

# Apex Exam Guidebook

**Engineering**  
Year 12 QCE  
Queensland Curriculum

2026 Edition  
Wilhelm Chadwick

# Apex Exam Guidebook

## Engineering

### Year 12 QCE

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#### Acknowledgements

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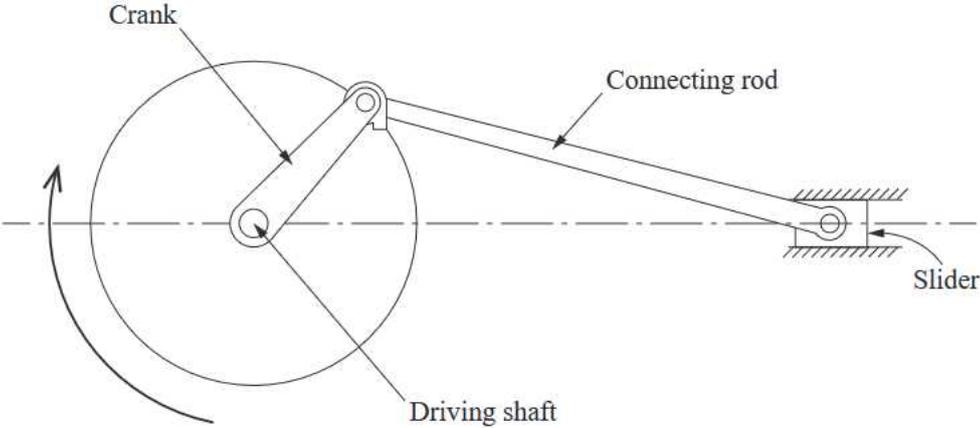
# Contents

<b>Unit 4 Machines and mechanisms .....</b>	<b>4</b>
<b>Unit 4 – Topic 1: Machines in society.....</b>	<b>4</b>
Paper 1 Section 1 .....	4
Paper 1 Section 2 .....	13
Paper 1 Section 3 .....	21
Marking Guide – Paper 1 Section 1.....	47
Marking Guide – Paper 1 Section 2.....	56
Marking Guide – Paper 1 Section 3.....	61
<b>Unit 4 – Topic 2: Materials .....</b>	<b>85</b>
Paper 1 Section 1 .....	85
Paper 1 Section 2 .....	91
Paper 1 Section 3 .....	106
Marking Guide – Paper 1 Section 1.....	110
Marking Guide – Paper 1 Section 2.....	116
Marking Guide – Paper 1 Section 3.....	125
<b>Unit 4 – Topic 3: Machine control.....</b>	<b>129</b>
Paper 1 Section 1 .....	129
Paper 1 Section 2 .....	132
Paper 1 Section 3 .....	139
Marking Guide – Paper 1 Section 1.....	140
Marking Guide – Paper 1 Section 2.....	143
Marking Guide – Paper 1 Section 3.....	148

## Unit 4 Machines and mechanisms

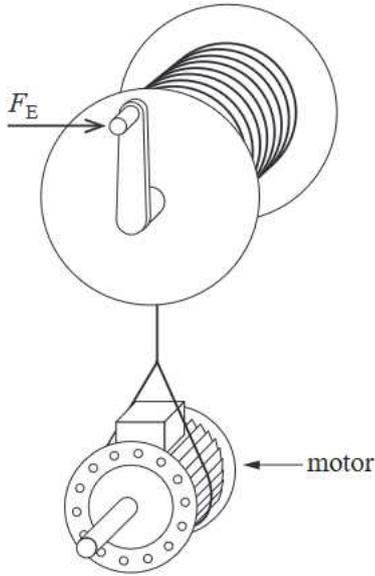
### Unit 4 – Topic 1: Machines in society

#### Paper 1 Section 1

<p><b>2024</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 3</b></p> <p><b>Machines in society</b></p>	<p>The crank moves continually in the direction shown.</p>  <p>Identify the type of motion that best describes what is experienced by the slider.</p> <p>(A) oscillatory (B) reciprocal (C) rotary (D) linear</p>
<p><b>2024</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 6</b></p> <p><b>Machines in society</b></p>	<p>A cyclist exerts an effort force of 125 N on the pedal of a bicycle. The load force on the rear wheel is 500 N. The velocity ratio of the bicycle is 5.</p> <p>What is the efficiency of the bicycle?</p> <p>(A) 125% (B) 80% (C) 8% (D) 5%</p>
<p><b>2024</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 8</b></p> <p><b>Machines in society</b></p>	<p>A fibreglass swimming pool has a potential energy of 98 kJ when raised 20 m from the ground by a crane. The mass of the swimming pool is</p> <p>(A) 500 kg. (B) 4900 kg. (C) 10 000 kg. (D) 48 020 kg.</p>

**2024  
Paper 1  
Section 1  
Question 9**  
**Machines in  
society**

A drum winch is used to vertically raise a 50 kg motor as shown. It has a velocity ratio of 3 and is 90% efficient.

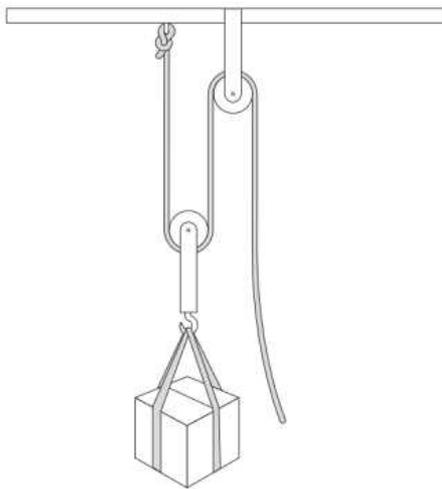


What is the minimum effort force required to raise the motor using the drum winch?

- (A) 18.52 N
- (B) 163.33 N
- (C) 181.48 N
- (D) 1323.00 N

**2024  
Paper 1  
Section 1  
Question 10**  
**Machines in  
society**

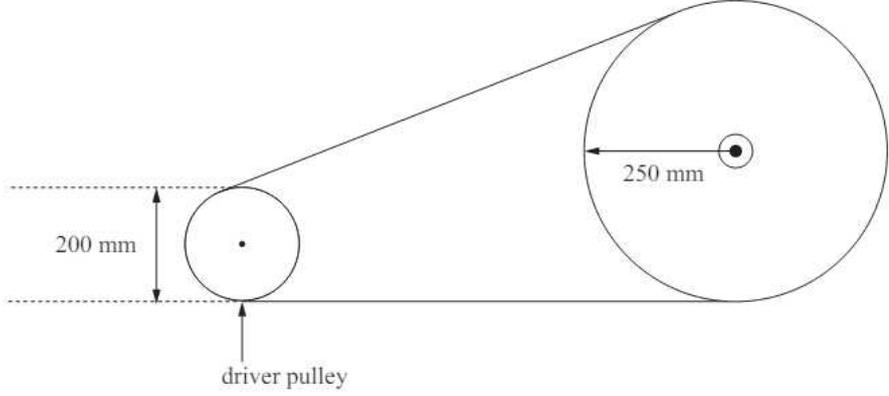
A 15 N force is required to raise a box a distance of 12 m using the simple pulley system shown. Assume the friction in the rope is negligible.



What is the work done to raise the box 12 m?

- (A) 3 J
- (B) 90 J
- (C) 180 J
- (D) 360 J

<p><b>2023</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 2</b> <b>Machines in society</b></p>	<p>The force required to just stop an 80 kg box from sliding down a 20° incline is</p> <p>(A) 97 N (B) 250 N (C) 265 N (D) 282 N</p>
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<p><b>2023</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 4</b> <b>Machines in society</b></p>	<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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<p><b>2023</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 5</b> <b>Machines in society</b></p>	<p>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?</p> <p>(A) 29% (B) 70% (C) 80% (D) 88%</p>
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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  
(B) II  
(C) III  
(D) IV

**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

**2023  
Paper 1  
Section 1  
Question 8**

**Machines in society**

A 45 kg box is pulled up an incline as shown

Not to scale

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  
(D) 441 N

<b>2023</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 10</b>  <b>Machines in society</b>	A 40 kg object is pushed 3 m up a 25° incline at a uniform velocity.  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  (A) 489 J (B) 497 J (C) 986 J (D) 1066 J
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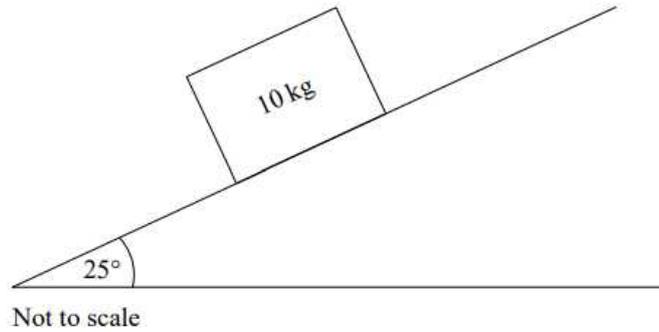
<b>2022</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 3</b>  <b>Machines in society</b>	During a race, the rear wheels of a go-kart exert a horizontal force of 100 N on the racetrack surface when the rear axle is rotating at 1000 revolutions per minute (rpm). The wheels have a diameter of 280 mm.  The power being transmitted to the track by the rear wheels is  (A) 88 kW (B) 2.9 kW (C) 1.5 kW (D) 0.73 kW
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<b>2022</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 5</b>  <b>Machines in society</b>	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.  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  (A) 1.47 MJ (B) 1.67 MJ (C) 1.76 MJ (D) 1.86 MJ
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<b>2022</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 7</b>  <b>Machines in society</b>	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.  The minimum amount of additional force required to stop the wheelbarrow from sliding is  (A) 59 N (B) 34 N (C) 25 N (D) 8 N
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<b>2022</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 9</b>  <b>Machines in society</b>	A mechanism extends an initially stationary rod 15 mm at a final velocity of 2.5 m/s.  The acceleration of the rod is  (A) 417 m/s <sup>2</sup> (B) 208 m/s <sup>2</sup> (C) 38 m/s <sup>2</sup> (D) 21 m/s <sup>2</sup>
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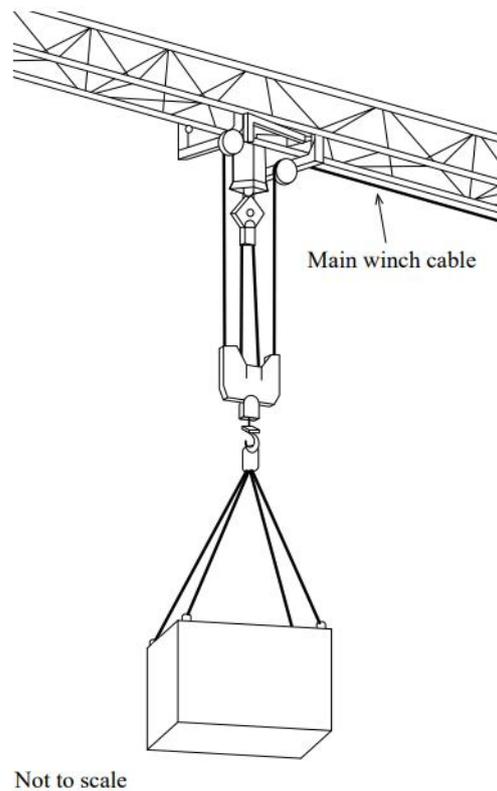
2021  
Paper 1  
Section 1  
Question 4  
  
Machines in  
society



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?

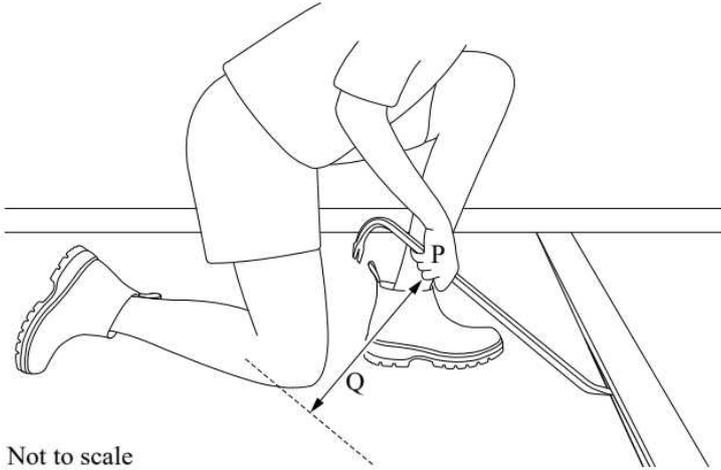
- (A)  $8.0 \text{ m/s}^2$
- (B)  $4.1 \text{ m/s}^2$
- (C)  $2.4 \text{ m/s}^2$
- (D)  $1.8 \text{ m/s}^2$

2021  
Paper 1  
Section 1  
Question 5  
  
Machines in  
society



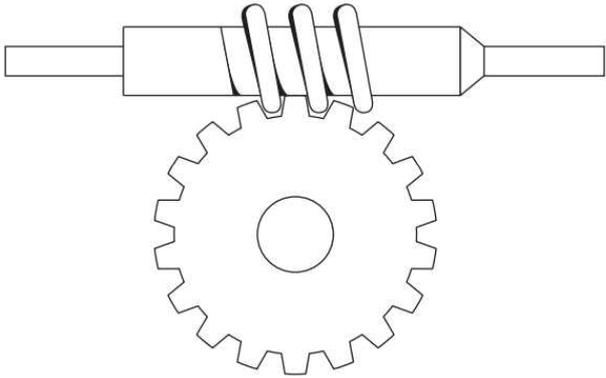
This crane vertically lifts a load a distance of 20 m using a pulley system. What distance must the main winch cable move during the vertical lift?

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

<p><b>2021</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 6</b></p> <p><b>Machines in society</b></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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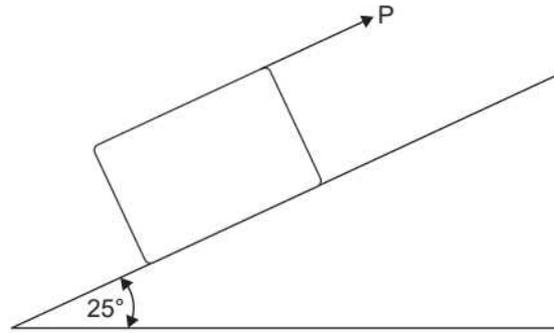
<p><b>2021</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 7</b></p> <p><b>Machines in society</b></p>	<p>A pulley system with an efficiency of 75% is used to vertically raise a 120 kg load a distance of 3 m. If the length of pulley rope pulled to raise the load is 8 m, the effort required is</p> <p>(A) 330 N. (B) 392 N. (C) 440 N. (D) 588 N.</p>
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<p><b>2021</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 9</b></p> <p><b>Machines in society</b></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><b>2020</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 1</b></p> <p><b>Machines in society</b></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

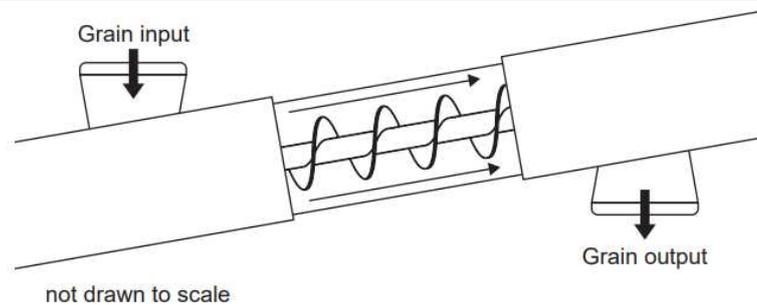


A 25 kg block is pulled up an incline using a force  $P$  as shown. What is the minimum value of  $P$  required to just move the box from rest if the coefficient of static friction is 0.4?

- (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 <sup>3</sup>	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 m<sup>3</sup>
- (B) 24 m<sup>3</sup>
- (C) 2.4 m<sup>3</sup>
- (D) 1.5 m<sup>3</sup>

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°

<b>2020 Paper 1 Section 1 Question 9 Machines in society</b>	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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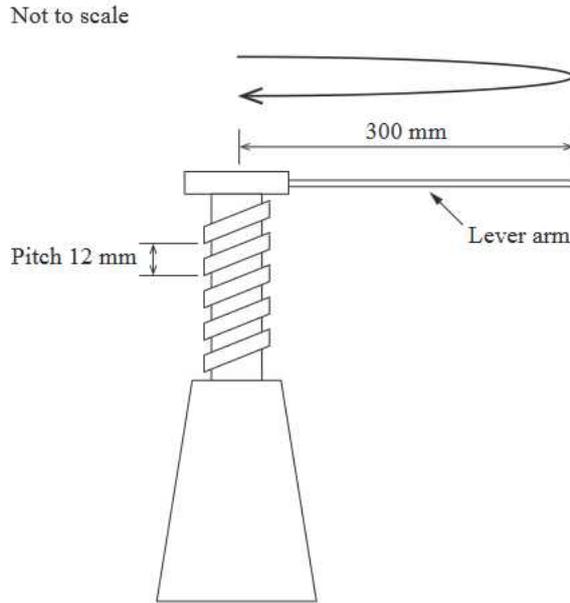






**2024  
Paper 1  
Section 3  
Question 18**  
**Machines in  
society**

An effort of 120 N is applied at the end of the lever arm of a screw jack for 180 seconds to raise an object 150 mm.



a) Calculate the work done on the lever arm. [4 marks]

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b) Calculate the power input. [1 mark]

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<b>2024 Paper 1 Section 3 Question 22</b>  <b>Machines in society</b>	<p>A sorting conveyor cart in a recycling plant is initially at rest and has a mass of 5 kg. It is pushed a distance of 3 m up a 30° incline using a force of 60 N parallel to the incline. Assume <math>\mu_k = \mu_s = 0.58</math>.</p> <p>Determine the time taken to move the cart 3 m up the incline. Include a free-body diagram showing all the forces involved.</p>







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]

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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]

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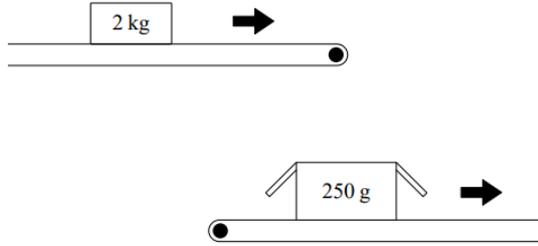
<b>2022 Paper 1 Section 3 Question 18</b>  <b>Machines in society</b>	Determine the force required to launch a rocket with a mass of 2000 kg vertically from rest to a height of 20 km in 20 seconds. Assume that the rocket's mass and acceleration due to gravity remain constant during the launch and that air resistance is not a factor.
	Include a free-body diagram showing the forces at launch. Answer to the nearest whole unit in kN.
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**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]

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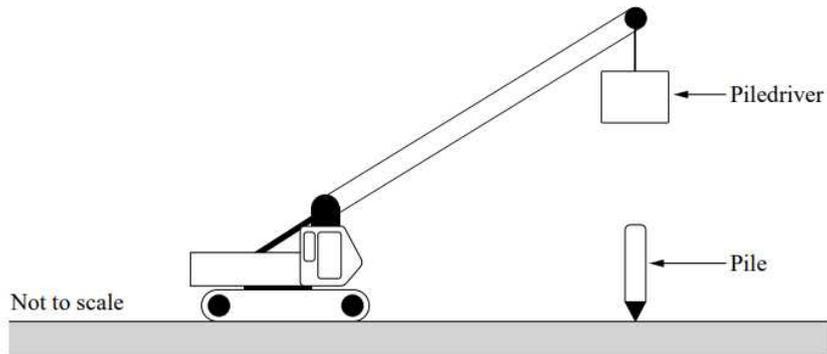
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2021  
Paper 1  
Section 3  
Question 20

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]

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b) If the pile and piledriver decelerate at a constant rate of  $30 \text{ m/s}^2$  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]

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**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  $0.75 \text{ m/s}^2$  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]

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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]

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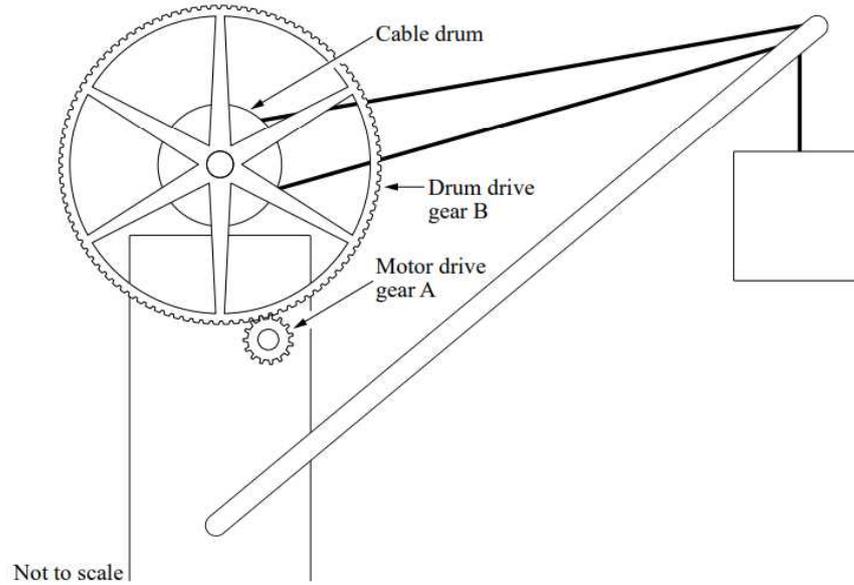
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**2021  
Paper 1  
Section 3  
Question 22**  
**Machines in  
society**

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]

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

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**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  $30^\circ$  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  $30^\circ$  incline on Mars. Answer to two decimal places. [1 mark]

