the basis for your design. Turn these ideas into a written design brief.

### TASK 2 Criteria for success

Use your design brief, and the 'requirements' and 'design choices' dot points in the design challenge to develop four criteria for success. Make sure you cover how the product should work, how well it should be made and what it could look like.

### TASK 3 Mood board

Create a mood board of existing USB flash drive designs you think are interesting (create a digital or hardcopy version).

- Collect a range of 4–6 images of interesting, creative USB flash drives. Write a comment explaining the features you like (shape, colour, style, etc.) and aspects that you don't think will work in your design.
- Collect and comment on 4–6 images that are NOT USB flash drives, but have shapes and/or objects that you could use in your design.

## Materials

### TASK 4 Materials research

Investigate the materials you can use for making your mini storage solution. Depending on your method of manufacturing, choose either 3D print material questions or sheet material questions.

#### 3D PRINT MATERIALS

The two main materials or filaments used in 3D printing are PLA and ABS (though there are other filaments that are available).

- 1 What do PLA and ABS stand for?
- 2 What are they made from?
- 3 What are the environmental issues or benefits of these materials?
- 4 Are there differences in the range of colours and material quality?
- 5 Which material would be best to use for your design?

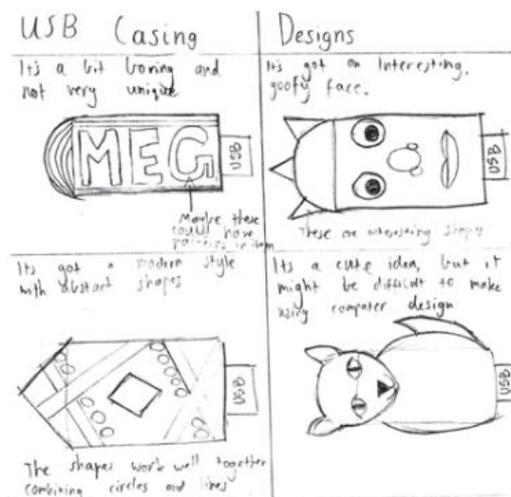


ABS plastic 3D printing filament

#### SHEET MATERIALS

You could use sheet acrylic, solid timber and/or plywood (including bamboo plywood) to make your design. Find out about the materials your teacher has suggested to use.

- 1 List the materials that are available for you to use for this product.
- 2 Where do they come from?
- 3 Are there any environmental issues or benefits related to these materials?
- 4 What different forms do these materials come in? (Discuss colour, thickness, etc.)
- 5 What are the differences between these materials in terms of quality and ease of use (cutting, gluing, sanding, etc.)? You can do small tests and trials for some of these aspects and include photos in your report.
- 6 Which material would be best to use to make your design?



Sheet materials

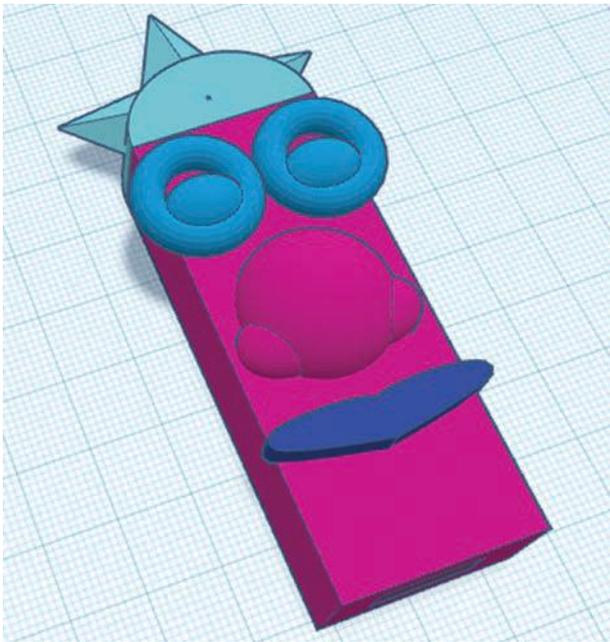
## Generating

### TASK 5 Sketches and final design

Think of three main areas or themes you want to explore in your mini storage designs. Write these on your design page, and then draw three alternative sketches for each of these themes. You could arrange these like mini visual mind maps.

Choose one of your design ideas and re-draw it accurately and in detail. Make sure the space for the component is drawn accurately. Either:

- use a digital drawing program (CAD) or app
- draw your design using orthogonal drawing technique (top, side and end view). You will need to draw the design larger than actual size – probably twice as big. Include dimensions on your drawing.



Student sketches showing different alternatives

## Planning and managing

### TASK 6 Production flowchart

List the production stages you will need to carry out to make your design into a product. Draw a flowchart (see page 30) to explain the order in which you will carry out these stages. Indicate the stages where you need to check your work for quality, and write brief notes about what you will look for.

## Producing

### 3D PRINTING

To use a 3D printer, follow these steps:

- 1 Develop a good three-dimensional design using design software or an app that creates an STL file.
- 2 Open the file in the 3D printer software and place it in the centre of the work space.
- 3 Rotate the object so that the supports are minimal.
- 4 The 3D printing software should convert your file so that it is 'hollow fill' – changing a solid form to one that has an internal mesh structure (to reduce weight, material use and print time).
- 5 Pre-heat the plate – the hotter the better (also, leave the plate alone – don't touch it, and don't open doors or allow draughts).
- 6 Print the file.
- 7 When the print is complete, remove from the plate while warm (if it sticks, reheat the plate).
- 8 Remove supports and the raft (if you have one) – break and sand surface of product.



Your teacher will help you to use a 3D printer

### TASK 7 Journal during production

Take photos of your work during each main stage of production. Present these with a brief explanation of what you are doing in each stage.

## Evaluating

### TASK 8 Testing and evaluation

Test your casing on your USB flash drive. Take a photo of your finished product and answer your criteria for success and the following questions.

- 1 Does your casing fit the USB flash drive well? Did you need to change or modify your casing to make it fit?
- 2 Does your casing function well? Is it easy to use, comfortable to hold, and easy to store and carry?

3 Does your casing look good? Is your USB casing easy to recognise? What are its main visual features? Is it attractive, appealing, stylish, cool, etc.?

4 How environmentally sustainable is your USB drive casing (materials, durability, etc.)?

## THINKING SKILLS

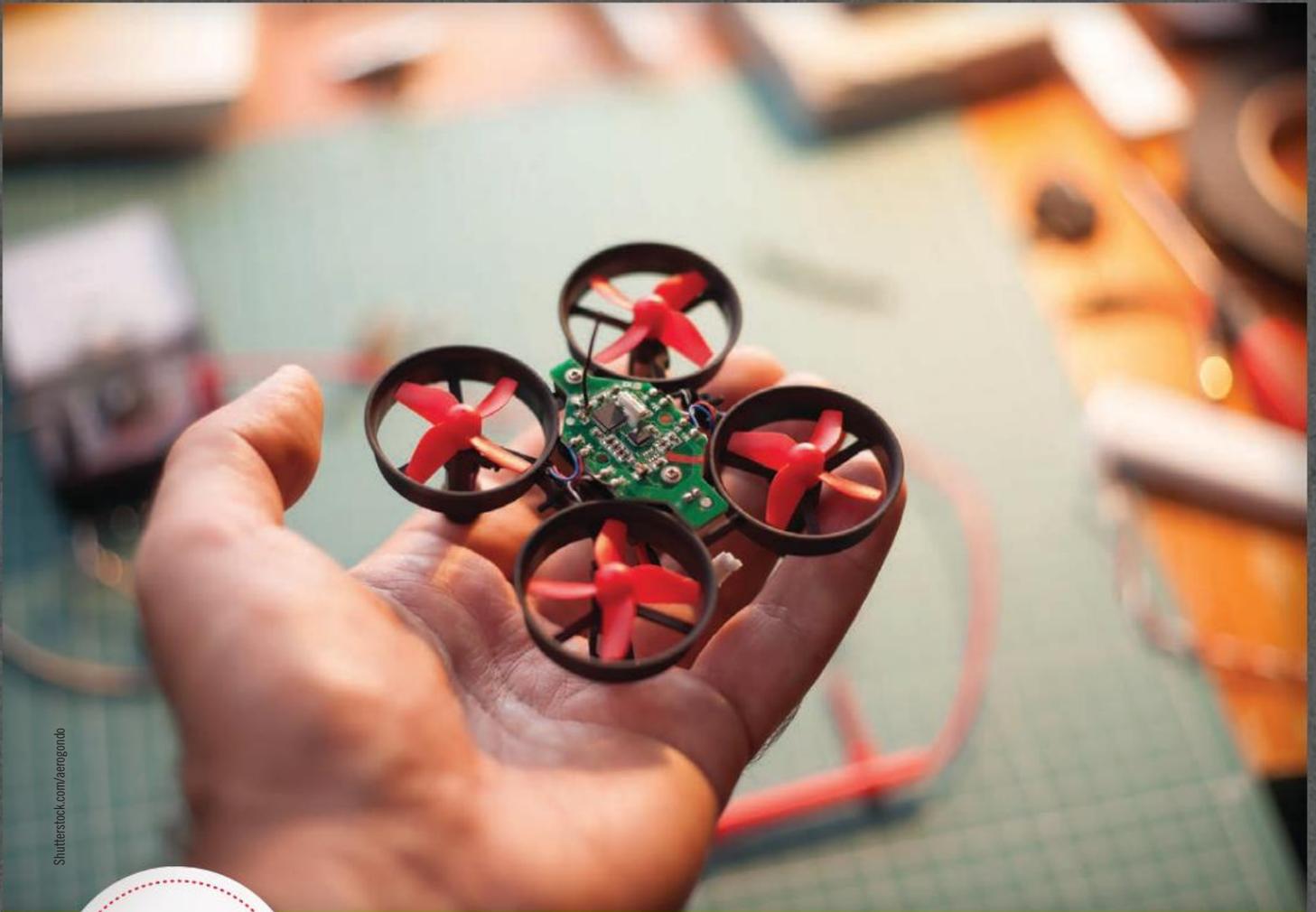
### USING THE DESIGN PROCESS – A REFLECTION

- 1 The stages of the design process are listed in the following table. For each stage, list the activities or tasks you did while designing and making your product. Explain why each stage is important (perhaps by describing what would go wrong if it wasn't done).
- 2 Highlight in colour the activities/tasks in the table that you did well and put a lot of effort into. Highlight in another colour the stages that you rushed or found difficult to do.
- 3 What skills do you need to learn or practise more to be able to carry out the design process better?
- 4 Read the following list of learning and work habits:
  - listening
  - showing persistence
  - cooperation
  - being open to new ideas

- asking questions
- focusing and avoiding distractions
- thinking flexibly
- showing consideration for others
- showing humour
- being accurate
- communicating clearly
- thinking creatively
- remembering
- thinking and working independently.

Select one learning and work habit that you used well during production, and give an example of how you did this. Then, select one learning and work habit that you could improve, and think of a practical strategy you could use next time to apply it better.

STAGE	ACTIVITIES/TASK	IMPORTANCE
Investigating and defining		
Generating		
Producing		
Evaluating		



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# 6

## MECHANICAL MOVES

### KEY KNOWLEDGE

In this chapter, students focus on mechanical robots and automatons. They use the design process to:

- ▶ investigate mechanisms and structures
- ▶ design efficient mechanisms
- ▶ create moving mechanical toys.

### DESIGN CHALLENGES

- ▶ Crank and cam automaton
- ▶ Pull-along automaton
- ▶ Fairground ride

# FOCUS ON MECHANICAL ROBOTS AND AUTOMATONS

Modern robots are controlled by electronics with moving mechanical parts. However, the world of robotics started with hand-powered mechanical robots. The first step in building robots is often to master the mechanical construction techniques.

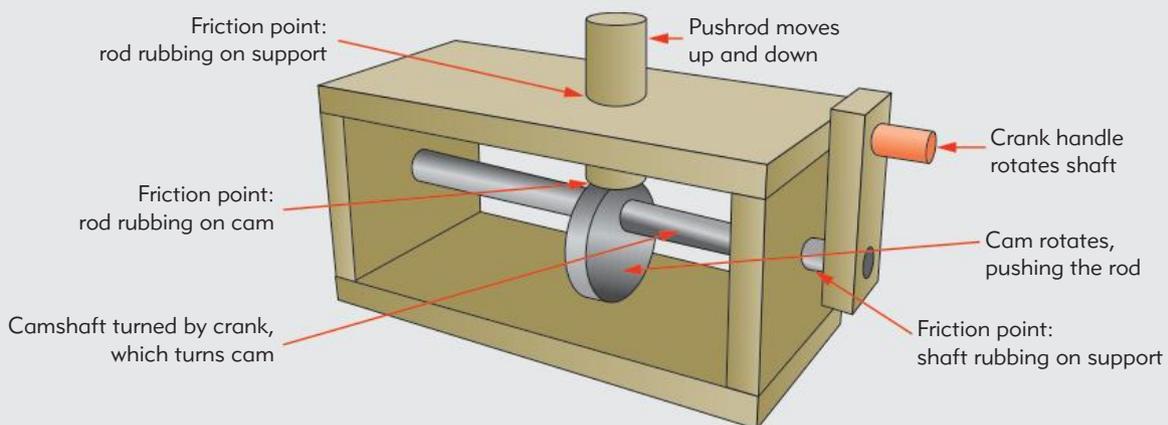
## DESIGN CHALLENGES

There are three design challenges in this chapter, each involving the creation of interesting and entertaining movement that comes from simply rotating a crank or cam. In the first challenge, a crank handle is used manually to turn a cam that moves a figurine. The second challenge involves a toy being pulled or pushed, which rotates a cam. In the third challenge, more complicated arrangements create movement in a theme park model.

## CRANK AND CAM TOY

### CRANK AND CAM AUTOMATON CHALLENGE

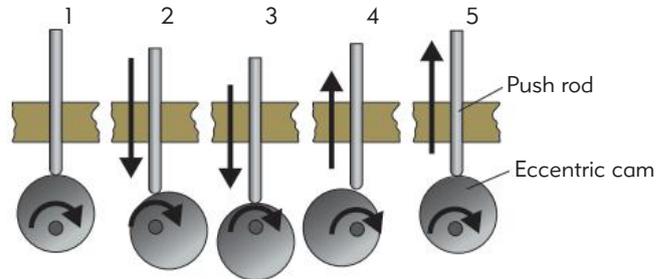
You are to create an automaton with a moving part (such as a child fishing with the fishing rod dipping up and down as a fish is caught, a cat jumping, or a runner's leg moving up and down). The automaton will be hand-powered by turning a crank. You will need to make every effort to lower unwanted friction, and your product must be well finished to look its best.



Possible crank and cam set-up – add your moving part of choice to the top of the pushrod

### Investigating cams

- 1 Identify three cam profiles that will create different movements.
- 2 For each cam, draw a series of four sketches to show how the movement moves up and down.



Pushrod reciprocating on a cam

## DESIGN CHOICES

You will need to make design decisions regarding:

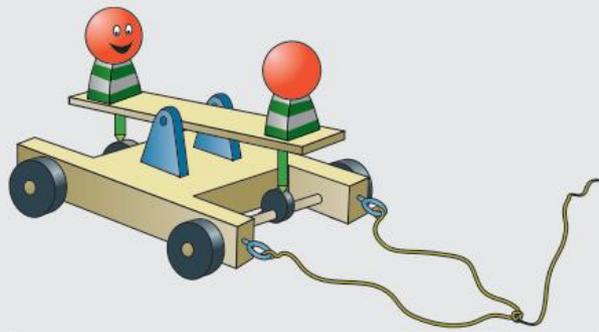
- the figurine that you are automating (boat rowing, bird flying, fish jumping, etc.)
- the length of the crank handle
- the shape of the cam
- how you will make the design aesthetic (beautiful to see and touch)
- how you will lower/reduce unwanted friction.

# PULL-ALONG CAM TOY

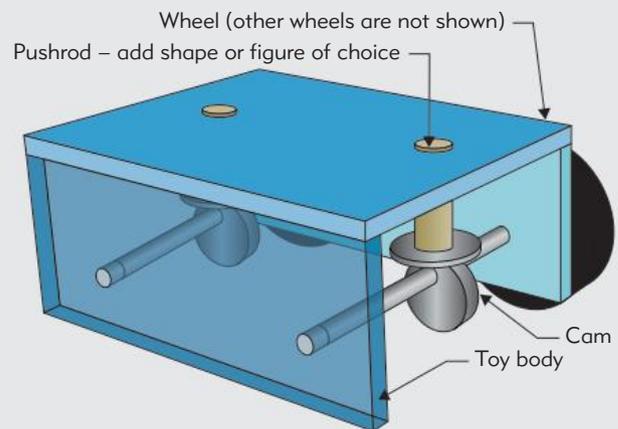
## PULL-ALONG AUTOMATON CHALLENGE

You will need to design and create a moving toy that will bring joy to a child. Children have enjoyed pushing and pulling toys since wheels were invented, and possibly even before that. Some of the best traditional toys contain parts that move with a turning axle.

Your moving toy product will be pulled or pushed on wheels, and will have an added part moving back and forth as the toy is pulled or pushed. Usually, these types of toys have two sides joined by a top plate. Each axle has a cam attached and pushes a pushrod. A further challenge could be to replace the cam with a crank. (see images below and on next page).



**Pull-along toy with mechanical movement**



### Anatomy of a push/pull cam toy

#### REQUIREMENTS (LIMITS OR CONSTRAINTS)

- The product size will be set by your teacher.
- Use the materials available in your school (or provide special materials from home).
- Your design must have a figurine moving up and down.
- The object must be moved by the cam on the vehicle's axle as it turns.

#### DESIGN CHOICES

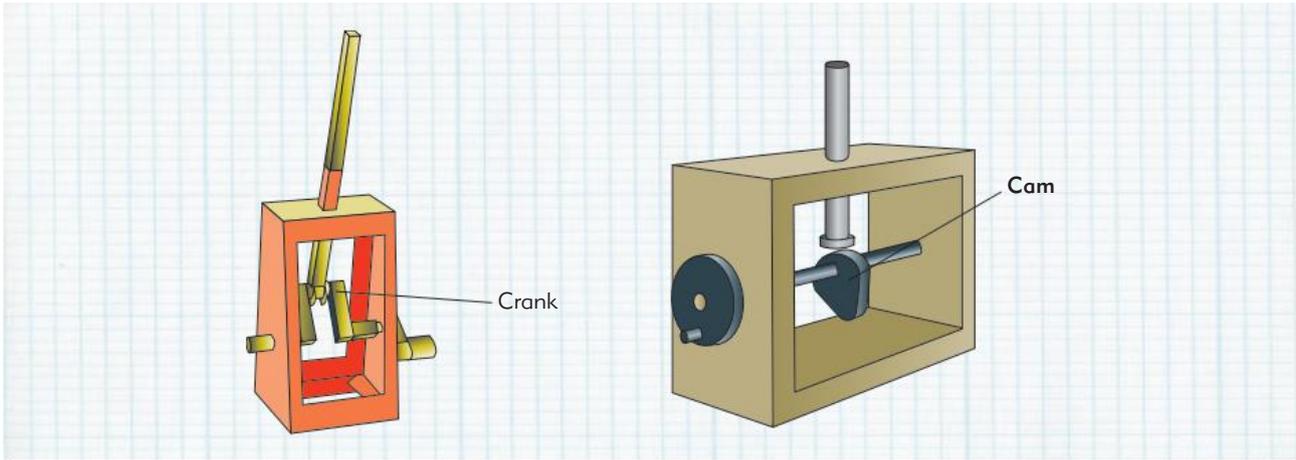
You will need to make design decisions regarding:

- the shape your pull-along toy will be
- the details of the figurine that will be moving up and down on top of the toy.

## Difference between cams and cranks

Cams and cranks are quite similar. They both change rotary motion into reciprocal motion, or vice versa. However, a cam can have varied profiles that create interesting movements, but a crank only moves up and down once per revolution of the axle.

A cam's pushrod is pushed up by the cam and returns down by gravitational force, which can be a problem if the automaton becomes stuck. The connecting rod of a crank is both pushed up and down by the user, which can be useful if the automaton becomes stuck.



Crank (left) compared with cam (right)

## FAIRGROUND RIDE

### FAIRGROUND MODEL CHALLENGE

Theme parks and fairgrounds are full of amazing rides that children (and adults!) enjoy. Rides can vary in intensity, from gentle Ferris wheels to exciting roller coasters. In this design challenge, you get to recreate the fun and drama of these rides.

You will need to design a ride and create a working model. The model will contain gears, a belt drive or a chain drive, which will allow the user to turn a crank handle at a comfortable speed and the model will then turn at the required speed.



Fairground rides



#### REQUIREMENTS (LIMITS OR CONSTRAINTS)

- Your model must look great and feel smooth.
- The mechanism must move with low friction.
- The crank needs to move easily.
- The cam needs to push the rod without sticking.
- Gears must be incorporated to change the speed.

#### DESIGN CHOICES

You will need to make design decisions regarding:

- type of ride to create
- materials
- mechanisms to use (such as belt or chain drive).

## Note

When checking whether you've designed and made a great product, your teacher will assess how well you have addressed the following questions.

- » How well does your product perform?
- » Is your research clear and detailed?
- » Are your design drawings accurate and creative, and do they have all the required information?
- » Is your cutting, shaping and assembly accurate?
- » Is your decorative design interesting and creative (in both the use of colour and shaping)?
- » Have you sanded and varnished/painted to a smooth finish?
- » Have you worked safely in a planned and productive way?
- » Is your evaluation clear, detailed and honest?

# TASKS FOR CHAPTER 6 CHALLENGES

## Investigating

### TASK 1 Design brief

Use the information in the design challenge to write your design brief – a paragraph explaining your individual design situation. Start with the following words: *'I need to design and make a model that ...'*

### TASK 2 Criteria for success

Your evaluation criteria need to be specific, and relate to your automaton, pull-along toy or fairground ride.

- Write a set of four criteria questions that you can use to judge whether your finished product meets your expectations. Make sure your questions cover the areas of function, construction and appearance.
- Remember to think about these criteria when you are developing and choosing your designs.

## Design research

### TASK 3 Mechanisms research

#### CAM AND CRANK MECHANISMS

Find a clear picture of a model that uses a cam, and a model that uses a crank. For each model,

- describe how the mechanism works
- explain the advantages and disadvantages of the mechanism.

## Note

It is important to remember the terminology associated with cam and crank mechanisms.

- » Cam – a shaped wheel that rotates, pushing a pushrod.
- » Cam shaft – a shaft with one or more cams.
- » Pushrod – a stiff rod moved up and down by a cam.
- » Crank handle – a handle that winds a shaft.
- » Friction – two surfaces rubbing together, which makes it difficult for things to move.
- » Crank shaft – an offset shaft that is connected to a slider.
- » Slider – connected to a crank that moves backward and forward.

#### GEAR MECHANISMS

Answer the following questions to think about the gears your model will need.

- How can gears change the speed of rotation?
- If you want to change the direction that the ride rotates, which gear type is added?
- Would it be an advantage to include a worm and worm wheel to increase torque, even if speed is lost?
- How can a rack and pinion change rotary motion into linear motion?

## Note

It is important to remember the terminology associated with gear mechanisms.

- » Gear – a wheel with teeth; gears can be joined/meshed to change speed.
- » Torque – a rotary force.
- » Aligned gears – gears that are perfectly lined up so they mesh and work.
- » Unaligned gears – gears that are not lined up, and therefore slip or jam.
- » Rotary motion – circular movement.

For more information about gears, see page 120 in Chapter 4.

#### BELT OR CHAIN DRIVE?

When designing your model, you will also need to decide if the mechanism uses a belt or chain drive. Consider the following questions.

- Which mechanism is quieter?
- Which one must be perfectly aligned?
- Which one is more efficient?

- Which one will slip if something gets stuck so that it can't turn?
- Which mechanism is best for your system?

For more information about belts and chain drives, see page 124 in Chapter 4.

## Materials

There are many different materials you could use for these design challenges, but not all of them will be available in your school.

### TIMBER

Possible timbers include:

- radiata pine – standard sizes are 140 mm × 12 mm, and 190 mm × 19 mm
- plywood – a sheet material supplied in large sheets, usually 1200 mm × 2400 mm; made from layers of thin veneer, which makes it light and strong; good for cutting small shapes that would be too weak in radiata pine
- dowel rod – made of a hardwood and can be any diameter from 2–25 mm.

Other timbers might be used in small amounts as a highlight or feature.

### METAL

Metal dowel could be used for the crank and cam shafts to lower friction. Stiff wire could be shaped to form fairground rides. Threaded rod or bolts and nuts could also be used.

### PLASTIC

The most useful type of plastic for these challenges is acrylic sheet or rod. It can be easily cut and bent, and is available in a wide range of colours, levels of transparency, and textures. Acrylic can also be easily cut and engraved using a laser cutter, if you have access to this technology. A 3D printer can also form other plastics into decorative and useful components of your design (such as handles, gears or pulleys).

### FABRICS

Fabrics can be used in combination with other materials in this challenge to create soft forms and divisions. You could also use any recycled material, scraps or offcuts from home or school (such as flattened aluminium cans). Make sure you choose a fabric that is strong and will cope with wear and tear.

## Generating

### TASK 4 Design development

#### SKETCHES AND OPTIONS

Brainstorm some ideas for your design brief. For example, your model could involve a simple cat (or other animal) sitting on the pushrod, or you could build a whole scene on top of the frame with one moving part (such as a person holding a fishing rod with a fish moving up and down). Develop the best ideas into sketches of character and cam shapes, each taking up half an A4 page.

Develop two or more ideas into more detailed drawings as design options. Each idea should take up a whole A4 page. Show different angles if necessary. Annotate (label) your design option to show how the product will work, and the materials and features of each design. Use colour to show how your finished product will look.

Think about each sketched idea. What is good or interesting about each one? What does/doesn't look appealing? What might be hard to make. Write at least three comments for each idea explaining your thoughts.

Ask for feedback from your class or teacher to help you choose the best design to make. You can also use a scoring grid using your criteria for success (as shown on page 12 of Chapter 1).

