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THIRD EDITION

NELSON

INTRODUCING TECHNOLOGY

BY BASIL SLYNKO

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Publishing editor: Deborah Barnes
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Editor: Sandra Balonyi
Senior designer: Vonda Pestana
Text designer: Ami Sharpe
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CONTENTS

ABOUT THIS BOOK

Introducing Technology, third edition, is designed to provide resources that students can use to:

- achieve technological literacy, and
- become responsible users and creators of technology.

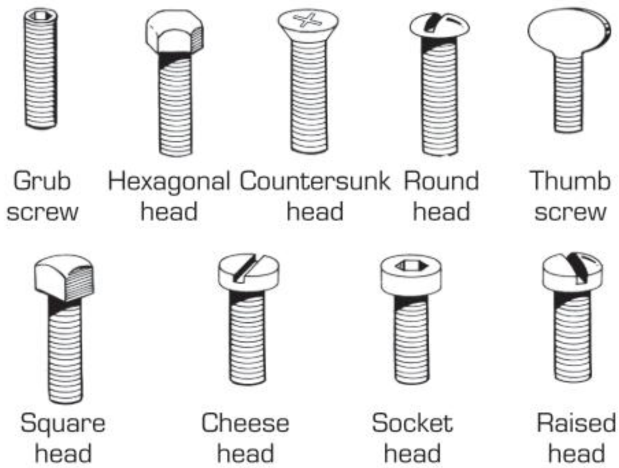
The text features Information Files, which highlight unusual or important details.

INFORMATION FILE

Testing materials

You might have to carry out tests on samples of different materials to see if they are suitable. You might also have to test the safety factors of materials. (See page 202.) Alternatively, you could refer to safe load tables. These show the safe load limits for materials of different sizes and shapes.

This book is very visual. It has 100 photographs and more than 650 illustrations. Many of these are detailed technical illustrations, clearly showing the differences between similar tools.



In Unit 9, Electronics, we have matched photographs with symbols of the major electronic components.

Symbol:

Introducing Technology is intended to be integrated into a problem-solving approach to technology education, whereby students are encouraged to 'learn by doing' – first identifying the problem and then designing, making and evaluating an appropriate solution to that problem. Students are also asked to consider the relationships between the problem, their solution, industry, society and the environment.

But the best thing about this book is the huge scope it covers as a general introduction for students studying technology for the first time.

There are many user-friendly aspects of *Introducing Technology*:

Safety warnings are clear and frequent, as needed.

REMEMBER:
- Always clearly mark hot metals.
- Use safety gear.

Rules are highlighted so that they can be clearly read at a glance.

RULE:
- The larger the diameter of the drill bit, the slower the drill speed.
- The harder the material, the slower the drill speed.

We hope you enjoy using this book!

ABOUT THE AUTHOR

Basil Slynko (B. Ed. St, MA) has taught design and technology related subjects for many years in secondary schools and tertiary institutions in Australia and overseas. He has also worked as an Education Officer, developing curricula and learning materials for distance education students.

With considerable practical experience in a variety of industries, Basil is particularly knowledgeable in most trades within the construction industry. He has been a member of curriculum and consultative committees at state and national levels.

Basil has written journal articles, books – including *Graphics 8 and Graphics 8 Teacher's Edition; Introducing Technology, Technology Activity Manual and Technology Activity Manual Teacher's Edition; Technology Activity Book 1 (as co-author), Technology Activity Book 1 Teacher's Edition, Technology Activity Book 2 (as co-author) and Technology Activity Book 2 Teacher's Edition; Senior Graphics Overview and Senior Graphics* – booklets and worksheets (including Teacher's Editions).

Basil has also won a peer-awarded International Laureate citation.

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The publication of this book would not have been possible without the support and encouragement of a host of people. The author and publisher wish to thank the following individuals for the helpful advice they gave during the writing of this text: Alison Gierke (design); Amanda Slynko, David Thurlow and Jason Hansen (materials); Neil Gordon and Bill Thomas (tools and processes); Andrew Krosch and Ernie Berghammer (processes); Rex Faldt (structures); Lindsay Wright (electronics); Charles Luck, Edward Mazurkiewicz, Dr Owen Barry and Alan Waldron. We would also like to thank Sandra Balonyi for her valuable input.

Responsibility for errors remains, of course, entirely with the author.

Dedicated to the Slynko family: my late father, Ivan; my late mother, Maria; my brother, Paul; my sister-in-law, Jenny; my nephews – Andrew, his wife Melissa and their son, Benjamin, and Mark and his wife, Amanda – and my late Uncle Ivan. Thank you for all your love, encouragement and support. A special 'thank you' to my former editor and publisher Col Cunnington – for his great insight and encouragement to realise my potential.

What is technology?

In this unit, you will learn:

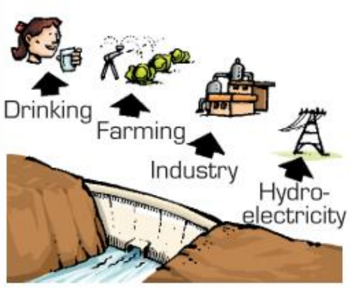
- what technology is
- about the role of technology throughout history
- about your responsibilities as a user and creator of technology.

In everyday life, people use technology to satisfy their needs, such as food, shelter, health care, communication and entertainment.

People use technology to solve problems in the world around them.

Technology can provide simple solutions (such as a catch to hold back a door) or complex solutions (such as a satellite system for international communication).

Technology provides some solutions that alter the environment. For example, rivers are dammed to store water for many purposes.



In many cases, a technological solution is found by using a problem-solving process.

A problem is identified

↓

Problem-solving

↓

A satisfactory solution is found

Some solutions change over a period of time as people gain new knowledge and develop new skills and materials.

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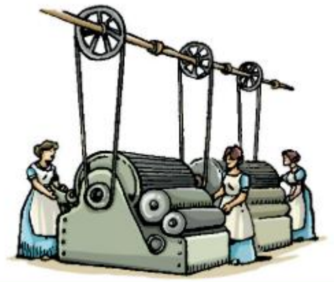
To meet their needs, early people developed tools made from stone, wood and bone. Later, they discovered how to make more efficient tools from metals such as bronze and iron.

In the eighteenth and nineteenth centuries, during the Industrial Revolution, people invented machines that greatly increased the number of goods they could manufacture.



By the twentieth century, mass production systems had been developed. These enabled huge numbers of items to be produced at a lower cost, so that larger numbers of people could afford to buy them.

In modern times, technology has provided many new solutions to people's problems. Advances in electronics have led to the widespread use of computers and industrial robots.

However, people have sometimes misused technology and harmed other people or the environment.

When new technology is developed or used, all its effects – good and bad – must be taken into account.

Technology should be appropriate to people's needs; it should suit the way they wish to live within their society.

Thus, technology is people using resources such as:

Ideas → Information → Skills → Materials → Tools and equipment → Energy

and a **problem-solving process** such as:

Investigating
Coming up with a general idea of how to solve the problem and considering the impacts on people and the environment

→

Designing
Making a detailed plan of how to produce the solution

→

Producing
Making the solution using resources such as tools, materials and skills

→

Evaluating
Testing the solution to see if it is satisfactory, and assessing its effects on people and the environment

to produce:

a satisfactory solution – product, process, environment or system – to a problem.

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Not all technology is the result of a problem-solving process; there are alternative processes.

One common process is refinement or improvement to an existing technology. The improvement is often the result of **trial-and-error** experiences in many and varied situations. These experiences provide an enormous wealth of knowledge of what works well in which situation. For example, **hands-on** people often make a modification to a product to suit their need.

There is a process called **innovation**. Innovation is often the result of **lateral thinking**. An example is the winged keel of the yacht *Australia II*, which challenged and won the America's Cup in 1983.

The winged keel of *Australia II*

Another process is transfer, or **adaptation**. Here, an existing technology is adapted to include a new technology – for example, a sewing machine interfaced with a computer.

A computerised sewing machine

The final process is serendipity; that is, discovery by accident (for example, the adhesive used on Post-it® notes). An adhesive was being produced at the 3M company in the USA. When the adhesive was applied it was noted that there was no permanent **adhesion**. Since the adhesive could not be used for its intended purpose, it was shelved. Some time later, the idea of Post-it® notes was proposed and the non-sticking adhesive found a use.

Technology can also be thought of as a system. A system, in technology, is a collection of parts or a group of activities used to complete a task. The parts of a system are input, process, output and feedback. (See 'What is a system?' on page 157.)

DEFINITION

Technology (tek-NOL-e-ji), noun.

1. the application of knowledge, tools and skills to solve practical problems and extend human capabilities [ability that can be used]; Jackson's Mill Curriculum Project, 1979.
2. the generation of knowledge and processes to develop systems that solve problems and extend human capabilities; International Technology Education Association (ITEA) Conference, Phoenix, Arizona, 1996.
3. the result of human activity. It is the result of combining ingenuity and resources to meet human needs and wants; *Technology for All Americans*, 1996, page 11.
4. human innovation in action. This involves the generation of knowledge and processes to develop systems that solve problems and extend human capabilities; *Technology for All Americans*, 1996, page 16.

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5. that branch of knowledge that deals with mechanical arts or applied sciences; *Shorter Oxford English Dictionary*, 2002.
6. the application of scientific knowledge for practical purposes, especially in industry; *The Australian Oxford Dictionary*, 2004.
7. the application of practical sciences to industry or commerce; *Collins Australian Dictionary*, Ninth Edition, 2007.
8. that branch of knowledge that deals with science and engineering, or its practice, as applied to industry; *Macquarie Dictionary*, Fifth Edition, 2009.

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Safety

In this unit, you will learn:

- what safety is
- about unsafe practices and unsafe conditions
- about workplace health and safety
- about personal safety
- about personal protective equipment
- how to develop safe working practices
- about material safety data sheets.

Technology has given us many things, such as tools and leisure items, to use and enjoy at work and at play. The responsibility for using these items safely rests with everyone. If you fail to use them in a safe manner, you could injure yourself and other people.

Safety banners promote safety

Federal and State governments spend much time and money promoting safety, mainly through lectures, posters, DVDs and films. Their aim is to educate people to 'think safety' and 'work safely' at all times. People who miss work because of injury are **unproductive**, and the cost of making them well again can be very high.

To protect people even more, governments have passed safety laws. To ensure that people obey these laws, safety officers are employed to inspect workplaces and to check that the safety rules are not being broken. People who break the safety laws can be fined and sent to gaol.

What is safety?

Safety is accident prevention. Accidents can happen anywhere, but they are common in the home, on the sports field and at work.

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To protect people from injury, safety rules have been established for most places in the community, including schools. Your responsibility is to:

- read the safety rules
- understand the safety rules
- obey the safety rules.

Accidents are usually caused by careless or ill-informed people. People are injured as a result of committing unsafe practices or as a result of unsafe conditions.

Unsafe practices

An unsafe practice is behaviour that is inappropriate for a particular situation. Examples of unsafe practices include:

- not using personal safety equipment such as goggles, helmets, ear muffs or gloves when there is a **risk** that you could get injured
- fooling around and thereby endangering yourself and other people
- using faulty tools and equipment
- using incorrect tools and equipment
- not concentrating on what you are doing
- distracting other people from what they are doing
- using incorrect lifting techniques
- ignoring the safety rules that have been laid down for the particular situation
- using tools and equipment before you understand how to use them correctly.

Be aware of unsafe practices. It is your responsibility to do the right thing and to help others to act in a safe manner. By encouraging other people to do the right thing, you could prevent an accident.

Identify the unsafe practices in illustrations A to H.

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Unsafe conditions

An unsafe condition is a situation in which an accident is likely to happen. Examples of unsafe conditions include:

- an untidy work area
- poor lighting
- slippery floors
- poorly stacked materials
- **defective** tools and equipment
- blocked pathways and exits
- lack of adequate ventilation
- collections of **combustible materials**.

KEEP YOUR WORKPLACE TIDY!

HEALTH & SAFETY IS EVERYONE'S RESPONSIBILITY!

Be on the lookout for unsafe conditions. It is your responsibility to **eliminate** any danger. You should always report unsafe conditions to someone in authority. Check things out at home – what unsafe conditions can you find there?

Personal safety

You might not be able to 'think safety' and 'act safely' for others, but you can look after yourself.

A racing-car driver would never think of racing without personal safety gear such as a helmet, gloves and a fire-resistant suit. If an accident happens, then the personal safety gear will protect the driver.

Here are some personal safety habits that you should develop.

- Wear the correct clothing and footwear for the activity.
- Do not wear rings or watches when using machinery.
- Wear head protection in areas where objects could fall and injure you.
- Wear ear protection in areas of loud noise.
- Wear gloves when handling materials such as glass and sheet metal.
- Wear a **respirator** if exposed to **toxic** substances.

No matter what sport or activity you choose, wear the correct protective gear at all times.

- Avoid back injuries by using the correct lifting and carrying techniques when handling heavy objects. (See page 18.)
- Use tools and equipment correctly.
- Obey the safety rules for the activity.
- Work in a **ventilated** area to expel fumes when performing activities such as gluing plastic or painting.

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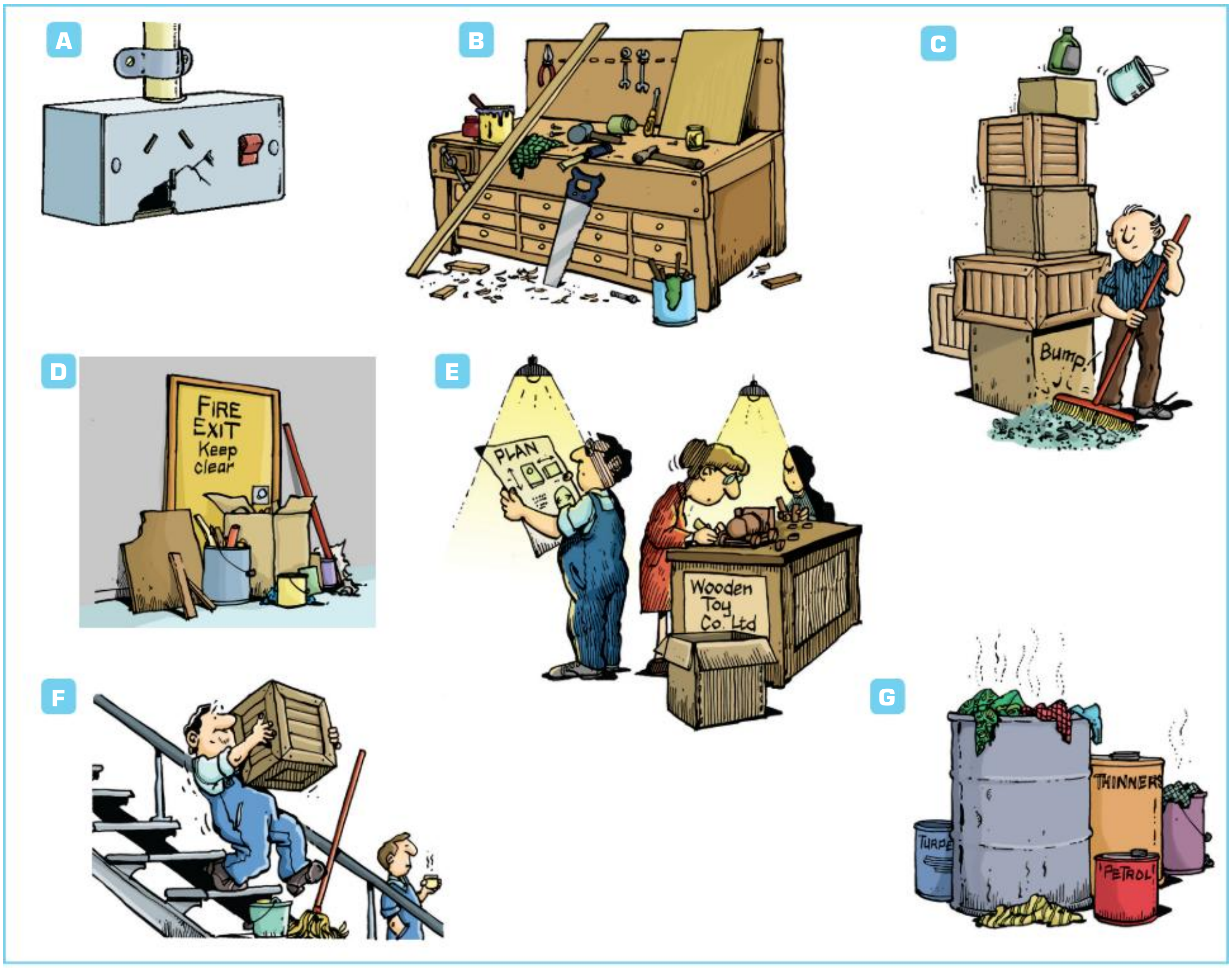
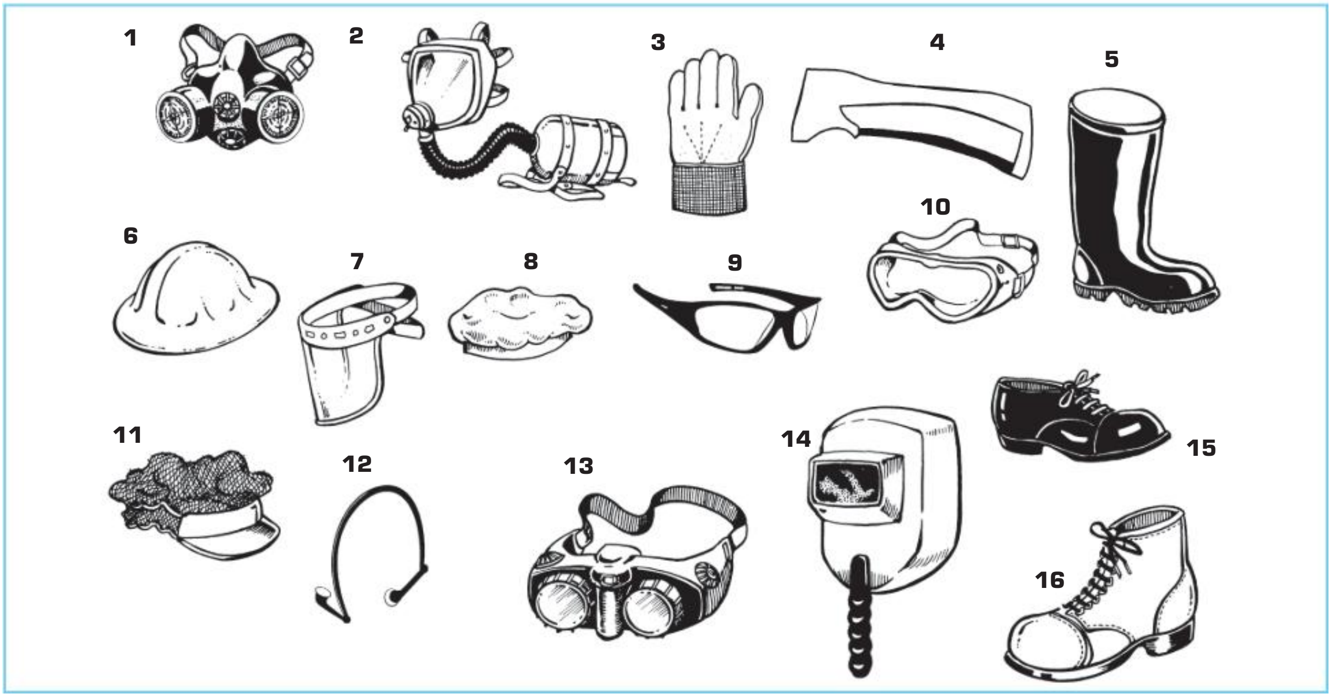


Identify the unsafe conditions in illustrations A to G.



Research and identify the safety equipment shown here. In your notebook, list the use of each piece of equipment.

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INFORMATION FILE

Personal Protective Equipment (PPE)

Personal Protective Equipment (PPE) is the term used to describe the range of personal safety equipment. Personal safety has two parts. It relies on:

- safe practices and safe conditions
- using the appropriate safety gear to protect yourself from injury.

The body

Protective clothing, including body suits, aprons and coats, is a good start. Other parts of the body require additional protection.

The eyes

Goggles or face masks protect the eyes from dust, chemical splashes and other flying objects.

The ears

Ear muffs or ear plugs prevent hearing loss. People who are exposed to sound levels above 85 dB every day need to take special care. (For more information, refer to the section headed 'Noise' below.)

The feet

Safety footwear, whether boots, shoes or joggers, with built-in steel toe caps gives good protection (for example, from falling objects) against foot injuries.

The hands

Gloves (including mittens, leather gloves and rubber gloves) must be worn to protect hands. Cuts, abrasions and splinters can be avoided when handling materials such as steel, rough timber or glass. Chemical burns are prevented when handling hazardous chemicals.

The type of glove you choose should be relevant to the risk exposure. For example, wear rubber gloves for acids as latex gloves may increase the risk of exposure.

The lungs

A disposable mask or a respirator must be worn to protect the respiratory system. Fine dust, airborne fragments and toxic fumes should not be inhaled.

The type of respirator you choose should be relevant to the risk exposure. For example, wear a dust mask for dust exposure and a cartridge filter mask for acid vapour.

The head

A safety helmet (or hard hat, as it is commonly known in industry) should be worn if there is any danger of injury to the head.

These fire-fighters are wearing the correct PPE.

USE PPE FOR YOUR PROTECTION!

No matter how simple the task is, *always* use the proper personal protective equipment and *never* take short cuts.

Noise

Noise is a part of everyday life in industrial societies. The level of sound is measured in decibels (dB). You can permanently damage your hearing if you are exposed for too long to sound levels above 85 dB. However, you can protect your hearing by

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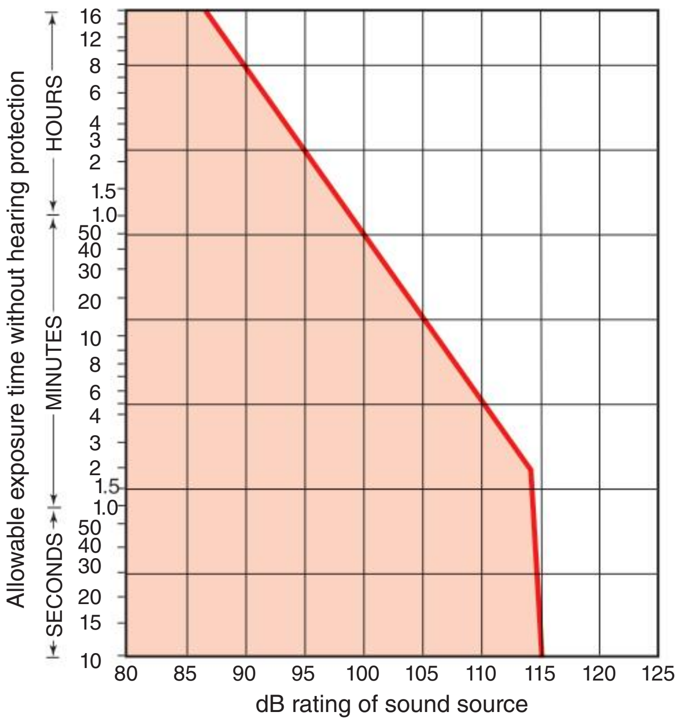
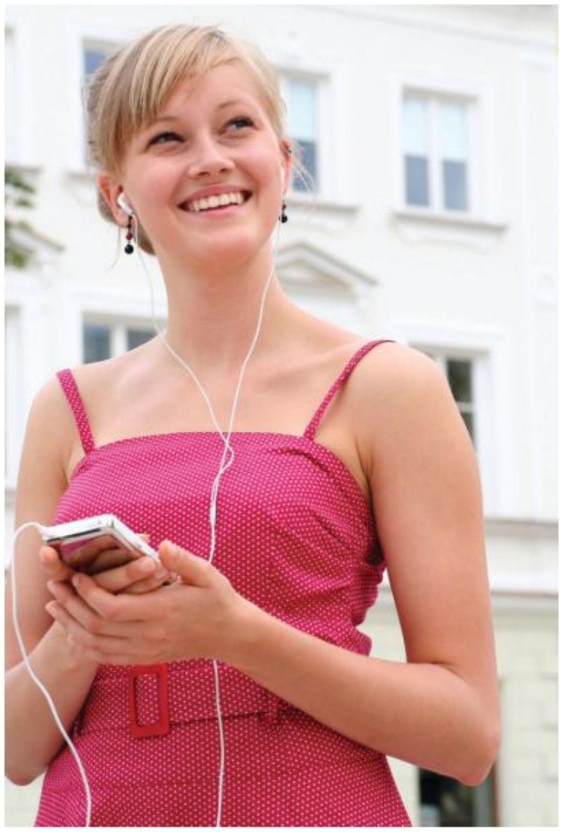
wearing ear plugs and/or ear muffs where there is a high level of sound.

To help protect your hearing, governments have prepared a graph such as the one below, which shows exposure times for various sound levels. It is important that you become aware of the allowable exposure times for a range of sound levels.



Allowable exposure times for a range of sound levels

Turn up the volume?



A recent study at the University of Colorado, USA, looked at the risk of hearing loss among MP3 users. The study found that teens could suffer hearing loss if music is too loud, or if it is listened to for a long time, depending on the ear sensitivity of the listener.

The sensitivity of your ears is to some extent a risk factor. For example, teens born with 'tender ears' are at greater risk of hearing damage than teens born with 'tougher ears'.

Here are some facts about iPods and MP3 players fitted with stock earphones and volume levels.

- At 70 per cent volume, you could safely listen for 4.6 hours.
- At 80 per cent volume, you could safely listen for 90 minutes.
- At full volume, you could safely listen for 5 minutes.

See the graph on the left ('Allowable exposure times for a range of sound levels') and have a go at answering the following question:

'What is the dB rating for each volume level?'

Having difficulty? Then ask your teacher how to read the graph.

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INFORMATION FILE

Workplace Health and Safety

Workplace Health and Safety Act

Federal and State governments have passed a Workplace Health and Safety Act. Some of the basic objectives of the Act are to:

- protect people – workers and the public – in the workplace against the improper actions of others
- set workplace health and safety standards
- provide practical advice on how to reduce risks in the workplace
- appoint safety officers within workplaces, and inspectors to enforce the law
- establish workplace health and safety committees
- create awareness about workplace health and safety within the community.

The Act has two types of regulations, which cover:

- administrative matters (for example, for preparing work plans and for record keeping)
- standards for risk management (for example, exposure to hazardous substances).

Should people fail to follow these regulations, there are penalties such as a fine or being sent to gaol.

The risk-management process

Safety laws in Australia are based on the risk management process. The risk-management process is made up of five steps. They are:

1. identify hazards
2. assess the risk
3. decide on an action to control the risk. The best action is to remove the risk. Should this not be possible:
   - replace it with a lesser risk, or
   - isolate the risk, or
   - reduce the risk by engineering means, or
   - set up rules to supervise the risk, or
   - make sure people use PPE (this is the last action you should consider to control the risk)
4. carry out a suitable control action
5. check the intended result of the control action and look back on how well the risk was handled.

These steps must be followed to manage exposure to risks.

A common control action for managing exposure to risks is to set up standard operating procedures. There is a standard operating procedure for each type of operation (for example, using a drill press or chain saw). The document lists the PPE requirements and the steps that must be followed in order to minimise exposure to risk while performing that operation.

Another term may be used to describe this document within the school environment. It is often known as a safe operating procedure (SOP).

As circumstances vary (for example, changes to a piece of equipment or the operation) the SOP needs to be reviewed and modified to reflect the changed circumstances.

Note that the risk-management process also needs to consider the variables (for example, the expertise of the individual, the age of the individual and the type of equipment). The variables will influence the kind of action to be undertaken to control the exposure to the risk. Thus the action to control the risk may differ for each person.

Workplace Health and Safety Committees

The purpose of a Workplace Health and Safety Committee is to provide a forum for people to air health and safety issues. Regular meetings must be held. The task of the committee is to promote an interest in and address any health and safety issues. The outcome may require an action or additional training of people. This is the responsibility of the Workplace Health and Safety Officer (WHSO). The WHSO is appointed by management as required under the Act.

The duties of the WHSO also include:

- inspecting the workplace to identify unsafe practices and conditions
- making sure that people observe the health and safety standards
- investigating and reporting all accidents and injuries
- advising the employer or principal contractor on health and safety.

The responsibility of the Workplace Health and Safety Committee and WHSO is to develop the right attitude among people.

Some ways that you can help are by:

- developing safe practices
- reporting any unsafe conditions and risks
- encouraging others to maintain safe practices
- encouraging others to report any unsafe conditions and risks
- becoming an active participant in health and safety in the community.

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Developing safe working practices

There are many safe working practices you should be aware of when using tools and equipment. We will look at some of these now.

Tools

Any tool can be dangerous. Cutting tools such as chisels, saws and tinsnips need to be sharp. To avoid cutting yourself, you must use them correctly.

You must also use the right tool for the task at hand (for example, a spanner is not a hammer, so it should not be used to strike objects). A screwdriver is for securing and releasing screws and should not be used as a lever to open paint tins. If you use a tool for the wrong purpose, you could injure yourself or damage the tool.

> ⚠ *Check* all tools and equipment before you use them. If they are faulty, *do not use them*!

Why shouldn't you use tools incorrectly like this?

Machines and power tools

Machines and power tools have moving parts that can cause injuries if you fail to take care. Before you switch on a machine or power tool make sure that you know how to use it safely. Read the manual for the machine or power tool and ask someone who knows how to use it safely to demonstrate it to you.

> ⚠ All electrical machines and power tools must have a tag attached to the electrical cord as shown above. The tag indicates that the item has been tested for electrical safety. *Do not use it* if there is no tag or the tag is out of date. The law requires periodic testing and tagging.

What is missing?

Here are some other points to remember.

- Make sure that all guards are in place before you switch on the machine or power tool.
- Make sure that the work is held securely – for example, use a vice.
- Make sure that you hold the power tool securely before it is turned on.

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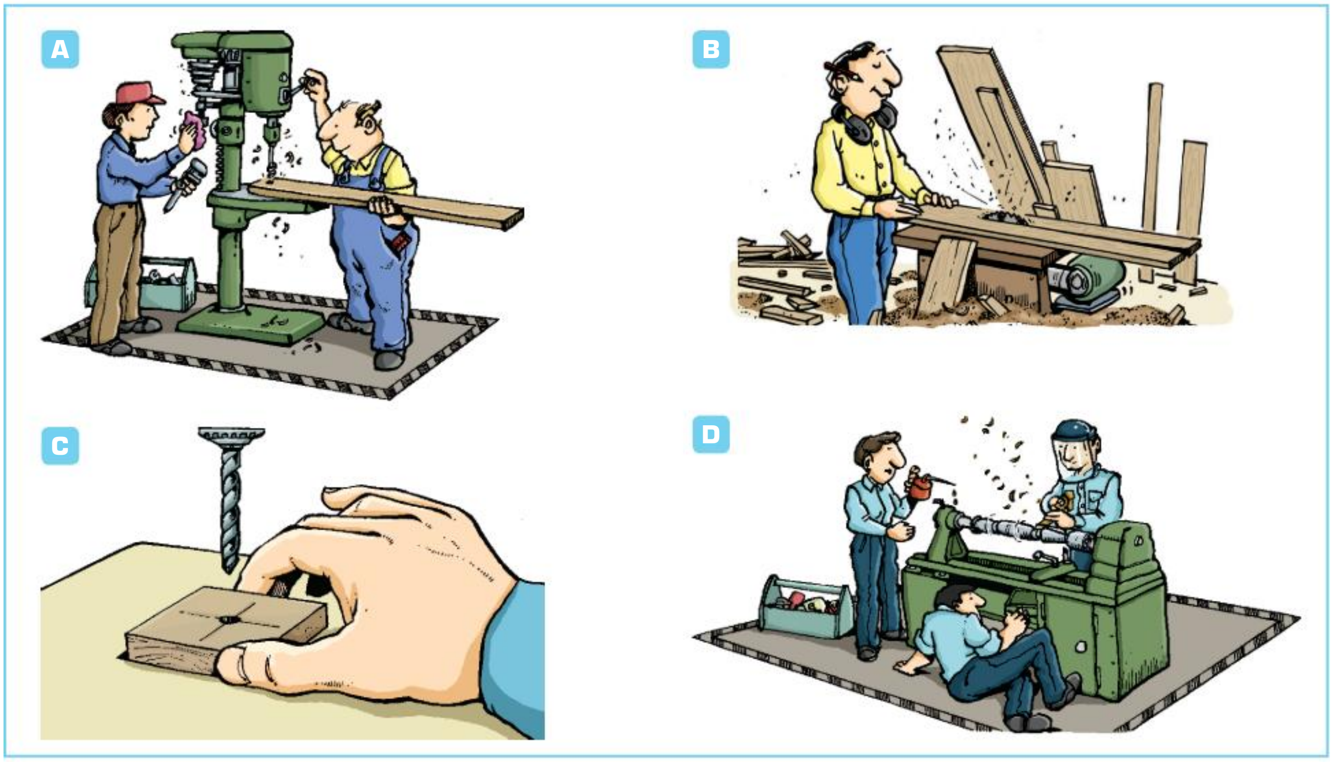
- Never adjust machinery or a power tool while it is running; always switch it off before making the adjustment.
- Keep all your body parts, especially fingers, away from moving and cutting parts and blades.
- Never walk away from machinery or a power tool that is running; always switch it off before leaving.
- Attach a warning sign to identify a faulty machine or power tool.
- Only the operator should be inside the safety zone when the machinery is in use.
- Only the operator should be controlling the power tool when it is in use.
- Keep your mind on the task.

Current legislation in your State or Territory may prevent you from using certain machines and power tools. These age restrictions are for your safety. Always check with your teacher.



Identify the unsafe practices in illustrations A to D.

Electrical safety

Electricity can kill!

Special care must be taken when using electrical equipment. You can protect yourself by using an earth leakage device (commonly called a safety switch). It is also known as a residual current device (RCD). The earth leakage device will switch off the power if a fault develops inside the electrical device. This could save your life!

Note that earth leakage devices are designed to minimise the risk of electric shock to people. A circuit breaker, on the other hand, is a device that protects electrical equipment.

Beware of power lines at all times – *look up.*

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A portable earth leakage device

For your safety and the safety of others, become aware of the locations of emergency stop buttons. Pressing the emergency stop button will turn off the power immediately. Hit the emergency stop button if you see someone in danger.

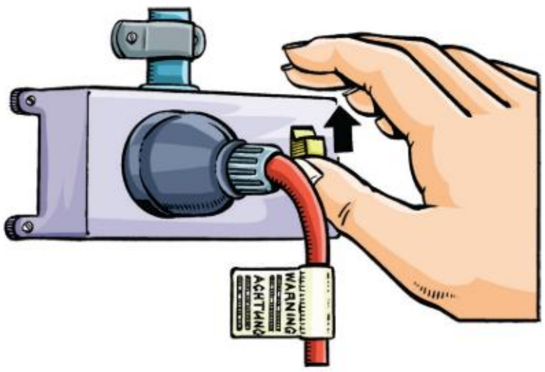
An emergency stop button

Beware of damp conditions when using electricity. If you must work in places that are damp, wear rubber gloves and rubber-soled shoes. The following drawings show some other precautions that should be taken to avoid electrical shocks.

Protect electrical leads, cables and hoses from being damaged.

Use a hauling line to lift electrical tools. Do not lift them by their cord as this could stretch or loosen the wiring.

Should an electrical accident occur, you need to know how to help someone. Follow these steps.
Step 1: Switch off the power supply.



If you cannot switch off the power supply, use a dry, non-conducting material such as plastic, rubber or wood to release the victim, as shown opposite.

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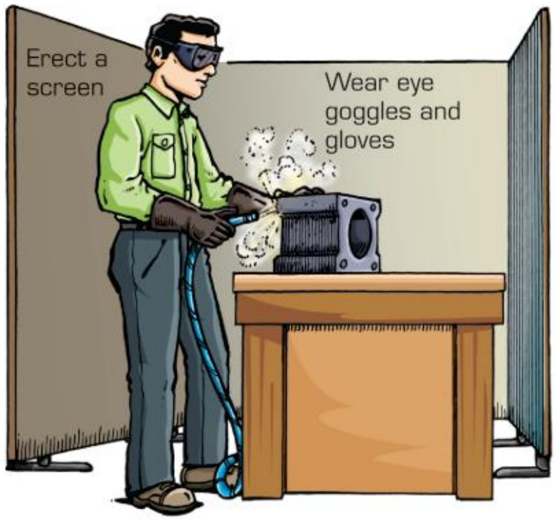
Alternatively, use a gloved hand, as shown below.

Step 2: Seek first aid for the victim.

Compressed-air (pneumatic) tools

Compressed air can be very dangerous. If you use it incorrectly, you could injure yourself or other people. Here are some points to remember.

- Wear goggles and gloves.
- Hold the end of the hose when turning on the air supply. Then the hose will not fly around.
- Screen off the work area if you are using compressed air to clean dismantled machine parts. Otherwise flying rubbish may injure other people.
- Do not use compressed air to clean down your clothes, your body or the bench.
- Obey the safety rules for each kind of compressed-air tool.

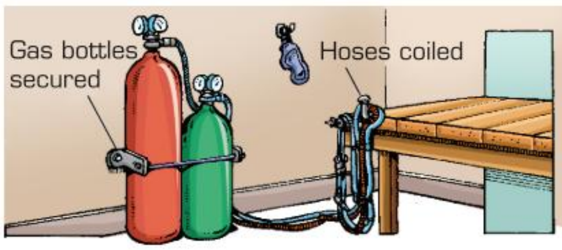


Cleaning with compressed air

Welding

Welding enables you to join materials quickly. However, it is a dangerous operation for an untrained person. You must:

- never attempt to weld unless you have been trained in welding
- wear the correct personal protective equipment, including gloves, mask and protective clothing
- be aware of flames, hot metal and flying sparks
- never look at the arc with the naked eye: it can damage your sight.



Oxyacetylene welding equipment must be stored properly. Keep it away from combustible substances such as oil and grease.

Screen off the work area when arc welding. Beware of combustible materials.

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Using ladders

Many people use ladders incorrectly. They often use the wrong-sized ladder for a particular purpose.

People also fail to follow the 'three points of contact' rule on ladders. That is, the human body must have three points of contact with the ladder at all times.

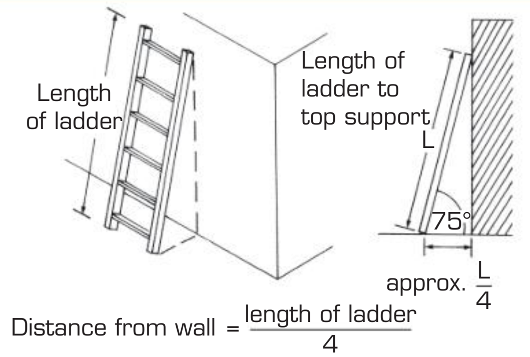
RULE: 2 feet + 1 hand = 3 points of contact

Step ladders

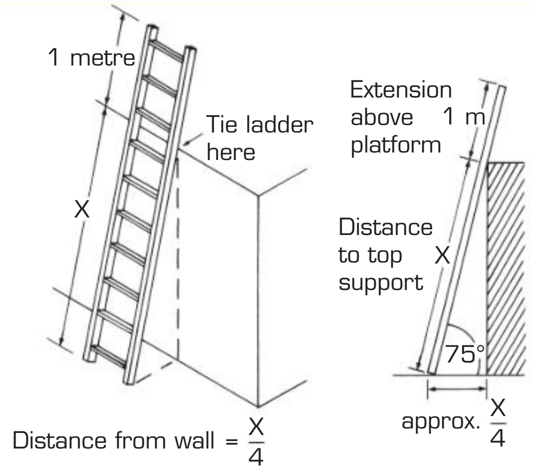
Step ladders should only be used if there is no support next to the work area (for example, when fitting a light bulb in the middle of a room). The drawing below shows how to use a step ladder safely.

Ladders and extension ladders

Ladders are used when there is support (such as a wall or a platform) next to the work area. You should tie the ladder to the support. This will prevent any slip. These diagrams show the safest way to position ladders on their supports.



Positioning ladders



Positioning extension ladders

As with step ladders, never climb past the third rung from the top of the ladder. Make sure also that the legs are resting on a flat surface.

When using ladders, people are often careless about the way they handle their tools and equipment. All tools need to be secure. For example:

- small tools should be carried securely in a pouch or bag
- larger tools and equipment should be hauled up with the aid of a hauling line.

Do not use a ladder if you are working with heavy tools or equipment. Instead, use a mobile platform or scaffolding.

Don't use a metal ladder when working near electricity.

Harmful substances

Many commonly used substances (such as paint stripper and acids used to clean materials) can be harmful to people. You must be aware of their dangerous properties and handle them safely at all times.

Store harmful substances in a lockable cupboard.

Always replace lids.

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Here are some precautions to take.

- Keep all known dangerous substances locked up.
- Read the label and the instructions before opening the container.
- Do not experiment with mixing different substances.
- Use the required personal protective equipment at all times.

PPE should include a mask or a respirator if dust or fumes are given off.

Use protective equipment when working with harmful substances. Work in a ventilated area to remove fumes.

- Always replace lids on containers.
- Clean up all spills immediately.
- Know what to do in case of an accident.
- To protect the environment, dispose of harmful substances thoughtfully – if necessary, consult your local council.

INFORMATION FILE

Material Safety Data Sheets

A Material Safety Data Sheet (MSDS) is a fact sheet about a hazardous substance. The MSDS includes the following information:

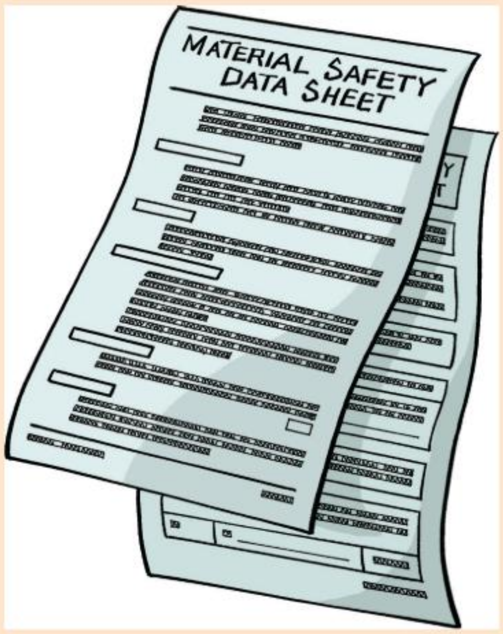
- product name
- chemical names of certain ingredients including generic names
- chemical and physical properties
- health hazard information – health effects, first aid, advice to doctor and toxicity
- precautions for safe use – exposure limits, ventilation, personal protection and flammability
- safe handling instructions – storage and transportation, spills, disposal and fire/explosion hazards
- manufacturer's or importer's name, Australian address and telephone number.

The purpose of the MSDS is for guidance on safe handling of the hazardous material when using and storing it. It also states the PPE requirements.

By following the guidelines of the MSDS you will protect your health and that of others.

You will also help to maintain a safe workplace.

The manufacturer of the materials is required to supply the MSDS and to update it as necessary.



Always read the MSDS.

Note that a hazardous substance in a container must also be labelled. The label must state the product name and the presence of certain ingredients, and it must list the risk and safety details.

READ THE LABEL, THEN THE MSDS

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Handling materials

Now that you are aware of harmful substances, you also need to know how materials are to be handled safely. This is for your protection as well as that of other people. Here are some guidelines to follow.

- Transparent materials such as plastics and glass need to be visible at all times. Use markers to define the surface area.
- Use gloves when handling warm materials, and tongs for hot materials or objects.
- Store materials safely (and securely) to prevent them from slipping or falling – and thus injuring someone – and to avoid blocking the movement of other people.
- Ensure that all materials placed on the work surface are not likely to fall.
- Erect a barrier to prevent injury to others if the material is overhanging the work area.
- Use a hook to remove **swarf**, not your bare hands.
- Do not remove swarf with your hands during a machining process.
- Remember to wear the correct gloves when handling each type of material to protect your hands from cuts, abrasions or splinters. Other parts of the body such as forearms and thighs may require additional PPE.
- Always use the correct lifting and carrying techniques as shown below. These drawings show the correct techniques for lifting and carrying. To lift or carry heavier loads, you should get help from another person or use a mechanical aid such as a hoist or a trolley.

AVOID BACK PROBLEMS BEFORE THEY START … BEND YOUR KNEES, AND LIFT BOXES THE RIGHT WAY

- Always use two people when carrying a long piece of stock – one person at each end, no matter how light it is.
- Always use two people when carrying a large sheet of stock – one person at each end.

Fires

Fires are a constant risk in the home, workplace or environment. You need to be aware of the three elements needed to produce a fire. They are:

- fuel: any material that can burn
- heat: from sources such as sparks, friction and electricity
- oxygen: one of the gases in the air around us.

FIRE = FUEL + HEAT + OXYGEN

The fire triangle

To prevent fires, you need to remove one element from the 'fire triangle'. For example:

- only HEAT + OXYGEN = NO FIRE
- only FUEL + OXYGEN = NO FIRE
- only FUEL + HEAT = NO FIRE.

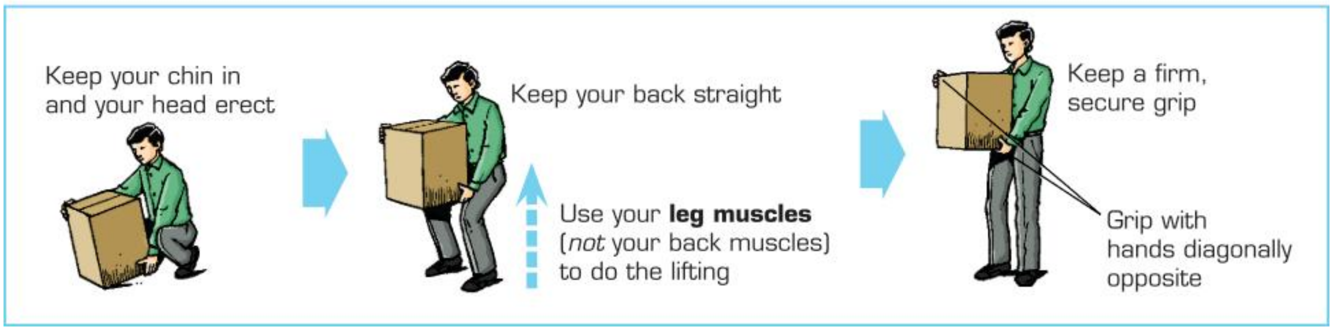
Good housekeeping
(e.g. a clean work area and careful storage of fuels)

+

Safe work practices
(e.g. not overloading electrical tools, and being aware of heat sources and sparks)

=

Will prevent most fires occurring



Correct lifting and carrying techniques reduce the risk of back injuries.

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Safety colour coding

We all know that at traffic lights red means stop, amber means caution and green means go.

Colour is used in other ways to convey safety messages, as shown in the table below. The colours listed can be used on their own, or with background colours such as black or white.

Table 2.1 Some colour codes used in industry

Colour	Message	Application	Examples of safety signs
Red	Danger, fire or not permitted	Danger signs, fire-fighting equipment, emergency stop buttons and actions or behaviour not permitted	
Yellow	Caution	Identifying hazards such as low beams and pipes, barriers, machinery or the safety zone around machinery	
Green	Safety	Location of safety features such as first-aid equipment, eye wash, safe exits, assembly point and safety message	
Blue	Mandatory information	Signs that state that a direction must be carried out, such as hard hats or safety glasses, are required by law in the area	

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Machinery is powered by a variety of energy sources, such as compressed air and electricity. If such energy is supplied by pipe, the pipes are colour-coded for ease of identification and safety. For example:

- steam: silver-grey
- air: light blue
- electricity (pipe containing cables): orange.

Pipe markers

Table 2.2 below shows some of the general colours used to mark pipes containing certain services. The pipe markers show the direction of flow with an arrow. Can you think of a reason to show the direction of flow?

Table 2.2 Colours for marking pipes

Pipeline service	Background colour
Drinking water	
Water	
Steam	
Oil: mineral, vegetable or animal oil; flammable or combustible liquids	
Gases: liquid or vapour	
Acids and alkalis	
Air	
Other fluids, including from drains	
Fire-fighting materials	
Electricity	
Communications	

Source: adapted from *Seton Source Book*, Feb–July 2009, p. 184.

INFORMATION FILE

Deaths during construction

The Panama Canal (length: 82 km)

During the construction of the Panama Canal (1904–14), 1219 construction workers died from injuries. Another 4766 workers died from other causes, such as tropical diseases.

The Empire State Building (height: 381 m)

During the construction of the Empire State Building in New York (completed in 1931), one person died for every 30 metres of height.

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Safety and health posters

Safety and health posters aim to educate people to 'think safety' and 'act safely'. The purpose of these posters is to draw attention to their safety messages.

A number of factors are considered when designing a safety and health poster.

- The poster must be colourful and eye catching.
- The poster must have a short message that captures people's attention. If there is too much information, people are unlikely to read it.
- The message may be humorous.
- The poster should have a picture or diagram to support the message.
- The poster should be easy to read.

Accident procedures

In spite of all the **precautions** that people take, accidents will still happen. You need to know what to do if an accident happens. First of all, *do not panic*. As calmly as possible, follow these basic steps.

1. **Remove the danger**
   (e.g. switch off power or turn off gas)
2. **Signal for help!**
3. **Apply first aid**
   (only if you know what to do)
4. **Assist**
   (as directed by qualified people)
5. **Evacuate the area**
   (if necessary)

World champions such as ski-jumper Alisa Camplin must 'think safety' when competing.

Racing-car drivers such as the Johnsons must 'think safety' when competing.

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Design

In this unit, you will learn:

- what design is
- about the basics of design
- about design processes
- how to use a design process.

What is design?

Design is the process of planning an outcome. This outcome might involve an object being made (for example, you might need a piece of furniture or an item of clothing). The outcome could also be a plan that solves a given problem – for example, you might want a system that lets you know when someone is approaching your room.

Designing, then, is a problem-solving activity. This activity may require the effort of one person or a group of people working together, as in industry. Designing is usually the basis of all technology.

A designer piece of clothing

A piece of designer furniture

Investigating	→	Devising	→	Producing	→	Evaluating
Coming up with a general idea of how to solve the problem and considering the impacts on people and the environment		Making a detailed plan of how to produce the solution		Making the solution using resources such as tools, materials and skills		Testing the solution to see if it is satisfactory and assessing its effects on people and the environment

A problem-solving process

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You do not have to look far to see evidence of design in our world. Objects and systems are designed daily by people in different industries. For example, manufacturing engineers design products such as stoves and cars and they also design mass-production systems. Clothing produced by the fashion industry is also the work of designers.

The way in which something is designed may vary from one industry to another. However, the outcomes are usually achieved using a design process. This is a framework to ensure that the designer's solution will be that person's best solution, within certain limits. The solution should

- not cost too much
- be easy to use
- look good.

In general, the solution should be designed in such a way that people will want to use it.

Good designers will also make sure that their solution will not harm their fellow human beings or the environment.

Examples of the design process

The design process is not used in the same way by all designers. There appear to be three basic methods of designing. Let's look at each of these methods.

Method 1

Synthesis → Analysis → Evaluation

This approach is often used by engineers. A general concept is first proposed with little information. The concept is then refined by using further research and investigation.

Method 2

Analysis → Synthesis → Evaluation

This method is used by industrial designers (and students of industrial technology and design). It is a more open-ended approach, which encourages **divergent thinking** from the start. The ideas are refined through research and experimentation before a best single solution is accepted.

Method 3

Thought + Imagination = Creativity

This method is more common among artists. Thought and imagination are the key elements, as often seen in the creative arts. The result is a combination of thoughts and things combined to produce something new.

Which method?

You should be aware that aspects of all three methods may be required to meet a design challenge.

The basics of design

A designer needs to consider the elements of design and the principles of design. These give an item its visual appeal.

Do you think these items have visual appeal? Why or why not?

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The elements of design

The elements of design are points, lines, shapes, forms, colours, tones and textures. They are the basic building blocks of design.

Points

A point is a spot in space. Points (or dots) can be organised in many ways – for example, to suggest lines or to show different tones.

Lines

Lines can create space, direction, rhythm, shape, tone and texture. They can be curved or straight, thick or thin, wavy, and so on.

Shapes

A shape is a **flat** image such as a circle or square. Lines are used to create shapes. Shapes can be regular (such as geometrical shapes) or irregular (such as many natural shapes).

Forms

A form is a three-dimensional (3D) object such as a sphere or a cube. It is presented through size, shape, proportion, colour, tone and texture. The form of an object should suit its purpose or function.

Colours

Colour is used to identify things. It can also be used to create a mood or feeling. (See 'Colour' on pages 25–6.)

Tones

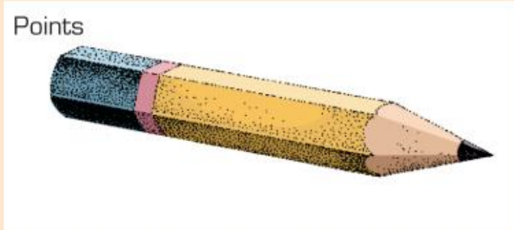
Tone is the degree to which a colour is light or dark. It can be used to show the form of an object. Tone is commonly called 'shading'.

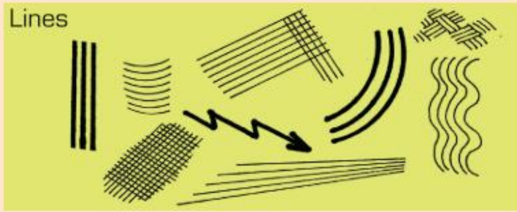
Textures

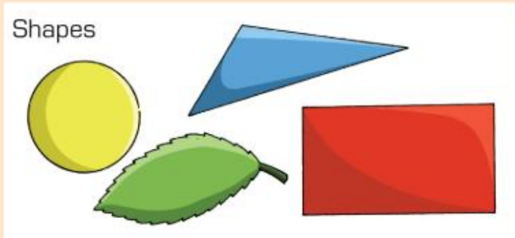
Texture is the surface finish that you can see or touch. Examples of types of texture are smooth, rough, fine and coarse.

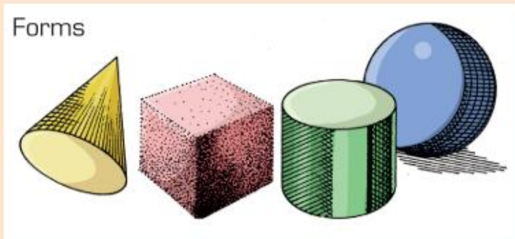
The principles of design

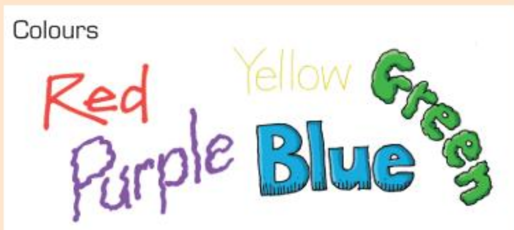
The principles of design include balance, unity, proportion, contrast, emphasis, movement and rhythm. They are used to organise and integrate the elements of design in a pleasing or effective way. The overall effect is sometimes called **aesthetic** appeal. Find some items that you think are well designed and discuss why they have aesthetic appeal.











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This lamp displays principles of design such as balance, proportion and contrast.

These vases display principles of design such as unity, movement and rhythm.

INFORMATION FILE

Colour

Colour is very much part of our daily life. Colours are used to create moods or feelings, or to attract people's attention – for example, in fashionable clothing, in commercial packaging and in safety colour-coding.

Designers use colour to add to the overall effect of the design and its aesthetic appeal. A good example is children's toys, which are usually bright and colourful.

A colour wheel (see overleaf) shows a range of different colours and their relationship to each other. It has three stages.

- **First stage:** primary colours, that is, red, blue and yellow. These colours cannot be made by mixing any other colours.
- **Second stage:** secondary colours, that is, a mixture of primary colours. For example:
  - red and yellow → orange
  - red and blue → violet
  - blue and yellow → green.
- **Third stage:** tertiary colours, that is, primary colours and secondary colours mixed together. For example:
  - red and violet → purple (plum)
  - blue and violet → indigo (grape)
  - blue and green → deep green (aqua)
  - yellow and green → yellow-green (lime)
  - yellow and orange → yellow-orange (peach)
  - red and orange → red-orange (watermelon).

Colours can be used to create contrast or harmony.

Colours opposite each other on the colour wheel (for example, red and green, violet and yellow or blue and orange) give contrast. These are known as complementary colours. These colours appear to clash or stand out. They are used to attract people's attention. They create a strong and lively feeling.

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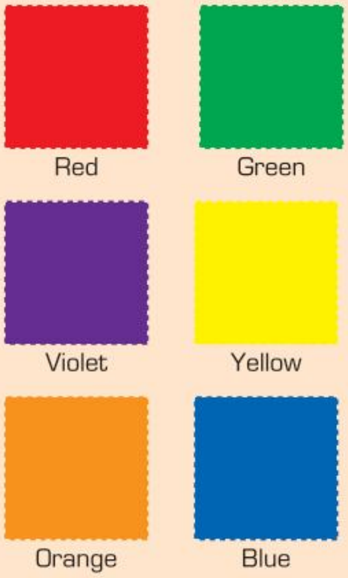
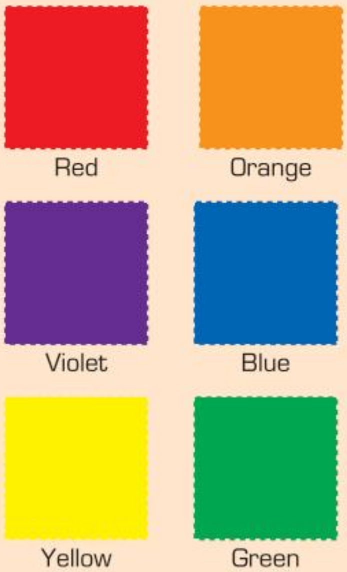


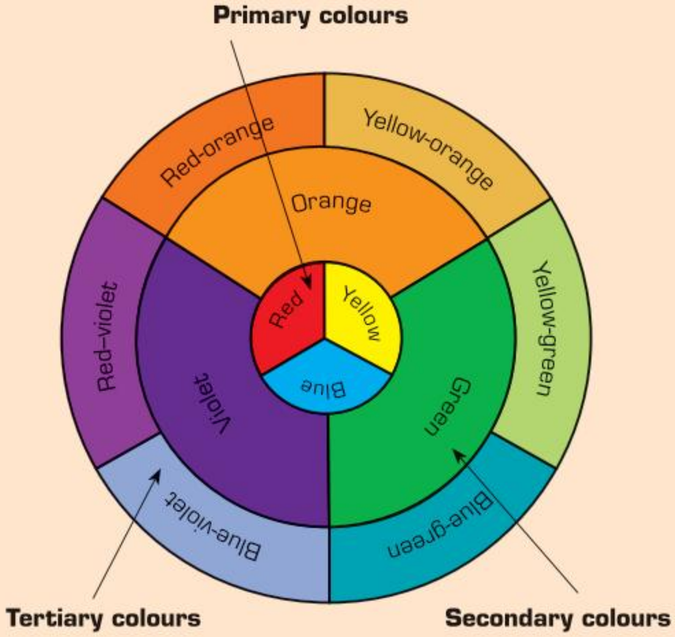
Harmony is achieved when you combine colours that are close to each other on the colour wheel. These are known as analogous colours. Examples are red and orange, blue and violet or yellow and green. These colours do not clash or stand out. Their calming effect is soft or subtle.

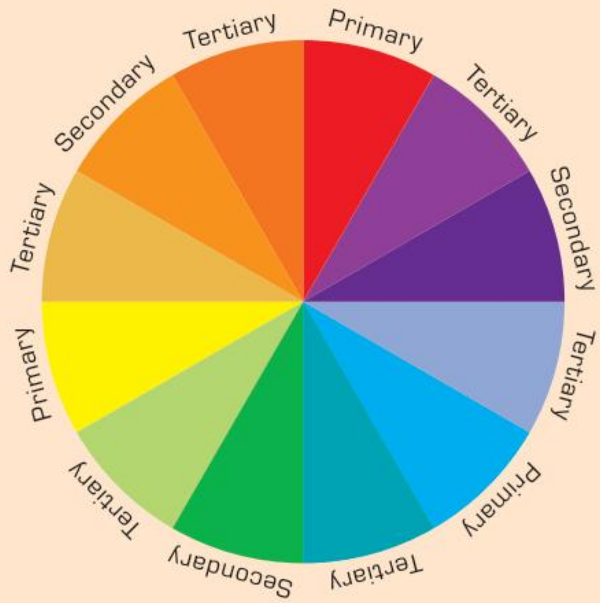


Colours can also be grouped as warm colours and cool colours.

Warm colours such as red, orange and yellow have the effect of heat, restlessness, excitement and stimulation. Warm colours also tend to come forward.

Cool colours such as violet, blue and green have the effect of being cool and peaceful. Cool colours tend to recede.





Two examples of a colour wheel

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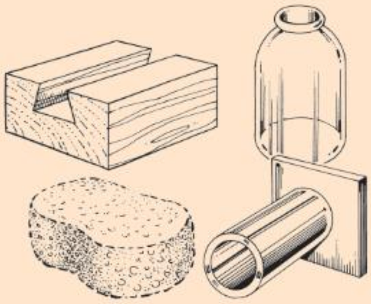
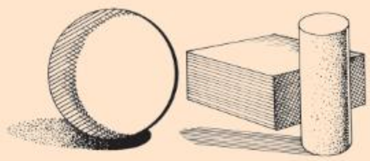
INFORMATION FILE

Rendering

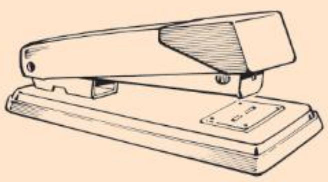
Designers use rendering to add realism to their drawings. Rendering involves using lines or dots to create tones and texture. The lines and dots can be spaced or angled differently to suggest a variety of finishes such as shiny surfaces, textured surfaces and wood grains.



Lines and dots can also be used to create a three-dimensional effect by suggesting tones and shadows.



Different weights of lines can also be used to emphasise particular features.



Colour can be added to make the drawing even more realistic. In industry, designers often make a number of copies with different colours so that managers and clients can decide on a colour range for the final product.

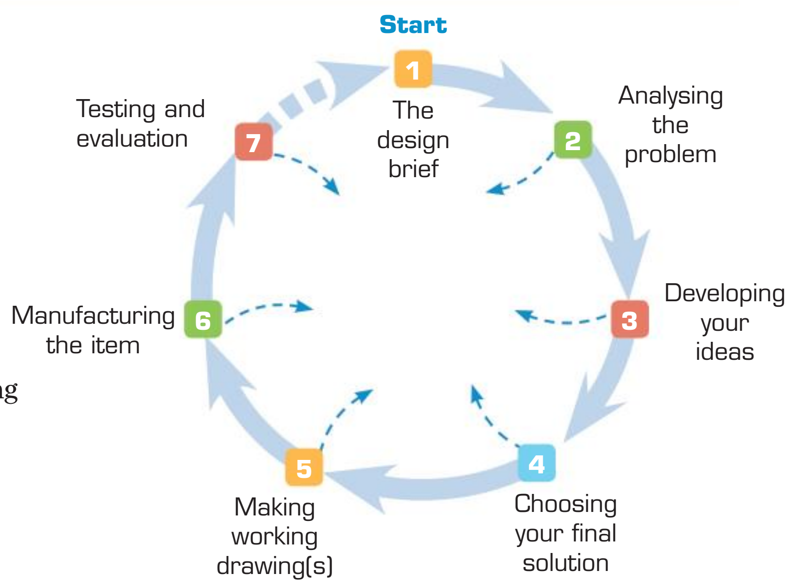
An example of the design process

Method 2 of the basic methods of designing discussed on page 23 is probably the process you will use most often.

Analysis → Synthesis → Evaluation

This process is expanded into more basic steps, as shown in this example. Study the diagram, noting the seven basic steps and the direction of flow.

You will notice that there is a starting point and a suggested flow pattern. In many cases you will begin the design process at stage 1, and end at Stage 7.



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The design process can be cyclical. This means that the cycle can continue until you are satisfied that your solution is the best possible outcome.

Sometimes the order might not be cyclical, as illustrated in the diagram by the broken arrow lines. For example, during stage 6 it may be necessary to return to stage 2 to do more testing in order to solve a manufacturing problem with the chosen material. This might lead to another stage before the problem is solved.

Alternatively, the design process can begin at any stage – for example, by starting at stage 7, you would evaluate an existing solution prior to writing a design brief and commencing analysis.

The terms used to describe these actions are **recursive** and **iterative**.

Therefore, design is the result of many different and varied actions by an individual or a group. There is no right way. Remember that the design process is a framework for guiding you to produce a satisfactory solution.

Now that you are aware of design processes, it is time to examine the seven steps in the basic design process in greater detail. *Please note:* The case study on pages 34–8, explains the seven steps.

1 The design brief

A design brief is a clear statement of a general problem or need. The requirements that it lists are often referred to as the design specifications.

Broad terms should be used in the brief – for example, 'container' instead of 'box'; 'device' instead of 'rack'. An open brief like this allows you to consider many possible outcomes.

An example of a design brief

The brief can be presented as a series of sentences or in point form. Point form is often used to record a list of specific details – for example, style, quality and performance requirements – that must be part of the final solution.

2 Analysing the problem

To analyse the problem, you gather all the information that you will need to consider. (You will have to carry out research to do this.)

As well as suitable dimensions and other basic details, you will require information about topics such as the following.

Possible environmental and social impacts

You should ask questions about the long-term and short-term effects on the environment and society, such as:

- How safe is your solution?
- Is it energy efficient?
- Does it conserve natural resources as much as possible?

Materials you could use

You need to think about the materials you could use.

- Natural – for example, timber, fabric or leather
- Synthetic – for example, plastics
- **Composite** – for example, fibreglass.

The limits of any material are subject to the set of properties for that material. (See Unit 4, Materials, for more details.)

The properties of a material – such as strength, toughness, comfort and durability – need to be considered when analysing the problem and developing your ideas.

For example, selecting a piece of timber with a number of loose knots is not a good choice if strength is important. (See page 46.) Likewise, since wood is strongest under **compression**, it will withstand large forces if used correctly.

INFORMATION FILE

Testing materials

You might have to carry out tests on samples of different materials to see if they are suitable. You might also have to test the safety factors of materials. (See page 202.) Alternatively, you could refer to safe load tables. These show the safe load limits for materials of different sizes and shapes.

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Processes you could use

To join materials, you could consider using:
- mechanical fasteners (screws, bolts and press studs)
- chemical adhesion (glues, adhesives, soldering)
- jointing (interlocking)
- cohesion (solvents and welding).

Tools/equipment you could use

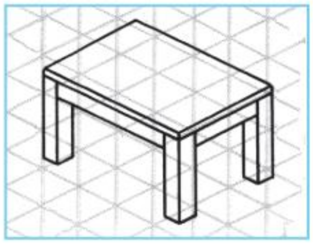
The tools and equipment you could use include:
- hand tools
- power tools
- other equipment, such as lathes and electric arc welders.

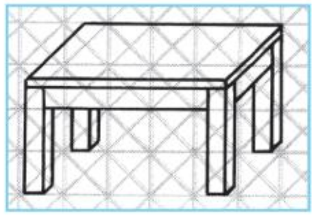
After you have gathered all the information you need, you will have to organise the details. One approach could be to use the following headings.
- **Time limit:** How urgent is the need? How much time do you have to make it?
- **Materials:** What is suitable? What is available? What is the cost? New or recycled?
- **Function:** Why is the item needed? Does it have a secondary purpose as well as a primary purpose?
- **Ergonomics:** How efficiently will people be able to use the item? Will its size and shape meet their needs in the best possible way?
- **Appearance/aesthetic appeal:** How will the item look? What finish could you give it?
- **Personal safety:** Could it injure users or bystanders?
- **Design consequences:** Is there any risk that making the item will harm the community or the environment?
- **Construction:** Do you have the skills, knowledge and equipment needed to make it?

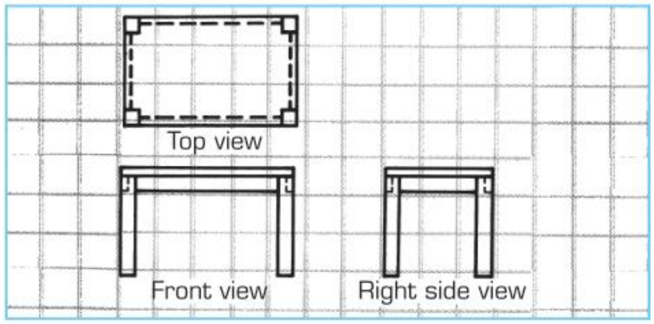
Generally, most people need some help to solve their design problems. You can get ideas and information from:
- books and magazines in the library
- analysing or looking at similar objects or systems in your community
- talking with people to find out their views
- experts in industry, in government and in colleges or universities.

3 Developing your ideas

At this stage, you record all your ideas using words and/or pictures.
- Make initial sketches. These could be pictorial drawings (such as isometric or cabinet oblique drawings), or they could be orthogonal drawings (front, top and side views). Remember to keep your sketches in proportion. It is a good idea to use grid paper for your sketches.

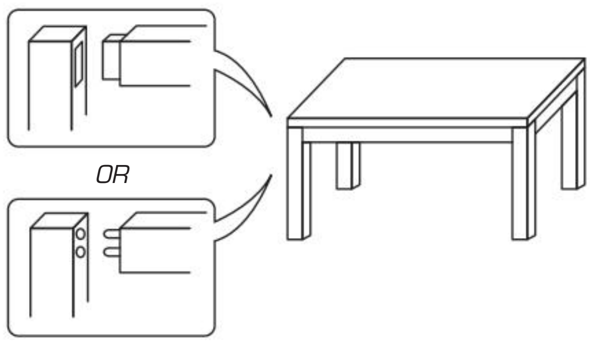

An isometric sketch


A cabinet oblique sketch



An orthogonal drawing

- Provide separate sketches to show greater detail or alternative solutions.



- Note down any features you may find difficult to sketch, such as type of material, and size and type of fasteners.
- Today, many designers use computer-aided design (CAD) to develop their ideas. (See page 165.) You too could use CAD.

(If you are working with other people, you may wish to use brainstorming to develop your ideas. When you brainstorm, you put everyone's ideas together.)

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INFORMATION FILE

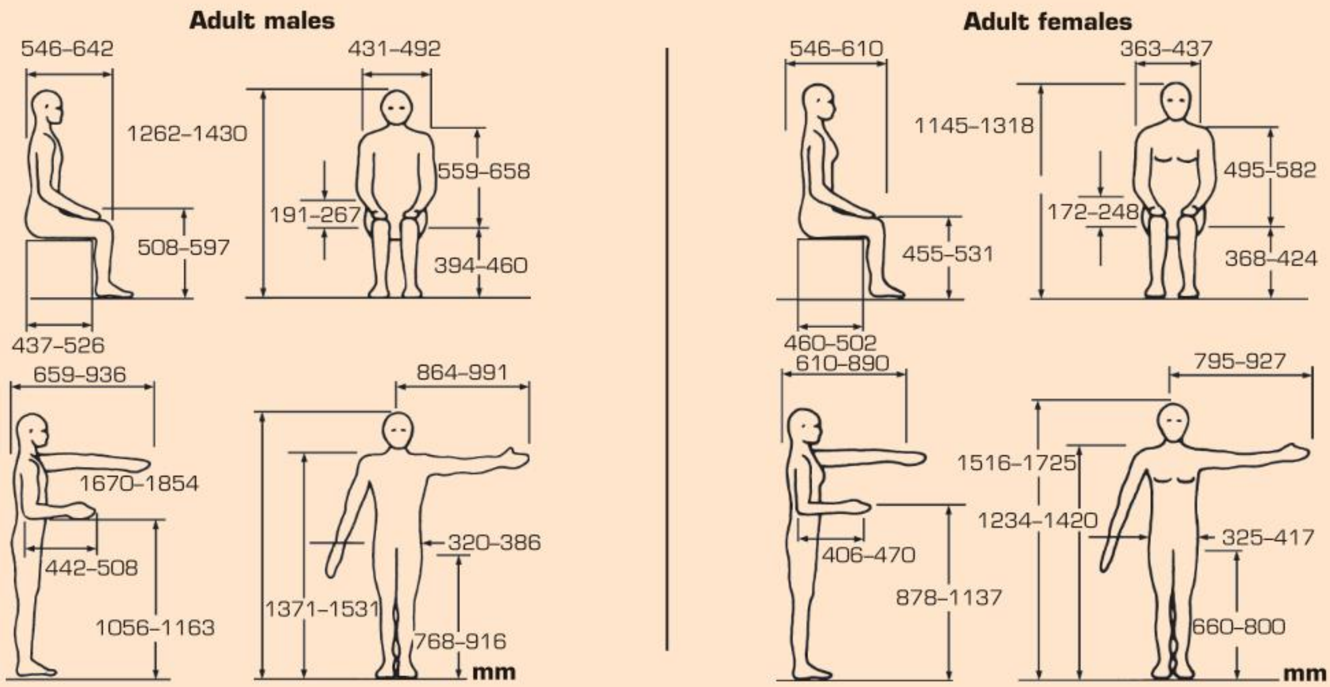
Anthropometry and ergonomics

Anthropometry is the science dealing with human body measurements for different sexes and different age groups. Anthropometric charts list all measurements for the various parts of the body, such as length of arms, length of legs, width of hips and overall height.

This information is very important, for example, when designing a chair for an adult or a child. Since the adult's trunk and legs are longer than the child's, the designer needs to consult the anthropometric chart. The anthropometric data give the designer the correct dimensions for each age group. This way, the final solution will be a suitable size.

Not only does the solution have to be the correct size, but people must be able to use it efficiently when they are working. The study of people in relation to their work environment (including space, lighting and layout) is known as ergonomics.

Well-designed tools have to be ergonomically efficient. For example, a screwdriver used by a tradesperson in cabinetmaking would most likely have a smooth, egg-shaped handle. A motor mechanic, on the other hand, would select a screwdriver whose handle has grooves. Why is this so?



Anthropometric data for adult males and adult females (seated and standing)

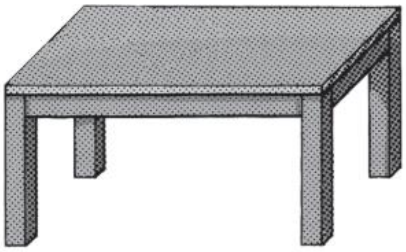
4 Choosing your final solution

Your first idea may not be the best solution. You may need to combine several ideas to come up with a final solution.

- Study your initial sketches and the features you have noted.
- Choose your final solution, and record all the requirements.
- Record your reasons for selecting these requirements. This record of requirements is called a final specification.

At this stage you should render your final solution to make it look real. This will help you to see how the finished article will look before you make it.

Consider using colours, if appropriate, on your final solution. Colour your sketch with crayons, felt-tip pens, watercolours or other appropriate media to give added realism.



Experiment with different colour schemes to assess the aesthetic appeal of the final solution. (You may need to present a number of coloured sketches.)

To help you **visualise** and test your final solution before manufacturing it, you can make a model. The model could be full-size, or it could be scaled down if it would be too large to make.

You can use inexpensive materials such as paper, cardboard, glue and staples to produce mock-ups. Alternatively, more realistic models can be made from foam, wood and metal, with an appropriate finish applied.

Model-making helps you to identify:

- weaknesses in the structure or the materials to be used
- design problems (such as instability caused by poorly balanced **components**)
- the steps in manufacturing the item
- improvements that could be made.

Some manufacturers may use a full-sized model to seek responses from the public. The model is displayed at a selected **venue**. People are asked to comment about the design. These comments help designers to **review** the design. If necessary, changes will be made to the final solution prior to producing it.

INFORMATION FILE

Modelling

Modelling is a quick way to help people see and test a design before producing it. The series of photographs below shows a process used to produce a full-size model of a concept car.

The shell of the car is modified so that it has the necessary design features. For example, this may include big, chrome wheels, a shield-like front grille and slanted headlights.

Note the use of foam to build up the outside and inside surfaces of the shell. The foam is then shaped and an appropriate finish is applied.

The completed mock-up looks like a new model of a vehicle that has just been released for sale by the automobile company.


The basic shell


Building up the outer shape


Shaping the model


Checking the profile


Building up the dashboard and centre console


The finished dashboard and centre console


The full-size model

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5 Making a working drawing

Make a detailed drawing (usually orthogonal) of the components, and write down your specifications. The working drawing should include your procedure, as well as a list of materials and the costs involved.

Your procedure can be recorded as either a list of steps and tools/equipment, for example:

1 Mark out (pencil, rule and square)
2 Cut out (coping saw or hacksaw)
3 _ _ _ _ _ _ _ _ _ _
4 _ _ _ _ _ _ _ _ _ _

or a flow chart (using words and/or pictures).

Your materials list can be drawn up as a table with headings, as in Table 3.1 below.

6 Manufacturing the item

Complete the item using the processes of forming, separating and combining (see page 121), as recorded in Step 5. This stage is often called realisation.

7 Testing and evaluation

You need to test whether or not your design has solved the problem or met the need. At this stage, your product is a **prototype**. The process of testing a prototype is called evaluation.

If testing shows that your prototype has not solved the problem, then you should repeat the design process either in whole or in part. This may mean that you have to do some more research.

It is not uncommon for designers to modify their solution. Unexpected problems often arise when the prototype is being made or tested. These problems must be solved before work can continue.

In industry, any modifications to a product are made at the prototype stage, before the factory tools up for mass production.

When evaluating your solution, you could ask yourself questions such as:

- How did my **artefact** turn out?
- What problems did I have in making the item?
- How did I solve these problems?
- How could I improve the design? (Consider material selection, joining methods, and so on.)

You could also draw up a table such as the one opposite ('Evaluation summary') and record your comments.

Table 3.1 Materials list

Component	Material	Size	Number required	Cost
Legs	Pine	42 × 42 mm	4 / 430 mm long	$
Rails	Pine	42 × 19 mm	2 / 1116 mm long	$
	Pine	42 × 19 mm	2 / 426 mm long	$
Top	Particleboard, pine	1150 × 460 × 19 mm	1 off	$
Screwing blocks	Pine	42 × 19 mm	4 / 60 mm long	$
Veneer edging	Pine	Comes in standard thickness	1 / 3300 mm long	$
Particleboard, wood screw, countersunk	Steel – zinc plated	10G × 30 mm	4	$
Adhesive	PVA wood glue			$
Polyurethane varnish	Satin finish			$
			Total cost	$

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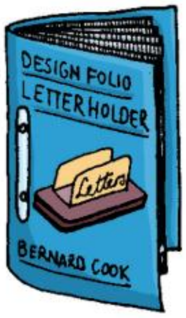
Table 3.2 Evaluation summary

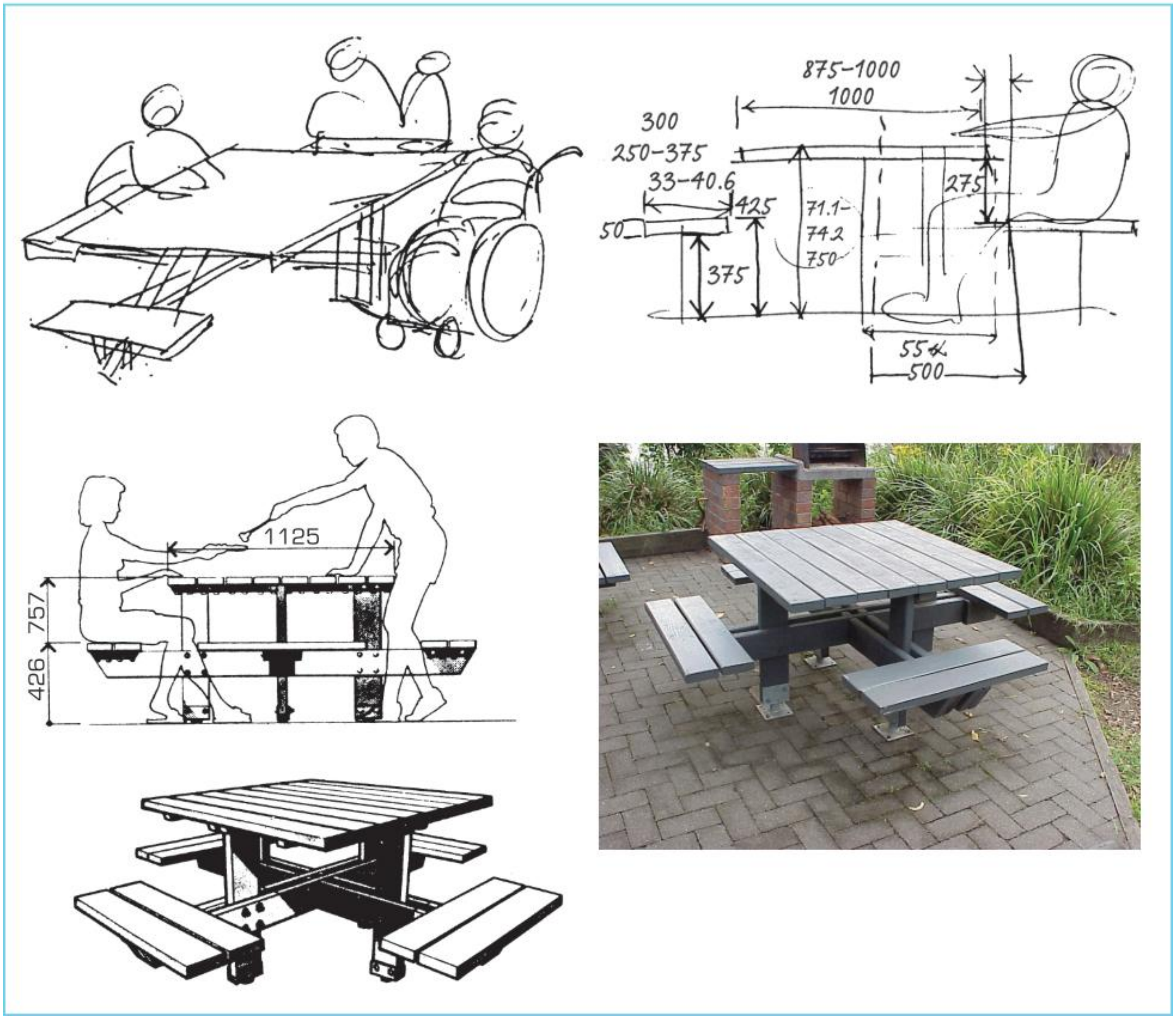
Good points	Weak points
•	•
•	•
•	•
•	•
My conclusion:	

Finally, to keep your work together:

- make a folder and put all your sheets in it
- sketch your solution on the front cover and add the title and your name.

Your design folio is now complete.





Stages of the design process for picnic tables in Brisbane Forest Park

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CASE STUDY: THE DESIGN FOLIO

The situation

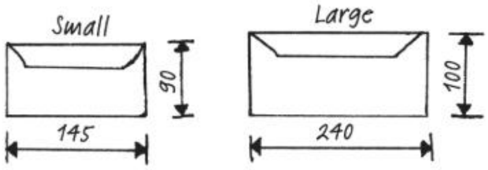
I have trouble finding letters from my friends. At the moment, they're somewhere in the piles of papers on my desk. I want to be able to find them quickly.

1 Design brief

To design and make an object that will store at least 10 letters in a neat manner, so that I can find them quickly.

2 Analysing the problem

Size of envelopes:



(Both 2 mm thick, including contents)

Time limit:

I have 4 hours to make it.

Materials:

It could be made of wood, metal or plastic (for example, 68 × 12; pine or mahogany; or 3mm thick acrylic).

Function:

- It must hold at least 10 envelopes (large and small).
- It must store the envelopes neatly so they are easily identifiable.
- It must be movable (free-standing).
- It could also be used to hold pencils and pens.

Ergonomics:

- The holder should be wide enough to allow the letters to be inserted and removed easily (at least 25 millimetres wide).
- Make front and back same or different heights?

Appearance/aesthetic appeal:

To be colourful and glossy (to match décor of my room). Shape(s)? Texture(s)? Colour(s)?

Personal safety:

There must be no sharp corners or edges. It must be stable. (Add feet?)

Design consequences:

It presents no danger to people or the environment. I will try to conserve resources by using leftover materials.

Construction:

I have access to hand tools and a disc sander, electric drill and bandsaw.

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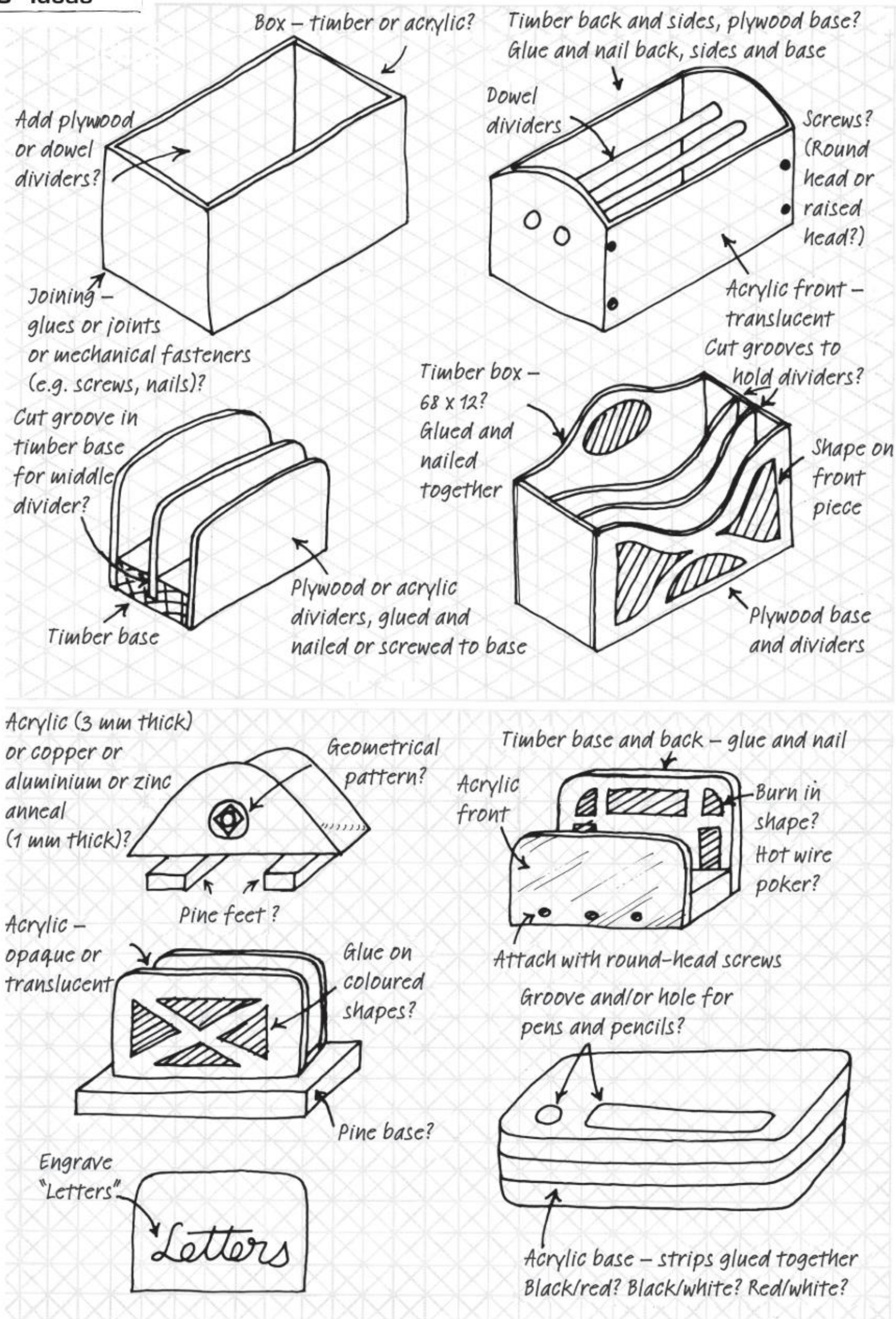
3 Ideas



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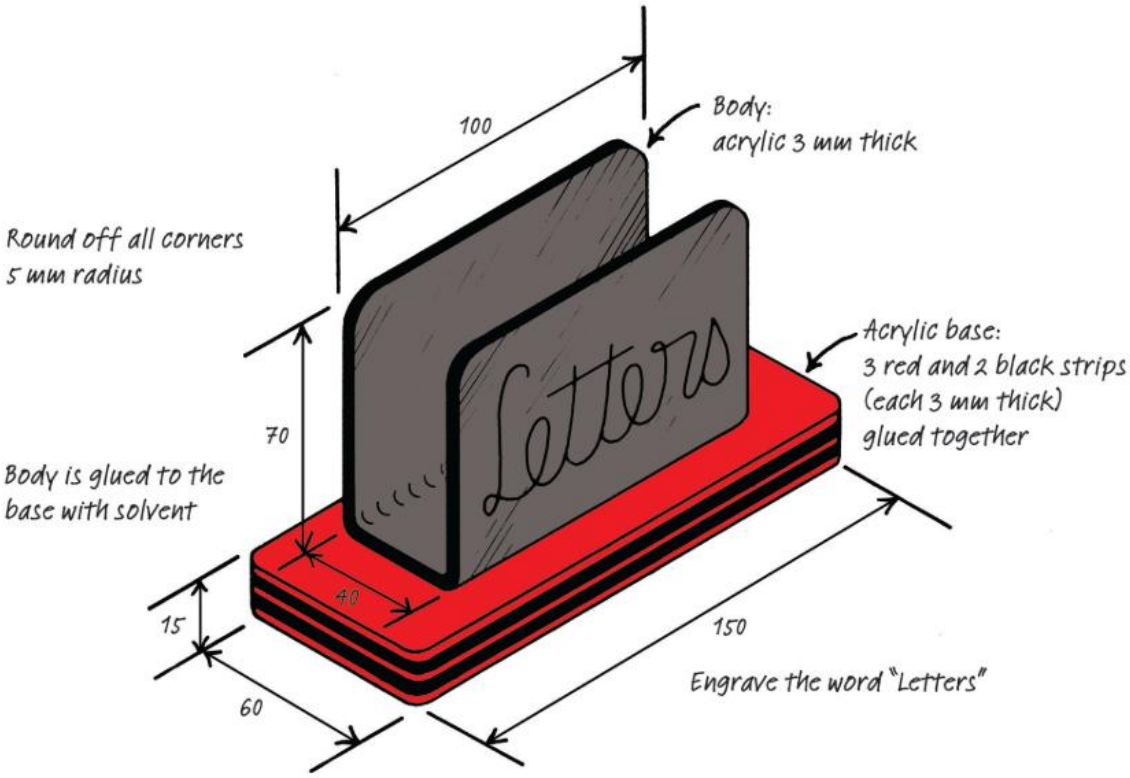
4 Final solution



<u>My reasons for making these choices:</u>

- I have selected acrylic because:
  - It looks good and I like the colours.
  - It is strong enough for this purpose.
  - It will fit in with the décor of my room.
  - It will be safe to use.
- I have tested the size and shape of the item to ensure that it is stable and that it will hold at least 10 letters.
- Cohesive bonding does not spoil the appearance of the item (unlike screws).

