

Apex Exam Guide

Engineering

Year 12 QCE

Queensland Curriculum

2025 Edition

Wilhelm Chadwick

Apex Exam Guide

Engineering

Year 12 QCE

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Acknowledgements

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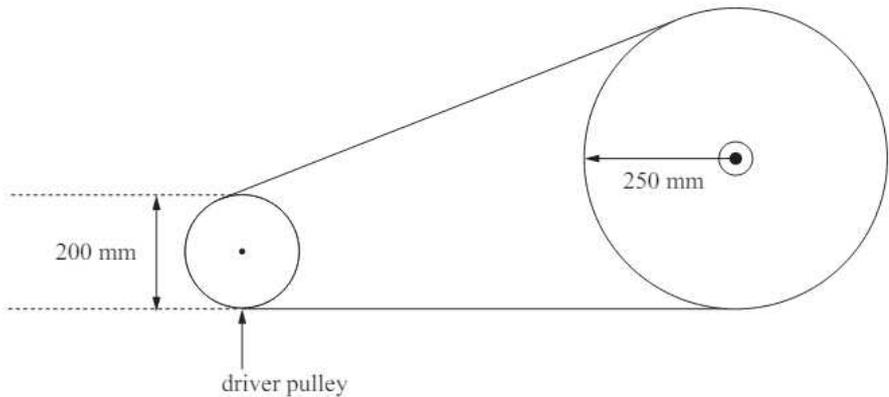
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Unit 4 Machines and mechanisms

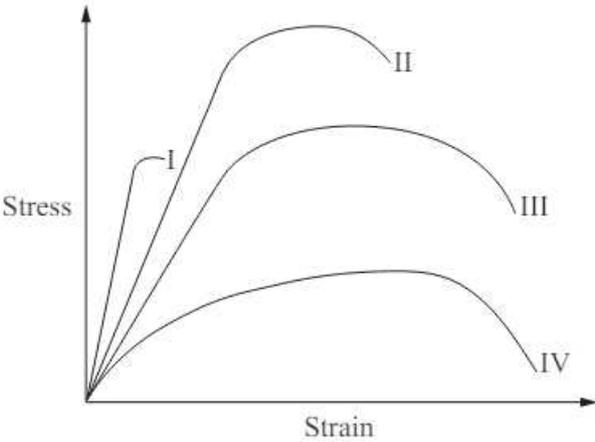
Unit 4 – Topic 1: Machines in society

Paper 1 Section 1

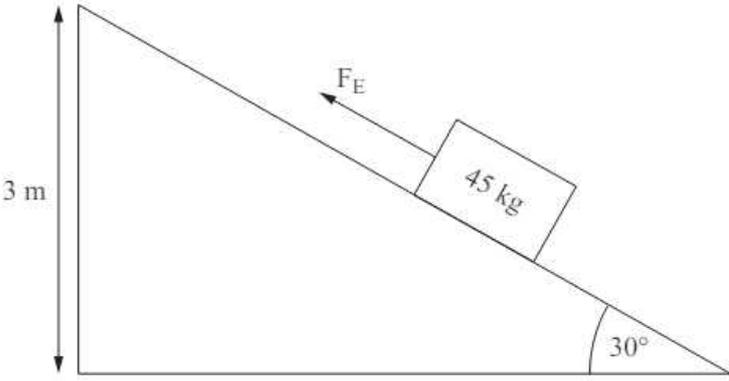
2023 Paper 1 Section 1 Question 2 Machines in society	The force required to just stop an 80 kg box from sliding down a 20° incline is (A) 97 N (B) 250 N (C) 265 N (D) 282 N
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2023 Paper 1 Section 1 Question 4 Machines in society	<p>A simple pulley and belt driving system is shown.</p>  <p>The velocity ratio of the system is</p> <p>(A) 0.40 (B) 0.80 (C) 1.25 (D) 2.50</p>
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2023 Paper 1 Section 1 Question 5 Machines in society	A conveyor belt moves 1 tonne of material with an effort of 3.5 kN. What is the efficiency of the conveyor when the velocity ratio is 4? (A) 29% (B) 70% (C) 80% (D) 88%
--	--

<p>2023 Paper 1 Section 1 Question 6</p> <p>Materials</p>	<p>The graph shows the stress–strain curves of four different materials.</p>  <p>Which material can best withstand deformation within its proportional limit?</p> <p>(A) I (B) II (C) III (D) IV</p>
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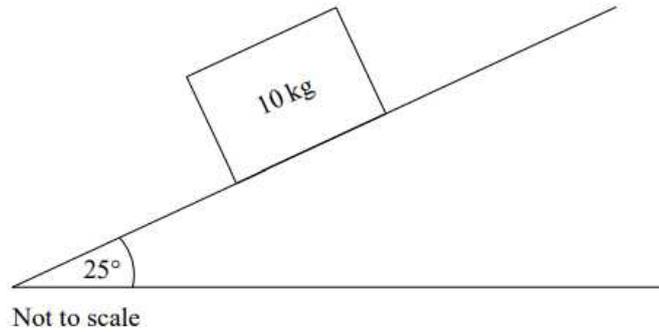
<p>2023 Paper 1 Section 1 Question 7</p> <p>Machines in society</p>	<p>A 15 kg steel beam is dropped from a height of 4 m. The velocity of the steel beam just before it hits the ground is</p> <p>(A) 2.83 m/s (B) 6.26 m/s (C) 7.75 m/s (D) 8.85 m/s</p>
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<p>2023 Paper 1 Section 1 Question 8</p> <p>Machines in society</p>	<p>A 45 kg box is pulled up an incline as shown</p>  <p>Not to scale</p> <p>If the system is 80% efficient and the velocity ratio is 2, what force is required to move the box?</p> <p>(A) 84 N (B) 221 N (C) 276 N (D) 441 N</p>
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<p>2023 Paper 1 Section 1 Question 10</p> <p>Machines in society</p>	<p>A 40 kg object is pushed 3 m up a 25° incline at a uniform velocity.</p> <p>If the frictional force opposing motion is 163 N and the weight force component acting down the incline is 165.66 N, the work done is</p> <p>(A) 489 J (B) 497 J (C) 986 J (D) 1066 J</p>
<p>2022 Paper 1 Section 1 Question 3</p> <p>Machines in society</p>	<p>During a race, the rear wheels of a go-kart exert a horizontal force of 100 N on the racetrack surface when the rear axle is rotating at 1000 revolutions per minute (rpm). The wheels have a diameter of 280 mm.</p> <p>The power being transmitted to the track by the rear wheels is</p> <p>(A) 88 kW (B) 2.9 kW (C) 1.5 kW (D) 0.73 kW</p>
<p>2022 Paper 1 Section 1 Question 5</p> <p>Machines in society</p>	<p>A pump transfers water vertically up to a cylindrical water tank sitting on a platform 7 m above the ground. The tank is 3 m deep and holds 20 kL when full.</p> <p>Given that 1 L of water has a mass of 1 kg, the potential energy of the full tank at its vertical midpoint relative to a water outlet 1 m above ground level is</p> <p>(A) 1.47 MJ (B) 1.67 MJ (C) 1.76 MJ (D) 1.86 MJ</p>
<p>2022 Paper 1 Section 1 Question 7</p> <p>Machines in society</p>	<p>A 10 kg wheelbarrow sits stationary but just on the point of sliding on an inclined ramp. When the ramp is raised by 5° to make an angle of 20° to the horizontal, the wheelbarrow slowly starts to slide.</p> <p>The minimum amount of additional force required to stop the wheelbarrow from sliding is</p> <p>(A) 59 N (B) 34 N (C) 25 N (D) 8 N</p>
<p>2022 Paper 1 Section 1 Question 9</p> <p>Machines in society</p>	<p>A mechanism extends an initially stationary rod 15 mm at a final velocity of 2.5 m/s.</p> <p>The acceleration of the rod is</p> <p>(A) 417 m/s² (B) 208 m/s² (C) 38 m/s² (D) 21 m/s²</p>

2021
Paper 1
Section 1
Question 4

Machines in
society

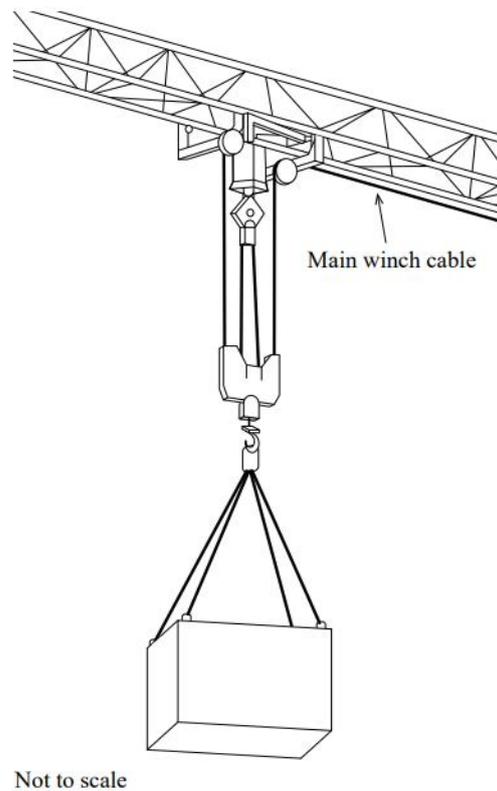


A box slides down a slope as shown. If the coefficient of friction between the box and the slope is 0.2, what is the acceleration of the box?

- (A) 8.0 m/s^2
- (B) 4.1 m/s^2
- (C) 2.4 m/s^2
- (D) 1.8 m/s^2

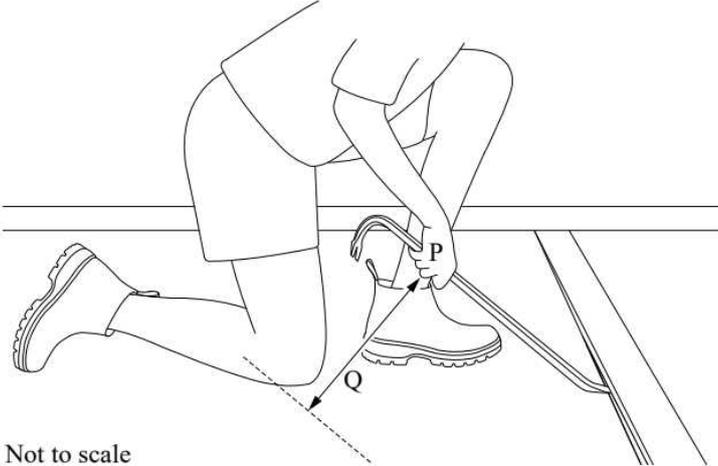
2021
Paper 1
Section 1
Question 5

Machines in
society



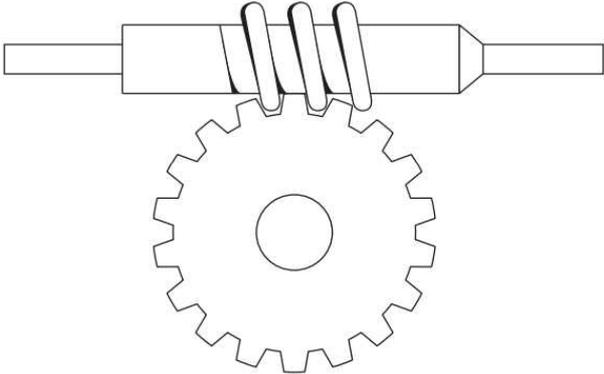
This crane vertically lifts a load a distance of 20 m using a pulley system. What distance must the main winch cable move during the vertical lift?

- (A) 100 m
- (B) 80 m
- (C) 20 m
- (D) 5 m

<p>2021 Paper 1 Section 1 Question 6</p> <p>Machines in society</p>	<p>A crowbar is used to lever a floorboard as shown. An effort of 55 N is applied to the crowbar at position P, generating a force of 550 N that raises the floorboard by 20 mm. If the crowbar displacement Q is 700 mm, what is the efficiency of the crowbar?</p>  <p>Not to scale</p> <p>(A) 79% (B) 36% (C) 29% (D) 10%</p>
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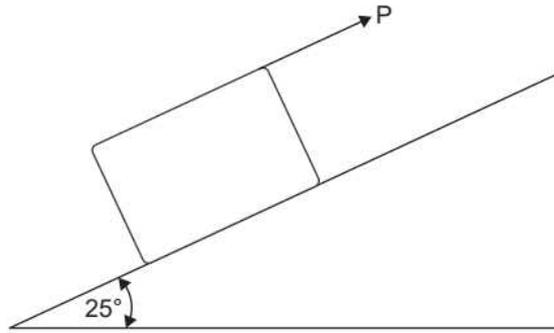
<p>2021 Paper 1 Section 1 Question 7</p> <p>Machines in society</p>	<p>A pulley system with an efficiency of 75% is used to vertically raise a 120 kg load a distance of 3 m. If the length of pulley rope pulled to raise the load is 8 m, the effort required is</p> <p>(A) 330 N. (B) 392 N. (C) 440 N. (D) 588 N.</p>
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<p>2021 Paper 1 Section 1 Question 9</p> <p>Machines in society</p>	<p>The work done by a jack to vertically raise a 1500 kg vehicle a distance of 180 cm is</p> <p>(A) 2700 J. (B) 8167 J. (C) 26 460 J. (D) 81 667 J.</p>
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<p>2020 Paper 1 Section 1 Question 1</p> <p>Machines in society</p>	 <p>What is the gear ratio of this worm and wheel?</p> <p>(A) 1:6 (B) 6:3 (C) 18:1 (D) 18:3</p>
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2020
Paper 1
Section 1
Question 2

Machines in
society

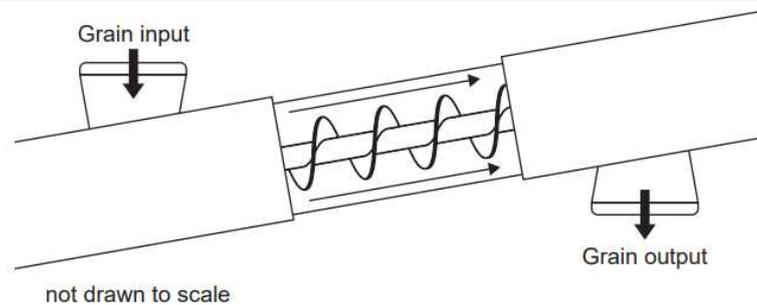


A 25 kg block is pulled up an incline using a force P as shown. What is the minimum value of P required to just move the box from rest if the coefficient of static friction is 0.4?

- (A) 192.3 N
- (B) 103.5 N
- (C) 41.4 N
- (D) 14.7 N

2020
Paper 1
Section 1
Question 5

Machines in
society



Screw conveyor specifications			
Screw pitch	Screw length	Capacity moved per individual screw	Conveyor rpm
150 mm	2400 mm	0.15 m ³	10

A screw conveyor is used to transport grain from an input chute up a 10° slope to a holding bin using the specifications shown. What is the volume of grain moved each minute?

- (A) 225 m³
- (B) 24 m³
- (C) 2.4 m³
- (D) 1.5 m³

2020
Paper 1
Section 1
Question 6

Machines in
society

An irrigation system uses a 7450 W electric motor to drive a pump that delivers 10 000 L of water per hour over a distance of 100 m. How efficient is the irrigation system? Assume that the system is without friction and that 1 L of water has a mass of 1 kg.

- (A) 45%
- (B) 37%
- (C) 27%
- (D) 10%

2020
Paper 1
Section 1
Question 7

Machines in
society

A 20 kg box sits just on the point of sliding on an incline plane. If the coefficient of static friction is 0.27, what is the angle of repose?

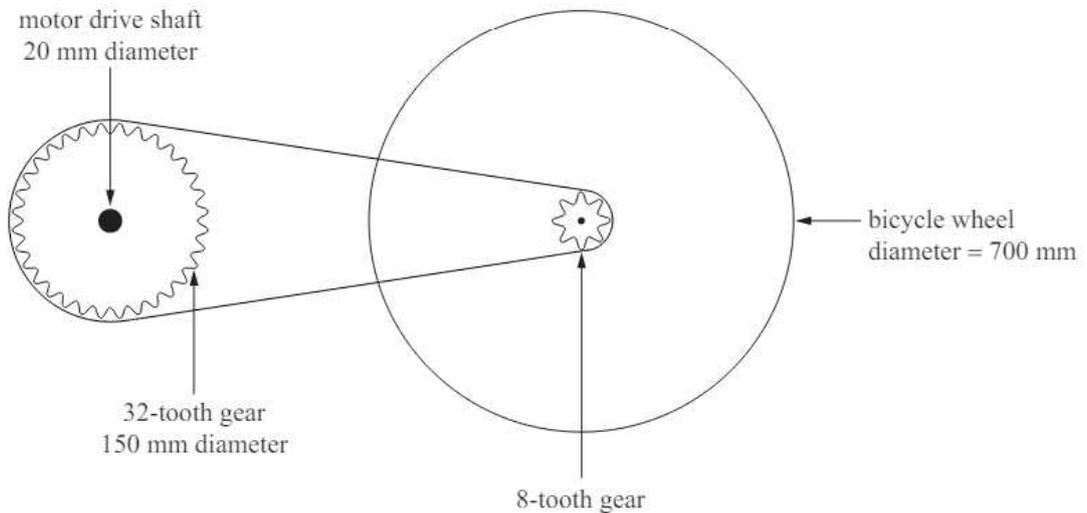
- (A) 5°
- (B) 13°
- (C) 15°
- (D) 16°

2020 Paper 1 Section 1 Question 9 Machines in society	A bicycle has gearing with a VR of 1:3. The rear tyre has an outside diameter of 740 mm. What is the distance travelled for every three rotations of the foot pedals? (A) 42 m (B) 21 m (C) 7 m (D) 2 m
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**2023
Paper 1
Section 3
Question 18**

**Machines in
society**

An electric motor with an output force of 600 N is attached to the driver gear of an electric-powered bicycle using a 20 mm diameter drive shaft.



Not to scale

a) Calculate the number of driver gear rotations required for the bicycle wheel to move 15 m. Answer to one decimal place. [2 marks]

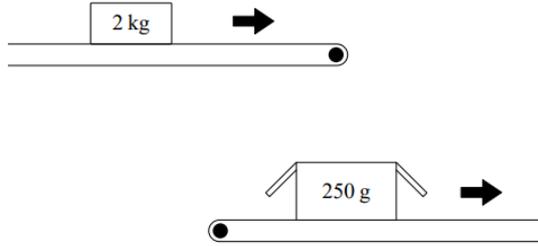
b) Calculate the number of motor drive shaft rotations required for the bicycle wheel to move 15 m. Answer to the nearest whole unit. [2 marks]

c) Determine the output power of the electric motor if the bicycle wheel takes 2 seconds to travel 15 m. Answer to the nearest whole unit. [3 marks]

2022 Paper 1 Section 3 Question 18 Machines in society	Determine the force required to launch a rocket with a mass of 2000 kg vertically from rest to a height of 20 km in 20 seconds. Assume that the rocket's mass and acceleration due to gravity remain constant during the launch and that air resistance is not a factor.
	Include a free-body diagram showing the forces at launch. Answer to the nearest whole unit in kN.
	<div style="border: 1px solid black; height: 200px; width: 100%;"></div>

**2021
Paper 1
Section 3
Question 19**
**Machines in
society**

A 2 kg package is moving at 5 m/s in the direction of the arrow, as shown. The package drops into a 250 g carton moving in the same direction at 2 m/s on a second conveyor.

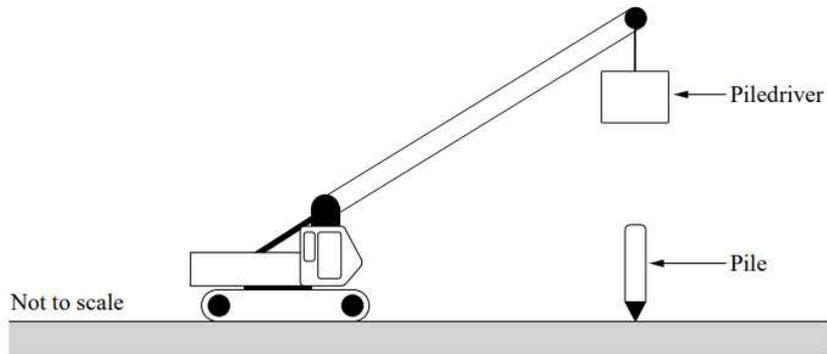


a) Calculate the force exerted by the package if it just causes the carton to begin sliding on the conveyor surface. The coefficient of static friction between the carton and the conveyor surface is 0.4. Answer to the nearest whole unit. Include a free-body diagram with your working. [3 marks]

2021
Paper 1
Section 3
Question 20

Machines in
society

A 500 kg piledriver is used to drive a 200 kg pile into the soil as shown. The piledriver falls freely through a distance of 4 m before impacting the pile with 19.6 kJ of energy. At the moment of impact, energy is lost as heat and sound. [5 marks]



a) If 5.4 kJ of energy is lost during the impact between piledriver and pile, determine the velocity of the piledriver just after impact. Answer to two decimal places. [3 marks]

b) If the pile and piledriver decelerate at a constant rate of 30 m/s^2 after impact due to the resistance of the soil, determine the distance the pile is driven into the ground.

Answer to the nearest whole unit (mm). [2 marks]

2021
Paper 1
Section 3
Question 21
Machines in
society

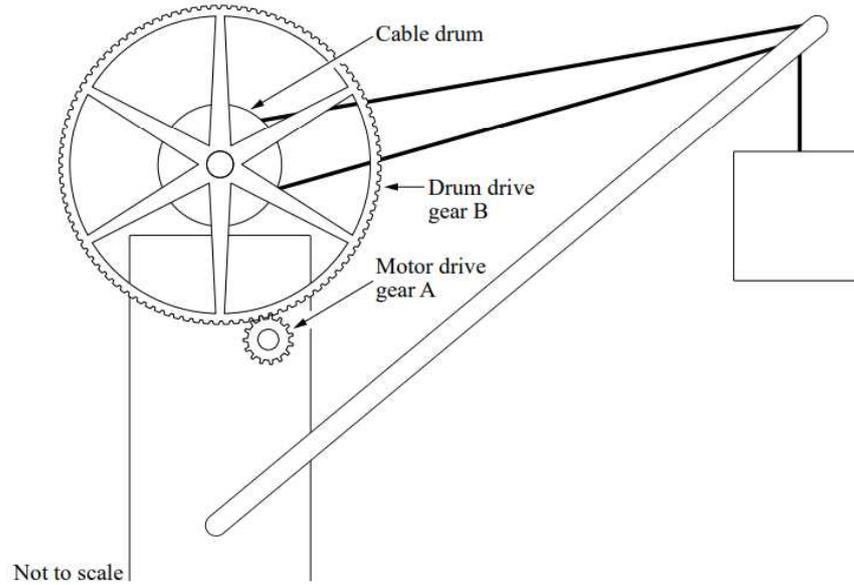
A bucket is used to carry iron ore vertically up a mine shaft from its base. The bucket is raised from rest at the base of the shaft and accelerates constantly upwards at a rate of 0.75 m/s^2 for 4 s. It then travels at a constant velocity before decelerating constantly to stop at the top of the shaft.

a) Determine the maximum velocity of the bucket to the nearest whole unit. [3 marks]

b) From rest, the bucket is lowered from the top of the shaft with a constant acceleration. Determine the bucket's acceleration if the bucket has been lowered 25 m after 10 s. Answer to one decimal place. [2 marks]

2021
Paper 1
Section 3
Question 22
Machines in society

This winch crane is driven by an electric motor. The motor drive shaft is fitted to a 15-tooth gear A, which drives a 100-tooth gear B attached to a cable drum. The 500 mm diameter cable drum houses a steel cable that is used to vertically raise 20 kg hay bales 2 m from the ground to be loaded onto trucks.



a) Calculate the output power of the crane if it takes 30 seconds to raise two hay bales. Answer to two decimal places. [2 marks]

b) Determine the number of motor revolutions required to produce the 2 m lift. Answer to one decimal place. [4 marks]

2020
Paper 1
Section 3
Question 18
Machines in
society

A 900 kg machine is designed to rest without slipping on a slope of up to 30° on the surface of Mars. The acceleration due to gravity on Mars is one-third of that on Earth.