#### WORKING DRAWING OF YOUR CHOSEN DESIGN

Create a two-dimensional drawing of your chosen design to work from. Include front, side and top views. When drawing, use a ruler to be accurate. You will need to show:

- the shapes to cut
- placement of parts
- names of the materials
- thicknesses of the materials
- the measurements of all parts
- details of the joins
- details of the moving mechanisms (for example, label the crank, cam and follower, and explain the key features).

Use a full page for your working drawing.

## Materials cutting list

PART	NO.	LENGTH	WIDTH	THICK	MATERIAL

### TASK 5 Materials cutting list

Create a table to list the materials needed for each part of your design. Include how many of each part is needed, and their size (length, width and thickness).

## Planning and managing

### TASK 6 production plan

Develop a production plan to help guide you while you are making your products. Production plans for products with moving parts can become complicated, so an example production plan for the crank and cam automaton has been provided. It can be altered to suit your design and materials used.

### EXAMPLE

Materials list:

- Frame – 12 mm pine (approximately 120 mm × 30 mm)
- Crank – 19 mm pine (approximately 60 mm)
- Axle, crank handle and pushrod – 8 mm hardwood
- Stopper – split pin
- Figurine – 6 mm plywood
- Cams – 19 mm pine circle (might be prepared by teacher)

## Example production plan

PRODUCTION STEP	TOOLS AND EQUIPMENT	SAFETY
<b>Frame</b>		
Cut the frame pieces: top, bottom and sides		
Drill holes for the pushrod (holes should be 8.5 mm, 0.5 mm wider than the rod and axle to reduce friction)		
Drill the sides in a pedestal drill both clamped together so that the holes are identically spaced at 8.5 mm		
Take photos and make a journal entry		
<b>Crank handle</b>		
Cut out the crank handle from 19 mm pine		
Drill 8 mm holes in crank for the crank handle and axle (these holes are exactly the width of axle and crank handle)		
Cut axle 22 mm longer than the frame (19 mm for the handle and 3 mm clearance)		
Take photos and make a journal entry		
<b>Cam</b>		
Cut a wheel 45 mm in diameter from 19 mm pine		
Drill a 10 mm hole (away from the centre)		
Push the cam onto the axle		
Take photo and make journal entry		

Putting it together		
Put all the parts together dry and check that everything lines up and works		
Glue and nail the frame		
Glue the crank to the axle and handle (don't glue the cam yet)		
Drill a hole in cam axle (inside the support next to the handle) for the split pin to stop the cam moving out of place		
Take photos and make a journal entry		
Figurine		
Create the figure that will move up and down on the pushrod		
Cut the pushrod		
Attach figurine to pushrod		
Consider attaching a wider disc to the bottom of the pushrod to make better contact with the cam		
Consider leaving the cam directly under the pushrod or moving slightly to one side and see the effect		
Take photos and make a journal entry		
Finish		
Sand and paint the whole project		
Take photos of final product and make last journal entry – enjoy a job well done!		

## Producing

Keep a journal while you are making your product to record your progress, and to reflect on the things that go well and what could be improved. Briefly summarise what you completed during each step (to see how it differs from your plan), and record how long this took (either in minutes or periods). For each entry, write in your reflections – explaining the things you've done well, what you had problems with, and what you could improve. Use photos to visually record your production.

### TASK 7 Joins, cutting and drilling practice

Watch a demonstration of the drilling, joints and cutting that you will need to carry out. If necessary, practise these techniques.

### TASK 8 Making your product

You need to construct your product. This will involve following your production plan, including:

- marking out your materials
- cutting your pieces, checking, and adjusting length
- marking out your joints and mechanisms

### Project journal

JOURNAL <i>What you completed in each stage</i>	TIME*	REFLECTION <i>What went well? What could be improved? What did you learn?</i>

\*Time – how long did it take to complete?

- cutting and shaping all joins and mechanisms
- a dry check and adjusting (if needed)
- assembly
- completing any decorative processes
- final sanding and varnishing/painting/finishing.

## Evaluating

### TASK 9 Evaluation of your finished product

Evaluate your work – make judgements about your finished product using the criteria for success you wrote in Task 2. Set up a table as shown below.

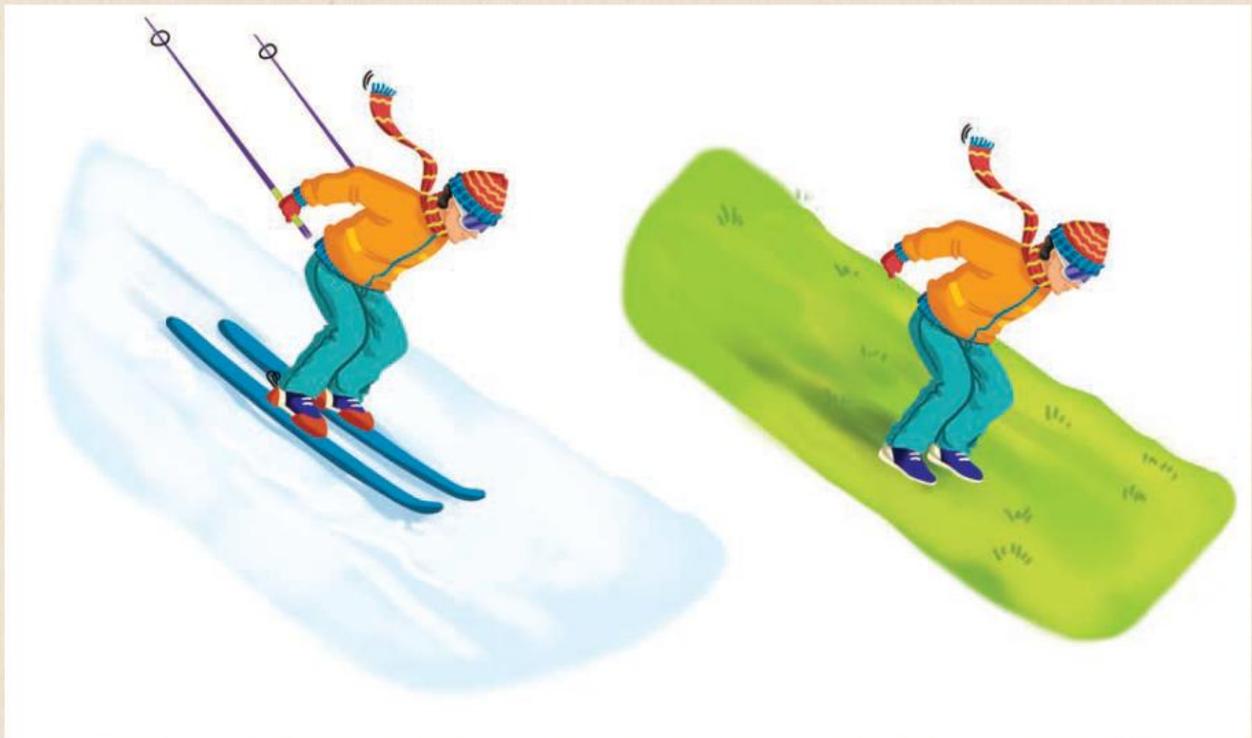
#### Evaluation

EVALUATION CRITERIA	HOW DID YOU CHECK THIS?	HOW WELL DID YOUR FINISHED PRODUCT PERFORM IN THIS AREA?

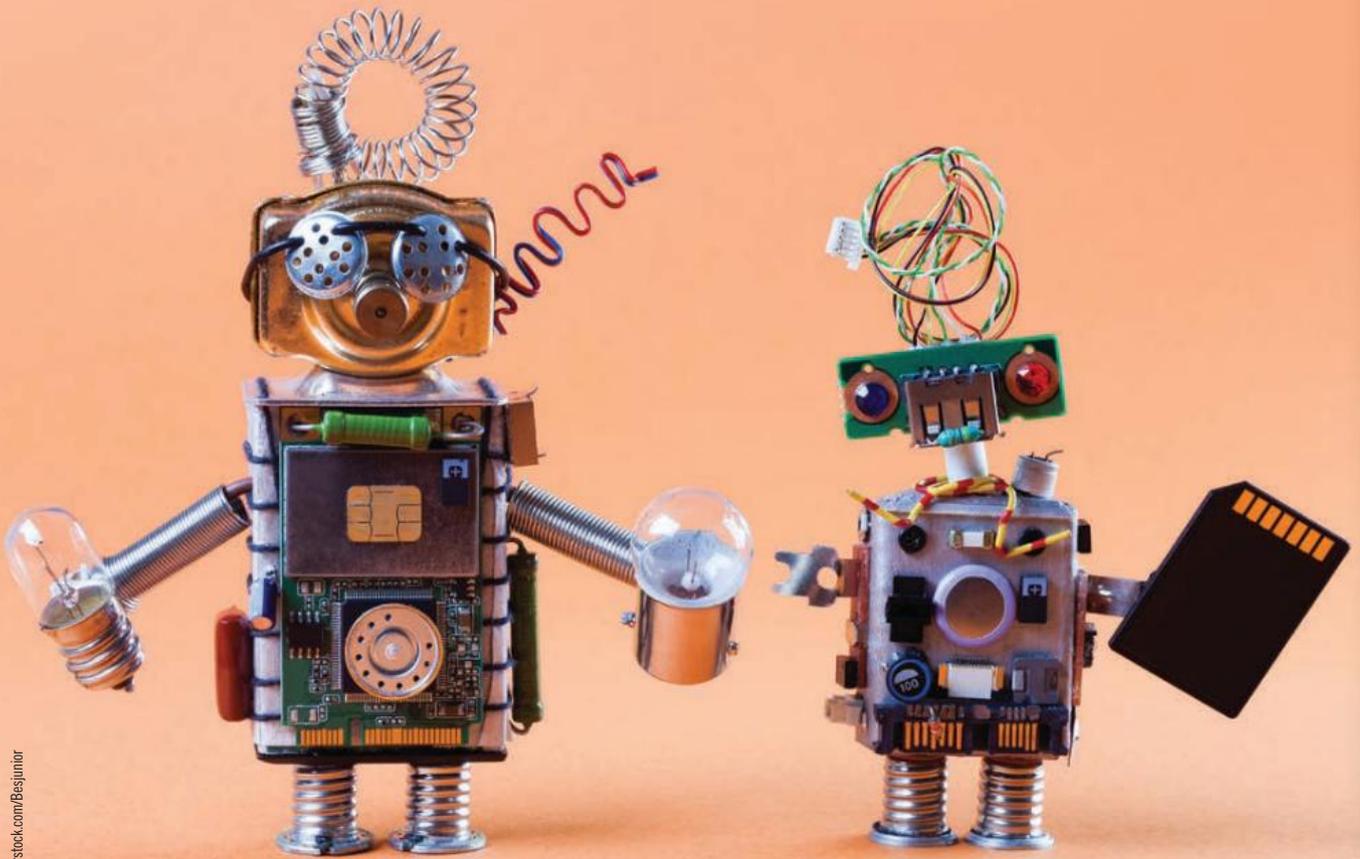
#### THINKING SKILLS

#### REDUCING FRICTION

- 1 Explain friction in your own words
- 2 Name six materials that we use in our technology class
- 3 Label each material as high, medium or low friction
- 4 Describe two ways that friction can be lowered in mechanical toys
- 5 When is friction useful?



Friction forces



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# 7

## ELECTRIFYING ROBOTS

### KEY KNOWLEDGE

In this chapter, students focus on using different controls to move simple electromechanical machines and robots. They will learn about:

- ▶ creating electric circuits
- ▶ steering simple machines and robots
- ▶ using switches
- ▶ wiring
- ▶ robot platforms
- ▶ light-sensing circuits
- ▶ creating a light-following robot

- ▶ Arduino microcontrollers
- ▶ motor modules
- ▶ simple commands to program an Arduino.

### DESIGN CHALLENGES

- ▶ Switch-controlled robot
- ▶ Sensor-controlled robot
- ▶ Micro-controlled robot

# FOCUS ON ELECTROMECHANICAL ROBOTICS

A **robot** is a machine that can do complicated tasks automatically, often programmed. Most robots can **sense** their environment and are programmed to respond automatically.

Electromechanical machines and robots are designed to automatically carry out the repetitive work that humans once performed. The work we once carried out in factories is now undertaken quickly and accurately by machines and robots. For example, cars are created on long **production lines** with very little human interaction. The machines do the hard, repetitive physical labour, while people design and program the machines.



**Robots on a car production line**

Automatic machines and robots also complete hard repetitive work in our homes. For example, washing machines and dishwashers automatically wash and dry our clothes and dishes.



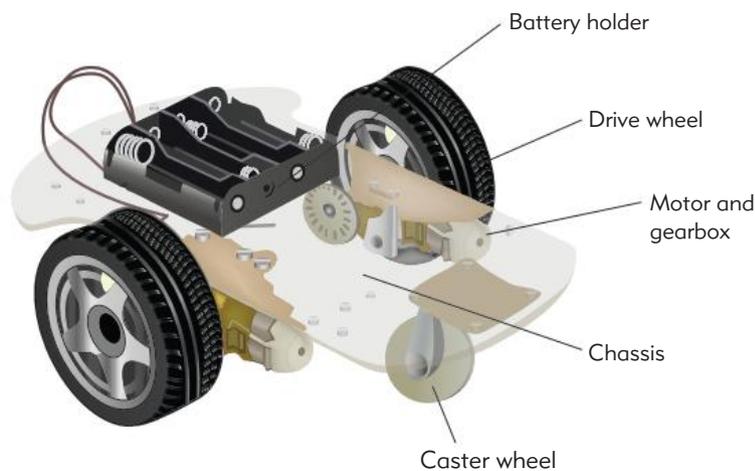
**Robotic vacuum cleaner**

The automatic vacuum cleaner moves beyond an automatic machine to a true robot – capable of being programmed to complete a difficult task. Robotic vacuum cleaners can sense objects in a room, map the room to ensure all the room is cleaned, and return to the charger when the battery runs low.

## Robot platform

The design challenges in this chapter involve designing and building robots. You will need to construct a robot similar to the robotic vacuum. All the robots will need the following components.

- **Chassis** – a good stable platform to hold all the components.
- **Electric motor** – to take energy from the battery and create movement of a shaft.
- **Batteries** – to provide the energy.
- **Gearbox** – to lower the motor's speed and increase the torque.
- **Caster wheel** – for stability and maneuverability.



**Robot car chassis**

## Chassis design

The simplest robot chassis shape is a rectangle, but consider creating a curved shape in your design so that the corners of your robot don't catch on anything as you drive it. The chassis needs to be symmetrical and large enough to comfortably house the battery, motor, gearbox and caster wheel. It is wise to create a large chassis so you can add more components later to further develop your robot. All parts can be bolted or glued to the chassis and controller.

## Sourcing robot parts

Hobby and electronic shops sell robotic kits that include the robot chassis, motors, gearboxes and wheels. Alternatively, the parts can be sourced individually.

## Electric motors and gearboxes

Hobby motor and gearbox sets can be purchased from electronic stores, hobby stores or cheaply online. It is recommended to use two 3–6 V motors with an attached reduction gearbox. Many gearboxes come with attached wheels. Some gearboxes allow the gear ratio to be changed, allowing you to tailor the robot for speed or force.

## Batteries

It is recommended to use two or three AA rechargeable batteries in a corresponding battery holder. More batteries will give greater power, but may damage some 3 V motors.

## Wheels

Wheel diameters around 50 mm work well. The most important consideration is matching the wheel's hub diameter to the gear shaft diameter – a separate coupling may be required. You can cut your own

wheels with a hole saw and glue an elastic band to the rim for grip.

## Chassis

Although the chassis can be purchased from electronic stores or hobby stores, it would be better to cut your own from plastic or plywood using a scroll saw. Layout the motors and wheels to ensure the motors are evenly spaced and in line with each other.

## Fixings

Parts can be bolted to the chassis with short bolts. M3 bolts (3 mm diameter) are commonly used.

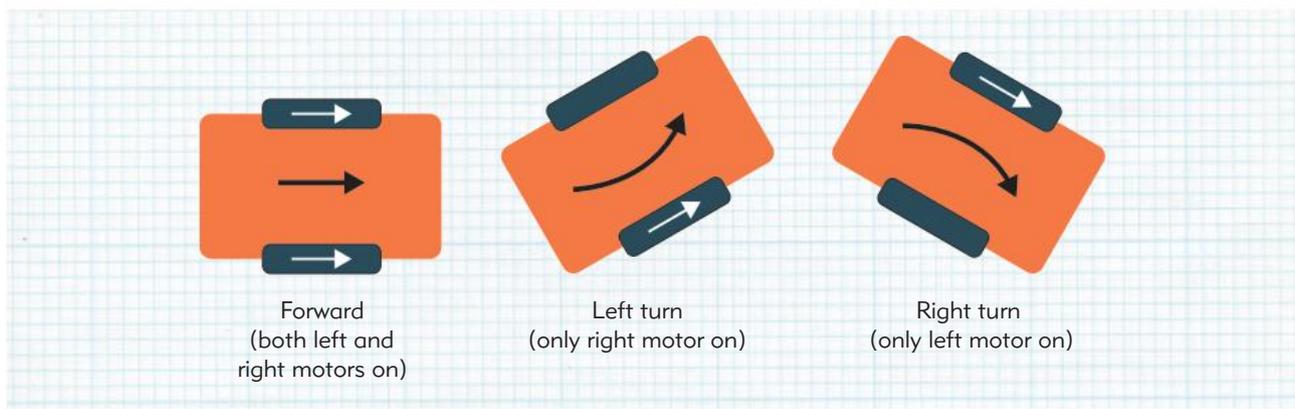
 JAYCAR ELECTRONICS

## Steering

Ever since wheeled carts, we have had to steer them left and right. Steering can be simple (such as the steering arms bolted onto the front of billy carts) or complicated (such as the steering in cars that allow each of the front wheels to turn at a different angle). Robots use **differential steering**, with only two drive wheels and one caster wheel for stability. By changing the speed and direction of each wheel's rotation, the robot can turn.

## Differential steering with SPST switches

When differential steering is used, the robot can be controlled forward, left and right by turning each motor on and off. The main drawback is that the two wheels will spin at slightly different speeds, which makes it very difficult to go straight. **SPST switches** (single-pole single-throw on/off switches) are the simplest to use, but they don't allow the motor to spin forward or backward and therefore limit the robot's movements.



Differential steering – controlling a two-wheeled robot with SPST switches

## Two-wheel steering with SPST switches

DIRECTION	LEFT MOTOR	RIGHT MOTOR
Forward	On	On
Left	Off	On
Right	On	Off
Stopped	Off	Off

## Wiring a circuit board for an SPST switch

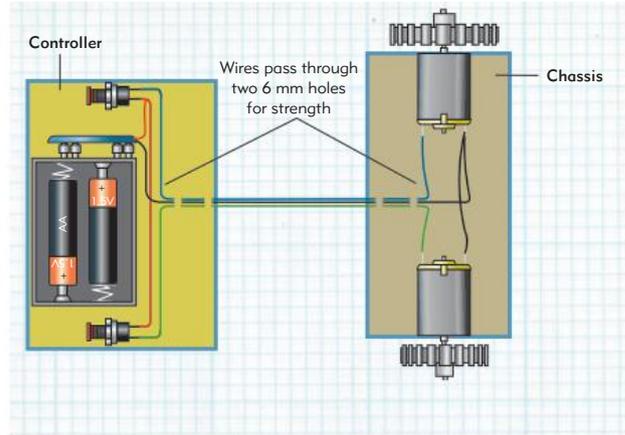
The following instructions explain one possible way to wire a robot with SPST switches. (Also see image at top of next column).

### CONTROLLER

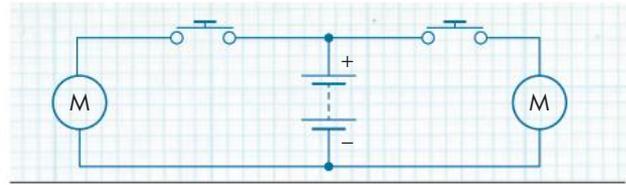
- Cut out a small controller board from plastic or plywood, large enough to house the battery pack and two SPST switches.
- Drill holes for the switches and bolt or glue the battery pack in place. It is a good idea to drill holes and thread the wires through the holes so that the solders don't get pulled when using the robot.
- Wire the positive red wire to both switches.
- Choose two different coloured wires (such as blue and green) to join from the other side of the switch down to the motors.
- Run a black negative wire straight from the battery to both of the motors (don't connect to the switch).

### ROBOT CHASSIS

- Cut a symmetrical robot chassis.
- Mount the motor, gearbox and wheel carefully in line.
- Drill two holes to pass the wires through.
- Join the black wire to both the motors, the green wire to one motor, and the blue wire to the other motor.
- Ask your teacher to check there are no short circuits.
- Test the circuit. If the motors go the wrong way, reverse the wires.



Wiring motors with SPST switches

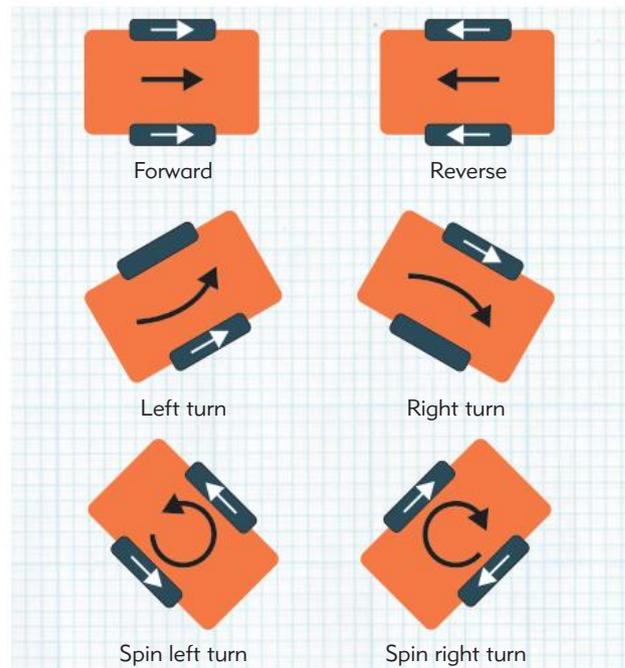


SPST switches circuit diagram

### FOCUS ACTIVITY

## DPDT forward/reverse switches

If you are up for a greater challenge, **DPDT switches** (double-pole double-throw switches) can be used to turn motors backward and forward. This gives many more steering options. Wiring a DPDT motor requires greater accuracy as the poles of the switch are very close together. If just a single wire wisp touches the wrong spot, the batteries can short circuit. However, a robot with a DPDT motor is more fun to control. Make sure the DPDT switch is an **on-off-on switch**.



Differential steering with DPDT

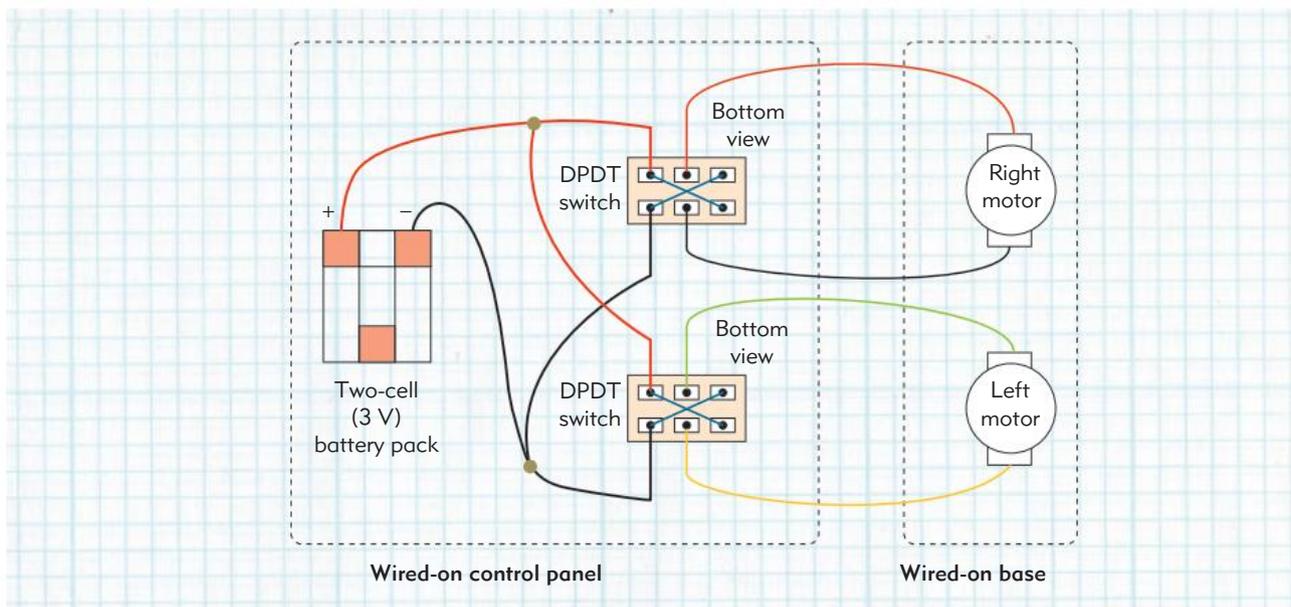
### Two-wheel steering with DPDT switches

DIRECTION	LEFT MOTOR	RIGHT MOTOR
Forward	Forward	Forward
Left turn	Off	Forward
Left spin	Backward	Forward
Right	Forward	Off
Right spin	Forward	Backward
Reverse	Backward	Backward

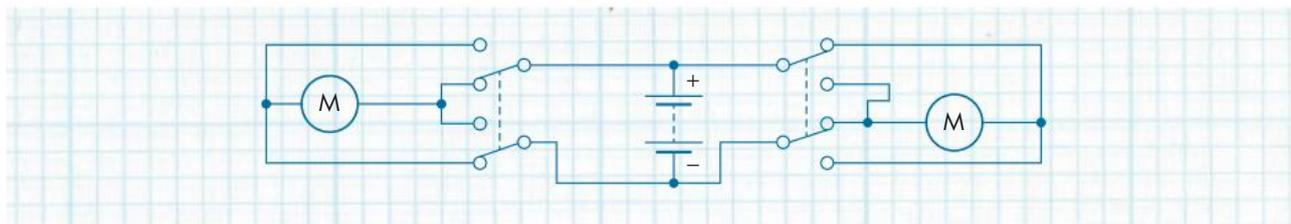
### Design alteration for DPDT forward/reverse switches.