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

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

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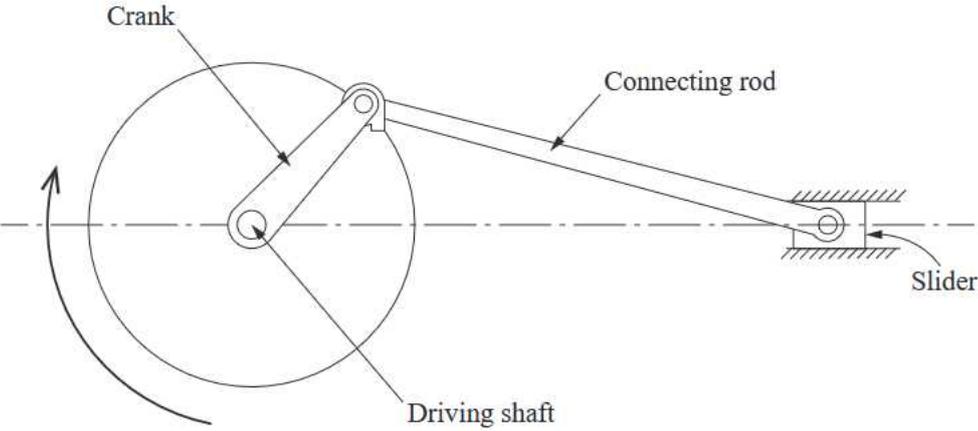







<b>2020 Paper 1 Section 3 Question 23  Machines in society</b>	An elevator starts from rest and accelerates upwards at a constant rate until the desired velocity of 10 m/s is achieved. The mass of the elevator and occupants is 2500 kg. The tension on the elevator cable is 30 000 N.
	Determine the distance the elevator travels during acceleration to the nearest whole unit (m). Include a force diagram with your working. [6 marks]

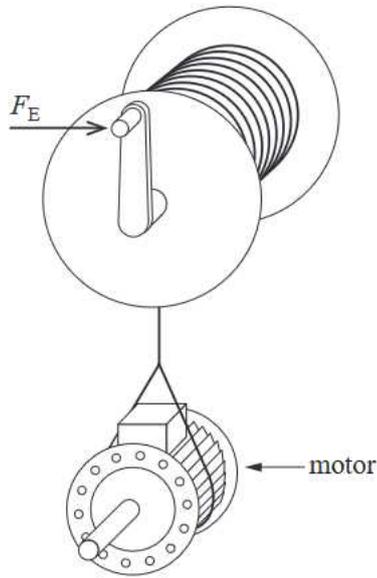
**Marking Guide – Paper 1 Section 1**

<p><b>2024 Paper 1 Section 1 Question 3</b></p> <p><b>Machines in society</b></p>	<p>The crank moves continually in the direction shown.</p>  <p>Identify the type of motion that best describes what is experienced by the slider.</p> <p>(A) oscillatory  <b>(B) reciprocal – Answer</b>          (C) rotary          (D) linear</p>
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<p><b>2024 Paper 1 Section 1 Question 6</b></p> <p><b>Machines in society</b></p>	<p>A cyclist exerts an effort force of 125 N on the pedal of a bicycle. The load force on the rear wheel is 500 N. The velocity ratio of the bicycle is 5.</p> <p>What is the efficiency of the bicycle?</p> <p>(A) 125%  <b>(B) 80% – Answer</b>          (C) 8%          (D) 5%</p>
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<p><b>2024 Paper 1 Section 1 Question 8</b></p> <p><b>Machines in society</b></p>	<p>A fibreglass swimming pool has a potential energy of 98 kJ when raised 20 m from the ground by a crane. The mass of the swimming pool is</p> <p>(A) <b>500 kg. – Answer</b>          (B) 4900 kg.          (C) 10 000 kg.          (D) 48 020 kg.</p>
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<p><b>2024 Paper 1 Section 1 Question 9</b></p> <p><b>Machines in society</b></p>	<p>A drum winch is used to vertically raise a 50 kg motor as shown. It has a velocity ratio of 3 and is 90% efficient.</p>
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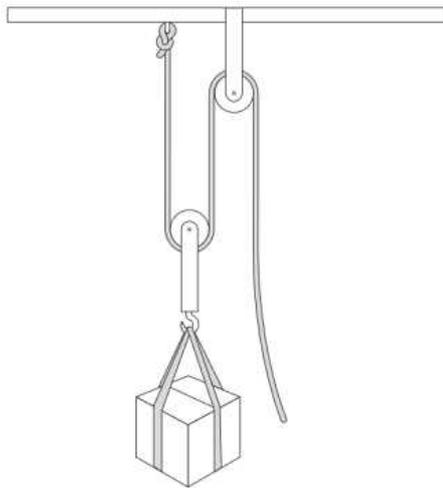
What is the minimum effort force required to raise the motor using the drum winch?

- (A) 18.52 N
- (B) 163.33 N
- (C) 181.48 N – Answer**
- (D) 1323.00 N

**2024  
Paper 1  
Section 1  
Question 10**

**Machines in  
society**

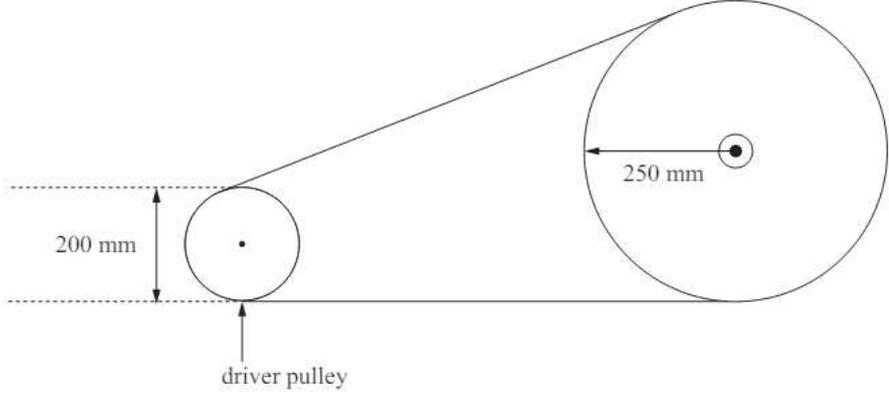
A 15 N force is required to raise a box a distance of 12 m using the simple pulley system shown. Assume the friction in the rope is negligible.



What is the work done to raise the box 12 m?

- (A) 3 J
- (B) 90 J
- (C) 180 J
- (D) 360 J – Answer**

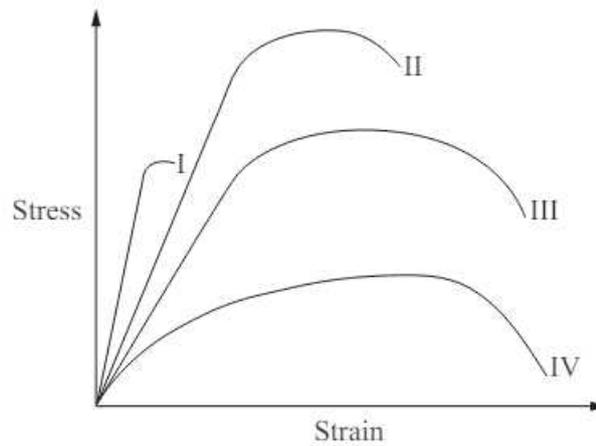
<p><b>2023</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 2</b> <b>Machines in society</b></p>	<p>The force required to just stop an 80 kg box from sliding down a 20° incline is</p> <p>(A) 97 N (B) 250 N <b>(C) 265 N – Answer</b> (D) 282 N</p>
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<p><b>2023</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 4</b> <b>Machines in society</b></p>	<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 <b>(D) 2.50 – Answer</b></p>
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<p><b>2023</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 5</b> <b>Machines in society</b></p>	<p>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?</p> <p>(A) 29% <b>(B) 70% – Answer</b> (C) 80% (D) 88%</p>
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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.**

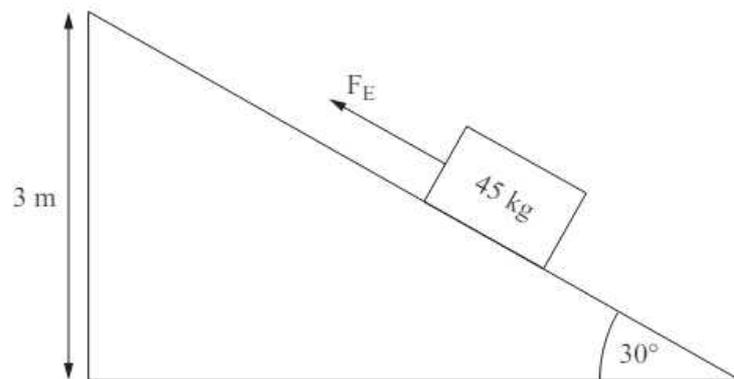
2023  
Paper 1  
Section 1  
Question 7  
  
Machines in  
society

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><b>2023</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 10</b></p> <p><b>Machines in society</b></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 <b>(C) 986 J – Answer</b> (D) 1066 J</p>
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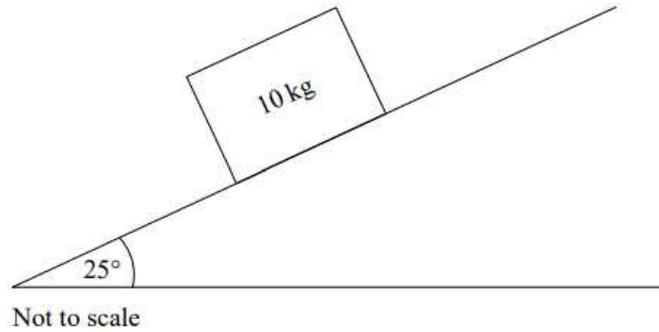
<p><b>2022</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 3</b></p> <p><b>Machines in society</b></p>	<p>During a race, the rear wheels of a go-kart exert a horizontal force of 100 N on the racetrack surface when the rear axle is rotating at 1000 revolutions per minute (rpm). The wheels have a diameter 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 <b>(C) 1.5 kW – Answer</b> (D) 0.73 kW</p>
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<p><b>2022</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 5</b></p> <p><b>Machines in society</b></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><b>(A) 1.47 MJ – Answer</b> (B) 1.67 MJ (C) 1.76 MJ (D) 1.86 MJ</p>
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<p><b>2022</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 7</b></p> <p><b>Machines in society</b></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 <b>(D) 8 N – Answer</b></p>
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<p><b>2022</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 9</b></p> <p><b>Machines in society</b></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/s<sup>2</sup> <b>(B) 208 m/s<sup>2</sup> – Answer</b> (C) 38 m/s<sup>2</sup> (D) 21 m/s<sup>2</sup></p>
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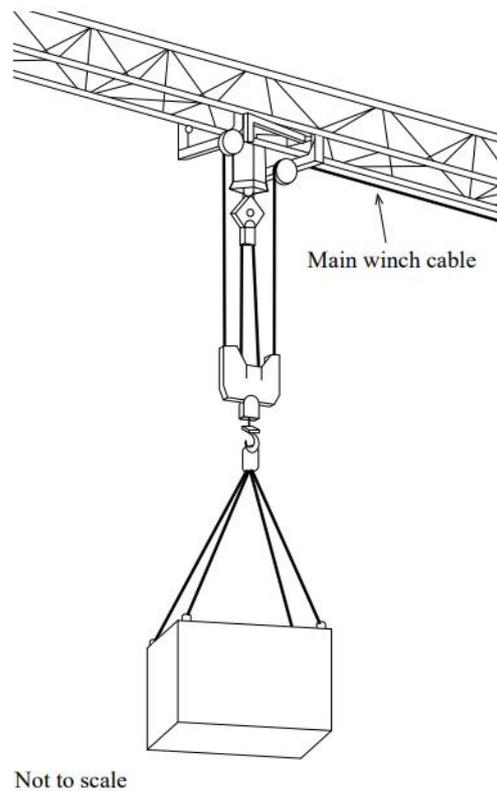
2021  
Paper 1  
Section 1  
Question 4  
  
Machines in  
society



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?

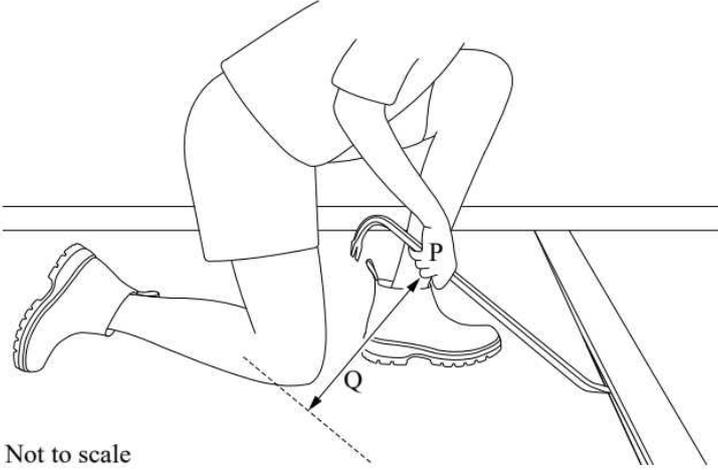
- (A)  $8.0 \text{ m/s}^2$
- (B)  $4.1 \text{ m/s}^2$
- (C)  $2.4 \text{ m/s}^2$  – Answer
- (D)  $1.8 \text{ m/s}^2$

2021  
Paper 1  
Section 1  
Question 5  
  
Machines in  
society



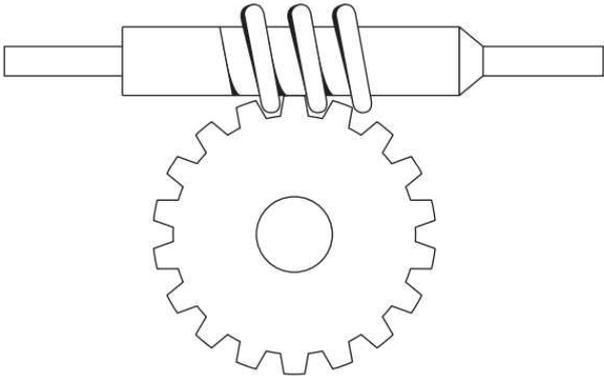
This crane vertically lifts a load a distance of 20 m using a pulley system. What distance must the main winch cable move during the vertical lift?

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

<p><b>2021</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 6</b></p> <p><b>Machines in society</b></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% <b>(C) 29% – Answer</b> (D) 10%</p>
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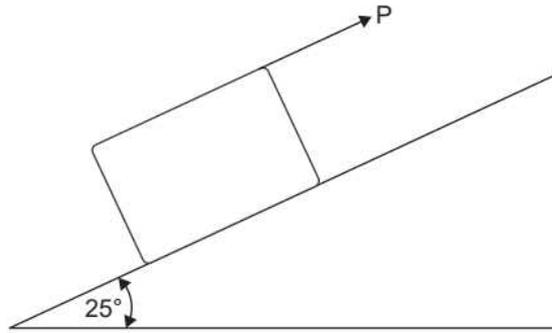
<p><b>2021</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 7</b></p> <p><b>Machines in society</b></p>	<p>A pulley system with an efficiency of 75% is used to vertically raise a 120 kg load a distance of 3 m. If the length of pulley rope pulled to raise the load is 8 m, the effort required is</p> <p>(A) 330 N. (B) 392 N. (C) 440 N. <b>(D) 588 N. – Answer</b></p>
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<p><b>2021</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 9</b></p> <p><b>Machines in society</b></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. <b>(C) 26 460 J. – Answer</b> (D) 81 667 J.</p>
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<p><b>2020</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 1</b></p> <p><b>Machines in society</b></p>	 <p>What is the gear ratio of this worm and wheel?</p> <p>(A) 1:6 (B) 6:3 <b>(C) 18:1 – Answer</b> (D) 18:3</p>
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2020  
Paper 1  
Section 1  
Question 2

Machines in  
society

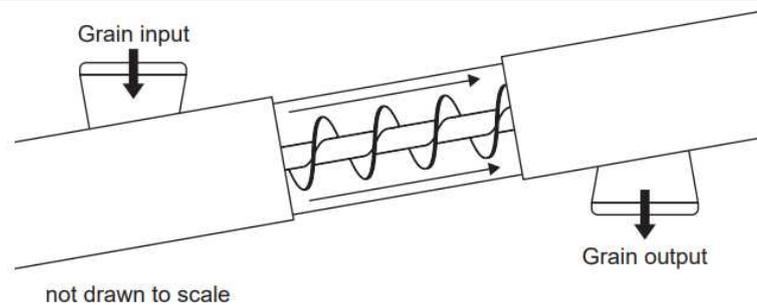


A 25 kg block is pulled up an incline using a force  $P$  as shown. What is the minimum value of  $P$  required to just move the box from rest if the coefficient of static friction is 0.4?

- (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 <sup>3</sup>	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 m<sup>3</sup>  
(B) 24 m<sup>3</sup> – Answer  
(C) 2.4 m<sup>3</sup>  
(D) 1.5 m<sup>3</sup>

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%

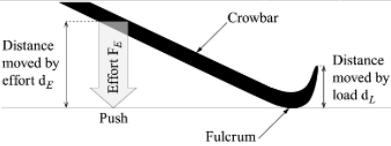
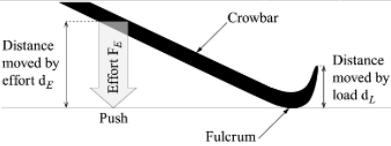
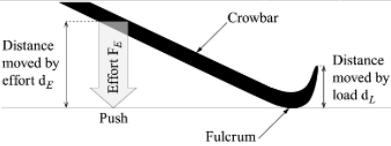
2020  
Paper 1  
Section 1  
Question 7

Machines in  
society

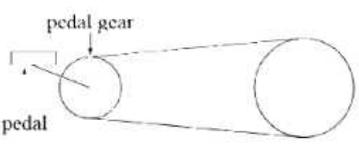
A 20 kg box sits just on the point of sliding on an incline plane. If the coefficient of static friction is 0.27, what is the angle of repose?

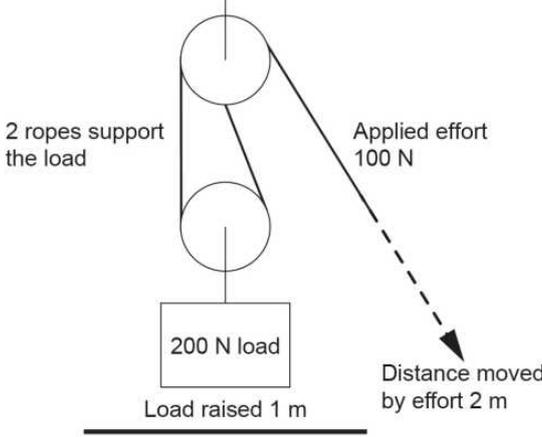
- (A) 5°  
(B) 13°  
(C) 15° – Answer  
(D) 16°