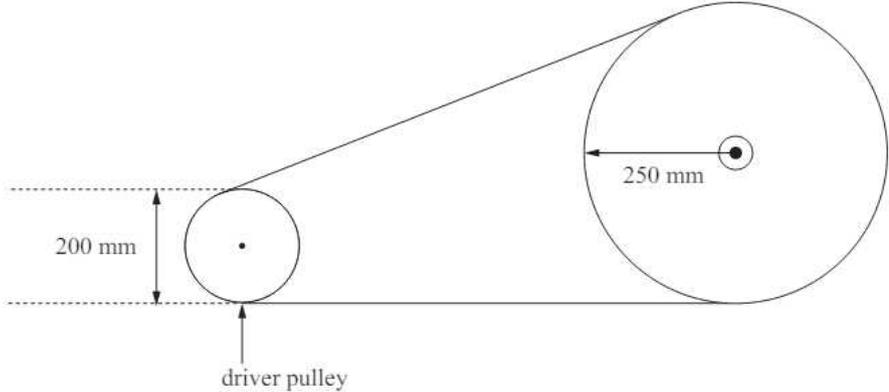
a) Determine the coefficient of static friction required to keep the machine from slipping on a 30° incline on Mars. Answer to two decimal places. [1 mark]

b) Calculate the resulting force of static friction between the machine and Mars' surface. Answer to the nearest whole unit. [2 marks]

c) Explain what would happen to the coefficient of static friction if the machine was tested on Earth. [2 marks]

Marking Guide – Paper 1 Section 1

2023 Paper 1 Section 1 Question 2 Machines in society	The force required to just stop an 80 kg box from sliding down a 20° incline is (A) 97 N (B) 250 N (C) 265 N – Answer (D) 282 N
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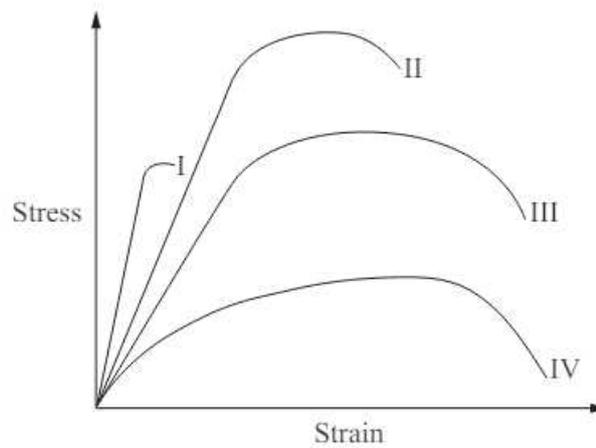
2023 Paper 1 Section 1 Question 4 Machines in society	<p>A simple pulley and belt driving system is shown.</p>  <p>Not to scale</p> <p>The velocity ratio of the system is</p> <p>(A) 0.40 (B) 0.80 (C) 1.25 (D) 2.50 – Answer</p>
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2023 Paper 1 Section 1 Question 5 Machines in society	A conveyor belt moves 1 tonne of material with an effort of 3.5 kN. What is the efficiency of the conveyor when the velocity ratio is 4? (A) 29% (B) 70% – Answer (C) 80% (D) 88%
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2023
Paper 1
Section 1
Question 6

Materials

The graph shows the stress–strain curves of four different materials.



Which material can best withstand deformation within its proportional limit?

- (A) I – Answer
- (B) II – Answer
- (C) III
- (D) IV

Note: The multiple-choice scrutiny panel reviewed this question and determined that there were two key terms for this item. Answer is both A and B.

2023
Paper 1
Section 1
Question 7

Machines in
society

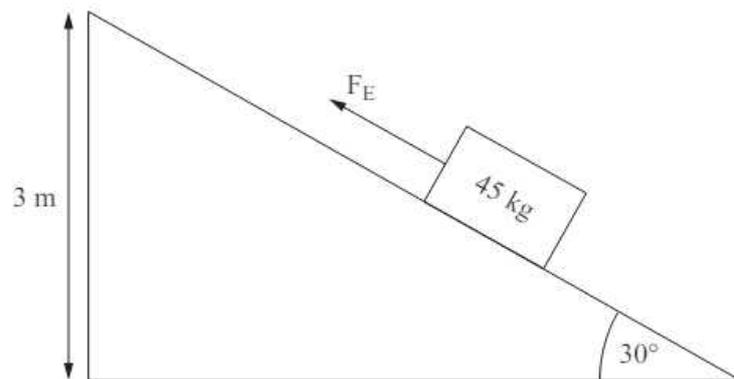
A 15 kg steel beam is dropped from a height of 4 m. The velocity of the steel beam just before it hits the ground is

- (A) 2.83 m/s
- (B) 6.26 m/s
- (C) 7.75 m/s
- (D) 8.85 m/s – Answer

2023
Paper 1
Section 1
Question 8

Machines in
society

A 45 kg box is pulled up an incline as shown



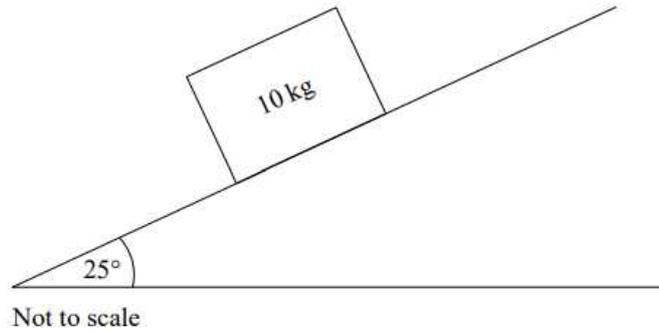
If the system is 80% efficient and the velocity ratio is 2, what force is required to move the box?

- (A) 84 N
- (B) 221 N
- (C) 276 N – Answer
- (D) 441 N

<p>2023 Paper 1 Section 1 Question 10</p> <p>Machines in society</p>	<p>A 40 kg object is pushed 3 m up a 25° incline at a uniform velocity.</p> <p>If the frictional force opposing motion is 163 N and the weight force component acting down the incline is 165.66 N, the work done is</p> <p>(A) 489 J (B) 497 J (C) 986 J – Answer (D) 1066 J</p>
<p>2022 Paper 1 Section 1 Question 3</p> <p>Machines in society</p>	<p>During a race, the rear wheels of a go-kart exert a horizontal force of 100 N on the racetrack surface when the rear axle is rotating at 1000 revolutions per minute (rpm). The wheels have a diameter of 280 mm.</p> <p>The power being transmitted to the track by the rear wheels is</p> <p>(A) 88 kW (B) 2.9 kW (C) 1.5 kW – Answer (D) 0.73 kW</p>
<p>2022 Paper 1 Section 1 Question 5</p> <p>Machines in society</p>	<p>A pump transfers water vertically up to a cylindrical water tank sitting on a platform 7 m above the ground. The tank is 3 m deep and holds 20 kL when full.</p> <p>Given that 1 L of water has a mass of 1 kg, the potential energy of the full tank at its vertical midpoint relative to a water outlet 1 m above ground level is</p> <p>(A) 1.47 MJ – Answer (B) 1.67 MJ (C) 1.76 MJ (D) 1.86 MJ</p>
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<p>2022 Paper 1 Section 1 Question 9</p> <p>Machines in society</p>	<p>A mechanism extends an initially stationary rod 15 mm at a final velocity of 2.5 m/s.</p> <p>The acceleration of the rod is</p> <p>(A) 417 m/s² (B) 208 m/s² – Answer (C) 38 m/s² (D) 21 m/s²</p>

2021
Paper 1
Section 1
Question 4

Machines in
society

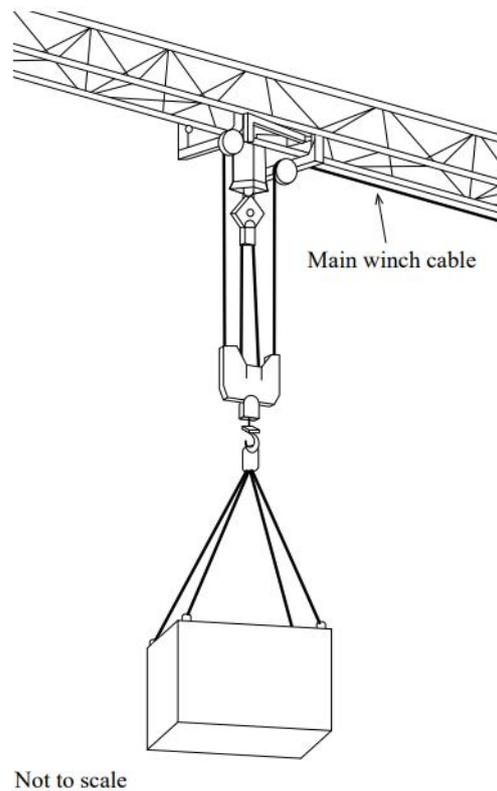


A box slides down a slope as shown. If the coefficient of friction between the box and the slope is 0.2, what is the acceleration of the box?

- (A) 8.0 m/s^2
- (B) 4.1 m/s^2
- (C) 2.4 m/s^2 – Answer
- (D) 1.8 m/s^2

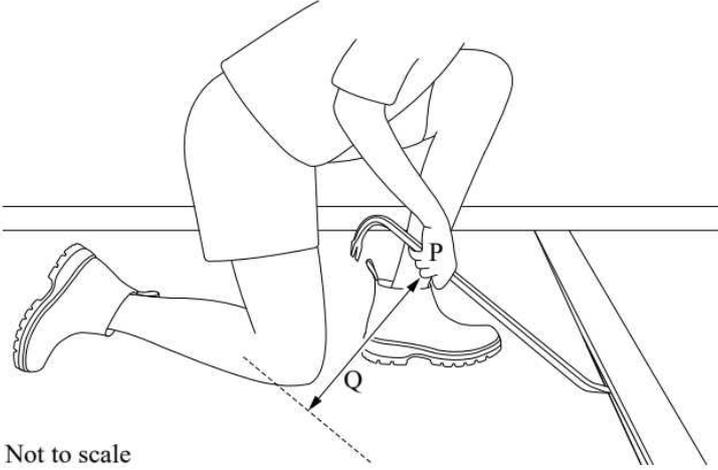
2021
Paper 1
Section 1
Question 5

Machines in
society



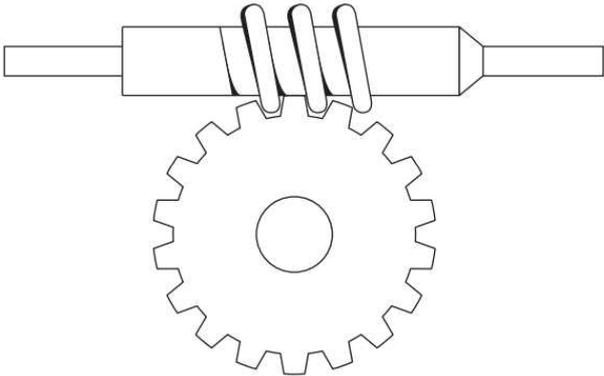
This crane vertically lifts a load a distance of 20 m using a pulley system. What distance must the main winch cable move during the vertical lift?

- (A) 100 m
- (B) 80 m – Answer
- (C) 20 m
- (D) 5 m

<p>2021 Paper 1 Section 1 Question 6</p> <p>Machines in society</p>	<p>A crowbar is used to lever a floorboard as shown. An effort of 55 N is applied to the crowbar at position P, generating a force of 550 N that raises the floorboard by 20 mm. If the crowbar displacement Q is 700 mm, what is the efficiency of the crowbar?</p>  <p>Not to scale</p> <p>(A) 79% (B) 36% (C) 29% – Answer (D) 10%</p>
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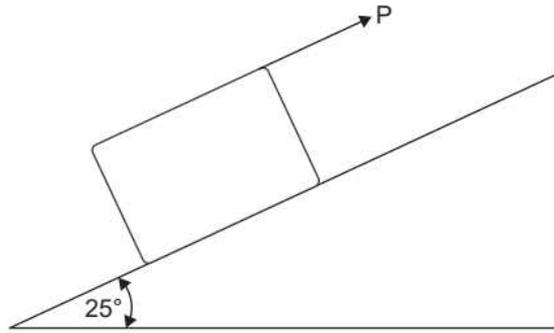
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<p>2021 Paper 1 Section 1 Question 9</p> <p>Machines in society</p>	<p>The work done by a jack to vertically raise a 1500 kg vehicle a distance of 180 cm is</p> <p>(A) 2700 J. (B) 8167 J. (C) 26 460 J. – Answer (D) 81 667 J.</p>
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<p>2020 Paper 1 Section 1 Question 1</p> <p>Machines in society</p>	 <p>What is the gear ratio of this worm and wheel?</p> <p>(A) 1:6 (B) 6:3 (C) 18:1 – Answer (D) 18:3</p>
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2020
Paper 1
Section 1
Question 2

Machines in
society

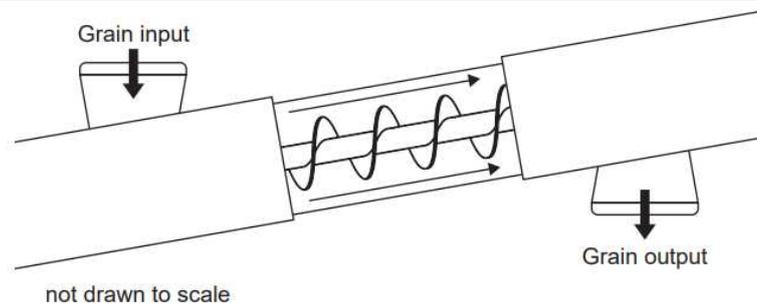


A 25 kg block is pulled up an incline using a force P as shown. What is the minimum value of P required to just move the box from rest if the coefficient of static friction is 0.4?

- (A) 192.3 N – Answer
- (B) 103.5 N
- (C) 41.4 N
- (D) 14.7 N

2020
Paper 1
Section 1
Question 5

Machines in
society



Screw conveyor specifications			
Screw pitch	Screw length	Capacity moved per individual screw	Conveyor rpm
150 mm	2400 mm	0.15 m ³	10

A screw conveyor is used to transport grain from an input chute up a 10° slope to a holding bin using the specifications shown. What is the volume of grain moved each minute?

- (A) 225 m³
- (B) 24 m³ – Answer
- (C) 2.4 m³
- (D) 1.5 m³

2020
Paper 1
Section 1
Question 6

Machines in
society

An irrigation system uses a 7450 W electric motor to drive a pump that delivers 10 000 L of water per hour over a distance of 100 m. How efficient is the irrigation system? Assume that the system is without friction and that 1 L of water has a mass of 1 kg.

- (A) 45%
- (B) 37% – Answer
- (C) 27%
- (D) 10%

2020
Paper 1
Section 1
Question 7

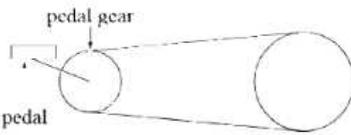
Machines in
society

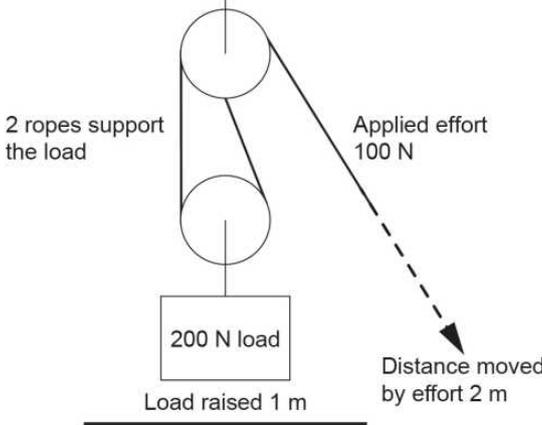
A 20 kg box sits just on the point of sliding on an incline plane. If the coefficient of static friction is 0.27, what is the angle of repose?

- (A) 5°
- (B) 13°
- (C) 15° – Answer
- (D) 16°

2020 Paper 1 Section 1 Question 9 Machines in society	A bicycle has gearing with a VR of 1:3. The rear tyre has an outside diameter of 740 mm. What is the distance travelled for every three rotations of the foot pedals? (A) 42 m (B) 21 m – Answer (C) 7 m (D) 2 m
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Marking Guide – Paper 1 Section 2

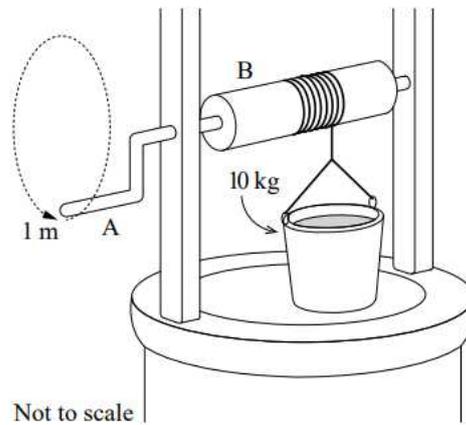
<p>2023 Paper 1 Section 2 Question 12</p> <p>Machines in society</p>	<p>Explain how the gearing system on a bicycle provides a mechanical advantage to a cyclist moving up an incline, and the system's effect on the work done on the pedals. Sketch the mechanical components involved to support your response. (5 marks)</p>	
	<p>Sample response</p>	<p>The response</p>
	 <p>When cycling up an incline, the cyclist will need a high mechanical advantage. The gear attached to the pedal arm that the cyclist pushes will need to be much smaller and have fewer teeth than the gear attached to the rear wheel. The smaller the pedal gear compared to the rear wheel gear, the higher the mechanical advantage and the easier it is for the cyclist to turn the pedals. As the gear attached to the pedals has a smaller circumference than the gear attached to the rear wheel it will need to make more rotations to get the bicycle to travel a greater distance. However, the work done by the cyclist remains the same, because while the force required to move the pedals will be less, the distance moved by the pedals will be more.</p>	<ul style="list-style-type: none"> • appropriately explains the mechanical advantage, using wording that indicates <ul style="list-style-type: none"> – the pedal gear would be smaller than the rear wheel gear [1 mark] – work done remains the same [1 mark] – less force is required to move the pedals [1 mark] – more rotations of the pedals will be required [1 mark] • provides an appropriate sketch, including the larger rear wheel gear linked to the smaller pedal gear [1 mark]

<p>2022 Paper 1 Section 2 Question 11</p> <p>Machines in society</p>	<p>Explain the concepts of mechanical advantage and velocity ratio using a simple pulley system. Provide an annotated sketch to support your response. [5 marks]</p>	
	<p>Sample response</p>	<p>The response</p>
	 <p>For a pulley system with two ropes that support the load, the mechanical advantage (MA) is 2:1 as the effort required is half the load. The velocity ratio (VR) is 2:1 as this is the amount of rope pulled through the system divided by the distance the load is moved.</p>	<ul style="list-style-type: none"> • explains MA appropriately using wording that indicates the number of ropes supporting the load proportionately reduces the effort required to move the load [1 mark] • explains VR appropriately using wording that indicates the distance moved by the effort divided by the distance the load is moved [1 mark] • provides an appropriately annotated sketch including <ul style="list-style-type: none"> - effort [1 mark] - load [1 mark] - distance moved by effort and load [1 mark]

**2021
Paper 1
Section 2
Question 16**

**Machines in
society**

This simple machine is used by turning handle A to raise a 10 kg bucket of water from a 10 m deep well. The hand-operated handle A has a turning circle of 1 m and the lifting arm B has a diameter of 250 mm. The machine takes 30 seconds to raise the water. Explain the work done by the machine and the power used to lift one bucket of water. Use mathematical reasoning to support your explanation. [5 marks]



Sample response	The response
<p>The work done by the machine is determined by calculating the force required to lift the load multiplied by the distance raised. The bucket of water exerts a 98 N force on the machine during the 10-metre lift. The 980 J of work is done during the lift (98 N x 10 m = 980 J). The mechanical advantage of 1.27 (assuming that efficiency is zero where $MA = VR = \frac{dE}{dL}$) reduces the effort being applied at the handle; however, the work done is still the same. Therefore the power, which is the rate of doing work, is calculated by dividing the work done by the time taken i.e. $\frac{980}{30} = 32.7W$.</p>	<ul style="list-style-type: none"> • explains appropriately showing logical organisation of relevant information about key steps that includes mathematical reasoning - using the correct formula for work [1 mark] - using the correct formula for power [1 mark] - using the correct value for MA [1 mark] • includes the correct determination of - work done [1 mark] - power used [1 mark]

**2021
Paper 1
Section 2
Question 17**

**Machines in
society**

Describe a community problem related to a sustainability issue. Explain how engineers have used their knowledge to develop a solution for this problem and how the solution has reduced the environmental impact to provide two benefits for the community involved. [6 marks]

Sample response	The response
<p>Stoves in developing countries, such as India, use biomass such as timber as a fuel. Burning timber has been detrimental to the environment by contributing to poor air quality.</p> <p>Engineers have used their knowledge of 'high-tech' alloys and ceramics to develop low-cost appropriate stove solutions. They have improved the burning efficiency of the stoves by up to 50% by using metal alloys in their construction, reducing size, and using heat-efficient ceramics and effective designs, which reduce smoke output by up to 95%.</p> <p>Reducing the mass of timber that is burned has long-term and short-term community benefits, including improving air quality, which has associated benefits for people's respiratory health, and reducing the effects of burning timber on global warming.</p>	<ul style="list-style-type: none"> • describes a relevant community problem related to a relevant sustainability issue [1 mark] • explains how engineers have - used relevant knowledge [1 mark] - to develop a solution [1 mark] • explains how the solution - reduced environmental impact [1 mark] - provided a relevant community benefit [1 mark] - provided another relevant community benefit [1 mark]

**2020
Paper 1
Section 2
Question 15**

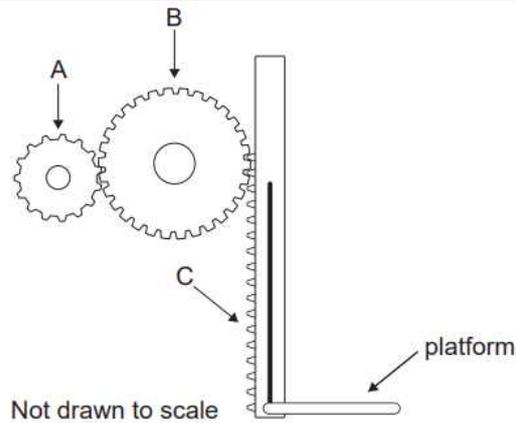
**Machines in
society**

Explain why an engineer would recommend solar-powered water pumps for crop irrigation to a community in a developing country. For three different types of technology knowledge, identify two factors of each to support your explanation. [6 marks]