Look at the bottom of both switches.

- Start by wiring the crossover (shown in blue in the diagram) by joining the top-left leg to the bottom-right leg.
- Finish the crossover by joining the bottom-left leg to the top-right leg.
- Join the positive terminal from the battery packs to both top-left legs.
- Join the negative terminal from the battery packs to both bottom-left legs.
- Join each motor to the two centre legs of its switch.



### Wiring a DPDT (on-off-on) switch



DPDT switched motors circuit diagram

# DESIGN CHALLENGES

The three design challenges in this chapter involve designing and creating robots with different control mechanisms. In the first challenge, you will build a robot controlled with two switches. In the second challenge, the robot has two light sensors and must move towards a light. In the third challenge, you will build and program an onboard controller.

## Note

When checking whether you've designed and made a great robot your teacher will assess how well you have addressed the following questions.

- » Is your research clear and detailed?
- » Are your design drawings accurate and creative, and do they have all the required information?
- » Is your cutting, shaping and assembly accurate?
- » Is your soldering neat and accurate?
- » Are your wires neatly laid out?
- » Does your robot work well?
- » Is your design interesting and creative (in both the use of colour and shaping)?
- » Have you sanded and varnished/painted to a smooth finish?
- » Have you worked safely in a planned and productive way?
- » Is your evaluation clear, detailed and honest?

# SWITCH-CONTROLLED ROBOT

## SWITCH-CONTROLLED ROBOT CHALLENGE

You will need to create a robot that you can control from two push-button switches. As well as the robot, you will also need to design a creative base and hand controller. The robot could be controlled for fun, made into a soccer robot to play against classmates, or whatever else you choose.

### REQUIREMENTS (LIMITS OR CONSTRAINTS)

- The product should be no larger than the size set by your teacher.
- Use the materials available in your school (or provide special materials from home).
- The motors and wheels must be well-aligned.
- The wiring diagram must be followed exactly.
- Soldering must be checked before adding batteries.

## DESIGN CHOICES

You will need to make design decisions regarding:

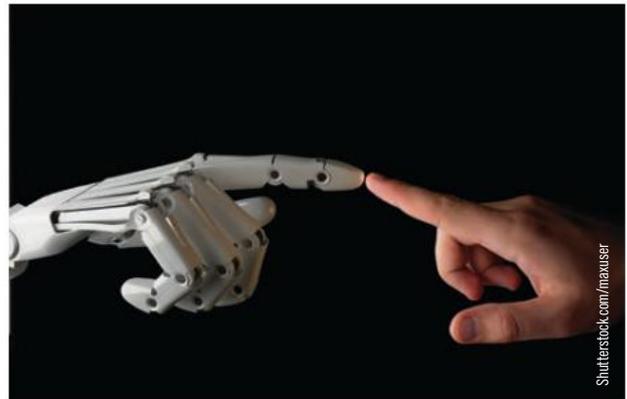
- the shape of the chassis and hand controller.

If your teacher advises that you have mastered the basics in this challenge, extend yourself with the harder DPDT-switched robot.

# SENSOR-CONTROLLED ROBOT

## FOCUS ACTIVITY

### Robot sensors



We are always trying to make robots more like us. We want robots to be able to walk like us, and to make decisions like us. To be like us, robots must sense the world like we do. In this activity, you will consider how we sense the world and the sensors that a robot uses.

- 1 What are the five senses that humans use?
- 2 Think of three machines or robots that you used this week. What task did the machines or robots perform for you?
- 3 Did the machines or robots have sensors to sense the world (such as light sensors, movement sensors or water-level sensors)?

### Touch

We use our sense of touch nearly all the time.

- 1 What happens if we touch a hot stove?
- 2 If a robot were to touch something hot, it could melt that part of itself. What kind of sensor would need to be added to a robot to protect it from a hot stove?

## Vision

When walking, we mainly use our vision to avoid obstacles and to see where we are going.

- 1 Take a blindfolded walk, guided by a friend for safety. Without sight, which senses did you rely on to walk?
- 2 Name a sensor that a robot could use for vision.

## Sound

A bat can sense its prey with echolocation by sending out a high-pitched sound that bounces back from objects and prey.

- 1 Play a game called 'bat and prey'.
  - A small area is cleared of obstacles.
  - One person is chosen as the bat and is blindfolded. All other people are possible prey.
  - The bat calls out 'dinner', and one selected prey calls out 'not me!' within two seconds.
  - The bat tries to find and catch the prey by placing a hand on the prey, while the prey tries to evade the bat. Once caught, another prey is chosen.
- 2 Name a sensor that a robot could use to detect sound.

## SENSOR-CONTROLLED ROBOT CHALLENGE

You are to design and make a hands-free wireless robot with light sensors that moves towards a light source, such as a torch. You can think of a purpose for your robot, such as a noisy moving alarm clock to wake you at the break of daylight.

The robot you design will go on a chassis as described on page 165.

### REQUIREMENTS (LIMITS OR CONSTRAINTS)

- Use the materials available in the school (or provide special materials from home).
- The motors and wheels must be well aligned.
- The wiring diagram must be followed exactly.
- Soldering must be checked before adding batteries.

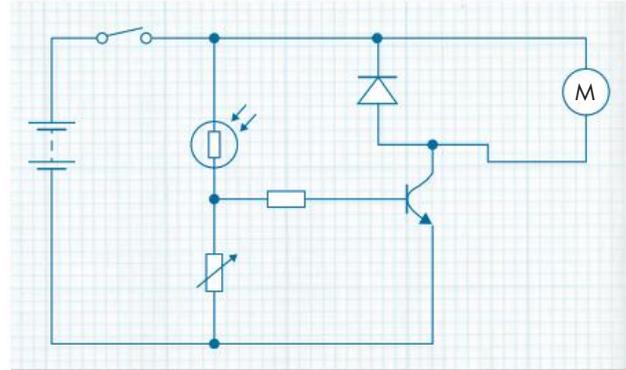
### DESIGN CHOICES

You will need to make design decisions regarding:

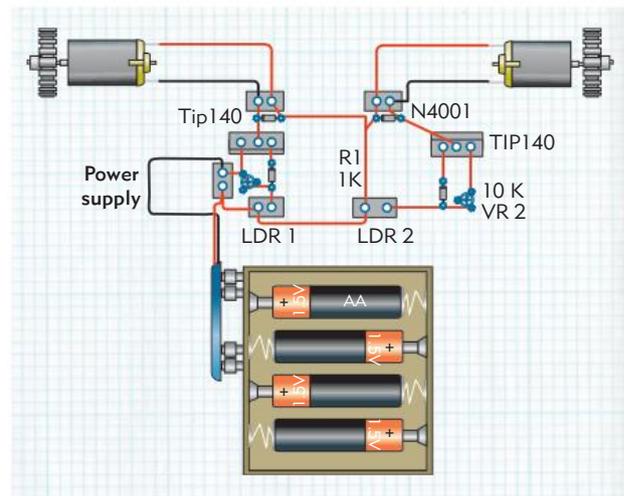
- the shape of the chassis and hand controller
- how you will decorate the chassis and hand controller.

## Tip

LDR motor controller boards and parts can be purchased as a kit from electronic hobby stores, or constructed at school if your school has the facilities to create printed circuit boards. One possible circuit has been provided (see diagram below), and this can be altered to suit the components and materials available at your school.



Circuit diagram for a sensor-controlled robot with one motor and controller



Circuit diagram for one motor and controller and PCB layout for light following vehicle

## Light-dependent resistor (LDR) circuits

An LDR circuit works by a transistor switching the motor on and off. If there is light on the LDR, the current flows into the base of the transistor and switches the transistor on, which then switches the motor on. If the LDR is in the dark, not enough current flows to the base of the transistor and the transistor is switched off, which turns the motor off. The trimpot (a small potentiometer) can be adjusted to allow for changes in background light.

## Using an LDR circuit

The LDRs must be set up so the LDR controlling the right motor looks left, and the LDR controlling the left motor looks right. Both LDRs must be able to see the torch if it is directly in front of the robot.

DIRECTION OF MOVEMENT	LEFT-LOOKING LDR	RIGHT-LOOKING LDR
Forward	Light	Light
Left	Light	Dark
Right	Dark	Light
Stop	Dark	Dark

# MICRO-CONTROLLED ROBOT

## ARDUINO-CONTROLLED ROBOT CHALLENGE (EXTENSION)

Advanced robots have their own onboard computers called microcontrollers. The robot you design in this challenge will go on a chassis as described on page 165.

You will need an Arduino Uno microcontroller, a motor-controller module, and Arduino software installed on your computer.

### REQUIREMENTS (LIMITS OR CONSTRAINTS)

- You must use an Arduino microcontroller.
- You must use a motor module.
- You will need a computer with the Arduino IDE installed.
- You will need a download cable.
- The motors and wheel must be perfectly aligned.
- Components must be arranged to be balanced.

### DESIGN CHOICES

You will need to make design decisions regarding:

- the Arduino board, motor module and chassis materials used
- the power of your robot (battery packs can vary from 5 to 12 volt).

## Arduino Uno microcontroller

An Arduino can be programmed to perform almost any task in robotics. It can monitor inputs such as light and heat, and control all sorts of outputs including motors and lights. An Arduino is

programmed in its own language, and the software required to do this is free. A huge online community is available to help with problems and inspire you to create amazing projects.



Arduino Uno microcontroller

### Note

In Australia, Arduino boards are sold under the brand name Genuino. They are exactly the same product, but with a different name.

The Arduino Uno board you will use for this challenge has:

- 14 digital input/output pins
- a USB connection for powering and programming
- a power jack for connecting to batteries or a power supply.

The Arduino Uno contains everything needed to support the microcontroller. Simply connect it to a computer with a USB cable or power it with a power pack or battery to get started.

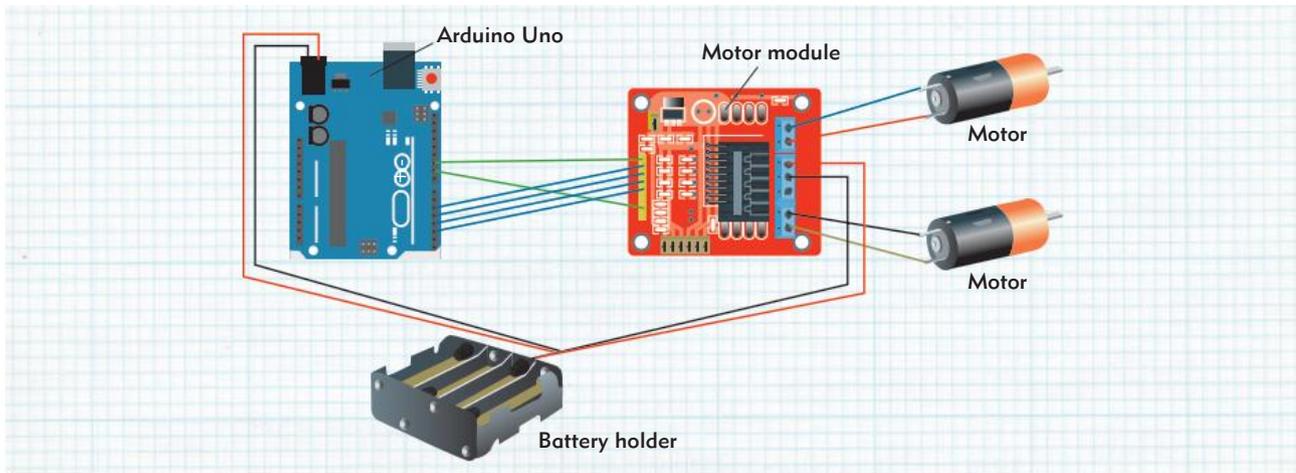
It is highly recommended that you follow the online tutorials to learn how to control outputs before beginning this task.



### Motor module

A motor module will be used to drive the motors. The high current required to run a motor would damage the Arduino if it weren't connected via a module. Each Arduino pin can only switch a maximum of 20 mA, while the motor module can switch up to 2000 mA (2A) per motor.

## Wiring the robot



### Wiring the Arduino, motor module, motors and battery pack

#### Wiring the motor module

- 1 Connect power from the batteries to the motor module and Arduino in parallel (do not use the 5V connection as a mistake can damage your USB port).
- 2 Make logic connections for left motor: Arduino pins 2, 3 to In1 and In2 on the motor module (male to female jumpers).
- 3 Make logic connections for right motor: Arduino pins 4, 5 to In3 and In4 on the motor module.
- 4 Solder motor wires to the motor, and connect wires to the motor terminal blocks on the motor module.
- 4 Optional: wire the EnA and EnB jumpers to PWM pins 9 and 10 (they can be used to change the speed of the motor).

#### Controlling motors with Arduino

Like the previous robot challenges, the robot is controlled by switching each of the motors forward, reverse and off. Refer back to the table on two-wheeled steering with a DPDT switch (see page 168).

To control the left motor, In1 and In2 are digitally switched on and off by the Arduino. To control the right motor, In3 and In4 are digitally switched on and off by the Arduino.

#### Coding motors

Arduino code is based on the computer languages C and C++. The code is divided into three main sections: variables, the void setup and the void loop.

##### DECLARING VARIABLES

In the first section, **variables** are declared. We declare (or tell the Arduino chip) which four pins control the robot (pins 2, 3, 4 and 5). We name the pins In1, In2, In3 and In4 to match the names of the inputs on the motor module. Unfortunately, we can't use pin 1 (this would have made for simpler naming).

##### VOID SETUP

The next section is the **void setup**, which only runs once. We use the setup to tell the Arduino which pins will be inputs and outputs.

We simply tell the Arduino that pins 2, 3, 4 and 5 (now called In1, In2, In3 and In4) will be outputs. We don't need any inputs yet.

##### VOID LOOP

The last section is the **void loop**. The void loop continuously loops, allowing the robot to check inputs and respond.

In code example 1, we will run the robot forward. In code example 2, we will run the robot in a rectangle pattern in a series of movements that will continue forever (or until the robot is turned off).

#### Controlling motors with Arduino

IN1	IN2	LEFT MOTOR	IN3	IN4	RIGHT MOTOR
High	High	Off	High	High	Off
High	Low	Forward	High	Low	Forward
Low	High	Reverse	Low	High	Reverse
Low	Low	Stops	Low	Low	Stops

## COMMENTS

Two forward slashes // are used for comments to explain the code to anyone reading it. The two forward slashes and comments are not sent to the robot when programming.

### Code example 1 – forward

The following code will make your robot go forward.

```
// name the Arduino outputs as the motor module
inputs to avoid confusion:
int ln1 = 2;
int ln2 = 3;
int ln3 = 4;
int ln4 = 5;
void setup() {
// setup code that runs once making the Arduino pins
outputs:
pinMode(ln1, OUTPUT);
pinMode(ln2, OUTPUT);
pinMode(ln3, OUTPUT);
pinMode(ln4, OUTPUT);
}
void loop() {
// main code that runs repeatedly:
// forward
digitalWrite(ln1, HIGH); // 5 V to front of left motor
digitalWrite(ln2, LOW); // 0 V to the back of left motor
digitalWrite(ln4, HIGH); // 5 V to front of right motor
digitalWrite(ln3, LOW); // 0 V to the back of right motor
}
```

### Code example 2 – rectangle pattern

The following will make your robot go forward for 2 seconds, turn for 0.5 seconds, then repeat both motions without stopping to complete a rectangle. You will need to change the timing of the forward and the turn to suit your robot.

```
// name the Arduino outputs as the motor module
inputs to avoid confusion:
int ln1 = 2;
int ln2 = 3;
int ln3 = 4;
int ln4 = 5;
void setup() {
// setup code that runs once making the Arduino pins
outputs:
pinMode(ln1, OUTPUT);
pinMode(ln2, OUTPUT);
```

```
pinMode(ln3, OUTPUT);
pinMode(ln4, OUTPUT);
}
void loop() {
// main code that runs repeatedly:
// forward for 2 seconds
digitalWrite(ln1, HIGH); // 5 V to front of left motor
digitalWrite(ln2, LOW); // 0 V to the back of right motor
digitalWrite(ln3, LOW); // 0 V to the back of right motor
digitalWrite(ln4, HIGH); // 5 V to front of right motor
delay(2000); // go forward for 2 seconds, 2000 mS
// turn for 2 seconds
digitalWrite(ln1, HIGH); // 5 V to front of left motor
digitalWrite(ln2, LOW); // 0 V to back of right motor
digitalWrite(ln4, LOW); // 0 V to front of right motor
digitalWrite(ln3, HIGH); // 5 V to back of left motor
delay(500); // turn for 0.5 second, 500 mS
}
```

## TASKS FOR CHAPTER 7 CHALLENGES

### Investigating

#### TASK 1 Design brief

Use the information from your design challenge to write your design brief – a paragraph explaining your individual design situation. Start with the words: *'I need to design and make a model that ...'*

#### TASK 2 Criteria for success

Write a set of four evaluation criteria questions that you can use to judge whether your finished product meets your expectations. Make sure your questions cover the areas of function, construction and appearance. Remember to think about these criteria when you are developing and choosing your designs.

### Design research

Ask your teacher which of these tasks you need to complete.

#### TASK 3A Design analysis

Find four images of existing product designs that are relevant and that you like. For each design, write a comment or analysis (2–3 sentences) that discusses:

- what the product is for

- its visual design (colour, shape and line) and style
- the layout of motors and wheels.

This research could be done in a group and your design analysis could be presented to your class.

### TASK 3B Situation research

Answer the following questions to think about what your robot will need.

- 1 What is the purpose of the robot? Will it be controlled for fun, used to play soccer against a friend or perhaps battle in a robot war?
- 2 What will the robot look like?

### TASK 3C Mechanisms research

Each robot requires a gear system to slow the speed and increase the torque.

- Describe the gears available at your school.
- Which gear must go on the motor: the smaller or larger gear?
- Calculate the gear ratio (or, if there is a choice of gears, calculate the gear ratios).

## Materials

The two most likely materials to use are plywood or acrylic.

- Plywood is a light but strong timber that is easy to drill, cut and glue.
- Acrylic is also strong and light, and can be easily cut or bent. It comes in a range of colours and transparency levels. Take care when drilling acrylic as it can be easily damaged.
- If available, 3D-printed parts and chassis are a great way of producing exactly what you want.

## Generating

### TASK 4 Design development

#### SKETCHES AND OPTIONS

Brainstorm some ideas for your design brief. For example, think of colourful and creative shapes for your base and controller. If using the robot for soccer, think of a curved front shape that can hold a ball. Choose your best idea and sketch all of the features that you would like your robot to include. Consider shape, mechanisms, component layout, colour, and anything else important to you.

#### WORKING DRAWING OF YOUR CHOSEN DESIGN

Develop and draw your chosen design based on your initial sketches and thinking. You must show a top view. When drawing, use a ruler and be accurate. You will need to show:

- the layout of battery and switches on the controller
- the layout of motor, gears and wheels on the chassis
- all details, including information that explains the measurements and materials
- names of all components – label the motor, gears, wheels, battery and switches
- the colours of your design.

Use a full page for your design drawing.

### TASK 6 Materials list

Create a table of materials to order, such as your base and hand controller, and other optional parts.

#### Example materials list

PART	QUANTITY	DETAILS

## Planning and managing

### TASK 7 Production plan

Develop a production plan to help guide you while you are making your robot. The following example

work plan for a switch-controlled robot can be followed or altered to suit your design. You will need to complete the tools and safety section of the plan.

#### Example production plan

PRODUCTION STEP	TOOLS AND EQUIPMENT	SAFETY
<b>Preparation</b>		
Gather all components: 2 motors, 2 gearboxes, 2 wheels, 1 battery pack, 2 switches		
Design base and controller		
Lay out parts on design to double-check that the design will work		
Order base and controller material		
Cut and shape base and controller		
Take photos and make a journal entry		
<b>Controller</b>		
Drill holes for switches, evenly spaced		
Sand and decorate the controller		
Place switches		
Glue or bolt battery holder in place		
Take photos and make a journal entry		
<b>Base</b>		
Rule lines for wheel axle		
Sand and decorate the base		
Drill holes for wires		
Glue or bolt motor and gearbox in place		
Clearance hole may have to be cut for the gears		
Check with a spare battery pack that each motor and gearbox spin freely		
Take photos and make a journal entry		
<b>Controller and base</b>		
Drill holes for wires through the base and controller		
Cut three long lengths of hook-up wire (or four for the DPDT model)		
Strip and tin the wires, and tin the switches and motor terminals	Soldering iron	
Thread the wires through the holes drilled on the chassis and controller. Wires can be knotted or threaded through two holes to ensure wires aren't pulled too hard when using the robot.		
Follow the wiring diagram to solder the wires in place		
Carefully check for any bad solders, solders that bridge the switch together or exposed wires touching the metal part of the motor		
If all solders are correct, add batteries and test		
Add any finishing touches		
Take photos of final product and make last journal entry – smile and celebrate a job well done!		

## Producing

### JOURNAL DURING PRODUCTION

Keep a journal while you are making your product to record your progress, and to reflect on the things that go well and what could be improved. Briefly summarise what you completed during each step

(this will probably match your plan), and record how long this took (either in minutes or periods). For each entry, write in your reflections – explaining the things you’ve done well, what you had problems with, and what you could improve. Use photos to visually record your production.

### Project journal

JOURNAL <i>What you completed in each stage</i>	TIME*	REFLECTION <i>What went well? What could be improved? What did you learn?</i>

\*Time – how long did it take to complete?

### TASK 8 Soldering, cutting and drilling practice

Watch demonstrations of the soldering, drilling and cutting you will need to carry out. If necessary, practise these techniques.

#### Safety

If you are using any machinery during production, make sure you complete any school safety tasks, and that you are competent before you start work. This might include:

- » a machine safety test
  - » a competency test (where you demonstrate to the teacher that you know how to use the machine)
  - » a completed entry in your machine safety passbook.
- Remember to always ask permission from your teacher before you use a machine.

### TASK 9 Making your product

Follow your production plan to construct the robot.

## Evaluating

### TASK 10 Evaluation

Evaluate your work – make judgements about your finished product using the assessment criteria you wrote in Task 2.

In your evaluation, answer the following questions or points:

- Which stage of design and production did you enjoy the most?
- How you could improve a stage of design and/or production?
- Give an example of when you showed persistence during the design and production process.

EVALUATION CRITERIA	HOW DID YOU CHECK THIS?	HOW WELL DID YOUR FINISHED PRODUCT PERFORM IN THIS AREA?

## THINKING SKILLS

### ACTING OUT A CIRCUIT

It can be very powerful learning to layout a circuit in a room and pretend to be a charged particle moving through the circuit. Either in a group or individually arrange the desks and chairs in a room to create a circuit. Charged particles can be pushed out of the battery into the circuit and give their energy to the lamp before returning to the battery to be re energised.

- 1 The first circuit should include a power supply, a continuous path and a lamp as a load. This is a Battery-lamp circuit.

- 2 In the second circuit change the lamp for an LED and resistor. This is a battery-resistor-LED circuit. Does the resistor have to be before the LED?
- 3 The third circuit could be a parallel lamp circuit. Battery splits into two or more parallel circuits each circuit containing a lamp.



Stock.com/Cameras



# DESIGN TO SHELTER AND PROTECT

## KEY KNOWLEDGE

In this chapter, students focus on shelter. They will use the design process to:

- ▶ identify and define a situation for shelter
- ▶ research the issues
- ▶ generate and develop ideas
- ▶ plan and manage the process
- ▶ evaluate the solution.

## DESIGN CHALLENGES

- ▶ House-it – design and make an animal shelter
- ▶ Clothe-it – design and make clothing for protection

## FOCUS ON PROTECTION

Shelter protects us – it is one of our basic needs. Not only do people need shelter, so do animals; particularly animals that exist near dense populations or who are endangered.

Clothing also protects us – it is another one of our basic needs. People need clothing more than animals, but there are times when it is justified for animals too.

There are many reasons why we need protection – some of them are similar to why we need storage. You could even think of clothing and shelter as things in which to store people or animals (sort of!).

- **Protection from the elements** – People and animals need shelter to protect them from weather (such as strong winds, rain, hail, snow and fierce sun) and from city noise. People also use clothing to protect themselves from the elements. Some pets are lucky enough to be clothed too.
- **Privacy** – People like to eat, rest, relax, wash and sleep in private where they can't be seen. Animals like to do this sometimes too.
- **Safety and security** – Animals face a variety of threats. They might have predators, be constantly disturbed by people, or be unable to cope with the constant light emitted in a city. Parents like to keep small children inside a house so they can see them at all times. Most of us would be afraid to sleep outside at night due to the fear of how other people might treat us. In Australia, there are also dangerous snakes and spiders that we like to keep from our houses.
- **Injury prevention** – People wear specialised clothing or equipment to prevent injury. Examples include helmets, steel-capped boots, bullet-proof vests and leather motorbike jackets. The PPE (personal protective equipment) that you wear in the technology classroom is to prevent injury.
- **Happiness and enjoyment** – Beautiful things can make us feel good. Shelter can be designed aesthetically to improve our quality of life. Clothing can enhance our appearance and make us feel good.

Other reasons for protection are to keep warm and dry, to stay clean, to keep dark or allow light, to be easily accessed, and to be lockable.

### Animal shelter and clothing

- 1 Think of an animal that might need some form of shelter. For what reason/s would shelter benefit this animal?
- 2 What is your favourite place of shelter? Is it your home? A room in your home? Your school? Or another place? What makes it your favourite?
- 3 What is your favourite piece of clothing that protects you? What does it protect you from and why is it your favourite?
- 4 Draw some sketches of the clothing you wear to protect you from different weather conditions.
- 5 Discuss clothing for animals – when do you think it might be appropriate?
- 6 Discuss animals that create their own shelter.