<b>2020</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 9</b> <b>Machines in</b> <b>society</b>	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>(B) 21 m – Answer</b> (C) 7 m (D) 2 m
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<p><b>2024</b> <b>Paper 1</b> <b>Section 2</b> <b>Question 11</b></p> <p><b>Machines in society</b></p>	<p>Explain the purpose of a crowbar using the concepts of mechanical advantage and velocity ratio. Include a sketch to support your response. [4 marks]</p> <table border="1" data-bbox="292 280 1489 728"> <thead> <tr> <th data-bbox="292 280 938 313">Sample response</th> <th data-bbox="938 280 1489 313">The response</th> </tr> </thead> <tbody> <tr> <td data-bbox="292 313 938 728">  <p>The purpose of a crowbar is to provide a mechanical advantage to reduce the effort (<math>F_E</math>) required to move a load (<math>F_L</math>) using a fulcrum. The crowbar provides mechanical advantage (<math>MA</math>) by dividing the force of the load by the force of the effort <math>MA = \frac{F_L}{F_E}</math>.</p> <p>When the fulcrum is closer to the load than the effort, the effort arm is longer and the crowbar has greater leverage, so the effort to move the load is reduced/amplified. The ratio between the distance moved by the effort (<math>d_E</math>) and the distance moved by the load (<math>d_L</math>) is referred to as the velocity ratio <math>VR = \frac{d_E}{d_L}</math>, which is a measure of how much a machine can amplify the effort applied to move the load.</p> </td> <td data-bbox="938 313 1489 728"> <ul style="list-style-type: none"> <li>includes an appropriate sketch of a crowbar [1 mark]</li> <li>explains the purpose of a crowbar appropriately, including wording relating to reduced/amplified effort force to move a load force [1 mark]</li> <li>uses the concept of <math>MA</math> appropriately, including wording that indicates that as the length of the effort arm increases, the effort required to move the load reduces [1 mark]</li> <li>uses the concept of <math>VR</math> appropriately, including wording that indicates the distance moved by the effort is divided by the distance the load is moved [1 mark]</li> </ul> </td> </tr> </tbody> </table>	Sample response	The response	 <p>The purpose of a crowbar is to provide a mechanical advantage to reduce the effort (<math>F_E</math>) required to move a load (<math>F_L</math>) using a fulcrum. The crowbar provides mechanical advantage (<math>MA</math>) by dividing the force of the load by the force of the effort <math>MA = \frac{F_L}{F_E}</math>.</p> <p>When the fulcrum is closer to the load than the effort, the effort arm is longer and the crowbar has greater leverage, so the effort to move the load is reduced/amplified. The ratio between the distance moved by the effort (<math>d_E</math>) and the distance moved by the load (<math>d_L</math>) is referred to as the velocity ratio <math>VR = \frac{d_E}{d_L}</math>, which is a measure of how much a machine can amplify the effort applied to move the load.</p>	<ul style="list-style-type: none"> <li>includes an appropriate sketch of a crowbar [1 mark]</li> <li>explains the purpose of a crowbar appropriately, including wording relating to reduced/amplified effort force to move a load force [1 mark]</li> <li>uses the concept of <math>MA</math> appropriately, including wording that indicates that as the length of the effort arm increases, the effort required to move the load reduces [1 mark]</li> <li>uses the concept of <math>VR</math> appropriately, including wording that indicates the distance moved by the effort is divided by the distance the load is moved [1 mark]</li> </ul>
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<p><b>2024</b> <b>Paper 1</b> <b>Section 2</b> <b>Question 16</b></p> <p><b>Machines in society</b></p>	<p>During a flood event communities can find themselves isolated, without power and unable to access basic supplies and health care. The risk of further rainfall and submerged roads can hamper rescue efforts.</p> <p>Explain how mechatronics engineers have used their expertise of control technology, materials science and mechanics to develop machines to benefit communities affected by flood events. Include the type of machine used and two benefits for the community. [6 marks]</p> <table border="1" data-bbox="292 1064 1489 1310"> <thead> <tr> <th data-bbox="292 1064 890 1097">Sample response</th> <th data-bbox="890 1064 1489 1097">The response</th> </tr> </thead> <tbody> <tr> <td data-bbox="292 1097 890 1310"> <p>Mechatronics engineers have used machines such as drones to benefit communities affected by flood events. Drones can be quickly deployed to survey flood-affected areas too dangerous for humans to access, assess damage, identify risks, e.g. submerged roads or fallen powerlines, and identify people who need to be rescued. Drones can also be used to get supplies to people until they can be safely rescued.</p> <p>Engineers have used their expertise with control technology to develop drones equipped with sensors, GPS and altitude controls that help to navigate and stabilise the drones during flight. They have used their expertise with materials science and mechanics to reduce the weight of drones and make them more aerodynamic, so they are more energy efficient.</p> </td> <td data-bbox="890 1097 1489 1310"> <ul style="list-style-type: none"> <li>identifies the machine involved [1 mark]</li> <li>describes a valid benefit for the community [1 mark]</li> <li>describes a second valid benefit for the community [1 mark]</li> <li>discusses how the engineers have used their expertise, including                             <ul style="list-style-type: none"> <li>a valid example from control technology [1 mark]</li> <li>a valid example from materials science [1 mark]</li> <li>a valid example from mechanics [1 mark]</li> </ul> </li> </ul> </td> </tr> </tbody> </table>	Sample response	The response	<p>Mechatronics engineers have used machines such as drones to benefit communities affected by flood events. Drones can be quickly deployed to survey flood-affected areas too dangerous for humans to access, assess damage, identify risks, e.g. submerged roads or fallen powerlines, and identify people who need to be rescued. Drones can also be used to get supplies to people until they can be safely rescued.</p> <p>Engineers have used their expertise with control technology to develop drones equipped with sensors, GPS and altitude controls that help to navigate and stabilise the drones during flight. They have used their expertise with materials science and mechanics to reduce the weight of drones and make them more aerodynamic, so they are more energy efficient.</p>	<ul style="list-style-type: none"> <li>identifies the machine involved [1 mark]</li> <li>describes a valid benefit for the community [1 mark]</li> <li>describes a second valid benefit for the community [1 mark]</li> <li>discusses how the engineers have used their expertise, including                             <ul style="list-style-type: none"> <li>a valid example from control technology [1 mark]</li> <li>a valid example from materials science [1 mark]</li> <li>a valid example from mechanics [1 mark]</li> </ul> </li> </ul>
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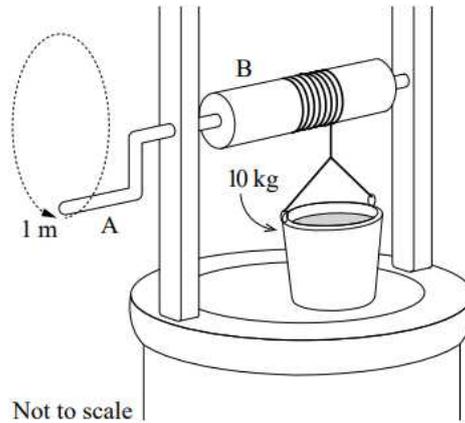
<p><b>2023</b> <b>Paper 1</b> <b>Section 2</b> <b>Question 12</b></p> <p><b>Machines in society</b></p>	<p>Explain how the gearing system on a bicycle provides a mechanical advantage to a cyclist moving up an incline, and the system's effect on the work done on the pedals. Sketch the mechanical components involved to support your response. (5 marks)</p>	
	<p style="text-align: center;"><b>Sample response</b></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>	<p style="text-align: center;"><b>The response</b></p> <ul style="list-style-type: none"> <li>• appropriately explains the mechanical advantage, using wording that indicates <ul style="list-style-type: none"> <li>- the pedal gear would be smaller than the rear wheel gear [1 mark]</li> <li>- work done remains the same [1 mark]</li> <li>- less force is required to move the pedals [1 mark]</li> <li>- more rotations of the pedals will be required [1 mark]</li> </ul> </li> <li>• provides an appropriate sketch, including the larger rear wheel gear linked to the smaller pedal gear [1 mark]</li> </ul>

<p><b>2022</b> <b>Paper 1</b> <b>Section 2</b> <b>Question 11</b></p> <p><b>Machines in society</b></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 style="text-align: center;"><b>Sample response</b></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>	<p style="text-align: center;"><b>The response</b></p> <ul style="list-style-type: none"> <li>• 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]</li> <li>• explains VR appropriately using wording that indicates the distance moved by the effort divided by the distance the load is moved [1 mark]</li> <li>• provides an appropriately annotated sketch including <ul style="list-style-type: none"> <li>- effort [1 mark]</li> <li>- load [1 mark]</li> <li>- distance moved by effort and load [1 mark]</li> </ul> </li> </ul>

**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 <math>MA = VR = \frac{dE}{dL}</math>) 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. <math>\frac{980}{30} = 32.7W</math>.</p>	<ul style="list-style-type: none"> <li>• explains appropriately showing logical organisation of relevant information about key steps that includes mathematical reasoning</li> <li>- using the correct formula for work [1 mark]</li> <li>- using the correct formula for power [1 mark]</li> <li>- using the correct value for MA [1 mark]</li> <li>• includes the correct determination of</li> <li>- work done [1 mark]</li> <li>- power used [1 mark]</li> </ul>

**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"> <li>• describes a relevant community problem related to a relevant sustainability issue [1 mark]</li> <li>• explains how engineers have</li> <li>- used relevant knowledge [1 mark]</li> <li>- to develop a solution [1 mark]</li> <li>• explains how the solution</li> <li>- reduced environmental impact [1 mark]</li> <li>- provided a relevant community benefit [1 mark]</li> <li>- provided another relevant community benefit [1 mark]</li> </ul>

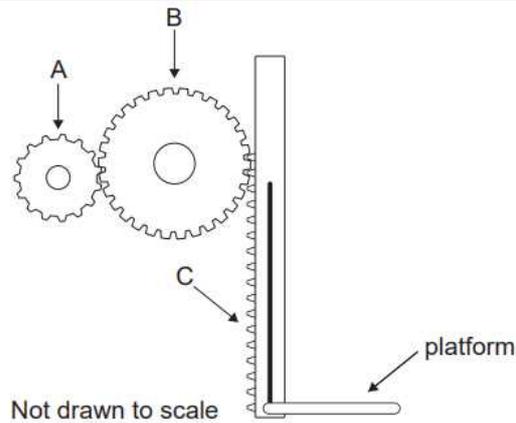
**2020  
Paper 1  
Section 2  
Question 15**

**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"> <li>• explains appropriately using               <ul style="list-style-type: none"> <li>- 1 relevant environmental factor [1 mark]</li> <li>- another relevant environmental factor [1 mark]</li> </ul> </li> <li>• explains appropriately using               <ul style="list-style-type: none"> <li>- 1 relevant economic factor [1 mark]</li> <li>- another relevant economic factor [1 mark]</li> </ul> </li> <li>• explains appropriately using               <ul style="list-style-type: none"> <li>- 1 relevant sustainability factor [1 mark]</li> <li>- another relevant sustainability factor [1 mark]</li> </ul> </li> </ul>

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"> <li>• explains correctly and includes</li> <li>- identification of rack and pinion gears [1 mark]</li> <li>- an accurate numerical relationship between linear and rotational movement of the rack and pinion gears [1 mark]</li> <li>- an accurate gear ratio of gear A to B [1 mark]</li> <li>- an accurate gear ratio of gear A to C [1 mark]</li> <li>- evidence of mathematical reasoning [1 mark]</li> </ul>

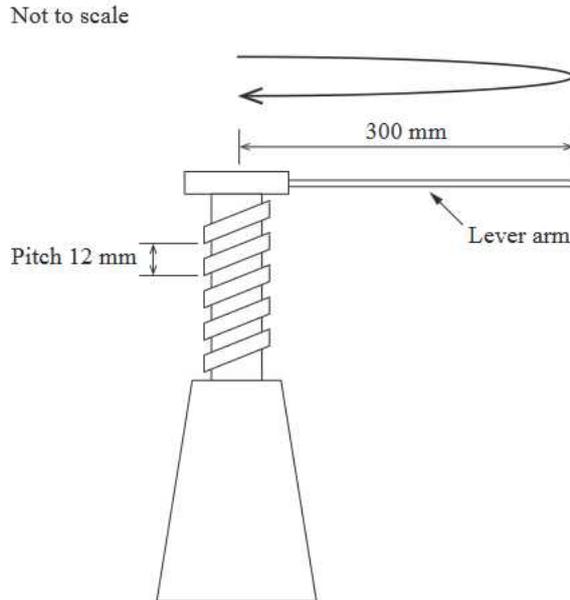
Marking Guide – Paper 1 Section 3

<p><b>2024</b> <b>Paper 1</b> <b>Section 3</b> <b>Question 17</b></p> <p><b>Machines in society</b></p>	<p>A car with a mass of 1300 kg is parked on a driveway that makes an inclined angle of 25° to the horizontal.</p>	
	<p>a) Calculate the normal force acting on the car. [2 marks]</p>	
	<p><b>Sample response</b></p> $\sum F_y = 0$ $F_N = F_V$ $= mg \cos \theta$ $= 1300 \times 9.8 \cos 25$ $= 11.55 \text{ kN}$	<p><b>The response</b></p> <ul style="list-style-type: none"> <li>• correctly determines the method required to calculate the normal force [1 mark]</li> <li>• correctly calculates the normal force acting on the car [1 mark]</li> </ul>
	<p>b) Calculate the coefficient of static friction required between the car tyres and the driveway to prevent the car from rolling. [2 marks]</p>	
<p><b>Sample response</b></p> $\sum F_x = 0$ $F_s = F_H$ $= mg \sin \theta$ $F_s = \mu_s F_N$ $\mu_s = \frac{F_s}{F_N}$ $= \frac{mg \sin \theta}{mg \cos \theta}$ $= \frac{1300 \times 9.8 \sin 25}{1300 \times 9.8 \cos 25}$ $= 0.47$	<p><b>The response</b></p> <ul style="list-style-type: none"> <li>• correctly determines the method required to calculate the coefficient of static friction [1 mark]</li> <li>• correctly calculates the coefficient of static friction required to prevent the car from rolling [1 mark]</li> </ul>	

**2024  
Paper 1  
Section 3  
Question 18**

**Machines in  
society**

An effort of 120 N is applied at the end of the lever arm of a screw jack for 180 seconds to raise an object 150 mm.



a) Calculate the work done on the lever arm. [4 marks]

Sample response	The response
<p>Number of rotations = <math>\frac{150}{12}</math> = 12.5 rotations</p> <p>Distance travelled for 12.5 rotations  <math>d = 12.5 \times 2\pi r</math>  <math>= 12.5 \times 2 \times \pi \times 0.3</math>  <math>= 23.56 \text{ m}</math></p> <p>Work done  <math>W = F \times d</math>  <math>= 120 \times 23.56</math>  <math>= 2827.2 \text{ J}</math></p>	<ul style="list-style-type: none"> <li>demonstrates appropriate mathematical reasoning to determine correct number of rotations [1 mark]</li> <li>recognises that radius needs to be converted from mm to metres [1 mark]</li> <li>calculates the distance travelled by the effort [1 mark]</li> <li>calculates work done [1 mark]</li> </ul>

b) Calculate the power input. [1 mark]

Sample response	The response
<p>Power  <math>P = \frac{W}{t}</math>  <math>= \frac{2827.2}{180}</math>  <math>= 15.71 \text{ W}</math></p>	<p>calculates power input [1 mark]</p>

**2024  
Paper 1  
Section 3  
Question 20**

**Machines in  
society**

A parcel slides down an inclined ramp, which is at  $20^\circ$  to the horizontal plane, at a constant velocity. The parcel experiences a normal force of 98.2 N. A coefficient of kinetic friction of 0.37 and a coefficient of static friction of 0.39 exist between the parcel and the ramp.

Determine the mass of the parcel. [4 marks]

Sample response	The response
<p><b>Method 1</b></p> <p>Forces perpendicular to the inclined plane are balanced, so  <math>F_{\perp} = F_N</math>  <math>F_N = mg \cos\theta</math></p> $m = \frac{9.82}{9.8 \cos 20}$ $m = 10.66 \text{ kg}$	<ul style="list-style-type: none"> <li>recognises that forces are balanced, therefore <math>F_{\perp} = F_N</math> [1 mark]</li> <li>recognises <math>F_N = mg \cos\theta</math> [1 mark]</li> <li>correctly substitutes values [1 mark]</li> <li>determines the mass of the parcel [1 mark]</li> </ul>
<p><b>Method 2</b></p> <p>When velocity is constant, acceleration = 0.  <math>\therefore</math> forces parallel to the inclined plane are balanced, so  <math>F_{\parallel} = F_f</math></p> $mg \sin\theta = \mu_k F_N$ $m = \frac{\mu_k F_N}{g \sin\theta}$ $m = \frac{0.37 \times 98.2}{9.8 \sin 20}$ $m = 10.84 \text{ kg}$	<ul style="list-style-type: none"> <li>recognises that forces are balanced, therefore <math>F_{\parallel} = F_f</math> [1 mark]</li> <li>recognises <math>F_{\parallel} = mg \sin\theta</math> and <math>F_f = \mu_k F_N</math> [1 mark]</li> <li>correctly substitutes values [1 mark]</li> <li>determines the mass of the parcel [1 mark]</li> </ul>

**2024  
Paper 1  
Section 3  
Question 21**

**Machines in  
society**

A lift has a total mass of 1000 kg. The lift undergoes uniform acceleration from a stationary position on the ground floor until it reaches a height of 10 m and has a total mechanical energy of 106 kJ. From this point it continues to travel vertically at a constant velocity.

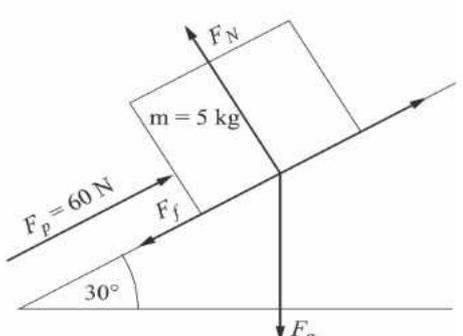
Determine the time taken for the lift to reach its constant velocity. [10 marks]

Sample response	The response
$PE = mgh$ $= 1000 \times 9.8 \times 10$ $= 98 \text{ kJ}$ $E = KE + PE$ $106 = KE + 98$ $KE = 106 - 98$ $= 8 \text{ kJ}$ $KE = \frac{1}{2}mv^2$ $8000 = \frac{1}{2}1000v^2$ $v = \sqrt{\frac{2 \times 8000}{1000}}$ $= \sqrt{16}$ $= 4 \text{ m/s}$ $v^2 = u^2 + 2as$ $4^2 = 0^2 + 2a(10)$ $16 = 20a$ $a = \frac{16}{20}$ $a = 0.8 \text{ m/s}^2$ $v = u + at$ $4 = 0 + 0.8t$ $t = \frac{4}{0.8}$ $t = 5 \text{ s}$	<ul style="list-style-type: none"> <li>• identifies that potential energy needs to be calculated first [1 mark]</li> <li>• correctly calculates the potential energy [1 mark]</li>   <li>• recognises that total mechanical energy is equal to the sum of potential energy and kinetic energy [1 mark]</li> <li>• calculates the kinetic energy [1 mark]</li>   <li>• identifies that velocity can be calculated from mass and kinetic energy [1 mark]</li>   <li>• calculates the velocity [1 mark]</li>   <li>• identifies the correct formula for motion to calculate the acceleration [1 mark]</li>   <li>• calculates the acceleration [1 mark]</li>   <li>• identifies the correct formula for motion to calculate the time [1 mark]</li>   <li>• calculates the time [1 mark]</li> </ul>

2024  
Paper 1  
Section 3  
Question 22  
Machines in  
society

A sorting conveyor cart in a recycling plant is initially at rest and has a mass of 5 kg. It is pushed a distance of 3 m up a 30° incline using a force of 60 N parallel to the incline. Assume  $\mu_k = \mu_s = 0.58$ .

Determine the time taken to move the cart 3 m up the incline. Include a free-body diagram showing all the forces involved.

Sample response	The response
<p>Not to scale</p>  <p>Horizontal component of weight <math>F_{\parallel} = mg \sin \theta</math> Vertical component of weight <math>F_{\perp} = mg \cos \theta</math></p> $F_N = F_{\perp}$ $F_N = mg \cos \theta$ $= 5 \times 9.8 \times \cos 30$ $= 42.44 \text{ N}$ $F_f = \mu_k F_N$ $= 0.58 \times 42.44$ $= 24.62 \text{ N}$ $F_{\parallel} = mg \sin \theta$ $= 5 \times 9.8 \times \sin 30$ $= 24.5 \text{ N}$ $F_{\text{net}} = F_H - F_{\parallel} - F_f$ $= 60 - 24.5 - 24.62 \text{ N}$ $= 10.88 \text{ N}$ $a = \frac{F}{m}$ $= \frac{10.88}{5}$ $= 2.18 \text{ m/s}^2$ $s = ut + \frac{1}{2}at^2$ $3 = 0t + \frac{1}{2}(2.18)t^2$ $6 = (2.18)t^2$ $t^2 = \frac{6}{2.18}$ $t = \sqrt{\frac{6}{2.18}}$ $t = 1.66 \text{ s}$ <p>The object takes 1.66 s to travel 3 m up the incline.</p>	<ul style="list-style-type: none"> <li>includes an appropriate free-body diagram showing all forces [1 mark]</li> <li>determines the normal force [1 mark]</li> <li>determines the frictional force [1 mark]</li> <li>determines the parallel force [1 mark]</li> <li>determines the net force [1 mark]</li> <li>determines the acceleration [1 mark]</li> <li>demonstrates appropriate mathematical reasoning to calculate the time [1 mark]</li> <li>determines the time taken to displace the object 3 m up the incline [1 mark]</li> </ul>

**2023**  
**Paper 1**  
**Section 3**  
**Question 16**  
**Machines in**  
**society**

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.

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)

Sample response	The response
$KE = \frac{1}{2}mv^2$ $\text{Storage container mass} = \frac{2 \times KE}{v^2} = \frac{2 \times 850}{1.5^2} = \frac{1700}{2.25} = 755.56 \text{ kg}$ $PE = mgh$ $PE = 755.56 \times 9.8 \times 2 = 14\,808.98 \text{ J}$ $ME = KE + PE$ $ME = 850 + 14\,808.98$ $ME = 15\,659 \text{ J}$	<ul style="list-style-type: none"> <li>• provides correct formula and substituted values for mass [1 mark]</li> <li>• determines mass [1 mark]</li>   <li>• provides correct formula and substituted values for PE [1 mark]</li> <li>• determines PE [1 mark]</li>   <li>• determines the answer in J to the nearest whole unit [1 mark]</li> </ul>

**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%.

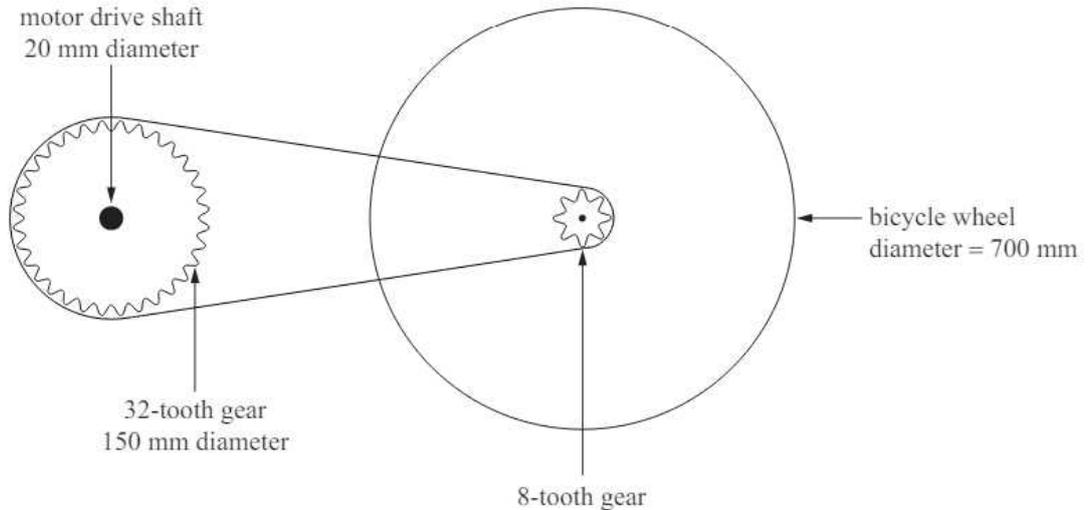
Determine the power required from the motor to raise the load in 15 seconds. Answer to one decimal place. (9 marks)

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 = <math>\frac{2.5 \text{ m}}{0.0025} = 1000</math></p> <p>Distance travelled by effort = 1000 x <math>\pi</math> 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"> <li>• determines the vertical distance the load is raised [1 mark]</li> <li>• provides correct formula and substituted values for VR of the thread mechanism [1 mark]</li> <li>• determines VR of the thread mechanism [1 mark]</li> <li>• determines MA [1 mark]</li> <li>• determines effort [1 mark]</li> <li>• determines rotations of shaft [1 mark]</li> <li>• determines distance effort [1 mark]</li> <li>• determines input Work [1 mark]</li> <li>• determines Input power [1 mark]</li> </ul>
<p><b>OR</b></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><b>OR</b></p> <ul style="list-style-type: none"> <li>• Identify that output work =change in PE [1 mark]</li> <li>• Correctly identify power equation [1 mark]</li> <li>• Correctly substitute into power equation [1 mark]</li> <li>• Correctly determine output power [1 mark]</li> <li>• Correctly identify efficiency equals output power/ input power [1 mark]</li> <li>• Correctly substitute into equation [1 mark]</li> <li>• Correctly determine input power [1 mark]</li> <li>• Correctly round to 1 decimal place [1 mark]</li> <li>• Correct unit for power [1 mark]</li> </ul>