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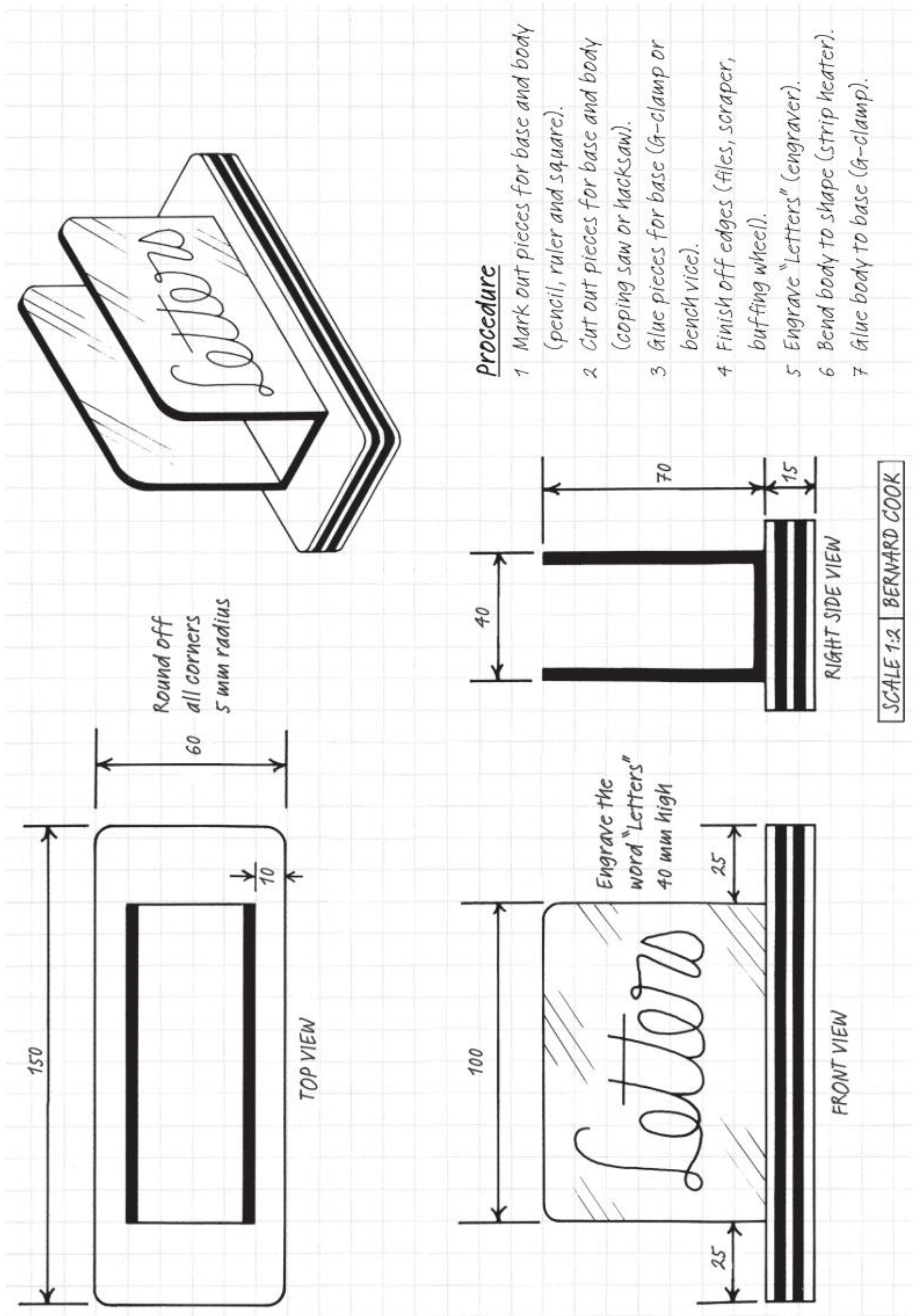
5 Working drawings



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Material list

Component	Material	Size (mm)	No. required	Cost
1 Base	Acrylic: opaque (black and red)	150 × 60 × 3	5 (2 black, 3 red)	...
2 Body	Acrylic: translucent (black)	180 × 100 × 3	1	...
Adhesive	Ethylene dichloride	...		
Polish	Rouge	...		
			Total cost	$ ...

6 Realisation

Make the letter holder, using the procedures outlined in step 5.

7 Testing and evaluation

Good points

- It looks good – for example, the "clean look" of acrylic is visually appealing to me. The clash of colours – black and red – attracts attention. It also gives it a bold appearance.
- It is easy to use – for example, there is plenty of width for 10 envelopes. The length of the body makes it easy to insert envelopes.
- It is stable – for example, the base is heavy enough to stop it from falling over if bumped. The 3mm thick acrylic used for the body is rigid enough to take a knock without breaking.
- It is safe – for example, there are no sharp corners or edges.

Weak points

- Two corners on the base are not rounded off well. (I should have checked it better. Next time I will use a template to make sure that all corners are the same.)

- The body is at a slight angle to the base. Again, I need to take more care when gluing it. A cardboard template could have been used to locate the body parallel to the edge of the base.

My conclusion

It took 4½ hours to complete the task. I need to be more aware of the time limit next time.
The letter holder works well. I'm very pleased with it. (My friends like it too.)

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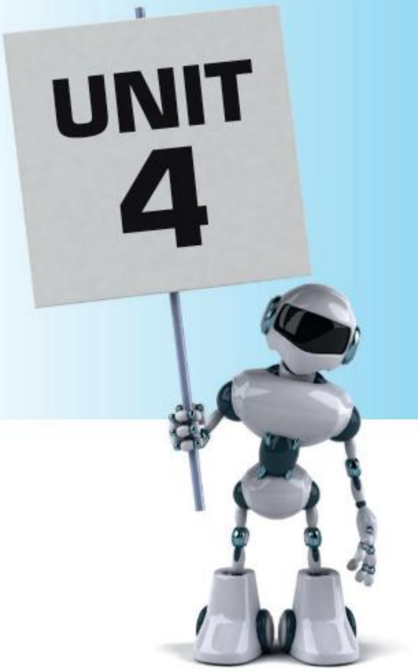

Materials

All technology depends on the use of materials to produce a solution to a problem. People use some materials in their *natural* form – for example, wood, stone and clay can be used as building materials. Other materials have to be processed before they can be used – for example, bauxite ore is refined to give the metal aluminium. There are also *synthetic* materials (such as plastics) that industrial chemists make from chemical compounds.

Each material has a set of properties such as colour, strength and texture. These affect the appearance of the material – that is, its aesthetic quality – and how it can be used. When selecting materials for a specific task, you must consider these properties. For example, one may be very stiff or rigid, while another material might bend easily. If you make a poor choice of materials, the item could break when it is used.

In industry, the choice of material is very important. Manufacturers need materials that work properly, are safe to use, and are attractive to the purchaser. Often, there are several materials that can be used for the same purpose. Because manufacturers need to sell their products at competitive prices, they also need to consider other aspects such as the availability and cost of the material.

The use of recycled materials is also gaining popularity given the debate about the environment. Years of use often adds aesthetic appeal to the material. The everyday 'knocks and bumps' or the constant rubbing of skin can **enhance** the appearance of the material. This visual appeal cannot be easily **duplicated** by industry.

As a creator and user of technology, you need to study the properties of different materials, how they are produced and the uses to which they can be put, to enable you to make a wise choice. In the following sections we will look at:

- timber
- metals
- plastics
- other common materials, including composite materials.

STRENGTH: How easy or difficult is it to break?

TOUGHNESS: How much impact can it stand without breaking?

HARDNESS: How well does it resist denting or scratching?

ELASTICITY: How well does it return to its original shape and size after being subjected to external loads and forces?

DENSITY: How heavy or light is it for its size?

CONDUCTIVITY: How well does it conduct (or insulate against) heat, electricity or sound?

DURABILITY: How well does it resist environmental stresses such as the weather or insects, or does it tear easily or wear out (e.g. fabric)?

FLAMMABILITY: How easily does it burn (or smoulder) when exposed to heat or fire?

Some properties of materials

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Part A: Timber

In this section, you will learn about:

- trees and forests
- the properties of timber
- timber products
- other forest products.

How trees benefit us

Trees cover 20 per cent of the Earth's land surface. They grow as natural forests and also as specially cultivated plantations.

Trees play a vital part in life on Earth. They provide people with a number of benefits. For example:

- they make much of the oxygen in the air we breathe
- their roots protect the soil from being eroded by wind and rain
- they help to control the climate – for example, they help to reduce 'global warming' by using up carbon dioxide from the atmosphere. In addition, their leaves return water to the air and this moisture helps to form clouds
- they beautify our environment
- they are a source of food (such as fruit and nuts) for people and animals
- they provide a wide range of timber products that we use in our homes, offices and factories.

Classifying trees

Trees can be classified into two groups:

- hardwoods
- softwoods.

A natural eucalypt forest

A softwood plantation

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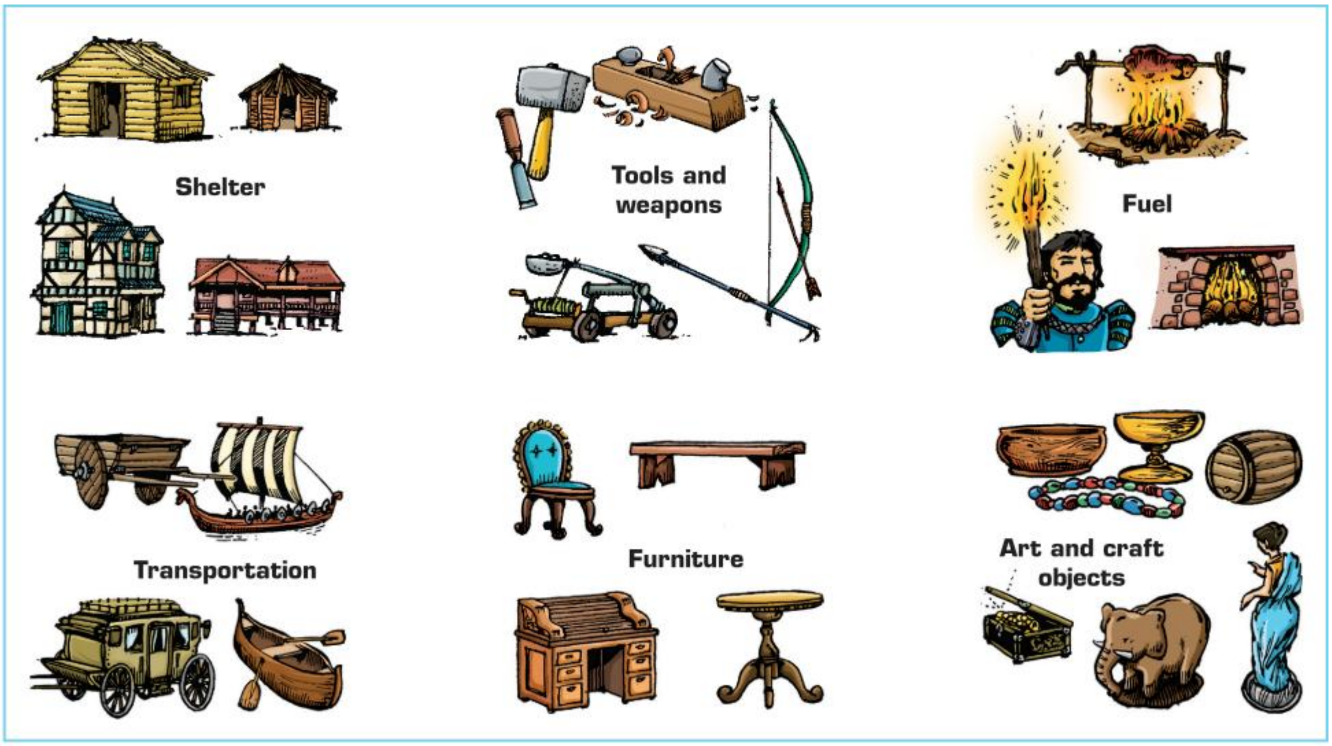


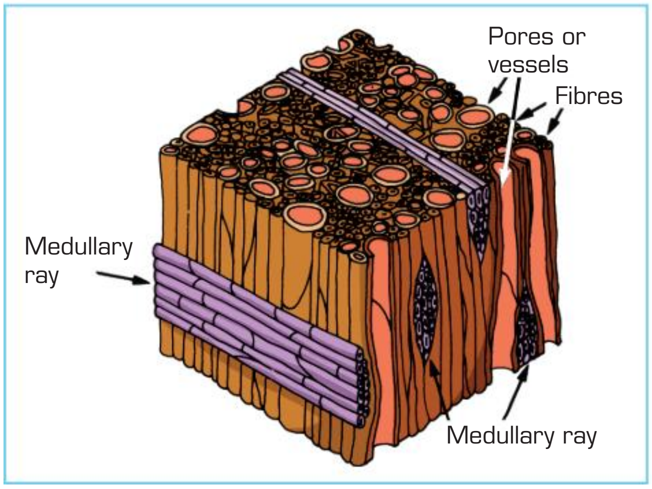
Some uses of timber through the ages

People usually say that timber is hardwood or softwood depending on the ease with which they can shape the timber with tools. However, a botanist would classify balsa wood – the softest wood in the world – as a hardwood. Scientifically speaking, the terms hardwood and softwood refer to the *structure of the cells* in the timber rather than the relative hardness or softness of the timber.

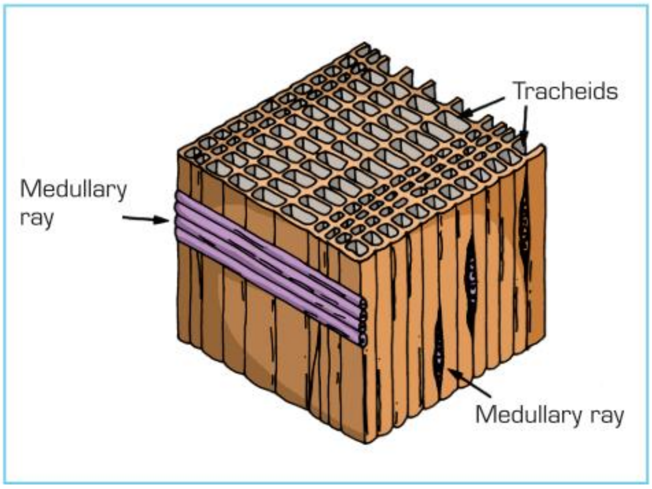
Hardwoods have pored wood, while softwoods have non-pored wood, as shown in the diagrams below.

RULE:

- Pored wood is usually (but not always) hard.
- Non-pored wood is usually (but not always) soft.



A microscopic view of a section of hardwood (pored wood)



A microscopic view of a section of softwood (non-pored wood)

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	Hardwoods	Softwoods
	 Hardwoods are broad-leafed flowering trees.	 Softwoods are cone-bearing trees with thin, needle-like leaves. They are often called conifers.
	 *Examples*: Native: IRONBARK Exotic: MERANTI	 *Examples*: Native: HOOP PINE Exotic: WESTERN RED CEDAR
Botanical classification	Angiosperms – 'enclosed seed' plants. The flowers produce seeds enclosed in fruit.	Gymnosperms – 'naked seed' plants. There are no flowers; instead, the cones produce seeds.
Leaves	Leaves are usually broad and flat. Many hardwoods are deciduous; that is, they shed their leaves in autumn.*	Leaves are needle like. Most softwoods are evergreens; that is, they do not shed their leaves.
Cell structure	**Pored wood**, with two types of cells: • Large, tube-like pores or vessels. These carry sap. • Smaller, thick-walled fibres. These support the tree.	**Non-pored wood**, with only one type of cell: • Long, thin cells called *tracheids*. These carry sap and support the tree.
Geographical location	Best suited to more temperate or tropical climates.	Best suited to cooler climates.

*Most Australian hardwoods (such as eucalypts) are not deciduous.

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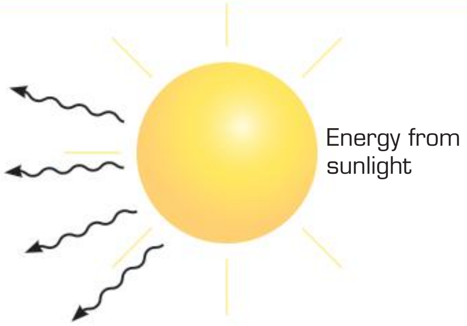
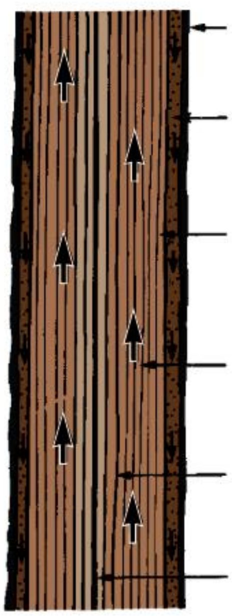


Crown
- Made up of leaves and branches
- Produces plant food through photosynthesis in leaves
- Contains special cells at tips of branches, which cause increase in height of tree



Outer bark protects the trunk and branches from being damaged and from drying out

Inner bark or **bast** carries food from the leaves to the branches, trunk and roots so that the tree can grow

Cambium – new wood cells grow from the inside of this layer and new bark cells from the outside. As these new cells grow, the trunk expands in thickness

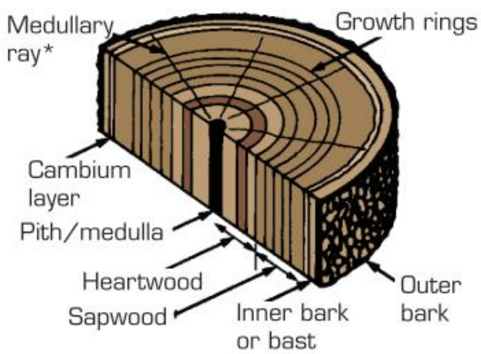
Sapwood is composed of living cells that carry water and minerals from the roots to the leaves

Heartwood consists of dead cells that support the tree. This strong, older wood provides most of the timber that people use

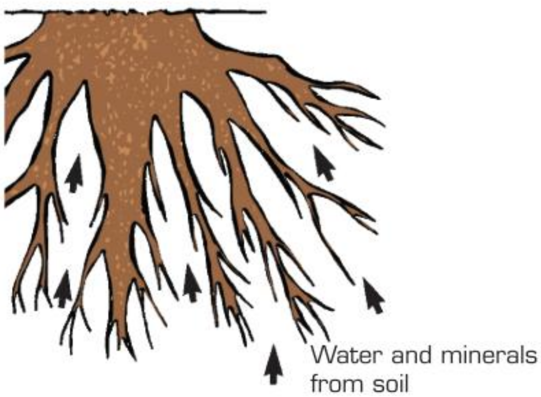
Pith or **medulla** – the central shaft of the tree. Food is stored here in young trees

Trunk or stem
- Supports the crown
- Transports water and plant food between the roots and the crown

Section of trunk



*Medullary rays carry plant food to the inner living parts of the tree and also store food.



Tree roots
- Anchor the tree in the ground
- Gather water and minerals from the soil

The parts of a tree

Carbon dioxide + Water + Energy from sunlight ⟶ Sugars + Oxygen

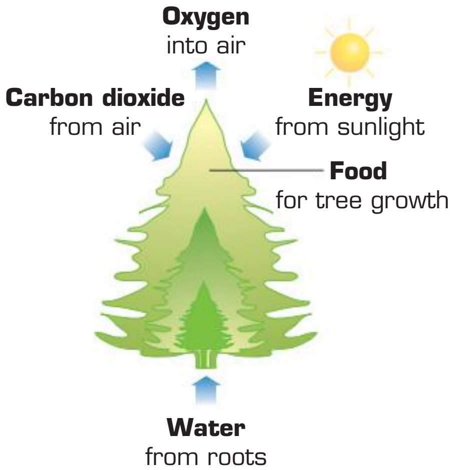
The process of photosynthesis

ISBN 9780170185677

Tree growth

For trees to grow, they need food. They make this food in their leaves by a process called photosynthesis. The energy from sunlight is taken in by the green matter (chlorophyll) in the leaves. The leaves absorb carbon dioxide gas from the air and receive water from the roots of the tree. The carbon dioxide and the water then react to form sugars and oxygen.

The sugars are used to make food for the tree to grow, and the leaves release the oxygen into the air. This is why people say that trees are the 'lungs' of the world.



Every year the tree increases in height, while the trunk is enlarged in diameter. The increase in diameter of the trunk is caused by the development of growth rings (sometimes called annual rings). These are concentric rings of new wood cells produced by the cambium layer. In many tropical trees, growth is generally even through the year and growth rings may not be visible. Trees from areas with **variations** of climate through the year have quite distinct growth rings, which can often be used to tell the tree's age.

The amount by which a tree grows is influenced by the following factors.

- **Soil:** The type of soil in which a tree is growing (for example, sand or clay) will affect the supply of water and minerals to the tree's roots.
- **Position:** The position in which the tree is growing will determine how much sunlight its leaves will receive, or how much protection it gets from strong winds.
- **Climate** (temperature and rainfall through the year): Different types of trees are suited to particular types of climate – for example, cold-climate conifers do not grow well in tropical areas that are hot and wet all year round.
- **Weather:** Daily weather conditions such as high winds, hail and frost also affect how well a tree grows.

The properties of timber

There are many different **species** of hardwood and softwood trees. Each type of timber has unique properties such as colour, grain and texture. These characteristics, as well as the defects that occur naturally in wood, must be considered when selecting timber for a particular use.

Colour

The natural colours of timber range from the white of some pines, through yellows, reds and browns, to the

INFORMATION FILE

The world's tallest tree

Did you know that the world's tallest hardwood tree grows in Australia? It is a swamp gum of the Arve Valley in Tasmania. The tree is between 100 metres and 101 metres tall and has a diameter of just over 4 metres. The tree has been named 'Centurion'. This giant swamp gum is a recent discovery. Centurion has replaced the previously tallest hardwood tree, a mountain ash of the Styx River area, also in Tasmania. The mountain ash is 98 metres high and it has a diameter of 5.2 metres. It is believed to be about 350 years old.

However, the world's tallest tree is a softwood. It is a Californian redwood and is 112 metres tall.

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black of ebony. The heartwood is usually darker than the sapwood because of the chemicals stored there.

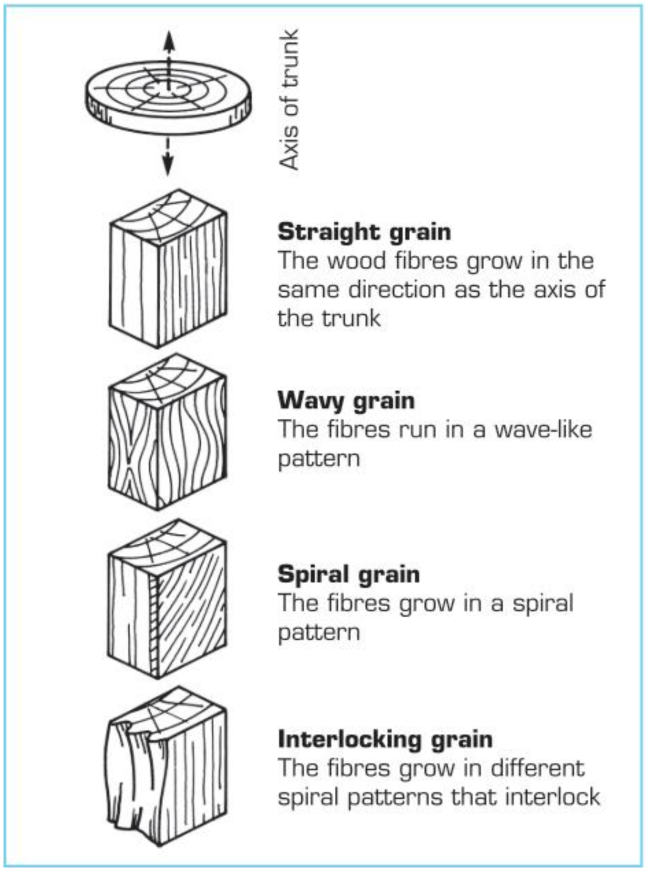
The colour of a particular timber is very important if you are:

- trying to match existing furniture or décor
- applying a clear finish to enhance the natural properties of the timber.

The natural colour is less important if you are going to paint or stain the timber.

Grain

The direction of cell growth along the trunk of the tree determines the grain of the timber. Examples of grain types are straight grain, wavy grain and interlocking grain.



The type of grain affects the strength of the timber and its ability to be worked or shaped easily – for example, hoop pine has a straight grain that is easy to work, whereas ironbark, with its interlocking grain, is hard to work.

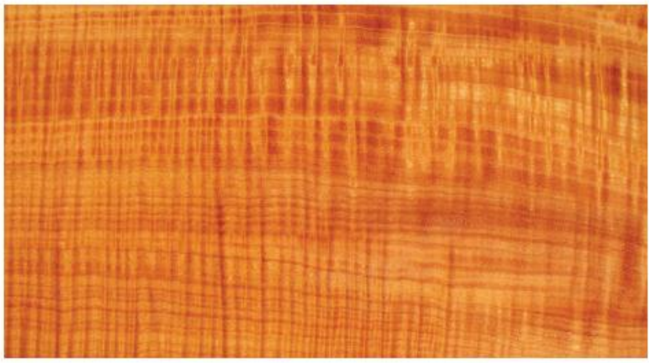
Texture

The size and arrangement of the cells in timber determine its texture. Texture is often described as coarse or fine, and uneven or uniform.

Figure

Figure is the overall effect produced by the grain, texture and colour. A piece of timber can show different figures if it is cut at different angles.

The flakey figure in silky oak



The fiddleback figure in blackwood

Hardness

Hardness of timber is its ability to resist denting, scratching or wearing by abrasion. Timber is hardest when it has small, closely packed cells with thick walls that contain plenty of plant chemicals.

Strength

The strength of timber is its ability to bear loads or withstand forces. Wood with long, thick-walled cells is usually strongest.

Toughness

When timber is able to resist sudden shocks (or a high degree of bending or twisting) without **fracturing**, it is said to be tough.

Durability

Durability of timber is the natural ability of the timber to resist:

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- attack by insects (such as termites and borers)
- attack by fungi (such as those causing wet rot and dry rot)
- weathering by the sun's rays and moisture in the air.

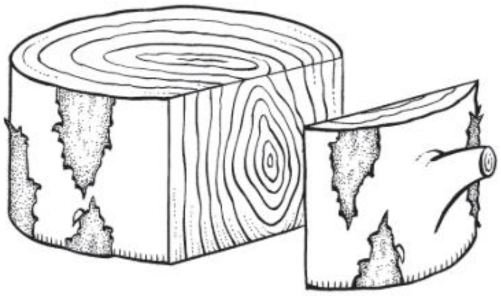
Chemicals in the cell walls are mainly responsible for the durability of timber.

Natural defects

Natural defects are irregularities that develop in the timber as the tree grows. They may lessen the quality of timber by affecting its strength, appearance or durability. Defects are often removed during the milling process. Some common defects are knots, gum veins and pockets, and shakes.

Knots

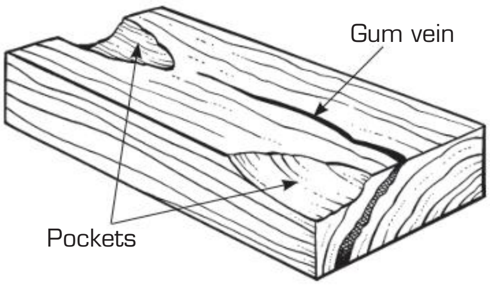
Knots are formed by branches joining the trunk. In most cases they weaken the timber and spoil its appearance.



Knots are formed where branches join the trunk.

Gum veins and pockets

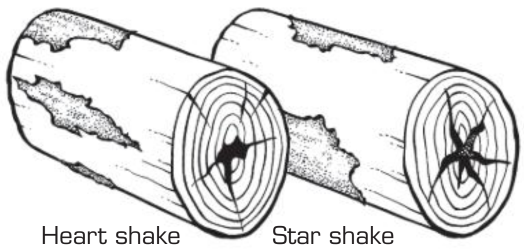
Gum veins and pockets are **cavities** formed in the timber by the separation of fibres. These cavities become filled with a dark-coloured deposit of gum. They tend to lessen the strength and attractiveness of the timber.



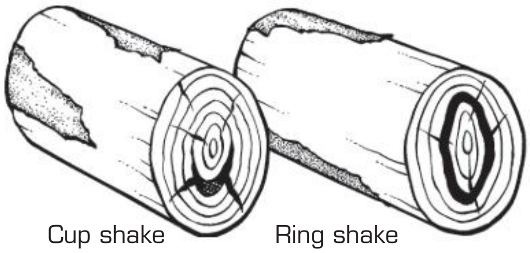
Shakes

Shakes are caused by the separation of wood fibres. This may occur naturally as a result of growth stress or wind stress while the tree is growing.

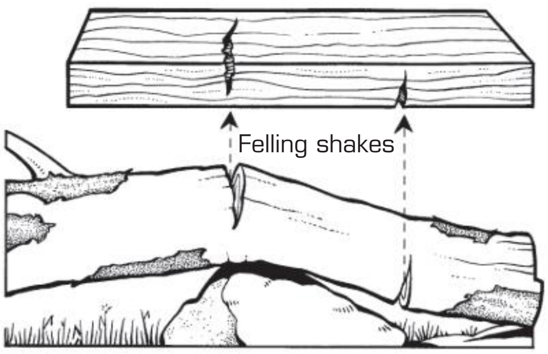
Heart shakes and star shakes are fibre separations along the medullary rays.



Cup shakes and ring shakes are fibre separations along the growth rings. A ring shake is a cup shake that extends all the way around a growth ring.



Felling shakes are artificial defects caused during felling or transportation if a tree falls on an uneven surface. The fibres separate across the grain.



The forestry industry

The forestry industry harvests trees from natural forests and cultivated plantations to meet people's needs for timber and other forest products.

In Australia today, the forests that produce our timber are managed so that new trees grow to replace those that are cut down. The forestry industry aims at achieving a sustainable yield of timber. In many parts of the world, however, people are cutting down forests much faster

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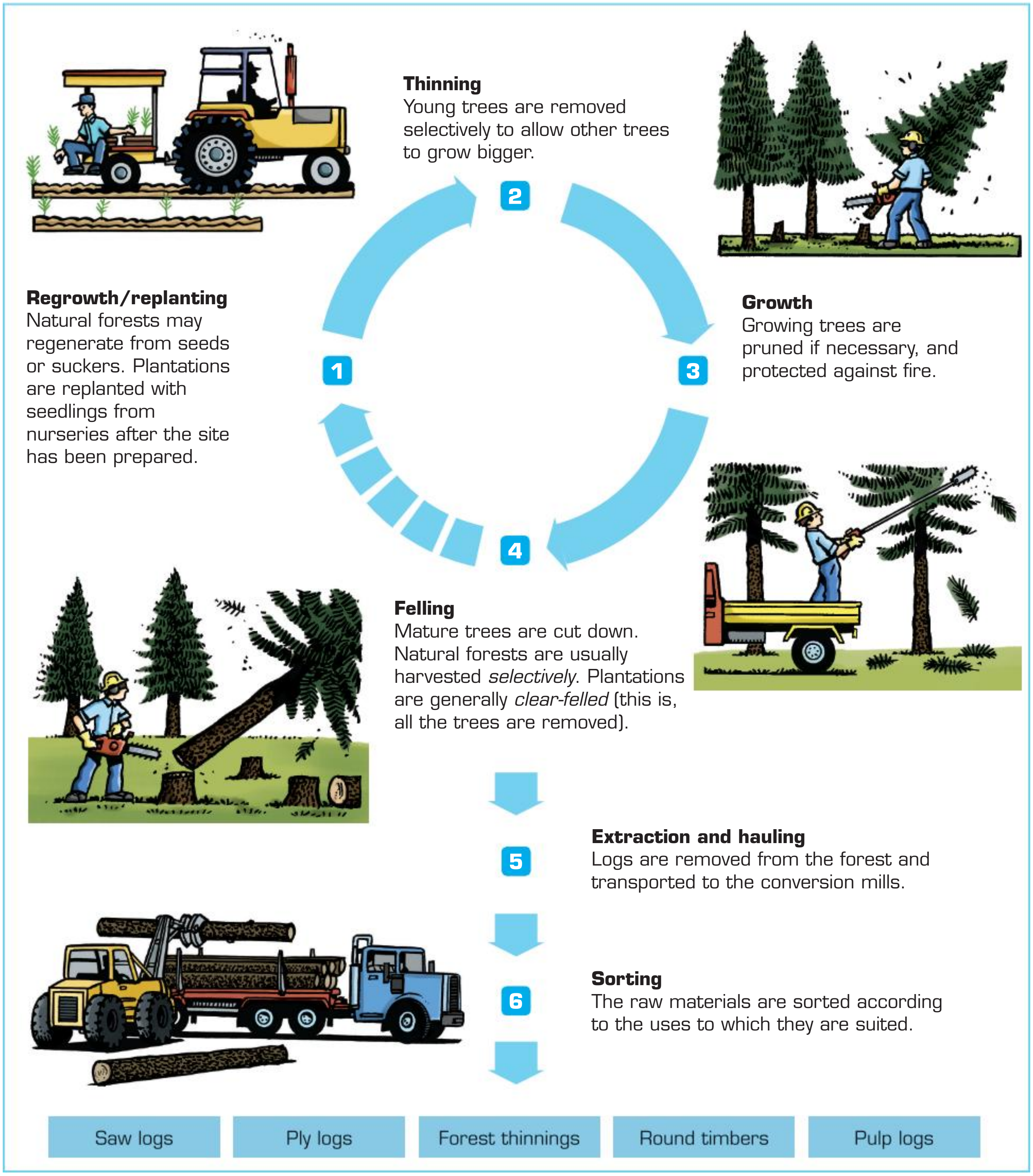
than the trees can be replaced. As we saw at the start of this section, trees are very important in maintaining life on Earth; therefore it is vital that forestry industries around the world are run on a sound scientific basis that will protect the environment. The forestry industry is made up of people from government departments and commercial timber companies. They try to ensure a continued supply of timber by managing forests, as shown in the chart below.



The forestry management process

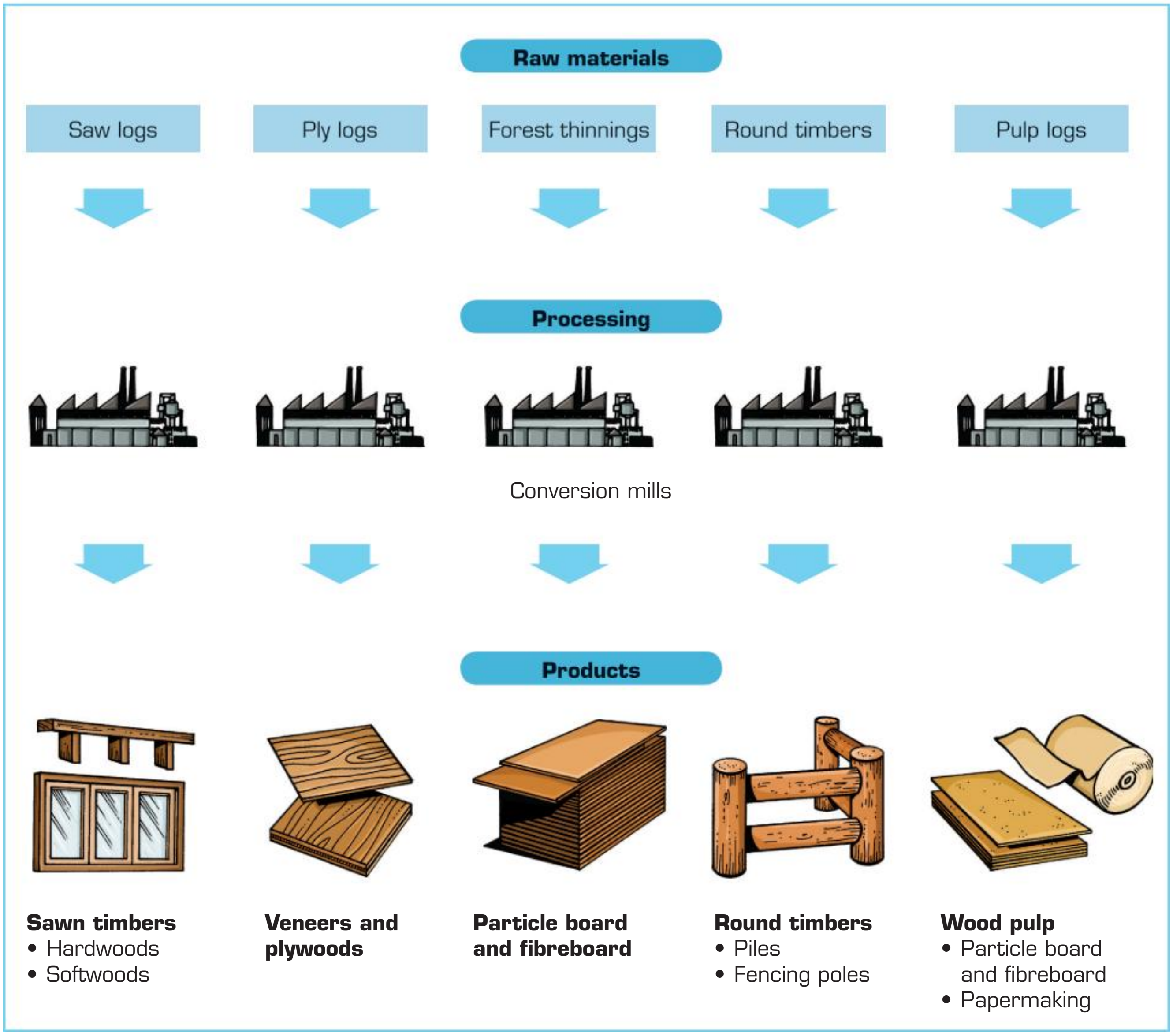
Timber conversion processes

At timber conversion mills, the raw materials that have been harvested from the forests are processed into timber products. The **waste** materials are reused – for example, the bark is used by landscapers, while the sawdust can be burnt as a fuel for electricity generation in the mill.

The five main groups of timber products are:

- sawn timbers
- veneers and plywood
- particle board and fibreboard
- round timbers
- wood pulp.

A veneer being reeled off after it has been peeled from a log



Timber products

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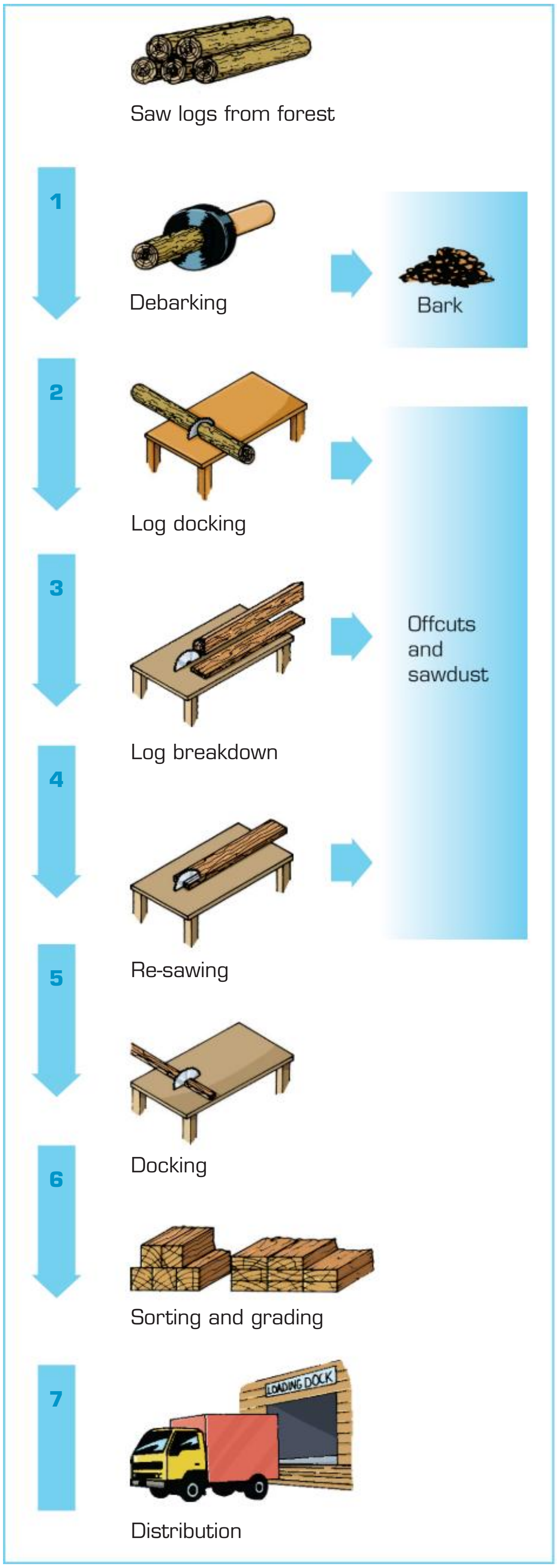


Sawn timbers

The following process is used to convert saw logs into sawn timbers.

1 The bark is removed from the saw log.
2 The logs are docked:
    - to suit market requirements
    - to remove defects in the log
    - for ease of handling.
3 Log breakdown is the first stage of cutting the trunk into usable timber. The logs are cut into large pieces called flitches, using twin circular saws or a bandsaw.
4 The flitches are resawn into smaller standard ('stock') sizes suitable for use in the construction industry.
5 The stock-sized timber is docked to standard lengths in 300-millimetre increments – for example, 1.2 metres, 1.5 metres, 1.8 metres and 2.1 metres.
6 The timber is sorted into its various sizes and then graded on the basis of its strength. The grading is carried out by trained people or by machines. The strength of a piece of timber is determined by the number of defects found in it. The timber is also seasoned, if required.
7 Timber stock is warehoused and distributed as required by wholesalers and retailers.

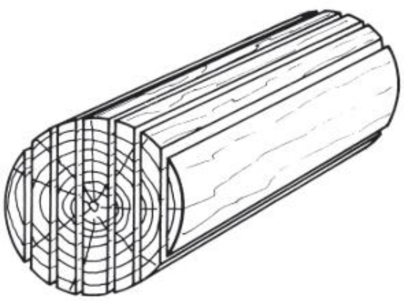
Log breakdown

Logs are cut using one of these three methods:

- live sawing
- back sawing
- quarter sawing.

Live sawing

Live sawing is the simplest method of cutting a log into boards. A number of parallel saw cuts are made without turning the log. There is very little waste. However, live-sawn timber distorts badly because of warping and shrinkage. It is used mainly for fence palings and packing cases.



Live sawing

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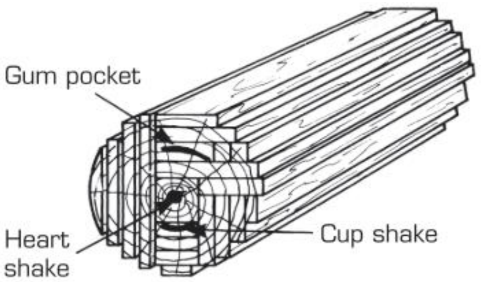
Back sawing

In back sawing, the saw cuts are at a tangent to the growth rings. Back sawing is usually used to produce good-quality timber, as it allows defects to be removed quite easily.

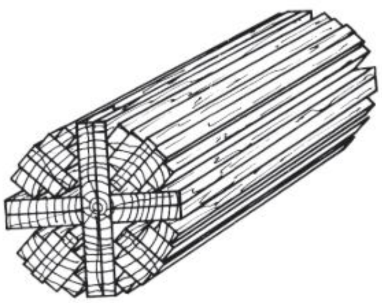
Back sawing shows off the grain in timbers such as red cedar, which have distinct growth rings. Back-sawn timber also has good strength, and is therefore used for tool handles and for structural timber such as beams.



Back sawing

Quarter sawing

In quarter sawing, timber is cut at right angles to the growth rings. Quarter-sawn timber seasons slowly but wears well and retains its shape. Therefore, it is used in door frames, mouldings and flooring boards. As well, quarter sawing shows off the decorative figure in timbers such as silky oak and maple.



Quarter sawing

Types of finishes

The way in which the sawn timber is finished is determined by its use in the construction industry.

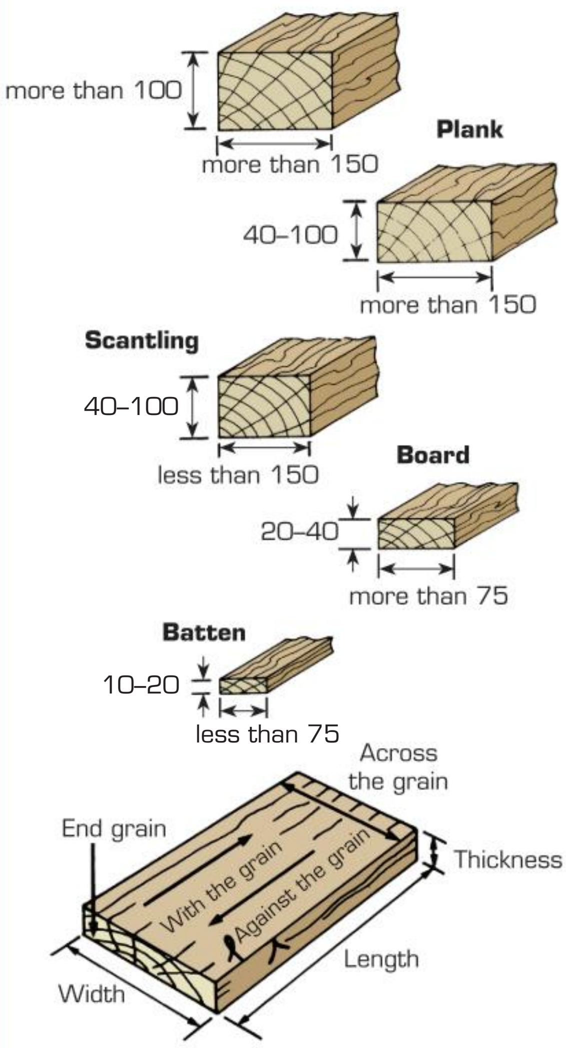
Hardwood stock is usually left rough sawn, except for boards that have special applications. For example, flooring timbers are **planed**.

Some softwood stock is left rough sawn, but softwood that is used for mouldings, cabinet work, studs for framing, and so on, is **dressed**.

Timber terms and sizes

The names commonly given to different sizes of sawn timber are shown in the boxed diagrams below. (All measurements are in millimetres.) The terms refer to the cross-section – or 'shape' – of the end, which gives the width and thickness dimensions. The terms are:

- flitch (or baulk): width (more than 150) and thickness (more than 100)
- plank: width (more than 150) and thickness (40–100)
- scantling: width (less than 150) and thickness (40–100)
- board: width (more than 75) and thickness (20–40)
- batten: width (less than 75) and thickness (10–20).



= **face side**
(the best flat, straight surface on the timber)
= **face edge**
(the best flat, straight edge on the timber)

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A common method used when ordering stock timber is:

42	×	12	2	/	300	Pine
Width in mm		Thickness in mm	Number required		Length in mm	Type of material

Timber is generally available commercially in lengths ranging from 0.9 metre to 6 metres.

All timber is graded to determine its strength and to comply with the building code in the construction industry. The grades range from F5 to F34 (the higher the number, the greater the strength). For example, radiata pine is generally graded at F5, whereas ironbark is graded at F34.

Seasoning timber

Green timber contains large amounts of water inside the cell cavities and in the cell walls. Most of this moisture has to be removed to prevent the timber from warping and shrinking too much. Timber that has a moisture content of about 15 per cent is known as seasoned or dry timber.

Seasoning is the process by which the moisture content of the timber is reduced to equal the moisture content of the environment. This is known as the equilibrium moisture content or EMC. It will vary from region to region, but is generally between 10 per cent and 15 per cent.

Correctly seasoned timber is:

- more stable (resistant to shrinking, warping and cracking)
- lighter and stronger
- less likely to decay or be attacked by insects.

Timber is seasoned by:

- air seasoning
- kiln seasoning
- combined seasoning.

Air seasoning

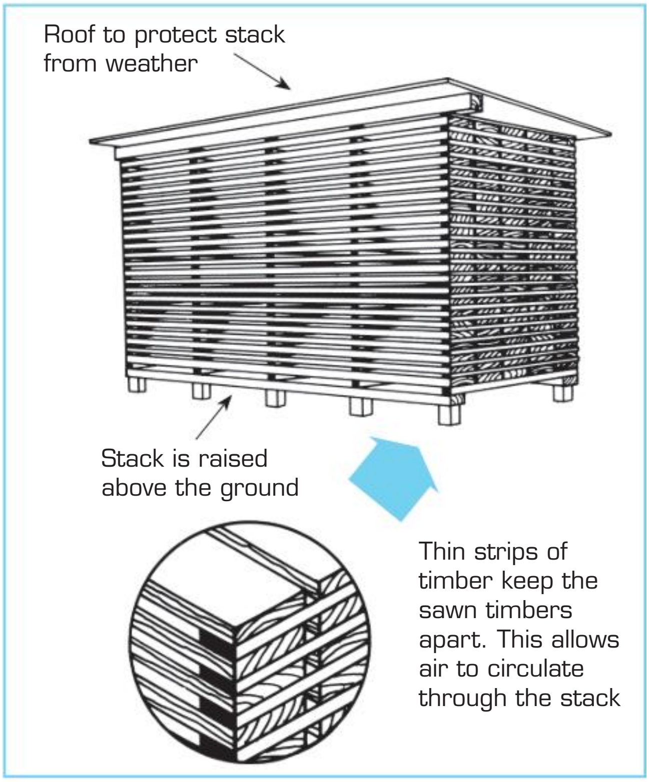
Air seasoning is the traditional method of drying sawn timber. Because it depends on natural circulation of air, it is a very slow and inaccurate process. It can take up to two years to remove the moisture, depending on the size of the timber.

Kiln seasoning

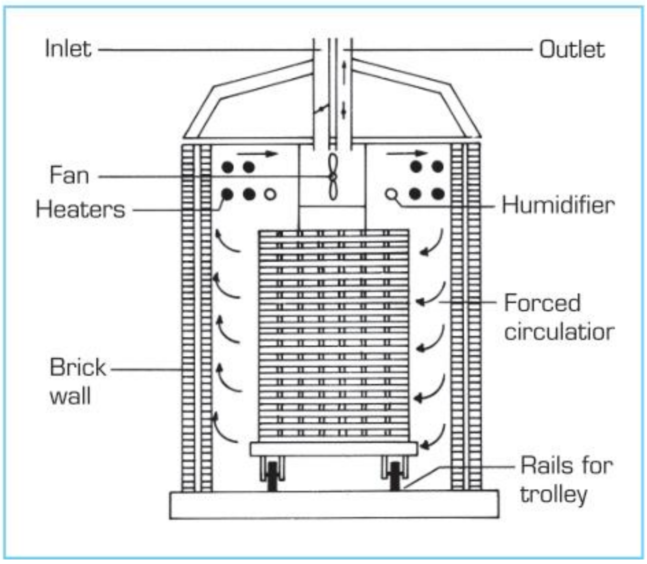
Kiln seasoning is carried out in large, oven-like structures called kilns. Sawn timber is stacked on trolleys (using the air-seasoning stacking system) and wheeled into a kiln. There it is dried by heated, air, which is driven by fans. The moisture level is controlled by a steam humidifier.

Because the temperature, air flow and moisture level can be controlled, green timber can be kiln seasoned in as little as one to two weeks.

The main advantage of this method is its speed. In addition, seasoning defects are reduced, and insects and fungi in the timber are destroyed.



Air seasoning



Kiln seasoning

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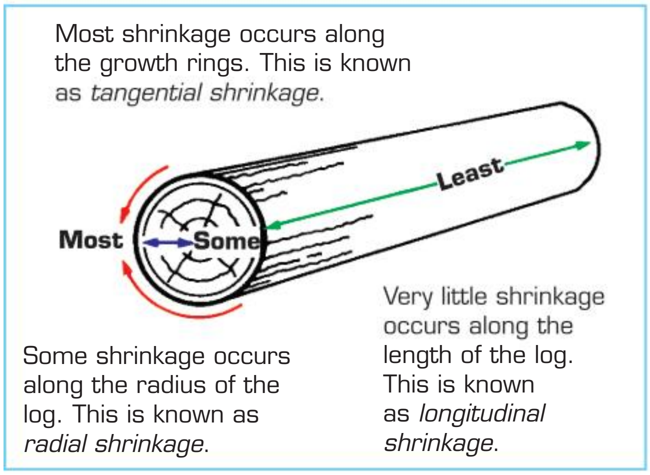
Combined seasoning

To reduce seasoning defects (particularly in hardwoods), it is common to combine the air-seasoning and kiln-seasoning methods.

The green timber is air seasoned for about three months to remove water from the cell cavities. It is then moved into a kiln to complete the seasoning process, which takes only three to seven days.

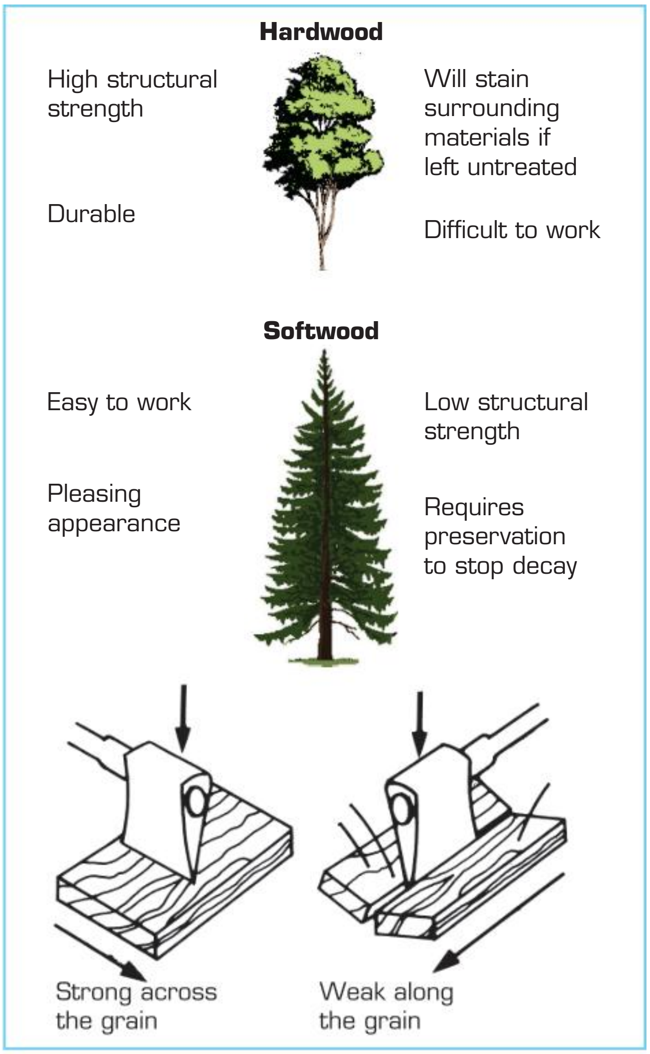
Seasoning defects

Shrinkage occurs when all the moisture inside the cell cavities is dried up and the cell walls start to lose their moisture.

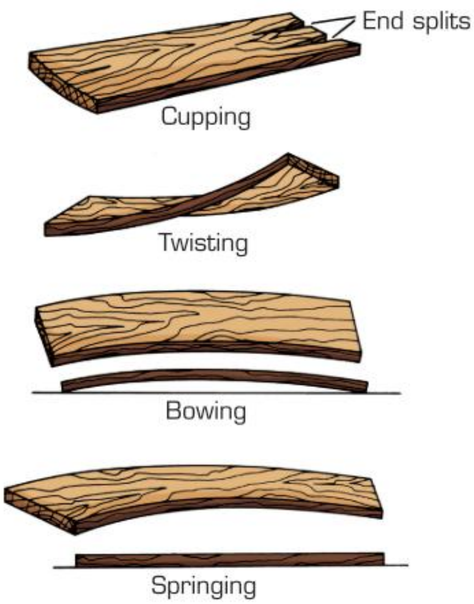


How timber shrinks

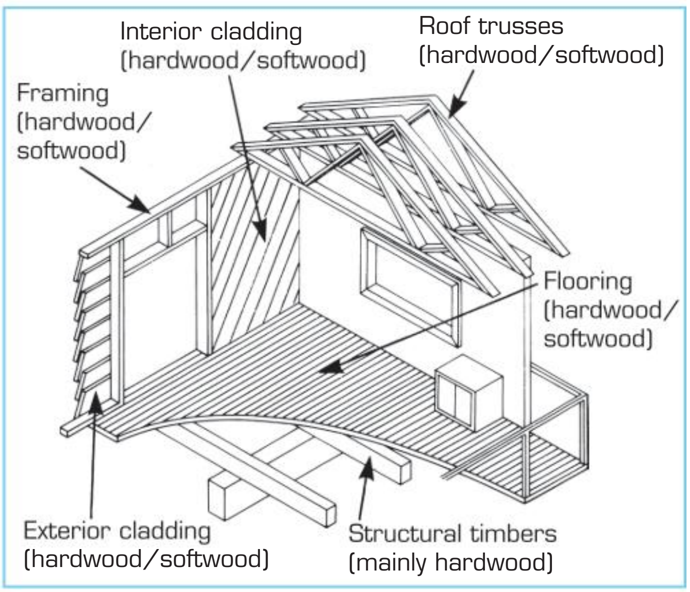
Uneven shrinkage in sawn timber during seasoning can cause the timber to distort or warp badly. Warped timber is difficult to use and has less commercial value.



Advantages and disadvantages of sawn timber



Common seasoning defects in sawn timber



Uses of sawn timber

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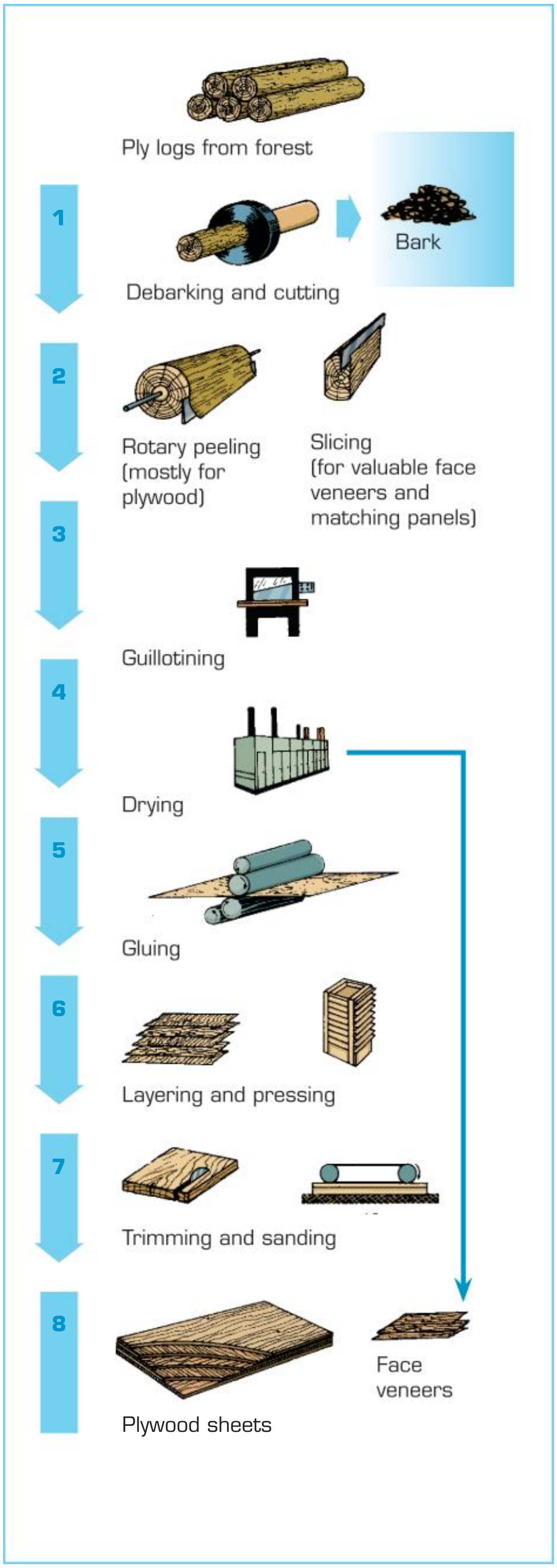

Veneers and plywood

The following process is used to convert ply logs into veneers and plywood.

1 The bark is removed from the ply log. The log is cut to a size that is convenient for processing.

2 With rotary peeling, the log is softened by steam and then rotated in a **lathe**-like machine against a long blade. This blade cuts a uniformly thin sheet of timber (the veneer).

With slicing, a blade is used to make parallel cuts through the timber. This method is used to produce face veneers from valuable woods. The sliced veneer sheets (or plies) are numbered so that they can later be matched when they are glued onto a surface.

3 A guillotine is used to remove faults from the veneer. The various-sized sheets are stacked on a trolley for drying.

4 The excess moisture is removed from the veneers in a large, oven-like dryer.

5 The veneer sheets are first glued edge to edge to form larger sheets of suitable sizes. A glue is then spread over the surfaces of each veneer sheet. The adhesive used for interior plywood is not waterproof. The glue used in exterior plywood, such as marine ply or structural ply, is a waterproof glue.

6 The veneer sheets are arranged in layers so that the grain of each sheet is at right angles to the sheets above and below it. This is known as crossbanding. These glued layers of veneer sheets are placed in a hot press to bond and cure them. Plywood is manufactured in a range of thicknesses. The number of layers is usually odd, ranging from 3-ply to 21-ply.

7 The edges are trimmed to produce plywood sheets of standard sizes. The plywood sheet is passed through a drum or belt sander to finish its surfaces.

8 The veneers and plywood are warehoused, marketed and transported to purchasers.

Face veneers

Veneers are glued onto the face of sheet materials such as particle board to give an attractive finish. A large number of timber species is used, including pine, teak, walnut and silky oak.

Matching-edge veneer strips can also be purchased. (These are often pre-glued, to be applied with the aid of a hot iron.)

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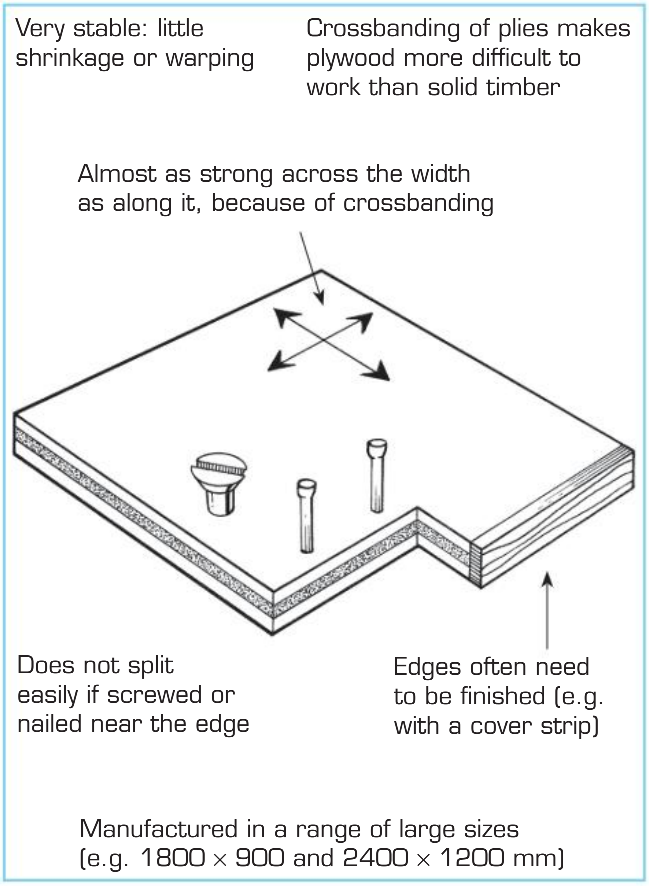
Veneers can be laminated to form curved shapes such as spoons, water skis and snow skis.

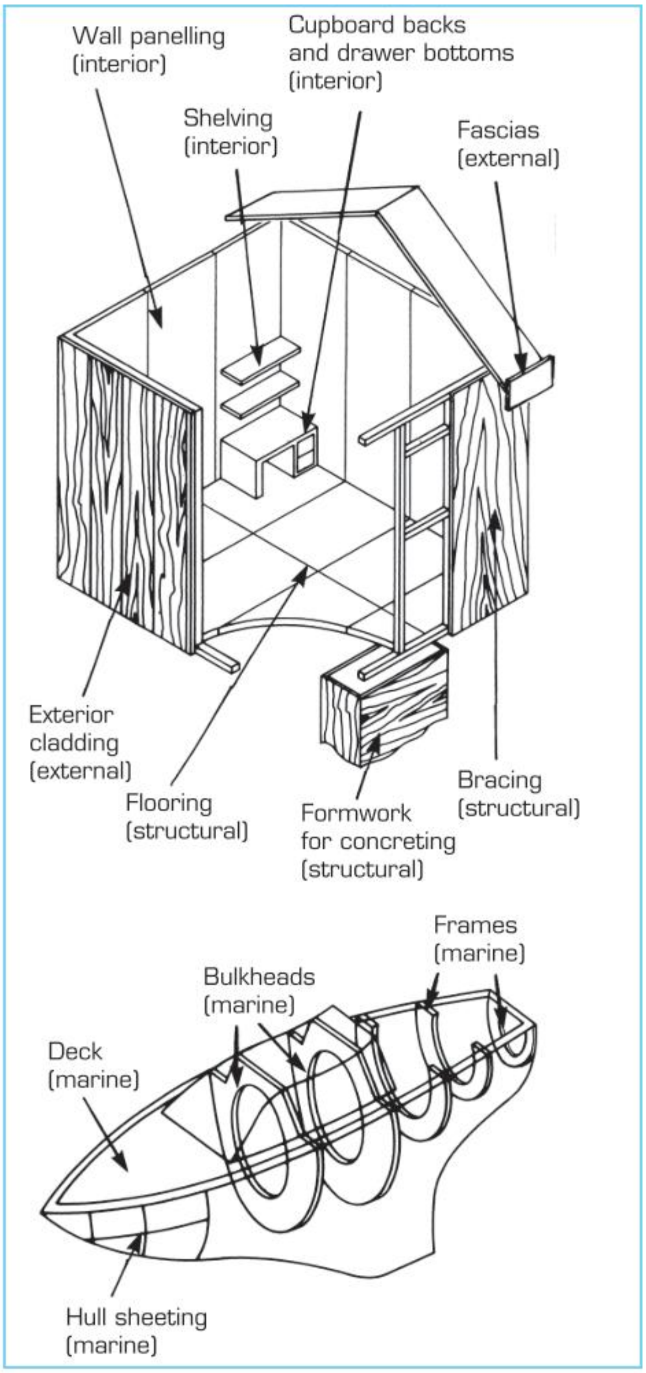
Plywood

Plywood is manufactured in four types.

- **Structural ply:** waterproof glue; lowest-quality veneers used for face and back of sheet
- **Exterior ply:** waterproof glue; good-quality veneers used for face of sheet
- **Interior ply:** non-waterproof glue; good-quality veneers used for face of sheet
- **Marine ply:** waterproof glue; good-quality veneers used (only particular species of timber).



Advantages and disadvantages of plywood



Uses of plywood

Sheet material, whether a metal, plastic or timber product (for example, plywood), is ordered in this way:

1800	×	900	×	3	Interior plywood – Pine	1 off
Length in mm		Width in mm		Thickness in mm	Type of material	Number required

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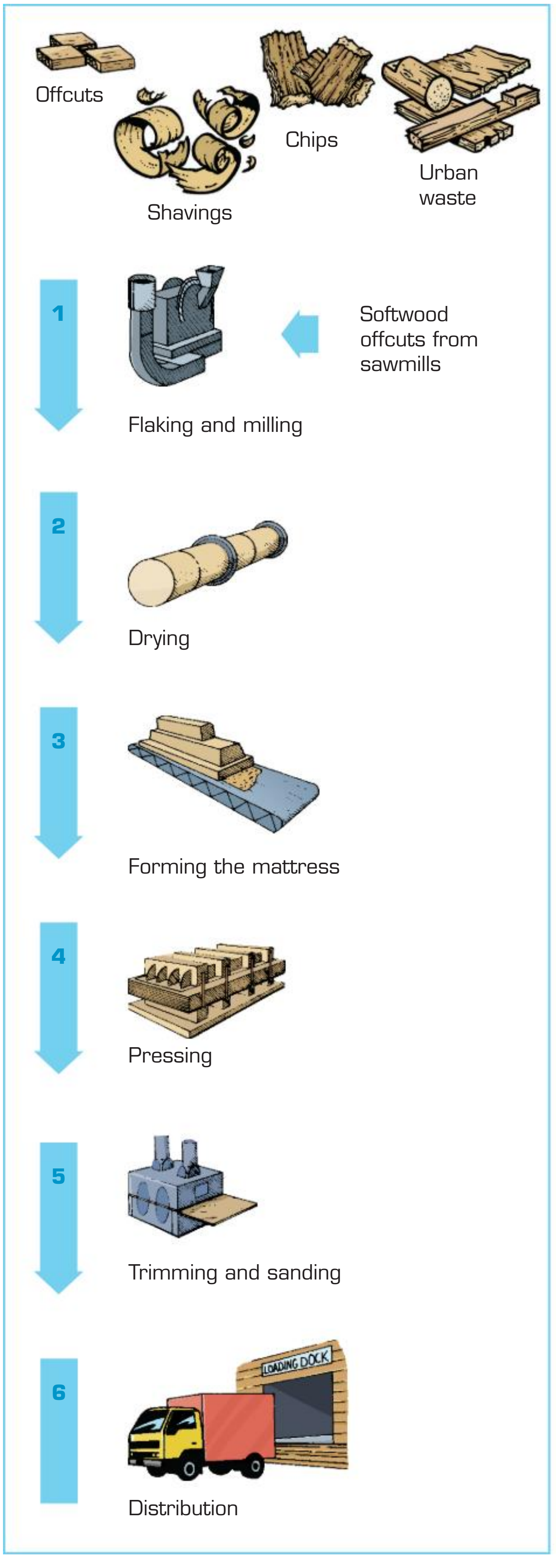

Particle board

Particle board is manufactured only from softwoods. The particle board industry is often referred to as a scavenger industry. The term 'scavenger' is used because particle board is manufactured using waste materials from timber mills.

The waste materials include offcuts, shavings and **chipped-up** slab offcuts of logs. Urban waste – for example, recycled demolition softwoods – is also used.

1 The waste materials are fed into a flaker, where revolving blades shave off flakes. The flakes are then milled to a uniform size. The size of the flakes can be varied to suit the desired end product.

2 The flakes are dried in a kiln so that their moisture content is 2 to 5 per cent. They are stored in large bins ready for the bonding process.

3 The flakes are sprayed with an adhesive. They are then spread on a mat to form a 'mattress'. The mattress can be made up of similar-sized flakes or a core of coarse flakes sandwiched between finer flakes.

4 Several mattresses are loaded into a hot press, which bonds the glue-coated flakes to form particle board.

5 After cooling and curing, the sheets of particle board are trimmed to size and sanded. Finally, they are inspected and graded prior to distribution.

6 Particle board is warehoused, marketed and transported to consumers.

Particle board is manufactured in two grades:

- general-purpose-grade particle board. This is bonded with non-waterproof glue and is often finished with a variety of decorative surfaces such as veneers, plastic laminates and vinyls
- structural-grade particle board. Since it will be exposed to moisture or the weather, this material is bonded with a water-resistant adhesive.

General-purpose-grade particle board is available as:

- standard particle board. This is for interior use and dry conditions only
- moisture-resistant (MR) particle board. This is for high-humidity conditions and possible occasional wetting, but not continuous wetting
- particle-board flooring. This is available in a range of treatments – for example, fungicide (F), termiticide (H2) and fire retardant (FR).

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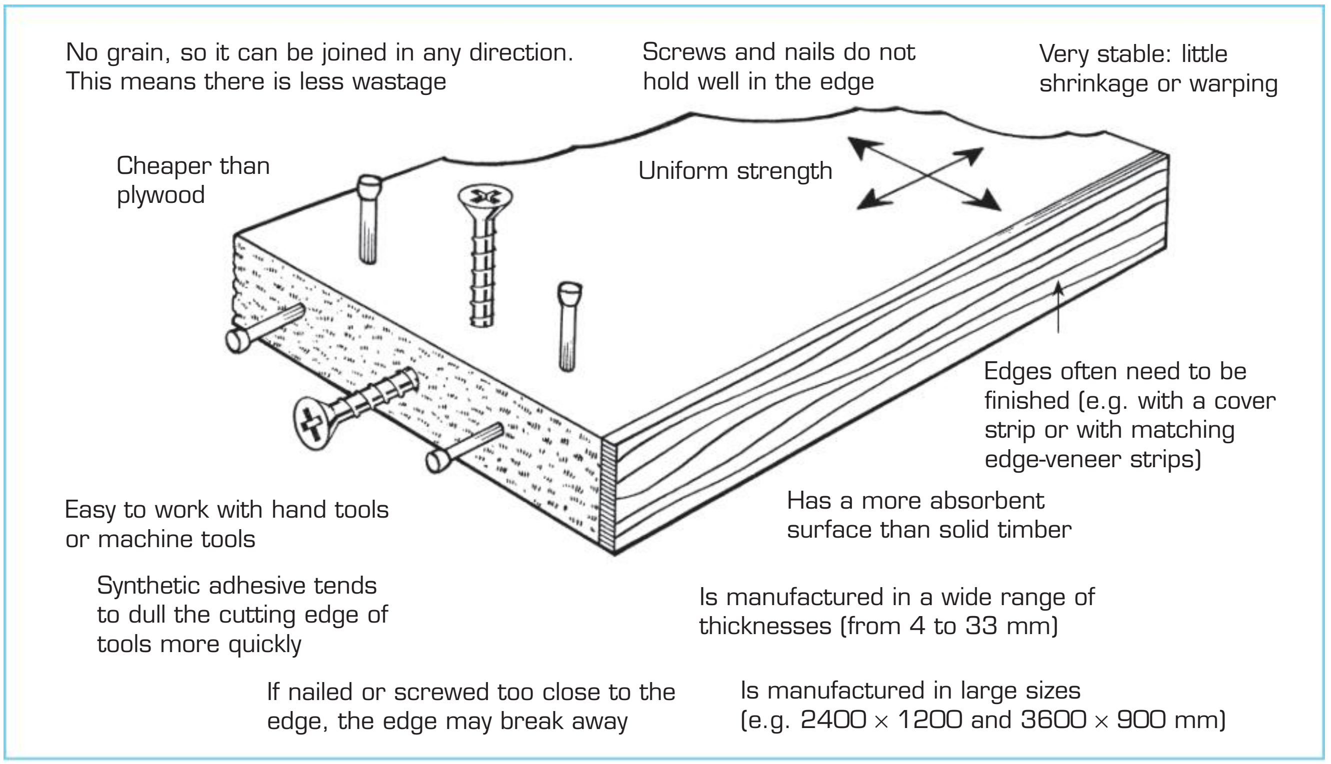
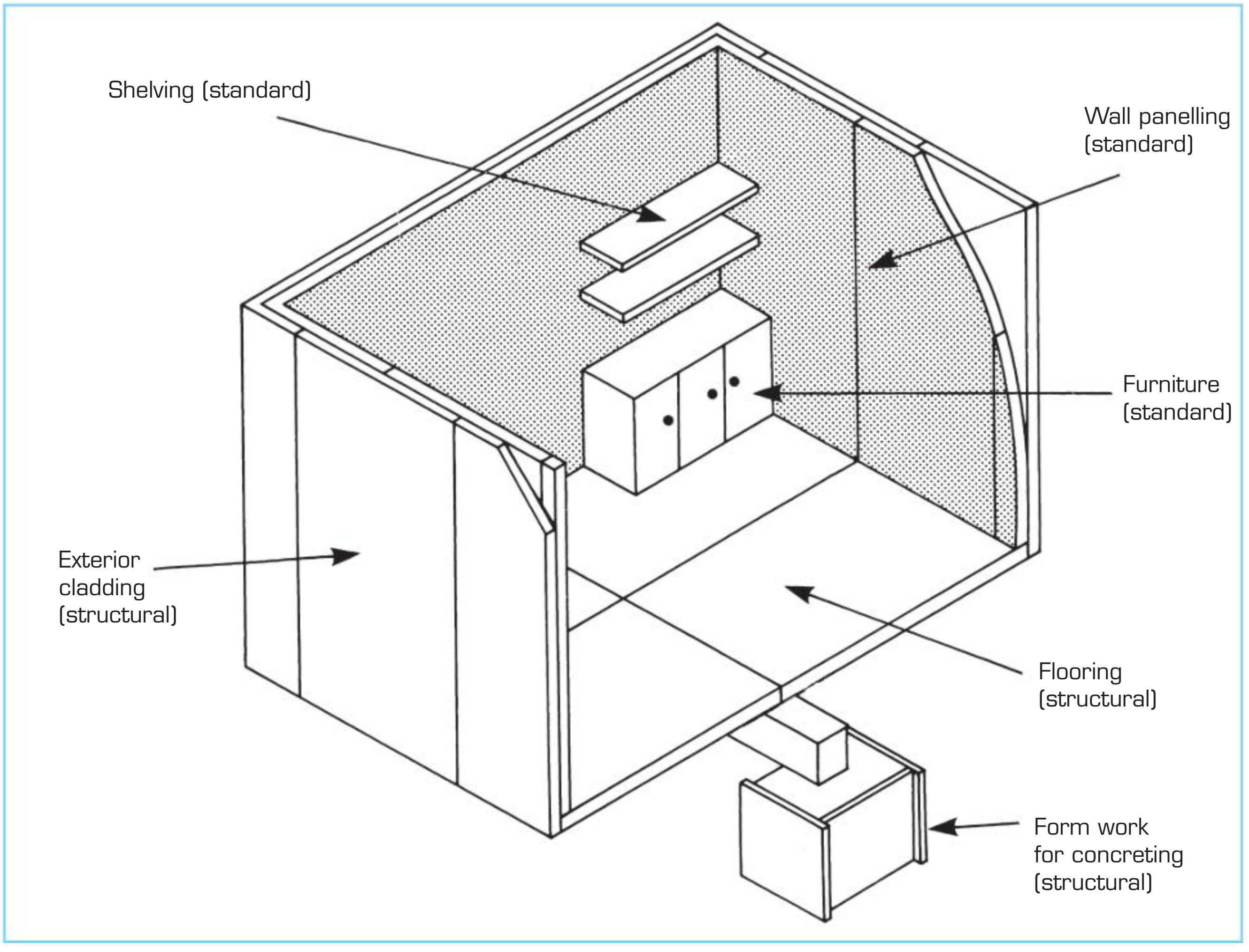


Advantages and disadvantages of particle board



Uses of particle board

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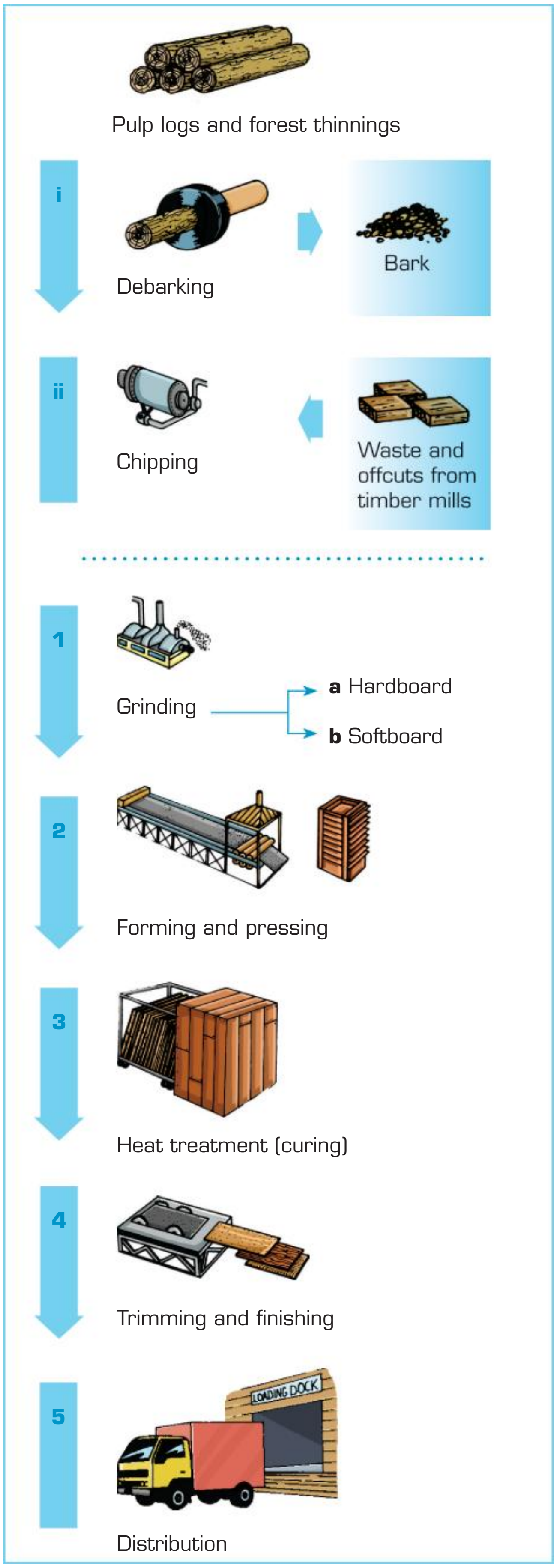

Fibreboard

Fibreboard is manufactured in three densities:

- high-density fibreboard (hardboard) – this is made from hardwoods
- medium-density fibreboard (MDF) – this is made from softwoods
- low-density fibreboard (softboard) – this is made from softwoods
  - **a** Bark is removed from the logs.
  - **b** The logs and waste from timber mills are fed into a chipper. Inside the chipper, revolving blades cut the logs into bark chips approximately 25 × 25 × 5 millimetres in size.

There are two processes for manufacturing fibreboard. They are:

- wet-processed fibreboard
- dry-processed fibreboard.

Wet-processed fibreboard

Wet-processed fibreboard includes high-density and low-density fibreboards. The following process is used to manufacture wet-processed fibreboard.

1 The chips are ground so that the wood fibres separate and a pulp is formed.

2 The pulp is filtered and then deposited onto a wire mesh belt.

- **a** With hardwood, the layer of pulp is passed through rollers to form a 'mattress'. The hardwood pulp mattresses are then loaded into a hot press, which bonds the interlocking fibres to form hardboard.
- **b** With softwood, the layer of pulp is passed through a series of rollers to remove the excess water. This produces a damp sheet of roll-pressed softboard.

3
- **a** The hardboard is heated in a humidifying oven to cure it.
- **b** The damp softboard sheets are fed into a dryer to further reduce their moisture content.

4 The edges are trimmed to produce hardboard and softboard sheets of standard sizes. (Some boards are painted to meet market needs.)

5 Hardboard and softboard sheets are warehoused, marketed and distributed to consumers under trade names such as Masonite (hardboard) and Cane-ite (softboard).

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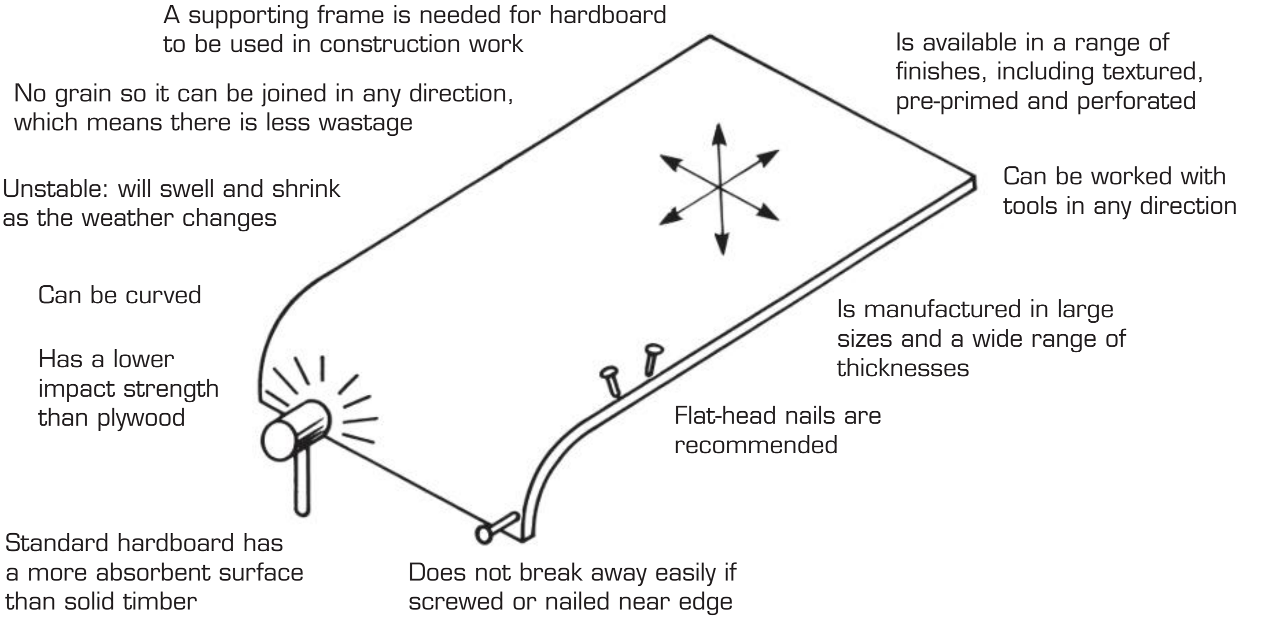
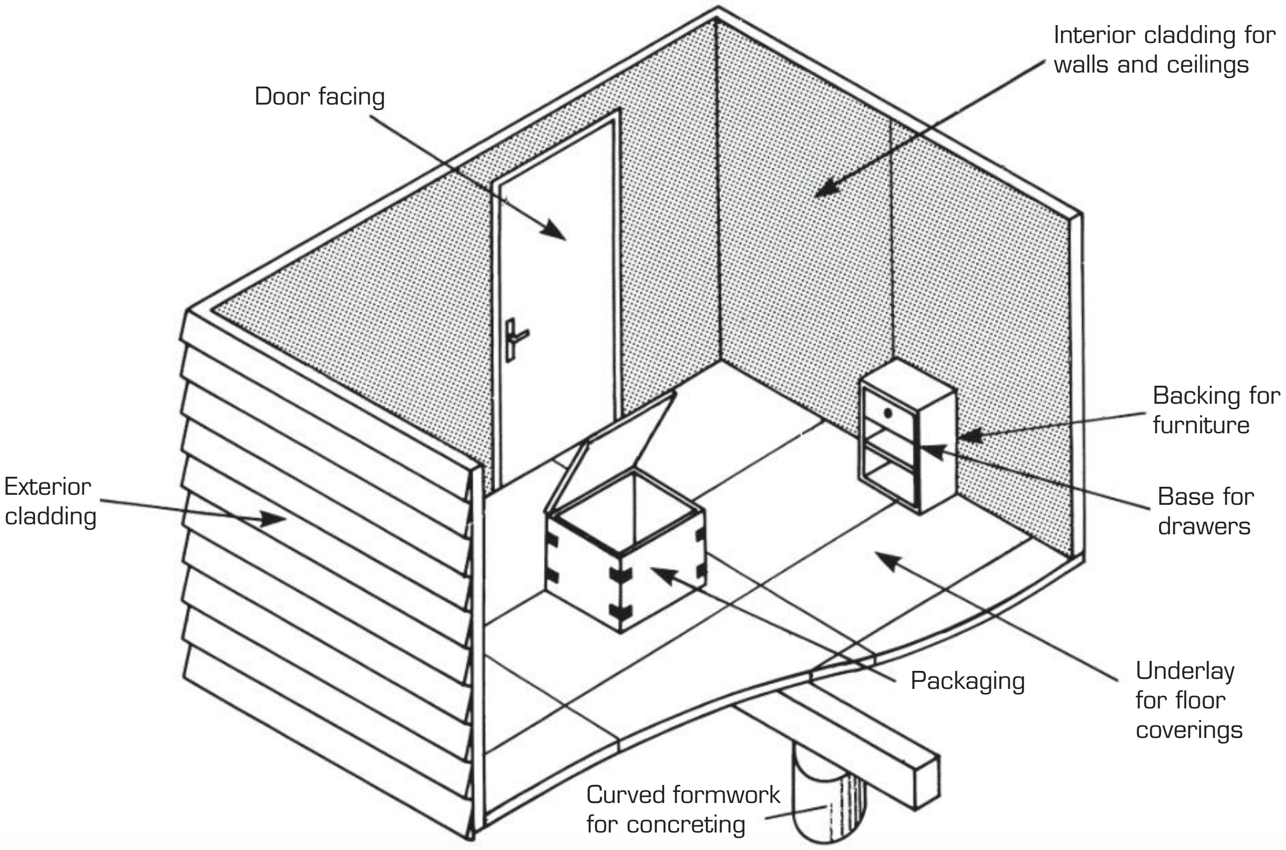
High-density fibreboard (hardboard)

There are two types of high-density fibreboard or hardboard:

- standard hardboard
- tempered hardboard, which has been soaked in oil and then rebaked. The end product is stronger, smoother, harder and more water resistant than standard hardboard. It is used mainly for exterior work in the construction industry.



Advantages and disadvantages of hardboard



Uses of hardboard

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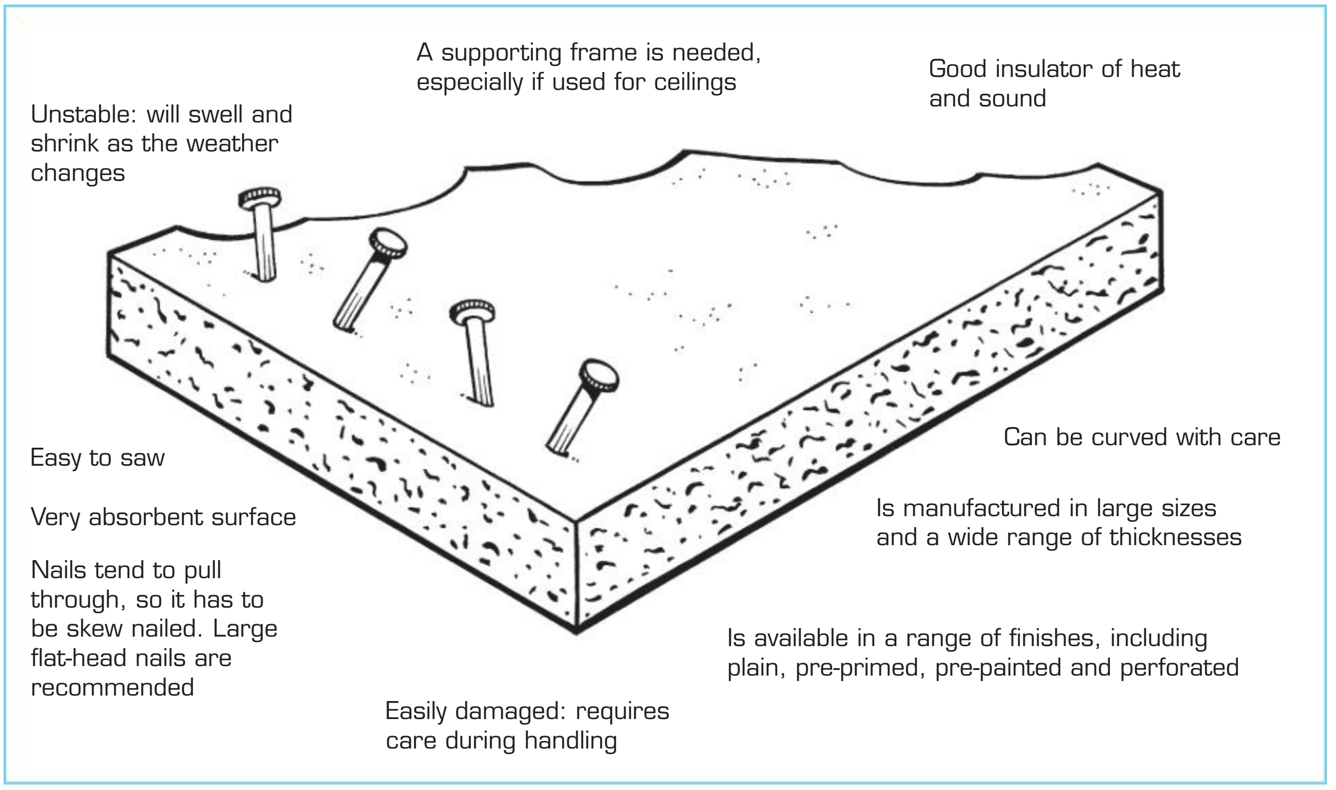
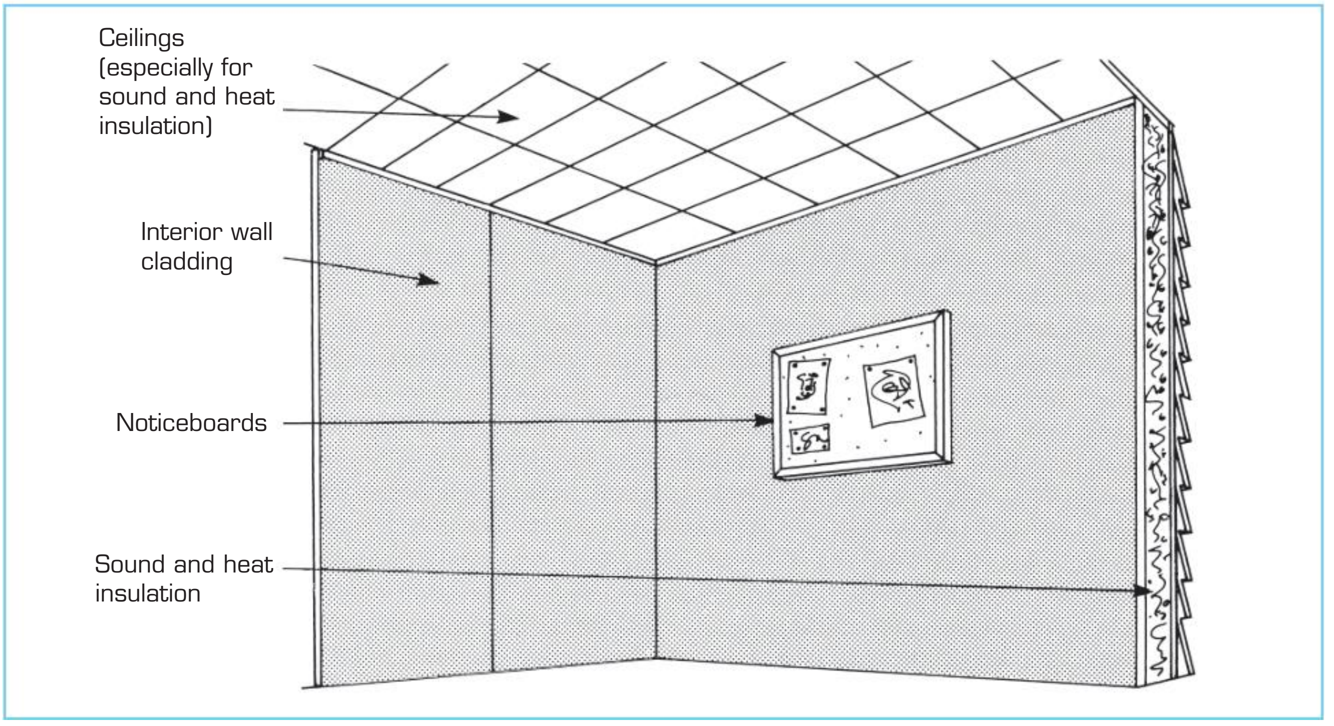
Low-density fibreboard (softboard)

Low-density fibreboard, or softboard, is a soft material that is suitable only for interior use.