### Housing animals

Many of us have pets that are housed quite comfortably. We build animal housing such as kennels for dogs, birdcages for canaries and budgies, ponds or terrariums for fish, hutches for rabbits, cages for mice and small sheds for guinea pigs.

Chickens can live in battery cages, free-range farms or suburban backyards. Chickens need to be protected from foxes and dogs, and they need a quiet, dark and safe place to lay eggs.

In addition to creating housing for our pets, many people create housing for wildlife. Nesting boxes can be made to replicate tree hollows for both birds and possums.

Possums are Australian marsupials that are arboreal and nocturnal, which means they live in trees and are active at night. Their natural predators are dogs, cats and foxes. Possums are often hit by cars, and are victims of bushfire and drought. In some areas, possums are considered a nuisance as they make nests in roofs and cause damage. A good way to protect possums and keep them out of the house is to build a nesting box.

### Sustainability

According to a World Wildlife Fund (WWF) report, animal species have been in rapid decline since the 1970s. This is a problem because we need biodiversity (a large variety of plant, marine and animal species) on the planet to support us. Marco Lambertini,

director general of WWF, says, 'Humanity is completely dependent on nature for clean air and water, food and materials, as well as inspiration and happiness.'



## The global decline of bees

One very important insect in global decline is the bee. It is thought that widespread use of

insecticides is to blame. Bees give us honey but they are also pollinators; different bee species are responsible for pollinating different plants. Pollination is important for our food supply, because without pollination, plants do not bear fruit or seeds to grow more plants.

[HTTP://SOS-BEES.ORG/](http://sos-bees.org/) SOS BEES

### CASE STUDY

#### Flow™ Hive – honey on tap

Father and son, Stuart and Cedar Anderson, are the creators of Flow™ Hive. After years of beekeeping, Cedar decided there had to be a better way to extract the honey from the hive that didn't involve smoking, upsetting and squashing bees, and occasionally getting stung in the process. From their home in northern NSW, Cedar and his father spent a decade on inventing, developing and obtaining a patent for the Flow™ Hive.

In a beehive, bees create a honeycomb structure made of beeswax, which they fill with honey then cap with wax. Flow™ Hive has a frame that consists of partly formed honeycomb cells made from plastic. The bees build the remainder of the cell. To extract honey, a lever is turned and the frame moves to allow the honey to flow out.

Not only does their invention function like a dream, it also looks beautiful. Flow™ Hives aren't nailed together in a rough fashion – they are made to a simple clean design with precise joining techniques, and are finely sanded and polished. The Flow™ Hive design has a gabled roof that protects the main parts and includes features such as a removable side window for viewing.

Flow™ Hive boxes and parts are made from sustainably sourced Australian hoop pine or North American western red cedar.



Flow™ Hive box made from hoop pine with side viewing window

### FOCUS ACTIVITY

#### Bees and protection

The creators of Flow™ Hive had a lot of knowledge about bees and beekeeping before they went into business. This helped them to create a product that suited both bee and keeper.

**1** List as many aspects of bees and beekeeping they researched as you can (you can read about many aspects on their website).

- 2** What areas will you need to research if designing a solution for housing an animal?
- 3** Discuss the types of clothing protection that a beekeeper needs.
- 4** Discuss the environmental positives and negatives for the Flow™ Hive.

## Clothing for protection

Workers and sports people often require special clothing or equipment to protect them from dangerous activities. Creating a protective piece of clothing may be beyond your ability in the classroom, as many of these have an Australian Standard that would need to be followed. However, you have plenty of scope to create a fantastic piece of clothing (or equipment) to protect a user or an animal from the weather. People (and animals) need protection from the elements.



**Clothing for protection: Dog jacket with press stud fastener (left) and baby sun hat with ties (right)**

## HOUSE-IT SOLUTION

### HOUSE-IT DESIGN CHALLENGE

You are to design and make a shelter to house an animal.

#### REQUIREMENTS (LIMITS OR CONSTRAINTS)

- The shelter should be no larger than the size set by your teacher.
- You need to make a feature of (showcase) your accuracy in one joining method or process (discuss this with your teacher).
- You must include other joining methods specified by your teacher.
- Joins must be accurate to 0.5 mm or less.
- Use the materials specified by your teacher (or provide special materials from home).



**Shelters for animals: a wooden birdhouse (left) and a dog kennel (right)**

## DESIGN CHALLENGES

There are two design challenges in this chapter, both involving design solutions for protection against weather conditions.

### Focus for assessment

For assessment of each of the challenges, your teacher will be looking for:

- » a design brief that outlines the problem, states what form the solution will be, and gives criteria for success
- » clearly presented research relevant to your challenge (either the animal or the user of your protective shelter or clothing) that includes some ideas to inspire your product
- » diagrams, drawings and annotations that show ideas to suit the challenge
- » photos of trials of your joins that show improvement
- » some planning, making and a journal of progress
- » the quality of your finished protection product, particularly of the two joins
- » an evaluation of product and process.

- You must include a roof, flap, closable lid or door (discuss this with your teacher).
- The shelter needs to be aesthetically pleasing and professional looking.

#### DESIGN CHOICES

You will need to make design decisions regarding:

- what animal your shelter is for (pet or wildlife)
- the form, shapes and colour of your shelter
- how it will work (i.e. the shape of the roof, and how to attach a flap, lid or door)
- the materials to use
- the joining method or process you will showcase.

# CLOTHE-IT SOLUTION

## CLOTHE-IT DESIGN CHALLENGE

You will need to design and make an item of clothing for yourself or a pet to protect from the elements or a dangerous situation.

### REQUIREMENTS (LIMITS OR CONSTRAINTS)

- The clothing item must be comfortable.
- Your design must include a fastener of some sort.
- There must be two different types of seams.
- All seams (or joins) must be straight and accurate.
- The clothing needs to be aesthetically pleasing and professional looking.

### DESIGN CHOICES

You will need to make design decisions regarding:

- what the clothing will protect you from (weather or a hazard)
- how it will fasten (ties, press studs, buttons, zipper, hook and eye, etc.)
- the material to use (cotton, leather, wool, PVC, etc.)
- the colours, shapes, textures and form it will be.

## TASKS FOR CHAPTER 8 CHALLENGES

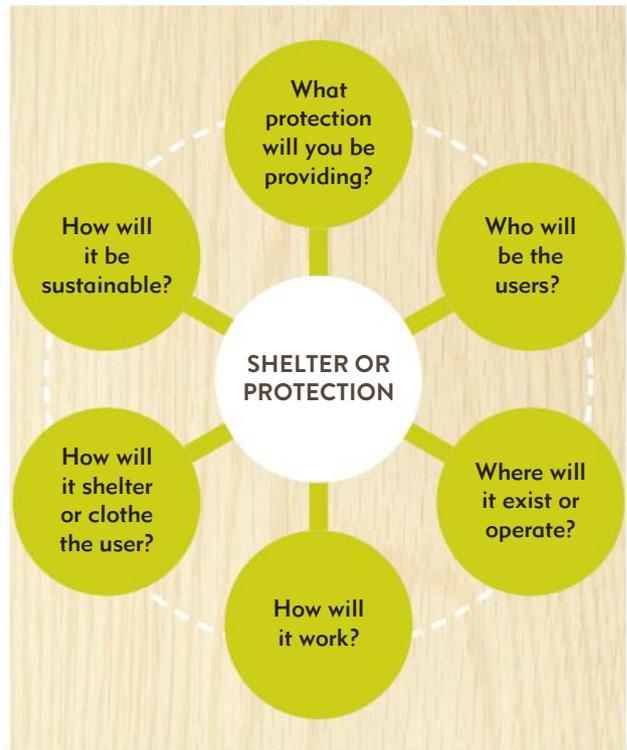
### Investigating

#### TASK 1 Brainstorm and select the challenge

As an individual or in your team, brainstorm ideas to help you decide on who or what your product will be for. Discuss the brainstorm list and discard the least-suitable idea until one challenge (and the details you will focus on) remains. This idea will be the title of your design brief.

#### TASK 2 Graphic organiser to help define the challenge

Choose a graphic organiser to help define your challenge. You could use a web diagram, lotus diagram, fishbone diagram or concept map.



Concept map template – insert the details of your challenge by making a statement to answer each question

### TASK 3 Writing a design brief

Use the information from your graphic organiser to write a design brief. Start with a statement of the problem you will be improving or solving, such as: *'My uncle wants to have chickens in his backyard. He has a shed, but the nest for laying eggs looks really rough and he wants a classy one.'*

Include the requirements of a solution. You will also need to state the finished form that your solution will take (what type of clothing item or housing it will be).

This design brief will include your 'criteria for success' (see page 180). Create four or more 'criteria for success' relevant to your challenge that cover any of these areas: function, appearance, usability, safety, quality of the joins (or how the fasteners are attached) and environmental sustainability.

### Materials

In addition to the materials suggested below, refer to Chapter 2 (Materials) or to other challenges for ideas on materials to use.

#### ANIMAL SHELTER

You could use any number of materials for your animal shelter, and you may consider other useful items such as:

- chicken wire with a suitable-sized hole
- wire suitable for cage walls
- leather for fasteners or as hinges
- contraptions for animals (such as mice) to play on
- recycled material such as timber, corrugated iron wire coathangers, etc.
- clear acrylic for any windows, spyholes, etc.

#### CLOTHING ITEM

You could use any number of materials for your clothing item such as:

- new fabric or fabric from used clothing (for example, second-hand woollen jumpers washed in hot water and detergent to felt them)
- yarn to knit with
- leather or PVC.

### TASK 4 Research

Depending on your design problem, complete and present some research.

#### USER REQUIREMENTS

Present one to two A4 pages about the user or animal with research such as:

- interesting and relevant facts about the animal (or the user if you are designing clothing for a person)
- some requirements of your product (for example, waterproof, windproof, insulating, have air flow, humidity control, sun protection, transparent, movable), and how you could achieve the requirements or images of how it is achieved in existing products
- existing products that shelter or protect your user (or animal).

#### CONSTRUCTION

Present one to two A4 pages about your research construction. You could:

- collect ideas for fastening for the clothing or how to join the lid, flap, door or opening of a shelter
- list construction techniques you could incorporate
- include images of the joins (or seams) that your teacher has specified
- search for instructional videos on 'best practice' for these processes and note the URL so you can find it easily later during production
- annotate your research to remind you of how it will help you when designing.

### Generating

Move into the ideas and design development stage with the next few tasks.

### TASK 5 Idea sketches and notes

Create one to two A4 pages of idea sketches of the ideas you have for your shelter or clothing. This can be for parts such as the fasteners of the clothing or the lid/flap/door/opening of the shelter. Annotate and include arrows to explain your ideas, especially for the parts that might be hard to draw clearly.

Give your page/s a clear title such as: 'My quick ideas for a birdhouse'. Also, note how you could construct your ideas, or what skill you will need to learn to construct them.

Start thinking about how to incorporate the requirements of the challenge, such as:

- the join to be showcased and the opening for the shelter
- the two seams and fastener to be included in the clothing.

### TASK 6 Refining and deciding on the details



Ideas for a wire birdcage

#### Note

In some cases, it might be necessary to complete the trials in Task 7 before deciding on the final idea as you will then be more experienced in how the processes will work in your product. The trials will inform your design.

Using your critical thinking, look at all your ideas and choose the most suitable. Which idea can you achieve in the time available? Be sure to ask the questions that will help you decide on the most achievable and suitable idea.

#### SHOW DETAILS OF YOUR IDEA IN 3D AND 2D

Use a full page to show your final idea in both a 3D visual drawing and a 2D working drawing (see page 22). Your teacher will explain the type of drawings required.



iStock.com/saamilea

Sketch of knitted or fabric hat, showing patterns and ties

### TASK 7 Trialling two joins

With your teacher's guidance, safely practise two joining methods until your quality improves. See the examples in other challenges in this book.

If knitting your product, be sure to create a sample of knitting to check your tension and how it measures with different-sized needles. There are many online tutorials to teach knitting to beginners.

### Planning and managing

#### TASK 8 Production plan

Think ahead to the main steps involved and create a production plan. When creating a sequence of steps or processes, remember to consider:

- the measuring and marking of the material
- all cutting that will be involved – name the pieces to be cut (for example, top of birdhouse) and include any shaping that is required
- all joining, and the steps required for each join
- any attachments (parts, fasteners, decorating or embellishing) that needs to be done and the best place in the sequence to do it
- assembling and/or checking of all parts
- final touch ups such as tidying, fixing, painting, etc.

Create a table with headings and step numbers similar to the example table below. Add the table heading and the rows you need.

### My detailed production plan for ...

PRODUCTION STEP	MATERIALS NEEDED	TOOLS/EQUIPMENT NEEDED	SAFETY MEASURES (WHERE NEEDED)
1.			

Develop a timeline for your project. Ask your teacher how many classes you have for this project and work out some milestones (dates for steps or parts to be completed), so that you can meet the due date. A simple example is shown in the

example table below. Draw up a similar table and insert the steps required to construct your product and the dates by which they should be completed. Add the table heading and columns and rows as required.

TIMELINE FOR MY PROJECT						
PRODUCTION STEP (OR PART OF PRODUCT TO BE COMPLETED)	WEEK 1 (INSERT DATE)	WEEK 2 (INSERT DATE)	WEEK 3 (INSERT DATE)	WEEK 4 (INSERT DATE)	WEEK 5 (INSERT DATE)	WEEK 6 (INSERT DATE)
1 Measuring and marking						
2 Cutting all pieces						
3 Joining (or attaching)						
4 Assembling and checking						
5 Final touch ups						

### Safety

Follow all your teacher's safety instructions, completing any documentation required. Refer to page 112 for more about safety.

### Producing

#### TASK 9 Making your product

Make your product safely. Keep a journal and take photos (or make quick sketches) of the different steps. Date your journal entries and describe what you did for each session.

### Evaluating

#### TASK 10 Presenting your solution

- 1 Present your solution to the class. Tell the class your criteria for success and how your solution met each criterion. If possible, ask classmates for questions.
- 2 Evaluate two of your production processes. Draw a diagram of the two processes you learnt and insert a close-up photo of where they appear on your product. Insert a photo of these processes from the internet and compare with your own work by annotating the differences. Give suggestions for how the quality of these joins could be improved further for next time.

## THINKING SKILLS

### DESIGNING FOR PROTECTION: A REFLECTION

- 1 Draw or take a photo of your product in use, and annotate the image to explain how your product protects the user.
- 2 List three things that you learnt from your research. Explain how one of them helped you to develop ideas for your solution.
- 3 During these challenges, you were asked to trial two new processes to show improvement. Create clear step-by-step instructions for a student younger than yourself to complete these processes. Use the photos you took of your own work to assist you.

### MARKETING AND ENTERPRISE

- 1 Refer to the case study of the Flow™ Hive on page 179. The Flow™ Hive is patented. Look up Intellectual Property Australia and read about patents. For what aspect of the Flow™ Hive did Cedar and Stuart Anderson get a patent? Why is it in the interest of creators to apply for and pay for a patent?

 IP AUSTRALIA

- 2 To start their business, Flow™ Hive used a crowd-funding group called Indiegogo. An Australian company called KNOG also used this method (via Kickstarter.com) to start mass production of a new bicycle bell called 'Oi'. Research crowd-funding and how it works. Discuss why it could be beneficial for new products.

 KNOG

- 3 Imagine you wanted to manufacture thousands of units of your product to sell. You will need cash to 'kickstart' the production. Create a 'pitch' about your product to put onto a crowd-funding website. Use your ICT skills to create one of the following: a brochure, a document, a video, an interactive digital presentation, a digital 'coming soon' page or a full website.



# 9

## HUMAN-CENTRED DESIGN

### KEY KNOWLEDGE

In this chapter, students will:

- ▶ learn about the human-centred design approach
- ▶ learn how the human-centred design approach is used to successfully create solutions that work in difficult circumstances
- ▶ apply the human-centred design approach to develop solutions for a range of situations.

### DESIGN CHALLENGES

- ▶ Design a solution to provide clean water
- ▶ Design a solution to provide appropriate housing
- ▶ Design a solution to create play equipment for children

## FOCUS ON PEOPLE

What do you think the term ‘human-centred design’ means? Think about the individual words – it means that humans (and their needs and wants) should be at the centre of the design process. It isn’t a design process based on the latest technologies or new ‘whiz-bang’ materials (although they can be used). Human-centred design always comes back to the questions: ‘Who is this design for?’, ‘What do they need/want?’ and ‘How can we make their lives better?’.

**Human-centred design** doesn’t just focus on the people who use the product or solution, but also considers the impact of the solution on other people, such as individuals, families, social groups and surrounding communities. It considers the social sustainability of a product or solution – asking the questions: ‘How will this solution affect the way people interact and live?’ and ‘Will the solution be positive and strengthen the community?’.

The starting point of any human-centred design process is observing, talking with and listening to people. It means that designers need to get forget what they *think* they know about a situation, and use fresh eyes and ears to come up with ideas that haven’t been considered before and that suit the people and place.

### Humanitarian design

**Humanitarian design** applies human-centred design one step further, and considers people who are in special need and who require support. All over the world, there are many people in very difficult situations – they need food, shelter, clean water, transport, medical care and schooling. It is easy for us, in our comfortable and well-resourced cities and towns, to think that we have the answers to problems elsewhere. However, previous development and aid-money has been wasted on solutions that have failed because the local situation, community culture and environmental limitations weren’t considered.

There are also people in our own community who have special needs – people without housing, who have disabilities, or who live in isolated communities. Unless designers listen to and understand the situations of these people, it is likely that their solutions won’t be very useful.

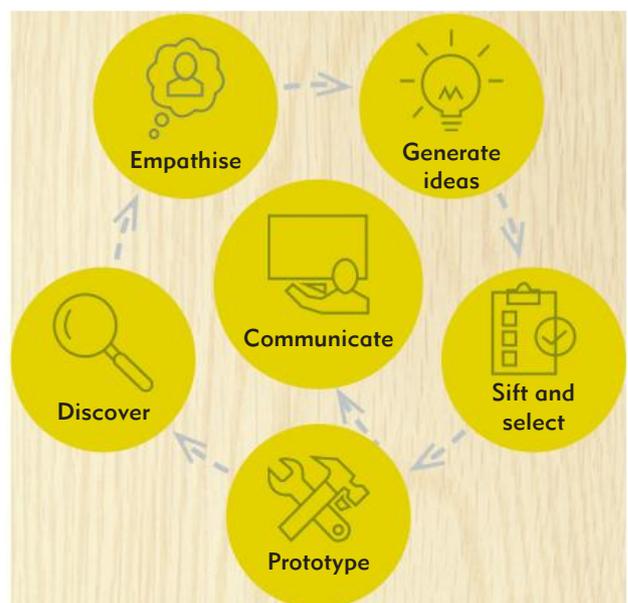


Alamy Stock Photo/Jake Lyell

**Working with people in need**

### How is humanitarian design ‘done’?

There are many organisations actively involved in humanitarian design projects and they all use a similar people-focused design approach. The process shown in the diagram is adapted from a process used by Engineers Without Borders teams to guide the contact they have with local communities.



**Humanitarian design cycle (adapted from IDEO and Engineers Without Borders)**

## Enriching lives

Imagine having the opportunity to make a real difference for people who can't communicate easily, or for people who struggle with basic movements due to a brain injury or disorder. Through the Science Students@Work Program, Year 10 students from St Catherine's School worked with Akorn Educational Services and Victoria University (VU), SCOPE and Diamond Valley Special Development School on two life-enriching projects for differently abled children and adults.

Students worked with engineering staff at VU to develop **iTED** – a 'talking' teddy bear for very young children with autism spectrum disorder (ASD). Students observed and worked with children with ASD who struggle with personal interaction. The student developers thought carefully about the specific needs of the children and the practicalities of how to make a functional and durable aid that could be easily maintained by parents and carers. Their solution was iTED – a soft toy with an interactive electronic device inside it that allows the toy to 'speak' when different pads are squeezed. iTed encourages children with ASD to communicate by saying words and phrases through the toy to communicate their needs.

The electronic device inside the toy was made using readily accessible hardware and software – a PICAXE microcontroller and Audacity recording software. The device can be removed when the toy is washed, and the words can be easily changed to match the specific needs of each child.



**A happy iTED user**

Students also met with children and adults with severe physical and brain function limitations. Students observed how the people they met with struggled without one-on-one interaction with a personal carer, and had only a few independent ways of developing their physical and mental skills. Their solution was **iThing** – an interactive enrichment 'box'.

Again, working with the VU engineering faculty, student developers designed and produced iThing – an interactive device that stimulates the senses with sound and colour. The device responds positively to motion or pressure on large pads, triggering flashing lights and music.



**Students programming the iThing electronic device**

Both of these products were very successful because they were developed with the specific users and their needs at the centre of all design decisions. At the start of the design process, students spent a lot of time observing and interacting with the people they were designing for. They discussed ideas with carers, and trialled their products with the end users to make sure the products would work for them in the right way, and were also user-friendly and fun.

The humanitarian design process involves six main stages.

- **Discover and empathise** – being invited to partner with the community, observing the people in their setting, and identifying needs and opportunities. This involves understanding the situation from the perspective of the users and the community, checking that interpretations are correct, getting feedback, and gathering details about particular needs and their context.
- **Generate ideas** – focusing on specific needs, exploring a wide range of possible ideas and practical solutions, and developing the most suitable solutions.
- **Sift and select** – narrowing down and assessing the ideas, ranking, and working out which are the most appropriate and workable.
- **Prototype** – creating a trial or model of the best idea and putting it into practice, testing, observing and getting feedback, which may lead to further idea generation and prototyping and testing,
- **Communicate** – presenting tested ideas to the whole community, with clear explanations of how the solution works and how it can be sustained and maintained for the long term.

Design decisions throughout the process are done in **partnership** with the community.

## Using different ways of thinking

Though the process of humanitarian design, it is important to use both creative thinking (coming up with lots of imaginative and innovative ideas), and critical thinking (thinking practically about what will and won't work, and what is doable in the local

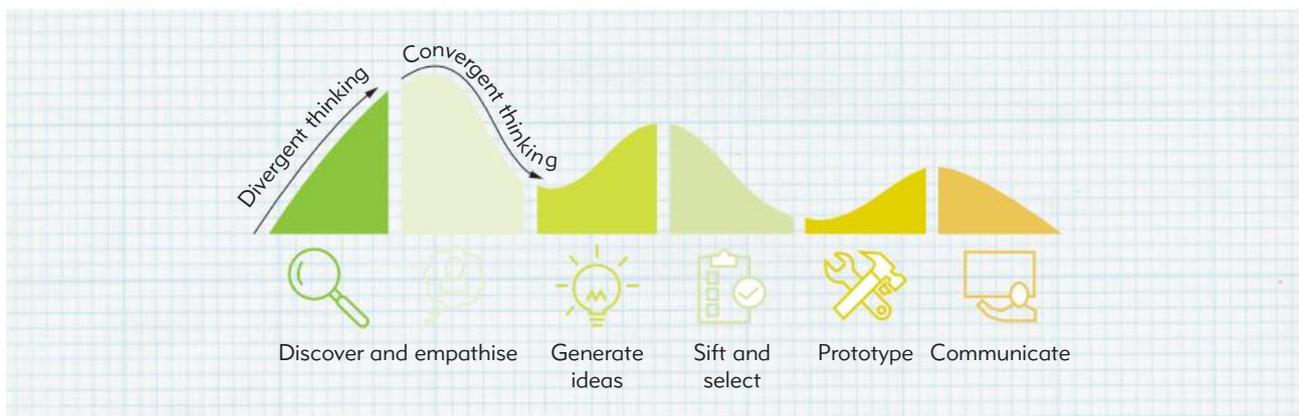
situation). This is sometimes called **divergent thinking** and **convergent thinking**.

When ideas are divergent, they go off in a lot of different directions and explore all sorts of possibilities. Convergent thinking is critical and analytical, gets rid of suggestions that won't work and narrows the field to a few that might. There are times in the humanitarian design process when one form of thinking is more helpful than the other. For example, when you are generating ideas, divergent thinking is useful. Convergent thinking is useful during the 'sift and select' stage.

### FOCUS ACTIVITY

## Thinking about human-centred and humanitarian design

- 1 Choose two products that you think have been designed with humans in mind (human-centred design), and two other products that haven't been designed well for humans. Explain the reasons for your choices.
- 2 Compare the humanitarian design cycle with the design process on page xx. What are the similarities? What are the differences? How do the differences reflect the approach of humanitarian design?
- 3 In the case study about student designers developing products for people with a disability, discuss what made the design and development process successful.
- 4 Think about the people around you and identify someone that has a special or individual need. Ask them what they find difficult in their everyday life and talk together about a solution that might help their life to be easier. The solution could be a new or improved product, a service, or a change to their environment.



Flow of ideas in the humanitarian design process (adapted from IDEO and Engineers Without Borders)

# DESIGN CHALLENGES

## Timor-Leste: working with hillside communities

Timor-Leste (also known as East Timor) is a very poor, independent country to the north of Australia with a population of just over 1.1 million people. It is the independent half of an island partly controlled by Indonesia. Timor-Leste has had a very troubled history, but has been an independent country since 2002. The country is mountainous and the climate is tropical – hot and humid with wet and dry seasons. Although the running of the country is mainly funded by selling oil and gas reserves, most of the population work in agriculture (80% of workers) and live in villages. Many of these villages rely on subsistence farming (growing the food and materials they need to survive), but the country also exports coffee, cocoa and cinnamon.

In 2010, only 19% of rural houses had access to electricity, and only 58% of adults were literate (could read and write). However, literacy is rapidly improving as access to education increases. Access to health care has also increased due to medical training programs – the current life expectancy is 67–70 years and rising. Transportation is an issue in rural areas – roads are in very poor condition and aren't well maintained. Most families don't own a vehicle and public transport is unreliable. Getting to school in rural villages can sometimes mean walking for hours.

The people of Timor-Leste have a strong connection to culture and traditions. The government is keen to support and protect the country's cultural identity, its creative arts and crafts, and traditional architecture. The people also have a close relationship with the natural environment, as they have traditionally depended on it for resources such as food, shelter and natural medicines. The environmental exploitation and damage caused in some areas by occupying regimes has created significant hardship to many communities.