**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 =  <math>\pi D = \pi \times 0.7 = 2.199 \text{ m}</math></p> <p>Number of rotations of driven for 15m  <math>= \frac{15}{2.199} = 6.82 \text{ rotations}</math></p> <p><math>\therefore</math> Number of rotations of driver = <math>6.82 \times 0.25 = 1.7</math></p>	<ul style="list-style-type: none"> <li>determines the VR / GR of the driven to driver gears [1 mark]</li> <li>determines answer to one decimal place [1 mark]</li> </ul>

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

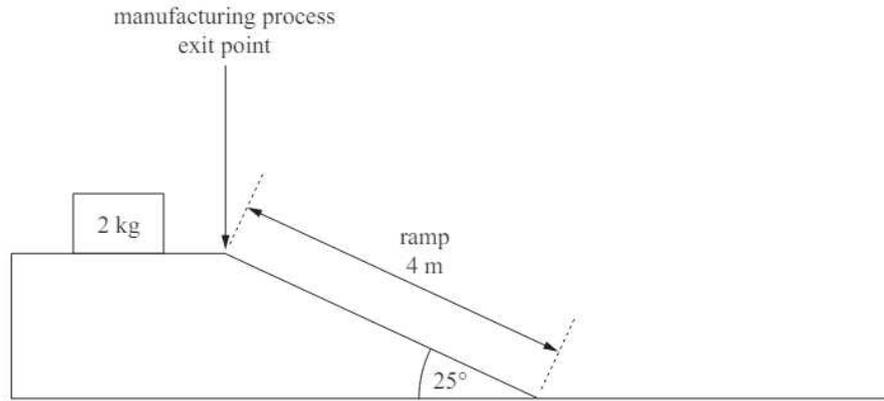
c) Determine the output power of the electric motor if the bicycle wheel takes 2 seconds to travel 15 m. Answer to the nearest whole unit. [3 marks]

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

**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"> <li>determines the force of friction on the ramp [1 mark]</li> </ul>
<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"> <li>determines parallel force down the ramp [1 mark]</li> </ul>
<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"> <li>determines resultant force down the ramp [1 mark]</li> </ul>
<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"> <li>determines ramp acceleration [1 mark]</li> </ul>
<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"> <li>provides correct formula and substituted values for velocity [1 mark]</li> <li>determines velocity at the bottom of the ramp [1 mark]</li> </ul>

	<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"> <li>• determines force of friction on the horizontal surface [1 mark]</li> <li>• determines deceleration on the horizontal surface [1 mark]</li> <li>• determines the answer to the nearest whole unit [1 mark]</li> </ul>
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<p><b>2023</b> <b>Paper 1</b> <b>Section 3</b> <b>Question 20</b></p> <p><b>Machines in society</b></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="width: 50%; text-align: center;">Sample response</th> <th style="width: 50%; text-align: center;">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 = <math>\mu_k</math></p> <p>160 N = <math>F_f</math> + weight force component parallel to the incline</p>   <math display="block">160 = \mu_k F_N + mg \sin 10</math> <math display="block">160 - mg \sin 10 = \mu_k \times mg \cos 10</math> <math display="block">160 - 20 \times 9.8 \times \sin 10 = \mu_k \times 20 \times 9.8 \times \cos 10</math> <math display="block">\mu_k = \frac{160 - 196 \times \sin 10}{196 \times \cos 10}</math> <math display="block">\mu_k = \frac{160 - 34.04}{193} = 0.65</math> <p>∴ the coefficient of friction = 0.65</p> </td> <td style="padding: 5px; vertical-align: top;"> <ul style="list-style-type: none"> <li>• indicates that the system is in equilibrium [1 mark]</li> <li>• identifies three forces parallel to the incline [1 mark]</li> <li>• provides correct formula and substituted values [1 mark]</li> <li>• correctly manipulates equation to isolate coefficient of friction [1 mark]</li> <li>• determines the answer to two decimal places [1 mark]</li> </ul> </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 = <math>\mu_k</math></p> <p>160 N = <math>F_f</math> + 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"> <li>• indicates that the system is in equilibrium [1 mark]</li> <li>• identifies three forces parallel to the incline [1 mark]</li> <li>• provides correct formula and substituted values [1 mark]</li> <li>• correctly manipulates equation to isolate coefficient of friction [1 mark]</li> <li>• determines the answer to two decimal places [1 mark]</li> </ul>	
Sample response	The response					
<p>Uniform or constant velocity ∴ forces up incline = forces down incline</p> <p>Let the coefficient of friction = <math>\mu_k</math></p> <p>160 N = <math>F_f</math> + 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"> <li>• indicates that the system is in equilibrium [1 mark]</li> <li>• identifies three forces parallel to the incline [1 mark]</li> <li>• provides correct formula and substituted values [1 mark]</li> <li>• correctly manipulates equation to isolate coefficient of friction [1 mark]</li> <li>• determines the answer to two decimal places [1 mark]</li> </ul>					

**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"> <li>• determines the work done by the first pump [1 mark]</li>   <li>• determines the power output of the first pump [1 mark]</li>   <li>• determines the power input of the first pump [1 mark]</li>   <li>• determines the work done by the second pump [1 mark]</li> </ul>

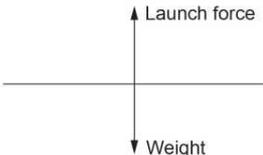
	<p>Power output: Second pump</p> $P = \frac{\text{work done}}{\text{time taken}} = \frac{W}{t}$ $P = \frac{19\,600}{60}$ $P = 326.67 \text{ W}$ <p>Power input: Second pump</p> $\eta = \frac{\text{useful output}}{\text{input}}$ $\text{input} = \frac{\text{useful output}}{\eta}$ $\text{Power input} = \frac{326.67}{0.75}$ $\text{Power input} = 435.56 \text{ W}$ <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"> <li>determines the power output of the second pump [1 mark]</li> <li>determines the power input of the second pump [1 mark]</li> <li>determines the overall power input of the current two-stage system [1 mark]</li> <li>determines the power output of the new single-pump system [1 mark]</li> </ul>
	<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"> <li>determines the work done by the new single-pump system [1 mark]</li> <li>determines the answer in litres per minute to the nearest whole unit [1 mark]</li> </ul>

**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 = <math>2000 \times 9.8 = 19\,600\text{ N}</math></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><math>F = ma</math></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 <b>220 kN</b> to reach a vertical height of 20 km in 20 s.</p>	<ul style="list-style-type: none"> <li>• provides an appropriate free-body diagram [1 mark]</li> <li>• correctly determines weight [1 mark]</li> <li>• provides correct formula and substituted values for acceleration [1 mark]</li> <li>• correctly determines acceleration [1 mark]</li> <li>• correctly determines the answer in kN to the nearest whole unit [1 mark]</li> </ul>

**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.

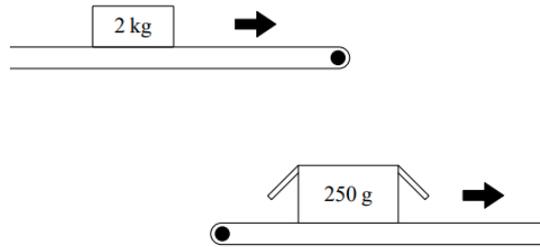
Determine the stopped position of the cable car relative to the warning siren's activation point. Answer to the nearest whole unit in metres. [9 marks]

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"> <li>correctly determines the initial frictional force [1 mark]</li> </ul>
$F_p = mg \sin \theta$ $F_p = 1500 \times 9.8 \times \sin 25 = 6212.49 \text{ N}$	<ul style="list-style-type: none"> <li>correctly determines the force down the incline [1 mark]</li> </ul>
$F_{\text{net}} = 6212.49 - 133.23 = 6079.26 \text{ N}$	<ul style="list-style-type: none"> <li>correctly determines the net force [1 mark]</li> </ul>
$F = ma$ $a = \frac{F}{m} = \frac{6079.26}{1500} = 4.1 \text{ m/s}^2$	<ul style="list-style-type: none"> <li>correctly determines the acceleration [1 mark]</li> </ul>
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"> <li>correctly determines the displacement before brakes engage [1 mark]</li> </ul>
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"> <li>correctly determines the net force after brakes engage [1 mark]</li> </ul>
$F = ma$ $a = \frac{F}{m} = \frac{-1781.14}{1500} = -1.19 \text{ m/s}^2$	<ul style="list-style-type: none"> <li>correctly determines the deceleration after brakes engage [1 mark]</li> </ul>
$u = \frac{5\text{m}}{\text{s}} \quad v = \frac{0\text{m}}{\text{s}}$ $v^2 = u^2 + 2as$ $s = \frac{v^2 - u^2}{2a} = \frac{0^2 - 5^2}{2 \times -1.19} = 10.50 \text{ m}$	<ul style="list-style-type: none"> <li>correctly determines the displacement after brakes engage [1 mark]</li> </ul>
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"> <li>correctly determines the answer to the nearest whole unit [1 mark]</li> </ul>

**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]

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

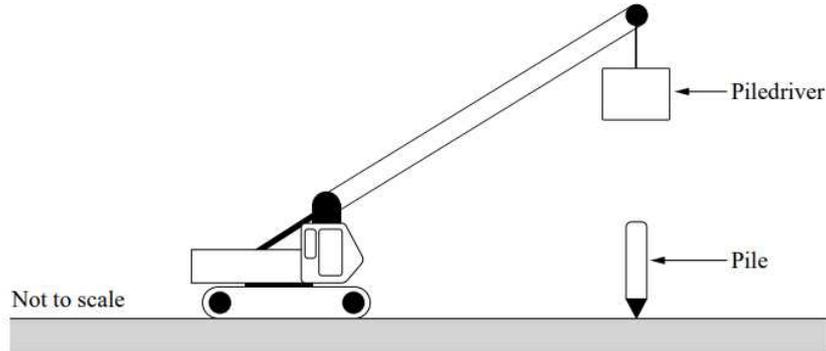
b) If the coefficient of kinetic friction is 0.3, determine the distance the carton slides along the conveyor surface after the package lands in it. Answer to the nearest whole unit (mm). Include a free-body diagram with your working. [5 marks]

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  <math>u_k = 0.30</math>  <math>F_N = 2.25 \times 9.8 = 22.05 \text{ N}</math>  <math>F_f = u_k \times F_N = 0.30 \times 22.05 = 6.62 \text{ N}</math>            Deceleration <math>\approx a = \frac{F}{m} = \frac{6.62}{2.25} = 2.94 \text{ m/s}^2</math>  <math>s = \frac{v^2 - u^2}{2a}</math>  <math>= \frac{0 - 3^2}{2 \times -2.94} = 1.53 \text{ m} = 1530 \text{ mm}</math> </p>	<ul style="list-style-type: none"> <li>• provides an appropriate free-body diagram [1 mark]</li> <li>• provides correct working to give correct normal force acting on the box and carton [1 mark]</li> <li>• provides correct working to give correct force of kinetic friction [1 mark]</li> <li>• provides correct working to give correct deceleration [1 mark]</li> <li>• provides correct working to give correct answer to the nearest whole unit with correct unit provided [1 mark]</li> </ul>

**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]

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

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

**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  $0.75 \text{ m/s}^2$  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"> <li>• provides correct formula and substituted values [1 mark]</li> <li>• provides correct working to give correct answer to the nearest whole unit [1 mark]</li> <li>• provides correct unit for velocity (m/s) [1 mark]</li> </ul>

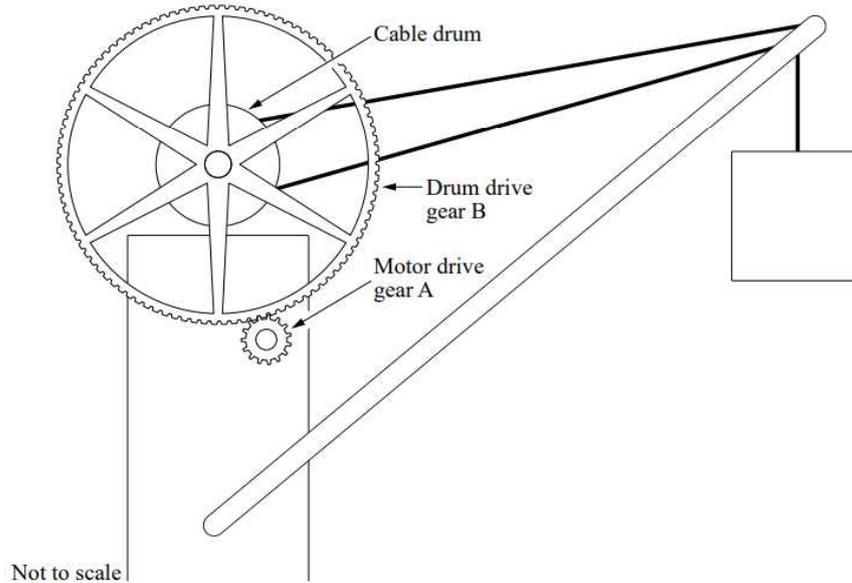
b) From rest, the bucket is lowered from the top of the shaft with a constant acceleration. Determine the bucket's acceleration if the bucket has been lowered 25 m after 10 s. Answer to one decimal place. [2 marks]

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"> <li>• provides correct formula and substituted values [1 mark]</li> <li>• provides correct working to give correct answer to one decimal place with correct unit provided [1 mark]</li> </ul>

**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]

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"> <li>• provides correct working to give correct work [1 mark]</li> <li>• provides correct working to give correct answer to two decimal places with correct unit provided [1 mark]</li> </ul>

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

**2021  
Paper 1  
Section 3  
Question 23**

**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  $2 \text{ m/s}^2$ , 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><math>\therefore</math> 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"> <li>• provides correct formula and substituted values for velocity [1 mark]</li> <li>• provides correct working to give correct velocity [1 mark]</li> <li>• provides correct formula and substituted values for time [1 mark]</li> <li>• provides correct working to give correct time [1 mark]</li> <li>• provides correct working to give correct 20% time reduction [1 mark]</li> <li>• provides correct formula and substituted values for acceleration [1 mark]</li> <li>• provides correct working to give correct acceleration [1 mark]</li> <li>• provides correct working to give correct force of friction [1 mark]</li> <li>• provides correct formula and substituted values for coefficient of static friction [1 mark]</li> <li>• provides correct working to give correct answer to two decimal places [1 mark]</li> </ul>

<p><b>2020</b> <b>Paper 1</b> <b>Section 3</b> <b>Question 18</b></p> <p><b>Machines in society</b></p>	<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> <math>\mu_s = \tan \theta = \tan 30 = 0.58</math> </td> <td> <ul style="list-style-type: none"> <li>provides correct working to give correct coefficient of static friction to two decimal places [1 mark]</li> </ul> </td> </tr> </tbody> </table>	Sample response	The response	$\mu_s = \tan \theta = \tan 30 = 0.58$	<ul style="list-style-type: none"> <li>provides correct working to give correct coefficient of static friction to two decimal places [1 mark]</li> </ul>
	Sample response	The response			
	$\mu_s = \tan \theta = \tan 30 = 0.58$	<ul style="list-style-type: none"> <li>provides correct working to give correct coefficient of static friction to two decimal places [1 mark]</li> </ul>			
<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 = <math>\frac{9.8}{3} = 3.27 \text{ m/s}^2</math></p> <p><math>F_f = \mu_s F_N</math></p> <p><math>F_f = \mu_s mg \cos \theta</math></p> <p><math>= 0.58 \times 900 \times 3.27 \times \cos 30</math></p> <p><math>= 1478.25 \text{ N} \approx 1478 \text{ N}</math></p> </td> <td> <ul style="list-style-type: none"> <li>provides correct formula and substituted values [1 mark]</li> <li>provides correct answer to the nearest whole unit with correct unit provided [1 mark]</li> </ul> </td> </tr> </tbody> </table>	Sample response	The response	<p>Acceleration on Mars = <math>\frac{9.8}{3} = 3.27 \text{ m/s}^2</math></p> <p><math>F_f = \mu_s F_N</math></p> <p><math>F_f = \mu_s mg \cos \theta</math></p> <p><math>= 0.58 \times 900 \times 3.27 \times \cos 30</math></p> <p><math>= 1478.25 \text{ N} \approx 1478 \text{ N}</math></p>	<ul style="list-style-type: none"> <li>provides correct formula and substituted values [1 mark]</li> <li>provides correct answer to the nearest whole unit with correct unit provided [1 mark]</li> </ul>	
Sample response	The response				
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<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 <math>\mu_s</math> will be the same quantity on both Mars and Earth.</p> </td> <td> <ul style="list-style-type: none"> <li>explains using wording indicative of</li> <li>- <math>\mu_s</math> depends only on the angle of repose [1 mark]</li> <li>- <math>\mu_s</math> is the same on Mars and Earth [1 mark]</li> </ul> </td> </tr> </tbody> </table>	Sample response	The response	<p>The coefficient of static friction depends only on the angle of repose. Therefore <math>\mu_s</math> will be the same quantity on both Mars and Earth.</p>	<ul style="list-style-type: none"> <li>explains using wording indicative of</li> <li>- <math>\mu_s</math> depends only on the angle of repose [1 mark]</li> <li>- <math>\mu_s</math> is the same on Mars and Earth [1 mark]</li> </ul>	
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<p><b>2020</b> <b>Paper 1</b> <b>Section 3</b> <b>Question 19</b></p> <p><b>Machines in society</b></p>	<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> <math>P = \frac{W}{t}</math>  <math>4355 = \frac{W}{90}</math>  <math>W = 4355 \times 90 = 391\,950 \text{ J}</math>  <math>W = F \times d \approx PE = mgh</math>  <math>\therefore W = mgh</math>  <math>391\,950 = m \times 9.8 \times 20</math>  <math>m = \frac{391\,950}{9.8 \times 20}</math>  <math>= 1999.75 \approx 2000 \text{ kg}</math>  <math>\therefore</math> The mass of the full scrap metal bin is 2000 kg. </td> <td> <ul style="list-style-type: none"> <li>provides correct working to give correct result for work done [1 mark]</li> <li>provides correct formula and substituted values [1 mark]</li> <li>provides correct working to give correct answer to the nearest whole unit with correct unit provided [1 mark]</li> </ul> </td> </tr> </tbody> </table>	Sample response	The response	$P = \frac{W}{t}$ $4355 = \frac{W}{90}$ $W = 4355 \times 90 = 391\,950 \text{ J}$ $W = F \times d \approx PE = mgh$ $\therefore W = mgh$ $391\,950 = m \times 9.8 \times 20$ $m = \frac{391\,950}{9.8 \times 20}$ $= 1999.75 \approx 2000 \text{ kg}$ $\therefore$ The mass of the full scrap metal bin is 2000 kg.	<ul style="list-style-type: none"> <li>provides correct working to give correct result for work done [1 mark]</li> <li>provides correct formula and substituted values [1 mark]</li> <li>provides correct working to give correct answer to the nearest whole unit with correct unit provided [1 mark]</li> </ul>
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<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 = <math>mgh</math></p> <p><math>= 5 \times 9.8 \times 20</math></p> <p><math>\therefore \text{KE} = 980 \text{ J}</math></p> <p><math>\text{KE} = \frac{1}{2} \times m \times v^2</math></p> <p><math>v^2 = \frac{980}{0.5 \times 5}</math></p> <p><math>v = \sqrt{392}</math></p> <p><math>= 19.80 \approx 20 \text{ m/s}</math></p> <p><math>\therefore</math> The velocity of the scrap metal on impact with the ground is 20 m/s.</p> </td> <td> <ul style="list-style-type: none"> <li>provides correct working to give correct KE [1 mark]</li> <li>provides correct formula and substituted values [1 mark]</li> <li>provides correct working to give correct answer to the nearest whole unit with correct unit provided [1 mark]</li> </ul> </td> </tr> </tbody> </table>	Sample response	The response	<p>KE on impact = PE = <math>mgh</math></p> <p><math>= 5 \times 9.8 \times 20</math></p> <p><math>\therefore \text{KE} = 980 \text{ J}</math></p> <p><math>\text{KE} = \frac{1}{2} \times m \times v^2</math></p> <p><math>v^2 = \frac{980}{0.5 \times 5}</math></p> <p><math>v = \sqrt{392}</math></p> <p><math>= 19.80 \approx 20 \text{ m/s}</math></p> <p><math>\therefore</math> The velocity of the scrap metal on impact with the ground is 20 m/s.</p>	<ul style="list-style-type: none"> <li>provides correct working to give correct KE [1 mark]</li> <li>provides correct formula and substituted values [1 mark]</li> <li>provides correct working to give correct answer to the nearest whole unit with correct unit provided [1 mark]</li> </ul>	
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**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"> <li>• provides correct working to give correct gear ratio (VR) [1 mark]</li> <li>• provides correct formula and substituted values for mechanical advantage [1 mark]</li> <li>• provides correct working to give correct L [1 mark]</li> <li>• provides correct formula and substituted values for mass [1 mark]</li> <li>• provides correct working to give correct answer to the nearest whole unit with correct unit provided [1 mark]</li> </ul>

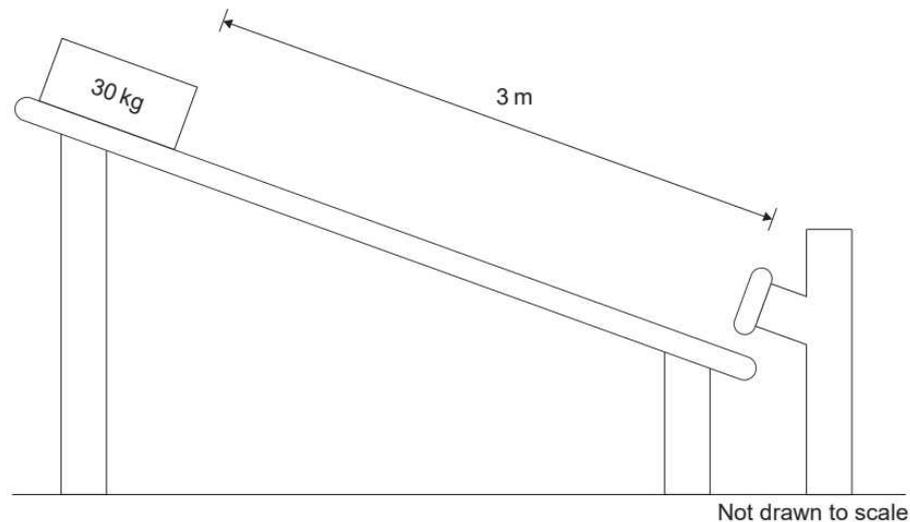
b) An effort wheel is added to the worm axle, decreasing the efficiency of the compound machine to 36%. Determine the velocity ratio of the added component. Answer to two decimal places. [4 marks]