Sample response	The response
<p>The engineer would have considered the local environmental conditions. Effective use of solar energy requires that most days are cloud free. This would allow the solar-powered pumps to operate efficiently. On overcast, cloudy days when rain is likely, the solar pumps would operate less often, saving water.</p> <p>The engineer would also have considered the economics of the use of solar water pumps. The initial cost of the pumps is possibly high when compared to other methods, but running costs are low, which allows the community to transport water cheaply and efficiently.</p> <p>It would be important to have a sustainable water supply, as solar pumps are able to supply large volumes of water. The engineer would have considered the sustainability of the solar pumps and the irrigation system, as breakdowns in the system would need to be repaired. This aspect of implementation of any mechanical system would need to be considered in the maintenance of the system.</p>	<ul style="list-style-type: none"> • explains appropriately using - 1 relevant environmental factor [1 mark] - another relevant environmental factor [1 mark] • explains appropriately using - 1 relevant economic factor [1 mark] - another relevant economic factor [1 mark] • explains appropriately using - 1 relevant sustainability factor [1 mark] - another relevant sustainability factor [1 mark]

2020
Paper 1
Section 2
Question 16

Machines in
society



The 15-tooth gear A drives a gear train used to raise a platform a distance of 1.2 m. The teeth of gear C have a pitch of 10 mm and gear B has 30 teeth. Identify the gear train used and determine the ratio of gear A to gear C. Explain your reasoning. [5 marks]

Sample response	The response
<p>A gear ratio of the system is determined using the distance travelled by the rack for each revolution of the pinion gear B. The pitch of the teeth on the rack is 10 mm, which means that each revolution of the pinion gear that has 30 teeth will raise the rack by 300 mm. To lift the platform 1.2 m, the pinion gear must rotate 4 times. The gear ratio between gear A and gear B is 30 divided by 15 or 2:1. To raise the rack 1.2 metres, gear A is required to turn 8 times to turn gear B 4 times. Therefore, the gear ratio of gear A to gear C is 1 to 150 mm.</p>	<ul style="list-style-type: none"> • explains correctly and includes - identification of rack and pinion gears [1 mark] - an accurate numerical relationship between linear and rotational movement of the rack and pinion gears [1 mark] - an accurate gear ratio of gear A to B [1 mark] - an accurate gear ratio of gear A to C [1 mark] - evidence of mathematical reasoning [1 mark]

Marking Guide – Paper 1 Section 3

<p>2023 Paper 1 Section 3 Question 16</p> <p>Machines in society</p>	<p>A crane lowers a storage container off the back of a truck at a velocity of 1.5 m/s, giving the container a kinetic energy of 850 J.</p> <p>Calculate the total mechanical energy of the lowering system when the base of the storage container is 2 m above the ground. Answer to the nearest whole unit. (5 marks)</p>	
	<p>Sample response</p>	<p>The response</p>
<p> $KE = \frac{1}{2}mv^2$ Storage container mass = $\frac{2 \times KE}{v^2} = \frac{2 \times 850}{1.5^2} = \frac{1700}{2.25} = 755.56 \text{ kg}$ </p> <p> $PE = mgh$ $PE = 755.56 \times 9.8 \times 2 = 14\,808.98 \text{ J}$ </p> <p> $ME = KE + PE$ $ME = 850 + 14\,808.98$ $ME = 15\,659 \text{ J}$ </p>		<ul style="list-style-type: none"> • provides correct formula and substituted values for mass [1 mark] • determines mass [1 mark] • provides correct formula and substituted values for PE [1 mark] • determines PE [1 mark] • determines the answer in J to the nearest whole unit [1 mark]

**2023
Paper 1
Section 3
Question 17**

**Machines in
society**

A threaded rod with a pitch of 2.5 mm and an outside diameter of 30 mm is used as a mechanism to vertically raise a 40 kg load with a potential energy of 980 J. The threaded rod is directly driven by a variable-speed electric motor with an efficiency of 62%.

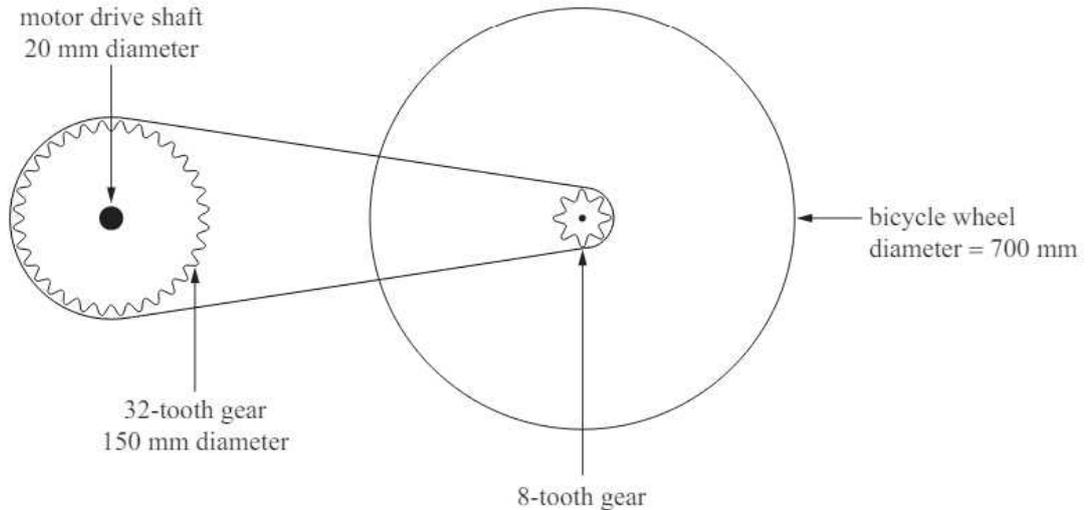
Determine the power required from the motor to raise the load in 15 seconds. Answer to one decimal place. (9 marks)

Sample response	The response
<p>PE= mgh 980= 40 x 9.8 x h</p> $h = \frac{980}{40 \times 9.8} = 2.5 \text{ m}$ $VR = \frac{D_E}{D_L} = \frac{\pi D}{\text{thread pitch}} = \frac{\pi \times 30}{2.5} = 37.70$ $\text{efficiency} = \frac{MA}{VR}$ <p>MA=0.62 x 37.70 = 23.37</p> $MA = \frac{F_L}{F_E}$ $F_E = \frac{40 \times 9.8}{23.37} = 16.77 \text{ N}$ <p>Number of rotations of input shaft = $\frac{2.5 \text{ m}}{0.0025} = 1000$</p> <p>Distance travelled by effort = 1000 x π x 0.03 = 94.25 m</p> <p>W = Fd = 16.77 x 94.25 = 1580.57 J</p> $P = \frac{W}{t} = \frac{1580.57}{15} = 105.4 \text{ W}$	<ul style="list-style-type: none"> • determines the vertical distance the load is raised [1 mark] • provides correct formula and substituted values for VR of the thread mechanism [1 mark] • determines VR of the thread mechanism [1 mark] • determines MA [1 mark] • determines effort [1 mark] • determines rotations of shaft [1 mark] • determines distance effort [1 mark] • determines input Work [1 mark] • determines Input power [1 mark]
<p>OR</p> <p>Output Work is equal to 980 J of PE to load, thus output power</p> $P = \frac{W}{t} = \frac{980}{15}$ $= 65.33 \text{ W}$ <p>Efficiency = output / input</p> <p>Input Power (motor power) = output / efficiency</p> <p>Input power = 65.33 / 0.62 = 105.37 W</p> <p>Input motor power = 105.4 W</p>	<p>OR</p> <ul style="list-style-type: none"> • Identify that output work =change in PE [1 mark] • Correctly identify power equation [1 mark] • Correctly substitute into power equation [1 mark] • Correctly determine output power [1 mark] • Correctly identify efficiency equals output power/ input power [1 mark] • Correctly substitute into equation [1 mark] • Correctly determine input power [1 mark] • Correctly round to 1 decimal place [1 mark] • Correct unit for power [1 mark]

**2023
Paper 1
Section 3
Question 18**

**Machines in
society**

An electric motor with an output force of 600 N is attached to the driver gear of an electric-powered bicycle using a 20 mm diameter drive shaft.



Not to scale

a) Calculate the number of driver gear rotations required for the bicycle wheel to move 15 m. Answer to one decimal place. [2 marks]

Sample response	The response
$VR = GR = \frac{d_E}{d_L} = \frac{\text{number of teeth on driven}}{\text{number of teeth on driver}} = \frac{8}{32} = 0.25$ <p>Distance moved by bicycle wheel in 1 rotation of driven = $\pi D = \pi \times 0.7 = 2.199 \text{ m}$</p> <p>Number of rotations of driven for 15m $= \frac{15}{2.199} = 6.82 \text{ rotations}$</p> <p>$\therefore$ Number of rotations of driver = $6.82 \times 0.25 = 1.7$</p>	<ul style="list-style-type: none"> determines the VR / GR of the driven to driver gears [1 mark] determines answer to one decimal place [1 mark]

b) Calculate the number of motor drive shaft rotations required for the bicycle wheel to move 15 m. Answer to the nearest whole unit. [2 marks]

Sample response	The response
<p>Drive shaft rotations = Number of rotations of the driver gear = 1.7</p> <p>\therefore The number of rotations of the drive shaft = 2</p>	<ul style="list-style-type: none"> correct interpretation of the mechanical system [1 mark] determines answer to the nearest whole unit [1 mark]

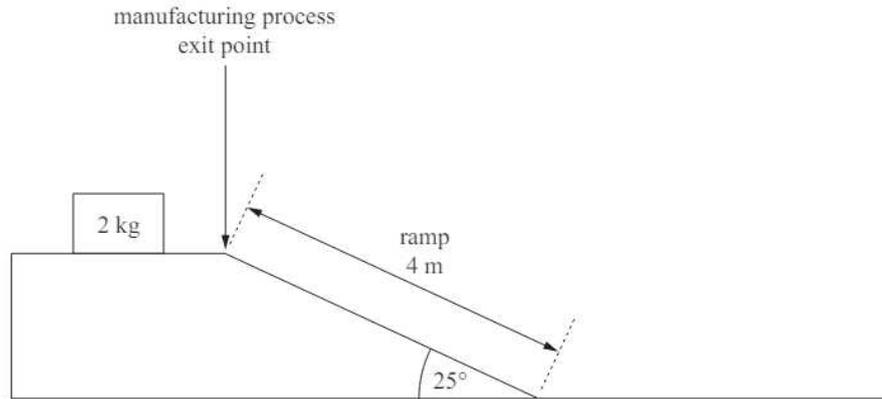
c) Determine the output power of the electric motor if the bicycle wheel takes 2 seconds to travel 15 m. Answer to the nearest whole unit. [3 marks]

Sample response	The response
<p>Distance moved by motor drive shaft = $2 \times \pi \times 0.02 = 0.126m$</p> <p>$W = Fd = 600 \times 0.126 = 75.6 J$</p> <p>$P = \frac{W}{t} = \frac{75.6}{2} = 37.8 W \approx 38 W$</p> <p>The output power of the electric motor is 38W</p>	<ul style="list-style-type: none"> • determines the distance moved by the motor drive shaft [1 mark] • determines work [1 mark] • determines the answer in W to the nearest whole unit [1 mark]

**2023
Paper 1
Section 3
Question 19**

**Machines in
society**

A 2 kg box exits a manufacturing process at a velocity of 0.5 m/s and then slides down a ramp onto a horizontal surface as shown.



Not to scale

Determine the distance the box slides along the horizontal surface before coming to a complete stop if the coefficient of kinetic friction between the box and all surfaces is 0.35. Answer to the nearest whole unit. (9 marks)

Sample response	The response
<p>Forces acting on the ramp</p> $F_f = \mu F_N = \mu mg \cos \theta$ $F_f = 0.35 \times 2 \times 9.8 \times \cos 25^\circ$ $F_f = 6.22 \text{ N}$	<ul style="list-style-type: none"> determines the force of friction on the ramp [1 mark]
<p>Parallel force down the ramp</p> $F_p = mg \sin \theta$ $F_p = 2 \times 9.8 \times \sin 25^\circ$ $F_p = 8.28 \text{ N}$	<ul style="list-style-type: none"> determines parallel force down the ramp [1 mark]
<p>Resultant force down the ramp</p> $F_r = F_p - F_f$ $F_r = 8.28 - 6.22$ $F_r = 2.06 \text{ N}$	<ul style="list-style-type: none"> determines resultant force down the ramp [1 mark]
<p>Acceleration down the ramp</p> $F = ma$ $a = \frac{F}{m} = \frac{2.06}{2} = 1.03 \text{ m/s}^2$	<ul style="list-style-type: none"> determines ramp acceleration [1 mark]
<p>Velocity at the bottom of the ramp</p> $v^2 = u^2 + 2as$ $v^2 = 0.5^2 + 2 \times 1.03 \times 4$ $v^2 = 8.49$ $v = \sqrt{8.49}$ $v = 2.91 \text{ m/s}$	<ul style="list-style-type: none"> provides correct formula and substituted values for velocity [1 mark] determines velocity at the bottom of the ramp [1 mark]

<p>Horizontal surface</p> $F_f = \mu F_N = \mu mg$ $F_f = 0.35 \times 2 \times 9.8 = 6.86 \text{ N}$ $F = ma$ $\text{Deceleration} = \frac{F}{m} = \frac{6.86}{2} = 3.43 \text{ m/s}^2$ <p>Distance box slides along horizontal surface</p> $v^2 = u^2 + 2as$ $s = \frac{v^2 - u^2}{2a}$ $s = \frac{0^2 - 2.91^2}{2 \times 3.43}$ $s = \frac{-8.47}{-6.86}$ $s = 1.235 \text{ m}$ <p>The box slides 1.235 m along the horizontal surface before coming to a complete stop.</p>	<ul style="list-style-type: none"> • determines force of friction on the horizontal surface [1 mark] • determines deceleration on the horizontal surface [1 mark] • determines the answer to the nearest whole unit [1 mark]
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<p>2023 Paper 1 Section 3 Question 20</p> <p>Machines in society</p>	<p>A 20 kg trolley is pushed up a 10° incline using a force of 160 N.</p> <p>Determine the coefficient of friction between the trolley and the incline if the trolley is travelling at a uniform velocity. Answer to two decimal places. (5 marks)</p>				
	<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="background-color: #e0e0e0; padding: 5px;">Sample response</th> <th style="background-color: #e0e0e0; padding: 5px;">The response</th> </tr> </thead> <tbody> <tr> <td style="padding: 5px;"> <p>Uniform or constant velocity ∴ forces up incline = forces down incline</p> <p>Let the coefficient of friction = μ_k</p> <p>160 N = F_f + weight force component parallel to the incline</p> $160 = \mu_k F_N + mg \sin 10$ $160 - mg \sin 10 = \mu_k \times mg \cos 10$ $160 - 20 \times 9.8 \times \sin 10 = \mu_k \times 20 \times 9.8 \times \cos 10$ $\mu_k = \frac{160 - 196 \times \sin 10}{196 \times \cos 10}$ $\mu_k = \frac{160 - 34.04}{193} = 0.65$ <p>∴ the coefficient of friction = 0.65</p> </td> <td style="padding: 5px;"> <ul style="list-style-type: none"> • indicates that the system is in equilibrium [1 mark] • identifies three forces parallel to the incline [1 mark] • provides correct formula and substituted values [1 mark] • correctly manipulates equation to isolate coefficient of friction [1 mark] • determines the answer to two decimal places [1 mark] </td> </tr> </tbody> </table>	Sample response	The response	<p>Uniform or constant velocity ∴ forces up incline = forces down incline</p> <p>Let the coefficient of friction = μ_k</p> <p>160 N = F_f + weight force component parallel to the incline</p> $160 = \mu_k F_N + mg \sin 10$ $160 - mg \sin 10 = \mu_k \times mg \cos 10$ $160 - 20 \times 9.8 \times \sin 10 = \mu_k \times 20 \times 9.8 \times \cos 10$ $\mu_k = \frac{160 - 196 \times \sin 10}{196 \times \cos 10}$ $\mu_k = \frac{160 - 34.04}{193} = 0.65$ <p>∴ the coefficient of friction = 0.65</p>	<ul style="list-style-type: none"> • indicates that the system is in equilibrium [1 mark] • identifies three forces parallel to the incline [1 mark] • provides correct formula and substituted values [1 mark] • correctly manipulates equation to isolate coefficient of friction [1 mark] • determines the answer to two decimal places [1 mark]
Sample response	The response				
<p>Uniform or constant velocity ∴ forces up incline = forces down incline</p> <p>Let the coefficient of friction = μ_k</p> <p>160 N = F_f + weight force component parallel to the incline</p> $160 = \mu_k F_N + mg \sin 10$ $160 - mg \sin 10 = \mu_k \times mg \cos 10$ $160 - 20 \times 9.8 \times \sin 10 = \mu_k \times 20 \times 9.8 \times \cos 10$ $\mu_k = \frac{160 - 196 \times \sin 10}{196 \times \cos 10}$ $\mu_k = \frac{160 - 34.04}{193} = 0.65$ <p>∴ the coefficient of friction = 0.65</p>	<ul style="list-style-type: none"> • indicates that the system is in equilibrium [1 mark] • identifies three forces parallel to the incline [1 mark] • provides correct formula and substituted values [1 mark] • correctly manipulates equation to isolate coefficient of friction [1 mark] • determines the answer to two decimal places [1 mark] 				

2023
Paper 1
Section 3
Question 21
Machines in society

A factory uses a two-pump system to vertically lift water into a main reservoir.

The first pump is 80% efficient and lifts 500 litres of water per minute into a holding tank 6 m above the ground. The second pump is 75% efficient and lifts 500 litres of water per minute from the holding tank into the main reservoir 10 m above the ground.

This current system is being replaced with a single-pump system that is 90% efficient and has the same power input as the two-pump system. Determine the rate at which the new system will lift water into the main reservoir. Answer to the nearest whole unit (litres per minute).

Note: 1 litre of water has a mass of 1 kg. (10 marks)

Sample response	The response
<p>First pump</p> $W = \text{force} \times \text{distance} = Fd$ $W = mgh$ $W = 500 \times 9.8 \times 6$ $W = 29\,400 \text{ J}$ <p>Power output: First pump</p> $P = \frac{\text{work done}}{\text{time taken}} = \frac{W}{t}$ $P = \frac{29\,400}{60}$ $P = 490 \text{ W}$ <p>Power input: First pump</p> $\eta = \frac{\text{useful output}}{\text{input}}$ $\text{input} = \frac{\text{useful output}}{\eta}$ $\text{Power input} = \frac{490}{0.8}$ $\text{Power input} = 612.5 \text{ W}$ <p>Second pump</p> $W = \text{force} \times \text{distance} = Fd$ $W = mgh$ $W = 500 \times 9.8 \times 4$ $W = 19\,600 \text{ J}$	<ul style="list-style-type: none"> • determines the work done by the first pump [1 mark] • determines the power output of the first pump [1 mark] • determines the power input of the first pump [1 mark] • determines the work done by the second pump [1 mark]

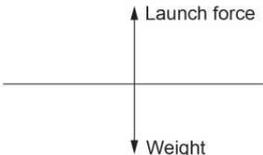
	<p>Power output: Second pump</p> $P = \frac{\text{work done}}{\text{time taken}} = \frac{W}{t}$ $P = \frac{19\,600}{60}$ $P = 326.67 \text{ W}$ <p>Power input: Second pump</p> $\eta = \frac{\text{useful output}}{\text{input}}$ $\text{input} = \frac{\text{useful output}}{\eta}$ $\text{Power input} = \frac{326.67}{0.75}$ $\text{Power input} = 435.56 \text{ W}$ <p>Overall power input of two-pump system</p> $\text{Power} = 612.5 + 435.56$ $\text{Power} = 1048.06 \text{ W}$ <p>New single-pump system</p> $\text{Power input} = 1048.06 \text{ W}$ $\text{Power output} = 90\% \times 1048.06$ $\text{Power output} = 943.25 \text{ W}$	<ul style="list-style-type: none"> determines the power output of the second pump [1 mark] determines the power input of the second pump [1 mark] determines the overall power input of the current two-stage system [1 mark] determines the power output of the new single-pump system [1 mark]
	<p>New single-pump system: mass of water delivered per minute</p> $P = \frac{W}{t}$ $W = P \times t$ $W = 943.25 \times 60$ $W = 56\,595 \text{ J}$ $W = mgh$ $m = \frac{W}{gh}$ $m = \frac{56\,595}{9.8 \times 10}$ $m = 577.5 \text{ kg} = 578 \text{ litres per minute}$ <p>∴ The new single-pump system will deliver 578 litres of water per minute directly to the main reservoir.</p>	<ul style="list-style-type: none"> determines the work done by the new single-pump system [1 mark] determines the answer in litres per minute to the nearest whole unit [1 mark]

2022
Paper 1
Section 3
Question 18

Machines in society

Determine the force required to launch a rocket with a mass of 2000 kg vertically from rest to a height of 20 km in 20 seconds. Assume that the rocket's mass and acceleration due to gravity remain constant during the launch and that air resistance is not a factor.

Include a free-body diagram showing the forces at launch. Answer to the nearest whole unit in kN.

Sample response	The response
 <p>Rocket weight = $2000 \times 9.8 = 19\,600\text{ N}$</p> $s = ut + \frac{1}{2}at^2$ $20\,000 = (0 \times 20) + \left(\frac{1}{2} \times a \times 20^2\right)$ $20\,000 = \frac{1}{2} \times a \times 20^2$ $\frac{40\,000}{400} = a = 100\text{m/s}^2$ <p>$F = ma$</p> $F_{\text{net}} = \text{launch force} - 19\,600 = 2000 \times 100$ $\text{Launch force} = 200\,000 + 19\,600 = 2019\,600\text{N}$ $\approx 220\text{ kN}$ <p>The rocket requires a launch force of 220 kN to reach a vertical height of 20 km in 20 s.</p>	<ul style="list-style-type: none"> • provides an appropriate free-body diagram [1 mark] • correctly determines weight [1 mark] • provides correct formula and substituted values for acceleration [1 mark] • correctly determines acceleration [1 mark] • correctly determines the answer in kN to the nearest whole unit [1 mark]

2022
Paper 1
Section 3
Question 19
Machines in society

An empty cable car with a mass of 1500 kg is being lowered down a track on a 25° incline at a constant velocity of 2 m/s when the cable snaps, releasing the cable car. The cable car's emergency braking system engages when its velocity reaches 5 m/s and increases the coefficient of friction between the cable car and the track from 0.01 to 0.6, bringing it to a complete stop. A warning siren activates when the cable car is 10 metres from the original point of cable failure if it has not come to a stop.