The tiny air pockets among its interlocking fibres make softboard an excellent insulator against noise and heat.



Advantages and disadvantages of softboard



Uses of softboard

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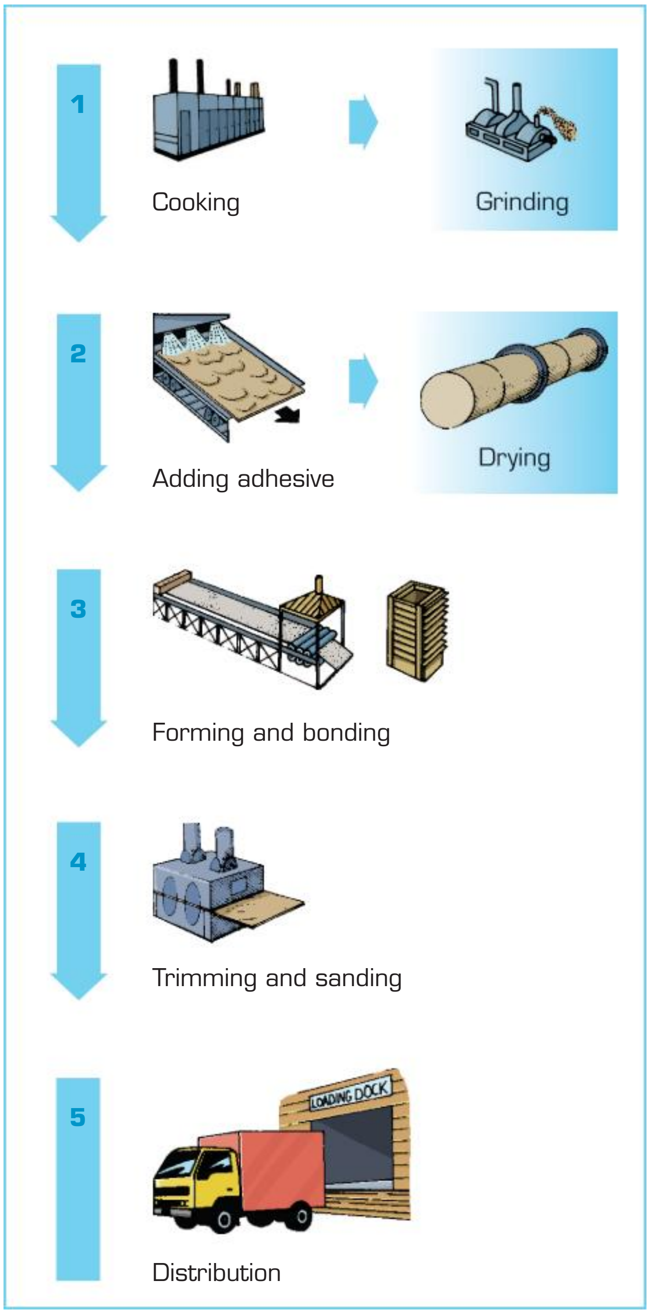

Dry-processed fibreboard

The following process is used to manufacture medium-density fibreboard.

1. The chips are cooked and then ground to fibre.
2. The fibre is sprayed with adhesive. It is then dried to a 10-per-cent moisture content.
3. The *dry* fibres are used to form a mattress. The mattress is fed continuously through a heated roller press for bonding.
4. The cured mattress is trimmed and cut to give **master panels**. These master panels are sanded before being cut to standard sizes.
5. Medium-density fibreboard is warehoused, marketed and transported to consumers.

Medium-density fibreboard (MDF)

There are two types of medium-density fibreboard or MDF:

- standard medium-density fibreboard. This is for interior use and dry conditions only
- moisture-resistant (MR) medium-density fibreboard. This is for high-humidity conditions and possible occasional wetting, but not continuous wetting.

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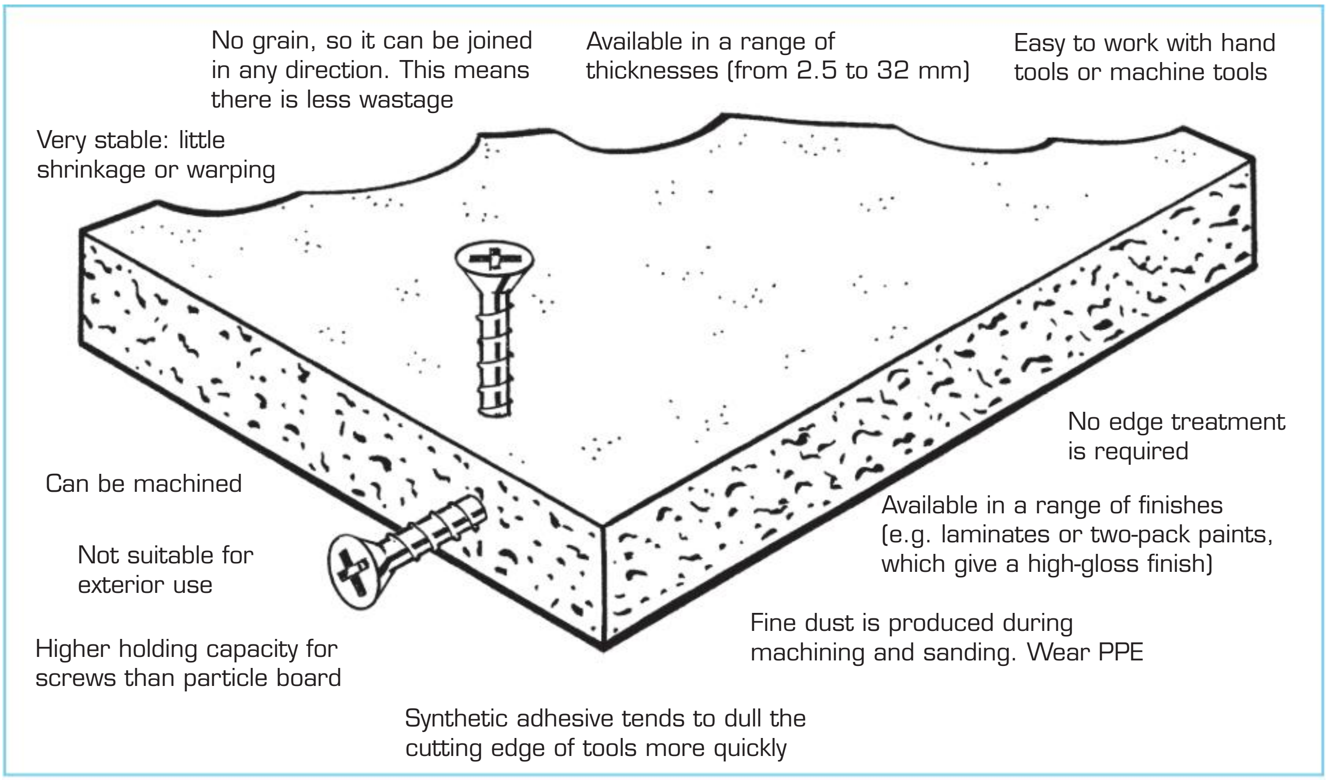
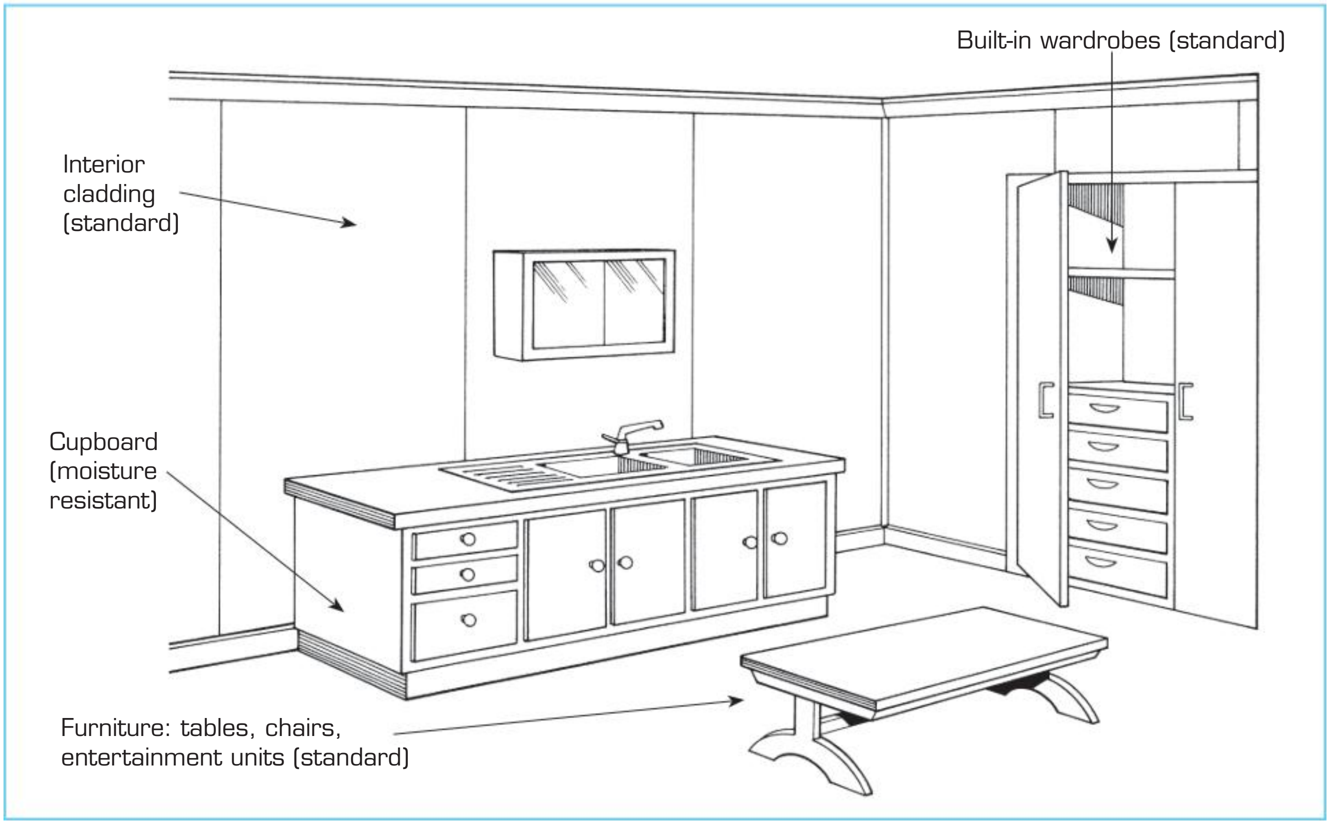


Advantages and disadvantages of medium-density fibreboard



Uses of medium-density fibreboard

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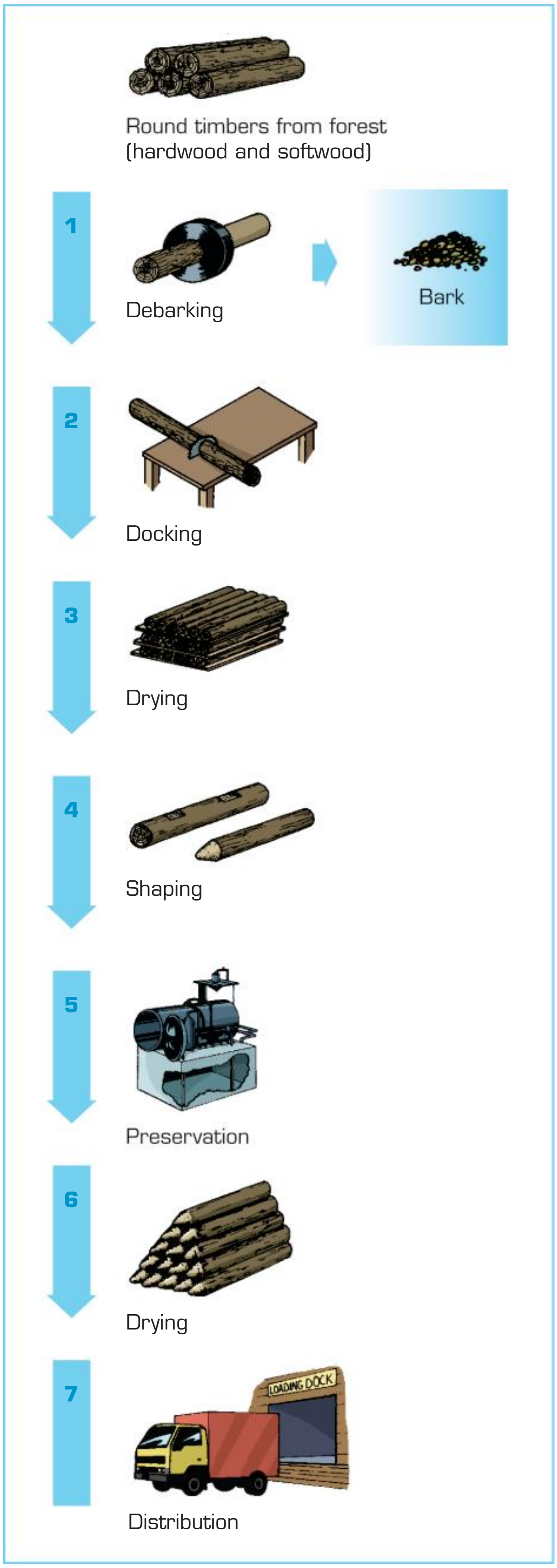


Round timbers

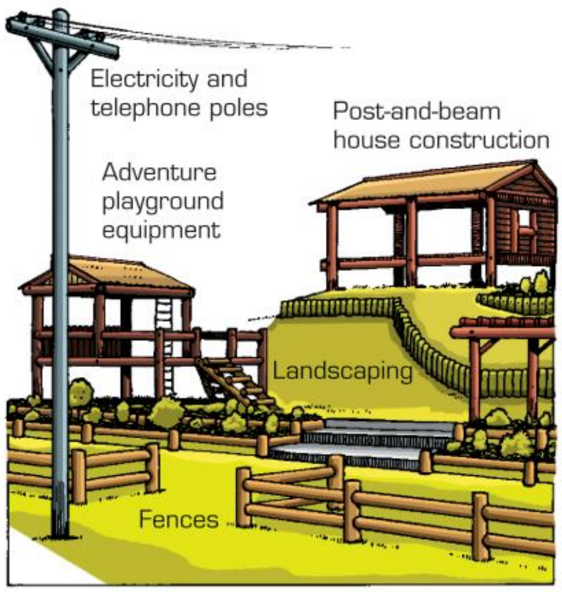
The following process is used to convert logs into round timbers.

1 The bark is removed from the logs.
2 The logs are docked to length to suit market requirements.
3 The logs are air seasoned to remove the excess moisture.
4 The logs are shaped to suit market requirements – for example, grooves and notches are cut so that other round timbers can be fitted in position to build structures such as outdoor play equipment.
5 The logs are treated with preservative to protect the timber from attack by insects and fungi.

   Hardwood logs require very little treatment: their heartwood is naturally durable because of the chemicals it contains. However, the sapwood has to be protected. One method of protection is with a preserving oil such as creosote.

   Most types of softwood are not naturally durable. They require treatment with a chemical preservative to protect the timber.

6 The treated logs are air dried once more.
7 Round timbers are stored, marketed and distributed to consumers.



Uses of round timber

Preservation

Round timbers are usually used for exterior construction work so they need to be durable.

Except for their sapwood, hardwoods such as ironbark and jarrah are naturally durable and require little preservation. Today, the sapwood is often removed during the milling process.

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Most softwoods are not naturally durable. They require some form of preservation to prevent damage caused by insects and fungi.

Timber can be preserved using:

- preserving oils such as creosote
- water-borne preservatives such as copper-chromium-arsenic (CCA) compounds.

The preservative can be applied by brushing, spraying or dipping. However, the most effective treatment is pressure-impregnation. During this process, timber is placed into steel cylinders and filled with preservative. The steel cylinder is pressurised to force the preservative into the cells of the timber. This method is now commonly used in the timber industry.

All wood preservatives are toxic and many can irritate or burn the skin. When applying preservatives, always wear protective clothing.

Protect the Earth

- *Do not* empty preservatives into the sewer or stormwater drains. Dispose of them properly at a toxic waste dump.
- *Do not* burn CCA-treated timber; it gives off toxic fumes. Dispose of it thoughtfully – check with your local council.

Other forest products

Forests give us many other products besides timber. These products fall into two groups:

- natural products, such as fruits and sawdust
- chemical products, such as creosote and turpentine.

Natural products

There are three groups of natural products.

Edible fruits and nuts

Examples include stone fruits, tropical fruits, walnuts, almonds, pecans, coconuts and pine nuts.

Sawdust

Sawdust is used as a fuel in industry or in the home. (Household sawdust is compacted into ‘logs’, pellets or briquettes.) It can also be used as mulch or compost for gardening. Brick manufacturers use sawdust as a filler in bricks.

Leaves, flowers and bark

Leaves, flowers and bark can be used for decorative purposes such as floral arrangements and bark paintings. Landscapers make extensive use of bark as a ground cover. The bark of the cork tree is used for insulation.

Chemical products

Trees provide many chemical compounds that can be used directly or processed into other substances. Some important products and their uses are shown in Table 4.1 on page 64.

Common timbers

Timbers are classed according to their use.

- Construction timbers are used mainly in the construction industry to build structures such as homes
- Cabinet timbers are used mainly for high-quality furniture and decorative veneers.

The use to which a species of timber will be put is determined by its properties, its availability and its cost. For example, spotted gum (a hardwood) is very strong and tough, and is readily available. It is used mainly for general construction. On the other hand, teak (a strong, water-resistant hardwood) is now used mainly as a cabinet timber because it has become very scarce. See Table 4.2 on page 64.

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Table 4.1 Products and their uses

Chemical product	Uses	
Tannins	• leather manufacturing • adhesives • dyeing fabrics	
Wood turpentine	• thinners for paints and varnishes • medicines • insecticides	
Creosote (from wood tar)	• timber preservatives • disinfectants	
Charcoal	• fuel • explosives manufacturing • medicines	

Table 4.2 Trees and their characteristics

Name, classification, habitat and colour	Characteristics, uses and availability
Ash, Mountain – Hardwood Grows in mountain regions of Tasmania and eastern Victoria. Colour: Heartwood is pale pink or straw coloured. Sapwood is not always clearly distinguishable.	• Grain is straight. • Texture is coarse. • It has distinct growth rings. • Gum veins are common. • Used for furniture, flooring, panelling and general construction. • It is a major timber species in Victoria and Tasmania.
Bean, Black – Hardwood Grows in rainforests from northern NSW to north Queensland. Colour: Heartwood is dark brown to almost black. Sapwood is pale yellow.	• Grain is usually straight. • Texture is moderately coarse. • It is greasy to touch. • Heart shakes are common in logs. • Used for furniture, woodcarving and decorative veneers. • It is scarce.
Blackbutt – Hardwood Grows in coastal forests between Bega, NSW, and Maryborough, Queensland. Colour: Heartwood is pale brown. Sapwood is distinctly paler.	• Grain is usually straight. • Texture is medium and even. • Gum veins are common. • Used for home construction (flooring and framework), poles and sleepers. • It is readily available.
Cedar, Red – Hardwood Grows in coastal rainforests of eastern Australia, Papua New Guinea and South-East Asia. Colour: Heartwood is pale to dark red. Sapwood is very pale pink or yellow.	• Grain is straight or slightly interlocking. • Texture is rather coarse and uneven. • It has a distinctive odour. • Used for furniture, woodcarving and decorative veneers. • It is scarce in Australia. Small quantities are being imported.

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Table 4.2 Trees and their characteristics (*continued*)

Name, classification, habitat and colour	Characteristics, uses and availability
Cedar, Western Red – Softwood Grows along the west coast of North America, from British Columbia to Oregon. Colour: Heartwood is pale to dark brown. Sapwood is yellowish-white.	• Grain is straight. • Texture is fine but uneven. • When damp, it is corrosive to iron nails. (Galvanised nails are used.) • Used for exterior and interior cladding, furniture and joinery. • It is imported in considerable quantities.
Fir, Douglas (also called Oregon Pine) – Softwood Natural habitat is the west coast of North America, from Mexico to British Columbia. It has been planted in small areas in Australia. Colour: Heartwood is yellow-brown to pale reddish-brown. Sapwood is distinctly paler.	• Grain is generally straight. • Texture is coarse and uneven. • It has distinctive growth rings. • There are some knots. • When the timber is freshly cut, the resin produces a distinctive odour. • Used for structural framing, joinery, boat-building and vats. • It is imported in considerable quantities. The large sections and long lengths are converted locally to meet market requirements.
Gum, Spotted – Hardwood Grows along the east coast from the Victorian/NSW border to Maryborough, Queensland. Colour: Heartwood is pale to dark brown. Sapwood is distinctly paler.	• Grain is variable, with frequent wavy grain. • Texture is moderately coarse. • Gum veins are common. • It is slightly greasy to touch. • Used for heavy construction, flooring, poles and piles. • It is fairly common in NSW and southern Queensland.
Ironbark, Red (also called Mugga) – Hardwood Grows mainly in north–central Victoria and on the inland slopes of NSW, with some trees along the east coast. Colour: Heartwood is dark red. Sapwood is pale yellow.	• Grain is interlocking. • Texture is medium and even. • Heartwood is very durable. • It is hard to work. • Used for heavy construction, poles and sleepers. • Its use is limited mainly to the areas in which it grows.
Jarrah – Hardwood Grows in the south-west corner of Western Australia. Colour: Heartwood is dark red. Sapwood is pale yellow.	• Grain is slightly interlocking. • Texture is coarse but even. • Heartwood is durable. • Relatively easy to work. • Used for general construction, sleepers, poles, piles, flooring and panelling. • It is a major timber species of Western Australia. >>

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Table 4.2 Trees and their characteristics (*continued*)

Name, classification, habitat and colour	Characteristics, uses and availability
Meranti, Red – Hardwood Grows in South-East Asia: Malaysia, the Philippines, Indonesia and Thailand. Colour: Heartwood is pale to dark reddish-brown. Sapwood is paler – may be yellow, pink or grey.	• Grain is usually interlocking. • Texture is coarse but even. • When working meranti, sharp tools are necessary to prevent a 'woolly' surface finish. • Used for joinery, furniture, plywood and internal mouldings. • It is imported in large quantities from South-East Asia. (There is growing concern that rainforest timbers such as meranti are not being harvested on a sustainable basis.)
Pine, Cypress – Softwood Grows in inland areas of Australia, especially in NSW and Queensland. Colour: Heartwood is brown to yellowish-brown. Sapwood is pale yellow.	• Grain is straight. • Texture is very fine and even. • Knots are very common. • It has a strong, distinctive odour. • Its natural resistance to termites makes it a valued timber. • Used for home construction: framework and flooring, posts and small poles. • It is in plentiful supply in Queensland and NSW.
Pine, Radiata (also called Monterey Pine) – Softwood Its natural habitat is a very limited area of the west coast of North America. It grows well in temperate climates and has been planted in South Africa, Chile, New Zealand and Australia for this reason. It can grow four to ten times faster than native eucalypts. Colour: Heartwood is pale yellow-brown. Sapwood is not always clearly distinguishable.	• Grain is usually straight, except for the central core, which can have a spiral grain. • Texture is fine but uneven. • Knots are common. • It has distinctive growth rings. • Used for general construction, furniture, particle board, plywood, fibreboard and paper. If treated with a preservative such as CCA, it can be used externally for cladding, poles and fence posts. • It is in plentiful supply because large plantations have been established.

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Part B: Metals

In this section, you will learn:

- what metals are
- about the properties of some different metals
- about the production of metals
- about the uses of metals.

What are metals?

Metals such as iron, copper, aluminium, lead, zinc, nickel, tin, silver and gold make up about two-thirds of the chemical elements. They occur naturally in the Earth’s crust as minerals. For example, aluminium occurs naturally as the mineral **bauxite**, a compound of aluminium and oxygen.

Thousands of years ago, people learnt how to mine rich deposits of minerals and refine this **ore** into usable metals. From the beginning of the Bronze Age (approximately 3000 BCE), metals played an important part in the daily lives of people. Metals have many uses, as shown in these drawings.

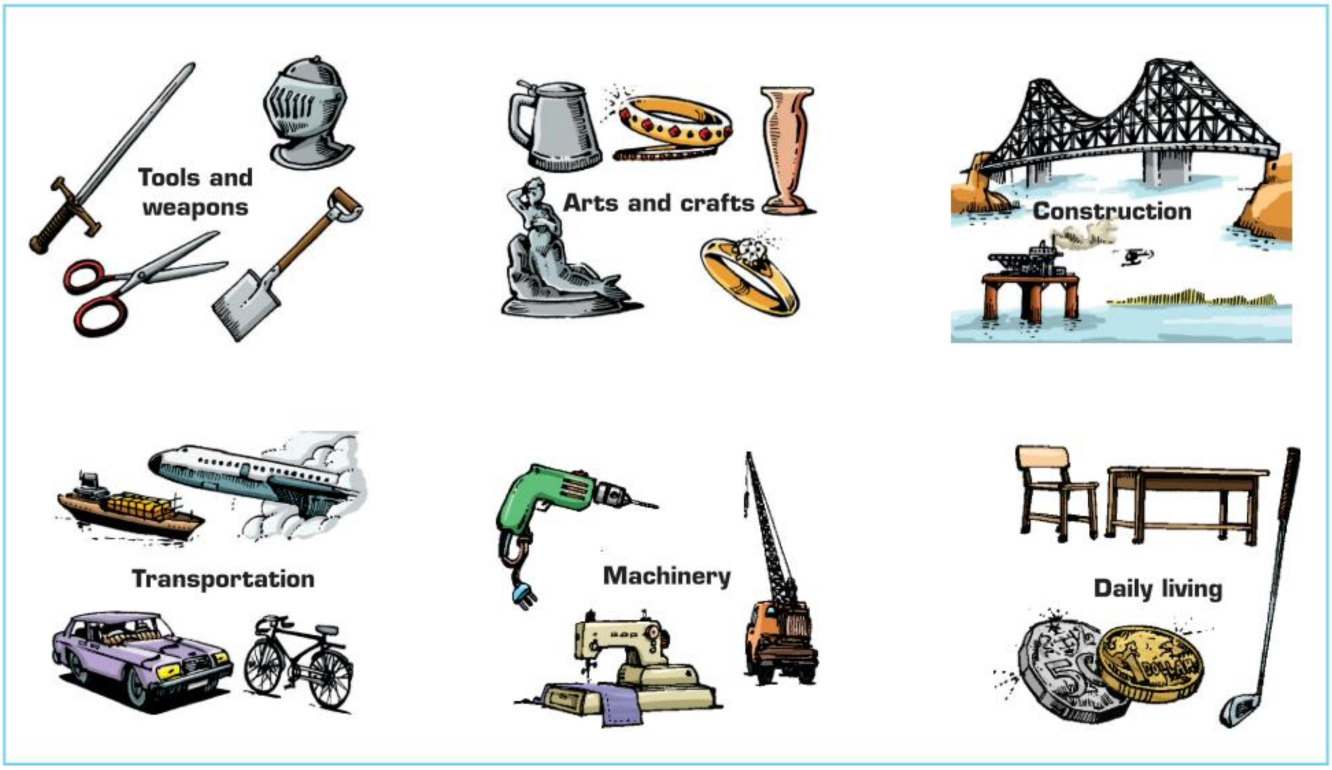
Classifying metals

All metals can be classified as one of the following.

- Ferrous metals: those that mainly consist of iron, such as steel. Most ferrous metals are attracted to a magnet.
- Non-ferrous metals: those that do not contain iron, such as copper, aluminium and lead.

As well, metals can be pure metals or alloys.

- A pure metal has no other chemical elements mixed with it. Iron is a pure metal.
- An alloy is usually a mixture of two or more pure metals. Alloys are often used when special



Some uses for metals through the ages

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properties are needed – for example, stainless steel (an alloy of iron, carbon, chromium and nickel) provides a high resistance to corrosion.

Properties of metals

Some common properties of metals are outlined below.

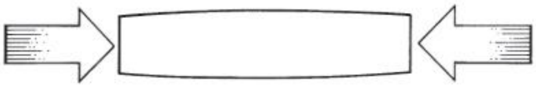
Hardness

The *hardness* of a metal is its ability to resist denting, scratching or wearing by abrasion.

Strength

The *strength* of a metal can be measured in five ways. They are:

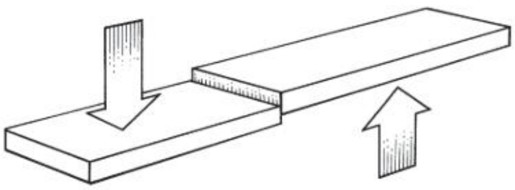
1 compressive strength: resistance to being squeezed together



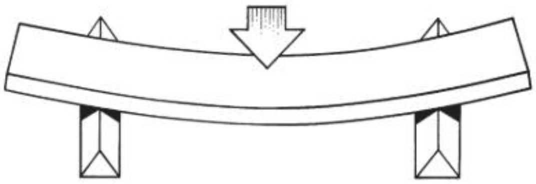
2 tensile strength: resistance to being pulled apart

3 torsional strength: resistance to twisting forces

4 shear strength: resistance to sliding forces acting in opposite directions



5 bending strength: resistance to a bending force.



Toughness

When a metal is able to resist sudden shocks (or a high degree of bending or twisting) without fracturing, it is said to be tough.

Brittleness

A metal is brittle if it breaks as the result of a light blow or slight bending. (Brittleness is the opposite of toughness.)

INFORMATION FILE

The strength of metals

The Eiffel Tower, 300 metres tall, was built for the 1889 Paris International Exposition – an industrial fair displaying new inventions.

Iron had been used to make tools and weapons for hundreds of years, but never before for a construction project such as a tower. Gustave Eiffel, the engineer who designed and built the tower, had to come up with a completely new building method. The material used for the lattice-like structure was wrought iron. It was strong enough to withstand the force of high winds, but quite light compared to stone or brick.

Until 1930, the Eiffel Tower was the tallest building in the world.

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Ductility

A metal is ductile when it can be permanently **deformed** by stretching (for example, into wire).

Malleability

The **malleability** of a metal is its ability to be shaped by hammering, rolling or pressing without breaking.

Conductivity

A metal that has a high degree of conductivity can conduct heat and electrical current very well.

Metals are solids at room temperature (except for mercury). Most have high melting points.

Many metals have shiny surfaces when they are freshly cleaned. Most become dull as they **oxidise**.

The properties of some metals can be altered by using heat. Heat treating is the process of heating and cooling metal under controlled conditions.

- Annealing is the process of softening a metal by heating it in such a way that internal stresses are reduced. Annealed metal can be formed or machined more easily. The annealing process varies for different metals. (See the Information File below.)
- Hardening and tempering are processes by which some carbon steels can be made harder and tougher. The steel is first hardened by heating it to cherry-red heat and quenching it in oil or water. The steel is now very hard and brittle, and has to be tempered to reduce its brittleness and increase its toughness. This is done by reheating it to a lower temperature. (The temperature depends on the required balance between hardness and toughness.)

INFORMATION FILE

Annealing techniques

REMEMBER:
- Always clearly mark hot metals.
- Use safety gear.

Annealing steel

Heat the steel to a bright red colour

Leave in a safe place and allow to cool slowly

Annealing aluminium

Rub soap over the surface of the aluminium

Heat gently until the soap blackens

Allow to cool in air

Annealing copper

Heat the copper to a dull red colour

Allow to cool in air

Quench (cool) in water

Dilute sulphuric acid

Copper or brass tongs

Glazed earthenware

Pickling

To remove scale:
- Pickle in acid bath
- Scrub with pumice soap

Wash clean with water

Annealing brass

Heat to a dull red colour → Allow to cool slowly → Remove the scale as for copper

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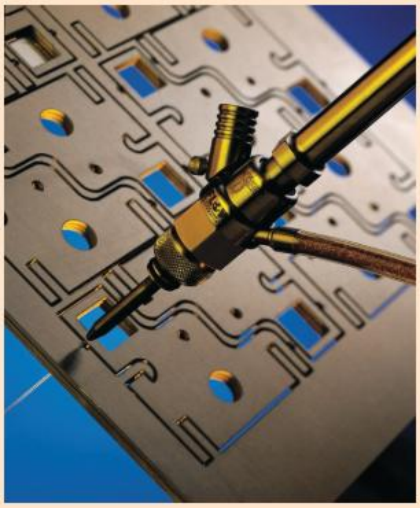
INFORMATION FILE
Cutting metal with water

A water-jet system, called the paser, has been developed to cut metal. Water mixed with abrasive particles is forced from a nozzle at extremely high pressure.

The water-jet system will cut metal up to 200 millimetres thick. Unlike flame cutting, the water-jet system does not create heat. There is no metal distortion and the edge is very cleanly finished.



Producing metals

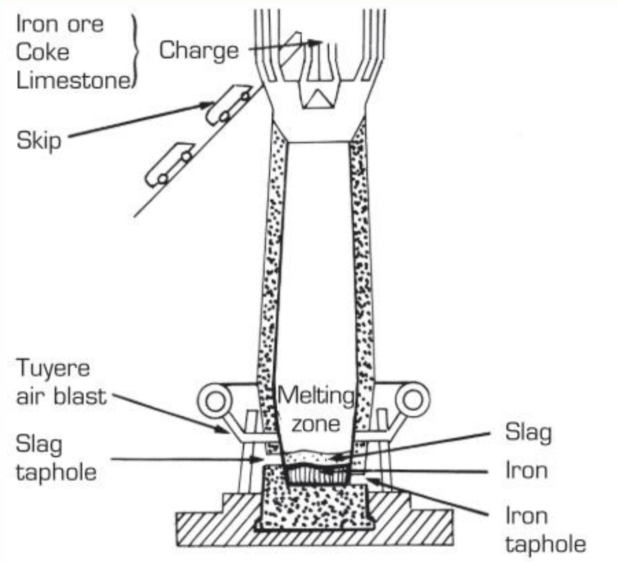
After mining companies remove ore by open-cut methods or underground mining, it has to be refined into usable metals.

The various ferrous metals are produced by smelting iron ore in a blast furnace to produce pig iron, and then further refining the pig iron and adding other elements to it.

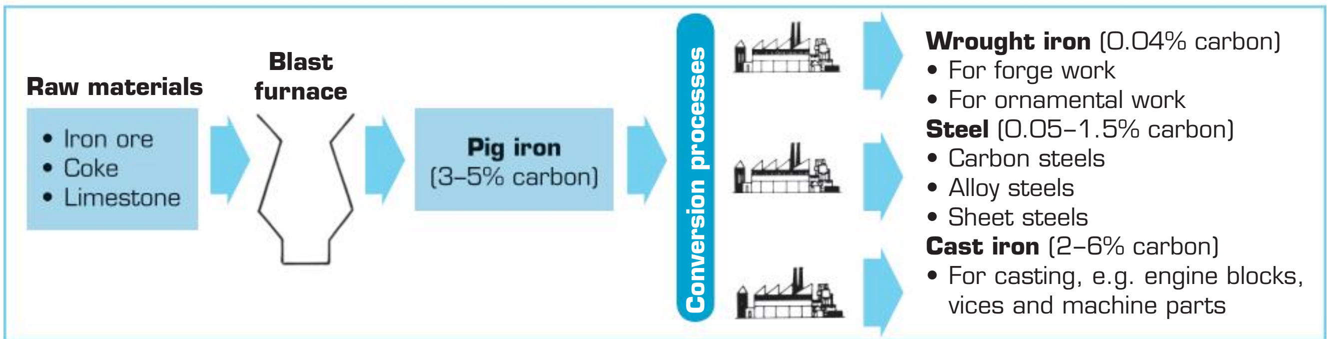
Producing iron

The blast furnace used to produce pig iron stands about 30 metres high. It is lined with fire bricks. The furnace burns for years and is only stopped when the lining has to be replaced.

1 The raw materials – crushed iron ore, coke and limestone – are raised to the top of the furnace by skip cars.
2 The raw materials are fed into the furnace.
3 Hot air is blasted into the base of the furnace through nozzles called tuyeres. This makes the coke burn fiercely, and the temperature rises to approximately 1900 degrees Celsius.
4 In the melting zone, the burning coke melts the iron in the ore, and the molten iron collects at the bottom of the furnace. The limestone breaks down and combines with most of the impurities from the ore to form a liquid slag. This floats on top of the molten iron.
5 From time to time, the slag and the iron are **tapped off**.



A blast furnace



The production of iron and steel

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The molten iron is then cast into blocks (pig iron) or fed directly into steel-making furnaces. The pig iron contains 3- to 5-per-cent carbon and small amounts of other impurities.

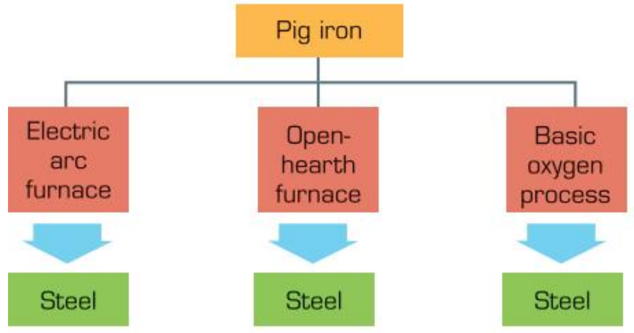
Cast iron is pig iron that has been refined in a smaller furnace called a cupola furnace. The molten iron is poured into moulds to make castings such as engine blocks. Cast iron is produced in different grades such as grey cast iron and white cast iron, with a carbon content ranging from 2 per cent to 6 per cent. Cast iron is brittle, but it has good compressive strength and is resistant to abrasion.

Wrought iron is purified pig iron with a carbon content of only 0.04 per cent. Wrought iron can be worked easily, and it is tough and corrosion resistant. In the past this made it an ideal material to use for items such as chains and horseshoes. Today, hot-rolled, low-carbon steels are usually used instead of wrought iron.

Producing steel

Steel is pig iron that has been refined to remove some of the carbon and the impurities it contains. Scrap steel is usually mixed with the pig iron at the start of the steel-making process. Once the iron has been refined, small amounts of other elements can be alloyed with it to produce different types of steel to meet the needs of industry.

There are three basic ways in which steel can be produced.

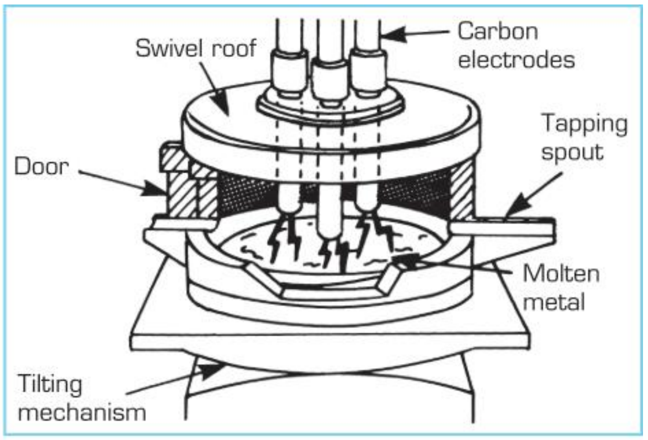


Methods of steel production

The electric arc furnace

The electric arc furnace is used to produce high-carbon steel or special alloy steels. It has the advantage of allowing the composition of the steel to be finely controlled.

1 Pig iron and scrap steel are loaded into the furnace.
2 The iron is melted by powerful electric arcs from the electrodes to the metal in the furnace.
3 The molten iron is sampled. Alloying elements are added as required.
4 The slag is removed. The molten steel is then tapped into a ladle.

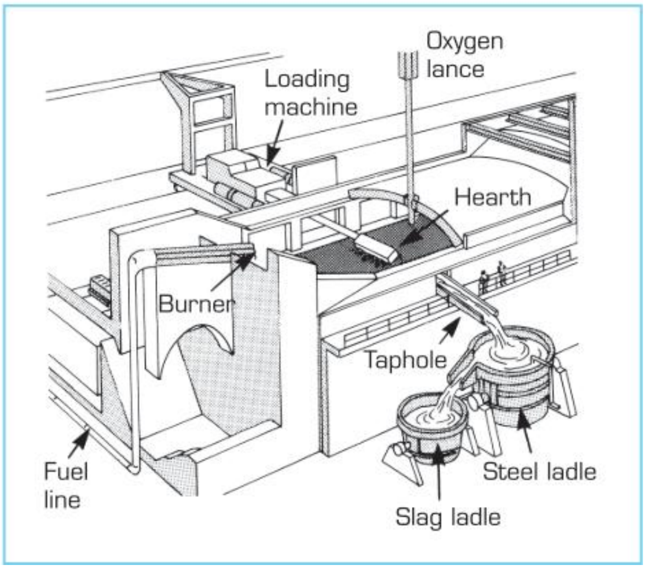


An electric arc furnace

The open-hearth furnace

The open-hearth furnace is like a huge oven. It is used to produce high-grade steel. However, this process is slow and it has largely been replaced by the basic oxygen process.

1 Pig iron (or molten iron), scrap steel and limestone are loaded into the furnace and placed on the hearth, which is open to flames that blow across it from gas burners.
2 The raw materials are then heated by the burning gas. Oxygen is also blown onto the melt to help burn out carbon and other impurities.
3 Before the furnace is tapped, the molten metal is sampled to determine its carbon content. Alloying materials are added to the steel after tapping.



An open-hearth furnace

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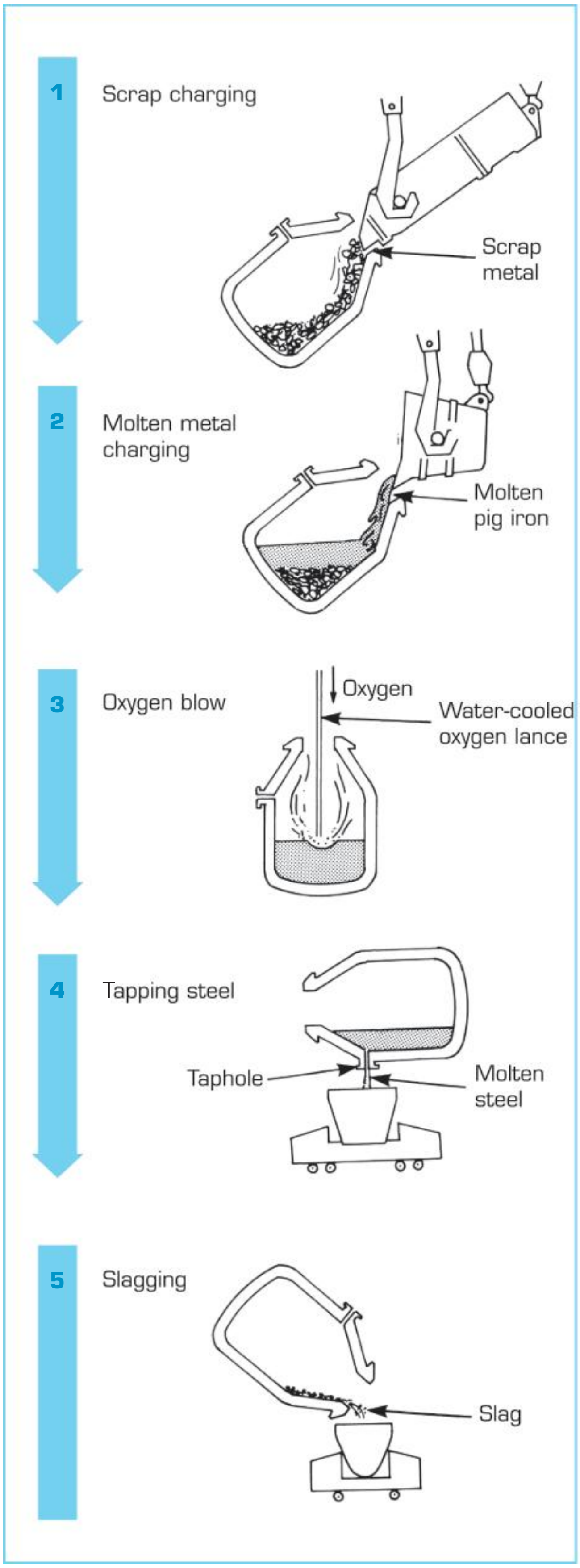


The basic oxygen process

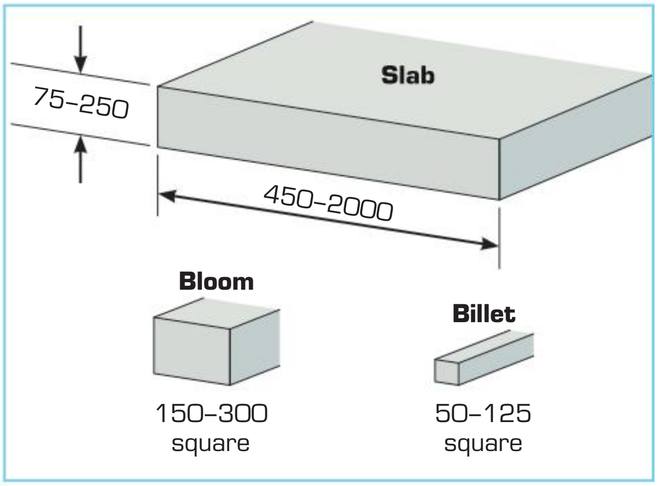
The basic oxygen process

The basic oxygen process uses oxygen to refine metal. It is a rapid operation.

1 First the furnace is charged with scrap metal.
2 Then molten pig iron is added.
3 A jet of pure oxygen is blown down onto the molten metal to burn off carbon and other impurities. During the blow, lime is added to combine with impurities and form a slag.
4 The molten metal is sampled. Elements are added to produce the required type of steel. Then the molten steel is tapped off into a ladle.
5 Finally the slag is poured off (see diagram on the left).

Shaping steel

Molten steel can be poured into ingot moulds and allowed to solidify. Later the ingots are rolled into slabs, blooms or billets.



Note: All measurements are in millimetres.

Alternatively, the molten steel can be cast directly to form slabs, blooms or billets. This method, called continuous casting, produces steel at a lower cost.

Steel is rolled to shape in rolling mills. It can be rolled while it is hot or cold, depending on the required finish and its intended use.

- Hot-rolled steel has a black coating, called scale. An example is black mild steel, which is generally used to forge items such as hooks and U-bolts.
- To produce a bright finish (as in the case of bright mild steel), hot-rolled steel is cooled and then passed through an acid bath to remove the scale. The cold steel is oiled and finally re-rolled to produce a smooth, shiny surface. This process enables the steel to be rolled to more accurate sizes than is the case with hot-rolled steel.

Commonly used steel products

Different types of steel are produced to meet the needs of industry.

Sheet steels: Steel can be rolled into sheets. To protect it from moisture, it can be coated with tin or zinc, forming products such as tinplate, Galvabond and Zinc Anneal.

Carbon steels: Carbon steel is available in three grades:

- low-carbon (0.05–0.3 per cent carbon): referred to as mild steel; easily formed, welded and machined
- medium-carbon (0.3–0.6 per cent carbon): stronger and harder than low-carbon steel, but still easily workable; can be hardened (reasonably hard)
- high-carbon (0.6–1.5 per cent carbon): difficult to cut and bend; can be hardened (very hard) and tempered.

Other alloy steels: Steel is often combined with other metals to produce alloys with special properties such as:

- stainless steel: chromium and nickel are added, forming a corrosion-resistant alloy
- high-speed steel (HSS): tungsten, chromium and molybdenum are added. High-speed steel is very hard and retains its hardness at high temperatures.

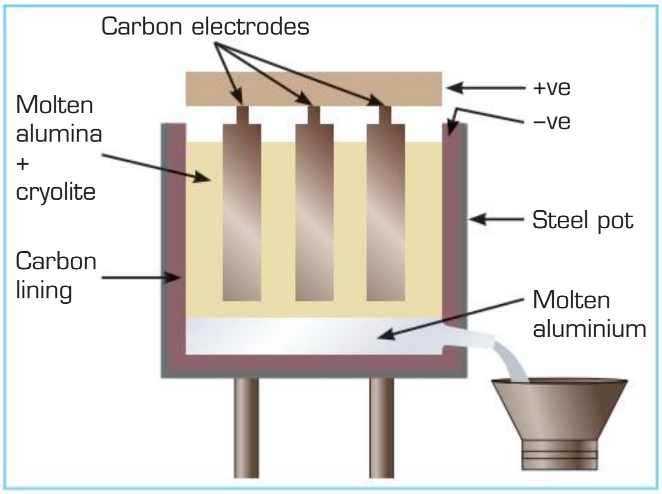
Steel is also rolled into heavier sections such as I and [beams, which are used in the construction industry.

Common non-ferrous metals

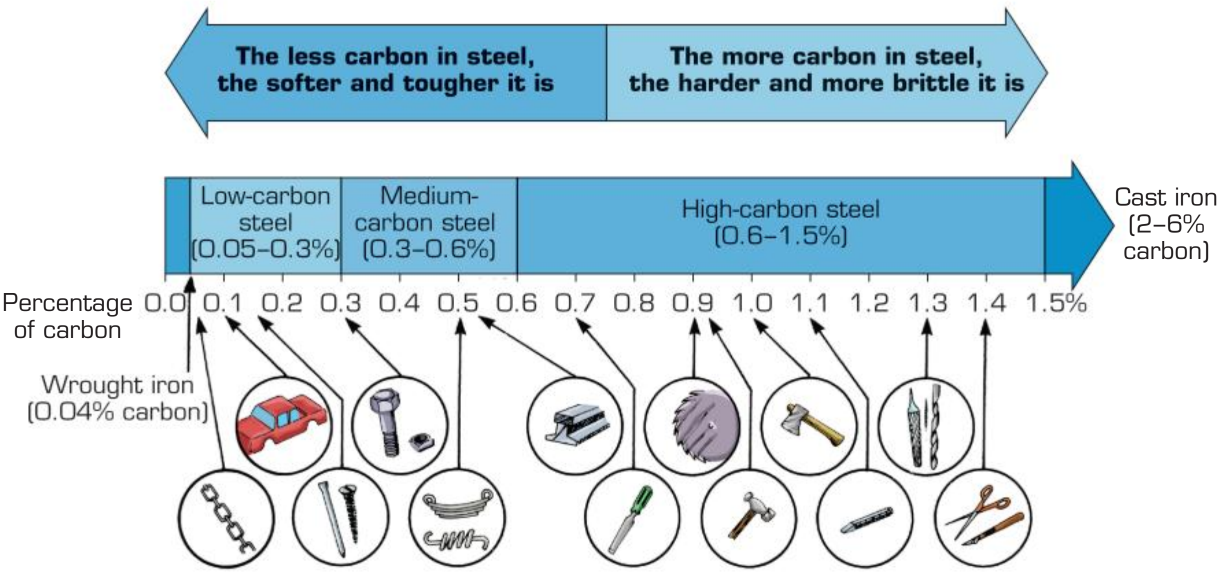
Aluminium

Aluminium is the most plentiful metal on Earth. It is refined from the ore called bauxite.

1. The bauxite is first crushed and processed chemically to produce **alumina**.
2. Aluminium is then smelted from the alumina via the process of **electrolysis**.
3. The alumina is dissolved in molten cryolite in an electrolytic cell. This is a carbon-lined steel pot with carbon electrodes.
4. A powerful electric current is passed through the molten mixture. This causes the aluminium to separate out and sink to the bottom of the cell.
5. It is drained off and poured into ingots for further processing.



An electrolytic cell, used for smelting aluminium



Carbon steels and their uses

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Pure aluminium is a light, greyish-white metal that is very soft and can be worked easily. It is malleable and ductile, and has good conductivity. It resists corrosion because of the dull film of oxide that forms on its surface in the atmosphere. Thus it requires virtually no maintenance. Aluminium is widely used for items such as cooking utensils, drink cans, window frames, wiring and machine parts.

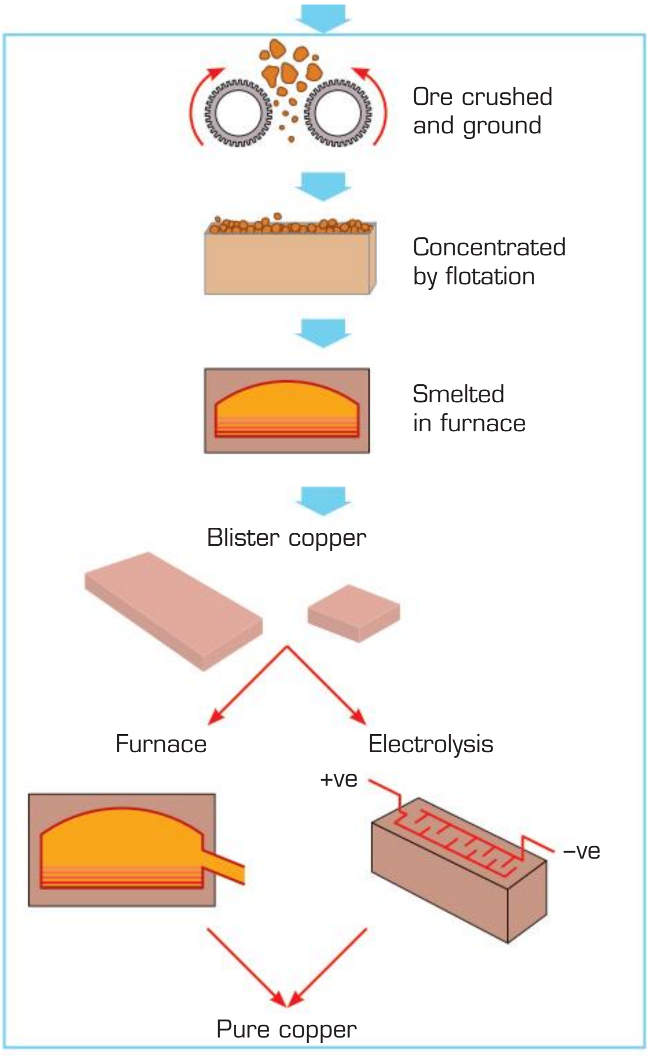
Aluminium is often alloyed with other metals, such as copper and manganese, to improve its hardness and strength. The alloyed metal can be processed in rolling mills like steel, or **extruded** into many different shapes. Duralumin is an alloy of aluminium, copper and manganese used for aircraft and automotive parts.

Copper

Copper is a soft, reddish-brown metal that is probably the earliest metal to have been used. Like aluminium, it is malleable and ductile, and has good conductivity. It resists corrosion, but will tarnish if not treated. It is mainly used for electrical wiring, water pipes, jewellery and alloys such as brass and bronze.

Copper ore usually contains less than 5 per cent copper. The mined ore is crushed, concentrated by a flotation process and then smelted into cakes or slabs of 'blister copper'.

To remove the remaining impurities, the copper is refined either in a furnace or (more commonly) by electrolysis.

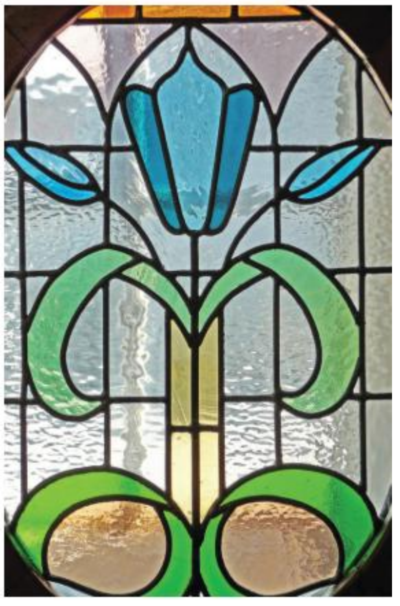


Refining copper

Pouring ingots of copper at a copper extraction plant

Lead

Lead is a soft, heavy, silver-white, poisonous metal. It can be worked easily and does not corrode. When freshly cut, lead is bright, but it tarnishes when exposed to air. It is used in plumbing (as in flashing for roofing), for plates in car batteries, for X-ray shielding and in alloys (especially in combination with tin in solders).



A leadlight window

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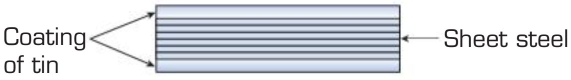
Tin

Tin is a soft, white metal that is highly resistant to corrosion. It is seldom used on its own, but is commonly used as a protective coating. For example, sheet steel is coated with tin to form tinplate, which is used for food cans, pots and roofing materials. Tin is also part of alloys such as bronze, solder and pewter.



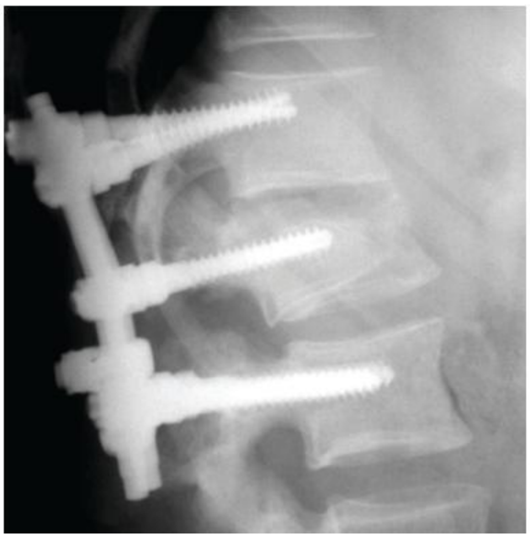
A tinplate

Brass

Brass is an alloy of copper and zinc. The bright yellow metal resists corrosion and machines well. It can also be cast and shaped easily. It is used for plumbing and boat fittings, musical instruments and decorative items such as hinges, catches and ornaments.

Titanium

Titanium is a silver-grey metal that is relatively **inert**. This makes it ideal for using to make the plates and pins that surgeons leave inside a patient's body to repair damaged bones. Its high strength and heat resistance also make it an ideal material to use for parts of spacecraft and supersonic aircraft that are exposed to heat and vibration.

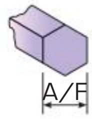


An X-ray showing titanium pins

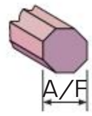
Round rod:
State diameter and length

Square rod:
State side and length

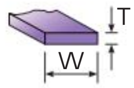
Hexagonal rod:
State greatest distance 'across flats' (A/F) and length



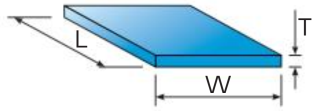
Octagonal rod:
State greatest distance A/F and length



Flat bar:
State width × thickness plus length



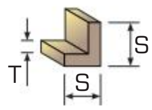
Sheet:
State length × width × thickness



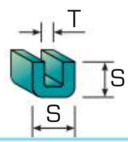
Round tube:
State outside diameter (O/D), wall thickness and length

Square tube:
State side, wall thickness and length

Angle:
State sides, thickness and length



Channel:
State sides, thickness and length



Commonly available forms of metal and how to order them (do not forget to identify the metal)

ISBN 9780170185677

Part C: Plastics

In this section, you will learn:
- what plastics are
- about the properties of different plastics
- about manufacturing processes for plastics
- about the uses of plastics.

What are plastics?

Plastics is the term used to describe all plastic materials and products made from them. It comes from the Greek word meaning 'capable of being moulded or formed'.

Plastics are a group of **synthetic** materials. Some early plastics were made using substances from plants (cellulose), cow's milk and coal. Since about 1950, crude oil has been the main raw material used to make plastics.

The basic building blocks of plastics are single molecules called monomers. The monomers of most plastics consist of atoms of carbon combined with other atoms such as hydrogen, oxygen, chlorine or nitrogen. To make plastics, industrial chemists link large numbers of these monomers together to form long chains of molecules known as polymers.

By combining different atoms, industrial chemists can create plastic materials with special properties. For example, the cast nylon used for rollers and bearings has extremely high resistance to wearing, while the acrylic sheet often used for glazing is lighter, more transparent and far more break resistant than glass.

Plastics can be mixed with many other substances – for example, glass fibre, wood dust, asbestos and metallic compounds. These substances are known as fillers. Fillers are added to plastics to change the properties of the plastic material. For example, plastics reinforced with glass fibre or glass cloth have greater strength.

Classifying plastics

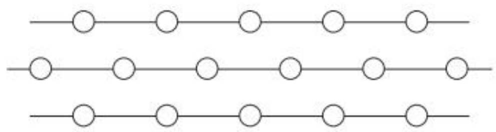
All plastics can be classified into one of two groups, depending on how the plastic reacts to heat. They are:
- thermoplastics
- thermosetting plastics.

Thermoplastics

Thermoplastic polymers consist of long chains of molecules that are relatively independent of each other. At room temperature, these individual chains form a rigid plastic material.

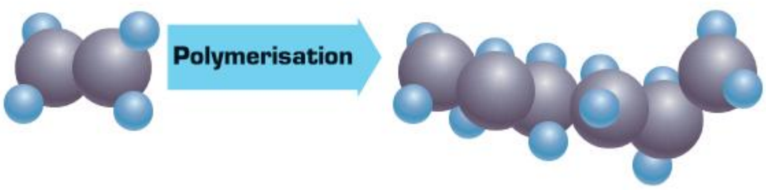
When moderately heated, the chains can move or slide, enabling the plastic to be formed to any desired shape. Upon cooling, the long chains retain the new shape.

This process can be repeated many times.



A thermoplastic polymer consists of long chains of molecules without any links between the chains.

Ethylene molecule: Two carbon and four hydrogen atoms



Polyethylene (Polythene): A catalyst causes the molecules to join together in a chain or polymer

The polymer commonly called polythene is produced from ethylene molecules by the process of polymerisation.

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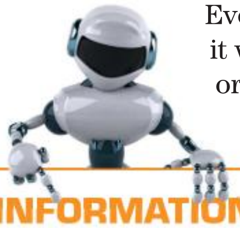
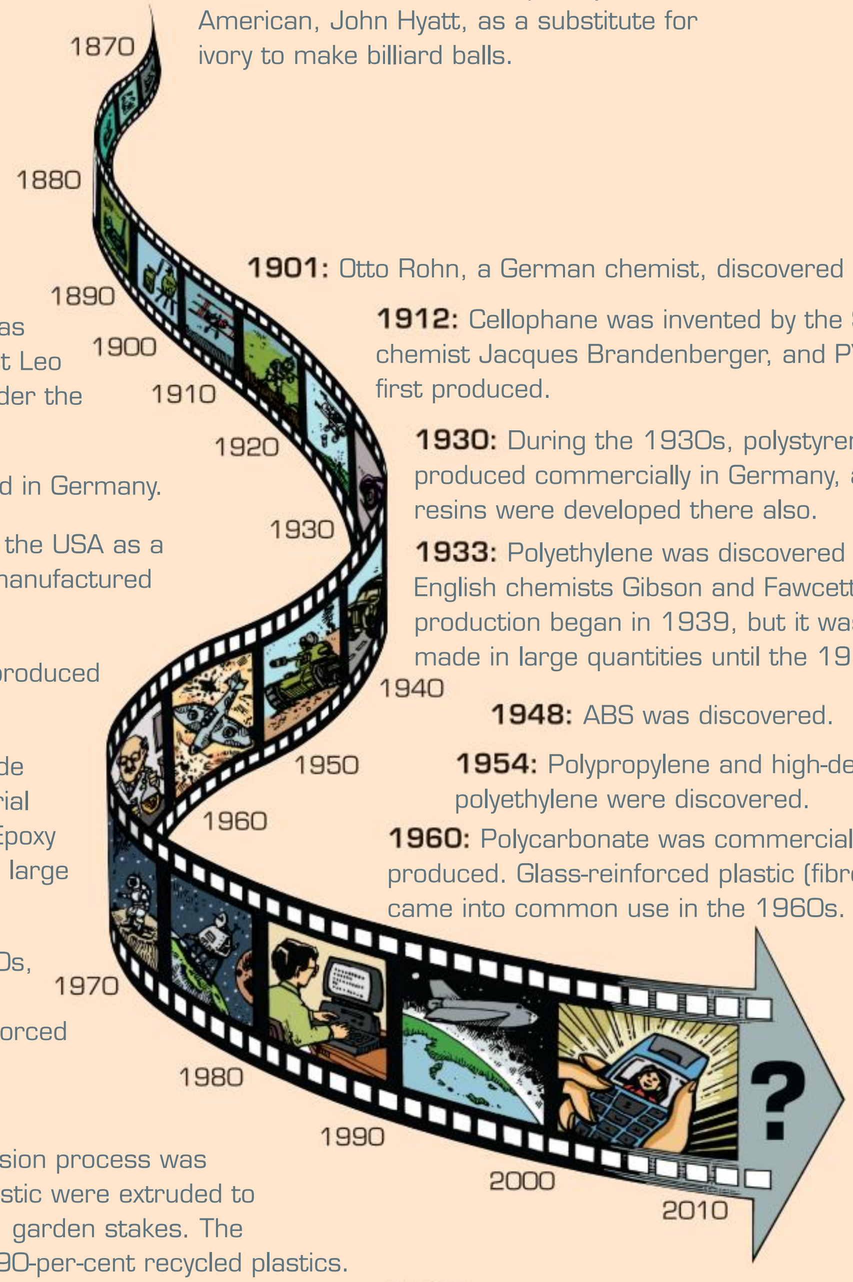
Every time the plastic is heated, it will soften and return to its original shape. This is known as 'plastic memory'. Care must be taken not to overheat the plastic, otherwise it will blister and bubble.



INFORMATION FILE

The history of plastics



1868: Celluloid was developed by an American, John Hyatt, as a substitute for ivory to make billiard balls.

1889: Cellulose nitrate photographic film was manufactured by George Eastman in the USA.

1901: Otto Rohn, a German chemist, discovered acrylic.

1907: Phenol formaldehyde was invented by the Belgian scientist Leo Baekeland. It was produced under the trade name Bakelite.

1912: Cellophane was invented by the Swiss chemist Jacques Brandenberger, and PVC was first produced.

1927: Rigid PVC was produced in Germany.

1930: During the 1930s, polystyrene was produced commercially in Germany, and epoxy resins were developed there also.

1933: Polyethylene was discovered by the English chemists Gibson and Fawcett, and production began in 1939, but it was not made in large quantities until the 1950s.

1934: Nylon was developed in the USA as a substitute for natural silk and manufactured commercially in 1937.

1942: Polyester resins were produced commercially.

1948: ABS was discovered.

1950: During the 1950s, crude oil became the main raw material for the production of plastics. Epoxy resins began to be produced in large quantities.

1954: Polypropylene and high-density polyethylene were discovered.

1960: Polycarbonate was commercially produced. Glass-reinforced plastic (fibreglass) came into common use in the 1960s.

1970: In the 1970s and 1980s, composite materials such as graphite epoxy and plastic reinforced with Kevlar were introduced.

1980s:

- In the early 1980s a coextrusion process was developed. Two grades of plastic were extruded to produce items – for example, garden stakes. The first grade – the core – was 90-per-cent recycled plastics. This was then coated with 10-per-cent virgin plastic, the second grade, to give a smooth exterior finish.
- In the mid-1980s a blow agent such as bicarbonate of soda was added to the coextrusion process. The result was a honeycomb core with a smooth exterior coating (a lighter material). Products manufactured include sewerage pipes.

1990: In early 1990, a new recycling process was developed in Belgium. Different types of plastic and some other materials such as aluminium and ceramics could be recycled together to produce items such as pallets for storage purposes.

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Table 4.3 Some common thermoplastics

Name	Properties	Uses
Polymethylmethacrylate (ACRYLIC)	• resists weather and chemicals very well • has high optical clarity, i.e. 90% of light is transmitted through clear acrylic • is light in weight, yet quite strong • has no grain • light is 'piped' (passed) along acrylic rod • can be formed when heated at 150°C	Outdoor and indoor advertising signs, display cases, optical lenses, safety shields, aircraft canopies and windshields, automobile tail-lights, baths, fabrics, paints
Acrylonitrile butadiene styrene (ABS)	• is very strong and tough • resists chemicals and staining • has machining properties similar to brass • is often referred to as 'engineering plastic'	Telephones, radio and TV cabinets, chairs, suitcases, car consoles
Cellulose acetate	• resists most household chemicals • is tough and flexible, but easily scratched • will dissolve if in contact with acetone or alcohol	Children's toys, buttons, combs, handles, blister packaging, photographic film, ballpoint pens
Polyamide (NYLON)	• has great resistance to wear and chemicals • is very strong, durable and light in weight • does not need to be lubricated • can be coloured easily	Gears, bearings, ropes, bristles, tubing, fabrics, electrical insulation, electrical parts, fishing line, zippers
Polycarbonate	• is very tough • is heat resistant and flame resistant • has high impact resistance • is light in weight • resists the weather very well • is a very versatile thermoplastic – one of the best	Safety equipment, face shields, space helmets, windows, street lighting covers, medical equipment (as an alternative to glass and stainless steel)
Polyethylene (POLYTHENE)	• is strong and water resistant • is tough • has excellent chemical resistance • is a good electrical insulator • has good impact resistance at sub-zero temperatures • is manufactured in two forms: – low-density (extremely flexible) – high-density (more rigid and heat resistant)	• Low-density polythene: squeeze bottles, freezer bags, film for food wrapping, electrical insulation, underwater cable insulation, plastic sheeting for damp courses or laying beneath concrete • High-density polythene: bottle crates, pressure piping for liquids and gases
Polypropylene	• is very strong • has excellent chemical resistance • has a high resistance to abrasion • has good impact resistance • is very light – will float on water • can be formed if heated to 170°C	Bowls, buckets, food containers, picnic ware, spatulas, woven material (e.g. sacks, webbing and carpets), ropes, slings, fishing nets, hinged lids and containers (e.g. flip-top bottles), children's toys, medical equipment (e.g. disposable syringes and body implants)

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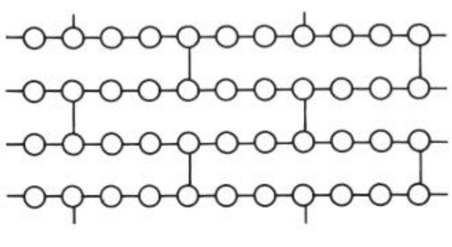
Table 4.3 Some common thermoplastics (*continued*)

Name	Properties	Uses
Polystyrene	Polystyrene: • is colourless • is hard and rather brittle • can be toughened to have high impact resistance • can be coloured Expanded polystyrene (foam): • is very light in weight • has good insulating qualities for heat and sound • does not absorb water • absorbs shocks but crumbles easily	Polystyrene: Disposable cups, dairy food containers, refrigerator linings, kitchen ware (e.g. food containers and measuring jugs) Expanded polystyrene (foam): Heat insulation, sound insulation, packaging for delicate equipment, flotation material (e.g. kickboards and surfboards)
Polytetrafluoroethylene (PTFE)	• has excellent non-stick properties (a low coefficient of friction) • has excellent chemical resistance • is a very good electrical insulator • resists heat	Cable insulation, gaskets, valve seats, plumber's pipe-jointing tape, coating for non-stick utensils, protective fabrics, e.g. Gore-Tex®
Polyurethane	• can be flexible or rigid • is manufactured in a variety of forms, e.g. foam, film and sheets	Flexible foam: upholstery (e.g. seat cushions and pillows), carpet underlay Rigid foam: insulation (e.g. sound and refrigeration) Coatings: wood finishes and paints Film: blister packaging, high-altitude balloons
Polyvinyl chloride (PVC or VINYL)	• is strong • is a good electrical insulator • has good chemical resistance • resists abrasion • can be rigid or flexible • can be coloured easily	Rigid PVC: gutters, downpipes, pipe fittings for plumbing, electrical conduits Flexible PVC: coating on fabric (e.g. suitcases), floor and wall coverings (e.g. vinyl tiles and wallpaper), electrical insulation (e.g. wiring)

Thermosetting plastics

A thermosetting plastic is changed chemically during its formation. It is either heated, shaped and allowed to cool, or moulded and hardened using chemical agents. The polymer then consists of long chains of molecules that have formed cross-links with adjacent chains.

This cross-linking between the chains cannot be broken if the plastic is reheated. Thus, once a thermosetting plastic is formed and sets hard, it cannot be softened again and reshaped (unlike thermoplastics).



The cross-linking between chains of molecules in a thermosetting polymer

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Table 4.4 Some common thermosetting plastics

Name	Properties	Uses
Alkyds	• resist heat • are good electrical insulators	Paints, radio and TV components, electrical parts
Epoxy resins	• are hard and tough • are strong • have high impact resistance • have high chemical resistance • can be used with fillers such as glass fibre • have good resistance to abrasion (wear) • have good adhesive qualities	Surface coatings (e.g. for surfboards and surf skis), adhesives, insulating material, electrical laminates, reinforced fabrics
Melamine formaldehyde (MELAMINE)	• has excellent heat resistance • is resistant to staining and scratching • is non toxic • has good chemical resistance	Tableware, picnicware, electrical components, marine adhesive, decorative laminates for furniture manufacture (e.g. Laminex and Formica)
Phenol formaldehyde (PHENOLIC – better known as Bakelite)	• has good strength and rigidity • is heat resistant • is quite brittle, but can be combined with fillers to reduce this • is always dark in colour, e.g. black or brown	Handles for heating appliances, electrical insulators, waterproof adhesive (for plywood, particle board and abrasive wheels)
Polyester resins	• are light in weight • have a high resistance to heat • have good resistance to impact • have good chemical resistance • can be reinforced, e.g. with glass fibre • can be cured at room temperature without additional pressure • have excellent clarity and are ideal for casting and embedding	Glass-reinforced plastic (e.g. boats, surfboards, surf skis, fishing rods, skateboards, outdoor furniture, swimming pools, automotive bodies), castings, yarn (for clothing and sails)
Silicones	• have excellent resistance to weathering • have high elasticity • are good electrical insulators • can withstand extremes of temperature • have good resistance to abrasion	Electrical insulation, gaskets and seals, waterproofing materials, heat-resistant paints
Urea formaldehyde (UREA)	• has some resistance to heat • is free of odour • has good impact resistance • is quite hard • can be coloured	Buttons, handles, knobs, electrical fittings, adhesives (e.g. for timber and plywood)

Plastic: the alternative material

The properties of plastics make them well suited to the mass production of everyday items. Most plastics can be changed into finished products via fairly simple manufacturing processes on automated machines. This means that products made from plastics are generally cheaper than products made from traditional materials such as wood and metal.

Plastics have become a popular alternative material to use because they:

- are easy to shape
- are light in weight and strong
- will not rot or corrode

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- are waterproof
- are a very good insulator of electricity
- are easy to keep clean
- have good hygienic qualities
- are available in a wide range of colours and finishes.

However, we need to be aware that there are some problems with plastics.

- Most plastics are not biodegradable. They take hundreds of years to break down through natural processes.
- Plastics pollute the environment and may harm wildlife if they are disposed of carelessly.
- Some plastics give off toxic fumes when they are burnt.

Windsurfing*

*The materials used for making windsurfer boards may include ASA (acrylonitrile–styrene–acrylate) for the board; fibreglass with up to 60-per-cent carbon fibre for the mast; nylon or PVC sheeting (reinforced with a mesh of Kevlar fibres) for the sail; and polycarbonate for the tail fins and dagger board.

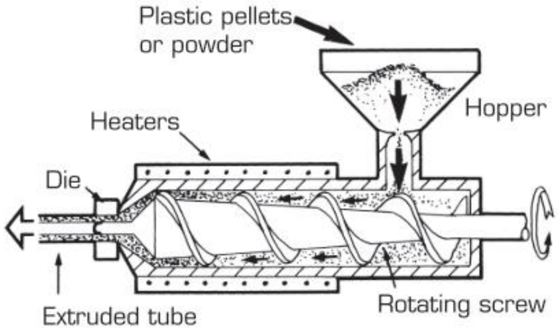
Manufacturing processes

Various manufacturing processes can be used to transform plastics into everyday items. Some commonly used processes are:

- extrusion
- moulding
- forming
- laminating
- calendering
- casting.

Extrusion

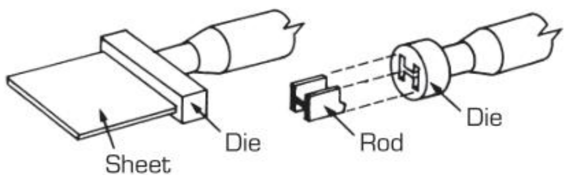
The extrusion press is generally used to manufacture products such as pipes, rods or tubular films. Both thermoplastics and thermosetting plastics can be used. Extrusion is also used to coat bare wire with plastic.



An extrusion press

1. Plastic pellets or powder are fed into the hopper.
2. The raw material is forced along the cylinder by the rotating screw.
3. The heated raw material is changed into a thick liquid.
4. The thick liquid is forced through the **die**. (The shape of the die determines the final shape of the product.)
5. The extruded plastic is allowed to cool.

Interchangeable steel dies can be fitted to the press to produce many shapes.



Extruded sections

Moulding

Moulding is used to manufacture objects ranging from the simple to the complex. There are three commonly used moulding processes:

- injection moulding
- compression moulding
- blow moulding.

Each method requires a mould that is a hollow shape of the object. Molten plastic is forced into the mould. After the item has cooled, it is removed from the mould.

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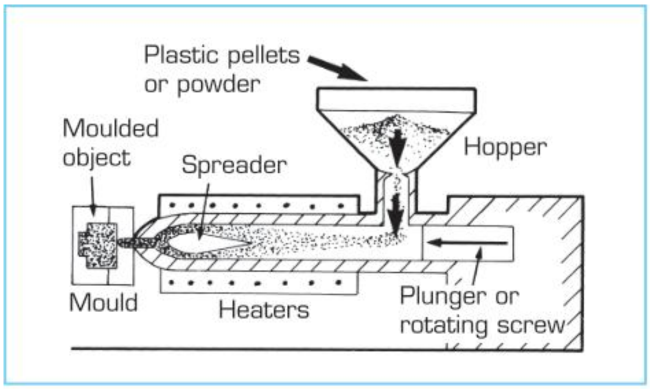
Injection moulding

Injection moulding is used to make items such as buckets, nylon gear wheels, drinking cups and children's toys. Thermoplastics and thermosetting plastics can be used for this process.



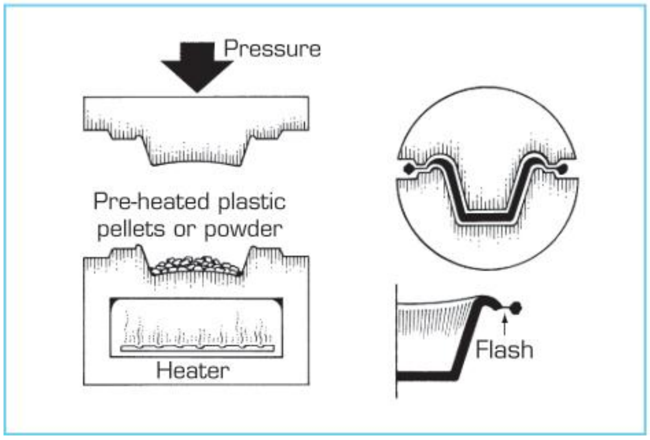
Injection moulding

1 Plastic pellets or powder are loaded into the hopper.
2 The raw material is heated to a molten state.
3 A plunger or rotating screw forces the molten material around a spreader and through the nozzle into the hollow mould.
4 After cooling, the mould is opened and the object is removed.

Injection moulding is well suited to the commercial production of large numbers of items from a single mould. Items can be produced quickly and inexpensively using this automated process.

Compression moulding

Compression moulding is used to manufacture items such as lamp sockets, bottle caps, melamine dinnerware and distributor caps. Thermosetting plastics are the main raw material used for this process.



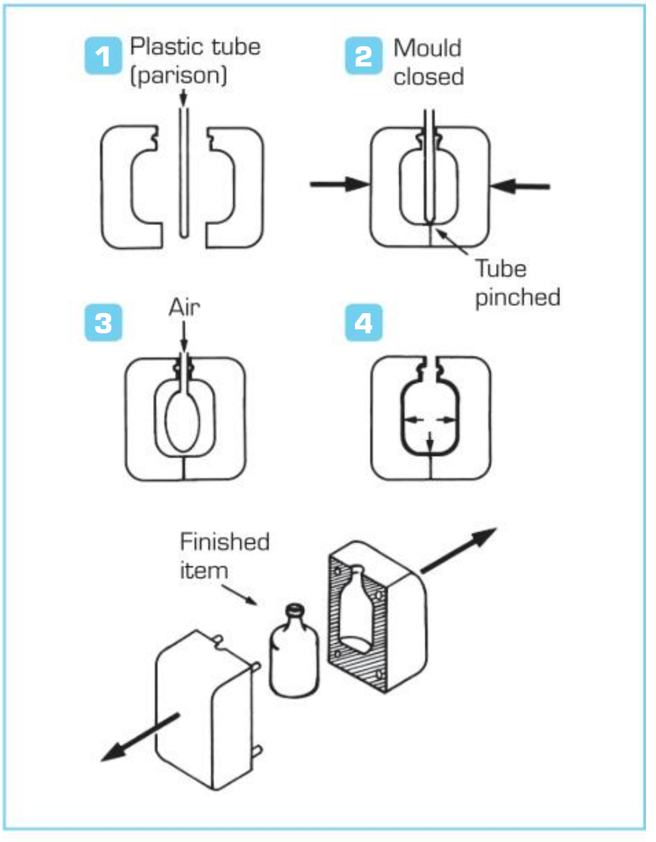
Compression moulding

1 A measured amount of pre-heated plastic pellets or moulding powder is placed in the lower half of the mould.
2 The upper half of the mould is compressed onto the lower half.
3 Under heat and pressure, the liquid raw material is forced into the shape of the mould. It is allowed to cure.
4 After cooling, the mould is opened and the moulded item is ejected.
5 The **flash** is removed by grinding or tumbling, or is simply broken off by hand.

Compression moulding is slow compared to injection moulding.

Blow moulding

Blow moulding is used to manufacture hollow items such as squeeze bottles. Thermoplastics are used for this process.



Blow moulding

1 A length of softened plastic tube (a parison) is passed into an open mould.
2 The mould is closed, sealing off one end of the softened plastic tube.
3 Air is blown into the open end of the plastic tube. This forces the tube to expand and touch the inner walls of the mould.

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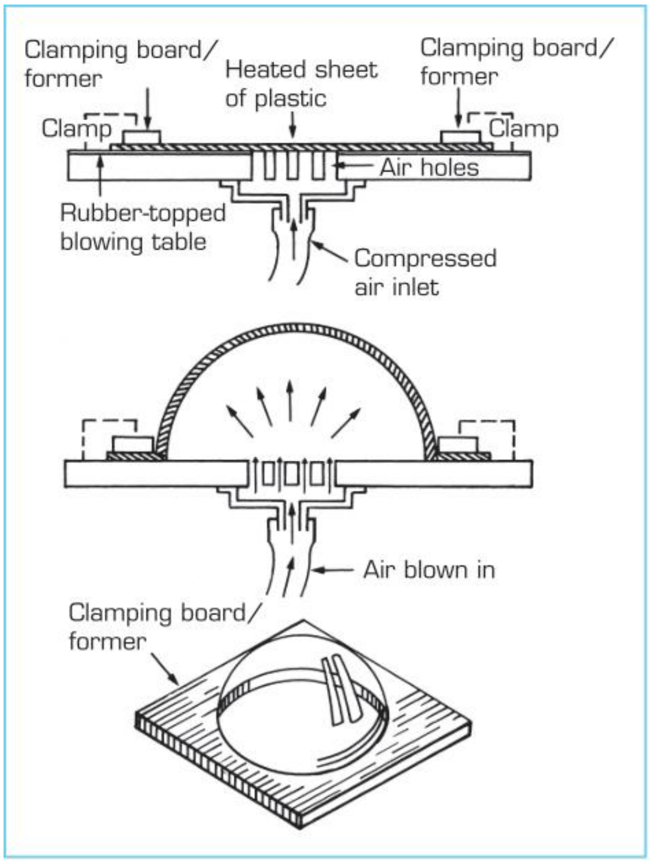
4 After cooling, the mould is opened and the item is ejected.

Free blowing

The blow-moulding process can be used to form dome shapes. This process is known as free blowing.



Free blowing

1 A former and clamping board are prepared by cutting the required shape from a suitable sheet material such as plywood or particle board.
2 A sheet of thermoplastic is heated until it is soft.
3 The heated thermoplastic is placed on top of a rubber-topped blowing table that has a central inlet for compressed air. The former/clamping board is then laid on top of the plastic, and its edges are clamped to prevent air loss.
4 Compressed air is blown in, inflating the heated thermoplastic to the desired height. The air pressure is maintained until the plastic cools (otherwise the heated thermoplastic will return to its original flat shape).

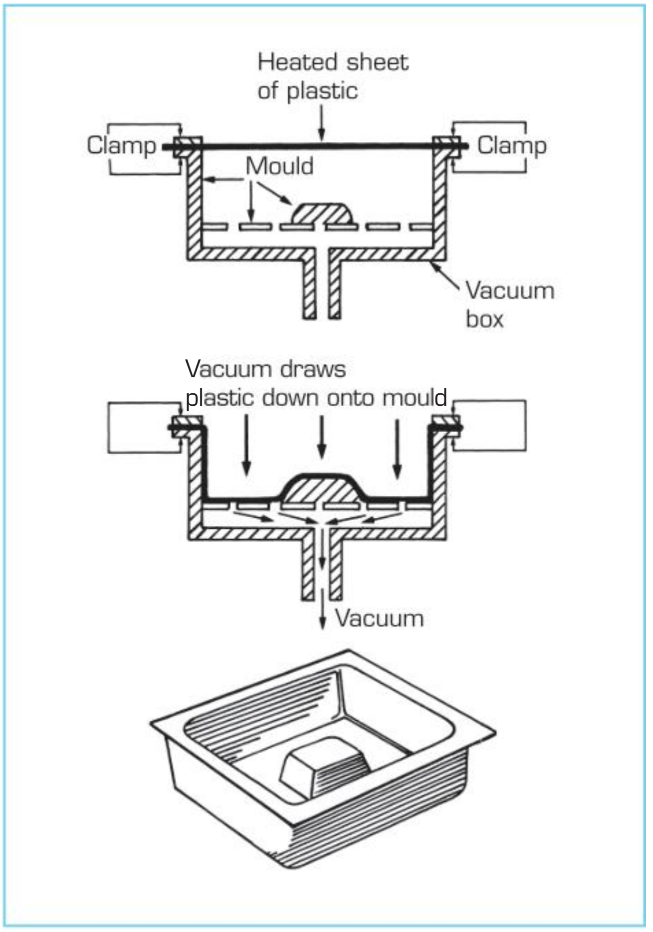
Forming

Forming is the process of changing the shape of a sheet of thermoplastic into items such as trays and bowls. Two forming processes are commonly used:

- vacuum forming
- pressure forming.

Vacuum forming

Vacuum forming is used to manufacture many items such as advertising signs, trays and inside door liners for refrigerators. This process requires a male mould of the finished item.



Vacuum forming

1 A sheet of thermoplastic is heated until it sags under its own weight.
2 The heated plastic sheet is drawn over the mould and clamped down.
3 A vacuum is created between the mould and the plastic. This causes the thermoplastic sheet to be forced down onto the mould.
4 After cooling, the moulded item is removed and trimmed as required.

Pressure forming

Pressure forming requires a male mould and a female mould. A heated sheet of thermoplastic is placed between the male and female moulds and pressure is then applied until it cools. (See page 125.)

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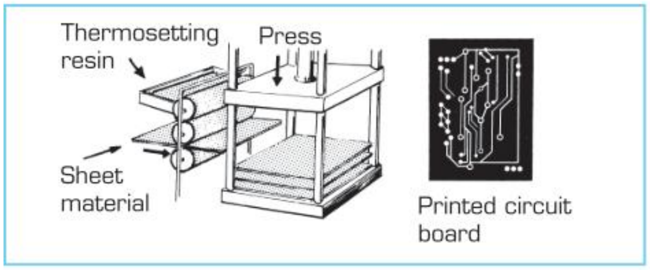
Laminating

Laminating is the process of sandwiching together layers of paper, cloth or metal foil that have been coated in thermosetting plastics. The bonded sheets that result are very strong. Plastic laminates are used for items such as table tops and printed circuit boards (PCBs). (See page 191.)



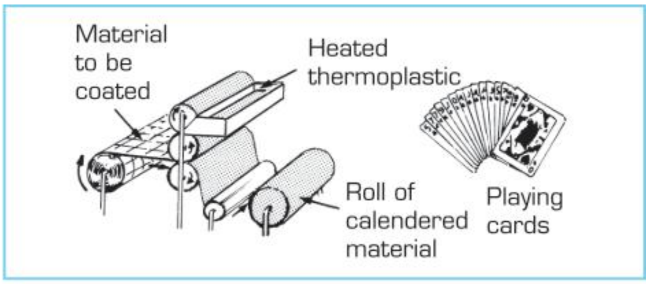
Laminating

1 Sheets of paper, cloth or metal foil are passed between rollers and coated with thermosetting resin.
2 The sheets are stacked on top of one another and placed in a press.
3 The sheets are squeezed together and heated to cure and bond them.