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"> <li>• provides correct formula and substituted values for effort wheel efficiency [1 mark]</li> <li>• provides correct working to give correct effort wheel efficiency [1 mark]</li> <li>• provides correct formula and substituted values for velocity ratio [1 mark]</li> <li>• provides correct working to give correct answer to two decimal places [1 mark]</li> </ul>

**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.



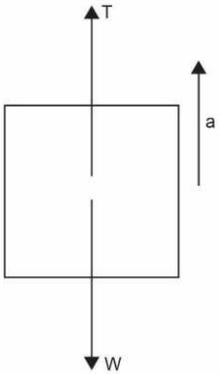
Determine the difference between the coefficients of friction for the modified chute and the original with the cushioning device. Answer to two decimal places. [9 marks]

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 <math>0.38 - 0.36 = 0.02</math>.</p>	<ul style="list-style-type: none"> <li>• provides correct working to give correct force of friction [1 mark]</li> <li>• provides correct working to give correct normal force [1 mark]</li> <li>• provides correct working to give correct coefficient of kinetic friction [1 mark]</li> <li>• provides correct formula and substituted values [1 mark]</li>   <li>• provides correct working to give correct deceleration [1 mark]</li> <li>• provides correct working to give correct force of deceleration [1 mark]</li> <li>• provides correct working to give correct force of friction required for deceleration [1 mark]</li> <li>• provides correct working to give correct coefficient of kinetic friction required for bag deceleration [1 mark]</li> <li>• provides correct working to give a correct answer to two decimal places [1 mark]</li> </ul>

**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"> <li>• provides an appropriate force diagram [1 mark]</li> <li>• provides correct working to give correct force required for acceleration [1 mark]</li> <li>• provides correct working to give correct acceleration [1 mark]</li> <li>• provides correct working to give correct time to complete acceleration [1 mark]</li> <li>• provides correct formula and substituted values [1 mark]</li> <li>• provides correct working to give correct answer to the nearest whole unit (m) with correct unit provided [1 mark]</li> </ul>

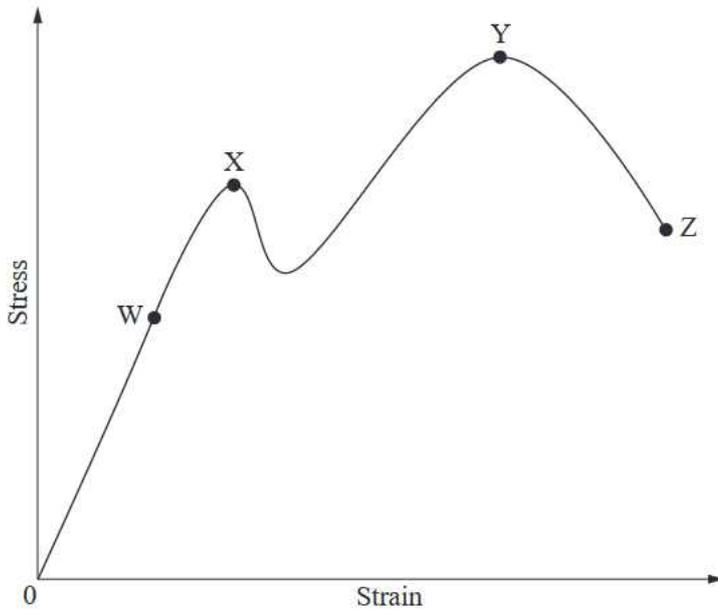
## Unit 4 – Topic 2: Materials

### Paper 1 Section 1

<b>2024 Paper 1 Section 1 Question 1  Materials</b>	<p>A lead–tin thermal-equilibrium phase diagram is shown.</p> <p>The phase diagram shows the following key features:</p> <ul style="list-style-type: none"><li>Temperature (°C) on the y-axis: 0, 50, 100, 150, 200, 250, 300, 350, 400.</li><li>% Tin (Sn) on the x-axis: 0 (Pb), 10, 20, 30, 40, 50, 60, 70, 80, 90, 100 (Sn).</li><li>Phase regions: <math>\alpha</math> (Pb-rich solid solution), <math>\beta</math> (Sn-rich solid solution), L (liquid), <math>\alpha + \beta</math> (two-phase region), <math>\alpha + L</math> (two-phase region), <math>\beta + L</math> (two-phase region).</li><li>Key temperatures: 327°C (melting point of pure Pb), 183°C (eutectic temperature), 227°C (peritectic temperature).</li><li>Key compositions: 18.3% Sn (eutectic composition), 61.9% Sn (peritectic composition).</li></ul>
	<p>What phase would be present in an alloy containing 35% Sn at a temperature of 225 °C?</p> <p>(A) <math>\beta</math> (B) L (C) <math>\alpha + \beta</math> (D) <math>\alpha + L</math></p>

<b>2024 Paper 1 Section 1 Question 2  Materials</b>	<p>Which material is most suitable for highly tempered punches and axles?</p> <p>(A) mild carbon steel (B) medium carbon steel (C) high carbon steel (D) ultra-high carbon steel</p>
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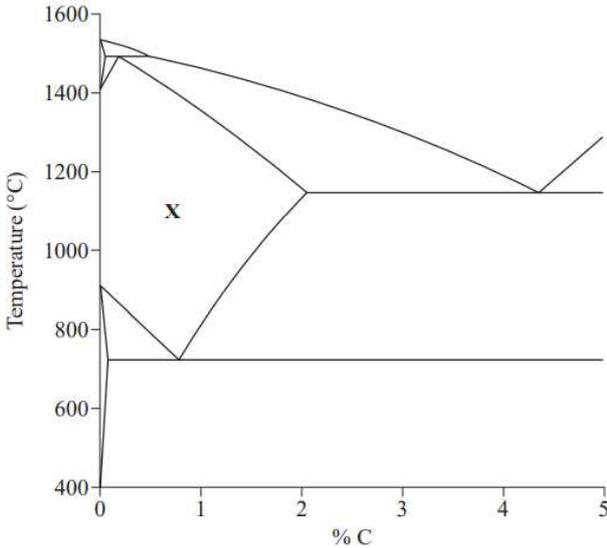
<b>2024 Paper 1 Section 1 Question 4  Materials</b>	<p>Which plastic is the most suitable for use as a medical screw?</p> <p>(A) nylon (B) polypropylene (C) polylactic acid (D) polyvinyl chloride</p>
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<p><b>2024</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 7</b></p> <p><b>Materials</b></p>	<p>A stress–strain diagram is shown.</p>  <p>Identify the key feature represented by point X on the diagram.</p> <p>(A) yield stress (B) plastic limit (C) proportional limit (D) ultimate tensile strength</p>
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<p><b>2023</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 1</b></p> <p><b>Materials</b></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>
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<p><b>2023</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 9</b></p> <p><b>Materials</b></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>
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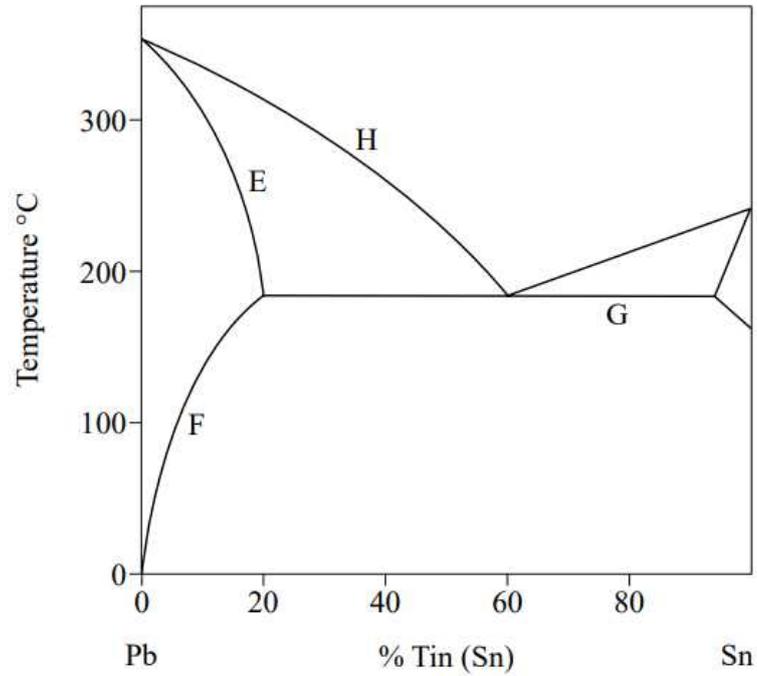
<p><b>2022</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 2</b></p> <p><b>Materials</b></p>	<p>Waste water drainage pipe is commonly manufactured using</p> <p>(A) nylon. (B) polypropylene. (C) polylactic acid. (D) polyvinyl chloride.</p>
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<p><b>2022</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 6</b></p> <p><b>Materials</b></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. (C) pearlite. (D) ferrite.</p>
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<p><b>2022</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 8</b></p> <p><b>Materials</b></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>
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<p><b>2021</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 1</b></p> <p><b>Materials</b></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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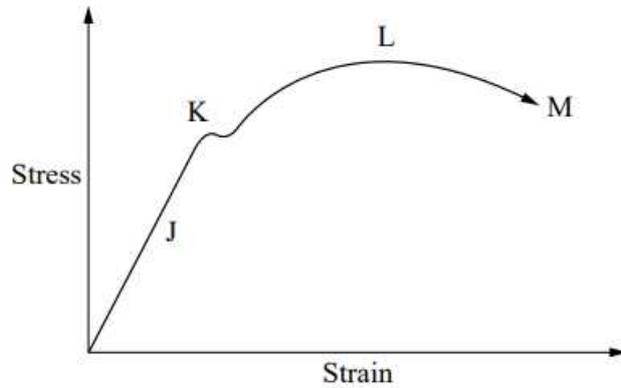
2021  
Paper 1  
Section 1  
Question 8  
  
Materials



In the lead–tin thermal equilibrium phase diagram, a liquidus line is represented by the letter

- (A) E.
- (B) F.
- (C) G.
- (D) H.

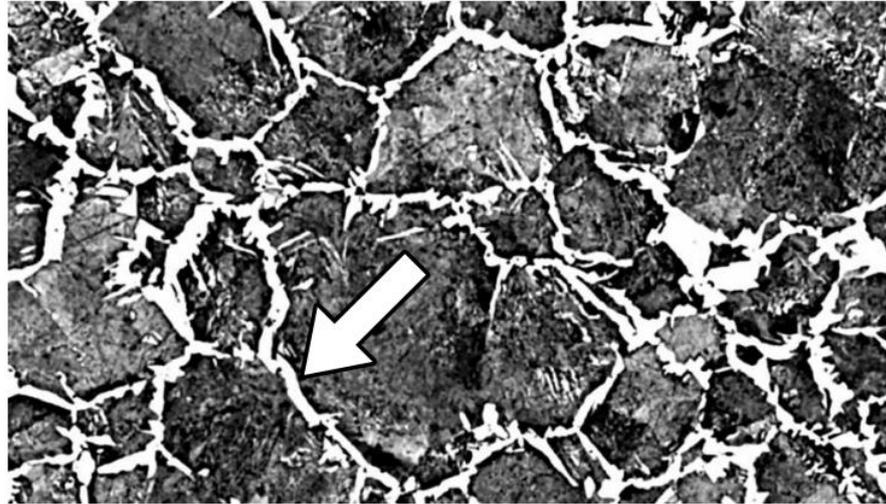
2021  
Paper 1  
Section 1  
Question 3  
  
Materials



The stiffness of a material can be identified using which area of the stress–strain diagram?

- (A) J
- (B) K
- (C) L
- (D) M

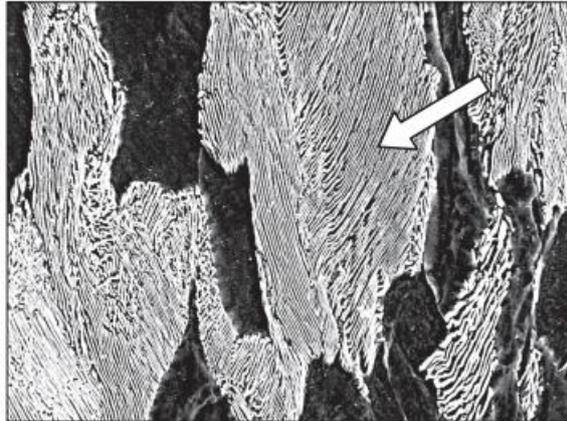
2021  
Paper 1  
Section 1  
Question 10  
  
Materials



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

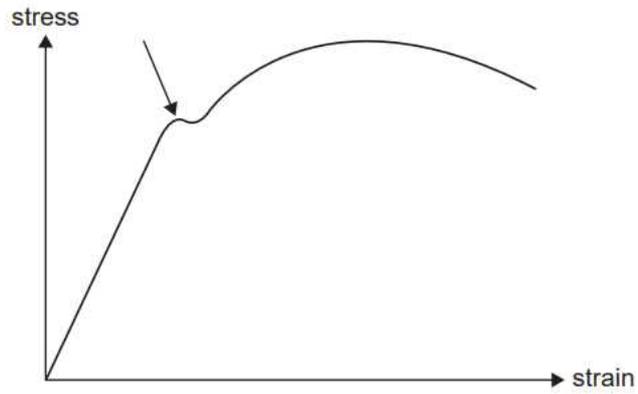
2020  
Paper 1  
Section 1  
Question 4  
  
Materials

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.












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

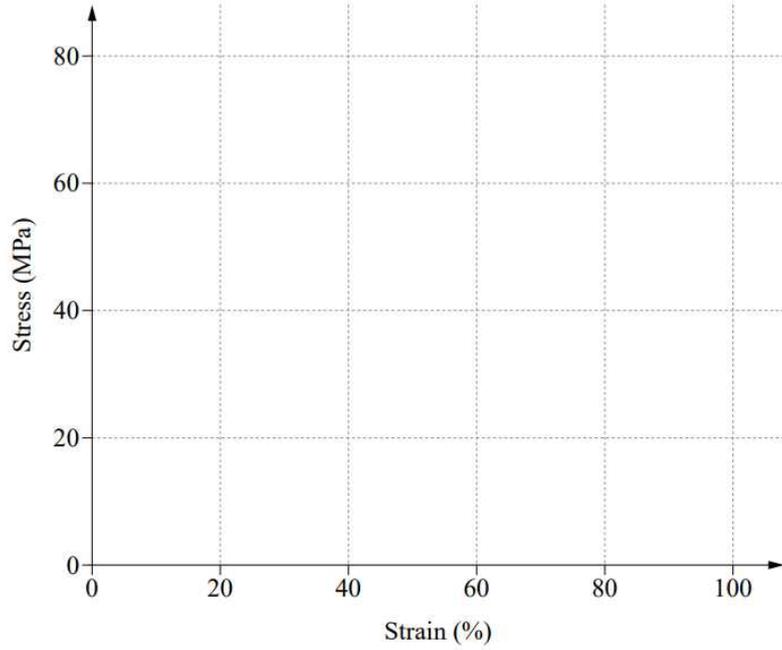
<b>2022</b> <b>Paper 1</b> <b>Section 2</b> <b>Question 14</b>  <b>Materials</b>	
	Use the information included in the lead-tin thermal-equilibrium phase diagram to identify each key feature. [6 marks]
	I) solidus line
	II) liquidus line
	III) eutectic point
	IV) eutectic temperature
	V) maximum solubility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

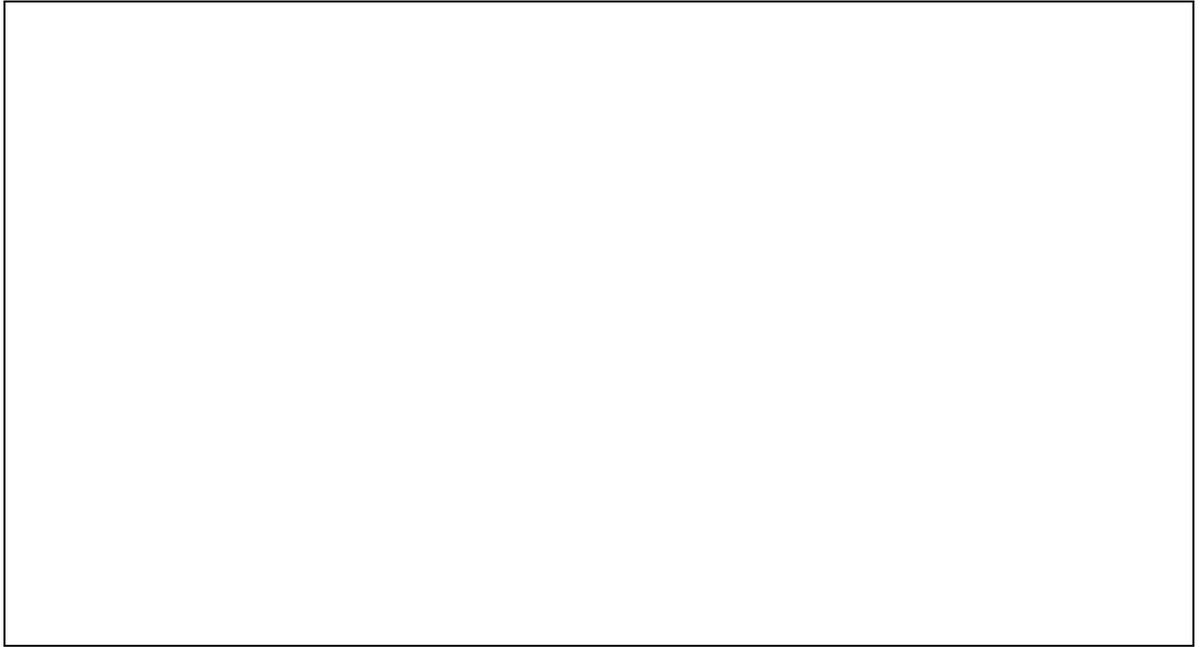






**2021**  
**Paper 1**  
**Section 2**  
**Question 14**  
  
**Materials**

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]



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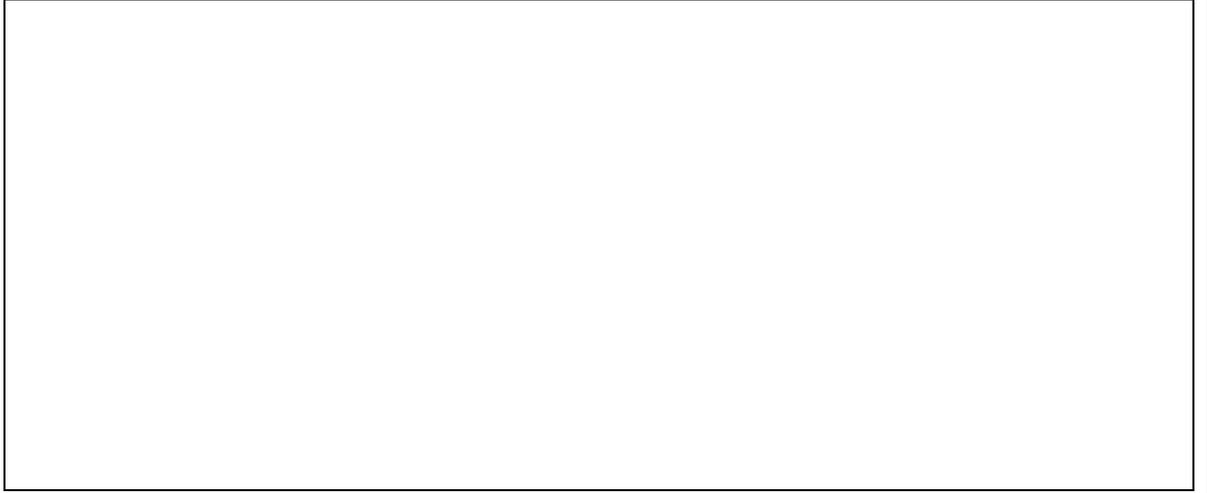
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**2020**  
**Paper 1**  
**Section 2**  
**Question 11**  
  
**Materials**

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]



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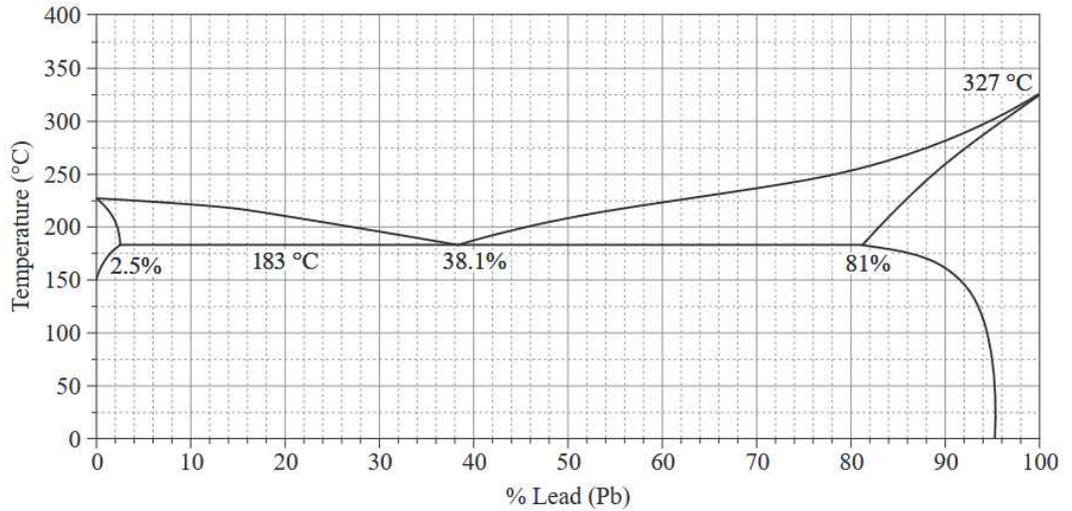
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2024  
Paper 1  
Section 3  
Question 19  
  