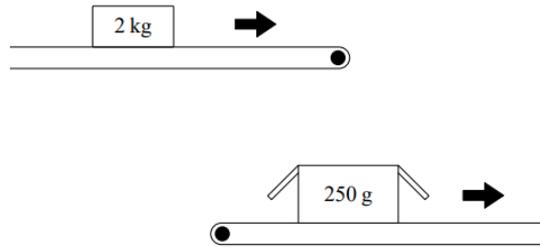
Determine the stopped position of the cable car relative to the warning siren's activation point. Answer to the nearest whole unit in metres. [9 marks]

Sample response	The response
$F_N = mg \cos \theta$ $F_N = 1500 \times 9.8 \times \cos 25 = 13322.72 \text{ N}$ $F_f = \mu F_N$ $= 0.01 \times 13322.72 = 133.23$	<ul style="list-style-type: none"> correctly determines the initial frictional force [1 mark]
$F_p = mg \sin \theta$ $F_p = 1500 \times 9.8 \times \sin 25 = 6212.49 \text{ N}$	<ul style="list-style-type: none"> correctly determines the force down the incline [1 mark]
$F_{\text{net}} = 6212.49 - 133.23 = 6079.26 \text{ N}$	<ul style="list-style-type: none"> correctly determines the net force [1 mark]
$F = ma$ $a = \frac{F}{m} = \frac{6079.26}{1500} = 4.1 \text{ m/s}^2$	<ul style="list-style-type: none"> correctly determines the acceleration [1 mark]
Brakes engage at 5 m/s $u = 2 \frac{\text{m}}{\text{s}}$ $v^2 = u^2 + 2as$ $s = \frac{v^2 - u^2}{2a} = \frac{5^2 - 2^2}{2 \times 4.1} = 2.56 \text{ m}$	<ul style="list-style-type: none"> correctly determines the displacement before brakes engage [1 mark]
After braking: $F_f = \mu F_N$ $= 0.6 \times 13322.72 = 7993.63 \text{ N}$ $F_{\text{net}} = 6212.49 - 7993.63 = -1781.14 \text{ N}$	<ul style="list-style-type: none"> correctly determines the net force after brakes engage [1 mark]
$F = ma$ $a = \frac{F}{m} = \frac{-1781.14}{1500} = -1.19 \text{ m/s}^2$	<ul style="list-style-type: none"> correctly determines the deceleration after brakes engage [1 mark]
$u = \frac{5\text{m}}{\text{s}} \quad v = \frac{0\text{m}}{\text{s}}$ $v^2 = u^2 + 2as$ $s = \frac{v^2 - u^2}{2a} = \frac{0^2 - 5^2}{2 \times -1.19} = 10.50 \text{ m}$	<ul style="list-style-type: none"> correctly determines the displacement after brakes engage [1 mark]
Total distance travelled by the cable car after the cable fails = 2.56 + 10.50 = 13.06 m ≈ 13 m ∴ The cable car stops 3 m after the warning siren activates.	<ul style="list-style-type: none"> correctly determines the answer to the nearest whole unit [1 mark]

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Question 19

Machines in
society

A 2 kg package is moving at 5 m/s in the direction of the arrow, as shown. The package drops into a 250 g carton moving in the same direction at 2 m/s on a second conveyor.



a) Calculate the force exerted by the package if it just causes the carton to begin sliding on the conveyor surface. The coefficient of static friction between the carton and the conveyor surface is 0.4. Answer to the nearest whole unit. Include a free-body diagram with your working. [3 marks]

Sample response	The response
<p>Diagram</p> <p> $u_s = 0.4$ $F_N = mg = 0.25 \times 9.8 = 2.45 \text{ N}$ $F_f = u_s \times F_N = 0.4 \times 2.45 = 0.98 \text{ N} \approx 1 \text{ N}$ </p>	<ul style="list-style-type: none"> provides an appropriate free-body diagram [1 mark] provides correct working to give normal force acting on the box [1 mark] provides correct working to give correct answer to the nearest whole unit with correct unit provided [1 mark]

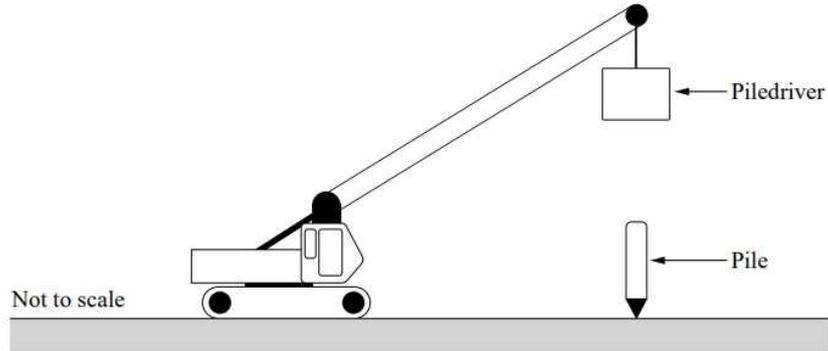
b) If the coefficient of kinetic friction is 0.3, determine the distance the carton slides along the conveyor surface after the package lands in it. Answer to the nearest whole unit (mm). Include a free-body diagram with your working. [5 marks]

Sample response	The response
<p> Assume initial velocity of combined carton and package is 3 m/s (5 m/s – 2 m/s) Total mass = 2 kg + 0.25 kg = 2.25 kg $u_k = 0.30$ $F_N = 2.25 \times 9.8 = 22.05 \text{ N}$ $F_f = u_k \times F_N = 0.30 \times 22.05 = 6.62 \text{ N}$ Deceleration $\approx a = \frac{F}{m} = \frac{6.62}{2.25} = 2.94 \text{ m/s}^2$ $s = \frac{v^2 - u^2}{2a}$ $= \frac{0 - 3^2}{2 \times -2.94} = 1.53 \text{ m} = 1530 \text{ mm}$ </p>	<ul style="list-style-type: none"> provides an appropriate free-body diagram [1 mark] provides correct working to give correct normal force acting on the box and carton [1 mark] provides correct working to give correct force of kinetic friction [1 mark] provides correct working to give correct deceleration [1 mark] provides correct working to give correct answer to the nearest whole unit with correct unit provided [1 mark]

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Paper 1
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Question 20

Machines in society

A 500 kg piledriver is used to drive a 200 kg pile into the soil as shown. The piledriver falls freely through a distance of 4 m before impacting the pile with 19.6 kJ of energy. At the moment of impact, energy is lost as heat and sound. [5 marks]



a) If 5.4 kJ of energy is lost during the impact between piledriver and pile, determine the velocity of the piledriver just after impact. Answer to two decimal places. [3 marks]

Sample response	The response
At impact energy = 19.6 kJ Energy lost = 5.4 kJ Remaining energy = 19.6 – 5.4 = 14.2 kJ KE after the impact = 14 200 J $KE = \frac{1}{2} mv^2$ $14\,200 = \frac{1}{2} (500 + 200)v^2$ $14\,200 = \frac{1}{2} \times 700 \times v^2$ $v = \sqrt{\frac{14\,200 \times 2}{700}}$ $v = 6.37 \text{ m/s}$ \therefore the velocity of the driver and pile just after impact is 6.37 m/s.	<ul style="list-style-type: none"> • provides correct working to determine remaining kinetic energy [1 mark] • provides correct formula and substituted values [1 mark] • provides correct working to give correct answer to two decimal places with correct unit provided [1 mark]

b) If the pile and piledriver decelerate at a constant rate of 30 m/s² after impact due to the resistance of the soil, determine the distance the pile is driven into the ground.

Answer to the nearest whole unit (mm). [2 marks]

Sample response	The response
$v^2 = u^2 + 2as$ Final velocity = 0 m/s $s = \frac{v^2 - u^2}{2a} = \frac{0^2 - 6.37^2}{2 \times -30} = 0.676 \text{ m}$ \therefore The distance the pile is driven into the soil is 676 mm.	<ul style="list-style-type: none"> • provides correct formula and substituted values [1 mark] • provides correct working to give correct answer to the nearest whole unit with correct unit provided [1 mark]

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Question 21

Machines in society

A bucket is used to carry iron ore vertically up a mine shaft from its base. The bucket is raised from rest at the base of the shaft and accelerates constantly upwards at a rate of 0.75 m/s^2 for 4 s. It then travels at a constant velocity before decelerating constantly to stop at the top of the shaft.

a) Determine the maximum velocity of the bucket to the nearest whole unit. [3 marks]

Sample response	The response
$v = u + at$ $= 0 + 0.75 \text{ m/s}^2 \times 4$ $= 3 \text{ m/s}$	<ul style="list-style-type: none"> • provides correct formula and substituted values [1 mark] • provides correct working to give correct answer to the nearest whole unit [1 mark] • provides correct unit for velocity (m/s) [1 mark]

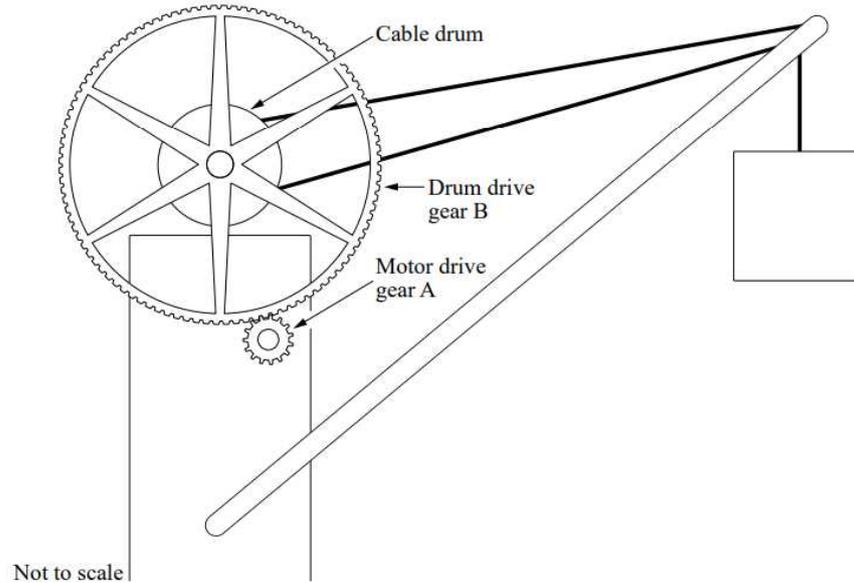
b) From rest, the bucket is lowered from the top of the shaft with a constant acceleration. Determine the bucket's acceleration if the bucket has been lowered 25 m after 10 s. Answer to one decimal place. [2 marks]

Sample response	The response
$s = ut + \frac{1}{2} \times at^2$ $25 = 0 \times 10 + \frac{1}{2} \times a \times 10^2$ $a = \frac{25 \times 2}{10^2}$ $a = 0.5 \text{ m/s}^2$	<ul style="list-style-type: none"> • provides correct formula and substituted values [1 mark] • provides correct working to give correct answer to one decimal place with correct unit provided [1 mark]

**2021
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Question 22**

**Machines in
society**

This winch crane is driven by an electric motor. The motor drive shaft is fitted to a 15-tooth gear A, which drives a 100-tooth gear B attached to a cable drum. The 500 mm diameter cable drum houses a steel cable that is used to vertically raise 20 kg hay bales 2 m from the ground to be loaded onto trucks.



a) Calculate the output power of the crane if it takes 30 seconds to raise two hay bales. Answer to two decimal places. [2 marks]

Sample response	The response
$W = Fd$ $= (20 \times 2) \times 9.8 \times 2$ $= 784 \text{ J}$ $P = \frac{W}{t}$ $= \frac{784}{30}$ $= 26.13 \text{ W}$	<ul style="list-style-type: none"> • provides correct working to give correct work [1 mark] • provides correct working to give correct answer to two decimal places with correct unit provided [1 mark]

b) Determine the number of motor revolutions required to produce the 2 m lift. Answer to one decimal place. [4 marks]

Sample response	The response
$\text{Drum circumference} = 2\pi r$ $= 2\pi \times 0.25 \text{ m} = 1.57 \text{ m}$ $\therefore \text{number of drum revolutions to lift 2 m} = \frac{2}{1.57} = 1.27$ $\text{Motor revolutions required to lift 2 m}$ $= (\text{GR})$ $\times \text{number of drum revolutions required to lift 2 m}$ $= \frac{100}{15} \times 1.27 = 8.466$ $\therefore \text{the number of motor revolutions to lift 2 m} = 8.5$	<ul style="list-style-type: none"> • provides correct working to give correct drum circumference [1 mark] • provides correct working to give correct solution for drum revolutions per lift [1 mark] • provides correct formula and substituted values [1 mark] • provides correct working to give correct answer to one decimal place [1 mark]

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**Machines in
society**

A conveyor transfers a 2 kg component between two assembly points during a product manufacturing process. Initially stationary at assembly point 1, the component moves 10 m with a uniform acceleration of 2 m/s^2 , just without slipping on the conveyor, to assembly point 2, where it stops.

Determine the coefficient of static friction required between the conveyor and the component if the transfer time between the two assembly points is reduced by 20%. Answer to two decimal places.

Sample response	The response
$u = 0 \quad s = 10 \text{ m} \quad v = ? \quad t = ? \quad a = 2 \text{ m/s}^2$ $v^2 = u^2 + 2as$ $v = \sqrt{u^2 + 2as}$ $v = \sqrt{0^2 + 2 \times 2 \times 10} = 6.32 \text{ m/s}$ $t = \frac{v - u}{a}$ $t = \frac{6.32 - 0}{2} = 3.16 \text{ s}$ $20\% \text{ time reduction required} = 3.16 - (0.2 \times 3.16)$ $= 2.53 \text{ s}$ $s = ut + \frac{1}{2}at^2$ $10 = 0 \times 2.53 + \frac{1}{2}a \times 2.53^2$ $10 = \frac{a \times 6.4}{2}$ $a = \frac{10 \times 2}{6.4} = 3.13 \text{ m/s}^2$ $F = ma$ $= 2 \times 3.13 = 6.26 \text{ N}$ $F_f = u_s \times F_N$ $u_s = \frac{F_f}{F_N}$ $= \frac{6.26}{2 \times 9.8} = \frac{6.26}{19.6} = 0.32$ <p>\therefore the coefficient of static friction required between the component and conveyor at a 20% time reduction is 0.32.</p>	<ul style="list-style-type: none"> • provides correct formula and substituted values for velocity [1 mark] • provides correct working to give correct velocity [1 mark] • provides correct formula and substituted values for time [1 mark] • provides correct working to give correct time [1 mark] • provides correct working to give correct 20% time reduction [1 mark] • provides correct formula and substituted values for acceleration [1 mark] • provides correct working to give correct acceleration [1 mark] • provides correct working to give correct force of friction [1 mark] • provides correct formula and substituted values for coefficient of static friction [1 mark] • provides correct working to give correct answer to two decimal places [1 mark]

2020 Paper 1 Section 3 Question 18 Machines in society	<p>A 900 kg machine is designed to rest without slipping on a slope of up to 30° on the surface of Mars. The acceleration due to gravity on Mars is one-third of that on Earth.</p> <p>a) Determine the coefficient of static friction required to keep the machine from slipping on a 30° incline on Mars. Answer to two decimal places. [1 mark]</p>				
	<table border="1"> <thead> <tr> <th>Sample response</th> <th>The response</th> </tr> </thead> <tbody> <tr> <td> $\mu_s = \tan \theta = \tan 30 = 0.58$ </td> <td> <ul style="list-style-type: none"> provides correct working to give correct coefficient of static friction to two decimal places [1 mark] </td> </tr> </tbody> </table>	Sample response	The response	$\mu_s = \tan \theta = \tan 30 = 0.58$	<ul style="list-style-type: none"> provides correct working to give correct coefficient of static friction to two decimal places [1 mark]
	Sample response	The response			
	$\mu_s = \tan \theta = \tan 30 = 0.58$	<ul style="list-style-type: none"> provides correct working to give correct coefficient of static friction to two decimal places [1 mark] 			
<p>b) Calculate the resulting force of static friction between the machine and Mars' surface. Answer to the nearest whole unit. [2 marks]</p>					
<table border="1"> <thead> <tr> <th>Sample response</th> <th>The response</th> </tr> </thead> <tbody> <tr> <td> <p>Acceleration on Mars = $\frac{9.8}{3} = 3.27 \text{ m/s}^2$</p> <p>$F_f = \mu_s F_N$</p> <p>$F_f = \mu_s mg \cos \theta$</p> <p>$= 0.58 \times 900 \times 3.27 \times \cos 30$</p> <p>$= 1478.25 \text{ N} \approx 1478 \text{ N}$</p> </td> <td> <ul style="list-style-type: none"> provides correct formula and substituted values [1 mark] provides correct answer to the nearest whole unit with correct unit provided [1 mark] </td> </tr> </tbody> </table>	Sample response	The response	<p>Acceleration on Mars = $\frac{9.8}{3} = 3.27 \text{ m/s}^2$</p> <p>$F_f = \mu_s F_N$</p> <p>$F_f = \mu_s mg \cos \theta$</p> <p>$= 0.58 \times 900 \times 3.27 \times \cos 30$</p> <p>$= 1478.25 \text{ N} \approx 1478 \text{ N}$</p>	<ul style="list-style-type: none"> provides correct formula and substituted values [1 mark] provides correct answer to the nearest whole unit with correct unit provided [1 mark] 	
Sample response	The response				
<p>Acceleration on Mars = $\frac{9.8}{3} = 3.27 \text{ m/s}^2$</p> <p>$F_f = \mu_s F_N$</p> <p>$F_f = \mu_s mg \cos \theta$</p> <p>$= 0.58 \times 900 \times 3.27 \times \cos 30$</p> <p>$= 1478.25 \text{ N} \approx 1478 \text{ N}$</p>	<ul style="list-style-type: none"> provides correct formula and substituted values [1 mark] provides correct answer to the nearest whole unit with correct unit provided [1 mark] 				
<p>c) Explain what would happen to the coefficient of static friction if the machine was tested on Earth. [2 marks]</p>					
<table border="1"> <thead> <tr> <th>Sample response</th> <th>The response</th> </tr> </thead> <tbody> <tr> <td> <p>The coefficient of static friction depends only on the angle of repose. Therefore μ_s will be the same quantity on both Mars and Earth.</p> </td> <td> <ul style="list-style-type: none"> explains using wording indicative of - μ_s depends only on the angle of repose [1 mark] - μ_s is the same on Mars and Earth [1 mark] </td> </tr> </tbody> </table>	Sample response	The response	<p>The coefficient of static friction depends only on the angle of repose. Therefore μ_s will be the same quantity on both Mars and Earth.</p>	<ul style="list-style-type: none"> explains using wording indicative of - μ_s depends only on the angle of repose [1 mark] - μ_s is the same on Mars and Earth [1 mark] 	
Sample response	The response				
<p>The coefficient of static friction depends only on the angle of repose. Therefore μ_s will be the same quantity on both Mars and Earth.</p>	<ul style="list-style-type: none"> explains using wording indicative of - μ_s depends only on the angle of repose [1 mark] - μ_s is the same on Mars and Earth [1 mark] 				

2020 Paper 1 Section 3 Question 19 Machines in society	<p>A crane requires 4355 W to vertically lift a full scrap metal bin a distance of 20 m from the ground at constant velocity over a period of 90 s.</p> <p>a) Determine the mass of the full scrap metal bin to the nearest whole unit. [3 marks]</p>				
	<table border="1"> <thead> <tr> <th>Sample response</th> <th>The response</th> </tr> </thead> <tbody> <tr> <td> $P = \frac{W}{t}$ $4355 = \frac{W}{90}$ $W = 4355 \times 90 = 391\,950 \text{ J}$ $W = F \times d \approx PE = mgh$ $\therefore W = mgh$ $391\,950 = m \times 9.8 \times 20$ $m = \frac{391\,950}{9.8 \times 20}$ $= 1999.75 \approx 2000 \text{ kg}$ <p>\therefore The mass of the full scrap metal bin is 2000 kg.</p> </td> <td> <ul style="list-style-type: none"> provides correct working to give correct result for work done [1 mark] provides correct formula and substituted values [1 mark] provides correct working to give correct answer to the nearest whole unit with correct unit provided [1 mark] </td> </tr> </tbody> </table>	Sample response	The response	$P = \frac{W}{t}$ $4355 = \frac{W}{90}$ $W = 4355 \times 90 = 391\,950 \text{ J}$ $W = F \times d \approx PE = mgh$ $\therefore W = mgh$ $391\,950 = m \times 9.8 \times 20$ $m = \frac{391\,950}{9.8 \times 20}$ $= 1999.75 \approx 2000 \text{ kg}$ <p>\therefore The mass of the full scrap metal bin is 2000 kg.</p>	<ul style="list-style-type: none"> provides correct working to give correct result for work done [1 mark] provides correct formula and substituted values [1 mark] provides correct working to give correct answer to the nearest whole unit with correct unit provided [1 mark]
	Sample response	The response			
$P = \frac{W}{t}$ $4355 = \frac{W}{90}$ $W = 4355 \times 90 = 391\,950 \text{ J}$ $W = F \times d \approx PE = mgh$ $\therefore W = mgh$ $391\,950 = m \times 9.8 \times 20$ $m = \frac{391\,950}{9.8 \times 20}$ $= 1999.75 \approx 2000 \text{ kg}$ <p>\therefore The mass of the full scrap metal bin is 2000 kg.</p>	<ul style="list-style-type: none"> provides correct working to give correct result for work done [1 mark] provides correct formula and substituted values [1 mark] provides correct working to give correct answer to the nearest whole unit with correct unit provided [1 mark] 				
<p>b) Determine the velocity on impact of a 5 kg section of scrap metal that falls to the ground unobstructed from the bin at the top of the lift. Answer to the nearest whole unit. [3 marks]</p>					
<table border="1"> <thead> <tr> <th>Sample response</th> <th>The response</th> </tr> </thead> <tbody> <tr> <td> <p>KE on impact = PE = mgh</p> <p>$= 5 \times 9.8 \times 20$</p> <p>$\therefore \text{KE} = 980 \text{ J}$</p> <p>$\text{KE} = \frac{1}{2} \times m \times v^2$</p> <p>$v^2 = \frac{980}{0.5 \times 5}$</p> <p>$v = \sqrt{392}$</p> <p>$= 19.80 \approx 20 \text{ m/s}$</p> <p>$\therefore$ The velocity of the scrap metal on impact with the ground is 20 m/s.</p> </td> <td> <ul style="list-style-type: none"> provides correct working to give correct KE [1 mark] provides correct formula and substituted values [1 mark] provides correct working to give correct answer to the nearest whole unit with correct unit provided [1 mark] </td> </tr> </tbody> </table>	Sample response	The response	<p>KE on impact = PE = mgh</p> <p>$= 5 \times 9.8 \times 20$</p> <p>$\therefore \text{KE} = 980 \text{ J}$</p> <p>$\text{KE} = \frac{1}{2} \times m \times v^2$</p> <p>$v^2 = \frac{980}{0.5 \times 5}$</p> <p>$v = \sqrt{392}$</p> <p>$= 19.80 \approx 20 \text{ m/s}$</p> <p>$\therefore$ The velocity of the scrap metal on impact with the ground is 20 m/s.</p>	<ul style="list-style-type: none"> provides correct working to give correct KE [1 mark] provides correct formula and substituted values [1 mark] provides correct working to give correct answer to the nearest whole unit with correct unit provided [1 mark] 	
Sample response	The response				
<p>KE on impact = PE = mgh</p> <p>$= 5 \times 9.8 \times 20$</p> <p>$\therefore \text{KE} = 980 \text{ J}$</p> <p>$\text{KE} = \frac{1}{2} \times m \times v^2$</p> <p>$v^2 = \frac{980}{0.5 \times 5}$</p> <p>$v = \sqrt{392}$</p> <p>$= 19.80 \approx 20 \text{ m/s}$</p> <p>$\therefore$ The velocity of the scrap metal on impact with the ground is 20 m/s.</p>	<ul style="list-style-type: none"> provides correct working to give correct KE [1 mark] provides correct formula and substituted values [1 mark] provides correct working to give correct answer to the nearest whole unit with correct unit provided [1 mark] 				