**Timor-Leste – an independent country located to the north of Australia**

The design challenges in this chapter focus on the Timor-Leste rural village of Codo, in the north-east subdistrict of Lautém. Codo depends on local farming for food and income, but food supply is not always reliable due to seasonal and climatic changes. About half the population is under 18 years, which means education, shelter, health and safety, and food supply are very important.

Organisations such as Plan Timor Leste and Engineers Without Borders have been working with the Codo community, and have identified a variety of areas or needs for which solutions could be developed. Some of these needs are for:

- clean water
- appropriate housing
- safe play areas.

### Focus for assessment

When assessing each of the challenges, your teacher will be looking for:

- effective teamwork
- in-depth research into and understanding of the people's situation
- in-depth research and trialling of concepts that might be helpful in design
- original and useful design solutions
- clear design drawings, models and explanations
- understanding and depth in your group's evaluation.

# CLEAN WATER SOLUTION

The water for Codo is sourced from three natural springs in the surrounding hills. At the spring locations, the water is of very high quality. The water is then piped to holding tanks and onto taps located inside the village. Families collect water in plastic containers for use in their homes.



Shutterstock/ILYA AKRISHIN

**A natural spring**

## Issues

- Areas around the springs are being eroded and damaged, and are not properly capped or fenced off. This reduces the water quality.
- Pipes carrying the water are not clean and contaminate the water with bacteria.

- Water is transported to homes using unclean storage containers.
- Before use, water needs to be boiled to make it safe to drink – this takes time and fuel. Villages are turning to bottled water as an alternative, because it is faster than boiling the water.



Shutterstock/Photographic

**A water tap similar to the one in Codo**

## Discussion

- How is this different from the way you get your water?
- What are the issues and consequences of drinking poor-quality water? You may need to research this subject further.
- What aspects of this water provision 'system' do you think could be improved?
- What are some issues arising from the situation/location that might limit what can be done?

## CLEAN WATER CHALLENGE

### REQUIREMENTS

Although there are a range of things that could be done to improve the entire process of getting drinkable water to people in their homes, your team is being asked to concentrate on making the water drinkable once it gets there.

- Your team needs to develop a solution that will purify the water that has been collected from the Codo village drinking taps.
- You will need to test your ideas and assess whether a difference has been made.

### DESIGN CHOICES

You need to use:

- materials that are readily available
- any form of manufacturing and construction that is available.

Your team can make a model or prototype from alternative materials if you do not have access to the materials suitable for your design.

## Investigating

### TASK 1 Researching purification

Find out how water can be purified. Conduct some research and investigate different methods of purification (for example, filtering, sunlight and chemicals). What did your team find out? What solutions are already commercially available? Why do you think they aren't being used in Codo?



istock.com/manifreddy

#### Filtration is a water purification method

Organise trials of different purification methods. You will need to plan, and ask your science faculty for help with equipment, materials and procedures. You will need to consider the following aspects:

- Where is your team going to get the 'dirty' water from?

- What methods of purification are you going to trial?
  - How can you use everyday equipment and materials to set up the trial?
  - How are you going to test your results?
- Carry out the trials and report your team's results.
- Which purification method worked best in terms of water quality? How did you measure this?
  - Which method was the easiest to set up? Which method took the most effort? Which took the longest to carry out?
  - What method do you think could be turned into a product?

#### DISCUSSION

- Which method would be the easiest to turn into a usable product/system to use in Codo?
- What are some of the local limitations or issues that might stop an effective purification method being used? (Think about cost, transportation, access to materials, etc.)

### TASK 2 Criteria for success

Remember that the villagers in Codo are turning to bottled water instead of boiling their water to purify it. What issues arise from the use of bottled water – is this a sustainable solution? List the reasons the villagers might choose bottled water. (If we were able to visit the villagers, we could ask them about this and find out what they do and why in more detail.)

These reasons will have an impact on your solution. If your team doesn't think about the reasons when designing the solution, the locals may not choose to use your team's product as it may not address their needs. How do you think these reasons will affect the design of your product or solution?

- Write a list of requirements that your team's purification solution needs to fulfil for it to be effective, used regularly by the locals, and easily made. These are your team's criteria for success.

## Generating

### TASK 3 Generating ideas

Choose one of the methods of purification. On one large sheet of paper, develop and sketch a range of ideas that could turn your team's chosen method into a product or system easily used in Codo. Continue until you have filled the page and explored a wider range of possibilities.

## SIFTING AND SELECTING

Use coloured pens to review your ideas. Take turns in writing positives and negatives about each idea or groups of ideas. Make sure your comments consider the choices and behaviour of the local people, the effectiveness of the ideas, and whether the idea can be made. Afterwards, work out which design received the most positive responses.

Think about what you have learnt from the other ideas – can the best idea be refined further and made even better?

## Planning and managing

### TASK 4 Practicalities

Discuss and plan how this solution can be made. Draw your team's design in greater detail and indicate:

- what materials are used, and whether any are recycled
- whether the solution has different components
- the size of the solution and the dimension of all its parts
- details of joins and construction methods
- how it works, including an explanation of how much water it can purify and the approximate time it takes.

## Producing

### TASK 5 Making a prototype

Make a working version of your final design. It can be made from a combination of new and/or recycled materials, or materials that mimic the chosen materials of your design. If your design is too complex to make, create a model that explains how it works.

## Evaluating

### TASK 6 Does it work?

If you can, test your prototype to see if it works and it is easy to use. What was your team's result? Did it work?

Evaluate your prototype or model against the requirements your team wrote in Task 2. How well does your solution satisfy these requirements? Are there some areas where your solution easily meets the requirement? Are there other areas that need further thinking, designing and modelling?

Remember that one of the keys to good humanitarian design is testing with the people, and tweaking and testing and redesigning and testing again. If you think you can improve your design, modify it and test it again.

## APPROPRIATE HOUSING SOLUTION

In the Lautém district of Timor-Leste, home ownership is very high – 99% of people either own their own home or live with their extended family. There's a wide range of materials that are used for building. Local materials are cheap and readily available. These local materials include bamboo, palm and coconut leaves, timber from surrounding trees, locally made mud bricks, stones and rocks, and materials from abandoned buildings. Other more-permanent materials such as concrete and corrugated iron need to be transported from the capital, Dili, and are very expensive. The quality of the building materials in the Lautém district indicates the economic standing of the owners, so people want to use the best materials available.

Of the current buildings in the Lautém district,

- about 75% have dirt floors and 21% have concrete floors; some are built on raised bamboo platforms
- 36% of walls are constructed from bamboo, and about the same from stones and rocks
- 76% of roofs are made from corrugated iron and 16% are made from palm or coconut fronds
- most buildings don't have glass windows.



**A Codo house made with stone foundations, earth floor, bamboo walls and corrugated iron roof**



**This house is raised on stilts and has a bamboo floor and walls, and the roof made from coconut leaves**

The construction techniques used for building need to be simple, as most buildings are constructed by untrained locals (some specific skills can be taught). There is very limited access to electricity, so most work is done with hand tools. Buildings need to be well made and strong enough to remain standing through flash floods, monsoonal rain, earthquakes and strong winds.

The weather is mainly hot, and stormy and humid during the wet season. Bricks and stone provide better protection from the heat, but corrugated iron on a roof allows a house to get very hot. House windows are often very small. In communal buildings, the walls are often not full height and allow light in and air to flow through.

Another distinct type of structure found in Timor-Leste is a small ceremonial building used to house special family keepsakes. These buildings are much more traditional in form and materials, but they are also very well made and durable to protect the objects inside.



**The owner of this house made the bricks for its walls**



**Codo community centre**

## APPROPRIATE HOUSING CHALLENGE

### REQUIREMENTS

As a team, you are challenged to design and create a model house for a family in Codo village. Your team needs to consider the following.

- Local materials are preferred as imported materials are very expensive.
- The house needs to withstand extreme weather and possible earthquakes.
- The house needs to protect people from heat, wind and rain.
- The house needs to be simple to build.

### DESIGN CHOICES

Your team needs to explore and make decisions about:

- materials that are the most cost-effective (do well for the least amount of money)
- materials that give the best results in terms of protection and strength
- house shapes and structures that best suit the conditions
- the types of construction techniques that can be made simply and without electrical tools.

## Investigating

### TASK 1 People's needs and wants

Re-read the information on page 190 under the heading 'Timor-Leste: working with hillside communities' and on page 193 under the heading 'Appropriate housing solution'. Make a list of the things that you think the Codo people want in their housing by following these steps:

- 1 Make a list of the needs that have been clearly stated.
- 2 List the aspects that are suggested or hinted at.

- 3 List the things your team think are important but haven't discussed or explained in detail.

CLEARLY STATED NEEDS	HINTED SUGGESTIONS	YOUR TEAM'S SUGGESTIONS

If we could talk to the people of Coda, there would be plenty of questions that would be helpful to ask about their housing needs and wants. Make a list of those questions (these might need to be answered by further research).

MATERIAL	COST (LOW/MEDIUM/HIGH)	PREPARATION REQUIRED (LOW/MEDIUM/HIGH)	STRENGTH, DURABILITY	PROTECTION FROM HEAT

## TASK 2 Exploring available materials

List the materials that are available, and think about the nature and qualities of each material. Conduct some research – if you hit a dead end, make an educated guess after thinking about where the material comes from and how it might be used.

## Generating

### TASK 3 Testing materials and shapes

#### THERMAL COMFORT TEST – HOW HOT DOES IT GET?

Make small four-sided boxes from two of the possible housing materials (or as close to them as you can get). For example, for traditional cob walls, you could make a small structure out of clay or clay-like mud mixed with river sand (1:2 ratio – press dried grass into the mud to make it stronger), and let it dry. To represent bamboo, you might have access to bamboo that you could carefully split and join together (perhaps with masking tape), or you could use icy-pole sticks. Try to join these without too many gaps.

- 1 Make a simple roof from very thin sheet metal or a triple layer of a folded aluminium take-away container, and another from thatch-like plant material (dried grass bound tightly together with thread or string).
- 2 Place a temperature sensor in each 'house' and place the roof material on top.
- 3 Place a heat source near your 'house' (make sure it is a safe distance and won't burn the materials).
- 4 Measure and record the inside temperature of the house over regular periods of time.
- 5 Repeat for the other 'house'. Measure and record these results.
- 6 Swap the roof materials and re-run the test.
- 7 Display your results in a graph and compare.

The results from this test will only give you an indication of the insulating qualities of materials. The only reliable results would be from full-scale testing of different materials in situ (onsite in Timor-Leste).



Courtesy Peter Hickson, Earth Building Solutions

Students at the University of Technology, Sydney, testing earthquake-proof building materials

#### TESTS FOR HOUSE SHAPES IN WIND AND RAIN

Think about the basic shapes of houses (including their roof shape). Some examples are shown in the diagram. Are there other shapes you can find that are used for the roofs of houses in tropical areas?



Some basic roof shapes of houses

- 1 Choose four roof shapes and make cardboard models of each shape.
- 2 Set up an experiment where you test how well each shape holds up to wind or rain. Plan how to do these tests. What will you use to simulate (mimic) wind or rain? Could you use a hairdryer or a watering can? How will you make sure each model house gets the same treatment? How will you hold your models in place so they won't move? What other things do you need to prepare for?
- 3 Carry out your experiment, making sure you are safe and don't make too much of a mess – use

a big tray to catch the water, or conduct the experiment outside.

- 4 What were your results? Which shapes performed best in extreme situations? Why do these shapes work well in these conditions?

#### **TASK 4** Generating ideas

As a team, explore a range of ideas for a basic house. Think about the possibilities in terms of materials, different building and roof shapes, flooring options, windows, etc. Come up with at least 6–10 sketches on a large sheet of paper. Show details and explain how each design works (with annotations).

Take turns commenting on the different ideas – writing about how each idea might work, its good points, and aspects you are concerned about (each person should comment on at least two ideas).

Reflect back on the list you wrote for Task 1. Does this make you think of other things you need to comment on?

### Producing

#### Choosing and making a model

On your sketch page, identify the design that seems to address all the requirements and is the best solution (mark it with a big tick and write some reasons for your choice).

Make a model of your design, imitating the planned materials as closely as possible. To make the size and scale of your model standard across the class, imagine the family that will live in your house are the size of a Lego person (40 mm high).

#### Sharing your ideas with others

Present your team's completed model house to your class. Describe the materials chosen and the features of the house, and explain your team's design choices.

## CHILD-FRIENDLY PLAY AREA SOLUTION

In the Lautém area of Timor-Leste, there are three Child-Friendly Spaces. These Child-Friendly Spaces are similar to preschool centres for children of two to five years of age. There are about 60 children and two teachers in each centre. The focus for the younger children is on learning through play activities, whereas the older children start having more structured class to prepare them for primary school. The children are also given lunch while they are there.

### CHILD-FRIENDLY PLAY AREA CHALLENGE

#### REQUIREMENTS

The community would like a play area to be developed in the Lautém Child-Friendly Space that is safe, fun and educational for children aged two to five years old. The following points explain the limitations and requirements of the situation.

- There is little or no money available for building the play area.
- The equipment must be safe for young children.
- Volunteers will build the play area (both local volunteers and partner organisations overseas).
- There is limited access to electricity for construction.

#### DESIGN CHOICES

Your team needs to consider:

- the types of activities/equipment that can be fun and educational
- the materials that are locally available (refer to the list for the previous challenge on page 195)
- how to make it simple to construct with hand tools.

## Investigating

### TASK 1 Exploring ideas

Collect as many pictures as you can of children's playgrounds. Glue them onto a large sheet.

- Think about the restrictions of your design situation. Write comments around your pictures that analyse what is possible in Timor-Leste and what isn't.
- Identify the aspects of the equipment that are fun, and explain why.
- Think about how some designs could be changed or modified to make them more suitable or practical.

## Generating

### TASK 2 Generate ideas

- On a separate piece of paper, each team member needs to develop and draw 2–3 ideas for sections of the play area. Make sure each idea is explained – the materials identified, descriptions of the playful and educational components, etc.
- As a team, spend 10–15 minutes discussing the positive and negative aspects of the designs.
- Swap pages with a team member, and develop new and extended ideas using someone else's original sketches as a starting point.

### TASK 3 Sift and select

Put all the ideas together on a table. As a group, decide on the play equipment components that best fulfil the needs of the children and the community, and which can be made within the limitations of materials, skill and equipment. Decide on 3–6 playground sections or components. Carefully draw a top view of each chosen component to a similar scale. Cut around the shape and experiment with the placement of the parts, thinking about how they join together and work as a whole.

## Producing

### TASK 4 Prototype

As a team, make a scale model of the play equipment using construction materials that mimic the real thing. Place the model equipment on a cardboard base board that is coloured to show the landscaping around the play equipment features. Explain your model and the ideas behind it to the rest of the class. As a class, share feedback about each team's model (remember to be encouraging).

## CASE STUDY

### Play in Zambia

#### Overnewton Anglican Community College partners with the Chibobo Orphanage

In 2004 and 2009, students, parents and staff from Overnewton Anglican Community College worked with locals in Zambia to develop playground areas for the Chibobo Orphanage and local primary school. In 2004, the playground design was developed by a Year 12 student designer as part of his VCE Product Design and Technology studies. He had to work within the limits of the situation, and had the added difficulty of developing the design before he had visited the site – knowing that it would probably change after talking with the locals.

The student designer completed a lot of planning in Australia before the school team flew out. His planning involved drawing up designs, listing materials and pricing components. The design was organised in stages or parts – if needed, these could have been easily modified to respond to the local

situation. However, most of the playground was built to the original plan. Mike, the teacher working with the design student and leading the visiting team of students and teachers, made the following observations.

#### Issues with materials:

- It was important to use locally available materials, so the design mainly used logs (locally grown eucalypts), chain and tyres. The tyres and chain were more difficult to obtain than expected, as the community typically uses everything until it falls apart (therefore, it is difficult to find materials to recycle and repurpose).
- The team had to debark the trees – this was a tedious process.
- The team encountered termites that ate through sections of the playground, even though the timbers were treated before they went into the ground.

- Nuts, bolts and washers were hard to source. Many were handmade and not a lot were available locally.

#### Other aspects:

- It was easy to dig holes in the ground (this was done by locals with a sharpened metal pole).
- The Overnewton team relied a lot on the local community to get some items ahead of time. This mostly worked well, but there were some little hiccups due to their limited experience with items such as enamel paint and solvents.
- Slides had to be specially made before the team arrived as they weren't commercially available in Zambia.
- A lot of the tools and a generator for construction were brought in with the school team, as they knew access to electricity would be limited.

#### Positives of the experience:

- Working with the locals in the building – a lot of two-way teaching happened.
- The creative problem-solving that came out of the shared nature of the task, particularly when designs needed to be modified.
- Seeing some of the anxious 'doubting' people become more positive. When the aims for the day were outlined, there were team members who found it hard to see that the team could achieve these goals. On the flip-side, when the team achieved more than it initially set out to do, these people were surprised and very excited. Having 16 team members and a lot of locals working together meant that a lot could be done in a day.
- Good planning, and breaking the tasks up into smaller achievable areas for different groups to do, worked really well.

From Mike, the team leader:

*'Seeing the community appreciation, and the joy on the children's faces when they got to use the playgrounds, was special. A lasting memory was when a lot of the women came to the playground late one day, after all the men had left, to have a look and then a 'play' (after some encouragement). To see their hesitancy give way to joy was quite special.'*



**Stripping the bark from the logs**



**Construction in progress**



**The finished playground**



**Women in the community enjoying the finished playground**

- 1 The focus in the early stages of the human-centred and humanitarian design processes is on observation, communication and collaboration. Explain why these things are so important. How does this lead to the development of better solutions?
- 2 Identify something in your school (a product or service, or a system) that could be improved to suit your school community better, or could be better designed for a particular group within your school. Discuss the problem and the needs of the people involved. Develop a questionnaire that finds out what people really think about the situation.
- 3 Find a story in the media about someone in need whose life was improved by a new solution to a problem. Describe the problem/need and the process of developing a solution, and explain why the solution works.
- 4 Discuss whether human-centred and humanitarian design is more **socially sustainable** than other ways of designing.
- 5 There are groups of people in need in Australia. Identify a group or community that has a specific problem or need – it could be related to health, their living environment, education, transport, etc. Discuss the details of the situation and explore why an effective solution hasn't been developed yet. If possible, invite someone from that community to talk with the class and answer questions. Can your class develop and test possible solutions?



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# 10

## SUSTAINABLE SOLUTIONS

### KEY KNOWLEDGE

The focus for this challenge is sustainability in the classroom – creating a new product from an old one. Students will use the design process to:

- ▶ investigate sustainability issues related to specific materials and products
- ▶ generate and develop ideas to re-use materials
- ▶ trial production methods suitable for these materials
- ▶ make and evaluate the finished product.

### DESIGN CHALLENGES

- ▶ Recycle a pallet into a sustainable product
- ▶ Recycle a pair of jeans into a sustainable product
- ▶ Form a 'Green Team' and build a kitchen garden

# FOCUS ON RE-USING MATERIALS

Re-using materials is one sustainable technique in designing products that can easily be adapted in the classroom. By re-using materials that have already served a purpose, you are replacing the need for new materials. You are also stopping those materials from becoming rubbish or going to landfill.

There are a lot of terms that need to be clarified regarding the continuous use of materials.

- **Re-use** – take something that has already been used in a product and make it into another product.
- **Upcycle** – re-use the materials in existing objects to create a product of higher quality or value. Ideally, materials that are upcycled can be used over and over and won't ever need to be discarded for landfill.
- **Recycle** – can mean the same as re-use but often implies that a process or system has been involved, such as a chemical process or machinery; for example, recycling plastics. Sometimes recycling also has a negative environmental impact or is too costly to sustain.
- **Recycled** – a material that has gone through a process or system making it suitable for use in a new product.
- **Recyclable** – a material (or product) that can be recycled.
- **Reclaim** – another term for re-use, usually referring to timber. It involves taking a material from a long-standing building or structure; for example, timber from a pier.

Other words relating to sustainability are often used around materials and their use in products.

- **Reduce** – to use materials carefully, not excessively, and to cut back when possible. This term is used in regard to sustainability
- **Rethink** – to consider if a product can have less of a negative impact. This applies to both the design stage of a new product and to the discarding of a 'used' product.
- **Repair** – to take action on existing products to make them last longer.

## Re-using materials

- 1 Make a list of materials you can see in the structure or interior of your classroom, and whether the materials could be recycled, re-used, reclaimed or upcycled. For each material, list possible new products that could be created.
- 2 Investigate one material you are familiar with in an existing product including its use and what needs to happen for it to be suitable for re-use. Draw a diagram to show this.
- 3 Name several products or objects that were purchased by your household in the last month. What will happen to them once discarded? What other uses could they be put to? Discuss your answers as a group or write a brief report.

## DESIGN CHALLENGES

There are three challenges in this chapter, all relating to creating a new product from an old one. The first challenge is to recycle a pallet into a sustainable product. The second challenge involves recycling a pair of jeans into a sustainable product. The final one is a team challenge to build a kitchen garden.

## RECYCLE A PALLET

### What is a pallet?

A pallet is a type of stackable platform on which to stack boxes or goods that can be lifted by forklifts. Strapping or plastic wraps secure the loads onto the pallet. They are used to transport goods all over the world by trucks and ships, and double up as useful storage organisers.

Pallets are made to be sturdy to handle extremely heavy goods, durable to withstand long-distance journeys, and flexible to avoid cracking, splintering and warping.

Wooden pallets have supports called stringers, which are pieces that make up the frame. Deck boards are fixed to the frame, usually with nails or staples, to create a platform. Different constructions are used for different materials and for different pallet uses.

Pallets come in a variety of sizes to suit different sizes of boxes and containers. They also come in a variety of materials, and many pallets are fitted with tracking devices.

If pallets are in use for shipping overseas, they must be made of materials that don't carry invasive insects or plant viruses.

### What are pallets made from?

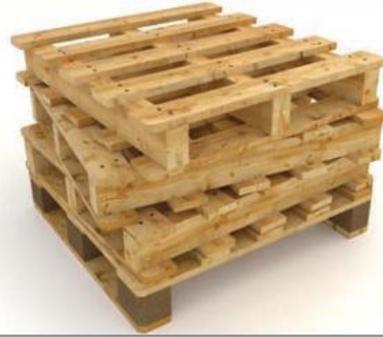
Most pallets are wooden, but they can also be made of other materials such as plastic, cardboard, metal and composite materials. Pallets are suitable for different purposes depending on the materials they are made from.

#### Timber

Most Australian pallets are square, are usually made of hardwood, and the deck boards are 1165 mm long. They are made from timber of varying quality. Less expensive pallets are made from softwood, such as radiata pine. Better-quality pallets are made from hardwood, such as Tasmanian oak.

Reclaimed timber, which is usually good quality, is often used to make pallets and comes in various grades. Raw untreated timber can be susceptible to insects, bacteria and viruses, so it is not compliant with international standards and regulations. To be compliant, it must be heated (to specifications) or

chemically fumigated (which is poisonous), and labelled as such.



Shutterstock.com/Svens

#### Wooden pallets

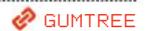


Shutterstock.com/Carl Stewart

#### Planter made from pallets

#### Tip

Free pallets are often advertised on classified websites such as Gumtree.



## CASE STUDY

### Kristen Montgomery – sneaky boarding design

Kristen Montgomery is a designer who uses materials from pallets, skateboards and dismantled buildings. She draws upcycling inspiration from many places such as Danish furniture, artists, and from the people around her. When travelling in Europe, she saw old doorways made into walls, table lights made from connecting old light fittings and toys, and containers turned into vibrant restaurants and bars.

Kristen started building furniture 10 years ago as a joinery apprentice, and has a solid understanding of how things go together. The recycled wood in her projects is matched and joined to create the right look, and then sanded and polished by hand. She says that upcycling involves a lot of trial and error due to the pre-used aspect of the material and the

irregularity of dimensions. It is very rarely straight, or without cracks and knots. Her advice is to let the timber dictate the shape, do practice runs, and keep designs simple.



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#### Sofa chair made from reclaimed pallets by Kristen Montgomery

Upcycle That is a website dedicated to upcycling. It was founded by Jacques Karsten and Judy Rom and provides upcycling ideas, inspiration and tutorials. Many of the projects have been created with re-used pallet timber. Make It Wood website also showcases projects upcycling wooden pallets.

 UPCYCLE THAT

## Plastic

Plastic is lightweight and suited to pallets for long-distance transportation of goods. Plastic pallets move fast through customs due to the lack of bacteria and other organisms. They are easily cleaned and sterilised, which means they are also suitable to transport food.

Plastic can be **moulded**, which means plastic pallets are made without joins and can have grooves and slots that make them safe and convenient to stack. If required, plastic pallets can also be reinforced with steel.

Plastic pallets have some negative aspects. They are susceptible to plastic creep (deterioration due to heat and pressure over time), cannot be easily repaired, and cost more than timber pallets.



Plastic pallets

## Metal

A small number of pallets are made from steel, carbon steel, stainless steel or aluminium. The different metals have different qualities and are suited for specific purposes; for example, steel is suited for heavy loads and long-term storage.

In general, metals are strong, rigid, durable and insect-free. Because metals don't have splinters, metal pallets are safer for handling. Metals don't harbour bacteria, but some metals are susceptible to rust over time. While metal can be expensive, it can be cost-effective for pallets due to both its durability and recyclability.

## Cardboard

The cardboard used in pallets is usually corrugated. Cardboard pallets are lightweight and inexpensive, making them easy to handle and with lower shipping costs. They are suitable for transporting lightweight products, particularly foodstuffs.

Cardboard pallets do not have nails, therefore handlers will not get splinters. They are usually custom-made and manufactured to specific sizes, which makes them easily stackable and also saves storage space. Cardboard pallets are usually 'single-use', which has its benefits for hygiene and lack of ongoing maintenance required. But single-use is a negative aspect in terms of sustainability, unless the pallet is put out for recycling. Australia has many companies making cardboard pallets.