Glass-reinforced plastic (GRP), commonly called fibreglass, can be laminated. (See page 90.) It forms a very strong material that is used to manufacture items such as boats, yachts and furniture. Hand-laminating is often used to laminate smaller items. For larger items, a spray lay-up gun is used to apply the resin and glass fibre. The mould used could be a one-piece mould (male or female, depending on the surface finish required), or a two-piece mould if a good surface finish is required on both sides. (See pages 125–6.)

Calendering

Calendering machines are used to make plastic films or thin sheets. Heated thermoplastic is passed through a series of rollers to achieve the desired thickness. Calendering is also used to coat materials such as paper and cloth with a thin layer of thermoplastic, to give them a protective finish and added strength. Examples of calendered products include vinyl wallpaper and plastic-coated playing cards.

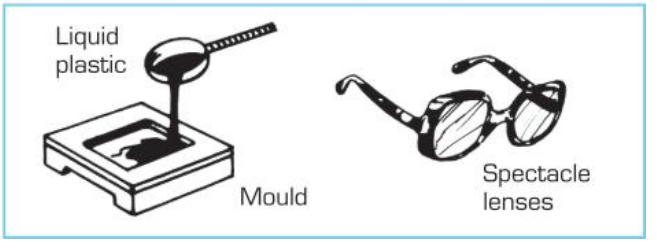


Calendering

1 Plastic is heated until it has softened.
2 The heated plastic is squeezed through the calendering rollers. The thickness of the coating can be controlled by the gap between the rollers.
3 Paper or fabric is fed into the calendering rollers. The heated plastic is bonded to the paper or fabric.
4 The bonded material is cooled, trimmed to width and wound onto a roll.

Casting

Casting is used to shape thermoplastics and thermosetting plastics. The mould used can be a one-piece mould or a two-piece mould that fits together. Liquid plastic is poured into the mould and allowed to harden. This process is used to make a range of items, such as spectacle lenses.



Casting

1 The melted resin is poured into the mould.
2 The resin is allowed to cure.
3 Upon hardening, the item is removed from the mould.

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Part D: Other common materials

In this section, you will:

- learn about the properties of other materials
- learn about their uses
- gain knowledge of tools to use with them
- become aware of the role of composite materials.

Textiles

Textile is the term used to describe any **fabric** or fabric product. Products made from fabric include clothing and furnishing items such as those found in homes, offices and schools.

A range of fabrics

The clothing worn in prehistoric times was made from natural materials such as animal skins and fur, leaves and woven grass. Bone and thorns were used to make needles, while animal sinew or lengths of grass were used as thread.

The invention of the spinning wheel in India enabled people to twist fibres into **thread**. The yarn could then be woven into fabric. Woven fabrics were made from natural vegetable fibres and animal fibres.

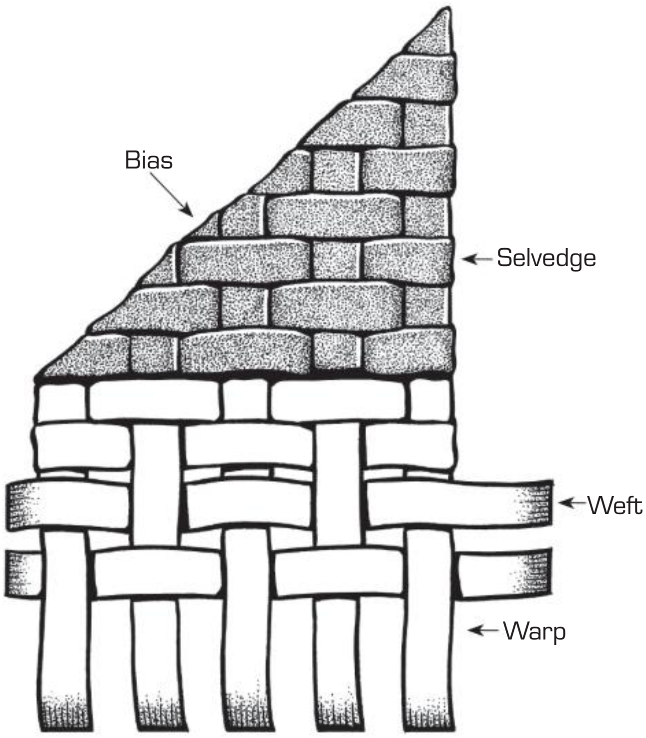
Natural plant fibres include cotton, flax, hemp and jute. Animal fibres include wool from sheep, silk from silkworms and hair from camels, horses, rabbits, goats and llamas. Human hair might also have been used.

The invention of the mechanised loom enabled people to weave cloth faster than before. The **weft** thread could be passed quickly through the **warp** thread.

Warp threads, also known as ends, run the length of the fabric. Warp yarns are very strong.

Weft threads, also known as picks, run the width of the fabric. Weft yarns are not as strong as warp yarns.

A piece of fabric consists of a series of picks passing over and under a series of ends.



Fabric has two grains. One grain is in the direction of the length (warp) and the other is in the direction of the width (weft). There is usually very little stretch along the grains. The greatest stretch possible is along the bias. The bias is the diagonal direction across the grains. (See the diagram overleaf.)

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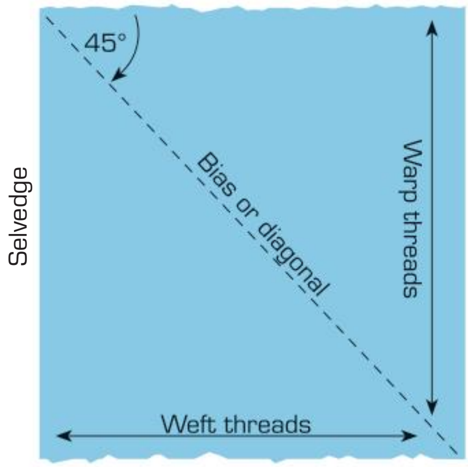
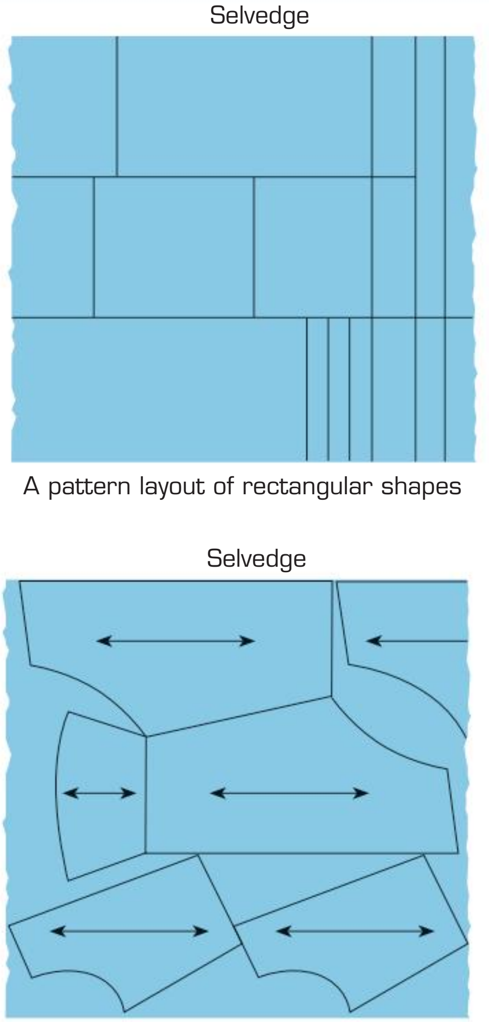
When marking out fabrics, line up the pattern with the warp grain to ensure **dimensional stability**. On the other hand, if the fabric needs to be stretched, line up the pattern with the bias.



The parts of a piece of fabric

The Jacquard loom (invented in 1801) used perforated cards that lifted the warp threads in a particular order to make complex patterned fabrics.

Using a loom to weave a piece of fabric



Marking out pieces of fabrics

Table 4.5 Common textiles and their main properties

Fibre	Main properties
Cotton	durable; strong – wet or dry; water absorbent; creases easily; good conductor – feels cool; very little elasticity; burns to ash
Linen	durable; very strong – wet or dry; water absorbent; creases easily; good conductor – feels cool; no elasticity; burns to ash
Wool	moderately weak; water absorbent; does not crease easily; very poor conductor – feels warm; very elastic; not insect resistant; smoulders
Silk	durable; very strong; water absorbent; resists creasing; very poor conductor – feels warm; reasonable elasticity; soft to touch; smoulders
Rayon	good strength; very absorbent; creases readily; good conductor – feels cool; burns and melts
Polyamides	very durable; very strong – wet or dry; does not crease easily; very poor conductor – feels warm; very high elasticity; easy-care; burns and melts
Polyester	durable; water repellent; good strength; resists creasing; fair conductor – feels cool; easy care; burns and melts
Acrylic	good strength; very little stretch; resists creasing; low conductor – feels warm; fairly easy care; melts

ISBN 9780170185677

The twentieth century saw the development of manufactured fibres and dyes. Rayon was invented in 1930 and manufactured in Britain. Other new materials such as Lycra, Teflon, Nomex, Gore-Tex® and Tencel® have been developed in recent times.

Every fibre has a variety of properties. Some basic properties of fibres are strength, absorbency, stretch, elasticity, warmth, crease recovery, chemical resistance, flammability, washability and resistance to insects and micro-organisms. Fibres can be combined to create fabrics with specific properties. There are two ways to achieve this:

- as a mixture
- by **blending**.

INFORMATION FILE

The production of fibres

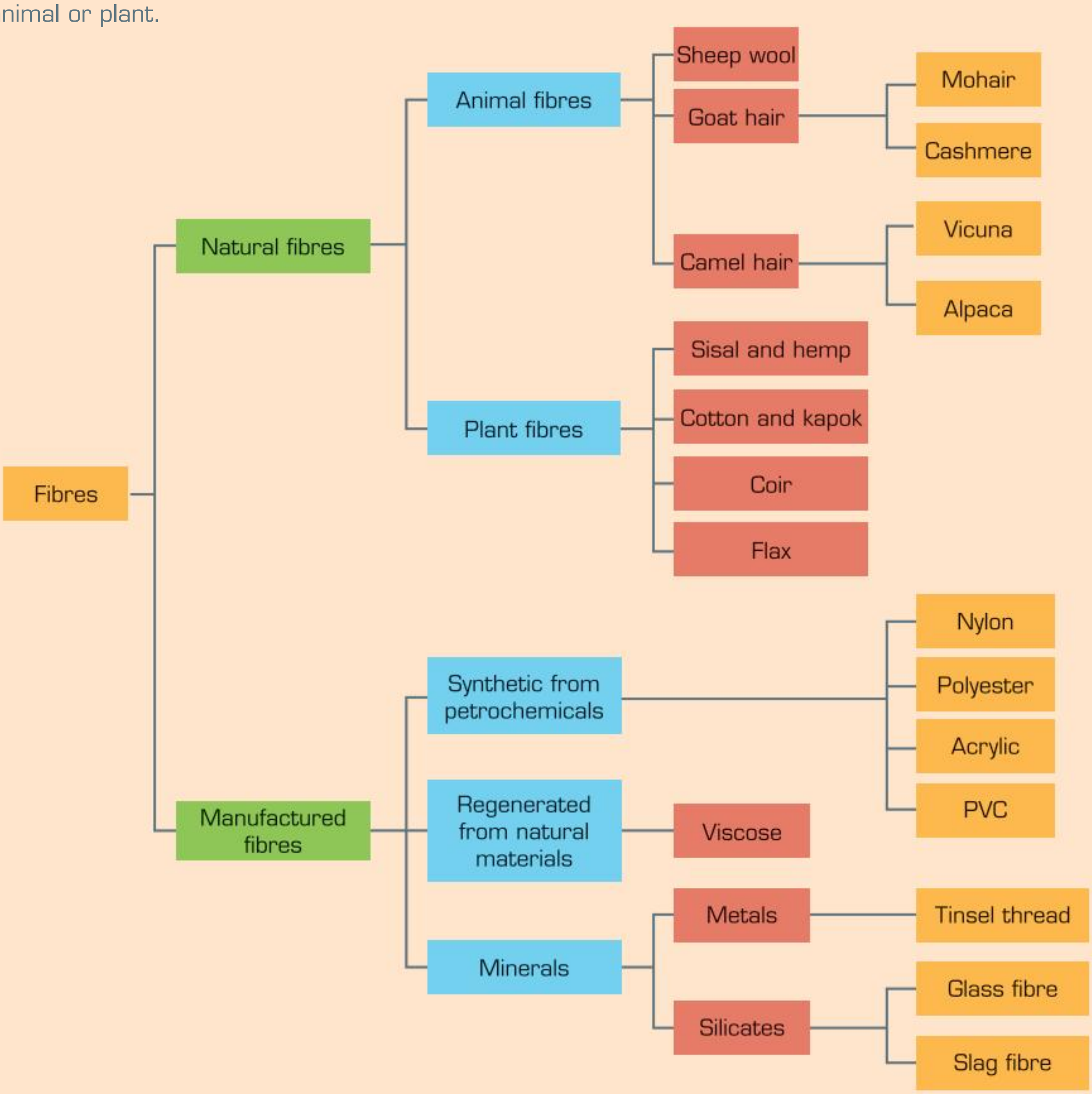
Fibres can be classified into two groups. They are:

- natural fibres
- manufactured fibres.

Natural fibres come from one of two sources: animal or plant.

Manufactured fibres are also derived from two sources: synthetic fibres from petrochemicals, and regenerated fibres from natural materials such as wood pulp.

The chart below shows the production of fibres.



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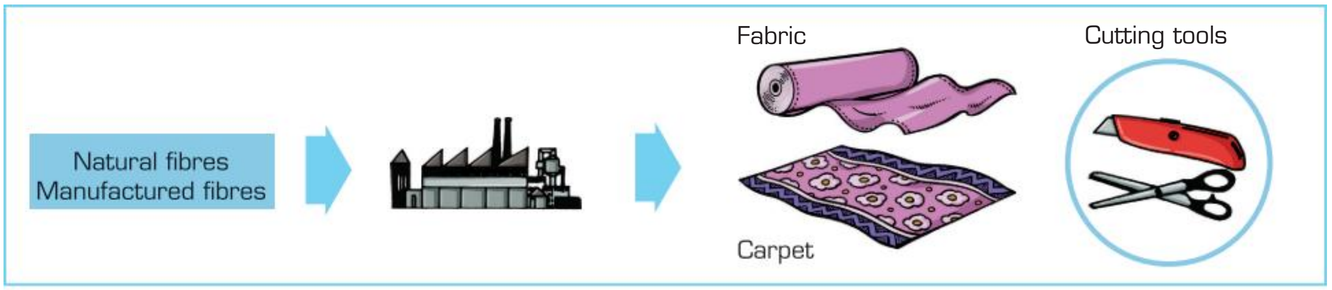


Manufacturing fabric

A mixture of a fabric refers to the combining of different yarns – for example, cotton and polyester in the warp and weft – in the weaving of the cloth. The result is an easy-to-iron fabric with the aesthetic appeal of cotton.

Different fibres can be blended during the production of yarn. The result is an improvement in performance and overall properties, enhanced aesthetic appeal, cheaper production and a large variety of yarns and fabrics.

The combination of fibres in recent times has also resulted in the production of protective fabrics for specific applications and work environments. This range of fabrics protects people from chemicals, heat, cold and infection, as well as reducing static.

Oil industry employees and construction workers wear clothing that reduces static and is fire resistant. Motorcycle racing suits are made of Kevlar and Lycra, which offer protection from abrasions during a fall and yet are elastic and breathable.

There is another group of textiles known as bonded fabrics. As the name implies, fibres are bonded to each other. These fibres can be arranged in one direction, in more than one direction or randomly to form a web. The fibres within the web are bonded using one or more bonding processes – for example, stitch, thermal or adhesive.

Examples of bonded fabrics include nappies, dish cloths, gowns and masks, and geotextiles or geosynthetics – fabrics that are **permeable** and are used in filters and drainage in civil engineering.

Glass

Standard glass is made by heating sand, soda ash and limestone in a furnace. The molten glass is then shaped by blowing, pressing, casting or **drawing**.

Many different kinds of glass are manufactured to meet particular requirements; examples include tempered glass for sliding doors, glass fibre for fibreglass reinforcement, Pyrex for cooking utensils and crystal for decorative glassware.

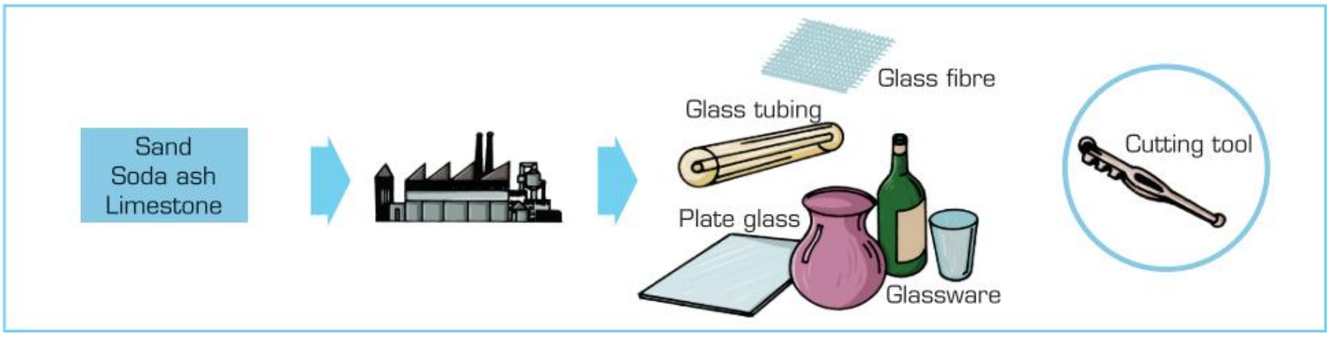
Standard glass is brittle, and special care should be taken when handling it.

To avoid injury when working with glass, wear gloves, long sleeves, a thick cotton shirt and an apron.

Rubber

Rubber is an elastic, water-resistant, non-conductive and shock-absorbing material. Natural rubber is usually heated with varying amounts of sulphur in the process known as vulcanisation to make it harder, more elastic and more heat resistant.

Rubber products can be moulded (for example, tyres), extruded (for example, tubing), calendered (for example, sheets) or dipped (for example, gloves). However, rubber deteriorates when exposed to heat, and toxic fumes are given off when it is burnt.



Manufacturing glass

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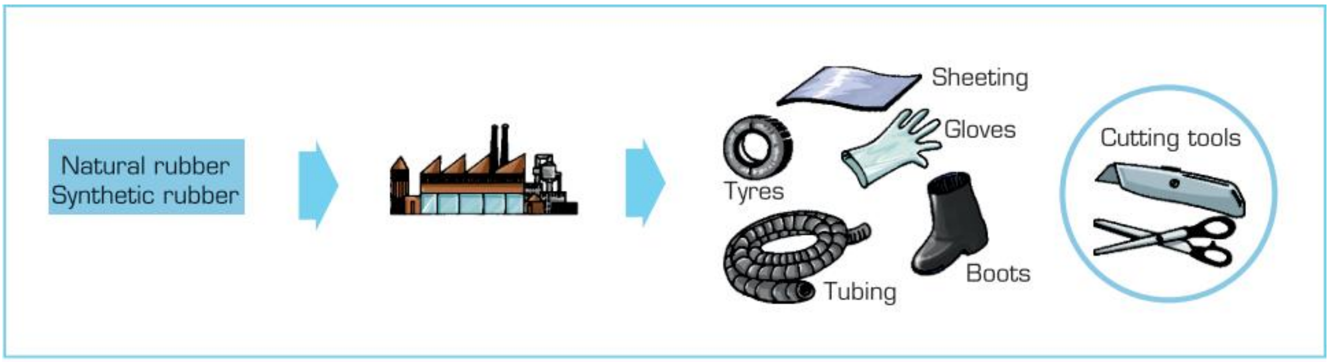
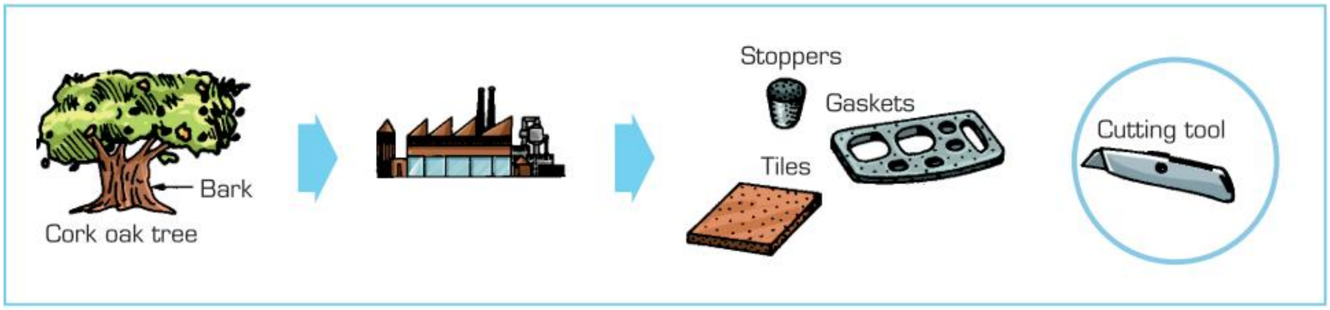


Manufacturing rubber



Manufacturing cork

Cork

Cork is the thick outer bark of the cork oak tree. It is a light, spongy substance that is used for sound and heat insulation (for example, tiles) and to make seals (for example, gaskets). Cork can be compressed a great deal, but it springs back to its original shape.

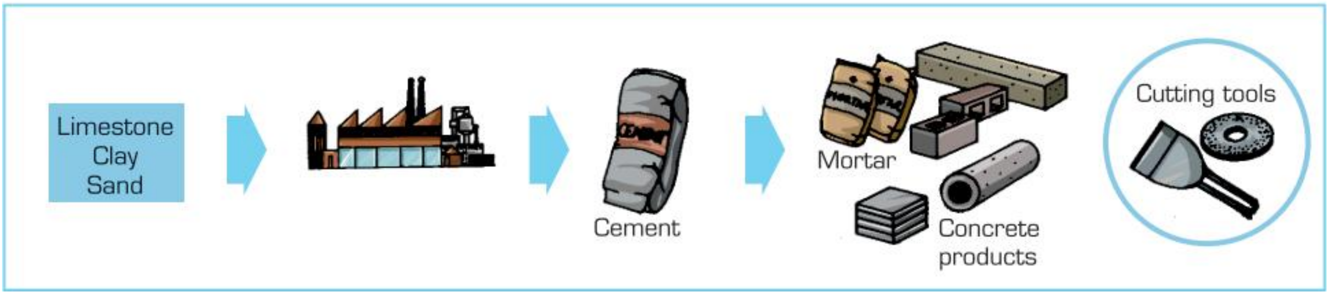
Cement

Cement is made by heating limestone, clay and sand in a kiln and grinding the product to a fine powder. When water is added to it, cement becomes a bonding agent. Its main uses are to make:

- mortar (cement, sand, slaked lime and water): used for bonding bricks
- concrete (cement, sand, stone aggregate and water): used for building components such as beams, blocks, slabs and pavers.

Cement products are durable and water-resistant, but they are quite brittle when not reinforced. (See also page 204.)

> Avoid cement dust if possible. Do not handle cement dust with bare hands.



Manufacturing cement

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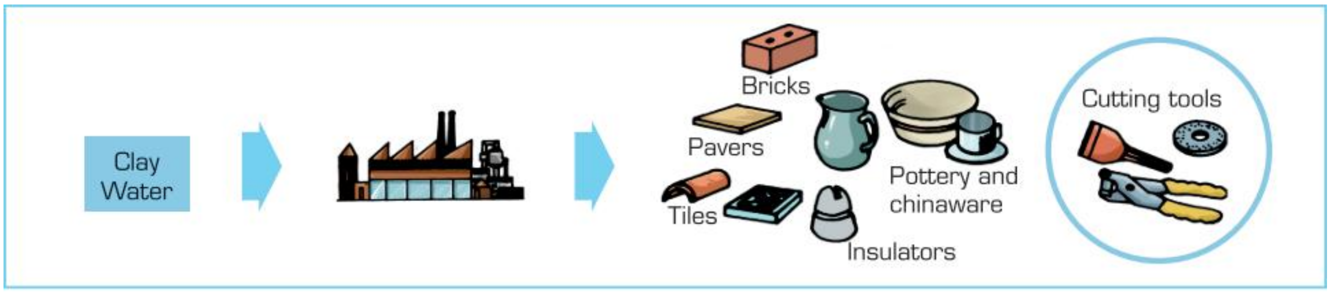


Manufacturing ceramics

Ceramics

A ceramic is a hard, brittle material formed by baking wet clay in a kiln. Ceramics are mostly thermosetting materials – once set, they cannot be re-formed. They are not only hard and brittle, but also very stiff. Their ability to conduct heat and electricity is very poor, making them an ideal material to be used as an insulator.

For centuries, people have used clay bricks and tiles to construct buildings and pottery vessels for practical and ornamental purposes. The clay is often coated with a glaze before it is fired in the kiln. This forms a glassy covering that can be used to decorate the surface as well as sealing it and making it smooth.

Today, technologists are developing new forms of this ancient but versatile material. For example, special ceramics have been used for cutting tools, for engine linings and for the heat shields of spacecraft such as American space shuttles.

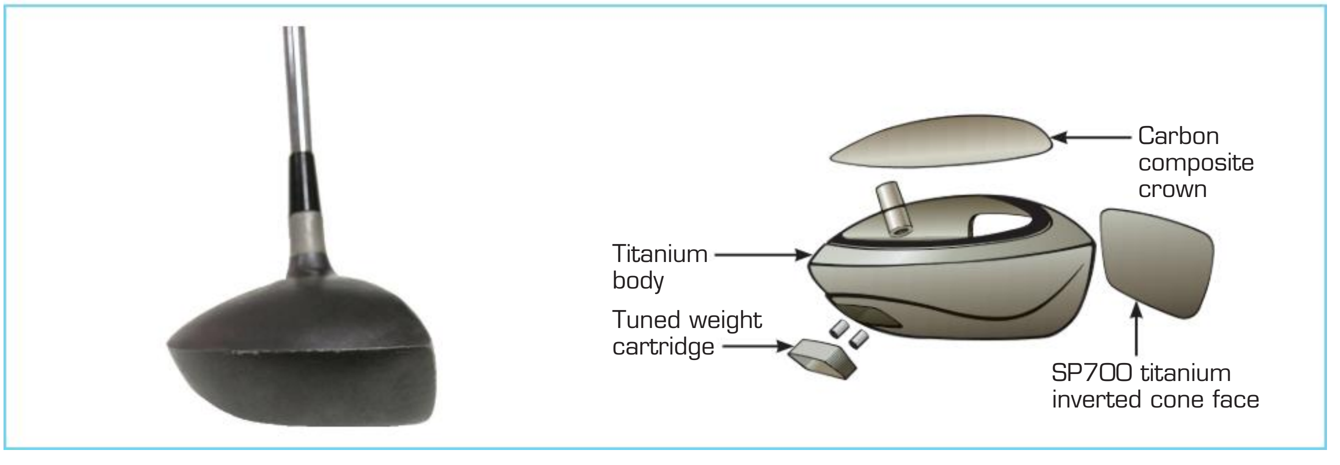
Composite materials

There are many other materials used by technologists. They may be used on their own, with traditional materials such as wood, metal and plastics, or combined with other materials to form new composite materials.

The purpose of combining two or more materials (such as glass fibre and epoxy resin) is for the composite material to acquire properties that are superior to those of its components. Composites can be grouped into three broad categories.

- **Layered composites** – for example, a laminated windscreen (a piece of plastic sandwiched between sheets of glass) and laminated fabric such as Gore-Tex® (fabric laminated with plastic film and a thin layer of foam)
- **Particle composites** – for example, concrete
- **Fibre composites** – for example, fibreglass and bonded fabrics.

Modern composite materials have many remarkable properties, such as greatly improved stiffness or tensile strength or resistance to corrosion. For example, **graphite epoxy**, used in tennis racquets, combines stiffness with low weight. Plastic reinforced with Kevlar fibres is a lightweight ‘space-age’ composite used for high-stress components in aircraft, spacecraft, ocean-racing yachts and Formula 1 racing cars.



The composite materials in this golf club combine stiffness and strength with low weight.

ISBN 9780170185677

The number of composite materials continues to grow with ongoing research. Currently, a range of materials known as **hybrid** materials is emerging. One example is the use of a textile combined with E-glass roving, which is used in the manufacture of fibreglass. This composite is used in **car silencers**.

Tennis racquets are made of composite materials for added strength.

Recycled materials

There is a greater awareness in the world of the amount of waste material being dumped every day. People know that energy was used to process the raw material into its final **state**. The processes used to make materials have an impact on the environment. Many materials used to make items can be reused once the product has no further use. Today, most designers and engineers think about how the materials can be recycled once the products are no longer of use.

Some materials, such as plastics and metals, may be reprocessed and used again.

Other materials, such as urban waste – for example, demolition softwoods or metals such as steel, aluminium and copper – are recycled by artists and craftspeople to make 'distressed' or 'retro' furniture, sculptures, wind chimes and so on. Years of wear and tear on the material can produce some unique results on its surface. For example, brass that has been rubbed by skin develops a **sheen**, and when copper is exposed to air it turns green. These effects are referred to as the patina. The patina often enhances the visual appeal of the material and is hard to duplicate.

The patina of copper

Textiles are also reused and recycled. Some fibres, such as wool, are suitable for re-spinning while others can be reused as filling material – for example, for upholstery, insulation or bonded fabrics such as nappies and wiping cloths. Alternatively, out-of-fashion fabrics can be recycled into new items such as bags, jackets or dresses.

Recycled out-of-fashion fabrics

ISBN 9780170185677

Manufacturers are becoming more aware of the environmental, economic and cost benefits of using recycled materials. The public is quite aware of the need to recycle materials due to the debate about the environment. Manufacturers know that recycling can also be good for business. Some manufacturers are looking at recycled materials in a new way and addressing the concerns of waste management and the environment.

One example is car manufacturer Volkswagen. The new VW Golf has been built with 40 per cent of its mass made from recycled materials. Much of the car is recyclable.

Use the Internet to research more information about recycled materials.

INFORMATION FILE

Recycled materials produce a composite

An American company is using recycled materials to manufacture a composite material. The composite material is made from wood waste and recycled high-density polyethylene (HDPE). (See page 78.)

An example is when hardwood (maple) flooring offcuts are ground into a fine, soft powder – a flour. The flour is processed into pellets. Recycled HDPE in the form of pellets is combined with the hardwood pellets and mixed with a colour. The mixture is fed into a hopper of an extrusion press (see 'Extrusion' on page 81) and extruded. The extruded material, known as a wood composite, is allowed to cool. The extruded material is shaped like a board (see page 50).

The properties of the wood composite material are durability, toughness, stiffness, low absorption and low maintenance. The wood composite material can also be easily worked with **conventional** woodworking tools.

The properties of the wood composite make it a good choice for use in many outdoor applications such as decking, patios, walkways and as wall cladding.

ISBN 9780170185677

Tools

In this unit, you will learn:

- what tools are
- about the various families of tools
- about the functions of different tools
- how to select the correct tool for a particular purpose.

What are tools?

Tools are devices that enable people to perform tasks more easily. A knife is such a tool. Without it, people would have to tear food with their teeth and hands.

Early people used tools made from stone, wood or bone. As their knowledge of materials increased, they made many tools from newly discovered materials such as metals.

The earliest tools all worked by muscle power alone. Later, as new sources of energy were discovered, hand tools were modified. For example, hand saws were adapted to be driven by electric motors or petrol engines.

Tools are designed to multiply the force applied, or to change the speed produced by a person. This is achieved using basic machines.

There are six basic machines: the lever, the pulley, the wheel, the screw, the wedge and the inclined plane. All tools are related to these basic machines.

Today's tools belong to four main groups.

1 **Hand tools:** any tools that require only muscle power. Examples include hammers, planes and scissors. Note that some of the old hand tools such as spokeshaves, braces and bits (see pages 102 and 105) are generally used by craftspeople and hobbyists today and not the general public.
2 **Portable power tools:** any easily transportable tools that require an additional power supply such as electricity or compressed air. Examples include electric sanders and pneumatic drills.
3 **Universal equipment:** lightweight equipment for general use in home workshops, school workshops and small businesses. Examples include electric **arc welders**, lathes (metal or woodturning) and sewing machines.
4 **Industrial equipment:** powerful, heavy-duty equipment for special uses in the heavy manufacturing and construction industries. Examples include hydraulic presses and cranes.

From prehistoric implements to modern power tools

ISBN 9780170185677

Hand tools

All tools can be classified according to the particular function they perform. There are five families of hand tools.

1 **Marking-out/measuring tools**, such as pencils and steel rules
2 **Cutting tools**, such as saws and files
3 **Clamping and holding devices**, such as clamps and vice grips
4 **Percussion tools**, such as hammers and mallets
5 **Torsion** (twisting) **tools**, such as spanners and screwdrivers.

(Families 3 to 5 are sometimes called assembling tools, because they are often used for assembly work.)

Marking-out/measuring tools

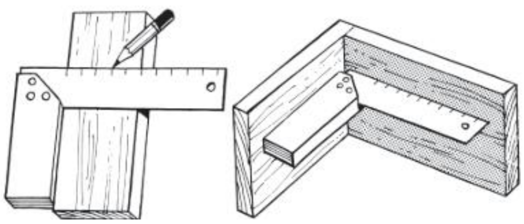
Marking-out tools are used to mark lines or points on a surface as a guide for the work that is to be done. The marks made by the tools can be:

- temporary – for example, the marks made by a pencil or tailor's chalk can be removed easily from the surface
- semi-permanent – for example, the marks made by a spirit pen on non-porous surfaces can be removed with the aid of a solvent
- permanent – for example, a scriber or centre punch cuts into the surface of the material. Any attempt to remove the mark usually causes further damage to the surface.

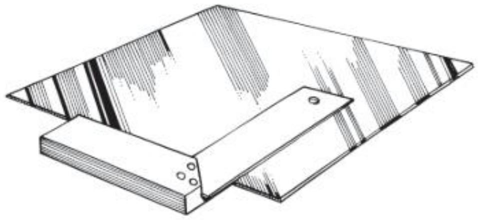
Special tools have been developed to mark out points, lines and curves.

Common marking-out tools

Try-squares or engineer's squares are used for checking or marking squareness.

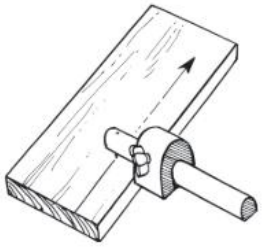


A try-square

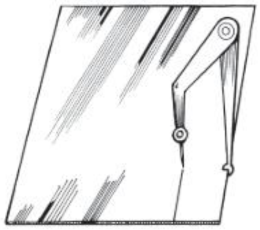


An engineer's square

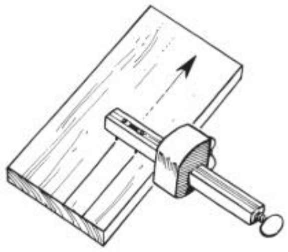
Marking gauges, mortice gauges, odd-leg calipers and scratch gauges are used to scribe lines parallel to an edge.



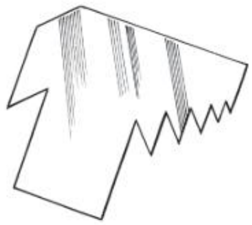
A marking gauge



Odd-leg calipers

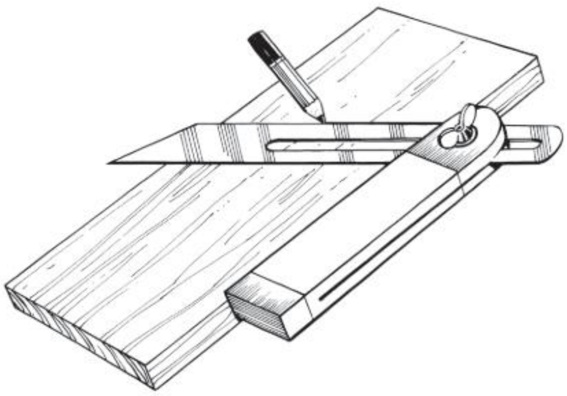


A mortice gauge



A scratch gauge

Sliding bevels are used to draw lines at any angle to an edge. (Engineer's bevels are usually used with metal.)



A sliding bevel

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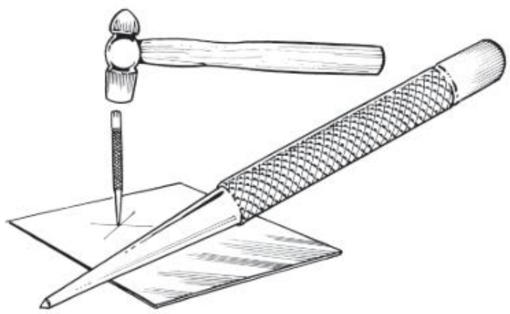
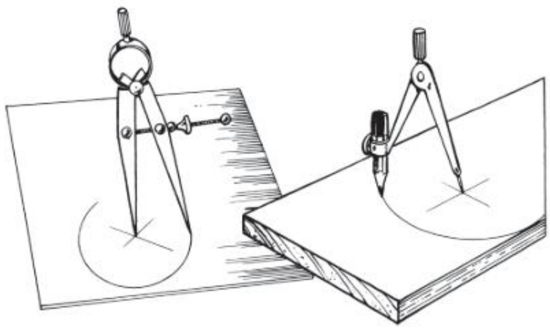
Centre punches are hit with a hammer to make a centre mark (used to start a drill) in metal.



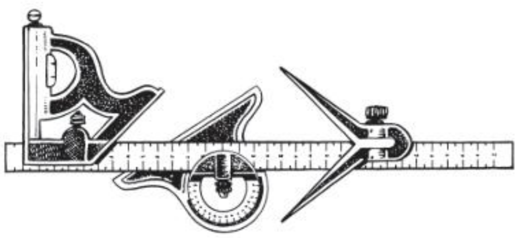
A centre punch

Spring dividers or drawing compasses are used to draw arcs or complete circles.



Spring dividers Drawing compasses

Combination squares are a combination of a try-square or engineer's square and a sliding bevel. This tool can be used for a number of marking-out operations.



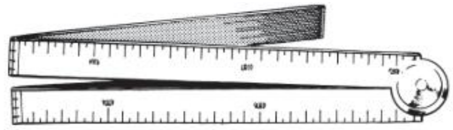
A combination square

Measuring tools are used to find the dimensions of materials. Special tools have been developed for particular purposes.

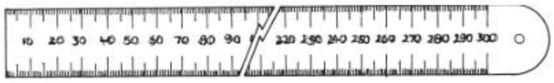
Common measuring tools

Rules are used for general measuring. They can also be used for marking out or for testing flatness. The basic unit of measurement is the millimetre (mm). 1000 millimetres = 1 metre (m).

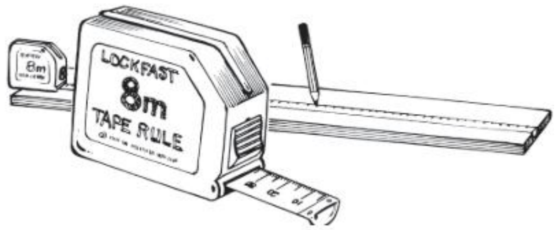
Flexible tape measures for textiles are available in 1-metre or 1.5-metre lengths.



A folding rule, usually 1 m long (folded for storage)

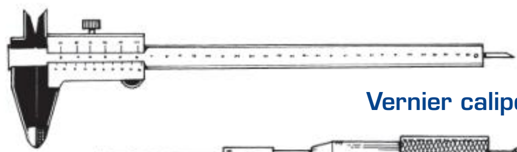


A steel rule, 150–1200 mm long (300 mm is common)

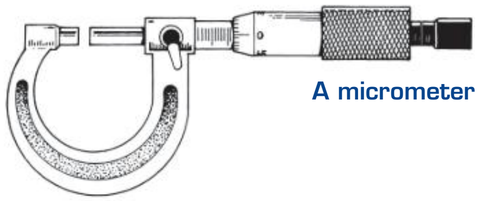


A tape rule, for long measurements (e.g. 5 m or 8 m)

Vernier calipers or micrometers are used for measuring when a high degree of accuracy is required.

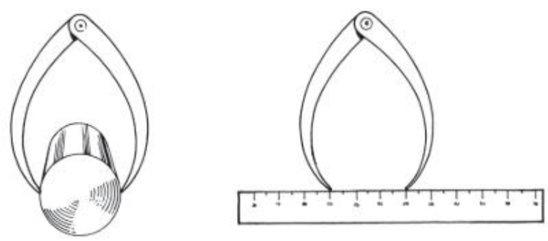


Vernier calipers



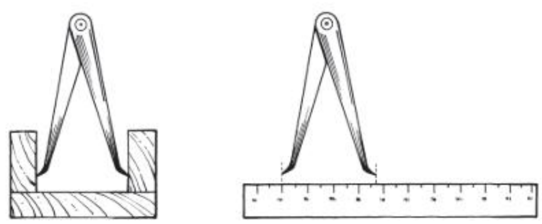
A micrometer

Outside calipers are used mainly for measuring the external diameter of an object.



Outside calipers

Inside calipers are used mainly for measuring the internal diameter of an object.



Inside calipers

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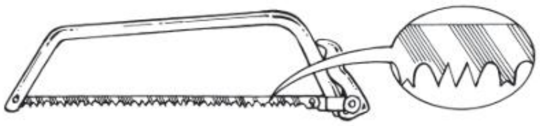
Cutting tools

Cutting tools are used to shape and/or modify materials. (There are many different standard sizes and forms of materials.) Examples include saws, files, chisels and gouges, planes and shearing tools.

Saws

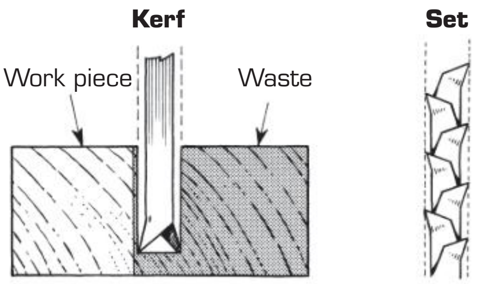
Saws are cutting tools based on a steel blade that has triangular teeth along one edge. In most saws the teeth point forward and the saw cuts on the forward stroke. The number of teeth (counted in 25-millimetre lengths) varies according to the use for which the saw is designed. For example: large, coarse teeth are required to cut through tree trunks or branches, while small, closely spaced teeth are required to produce a fine, accurate cut for cabinet work.



Large saw teeth

Small saw teeth

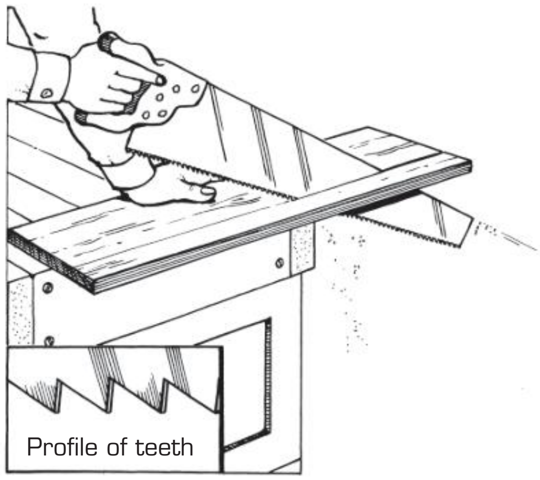
The slot cut by the saw teeth is called the kerf. The set of a saw is the distance across its teeth. This is slightly wider than the thickness of the blade, to prevent the blade from becoming jammed in the kerf.



Saws can be used to make straight or curved cuts.

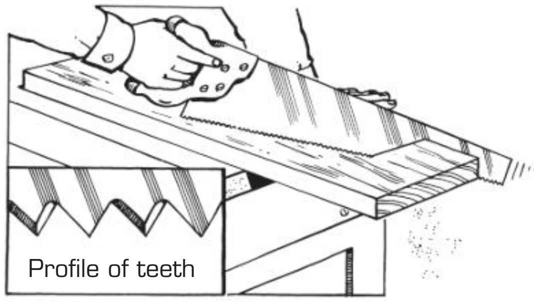
Sawing straight

Rip saws are used for cutting along the grain of large pieces of timber.



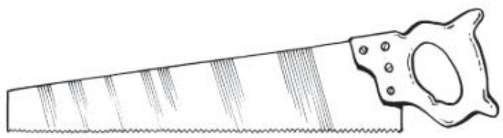
A rip saw

Cross-cut saws are used to cut across the grain of large pieces of timber. The teeth are sharpened in a different way from those of a rip-saw.

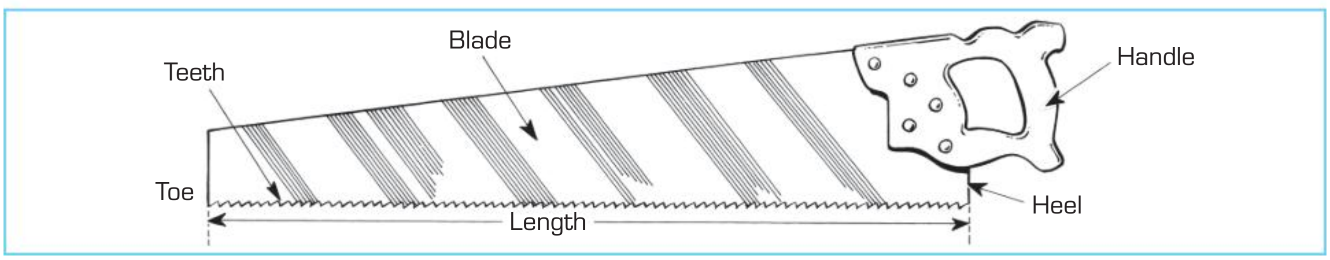


A cross-cut saw

Panel saws are like cross-cut saws, but smaller. They are used to cut thinner timber stock, such as plywood.



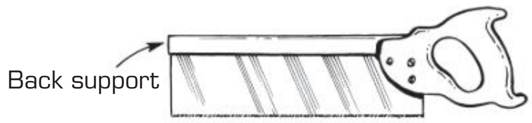
A panel saw



The parts of a saw

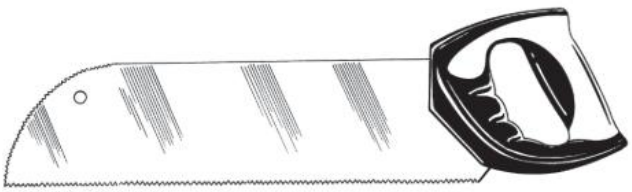
ISBN 9780170185677

Tenon saws, or back saws, are used to make fine, accurate cuts such as joints in wood. They can also be used to cut plastic.



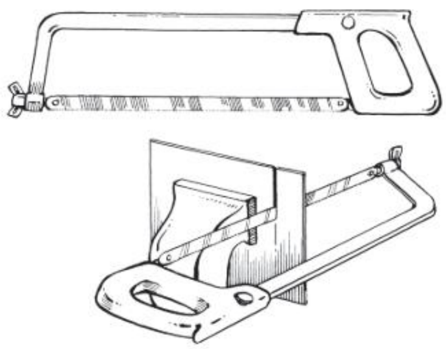
A tenon saw (back saw)

Veneer saws are used to make fine, accurate cuts in delicate or thin materials such as plastic and plywood. The round nose also has teeth that can be used to start a cut in the middle of a sheet.



A veneer saw

Hacksaws are used mainly for cutting metals. The replaceable blade can be turned 90 degrees to allow for long cuts. A coarse blade is used with soft materials, while a fine blade is used with hard materials and thin-sectioned materials, as shown in the table below.



Hacksaws

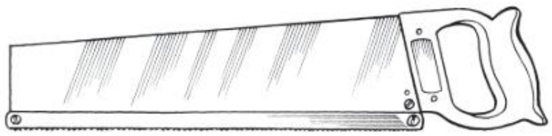
Table 5.1 Hacksaw blade selection

Teeth per 25 mm	Used for these materials
14	Large, solid sections of metals or softer materials
18	All general purposes
24	Thick tube and sheet (3 mm–6 mm); small, solid sections of hard materials
32	Thin tube and sheet

Junior hacksaws are used to cut thin sheet material and light sections such as thin-walled tubing.

A junior hacksaw

Sheet saws, like hacksaws, have replaceable blades. They are used to cut sheet materials such as metal and plastic, and corrugated materials.



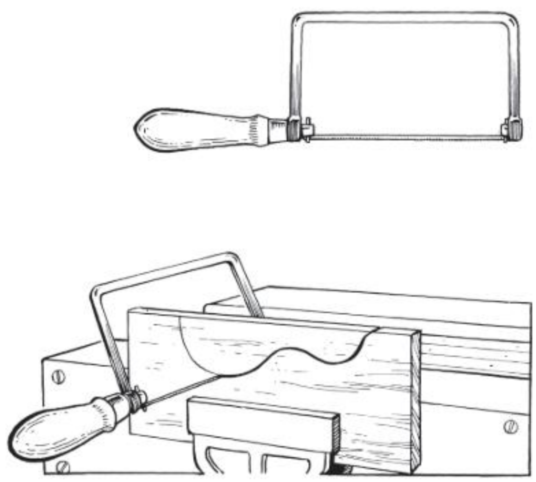
A sheet saw

General-purpose saws may be used to cut timber, plastic and soft metals. The handle can be adjusted for hard-to-reach places.

A general-purpose saw

Sawing curves

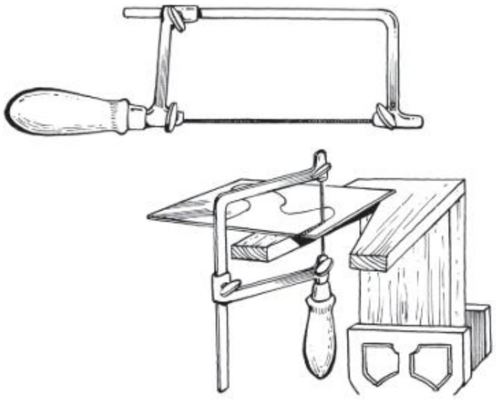
Coping saws are used to cut curves in wood and plastic. Their replaceable blades can be rotated to any angle. They can be used to cut slots and holes.



Coping saws

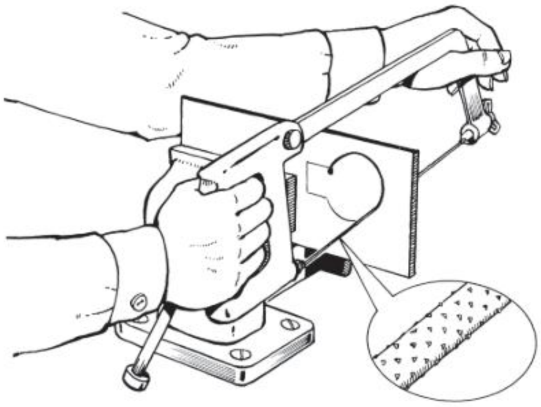
ISBN 9780170185677

Piercing saws are used to cut curves in very thin metal and plastic. They cut on the downward stroke.



Piercing saws

Abrafiles are fitted into hacksaw frames. Their cylindrical blades have teeth running around them, enabling them to cut in any direction.



An abrafile

Files

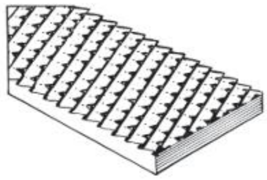
Files are cutting tools with small, saw-like teeth that remove particles of material (filings). The teeth point forward and the file cuts on the *forward stroke*. Files are manufactured in many different shapes, sizes and grades.

Files are used to cut shapes and profiles, or to achieve a particular surface finish. The choice of file depends on the shape involved, the nature of the material, or the surface finish required.

Files may be single cut or double cut.

- Single-cut files have only one row of teeth. Light pressure is used with these files to produce a fine finish. They are often used on soft materials that tend to choke or 'pin' double-cut files.
- Double-cut files have two rows of teeth. They are used mainly for fast removal of material such as metal or plastic. They require heavier pressure than single-cut files.

A single-cut file



A double-cut file

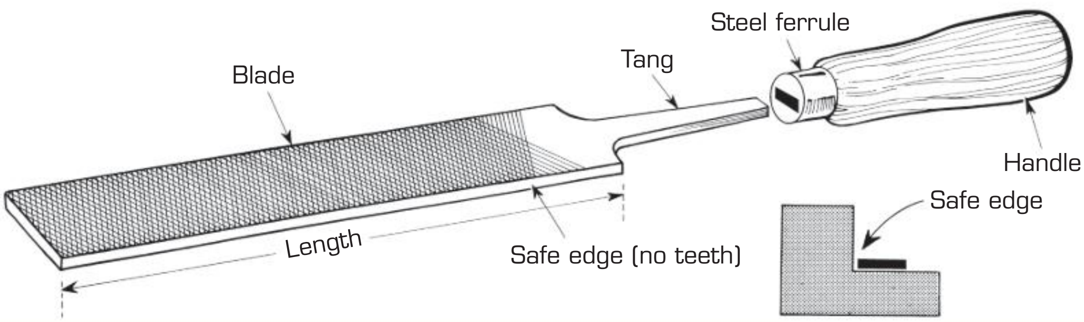
Files are manufactured in a large range of shapes and sizes.

Common shapes of files

Hand files are used for filing flat and convex surfaces, and particularly for filing into corners (they have one edge without teeth, called the safe edge, especially for this purpose).

The **tang** is driven into the handle. The taper of the tang prevents slip.

Never use a file without a handle as the tang could injure you.



The parts of a hand file, including the handle

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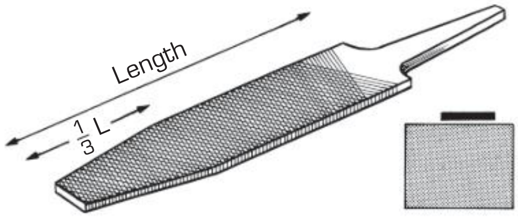
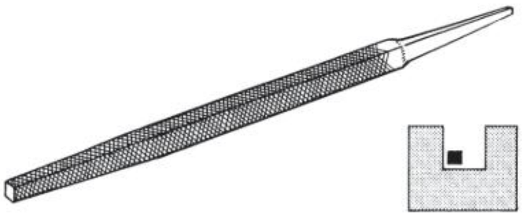
Flat files are used for filing convex and flat surfaces. The ends of their blades are tapered for one-third of their length so that they can be used to enlarge small openings.



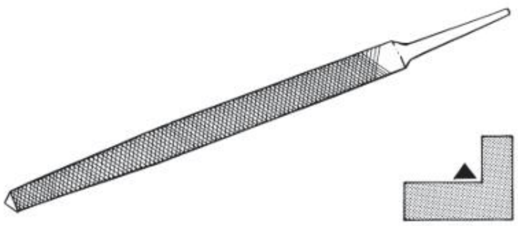
A flat file

Square files are used for filing square or rectangular holes.



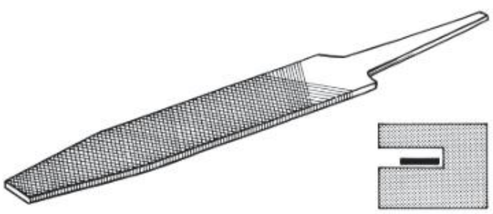
A square file

Triangular files are used for filing internal corners (and saw teeth).



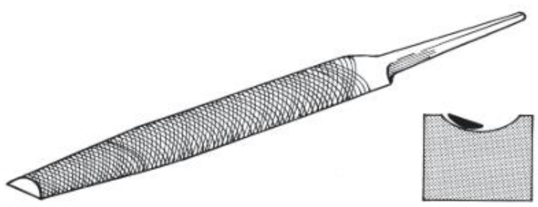
A triangular file

Warding files are used for filing narrow slots.



A warding file

Half-round files are used for filing concave surfaces.

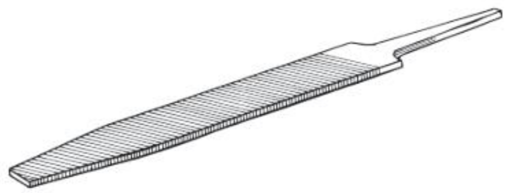


A half-round file

Round files are used for filing circular holes.

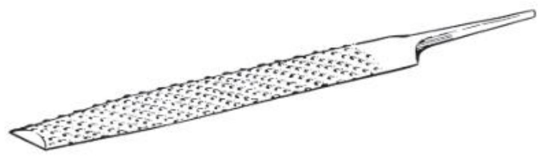
A round file

Mill saw (single-cut) files are used for soft materials such as acrylic.



A mill saw file

Rasps are used for rough shaping of wood and other soft materials.

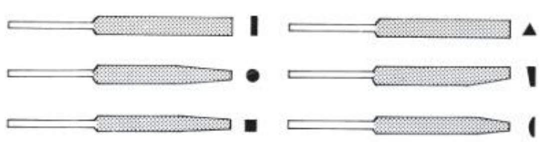


A rasp

Dreadnought files are used for soft materials such as copper and aluminium. The curved teeth remove the waste quickly.

A dreadnought file

Needle files are used for very fine work, for example in **die-making** and watch-making.



Needle files

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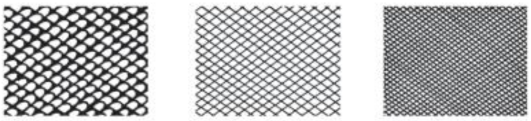
Selecting a file

This label has been taken from the end of a carton of files.

When selecting a file, you need to consider three features:

- size – the length of the file. For example, on this label the length is given as 250 millimetres (10 inches). (Why are two units of measurement given?)
- type – the cross-section of the file. This label shows that the files are hand files
- grade – indicates the coarseness of the teeth and the amount of material that can be removed. There are three basic grades:



Bastard (gives a rough finish) | **Second cut** (gives a medium finish) | **Smooth** (gives a fine finish)

Surform tools

Surform tools are cutting tools consisting of a replaceable blade that is held in a frame. The blade has many small teeth and holes to help clear the filings. Surforms are used to cut wood, plastic and other soft materials to the required size and shape.

Surforms are made in a variety of sizes and shapes – for example, the blade can be flat or round. They are also available with file-type or plane-type handles.

Surform tools

Chisels and gouges

Chisels and gouges are cutting tools used to remove waste material from the parent material – for example, they are used to cut grooves and slots or to carve curved shapes.

Chisels for wood

There are four kinds of wood chisel, each designed for a different purpose. The size of the chisel is measured across the width of the blade. Wood chisels are available in a range of sizes from 3 millimetres to 50 millimetres wide.

Firmer chisels are used as a general-purpose woodcutting tool. Whenever possible, a firmer chisel should be used in preference to a bevel-edged chisel, which has a blade that is less strong.

A firmer chisel

Bevel-edged chisels are used for light general woodworking, especially for cutting into corners less than 90 degrees.

A bevel-edged chisel

Mortice chisels are used for heavy-duty work such as levering out waste in a mortice joint.

A mortice chisel

Carving chisels are used to finish shapes carved by a gouge.

Carving chisels

Gouges

Gouges differ from wood chisels in their cross-section. The cross-section of the gouge blade is curved. Gouges are mainly used to carve curved shapes in timber. Like chisels, they come in a range of sizes. There are two types of gouge:

- out-cannel gouges – used to hollow out concave shapes. They are ground on the outside of the blade, and are also called firmer gouges.

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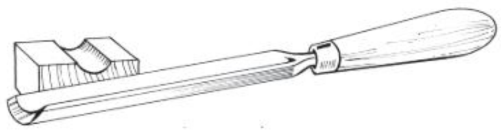
An out-cannel gouge

- in-cannel gouges: used for channelling and other curved paring work. They are ground on the inside of the blade, and are also called scribing or paring gouges.



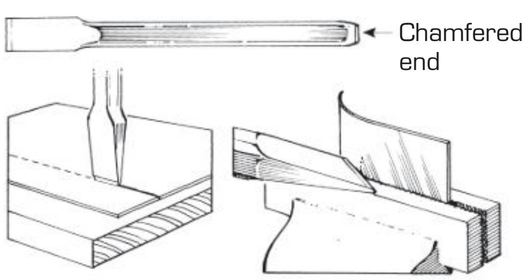
An in-cannel gouge

Chisels for metal

Cold chisels are used to cut metal without heating it. The cutting edge is hardened, tempered steel. The other end is relatively soft and **chamfered** to absorb the hammer blows. The size of the cold chisel is measured across the width of the blade.

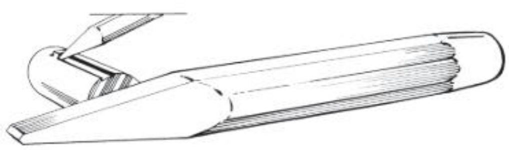
There are four kinds of cold chisel:

- flat – used for general cutting purposes, such as shearing metal in a vice, removing waste or trimming to size



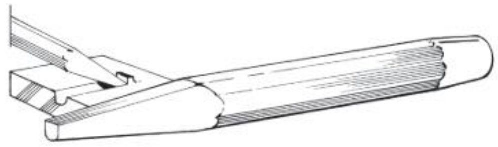
Cutting and shearing thin sheet metal with a flat cold chisel

- cross-cut – used for cutting grooves or slots



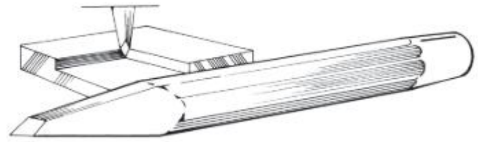
A cross-cut chisel

- round-nose – used for cutting round-bottomed grooves



A round-nose chisel

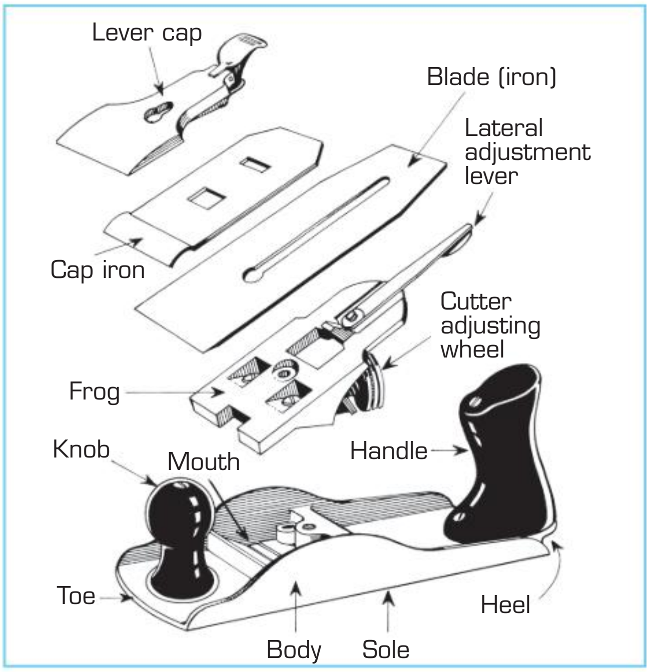
- diamond-point – used for cleaning out corners.



A diamond-point chisel

Planes

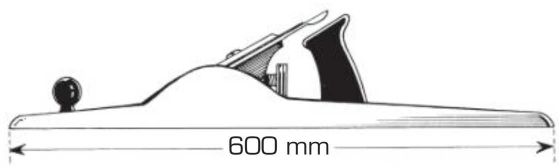
Planes are cutting tools based on a sharp blade held in a frame. They are used to reduce the material to the required size, shape and smoothness. The material is reduced gradually as the plane removes thin shavings. Planes are mainly used on wood, but sometimes also on plastic such as acrylic.



The parts of a plane

Common planes

Try planes (also called jointer planes) are used to square up long edges or large surfaces.



A try plane

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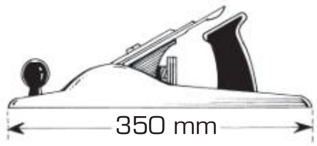
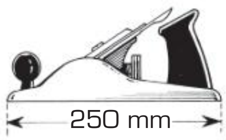
Jack planes are general-purpose planes.



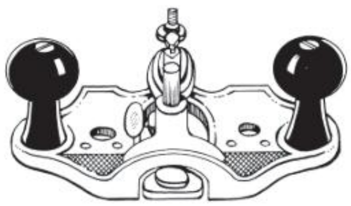
A jack plane

Smoothing planes are used for cleaning up and finishing.



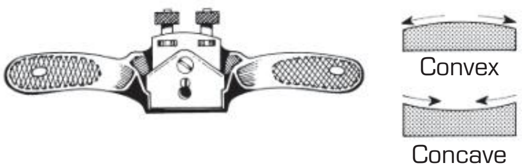
A smoothing plane

Router planes are used for cleaning up the bases of grooves.



A router plane

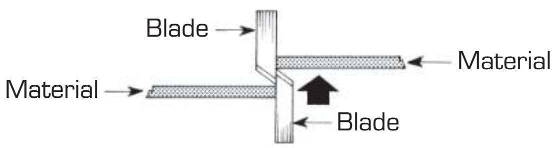
Spokeshaves are used to smooth curves. Flat-faced spokeshaves are used for convex curves and round-faced spokeshaves are used for concave curves.



A spokeshave

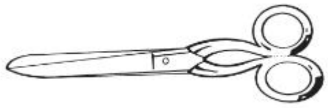
Shearing tools

Shearing is a process in which material is separated by two cutting edges that pass each other.



Common shearing tools

Trimming scissors are used to cut and trim materials such as fabrics, rubber and vinyl in awkward places.

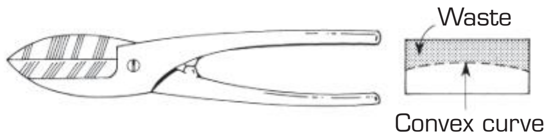


Traditional trimming scissors

Cutting shears are used for making long, straight cuts.

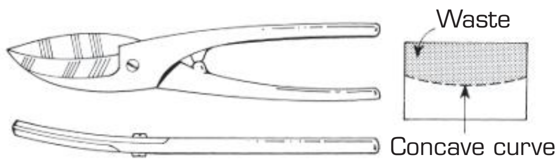
Cutting shears

Tinsnips are used to cut thin sheets of sheet metal or soft plastic. Straight tinsnips are used for cutting straight lines or convex curves (that is, the waste material is on the outside of the curve).



Straight tinsnips

Curved tinsnips are used for cutting concave curves (that is, the waste material is on the inside of the curve).



Curved tinsnips

Heavy-duty shears or aviation snips are used for thicker material. Aviation snips have small teeth next to the cutting blades to grip the material and prevent slipping.

Heavy-duty shears

Aviation snips

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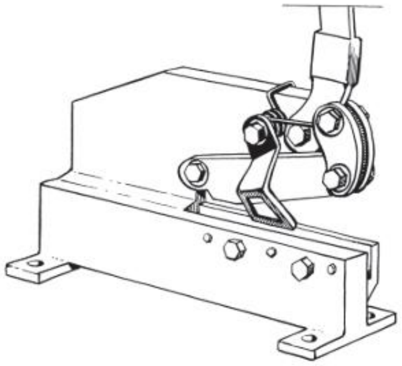
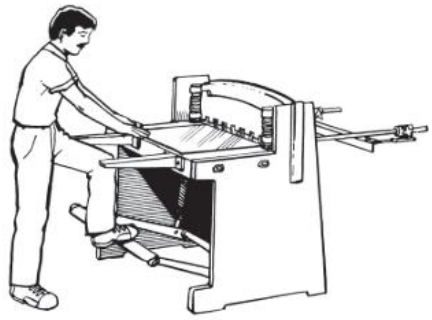
Bench shears are mainly used for cutting rods or flat bars.



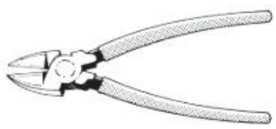
Bench shears

Guillotines are used for cutting sheet material such as metal, paper and cardboard. They can be hand or foot operated.



A guillotine

Diagonal-cutting pliers are used to cut wire, including staples and small-diameter rods.



Diagonal-cutting pliers

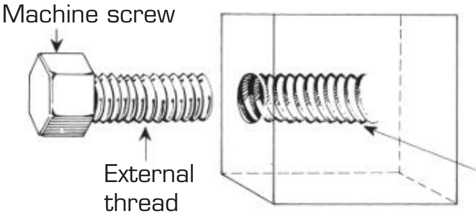
End-cutting pliers can also be used to cut wire and small-diameter rods.

End-cutting pliers

Taps and dies

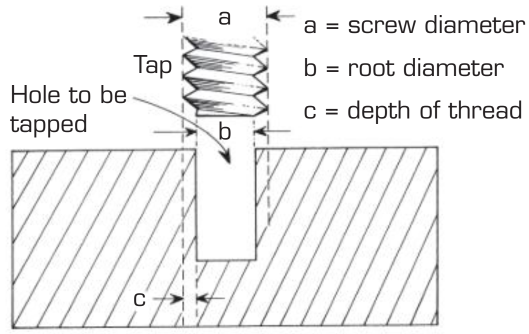
Taps and dies are tools that are used to cut standard threads for nuts, bolts and machine screws. Their cutting edges leave a continuous groove in the parent material. This can take the form of:

- an internal thread or
- an external thread.



Taps

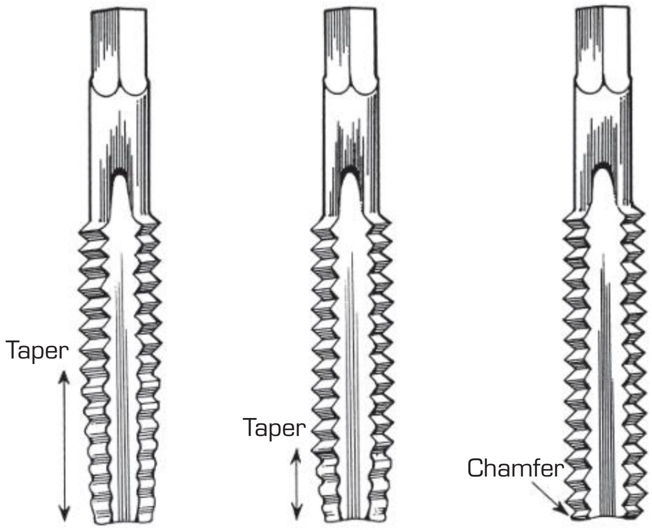
Taps cut internal threads in holes. The hole to be tapped should be only slightly larger than the root diameter of the tap.



The process of cutting an internal thread is called tapping. Three kinds of tap can be used.

- A taper (starting) tap: this tap is tapered over the first eight or nine threads to provide a lead in. It is used to start threads and to thread holes through thin material.
- An intermediate (second) tap: this tap is tapered over three or four threads to provide a fuller thread pattern than the taper tap. It is used to finish threads through thicker material.
- A plug (bottoming) tap: this tap has no taper except for a small chamfer on the first thread; it is used to cut a full thread in a blind hole. (Note that it should not be used to start a thread.)

For further details on tapping drill sizes, see page 131.

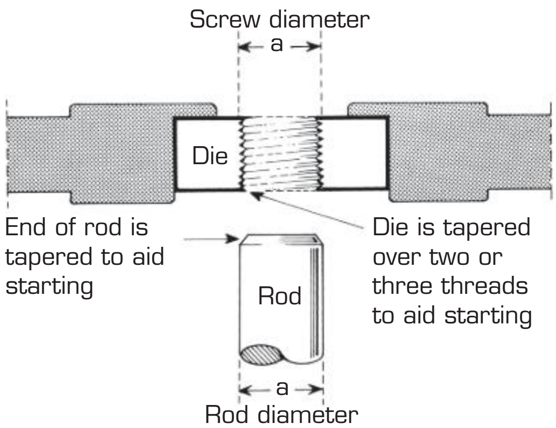


A taper tap   An intermediate tap   A plug tap

ISBN 9780170185677

Dies

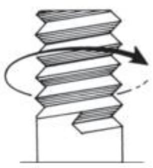
Dies are tools that cut external threads on rods. The diameter of the rod to be threaded is equal to the screw diameter of the die. The process of cutting an external thread is called threading.



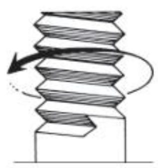
Threading a rod

Threads can be either:

- right-hand threads, for *clockwise* rotation, or
- left-hand threads, for *anticlockwise* rotation.

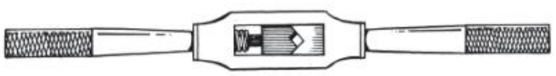


A right-hand thread

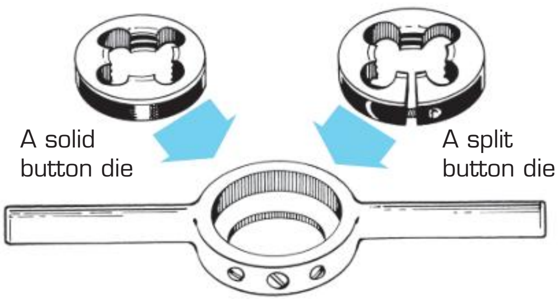


A left-hand thread

A holding device must be used when cutting a thread with taps and dies. A tap wrench is used with taps, and a die stock with dies.



A tap wrench

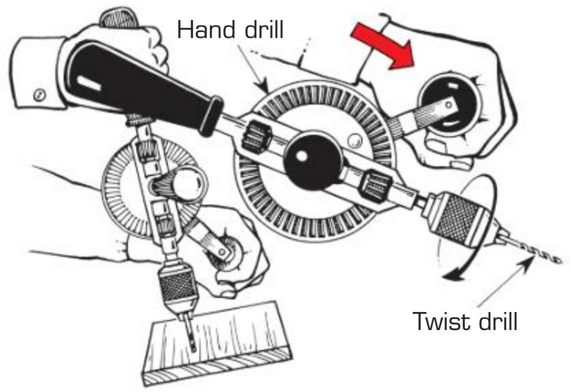


A die stock

Boring tools

Boring tools are used to cut holes in material by removing shavings (known as swarf) from the parent material. Most boring tools have two components:

- a cutting tool such as a twist drill or spade bit
- a cutting-tool holder such as a hand drill or bench drill.



Examples of boring tools

The choice of drill bit depends on the type of material in which holes are to be bored. For example, tungsten carbide-tip drills work best for drilling masonry because they are tough and will not wear out as quickly as steel twist drills.

Thought must also be given to the speed at which a drill should be operated.

RULE:

- The larger the diameter of the drill bit, the slower the drill speed.
- The harder the material, the slower the drill speed.

Table 5.2 Approximate drill speed in rpm* for high-speed steel drill bits

Materials to be drilled	Drill diameter (mm)					
	1.5	**3**	**6**	**8**	**10**	**12**
Mild steel	5200	2600	1300	975	775	650
High-carbon steel	2600	1300	650	485	385	325
Aluminium alloys	6500	3250	1625	1200	975	800
Brass	6500	3250	1625	1200	975	800
Grey cast iron	5200	2600	1300	975	775	650
Acrylic	7000	3720	1800	1400	1110	900

* rpm = revolutions per minute

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Common drills

Twist drills are used for cutting a circular hole in most materials. Sets of twist drills are produced specifically for drilling holes in wood, metal or plastics.

A taper-shank twist drill

A straight-shank twist drill

Straight-shank drills are used with hand and power tools. Morse taper-shank drills are used with special drilling machines.

A straight-shank drill

A morse taper-shank drill

Bits are used to drill holes in timber. There are many different kinds of bits for drilling hardwood or softwood, and for drilling small holes, large holes or shallow holes.

A jennings-type auger bit

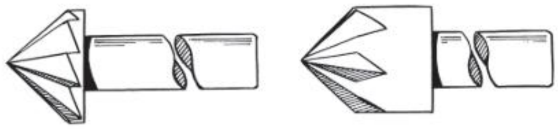
Bits are used with a brace.

A brace

Spade bits come in a range of sizes. They are used to drill holes in timber at high speed, using a portable electric drill or a bench drill.

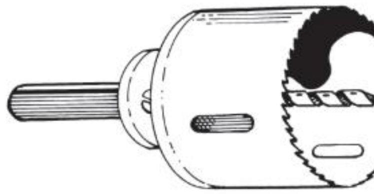
A spade bit

Rose countersinks are used to bore tapered holes for screw heads to be countersunk in most materials. (See page 143.)



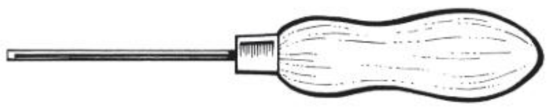
Rose countersinks

Hole saws are used for cutting large holes, mainly in sheet material. There are many different kinds of hole saws. They are all used with a power tool.



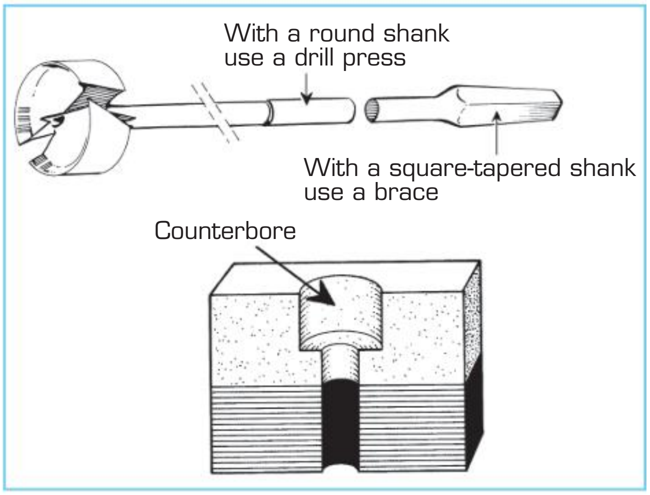
A hole saw

Bradawls are used to make small starting holes in wood for nails and screws. The blade is placed across the grain to avoid splitting, and pushed down and twisted from side to side.



A bradawl

Forstner bits are used to drill a clean, flat-bottomed hole in wood – for example, a counterbore. The counterbore enables the head of the bolt or screw to be below the surface of the material, as shown here.



A Forstner bit

Centre drills or combination drills are used to make a starting hole or a centre hole in a piece of material that is to be turned on a lathe (see overleaf).

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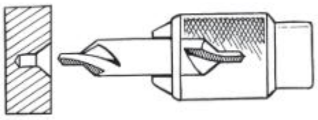
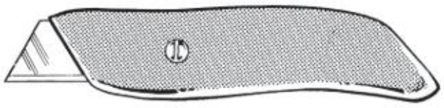


A centre (combination) drill

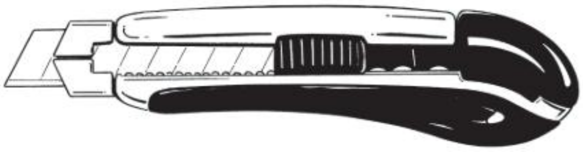
Other commonly used cutting tools

Trimming knives can be used to cut to size many materials such as paper, cardboard, veneers and vinyl. A range of blades is available for different purposes – for example, a straight blade can be used to trim paper or cardboard, while a hooked blade can be used to cut soft materials such as leather and corrugated cardboard.



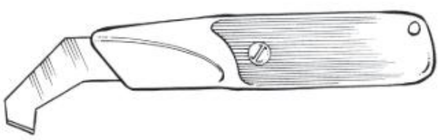
A trimming knife

Snap blade knives are a popular alternative to trimming knives. The **retractable** blade can be snapped at set points along the blade once it has lost its edge.



A snap blade knife

Scoring knives (sometimes called 'score-and-snap' knives) are used to score a line in material so that it can then be snapped along the line. It is used on materials such as plastic laminates and fibre-cement building products.

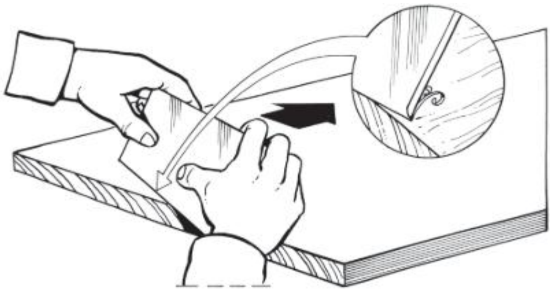


A scoring knife

Scrapers are used to produce a very smooth surface. They are made from hardened and tempered tool steel. There are two kinds of scraper:

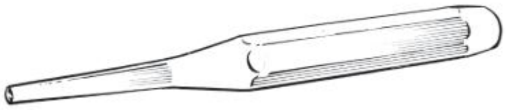
- rectangular – for flat surfaces
- curved – for shaped surfaces.

These are used mainly on timber and plastic, but a scraper for metal is also available.



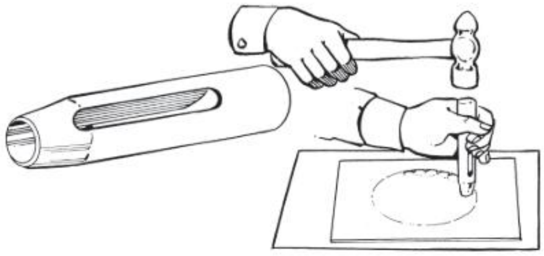
A rectangular scraper

Solid punches are used to punch small-diameter holes in metal.



A solid punch

Hollow punches are used to cut holes in materials such as sheet metal, cardboard and leather.



A hollow punch

Clamping and holding devices

Clamping and holding devices are a means of providing a temporary holding or fixing force. They are used to:

- hold the work during processes such as cutting or shaping
- hold two or more components together while glue sets or while they are screwed together.

Common clamping and holding devices

Engineer's vices are used to hold metal and plastic. Jaw covers (sometimes called soft jaws) should be used on an engineer's vice to protect soft materials from being marked by the grooves on the vice jaws.

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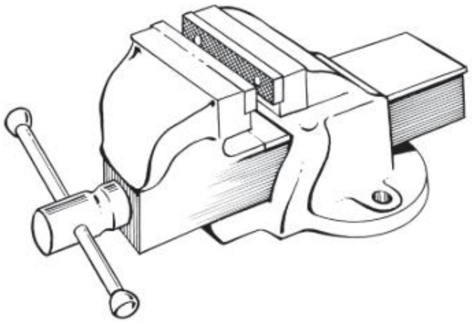
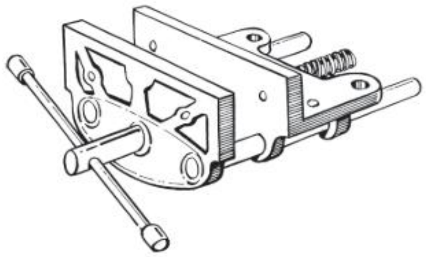


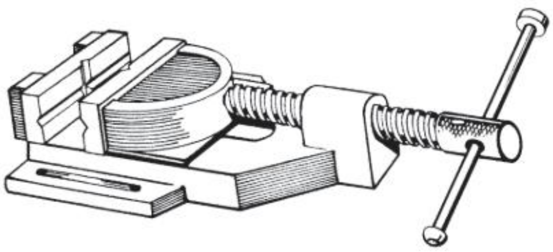
An engineer's vice

Woodworker's vices are mainly used for holding wood. Timber jaws are fitted to the inside of the metal jaws to protect the wood.



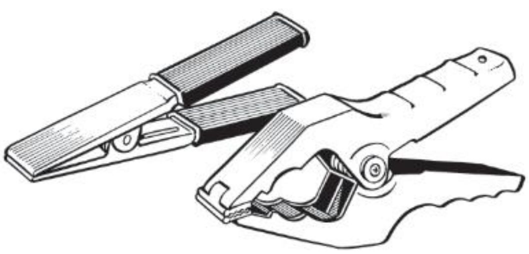
A woodworker's vice

Machine vices are used to hold work flat and square. For heavy-duty work, the vice must be bolted to the table.



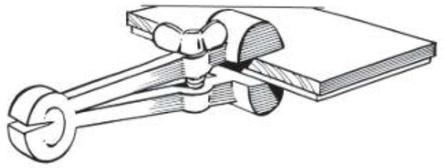
A machine vice

Spring clamps are a quick way to hold a variety of materials in many different situations – for example, holding sheet metal while welding, or when gluing wood. They are available in a range of sizes and springiness.



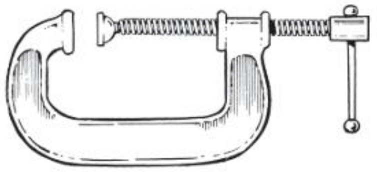
Spring clamps

Hand vices are used to hold small or awkward pieces of material, especially when drilling sheet material or riveting.



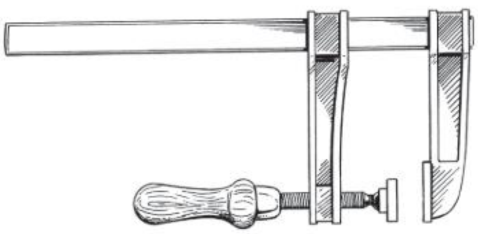
A hand vice

G-clamps are used when gluing wood together or to hold work down onto a bench. G-clamps are available in a range of sizes.



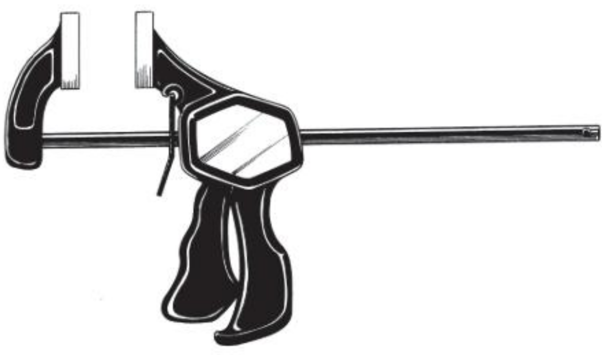
A G-clamp

Quick-action clamps, like G-clamps, are used to hold material in place. A movable jaw can be adjusted quickly to secure the work. They are commonly known as F-clamps.



A quick-action clamp

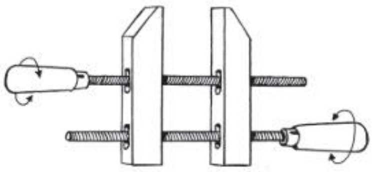
Quick-grip clamps/spreaders, or one-handed bar clamps/spreaders, can be used to hold material. The jaws can be reversed to act as a spreader. The clamping action can be done with one hand.



A quick-grip clamp/spreader

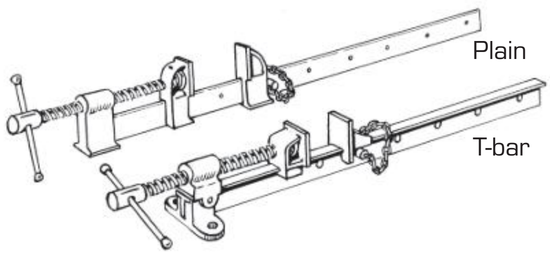
ISBN 9780170185677

Toolmaker's clamps, or hand-screw clamps, are perhaps the oldest form of clamp. They are used to hold material together when drilling, shaping and gluing. The jaws can be adjusted to be parallel, tapered or offset.



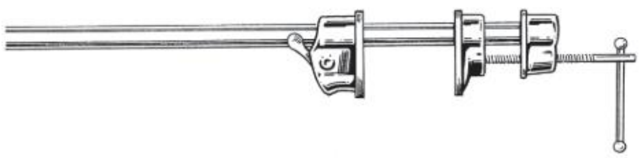
A toolmaker's clamp

Sash cramps (plain or T-bar) are used to hold materials while glue is setting or while frames are being welded. Sash cramps come in various sizes. The plain bar is used for light work and the T-bar for heavy-duty work. The fixed jaw of the T-bar has a foot with holes that can be used to secure the cramp (to a work bench, for example).



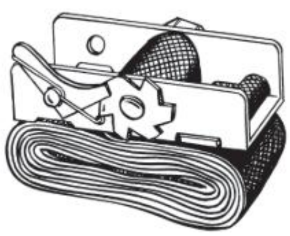
Sash cramps

Gluing clamps, like sash cramps, are used to hold materials. The clamping distance is only limited by the length of the pipe.



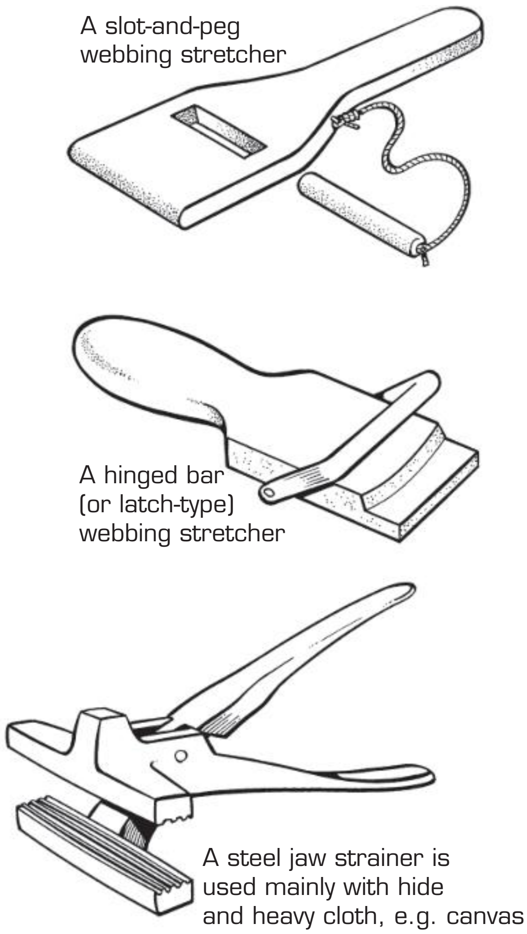
A gluing clamp

Webbing clamps are used when gluing awkwardly shaped objects or large frames.



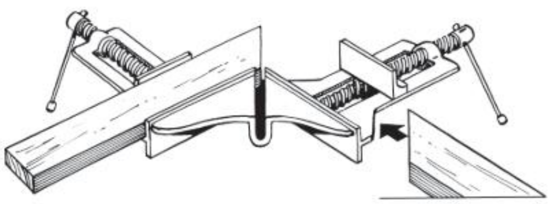
A webbing clamp

Webbing stretchers (or strainers) are used to stretch webbing taut. There are three basic types, as shown below.



Webbing stretchers

Mitre clamps can be used to hold framing materials in place while a mitre joint is cut (at an angle of 45 degrees). They also hold the joint in place while the glue sets.



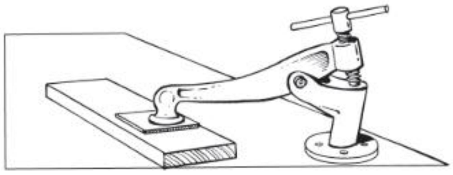
A mitre clamp

Workmates® are collapsible devices that can be used to hold a range of materials such as timber, sheet material and pipe. The jaws can be adjusted to hold irregularly shaped objects.

ISBN 9780170185677

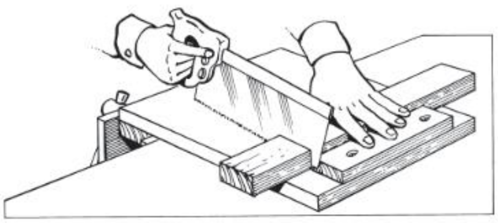
A Workmate®

Bench holdfasts are used to hold long, large or awkward pieces of material onto a bench while they are being chiselled or carved.



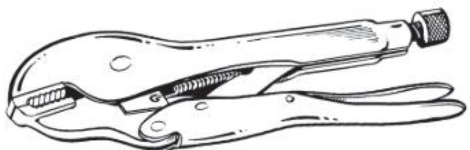
A bench holdfast

Bench hooks are used to hold materials while they are being sawed. One end of the bench hook is usually held in a vice to prevent movement. Bench hooks can be right handed or left handed.



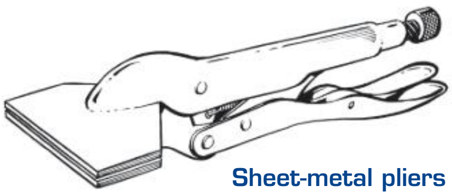
A bench hook

Locking pliers can be adjusted to lock onto material and hold it securely.