Materials

A lead–tin thermal-equilibrium diagram is shown.



a) Determine the composition of the solid and liquid in a 70% lead 30% tin alloy at 200 °C. Annotate the diagram to develop your response. [3 marks]

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b) Determine the percentages of solid and liquid in a 70% lead 30% tin alloy at 200 °C. [2 marks]

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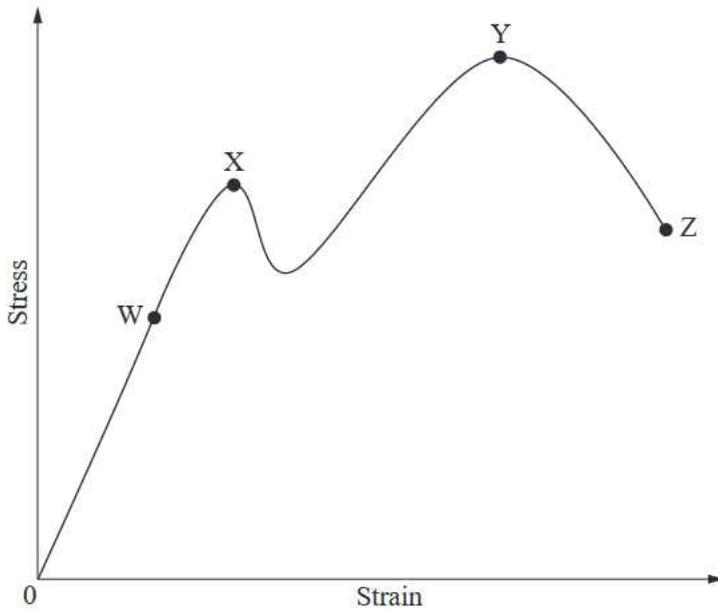


**Marking Guide – Paper 1 Section 1**

<p><b>2024</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 1</b></p> <p><b>Materials</b></p>	<p>A lead–tin thermal-equilibrium phase diagram is shown.</p> <p>What phase would be present in an alloy containing 35% Sn at a temperature of 225 °C?</p> <p>(A) <math>\beta</math></p> <p>(B) L</p> <p>(C) <math>\alpha + \beta</math></p> <p>(D) <math>\alpha + L</math></p> <p><b>Answer is D.</b></p>
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<p><b>2024</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 2</b></p> <p><b>Materials</b></p>	<p>Which material is most suitable for highly tempered punches and axles?</p> <p>(A) mild carbon steel</p> <p>(B) medium carbon steel</p> <p>(C) high carbon steel</p> <p><b>(D) ultra-high carbon steel – Answer</b></p>
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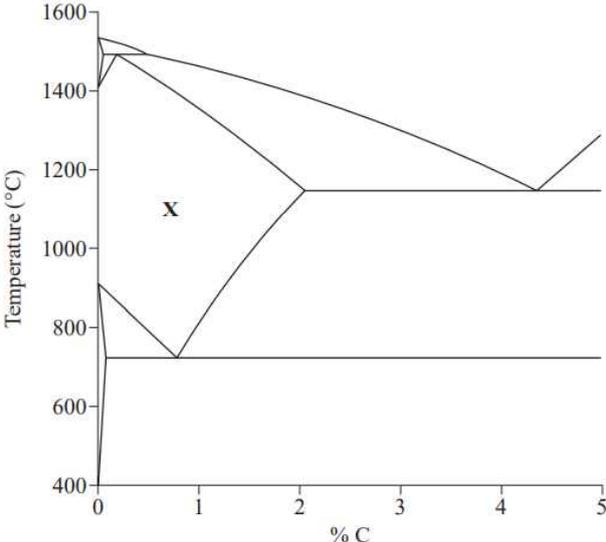
<p><b>2024</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 4</b></p> <p><b>Materials</b></p>	<p>Which plastic is the most suitable for use as a medical screw?</p> <p>(A) nylon</p> <p>(B) polypropylene</p> <p><b>(C) polylactic acid – Answer</b></p> <p>(D) polyvinyl chloride</p>
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<p><b>2024</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 7</b></p> <p><b>Materials</b></p>	<p>A stress–strain diagram is shown.</p>  <p>Identify the key feature represented by point X on the diagram.</p> <p>(A) <b>yield stress – Answer</b> (B) plastic limit (C) proportional limit (D) ultimate tensile strength</p>
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<p><b>2023</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 1</b></p> <p><b>Materials</b></p>	<p>A plastic beaker used to hold liquids in a laboratory is commonly manufactured using</p> <p>(A) polyethylene. (B) <b>polypropylene. – Answer</b> (C) polylactic acid. (D) polyvinyl chloride.</p>
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<p><b>2023</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 9</b></p> <p><b>Materials</b></p>	<p>Steel containing 0.11% carbon is</p> <p>(A) <b>low carbon steel. – Answer</b> (B) mild carbon steel. (C) medium carbon steel. (D) high carbon steel.</p>
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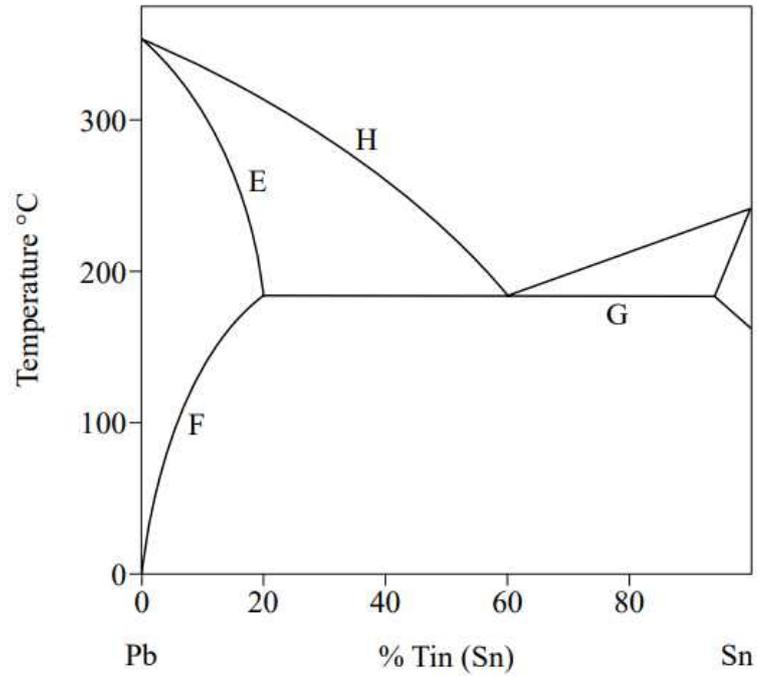
<p><b>2022</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 2</b></p> <p><b>Materials</b></p>	<p>Waste water drainage pipe is commonly manufactured using</p> <p>(A) nylon. (B) polypropylene. (C) polylactic acid. (D) <b>polyvinyl chloride. – Answer</b></p>
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<p><b>2022</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 6</b></p> <p><b>Materials</b></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>(B) austenite. – Answer</b> (C) pearlite. (D) ferrite.</p>
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<p><b>2022</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 8</b></p> <p><b>Materials</b></p>	<p>High carbon steel is used in the manufacture of</p> <p>(A) boiler plates. (B) railway tracks. <b>(C) punching tools. – Answer</b> (D) engine crankshafts.</p>
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<p><b>2021</b> <b>Paper 1</b> <b>Section 1</b> <b>Question 1</b></p> <p><b>Materials</b></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. <b>(D) medium-carbon steel. – Answer</b></p>
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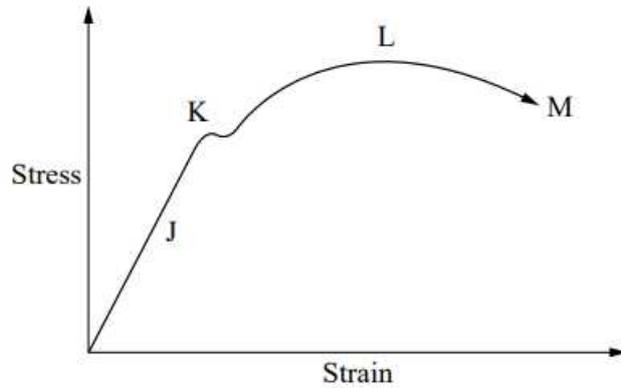
2021  
Paper 1  
Section 1  
Question 8  
  
Materials



In the lead–tin thermal equilibrium phase diagram, a liquidus line is represented by the letter

- (A) E.
- (B) F.
- (C) G.
- (D) H. – Answer

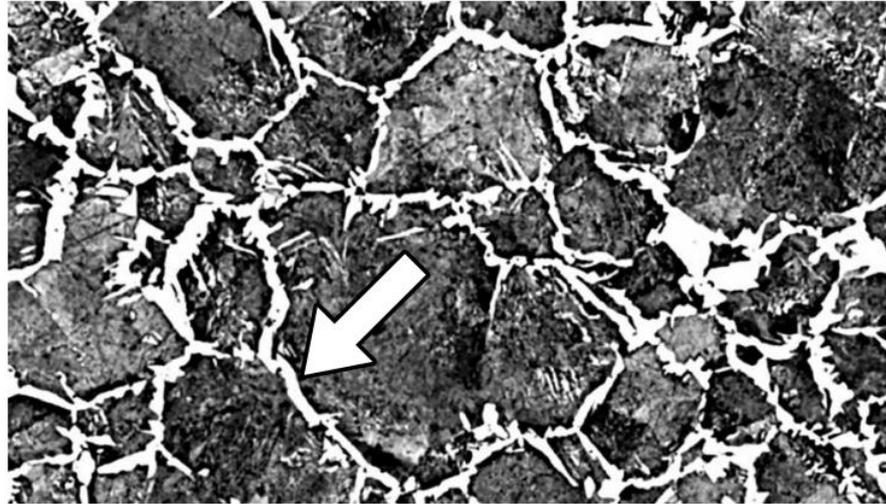
2021  
Paper 1  
Section 1  
Question 3  
  
Materials



The stiffness of a material can be identified using which area of the stress–strain diagram?

- (A) J – Answer
- (B) K
- (C) L
- (D) M

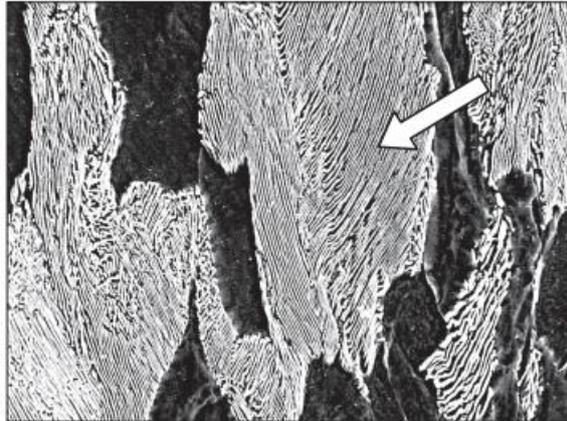
2021  
Paper 1  
Section 1  
Question 10  
  
Materials



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?

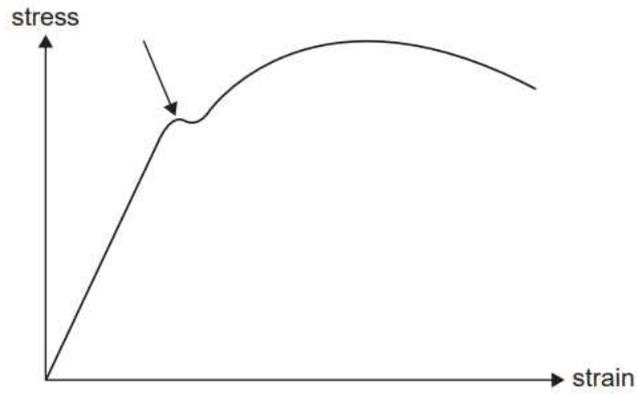
- (A) ferrite
- (B) **pearlite – Answer**
- (C) austenite
- (D) cementite

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**

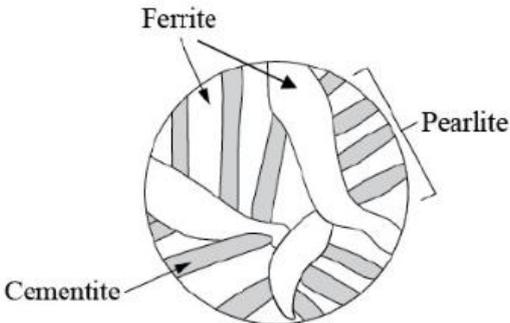
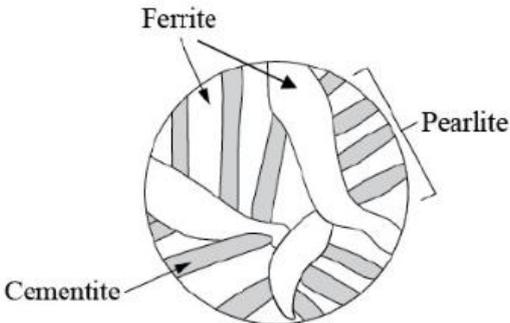
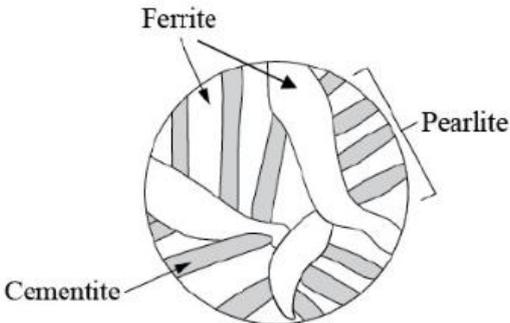
<p><b>2024</b> <b>Paper 1</b> <b>Section 2</b> <b>Question 12</b></p> <p><b>Materials</b></p>	<p>Analyse the information in the table to determine whether polyvinyl chloride (PVC) or polyethylene is the most suitable material for wastewater pipes in the home. Justify your response with four properties from the table. [5 marks]</p>																										
	<table border="1"> <thead> <tr> <th>Properties</th> <th>PVC</th> <th>Polyethylene</th> </tr> </thead> <tbody> <tr> <td>Mechanical</td> <td>resistant to abrasion, impact and weathering rigid — limited flexibility, can withstand high pressure</td> <td>resistant to cracking, impact and environmental stress; strong; durable malleable — highly flexible</td> </tr> <tr> <td>Young's modulus</td> <td>2.41–4.14 GPa</td> <td>1.08 GPa</td> </tr> <tr> <td>Yield strength</td> <td>40.7–44.8 MPa</td> <td>26.2–33.1 MPa</td> </tr> <tr> <td>Tensile strength</td> <td>40.7–51.7 MPa</td> <td>22.1–31.0 MPa</td> </tr> <tr> <td>Chemical</td> <td>excellent chemical resistance (including corrosive chemicals)</td> <td>good chemical resistance</td> </tr> <tr> <td>Thermal</td> <td>good heat resistance</td> <td>very good heat resistance</td> </tr> <tr> <td>Manufacturing cost</td> <td>low</td> <td>high</td> </tr> </tbody> </table>	Properties	PVC	Polyethylene	Mechanical	resistant to abrasion, impact and weathering rigid — limited flexibility, can withstand high pressure	resistant to cracking, impact and environmental stress; strong; durable malleable — highly flexible	Young's modulus	2.41–4.14 GPa	1.08 GPa	Yield strength	40.7–44.8 MPa	26.2–33.1 MPa	Tensile strength	40.7–51.7 MPa	22.1–31.0 MPa	Chemical	excellent chemical resistance (including corrosive chemicals)	good chemical resistance	Thermal	good heat resistance	very good heat resistance	Manufacturing cost	low	high		
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<p><b>2024</b> <b>Paper 1</b> <b>Section 2</b> <b>Question 13</b></p> <p><b>Materials</b></p>	<p>Identify two industrial applications of high carbon steel. Describe two mechanical properties of this material that make it suitable for each application. [6 marks]</p>					
	<table border="1"> <thead> <tr> <th>Sample response</th> <th>The response</th> </tr> </thead> <tbody> <tr> <td> <p>Application 1</p> <p>An industrial application for high carbon steel could be springs because they need to have strength to resist deformation under the applied forces the spring will experience. A spring also needs to be wear/fatigue resistant for their springiness (compression/flexing during operation), so they can withstand repeated flexing without breaking.</p> <p>Application 2</p> <p>Another industrial application could be cutting tools, such as dies, industrial knives or punches, because they need to be hard and very strong to cut or punch out shapes.</p> </td> <td> <ul style="list-style-type: none"> <li>identifies one suitable industrial application for high carbon steel [1 mark]</li> <li>describes appropriately a mechanical property that makes it suitable for the application [1 mark]</li> <li>describes appropriately a second mechanical property that makes it suitable for the application [1 mark]</li> <li>identifies a second suitable industrial application for high carbon steel [1 mark]</li> <li>describes appropriately a mechanical property that makes it suitable for the application [1 mark]</li> <li>describes appropriately a second mechanical property that makes it suitable for the application [1 mark]</li> </ul> </td> </tr> </tbody> </table>	Sample response	The response	<p>Application 1</p> <p>An industrial application for high carbon steel could be springs because they need to have strength to resist deformation under the applied forces the spring will experience. A spring also needs to be wear/fatigue resistant for their springiness (compression/flexing during operation), so they can withstand repeated flexing without breaking.</p> <p>Application 2</p> <p>Another industrial application could be cutting tools, such as dies, industrial knives or punches, because they need to be hard and very strong to cut or punch out shapes.</p>	<ul style="list-style-type: none"> <li>identifies one suitable industrial application for high carbon steel [1 mark]</li> <li>describes appropriately a mechanical property that makes it suitable for the application [1 mark]</li> <li>describes appropriately a second mechanical property that makes it suitable for the application [1 mark]</li> <li>identifies a second suitable industrial application for high carbon steel [1 mark]</li> <li>describes appropriately a mechanical property that makes it suitable for the application [1 mark]</li> <li>describes appropriately a second mechanical property that makes it suitable for the application [1 mark]</li> </ul>	
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<p><b>2024</b> <b>Paper 1</b> <b>Section 2</b> <b>Question 14</b></p> <p><b>Materials</b></p>	<p>Explain how the chemical composition of mild carbon steel contributes to its suitability for seamless tubes. Include two properties of mild carbon steel in your response. [4 marks]</p>					
	<table border="1"> <thead> <tr> <th>Sample response</th> <th>The response</th> </tr> </thead> <tbody> <tr> <td> <p>Mild carbon steel is suitable for seamless tubes due to its low carbon content. It is made up mainly of ferrite, which is a soft and ductile form of iron. This provides the material with ductility, which allows it to be formed into a tubular shape.</p> <p>Mild carbon steel also contains pearlite with small amounts of cementite. Cementite is hard and brittle, and excessive amounts can make a material too brittle to be formed. The small amount of cementite in mild carbon steel provides toughness, allowing the material to be shaped without fracturing.</p> </td> <td> <ul style="list-style-type: none"> <li>identifies that mild carbon steel is mostly made of ferrite [1 mark]</li> <li>identifies that ferrite adds to the ductility of the material, which allows the material to be formed into shape [1 mark]</li> <li>identifies that mild steel contains pearlite [1 mark]</li> <li>identifies that pearlite (or cementite in pearlite) adds to the toughness of the material, which prevents fracturing [1 mark]</li> </ul> </td> </tr> </tbody> </table>	Sample response	The response	<p>Mild carbon steel is suitable for seamless tubes due to its low carbon content. It is made up mainly of ferrite, which is a soft and ductile form of iron. This provides the material with ductility, which allows it to be formed into a tubular shape.</p> <p>Mild carbon steel also contains pearlite with small amounts of cementite. Cementite is hard and brittle, and excessive amounts can make a material too brittle to be formed. The small amount of cementite in mild carbon steel provides toughness, allowing the material to be shaped without fracturing.</p>	<ul style="list-style-type: none"> <li>identifies that mild carbon steel is mostly made of ferrite [1 mark]</li> <li>identifies that ferrite adds to the ductility of the material, which allows the material to be formed into shape [1 mark]</li> <li>identifies that mild steel contains pearlite [1 mark]</li> <li>identifies that pearlite (or cementite in pearlite) adds to the toughness of the material, which prevents fracturing [1 mark]</li> </ul>	
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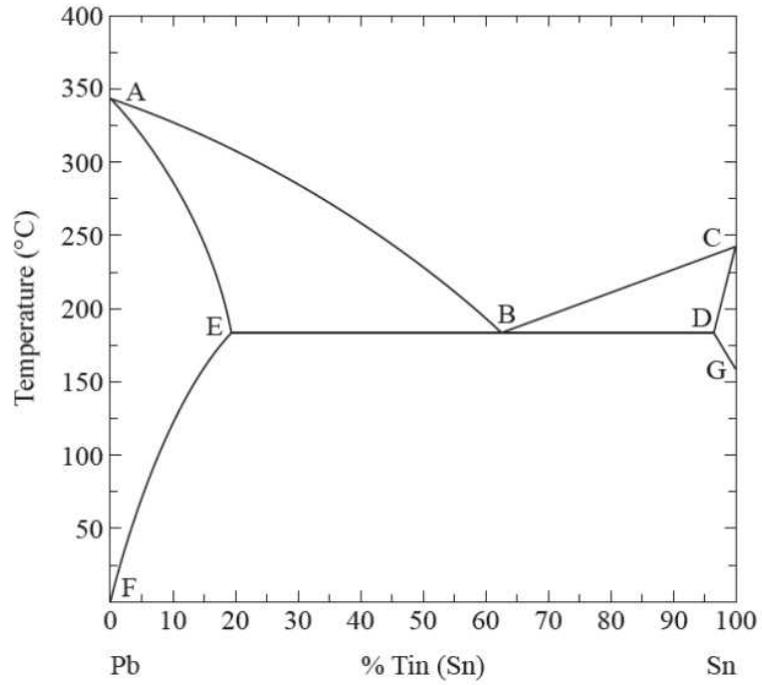
<b>2023</b> <b>Paper 1</b> <b>Section 2</b> <b>Question 11</b>  <b>Materials</b>	State four contemporary engineering applications for acrylonitrile butadiene styrene (ABS). (4 marks)	
	<b>Sample response</b>	<b>The response</b>
	1. automobile bumper bar 2. electrical wall socket 3. face shield 4. hard hat	<ul style="list-style-type: none"> <li>• provides a contemporary engineering application [1 mark]</li> <li>• provides a second contemporary engineering application [1 mark]</li> <li>• provides a third contemporary engineering application [1 mark]</li> <li>• provides a fourth contemporary engineering application [1 mark]</li> </ul>