**2020
Paper 1
Section 3
Question 20**

**Machines in
society**

A double-threaded worm and 40-tooth worm wheel are used to drive a mechanical winch. The efficiency of the machine is 45%. The pitch of a double-threaded worm is halved.

a) Determine the mass of the load lifted by the winch using an effort of 50 N on the circumference of the worm wheel. Answer to the nearest whole unit. [5 marks]

Sample response	The response
$\begin{aligned} \text{gear ratio of double-thread worm and wheel} \\ &= \frac{\text{worm wheel teeth}}{\text{worm teeth}} \\ &= \frac{40}{2} = 20 \therefore \text{VR} = 20 \\ \\ \eta &= \frac{\text{MA}}{\text{VR}} \\ 0.45 &= \frac{\text{MA}}{20} \\ \text{MA} &= 0.45 \times 20 = 9 \\ \text{MA} &= \frac{L}{E} \\ L &= \text{MA} \times E \\ &= 9 \times 50 = 450 \text{ N} \\ F &= mg \\ m &= \frac{F}{g} = \frac{450}{9.8} = 45.92 \approx 46 \text{ kg} \end{aligned}$	<ul style="list-style-type: none"> • provides correct working to give correct gear ratio (VR) [1 mark] • provides correct formula and substituted values for mechanical advantage [1 mark] • provides correct working to give correct L [1 mark] • provides correct formula and substituted values for mass [1 mark] • provides correct working to give correct answer to the nearest whole unit with correct unit provided [1 mark]

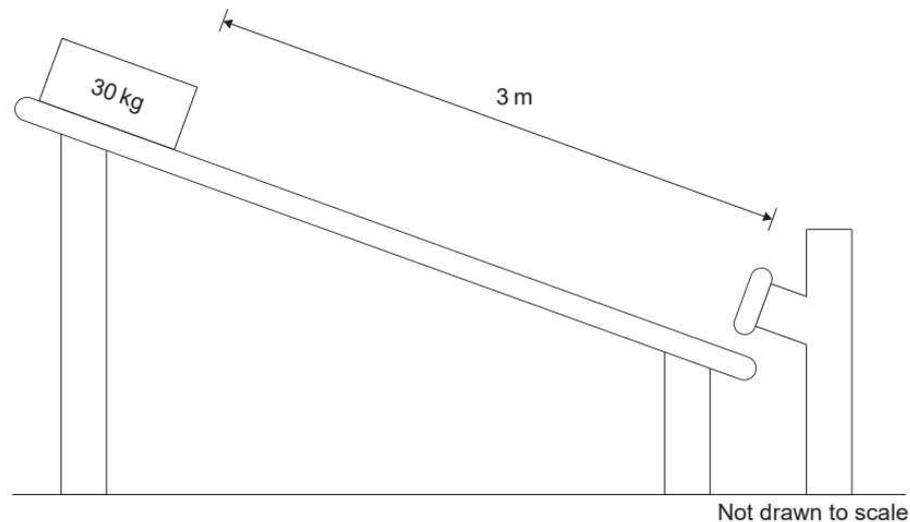
b) An effort wheel is added to the worm axle, decreasing the efficiency of the compound machine to 36%. Determine the velocity ratio of the added component. Answer to two decimal places. [4 marks]

Sample response	The response
$\begin{aligned} \eta_{\text{total}} &= \eta_1 \times \eta_2 \\ 0.36 &= 0.45 \times \eta_2 \\ \eta_2 &= \frac{0.36}{0.45} = 0.80 \\ \eta &= \frac{\text{MA}}{\text{VR}} \\ \text{VR} &= \frac{\text{MA}}{\eta} = \frac{9}{0.80} = 11.25 \end{aligned}$	<ul style="list-style-type: none"> • provides correct formula and substituted values for effort wheel efficiency [1 mark] • provides correct working to give correct effort wheel efficiency [1 mark] • provides correct formula and substituted values for velocity ratio [1 mark] • provides correct working to give correct answer to two decimal places [1 mark]

**2020
Paper 1
Section 3
Question 22**

**Machines in
society**

A bag slides for 3 seconds at a constant velocity of 1 m/s down a 20° luggage chute until it impacts with a cushioning device as shown in the diagram. If the cushioning device is removed, the surface of the chute will need to be modified to slow the bag to a stop at the base of the chute.



Determine the difference between the coefficients of friction for the modified chute and the original with the cushioning device. Answer to two decimal places. [9 marks]

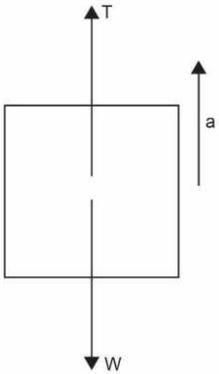
Sample response	The response
<p>Constant velocity</p> $F_f = mg \sin \theta$ $= 30 \times 9.8 \times \sin 20 = 100.55 \text{ N}$ $F_N = mg \cos \theta$ $= 30 \times 9.8 \times \cos 20 = 276.27 \text{ N}$ $F_f = u_k F_N$ $u_k = \frac{F_f}{F_N}$ $= \frac{100.55}{276.27} = 0.36$ <p>∴ coefficient of kinetic friction for chute with cushion is 0.36.</p> $v^2 = u^2 + 2as$ $a = \frac{v^2 - u^2}{2s}$ $= \frac{0 - 1}{2 \times 3} = -0.17 \text{ m/s}^2$ $-a = 0.17 \text{ m/s}^2$ $F_{\text{dec}} = ma = 30 \times 0.17 = 5.10 \text{ N}$ $F_f \text{ required} = 5.10 + mg \sin 20$ $= 5.10 + 100.55 = 105.65 \text{ N}$ $F_f = u_k F_N$ $u_k = \frac{F_f}{F_N}$ $= \frac{105.65}{276.27} = 0.38$ <p>∴ coefficient of kinetic friction for the modified chute is 0.38.</p> <p>∴ the difference in kinetic friction between the cushioned and modified surface chute is $0.38 - 0.36 = 0.02$.</p>	<ul style="list-style-type: none"> • provides correct working to give correct force of friction [1 mark] • provides correct working to give correct normal force [1 mark] • provides correct working to give correct coefficient of kinetic friction [1 mark] • provides correct formula and substituted values [1 mark] • provides correct working to give correct deceleration [1 mark] • provides correct working to give correct force of deceleration [1 mark] • provides correct working to give correct force of friction required for deceleration [1 mark] • provides correct working to give correct coefficient of kinetic friction required for bag deceleration [1 mark] • provides correct working to give a correct answer to two decimal places [1 mark]

**2020
Paper 1
Section 3
Question 23**

**Machines in
society**

An elevator starts from rest and accelerates upwards at a constant rate until the desired velocity of 10 m/s is achieved. The mass of the elevator and occupants is 2500 kg. The tension on the elevator cable is 30 000 N.

Determine the distance the elevator travels during acceleration to the nearest whole unit (m). Include a force diagram with your working. [6 marks]

Sample response	The response
<div style="text-align: center;">  </div> $ \begin{aligned} ma &= T - W \\ &= 30\,000 - (2500 \times 9.8) \\ &= 5500 \text{ N} \\ a &= \frac{5500}{2500} = 2.20 \text{ m/s}^2 \\ v &= u + at \\ 10 &= 0 + (2.20 \times t) \\ t &= \frac{10}{2.20} = 4.55 \text{ s} \\ s &= ut + \frac{1}{2}at^2 \\ &= (0 \times 4.55) + \frac{1}{2}(2.2 \times 4.55^2) \\ &= 22.77 \text{ m} \\ \therefore &\text{ the elevator travels 23 m during acceleration} \end{aligned} $	<ul style="list-style-type: none"> • provides an appropriate force diagram [1 mark] • provides correct working to give correct force required for acceleration [1 mark] • provides correct working to give correct acceleration [1 mark] • provides correct working to give correct time to complete acceleration [1 mark] • provides correct formula and substituted values [1 mark] • provides correct working to give correct answer to the nearest whole unit (m) with correct unit provided [1 mark]

Unit 4 – Topic 2: Materials

Paper 1 Section 1

<p>2023 Paper 1 Section 1 Question 1</p> <p>Materials</p>	<p>A plastic beaker used to hold liquids in a laboratory is commonly manufactured using</p> <p>(A) polyethylene. (B) polypropylene. (C) polylactic acid. (D) polyvinyl chloride.</p>
<p>2023 Paper 1 Section 1 Question 9</p> <p>Materials</p>	<p>Steel containing 0.11% carbon is</p> <p>(A) low carbon steel. (B) mild carbon steel. (C) medium carbon steel. (D) high carbon steel.</p>
<p>2022 Paper 1 Section 1 Question 2</p> <p>Materials</p>	<p>Waste water drainage pipe is commonly manufactured using</p> <p>(A) nylon. (B) polypropylene. (C) polylactic acid. (D) polyvinyl chloride.</p>
<p>2022 Paper 1 Section 1 Question 6</p> <p>Materials</p>	<p>A section of an iron–carbon phase diagram is shown.</p> <div style="text-align: center;"> </div> <p>The microstructure of the phase represented by X is solid</p> <p>(A) cementite. (B) austenite. (C) pearlite. (D) ferrite.</p>
<p>2022 Paper 1 Section 1 Question 8</p> <p>Materials</p>	<p>High carbon steel is used in the manufacture of</p> <p>(A) boiler plates. (B) railway tracks. (C) punching tools. (D) engine crankshafts.</p>

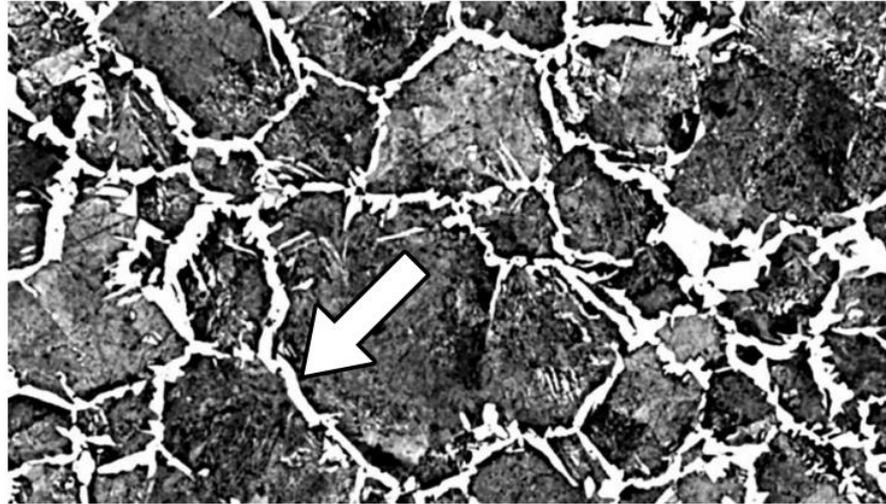
<p>2021 Paper 1 Section 1 Question 1</p> <p>Materials</p>	<p>Conventional automotive torsion bars are manufactured using steel with a carbon content of 0.3% to 0.5%, which is</p> <p>(A) low-carbon steel. (B) high-carbon steel. (C) mild-carbon steel. (D) medium-carbon steel.</p>
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<p>2021 Paper 1 Section 1 Question 8</p> <p>Materials</p>	<p>In the lead–tin thermal equilibrium phase diagram, a liquidus line is represented by the letter</p> <p>(A) E. (B) F. (C) G. (D) H.</p>
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<p>2021 Paper 1 Section 1 Question 3</p> <p>Materials</p>	<p>The stiffness of a material can be identified using which area of the stress–strain diagram?</p> <p>(A) J (B) K (C) L (D) M</p>
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2021
Paper 1
Section 1
Question 10

Materials

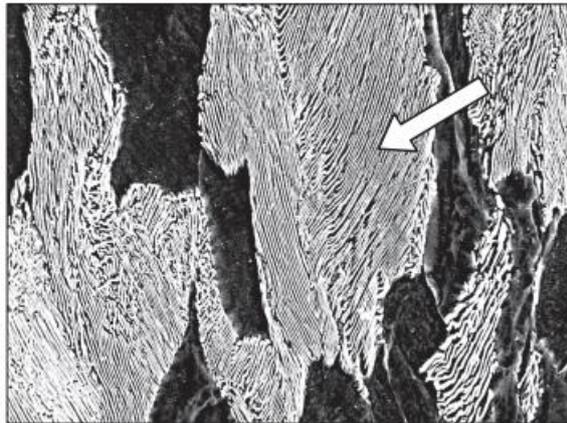


What is the hypereutectoid formation indicated by the arrow in the carbon steel microstructure?

- (A) cementite
- (B) austenite
- (C) pearlite
- (D) ferrite

2020
Paper 1
Section 1
Question 3

Materials



What is the hypo-eutectoid formation indicated by the arrow in this carbon steel microstructure?

- (A) ferrite
- (B) pearlite
- (C) austenite
- (D) cementite

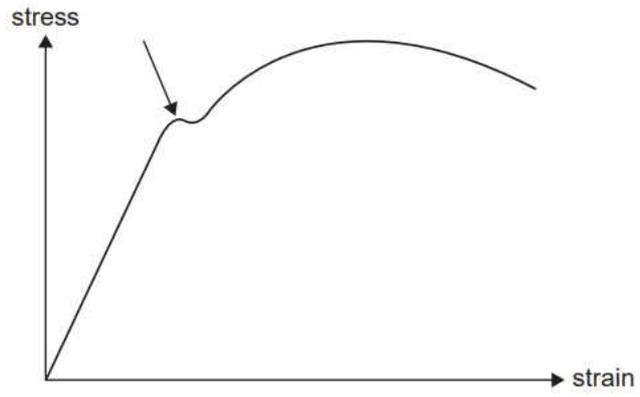
2020
Paper 1
Section 1
Question 4

Materials

High-voltage transmission cable insulation would most likely be manufactured from

- (A) polyvinyl chloride.
- (B) polypropylene.
- (C) polyethylene.
- (D) polystyrene.

**2020
Paper 1
Section 1
Question 10
Materials**



The key feature indicated by the arrow in this mild steel stress–strain diagram is

- (A) ultimate tensile stress.
- (B) Young's modulus.
- (C) plastic limit.
- (D) yield stress.

Paper 1 Section 2

2023 Paper 1 Section 2 Question 11 Materials	State four contemporary engineering applications for acrylonitrile butadiene styrene (ABS). (4 marks)
	1. _____
	2. _____
	3. _____
	4. _____

2023 Paper 1 Section 2 Question 14 Materials	Explain how a mechanical engineer might use the problem-solving process to develop a solution for automotive components in a production line to be automatically pressed and moved. Support your response with two areas of engineering expertise the engineer could draw on. (5 marks)

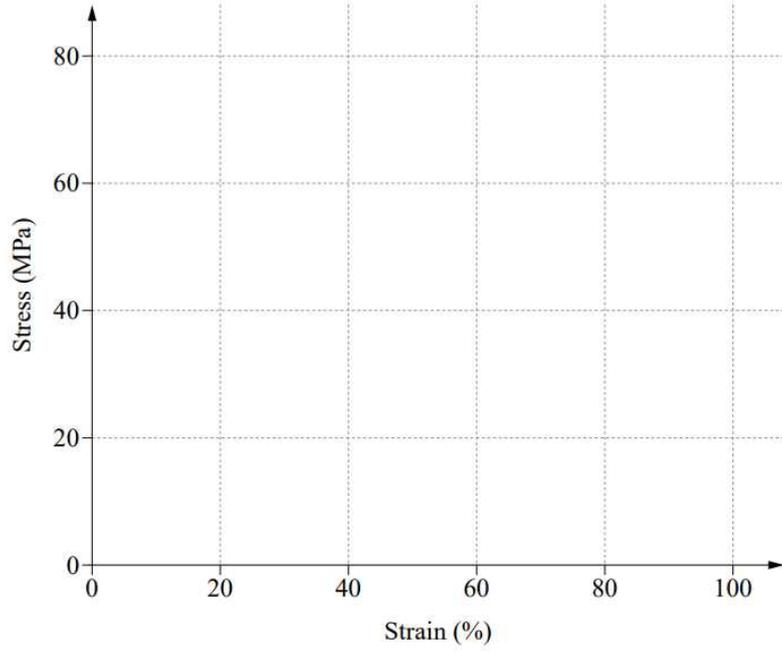
2022 Paper 1 Section 2 Question 12 Materials	State four industrial applications for carbon steel with 0.15% to 0.30% carbon content. [4 marks]
	1. _____
	2. _____
	3. _____
	4. _____

2022 Paper 1 Section 2 Question 14 Materials	
	Use the information included in the lead-tin thermal-equilibrium phase diagram to identify each key feature. [6 marks]
	I) solidus line
	II) liquidus line
	III) eutectic point
	IV) eutectic temperature
	V) maximum solubility of lead in tin
VI) maximum solubility of tin in lead	

**2021
Paper 1
Section 2
Question 11**

Materials

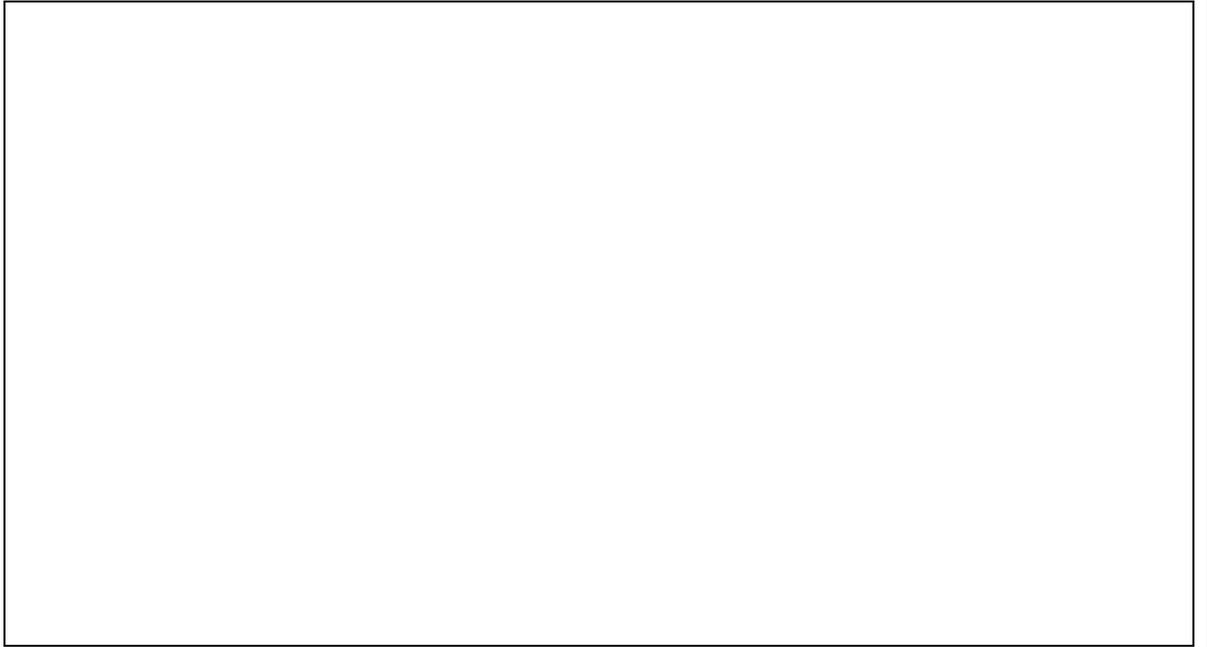
Sketch the stress–strain curve for nylon on the graph. Clearly label the features that indicate the material’s ability to absorb and store energy and to withstand elastic deformation within the material’s proportional limit. [4 marks]



2021
Paper 1
Section 2
Question 14

Materials

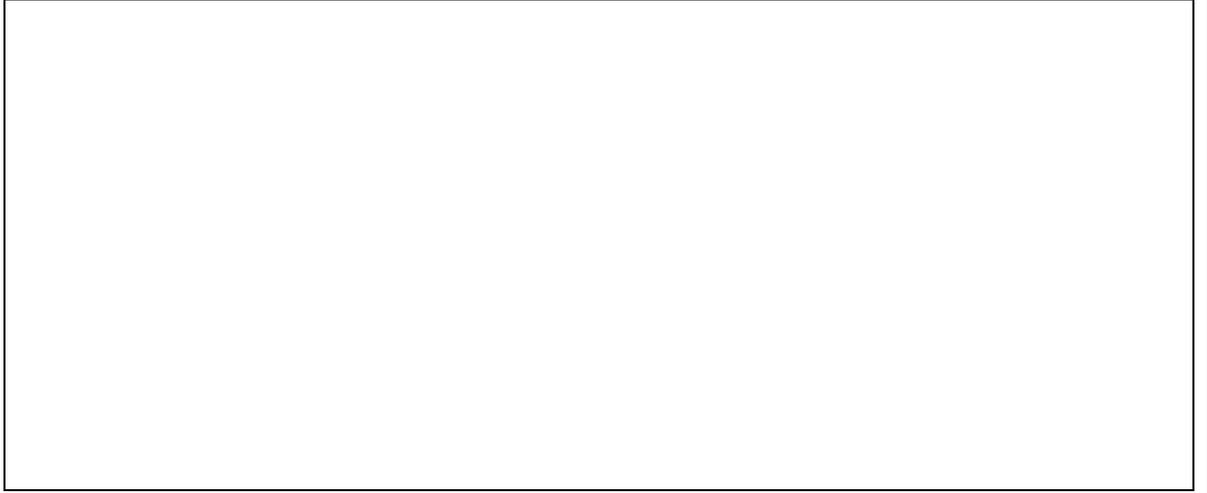
Explain how the tensile test for a low-carbon steel material can be used to determine the ductility of the material. Sketch and annotate a stress–strain diagram to support your explanation. [6 marks]



2020
Paper 1
Section 2
Question 11

Materials

Explain what is meant by the proportional limit of a material as indicated on a stress–strain diagram.
Provide an annotated sketch to support your explanation. [4 marks]