 CARDBOARD PALLETS

## Composite materials

Some pallets are made from composite materials such as waste timber from unwanted pallets and waste wood fibre from sawmills. Other materials used include plywood, strand board and corrugated fibreboard. This use of waste material can reduce the felling of thousands of trees every year.

 CHEP PALLETS

FOCUS ACTIVITY

### Selecting pallets

- 1 Look at some pallets of different sizes that are made of different materials. What goods would be suitable to transport in each type of pallet? Give reasons for your answers.
- 2 Look for pallets in your neighbourhood and discuss their purpose. Do you think they are headed for landfill or to be collected by a pallet service?

## Sustainability issues

Pallets would have been used to move almost every product you purchase. You can imagine how many millions of pallets exist worldwide. Thousands of these get sent to landfills all over the world (except for metal pallets, which are almost always recycled).

On the positive side, timber pallets that haven't been treated chemically can be turned into low-grade mulch for parks and gardens. Good-quality pallets

are often owned by a pallet company and are sold, collected, cleaned, repaired and re-used as much as possible. However, many of these become broken at some stage and, if not used for composite materials, they are sent to landfill.

Many warehouses and stores are happy to give away some pallets for free. By using a pre-used pallet, you are reducing the need for new timber.

## Obtaining pallets

This challenge assumes you will be using timber pallets. Other materials can be used, but different tasks will need to be created. If you plan to use plastic or metal pallets, you may need to purchase them yourself and you will also need suitable equipment and the necessary safety set-up. Pallets made of composite materials could also be hazardous, depending on how much cutting and sanding is involved. Cardboard pallets would probably need to be purchased.

With some enquiries, you will be able to gather timber pallets for free or for a small fee. Depending on their availability, you may have a whole pallet per student or several pallets can be shared among the class.

Once timber pallets are found, it's important to determine if they have been treated with wood preservatives, fungicides or pesticides, or if they have had any chemicals spilt on them. This can be hazardous when sawing or sanding due to dust inhalation. You can check the markings on the pallets but it's better if you can find the source. In most cases, those without any marking are used within Australia only and will be safe. However, the marking 'MB' indicates the pallet was treated with methyl bromide, which is not safe. It is not recommended to use coloured pallets for indoor use as the paint could be hazardous.



## What you need

You are free to combine the pallet timber with other materials, but this will depend on availability and the time you have. Your teacher will direct you with this.

## What you will need for this design challenge

ESSENTIALS	HELPFUL	OPTIONAL
A timber pallet	Spirit level	Twine
Lever and claw hammer	Hand plane and coping saw	Drawer knobs
Steel ruler and set square	Power drill or pedestal drill	Cushions
Bench hook and saw	Sander	Coat hooks
Sand paper	Nails and screws	Shelf bracket
Varnish	Other materials (e.g. plywood, acrylic sheet, metal sheet)	Washers, nuts and bolts

## Possible products

Depending on your timeframe and amount of pallet timber available, here are some product ideas.

- **Small items** (or parts of other products) – lid, silhouette for the side of a box, handle, rail, pen-holder, photo frame, coat hook or coathanger, iPad stand, class or individual mobile phone holder, jewellery (earrings, bangles, necklaces, brooches, etc.), jigsaw puzzle, toys.
- **Larger indoor items** – lounge furniture, umbrella rack, bicycle gear storage, planter, sofa, foot stool, magazine holder, coffee table, wine rack, step ladder, mini-stool.
- **Outdoor items** – hammock base, compost bin, birdhouse, gate, kennel, picnic stool, table and stools for the garden.

## RECYCLE A PALLET CHALLENGE

You are to use an existing pallet to design and make a new useful product.

### REQUIREMENTS (LIMITS OR CONSTRAINTS)

- Your product needs to be made from a certain percentage of pallet pieces, as specified by your teacher.
- You can combine your product with other materials as specified by your teacher (or provide materials and components from home).
- Size limits will be set by your teacher.
- You must include joints other than butt joints, as specified by your teacher.

## DESIGN CHOICES

You will need to make decisions regarding:

- the product to make, its purpose and the user
- how to improve the aesthetics of the used pallet pieces (either by decoration, fine sanding or emphasis on faults)
- any decorative element (such as holes, carving, gluing of plywood shapes or acrylic additions)
- other components you might add.

## Focus for assessment

For the assessment of your design work, your teacher will be looking for:

- » your research into and understanding of the limits of the pallet material available
- » the effort you put into preparing your pallet pieces
- » a design brief that states the requirements of the challenge, the intended product, and gives criteria for success
- » trial processes on pallet pieces and any other material
- » diagrams or drawings with annotations that show ideas and how the product will be made
- » some planning, making and a journal of progress
- » the joining methods used and their accuracy
- » the aesthetics of your finished product (how you made it look beautiful)
- » a finished product and an evaluation that reflects on your input.

## Investigating

### TASK 1 Investigate your pallet

- 1 Conduct some research and discuss or write a report of your findings: What are pallets used for? Where did your pallet come from? What is it made from? Why are pallets discarded? What usually happens to them when they are discarded?
- 2 Take a photo of your pallet and insert it into a document. Use annotations to explain what the pallet was used for (if you know) and what it is made from. Write a paragraph underneath that answers the other research questions. Comment on the sustainability issues regarding the use and discarding of pallets.
- 3 On a new page, insert the photo again or draw a diagram to show its structure, and analyse the pallet's sustainability by considering some of the following aspects.

- Source of materials – Are they finite or renewable?
- Pallet structure – Is it durable or fragile? Is it easy to repair or better to take apart for re-use or recycling?
- Materials – Can they be reclaimed or recycled?
- Benefits – What are the economic, social and/or environmental benefits of this type of pallet?
- Dimensions – What are the measurements of your pallet?

### TASK 2 Disassemble

Pallets come in different sizes and each pallet is made up of timber that is not strictly of the same dimension. For these reasons, it is a good idea to dismantle your pallet and take stock of what you have. You may need to be flexible with the design process – will you write the design brief first or will you wait until you know the dimensions of your timber?

### Safety

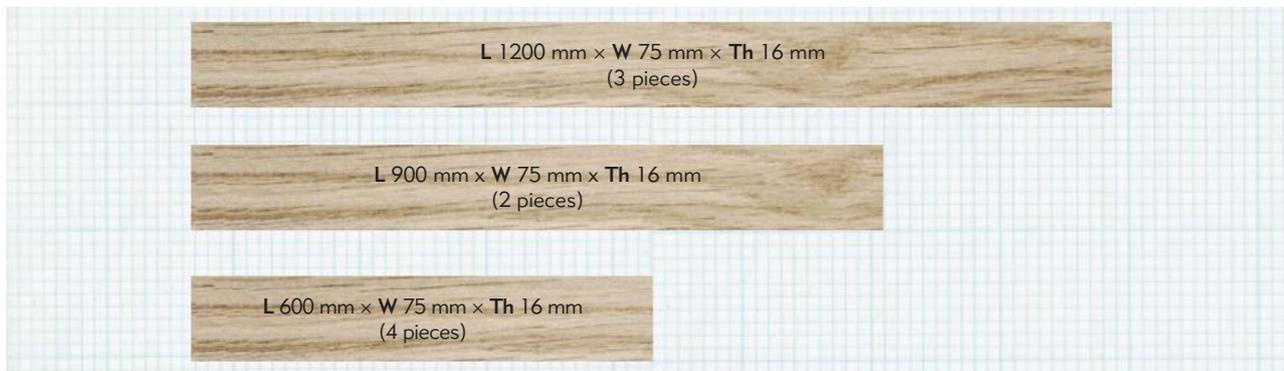
When taking your wooden pallet apart, proceed gently and with caution to avoid any damage. Follow your teacher's instructions for safety, and only work with tools you have been directed to use. Wear safety goggles and safety gloves to avoid splinters. Tidy up the pallet pieces when you are done.

### HOW TO DISMANTLE A WOODEN PALLET

### AESTHETIC DECISIONS

- Are you are going to leave the splits, holes and cracks in your pieces? Pallet pieces can be different sizes, so you will need to check them and cut them all to the same size.
- Are you are going to trim the pallet pieces so you only used undamaged pieces? If so, get rid of any metal (nails, screws, staples, etc.) and cut off damaged parts so you are left with only 'clean' pieces.

When cutting, follow your teacher's instructions on how to make each piece of timber square, and how to cut accurately without damaging the timber (for example, to avoid chipping or splintering the underside when you saw). This will make a big difference when joining the pieces together. If your pieces are a few millimetres different and not square, you may end up with a skewed product.



### A visual list can be helpful

#### STOCKTAKE OF PALLET PIECES

Check the width and thickness of all the pieces, as they will not be the same. Consider grouping similar pieces together for the one project.

Create an inventory (measure up what is available to you) from the pallet. A visual method might help here.

#### TASK 3 Design brief

Start your design brief with a short explanation of your pallet (type of timber and dimensions), what you intend to make it into, and who the user will be.

Next, give some requirements such as the size, type of joints to be used, quality expected, what aesthetics will suit the user, and the finish date.

Create four or more criteria for success from areas such as aesthetics, suitability or usefulness to the user, quality of the product, and safe to use.

#### TASK 4 Research for inspiration

Investigate existing products for the user. Present the products on a page and annotate to explain how you will use some of these ideas. This could be a combination of products made from recycled pallets and images of the type of product you intend to create.

## Generating

#### TASK 5 Drawing up your ideas

Draw some ideas for what your product could look like and how to make your product. Remember to consider the limits of time, size of pallet pieces, joints required, and skills you have. Consider aesthetics –

how can you make the product look beautiful. What shapes could be cut out, or added to the exterior?

Decide on the best idea (circle and name it as the best idea).

Create a working drawing by determining the dimensions (how big will your product be, the length of parts, where the joints will go, decorative features, other materials, etc.).

If you have decided to use your pallet pieces to 'house' something, such as a cushion or mattress, you will need to create the dimensions accordingly.

#### TASK 6 Practise two joins

Use small parts of the pallet or share a pallet with classmates to do trial runs of some joins. Aim to practise a joint your teacher has specified and to practise it until you achieve an accurate result.

Follow the tips and instructions your teacher gives you to practise joins, or try the following examples.

#### EXAMPLE 1: MEASURING AND MARKING

- Use a steel rule and a pencil to mark a spot lightly along the edge for the desired length. Be fussy here and mark the exact number of millimetres required.
- Find the straightest edge of your piece of timber and place your set square exactly so that when you rule with your pencil, it matches perfectly with the spot you marked.
- Hold the set square firmly and rule a line across the timber.
- Check your measurement with the steel ruler.



**Measuring and marking**

**EXAMPLE 2: SAWING (PRACTISE, PRACTISE, PRACTISE)**

- Draw a straight line across a scrap piece close to one end.
- Mark the material closest to the edge as waste with a scribble or crosses.
- Check to make sure you have a sharp saw.
- Practise cutting on the waste side of the line with your saw. Try again and again until your sawing becomes straighter and more accurate, or until the scrap is too small. Ask your teacher for tips on how to handle the saw and how to stand.
- To avoid chipping the underside of your saw cut, use a bench hook or a piece of scrap wood under the timber to be cut.
- If using a bench hook, press the pallet piece up against the support, hold firmly, and saw against the guiding edge.
- If not using a bench hook, clamp the work to bench with a piece of scrap wood underneath, and with a straight-edged piece of scrap wood clamped on top to guide the cutting.

Visit the Popular Woodworking website to search for hand-sawing tricks and information on how to use a bench hook.



**Sawing**

**EXAMPLE 3: USING A MARKING GAUGE**

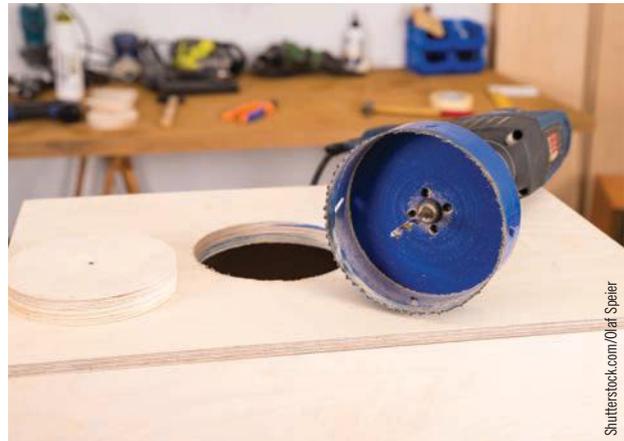
- Use a marking gauge to mark out three different depths: 7 mm, 10 mm and 12 mm.
- With a steel ruler, check your marks for accuracy.

Visit the Joint Selection website for information on joints, uses, varieties, and how to mark and cut.

 **WOODWORKING TIPS**

**EXAMPLE 4: DECORATIVE METHODS**

- For circles – mark out their placement, and then use a hole saw or drill (following your teacher's instructions).
- To cut out shapes – mark out the shape, drill several holes inside the shape near the edge; 'thread' a coping saw through the hole, secure your work in a vice and cut, and lastly smooth out the cuts with a file or sandpaper.
- To add shapes – cut the shapes out of the material you are using (plywood, acrylic, etc.) and trial methods of attaching or gluing them. If using acrylic, refer to page 142 in Chapter 5.



**Using a hole saw creates a circle**

**Safety**

When sawing, protect yourself from dust at all times by wearing protection and having good ventilation. Wear an apron that covers as much of your skin and clothing as possible. Vacuum up dust when possible, and do not blow it.

Whatever tools you use, be aware of what's going on around you, use the proper safety measures and equipment, and use the correct tool for the task. Accidents can occur from minor incidents such as trying to catch a chisel rolling off the bench.

## Example production plan

PRODUCTION STEP	MATERIALS NEEDED	TOOLS/EQUIPMENT NEEDED	SAFETY MEASURES (WHERE NEEDED)
1 Measure, mark and cut pallet pieces; use a plane if needed	Pallet pieces		
2 Measure, mark and cut joints			
3 Measure, mark and cut ... (other materials)			
4			
5			
6			
7 Dry check to make sure all parts fit; assemble as required; sand and varnish			
8 Test product for quality and safety			

## Planning and managing

### TASK 7 Plans

Think ahead to the main processes involved in your production, such as measuring and marking, cutting, shaping, joining (or attaching) and finishing (filing or sanding, varnishing or painting). Create your own production plan table based on the example above. You will need to fill in the missing steps.

## Producing

### TASK 8 Making your product

Use your plans to guide you to make your product, following appropriate safety precautions at all times. Wear a mask to prevent any dust inhalation. Aim to get the best quality in all your processes by following instructions and practising.

Take photos as you go to create a journal of your progress. There may be a lot of changes to your original plans. Add captions to explain these changes and present the journal when finished. You can use a table format as follows.

## Production journal

JOURNAL	DATE	TIME TAKEN	REFLECTION
Photo and explanation of what you completed			What went well? What needed to be changed or adjusted?
Add a row for each session			

## Evaluating

### TASK 9 Evaluation of your finished product

Write down the criteria for success from your design brief. Directly underneath each criterion, explain how you checked it and how your finished product measures up.

#### EXAMPLE EVALUATION FOR THE PALLET CHALLENGE

##### Criterion for success 1:

- The magazine box must be safe and firm.

**Checked by:** *I wriggled the box to see if it was solid; I ran my fingers around all the edges to see if there were any rough bits or any chance of splinters; I inspected the box for any sharp edges; I checked the accuracy of the joints by measuring the gaps; I picked the box up to see if it held together well; I tugged the added decorative bits to see they were secure.*

**My opinion:** *My box is safe as it is sanded smoothly everywhere with no chance of splinters. The only weak point is the joint where there is a gap of 3 mm, and it might come apart there in future. I will need to fix that. The acrylic animal shapes are screwed on so they will not come off.*

# RECYCLE A PAIR OF JEANS

## What are jeans and what are they made of?

Levi Strauss and Jacob Davis patented jeans in 1873. Jeans were named after the Italian city Genoa, where a cotton called jeane was manufactured. Strauss and Davis made a pair of sturdy work pants from denim and reinforced them at stress points (such as pockets where they tend to rip) with copper rivets.



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### Denim jeans

The word denim comes from 'serge de Nîmes', the French phrase for a sturdy cotton fabric from Nîmes, which became denim in English. Denim is a twill fabric, which means the weft passes under two or more warp threads. Warp threads are dyed in indigo and pressed tighter together, while weft threads remain white. This is why denim appears more blue on one side and more like white on the other. Blue was chosen in the original design as dark colours hide the dirt. Denim was always 100% cotton until the 1970s when it was mixed with elastane for stretch.



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### Denim fabric

Originally, the blue colour came from *Indigofera tinctoria*, a native plant of India. However, the colour didn't last more than a few washes. Today, most

denim is dyed with a synthetic indigo as organic indigo dye needs to go through an elaborate process. Synthetic blue lasts through many washes but still fades to give the desired worn out look.

Jeans moved from work pants to a fashion item in the 1950s. Since then, jeans have evolved through many styles; for example, baggy, boot-cut, flared, high-waisted, low-waisted and skinny leg. Most jeans are made of stretch denim, which has elastane or lycra added.

### FOCUS ACTIVITY

## Jeans

- 1 Think about the style of the jeans you own. Check the label of each style of jeans to see the fibre content (what the denim is made from).
- 2 Total up how many pairs of jeans the class owns as a whole. Discuss how long you have had them and how long you intend to keep them. Discuss the variety of jeans that are owned by class members.

## Sustainability issues

There is a long chain of processes that go into making a pair of jeans, and each stage has its own environmental implications.

Firstly, the cotton that is grown requires a large amount of chemicals. This is to deal with boll weevils – beetles that destroy the cotton boll. Picking cotton exposes workers directly to these hazardous chemicals. Over 50% of cotton is produced in China, India and Bangladesh, where labour costs are low. Communities in cotton-growing areas statistically have poor health outcomes.



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Once picked, the cotton must be cleaned and processed, turned into yarn and dyed, and treated with sizing. The cotton yarn is then woven as twill, cut in layers, sewn on an assembly line, and washed or treated (for example, stone-washed or sprayed with sand or chemicals to achieve a look). The jeans are then pressed, boxed and distributed. Apart from the hazardous chemicals involved, thousands of litres of water are needed for all this processing.

Worldwide, close to 20 000 tons of indigo is produced for dyeing jeans. Synthetic indigo is created from benzene derivatives from petroleum, and needs to be treated with yet more chemicals, including hydrogen cyanide, to turn it into indigo dye. This process requires a lot of water and also creates huge issues with waste, most of which pollutes waterways and water sources.

One big negative for a fashion item such as jeans is the amount that consumers buy, wear a few times, and then discard into landfill.

On the positive side, many companies are looking to use organic cotton and safer dyes in the future. They are urging consumers to wash and dry their jeans less to save on water and energy.

By using an existing pair of jeans, you are saving them going to landfill and reducing the need for the resources that go into creating new denim fabric.

Mud Jeans Circular Denim is a Dutch company that 'rent' their jeans to customers, offer free repairs, and at the end of use they take the jeans back to be cut, shredded and re-spun into a new pair. Visit the Mud Jeans website to learn about traditional cotton and the process this company uses.

 MUD JEANS

For more information about the hazardous chemicals used in the fashion industry, look for Greenpeace's article '*Toxic threads: The Big Fashion Stitch-up*' (2012) and the accompanying technical report.

 TOXIC THREADS

## Obtaining jeans

Jeans can be found not only in your own household but in opportunity shops (where they are notoriously hard to 'on-sell'). Choose a pair that has the label intact so that you can be sure of the fibre content. Fibre content is a term that refers to what the yarn is made from (such as 100% cotton, 100% polyester, or a mixture).



A cushion cover made from recycled jeans

## Possible products

Depending on the timeframe you can choose a very simple product or a complicated product. To make a bag of any description, refer to the detailed instructions given for the Carry-it challenge on page 144.

- Simple products – book cover (with a button, button loop, and a tie to keep it from getting lost), simple bag, sleeping mask, belt, pocket, table napkins in a packet.
- More complicated products – bag with straps and inner pockets, vest, skirt, pair of shorts (not just by cutting the legs off a pair of jeans, but by creating a completely new design), hat with a brim, apron, soft toys.

## Tip

Type the term 'recycling jeans' into a search engine to see hundreds of ideas for your product.

## RECYCLE A PAIR OF JEANS CHALLENGE

You are to use an existing pair of jeans and turn them into a new useful product.

### REQUIREMENTS (LIMITS OR CONSTRAINTS)

- Your product needs to be made from a pair of jeans.
- You can combine it with other materials as specified by your teacher (or provide materials and components from home).
- You must include a fastener and some other **embellishing** processes as specified by your teacher.

### DESIGN CHOICES

You will need to make decisions regarding:

- the product to make, its purpose and the user
- the type of fastener, **embellishments** and whether they will be functional or decorative
- the types of seams
- other fabric or components you might add (such as buckles, buttons, press studs, etc.).

## Focus for assessment

For the assessment of your design work, your teacher will be looking for:

- » the analysis of your jeans to re-use
- » a design brief that states the requirements of the challenge, the intended product, and gives criteria for success
- » trial processes on your material
- » diagrams or drawings with annotations that show ideas and how the product will be made
- » some planning, making and a journal of progress
- » accuracy and neatness of seams used and how the fastener is attached
- » the aesthetics of your finished product (how you made it look beautiful)
- » a finished product and an evaluation that reflects on your input.

## Investigating

### TASK 1 Analyse your jeans

Take a photo of the pair of jeans you have chosen to re-use. Insert it into a document and annotate the image to show:

- the fabric it is made from (check the label)
- the care instructions
- parts of the jeans (such as rivets, belt loops, zippers, buttons and studs) and indicate which of these are fasteners
- state what each of the parts are made from (for example, plastic or steel zipper)
- type of joins and seams used (such as straight stitch only, double seams, overlocking, extra stitching, reinforced spots, etc.)
- the thread colour used.

### TASK 2 Taking the jeans apart

You may like to wash and dry your jeans before you start your project. Allow plenty of time for this step.

The fastest and simplest method to access the fabric is to cut the jeans apart with scissors. Cut as close as possible to the seams to maximise the fabric available. A slower method is to use a 'quick-unpick', and pick all the thread out of the jeans.

Once you have your pieces ready, move on to thinking about what you will design and make with them.

### SOME IDEAS TO CONSIDER

- Cut the denim into strips.
- Use strips to knit the denim.

- Combine denim strips with different-coloured denim or a different material.
- Use strips for weaving or plaiting, or making pom-poms or tassels
- Dye some or all the denim to get a different shade of blue (make sure you research the correct dye for the fibre content).
- Distress the denim by tying up parts and soaking in strong detergent and/or rubbing with a pumice stone.
- Ruche or gather the denim, sew denim as panels, or combine denim with other fabric.
- Make rosettes or ruffles.
- Decorate with hand-stitching, or machine-stitching in contrasting thread.



Denim rosette

### TASK 3 Design brief

Start your design brief by explaining that you have a pair of jeans to turn into something useful, the product you intend to make out of them, its purpose, and who the user will be. State some of the challenge requirements and your own product requirements; for example, a fastener must be included, the processes to be used, the quality expected (such as straight seams, no missed sections of sewing, no unfinished edges, buttons aligned with buttonholes, fastener to

match on both sides, etc.), functional aspects, what aesthetics will suit the user, and the finish date.

Create four or more criteria for success from the following areas:

- function (how it should work, and suitability or usefulness to the user)
- aesthetics (how it should look to suit the user, colours, shapes that they would like, decorative elements, etc.)
- quality of construction (straight, accurate seams, reinforced if and where necessary, neat and tidy finish, reliability of fastener, etc.).

#### TASK 4 Research for inspiration and processes

Investigate existing products for the user. Present them on a page and annotate to explain how you will use some of these ideas. This could be a combination of products made from recycled jeans and images of the type of product you intend to create.

Include some processes and 'how to do' them, and also include some decorative ideas. There are many short videos online to show you how to complete processes to a high standard.

### Generating

#### TASK 5 Drawing up your ideas

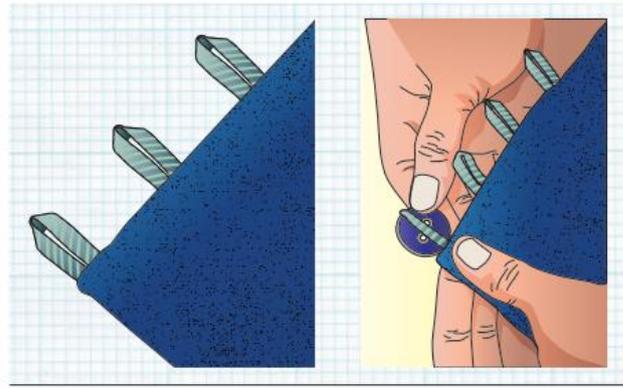
Draw some ideas for what your product could look like. Remember to take into account the amount of denim you have, a type of fastener, the processes required, other materials you would like to include, and the skills you have. Think about aesthetics – how can you make the product look beautiful for your user? Consider shapes and processes that could be decorative.

Decide on the best idea (circle and name it as the best idea). Create a 'flat' (working drawing) by working out the pieces, where they will be joined, and their placement. See the example of a flat for a backpack in Chapter 1 on page 24.

#### TASK 6 Practise two processes

Use scrap denim to practise your sewing. Aim to practise a process your teacher has specified, and to practise it until you get an accurate and professional-looking result.

Start your journal at this point and show how your skill has improved with your first and following attempts of each process.



Example of a process to trial button loops made from lengths of fabric tube.

 HOW TO SEW BUTTON LOOPS

### Planning and managing

#### TASK 7 Making plans

Think ahead to the main processes involved in your production, such as measuring and marking, cutting, shaping, joining (or attaching) and finishing (sewing in threads and ironing). Create your own work plan in a table based on the following example. You will need to fill in the missing steps.

#### Safety

When sewing, follow the safety guidelines on page 147 for the Carry-it design challenge. Follow up on the quality tips given on page xx for the Carry-it design challenge. You can also find many processes explained step-by-step online. Make sure your machine is fitted with the correct needle (and that it is sharp) for sewing the type of denim you have. Consider topstitching to strengthen all seams.