<b>2023</b> <b>Paper 1</b> <b>Section 2</b> <b>Question 14</b>  <b>Materials</b>	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)	
	<b>Sample response</b>	<b>The response</b>
	<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>	<ul style="list-style-type: none"> <li>• appropriately explains how a mechanical engineer might use the problem-solving process, using wording that indicates             <ul style="list-style-type: none"> <li>– phases of the problem-solving process in engineering                 <ul style="list-style-type: none"> <li>▪ explore [1 mark]</li> <li>▪ develop or generate [1 mark]</li> <li>▪ evaluate or refine [1 mark]</li> </ul> </li> <li>– one area of engineering expertise [1 mark]</li> <li>– another area of engineering expertise [1 mark]</li> </ul> </li> </ul>

<b>2023</b> <b>Paper 1</b> <b>Section 2</b> <b>Question 15</b>  <b>Materials</b>	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"> <li>• provides an appropriate sketch of the microstructures that <ul style="list-style-type: none"> <li>– clearly distinguishes between ferrite and pearlite [1 mark]</li> <li>– identifies ferrite [1 mark]</li> <li>– clearly distinguishes lamellar structure of pearlite [1 mark]</li> <li>– identifies pearlite [1 mark]</li> </ul> </li> </ul> </td> </tr> </tbody> </table>	Sample response	The response		<ul style="list-style-type: none"> <li>• provides an appropriate sketch of the microstructures that <ul style="list-style-type: none"> <li>– clearly distinguishes between ferrite and pearlite [1 mark]</li> <li>– identifies ferrite [1 mark]</li> <li>– clearly distinguishes lamellar structure of pearlite [1 mark]</li> <li>– identifies pearlite [1 mark]</li> </ul> </li> </ul>	<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"> <li>• appropriately explains medium carbon steel's usefulness as a material for train rails, referring to <ul style="list-style-type: none"> <li>– the microstructures of medium carbon steel including lamellar or layered <ul style="list-style-type: none"> <li>▪ soft, ductile ferrite [1 mark]</li> <li>▪ hard, brittle cementite [1 mark]</li> </ul> </li> <li>– an appropriate mechanical property of medium carbon steel linked to use [1 mark]</li> <li>– a second appropriate mechanical property of medium carbon steel linked to use [1 mark]</li> </ul> </li> </ul> </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>
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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]									

<b>2022</b> <b>Paper 1</b> <b>Section 2</b> <b>Question 12</b>  <b>Materials</b>	State four industrial applications for carbon steel with 0.15% to 0.30% carbon content. [4 marks]				
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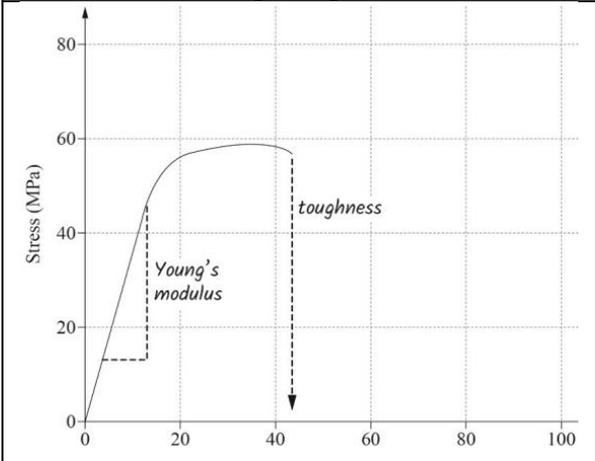
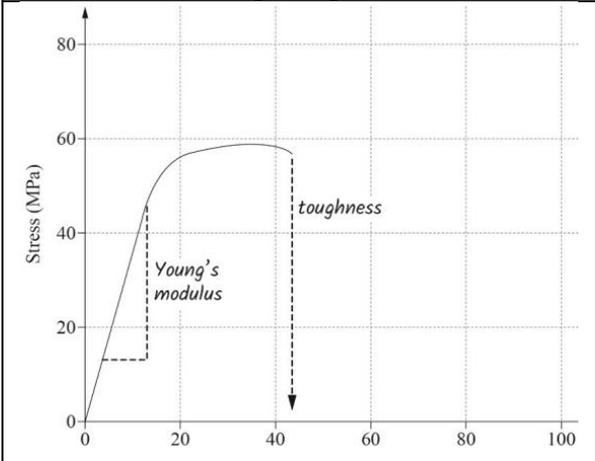
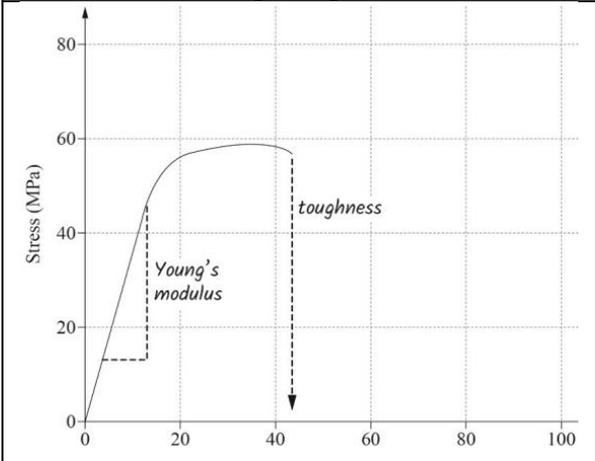
2022  
Paper 1  
Section 2  
Question 14  
  
Materials



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"> <li>• correctly identifies the</li> <li>- solidus line [1 mark]</li> <li>- liquidus line [1 mark]</li> <li>- eutectic point [1 mark]</li> <li>- eutectic temperature [1 mark]</li> <li>- maximum solubility of lead in tin [1 mark]</li> <li>- maximum solubility of tin in lead [1 mark]</li> </ul>

<p><b>2022</b> <b>Paper 1</b> <b>Section 2</b> <b>Question 15</b></p> <p><b>Materials</b></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="292 221 887 253">Sample response</th> <th data-bbox="887 221 1481 253">The response</th> </tr> </thead> <tbody> <tr> <td data-bbox="292 253 887 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="887 253 1481 1169"> <ul style="list-style-type: none"> <li>• appropriately contrasts mild and high carbon steel and includes wording that indicates               <ul style="list-style-type: none"> <li>- the microstructure of mild carbon steel is                   <ul style="list-style-type: none"> <li>▫ higher in ferrite than high carbon steel [1 mark]</li> <li>▫ lower in pearlite than high carbon steel [1 mark]</li> </ul> </li> <li>- high carbon steel has a higher yield strength than mild carbon steel [1 mark]</li> <li>- high carbon steel is less ductile than mild carbon steel [1 mark]</li> <li>- mild carbon steel has better toughness than high carbon steel [1 mark]</li> <li>- 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]</li> </ul> </li> </ul> </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"> <li>• appropriately contrasts mild and high carbon steel and includes wording that indicates               <ul style="list-style-type: none"> <li>- the microstructure of mild carbon steel is                   <ul style="list-style-type: none"> <li>▫ higher in ferrite than high carbon steel [1 mark]</li> <li>▫ lower in pearlite than high carbon steel [1 mark]</li> </ul> </li> <li>- high carbon steel has a higher yield strength than mild carbon steel [1 mark]</li> <li>- high carbon steel is less ductile than mild carbon steel [1 mark]</li> <li>- mild carbon steel has better toughness than high carbon steel [1 mark]</li> <li>- 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]</li> </ul> </li> </ul>
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<p><b>2021</b> <b>Paper 1</b> <b>Section 2</b> <b>Question 11</b></p> <p><b>Materials</b></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 1393">Sample response</th> <th data-bbox="887 1361 1481 1393">The response</th> </tr> </thead> <tbody> <tr> <td data-bbox="292 1393 887 1854">  </td> <td data-bbox="887 1393 1481 1854"> <ul style="list-style-type: none"> <li>• sketches an appropriate stress–strain curve for nylon, including               <ul style="list-style-type: none"> <li>- a straight line proportion with strain less than 20% [1 mark]</li> <li>- a rupture point with less than 80% strain [1 mark]</li> </ul> </li> <li>• accurately identifies toughness on the curve [1 mark]</li> <li>• accurately identifies Young’s modulus on the curve [1 mark]</li> </ul> </td> </tr> </tbody> </table>	Sample response	The response		<ul style="list-style-type: none"> <li>• sketches an appropriate stress–strain curve for nylon, including               <ul style="list-style-type: none"> <li>- a straight line proportion with strain less than 20% [1 mark]</li> <li>- a rupture point with less than 80% strain [1 mark]</li> </ul> </li> <li>• accurately identifies toughness on the curve [1 mark]</li> <li>• accurately identifies Young’s modulus on the curve [1 mark]</li> </ul>
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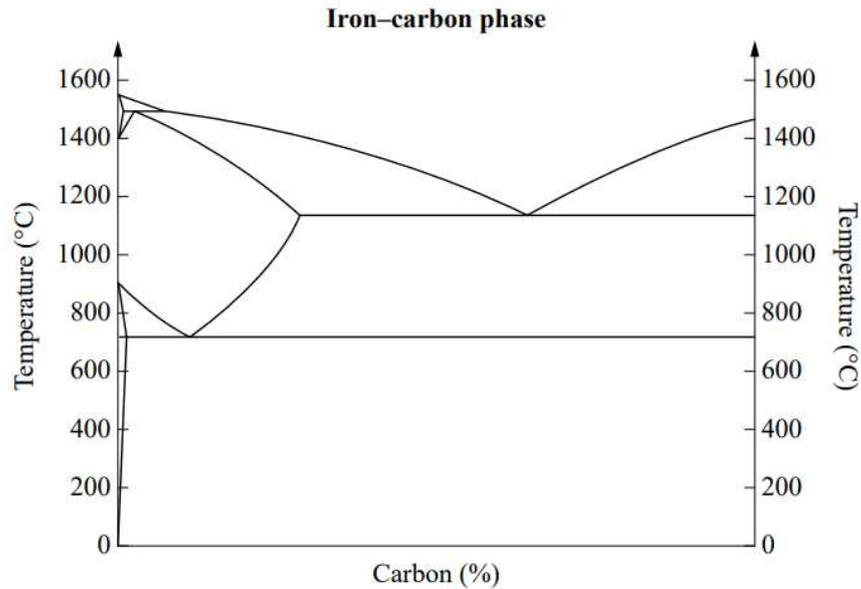
<b>2021</b> <b>Paper 1</b> <b>Section 2</b> <b>Question 14</b>  <b>Materials</b>	Explain how the tensile test for a low-carbon steel material can be used to determine the ductility of the material. Sketch and annotate a stress–strain diagram to support your explanation. [6 marks]	
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	<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"> <li>• explains appropriately using wording that indicates           <ul style="list-style-type: none"> <li>- withstanding strain after yield point or UTS [1 mark]</li> <li>- plastic deformation [1 mark]</li> <li>- fracture [1 mark]</li> </ul> </li> <li>• provides an appropriately annotated stress–strain diagram that accurately shows           <ul style="list-style-type: none"> <li>- the plastic region [1 mark]</li> <li>- the upper yield point [1 mark]</li> <li>- the point of fracture [1 mark]</li> </ul> </li> </ul>

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

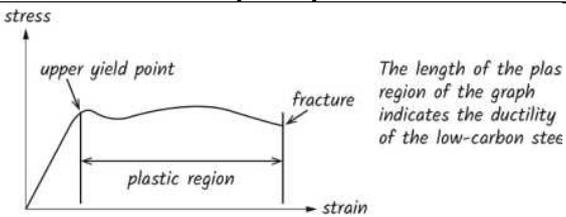
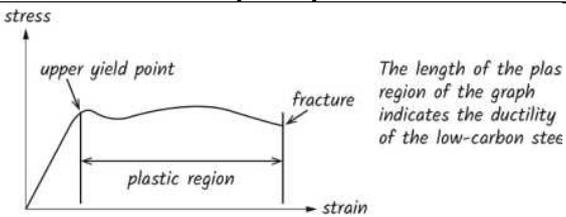
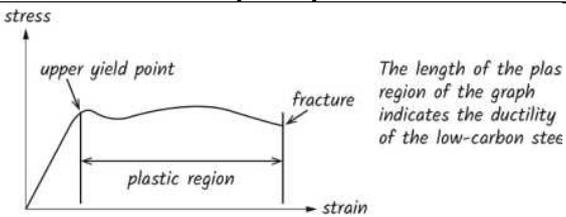
**2021  
Paper 1  
Section 2  
Question 13**

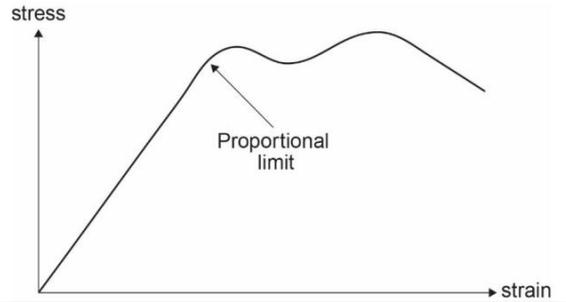
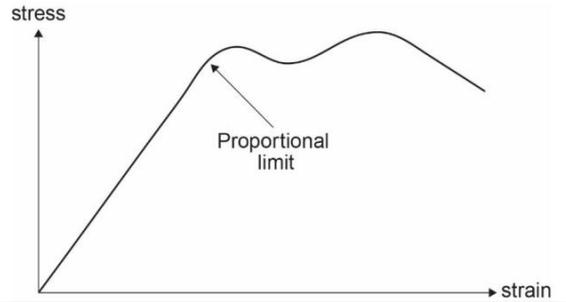
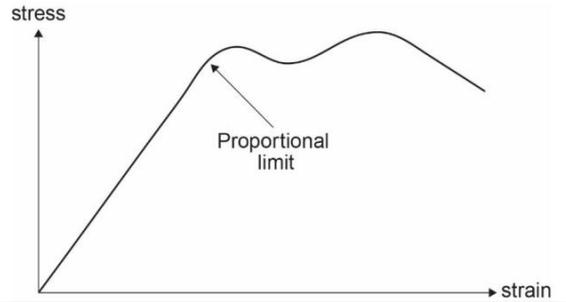
**Materials**

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;"><b>Iron-carbon phase</b></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"> <li>• explains appropriately using wording indicative of           <ul style="list-style-type: none"> <li>- upper eutectic residual liquid forms a mixture of austenite and cementite [1 mark]</li> <li>- carbon precipitates out of the austenite to form eutectic cementite [1 mark]</li> <li>- pearlite forms at the eutectoid [1 mark]</li> </ul> </li> <li>• provides an appropriately annotated sketch indicating           <ul style="list-style-type: none"> <li>- an approximately correct location for 3% carbon [1 mark]</li> <li>- the eutectic and eutectoid temperatures (A and B locations) [1 mark]</li> </ul> </li> </ul>

<b>2021</b> <b>Paper 1</b> <b>Section 2</b> <b>Question 14</b>  <b>Materials</b>	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]			
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<b>2020</b> <b>Paper 1</b> <b>Section 2</b> <b>Question 11</b>  <b>Materials</b>	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]			
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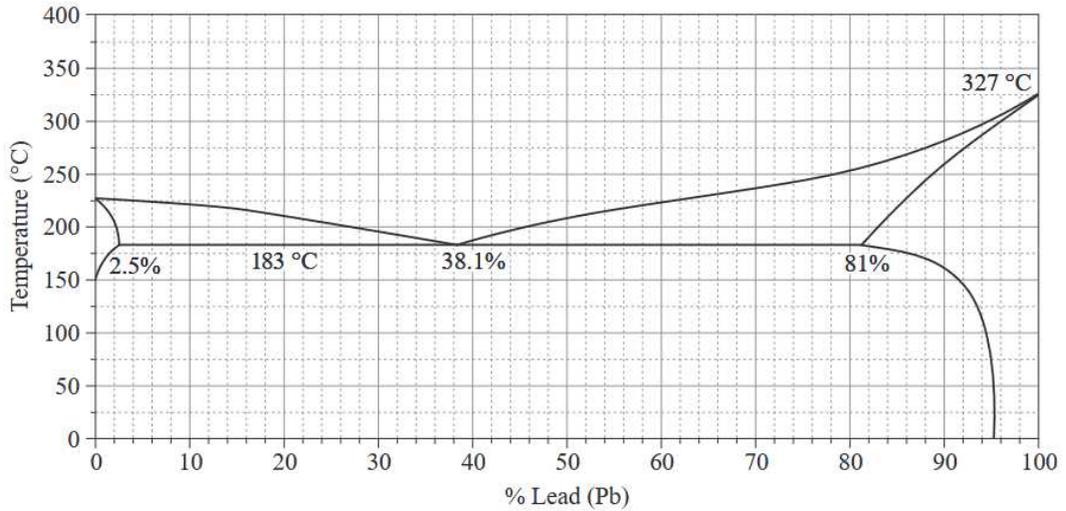
<b>2020</b> <b>Paper 1</b> <b>Section 2</b> <b>Question 13</b>  <b>Materials</b>	Explain how the microstructure of a 62% tin and 38% lead binary alloy changes during cooling from liquid to solid. Provide an annotated sketch of the microstructure to support your explanation. [5 marks]			
	<table border="1"> <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>  <p>Solid mixture of finely divided and intimately mixed alpha and beta phases.</p> </td> <td> <ul style="list-style-type: none"> <li>explains changes correctly using wording indicative of the               <ul style="list-style-type: none"> <li>laminar structure [1 mark]</li> <li>mixture solidifies directly from liquid to solid [1 mark]</li> <li>eutectic mixture [1 mark]</li> </ul> </li> <li>provides a sketch that               <ul style="list-style-type: none"> <li>indicates a laminar structure [1 mark]</li> <li>is appropriately annotated [1 mark]</li> </ul> </li> </ul> </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>  <p>Solid mixture of finely divided and intimately mixed alpha and beta phases.</p>
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<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>  <p>Solid mixture of finely divided and intimately mixed alpha and beta phases.</p>	<ul style="list-style-type: none"> <li>explains changes correctly using wording indicative of the               <ul style="list-style-type: none"> <li>laminar structure [1 mark]</li> <li>mixture solidifies directly from liquid to solid [1 mark]</li> <li>eutectic mixture [1 mark]</li> </ul> </li> <li>provides a sketch that               <ul style="list-style-type: none"> <li>indicates a laminar structure [1 mark]</li> <li>is appropriately annotated [1 mark]</li> </ul> </li> </ul>			

<b>2020</b> <b>Paper 1</b> <b>Section 2</b> <b>Question 17</b>  <b>Materials</b>	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"> <li>explains correctly and includes</li> <li>- the carbon content of high-carbon steel [1 mark]</li> <li>- the microstructure of high-carbon steel [1 mark]</li> <li>- 2 industrial/mechanical uses for high-carbon steel [1 mark]</li> </ul> </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"> <li>explains correctly and includes</li> <li>- the carbon content of high-carbon steel [1 mark]</li> <li>- the microstructure of high-carbon steel [1 mark]</li> <li>- 2 industrial/mechanical uses for high-carbon steel [1 mark]</li> </ul>	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"> <li>explains correctly and includes</li> <li>- the carbon content of high-carbon steel [1 mark]</li> <li>- the microstructure of high-carbon steel [1 mark]</li> <li>- 2 industrial/mechanical uses for high-carbon steel [1 mark]</li> </ul>					
	Prpt - 2 mechanical properties of highcarbon steel [2 marks] OR - 1 mechanical property of highcarbon steel [1 mark]					

<b>2020</b> <b>Paper 1</b> <b>Section 2</b> <b>Question 12</b>  <b>Materials</b>	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"> <li>provides 4 correctly identified PLA properties [4 marks]</li> <li>OR</li> <li>provides 3 correctly identified PLA properties [3 marks]</li> <li>OR</li> <li>provides 2 correctly identified PLA properties [2 marks]</li> <li>OR</li> <li>provides 1 correctly identified PLA property [1 mark]</li> </ul> </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"> <li>provides 4 correctly identified PLA properties [4 marks]</li> <li>OR</li> <li>provides 3 correctly identified PLA properties [3 marks]</li> <li>OR</li> <li>provides 2 correctly identified PLA properties [2 marks]</li> <li>OR</li> <li>provides 1 correctly identified PLA property [1 mark]</li> </ul>
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"> <li>provides 4 correctly identified PLA properties [4 marks]</li> <li>OR</li> <li>provides 3 correctly identified PLA properties [3 marks]</li> <li>OR</li> <li>provides 2 correctly identified PLA properties [2 marks]</li> <li>OR</li> <li>provides 1 correctly identified PLA property [1 mark]</li> </ul>				

2024  
Paper 1  
Section 3  
Question 19  
  
Materials

A lead–tin thermal-equilibrium diagram is shown.



a) Determine the composition of the solid and liquid in a 70% lead 30% tin alloy at 200 °C. Annotate the diagram to develop your response. [3 marks]

Sample response	The response									
<table border="1"> <thead> <tr> <th></th> <th>Solid</th> <th>Liquid</th> </tr> </thead> <tbody> <tr> <td>Composition</td> <td>83% Pb 17% Sn</td> <td>45% Pb 55% Sn</td> </tr> <tr> <td>Percentage</td> <td>25/38 = 65.8%</td> <td>13/38 = 34.2%</td> </tr> </tbody> </table>		Solid	Liquid	Composition	83% Pb 17% Sn	45% Pb 55% Sn	Percentage	25/38 = 65.8%	13/38 = 34.2%	<ul style="list-style-type: none"> <li>• annotates the diagram appropriately [1 mark]</li> <li>• determines the composition of the solid from the tie line from the line of intersection at 200 °C in the solid phase = 83% Pb and 17% Sn [1 mark]</li> <li>• determines the composition of the liquid from the tie line from the line of intersection at 200 °C in the liquid phase = 45% Pb and 55% Sn [1 mark]</li> </ul>
	Solid	Liquid								
Composition	83% Pb 17% Sn	45% Pb 55% Sn								
Percentage	25/38 = 65.8%	13/38 = 34.2%								