Marking Guide – Paper 1 Section 1

<p>2023 Paper 1 Section 1 Question 1 Materials</p>	<p>A plastic beaker used to hold liquids in a laboratory is commonly manufactured using</p> <p>(A) polyethylene. (B) polypropylene. – Answer (C) polylactic acid. (D) polyvinyl chloride.</p>
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<p>2023 Paper 1 Section 1 Question 9 Materials</p>	<p>Steel containing 0.11% carbon is</p> <p>(A) low carbon steel. – Answer (B) mild carbon steel. (C) medium carbon steel. (D) high carbon steel.</p>
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<p>2022 Paper 1 Section 1 Question 2 Materials</p>	<p>Waste water drainage pipe is commonly manufactured using</p> <p>(A) nylon. (B) polypropylene. (C) polylactic acid. (D) polyvinyl chloride. – Answer</p>
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<p>2022 Paper 1 Section 1 Question 6 Materials</p>	<p>A section of an iron–carbon phase diagram is shown.’</p> <p>The microstructure of the phase represented by X is solid</p> <p>(A) cementite. (B) austenite. – Answer (C) pearlite. (D) ferrite.</p>
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<p>2022 Paper 1 Section 1 Question 8 Materials</p>	<p>High carbon steel is used in the manufacture of</p> <p>(A) boiler plates. (B) railway tracks. (C) punching tools. – Answer (D) engine crankshafts.</p>
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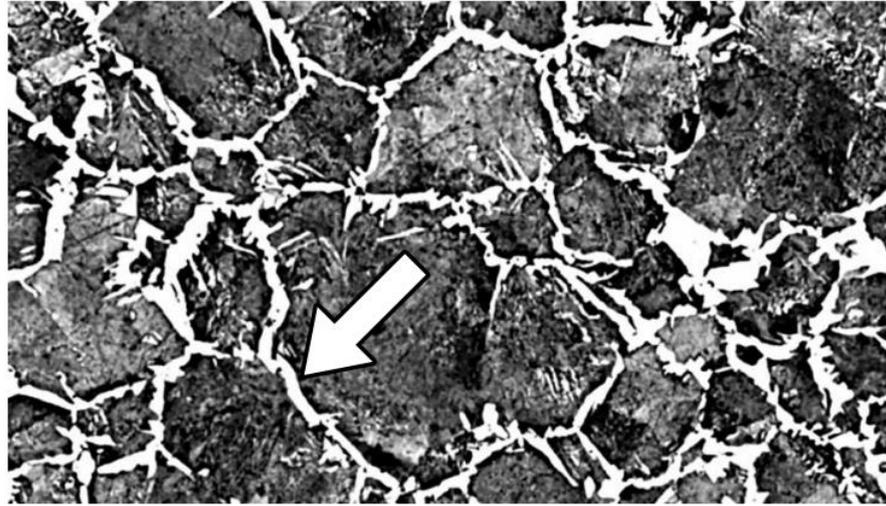
<p>2021 Paper 1 Section 1 Question 1</p> <p>Materials</p>	<p>Conventional automotive torsion bars are manufactured using steel with a carbon content of 0.3% to 0.5%, which is</p> <p>(A) low-carbon steel. (B) high-carbon steel. (C) mild-carbon steel. (D) medium-carbon steel. – Answer</p>
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<p>2021 Paper 1 Section 1 Question 8</p> <p>Materials</p>	<p>In the lead–tin thermal equilibrium phase diagram, a liquidus line is represented by the letter</p> <p>(A) E. (B) F. (C) G. (D) H. – Answer</p>
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<p>2021 Paper 1 Section 1 Question 3</p> <p>Materials</p>	<p>The stiffness of a material can be identified using which area of the stress–strain diagram?</p> <p>(A) J – Answer (B) K (C) L (D) M</p>
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2021
Paper 1
Section 1
Question 10

Materials

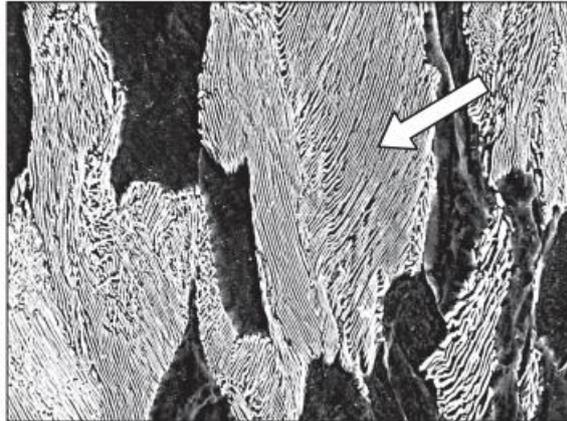


What is the hypereutectoid formation indicated by the arrow in the carbon steel microstructure?

- (A) **cementite – Answer**
- (B) austenite
- (C) pearlite
- (D) ferrite

2020
Paper 1
Section 1
Question 3

Materials



What is the hypo-eutectoid formation indicated by the arrow in this carbon steel microstructure?

- (A) ferrite
- (B) **pearlite – Answer**
- (C) austenite
- (D) cementite

2020
Paper 1
Section 1
Question 4

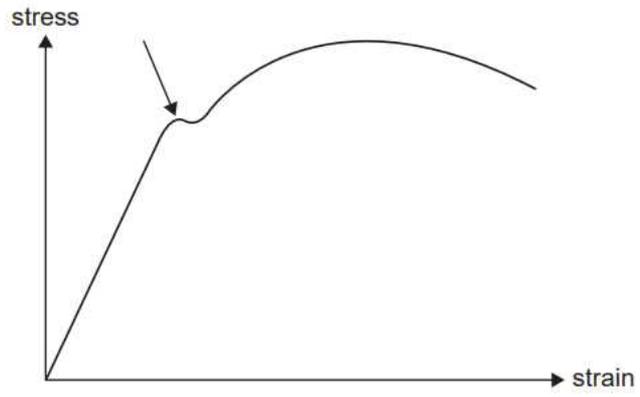
Materials

High-voltage transmission cable insulation would most likely be manufactured from

- (A) polyvinyl chloride.
- (B) polypropylene.
- (C) **polyethylene. – Answer**
- (D) polystyrene.

2020
Paper 1
Section 1
Question 10

Materials



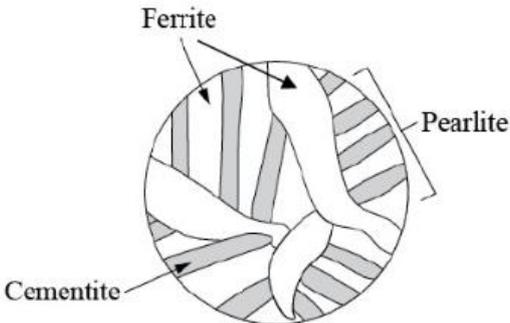
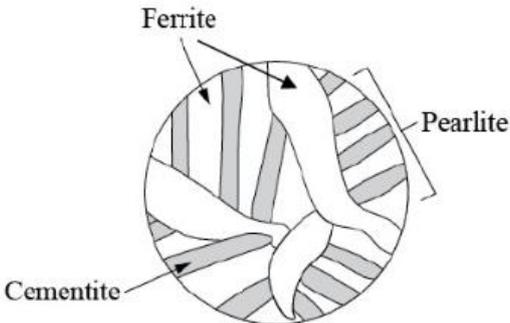
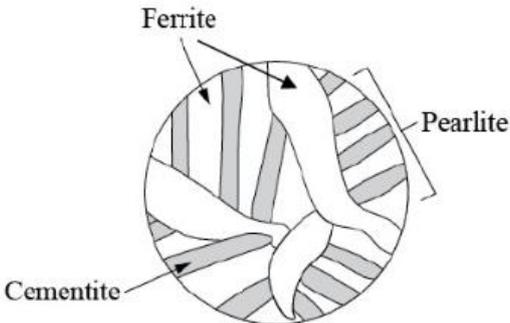
The key feature indicated by the arrow in this mild steel stress–strain diagram is

- (A) ultimate tensile stress.
- (B) Young's modulus.
- (C) plastic limit.
- (D) yield stress. – Answer**

Marking Guide – Paper 1 Section 2

<p>2023 Paper 1 Section 2 Question 11</p> <p>Materials</p>	State four contemporary engineering applications for acrylonitrile butadiene styrene (ABS). (4 marks)	
	<p style="text-align: center;">Sample response</p> <p>1. automobile bumper bar 2. electrical wall socket 3. face shield 4. hard hat</p>	<p style="text-align: center;">The response</p> <ul style="list-style-type: none"> • provides a contemporary engineering application [1 mark] • provides a second contemporary engineering application [1 mark] • provides a third contemporary engineering application [1 mark] • provides a fourth contemporary engineering application [1 mark]

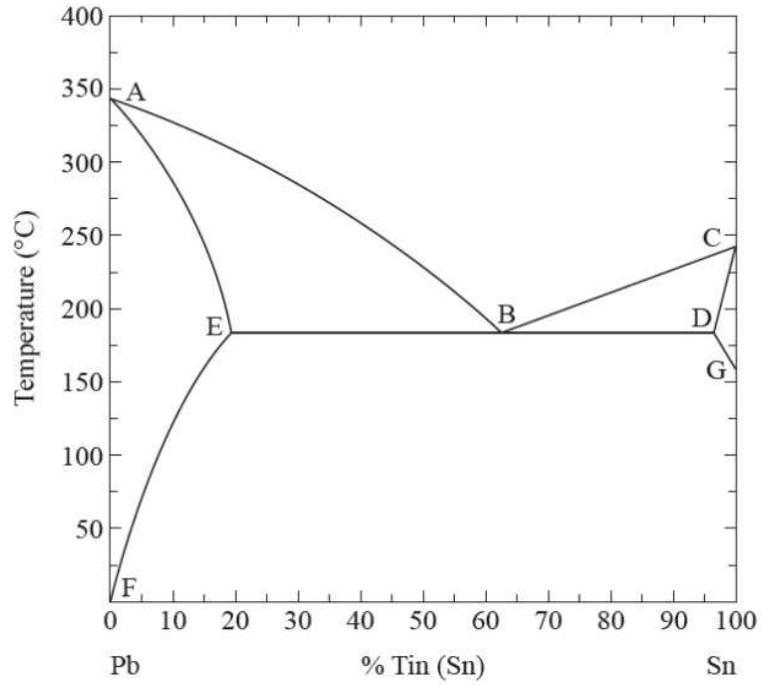
<p>2023 Paper 1 Section 2 Question 14</p> <p>Materials</p>	Explain how a mechanical engineer might use the problem-solving process to develop a solution for automotive components in a production line to be automatically pressed and moved. Support your response with two areas of engineering expertise the engineer could draw on. (5 marks)	
	<p style="text-align: center;">Sample response</p> <p>A mechanical engineer might explore similar problems involving machines that automatically press and move components from one location to another in the automotive manufacturing industry. They would determine solution success criteria to develop, test and evaluate ideas and a prototype, using knowledge of how metal is plastically deformed into components, and how movement sensors control the function of automated stamping machines. A solution to the problem would then be manufactured and refined after evaluation of its function using success criteria.</p>	<p style="text-align: center;">The response</p> <ul style="list-style-type: none"> • appropriately explains how a mechanical engineer might use the problem-solving process, using wording that indicates <ul style="list-style-type: none"> – phases of the problem-solving process in engineering <ul style="list-style-type: none"> ▪ explore [1 mark] ▪ develop or generate [1 mark] ▪ evaluate or refine [1 mark] – one area of engineering expertise [1 mark] – another area of engineering expertise [1 mark]

2023 Paper 1 Section 2 Question 15 Materials	a) Provide an annotated sketch of the microstructures of medium carbon steel at room temperature. [4 marks]								
	<table border="1"> <thead> <tr> <th>Sample response</th> <th>The response</th> </tr> </thead> <tbody> <tr> <td>  </td> <td> <ul style="list-style-type: none"> • provides an appropriate sketch of the microstructures that <ul style="list-style-type: none"> – clearly distinguishes between ferrite and pearlite [1 mark] – identifies ferrite [1 mark] – clearly distinguishes lamellar structure of pearlite [1 mark] – identifies pearlite [1 mark] </td> </tr> </tbody> </table>	Sample response	The response		<ul style="list-style-type: none"> • provides an appropriate sketch of the microstructures that <ul style="list-style-type: none"> – clearly distinguishes between ferrite and pearlite [1 mark] – identifies ferrite [1 mark] – clearly distinguishes lamellar structure of pearlite [1 mark] – identifies pearlite [1 mark] 	<table border="1"> <thead> <tr> <th>Sample response</th> <th>The response</th> </tr> </thead> <tbody> <tr> <td> <p>The microstructures of medium carbon steel include grains of ferrite together with areas of very strong pearlite. The pearlite is a lamellar structure of soft, ductile ferrite and hard, brittle cementite. The amount of pearlite in the composition provides medium carbon steel with high strength and good toughness, which can withstand the heavy loads and repeated impact stresses that occur when trains are running on rails.</p> </td> <td> <ul style="list-style-type: none"> • appropriately explains medium carbon steel's usefulness as a material for train rails, referring to <ul style="list-style-type: none"> – the microstructures of medium carbon steel including lamellar or layered <ul style="list-style-type: none"> ▪ soft, ductile ferrite [1 mark] ▪ hard, brittle cementite [1 mark] – an appropriate mechanical property of medium carbon steel linked to use [1 mark] – a second appropriate mechanical property of medium carbon steel linked to use [1 mark] </td> </tr> </tbody> </table>	Sample response	The response	<p>The microstructures of medium carbon steel include grains of ferrite together with areas of very strong pearlite. The pearlite is a lamellar structure of soft, ductile ferrite and hard, brittle cementite. The amount of pearlite in the composition provides medium carbon steel with high strength and good toughness, which can withstand the heavy loads and repeated impact stresses that occur when trains are running on rails.</p>
Sample response	The response								
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Sample response	The response								
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b) Explain how the microstructures of medium carbon steel demonstrate two mechanical properties that make it a suitable material for train rails. [4 marks]									

2022 Paper 1 Section 2 Question 12 Materials	State four industrial applications for carbon steel with 0.15% to 0.30% carbon content. [4 marks]				
	<table border="1"> <thead> <tr> <th>Sample response</th> <th>The response</th> </tr> </thead> <tbody> <tr> <td> 1. Structural plates 2. Stampings 3. Forgings 4. Seamless tubes </td> <td> <ul style="list-style-type: none"> • provides a correct industrial application [1 mark] • provides a second correct industrial application [1 mark] • provides a third correct industrial application [1 mark] • provides a fourth correct industrial application [1 mark] </td> </tr> </tbody> </table>	Sample response	The response	1. Structural plates 2. Stampings 3. Forgings 4. Seamless tubes	<ul style="list-style-type: none"> • provides a correct industrial application [1 mark] • provides a second correct industrial application [1 mark] • provides a third correct industrial application [1 mark] • provides a fourth correct industrial application [1 mark]
Sample response	The response				
1. Structural plates 2. Stampings 3. Forgings 4. Seamless tubes	<ul style="list-style-type: none"> • provides a correct industrial application [1 mark] • provides a second correct industrial application [1 mark] • provides a third correct industrial application [1 mark] • provides a fourth correct industrial application [1 mark] 				

2022
Paper 1
Section 2
Question 14

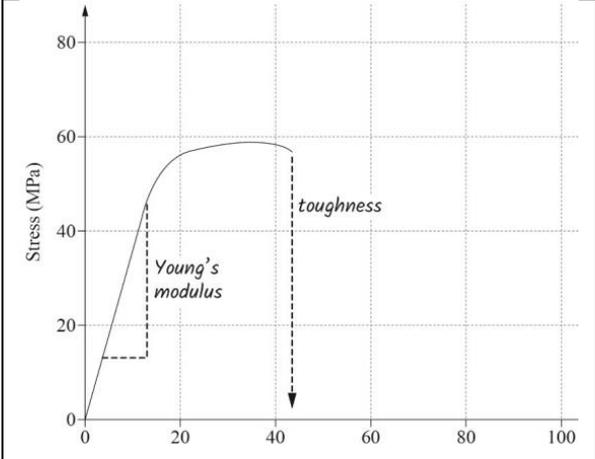
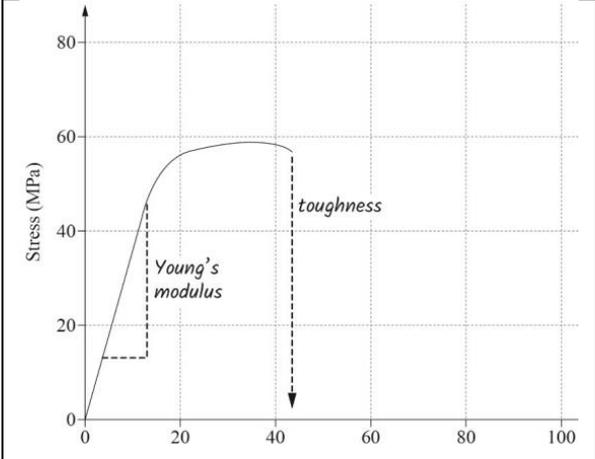
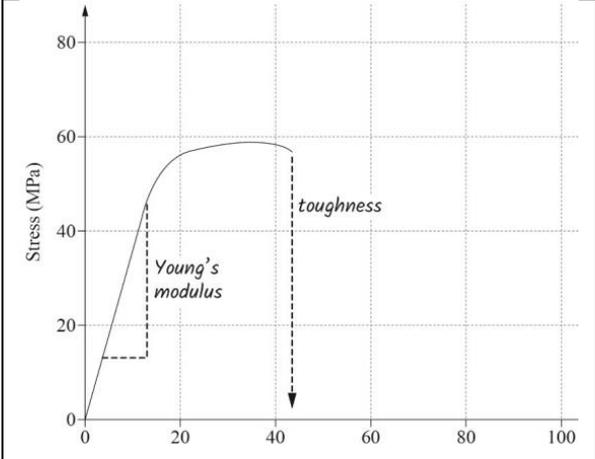
Materials



Use the information included in the lead-tin thermal-equilibrium phase diagram to identify each key feature. [6 marks]

Sample response	The response
I. solidus line: AEDC II. liquidus line: ABC III. eutectic point: B IV. eutectic temperature: 183° C V. maximum solubility of lead in tin: D VI. maximum solubility of tin in lead: E	<ul style="list-style-type: none"> • correctly identifies the - solidus line [1 mark] - liquidus line [1 mark] - eutectic point [1 mark] - eutectic temperature [1 mark] - maximum solubility of lead in tin [1 mark] - maximum solubility of tin in lead [1 mark]

<p>2022 Paper 1 Section 2 Question 15</p> <p>Materials</p>	<p>Contrast the suitability of mild and high carbon steel for applications in the manufacture of automotive subframes that experience repeated loads and high impacts, using their microstructure and three relevant mechanical properties. [6 marks]</p> <table border="1"> <thead> <tr> <th data-bbox="292 221 887 255">Sample response</th> <th data-bbox="887 221 1481 255">The response</th> </tr> </thead> <tbody> <tr> <td data-bbox="292 255 887 1169"> <p>The composition of mild carbon steel includes a higher amount of ferrite, providing ductility. The lower amount of pearlite in the composition still provides a high yield strength.</p> <p>High carbon steel includes a high amount of cementite compared to ferrite (in pearlite), contributing to a higher yield strength than mild carbon steel. The amount of cementite in the composition provides a less ductile material than mild carbon steel.</p> <p>Automotive subframes are subject to repeated stresses due to a range of loads caused by different road surfaces, conditions, loading and collision impacts.</p> <p>The very high yield strength and the lower ductility of high carbon steel produces lower toughness, which makes the material susceptible to fatigue cracking and less able to absorb the energy of repeated loading and collision impacts. The relatively high yield strength and good ductility of mild carbon steel provides high toughness that allows the frame to absorb the repeated loads and impacts.</p> <p>Therefore, mild carbon steel is more suitable than high carbon steel for use in the manufacture of automotive subframes.</p> </td> <td data-bbox="887 255 1481 1169"> <ul style="list-style-type: none"> • appropriately contrasts mild and high carbon steel and includes wording that indicates <ul style="list-style-type: none"> - the microstructure of mild carbon steel is <ul style="list-style-type: none"> ▫ higher in ferrite than high carbon steel [1 mark] ▫ lower in pearlite than high carbon steel [1 mark] - high carbon steel has a higher yield strength than mild carbon steel [1 mark] - high carbon steel is less ductile than mild carbon steel [1 mark] - mild carbon steel has better toughness than high carbon steel [1 mark] - mild carbon steel is a better material for automotive subframes, because of its higher toughness and ability to resist or absorb the repeated loads and impacts [1 mark] </td> </tr> </tbody> </table>	Sample response	The response	<p>The composition of mild carbon steel includes a higher amount of ferrite, providing ductility. The lower amount of pearlite in the composition still provides a high yield strength.</p> <p>High carbon steel includes a high amount of cementite compared to ferrite (in pearlite), contributing to a higher yield strength than mild carbon steel. The amount of cementite in the composition provides a less ductile material than mild carbon steel.</p> <p>Automotive subframes are subject to repeated stresses due to a range of loads caused by different road surfaces, conditions, loading and collision impacts.</p> <p>The very high yield strength and the lower ductility of high carbon steel produces lower toughness, which makes the material susceptible to fatigue cracking and less able to absorb the energy of repeated loading and collision impacts. The relatively high yield strength and good ductility of mild carbon steel provides high toughness that allows the frame to absorb the repeated loads and impacts.</p> <p>Therefore, mild carbon steel is more suitable than high carbon steel for use in the manufacture of automotive subframes.</p>	<ul style="list-style-type: none"> • appropriately contrasts mild and high carbon steel and includes wording that indicates <ul style="list-style-type: none"> - the microstructure of mild carbon steel is <ul style="list-style-type: none"> ▫ higher in ferrite than high carbon steel [1 mark] ▫ lower in pearlite than high carbon steel [1 mark] - high carbon steel has a higher yield strength than mild carbon steel [1 mark] - high carbon steel is less ductile than mild carbon steel [1 mark] - mild carbon steel has better toughness than high carbon steel [1 mark] - mild carbon steel is a better material for automotive subframes, because of its higher toughness and ability to resist or absorb the repeated loads and impacts [1 mark]
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<p>2021 Paper 1 Section 2 Question 11</p> <p>Materials</p>	<p>Sketch the stress–strain curve for nylon on the graph. Clearly label the features that indicate the material’s ability to absorb and store energy and to withstand elastic deformation within the material’s proportional limit. [4 marks]</p> <table border="1"> <thead> <tr> <th data-bbox="292 1361 887 1395">Sample response</th> <th data-bbox="887 1361 1481 1395">The response</th> </tr> </thead> <tbody> <tr> <td data-bbox="292 1395 887 1854">  </td> <td data-bbox="887 1395 1481 1854"> <ul style="list-style-type: none"> • sketches an appropriate stress–strain curve for nylon, including <ul style="list-style-type: none"> - a straight line proportion with strain less than 20% [1 mark] - a rupture point with less than 80% strain [1 mark] • accurately identifies toughness on the curve [1 mark] • accurately identifies Young’s modulus on the curve [1 mark] </td> </tr> </tbody> </table>	Sample response	The response		<ul style="list-style-type: none"> • sketches an appropriate stress–strain curve for nylon, including <ul style="list-style-type: none"> - a straight line proportion with strain less than 20% [1 mark] - a rupture point with less than 80% strain [1 mark] • accurately identifies toughness on the curve [1 mark] • accurately identifies Young’s modulus on the curve [1 mark]
Sample response	The response				
	<ul style="list-style-type: none"> • sketches an appropriate stress–strain curve for nylon, including <ul style="list-style-type: none"> - a straight line proportion with strain less than 20% [1 mark] - a rupture point with less than 80% strain [1 mark] • accurately identifies toughness on the curve [1 mark] • accurately identifies Young’s modulus on the curve [1 mark] 				