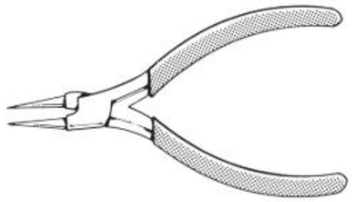
Straight-jaw pliers

Long-nose pliers



Sheet-metal pliers

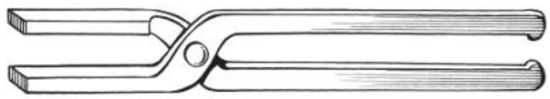
There are many different kinds of pliers. They are used mainly to grip small objects. Round-nose pliers can be used to bend wire, while combination pliers can also cut it.



Round-nose pliers

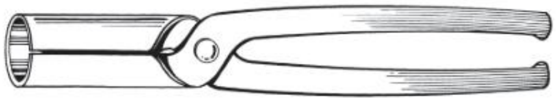
Combination pliers

Tongs are used mainly to grip short lengths of hot metal. There are different types, such as open-mouth tongs for thick, flat pieces of metal, and square or round hollow-bit tongs, which can hold square or round bars.



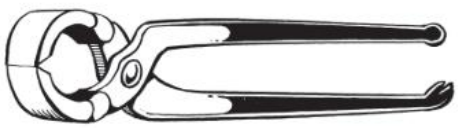
Open-mouth tongs

Closed-mouth tongs



Hollow-bit tongs

Pincers are used to grip and remove staples, tacks and nails that a claw hammer cannot grip.

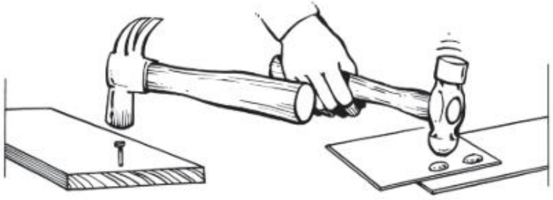


Pincers

ISBN 9780170185677

Percussion (impact) tools

Percussion tools are used to strike another tool or object. The impact of the percussion tool produces a desired effect – for example, driving a nail into wood or shaping the head of a rivet. Percussion tools are sometimes referred to as driving tools.



Hammers are the most commonly used percussion tools. Which hammer you select will depend on:

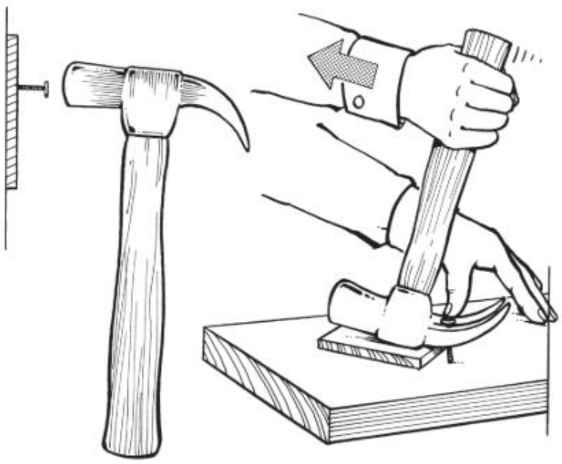
- the scale of the task to be performed – for example, it may be light work such as assembling a wall cabinet, or heavy work such as erecting a wall frame
- the size of the object to be driven – for example, it may be a nail, a cold chisel or a star picket.

RULE: The larger the object or task, the larger the hammer.

For example, to drive a 75-millimetre nail you should use a claw hammer rather than a Warrington hammer. Each type of hammer comes in various sizes, graded according to the mass of the head.

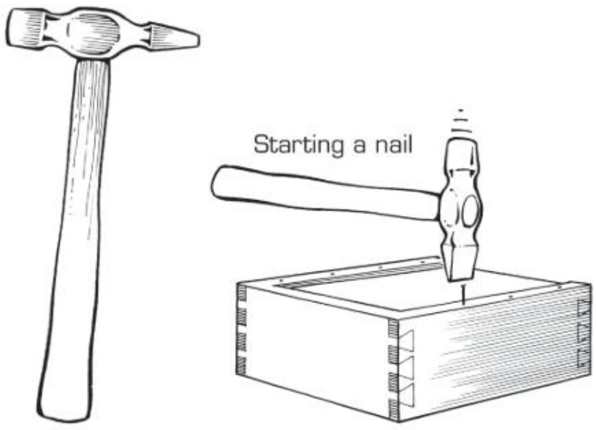
Common percussion tools

Claw hammers are used for driving large nails into timber. Nails are removed with the claw. To protect the surface, use a piece of scrap wood when pulling out nails.



Claw hammers

Warrington hammers are used for driving small nails into timber – for example, when nailing plywood onto the base of a box.

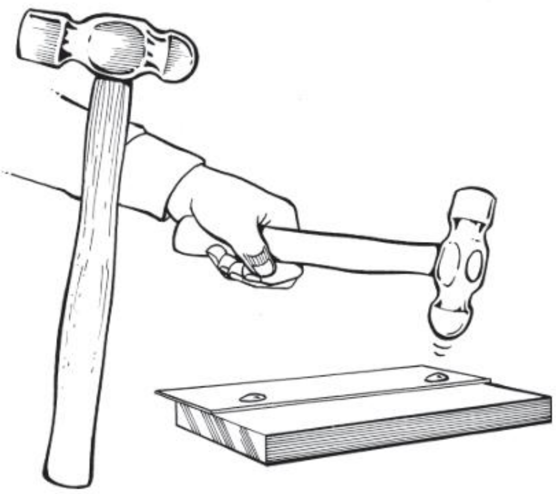


Warrington hammers

Nail punches are used to drive the heads of bullet-head nails below the surface. Different sizes are available.

A nail punch

Ball-pein hammers are used mainly as a general-purpose tool when working with metals – for example, when bending metal. They are also used to shape the heads of rivets.



Ball-pein hammers

Cross-pein hammers are mainly used for lighter work with metals. They can be used in narrow spaces or in corners, and to start nails.

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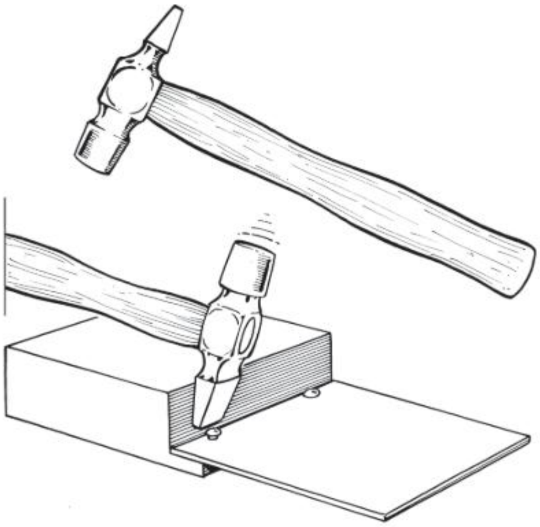
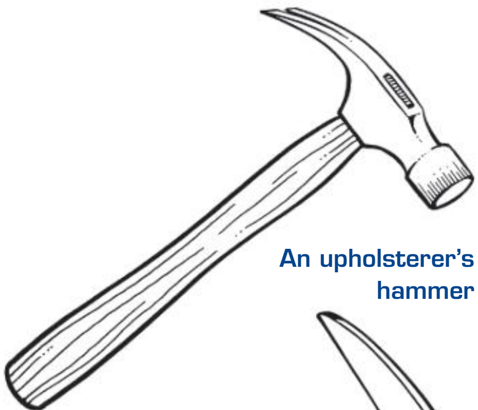


Cross-pein hammers

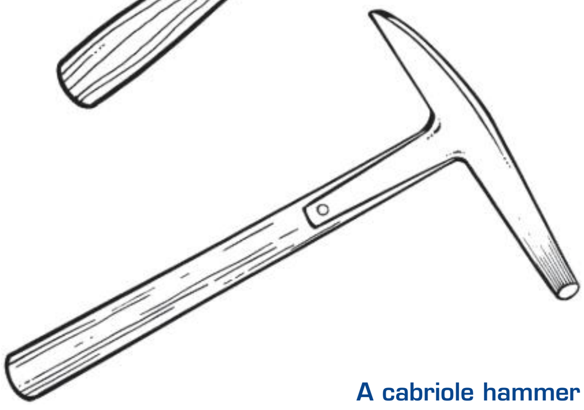
Upholsterer's hammers (or tacking hammers) are general-purpose hammers. They are used to drive tacks, gimp pins and decorative nails into timber and have a claw for removal of temporary tacks. (See 'Mechanical fastening', starting on page 136.)

Other types of hammer used in upholstery are:

- two-headed hammers, which have a general-purpose head and a cabriole – a small face and head used for fine work on wood that will be seen and cannot be damaged. They are also used in areas where a larger head would cause damage
- magnetic-head hammers, which hold tacks on their faces – useful for awkward places.

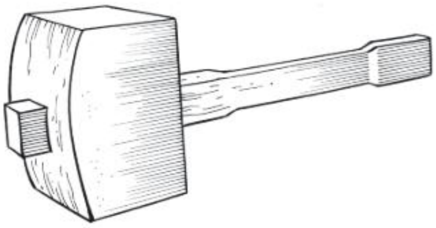


An upholsterer's hammer



A cabriole hammer

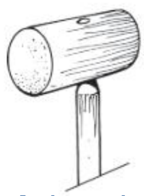
A mallet (often called a carpenter's or joiner's mallet) is used in woodwork for striking chisels or gouges.



A mallet

A range of other mallets is used when shaping metals or soft materials to prevent damage to the material. For example:

- tinman's mallets – for shaping sheet metal
- bossing mallets – for forming hollow shapes in sheet metal
- rawhide mallets – for shaping soft sheet metals such as aluminium and brass, or for driving delicate tools.

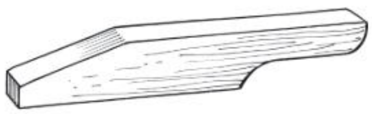


A tinman's mallet

A bossing mallet

A rawhide mallet

Dressers, like tinman's mallets, are used for shaping sheet metal.



A dresser

Soft-faced hammers are used to provide a heavier blow without damaging the material. They have replaceable faces made from a soft material such as nylon, copper or rubber.

A soft-faced hammer

ISBN 9780170185677

Torsion (twisting) tools

Torsion tools depend on the application of a twisting or turning force for their operation. They are used mainly to secure or release mechanical fasteners such as screws or nuts and bolts. Torsion tools are sometimes referred to as driving tools or assembly tools.

There are two main types:

- screwdrivers
- spanners.

Screwdrivers

Screwdrivers are used to turn screws. They are available in many different types and sizes.

Cabinet screwdrivers are used for slotted screws, mainly when working with wood.

A cabinet screwdriver

Flat screwdrivers are used for slotted screws, mainly when working with wood.

A flat screwdriver

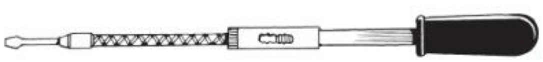
Engineer's screwdrivers are used for slotted screws, mainly when working with mechanical components.

An engineer's screwdriver

Ratchet screwdrivers ensure the blade stays in contact with the screw.

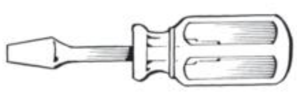
A ratchet screwdriver

Spiral ratchet screwdrivers (or Yankee screwdrivers) have a pump action for fast operation.



A spiral ratchet screwdriver

Stubby screwdrivers are used for small spaces.



A stubby screwdriver

Phillips screwdrivers are used for Phillips-head screws.

A Phillips screwdriver

Pozidriv screwdrivers are used for Pozidriv screws.

A Pozidriv screwdriver

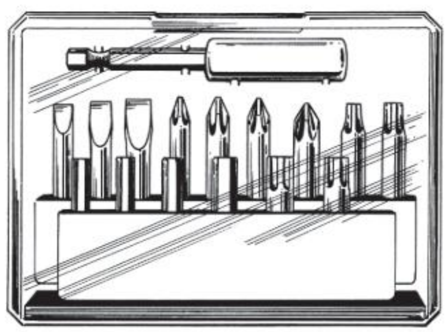
The blade size of Phillips and Pozidriv screwdrivers is identified by a number from 1 to 5, where 1 is the smallest.

Screwdriver bits can be fitted to power tools for faster operation. Phillips and Pozidriv bits are often used for this purpose as they do not slip out of the screw slots as easily as straight blades.

There are also other types of screwdrivers. They are available with various handles – for example, pistol grip – and are sold with a range of interchangeable bits. These bits fit different types of heads of screws and bolts. (See 'Semi-permanent fasteners' on page 140.) The bits are inserted into a hole in the end of the metal shaft of the screwdriver.

A number of boxed tool kits sold today include various interchangeable driver bits. Common driver bits are Phillips, Pozidriv, Torx, hexagon and socket.

These driver bits often come in a range of different sizes to match the heads of screws. Using driver bits with portable power drills has become a popular way to tighten and loosen screws.



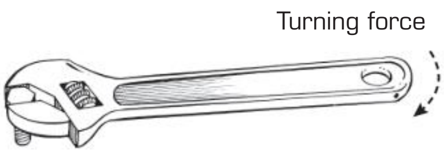
Interchangeable driver bits

ISBN 9780170185677

Spanners

Spanners, like screwdrivers, come in many different shapes and sizes. They are used to tighten or loosen nuts and bolts.

Adjustable spanners fit various-sized nuts and bolts. Always position the spanner so that the fixed jaw (not the moveable jaw) is taking most of the turning force when the nut or bolt is being tightened or loosened.



An adjustable spanner

Open-ended spanners are made in standard sizes. Each end is a different size.

An open-ended spanner

Ring spanners are like open-ended spanners, but they have a better grip and are less likely to slip. They can be used more easily in confined spaces.

A ring spanner

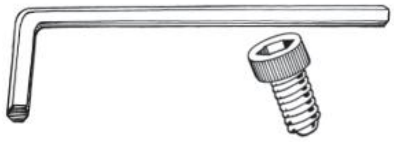
Combination ring and open-ended spanners are also available. There is a ring at one end while the other end is open. Both ends are the same size.

A combination spanner

Sockets are used to turn nuts and bolts that are recessed. They come in a range of standard sizes such as metric and Whitworth.

Sockets

Allen keys are used to tighten or loosen set screws or grub screws with a hexagonal-shaped hole. They come in a range of sizes.



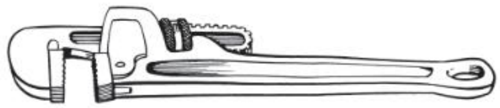
An allen key

A set screw

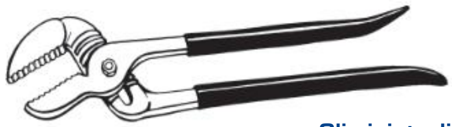
A grub screw

Wrenches

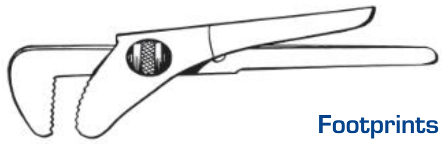
Wrenches, unlike spanners, are not designed for use on nuts and bolts. They are used to turn pipes or rods. A number of common wrenches is shown below.



A Stillson® wrench



Slip-joint pliers



Footprints

Power tools

Unlike hand tools, which require only muscle power, power tools require an additional energy source for their operation. Three energy sources are commonly used:

- electricity, as in a bench grinder, a portable jig saw or a cordless drill
- compressed air, as in a pneumatically operated nailing gun or drill
- explosive cartridges, as in a cartridge nailing gun used to drive special nails into masonry or steel.

Note that some power tools, machines and universal equipment may have an age restriction in your State or Territory. Legislation may prevent you from using this tool. This is for your safety. Check with your teacher.

Most power tools are available in a range of sizes and capabilities. A power tool should be chosen with its intended use in mind. For example, for

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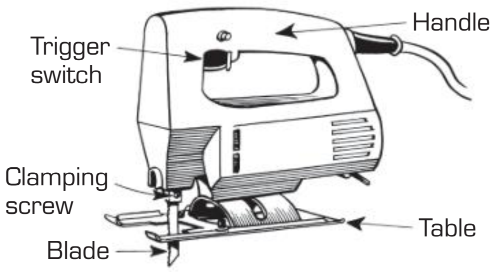
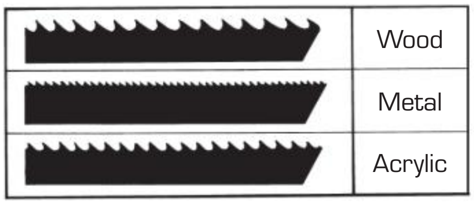
light work such as cutting thin sheets of plywood, a 150-millimetre portable circular saw may be used, while a 284-millimetre portable circular saw would be selected to cut timber for a house frame.

Cordless power tools have become a popular alternative. They are quick and easy to use, and safe (no leads). (See the Information File, 'Cordless power tools', on page 116.)

Portable jig saws (with cord or cordless) can be used to cut curves and irregular shapes in most materials if the proper blade is selected. The blade moves up and down. The teeth of the blade point forwards and cut the material on the upward stroke. They can also be used to cut slots, holes and straight lines. The table on some jig saws can be tilted to produce a sloping cut.

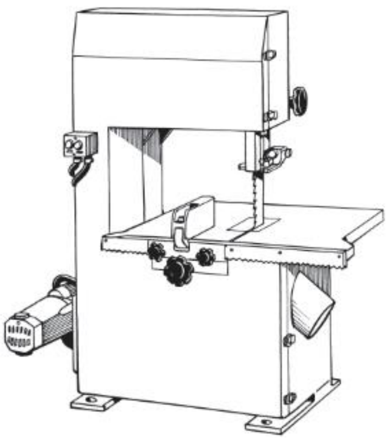


A portable jig saw



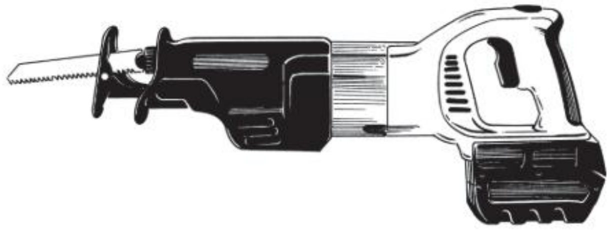
Saw blades for different materials

Bandsaws (with cord or cordless), like jig saws, can be used to cut curves and irregular shapes in most materials if the proper blade is selected.



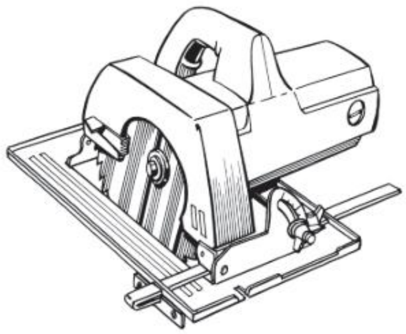
A bandsaw

Reciprocating saws (with cord or cordless) can be used to cut curves and irregular shapes in most materials if the proper blade is selected. The blade moves forwards and backwards. The teeth of the blade are along the bottom edge and cut on the backwards stroke. Reciprocating saws are also known as sabre saws.



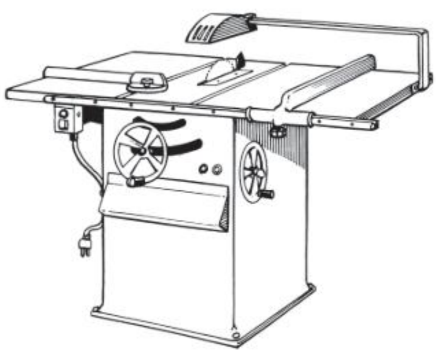
A reciprocating saw

Portable circular saws (with cord or cordless) can be used to cut most materials if the proper blade is selected. The base can be tilted to produce a sloping cut. An adjustable guide (or fence) can be fitted so that the saw can cut parallel to an edge. The depth of the cut can also be varied to produce a deep or shallow kerf.



A portable circular saw

Circular table saws, like portable circular saws, are used for cutting wood or plastic. The height of the blade can be adjusted to suit the thickness of the stock. In some machines, the blade can be tilted to produce a sloping cut such as a bevel or a mitre.



A circular table saw

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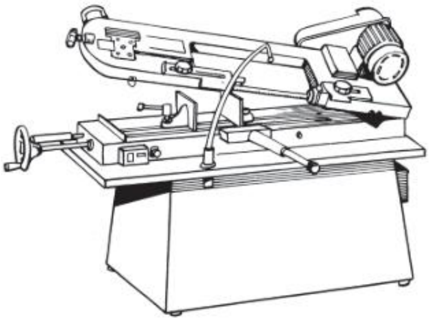
Power hacksaws are used for cutting metals, especially to cut thick pieces such as large-diameter rods and bars.

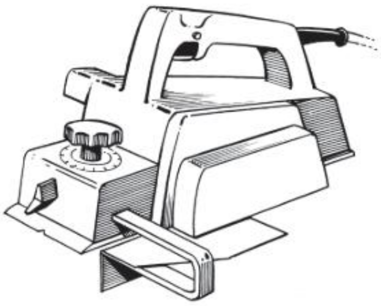


A power hacksaw

Combination circular saws/planers are used as general-purpose tools in home workshops and small businesses. The various functions of the machines enable timber to be processed in many different ways, including sawing, planing and shaping.

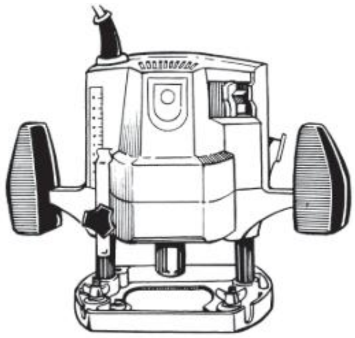
A combination circular saw/planer

Portable hand planers are used as general-purpose planes in the construction industry.



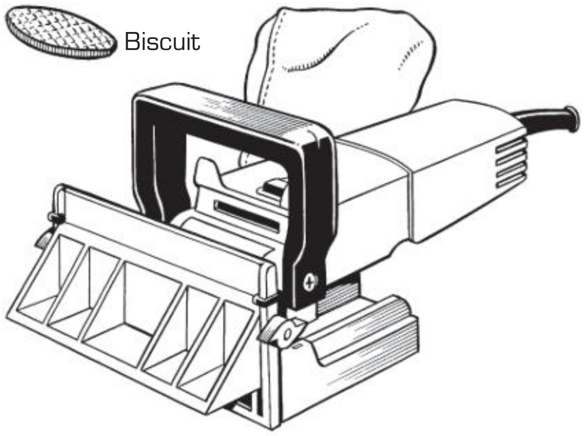
A portable hand planer

Routers are used mainly to cut out various profiles along the edges of timber and plastics. They can also be used to hollow out materials if the proper cutter is selected. The depth of the cutter can be varied, and an adjustable guide can be fitted so that the cutter can cut parallel to an edge or surface.



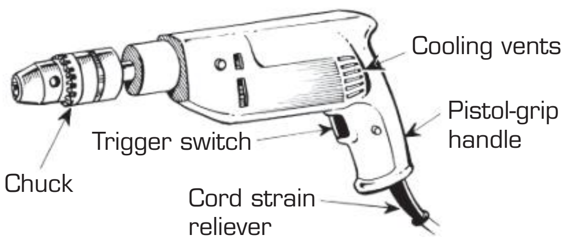
A router

Biscuit joiners are used to cut curved slots in the edges of timber or particle board to be joined. A small, oval piece of thin wood called a biscuit is inserted into the slot when gluing the material.



A biscuit joiner

Portable electric drills (with cord or cordless) are used with many drill bits. The size of the chuck will determine the largest diameter twist drill that can be used (common maximums are 10 millimetres and 13 millimetres). Today, many portable electric drills have variable speed control as well as a hammer drill function for drilling masonry.



A portable electric drill

Drill presses are fixed in place. The pedestal drill press is fixed to the floor, while the bench drill press, with its shorter column, is fixed to a bench. Drill presses are generally used for more accurate drilling than can be achieved with a portable electric drill. (See the diagram overleaf.)

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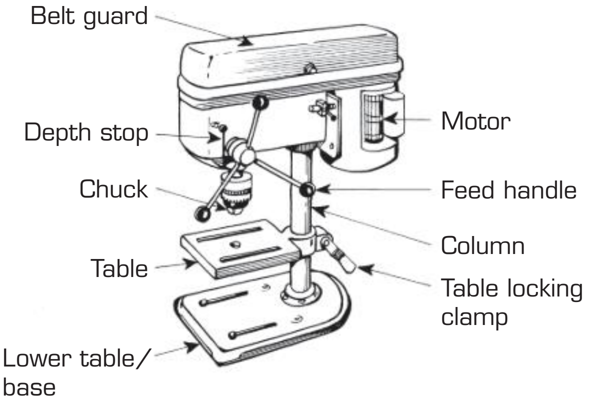
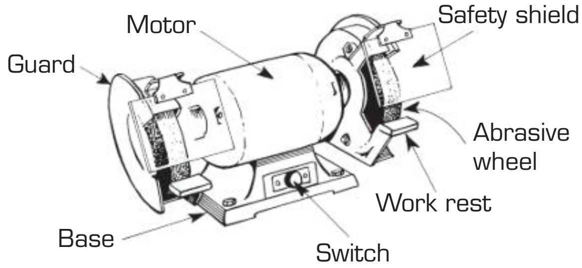


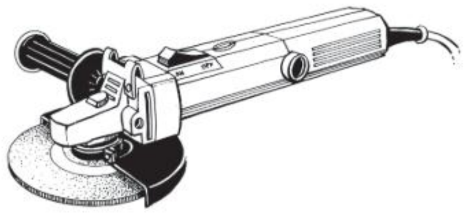
A bench drill press

Bench grinders are used to **abrade** metals. They have a work rest that can be adjusted to give a square cut or angled cuts.



A bench grinder

Angle grinders (with cord or cordless) are used mainly for abrading metals. They are general-purpose tools used in the metal fabrication industry.



An angle grinder

INFORMATION FILE

Cordless power tools

Cordless power tools have become a popular alternative to portable power tools. They are quick and easy to use, and safe (no leads). There are four basic factors that you need to consider when purchasing a cordless power tool. They are:

- application
- size of battery
- rate of charge
- cost and quality.

There is another cordless system. Its energy source is gas. The gas is stored in a disposable fuel cell.

Application

The questions to ask are:

- What will its use be? Will it be used at home or for trade purposes?
- What about its usage? How regularly will the tool be used?

Size of battery

There is a range of voltage available (7.2V, 9.6V, 12V, 14V, 18V, 24V, 28V, 36V and more). A variety of torque 'grunt' is needed for different applications. For example, to drill a 12-millimetre hole in steel, you need a 24V battery. To assemble flat-pack office furniture with self-tapping screws you would need a 12V battery.

The voltage range for the home is generally 7.2V to 12V, while for trade purposes it is 14V to 36V.

The 36V battery is seen as a replacement for mains (240V) power tools. Their 'grunt' is equal to that of corded tools. Note that there is a limited range of 36V cordless power tools (for example, the circular saw and demolition hammer). The 36V tools are quite heavy and physical exhaustion is an issue.

The two types of batteries used are nickel cadmium (NiCd) and lithium. Some countries have banned NiCd batteries because of environmental

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concerns. It is expected that NiCd batteries will be phased out in the future. The new range of voltage of lithium batteries will include 10.8V, 14.4V, 18V, 21.6V, 28V and 36V.

Rate of charge

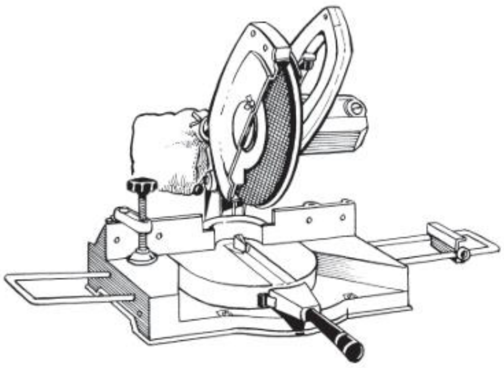
This is how quickly the battery can be recharged. The time taken can vary between 1 hour and 3 hours. A quick charge takes about 1 hour, generally for trade purposes, whereas a 'trickle charge' takes about 3 hours and is suitable where time is not a factor.

Cost and quality

In general, quality will cost extra. The advantage is added longevity without the tool breaking down.

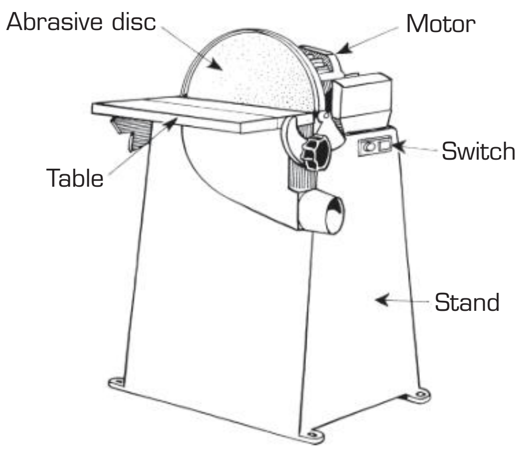
The range of cordless power tools is expanding to meet new applications.

Cut-off wheels can be used to abrade or cut most materials, provided that a suitable blade is selected. The base plate can be rotated to produce cuts other than 90 degrees.



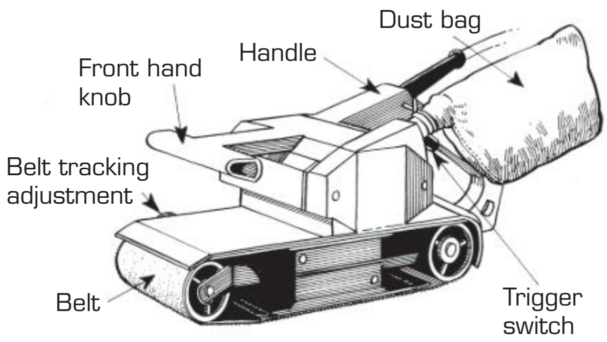
A cut-off wheel

Disc finishing sanders can be used to abrade wood, metal or plastic when fitted with the appropriate abrasive sheet. They have an adjustable table. Some disc sanders have an adjustable sliding fence to finish sloping surfaces accurately.



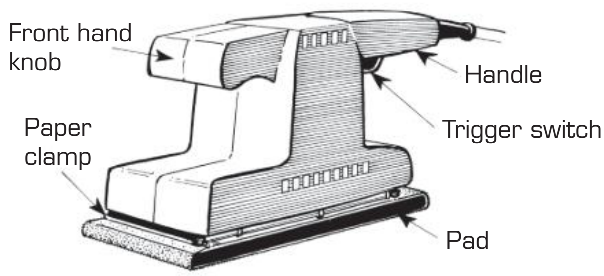
A disc finishing sander

Belt sanders (fixed or portable) are used to abrade wood, metal or plastic when fitted with the appropriate belt. The belt, a continuous abrasive sheet, is fitted over two rollers. The belt must be adjusted after the machine is switched on, but before sanding begins.



A portable belt sander

Portable finishing sanders (with cord or cordless) are used to abrade materials such as wood and thermosetting plastics. The abrasive sheet is fitted to a pad that rotates or **reciprocates**. This type of sander (sometimes called an orbital sander) is used to achieve a fine finish.



A portable finishing sander

Compressed-air (pneumatic) tools are used for many different purposes, such as unlocking and locking nuts and bolts on motors, driving nails into timber framing and stapling upholstery. They have fewer moving parts than electric tools.

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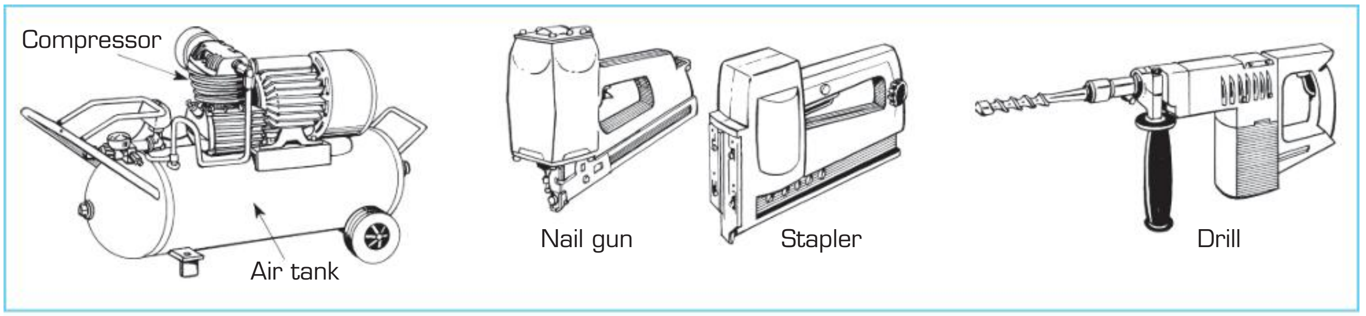


Compressed-air tools

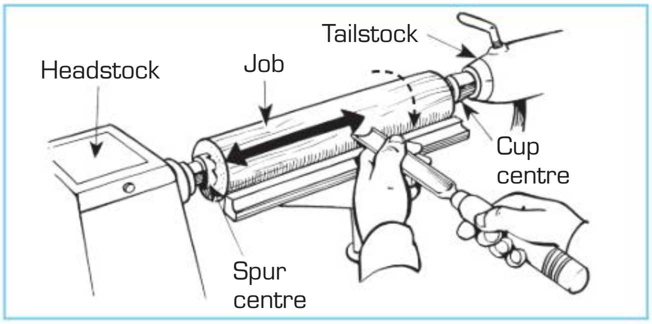
Their high degree of efficiency, their reliability and their relatively low cost make them a very popular tool in industry (particularly in industries that already use compressed air for other purposes). The compressed air that powers the tool is generated by the compressor and stored in the air tank until it is required.

Lathes

Woodturning lathes

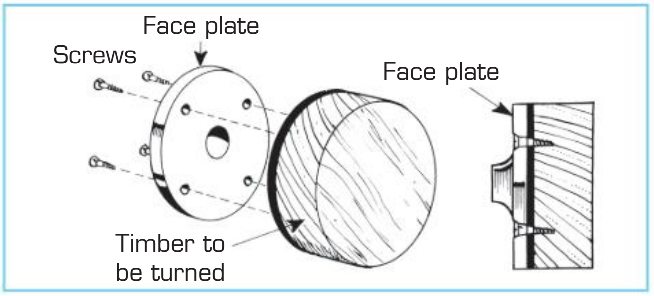
Woodturning lathes are used for shaping wood. Shavings are removed by rotating the material against a scraping or cutting tool. (See 'Turning wood' on page 134).

Wood can be turned between centres (as when turning a long cylinder to form a handle), or it can be held by screws on a face plate (as when turning a bowl).



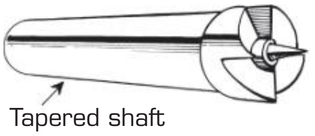
Turning between centres

Using a woodturning lathe



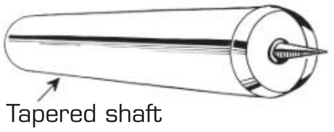
Work screwed to a face plate

Spur centres fit into a tapered hole in the headstock and are used to rotate the work.



A spur centre

Cup centres are used to support long stock. They are fitted into a tapered hole in the tailstock.



A cup centre

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Expandable chucks can be used instead of face plates to hold material. The four jaws, or quadrants, can be moved.

A shallow hole is bored into the base of the work. The jaws are then placed inside the bored hole and expanded to hold the material.

The expanded chuck, like the face plate, is attached to the headstock (see the photograph opposite).

An expandable chuck

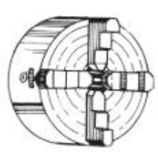
Centre lathes

Centre lathes (commonly referred to as metal lathes) are mainly used for cutting metal and plastic. The material is usually held in a three-jaw or four-jaw chuck. Material is removed by rotating the work against one of a range of different cutting tools. Many different processes can be performed, such as turning a cylinder or taper, drilling a hole in the centre of the material and facing off (that is, producing a flat surface, usually at 90 degrees to the axis of rotation).

Three-jaw chucks are self-centring, and hold circular or hexagonal stock.

Four-jaw chucks hold square, rectangular or irregularly shaped stock. Each jaw can move independently.

A three-jaw chuck



A four-jaw chuck

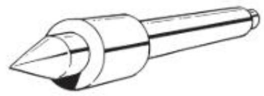
The jaws can usually be reversed in both chucks.

The chuck can be threaded onto a hollow shaft, which sticks out of the headstock. The hollow shaft is rotated by stepped-cone pulleys. (See page 172.)

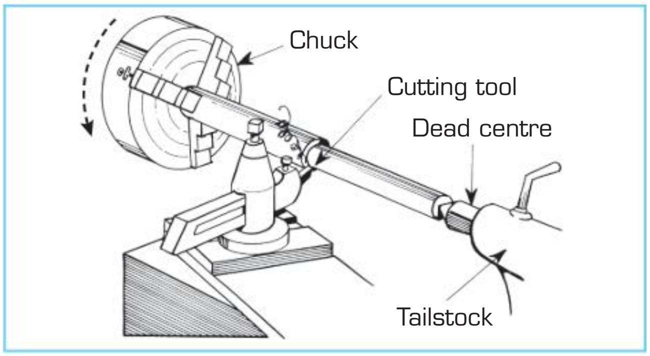
A tailstock centre must be used to hold and support long stock. (It fits into a tapered hole in the tailstock.) A centre hole must be pre-drilled in the end of the material, using a centre or combination drill. (See pages 105–6.) There are two kinds of tailstock centre.

- A dead centre – a hardened steel centre that does not rotate. It requires a lubricant such as grease to reduce the friction.
- A live centre – the centre is mounted in a bearing and rotates with the work. It is sometimes referred to as a revolving centre, and it does not require any lubricant.

Dead centre



Live centre



Turning long stock with a tailstock centre

A centre lathe

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Computer numerically controlled machines

Today, many metal lathes have been connected with computers. These machines are known as computer numerically controlled (CNC) lathes. The machining process is first programmed into the computer by the operator. The computer then monitors the machining processes to produce the item.

A gantry-style router

A CNC lathe

Other CNC machines that perform a range of tasks are also available. Two examples are shown here. They are:

- gantry-style routers, which can be used to cut various materials, such as metals, wood, plastics and other light materials
- office mills, which are used for rapid prototyping of small precision 2D or 3D parts.

An office mill

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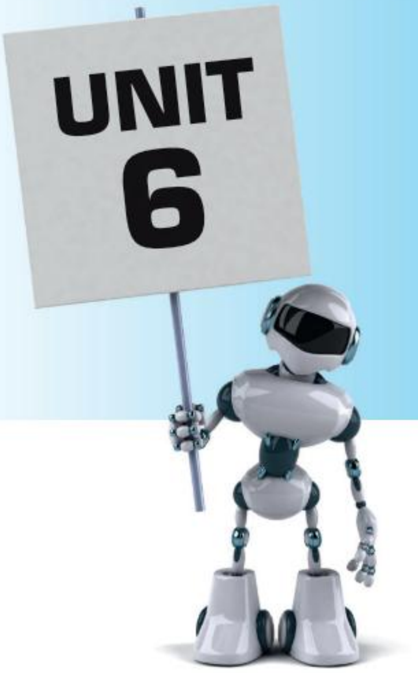


Processes

People use tools to **transform** materials. There are three processes by which materials are transformed.

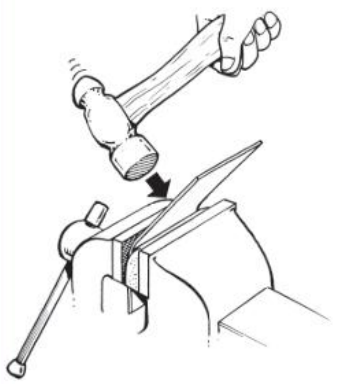
1 **Forming:** the process of changing the shape of the material without removing any part of it. (This is sometimes referred to as deforming.)

2 **Separating:** the process of removing part of the material from the parent material. (This is sometimes referred to as wasting.)

3 **Combining:** the process of joining two or more similar or dissimilar materials. (This is sometimes referred to as fabricating or assembling.)

In addition, finishing techniques are used to protect and beautify the surfaces of materials. Adding a coat of finish or applying a covering to a material can be seen as a type of combining process.

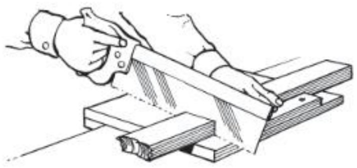
Forming



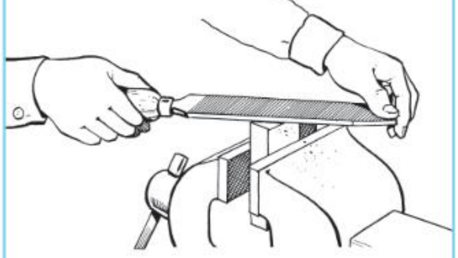
Shaping sheet metal

Bending a steel rod

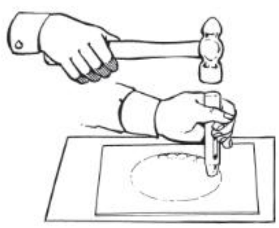
Separating



Sawing a piece of timber

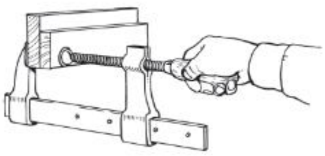


Filing plastic



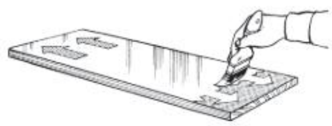
Punching a hole into leather

Combining



Gluing wood

Soldering tinplate



Painting a surface

Polishing a surface

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Part A: The forming process

The properties of a particular material determine how that material can be formed. Different forming processes are generally used for metals, timber, plastics and other materials.

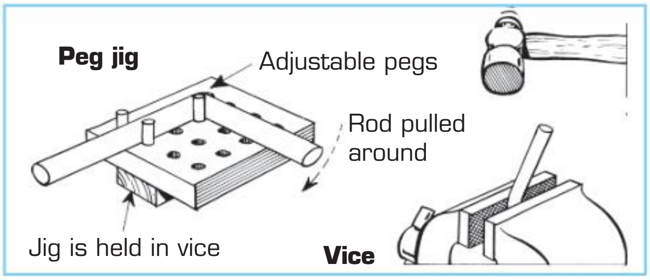
In this section, you will learn:

- about different forming techniques
- how to select appropriate forming techniques
- how to use forming techniques.

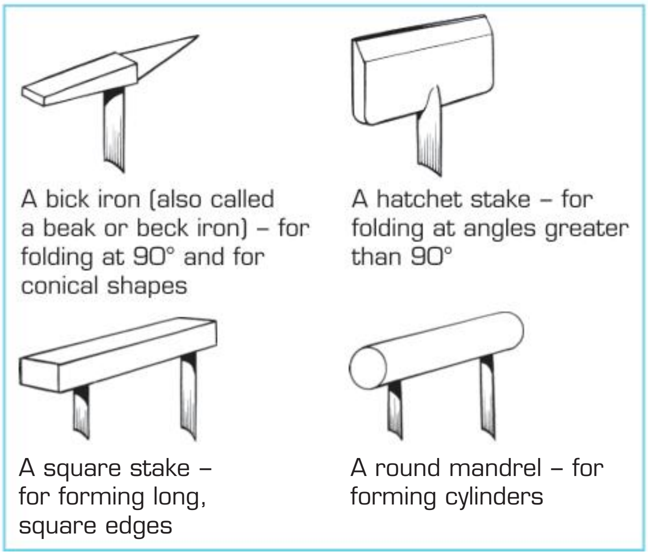
Forming metals

Bending

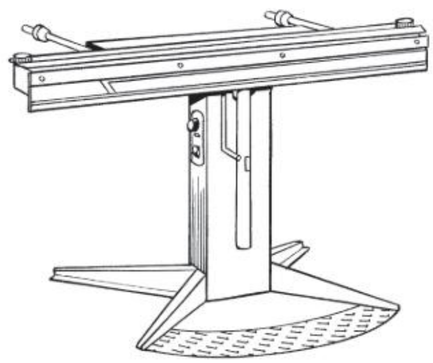
Small pieces of metal such as rods or flat bars can be bent when cold by using a jig or a vice.



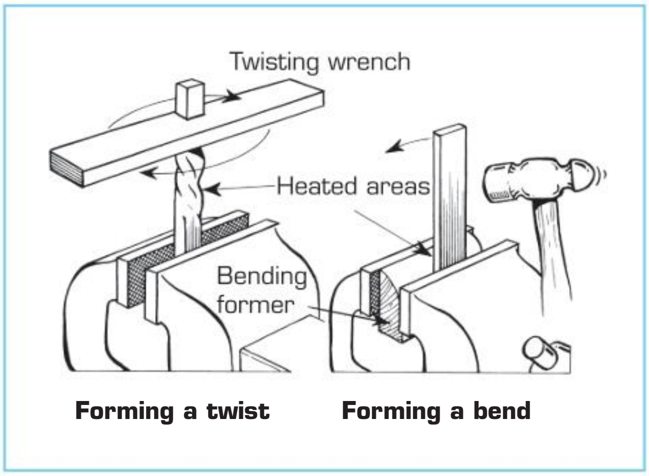
Sheet metal can be bent using various stakes or a folding machine. When folding sheet metal on a stake, a dresser or mallet is often used to produce a neat fold.



A sheet metal folding machine clamps and holds the material during folding. The clamping device is a set of interchangeable fingers. Long, straight folds or shorter folds (to produce, for example, boxes of varying sizes) are possible.



Large pieces of metal can be bent, folded or twisted by heating the material before using a tool to form it.



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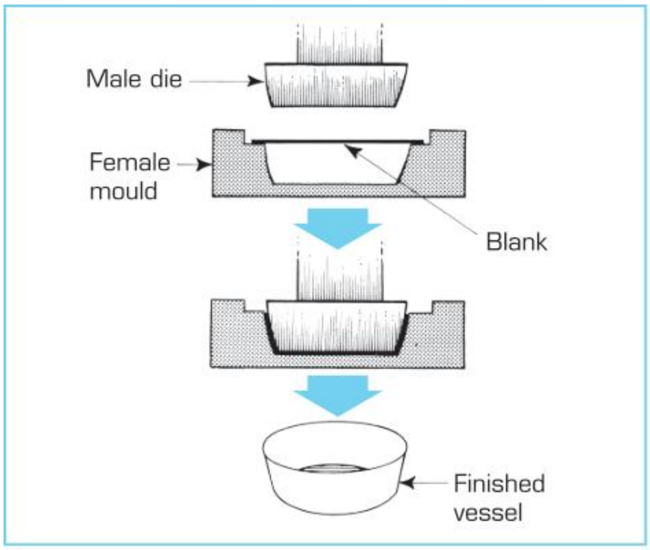
Pressing

Thin sheet metal can be pressed into shape using a mould and die. Pressing is commonly used in industry for mass-production processes such as making panels for car bodies.

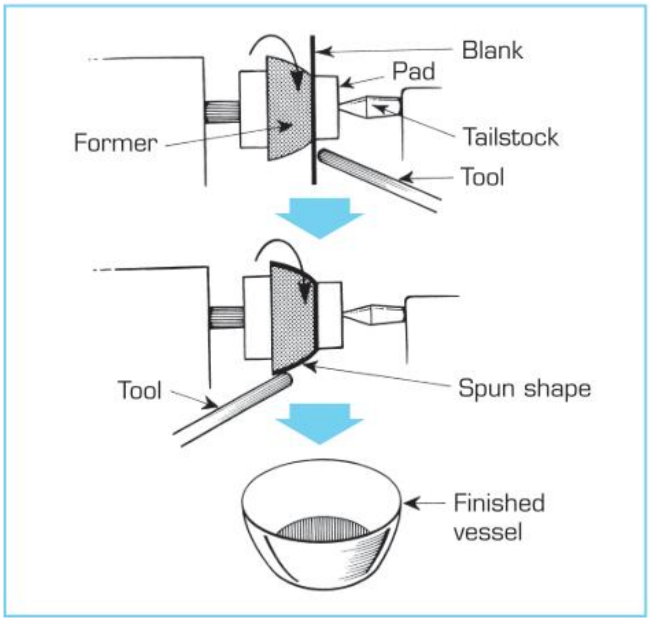


Pressing

Spinning

Spinning is a commonly used process in the mass production of metal containers such as steel or aluminium saucepans.

A disc of sheet metal is fixed between a former and a pad on a lathe. As the work rotates, a tool forces the disc over the former.

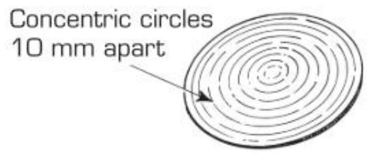


Spinning

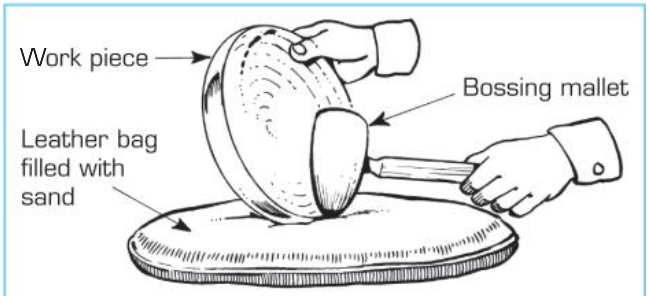
Beating

Beating is a similar process to pressing. Beaten metalwork is made using copper, brass, silver or other malleable sheet metals. The metal must be **annealed** before it is beaten. It will work-harden as it is deformed, and therefore it must be annealed from time to time to prevent tearing.

The first step is to cut the piece of metal to size and file away any sharp edges. Then use compasses and a pencil to draw concentric circles 10 millimetres apart.



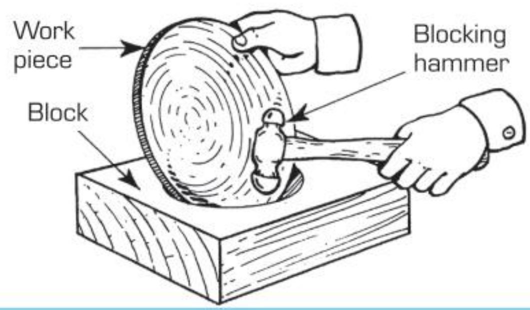
Hollow out the desired shape by beating. Start from the outside and work slowly towards the centre in a circular path. Anneal the metal as necessary.



The small end of the mallet is for hollowing and the large end is for smoothing out wrinkles

Alternative method

Use a blocking hammer and a hardwood block shaped to the required size



Planishing is used to smooth off the metal and work-harden it in its final shape. The metal is first annealed, pickled and cleaned. Then it is beaten with a special planishing hammer and stake, which are both very smooth and polished. (When planishing, you should start at the centre and work outwards in a circular path.)

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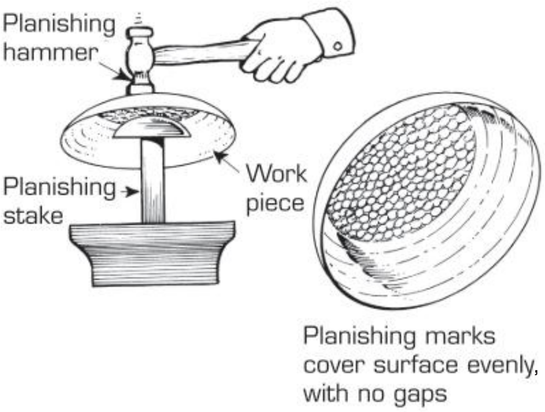
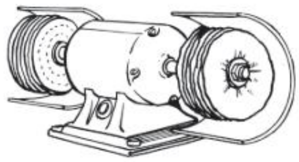


The metal is polished and finally coated with a clear sealer such as lacquer.

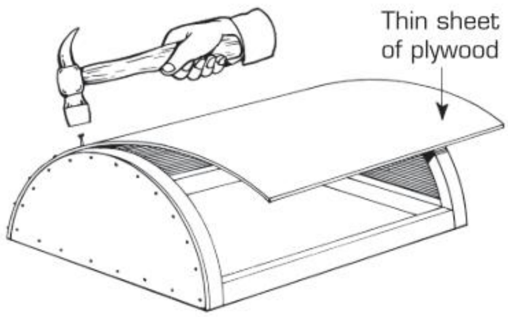


A buffing wheel

Metal polish and a cloth

Forming timber

Thin pieces of timber and sheets of timber products such as hardboard and plywood can simply be bent over a solid framework and fastened with nails or screws.



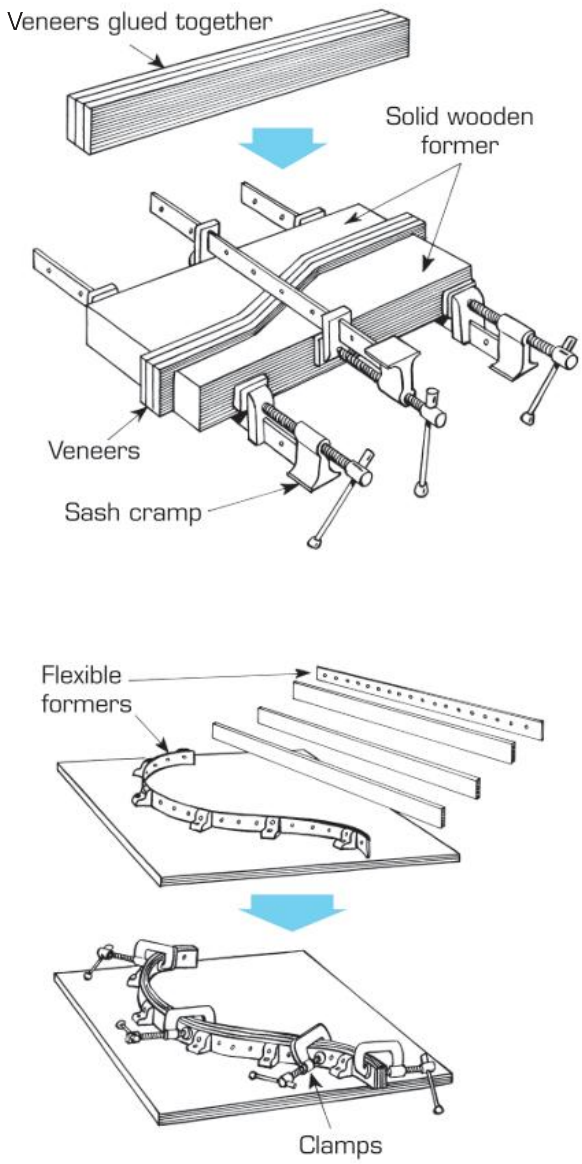
Forming sheet material

Thicker pieces of timber can be formed by steaming. This process is most commonly used in boat building and furniture making.

Steamed timber

Veneers (thin strips of timber 1.5–3.0 millimetres thick) can be glued together between formers to form various complex shapes. When the glue has dried, the bonded material will retain its new shape. This is known as laminating.

A flexible former consists of a flexible steel strip that can be attached to a base board to produce various shapes. Glued veneer is placed between the fixed former and another flexible steel strip. The formers are then clamped together and the veneer is allowed to dry.



Laminating

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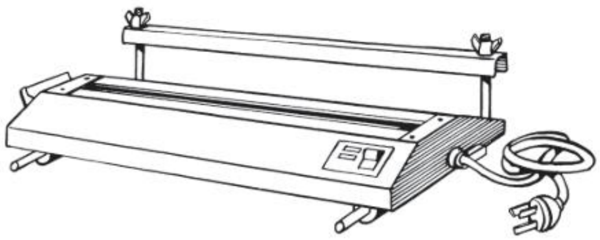
Forming plastic

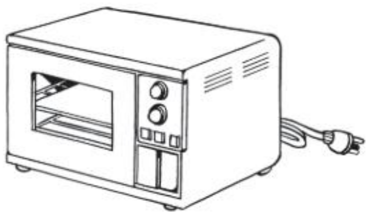
Thermoplastics

Thermoplastics such as acrylic need to be heated moderately before they can be bent. A strip heater is used to heat a narrow strip across a sheet of thermoplastic, so that a comparatively sharp bend is produced.



A strip heater

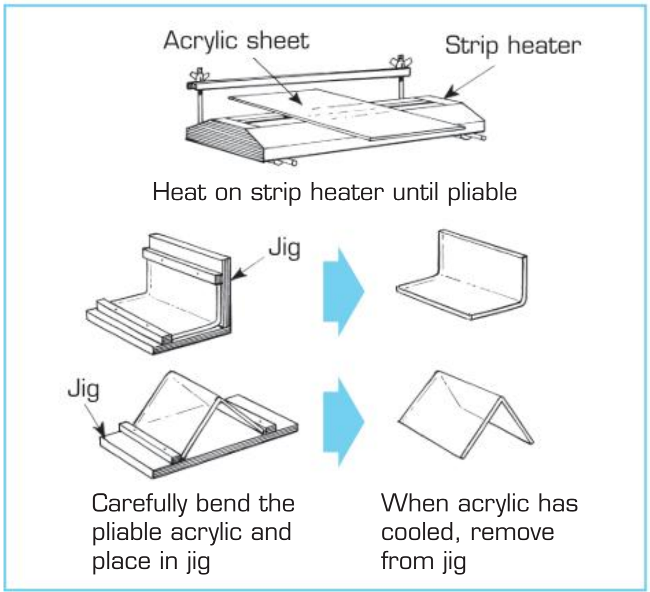
An oven is used when the sheet has to be bent over a larger area to produce a moulded 3D shape.



An oven

Straight bending

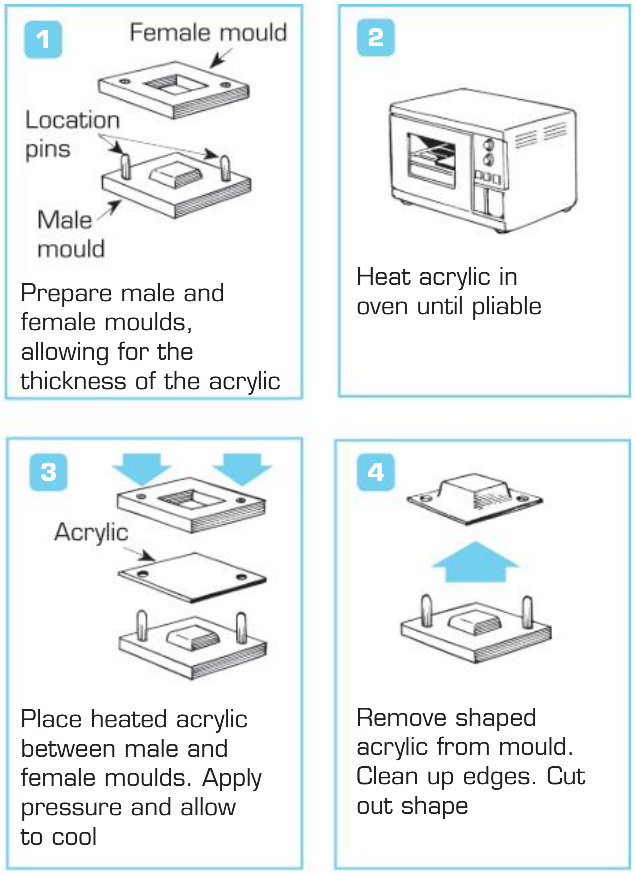
To produce a straight bend, a narrow strip of the thermoplastic is heated on a strip heater. The sheet is then bent along this strip and held (usually in a jig) until it has cooled.



Straight bending

Pressure forming

To mould a sheet of thermoplastic into three-dimensional shapes, it is first heated in an oven and then it is held under pressure in a mould until it has cooled. A similar process is used for blow moulding and vacuum forming. (See pages 82–3.)



Thermosetting plastics

Thermosetting plastics such as epoxy resin can also be formed into complex shapes by laminating. The epoxy resin is combined with glass fibre to form a strong composite material known as fibreglass or glass-reinforced plastic (GRP).

Select a well-ventilated area before starting any fibreglass activity.

The lamination process involves building up layers of GRP on a mould to the desired thickness. A gel coat is first applied, followed by a layer of glass

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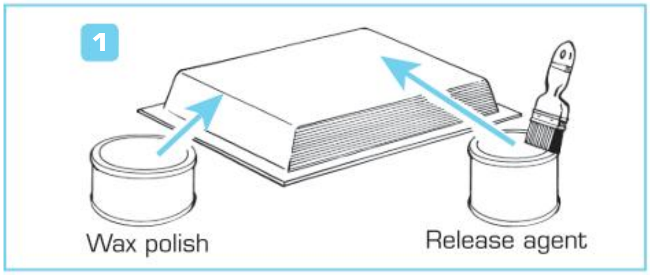
fibre, which is soaked with resin before the next layer is applied. The material is allowed to cure before it is removed from the mould.

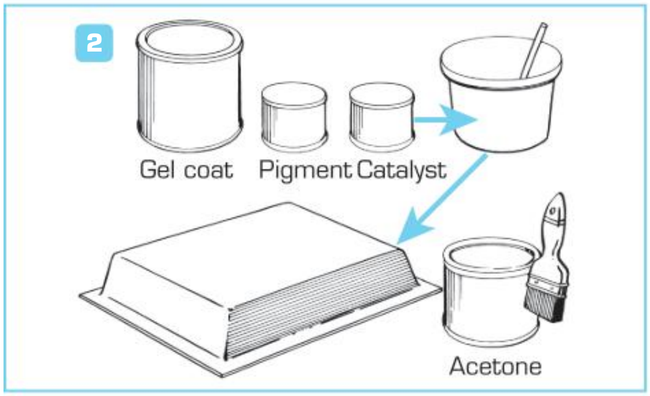
> Always use *pre-accelerated* resins. An explosion can occur if the catalyst and the accelerator are mixed together into the resin.

Hand lay-up of GRP

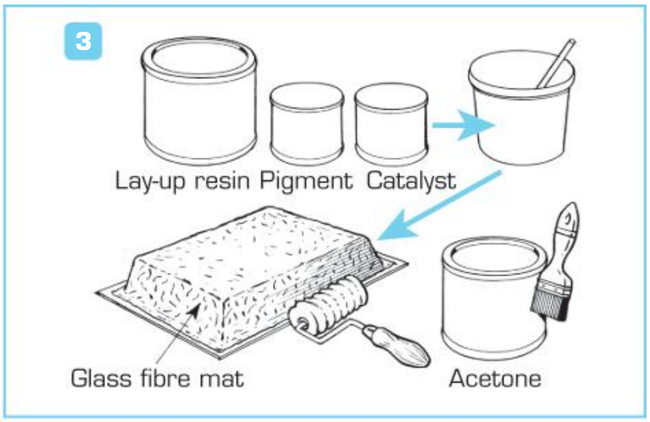
1 Check that the mould is clean and smooth. Apply a wax polish to its surface and then coat it with a release agent.



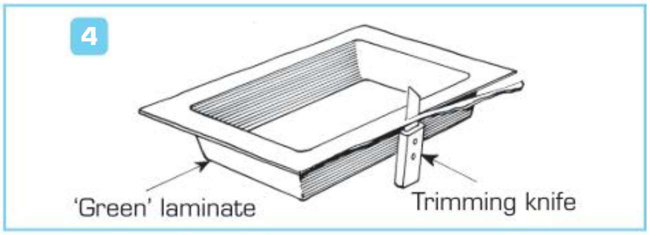
2 Apply a catalysed gel coat to the mould. It can be pigmented (coloured). Allow it to cure for about 30 minutes until it is still tacky. Clean up equipment with a solvent such as acetone.



3 Brush a thick coat of catalysed lay-up resin onto the gel coat and lay a glass fibre mat on the resin. Use a brush to **stipple** the resin into the mat. Repeat this process until the required number of layers has been built up. Use a fluted roller to help remove air bubbles. Clean up equipment.



4 Once the laminate has cured, carefully remove it from the mould. Trim and clean up the laminate. Alternatively, the excess glass fibre and resin can be cut away with a sharp knife while the laminate is 'green' and still in the mould. *Be careful not to damage the mould.*



> When sanding cured fibreglass, wear a respirator or mask, and goggles or safety glasses.

Forming other materials

Other materials can be formed. For example:

- clay can be formed by adding water to it and then shaping it by hand or in a mould. After it is baked dry in a kiln, it retains its new shape. This process is used industrially to make bricks, pavers and tiles, while potters 'throw' art objects such as vases on potters' wheels
- leather can be formed by wetting it. Upon drying, the leather retains its new shape. This process is used to shape leather or to make it easier to carve

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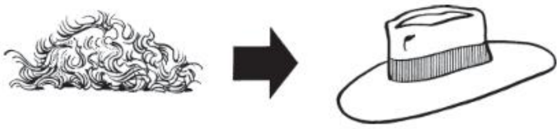
'Throwing' a pot on a potter's wheel

- concrete can be cast into many different shapes for use in construction such as pipes, posts and beams. It is often reinforced (for example, with steel rods (see page 204) to give it added strength. Concrete can also be used instead of clay to make bricks, pavers and roofing tiles
- non-woven fabrics that use fibres, and not yarns, can be formed. The fibres – for example, cotton, wool, animal or polyester – are bonded using heat, pressure (including water) or glue. (See page 88.) The mat consisting of interlocked fibres can be processed to produce the desired form – for example, a felt hat



- woven woollen fabrics can be **temporary set** into shape by a process of wetting and drying. Further wetting will cause the fabric to lose its original shape. **Permanent setting**, or damp-heat setting, is possible with steaming. However, the creases and pleats can be removed with additional steaming. The fibres of wool can be permanently set using **chemical setting** such as in Si-Ro-Set® process and steaming. (The Si-Ro-Set® process was developed by the CSIRO.)
- other fabrics can also be formed using resins. The resins are added to the fabric at the mill. There are two techniques – deferred cure and precured – used to set fabrics. With the deferred cure technique, garments are made, pressed and then placed in an oven to produce the desired permanent-press finish. With the precured technique a chemical is first sprayed onto the area to be formed. A hot press is then used to set the shape of the fabric.

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Part B: The separating process

In this section, you will learn:

- about different processes for separating materials
- how to choose an appropriate separating process
- how to perform a range of separating processes.

The separating process has many hazards since many of the tools used are cutting tools.

During all separating processes, hold the material securely to reduce the risk of injury from movement of the material or the cutting tool. Also, keep your hands (especially your fingers) away from the cutting edge.

Sawing

Sawing is generally used to remove unwanted material – for example, to shorten a piece of stock or to cut out a shape. The correct choice of saw will depend on the type of material and the type of cut (that is, whether it is to be straight or curved).

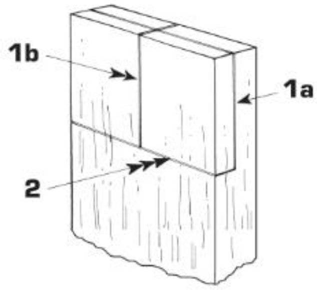
When sawing, always cut on the waste side of the line to ensure a good fit. When working with wood, the saw should cut right next to the line. However, when cutting metal and plastics, the practice is to cut slightly away from the line, leaving a small amount of waste that is filed to the line to finish it.

Sawing timber

There are two stages to sawing timber – the rip and the cross-cut.

1 Rip (cut) along the grain:
   - first **a** – that is, make a cut along the width
   - then **b** – that is, make a cut across the thickness.

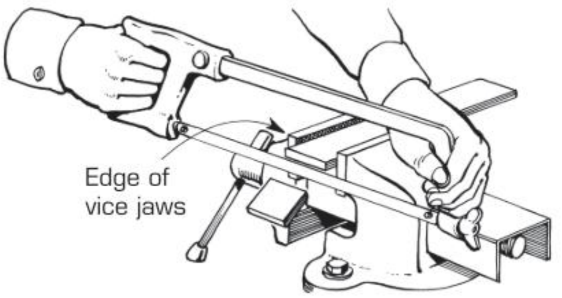
2 Cross-cut.



Keep the material low in the vice to minimise movement or vibration.

Sawing metals and plastics

Whenever possible, cut the material close to the edge of the vice jaws to prevent vibration.



Holding material in a vice

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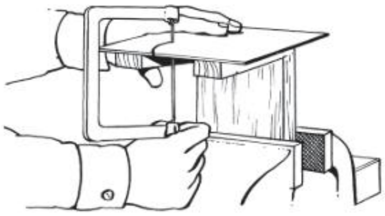
Use a 'V'-board when cutting thin or small pieces of material.



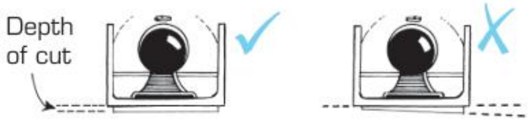
A 'V'-board

Planing

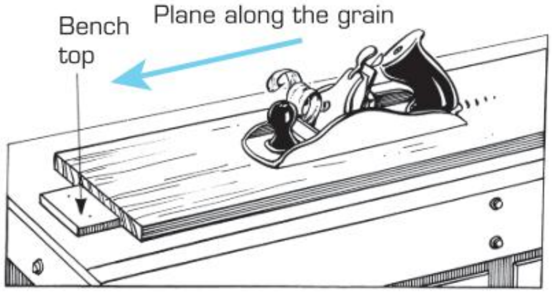
Planing is mainly used to remove shavings from wood. It can also be used with some thermoplastics, such as PVC and acrylic. To achieve a smooth and flat finish, a firm, steady planing action is required.

To begin planing, adjust the plane blade:

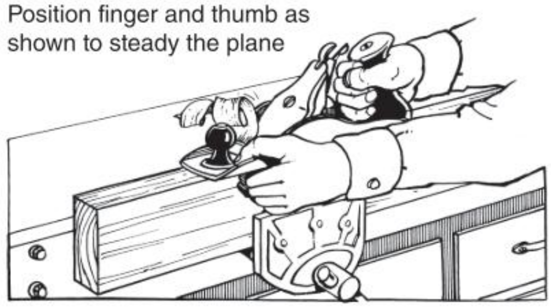
- to be parallel to the base of the plane
- to determine the depth of the cut.



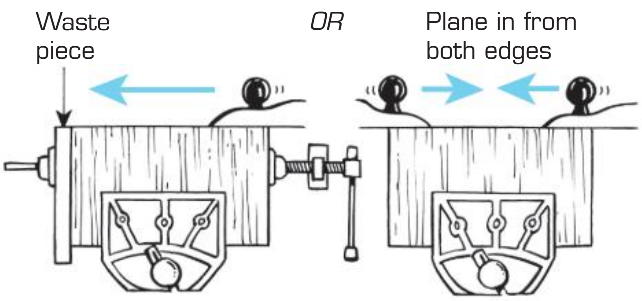
When planing a side, keep the material on a flat surface.



When planing an edge, clamp the material in a vice.



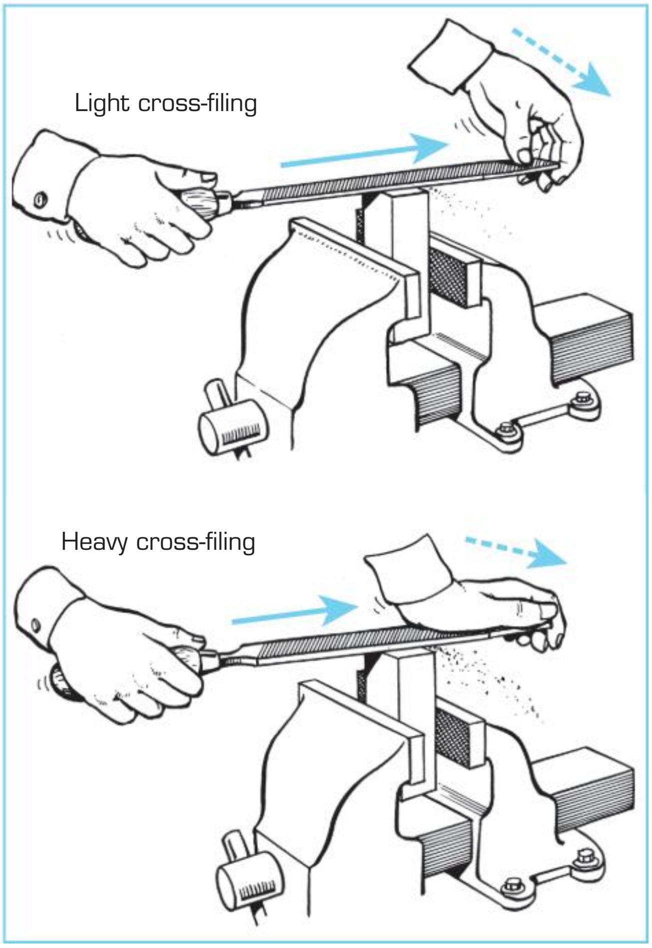
When planing end grain in timber, always support the end of the material to avoid breaking or splitting it. Alternatively, plane towards the centre from both edges.



Filing

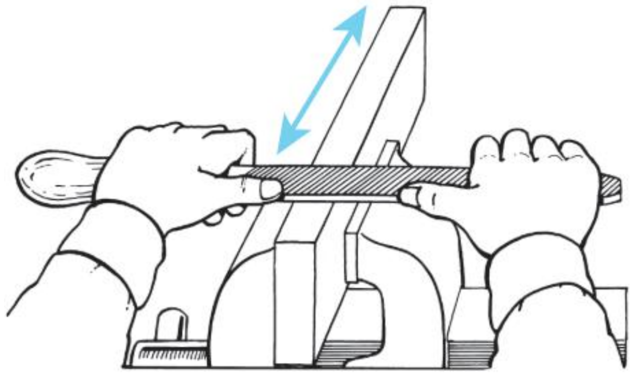
Filing is generally used to finish shaping materials such as metals, plastics and wood after they have been cut. Force is applied to the file on the forward stroke and it is lifted slightly above the work on the backward stroke. There are two techniques.

1 Cross-filing is generally used for quick removal of waste material and shaping the material. The file is pushed forwards and across the work at the same time



Cross-filing

2 Draw-filing is used to give the material a fine finish. The file is usually pushed sideways along the surface



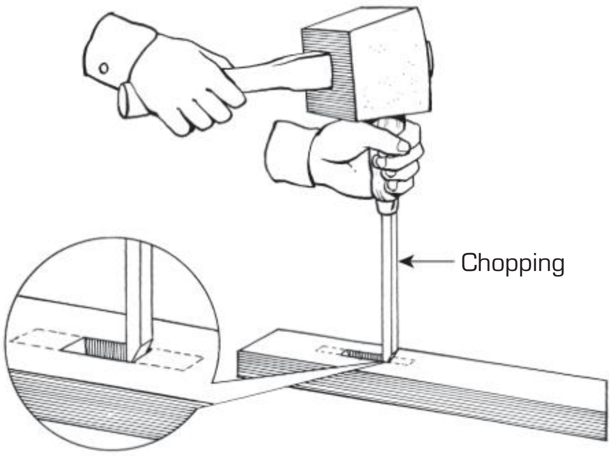
Draw-filing

Waste material caught between the file teeth is called pinning. It may scratch the material and must be removed either with a file card or the end grain of timber.

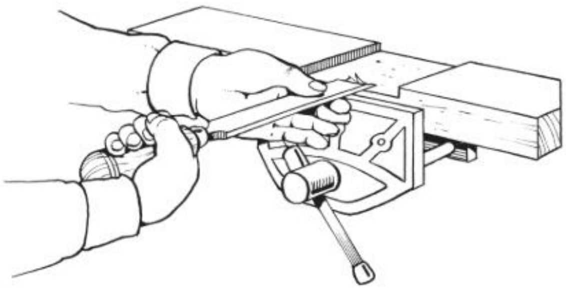
Chiselling

Chiselling is used to remove unwanted material in wood and metals. There are two techniques used when working with wood: chopping and paring.

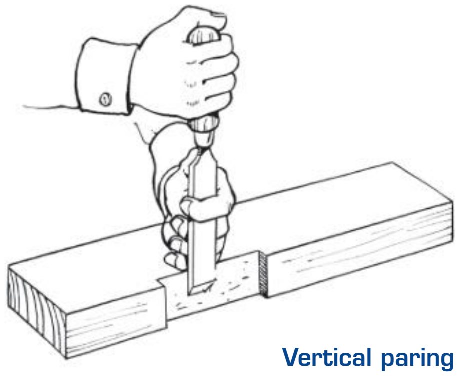
1 Chopping: the chisel is struck with a mallet to remove large pieces of waste.



2 Paring: the chisel is pushed with one hand while the fingers and thumb of the other hand are squeezed to guide and control the cutting edge to remove fine shavings. When paring, keep the flat side of the chisel against the material.

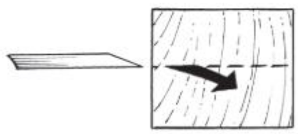


Horizontal paring

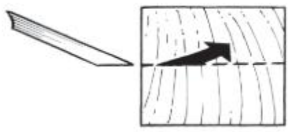


Vertical paring

When chopping a **housing**, use of the chisel with the bevelled surface facing upwards will cause the chisel to dig into the timber. However, keeping the bevelled surface of the chisel against the material will tend to push the chisel away.



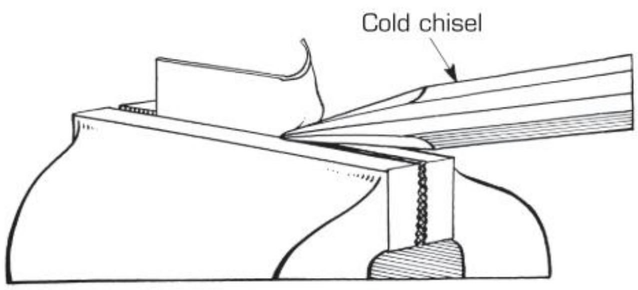
Chisel digs in



Chisel moves up

Metals can be chiselled by using one of two basic techniques: shearing or vertical chiselling.

1 Shearing: the material is held in a vice and the cold chisel is struck with a hammer. The cutting edge of the cold chisel moves along the top of the jaws.



Shearing

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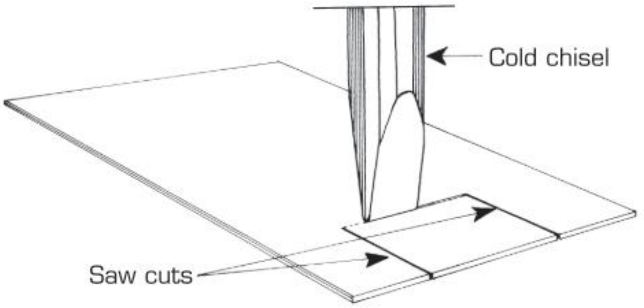
2 Vertical chiselling: the material is placed on a solid surface such as soft steel and the cold chisel is struck with a hammer.

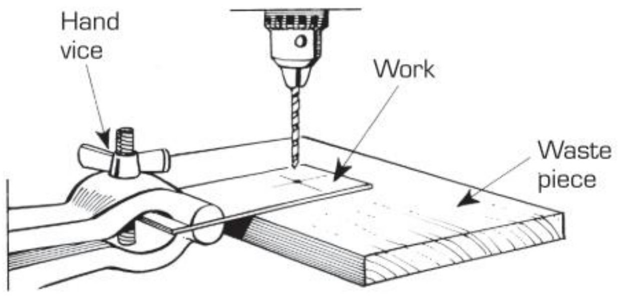


Vertical chiselling

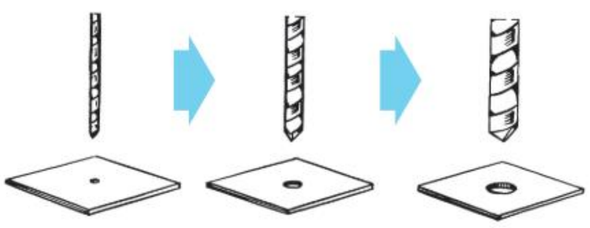
Drilling

Drilling is used to produce holes of various diameters in materials such as metal, plastic, timber and masonry. Before drilling, you need to select the correct drill for the material – for example, a tungsten carbide-tipped drill for masonry. When drilling, use the correct speed. (See page 104.) Also remember to pull the drill out from the work occasionally to clear the waste material and prevent clogging and overheating.

Place a flat piece of scrap material underneath the work to avoid damaging the bottom surface as the drill passes through the material.



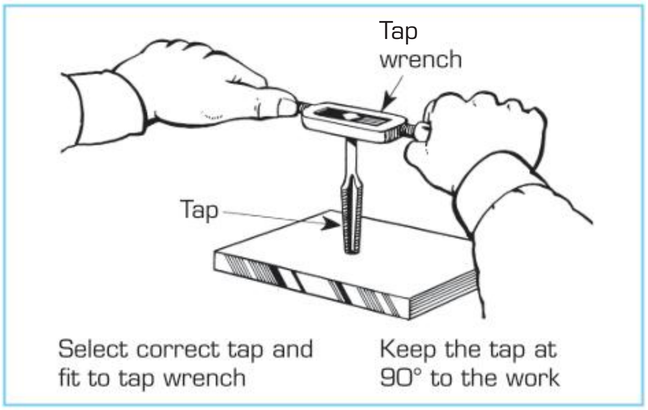
When drilling a large hole, use the series drilling technique: first drill a small pilot hole (say 2–3 millimetres in diameter), then use a series of progressively larger drill bits. This gives a round, accurate hole.



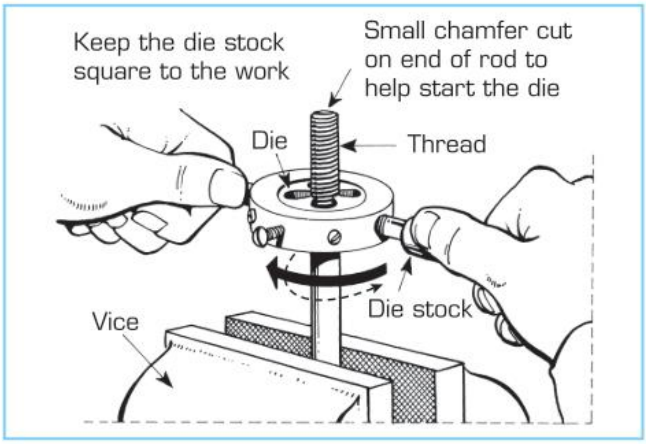
Series drilling

Cutting threads

Tapping is cutting an internal thread using a tap.



Threading is cutting an external thread using a die.



When cutting threads, lubricate with cutting paste where appropriate.

Use this action when cutting the thread: one half-turn clockwise, followed by a three-quarter turn anticlockwise to release the swarf.

You can use a table such as the following one to work out the diameter of a tapping hole for a particular thread size.

Table 6.1 Tapping drill sizes

Thread size	Tapping drill size
M2*	1.6 mm
M2.5	2.1 mm
M3	2.5 mm
M4	3.3 mm
M5	4.2 mm
M6	5.0 mm
M8	6.8 mm
M10	8.5 mm
M12	10.2 mm

*M = metric

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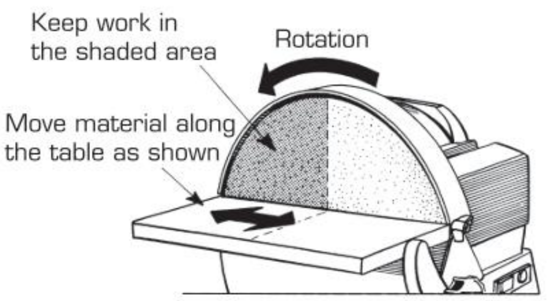
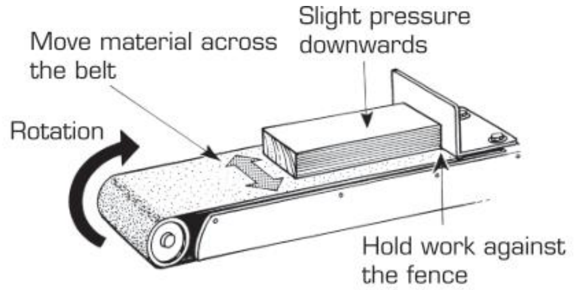
Abrading

Abrading can be used to shape and finish various materials if the appropriate abrasive is selected. (See 'Abrasives' on pages 150–1)

Disc sanders are mainly used for wood (and sometimes for plastic). They can be used to produce flat and convex shapes.



Belt sanders can abrade a range of materials. They can be used to produce flat, convex and (with some machines) even concave shapes. Belt sanders, unlike disc sanders, can be used to evenly abrade the surfaces of long pieces of material.



Take care of your fingers when abrading thin materials or small items.

INFORMATION FILE

Abrasive wheels and discs

Particles of grit are either bonded to one another in the form of a wheel, or coated to a backing material – paper or cloth – in the form of a sanding disc, belt, sheet or roll. A range of grit is used for abrading various materials – for example: silicon carbide; non-ferrous metals and masonry; zirconium; non-ferrous and ferrous metals; aluminium oxide; ferrous metals and ceramics; hard-to-grind metals.

Abrasive wheels have three basic actions. They are to grind, cut and polish.

1 Grinding discs and grinding wheels are available for portable power tools and for fixed power tools such as bench grinders. (See page 116.) Grinding discs and wheels are generally much thicker than cut-off wheels. The grinding disc and wheel need to resist greater forces – whether on the edge or its **face** – when abrading. The thickness of the disc/wheel is usually between 4.5 millimetres and 10 millimetres (for portable power tools); and 13 millimetres and 75 millimetres (for fixed power tools). The diameter of the disc/wheel also varies – for example, from 50 millimetres to 230 millimetres (for portable power tools); and from 100 millimetres to 450 millimetres (for fixed power tools).

   Grinding discs are available in a flexible or rigid form. The flexible disc (including sanding discs) must be used with a back-up pad. The purpose of the back-up pad is to support the disc while abrading.

2 Cut-off wheels are quite thin – 0.8 millimetres to 6.4 millimetres. The wheels are strong in a radial direction. Great care is required to avoid any sideways movement or pressure when cutting materials otherwise the wheel could **shatter**. Cut-off wheels are also available in a range of diameters (for example, 51 millimetres and 600 millimetres).

3 Polishing discs are used to clean, deburr and produce a desired finish. The finish could range from satin (smooth) to mirror.

Abrasive wheels are available in a number of shapes – for example, flat or depressed centre (also known as raised hub).

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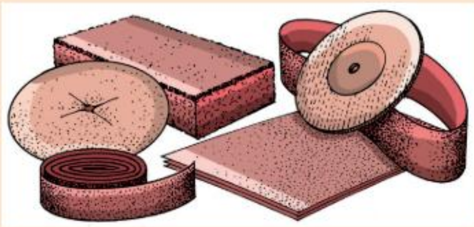
Is it a wheel or is it a disc?

RULE:
- It is a wheel if the edge is used to abrade.
- It is a disc if the face is used to abrade.

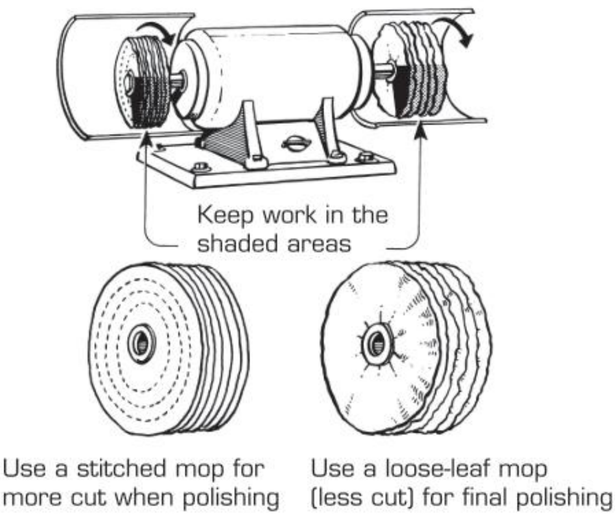


Particles flying off the wheel/disc could injure you and other people nearby.
- Erect a barrier or screen.
- Be aware of sparks, which could cause a fire.
- Hold the work securely in a clamp.
- Use the correct PPE.

Polishing

Polishing is used to remove very small irregularities from the surface of materials such as plastics and metals, and to provide a shiny finish.

A buffing wheel is often used to polish plastics and metal. Various grades of buffing mop are available for abrading or polishing. A buffing compound (such as Polastic for plastic or Tripoli Lustre for metal) is applied to the buffing mop to assist in the process. Cutting and polishing compounds such as Brasso can also be used when polishing by hand.



Buffing mops

Turning

Turning is the process of shaping materials such as metals, plastics and wood on a lathe by:
- holding one end of the material in a chuck or on a face plate
- turning between centres – the material is supported at either end by centres such as spur and cup centres on the woodturning lathe and live and dead centres on the metal lathe. (See pages 118–19.)

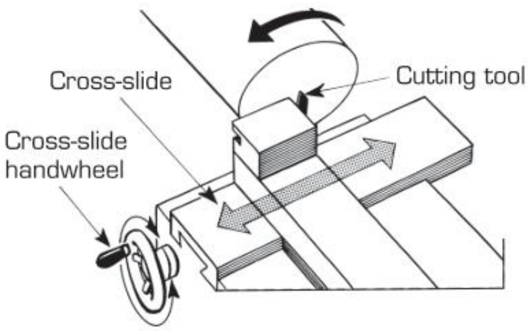
Lathe speed depends on the diameter of the work.

RULE: The *larger* the diameter of the work, the *slower* the lathe speed should be.

Turning metals and plastics

A centre lathe (metal lathe) is used to perform the following three operations.

1 Facing off: to produce a flat surface. The cross-slide handwheel is rotated to move the cutting tool in or out.



Facing off

2 Parallel turning: to produce a cylindrical form. The apron (or longitudinal) handwheel is rotated to move the cutting tool parallel to the axis of rotation.

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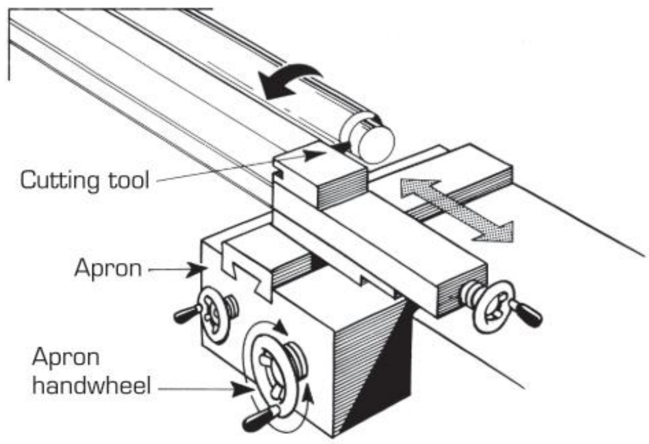
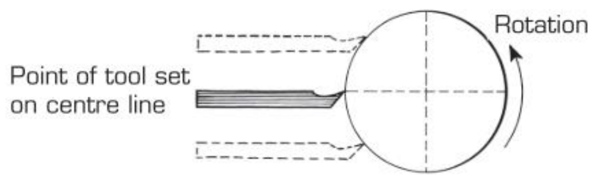
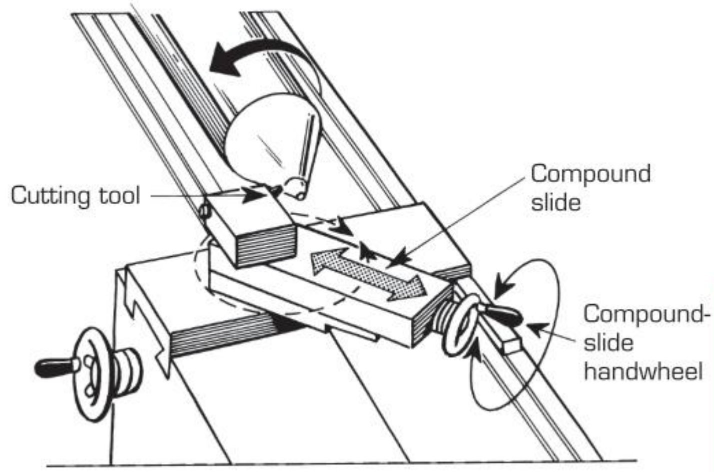


Parallel turning

The cutting tool must be set up with its point exactly at centre height. If the tool is set up above centre, it will rub against the work instead of cutting. A tool set up below centre will dig into the work.