#### Example work plan

PRODUCTION STEP	MATERIALS NEEDED	TOOLS/EQUIPMENT NEEDED	SAFETY MEASURES (WHERE NEEDED)
1 Measure, mark and cut denim for ... (name pieces)	Denim		
2 Sew (name piece or part) to ...			
Add rows for each process in your production.			

## Project journal

JOURNAL	DATE	TIME TAKEN	REFLECTION
Photo and explanation of what you completed			What went well? What needed to be changed or adjusted?
Add a row for each session			

## Producing

### TASK 8 Making your product

Use your plans to guide you to make your product, following appropriate safety precautions at all times. Aim to get the best quality in all your processes by following instructions and practising.

Take photos as you go to create a journal of your progress. There may be a lot of changes to your original plans. Add captions to explain these changes and present the journal when finished. You can use a table format above.

## Evaluating

### TASK 9 Evaluation of your finished product

Write down the criteria for success from your design brief. Directly underneath each criterion, explain how you checked it and how your finished product measures up.

#### EXAMPLE EVALUATION FOR THE JEANS CHALLENGE

##### Criterion for success 1:

- The pencil case must hold the pencils securely so they don't fall out.

**Checked by:** *I put 10 pencils in the case, held it upside down, and threw it around a bit.*

**My opinion:** *It keeps them secure – not one pencil fell out.*

### TASK 10 Evaluation of the process

Include an evaluation about the design process by responding to these points.

- Which part of this project did you enjoy?
- What was difficult about working with pre-used material?

- How hard was it to plan this challenge? Give an example of something that wasn't working as planned and the changes you made to fix it.
- Explain how the trial runs or practice helped you.
- What new skills did you learn and how you could you improve them further?
- How could your product be improved? Refer to the design (how it could fit together), the aesthetics (how look more beautiful), or the quality of its construction (accuracy of joins and attachments).

## 'GREEN TEAM' KITCHEN GARDEN

It is always healthier for us to eat food that is as fresh as possible. It is also good for the environment to grow our own food – it causes less environmental impact than transporting food from farm to shop to kitchen. This challenge asks teams of students to develop solutions for different elements of a big project – creating a garden system to grow herbs.



## KITCHEN GARDEN CHALLENGE

You are to work in teams to create a sustainable herb garden for your school or for a community space.

### REQUIREMENTS (LIMITS OR CONSTRAINTS)

- Consider the size and cost limits your teacher gives you.
- Recycled materials must be used as much as possible.
- The kitchen garden should be suitable for edible plants that are available for most of the year.
- The structure must hold plants.
- You must develop a system of watering and soil improvement that keeps plants growing.
- Consider the needs of your school or the community group to benefit from the kitchen garden.

Your class will be split into the following design focus groups:

Team 1: Plants – investigating and choosing plants

Team 2: Soil – investigating and developing a healthy soil plan

Team 3: Watering – developing a watering plan

Team 4: Planting structures – designing planting structures

Team 5: Environment – developing a landscape plan (thinking of the space/place)

### DESIGN CHOICES

Each of the teams will need to make decisions regarding their focus area.

### Focus for assessment

You will be assessed as a team and as an individual. Your teacher will be looking for:

- » good listening and perceptive thinking when considering the situation
- » detailed and relevant research that helps the team to make decisions
- » creativity and good problem-solving when developing design solutions
- » active participation during production
- » honest contributions when evaluating the project.

As an alternative approach, you class might be asked to develop:

- an indoor green area
- a vertical green wall
- a sensory garden (for people with vision impairment)
- an outdoor teaching space
- a small habitat area (such as a native wetland or pond)
- a planting product/solution for your home.



A vertical garden

### Investigating

#### TASK 1 Assessing the situation

Your teacher will discuss the place, space and people your class will be designing for. As a class, develop a wall display that describes the current situation. This will involve:

- taking photos of the space
- drawing a bird's-eye view plan of the area
- talking to the people who currently use the space
- talking to the people who might use the produce from the finished garden (for a school, talk to the Food Technology teachers and students from different levels)
- finding out the requirements of the people who manage the space – their limits and constraints (for a school, talk with the principal and the garden maintenance team).

Display and share this information with the rest of the class. Discuss the connections this challenge has with sustainability (think about environmental, social and economic sustainability).

#### TASK 2 Defining the challenge

As a class, write a design brief that clearly describes your garden development challenge. Give an outline of the situation that describes:

- who you are designing the space for
- why the planting area is needed

- what different uses it might have (in addition to growing produce, other purposes such as teaching, quiet space, eating area, etc.)
- the approximate size of the planting area needed
- the materials that might be available

You also need to list the limits you have, such as:

- budget
- time
- space/area.

As a class, develop a list of at least 8–10 criteria for success for the project. Make sure you cover all team areas, the needs of the people involved, and the constraints/limits of your brief.

Display your brief and criteria clearly on your project wall.

### TASK 3 What do you need to know?

Each team needs to conduct in-depth research into their area. Use the research questions below to help guide your investigations.

Display your team’s information, and share your findings with the class.

## Generating

### TASK 4 Developing solutions

Work as a team to develop a solution for your area. You will need to explore a range of possibilities (sketch, write notes, create models), make decisions, and draw your team’s solution. Some teams might need to share information as their designs have an impact on other areas. For example, the Planting Structures team need to discuss and share ideas with the Plants team and the Environment team. The outcomes of each of the teams are:

- Team 1 – a herb planting plan (drawing, list of herbs, and a planting schedule)
- Team 2 – a soil improvement and composting plan, including plans for a compost bin system
- Team 3 – a watering system plan (drawing, list of parts, and a seasonal schedule for watering)
- Team 4 – drawings and materials list/costing for planting structures
- Team 5 – an overall plan for the space (scale drawing and plans for any additional structures).

TEAM AREA	RESEARCH QUESTIONS
1. Plants	<ul style="list-style-type: none"> <li>• What herbs are available and grow well in your area?</li> <li>• Perennial or annual?</li> <li>• Growth patterns, size, required space?</li> <li>• Amount of sunlight required?</li> <li>• Soil and water requirements?</li> <li>• Propagation methods?</li> </ul>
2. Soil	<ul style="list-style-type: none"> <li>• How is soil tested?</li> <li>• What soil is currently in the area?</li> <li>• What soils are needed in the garden area for different plants?</li> <li>• How can the soil be improved?</li> <li>• Does the school/community have a compost heap? (If not, look at starting one.)</li> </ul>
3. Watering	<ul style="list-style-type: none"> <li>• How often do these plants need to be watered? (Talk to the Plants team.)</li> <li>• How much water is required?</li> <li>• How does this change over the seasons?</li> <li>• Types and cost of different watering systems? (Such as hose and reel, water capture, tanks, etc.)</li> <li>• The options for class rostering?</li> </ul>
4. Planting structures	<ul style="list-style-type: none"> <li>• Location of structures – ground, raised, vertical?</li> <li>• Types and cost of structures commercially available?</li> <li>• Materials – how do they withstand weather, soil and watering? Recycled?</li> <li>• Recommendations and costs?</li> </ul>
5. Environment	<ul style="list-style-type: none"> <li>• How much space is available?</li> <li>• Patterns of sun and shade during the day? Seasons?</li> <li>• What is the soil like? (Work with the Soil team.)</li> <li>• How can planting structures be joined with other garden elements to create a welcoming environment? (Look at existing solutions.)</li> </ul>

Explain your team's ideas to the class and display your plan. Note any feedback. Meet with the managers of the space and some of the people who might use the space. Check the plans are acceptable and are going to work for the people involved. Change or modify your ideas if required.



**Developing a plan for your space**

### Tip

There are people in your school or local community with specialist knowledge and experience in plants, landscape design, or building outdoor structures. They may be able to help your class during the design stage – to give advice and steer your team in useful directions. They might also help out during construction. Ask a lot of questions and listen carefully to their advice and expertise.

## Planning and managing

### TASK 5 Planning what needs to be done

Work with your teacher to develop a plan to make your garden area. Your teacher will probably work as an overall manager (organising an overall production plan and work schedule, allocating jobs, sourcing materials, etc.), but each team will also need to work together to get their production tasks done.

## Producing

### TASK 6 Working as a team

Your team needs to follow the work plan to complete your part of this challenge. Make sure your team's work is high quality – the garden area must be well made, safe and last a long time.

It is also important to:

- work safely
- contribute to the team

- communicate with other teams and your teacher about your progress
- take photos and record your experiences during production.



**Your team will need to work together**

## Evaluating

### TASK 7 Launch and evaluation of your garden space

When your herb garden is completed, organise a launch/celebration of your garden area. Invite all the people involved – the managers of the area (principals and garden maintenance), the people who use the area (students and teachers) and anyone who helped during the process.

During the event, ask for feedback about the positive aspects of the space and the areas that might need improvement. Use this feedback to help write an evaluation of your herb garden.

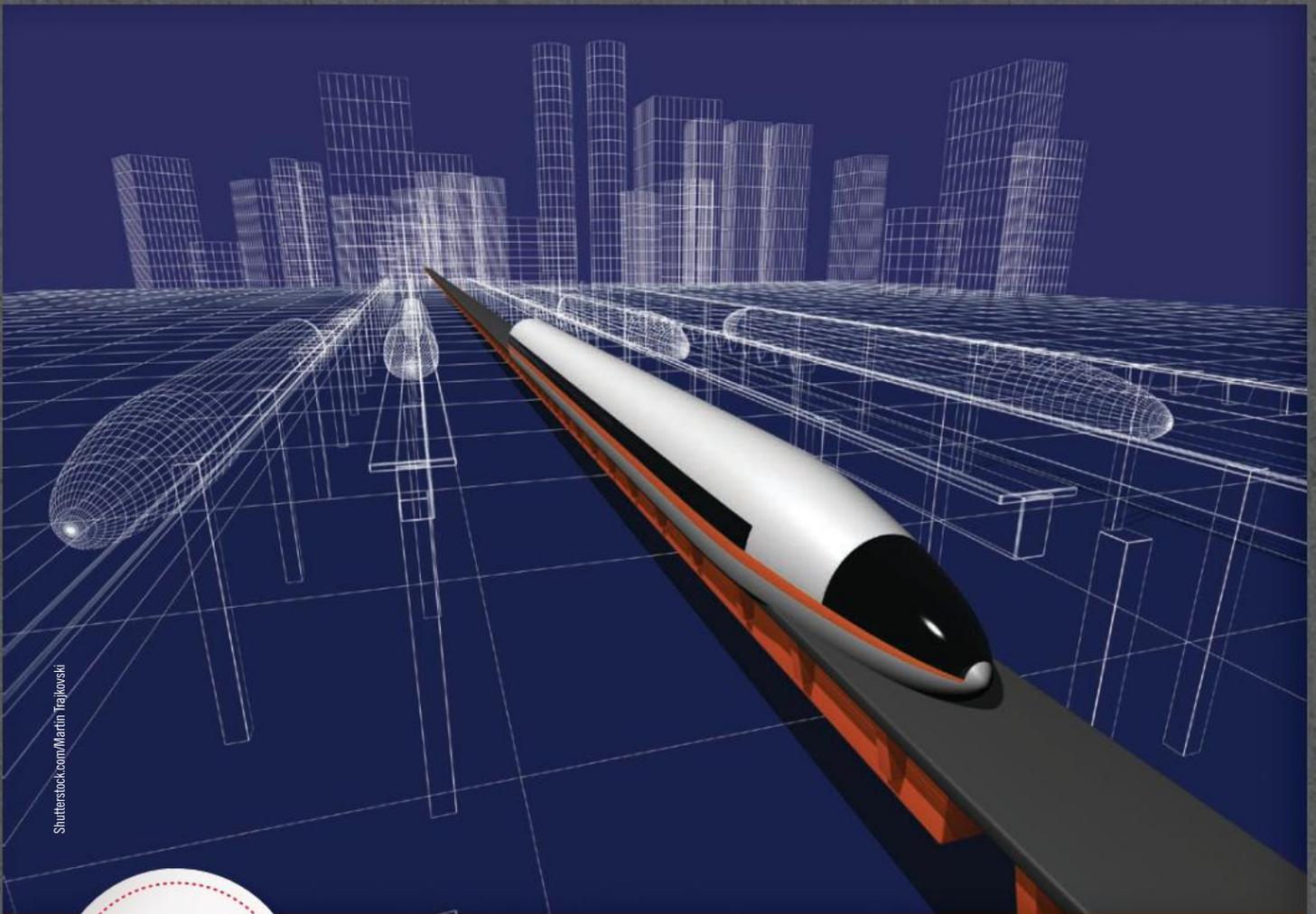
To ensure your garden is sustainable and keeps providing people with herbs for a long time, make sure the watering and composting plan is followed. Often people lose interest after a while, and gardens die due to lack of maintenance and regular care. Revisit the garden after six months:

- Is the garden still growing strongly?
- Are all the structural features withstanding weather and use?
- Are people using the herbs and enjoying the space?

## THINKING SKILLS

### USING PRE-USED MATERIALS (TEACHER-DIRECTED REFLECTION)

- 1** Choose a statement from the following list and write on the board (or read aloud).
  - Designers don't need to care about the environment.
  - Making products from recycled materials is easier than buying new materials.
  - Manufacturers should take responsibility for how their products affect people and the environment.
  - Designers should set an example by using recycled materials wherever possible.
  - We should always use recycled materials in our classroom.
  - Using recycled materials is a good way to get a high-quality product.
  - Laws should be made for recycling waste from homes and businesses.
- 2** Ask students to rate the statement out of 5 (with 0 being for a total disagreement and 5 for full agreement).
- 3** Ask four students to verbally justify the rating they gave.
- 4** Ask other students if their rating has changed after hearing the opinions of these students.
- 5** Continue with other statements from the list in Question 1 so that students have a chance to reflect and contribute a range of ideas and beliefs.



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# 11

## TRAVELLING TO THE FUTURE

### KEY KNOWLEDGE

In this chapter, students focus on the future of transportation. They will use the design process to:

- ▶ identify and define current transport issues
- ▶ research existing methods and emerging methods of transport
- ▶ generate and develop a transport solution for the future
- ▶ devise ways of evaluating the solution.

### DESIGN CHALLENGES

- ▶ Move-it – design a model of a public transport mode to move people around a city in the future
- ▶ Connect-it – design and communicate a public transport system for the future in your state, city or neighbourhood
- ▶ Inside-it – design and make a model of an interior aspect for a future transport mode

# FOCUS ON TRANSPORT

## Transport in Australia

Here is a brief timeline of transport developments in Australia.

- Early Australia – Indigenous people walked and used canoes for thousands of years.
- First European settlement – horses, horse and cab, and later horse and coach were introduced.
- 1860s – Afghan immigrants brought camels, which were used to transport goods long distances in the Australian outback.
- Late 1800s – horse-driven ‘buses’ with enclosed coaches for 10–20 passengers were introduced. This increased the popularity of public transport as it saved people the work and costs involved in housing their own horse and cart, and it was also seen as more social and enjoyable.
- 1850s – trains were introduced. The first trains in Australia were steam powered. Up until June 1995, Australian states had different gauge tracks and other compatibility problems, which meant passengers had to change trains when crossing the continent.
- Around 1900s – cable and electric trams were introduced.
- 1919 – electrification of trains began.
- Early 1900s – the first cars were being developed overseas; in 1948 the Holden car was ‘invented’ to suit Australian conditions.
- 1910 – powered flight was developed in Australia.
- 1930 – Australia’s speciality was long-distance flights, as well as aircraft for the Flying Doctor Service.
- 1950s – Ansett Australia and Qantas airlines introduced passenger jets.
- 1950s and 1960s – flying boats were popular in Australia for holidaymakers as they didn’t require airports but could land on the sea. With the increase of land runways, lighter faster aircraft, and more crowded waterways, flying boats became less viable.



Alamy Stock Photo/Heritage Image Partnership Ltd.

### Horse-driven ‘buses’ increased the popularity of public transport

In addition to land vehicles, modes for moving people across water have also evolved – from Indigenous canoes and sailing ships of the first settlers, to Sydney ferries, splendid yachts and luxury passenger ships.

Today, we are spoilt for choice. We have so many modes of transport to move us around. What will develop in the future? When you look at how much transport has changed over less than 200 years, imagine how much it could change in the next 200 years.

Up until recent years, most powered transport relied on the use of **fossil fuels**. With an increasing population, more transport will be needed. How do we achieve this without congestion and an increase in air pollution? Many cities around the world are now looking for and investing in more sustainable means of moving people around.

### Fossil fuels – non-renewable energy

Fossil fuels include petroleum, coal and natural gas. We burn these resources for energy. Fossil fuels are considered non-renewable because the process of decomposing dead organisms that creates them takes millions of years. Currently, fossil fuels provide most of the world’s energy. Burning of fossil fuels contributes to carbon dioxide in our atmosphere, which is considered to contribute to a faster rate of global warming.

Although use of fossil fuels has a negative impact on our world, it is still the cheapest and the most energy-dense form of energy. Most of our current transport methods are dependent on fossil fuels.

# TRANSPORT MODES

Most of us live in cities, and we all need to get out and about for a variety of reasons. Our nearby neighbourhood doesn't always provide us with the things that we need in life, such as education, schools, universities, employment, medical care, services, products and holidays or weekend breaks. We need to travel and move! We also need our goods delivered to shops. To do this, we need a **mode of transport**. Before we think about our future challenges, let's look at some common modes of today – both their benefits and problems.

## Car is king?

In Australia, most people travel and move in cars. Australians love their cars. People like to travel in private cars for many practical reasons:

- the freedom of leaving and arriving at times that suits them down to the minute
- to arrive in the shortest possible time
- to be able to throw bags and coats onto the back seat or the boot of the car
- to avoid contact with strangers
- to go the shortest route
- to be in a vehicle that matches their hygiene standards.

Although car travel has been a satisfactory system since motor cars became popular, it is becoming an increasingly inefficient way of getting across cities. Increased traffic volume has led to congested roads and longer travel times, as well as the issue of parking on arrival.

All these factors amount to spending longer time in cars, which gives rise to problems of:

- increased air pollution
- health implications due to long periods of inactivity
- mental and physical health issues, as longer time in cars means more frustration, and less time for leisure, activity and family time.

Look at any freeway in peak hour – in most cars there will only be one person. Cars are big enough to carry several passengers. Having a single occupant in a car is one of the factors that contribute to cars being very inefficient modes of moving lots of people across cities.

## Trams are fast ... sometimes!

Trams in Melbourne provide close to 3.5 million passenger trips every week. Although they make up a small percentage of all travel in a city, trams are considered the most effective way to move people per kilometre in peak hour. However, this is hampered outside of peak times due to stops (for picking up passengers) and the need to give way to other traffic when on shared roadways.



**The most effective form of transport depends on what is being transported and through what type of conditions.**

## Trains, trucks and buses

Trains, trucks and buses carry a multitude of people or goods. All of them have positives and negatives for transporting people and goods around in terms of sustainability, popularity and efficiency. All three are more efficient fuel-wise than decades ago, but trucks are still noisy and heavy, which adds to the wear and tear on our roads.

## Flying is cheaper than driving

Compared with decades ago, driving long distances across Australia can be very expensive when you factor in accommodation and food for a family. Jet airliners now use less fuel due to efficient engines and much lighter construction materials, which means flying is cheaper than it once was.

## Slow, healthy modes of moving

Walking and cycling are slow ways to get around, but are considered beneficial for cities as they create no harmful emissions. Walking and cycling also benefit individuals because they provide enjoyable forms of exercise and social interaction – two aspects that add to the quality of life. Most importantly, walking and cycling can be combined with other modes of transport for long distances.

Problems with walking and cycling include changing weather, transporting goods, and difficulties for those with a physical disability or impaired mobility.

## Problems for public transport users

Although driving to work in peak hour in cities can be unpleasant, there are many comparable grumbles about using public transport. Here are some common complaints by commuters:

- I can't get a seat.
- The timetable is irregular and unreliable, and I need to be on time.
- I don't feel safe at night.
- The stop or station is too far from my house or too far from where I need to go.
- There is no direct route and I must catch three modes of transport.
- I like to ride halfway, but there is no room for bicycles on trains in peak hour.
- I like to ride halfway, but it's on a bus route and buses don't take bicycles.

Can you list more problems with using public transport? Imagine if all our goods were to be delivered by public transport rather than trucks. What would be the positives and negatives?

## Preferred modes

- 1 Apart from practical reasons, such as time and the convenience of door-to-door travel, give three other reasons why people prefer to travel in private cars.
- 2 Explain the routes and destinations you take, and what you enjoy and don't enjoy about using the following modes of transport:
  - walking
  - cycling
  - outings by car
  - outings you take by public transport.
- 3 Should cars be given right of way ahead of people? Discuss this topic as a class.
- 4 What is wind resistance or drag and how do vehicle designs avoid this?
- 5 Create separate PMI charts (plus/minus/interesting) for two or more transport modes. List the positives, the negatives, and a wish-list for the future. An example PMI chart has been given for cycling.

## PMI example

### Example PMI chart for cycling

+	-	I
<ul style="list-style-type: none"><li>• I love the fresh air</li><li>• I get exercise</li><li>• Cycling keeps me warm in winter</li></ul>	<ul style="list-style-type: none"><li>• Riding at night is scary</li><li>• Getting wet when it rains</li><li>• Can't take bicycles on city buses</li></ul>	<ul style="list-style-type: none"><li>• Seeing my fitness improve</li><li>• Sometimes I meet people at the traffic lights</li><li>• Learning how to fix my bike</li></ul>

### Wish list for the future:

To make my bike an electric one. I can't wait until smaller, lighter, cheaper batteries are invented so that I can attach one to my bicycle. Then I can go longer distances without tiring, and I could zoom up hills.



iStock.com/dlaser

**Cycling has its positives and negatives**

**Possible space used for transport modes**

All transport involves moving us (and goods) through time and space. The different spaces are as follows.

- Ground-level transport – we mostly move around Australian cities at ground level. We do this in our beloved cars, and also in our buses, trams and trains for moving passengers, delivery vehicles and trucks for moving goods, and motorbikes and powered cycles for moving individuals. We also walk and cycle at ground level, except when using bridges, flyovers, tunnels or waterways crossings.
- Subterranean – most capital cities in Australia have some roads and railways that go through tunnels deep underground.
- Below the surface – some routes exist just below the surface, but not in underground tunnels; for example, when the road or rail is deepened to go under a flyover, bridge or through a hill.
- Above ground – sections of rail track are often built above the streets and houses. Sydney had a monorail system from 1988 to 2013, which was a single track mini-rail system travelling in one direction only. One of the problems with the

monorail was its lack of integration with other transport modes. Bangkok has a sky train with stations, which are all built on a structure that goes over roads and buildings.

- In the sky – small planes, helicopters and jet aircraft take off from the ground (except for seaplanes) but move high in the sky. However, there are strict regulations on the route and space they can occupy. Drones have been developing since World War I, but have recently become more accessible to consumers. There is currently little to regulate drones and the space they occupy. In 2016, drones did not carry people but were tested by Domino's in New Zealand as a faster and more economical way to deliver pizza.
- Across water – many types of boats travel across water, from a simple punt (one is still in use across the Yarra River in Melbourne, from Port Melbourne to Newport) to gigantic ocean liners and navy vessels.



Dreamstime.com/Fritz-Hersche



Alamy Stock Photo/Dunrobin Studios



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Shutterstock.com/Christian Lagerek

**Choose the space your future transport will move through**

**Space for a transport mode to move in** FOCUS ACTIVITY

If designing a future transport system or a model, you will need to decide which space it will occupy when moving. If designing an interior aspect for a future vehicle, decide on the space it will move through. Draw a diagram to show your choice.

**Transport modes for the future?**

How would you like to move around in the future? Technologies are being developed that could change

our cities immensely. Imagine if we didn't have any vehicles that travelled at ground level. We wouldn't have roads or bridges criss-crossing our landscape. Imagine never having to sit in a traffic jam. People could arrive at their destinations relaxed and feeling great.

Consider these inventions and emerging technologies:

- new and improved batteries that can store energy from renewable sources
- driverless vehicles – would they need seats to face the front?
- drones
- magnetic super-speed rail (maglev)
- A380 jet aircraft – larger, lighter and faster, and carries over 500 people
- hyperloop – a train-like vehicle that can travel as fast as an airliner
- supersonic flights for up to 12 people.

If you take on the Move-it challenge, think of a vehicle that could incorporate one of these technologies. Better still, outline a technology that doesn't exist yet!