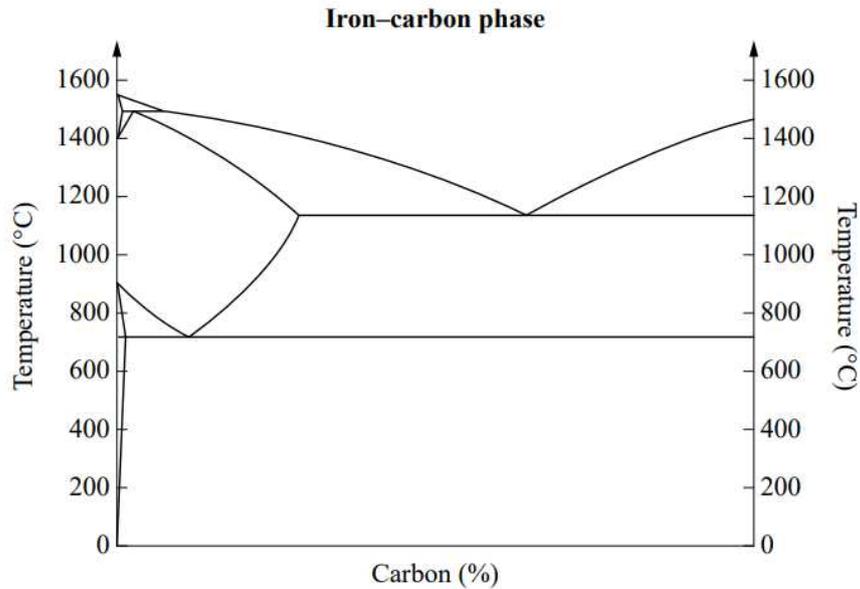
2021 Paper 1 Section 2 Question 14 Materials	Explain how the tensile test for a low-carbon steel material can be used to determine the ductility of the material. Sketch and annotate a stress–strain diagram to support your explanation. [6 marks]	
	Sample response	The response
	<p>The stress–strain graph generated as a result of the tensile test displays the material’s ability to withstand continued strain after yield, which is indicative of the material’s ductility. This occurs within the area of the graph that shows plastic deformation of the material up to fracture.</p>	<ul style="list-style-type: none"> • explains appropriately using wording that indicates <ul style="list-style-type: none"> - withstanding strain after yield point or UTS [1 mark] - plastic deformation [1 mark] - fracture [1 mark] • provides an appropriately annotated stress–strain diagram that accurately shows <ul style="list-style-type: none"> - the plastic region [1 mark] - the upper yield point [1 mark] - the point of fracture [1 mark]

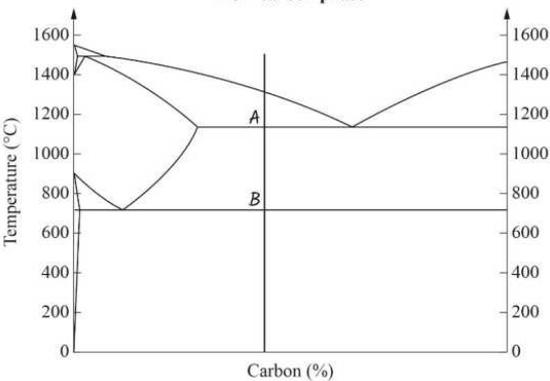
2021 Paper 1 Section 2 Question 12 Materials	State four fields of knowledge used by a biomedical engineer to perform their role. [4 marks]	
	Sample response	The response
	<ol style="list-style-type: none"> 1. Electronics 2. Electrical 3. Mechanical 4. Materials 	<ul style="list-style-type: none"> • provides a correct knowledge type [1 mark] • provides a second correct knowledge type [1 mark] • provides a third correct knowledge type [1 mark] • provides a fourth correct knowledge type [1 mark]

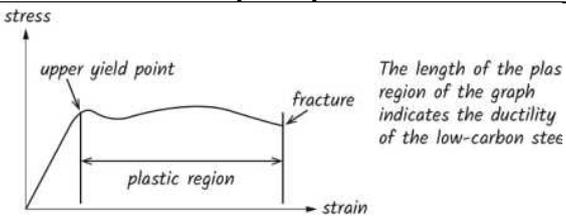
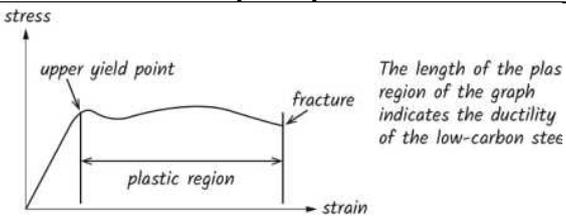
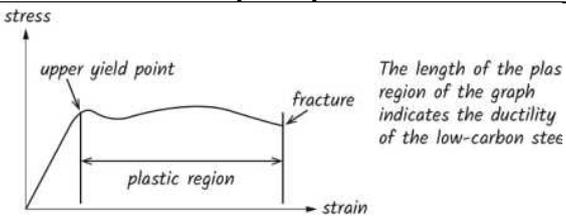
**2021
Paper 1
Section 2
Question 13**

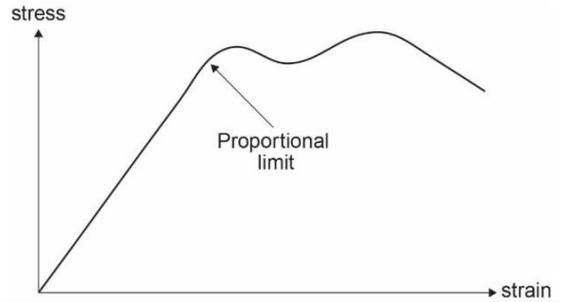
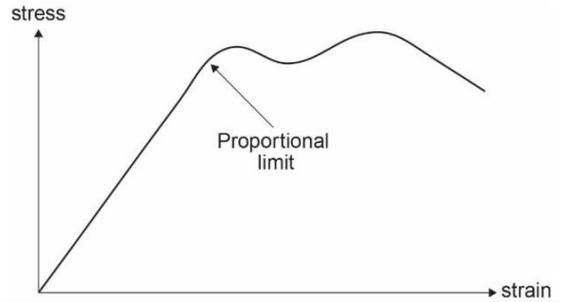
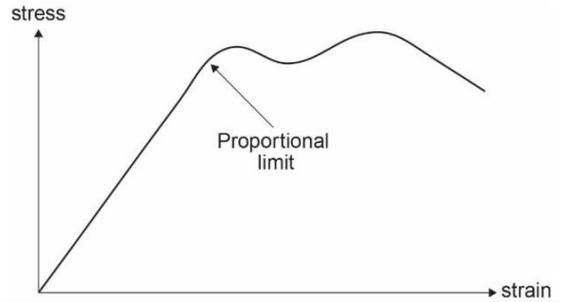
Materials

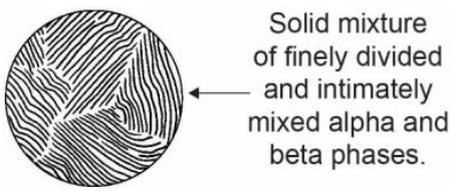
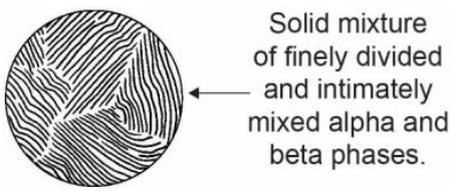
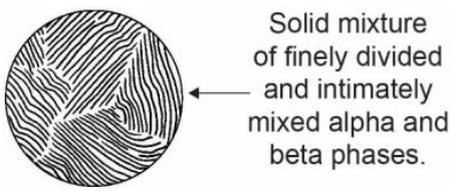
Explain how the microstructure of a 3% carbon cast iron changes during cooling between the eutectic and eutectoid temperatures. Annotate the diagram to identify the material's approximate location and the eutectic and eutectoid temperatures to support your explanation. [5 marks]



Sample response	The response
<p style="text-align: center;">Iron-carbon phase</p>  <p>When the eutectic temperature of approximately 1147° C is reached at point A, the residual liquid forms the eutectic mixture of austenite and cementite along with the previously formed austenite dendrites. As the temperature drops towards point B, carbon precipitates out of the austenite to be deposited as growing areas of eutectic cementite. When the eutectoid temperature of approximately 723°C is reached at point B, the remaining austenite with 0.8% carbon changes to pearlite.</p>	<ul style="list-style-type: none"> explains appropriately using wording indicative of <ul style="list-style-type: none"> upper eutectic residual liquid forms a mixture of austenite and cementite [1 mark] carbon precipitates out of the austenite to form eutectic cementite [1 mark] pearlite forms at the eutectoid [1 mark] provides an appropriately annotated sketch indicating <ul style="list-style-type: none"> an approximately correct location for 3% carbon [1 mark] the eutectic and eutectoid temperatures (A and B locations) [1 mark]

2021 Paper 1 Section 2 Question 14 Materials	Explain how the tensile test for a low-carbon steel material can be used to determine the ductility of the material. Sketch and annotate a stress–strain diagram to support your explanation. [6 marks]				
	<table border="1"> <thead> <tr> <th>Sample response</th> <th>The response</th> </tr> </thead> <tbody> <tr> <td>  <p>The stress–strain graph generated as a result of the tensile test displays the material’s ability to withstand continued strain after yield, which is indicative of the material’s ductility. This occurs within the area of the graph that shows plastic deformation of the material up to fracture.</p> </td> <td> <ul style="list-style-type: none"> explains appropriately using wording that indicates <ul style="list-style-type: none"> withstanding strain after yield point or UTS [1 mark] plastic deformation [1 mark] fracture [1 mark] provides an appropriately annotated stress–strain diagram that accurately shows <ul style="list-style-type: none"> the plastic region [1 mark] the upper yield point [1 mark] the point of fracture [1 mark] </td> </tr> </tbody> </table>	Sample response	The response	 <p>The stress–strain graph generated as a result of the tensile test displays the material’s ability to withstand continued strain after yield, which is indicative of the material’s ductility. This occurs within the area of the graph that shows plastic deformation of the material up to fracture.</p>	<ul style="list-style-type: none"> explains appropriately using wording that indicates <ul style="list-style-type: none"> withstanding strain after yield point or UTS [1 mark] plastic deformation [1 mark] fracture [1 mark] provides an appropriately annotated stress–strain diagram that accurately shows <ul style="list-style-type: none"> the plastic region [1 mark] the upper yield point [1 mark] the point of fracture [1 mark]
Sample response	The response				
 <p>The stress–strain graph generated as a result of the tensile test displays the material’s ability to withstand continued strain after yield, which is indicative of the material’s ductility. This occurs within the area of the graph that shows plastic deformation of the material up to fracture.</p>	<ul style="list-style-type: none"> explains appropriately using wording that indicates <ul style="list-style-type: none"> withstanding strain after yield point or UTS [1 mark] plastic deformation [1 mark] fracture [1 mark] provides an appropriately annotated stress–strain diagram that accurately shows <ul style="list-style-type: none"> the plastic region [1 mark] the upper yield point [1 mark] the point of fracture [1 mark] 				

2020 Paper 1 Section 2 Question 11 Materials	Explain what is meant by the proportional limit of a material as indicated on a stress–strain diagram. Provide an annotated sketch to support your explanation. [4 marks]				
	<table border="1"> <thead> <tr> <th>Sample response</th> <th>The response</th> </tr> </thead> <tbody> <tr> <td> <p>The proportional limit is the greatest stress that a material can withstand without losing straight-line proportionality between stress and strain within the material’s elastic limit.</p>  </td> <td> <ul style="list-style-type: none"> explains correctly using wording indicative of <ul style="list-style-type: none"> greatest stress [1 mark] straight-line proportionality [1 mark] within the elastic limit of the material [1 mark] provides an appropriately annotated stress–strain diagram sketch [1 mark] </td> </tr> </tbody> </table>	Sample response	The response	<p>The proportional limit is the greatest stress that a material can withstand without losing straight-line proportionality between stress and strain within the material’s elastic limit.</p> 	<ul style="list-style-type: none"> explains correctly using wording indicative of <ul style="list-style-type: none"> greatest stress [1 mark] straight-line proportionality [1 mark] within the elastic limit of the material [1 mark] provides an appropriately annotated stress–strain diagram sketch [1 mark]
Sample response	The response				
<p>The proportional limit is the greatest stress that a material can withstand without losing straight-line proportionality between stress and strain within the material’s elastic limit.</p> 	<ul style="list-style-type: none"> explains correctly using wording indicative of <ul style="list-style-type: none"> greatest stress [1 mark] straight-line proportionality [1 mark] within the elastic limit of the material [1 mark] provides an appropriately annotated stress–strain diagram sketch [1 mark] 				

2020 Paper 1 Section 2 Question 13 Materials	Explain how the microstructure of a 62% tin and 38% lead binary alloy changes during cooling from liquid to solid. Provide an annotated sketch of the microstructure to support your explanation. [5 marks]				
	<table border="1"> <thead> <tr> <th>Sample response</th> <th>The response</th> </tr> </thead> <tbody> <tr> <td> <p>Microstructure changes occur when the cooling of the completely soluble liquid solution reaches the eutectic temperature of 183 °C. Here the liquid solution completely freezes to become a totally solid eutectic mixture with partial solid solubility as the temperature continues to fall.</p>  </td> <td> <ul style="list-style-type: none"> explains changes correctly using wording indicative of the <ul style="list-style-type: none"> lamellar structure [1 mark] mixture solidifies directly from liquid to solid [1 mark] eutectic mixture [1 mark] provides a sketch that <ul style="list-style-type: none"> indicates a lamellar structure [1 mark] is appropriately annotated [1 mark] </td> </tr> </tbody> </table>	Sample response	The response	<p>Microstructure changes occur when the cooling of the completely soluble liquid solution reaches the eutectic temperature of 183 °C. Here the liquid solution completely freezes to become a totally solid eutectic mixture with partial solid solubility as the temperature continues to fall.</p> 	<ul style="list-style-type: none"> explains changes correctly using wording indicative of the <ul style="list-style-type: none"> lamellar structure [1 mark] mixture solidifies directly from liquid to solid [1 mark] eutectic mixture [1 mark] provides a sketch that <ul style="list-style-type: none"> indicates a lamellar structure [1 mark] is appropriately annotated [1 mark]
Sample response	The response				
<p>Microstructure changes occur when the cooling of the completely soluble liquid solution reaches the eutectic temperature of 183 °C. Here the liquid solution completely freezes to become a totally solid eutectic mixture with partial solid solubility as the temperature continues to fall.</p> 	<ul style="list-style-type: none"> explains changes correctly using wording indicative of the <ul style="list-style-type: none"> lamellar structure [1 mark] mixture solidifies directly from liquid to solid [1 mark] eutectic mixture [1 mark] provides a sketch that <ul style="list-style-type: none"> indicates a lamellar structure [1 mark] is appropriately annotated [1 mark] 				

2020 Paper 1 Section 2 Question 17 Materials	Explain how the chemical composition of high-carbon steel contributes to two of its mechanical properties in the context of two industrial applications. [5 marks]					
	<table border="1"> <thead> <tr> <th>Sample response</th> <th>The response</th> </tr> </thead> <tbody> <tr> <td rowspan="2"> High-carbon steel has a chemical composition that includes 0.60% to 1.25% carbon. This carbon content facilitates the formation of pearlite in the microstructure. Pearlite is a fine laminar mixture of ferrite and cementite. The mechanical properties of pearlite are intermediate to soft, ductile ferrite and hard, brittle cementite. The finer pearlite microstructure of high-carbon steel increases toughness, strength, hardness and wear resistance, which makes the steel useful for industrial applications such as cutting tools, punches, dies and springs. </td> <td> <ul style="list-style-type: none"> explains correctly and includes - the carbon content of high-carbon steel [1 mark] - the microstructure of high-carbon steel [1 mark] - 2 industrial/mechanical uses for high-carbon steel [1 mark] </td> </tr> <tr> <td> Prpt - 2 mechanical properties of highcarbon steel [2 marks] OR - 1 mechanical property of highcarbon steel [1 mark] </td> </tr> </tbody> </table>	Sample response	The response	High-carbon steel has a chemical composition that includes 0.60% to 1.25% carbon. This carbon content facilitates the formation of pearlite in the microstructure. Pearlite is a fine laminar mixture of ferrite and cementite. The mechanical properties of pearlite are intermediate to soft, ductile ferrite and hard, brittle cementite. The finer pearlite microstructure of high-carbon steel increases toughness, strength, hardness and wear resistance, which makes the steel useful for industrial applications such as cutting tools, punches, dies and springs.	<ul style="list-style-type: none"> explains correctly and includes - the carbon content of high-carbon steel [1 mark] - the microstructure of high-carbon steel [1 mark] - 2 industrial/mechanical uses for high-carbon steel [1 mark] 	Prpt - 2 mechanical properties of highcarbon steel [2 marks] OR - 1 mechanical property of highcarbon steel [1 mark]
Sample response	The response					
High-carbon steel has a chemical composition that includes 0.60% to 1.25% carbon. This carbon content facilitates the formation of pearlite in the microstructure. Pearlite is a fine laminar mixture of ferrite and cementite. The mechanical properties of pearlite are intermediate to soft, ductile ferrite and hard, brittle cementite. The finer pearlite microstructure of high-carbon steel increases toughness, strength, hardness and wear resistance, which makes the steel useful for industrial applications such as cutting tools, punches, dies and springs.	<ul style="list-style-type: none"> explains correctly and includes - the carbon content of high-carbon steel [1 mark] - the microstructure of high-carbon steel [1 mark] - 2 industrial/mechanical uses for high-carbon steel [1 mark] 					
	Prpt - 2 mechanical properties of highcarbon steel [2 marks] OR - 1 mechanical property of highcarbon steel [1 mark]					

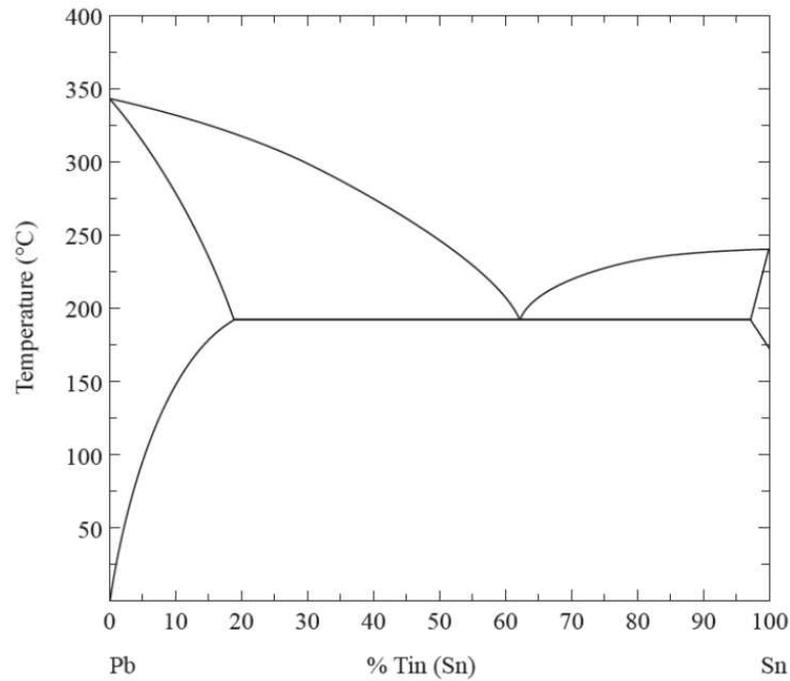
2020 Paper 1 Section 2 Question 12 Materials	List four properties of polylactic acid (PLA) that make it a useful material for medical implants. [4 marks]				
	<table border="1"> <thead> <tr> <th>Sample response</th> <th>The response</th> </tr> </thead> <tbody> <tr> <td> 1. Biodegradable 2. High tensile strength 3. Non-toxic in solid form 4. Resistant to chemicals </td> <td> <ul style="list-style-type: none"> provides 4 correctly identified PLA properties [4 marks] OR <ul style="list-style-type: none"> provides 3 correctly identified PLA properties [3 marks] OR <ul style="list-style-type: none"> provides 2 correctly identified PLA properties [2 marks] OR <ul style="list-style-type: none"> provides 1 correctly identified PLA property [1 mark] </td> </tr> </tbody> </table>	Sample response	The response	1. Biodegradable 2. High tensile strength 3. Non-toxic in solid form 4. Resistant to chemicals	<ul style="list-style-type: none"> provides 4 correctly identified PLA properties [4 marks] OR <ul style="list-style-type: none"> provides 3 correctly identified PLA properties [3 marks] OR <ul style="list-style-type: none"> provides 2 correctly identified PLA properties [2 marks] OR <ul style="list-style-type: none"> provides 1 correctly identified PLA property [1 mark]
Sample response	The response				
1. Biodegradable 2. High tensile strength 3. Non-toxic in solid form 4. Resistant to chemicals	<ul style="list-style-type: none"> provides 4 correctly identified PLA properties [4 marks] OR <ul style="list-style-type: none"> provides 3 correctly identified PLA properties [3 marks] OR <ul style="list-style-type: none"> provides 2 correctly identified PLA properties [2 marks] OR <ul style="list-style-type: none"> provides 1 correctly identified PLA property [1 mark] 				

Marking Guide – Paper 1 Section 3

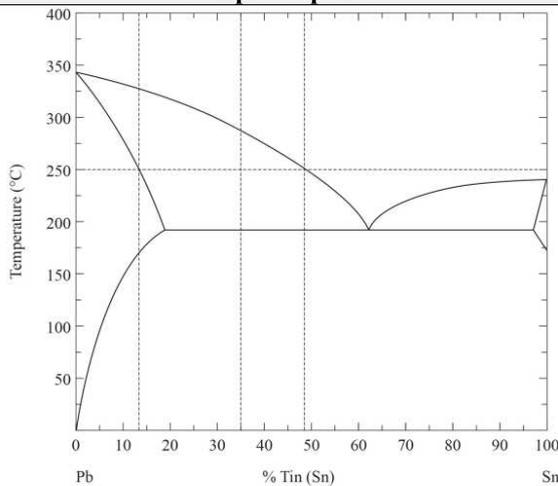
2022
Paper 1
Section 3
Question 21

Materials

Determine the percentage of the liquid components for an alloy containing 65% lead at a temperature of 250°C. Annotate the lead-tin equilibrium phase diagram as part of your response.



Sample response



$$\text{liquid} = \frac{35 - 13}{35} \times 100 = 63\%$$

$$\text{solid} = \frac{48 - 35}{35} \times 100 = 37\%$$

Liquid is 48% tin and 52% lead

$$\therefore \text{liquid tin at } 250^\circ\text{C} = (0.48 \times 0.63) \times 100 = 30\%$$

$$\text{and liquid lead at } 250^\circ\text{C} = (0.52 \times 0.63) \times 100 = 33\%$$

The response

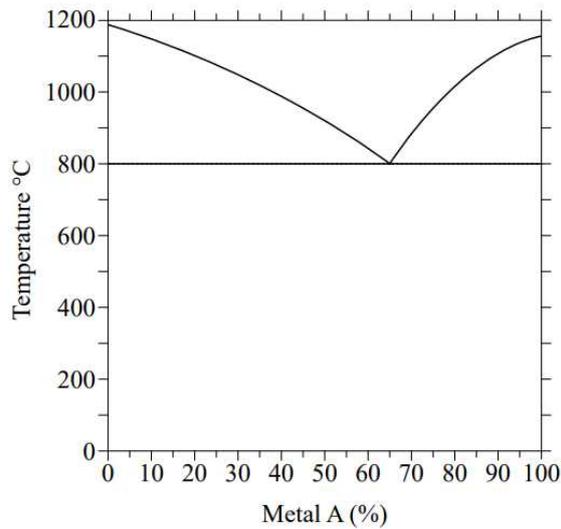
- uses the diagram to
 - determine the area representing 65% lead and 35% tin [1 mark]
 - plot the percentage of liquid or solid at 250° C [1 mark]
- correctly determines the percentage proportion of liquid [1 mark]
- identifies the correct percentage of tin and lead as liquid at 250° C [1 mark]
- correctly determines the percentage of the liquid components (tin and lead) [1 mark]

**2021
Paper 1
Section 3
Question 18**

Materials

Use and annotate the binary equilibrium diagram for an alloy of metals A and B to calculate the percentage of solid and liquid material present for an alloy of 20% Metal A and 80% Metal B at 900 °C.