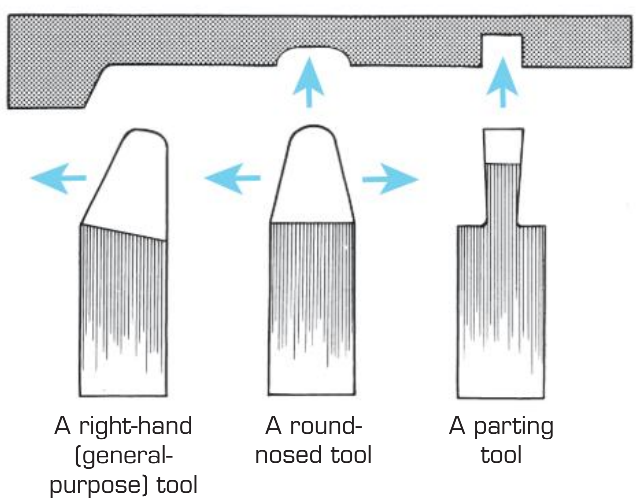


3 Taper turning: to produce a conical shape. The compound slide is set to the required angle and then the compound-slide handwheel is rotated to move the cutting tool.



Taper turning

Centre lathe tools (usually made of high-speed steel) have different shapes for different functions, as shown below.



Centre lathe cutting tools

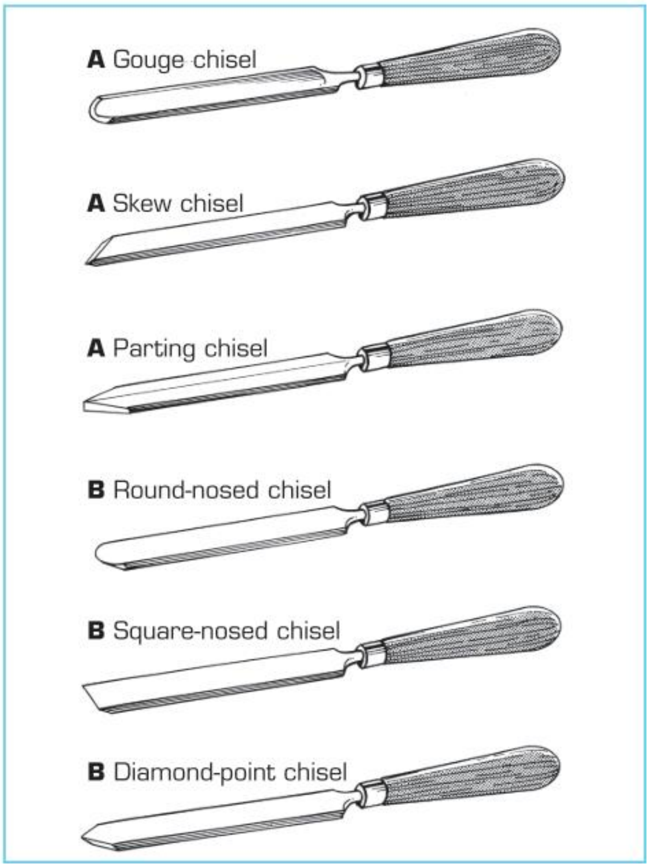
Turning wood

A woodturning lathe, like the metal lathe, is used for:

- turning between centres
- face-plate turning: to turn items such as bowls and moulds.

There are a number of lathe tools with specific functions. They fall into two categories:

- cutting tools, such as gouges and skew chisels
- scraping tools, such as square-nosed and diamond-point chisels.



A – cutting tools B – scraping tools

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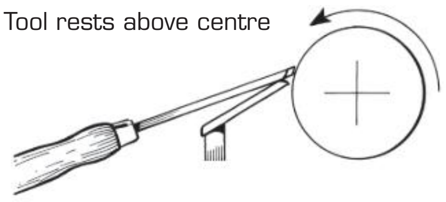
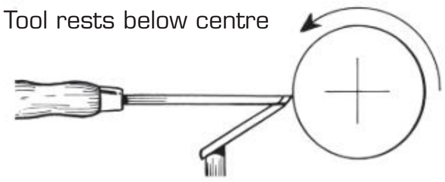
To achieve the correct cutting and scraping actions, the tools must be set up as shown here.

When turning between centres and shaping the material, start from the tailstock end. Then work towards the headstock to lessen the possibility of shearing the wood if the lathe tool digs in.

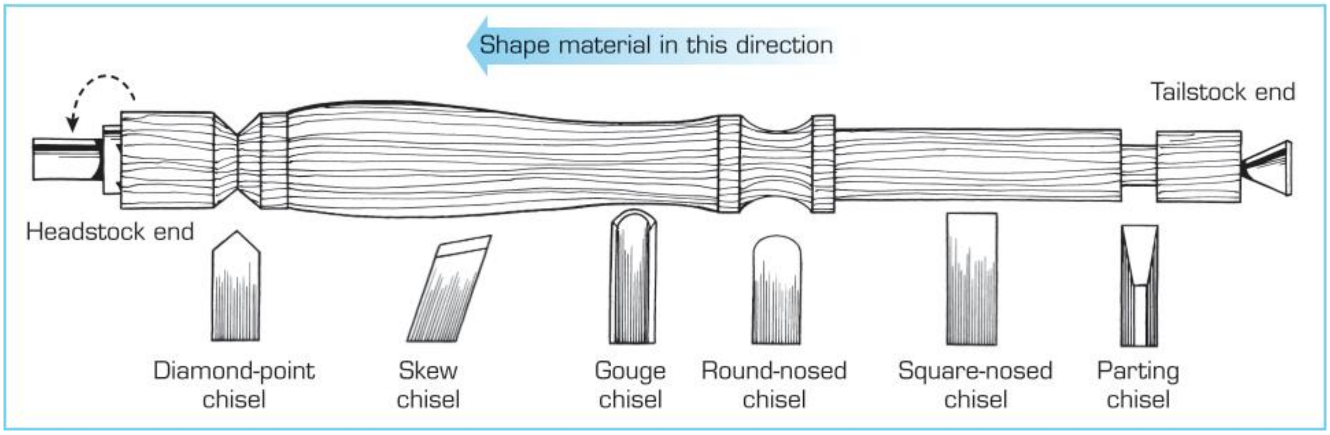


A cutting tool



A scraping tool

Woodturning tools have different shapes for different functions, as shown below.



Woodturning tools

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Part C: The combining process

In this section, you will learn:

- about techniques used to combine materials
- about different types of fasteners and their uses
- about adhesives and their uses
- in which situation to use particular joining techniques.

Materials are combined or joined using four methods. They are:

- mechanical fastening – using screws, bolts, nails and other types of fasteners
- chemical adhesion – using glues and adhesives or solder
- jointing – through interlocking of the components
- cohesion – by means of solvents or welding.

Mechanical fastening

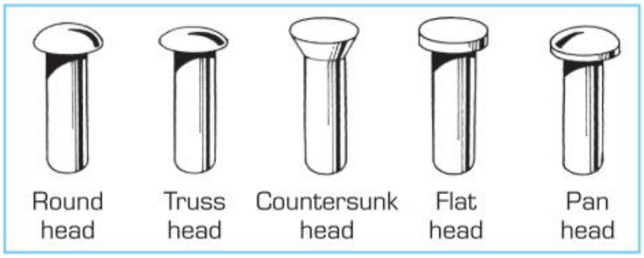
A fastening device is one that holds two or more parts firmly together. Fasteners can be grouped into two categories: permanent fasteners and semi-permanent fasteners.

Permanent fasteners

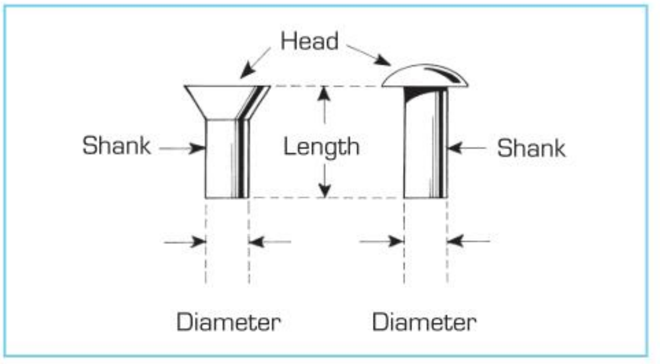
When a permanent fastener is used, the parts that it joins cannot be separated without causing damage or destruction.

Solid rivets

Rivets can be used to join metals and soft materials such as leather. They are named according to their head shape, and are available in various sizes and in different materials such as steel, copper and aluminium.

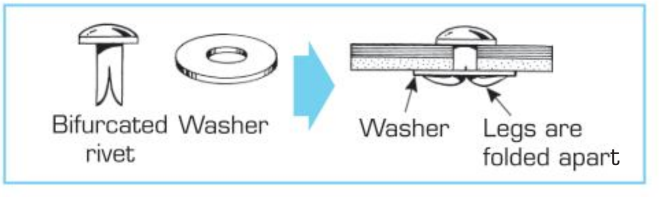


Rivets for general metalworking



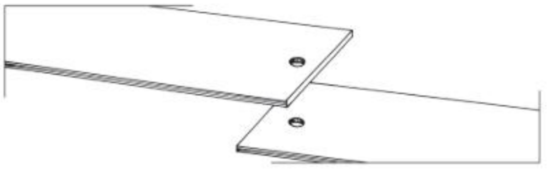
The parts of a rivet

Bifurcated rivets are used to join soft materials such as leather. A washer is sometimes used for added support.



Forming the rivet head

1 Drill or punch a hole through both pieces of material to be joined. Remove any **burrs** with a file.



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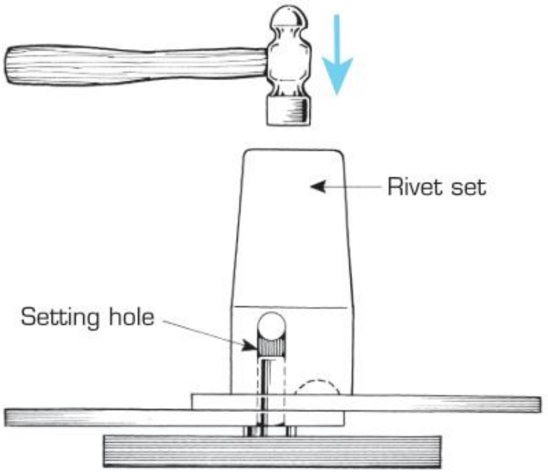
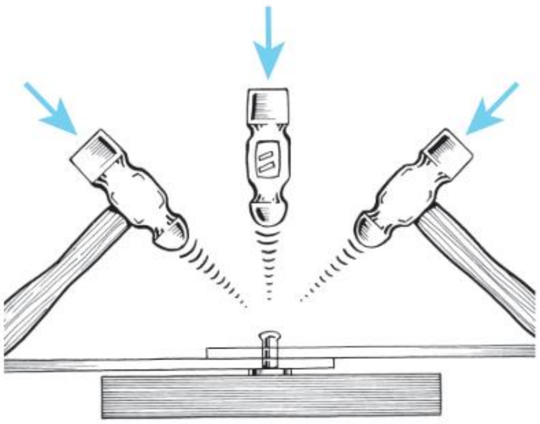
2 Put in the rivet and support its head. Use the setting hole of a rivet set to squeeze the materials together.



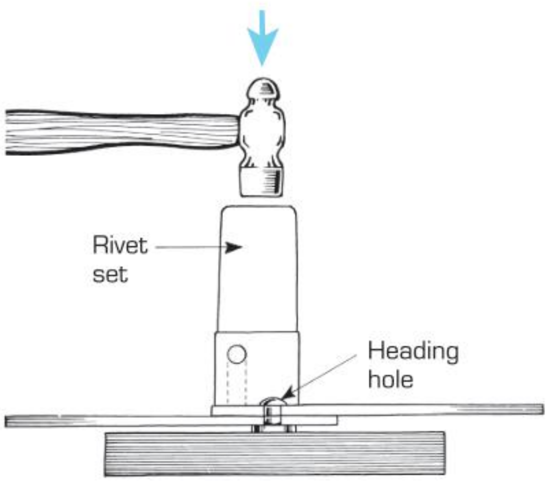
Setting the rivet

Then hammer the end of the rivet to form a mushroom shape. (Use a cross-pein or ball-pein hammer.)



Forming the head

3 Use the heading hole of the rivet set to form a uniform dome-shaped head.



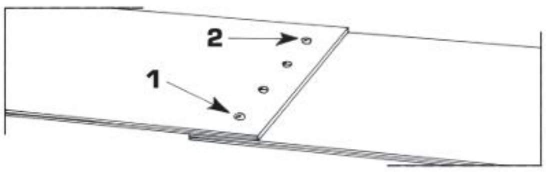
Shaping the head

If you need to use more than one rivet, follow these steps.

1 Drill or punch hole **1** and fit rivet.

2 Drill or punch hole **2** and fit rivet. Now the material cannot move.

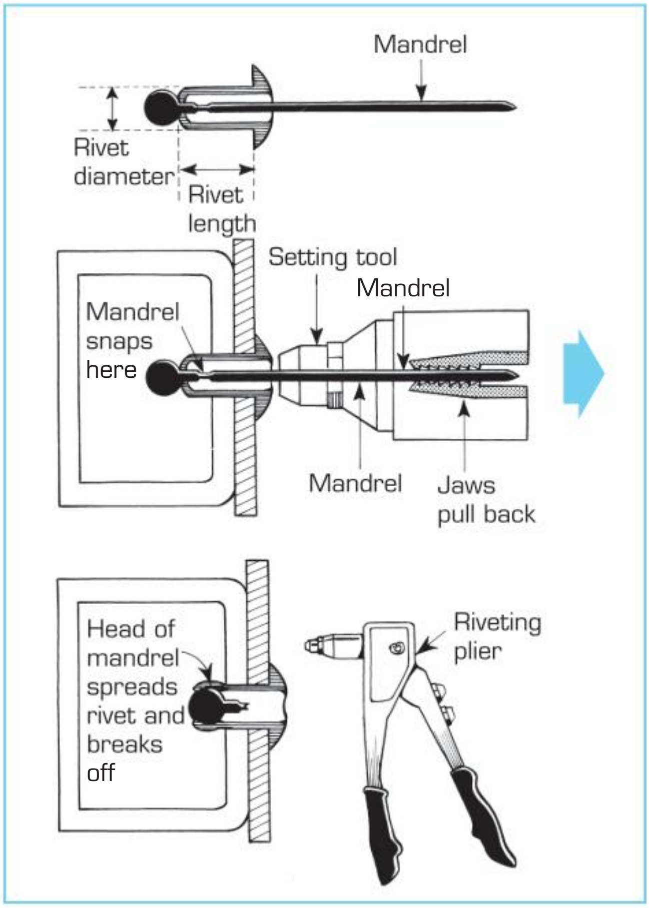
3 Drill holes and fit any rivets required between holes **1** and **2**.



If you try to drill all the holes at once, it is most unlikely that they will line up exactly.

Blind rivets

Blind (pop) rivets are used for speed and convenience. They are also used when the work cannot be supported on one side, or when it is accessible from one side only. A special plier is used to draw the mandrel through the rivet. Pop rivets are available in various types (such as open, sealed or hollow), in various sizes, and in various materials, such as steel, aluminium and stainless steel.



Setting a pop rivet

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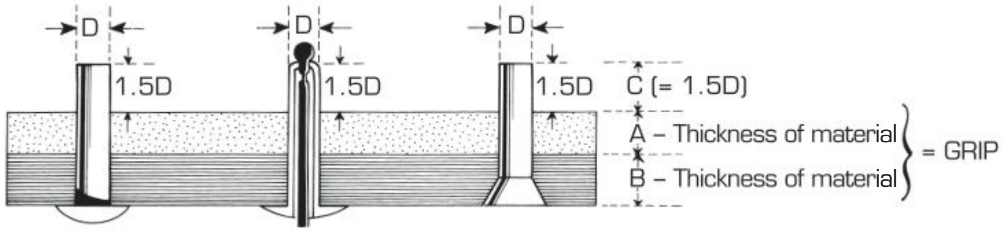
When buying rivets, you need to state:

200	12	×	3	Round head	Aluminium	Solid rivets
Quantity (number)	Length (mm)		Shank diameter (mm)	Type of head	Type of material	Type of rivet

To calculate how long a rivet should be when it is used to combine two materials, you should use the rule below: Note that the diameter of the rivet determines its strength.



RULE: A + B + C = Total length of rivet *OR* GRIP + 1.5D = Total length of rivet

Nails

Nailing is a quick and easy joining method. Nails are mainly used to join timber. They can also be used to join other materials (such as metal or upholstery) to timber. There are many different types of nail available for many different uses.

Table 6.2 Nail types and their applications

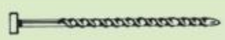
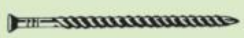
Applications	Nail types	
Hardwood and hardwood framing Edging and finishing work	**Bullet head** or **helical threaded nails** Galvanised if corrosion resistance is required	
Softwood and softwood framing	**Flat-head** or **threaded flat-head nails** Galvanised if corrosion resistance is required	
Hardboard underlay sheets	**Underlay nails** Annular threaded	
Plywood sheets/panelling and wallboard for interior walls	**Wallboard nails** Zinc plated	
Hardboard, e.g. Masonite	**Hardboard nails** Bright or zinc plated	
Particle board, e.g. Trudek, Pyneboard	**Particle board nails** Helical thread	
Fibre cement sheets, e.g. Hardiflex	**Flex sheet nails** Galvanised	
Timber decking, timber cladding	**Timberlok* nails** Galvanised – helical thread	
Exterior thin sheet metal	**Clouts** Galvanised	
Exterior thick sheet metal	**Bracket nails** Galvanised	

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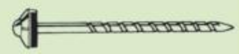
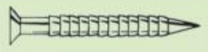
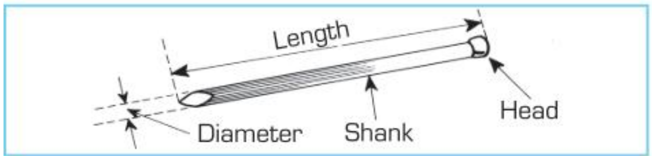
Table 6.2 Nail types and their applications (*continued*)

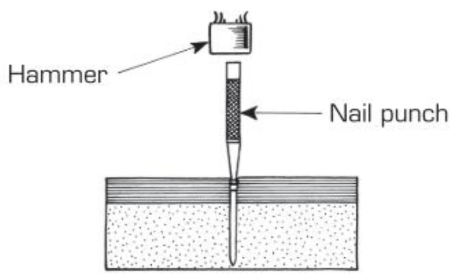
Applications	Nail types	
Steel corrugated roofing	**Roofing nails** Plain galvanised	
	Roofing nails Galvanised twisted shank	
	Roofing nails Super Holdfast* galvanised helical thread	
Plasterboard sheets, e.g. Victorboard, Gyprock, Plasterboard	**Lattice head* nails** Zinc plated – annular thread	
Finishing work and fine joinery	**Panel pins**	

*Registered trade names of Spurway Cooke nails

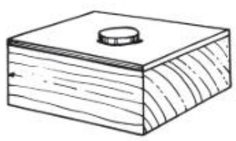


The parts of a nail

A small-diameter head (as with a bullet-head nail) is designed to be punched below the surface of the timber.



A large head is designed to exert a force on a material (as in the case of a clout fixing metal onto wood or a tack fixing fabric onto wood).



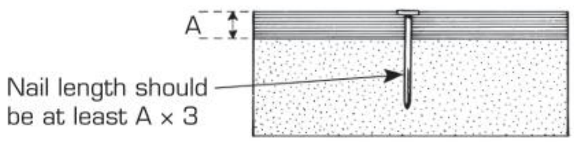
When buying nails you need to state:

1 kg	30	×	1.6	Bullet-head	Bright	Steel nails
Quantity (usually by mass)	Length (mm)		Shank diameter (mm)	Type of head	Finish	Type of material

Nails come in a variety of lengths. To select the correct length of nail, you need to know the thickness of the material to be nailed into place.

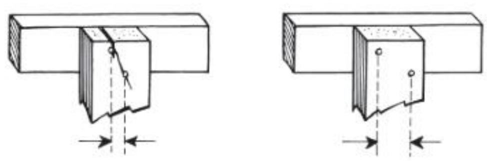
> **RULE:** Select a nail length at least *three times* the thickness of the material. The nail length should never be less than twice this thickness.

Always nail the thin piece of material to the thicker piece.



The length of a nail

Timber has a grain. If nails are placed too close to each other, the timber may split along the grain. You have to be especially careful to avoid splitting when nailing near the end of a piece of timber.



Nails are too close, causing splitting along the grain

Well-staggered nailing prevents splitting

Positioning nails

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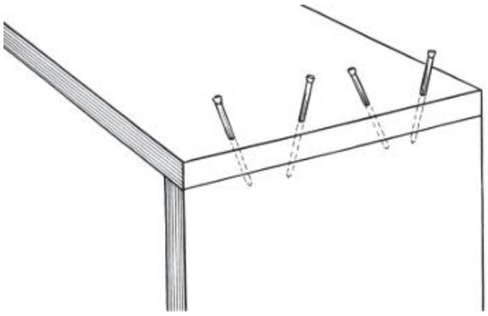
Alternatively, before nailing, drill a hole slightly smaller than the diameter of the shank. This is recommended for hardwood.

If you drive nails perpendicularly, you rely on the wood fibres to hold the nail into the timber. If you slope the nails in opposite directions, two pieces of timber can be held together much more strongly. This is called ‘dovetail’ nailing.



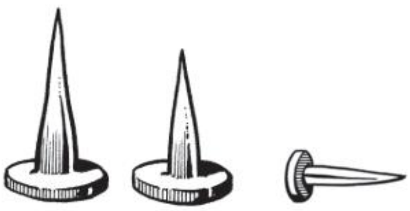
Dovetail nailing

Blue-cut tacks, gimp pins and furniture studs

Blue-cut tacks, gimp pins and furniture studs are mainly used in upholstery.

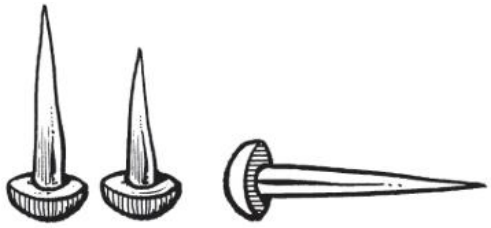
Blue-cut tacks (or tacks) are available in two basic types: fine and improved. The fine tack has a small head, while the improved tack has a larger head and is designed for exerting greater force on the fabric. They come in a range of sizes from 10 millimetres up to 16 millimetres. Tacks are used to attach webbing and fabrics that will not be seen.

Gimp pins are small, fine tacks that are available in a range of different colours. They are used in upholstery where the head of the tack is seen – for example, general tacking or fixing a braid.



Blue-cut tacks A gimp pin

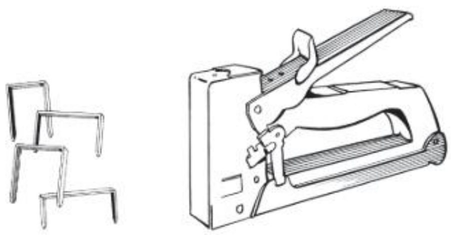
Furniture studs (or decorative nails) have a dome-shaped head. They are used in places where the head of the nail is seen. These nails are available in a range of shapes and finishes. The visual appeal of the item can be enhanced greatly by choosing an appropriate decorative nail and applying an elaborate nailing pattern.



Furniture studs

Staples

Staples, like nails and tacks, can be used to join materials such as plywood and upholstery to a timber frame. They are available in a range of sizes – for example, 3 millimetres to 13 millimetres leg length and various crown widths. Staples can be driven by a hand stapler, electric stapling gun or pneumatic stapling gun.



Staples A manual stapling gun

Semi-permanent fasteners

A semi-permanent fastener is one that is used when it might be necessary to dismantle or adjust components at a later date. The most common types of semi-permanent fastener are **threaded fasteners**.

- **Nuts:** these are fitted to the ends of bolts and metal thread screws or threaded round rods.
- **Bolts:** these have a solid head at one end and a metal thread at the other.
- **Screws:** metal thread screws, self-tapping screws or wood screws.

A commonly used screw head slot is the Phillips screw head. The Phillips slot centres the screwdriver bit and does not slip out easily when rotated. This type of screw head slot is preferred given the popularity of cordless power drills. It is a quick way to fasten materials.

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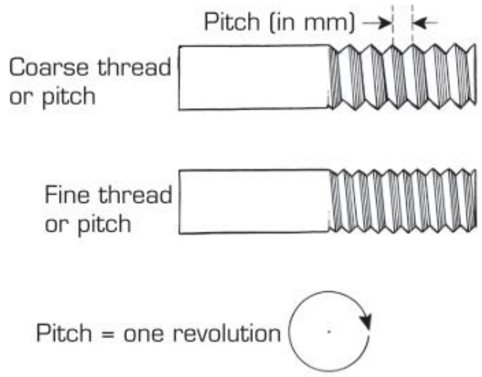
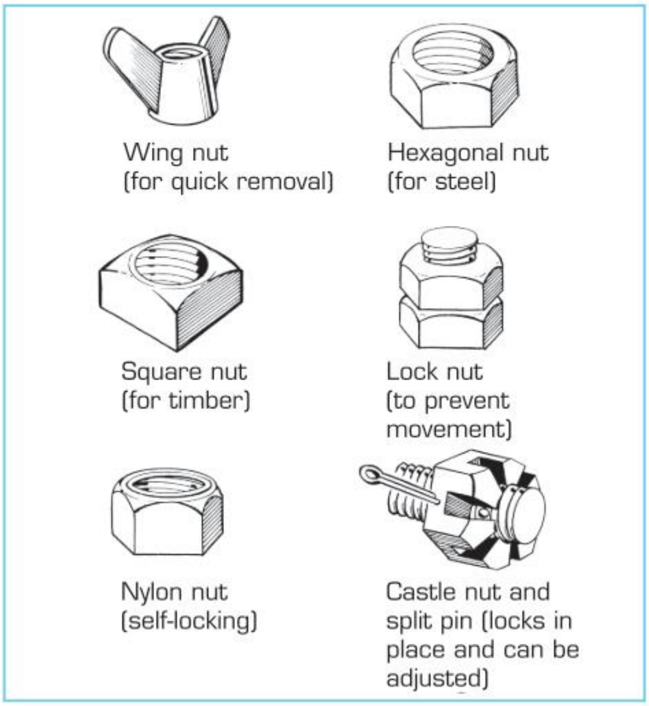
The threads on nuts, bolts and screws range from coarse thread or pitch to fine thread or pitch. Pitch is one revolution.



Nuts and bolts

Nuts are made in various shapes for a variety of applications as shown below.



Nuts

When ordering bolts, you need to state:

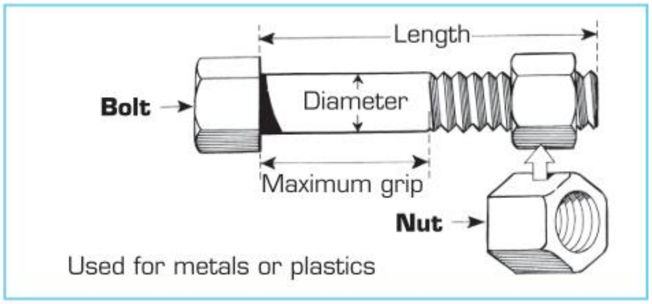
M*12	×	1.75	Hexagonal head	Steel bolt	3	/	75
Diameter (mm)		Pitch (mm)	Type of head	Type of material	Number required		Length (mm)

*M = metric

Note that bolts can also be purchased in imperial units, e.g. ½" × 3" Whitworth, hexagonal head, steel bolt (" = inches).

Bolts are available in various diameters and pitches. They are also made from various materials and in various strengths – for example, standard steel and high-tensile steel.

Nuts and bolts are usually sold together.



The parts of a bolt

Cup-head bolts are used for heavy construction in timber.

Cup-head bolt

Washers are used to spread the load of the nut on a surface or to lessen vibration. They are made from materials such as steel, brass, stainless steel, copper and nylon.

Washers

Metal thread screws

Metal thread screws have a thread (usually V-shaped) that matches a mating component such as a nut. These screws are made from a variety of metals and can have a variety of finishes. They are identified by their head shape.

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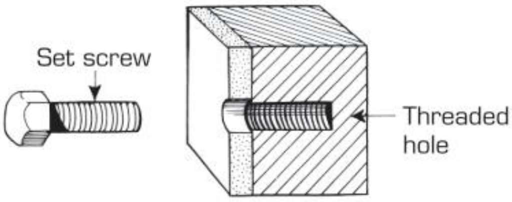
Metal thread screws can be used to join sheet metal to sheet metal or to a light metal frame (as in sheet metal cabinets).

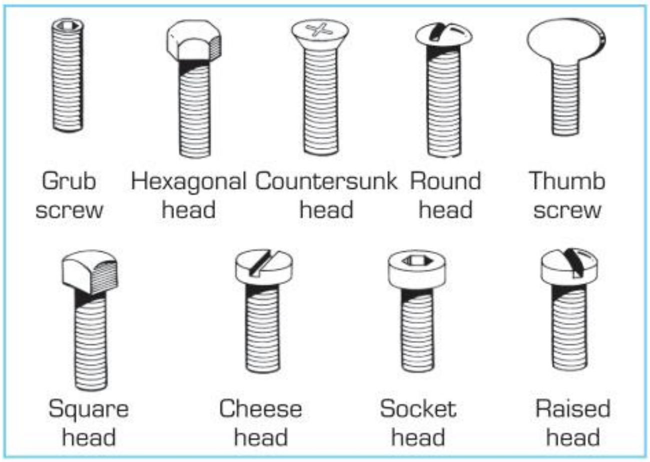
Metal thread screws and nuts

Set screws

Set screws are threaded along their shank as close as possible to the head. They are used in threaded holes and therefore do not require nuts. Because they are generally used to join machine components, they are sometimes called machine screws.



Set screws are available in a range of head shapes, as shown below.

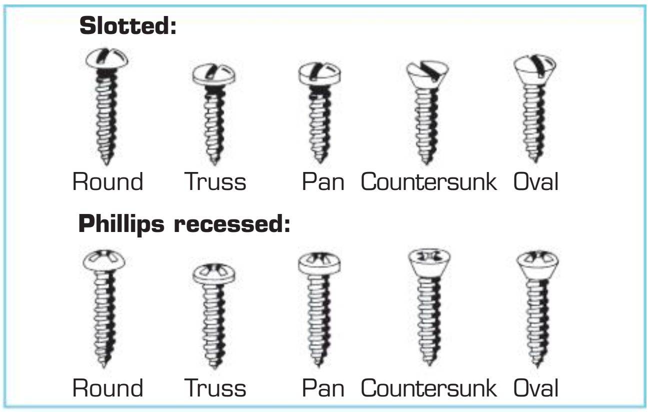


Set screws

Self-tapping screws

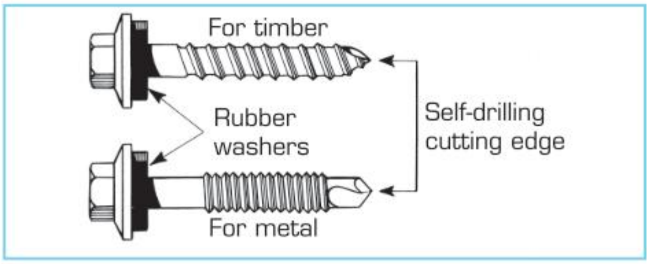
Self-tapping screws cut their own thread-path as they are screwed into a hole drilled in plastic, metal or wood to secure one component to another. They are generally used to secure thin-gauge materials to each other or to thicker material.

When ordering self-tapping screws, you need to state:



Self-tapping screws

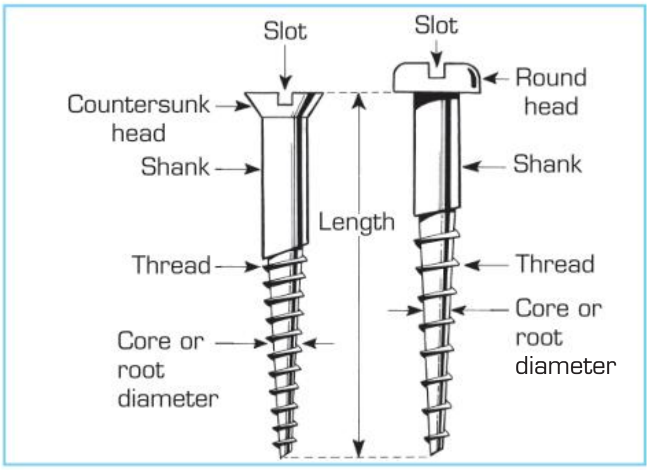
Self-drilling self-tapping screws drill their own hole as well as cutting their own thread.



Self-drilling, self-tapping roofing screws

Screws for wood

Wood screws can be used as semi-permanent fasteners as well as permanent fasteners. They join wood more strongly than nails (except when screwed into the end grain), and can be removed without causing any damage. They are made from various metals, such as steel and brass.



The parts of a countersunk screw (left) and a round-head screw

200	6G	×	20 mm	Phillips, countersunk	Stainless steel	Self-tapping screws
Quantity	Gauge*		Length	Type of head	Type of material	Type of fastener

*The gauge is a measure of the diameter of the screw shank.

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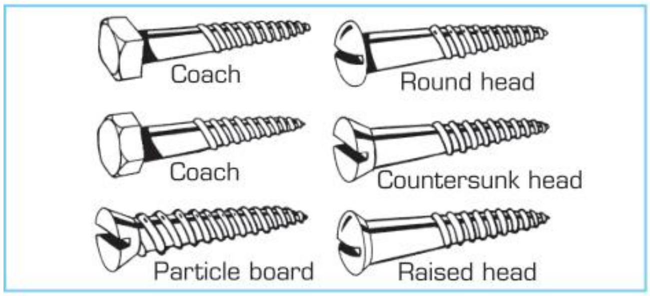
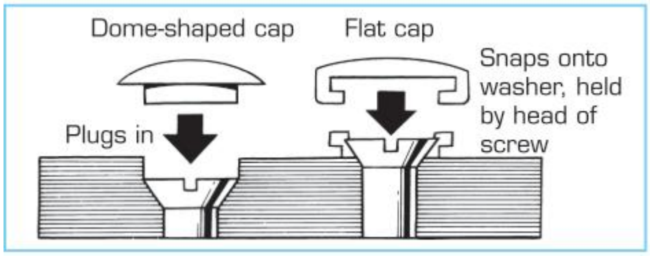
Types of wood screws and their uses

- **Coach:** for heavy work such as gate hinges and fastening down light machines to bench tops.
- **Particle board:** to screw into particle board.
- **Round head:** to fix metal to wood where the metal is too thin to be countersunk – for example, when fixing a barrel bolt to a door or gate.
- **Countersunk head:** for general-purpose work, where the head of the screw is to be flush with or below the surface – for example, when attaching a hinge to a door.
- **Raised head:** for decorative work, such as fastening metal handles and fittings on furniture.



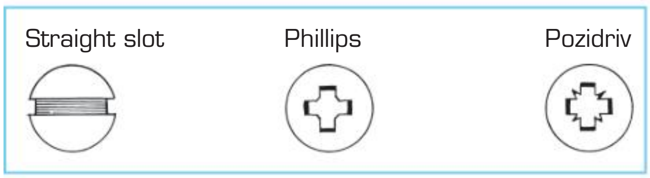
Wood screws

A variety of caps can be used to hide the head of the screw, as shown below.



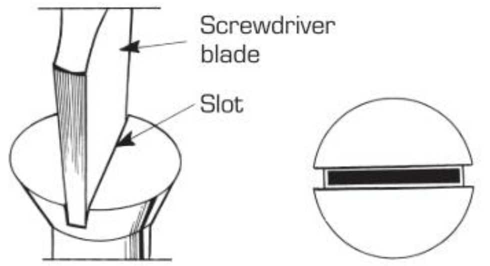
Screw caps

There are three basic types of screw slots.



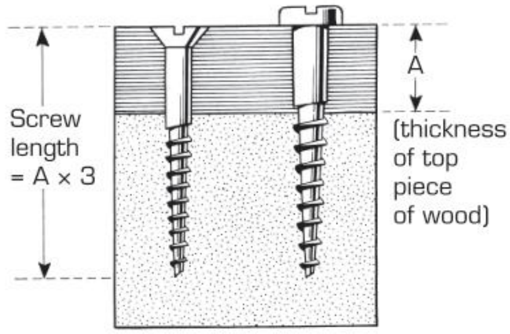
Screws

The screwdriver blade must fit the slot snugly. If it is too thin or if it is the incorrect width, damage may be caused to the screw or to the material.

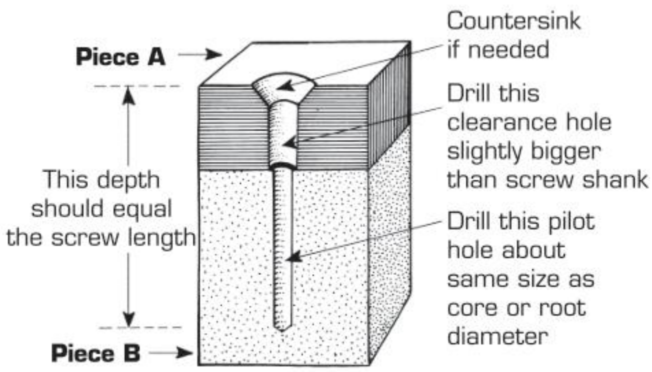


The screwdriver blade must fit the slot snugly.

To select the correct length of screw, use this formula:



When drilling holes for a screw to join two pieces of timber, you should follow the guidelines given in the diagram below.



When buying wood screws, you need to state:

200	6G	× 20 mm	(6G × 3/4")**	Phillips, countersunk	Particle board wood screws	Zinc plated	Steel
Quantity	Gauge*	Length (mm)	Length (inches)	Type of head	Type of screw	Type of finish	Type of metal

*The gauge is a measure of the diameter of the screw shank. The higher the gauge number, the larger the diameter. For example, a 6G screw has a diameter of about 3.5 mm, while a 14G screw has a diameter of about 6 mm.

**Note that the length of wood screws is still given in imperial units (inches) as well as metric units (mm).

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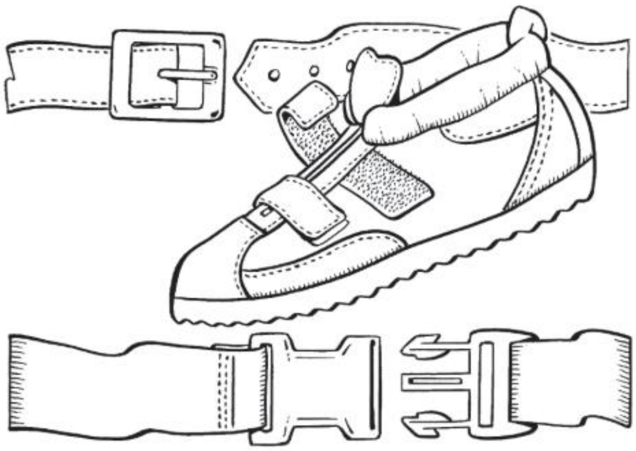
Pull-apart fasteners

Pull-apart fasteners such as zips, press studs, buckles and Velcro are generally used with natural materials such as textiles, rubber and leather. They allow for easy joining and separating of materials.

No tools are needed to open and close these fasteners. They use twin or mating parts that interlock.



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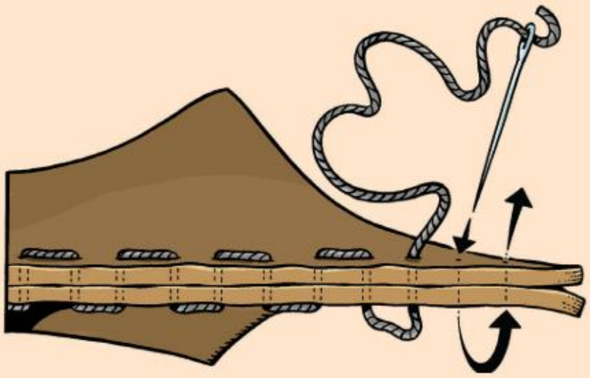
Other types of pull-apart fasteners

Stitching

Many natural materials, especially fabrics, can be combined using a thread and needle. This is known as stitching. Stitching can be done by hand or using a sewing machine.

The needle is used to produce a hole in the fabric in order to pass the thread through. As the thread is pulled tight, the materials are joined. This process is repeated along the seam.

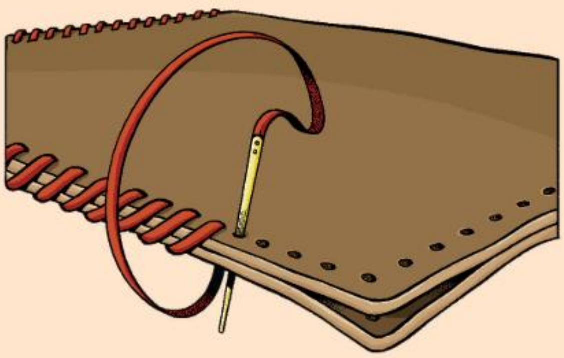
RULE: The finer the material, the thinner the needle.



Sewing leather using a running stitch

Lacing

Some materials are joined by lacing. The lace – cord, string or thong – can be round or flat. Like stitching, a hole or eye is required to pass the lace through the materials.



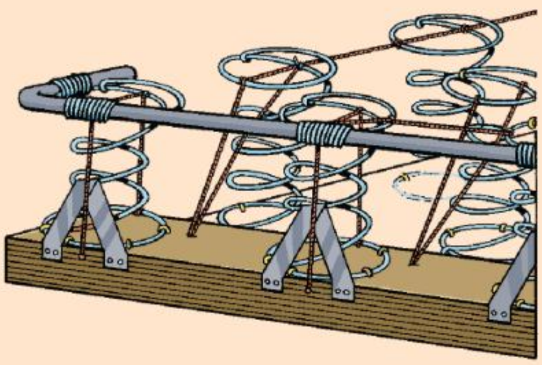
Lacing leather with a thong

Lashing

Materials can also be joined by lashing. In lashing, thread, twine or rope is used to secure items.

Whipping

Whipping is the process by which items are bound with a cord. The materials are first positioned in place. The cord is then passed around the materials a number of times to secure them.



Using lashing and whipping to secure springs

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Pull-apart fasteners are often secured to the material using stitching. In some instances, an adhesive is also applied to the surfaces being joined for additional strength.

Chemical adhesion

Most materials, whether they are similar or dissimilar, can be joined using either:

- pure animal or vegetable glues
- polymer-based adhesives.

There are four main aspects to consider when selecting a glue or adhesive.

1. The *types of materials* to be joined:
   - Are they similar or dissimilar?
   - Are they porous or non-porous?
   - Are they thick or thin?
2. The *surface condition* of the materials:
   - Must they be free from grease and dust?
   - Must they be dry or wet?
   - Must they be porous or non-porous?
   - Must they be smooth or rough?
3. The kinds of *stresses* to which the join will be subjected:
   - Will it have to bear a load?
   - Is it for indoor or outdoor use?
   - Are there gaps in the join that have to be filled?
4. Whether the adhesion is required to be *permanent* or *temporary*: Will the components be dismantled in the future?

There are four kinds of adhesive.

1. Natural adhesives such as animal glue
2. Thermoplastic adhesives such as polyvinyl acetate (PVA)
3. Thermosetting adhesives such as epoxy resin
4. Elastomers such as contact adhesives

Note: When similar materials are to be combined, there may be more suitable means of bonding them than using adhesives – for example, mortar can be used for bricks, and solvents can be used for plastics.

Commonly used adhesives

ADHESIVES

1 Animal glue – natural
- made from hoofs and hides of cattle
- must be used hot
- a non-staining glue that is very strong and durable when used in dry conditions
- *shelf life*: no limit

2 Polyvinyl acetate (PVA) adhesive (e.g. Aquadhere) – thermoplastic
- a white plastic emulsion in ready-to-use form
- a strong adhesive that is suitable for porous surfaces only
- not completely waterproof
- suitable for use with interior woodwork
- not recommended for joins under high permanent load, as the adhesive creeps when subjected to a load
- *shelf life*: indefinite if container is kept sealed

3 Urea formaldehyde adhesive – thermosetting
- available in liquid or powder form
- suitable for use with hard, resinous timber
- resists moisture better than PVA adhesive
- has some gap-filling properties
- produces a strong bond after one week
- *shelf life*: 6 to 12 months

4 Cyanoacrylate adhesive ('super glue') – thermoplastic
- gives an extremely strong bond
- cures quickly – handling strength is achieved within seconds
- no clamping is required
- only a thin film is applied
- suitable for bonding metals, plastics, rubber, ceramics, wood, leather, paper and cork in any combination
- *shelf life*: one year

Take extra care when using 'super glues' because of their powerful adhesive properties.
Wear PPE (e.g. gloves)

5 Epoxy resin adhesive (e.g. Araldite) – thermosetting
- may be two-part epoxy resin (equal parts of resin and hardener have to be mixed) or single-part epoxy resin (the components are pre-mixed and heat cures the adhesive)
- has good gap-filling properties
- gives an extremely strong bond, with no shrinkage
- suitable for bonding metals, glass, wood, rubber, ceramics and concrete
- water resistant
- expensive
- *shelf life*: 6 to 12 months

6 Contact or rubber-based adhesive (e.g. Kwik Grip) – elastomer
- both surfaces must be coated with a film of adhesive, which has to be 'touch dry' before the components are joined
- not suited to woodworking
- no clamping is required
- produces a flexible joint
- suitable for bonding dissimilar materials – for example, bonding laminated plastics, fabrics or vinyl to timber
- *shelf life*: 12 months if gelling has not occurred

7 Resorcinol formaldehyde adhesive – thermosetting
- highly resistant to moisture
- has good gap-filling properties
- excellent for boat-building and for outdoor furniture
- stains wood
- *shelf life*: 3 to 6 months

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Adhesive curing times may be lengthened by low atmospheric temperatures when adhesives are used in cold climates.

> Many adhesives are highly flammable and some also give off toxic fumes. Keep them away from naked flames and work in a well-ventilated area.

Hot-melt guns are fitted with a cylindrical glue stick. When the trigger is pressed, the glue is heated and driven out of the nozzle to set within seconds. A range of glue sticks is available to suit different materials.

A hot-melt gun

Soldering

Soldering is the process of joining two pieces of metal, usually sheet, by melting another metal (the solder) between them. There are two types.

- **Soft soldering** uses a solder such as a tinman's solder – an alloy of 50 per cent tin and 50 per cent lead.
- **Hard soldering** or brazing, as it is commonly known, uses solders – for example, brass and silver.

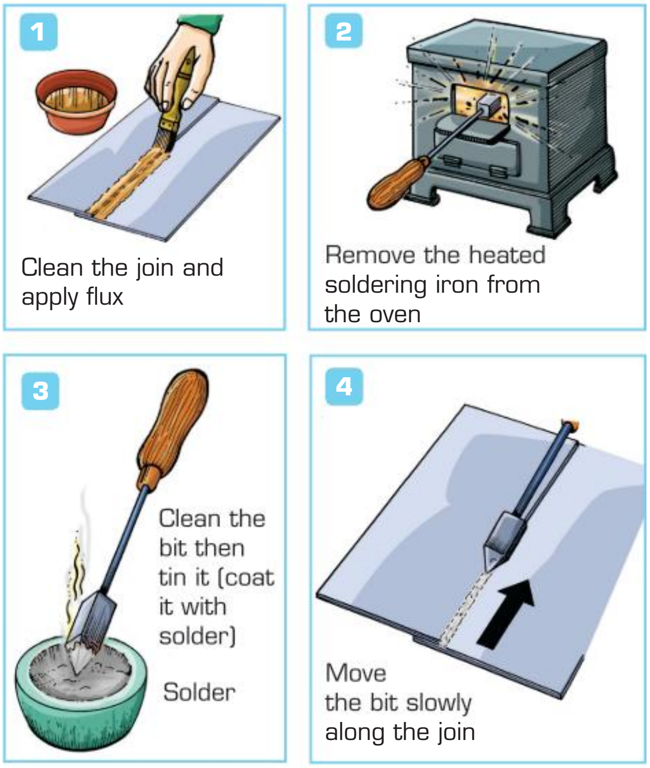
The surfaces to be soldered must be clean (that is, free from oil and rust) and close fitting. A **flux** is applied to the surface before soldering to:

- clean the metal and remove the film of oxide
- assist the solder to flow more easily into the join.

> Beware of hot surfaces. Use PPE (for example, gloves or tongs).

Soft soldering

The heated soldering iron or bit is dipped into a diluted solution of flux and water to remove the oxide from it. The cleaned bit is then tinned by rolling it in solder, which melts and flows onto it. The tinned bit is next moved slowly along the join to be soldered. As the metal heats up, the solder flows from the bit into the join. The excess flux should be removed with a damp cloth or by washing it off with water.



The steps in soft soldering

Brazing

The metals are heated with a flame using either a gas torch (for example, propane) or an oxyacetylene torch (a mixture of oxygen and acetylene gases). When the metal becomes hot – a dull red colour – the fluxed solder is applied to the join. The solder will flow easily if there is sufficient heat in the join. Additional heat may be applied to the join to aid flow of the solder.

Brazing

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Take care not to overheat the join. Allow it to cool. Clean the join with a damp cloth or water to remove excess flux.

Jointing

Joints are an alternative to mechanical fasteners and adhesives when combining similar materials – for example timber–timber, metal–metal and plastic–plastic.

Joints are used:

- to widen material (making large flat surfaces such as a sail or a table top)
- for carcase construction (building box shapes such as drawers)
- for framing (2D or 3D frames, such as flat frames in windows or supporting frames in tables).

Many joints have been developed for use with a particular material – for example, the dovetail joint is best suited to joining timber. However, as new materials and tools have been developed, it has become possible to use some joints with many materials.

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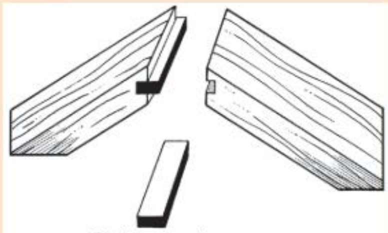
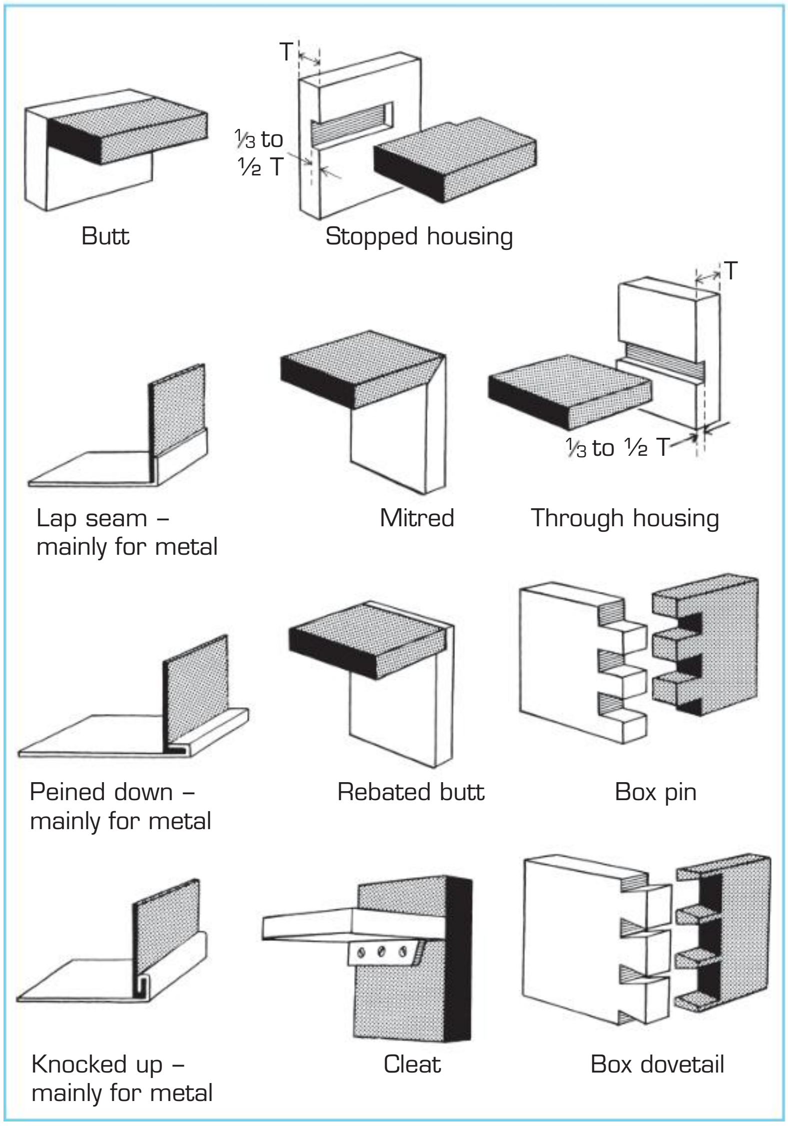
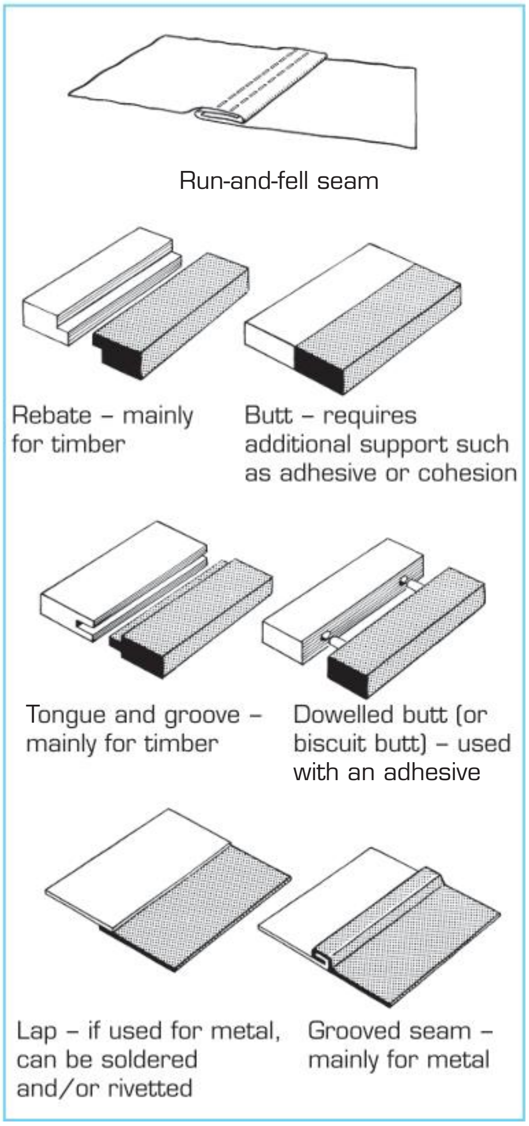
A **gluing strip**, or biscuit, is often used along mitred edges (or butt joints) to reinforce the joints.





The joints used for carcase construction



The joints used for widening

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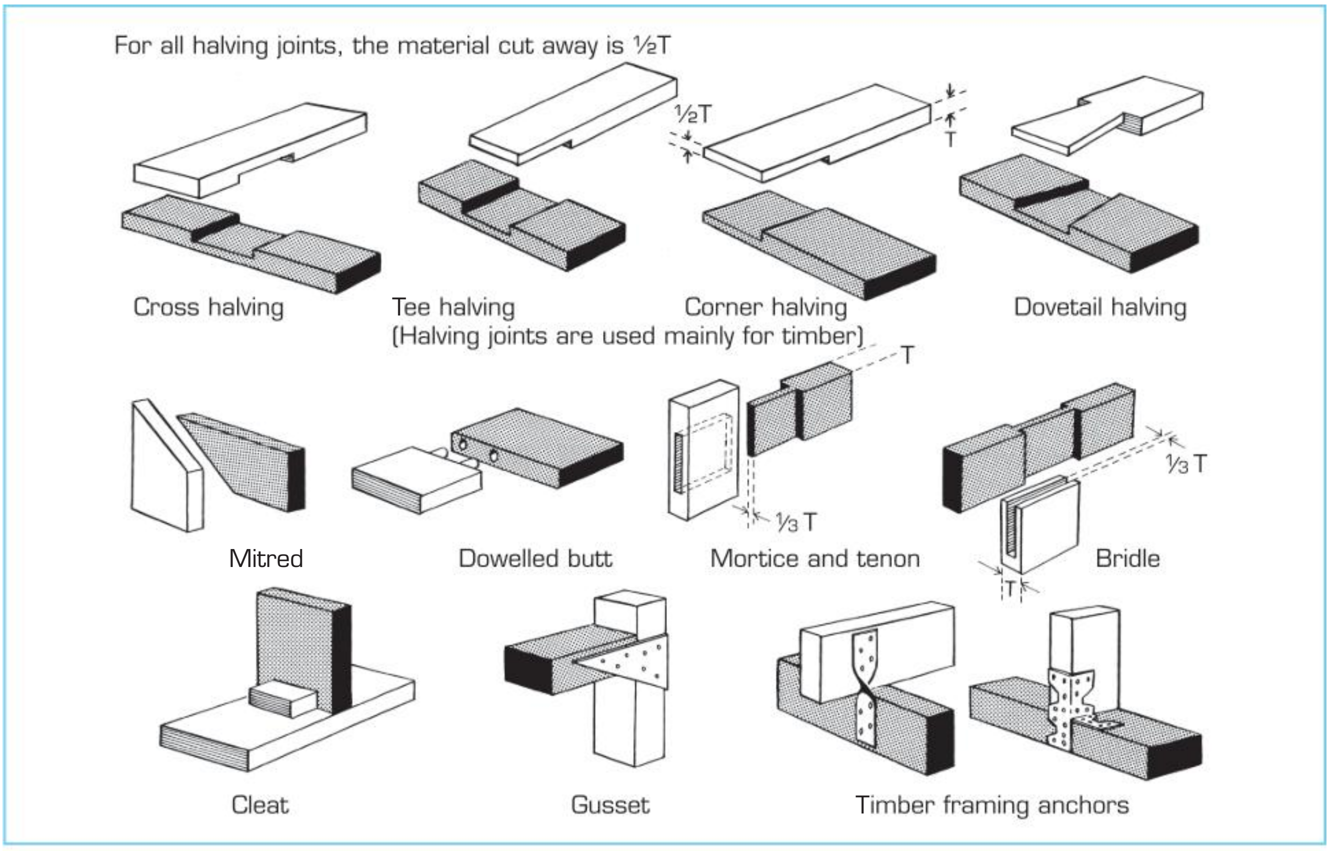


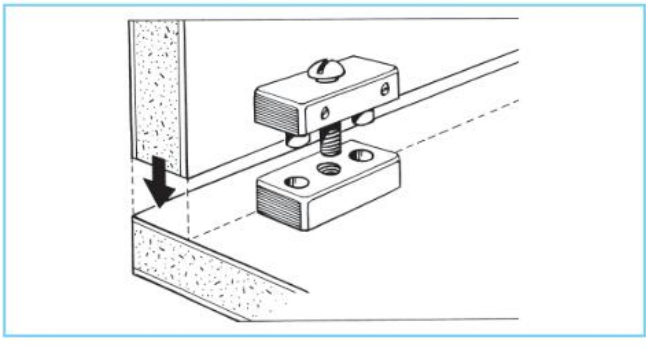
The joints used in framing

Knock-down fittings

Most joints are considered to be permanent, but knock-down (KD) fittings are semi permanent; they are a quick and easy way of assembling or dismantling parts of a construction. KD fittings are used mainly to join manufactured boards where traditional joining methods are not suitable. They are often used to assemble bulky items supplied in kit form, such as flat-pack furniture.

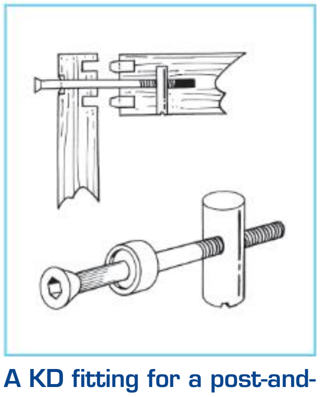
Flat-pack furniture

However, the cost of KD fittings prevents them from being used as a common joining method. Care must also be taken to select the appropriate KD fitting for the particular application.



A KD fitting for joining manufactured board such as particle board

KD fittings for joining timber



A KD fitting for a post-and-rail assembly such as a chair or coffee table

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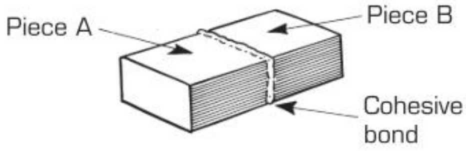
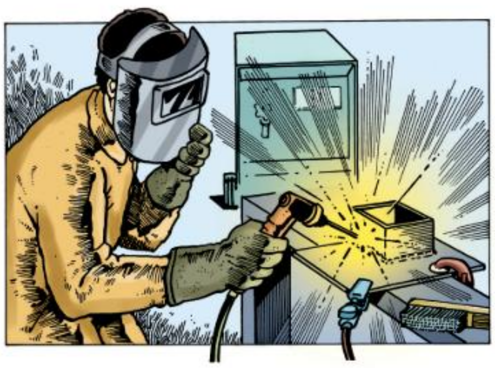
Cohesion

In the process of cohesion, two pieces of the same material (such as plastic–plastic or metal–metal) are joined through the intermingling of molecules from adjacent surfaces.



Cohesive bonding can be achieved by:

- using solvents – for example, to join acrylic, the surfaces to be joined are dissolved using a solvent such as ethylene dichloride. The solvent-softened surfaces are then placed together. As the solvent evaporates, the acrylic hardens to form a join.
- welding – for example, when joining steel by arc welding, an electric current flows between an electrode and the metal to be welded. The heat produced causes the metal to melt and the electrode itself melts, acting as a filler rod and helping to build up molten metal at the join. When the metal cools, a weld has been formed.

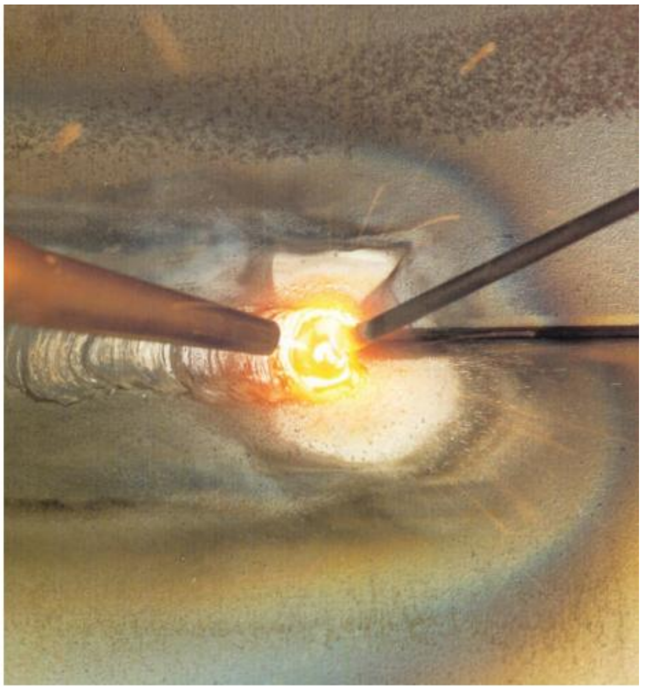


Arc welding (note the PPE that is worn)

In spot welding, two pieces of sheet metal are placed between electrodes that clamp onto them. When the current is switched on, it passes through the sheet metal between the electrodes and melts it to form a small, circular cohesive bond.

Spot welding

In oxyacetylene welding, the intense flame melts the metal at the join. A filler rod may also be melted into the join to form a pool of molten metal. Upon cooling, the metal is bonded.



Welding metal with an oxyacetylene torch and a filler rod

In the hot-air welding process for plastics, the plastic is heated with hot air until its surface softens. A filler rod is fed into the softened area. Upon cooling, a strong cohesive bond is formed.

A hot-air welder

Some universal equipment may have an age restriction in your State or Territory. Legislation prevents underaged people from using this tool. This is for your safety. Check with your teacher.

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Part D: Finishing

In this section, you will learn:

- about abrasives
- about finishes
- about finishing techniques
- in which situations to use particular abrasives and finishing techniques.

Finishing is the process of preparing and coating the surface of any manufactured or constructed item. The main function of a finish is to protect and beautify a surface.

Many finishes give off fumes during curing that are harmful to your health.

- Work in a well-ventilated area, as exposure to fumes may result in a headache or nausea.
- Wear PPE.

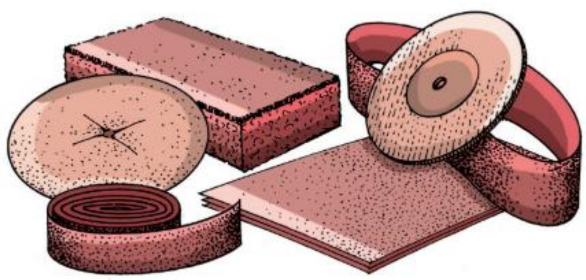
Many types of finishes have been developed for different materials and for special purposes. For example, metal objects can be painted, polished, galvanised or chromed – the choice of finish will depend on how the objects are going to be used, and the cost involved.

Note that some items may require a different finishing process. Their surfaces are not protected and beautified with a finish but by applying a covering. For example, pieces of furniture such as a sofa and an office chair would be finished with an upholstery covering such as fabric or leather.

Abrasives

Abrasives are used to clean and smooth a surface by cutting away the top layers or any irregularities in the material. The cutting agent in commonly used abrasives is particles of grit. These are generally bonded to a backing material – paper, cloth or foam – or bonded to one another in the form of a disc or wheel. The grit particles may be natural (such as garnet) or synthetic (such as aluminium oxide).

Common abrasives



Glass paper: grit (crushed glass) bonded to paper backing (mainly used for wood)
Garnet paper: natural red grit bonded to paper backing (mainly used for wood)
Emery cloth and emery tape: emery particles bonded to cloth backing (mainly used for metals)
Silicon carbide paper (wet and dry paper): can be used wet or dry (mainly used for plastics, non-ferrous metals, granite, marble and single-pack paint)
Aluminium oxide paper (wet and dry paper) can be used wet or dry (mainly used on two-pack paints)
Abrasive discs and wheels: mainly used for metals
Abrasive foam pad: grit bonded to foam pad, for use on curved or uneven surfaces

Other abrasives

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There is a range of other commonly used abrasives. They are:

- abrasive compound: for polishing
- steel wool: for awkward shapes
- grinding paste: mainly for metals
- buffing compound: for use with a buffing machine.

Abrasive paper

Abrasive papers can be classified as 'open coat' abrasives or 'closed coat' abrasives.

The abrasive particles are evenly spaced out on open-coat abrasive papers, which are used on painted surfaces or resinous timber (such as radiata pine) that could clog the abrasive. Closed-coat abrasive papers have tightly packed abrasive particles and are generally used on materials that do not readily clog the abrasive (such as metals and hardwood).

Abrasives are graded according to the size of the mesh through which the grit particles pass. There are three grades:

- coarse (grit size 20–80)
- medium (grit size 100–200)
- fine (grit size 200–600).

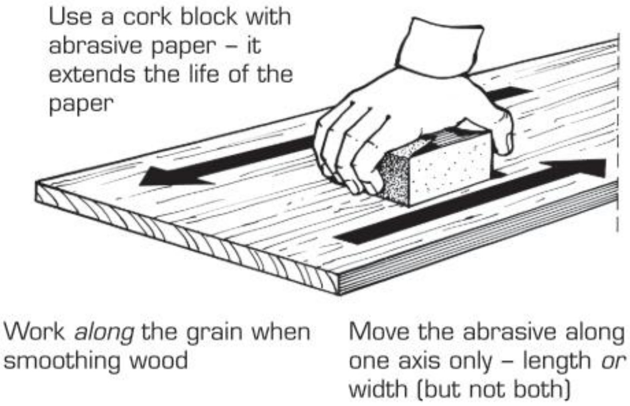
Note that there are a number of grading systems used for grit around the world. Thus, the grit size of the three basic grades may vary a bit.

Silicon carbide paper is available in grit sizes ranging from 60 to 2000.

Aluminium oxide paper is available in grit sizes ranging from 36 to 1500.

The grade is printed on the back of abrasive paper.

RULE:
1 Use a coarse-grade abrasive paper first.
2 Then use a medium-grade paper.
3 Finish off with a fine-grade paper.



The technique of sanding

Types of finish

There is a range of finishes for different materials and for special purposes.

Paint

Paint is a general term for a preparation that acts as a preservative, protecting against moisture, chemicals and the sun's rays. It also acts as a beautifying agent and adds aesthetic appeal – for example, when applying colour to fabrics (direct, spray or transfer painting). There are three types of paint.

1 **Primers and sealers**
   - for sealing bare surfaces (especially unpainted metal or bare timber)
   - to provide proper adhesion for the next coat
2 **Undercoats**
   - to provide a cover for bare surfaces
   - to provide a cover for primed or sealed surfaces
   - to smooth out any minor surface irregularities
3 **Finishing coats (topcoats)**
   - to protect previously painted or treated surfaces
   - to improve the appearance of the surface

Paints are manufactured for a wide range of special uses including exterior use, interior use or to resist steam. However, they all belong to two main groups:

- enamel (oil-based) paint: after use, clean up brushes and equipment in mineral turpentine

- acrylic (water-based) paint: clean up brushes and equipment in water.

Dispose of clean-up waste responsibly. Care for the environment.

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Transparent finishes

Transparent finishes are generally used to display or enhance the natural features of a material such as timber while still protecting it. Another example is Scotchguard, which is used on fabrics for protection from stains and moisture. They do not require special primers or undercoats.

Polyurethane varnish (gloss, satin or matt finish) – used on timber to show off the grain

Beeswax or carnauba wax – used to seal timber, especially when woodturning

Lacquer – used to protect metals or wood (generally sprayed on)

Oil finish – used on porous timbers

Stains

Stains are used to colour wood without concealing its grain. They are used to change from one timber colour to another – for example, from pine to mahogany – or to colour-match different varieties of timber. Stains enable the decorator to match or contrast timber with furnishings.

Some common stains are:

- water stains: dissolved in water
- spirit stains: dissolved in methylated spirits
- oil stains: dissolved in turpentine.

Dyes

Dyes are used to colour textiles and hides. Examples of dyeing fabric are batik and tie-dyeing. (A dye can also be added at different stages of textile production – for example, the fibre, yarn, fabric or product stage.) There are two types of dye.

- Natural dyes include beetroot, tea, turmeric and raspberries.
- Synthetic dyes are manufactured in powder form and available in a large range of colours. These dyes can be used in low-temperature or high-temperature water. Always read the manufacturer's instructions prior to use.

- Wear gloves and an apron when using dyes.
- Take care when handling dye solutions.
- Work in a well-ventilated area when using mordants, which are toxic and corrosive. (Mordants are used as a fixing agent for the dye.)
- Dispose of mordants responsibly.
- Care for the environment.

Inks

Inks, like dyes, can be used to colour fabrics using block and screen printing methods. They can also be used to colour other materials, but special care is often required to prevent bleeding.

Polishing

Polishing is a finishing process in which very small irregularities are removed from the surface of the material using an abrasive compound and a buffing cloth or mop. For example, metal can be polished using either Brasso and a cloth, or a buffing compound applied to a suitable buffing mop on a buffing machine.

Upholstery coverings

Upholstery coverings can be grouped into three categories:

- natural (such as cotton, silk, wool and leather)
- manufactured (such as rayon, polyester and acrylic)
- blended: natural (such as cotton-linen); natural and manufactured (such as cotton-rayon, cotton-polyester and wool-nylon).

When selecting a fabric for upholstery, consider using a medium- to heavy-weight cloth.

You also need to know its:

- fibre content
- thread count: higher is better (as measured in a square with 25-millimetre sides); a tight weave is a good indication
- abrasion rating (for example, light or heavy duty)
- fire-retardancy rating.

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This information will assist you in selecting a fabric that is suitable for the intended purpose and safe to use. (For more detail on selecting a covering, see 'The covering' on page 155.)

Some common upholstery fabrics are:

- hessian, scrim and calico: used mainly in traditional upholstery to locate and protect materials under the cover. (See 'What is upholstery?' on pages 154–5.)
- acrylic, chintz, cotton, linen and nylon (usually blended); polyester (usually blended); triacetate (usually blended); viscose rayon (usually blended); and wool can be used for the cover
- jacquard, tapestry, canvas, damask, denim, folkweave, muslin, satin and velvet (known as traditional woven fabrics) can also be used for the cover.

Finishing techniques

To achieve a good finish, it is essential to:

- prepare the surface thoroughly so that it is clean and smooth
- select the appropriate finish
- use the correct finishing technique.

Basic steps in finishing materials

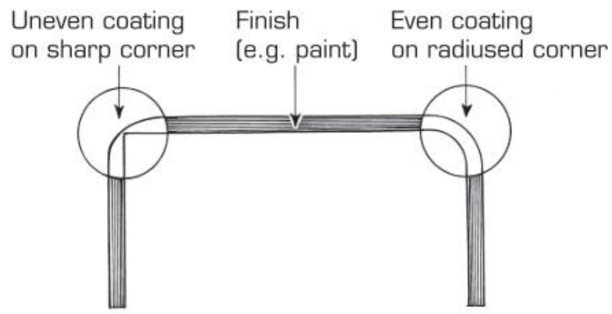
1. Plane or file
2. Fill blemishes
3. Grind or sand – coarse
4. Use scraper, if desired
5. Grind or sand – smooth
6. Cleanse surface
7. Apply finish*

*Carry out light sanding between coats to smooth off any irregularities and to slightly roughen the surface so that the next layer of finish has good adhesion.

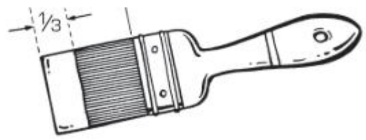
Finishes can be applied in a number of ways – for example, by brush, roller, cloth or spray gun.

Hints for solving finishing problems

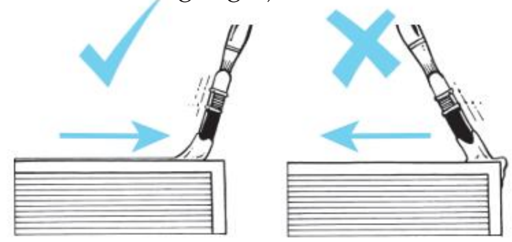
1 Round off sharp corners before applying a finish.



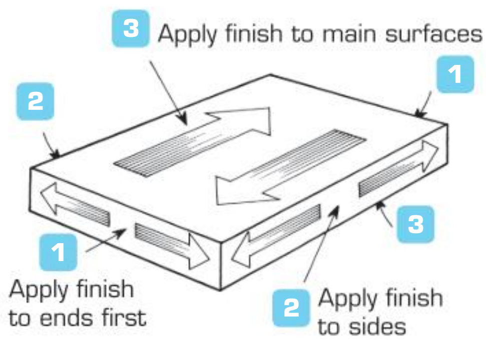
2 Don't overload a brush: dip it into the finish to cover only a third of the bristle length. Wipe off the excess finish.



3 To avoid runs along edges, brush *towards* the edge.

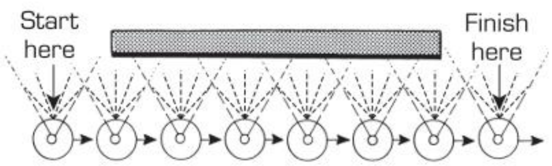


4 When applying a finish with a brush, follow this sequence if there are a number of faces to be coated.

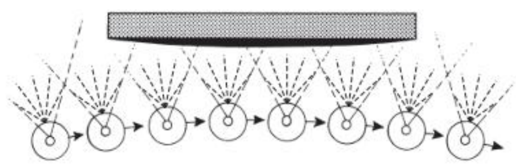


Using a spray gun or spray can

For an even coating, move the gun *parallel* to the surface being coated.



An uneven coating will result if the gun is moved in an arc.



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INFORMATION FILE

What is upholstery?

Upholstery is the process by which a raw piece of furniture such as a chair or sofa is covered with a material. The purpose of this material is to make the item more comfortable and to add aesthetic appeal to it and its surrounds.

The upholstery process is made up of four elements:

- the frame
- the springing
- the padding
- the covering.

A cut-away of an upholstered chair showing the four basic elements

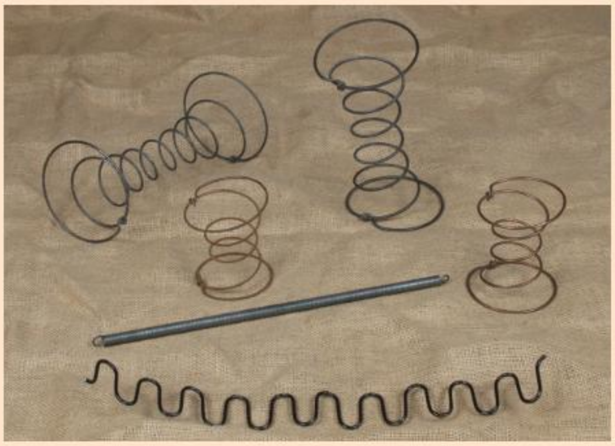
The frame

A well-constructed frame using the appropriate joints will ensure strength, stability and many years of service. (See the illustration 'The joints used in framing' on page 148.)

Traditionally, frames were made of timber. A frame may be covered or exposed. Rough-sawn timber can be used for frame members that are to have a covering. **Dressed-all round (DAR) timber** is used for frame members that will be seen. The application of an appropriate finish is essential to protect and enhance the grain of the wood and add aesthetic appeal.

The springing

The type of springing will dictate the comfort level. The range of springing includes **webbing** (least elasticity), rubber straps, no-sag (zig-zag) springs, tension (cable) springs and coil (hourglass or waisted) springs.



Types of springing

The quality of the springing when using webbing or straps is determined by the number used and how well they are attached. For example, webbing should be folded at the end for added strength, then fixed in place using tacks or staples.

Straps and webbing can also be fixed to the frame using clips, hooks and plates at each end. The webbing should be interlaced as in a weave to produce a firm and strong platform.

Webbing

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In traditional upholstery, coils (also known as double-cone springs) were mounted on webbing, lashed to each other and to the frame, and then covered with hessian. This provided the upholstery foundation for the piece of furniture prior to applying the padding.

The padding

Much of the padding used in mass-produced items is polyurethane foam. High resiliency (HR) foam is an ideal choice for seating cushions. Foam is available in a range of densities.

Wadding is a soft material – for example, polyester – consisting of loose fibres and is available in sheets. It is often placed over the foam for added comfort.

Stuffing is the term used to describe padding – for example, horse hair, fibre or coir made from coconut husks – used in traditional upholstery. It is used to shape the item and to add comfort.

The stuffing is held in place with woven cloth – for example, scrim (first layer cover) and calico (second layer cover). The scrim and calico are tacked to the frame. Stitching is used to hold and set the stuffing in place and prevent it from moving. A wadding must be used under the final cover to prevent the stuffing from working its way through.

The development of plastics and modern furniture-making processes has resulted in the use of many new padding materials.

Extruded plastic mouldings

For example, extruded plastic mouldings as shown below have replaced traditional edge padding and piping. This has resulted in time and cost savings.

The covering

There are many types of material that can be used as a covering. The range includes fabrics made of cotton, wool and linen; leather/hide; and vinyl.

At first your choice of covering will be influenced by factors such as period style, personal taste and cost. However, the choice of material should be decided after careful consideration of the following points.

- **Comfort:** Does the material look comfortable and inviting? Is the material soft and does it feel good against the skin? Will it feel warm or cool? Will the material become less comfortable as it wears? Will the material stick to the skin? Will the type of material irritate the skin?
- **Durability:** How much use will the item get? Heavy use requires a material that will not wear quickly – for example, cotton. For occasional use, a high-maintenance and more fragile material may be used – for example, silk. Will the material last as long as expected? How long will it take to wear out? What is its abrasion rating? Will it tear easily? How well does the material resist soiling and stains? Is it insect- and micro-organism resistant?
- **Aesthetics:** Is the material attractive? What type of material is it: plain, printed or textured? What is the effect of the colours: warm or cool? What is the feel? Will the upholstered item have visual appeal? Will it fit with the décor of the room?
- **Care:** What treatments are required to preserve the material: steam cleaning or wiping over with a damp cloth? How difficult will it be to remove stains and soiling?

For more information about upholstery materials, a good source is manufacturers' labels. All labels must provide some basic information about fibres and care instructions. Another good source is your local upholsterer.

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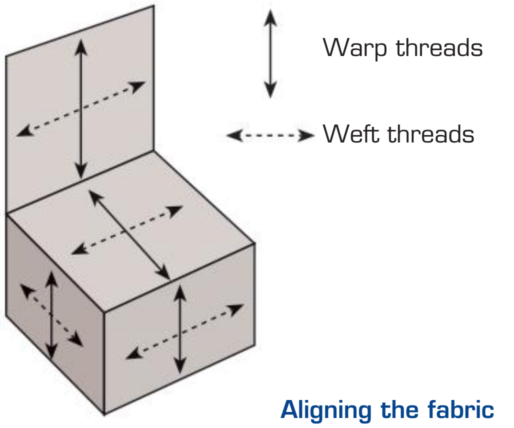
Upholstery techniques

To achieve a good result it is essential that the covering is measured and marked out accurately. As a general rule, allow an additional 50 millimetres of covering on all sides and 10 millimetres extra for a seam allowance.

Basic steps in upholstery

When marking out on fabric, remember to align with the warp. Position the fabric so that the warp and weft threads are aligned, as shown below.



Aligning the fabric

Basic steps in fixing a fabric covering

Mark out and cut out the fabric.

↓

If the fabric has a pattern, ensure that it is lined up and centred.

↓

Temporary-tack the covering with a few tacks in the centre of each side.*

↓

Begin to tack off, starting at the centre of each side and working to within 50 mm of the corners.**

↓

Fold and tack off the corners. Make sure that the corners are smooth and tight.†

*Check the squareness and tension of the fabric regularly during the fixing process. Do not over-tension the fabric.
**The material can be folded under itself or the excess trimmed off.
†There are two options: Use small folds or pleats, or cut away excess material before folding. The opening of the fold should be on the sides.

Fitting the covering

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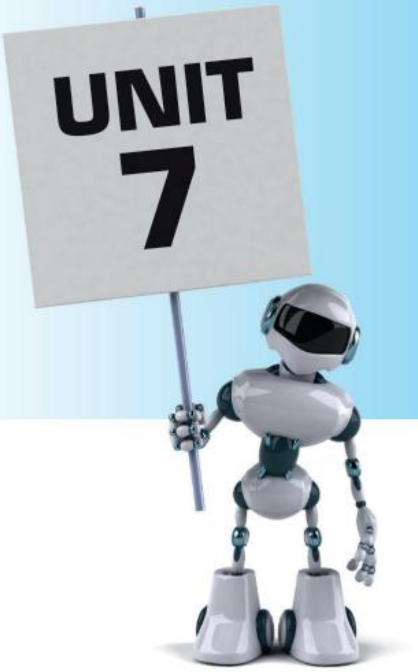


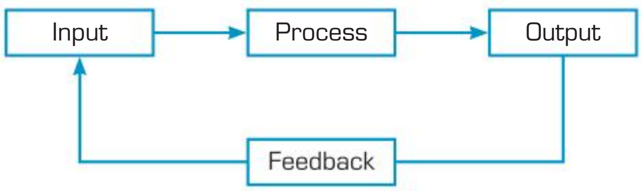
Manufacturing

In this unit, you will learn:

- about systems and subsystems
- what manufacturing is
- about the main stages of the manufacturing process in industry
- how to use production plans and manufacturing aids when making things yourself.

What is a system?

A system in technology is a collection of parts or a group of activities used to complete a task. The task may be a solution to a problem or a way of achieving a goal. The basic parts of a system are input, process, output and feedback. The system is a loop. Block diagrams are used to show a system.



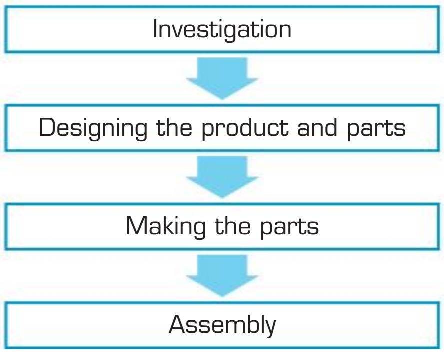
Each part (or activity) of the technological system has its own specific contribution and effect. Let's examine each part.

Input

An input is any resource that contributes to a technological system. The resource may be supplies or support for the system. The resources include people, information, materials, tools and equipment, energy, capital and time.

Process

The process is all the activities undertaken to solve the problem or to produce the desired result. A common process in an industrial technology and design system is:



Output

The output is the solution to the problem, or the achieved goal and its impacts. The impacts of the system may be **benefits** or **costs**.

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Feedback

The feedback is the information – positive or negative – about the output of the system; that is, the solution and its impacts. This information can then be used to assess the performance of the system. Any shortcomings or concerns are seen as an additional resource in the loop, thus ensuring improvement.

Each part (or activity) of a technological system can be shown using the systems approach.

The systems approach

The systems approach enables people to describe and devise technological systems. A technological system could be simple – for example, a torch – or more complex – for example, a manufacturing system.

A basic manufacturing system is shown in the flow chart below. Study it for a moment. What did you notice?

Each block describes one stage of the manufacturing system. Each stage is a subsystem of the overall system.

For example, in the subsystem 'Production of standard stock', raw materials are processed to produce standard stock.

A subsystem is often made up of lower subsystems that function on their own. They all have inputs, processes, outputs and feedback. (Can you name some of these lower subsystems?)

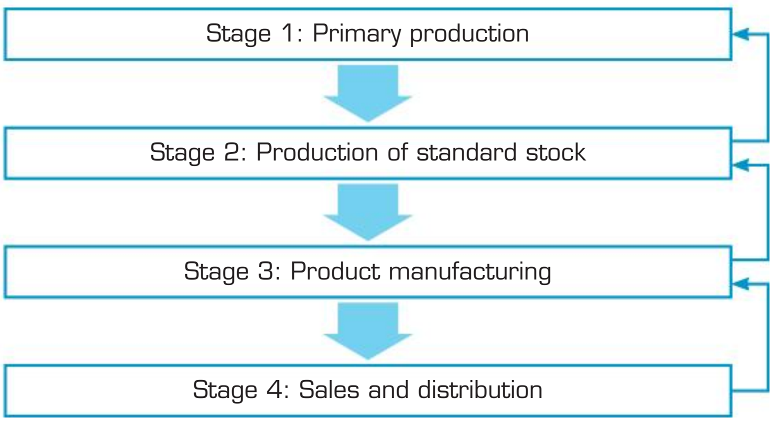
Every system is modified in response to feedback. For example, if people are concerned about deforestation of tropical rainforests, they will not purchase a piece of furniture made of rainforest timbers. The demand for plantation timbers will then increase. This has an effect on the 'Primary production' subsystem. The input and process stages may need to be modified to meet the demand.

The impact of the product on the environment could be another concern. Here, designers and engineers look at the life cycle of the product (that is, how long before the product wears out). They think about which materials and processes to use to make the item. Some testing of materials and processes may be done to determine the possible impacts.

Designers and engineers also think about what will happen to the product when it is no longer of use. The solution may be to use materials that can be recycled or to select another material that will have a lesser impact on the environment. The 'Product manufacturing' subsystem may need to be modified to meet the environmental concerns.

Each system is monitored, maintained and serviced by people. These procedures ensure that there is productivity within the system as well as response to societal concerns and community needs.

So far you have been introduced to manufacturing using the systems approach. It is a rather basic systems diagram. The world of manufacturing needs to be explored in greater detail. The chart opposite describes what manufacturing is.



A basic manufacturing system

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The world of manufacturing

1

Manufacturing is the process of making an item that satisfies people's needs or wants.

The a manufacturing industry produces quantities of such items.

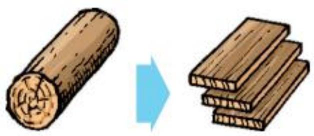
2

In manufacturing, people use materials, tools and skills to carry out a process (such as drilling a hole in timber).

Items are usually manufactured by a series of different processes. This is called production.

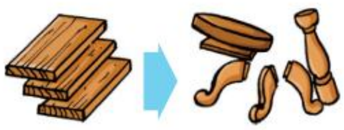
3

First, raw materials may have to be converted into standard stock.



Raw material Stock

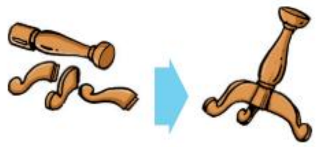
Components are then produced from the stock.



Stock Components

4

Different components are put together to make a sub-assembly.



Components Sub-assembly

Sub-assemblies are combined with other sub-assemblies to form a finished product.

Sub-assemblies Product

5

Manufacturing firms need not carry out all of these processes themselves. They can use stock, components or sub-assemblies that have been made by other companies.

6

Manufacturing involves more than just production. There are six main stages in the manufacturing process. Each stage is usually carried out by people working in teams or groups of different sizes.

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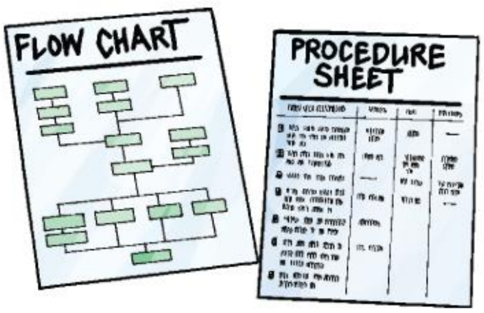
The manufacturing process

1 Researching consumer demand
Before manufacturing a new product, the company must carry out research to find out what consumers want and what price they would pay for it.

2 Developing the product
A team of designers and engineers make prototypes and evaluate them to create a product that not only looks good, but also works efficiently and can be produced at a profit.

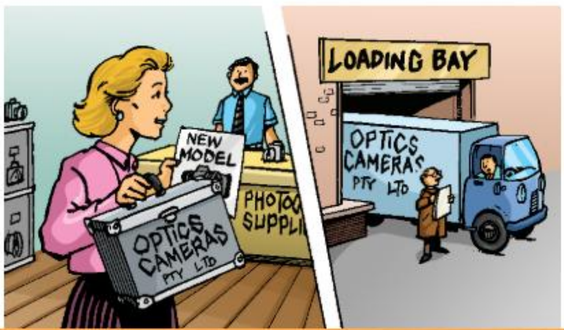
3 Production planning
Every stage of production, from raw materials to packaging, is planned to avoid delays, maintain quality and keep production costs low.



4 Tooling up for production
Machines and other equipment are obtained and installed according to the production plan so that production can begin.

5 Production (with quality control)
Finished products are made and packaged. Their quality is maintained through a system of checking or testing.

6 Marketing and distribution
The packaged products are warehoused, marketed and transported to purchasers. The manufacturer's selling price will have to be enough to allow a profit after paying for raw materials, production costs (wages, equipment, power, etc.), packaging, marketing and transportation.



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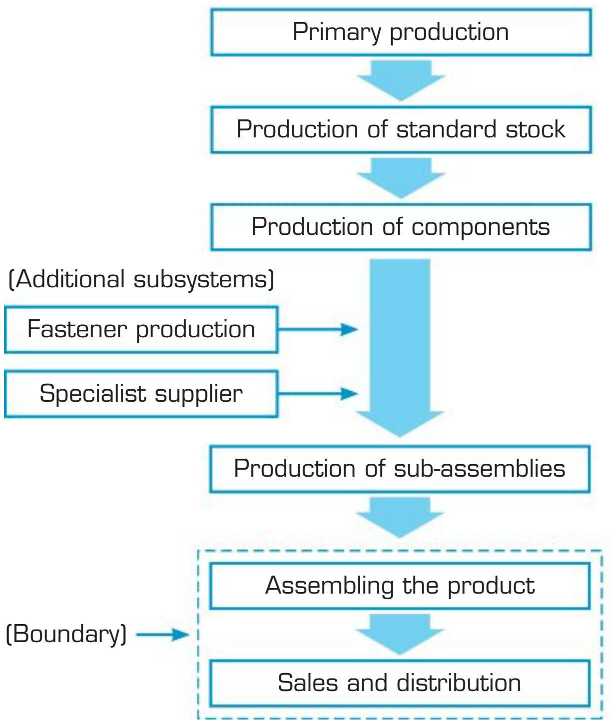
Now that you know what manufacturing is, a more complex systems diagram can be drawn.