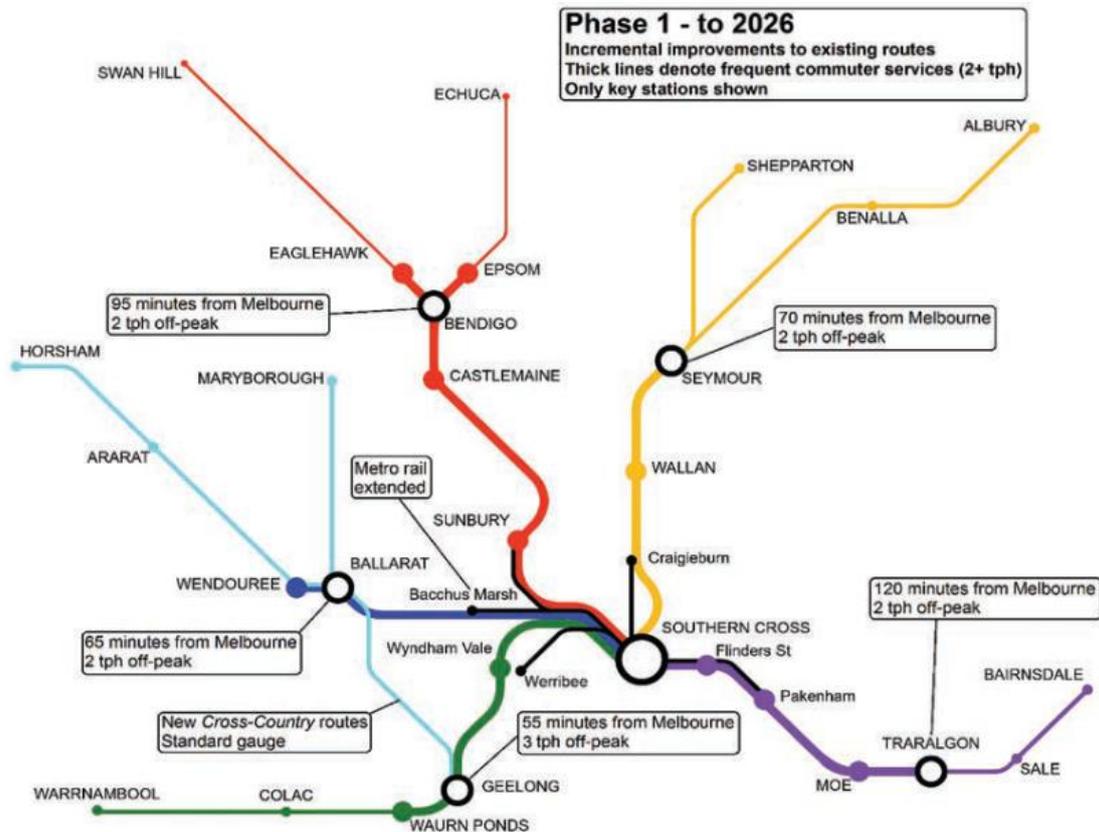


Shutterstock.com/Sivajjub Pantelic

**Could drones be used to make deliveries?**

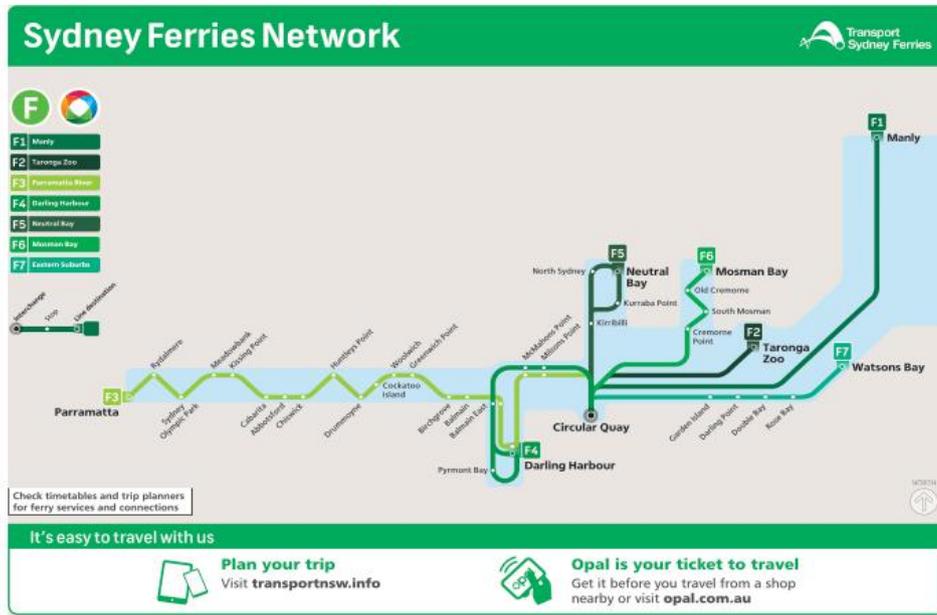
## TRANSPORT SYSTEMS

A transport system refers to how people move around. There are many smartphone applications and websites that show how modes and routes connect and help people move around cities and states. People on the move like to have this information in their pockets. However, it is not always easy to find this information on one small map – it would be a very detailed and crowded map, or it would be a large one that would need to be folded many times.



Source: The Rail Futures Institute Inc.

**A suggested plan for Victorian rail in 2026 from the Rail Futures Institute**



Reproduced with permission from Transport for NSW.

### Sydney Ferries Network

Most often we can find a map with one mode of transport, such as the diagram that shows possible improved train services for 2026.

You can find a map of tram routes for Melbourne inside most trams and at most stops. Bus routes can also be found at bus stops or online. Ferry routes in Sydney can be found online and in some of the pick-up points.

You can imagine how much information would need to be included on one map if all modes of transport were included.

### Transit or pick-up points

An important aspect for transport systems is the places where people must wait. These range from airports, large train stations, quays, bus stops, tram stops and taxi stands. These waiting places need to have footpaths for access and to be safe. Some places where there is a long wait need to provide shelter from winter rains or scorching summer sun.

Another aspect for public transport is the behaviour of users. Transport for NSW has put together a series of diagrams to encourage people to consider others. This covers behaviour that is not tolerated such as eating, drinking, smoking, talking loudly, shouting into mobile phones, listening to loud music, swearing, pushing, bumping others with backpacks, selfishly taking up space, dropping rubbish, blocking passages and exits, coughing and sneezing.

Yarra trams has created avatars of well-behaved commuters.



Reproduced with permission from Transport for NSW.

**A public behaviour message from Transport for NSW**

### A transport system for the future?

What would you like a transport system of the future to provide? Consider some of the transport mode technologies that are being developed. Which of them would be suited to cross parts of your locality, city or state? How should people behave? Where will they wait? What timetable will be on offer? How can you inform them?

If you take on the Connect-it challenge, think of how people could connect with different future transport modes, and how this could improve economic, social and environmental sustainability.

## Tip

Research the Chinese city of Yichang and their efforts to build a sustainable transport system.

# TRANSPORT INTERIORS

With increased patronage, public transport could offer a range of classes in travel that could be reflected by the interior. In metropolitan transport, this could include standing-room only when crowded, supported standing-room when less crowded, small seats, large seats or luxurious comfortable seats. These could be supported by different-priced tickets, storeys (levels) and doors for entering and exiting.

Long-distance travel also allows a variety of classes. In Europe, very fast trains offer luxurious seats, quiet carriages, drinks and meals, dining areas, bathrooms, entertainment, wi-fi and charging points.

When it comes to air travel, seating is provided for every passenger; however, various classes of air travel are offered. There is the standard seat; the standard seat with extra leg room or extra width; premium economy with larger seats, more room to recline and sleek design features; business and first-class with flat beds; and luxury suites with a private cabin.



NewsPix Photos/Erica Harrison

## Marc Newson's Qantas Skybed allows travellers to lie flat on long haul flights

In the future, with driverless cars, private vehicles could also offer luxurious interiors. If the occupant only has to type in the destination, perhaps they won't even be required to stay awake? Perhaps they can dine or complete work while on the move.

An important factor to consider for all interior 'furniture' of transport is that it needs to be securely attached.

## An interior for the future?

Consider a particular transport mode and look at the inventions and technologies that are being developed. The Inside-it challenge is about creating something fantastic for the interior of a future transport mode.

## CASE STUDY

### Holden – future vehicles

Franck Rudolph considers himself lucky to be a lead designer of cars at Holden in Port Melbourne. He has loved drawing cars since he was a boy and, once he realised there was a career doing this, he was determined to make it his. Franck's initial role was sketching, and later he moved into managing and leading a team. A team of designers and engineers will work on a wide variety of projects.

One of Franck's roles involved working on the development of future vehicles. He and others designed a car called EN-V (Electric-Networked Vehicle), which is a concept car for the year 2030. EN-V was developed all the way through, from a sketch to a finished fully working vehicle, for the Shanghai Expo in 2010. It is a small car that drives itself and can spin around in either direction on the

spot. EN-V is powered by battery, has a low weight and has all the modern sensing technologies, which make it ideal as a safe non-polluting urban car.



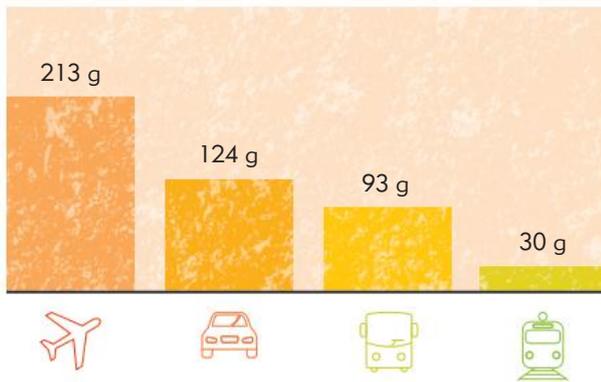
Digital sketches and impressions of the EN-V design being developed at Holden

# SUSTAINABILITY

## Environmentally sustainable solutions

The World Health Organization has set air quality targets for cities. As mentioned earlier, many cities are looking for more sustainable transport systems to replace cars. Of all ground transport, cars are considered to create the highest emissions per person per kilometre. Although one bus or one train itself emits more CO<sub>2</sub> than a single car, the number of seats available as well as a high occupancy rate enables them to be more environmentally friendly than a car.

Average CO<sub>2</sub> emission per mode of transport  
(grams per passenger kilometre)



Graph showing CO<sub>2</sub> emissions for different transport modes. (Source: Adapted from Gopili)

Many cities want to get people onto public or shared transport systems for several reasons such as air quality, to avoid congestion, to get people connecting more and to improve people's health.

### FOCUS ACTIVITY

## Sustainable transport

- 1 Which is the most polluting transport mode?
- 2 Research how technology has improved the environmental impact of different forms of transport. Present an A4 page with your findings. Research areas could include reduced mass of interiors, reduced power required, and hybrid and electric cars.
- 3 Research the World Health Organization's air-quality targets for cities. Present this information to the class.

## Socially sustainable solutions

When designing your transport mode, interior or system, consider the factors that could affect social connection among the users. Ideally, your system will give people the required privacy or individual control but will not 'build in' isolation or feelings of isolation among users. Isolation or feelings of being alone and unsupported can have a negative impact on people's wellbeing. Social connection is one way to impact positively on a community's quality of life – it allows people to feel included and safe.

## DESIGN CHALLENGES

The transport of the future challenges are best solved in either a team situation or as individuals that come together at various stages to brainstorm or to get feedback. Alternatively, an entire class may tackle different challenges that combine to create transport solutions that fit together (such as a vehicle, a system and an interior). There are open-ended choices in these challenges and focus is largely student-directed.

### Note

For the assessment of your design work in each of the challenges, your teacher will be looking for:

- » graphic organisers that show how you selected your challenge
- » a design brief that outlines the problem, states the future era and what form the solution will be, and gives criteria for success
- » clearly presented research relevant to your challenge
- » diagrams, drawings and annotations that show ideas to suit the challenge
- » some planning, making and a journal of progress
- » a model or presentation of the solution that covers the requirements listed for each challenge
- » sustainability impacts of your solution and an evaluation of your solution.

# MOVE-IT: TRANSPORT FOR THE FUTURE

## MOVE-IT DESIGN CHALLENGE

You are to design a model of a public transport vehicle to move people or goods around a city in the future.

### REQUIREMENTS (LIMITS OR CONSTRAINTS)

- You need to choose from the materials specified by your teacher (or provide materials from home such as recycled items).
- Sustainability must be considered – think of shapes or forms that will accommodate the way it will be powered (such as where batteries or solar panels might fit) or that will allow your model to move with the least amount of wind resistance.
- Size limits will be set by your teacher.
- Your model must look aesthetic and futuristic, which can be achieved by the shape and form, colour combinations, interesting use of line, textures, and careful consideration of positive and negative space.

- Include one special aspect (such as access for wheelchairs or a method to transport baggage on a bicycle).
- Focus on the design of the exterior – don't be too concerned about the interior.

### DESIGN CHOICES

You will need to make decisions regarding:

- the space your vehicle travels in and how it will be powered
- materials to use
- the shape and form of your model and how to achieve an aesthetic futuristic design
- the methods you will use to construct your model or to 3D-print its parts
- how it will be powered to make it sustainable.

# CONNECT-IT: A TRANSPORT SYSTEM FOR THE FUTURE

## CONNECT-IT DESIGN CHALLENGE

You are to design and communicate a public transport system for the future in your state, city or neighbourhood.

### REQUIREMENTS (LIMITS OR CONSTRAINTS)

- You must show an actual map of the area you are connecting, including notable landmarks (significant or important places that most people would know).
- You must include at least three different modes of transport that are sustainable.
- Modes should not all move at ground level.
- The modes must connect at points for passengers to transfer (be picked up or set down)
- A three-dimensional image of a connecting point (a point for picking up and setting down passengers, such as a bus stop or airport) that would help lone commuters feel safe. Ask your teacher if you need to include this aspect.
- You must communicate one behavioural standard relevant to this future system.

### DESIGN CHOICES

You will need to make decisions regarding:

- how to represent the mapped area your system will connect (you will probably need to distort the scale and true positions of landmarks)
- the colours and icons to use for different routes, modes and travel spaces
- the font to use and hierarchy of information (the size of different text to show importance and catch attention)
- how to communicate simply and clearly
- the final presentation formats (poster, PowerPoint, website, brochure, stickers, etc.).

# INSIDE-IT: AN INTERIOR FOR A FUTURE TRANSPORT MODE

## INSIDE-IT DESIGN CHALLENGE

You are to design and make a model of an interior aspect (such as seats, lounge chair, storage, bicycle rack, tray, wi-fi, power, toilets, taps, etc.) for a future transport mode.

### REQUIREMENTS (LIMITS OR CONSTRAINTS)

- Choose from the materials specified by your teacher (or provide materials from home such as recycled items).
- Size limits of the interior model will be set by your teacher.
- Your model must look aesthetic and futuristic, which can be achieved by the shape and form, colour combinations, interesting use of line, textures, and careful consideration of positive and negative space.
- Focus on the look of your model for the interior – don't be too concerned about whether the functional aspects work.

### DESIGN CHOICES

You will need to make decisions regarding:

- the type of future transport you are designing for and the interior aspect
- materials to use
- aesthetics to suit the end-users (achieved by shape, form, colour, texture, etc.)
- the methods you will use to construct your model or to 3D-print its parts.

## TASKS FOR CHAPTER 11 CHALLENGES

### Investigating

The first four tasks are about investigating and defining the situation.

#### **TASK 1** Brainstorm and select the challenge

Consider the transport challenges and all possibilities that you will focus on. Create a heading 'Brainstorming for transport of the future'. With a team, put as many words or phrases under this heading that you can think of that are related to any of the challenges in this

section. The aim of the brainstorm is to come up with many ideas, and then to choose the challenge and the area that you or your team will develop a solution for. You also need to define the future period you are designing for (such as 10, 20 or 50 years from now).

Make this a short, timed activity of 2–5 minutes. Team members can use sticky notes and place them on one sheet. Words or phrases for inclusion could be chosen from topics in this chapter or from the following list:

residents feeling connected  
sense of place in the community  
community involvement  
behaviour onboard  
services  
accessibility  
green design  
proximity  
cultural activities  
cycling, walking, lighting  
bus stops and train stations (benefits, problems, sit/stand, fixed/portable)  
bicycle storage  
car parking  
comfort on board (seating, hygiene, aesthetics)  
facilities (food, water, toilets, hygiene, wi-fi, charging stations)  
footpaths (safety, security, lighting, aesthetics)  
disabled people, cyclists  
collective passenger transport (car-sharing, car-pooling)  
low- and high-demand periods  
ferries, trucks (delivery and waste collection)  
smart cities (parking, waste, street lights, public transport, reporting issues with smartphones)  
drones  
distance and time between public transport modes  
tickets and pricing  
electrification, charging of batteries, autonomous driving

**Words and phrases to choose from to help define your challenge**

As an individual or with your team, discuss the brainstorm list and discard the least-suitable ideas until one challenge (and the details you will focus on) remains. This idea will be the title of your design brief.

### **TASK 2** Graphic organiser to help define the challenge

Choose a graphic organiser to help define your challenge. You could use a web diagram, lotus diagram, fishbone diagram or concept map.

For your chosen solution, you need to define the following:

- what it is for
- who the users will be
- how it will be sustainable
- where it will exist or operate
- how it will work
- when it will be implemented (future time-period)
- when or how often it will be used or operate
- what it should look like (old-fashioned but in a new way, futuristic, organic, scientific, etc.).

### **TASK 3** Writing a design brief

Use the information from your graphic organiser to write a design brief. Start with a statement of the problem you will be improving or solving, such as: *'Train passengers in 2016 are unhappy with ...'* or *'People in our community feel unsafe when catching public transport'*.

Include the requirements of a solution. Remember that it needs to be sustainable (uses less fuel), be made of sustainable materials, create less polluting emissions than what currently exists, or provide connectedness. You will also need to state the finished form that your solution will take (such as a three-dimensional model, a prototype, a digital three-dimensional model or a two-dimensional map with instructions).

This design brief will include your criteria for success (see page 9). Create four or more criteria for success relevant to your challenge that cover any of these areas: function, comfort, appearance, communication, efficiency, usability, safety, social connectedness or health benefits, and economic and environmental sustainability.

### **TASK 4A** Research and skills needed

Depending on your design problem, plan the research and skills you will need. A graphic organiser

could be used or a GANTT chart (spreadsheet showing a schedule with dates and roles) for team responsibilities. Your teacher will help you narrow down suitable areas to research and what evidence is required. The research required could be:

- a timetable of a particular route or network of routes
- photos of transport interiors to analyse
- interviews regarding public transport opinions
- emerging (current and new) technology being developed for transport
- sustainability issues, particularly carbon dioxide and other emissions created

The skills needed could be:

- model construction techniques
- drawing up maps
- creating timetables
- CAD.

### **TASK 4B** Primary research (your own)

Conduct and present some primary research relevant to your challenge.

#### **EXAMPLE OF PRIMARY RESEARCH**

Travel via private vehicle or public transport, or go to the nearest public transport 'station' or 'stop' and take photos and make notes. Choose the aspects most related to your challenge, such as comfort, timetable information, timetable update notifications, security, aesthetics, accessibility (wheelchairs, elderly, parents with young children, etc.).

- Insert the photos into a document titled 'My primary research for ...'
- Annotate the photos to explain how they are relevant to your challenge.
- Annotate the positives and negatives shown in the photos.
- Include some suggestions for what you could improve or change for your future time-period.

### **TASK 4C** Secondary research (from publications)

Conduct and present some secondary research relevant to your challenge.

#### **EXAMPLE OF SECONDARY RESEARCH**

Search for images related to your challenge on emerging transport modes or facilities, such as drones, driverless cars, electric vehicles, magnetic trains, bus stops, passenger facilities and comfort, etc.

Insert these images into a document – remember to include the name of the company or the inventor, and the source of your information. Annotate in a similar fashion as you did with your primary research.

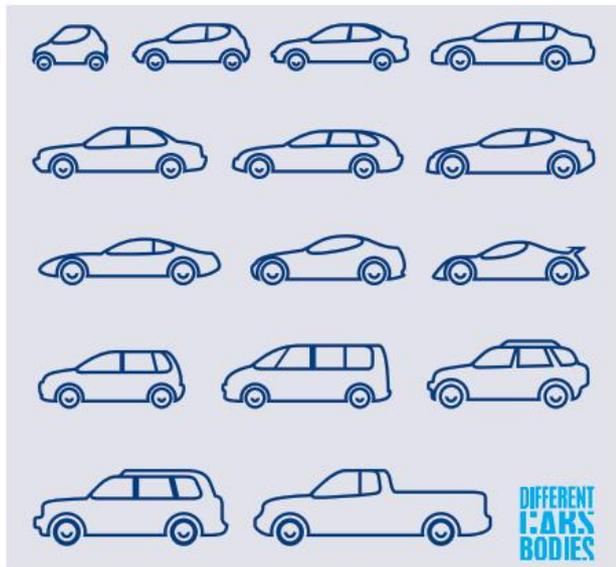
## Generating

Move into the ideas and design development stage with the next few tasks.

### TASK 5 Idea sketches and notes

For the Move-it challenge, start to draw ideas of what the exterior shape of your vehicle will look like. Consider the following aspects:

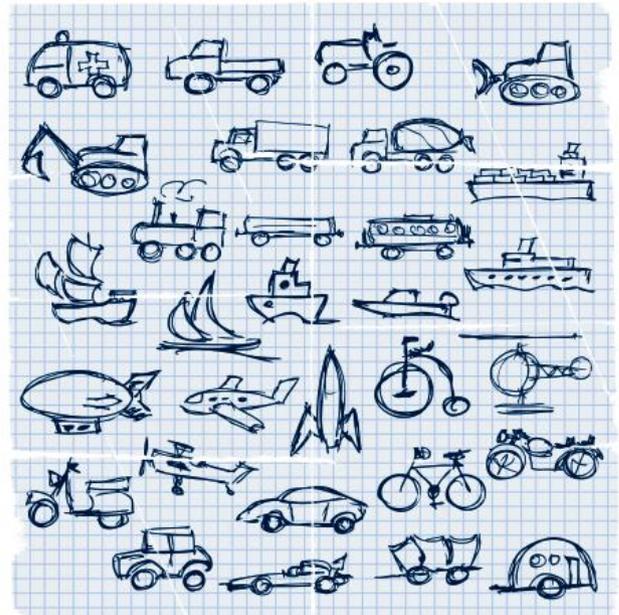
- front and back ends
- sides and any windows
- public or private use
- number of people your vehicle will carry
- accessibility – getting in and out for all passengers
- provision for bikes, wheelchairs, etc.
- type of wheels or feet
- moving parts – doors, wheels,
- aesthetics – play around with colours; interesting shapes for windows, doors and exterior; textures
- how the vehicle will be powered
- the space it will move in (underground, ground, sky, etc.).



Coloured ideas for a car exterior

For the Connect-it challenge, start to document ideas (draw and annotate) on what modes you will include, connecting the related points. Consider the following aspects:

- the modes you will include
- the ground area to be covered, such as local neighbourhood, whole suburb or town, multiple towns, a city, your state or the whole nation
- cartoons or diagrams to communicate the different modes of transport
- how users could connect with different transport modes
- the space different modes will move in (underground, ground, sky, etc.)
- ways to display and promote the availability of different modes to users
- where to display and communicate timetables, connections and routes
- the design of a waiting place or pick-up and set-down point
- privacy or connection with others.



Various transport mode sketches

For the Inside-it challenge, start to draw ideas for the interior aspect you are designing. Consider the following aspects:

- public or private use
- privacy or connection with others
- provision for bicycles, wheelchairs, shopping trolleys, prams, etc.
- features of the aspect that suit its future time-period
- placement of features and any movable parts
- design elements such as textures, shapes and lines
- how the part will be attached to the interior
- safety for all users.



### Antique bicycle rack – how could it be updated?

#### Note

Depending on the specifics of your challenge, you can use suggested ideas from any of the challenges.

#### TASK 6 Refining and deciding

Using your critical thinking, look at all your ideas and choose the most suitable. Which idea can you achieve in the time available?

Use a full page to show your final idea (two or more pages might be required for the Connect-it challenge). Use annotations to communicate how the idea will work and how it has considered sustainability.

#### Materials

If you are making a model, ask your teacher what materials are available. Suitable materials would be those that don't require a lot of difficult processes. You could use:

- balsa wood, thin plywood or varying thicknesses of cardboard, papier-mâché, or wood that can be carved easily
- some form of clay or plasticine that can have other materials adhered to it
- recycled drink cans (cut opened and flattened) or aluminium foil
- cloth with PVA glue or other stiffeners
- acrylic sheet of various thicknesses
- plastics such as polypropylene and modelling foam (you will need the MSDS)
- polycaprolactone – a biodegradable plastic that melts in hot water.

For components, you could use pins, paper clips, bolts, rivets, Velcro, or any other suitable items.



### Papier-mâché cars in 1950s style

#### Safety

Always refer to the MSDS for any hazardous materials you are planning to use, and follow your teacher's instructions. For more information about polystyrene and the associated environmental concerns, visit the Clean Up Australia website and read the polystyrene fact sheet. Research any other materials that may have safety issues.

#### Tip

You may have the opportunity to 3D-print your designs. If so, you will need to create your drawings in CAD beforehand (see page 21). Identify any weak or thin areas of your design and consider redesigning them as parts. Printing parts of the model that can be interlocked or joined with another material will avoid these weak spots.

#### Note

If you are designing a digital model or system for Connect-it, decide on how you will communicate your ideas and any software programs that could assist.

### Planning and managing

#### TASK 7 Schedule plan

If you are making a model, think ahead of the main steps involved and create a work plan.

Develop a timeline (a GANTT chart can be used again here), particularly if you are working in a team. Ask your teacher how many classes you have for this project and work out some milestones so that can meet the due date.

Follow your teacher's safety instructions, completing any documentation required.

## Producing

### TASK 8 Making your product

Make your model safely. Keep a journal and take photos of the different steps. This may involve some failures, so document the problems to avoid repeating them. Date the journal entries and describe what you did.

If using software, show progress of your work by saving images at the end of each session in a folder. Use a file naming system to help you find files quickly, such as putting the step number for each new file or adding the version number on the end.

## Evaluating

### TASK 9 Presenting your solution

Present your solution to the class as a model, or a print of the final designs. Tell the class your criteria for success and how your solution met each criterion. If possible, ask classmates for questions.

Think of all the positives of your solution. When presenting to the class, imagine how you would communicate it to the people who would be involved in your product, such as the users, the local council and a transport manufacturing company.

Choose the documents that best represent:

- your definition of the problem
- what your research told you
- how your ideas developed
- your final ideas
- positive sustainability impacts on social or environmental areas
- why this idea should be adopted.

## THINKING SKILLS

### DESIGNING FOR THE FUTURE – A REFLECTION

- 1 Draw up a timeline of transport history in Australia and make note of the different technologies that brought about big changes. Add the future date for your design challenge choice, include future or developing technologies, and explain how your transport mode will be different from the transport of today.
- 2 List three things that you learnt from your research about technologies that are being developed today for the future. Explain how one of them helped you to develop ideas for your solution.
- 3 As further evaluation, write the activities or tasks you completed for the two stages of the design process listed in the table below, and a suggestion for how each could be improved.

	WHAT YOU DID	HOW IT COULD BE IMPROVED
Planning and managing		
Evaluating and presenting your work		

# INDEX

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## **OVERVIEW**

- **Provides a framework for the creation of design solutions across a range of materials**
- **Opportunities for STEM learning and development of the relevant language, knowledge and skills required for senior-level study**
- **Supports students to meet the Victorian and Australian Curriculum Design and Technologies' achievement standards**
- **Covers technologies and society, engineering principles and systems, food and fibre production, materials and technologies specialisations, and creating designed solutions strands and sub-strands.**