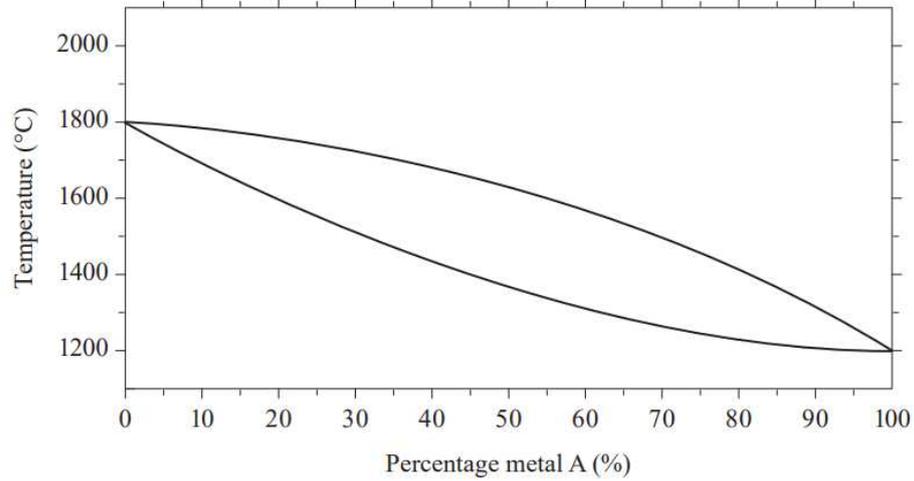
Answer to the nearest whole unit. [5 marks]



Sample response	The response
<p>Temperature °C</p> <p>Metal A (%)</p> $\text{solid} = \frac{52 - 20}{52 - 0} \times \frac{100}{1}$ $= \frac{32}{52} \times \frac{100}{1} = 61.54$ $= 62\%$ $\text{liquid} = \frac{20 - 0}{52 - 0} \times \frac{100}{1}$ $= \frac{20}{52} \times \frac{100}{1} = 38.46$ $= 38\%$	<ul style="list-style-type: none"> • provides evidence that the diagram is used to - determine the appropriate area representing 20% A and 80% B metal alloy [1 mark] - plot percentage A and B metal at 900 °C [1 mark] • includes correct use of the inverse lever rule [1 mark] • provides correct working to give correct percentage proportion of solid with correct unit provided [1 mark] • provides correct working to give correct percentage proportion of liquid with correct unit provided [1 mark]

2020
Paper 1
Section 3
Question 21

Materials



Use and annotate the binary equilibrium diagram for an alloy of metals A and B to calculate the percentage proportion of solid and liquid material present for an alloy of 50% metal A and B at 1400 °C. Answer to the nearest whole unit. [5 marks]

Sample response	The response
$\text{solid} = \frac{82 - 50}{82 - 45} \times \frac{100}{1}$ $= \frac{32}{37} \times \frac{100}{1} = 86.49 = 86\%$ $\text{liquid} = \frac{50 - 45}{82 - 45} \times \frac{100}{1}$ $= \frac{5}{37} \times \frac{100}{1} = 13.51 = 14\%$	<ul style="list-style-type: none"> • provides evidence that the diagram is used to plot percentage of metal A and B [1 mark] • includes correct use of the inverse lever rule to calculate solid [1 mark] • provides correct working to give correct percentage of solid to the nearest whole unit with correct unit provided [1 mark] • provides correct use of the inverse lever rule to calculate liquid [1 mark] • provides correct working to give correct percentage of liquid to the nearest whole unit with correct unit provided [1 mark]

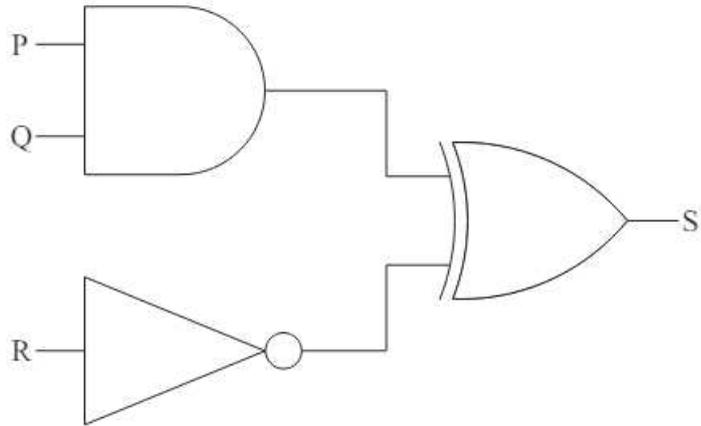
Unit 4 – Topic 3: Machine control

Paper 1 Section 1

2023
Paper 1
Section 1
Question 3

Machine
control

A logic circuit is shown.



Which truth table corresponds to the logic circuit?

(A)

P	Q	R	S
1	0	1	0
1	1	0	0
1	1	1	1

(B)

P	Q	R	S
1	0	1	1
1	1	0	1
1	1	1	0

(C)

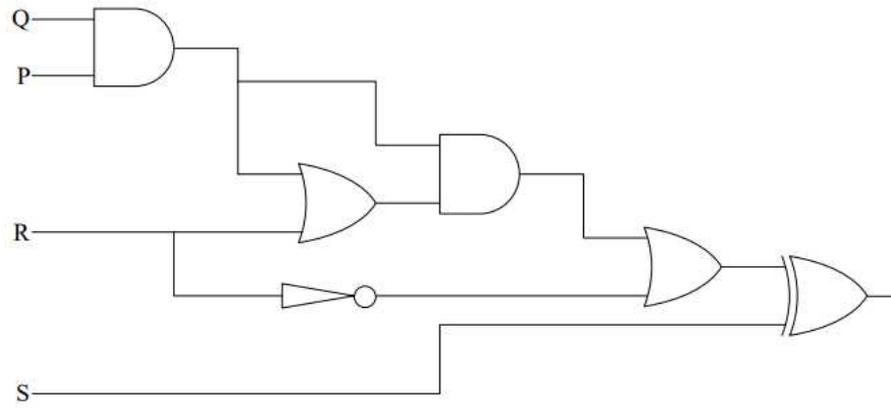
P	Q	R	S
1	0	1	0
1	1	0	1
1	1	1	0

(D)

P	Q	R	S
1	0	1	1
1	1	0	0
1	1	1	1

2021
Paper 1
Section 1
Question 2

Machine
control



When the output from the logic circuit is 1, the input to the circuit is

(A)

P	Q	R	S
1	1	1	1

(B)

P	Q	R	S
0	1	1	1

(C)

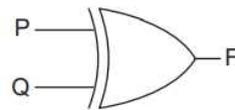
P	Q	R	S
1	1	0	1

(D)

P	Q	R	S
0	1	0	1

2020
Paper 1
Section 1
Question 8

Machine
control



The truth table that corresponds to this logic gate is

(A)

P	Q	F
0	0	0
0	1	1
1	0	1
1	1	0

(B)

P	Q	F
0	0	0
0	1	0
1	0	0
1	1	1

(C)

P	Q	F
0	0	1
0	1	1
1	0	1
1	1	0

(D)

P	Q	F
0	0	1
0	1	0
1	0	0
1	1	0

2022 Paper 1 Section 2 Question 13 Machine control	Describe the functions of a NAND gate. Include a truth table to support your response. [5 marks]

**2022
Paper 1
Section 2
Question 16**

**Machine
control**

The ceiling fans in a meeting room operate on demand. When staff access the room using a swipe card and the temperature in the room is above 25° C, the fans turn on, activating a one-hour time. The fans then turn off after one hour of operation, unless a movement sensor is activated, resetting the time to keep the fans on for another hour.

Analyse this information to create a logic circuit that meets the requirements for the ceiling fan operation. Clearly identify all inputs and outputs. [10 marks]



**2021
Paper 1
Section 2
Question 15**

**Machine
control**

An automated machine fabricates a metal component using a punching tool. The machine includes sensors that allow it to operate only when the punching tool is detected as correctly inserted with the safety guard in the punching position, and when either a component is detected as correctly positioned or with the manual shut-down switch not activated. All sensors send a 1 input for a yes/activated condition and a 0 input for a no/not activated condition.

Develop a logic gate circuit to control the given function of the automated punching machine to produce a 1 output from the circuit.

Clearly annotate all logic gate inputs and outputs and label all sensors. [6 marks]

Sensor description	Label
Punching tool detection	P
Component detection	C
Safety guard	S
Manual shut-down switch	M



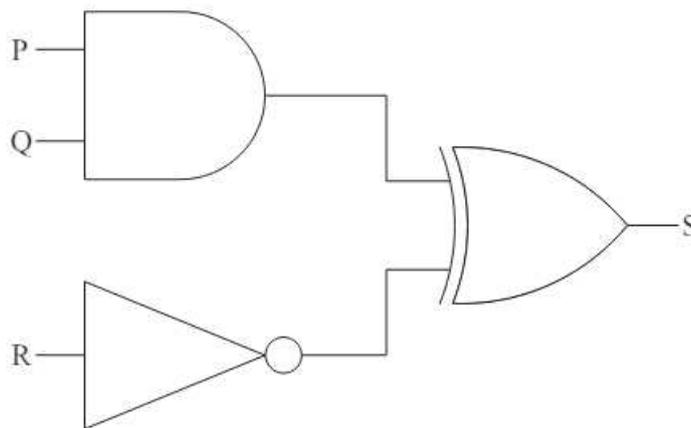
Paper 1 Section 3

Note: there have been no Unit 4, Topic 3 questions for Paper 1, Section 3 questions in recent years.

2023
Paper 1
Section 1
Question 3

Machine
control

A logic circuit is shown.



Which truth table corresponds to the logic circuit?

(A)

P	Q	R	S
1	0	1	0
1	1	0	0
1	1	1	1

(B)

P	Q	R	S
1	0	1	1
1	1	0	1
1	1	1	0

(C)

P	Q	R	S
1	0	1	0
1	1	0	1
1	1	1	0

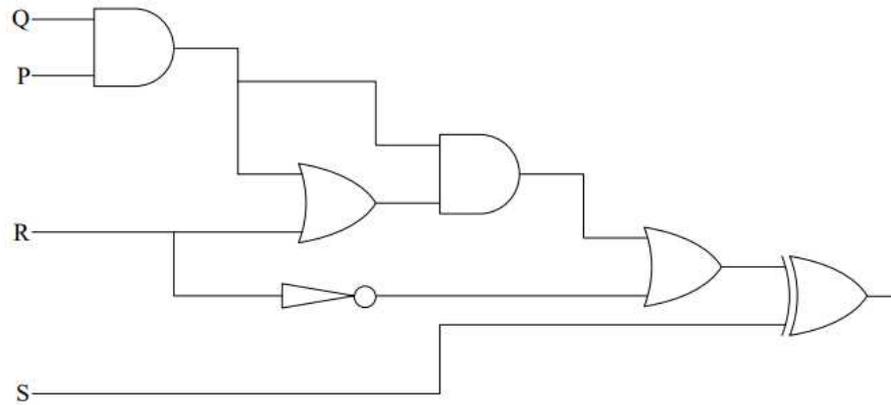
(D)

P	Q	R	S
1	0	1	1
1	1	0	0
1	1	1	1

Answer is A.

2021
Paper 1
Section 1
Question 2

Machine control



When the output from the logic circuit is 1, the input to the circuit is

(A)

P	Q	R	S
1	1	1	1

(B)

P	Q	R	S
0	1	1	1

(C)

P	Q	R	S
1	1	0	1

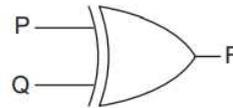
(D)

P	Q	R	S
0	1	0	1

Answer is B.

2020
Paper 1
Section 1
Question 8

Machine control



The truth table that corresponds to this logic gate is

(A)

P	Q	F
0	0	0
0	1	1
1	0	1
1	1	0

(B)

P	Q	F
0	0	0
0	1	0
1	0	0
1	1	1

(C)

P	Q	F
0	0	1
0	1	1
1	0	1
1	1	0

(D)

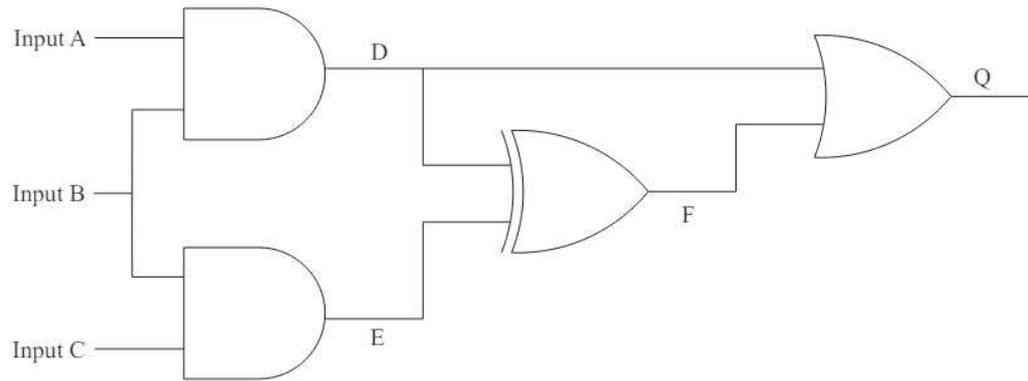
P	Q	F
0	0	1
0	1	0
1	0	0
1	1	0

Answer is A.

2023
Paper 1
Section 2
Question 13

Machine control

This logic circuit operates an electric motor driven using solar or wind power.



Key Input A — solar panel Input B — timer Input C — wind turbine

a) Complete the corresponding truth table. All inputs to the system are 1 for ON and 0 for OFF. [4 marks]

Sample response							The response
A	B	C	D	E	F	Q	
0	0	0	0	0	0	0	• correctly completes column D [1 mark]
0	0	1	0	0	0	0	• correctly completes column E [1 mark]
0	1	0	0	0	0	0	• correctly completes column F [1 mark]
0	1	1	0	1	1	1	• correctly completes column Q [1 mark]
1	0	0	0	0	0	0	
1	0	1	0	0	0	0	
1	1	0	1	0	1	1	
1	1	1	1	1	0	1	

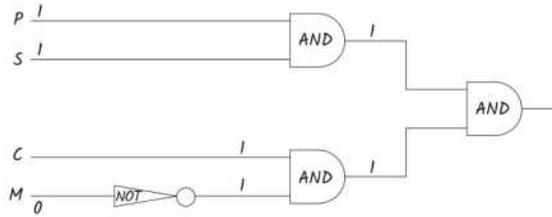
b) Explain how the logic circuit determines which source of power drives the electric motor under each condition for all possible inputs. [4 marks]

Sample response	The response
If the solar panel, wind turbine and timer are all on, the XOR gate will output 0 and only the solar panel will drive the electric motor because the XOR gate will prevent the wind turbine from operating the motor. If the solar panel is off and the wind turbine and timer are on, the XOR gate will have an input of 0 and 1 and only the wind turbine will drive the electric motor. If the wind turbine is off and the solar panel and timer are on, the OR gate will have an input of 1 and 1 allowing the solar panel to drive the electric motor.	<ul style="list-style-type: none"> uses wording indicating that when all three inputs are on <ul style="list-style-type: none"> the solar panel drives the electric motor [1 mark] the XOR gate will not allow the wind turbine to drive the motor [1 mark] uses wording indicating that when <ul style="list-style-type: none"> the solar panel is off and the wind turbine and timer are on, the XOR gate allows the wind turbine to drive the motor [1 mark] the wind turbine is off and the solar panel and timer are on, the OR gate allows the solar panel to drive the motor [1 mark]

2022 Paper 1 Section 2 Question 13 Machine control	Describe the functions of a NAND gate. Include a truth table to support your response. [5 marks]																			
	<table border="1"> <thead> <tr> <th colspan="3">Sample response</th> <th>The response</th> </tr> </thead> <tbody> <tr> <td>Input</td> <td>Input</td> <td>Output</td> <td rowspan="5"> <ul style="list-style-type: none"> appropriately describes NAND gate function using wording that indicates the <ul style="list-style-type: none"> output is 0 when all inputs are 1 [1 mark] output is 1 when all inputs are not 1 [1 mark] provides a truth table with <ul style="list-style-type: none"> one column correct [1 mark] a second column correct [1 mark] a third column correct [1 mark] </td> </tr> <tr> <td>0</td> <td>0</td> <td>1</td> </tr> <tr> <td>0</td> <td>1</td> <td>1</td> </tr> <tr> <td>1</td> <td>0</td> <td>1</td> </tr> <tr> <td>1</td> <td>1</td> <td>0</td> </tr> </tbody> </table> <p>A NAND gate output is 0 when and only when all its inputs are at 1. Otherwise the output is 1.</p>	Sample response			The response	Input	Input	Output	<ul style="list-style-type: none"> appropriately describes NAND gate function using wording that indicates the <ul style="list-style-type: none"> output is 0 when all inputs are 1 [1 mark] output is 1 when all inputs are not 1 [1 mark] provides a truth table with <ul style="list-style-type: none"> one column correct [1 mark] a second column correct [1 mark] a third column correct [1 mark] 	0	0	1	0	1	1	1	0	1	1	1
Sample response			The response																	
Input	Input	Output	<ul style="list-style-type: none"> appropriately describes NAND gate function using wording that indicates the <ul style="list-style-type: none"> output is 0 when all inputs are 1 [1 mark] output is 1 when all inputs are not 1 [1 mark] provides a truth table with <ul style="list-style-type: none"> one column correct [1 mark] a second column correct [1 mark] a third column correct [1 mark] 																	
0	0	1																		
0	1	1																		
1	0	1																		
1	1	0																		

2022 Paper 1 Section 2 Question 16 Machine control	<p>The ceiling fans in a meeting room operate on demand. When staff access the room using a swipe card and the temperature in the room is above 25° C, the fans turn on, activating a one-hour time. The fans then turn off after one hour of operation, unless a movement sensor is activated, resetting the time to keep the fans on for another hour.</p> <p>Analyse this information to create a logic circuit that meets the requirements for the ceiling fan operation. Clearly identify all inputs and outputs. [10 marks]</p>			
	<table border="1"> <thead> <tr> <th>Sample response</th> <th>The response</th> </tr> </thead> <tbody> <tr> <td> </td> <td> <ul style="list-style-type: none"> provides a correctly applied logic circuit including <ul style="list-style-type: none"> clearly identified swipe card input [1 mark] clearly identified temperature input with temperature requirement >25 [1 mark] clearly identified one-hour timer input [1 mark] clearly identified movement sensor input [1 mark] clearly identified ceiling fan operation output [1 mark] swipe card and temp sensor => AND1 [1 mark] condition 1 and condition 2 => AND2 => ceiling fan operation [1 mark] one-hour timer => XOR => AND2 => ceiling fan operation [1 mark] one-hour timer => NOT => AND3 => XOR => AND2 => ceiling fan operation [1 mark] movement sensor => AND3 => XOR => AND2 => ceiling fan operation [1 mark] </td> </tr> </tbody> </table>	Sample response	The response	
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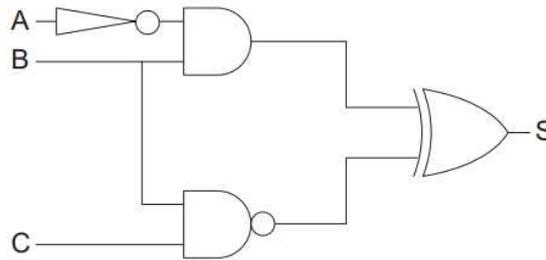
2021 Paper 1 Section 2 Question 15 Machine control	<p>An automated machine fabricates a metal component using a punching tool. The machine includes sensors that allow it to operate only when the punching tool is detected as correctly inserted with the safety guard in the punching position, and when either a component is detected as correctly positioned or with the manual shut-down switch not activated. All sensors send a 1 input for a yes/activated condition and a 0 input for a no/not activated condition.</p> <p>Develop a logic gate circuit to control the given function of the automated punching machine to produce a 1 output from the circuit.</p> <p>Clearly annotate all logic gate inputs and outputs and label all sensors. [6 marks]</p>													
	<table border="1"> <thead> <tr> <th>Sensor description</th> <th>Label</th> </tr> </thead> <tbody> <tr> <td>Punching tool detection</td> <td>P</td> </tr> <tr> <td>Component detection</td> <td>C</td> </tr> <tr> <td>Safety guard</td> <td>S</td> </tr> <tr> <td>Manual shut-down switch</td> <td>M</td> </tr> </tbody> </table> <table border="1"> <thead> <tr> <th>Sample response</th> <th>The response</th> </tr> </thead> <tbody> <tr> <td> </td> <td> </td> </tr> </tbody> </table>	Sensor description	Label	Punching tool detection	P	Component detection	C	Safety guard	S	Manual shut-down switch	M	Sample response	The response	
Sensor description	Label													
Punching tool detection	P													
Component detection	C													
Safety guard	S													
Manual shut-down switch	M													
Sample response	The response													



- provides an appropriately annotated logic gate showing
 - inputs and outputs to produce a logic circuit 1 output [1 mark]
 - correct sensor labels for logic circuit inputs [1 mark]
- includes use of the
 - AND gate for P and S sensors [1 mark]
 - NOT gate for M sensor prior to AND gate [1 mark]
 - AND gate for C and M sensors [1 mark]
 - AND gate linked to an AND gate and an AND gate to acknowledge the two conditions of machine operation [1 mark]

2020
Paper 1
Section 2
Question 14

Machine
control



Interpret the logic circuit to create the corresponding truth table. [6 marks]

Sample response							The response
A	\bar{A}	B	C	D	E	S	<ul style="list-style-type: none"> • provides a truth table including <ul style="list-style-type: none"> - 7 columns correctly labelled [1 mark] - 8 rows under the header row [1 mark] <p>LogGO</p> <ul style="list-style-type: none"> • includes correct logic gate outputs for all 4 columns \bar{A}, D, E, S [4 marks] <p>OR</p> <ul style="list-style-type: none"> • includes correct logic gate outputs for any 3 columns \bar{A}, D, E or S [3 marks] <p>OR</p> <ul style="list-style-type: none"> • includes consequentially correct logic gate outputs for any 2 columns \bar{A}, D, E or S [2 marks] <p>OR</p> <ul style="list-style-type: none"> • includes consequentially correct logic gate outputs for any 1 column \bar{A}, D, E or S [1 mark]
0	1	0	0	0	1	1	
1	0	0	0	0	1	1	
0	1	1	0	1	1	0	
1	0	1	0	0	1	1	
0	1	0	1	0	1	1	
1	0	0	1	0	1	1	
0	1	1	1	1	0	1	
1	0	1	1	0	0	0	

Marking Guide – Paper 1 Section 3

There have been no questions on this topic for this section in the exams of recent years.