A more complex systems diagram

You will note that the previous Stage 3 ('Product manufacturing') has been expanded to reflect what actually happens. There is more detail about the things being done within the process. In other words, some of the lower subsystems have been included in the diagram.

Additional subsystems – for example, fastener production or specialist suppliers – can be added to the flow chart to show their contribution to the whole process.

There may be times when you do not want to examine the whole system, but only part of it. This is possible by drawing in a boundary as shown.

This systems diagram has highlighted some of the processes used in manufacturing. The manufacturing process for an item will depend on the production system.

Production systems

Production can be organised in three ways:

- custom production
- job-lot production
- line production.

Custom production

In custom production (or 'one-off' production), many different versions of a particular item are made. For example, surfboards may be custom made to meet the needs of individual surfers.

Custom-made items are usually more expensive because they take longer to produce.

The workers employed in a custom-production system need to be highly skilled in a number of areas because every item they make is unique.

Job-lot production

In job-lot production (or batch production), workers make a fixed quantity of a particular item (for example, 500 identical coffee tables), then change to a new product (such as 250 dining tables).

This system is faster and therefore less expensive than custom production. However, the workers must be able to learn new tasks easily, as they have to produce batches of different items.

Line production

In line production (or mass production), large quantities of a single product are manufactured. This is the fastest and least expensive method of production.

The finished item is produced by a number of workers and machines, each with a particular part to play in the production process.

The workers and machines are positioned at workstations along an assembly line. The item is built up from components as it is carried around by a system such as a conveyor belt. This system is well suited to the mass production of complicated products such as motor vehicles and electronic equipment.

Production-line workers do not need to have a wide range of skills, though they may be very highly skilled in particular fields. Each worker does one task continually and so becomes specialised.

Automation

Automation in manufacturing is the use of machines and systems, instead of people, to control and perform tasks. In many industries, people work side by side with robots and automated machines to mass-produce items.

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The Uddevalla system

An alternative way of manufacturing items has been developed at the Volvo automobile assembly plant in Uddevalla, Sweden.

The Uddevalla system is based on teamwork. The team members have to assemble the entire product at one location. They are also responsible for their own quality control. Each member of the team is trained to perform a number of tasks – and some members can perform *all* the tasks. A replacement worker is therefore not needed when a worker is absent.

Materials and parts can be moved around the factory by automated guided vehicles (AGVs). One way the AGVs move about is to follow a wire, which has been placed in the floor of the factory. The path of the AGVs can be changed to meet the demands of production.

Automation has meant that people no longer need to perform many of the repetitive and sometimes hazardous tasks in the workplace, such as materials handling and spray painting.

Automation today relies heavily upon the computer and its ability to monitor and control data and processes. Computers are used in industry in three main ways:

- computer-aided design
- computer-aided manufacture
- data processing.

1 **Computer-aided design (CAD).** Here engineers and designers use the computer as a drafting tool to design an item and to draw it. The item can be viewed on the screen and modified quickly as needs change prior to manufacture. The stored data can then be used to manufacture the item.

2 **Computer-aided manufacture (CAM).** Here machines are **interfaced** with computers. They are known as computer numerically controlled (CNC) machines. Robots, like other machines, are interfaced with computers. The program in the computer controls the machine or robot as it performs specific tasks. These tasks can be repeated over and over to produce many identical components.

3 **Data processing.** Here computers are used to store, distribute and communicate data inside and outside the industry.

These factory robots are automated guided vehicles (AGVs).

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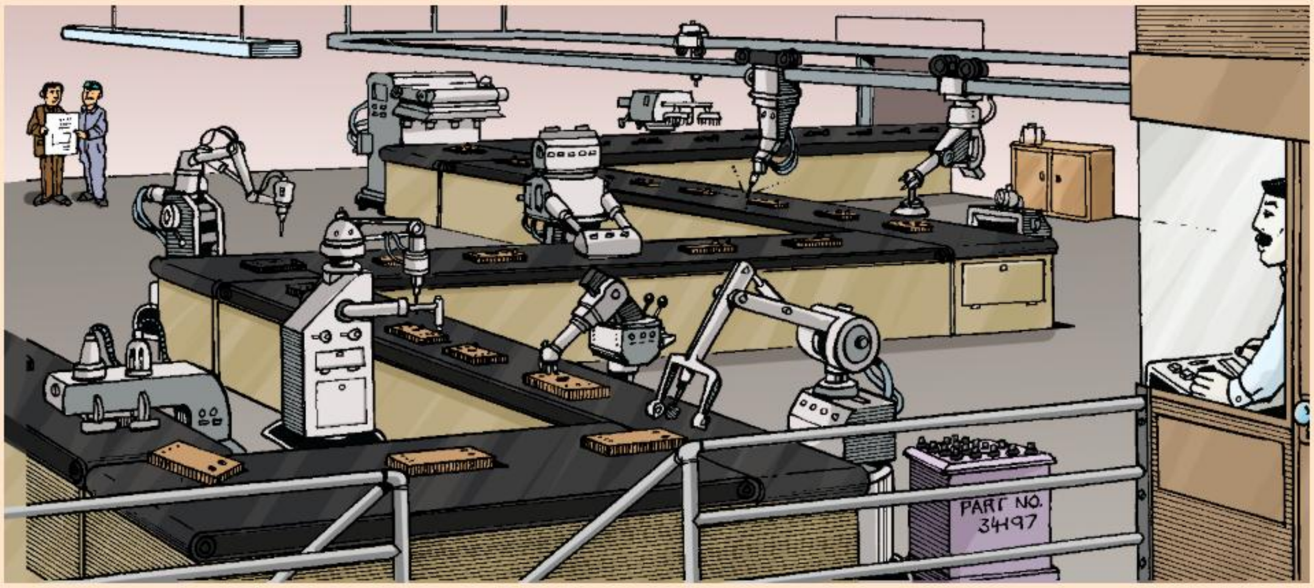
Factories of the future

Factories of the future will rely more and more upon automation; computers will monitor and control all operations, streamlining them and thus saving time and money. A new manufacturing system, known as computer-integrated manufacturing (CIM), has been developed to do this. It is hoped that this integrated system will mean greater efficiency and productivity, as well as flexibility in meeting consumers' demands.

The CIM factory is divided into centres such as fabrication and assembly centres. These are subdivided into work cells. Each work cell is further divided into workstations. Each station performs a specific process, such as welding, drilling or milling.



A work cell in a CIM factory

Now that you know about manufacturing in industry, you can use some of its principles when you are making things yourself.

Three very helpful ideas from industry are:

- production planning
- special manufacturing aids
- CAD/CAM systems.

Production planning

Manufacturers in industry use plans to streamline the production process, and you can use a production plan to improve your own organisation. For example, production plans:

- set out every step involved in making an item and so help you to avoid leaving anything out
- allow you to work out a logical sequence of production steps
- ensure that all the necessary equipment and materials are available when they are needed
- reduce delays to a minimum.

Note how the production plan for drink coasters overleaf uses a flow chart and a procedure sheet to achieve this.

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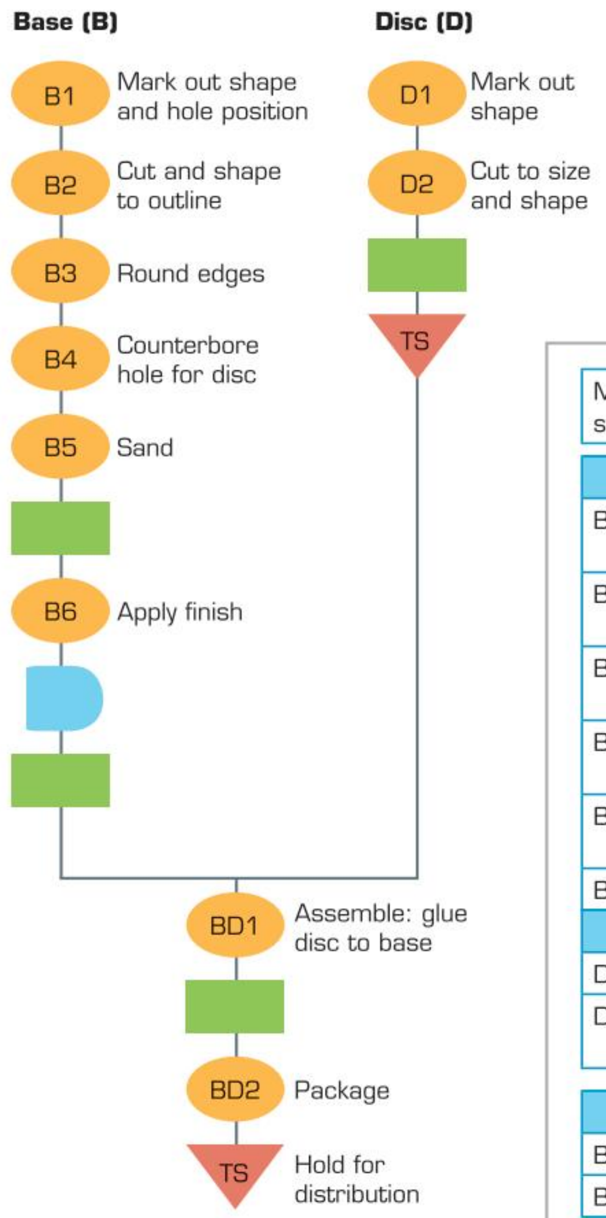
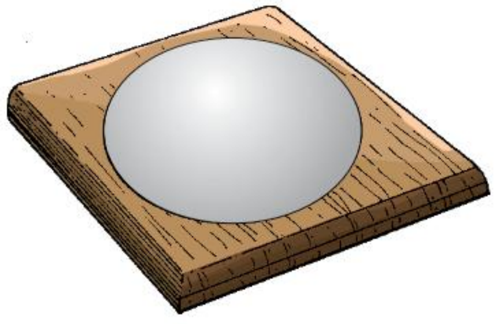
Flow chart: Drink coasters

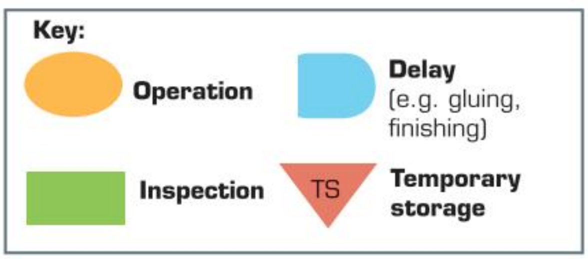




Procedure sheet: Drink coasters

Manufacturing sequence	Operation	Tools and equipment*
	Base:	
B1	Mark out shape and hole position	Template
B2	Cut and shape to outline	Hand saw/jig saw/bandsaw
B3	Round edges	Surform/files/disc sander
B4	Counterbore hole for disc	Forstner bit with bench drill
B5	Sand	Belt sander/orbital sander/hand sand
B6	Apply finish	Brush/spray
	Disc:	
D1	Mark out shape	Template
D2	Cut to size and shape	Tinsnips/files/disc sander
	Assembly:	
BD1	Glue disc to base	Jig/clamping device
BD2	Package	

*Note that you could add another column to record additional information and notes.



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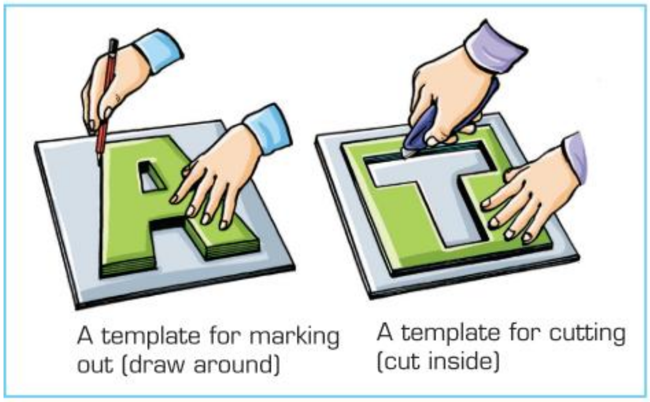
Special manufacturing aids

Since labour costs are generally the most expensive part of industrial manufacturing, special aids have been developed to reduce the time that people take to complete particular tasks. Some of these aids also reduce the likelihood that mistakes will be made.

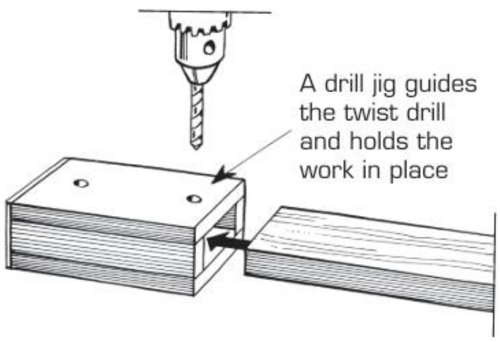
They include:

- templates: outlines that can be used over and over again to mark an accurate shape on material or to guide a tool when cutting the shape directly from the material



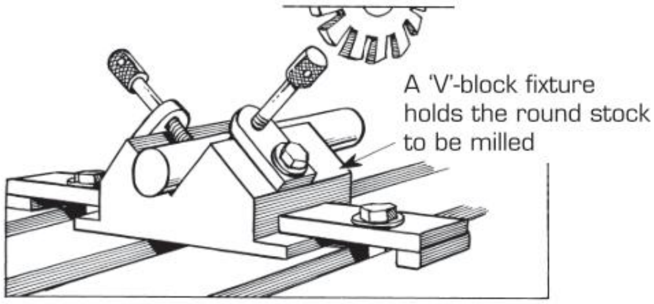
Templates

- jigs: devices that guide a cutting tool into the right position for use (they can also hold the material)



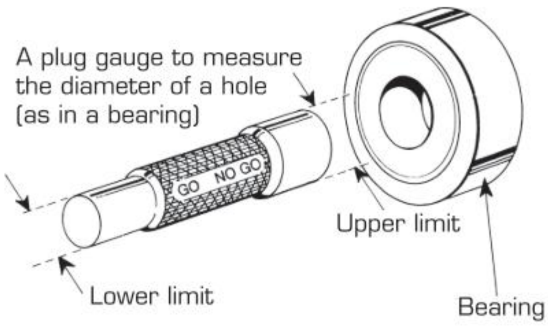
A jig

- fixtures: devices that hold the material in place during processes such as drilling, sawing and assembly. Fixtures are usually attached to a surface or a machine



A fixture

- gauges: devices used to check whether or not the size of an item is acceptable. Gauges all have an upper limit and a lower limit, and the size of the item must be between these limits. The difference in size that can be allowed is called the tolerance. It is recorded as ± 0.00 mm – for example, plus or minus 0.1 of a millimetre.



A gauge

Tolerance limits depend on the function of the item. For example, fast-moving parts have a very small tolerance, such as ± 0.1 millimetres. They must fit closely together so that they work properly and don't wear out. On the other hand, the base of a skateboard could have a tolerance of ± 1 millimetre. Such a variation in the size of the base is not critical to the performance of the skateboard.

CAD/CAM systems

Computer-aided design (CAD) uses computers to design products. Computer-aided manufacturing (CAM) uses CNC machines to manufacture products.

CAD/CAM is an important part of manufacturing around the world. Products can usually be designed and manufactured in less time than using traditional methods.

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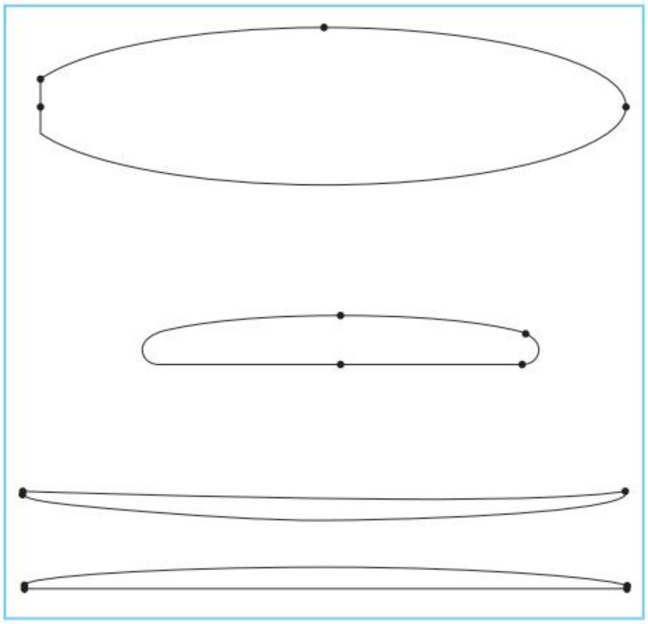
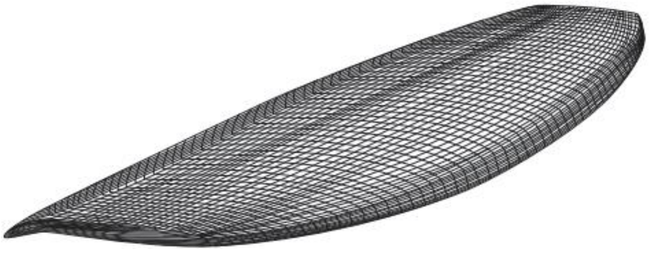
Computer-aided Design

CAD enables designers to draw lines, curves and circles accurately. These marks can be used to create two-dimensional (2D) or three-dimensional (3D) designs or objects to scale. Examples of 2D software packages include *Auto Cad* and *Auto Sketch*; an example of 3D software is *Pro Desktop*.



2D CAD images of a surfboard

Different parts of an object can be assembled to show the completed design. The object can then be rotated, copied and moved around the screen. The object can also be rendered to create a model.



A CAD wire-frame image

The model can be tested on screen to simulate real-life scenarios. CAD simulation can also be used to identify any problems during manufacture. Problems with the design or manufacturing can be corrected, thus saving time and money.

A CAD model of the wire-frame

Computer-aided Manufacturing

CAM can be used to produce a prototype from the CAD drawings with CNC machines such as milling machines or lathes. A product can be copied many times and made to the same standard every time.

A surfboard blank

A CAM surfboard

The materials commonly used are either thermoplastics – for example, acrylic or polystyrene – or non-ferrous metals – for example, aluminium. Other suitable materials include medium-density fibreboard (MDF) and modelling wax.

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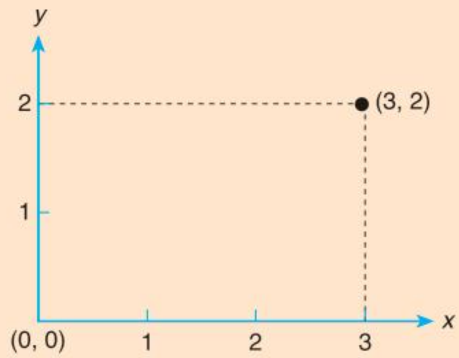
CAD/CAM systems

The accuracy of the CAD/CAM system is made possible by **coordinates**, which are used to locate all points. All positions are recorded as (x, y) coordinates in 2D, and (x, y, z) coordinates in 3D. Let's look at how the coordinates are located on the computer screen.

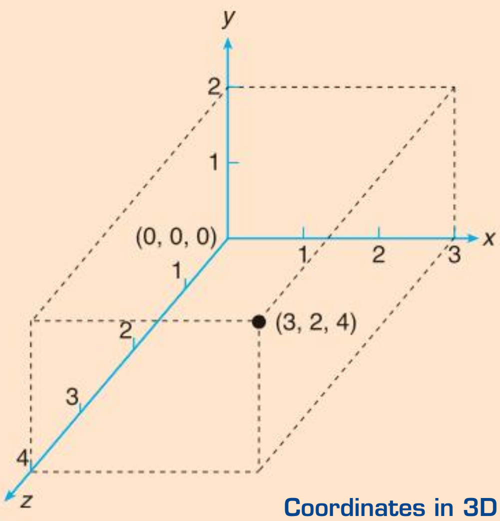
2D drawings use coordinates measured along the x-axis and y-axis – for example, as in plotting a graph. Study the diagram at the right to locate coordinate (3, 2). It is found by locating point 3 along the x-axis, then point 2 along the y-axis. The intersection of these points is the position of coordinate (3, 2).



Coordinates in 2D

3D drawings use a third coordinate, measured along the z-axis. The z-axis comes out of the screen towards the viewer. Study the diagram at the right to locate coordinate (3, 2, 4).

It is found by locating point 3 along the x-axis, then point 2 along the y-axis, as before. Point 4 is located along the z-axis towards the viewer. The intersection of these points is the position of coordinate (3, 2, 4).



Coordinates in 3D

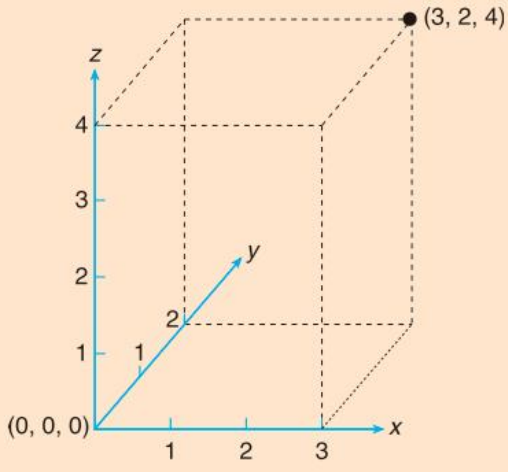
Now let's look at how the coordinates are processed by CNC machines.

CNC machines use the coordinates to move the cutting tool in a particular direction (axis) and an appropriate distance along the axis when manufacturing the part or product.

The diagram at the right shows the location of the axes and the location of coordinate (3, 2, 4).

The x-axis and the y-axis are located along the surface of the table of the CNC machine. Note that the z-axis is vertical to the table in this application.

The cutting tool is programmed to make a series of **passes** to produce the desired form.



Coordinates on a CNC machine

ISBN 9780170185677

INFORMATION FILE

V8 Supercars

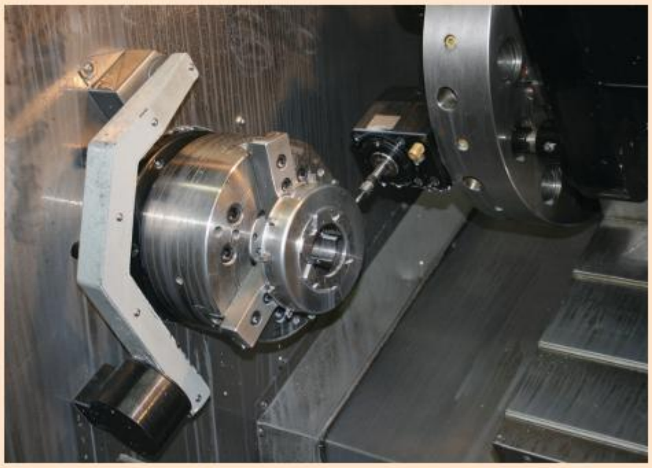
Dick Johnson Racing (DJR) is a big user of CAD/CAM systems. The CAD/CAM system enables DJR to produce parts for their race vehicles in-house, which saves time and money. The other advantage is that DJR's design and engineering ideas can be protected from other teams in the V8 Supercar Championship Series. The end result may be an advantage on the race circuit.

Technicians use CAD/CAM to design new parts or modify existing parts for its two V8 Supercars and then produce the prototype. The prototype can be tested and modified quickly because all work is done on site at DJR.

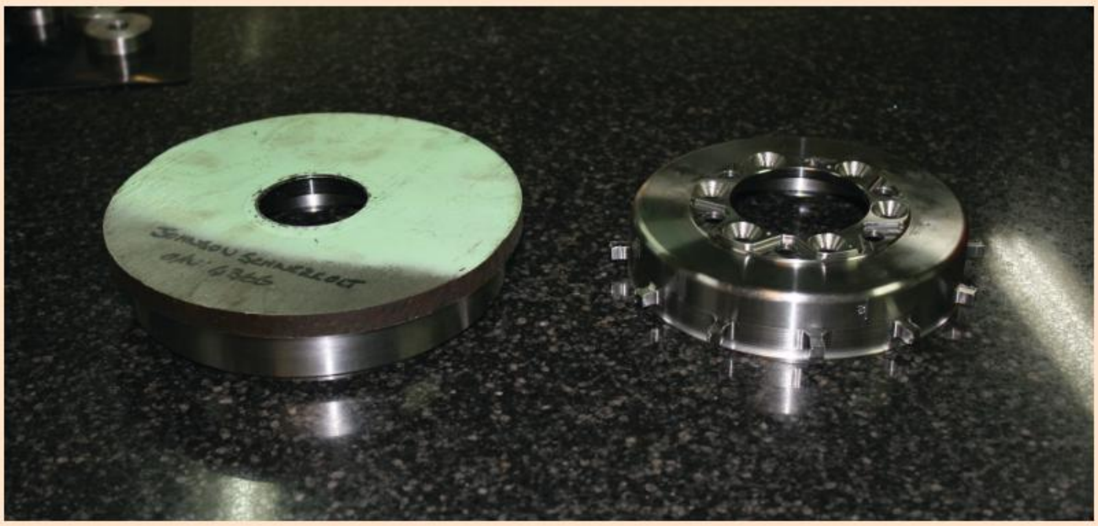
The CAD/CAM system at Dick Johnson Racing consists of the CAD software package, which is used to design an item. The CAM software assists in manufacturing the item that was designed on CAD via a range of CNC machines such as a lathe, milling machine and various axis CNC machines.

The photographs below show a trigger wheel for the engine, which was produced by DJR's CAD/CAM system. The trigger wheel is a component of a device that can measure the rotational speed.

A CAD model



A CNC machine



Stock material converted to a CAM product

ISBN 9780170185677

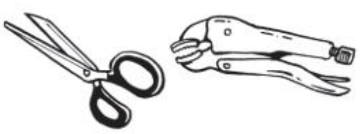
Mechanisms and energy

In this unit, you will learn:

- what a mechanism is
- about motion
- how some simple mechanisms work
- about control systems
- about energy conversion and energy sources.

What is a mechanism?

A mechanism is a device that helps people to carry out tasks more easily. Mechanisms can range from simple devices, such as scissors, to complex ones, such as car engines.



Simple

Complex

All mechanisms are designed to perform a specific task. However, they have some things in common:

- They make tasks easier to carry out.
- They involve some kind of movement (motion).
- They require some kind of effort or energy (that is, an input).
- They produce a result (that is, an output).

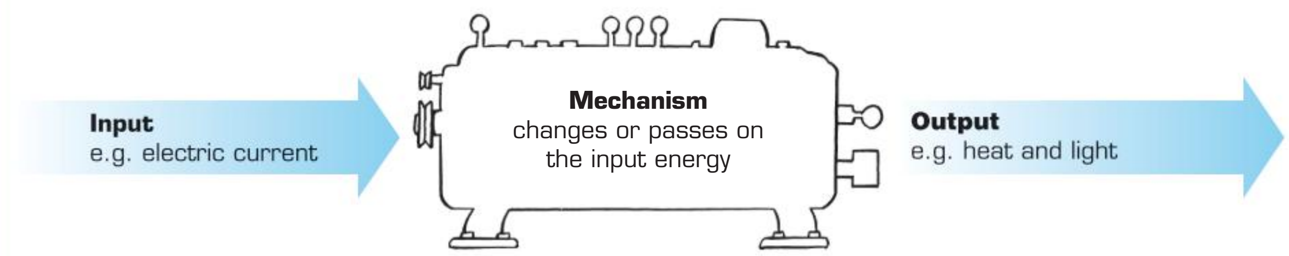
Some mechanisms are made up of many smaller mechanisms that work together. For example, a motor vehicle is made up of an engine, a gearbox and other parts. Complex mechanisms such as these are commonly called machines.

Types of motion

All mechanisms involve motion of some kind. The motion can be an input into the mechanism or an output from it. There are four types of motion.

1 **Linear motion** is movement in a straight line. A car travelling on a straight section of freeway is in linear motion. The symbol for linear motion is $\rightarrow$ (or $\leftarrow$).

Linear motion



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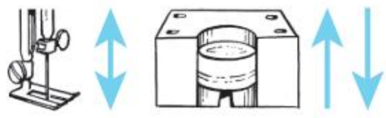
2 Reciprocating motion is movement forwards and backwards in a straight line. A sewing machine needle and a piston in an engine are examples of reciprocating motion. The symbol for reciprocating motion is ↔ (or ⇄).



Reciprocating motion

3 Rotary motion is movement in a circle. A car wheel and a circular saw are examples. The symbol for rotary motion is ↷.

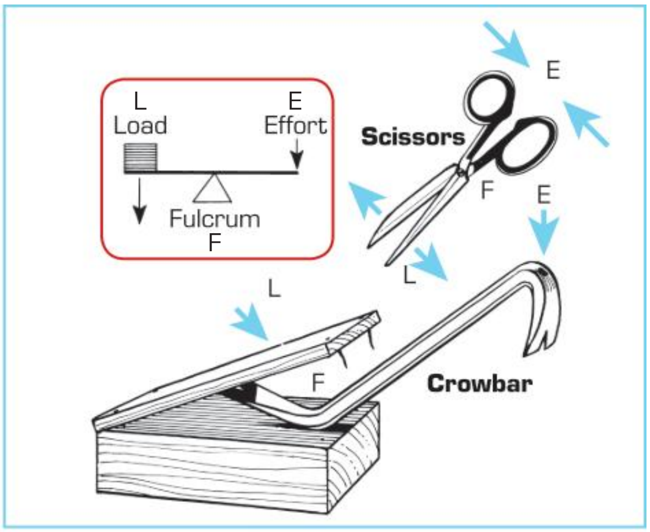
Rotary motion

4 Oscillating motion is movement forwards and backwards in an arc. A clock pendulum and a playground swing are examples. The symbol for oscillating motion is ↶↷ (or ⇆).

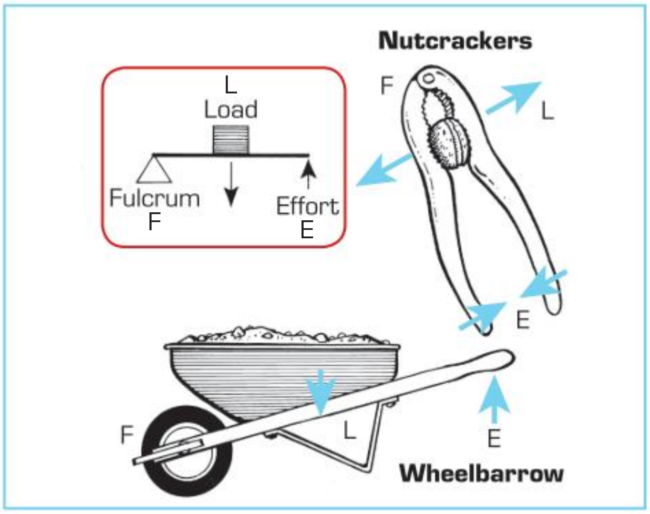
Oscillating motion

Levers

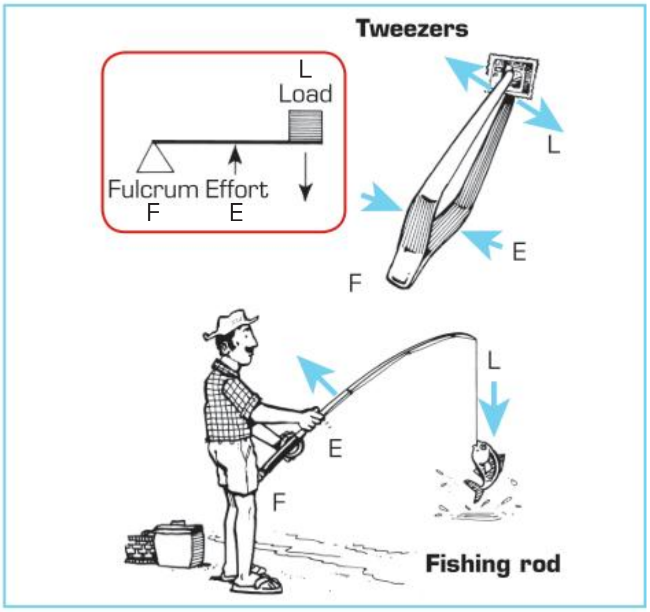
A lever consists of a rigid bar that pivots on a fixed point called a fulcrum. It is a simple mechanism by which an input force or effort moves the lever and produces an output force that can move a load. There are three classes of lever, as shown on the right.



Class-1 levers



Class-2 levers



Class-3 levers

The mechanical advantage

In many levers, the input force to lift a load is less than the load. Here the effort has been 'magnified' by the lever. This magnification is called the mechanical advantage of the lever.

$$\text{Mechanical advantage} = \frac{\text{Load}}{\text{Effort}}$$

The less effort needed to move a load, the greater the mechanical advantage.

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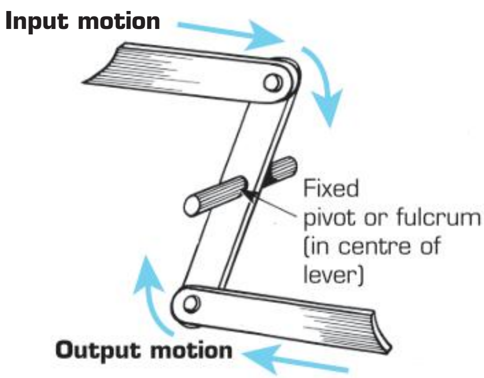
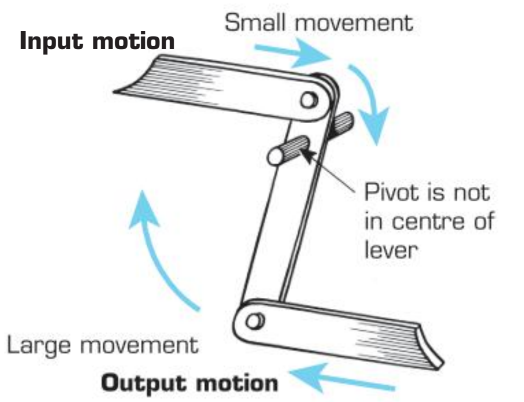
Linkages

A linkage is formed by joining together a number of levers. Linkages are used to transmit motion and force in a desired way.

These diagrams show some different linkages.

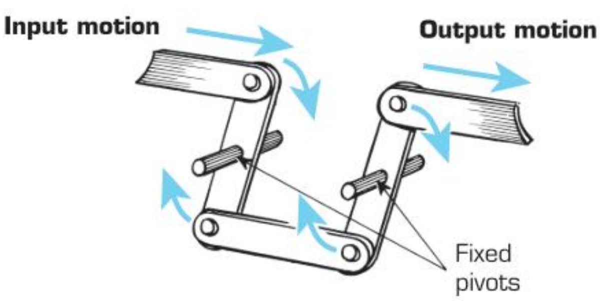


Input motion = output motion

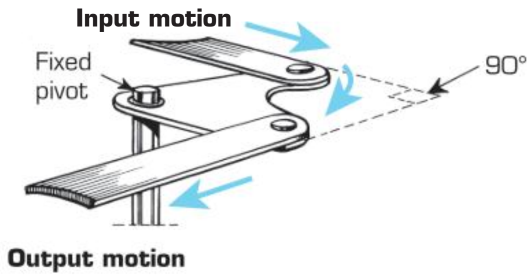


Output motion is greater than input motion

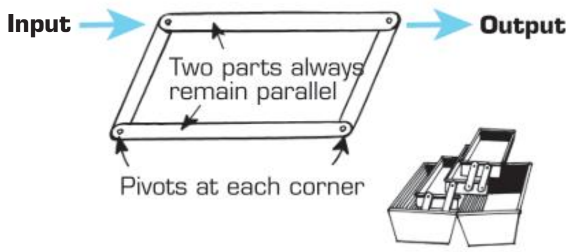
Two types of reverse-motion linkage



A push-pull linkage: the input and output motions are in the same direction.



A bell crank is used to transmit input motion through 90°.

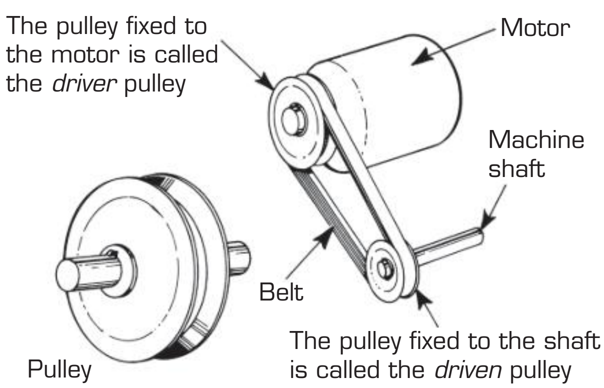


Parallel linkages ensure that opposite sides stay parallel to each other as they move.

Pulleys

Pulleys are another useful mechanism for transmitting force and movement. The basic form of pulley is a grooved wheel. Pulleys are often linked by a belt. Systems of pulleys and belts can be used to transmit rotary motion from a motor to a shaft in machines such as a bench drill.

One advantage of using pulleys is that they are fairly easy to adjust. However, under heavy loads the belt may slip.



Pulleys

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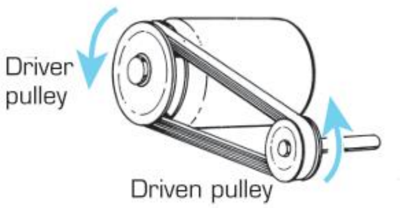
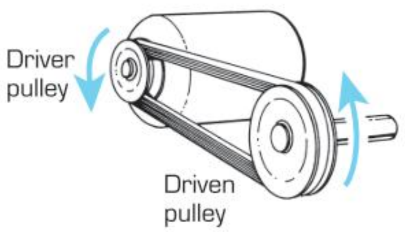
The output speed can be varied by changing the diameter of the driver and driven pulleys.

For a faster output speed, the driver pulley must be larger than the driven pulley.



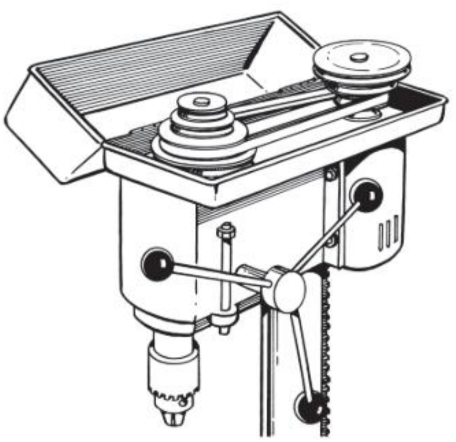
Faster output speed

A slower output speed is achieved if the driver pulley is smaller than the driven pulley.



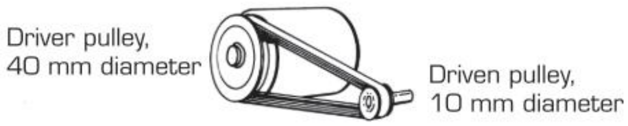
Slower output speed

Stepped-cone pulleys are a quick, easy method of changing output speeds through a particular range. They are used in machines such as wood and metal lathes and bench drills.



Stepped-cone pulleys

The velocity of pulleys



The relative **velocity** at which the pulleys turn is determined by their size. We can say:

$$\text{Velocity ratio} = \frac{\text{Circumference of driven pulley}}{\text{Circumference of driver pulley}}$$

Since the circumference depends on the diameter, this becomes:

$$\text{Velocity ratio} = \frac{\text{Diameter of driven pulley}}{\text{Diameter of driver pulley}}$$

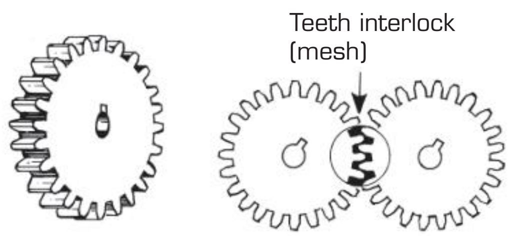
$$= \frac{10}{40} = \frac{1}{4} = 1:4$$

That is, for one revolution of the driver pulley the driven pulley will complete four revolutions. In other words, the rotary motion is speeded up.

If you know that the driver pulley is doing 200 rpm (revolutions per minute), the driven pulley must be doing 800 rpm (200×4).

Gears

A gear-wheel has teeth spaced evenly around its edge. Gears are designed to interlock smoothly or mesh with each other. To do this, their teeth must be the same size. Unlike pulleys, gears will not slip under heavy loads.



Gear-wheels

Gears meshed together form a gear train. They are used to transmit motion from one gear to another at different speeds or in different directions.

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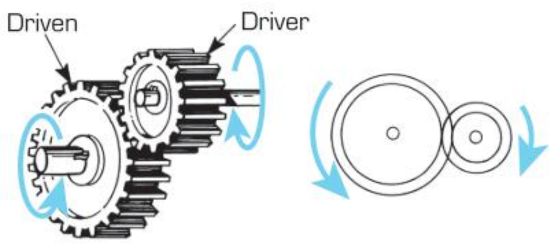
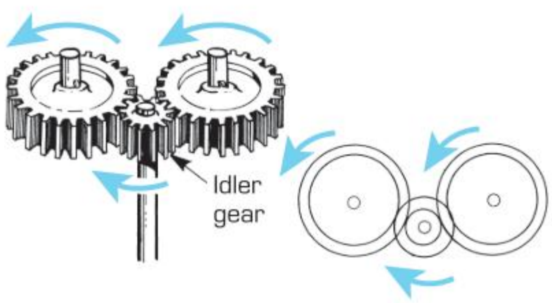
The driven gear will always turn in the opposite direction to the driver gear.



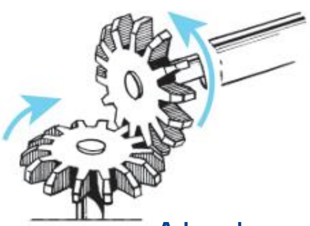
A small gear known as an idler gear can be used to change the direction of the driven gear. It does not change the speed of the gears.



As with pulleys, the output speed can be varied by changing the relative sizes of the driver and driven gears.

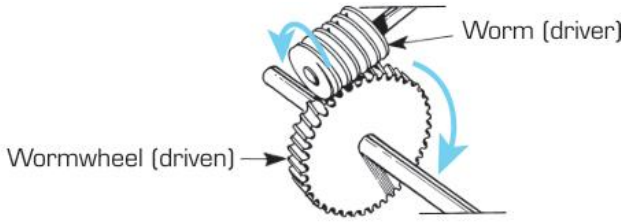
Gears are also used to transmit motion in a number of different ways.

Bevel gears have teeth with sloping faces that allow the gears to mesh at an angle. They are used to transmit motion at an angle (usually 90 degrees) to each other. Bevel gears are commonly used in hand drills.



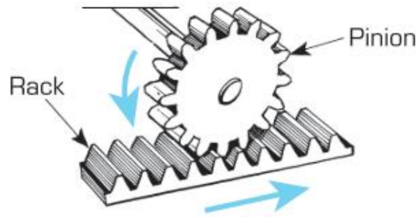
A bevel gear

Worm gears (consisting of a worm and a worm wheel) are also used to transmit motion through 90 degrees. The teeth on the worm wheel are cut at a slight angle to mesh with the thread on the worm. Worm gears are commonly used in machines where rotary motion has to be reduced greatly from one shaft to another.



Worm gears consist of a worm and a worm wheel.

Rack-and-pinion gears are used to change rotary motion into linear motion. They are common in car steering and bench drills (to lower the chuck as the handle turns).



A rack-and-pinion gear

Gear trains

There are two gear trains. They are:

- simple
- compound.

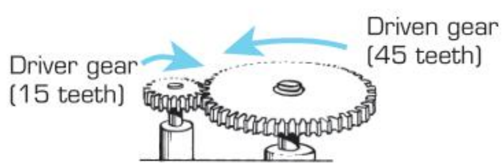
Simple gear trains

Simple gear trains are made up of two or more gears, fixed to separate shafts, that mesh together.

A simple gear train

The velocity of gears

As with pulleys, the size of the gear wheels will determine the velocity ratio, which is also called the gear ratio.



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The size of the wheels is governed by the number of teeth around their edges. Therefore we can say:

$$\text{Gear ratio} = \frac{\text{Number of teeth on driven gear}}{\text{Number of teeth on driver gear}}$$

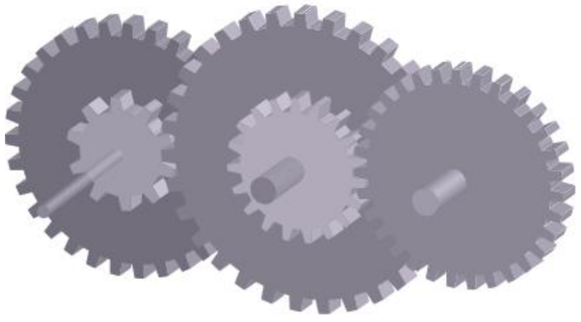
$$= \frac{45}{15} = \frac{3}{1} = 3:1$$

That is, for one revolution of the driven gear the driver gear must complete three revolutions. In other words, the rotary motion is slowed down.

If the driven gear is doing 100 rpm, the driver gear must be doing 300 rpm (100 × 3).

Compound gear trains

Compound gear trains are made up of two or more compound gears. A compound gear is made of two differently sized gears attached to the same shaft. A number of compound gears, each attached to its own shaft, can be used to produce a big change in output speed.



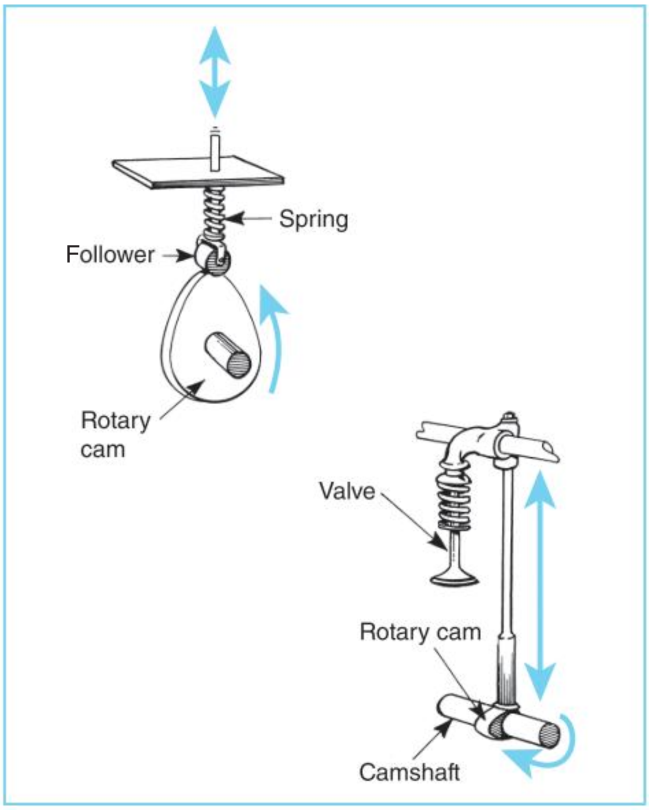
A compound gear train

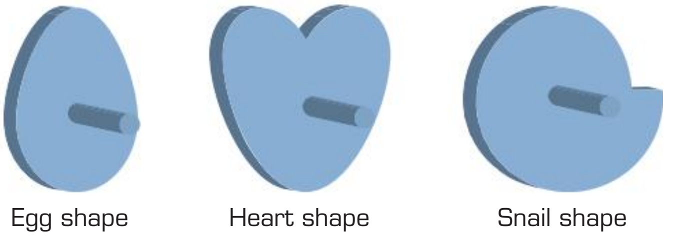
Other commonly used mechanisms

Cams

Cams are used in many mechanisms to produce a result such as opening and closing the valves in car engines or moving a cutting tool up and down on a machine.

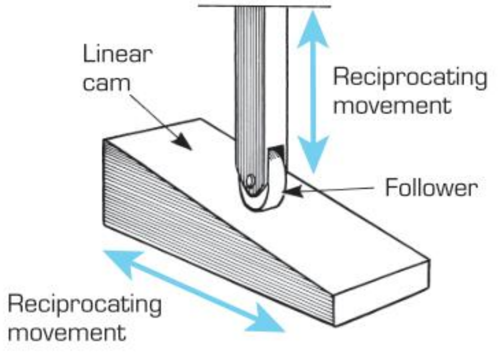
A rotary cam is a specially shaped wheel that is used to change rotary motion to reciprocating motion. As the cam turns, it causes a follower to move in and out or up and down in a particular way. Differently shaped cams produce different patterns of movement in the follower.





Common shapes of rotary cams

A linear cam is shaped so that when it moves backwards and forwards it causes the follower to move up and down in a particular way. It is commonly used to guide cutting tools on automatic or semi-automatic machines so that they produce identical results.



A linear cam

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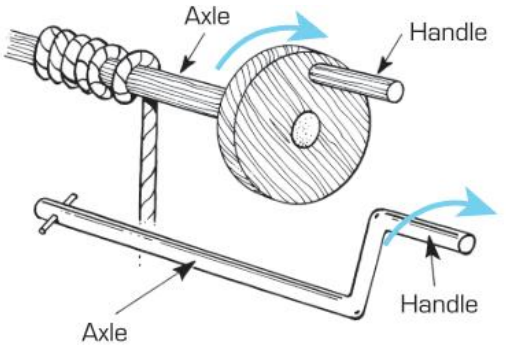
Cranks

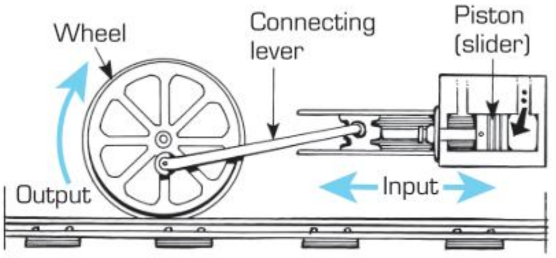
In a simple form of crank, force applied by means of a handle produces rotary motion of an axle. The greater the distance between the handle and the axle, the greater the turning force that is exerted on the axle (as show here).



Cranks

Crank-and-slider mechanisms

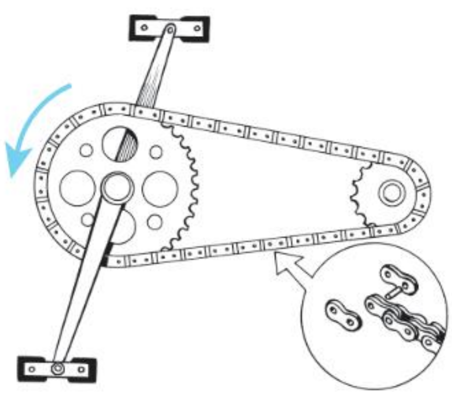
A crank-and-slider mechanism consists of a wheel and a sliding part connected by a lever. It changes reciprocating motion into rotary motion or vice versa.



A crank-and-slider mechanism

Chain-and-sprocket mechanisms

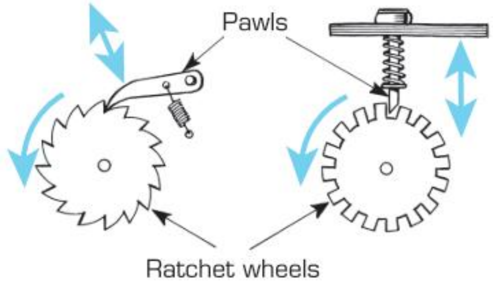
A chain and sprocket system is used to transmit rotary motion. It works just like a pulley system, but there is no possibility of slippage.



A bicycle chain

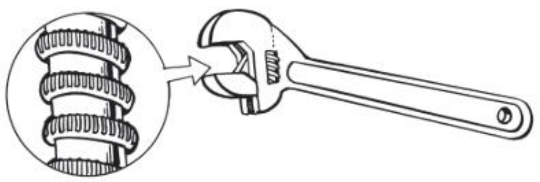
Ratchets

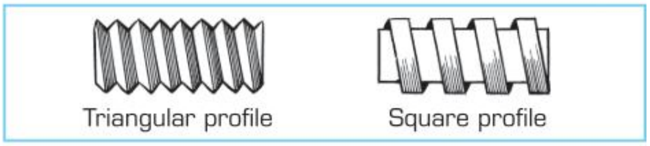
A ratchet wheel is like a gear wheel, but it will only rotate in one direction. The pawl (a pin or lever) drops into place and prevents the ratchet wheel from rotating backwards (as in a winch).



Screws

A screw consists of a threaded shaft that usually engages with another thread. It changes rotary motion into linear motion. For example, in an adjustable spanner the jaw moves in or out as the screw is turned. Screw threads can have different shapes or profiles.





Screw profiles

Control systems

People have developed control systems so that tasks can be done in an organised way. For example, some control systems enable mechanisms to work without people to operate them. For such a system to work efficiently, there must be:

- an input – the system has to be activated (turned on). This can be achieved through movement, light or sound – for example, voice activation
- a process – the input is processed. An electrical signal is processed, a lever moves or sound is amplified

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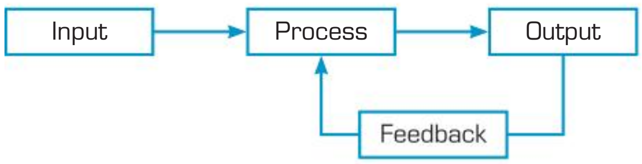
- an output – a result is produced. For example, a light comes on, the jaws of a machine move or music blasts from the speakers.

There are two kinds of control:

- An open-loop control has no means of checking its output. For example, when a bucket is being filled with water, the water will continue to flow unless the tap is turned off.

An open-loop control system

- A closed-loop control has a means of checking its output. For example, water flowing into a hot-water storage system is controlled by a valve that closes once the required level is reached. This is known as feedback.



A closed-loop control system

In industry, some machines are controlled by **pneumatic systems** and **hydraulic systems**.

Today, many control systems are monitored by a computer. For example, a computer can open and shut valves to produce a desired result in industrial robots, such as holding materials in place while a process is completed, and then releasing them.

Energy

Every mechanism and control system has to be supplied with some form of energy to operate. The human body itself cannot work without taking in chemical energy in the form of food.

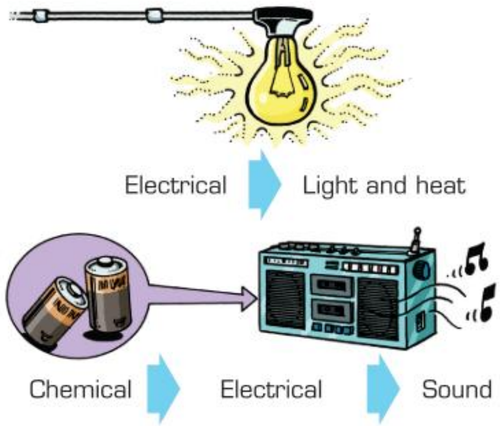
What is energy?

People and machines use energy to do work and produce results. For example, you would use up a certain amount of energy if you used muscular force to push a wheelbarrow for 100 metres.

Energy can be stored in many different forms, including chemical energy, electrical energy, light energy, heat energy, sound energy and mechanical energy (as in kinetic energy – that is, the energy of movement).

Energy conversion

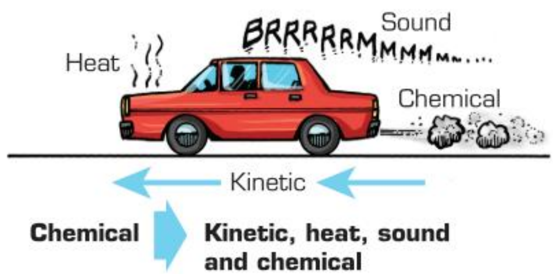
When work is done, one form of energy is often converted into other forms, as this illustration shows.



Energy conversion

In many cases the energy is not converted very efficiently: it is changed into some unwanted forms.

For example, when a car engine burns petrol, only a small part of the chemical energy becomes kinetic energy to turn the wheels. The engine wastes a great deal of energy in the form of the exhaust gases it produces. As well, much of the chemical energy is converted to sound and heat, including heat produced by friction between the moving parts. (A lubricant such as oil or grease is therefore often used to reduce friction.)



Electricity powerhouses suffer similar problems to those of car engines. They use fossil fuels such as coal and oil, which are non-renewable resources. They also waste much energy in the form of heat, and they emit waste gases into the atmosphere.

In the past, people had hoped to solve these problems by using nuclear reactors to generate electricity. However, this solution is not ideal. With

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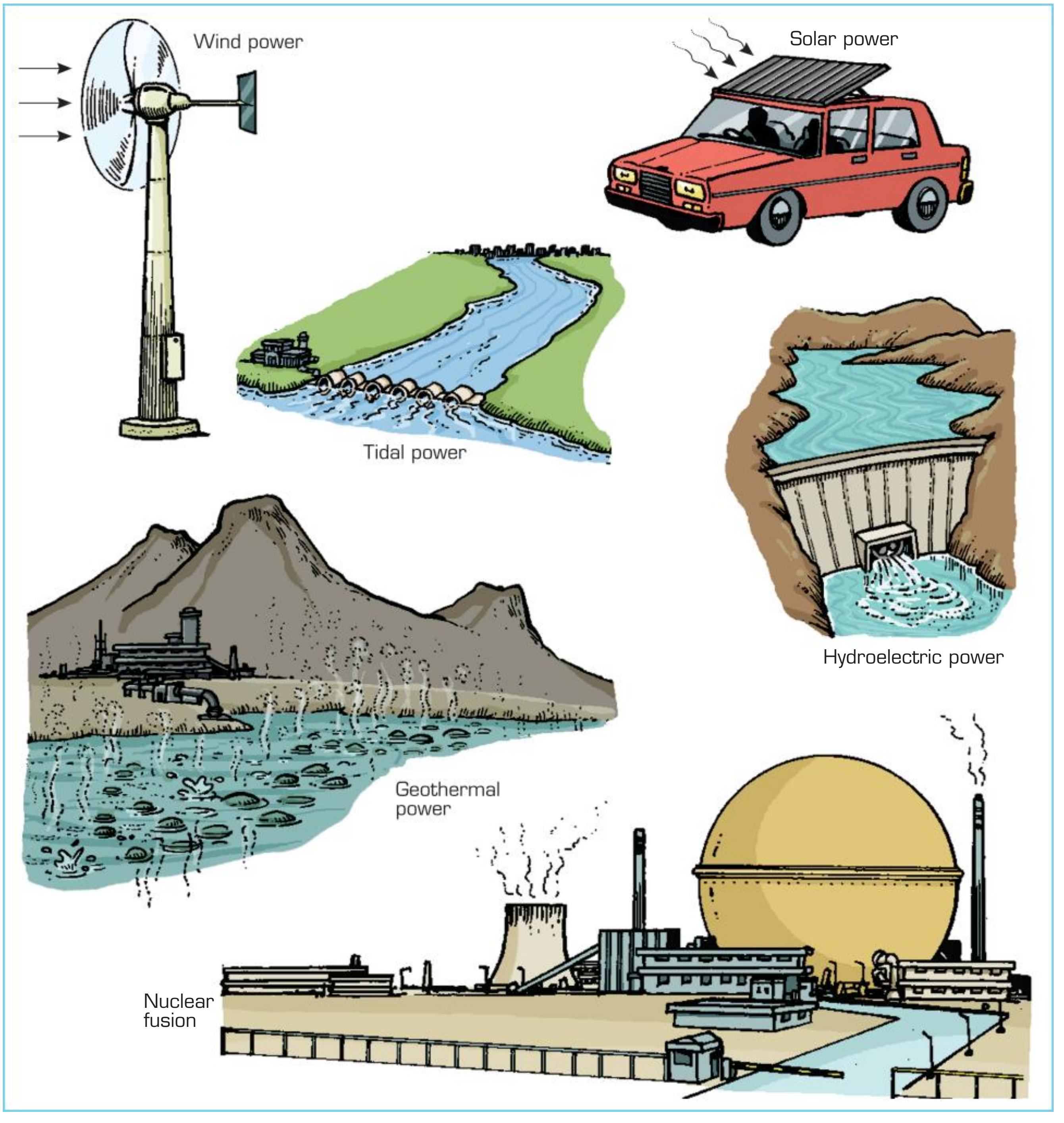
conventional fission reactors there is the problem of how to dispose of radioactive waste and the possibility of disastrous accidents, despite strict safeguards.

Energy and the future

People around the world are so concerned about conserving resources and preventing atmospheric pollution, and the 'greenhouse effect', that researchers are striving to improve the efficiency of our existing technology, in the home as well as in industry.

They are also trying to develop alternative energy sources in ways that will avoid the problems of energy generation from oil and coal, or from conventional nuclear fission.



Alternative energy sources

ISBN 9780170185677

Electronics

In this unit, you will learn:
- what electronics is
- about circuits and basic electronic theory
- about electronic components, including integrated circuits and printed circuit boards
- how to undertake an electronics project.

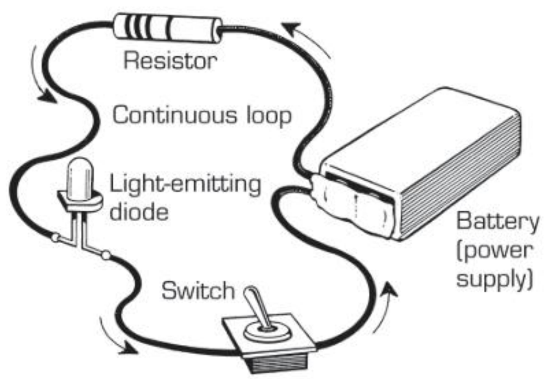
What is electronics?

Can you imagine a world without iPods, mobile phones, digital cameras and laptop computers? We have become so dependent on these items that we could not imagine life without them. All of them nowadays depend on electronics for their operation.

Electronics is one of the fastest-growing areas of technology today. It involves connecting a number of components in an electrical circuit so that a **current** can flow to produce a desired result.

Circuits

A circuit in electronics consists of a continuous loop that can carry an electric current. This is called a closed circuit. (If there is a break in the circuit, it is an open circuit and the current will not flow.) To have a flow of electricity in a circuit, you need:
- a power supply
- a material to conduct the electric current.



A simple circuit

Power supply

Power can be supplied by a wide range of sources such as:
- batteries
- generators
- mains power
- solar cells.

Two types of power can be supplied. They are:
- direct current (DC): here the current flows in one direction only. Batteries are a DC source
- alternating current (AC): here the flow of current constantly changes direction in a cycle between

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positive and negative. The frequency of an alternating current is the number of cycles per second; the unit of frequency is hertz (Hz). Mains power is an AC source.

Conductors and insulators

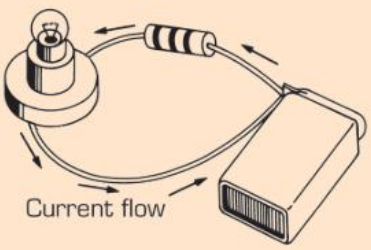
Electricity cannot flow through all materials. Materials that allow electricity to flow are called conductors (for example, copper and aluminium). Materials that do not permit the flow of electricity are called insulators (for example, wood, rubber and plastic).

INFORMATION FILE

Series and parallel circuits

Series circuits

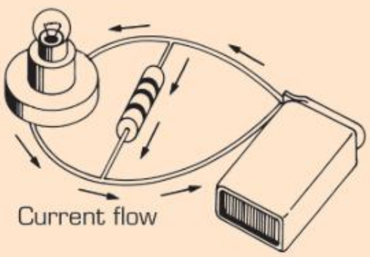
In a series circuit, the flow of electricity can only follow one pathway. The current must pass through all the components. Its value does not change.



A series circuit

Parallel circuits

In a parallel circuit, there are two or more pathways that the current can take. The current is not the same throughout the circuit.



A parallel circuit

Look at a number of circuits. Can you find any components connected in series and in parallel?

Basic electronic theory

A power supply (such as a battery or mains power) exerts a force on a circuit. This force produces a flow of electricity in the form of movement of electrons. It is known as the electromotive force (emf). The emf is the pressure difference between the terminals of the power supply. (All DC power supplies have a positive and a negative terminal; AC power has an active and a neutral terminal.)

This pressure difference or voltage (V) is measured in volts (symbol V). Voltage is also known as potential difference (pd).

The emf in a circuit is opposed or resisted by the electronic components. The resistance of the components thus controls the amount of current that flows in the circuit. The resistance (R) is measured in ohms (symbol Ω).

RULE: High resistance → Low current

RULE: Low resistance → High current

Electrical current (I) is the amount of electricity flow in a circuit. It is measured in amperes (amps – symbol: A).

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Ohm's law

You can calculate voltage, resistance or current in a circuit using a formula called Ohm's law. To use this formula, you need to know the values of two of the quantities. Ohm's law states that:

$$\underset{\text{(in volts)}}{\text{Voltage}} = \underset{\text{(in amps)}}{\text{Current}} \times \underset{\text{(in ohms)}}{\text{Resistance}}$$

That is, $V = I \times R$

$$\text{Resistance} = \frac{\text{Voltage}}{\text{Current}}$$

That is, $R = \dfrac{V}{I}$

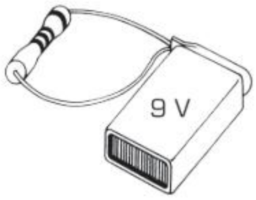
$$\text{Current} = \frac{\text{Voltage}}{\text{Resistance}}$$

That is, $I = \dfrac{V}{R}$

Learning aid
Cover the quantity you want; then you will know which ones to divide or multiply

An example using Ohm's law

Problem:
Find the current that would flow in a circuit consisting of a 9-volt power supply and a 330-ohm resistor.



Solution:
We know the voltage (V) and the resistance (R). Therefore, applying Ohm's law:

$$\text{Current} = \frac{\text{Voltage}}{\text{Resistance}} = \frac{9\text{V}}{330\ \Omega} = 0.027 \text{ amps (A)} = 27 \text{ milliamps (mA)}$$

Therefore, the current in this circuit is 27 milliamps.

INFORMATION FILE

Units of measurement in electronics

Prefixes are used to show large multiples and small fractions of numbers:

- mega (M) = one million (10^6)
- kilo (k) = one thousand (10^3)
- milli (m) = one thousandth (10^{-3})
- micro (μ) = one millionth (10^{-6})

Examples:
1 MV = 1000000 V
1 kΩ = 1000 Ω
1 mA = 0.001 A
1 μA = 0.000 001 A

DEFINITION

Prefix, noun.
A prefix is a syllable such as *un* placed in front of another word to change its meaning (for example, *un*healthy.)

Which way does the current flow?

Early scientists believed that electric current flowed from the positive terminal to the negative terminal of the DC power supply. However, scientists today believe that this is not correct. Instead, they believe that the electric current is the result of electrons moving from the negative to the positive terminal.

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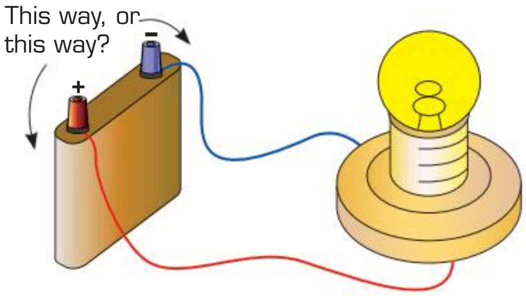


Which way does the current flow?

But many laws have been based on the first idea of current flow, known as **conventional current**, and for convenience we still think of current as flowing from positive (+ve) to negative (–ve).

The flow of conventional current

INFORMATION FILE

Using a multimeter

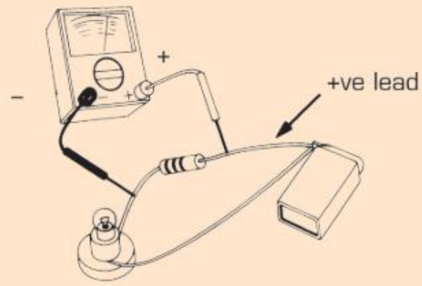
The multimeter is an instrument for measuring voltages, currents and resistances in circuits. It is a delicate instrument and must be used with care!

To use a multimeter, select the correct scale:

- DC volts
- AC volts
- amps
- ohms.

Always start at the higher end of the scale that you have selected. Then work down the range to get a more accurate reading. This way you will not damage your multimeter.

Voltage (volts) is measured in a circuit when the multimeter is connected in parallel with the circuit or component(s).

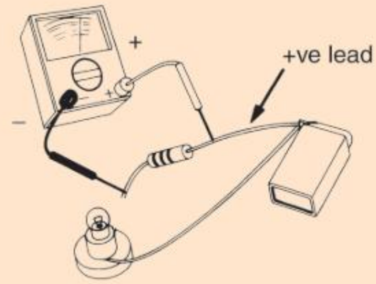


Measuring voltage

To measure current (amps) in a circuit the multimeter is placed in series with the circuit.

Measuring current

To measure the resistance (ohms) of the component, position the probes at either end of the component, as shown in the diagram below. (To avoid error, it is a good idea to disconnect one end of the component.)



Measuring resistance

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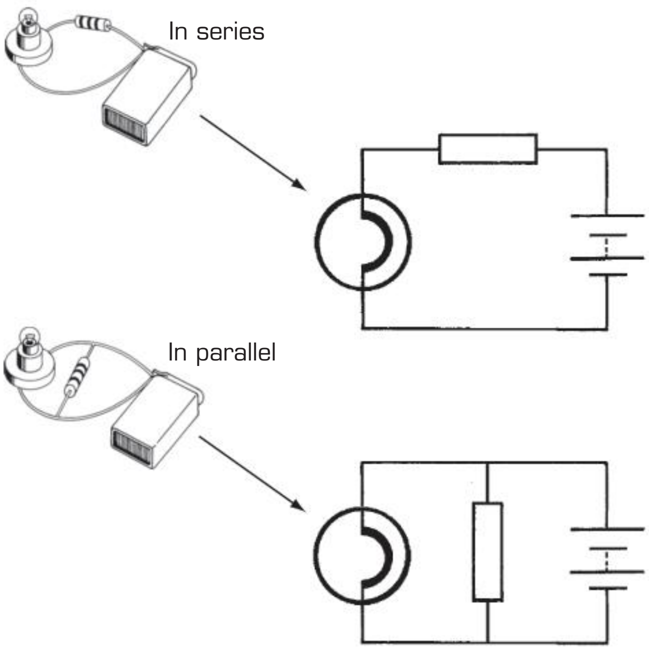
Electronic components

Each component of a circuit has a specific function to perform. Some components, such as capacitors, store electricity. Resistors, on the other hand, restrict the flow of electricity to the components of a circuit, thus protecting them. By joining components in a special way, we can complete a circuit and make it work.

Components such as batteries, resistors and capacitors can be connected either in series (that is, one after another) or in parallel (that is, there are two or more paths that the current can take). This decision is made by the circuit designer when designing a circuit.

Every component of a circuit has its own symbol. These symbols are related to what the components look like or how they work. Circuit designers use these symbols when designing a circuit. A design using these symbols is called a schematic circuit diagram.

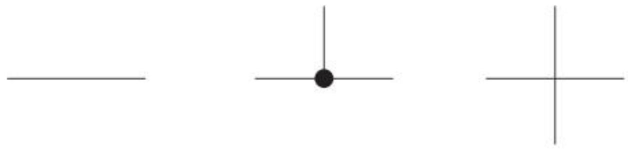


Schematic circuit diagrams

Each component has a threshold or maximum value; if the threshold is exceeded, the component will break down and the circuit will not work. For example, a capacitor rated at 25 V threshold should not be used in a circuit with voltage greater than 25 V.

Wire

Wire made of metal such as copper is a conductor and transmits the flow of electricity. It is used to connect the individual components in a circuit. (The connections are often made secure by soldering them.)



Plain wire | Connected wires | Crossed, but not connected, wires

Batteries

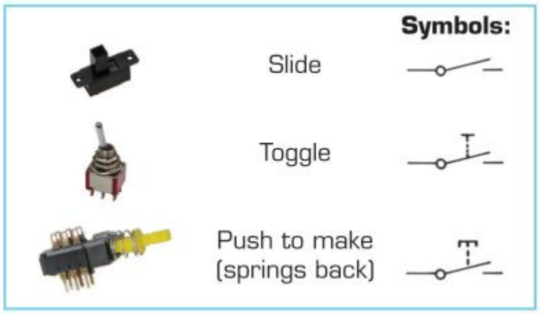
Batteries provide a continuous supply of direct current. They are very safe to use because of their relatively small voltages. Batteries are manufactured in a variety of standard voltages – for example, 1.5 V, 6 V and 9 V.

Batteries

Symbol:

Switches

Switches are used in circuits to make or break connections; that is, to turn power on or off. There are many different types of switches.



Switches

Resistors

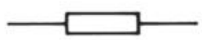
Resistors **impede** the flow of electricity in a circuit. Resistance is measured in ohms (Ω). There are two types of resistors:

- fixed-value resistors
- variable-value resistors.

Resistors can cause the voltage in a circuit to vary from one place to another.

Resistor

Symbol:



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Fixed-value resistors

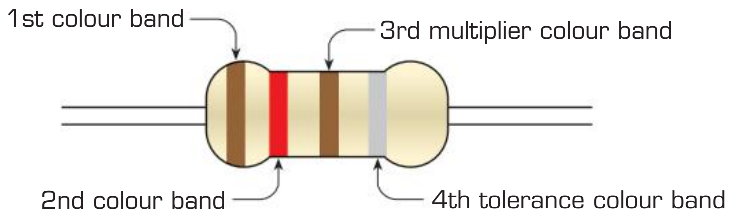
Fixed-value resistors are manufactured in a range of standard resistances. The resistance can be worked out from the coloured bands painted on the body of the resistor. The coloured bands are part of a code in which each colour is assigned a value. (See Table 9.1.)

Table 9.1 Resistor colour code (4-band)

Colour	1st band	2nd band	3rd band	4th band
	0	0	–	Tolerance band: Brown = 1% Red = 2% Gold = 5% Silver = 10%
	1	1	**0**	
	2	**2**	00	
	3	3	000	
	4	4	0000	
	5	5	00000	
	6	6	000000	
	7	7	0000000	
	8	8		
	9	9		

Note: There are also 5-band and 6-band colour-coding systems used for higher tolerance resistors.

Look at this 4-band resistor. Can you work out its value?



Using the resistor colour code (4-band)

To find the resistance of the example:	Brown = 1 ∴ 1st number is **1**	Red = 2 ∴ 2nd number is **2**	Add the zeros to the end: **0**	This gives **120 ohms**

The tolerance band is silver, giving a tolerance of ± 10%. This means that the resistor's value could be anywhere from 108Ω (120Ω − 10%) to 132Ω (120Ω + 10%).

Variable-value resistors

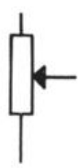
The resistance of variable-value resistors can be varied in a number of ways – for example, by hand, by heat or by light. Examples of these resistors include:

- potentiometers
- thermistors
- light-dependent resistors.

Potentiometers

A potentiometer enables the operator to change the resistance by turning a central spindle or sliding a knob. The volume control in a radio is an example of a potentiometer.

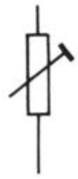
Symbol:



A rotary potentiometer

A smaller type is the pre-set potentiometer, which is adjusted with the aid of a small screwdriver and then left to work at that setting.

Symbol:



A pre-set potentiometer

Thermistors

The resistance of a thermistor is affected by temperature. In one type of thermistor, an increase in temperature brings about a *decrease* in resistance. In another type, an increase in temperature brings about an *increase* in resistance.

Thermistors can be used in thermostats to control air-conditioners, refrigerators and fire alarms. They can also be used to protect sensitive electronic equipment such as amplifiers and television sets.

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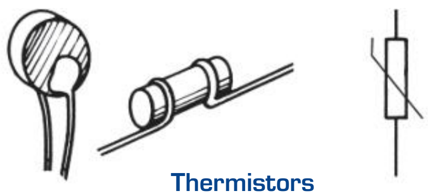
Thermistors are also known as temperature-dependent resistors (TDRs).



Thermistors

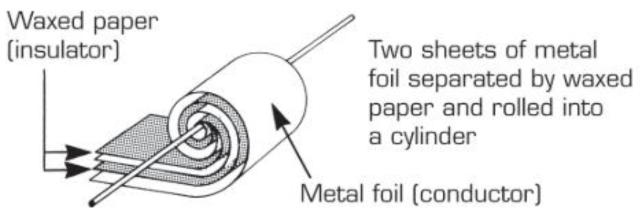
Light-dependent resistors

A light-dependent resistor (LDR) is a resistor whose resistance changes as the light intensity changes. When the light is bright, the LDR has a low resistance; when it is dark, it has a high resistance. LDRs are commonly used as light meters in cameras to detect the amount of light present.

A light-dependent resistor (LDR)

Capacitors

Capacitors consist of two layers of conducting material separated by a layer of insulation. They fill with an electrical charge when connected to a power source. The charge is stored by the capacitor and released as the circuit requires. The storage capacity is called the capacitance. It is measured in farads (F).



A simple capacitor

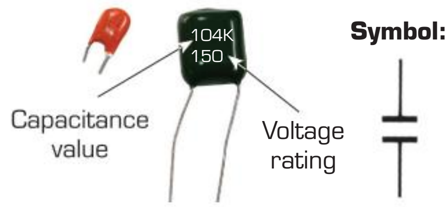
Two common types of capacitor are:

- polyester capacitors
- electrolytic capacitors.

Take care when working with charged capacitors or you might experience a shock.

Polyester capacitors

Polyester capacitors have only a small charge capacity. They can be connected either way round; that is, they are non-polarised. Like resistors, some polyester capacitors are colour banded to enable users to work out their value. Others have their values printed on them.

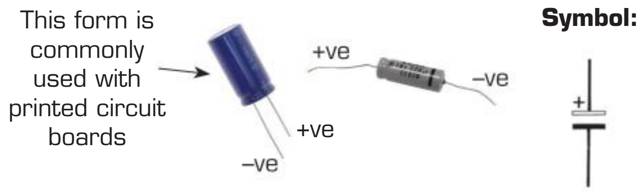


Polyester capacitors

Polyester capacitors are used in sound-making circuits such as burglar alarms. (Today, polycarbonate is often used instead of polyester because of its greater temperature stability.)

Electrolytic capacitors

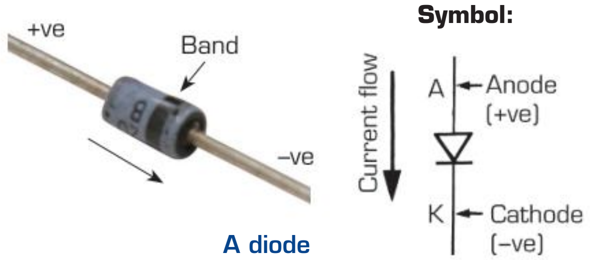
Electrolytic capacitors have a larger charge capacity than polyester capacitors. The value is inscribed on the body of the unit. Electrolytic capacitors are usually polarised; they have a positive and a negative leg that must be connected the right way round in a circuit. They are often used with resistors to produce a time delay, as in the case of egg-timers and time switches for electric lights.



Electrolytic capacitors

Diodes

A diode works like a one-way valve. Electricity can flow through it in one direction only. All diodes have a positive leg (anode) and a negative leg (cathode). (The cathode is shown by a band at one end of the diode.) They must be connected the right way round in a circuit. Diodes convert alternating current to direct current and are often used in circuits to protect components against accidental damage.



A diode

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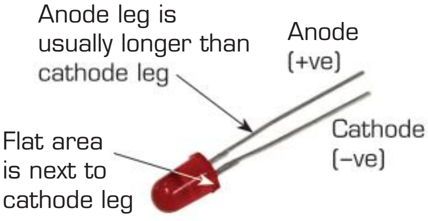
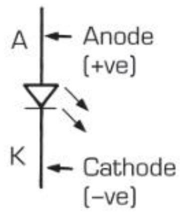
Light-emitting diodes

A light-emitting diode (LED) is a special kind of diode fitted into a small bulb-like package (red, green or amber in colour) that lights up when current flows through it in the right direction. An LED is used in a circuit to show that a current is flowing. LEDs often require a protective resistor so that they are not burnt out by too great a flow of current.



A light-emitting diode (LED)

Symbol:

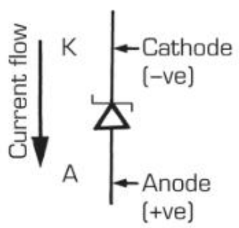


Zener diodes

When a Zener diode is connected in reverse, with the negative leg connected to the positive terminal of the power supply and the positive leg to the negative terminal of the power supply, current begins to flow at a particular voltage. Zener diodes can therefore be used with a limiting resistor to control voltage in a circuit. They are sold in predetermined voltages, for example 6.2 V and 12 V.

A Zener diode

Symbol:



INFORMATION FILE

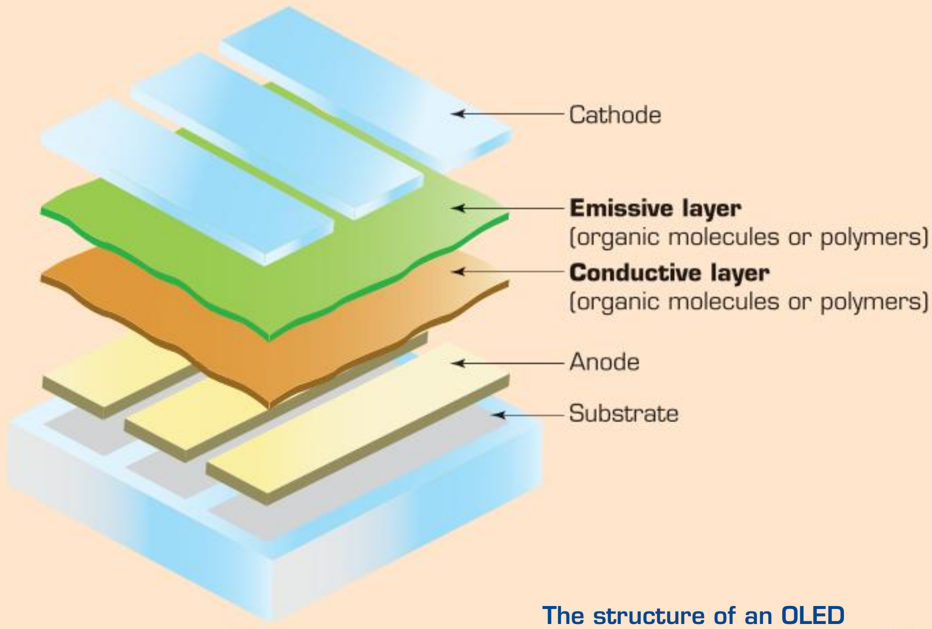
Organic light-emitting diodes

Organic light-emitting diodes (OLEDs) are at the cutting edge of illumination and display technology. Some of the new and exciting OLED display and illumination possibilities include such items as televisions, laptop computers, mobile phones, clocks, lighting and lamps.

OLED screens could also be used to make roll-up screens for laptops, wall-sized video panels of any shape for advertising and wearable head displays such as glasses. The screens are brighter, respond faster, are self-illuminating, consume less power and are thinner and lighter than other displays. The total thickness of the screen can be around 1 millimetre.

Cathode Ray Tube (CRT) was the display technology of the old big-box televisions and computer monitors. Present-day display technologies are Liquid Crystal Display (LCD) and Plasma display screens. These screens usually need to be back lit for illumination.

The OLED is made up of a number of layers including an organic polymer material layer (made up of two or three layers) that is sandwiched between a cathode (−ve) and an anode (+ve). All of this structure is supported by a substrate. The substrate could be made of plastic, glass or foil. The cathode(s) and anode(s) are usually aligned in rows and columns to produce a matrix of pixels or cells.



The structure of an OLED

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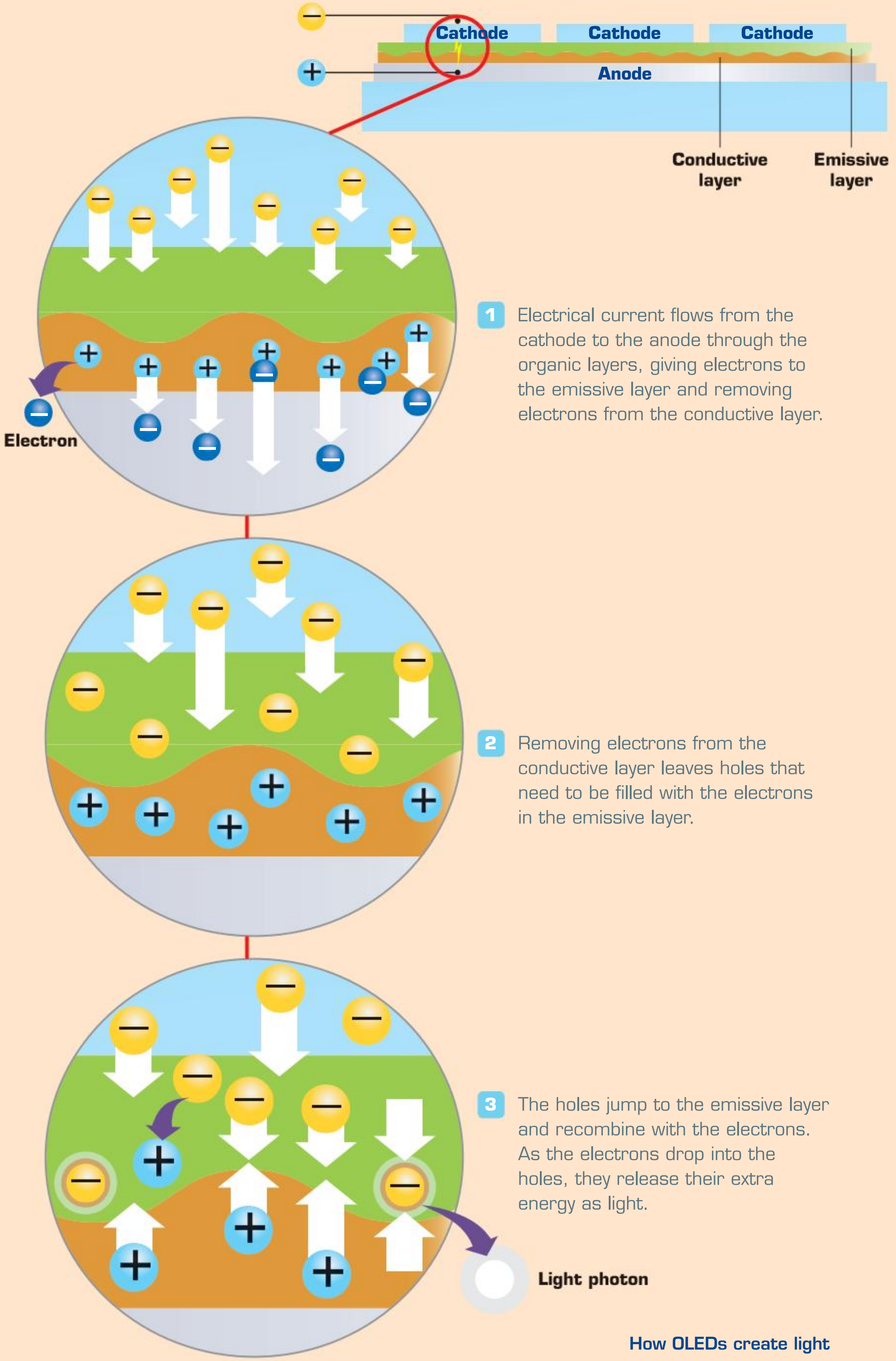


How OLEDs create light

The OLED process is as follows:

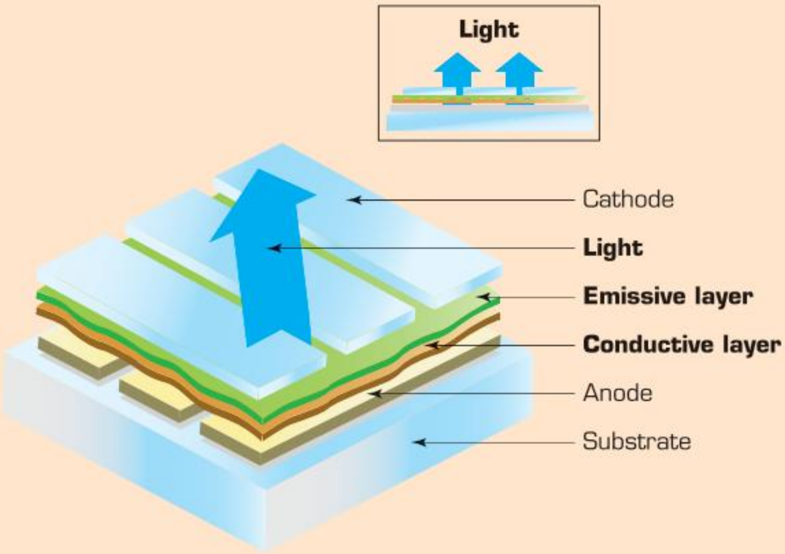
1 The battery or power supply of the device containing the OLED applies a voltage across the OLED.
2 An electrical current flows from the cathode to the anode through the organic layers (an electrical current is *a flow of electrons*).
   - The cathode gives electrons to the emissive layer of organic molecules.
   - The anode removes electrons from the conductive layer of organic molecules. (This is the equivalent of giving electron holes to the conductive layer.)
3 At the boundary between the emissive and the conductive layers, electrons find electron holes.
   - When an electron finds an electron hole, the electron fills the hole (it falls into an energy level of the atom that is missing an electron).
   - When this happens, the electron gives up energy in the form of a photon of light.
4 The OLED emits light.
5 The colour of the light depends on the type of organic molecule in the emissive layer. Manufacturers place several types of organic film on the same OLED to make colour displays.
6 The intensity or brightness of the light depends on the amount of electrical current applied: the more current, the brighter the light.

OLEDs fall into two basic categories. They are:

- non-transparent displays
- transparent displays.

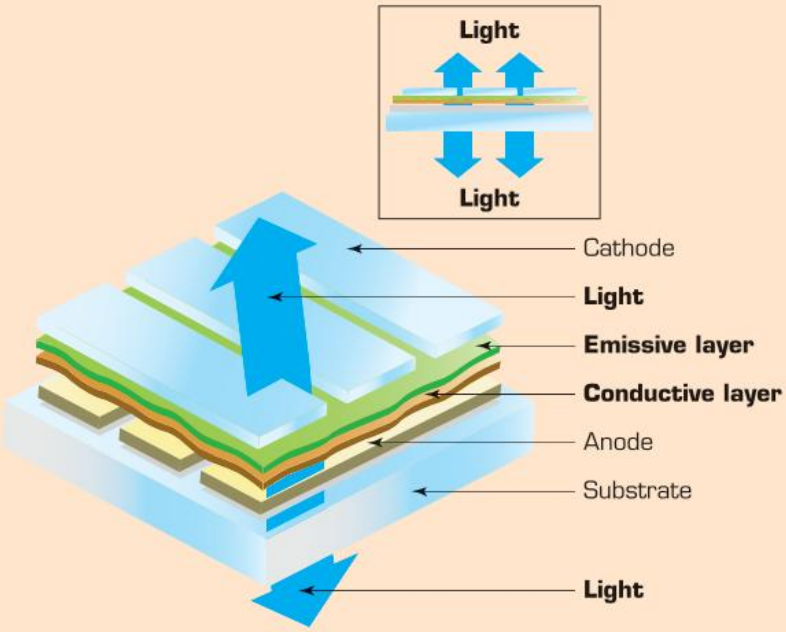
Non-transparent displays

The non-transparent (top-emitting) OLED display uses a non-transparent substrate that is reflective or opaque. You cannot look through the screen. When current is applied, the light is emitted in one direction – that is, away from the substrate and viewed in one direction only.



Transparent displays

The transparent OLED display uses a transparent cathode, anode and substrate. When the power is off, the structure has 70–85 per cent transparency. The result is that you can look through the screen. However, when current is applied the light is emitted in both directions and can be viewed from both sides. Transparent OLEDs can be used for head-up displays.



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White OLEDs

White OLEDs can be used for lighting. OLED lighting is a bright, white light that draws less power and is longer lasting than any other types of artificial light. OLED lighting is very thin and can be formed into any shape. OLED light panels have little weight and can be fitted to walls to create visual effect. For example, an OLED light panel can be transparent and can function as a window by day and a light source at night.

White OLED panels

Transistors

A transistor is a sensitive electronic device that is used to amplify an input current or act as a switch.

INFORMATION FILE

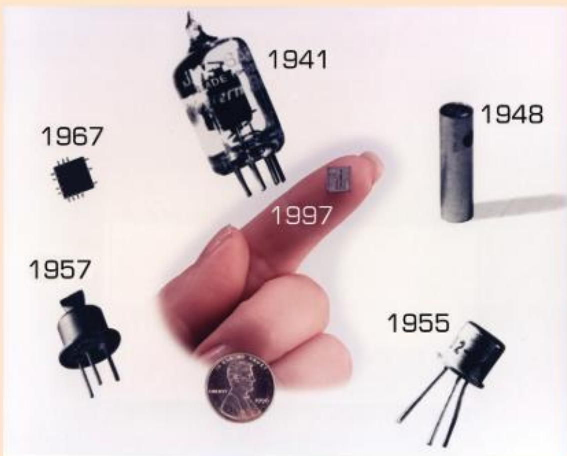
Transistors

The first transistor (the transfer resistor) was invented in 1947 at Bell Laboratories, New Jersey, USA. It was known as a point-contact transistor. When voltage was applied, the point of the triangle (covered in gold) contacted the germanium crystal (a semiconductor) and the current was amplified. This event was an important step in the development of electronics.

The transfer resistor was the first transistor.

The vacuum tube (see page 200), like the transistor, was able to regulate current and act as a switch or amplifier. However, its function made it difficult to **miniaturise** and the heat generated was also an issue. Over time, the development of the transistor became the basis for the integrated circuits and microprocessors of modern electronics.

The photograph below shows a vacuum tube and how the size of the transistor has decreased over time. Note that the early integrated circuits (ICs) such as the 1967 microchip contained a small number of transistors and other components, while the 1997 chip could have contained up to 5 million transistors. The first IC was developed by Jack Kilby in 1958.



Electronic components (1941–1997)

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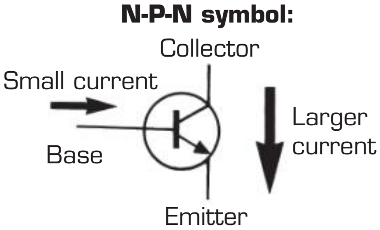
A commonly used transistor is the bipolar type, which usually has three legs – collector (C), base (B) and emitter (E) – that must be connected the right way round for it to work. There are two types of bipolar transistors:

- N-P-N
- P-N-P.

They are similar except for the direction in which the current flows. (N and P refer to the semiconducting materials used in the transistor.)

N–P–N transistors

N-P-N symbol:



To switch on an N-P-N transistor, an input voltage greater than 0.6 V would have to be applied to the base leg. The current in the base leg causes a larger current to flow from the collector leg to the emitter leg. Likewise, in an AC circuit a small signal can be amplified into a larger signal, as in a hi-fi power amplifier.

There is general agreement (often referred to as 'Moore's Law') within the electronics industry that the **density** of transistors on a chip would double over a set period of time. In the early days of computers that time period was 12 months and at one stage it was 18 months. Today, it is approximately two years.

Did you know that more than one billion transistors are contained in today's top microprocessors? Imagine that!

INFORMATION FILE

Semiconductors

A semiconductor (as in 'half', or 'part', conductor) refers to a type of material – for example, silicon – to which impurities have been added. This material resists the flow of electrons. The material can also conduct the flow of electrons if the current is sufficient to overcome the resistance of the material. By using a controlling current, semiconductors can be used to control the flow of electrons in electronic circuits. Examples of semiconductors include transistors and light-emitting diodes.

Integrated circuits

Circuits can be constructed by using separate components such as transistors, resistors and capacitors. The resulting circuits are often large in size and can take up much space. However, with the development of integrated circuits, the size of the circuit (and thus the object into which it has been built) has been reduced greatly. For example, compare the calculators or computers you are using now with models from the 1960s and 1970s.

An integrated circuit (IC) is also called an electronic chip or a silicon chip. It consists of a minute circuit embedded in a base material (commonly silicon). A single tiny chip may contain thousands of components, such as transistors, resistors and capacitors, connected to form a circuit and housed in a plastic case to protect it. There are exposed pins to enable the IC to be connected to external circuitry.

Silicon chips

Modern electronics relies heavily on micro-electronic circuits such as the IC. The IC is cheap to manufacture, takes up little space and can perform many complicated processes. For these reasons, it

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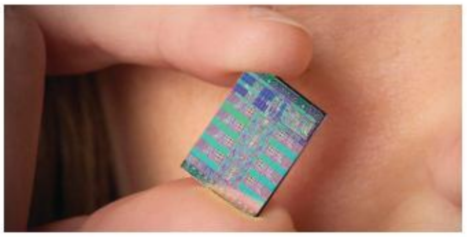
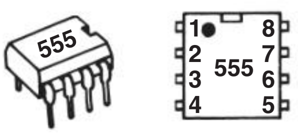
has made possible the widespread use of powerful technology such as mobile phones, fuel control systems in cars and industrial robots in manufacturing.



An IBM mobile-phone micro-processor

ICs can be designed to carry out special functions in a circuit. For example, a computer contains a number of ICs (memory, micro-processor and interface ICs) that work together. Many electronics projects such as timers and amplifiers include cheap, ready-made ICs that can be bought from electronics suppliers.

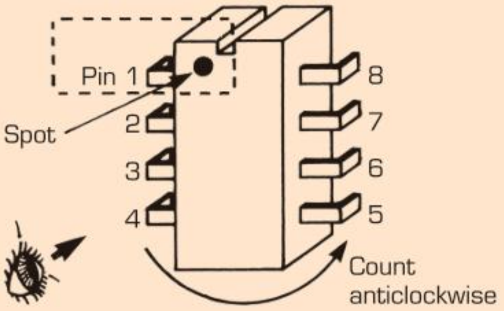
Symbol:



The 555 IC is used as a timer in circuits such as those for darkroom photographic timers

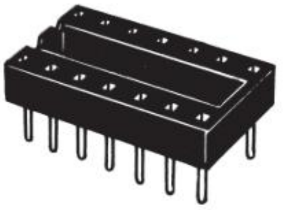
INFORMATION FILE: How to find Pin 1 on an IC

As with other electronic components, correct pin connection of an IC is very important. A standard system has been developed to help users identify the location of all pins.



1 Look down at the top of your IC. (The pins will be pointing away from you.)
2 One end of the IC has a mark of some kind. (It could be a notch, a printed symbol and/or a spot of paint.)
3 Pin 1 is the pin alongside this mark. Count pins in an anticlockwise direction to identify the other pins. The last pin will be opposite Pin 1.

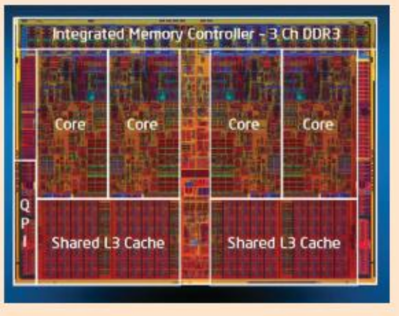
The manufacturing process used to place all the components on the same base material ensures that ICs are more reliable than conventional electronic circuitry. However, ICs can be damaged easily if they are overexposed to heat, such as heat from a soldering iron. To prevent heat damage to ICs, you can use an IC socket, as shown here. The IC socket is soldered into the circuit board and the IC is fitted into it. An IC socket is often used to hold more expensive ICs.



An IC socket

INFORMATION FILE: i7 chips (Nehalem micro-processor)

An i7 chip



An inside view of an i7 chip

Nehalem is the term used to describe the architecture of the chip (that is, the micro-processor). This chip has two main sections: the core; and the surrounding components, called the uncore.

- The core [processor(s)], which 'number crunches' simple to complex mathematical operations and schedules tasks, stores information temporarily in the cache memory. The cache takes up about one-third of the chip's core.
- The uncore, which contains additional memory outside the core, enables multiple cores to work from the same information at the same time.

The Nehalem chip also features a Power Control Unit, which can apportion power as needed to each

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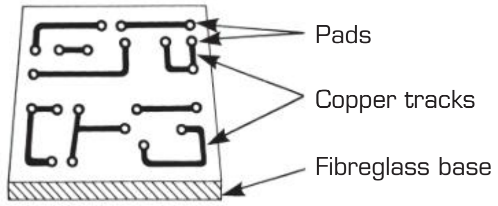
section of the chip; a Turbo Mode, which uses available power to boost processing speed; and a QuickPath, which enables processors to take shortcuts when they ask other processors or the chip for information.

The architecture of micro-processors such as the Nehalem chip is such that multiple cores (such as dual, quad and octo) arrangements can be built on one chip. The result is that data can be processed faster and more efficiently, much like a team of workers working together instead of one individual doing all the work.

The printed circuit board (PCB)

Early electronic circuitry consisted of components and a great deal of wire. The wire provided a pathway along which the current flowed. Modern electronic circuitry does not use much wire at all, but relies on printed circuits – a collection of copper tracks. The printed circuit is attached to a base material, and together they are called a printed circuit board (PCB).



A printed circuit board (PCB)

PCBs can be plain or photosensitive – that is, they react to ultraviolet (UV) light.

In modern electronics, most components are mounted and connected to one another on a PCB. It provides a rigid support for all the components.

For example, one type of PCB consists of a non-conducting base such as a fibreglass board, 1.5 millimetres thick, which is covered on one side by a thin layer of copper, 0.25 millimetres thick.

An etching process is used to remove the excess copper, leaving tracks and pads. The tracks provide a pathway along which the electricity can flow between the components. The pads, usually circular in shape, are the points at which the components are soldered to the PCB.

You can make many electronic projects – for example, a door bell, a burglar alarm or even a transistor radio. These projects consist of many components, such as ICs, resistors, LEDs and capacitors, mounted on a PCB to form a circuit. Like any other system, the circuit is designed to receive an input, process it and produce an output.

INFORMATION FILE

Types of assembly – PCBs

There are two basic types of assembly used for PCBs. They are:

- through-hole mount: this is where the component pins, legs or wires are mounted and soldered through a hole in the PCB
- surface mount (refer to 'Surface mounting' on page 199): this is where the component sits fully on top of the PCB and its pins or legs are soldered to the pads on the PCB. This type of mounting allows for more compact design and assembly.

Components – either 'active' or 'passive' – are packaged for both types of mounting. Active components include transistors, diodes and ICs. Passive components include resistors, capacitors and inductors such as coils.

Prior to PCBs, a popular type of assembly was 'point-to-point' wiring where the pins or legs of components and wire were connected to tags or other mounting points. A tag is a strip of conductive material with holes that enables the looping of legs and wire for connection and soldering.

Input, process and output devices

Circuits are systems designed to perform a specific task. Each component of the circuit also has a specific function to perform.

All components can be grouped into one of three categories depending on the function they perform. They are:

- input devices
- process devices
- output devices.

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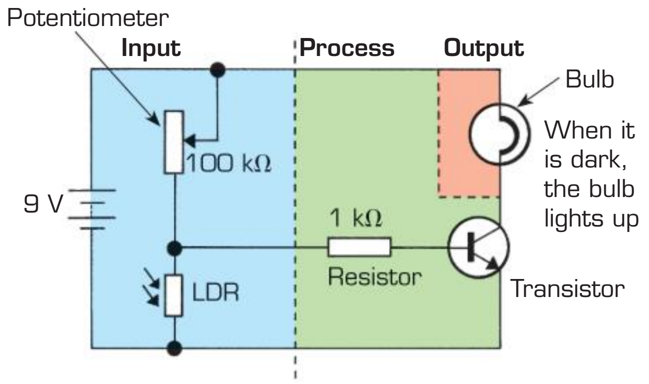


Input, process and output blocks in a circuit for an ambient light control switch

All circuits require some kind of input, such as electricity, light or sound. Examples of input devices include sensors, buttons and switches. These devices enter information into the system. Their task is to activate the circuit. The LDR is the input device in the circuit.

Process devices are components in the circuit that receive the information from the input and process it into an electrical signal. The signal is used to control the output.

For example, the transistor in the circuit diagram illustrated on the left acts as an electronic switch. Note that a resistor is placed in series with the base leg of the transistor to ensure that the transistor continues to function as a switch in all settings.

As light begins to fade, the resistance in the LDR will increase. Then the voltage across the LDR will rise. This will increase the current flow to the base leg of the transistor.

If an input voltage greater than 0.6 V is applied to the base leg, the transistor will switch on. Current will flow between the collector leg and emitter leg, and the bulb will light up.

The processed electrical signal is converted into a result or output. Here information is given out or something happens (such as light, sound or movement). Examples of output devices are bulbs, LEDs, motors and speakers.

INFORMATION FILE

What's in the computer case?

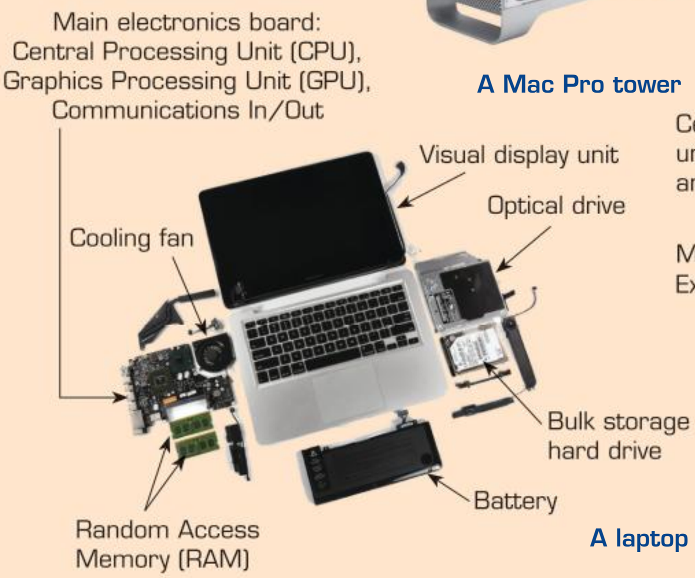
Have you ever looked inside the 'box' of a desktop, tower or mini-tower computer? Do you know what's inside that 'box'?

The box is a casing that provides shelter for a number of different items a computer needs in order to display images on the monitor screen and to perform set tasks.

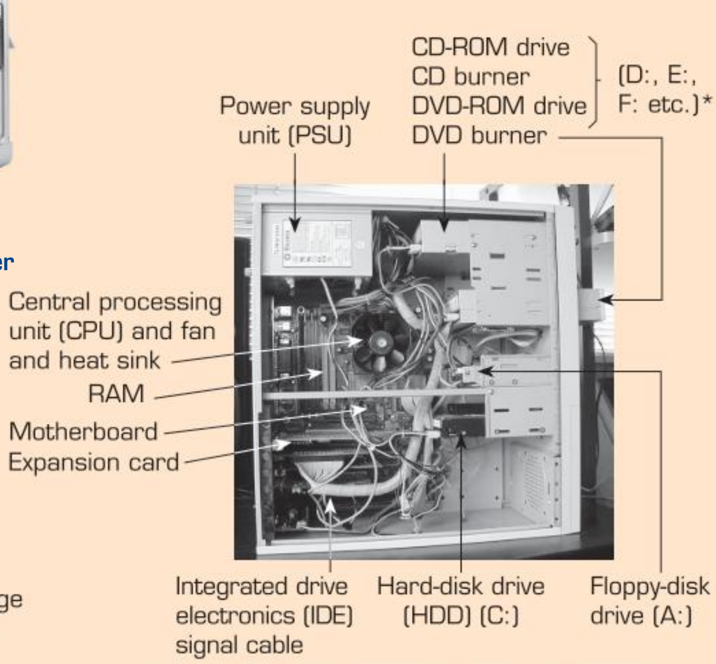
A Mac Pro tower

The design of the box and circuitry may change over time, as shown in the photographs below, but the basic items remain. Let's look at these items.

Every computer needs power. The power supply converts AC (alternating current mains power) into 5 V and 12 V DC (direct current) to run the computer. A fan is attached to the power supply to help keep it cool.



A laptop



*Note: (D:, E:, F: etc.) signifies that additional drives may be installed

The inside of a PC tower (early 2000)

There are a number of PCBs. The largest PCB is known as the motherboard. This holds the Central Processing Unit (CPU), Random Access Memory (RAM), Read-Only Memory (ROM) and other parts that process the input.

The smaller PCBs (known as expansion cards) plug into the large sockets on the motherboard. They are specific circuits used to operate accessories such as the monitor, disk drives, printers and other computer options.

Look closely at the motherboard PCB and you will see IC chips. Each IC has a specific function. The largest IC is usually the CPU, which is often thought of as a computer's engine. It needs to be big because of the complex circuit within the CPU package, which moves data and processes almost all the information using a software program. The software program (for example, the game or word processor) has its own orders, which are stored on the hard-disk drive. When the program is run, it is transferred to RAM and then to the CPU, which controls data transfer and information processing.

A great deal of heat can be generated by the CPU. The IC is often covered with fins, which act as a heat sink, and/or a fan is used to keep it cool.

Some of the ICs are RAM chips. Their function is to remember information for further use. The power must be on for the RAM chip to work. Switch off the power, and the RAM chip forgets everything.

Some of the ICs are ROM chips. Their function is to provide information burnt or stored in them. You can access the information as many times as you like, but you cannot change it.

Most of the remaining ICs are decision makers that are linked together and used to control the computer.

INFORMATION FILE

Data storage hard-disk drives and solid-state drives

The underside view of a hard-disk drive

The top view of a hard-disk drive with the cover removed

A hard-disk drive (HDD) is a bulk storage device or memory commonly used for your computer, iPod or larger MP3 player. The disk in the hard drive, called a platter, stores the information. The platter may be made from aluminium or glass and is coated with a thin layer of metal on each face. The face is divided into billions of tiny areas that can be magnetised or demagnetised. Information and data are stored as 1 (one = magnetised) or 0 (zero = demagnetised) on the platter. This number structure, made up of ones and zeros, is known as binary code.

A mechanical arm moves radially across the platter's face to read, record and store information. A tiny electromagnet known as a 'read-write' head is attached to the tip of the arm. There are two mechanical arms for each platter: one arm to read and write for the top face and another for the bottom face.

The hard-disk drive is fairly robust, but it can fail. As this is an electro-mechanical device, it is susceptible to wear and tear, vibration and shock, which can damage the unit, head, platter and other parts.

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There is a trend towards using solid-state drives as an alternative. A solid-state drive (SSD) is a storage device for data, just like the hard-disk drive. The SSD, unlike the hard-disk drive, has no moving parts, is less fragile, is silent and can operate in a greater range of temperatures and harsher environments. A semiconducting material such as silicon is used to store data. This is usually constructed as an array of silicon chips on a PCB with a controller.

A solid-state drive

Another type of solid-state storage device is the USB memory stick.

Carrying out an electronics project

Many electronics projects for beginners come complete with components, a PCB, schematic diagram(s) and a circuit layout. Detailed instructions are also included. As you learn more about electronics, you will realise that all you really need to begin with is the schematic diagram. After some practice, you will be able to design your own layouts and/or circuits.

Steps for making a PCB

Step 1: Designing a circuit layout

1 Check the components list for your project, then collect or buy all the components you need.
2 Study the schematic diagram for your project. Take the components and move them around to work out the best placement. (Make a careful note of series and parallel circuits.)

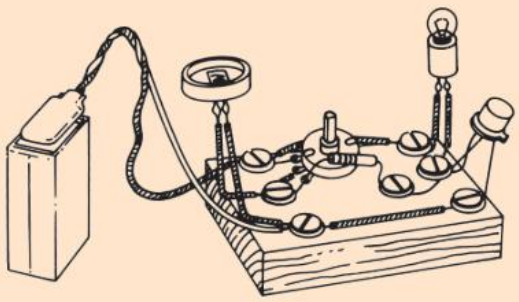
RULE: In a good circuit design, components are placed in rows, and similar components (such as resistors) are grouped together.

INFORMATION FILE

Modelling a circuit

Before you draw your circuit accurately and spend hours making a PCB, you should test the circuit.

Modelling is a quick way to test a circuit. A very simple model can be made with a piece of wood and some countersunk or raised-head screws and cup washers. Wires and leads of components are held in position by the screws and cup washers, as illustrated here. You can also use a software program such as *OrCad PSpice Suite* or *NI Multisim* to model and test your circuit.



A model based on the circuit diagram illustrated on page 192

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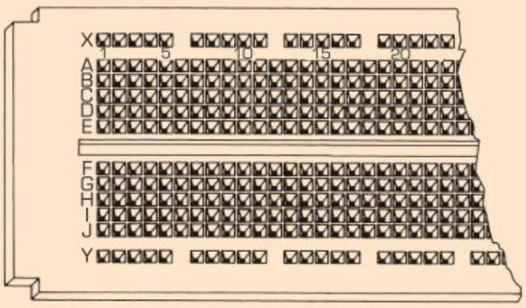
INFORMATION FILE

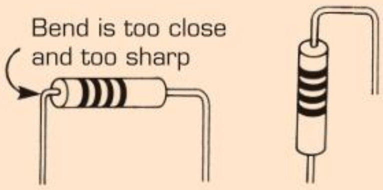
'Breadboarding'

Instead of using timber and screws to model your circuit, you can use a 'breadboard'. A breadboard has strips (rails) of conducting material encased in plastic that can be connected by components to allow the flow of current. Breadboarding is a quick and convenient way to test your circuit.



The five holes in each vertical row (e.g. 1A to 1E or 1F to 1J) are joined by a strip of copper inside the breadboard
All the holes in each of the top and bottom rails (X and Y) are also connected

Take care when bending the leads on components. Avoid bending the leads too close to the component. Also, a smooth, gentle curve is required, rather than a sharp bend.



Horizontal installation Vertical installation

3 Make a pencil sketch of your circuit, looking down on the components. Then draw in your proposed tracks to connect the components. (Alternatively, you could mount the components in their proposed locations on a sheet of polystyrene.)

4 Re-examine your proposed circuit and check for faults. For example, components should not touch each other. Check also for crossover tracks that could produce short-circuits. (Short-circuiting is when current flows along the wrong path through a circuit.) If you cannot find any faults, see if you can miniaturise your circuit.

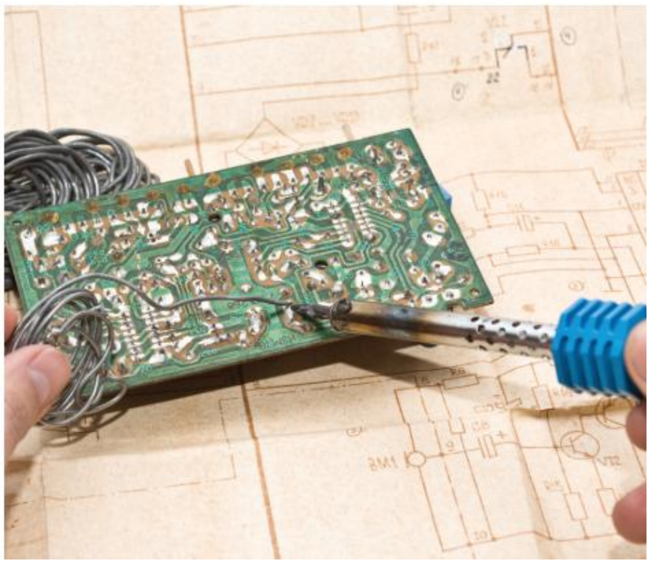
5 You are now ready to draw a detailed circuit layout as the basis for your printed circuit board.

Step 2: Preparing a detailed circuit layout

On a sheet of tracing paper, clear acetate or polyester film, draw your circuit accurately. You can use:

- graphics instruments such as set-squares and templates
- a CAD program such as *Goggle SketchUp* or *Autosketch*. There are also dedicated programs such as *OrCad* or *NI Multisim* for PCB design. You could download a free software pack such as *ExpressPCB*. Check with your teacher or electronics supplier.

Refer to the Information File on the dos and don'ts of circuit layout overleaf.



Soldering components onto a PCB

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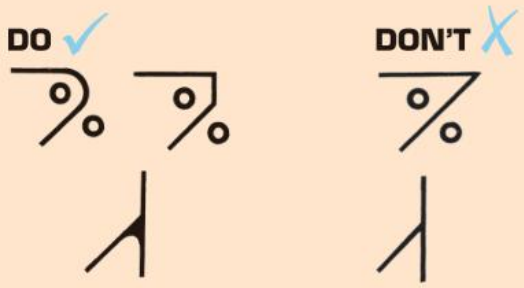
INFORMATION FILE

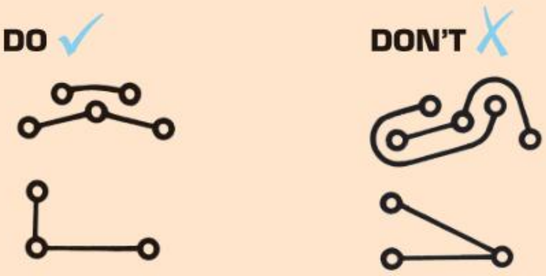
Some dos and don'ts of circuit layout

There are some dos and don'ts of good circuit layout that you need to know. They are shown here.

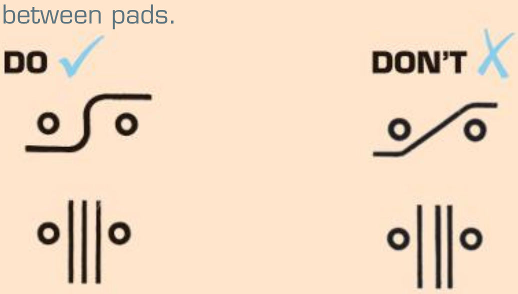
- Avoid sharp angles in tracks to prevent them from breaking.



- Always use the shortest possible track. This will minimise the resistance in the track.



- Maintain equal spacing where tracks pass between pads.



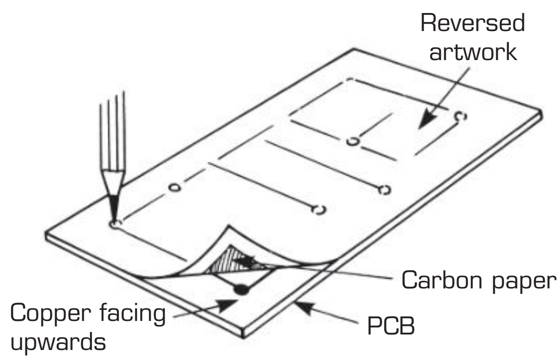
- Avoid using tracks that are the same size as the pads; otherwise solder may flow away from the pads.

Step 3: Transferring your artwork onto a PCB

There are two methods of transferring the circuit layout onto the photosensitive board.

The direct method

Clean the copper, using steel wool or fine abrasive paper. Set up the artwork (in reverse) with carbon paper between it and the PCB, as shown in the following diagram. Trace over your artwork. Remove the artwork and the carbon paper.



The direct method

Use an etch-resist pen to fill in the tracing on the copper. Allow to dry thoroughly.

The light-sensitive method

For this method, you need to buy light-sensitive exposure film and PCB, as well as developers.

Read the Material Safety Data Sheet (MSDS) before using the light-sensitive exposure film, PCB and developers. Follow the manufacturer's guidelines.

Once the photo-tool has been developed, it can be used to print the circuit on the PCB, as shown in the diagrams opposite.

There are two types of PCB manufacturing processes. They are:

- a negative resist process, as shown opposite
- a positive resist process that uses a positive image throughout the process. This eliminates the need to make a negative photo-tool.

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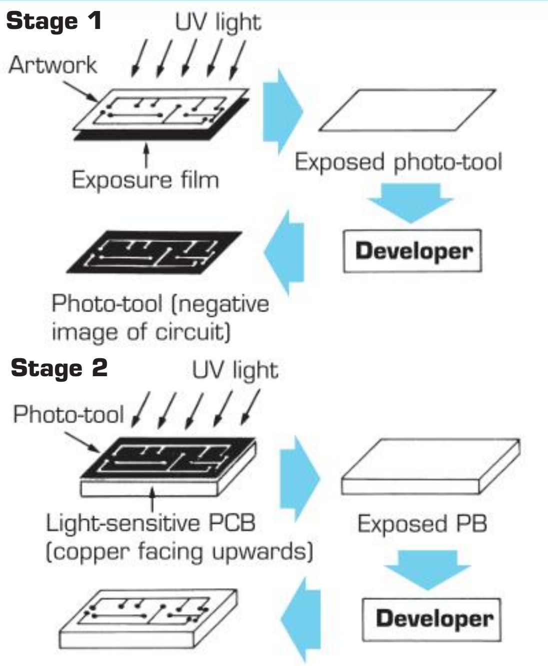


The light-sensitive coating on the PCB hardens where it has been exposed to light. The developer produces a positive image of the circuit

The light-sensitive method

The photo-tool can be re-used to make many copies of the circuit.

Note that an alternative process for plain PCBs is to use a CNC milling machine to remove the unwanted copper. Alternatively you could use a CAD/CAM system.

Step 4: Removing the unwanted copper

Etching is the process by which unwanted copper is removed from the PCB. You can use either ferric chloride or ammonium persulphate.

- Read the Material Safety Data Sheet (MSDS) before using the etchant. Follow the manufacturer's guidelines.
- Use safety equipment such as goggles or a face shield and a vinyl apron.
- Dispose of etchant responsibly. Care for the environment.

Once the PCB has been etched, remove it from the solution. Wash it thoroughly in water.

INFORMATION FILE

Soldering

Soldering is used to join components to each other or to the copper pads. Standard electronic solder is known as 60/40 solder; that is, it is an alloy of 60 per cent tin and 40 per cent lead. It has to be heated with a soldering iron, allowed to melt and then cooled. Cleanliness is very important when soldering; otherwise a poor joint is formed.

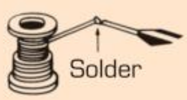
Work in a well-ventilated area when soldering. Consider using rosin-free solder, which is now available.
Beware of hot solders and soldering irons.

How to solder

1 Plug in soldering iron. Allow it to heat up.

2 Wipe the bit of the iron on a damp sponge to clean it.

3 If necessary, tin the bit with solder.



4 Place the hot iron so that it touches the copper pad and the lead for about a second. Touch the solder against the lead near the iron. Allow the solder to flow into the joint. Remove the solder and iron.

5 Inspect the joint after it has cooled down. It should be shiny and feel firm (if not, re-solder). Cut off the remaining lead.

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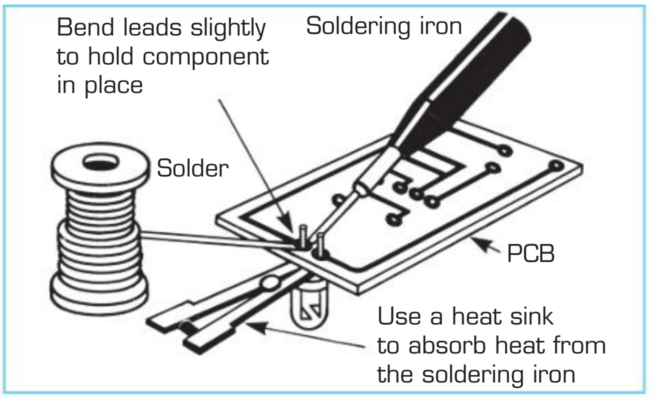


Soldering components

Step 5: Assembling your circuit

1. Drill holes in the PCB from the copper side, making them large enough to fit the through-hole mount component leads.
2. Clean the copper tracks, using steel wool or fine abrasive paper.
3. Also clean all the leads on the components.
4. Fit the components into the PCB and solder them in position. (Double-check the position of your components before soldering.)
5. Test your circuit.
6. Remove any remaining flux with methylated spirits or commercial flux remover.
7. If you wish, you may apply a sealer such as a commercial spray-pack sealer.

The final stage of your project is to design and make a container to hold and protect your circuitry. Remember that circuits heat up and they therefore require ventilation.

Fault-finding

So your circuit doesn't work! What do you do?

1. Make sure that all the components are in their correct positions on the PCB.
2. Check for missing components.
3. Check all soldering joints to make sure that the soldered components are not loose. A good solder joint is shiny, not dull-looking. (A poor joint is referred to as a 'dry' joint.)
4. Check the copper tracks and pads – look for breaks in the circuit or short-circuits caused by excess solder.
5. Check that all polarised components are connected the right way round.
6. Check for damaged components, especially damage caused by heat from the soldering iron.
7. Check the value of each component; make sure that you have used the correct-value resistors, capacitors and so on.
8. Check for short-circuits: make sure that no leads or wires are touching each other.

Still no luck? ... Seek advice from an expert!

INFORMATION FILE

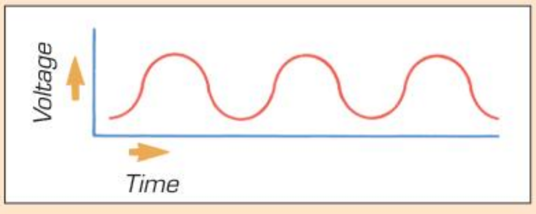
Analogue and digital signals

All the components in a circuit are receiving, sending or controlling electric currents. These currents are known as signals. There are two types of signal:

- analogue signals
- digital signals.

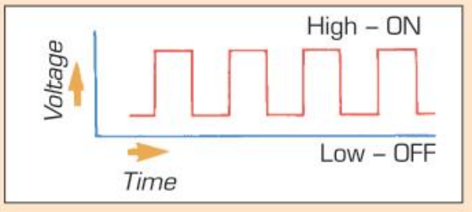
Analogue signals

An analogue signal can have any value between an upper and a lower limit at any time.



Digital signals

With a digital signal, the voltage or current is in one of two states at any time: either high or low (that is, on or off).



The digital signal is used in switching circuits, which are often called 'flip-flops'. Flip-flops form the basis of a computer's memory. They store data by switching on or off – 'on' is 1 in the computer's binary code, and 'off' is 0. The data stored in each flip-flop can then be processed by the computer.

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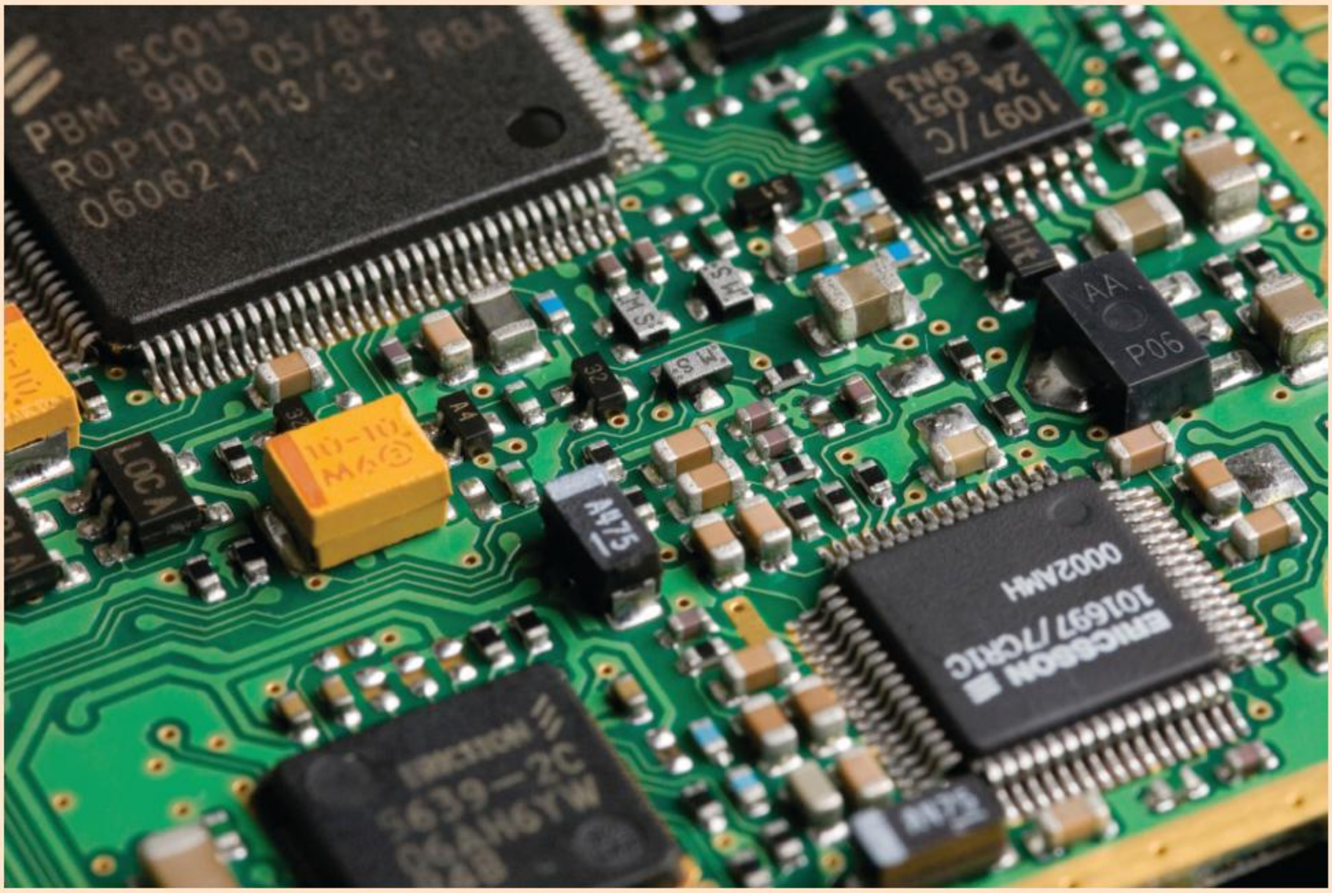
INFORMATION FILE

Surface mounting

The design and manufacture of PCBs in industry has changed with the introduction of surface mounting. To build a PCB, it is no longer necessary to drill holes for through-hole, mount components and solder their legs to the copper track.

In surface mounting, the components are soldered directly on top of the copper track, making this a quicker method of production. The surface-mounting components are tiny – for example, a surface-mounting resistor may be only 3 millimetres long × 1.5 millimetres wide. This has also meant a reduction in the total size of PCBs. PCBs can be of a mixed type, with both through-hole and surface-mount components together on the one board.



Surface-mounted PCB circuitry

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INFORMATION FILE

Vacuum tubes: the birth of the electronics industry

In 1904, John Fleming, a British scientist, displayed a device that converted alternating current into direct current. This was known as the Fleming Diode. The diode was an incandescent bulb (developed by Thomas Edison) that contained an extra electrode (also known as an anode or plate).

Fleming found that a direct current would flow through a vacuum under certain conditions. Electrons boiled off from the hot filament of the bulb were drawn to the cold electrode. The current could only flow in this direction and not the other way. Its initial use was to detect weak signals produced by the wireless telegraph. The diode vacuum tube has been used as a DC power supply for electronics equipment.

A New York inventor called Lee de Forest improved the Fleming Diode in 1907. He added an extra electrode, a bent wire called a grid, between the filament (cathode) and plate.

By applying a signal to the grid (and not to the filament), there was a much more sensitive detection of the signal. The result was that the grid modulated the current flowing from the filament to the plate. This device was the first successful electronic amplifier. It was known as the audion. This was the beginning of our present-day electronics industry.

An audion vacuum tube

From the 1920s through to the 1960s, different vacuum-tube families were developed. These tubes, also known as valves, were used in radios, amplifiers, radar, televisions and computers. Many tubes have been replaced with semiconductors – for example, LEDs, transistors and diodes. However, the technical benefits of a tube have meant that its role in radio and audio is assured.

An example of these types of vacuum tubes is the audio beam tetrode. This common power tube is used in modern, high-end audio amplifiers designed for the home and professional use.

An audio amplifier using the tetrode KT88: the KT was originally developed by the Marconi company in the UK ('KT' stands for 'Kinkless Tetrode').

Transistor amplifiers have captured the general electronics market over time. Transistor amplifiers have become more common than valve amplifiers because they were cheaper to produce and the amplifiers could be made smaller in size as the transistor shrank and the IC developed. For many people, the sound quality of the transistor amplifier was often an issue.

A recent trend is towards 'hybrid' designs, which use both transistor and valve amplifiers. A common 'hybrid' has a valve preamplifier connected to a transistor-based power amplifier. The result is a valve-generated *warm* sound, which is amplified by the transistor power amplifier.

A fatboy-iPod dock system

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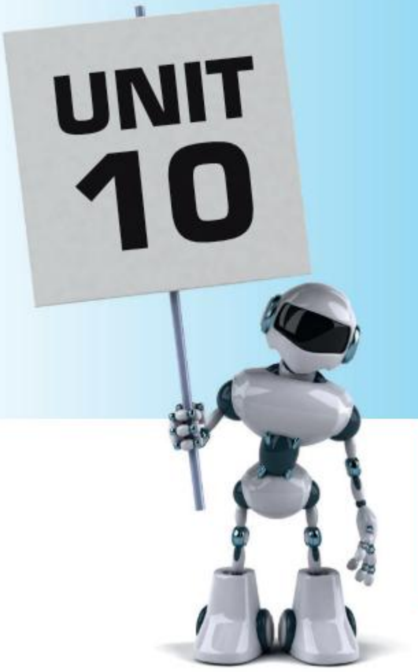


Structures

In this unit, you will learn:
- what structures are
- about different kinds of structures
- about techniques of constructing buildings.

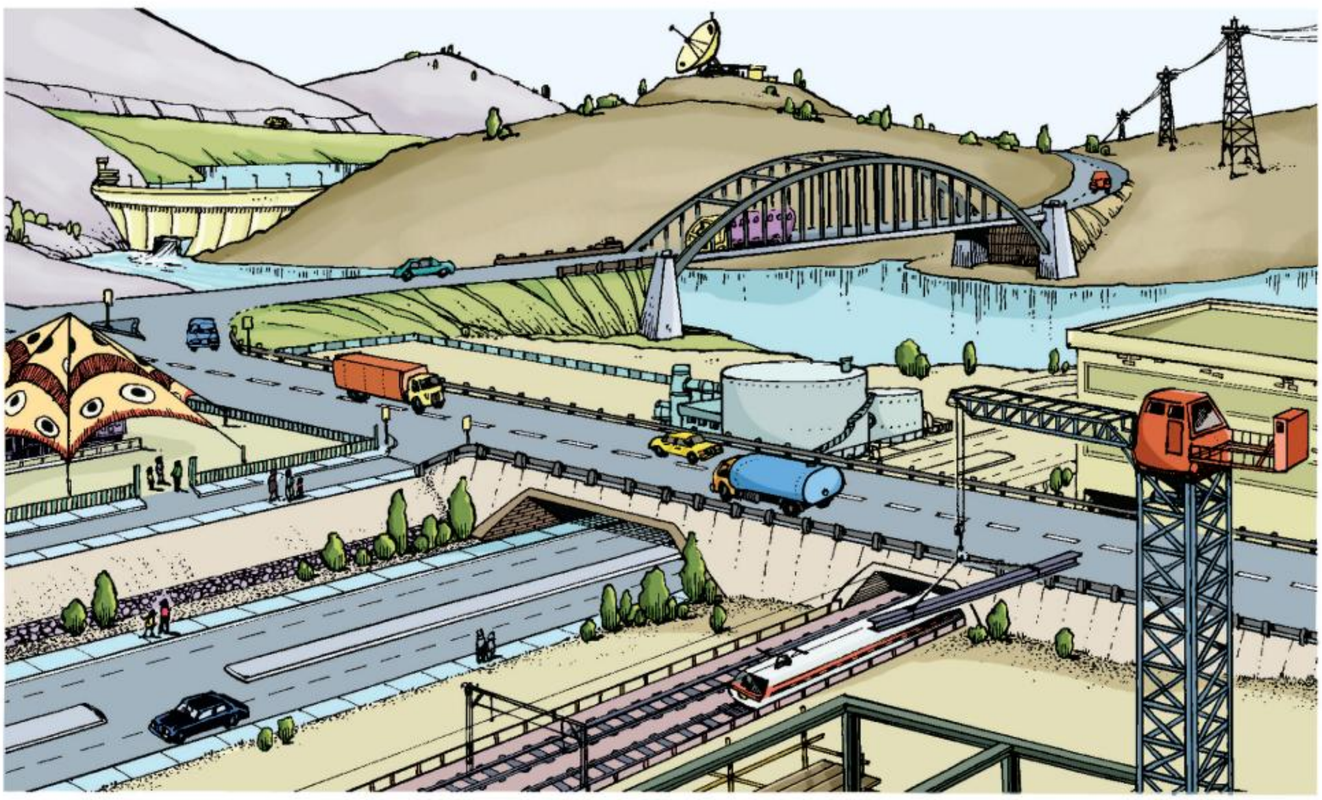
What are structures?

A structure is something that can carry a load and withstand other forces acting on it.

There are natural structures in the world around us. For example, the human skeleton is a bony structure that carries the mass of the body and withstands forces when the body moves.

People have made many different kinds of structures that carry loads and withstand other forces. Examples are:

- structures that provide shelter, such as homes and office buildings
- structures that carry loads, such as bridges, towers and cranes
- structures that control the environment, such as dams and retaining walls.



Which manufactured structures can you identify in this scene?

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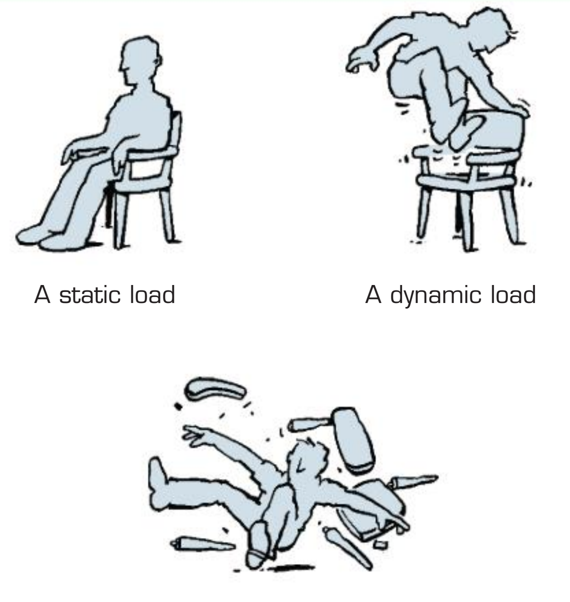
Loads

A structure has to support its own mass as well as any other loads. For example, a water tower has to carry the mass of steel and concrete from which it is made, as well as the water stored in it.

There are two kinds of load:

- static load: that is, a load that is not moving. When a person is sitting still on a chair, the chair is carrying a static load.
- dynamic load: that is, a moving load. When a person is bouncing up and down on a chair, the chair is carrying a dynamic load. Dynamic loads can be very destructive.



Some types of load

A structure must be designed to withstand static and dynamic loads. If it cannot, it will collapse or break. This is known as structural failure caused by overloading.

Forces

Forces act on structures as a result of their own mass and the loads they are carrying. There are several different kinds of force:

- compression force: the structure is being squeezed together
- tension force: the structure is being pulled apart
- torsion force: the structure is being twisted
- shear force: the structure is being cut in two by forces acting in opposite directions and at different places from each other
- bending force: the structure is being forced to bend.

If a structure is not strong enough to withstand these forces, it will **distort** or break.

To remove the risk that a structure will fail, it should be designed with a safety factor. This means that the structure will be much stronger than necessary. For example, if the safety factor is 3, the structure has been designed to withstand forces three times greater than those expected.

Types of structure

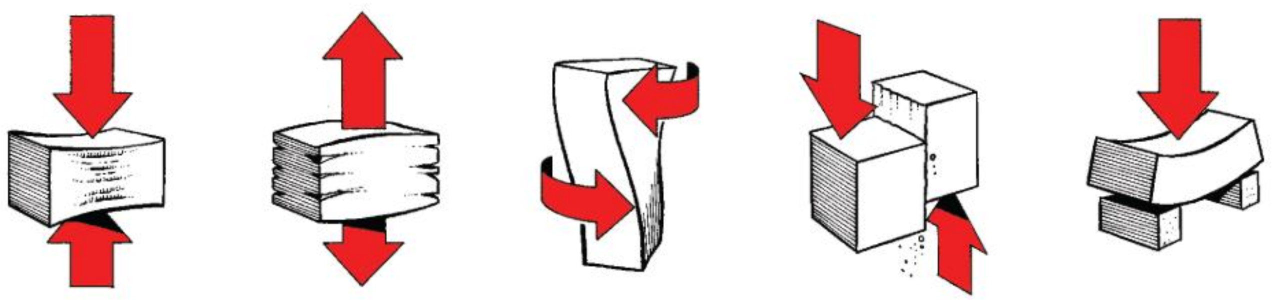
Structures can be classified as:

- frame structures, or
- shell structures.

Frame structures

A frame structure is made up of separate pieces of material, called members. Members are joined together to form basic shapes such as rectangles and triangles. These shapes can then be combined to form more complex structures such as ladders and cranes.

Frame structures are strong but relatively light. This type of construction is therefore common when distances have to be spanned or great heights have to be reached (as with bridges and skyscrapers).



Some types of force

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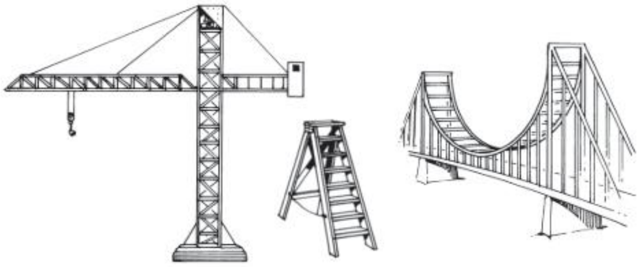
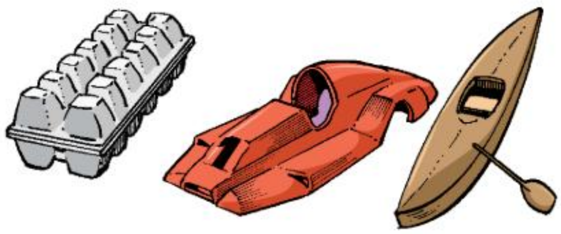


Examples of frame structures

Shell structures

A shell structure has no frame; instead, the load is carried by an outside skin. The support comes from the particular shape and the type of material used. A structure like this has the advantages of being very light (compared to frames) and being able to protect what is inside it.

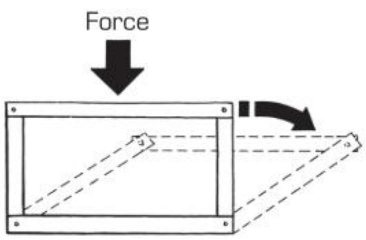
Shell structures are also called monocoques. Examples include some aircraft fuselages and the bodies of Formula 1 racing cars.



Examples of shell structures

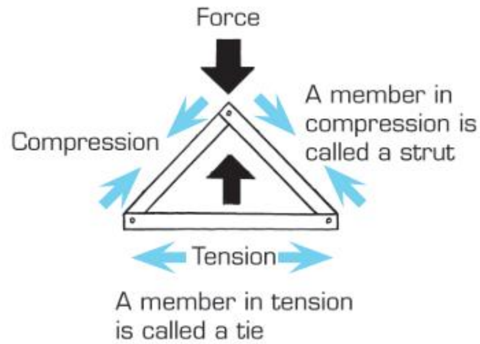
Frames

Rectangular structures are not rigid. If a force is applied, the structure will tend to change shape.



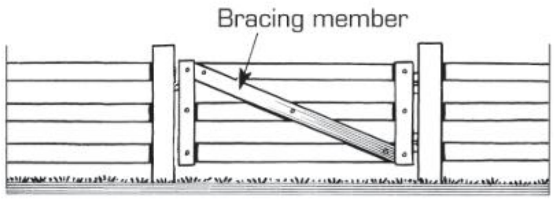
The effect of force on a rectangular frame

A triangle is a more rigid structure than a rectangle. If a load is applied, each of the three members supports the others in different ways. The triangle resists any change in shape. The guywires used to support flagpoles and masts are an application of this principle.

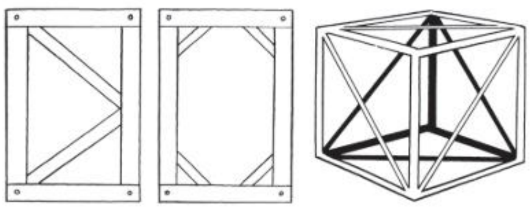


The effect of force on a triangular frame

A rectangular structure can be made more rigid by building it out of triangular shapes. This is known as triangulation. For example, the gate in the illustration below is made rigid by the diagonal member, called a bracing member. Without the bracing, the gate would sag under its own weight.

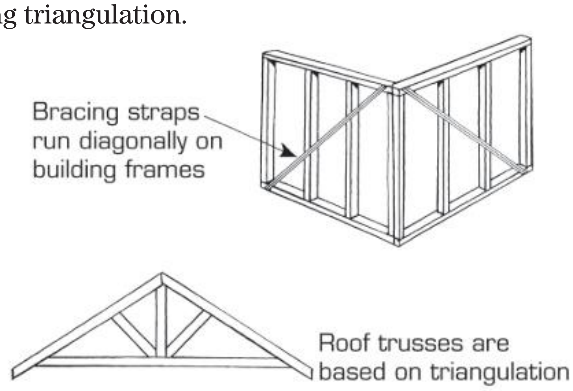


In this gate, which members are struts and which are ties?



Other methods of bracing

Triangulation is often used in buildings. For example, house frames are made more rigid by bracing. Pitched roofs are commonly constructed using triangulation.



Applications of triangulation in house construction

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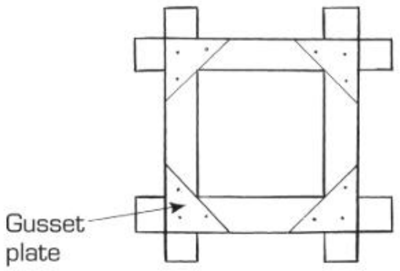
Another way of making a frame structure rigid is to fix a gusset plate to each of the joins. This strengthens the joins and prevents movement.

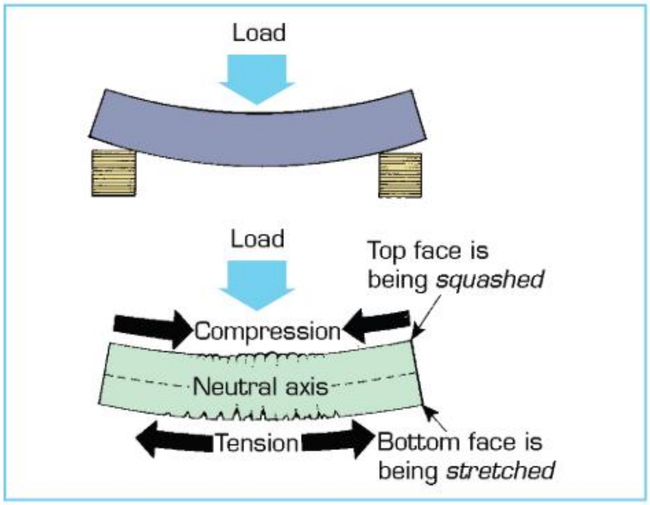


Gusset plates on the corners of a frame prevent movement.

Using the same idea, sheets of plywood can be attached to frames or house frames to make the structure rigid.

Beams

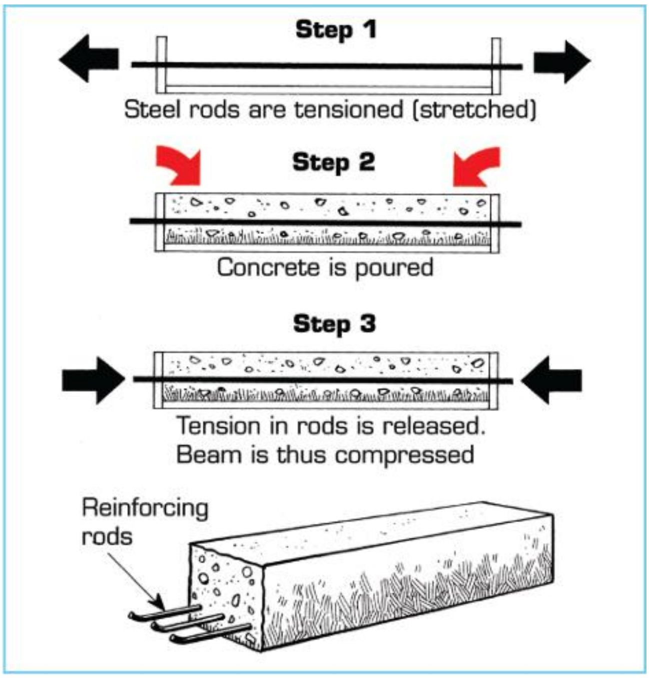
A beam spans a gap and supports a load. When it is loaded, the beam will tend to bend. The load produces forces on the beam as shown in the following diagrams.



Forces acting on a loaded beam

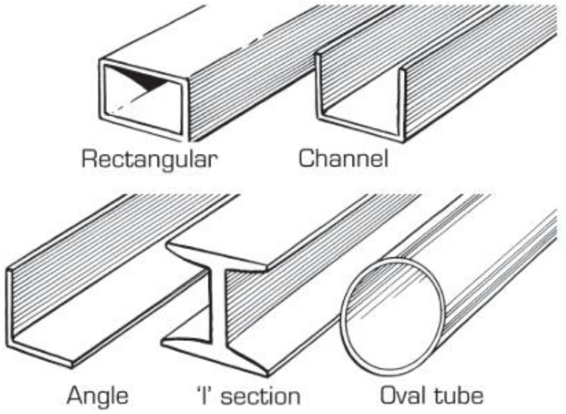
Concrete is strong in compression (along the top of a beam) and weak in tension (along the bottom). This is why steel reinforcing rods are built into the lower section of the horizontal concrete beams used in high-rise buildings.

A concrete beam can be made even stronger by pre-stressing the steel rods. Pre-stressed concrete beams can span greater distances than reinforced beams.



Pre-stressing a concrete beam

Because the **neutral axis** has no force acting on it, material can be removed from this area without greatly reducing the strength of the beam. The illustration below shows some of the different shapes that can be made. In this way, beams can be made lighter and less expensive.



Examples of different-shaped beams

This principle is seen in the pre-stressed concrete box-section girders used for bridges that have to span great distances.

A beam that is supported at one end only is called a cantilever. The forces acting on a cantilever are shown in the diagram opposite.

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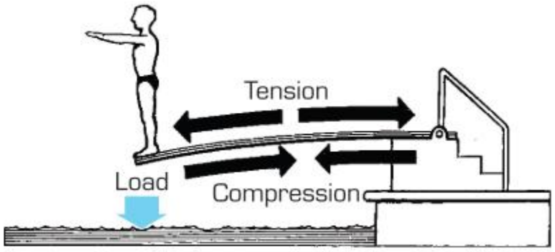


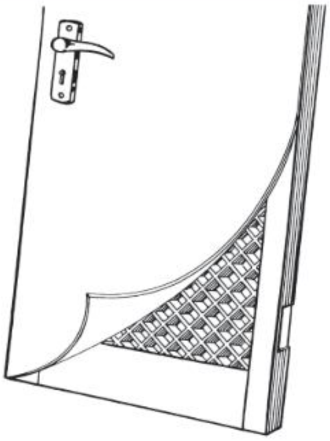
Forces acting on a loaded cantilever

Sheet materials

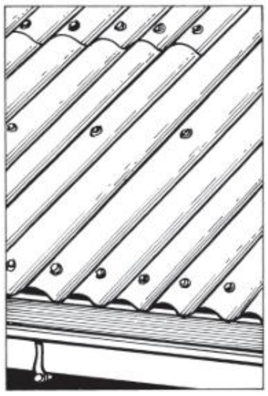
A thin, flat sheet of material is usually very flexible and has limited strength. It is seldom used to carry loads on its own. It can be made more rigid by:

- combining it with other structures
- folding it into different shapes.

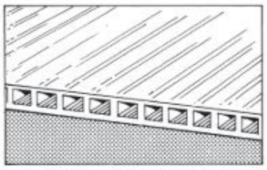
These processes create a kind of beam.



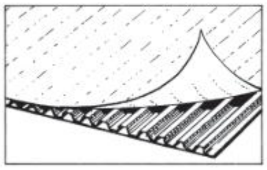
In door construction, thin sheet materials such as plywood or hardboard are combined with a 'honeycomb' support and an outer frame to produce a strong structure



Corrugated iron



Corflute



Corrugated cardboard

Corrugated iron, corrugated cardboard and corflute are all light yet quite strong and rigid

Ways in which sheet materials can be strengthened

World-famous structures

The Sydney Opera House (see page 212) is a famous structure. The three photographs below and overleaf show some other interesting and well-known structures around the world that have been built to carry loads and withstand forces.

Select one structure. Use the Internet to research some structural details about it.

The Oriental Pearl Tower, China

The Falkirk Wheel, Scotland

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The Statue of Liberty, USA

Construction

Buildings such as your home, your local shopping centre and your school were constructed using many of the principles we have just examined. When designing buildings, architects and engineers must work out all the loads and forces to ensure that the building will not collapse. They must also keep in mind any special functions of the building. For example, a hospital needs space for beds, rooms for interviewing sick people, operating theatres, car parking and so on.

Constructing a building

Before construction of a building begins, there should be a planning stage in which a number of factors are considered. They are:

- the character of the site
- the design of the building
- the need for approval to build
- the techniques to be used for
  - site preparation
  - building
  - landscaping
- building materials and services.

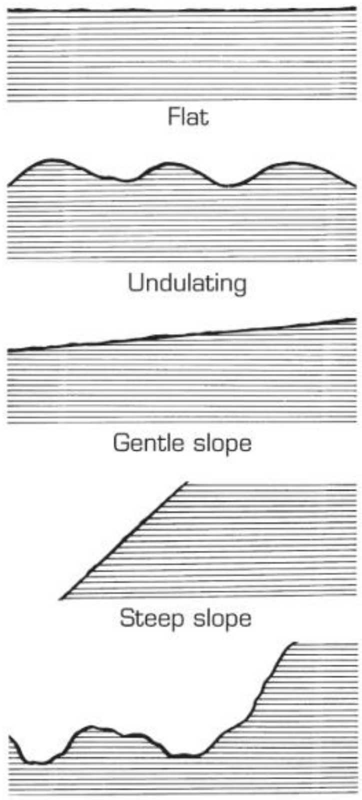
The planning stage involves preparing plans with specifications, costing the project and seeking council approval.

The character of a site

Sites can be classified as:

- flat sites (or almost flat)
- undulating sites
- gentle slopes (5-degree to 10-degree fall)
- steep slopes (more than 15-degree fall)
- irregular sites.

Each kind of site has advantages and disadvantages. For example, a flat site means lower building costs but restricted views and breezes. A steep slope can provide good views and breezes, but construction costs are generally much higher. Other problems such as erosion and difficulty of access must be considered when building on a steep slope.



Site profiles

Building design

All buildings should be designed with a specific site in mind. There is a variety of designs suitable for each kind of site. However, the design will also be influenced by factors such as:

- the purpose of the building
- the desired construction techniques and materials
- the construction cost
- personal choice
- the number of occupants (high density or low density).

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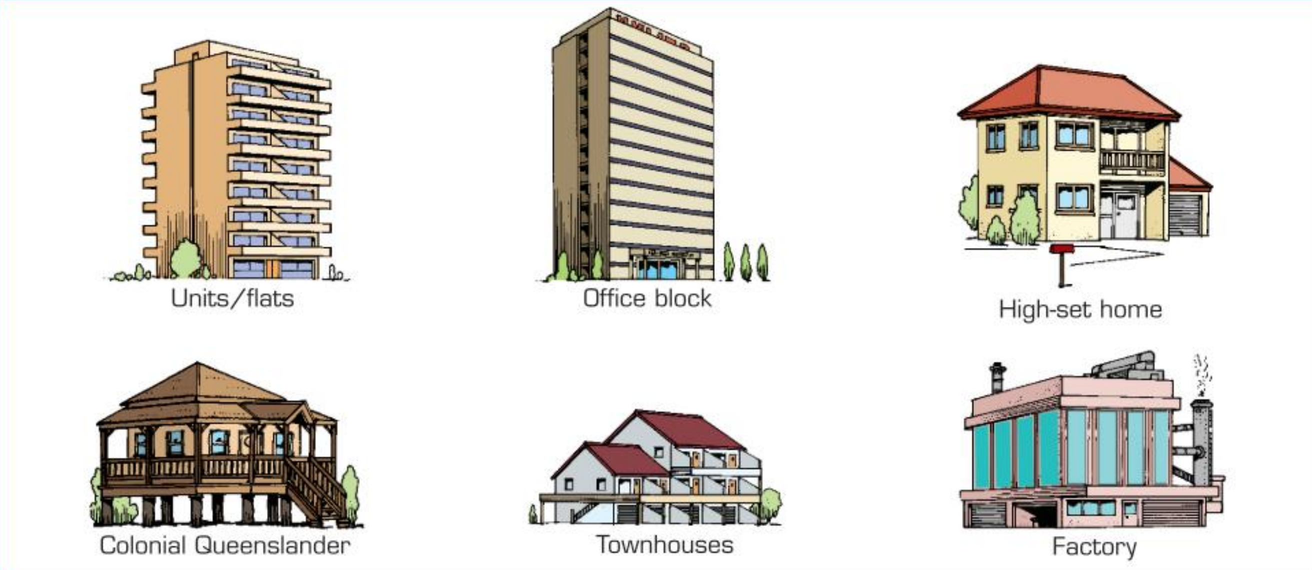
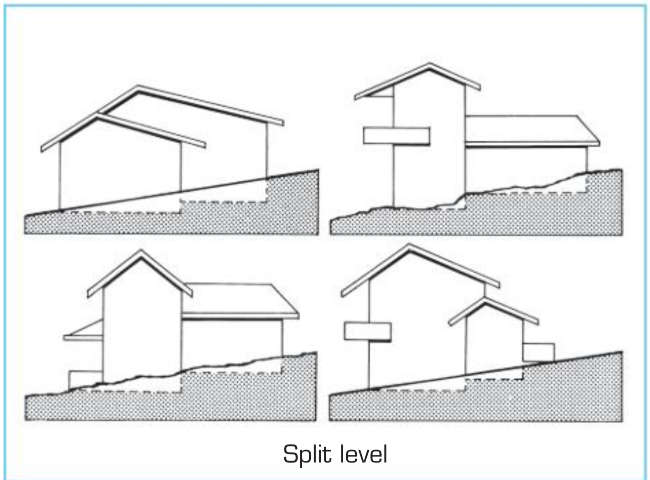
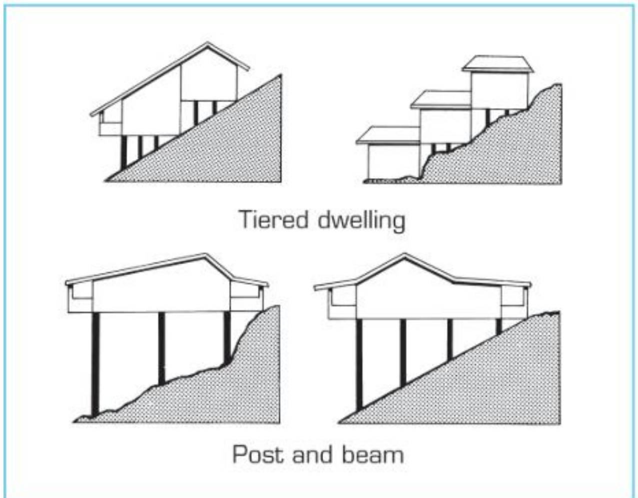


Examples of buildings suitable for a flat site or an undulating site



Examples of buildings suitable for a gentle slope or an irregular site



Examples of buildings suitable for a steep slope or an irregular site

INFORMATION FILE

Self-destructing skyscrapers

Many high-rise buildings are under attack by 'concrete cancer' caused by the steel rods used to make the concrete stronger.

The problem with steel is that it rusts when exposed to air and water. Concrete is not a waterproof material. Moisture and air can penetrate it and cause the steel reinforcing rods to rust. This builds up internal pressures that eventually cause the concrete to break up.

One method of preventing this is to seal the concrete with waterproof coatings. However, another technique avoids the costly task of sealing the concrete. An electrically conducting web is attached to the steel reinforcing, which is then covered with concrete as usual. A small electric charge passed through the web will halt the rusting process.

Approval to build

The place in which a building is constructed must conform to the local town plan. The town plan shows the areas set aside for homes, industry, recreation, roads and other uses. As well, it often shows where development is to be allowed in the future. Town plans are revised from time to time to meet the changing needs of the community.

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Before construction can begin, approval to build must be obtained from the local council. This is to ensure that the proposed structure will be built in the correct zone. For example, no one wants to build a home in the middle of an area zoned for heavy industry, or next to a future expressway.

The council also checks the plans to make sure that the structure meets all its building regulations. These lay down basic requirements, such as safety in building design, lighting, ventilation and size of rooms.

While the building is being constructed, a council inspector will check the structure to ensure that it matches the specifications stated on the approved plans.

Some local councils may offer an alternative approval process – that is, the use of private certifiers. A private certifier (that is, someone who can confirm that the required standards have been met) checks the plans to make sure that the structure meets all the local building regulations. Once approved, the private certifier – like the council inspector – will check the structure during its construction to ensure that it matches the specifications stated on the approved plans.

Construction techniques

A basic construction schedule can be used to organise the building process efficiently. The schedule arranges the tasks in the order in which they should be done. It also ensures that materials, equipment and workers are on site at the right time, to prevent delays.

The construction schedule can be divided into three stages:

- site preparation
- building
- landscaping.

See 'The construction system', opposite.

Materials and services

Many different materials can be used in the construction of buildings. The homes of the early pioneers were built mainly from wood, whereas buildings today use a combination of different materials such as wood, metal, plastic, glass and masonry. The major factors affecting choice of materials are cost, appearance and durability.

Likewise, there are many services that people can choose to have installed in a building for their comfort or convenience. For example, electricity can be used to heat water, to cook food and to keep the building warm or cool. All these services require energy to function, and people are becoming increasingly conscious of the need to conserve energy. There is growing interest in energy-efficient alternatives such as solar hot-water systems and wind generators.

INFORMATION FILE

Manufactured housing

Manufactured housing is a cheaper and faster alternative to traditional methods of building a house on site. It enables houses to be constructed all year round, whatever the climate.

In this system of building, the house components are manufactured in a factory, using mass-production techniques such as CAM (computer-aided manufacturing), which ensure that all components will be of high quality and fit together properly. Buyers can even design their own floor plans on a computer using CAD (computer-aided design).

There are three systems.

1 Pre-cut: all the components of the house are supplied cut to length. They are coded to enable quick assembly on site.

Panel walls

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2 Panelised: wall sections are made up as coded panels of standard sizes, for example 2400 millimetres high × 1200 millimetres long (and up to 12000 millimetres long). The panels are then joined together on site using nails, staples or adhesive. Roof trusses are usually included in the kit.
3 Modular: sections of the house are manufactured (about 90 per cent complete) as large units 3600 millimetres or 4800 millimetres wide and up to 18000 millimetres in length. The sections are transported to the site and joined together using a crane. They can be joined side by side or stacked on top of each other.


A completed house

Not only the initial cost of constructing a building and installing services, but also the running costs need to be considered. Thoughtful pre-planning can help to reduce these costs. For example, selecting an appropriate building style for the climate, and making wise use of insulating materials can reduce energy use.

Now that you are aware of the basic steps involved in constructing a building, it is time to look at the construction system.

The construction system

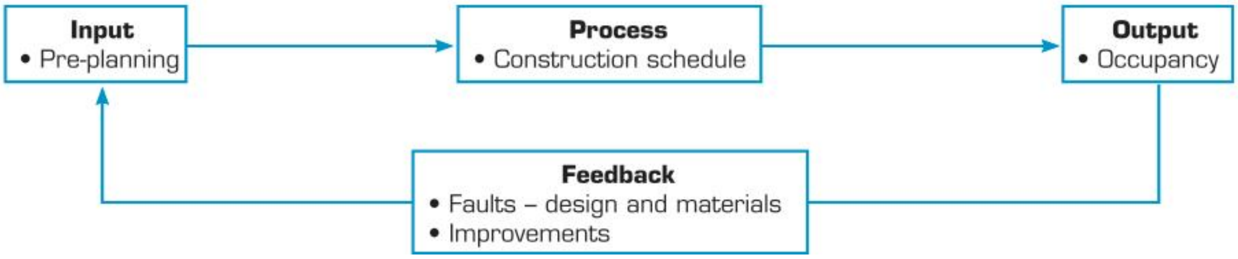
The construction system is another technological system that is made up of input, process, output and feedback (See 'What is a system?' on page 157). The construction system can then be shown as illustrated in the flow chart below.

The input activity is often referred to as pre-planning. The pre-planning stage, like any problem-solving activity, requires a good deal of effort to ensure a satisfactory result. (See the Information File 'The pre-planning stage of construction' overleaf.)

The process activity could be described as the construction schedule. It is made up of three lower subsystems or stages, as shown in the construction schedule overleaf.

Stage 1 (site preparation) must be completed before Stage 2 can commence. However, all the steps listed in Stage 2 do not need to be completed before undertaking some of the steps listed in Stage 3. It is a matter of managing the schedule to avoid delays. Each schedule has a timeline for completion and occupancy – the output.

The feedback activity often begins during the construction stage. Faults and poor workmanship are usually the areas of concern.



A construction system

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Feedback may also include a variation of the approved plan. The variation could be a minor alteration (for example, shifting the position of a doorway). Changing the layout of part of the building (for example, the kitchen and dining areas) could become a major alteration. Variations to the approved plans should be avoided as changes can be quite costly.

It is only after occupancy that feedback really occurs. As people begin to use the building, its design can be evaluated against the original design brief. Faults can be repaired and improvements can be highlighted.

Start → **Stage 1** → **Stage 2** → **Stage 3** → **Finish**

Stage 1

Site preparation
- ☐ Clearing
- ☐ Earthmoving
- ☐ Setting out
- ☐ Excavating

Stage 2

Building
- ☐ Foundation
- ☐ Base
- ☐ Structure
- ☐ Services
- ☐ Finishing

Stage 3

Landscaping
- ☐ Paths and drives
- ☐ Paved areas
- ☐ Fences
- ☐ Lawns and gardens

A construction schedule

INFORMATION FILE

The pre-planning stage of construction

A design process is also used in the pre-planning stage of constructing a building. These are the steps that an architect would follow:
- identifying needs
- developing preliminary ideas
- presenting a plan
- seeking client approval
- preparing final plans.

Identifying needs

Each structure has its own particular needs or problems. These must be addressed prior to construction. For example, some considerations when planning a family home include:
- a location plan
- the number of family members
- the family's lifestyle
- the budget
- future additions to the building.

Developing preliminary ideas

Rough plans are drawn showing a number of possible designs. A design is selected after discussion with the client. This is considered in greater detail and refined in the next step.

Presenting a plan

The best design is reviewed and processed to create the final design. A rendered 3D drawing is presented to the client to help them visualise the appearance of the structure. Sometimes a model is also prepared – especially if the structure is a commercial or public-works building.

The plan is also analysed by other people in the construction industry such as electrical, structural

A construction site

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and hydraulic engineers to ensure that all building regulations and codes have been addressed and to identify any potential construction problems.

Seeking client approval

The final plans can only be prepared after the client and others have finished reviewing the design. Once the approval is given, the final drawings and specifications can be prepared.

Preparing final plans

It is important for an engineer to do a soil test before working drawings are undertaken. The soil test will determine what type of foundation can be used – for example, floating slab or posts/piers. This may have a bearing on the building design of the home.

The working drawings of the building are drawn to a metric scale, which varies according to the type of drawing. These drawings include:

- a site plan, including the location of the property and its boundaries
- floor plans, which show every feature of the building, including walls, windows, plumbing and electricals
- elevations (side views of the building when viewed from the ground)
- detailed drawings
- sectional drawings, showing every detail of construction in a vertical plane.

The specifications are a set of written details serving as a record of requirements, such as materials and hardware to be used and standards to be followed.

INFORMATION FILE

Tilt-up construction

Tilt-up construction is a system that uses solid concrete panels as walls for structures. These structures include industrial, commercial, community and residential (particularly medium-density) buildings.

The panels are cast on a horizontal and level casting base. (The concrete floor of the structure is often used.) Edge formwork is constructed in the shape of the panels. Openings such as windows and doorways can also be included in the panels. The formwork contains the concrete during casting and curing. The shape of the panel is limited only by the formwork.

The panels are often cast on top of each other, which is known as stack casting. This requires minimal use of the site area. Furthermore, the panel surface can be used as a casting base for the next panel. The size of the panels is limited only by the lifting capacity of the crane.

The cured panels are lifted, tilted and moved into position. Temporary braces are used to hold the panels upright during assembly of the structure. Steel reinforcement such as posts and frames is used to strengthen and secure the structure. A sealant is used to seal the gaps between the panels.

An example of tilt-up construction

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The tilt-up system of construction was used in the 1960s to construct industrial buildings, warehouses and rural structures such as piggeries, dairies and storage facilities. Its advantages were strength, low maintenance and cost savings. However, many people saw the concrete finish as unattractive and drab.

The issue of aesthetic appeal of the panels was addressed in the early 1980s. The surfaces of the panels can be sculpted, painted or textured giving a range of appearances and finishes. The result is that tilt-up construction is now considered by some architects, developers and engineers as an alternative building system in the design of structures.

The tilt-up construction method provided a solution for the 'sails' design of the Sydney Opera House.

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Technology and the future

In this unit, you will:

- be challenged to think about the benefits of technology in the future
- be challenged to think about the possible costs of technology in the future
- decide what your responsibilities are.

By now you should have gained a greater awareness and understanding of technology. A number of the resources used in technology have been discussed in the preceding chapters. It is the use of these resources that enables technologists to meet the needs and wants of the local community, the nation or the world. The solution to these needs and wants is the result of people investigating their ideas, usually by devising a plan of action and then producing a prototype for evaluation. So, the solution is often the result of applying a problem-solving process and using various resources such as the ones you have studied in this textbook.

The number and type of resources is changing as new information and knowledge continue to add to the 'resource' bank. For example, traditional materials such as wood, glass and ceramics are being combined with other materials to form composite materials. The growth of composite materials has resulted in materials with remarkable properties that can be used in new ways and may also be kinder to the environment.

The concern for the environment has seen the growth of the 'reduce, reuse, recycle' movement. There is now a greater awareness of recycling materials in the production of new solutions. People are also concerned about what happens to the material(s) once the product is no longer of any use. Thus environmental issues are impacting on the way people design solutions and select materials.

Some of the materials may need to be transformed in new ways, so existing processes may need to be adapted or modified. New tools and equipment are being manufactured to help people process these materials in less time and in a safer manner.

Many machines use mechanisms to multiply the force or speed, and control systems to monitor the task. Computers are interfaced with machines to control the task(s). The growth of 'computer-aided' systems within industry is expanding as computers process data and information, generate graphics and model solutions at a faster rate than before, thanks to the development of the IC.

The ongoing research and development of electronic components is certain to expand the frontiers of electronics. The growth of electronic gadgetry will continue to shape our world and the way we live and work.

Technology is the result of people using various resources to produce satisfactory solutions.

Some of these solutions have proven to be *unsatisfactory* over time. The costs to people, society and the Earth have been greater than the benefits. We are now more aware of technology and its impact on society and the Earth.

So, as we look to the future, there are many questions to ask about the role of technology. You will find some of these on the following pages.

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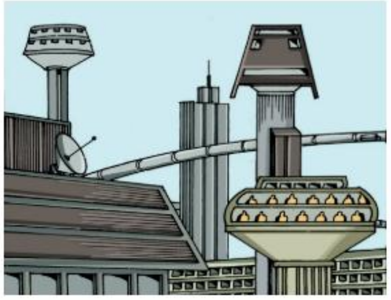
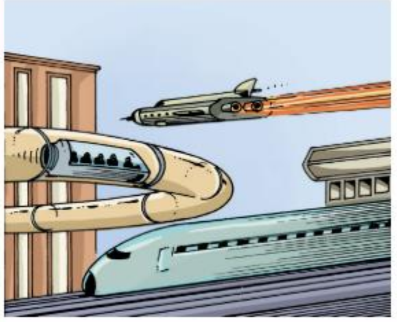
How will people use technology to solve their problems and meet their needs in the future?

Technology will continue to shape our world, but what changes will it bring?

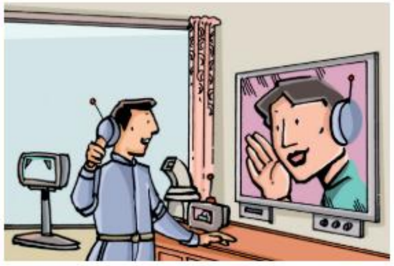
Will people develop new building materials and construction techniques so that they can create amazing new structures?



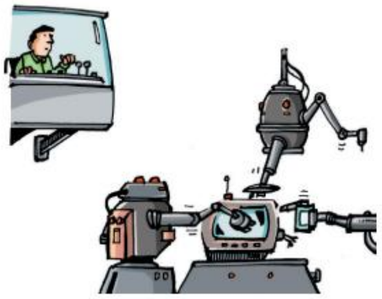
Will passengers be carried by faster and more efficient transportation systems?



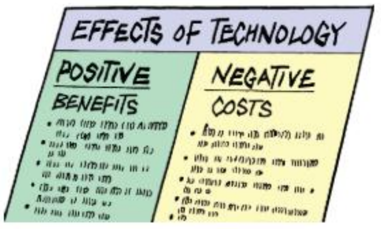
Will world-wide information and communication networks produce a better-informed society?



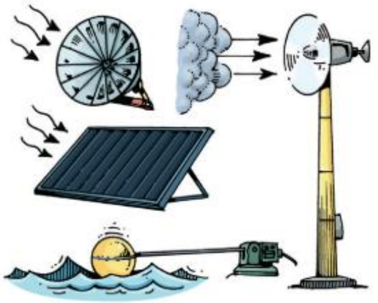
Will mass-production systems become fully automated so that repetitive, laborious jobs are eliminated forever?



New technology can improve people's lives, but as well as benefits there may be costs. We need to think about the possible harmful effects of new technology so that we can make wise decisions about using it.



Technology depends on the use of energy. Will we continue to rely on non-renewable fuels such as oil and coal, or will we develop other energy sources such as solar power? Will we *reduce* our energy needs?



Will users of technology have to conserve the world's resources of metals, timber and other materials more than they have in the past? Can we find new ways of re-using and recycling resources?

Will we learn to control the way we process materials so that the environment isn't harmed by pollution of the soil, water and atmosphere?

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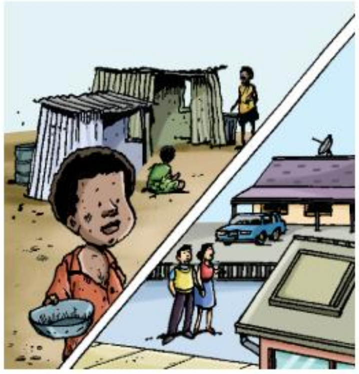
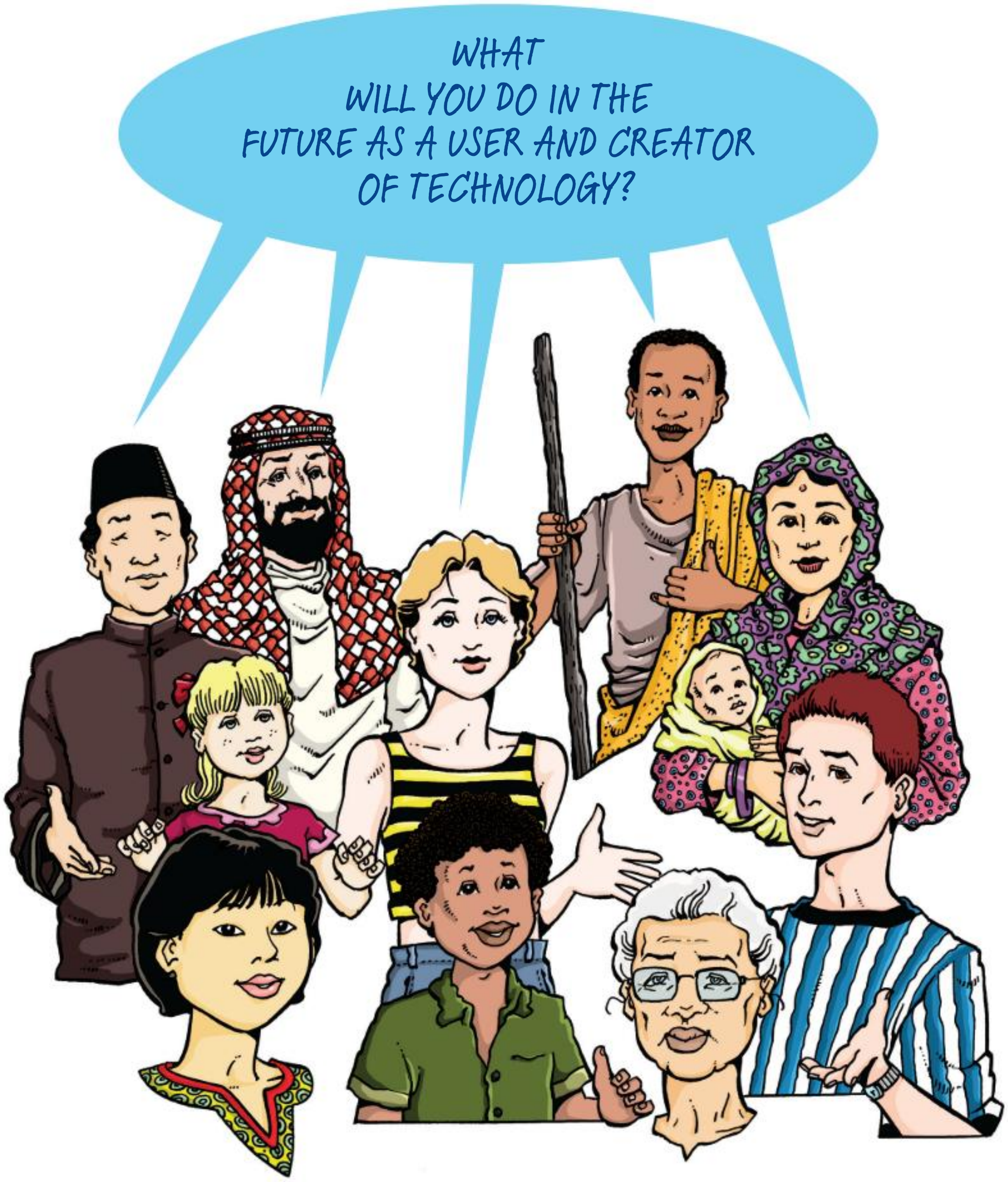
Will technology become so complicated that only very highly skilled people will be able to understand and control it?

Will technology be used to help all the people of the world, or will it create a wider gap between the 'haves' and 'have nots' in different countries?



To make sure that technology is a good servant for everyone, we all need to be well informed about it, and we all need to have a say in how it is used to change the world.



ISBN 9780170185677

GLOSSARY

abrade
to wear away

adaptation
an adjustment or modification

adhesion
sticking together

aesthetic
having visual appeal

alumina
aluminium oxide

annealed
softened by heating

apportion
to distribute a portion of

architecture
a term used to describe the inner workings of a computer chip

artefact
something made by a person

bauxite
an ore used in the production of aluminium

benefit
anything that is good for or helpful to people and the Earth

bifurcated
divided into two branches or forks

blending
mixing together

burr
a rough edge left after drilling

car silencer
muffler

cavity
an empty space

chamfered
at an angle or a sloping surface

chemical setting
using chemicals to set fabrics permanently

chipped-up
cut into small pieces

combustible material
a substance that burns readily

components
parts

composite
made up of a number of parts or materials

compression
a force that squeezes

concept
an idea

conventional
accepted usage

conventional current
the belief that the flow of electric current is from the positive terminal to the negative terminal, e.g. as in a battery

coordinates
numbers

cost
anything that is bad for or harmful to people and the Earth

current
a flow of electricity

defective
faulty

deform
to change the shape of something

density
the number of something

die
a mould with a hole of a particular shape through which material is forced to form that shape

die-making
the process of cutting shapes on a plate, which is then used to stamp that design onto a softer material

dimensional stability
to stop the stretching out of shape, especially relating to fabric

distort
to change shape

divergent thinking
to generate many possible solutions

drawing
passing through rollers or dies

dress
to make smooth

dressed-all round (DAR) timber
timber that has been planed smooth on all sides

ductile
can be stretched without breaking

duplicate
an exact copy

electrolysis
passing an electric current through a liquid

eliminate
to remove

enhance
to add to the result

extrude
to shape material by forcing it through a die

fabric
cloth

face
the flat, circular surface of a cylinder or disc

flammability
how easily something burns

flash
excess plastic material that has been squeezed out as a mould is compressed

flat
two-dimensional (2D)

flux
a substance applied to a surface to help fuse or join materials

fracturing
breaking

galvanise
to apply a coating of zinc to the surface of iron and steel

generic
common

gluing strip
a thin piece of material (e.g. timber) that is glued into slots along the edges of materials to be joined to reinforce the joint

graphite epoxy
when carbon fibres are combined with epoxy resin

hands-on
when people work on things with their hands

hazard
a risk, danger or potential to cause harm

housing
a slot

hybrid
a mixture of different sources

hydraulic system
using liquid such as water or oil to control a machine

illuminate
to give light

impede
to oppose

inert
when a substance does not react chemically with other substances

innovation
coming up with something new

interface
to connect with

iterative
to do again

lateral thinking
using knowledge in a way not previously considered

lathe
a machine that can turn materials into round forms

legislation
the law

longevity
the length of time an item continues to work

malleable
able to be shaped without breaking

mandatory
the law; must be followed

master panel
an over-sized panel that is later cut up to standard size

matrix
an array or grid

miniaturise
to make smaller

modify
to make changes

neutral axis
the middle of a beam

non-pored wood (softwood)
wood with only one type of cell (called a tracheid)

objective
a goal

order
a command or instruction to be carried out by a computer

ore
a mineral in the Earth's crust that can be processed to obtain metals

oxidise
to combine with oxygen from the air

pass
a cut

permanent setting
using damp-heat setting to shape woven woollen fabrics

permeable
when liquids are able to pass through a substance

planed
made smooth

pneumatic system
using compressed air to control a machine

pored wood (hardwood)
wood that has two types of cells: pores and fibres

precaution
an action taken to prevent problems

problem-solving process
a set of steps to follow to help solve a problem

procedure
the steps and tools/equipment needed to make an item

prototype
the first artefact of a design

reciprocate
to move backwards and forwards

recursive
the process of running back

regulations
the rules for ways of acting

relevant
connected with the ideas being discussed

respirator
a breathing mask

retractable
able to be drawn in

review
to have another look

risk
the chance of a harmful result – illness, injury or death – when exposed to a hazard

shatter
to break into small pieces

sheen
brightness

species
a distinct kind

state
a condition

stepped-cone pulleys
a set – or number – of pulleys, ranging in diameter, attached to a shaft

stipple
to use small strikes or blows

susceptible
easily affected

swarf
the metal shavings produced when cutting metals

synthesis
the combining of ideas to present a complete solution

synthetic
manufactured by people

tang
the tapered end of a hand file, which fits into a handle

tapped off
removed

temporary set
a process of wetting and drying to shape woven woollen fabrics

thread
a yarn

threaded fasteners
semi-permanent fasteners such as bolts, nuts and screws

toxic
poisonous

transform
to change

trial-and-error
solving problems by using a variety of real experiments

unproductive
unable to produce

variation
a change

velocity
speed

ventilated
exposed to fresh air

venue
a meeting place

visualise
to see

warp thread (end)
a thread that runs the length of the fabric

waste
excess; left-over materials

webbing
a woven strip of material used for springing in upholstery

weft thread (pick)
a thread that runs the width of the fabric

INDEX