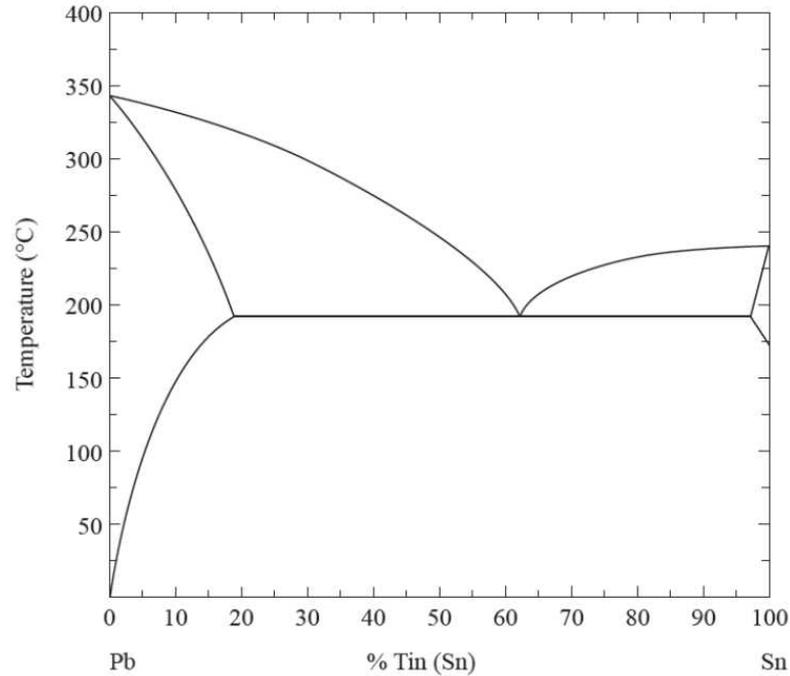
b) Determine the percentages of solid and liquid in a 70% lead 30% tin alloy at 200 °C. [2 marks]

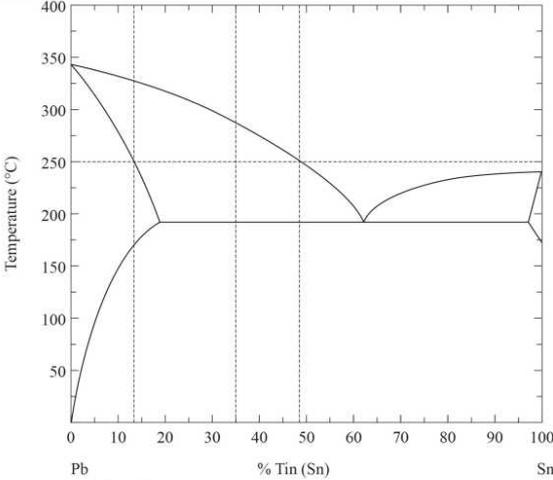
Sample response	The response
Percentage solid at 200 °C $= \frac{70 - 45}{83 - 45}$ $= \frac{25}{38}$ $= 65.8\%$ Percentage liquid at 200 °C $= \frac{83 - 70}{83 - 45} = \frac{13}{38}$ $= 34.2\%$	<ul style="list-style-type: none"> <li>• determines the percentage solid at 200 °C [1 mark]</li> <li>• determines the percentage liquid at 200 °C [1 mark]</li> </ul>

**2022  
Paper 1  
Section 3  
Question 21**

**Materials**

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



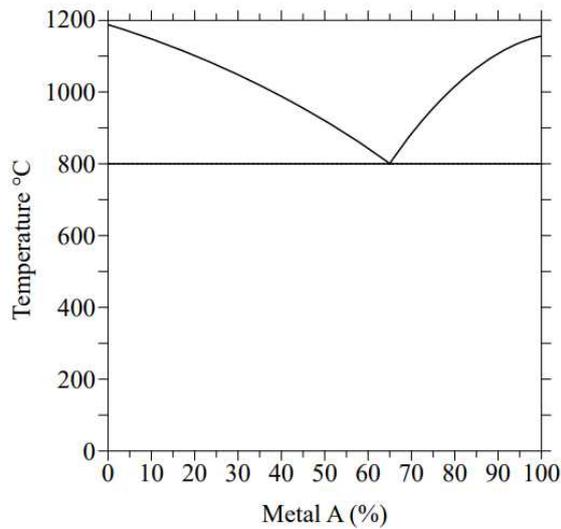
Sample response	The response
 <p>liquid = <math>\frac{35 - 13}{35} \times 100 = 63\%</math></p> <p>solid = <math>\frac{48 - 35}{35} \times 100 = 37\%</math></p> <p>Liquid is 48% tin and 52% lead</p> <p><math>\therefore</math> liquid tin at 250°C = <math>(0.48 \times 0.63) \times 100 = 30\%</math></p> <p>and liquid lead at 250°C = <math>(0.52 \times 0.63) \times 100 = 33\%</math></p>	<ul style="list-style-type: none"> <li>• uses the diagram to</li> <li>- determine the area representing 65% lead and 35% tin [1 mark]</li> <li>- plot the percentage of liquid or solid at 250° C [1 mark]</li> <li>• correctly determines the percentage proportion of liquid [1 mark]</li> <li>• identifies the correct percentage of tin and lead as liquid at 250° C [1 mark]</li> <li>• correctly determines the percentage of the liquid components (tin and lead) [1 mark]</li> </ul>

**2021  
Paper 1  
Section 3  
Question 18**

**Materials**

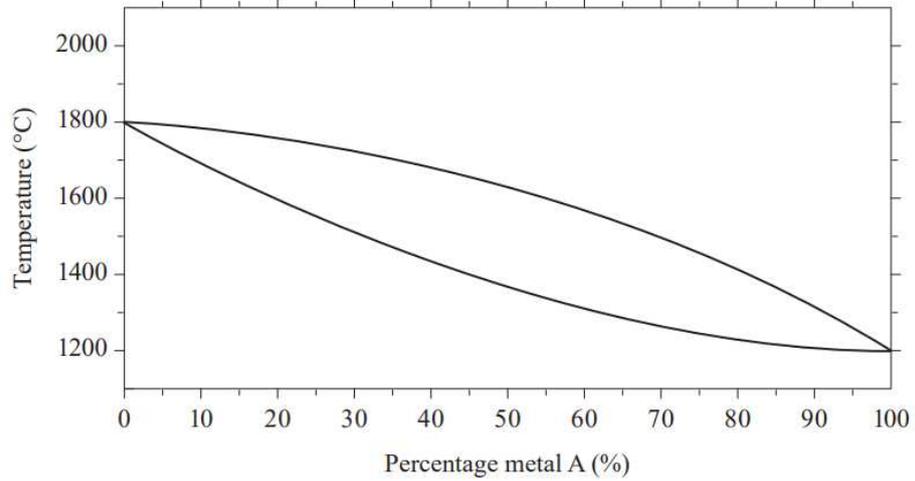
Use and annotate the binary equilibrium diagram for an alloy of metals A and B to calculate the percentage of solid and liquid material present for an alloy of 20% Metal A and 80% Metal B at 900 °C.

Answer to the nearest whole unit. [5 marks]



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

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"> <li>• provides evidence that the diagram is used to plot percentage of metal A and B [1 mark]</li> <li>• includes correct use of the inverse lever rule to calculate solid [1 mark]</li> <li>• provides correct working to give correct percentage of solid to the nearest whole unit with correct unit provided [1 mark]</li> <li>• provides correct use of the inverse lever rule to calculate liquid [1 mark]</li> <li>• provides correct working to give correct percentage of liquid to the nearest whole unit with correct unit provided [1 mark]</li> </ul>

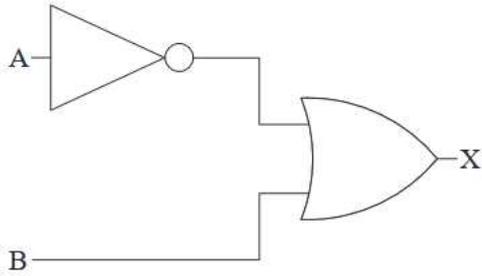
## Unit 4 – Topic 3: Machine control

### Paper 1 Section 1

2024  
Paper 1  
Section 1  
Question 5

Machine  
control

A logic gate circuit is shown.



Which truth table shows the correct output column for the logic gate circuit?

(A)

A	B	X
0	0	1
0	1	1
1	0	0
1	1	1

(B)

A	B	X
0	0	0
0	1	1
1	0	1
1	1	1

(C)

A	B	X
0	0	0
0	1	1
1	0	0
1	1	0

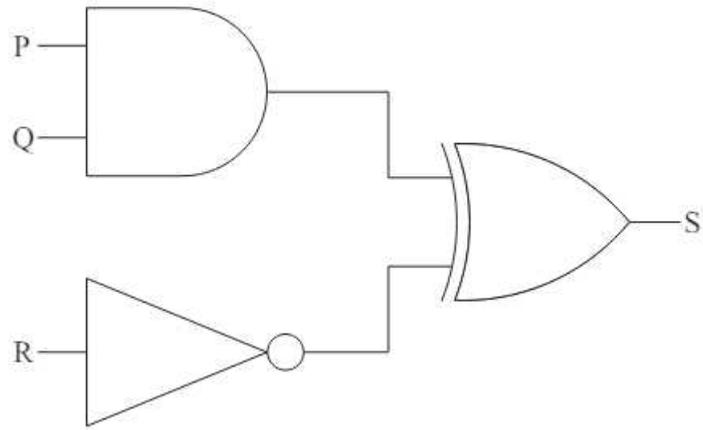
(D)

A	B	X
0	0	0
0	1	0
1	0	0
1	1	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)

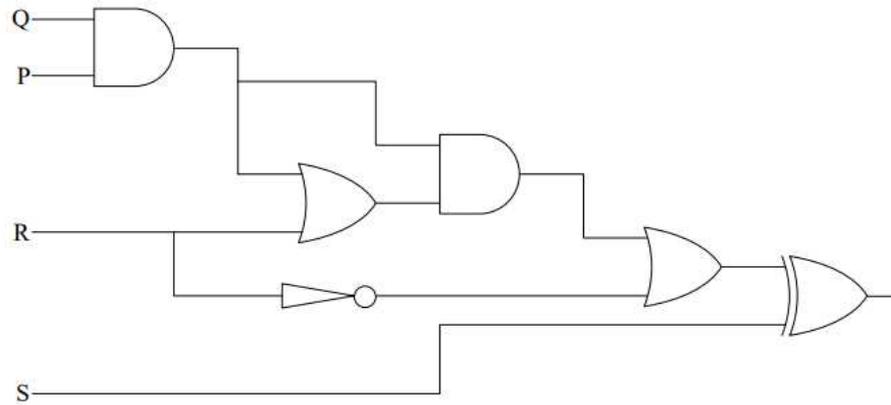
P	Q	R	S
1	0	1	0
1	1	0	1
1	1	1	0

(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)

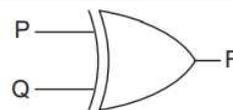
P	Q	R	S
1	1	0	1

(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

2024  
Paper 1  
Section 2  
Question 15

Machine  
control

A truth table for the reversing safety system of a forklift is shown.

Inputs				Intermediate signals			Output
A	B	C	D	E	F	G	X
0	0	0	0	0	1	0	0
0	0	0	1	0	1	0	0
0	0	1	0	0	0	0	0
0	0	1	1	0	0	0	0
0	1	0	0	1	1	1	0
0	1	0	1	1	1	1	1
0	1	1	0	1	0	0	0
0	1	1	1	1	0	0	0
1	0	0	0	1	1	1	0
1	0	0	1	1	1	1	1
1	0	1	0	1	0	0	0
1	0	1	1	1	0	0	0
1	1	0	0	1	1	1	0
1	1	0	1	1	1	1	1
1	1	1	0	1	0	0	0
1	1	1	1	1	0	0	0

The forklift has a motion sensor on each side at the back. If either sensor detects an obstacle while the forklift is reversing, a safety brake is activated. [8 marks]

Key

Input A = Left sensor (motion detected = 1)

Input B = Right sensor (motion detected = 1)

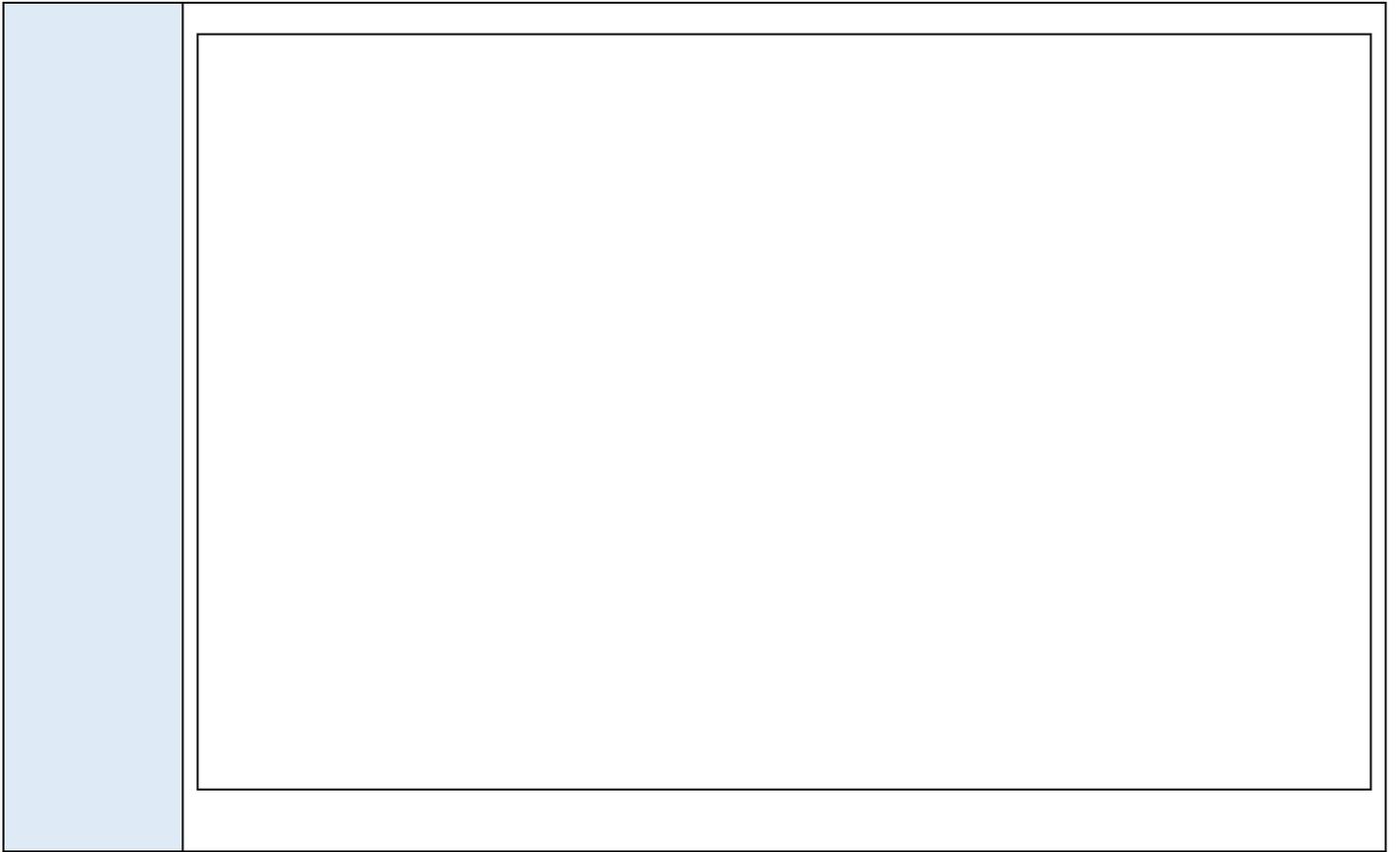
Input C = Gear (forward selected = 1, reverse selected = 0)

Input D = Engine (engine on = 1)

E, F and G are intermediate input/output signals to the logic gates.

Output X = Safety brake (brake on = 1)

Construct a logic gate circuit, based on the truth table, that meets the requirements for the safety brake to activate. Clearly label all inputs and outputs.






<b>2022 Paper 1 Section 2 Question 13</b>  <b>Machine control</b>	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



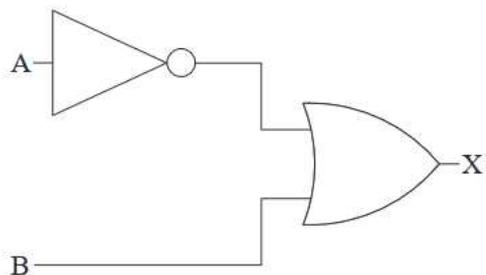


### Paper 1 Section 3

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

2024  
Paper 1  
Section 1  
Question 5  
  
Machine control

A logic gate circuit is shown.



Which truth table shows the correct output column for the logic gate circuit?

(A)

A	B	X
0	0	1
0	1	1
1	0	0
1	1	1

(B)

A	B	X
0	0	0
0	1	1
1	0	1
1	1	1

(C)

A	B	X
0	0	0
0	1	1
1	0	0
1	1	0

(D)

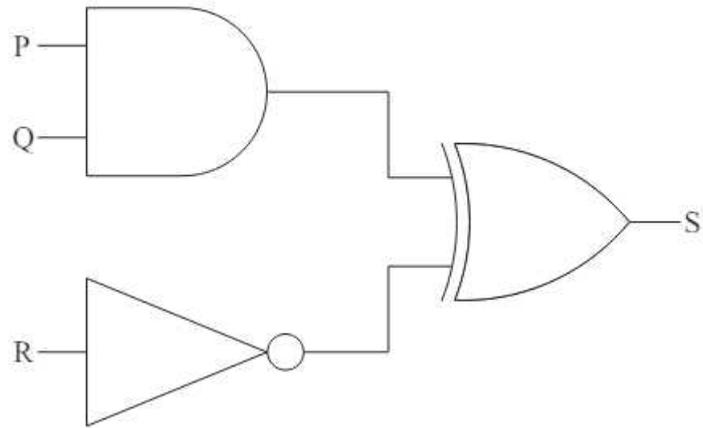
A	B	X
0	0	0
0	1	0
1	0	0
1	1	1

Answer is A.

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

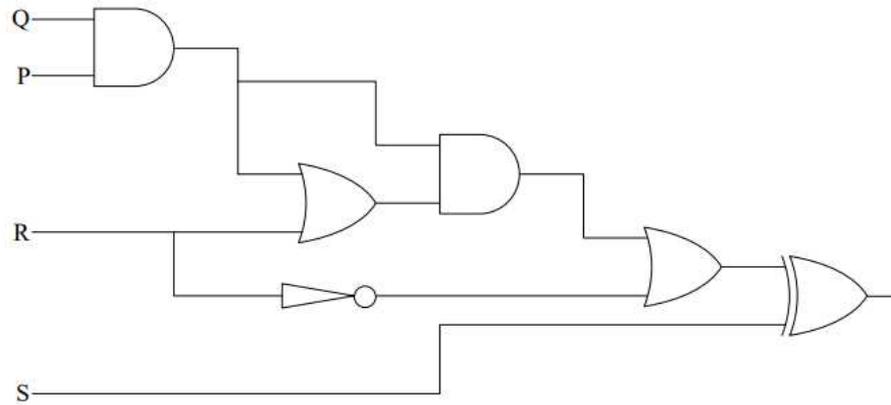
(D)

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

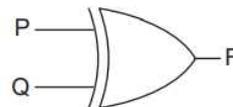
(D) 

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.

2024  
Paper 1  
Section 2  
Question 15  
  
Machine control

A truth table for the reversing safety system of a forklift is shown.

Inputs				Intermediate signals			Output
A	B	C	D	E	F	G	X
0	0	0	0	0	1	0	0
0	0	0	1	0	1	0	0
0	0	1	0	0	0	0	0
0	0	1	1	0	0	0	0
0	1	0	0	1	1	1	0
0	1	0	1	1	1	1	1
0	1	1	0	1	0	0	0
0	1	1	1	1	0	0	0
1	0	0	0	1	1	1	0
1	0	0	1	1	1	1	1
1	0	1	0	1	0	0	0
1	0	1	1	1	0	0	0
1	1	0	0	1	1	1	0
1	1	0	1	1	1	1	1
1	1	1	0	1	0	0	0
1	1	1	1	1	0	0	0

The forklift has a motion sensor on each side at the back. If either sensor detects an obstacle while the forklift is reversing, a safety brake is activated. [8 marks]

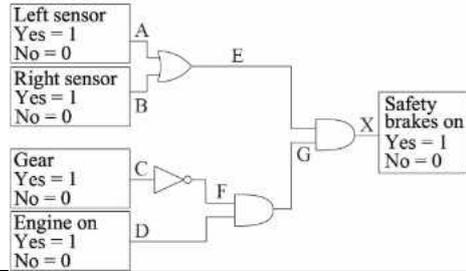
Key

- Input A = Left sensor (motion detected = 1)
- Input B = Right sensor (motion detected = 1)
- Input C = Gear (forward selected = 1, reverse selected = 0)
- Input D = Engine (engine on = 1)
- E, F and G are intermediate input/output signals to the logic gates.
- Output X = Safety brake (brake on = 1)

Construct a logic gate circuit, based on the truth table, that meets the requirements for the safety brake to activate. Clearly label all inputs and outputs.

Sample response	The response
<p>Method 1</p> <p>Left sensor Yes = 1 No = 0</p> <p>Right sensor Yes = 1 No = 0</p> <p>Gear Yes = 1 No = 0</p> <p>Engine on Yes = 1 No = 0</p> <p>Safety brakes on Yes = 1 No = 0</p>	<ul style="list-style-type: none"> <li>• provides a correctly applied logic gate circuit including                     <ul style="list-style-type: none"> <li>– left motion sensor and right motion sensor =&gt; OR =&gt; AND1 =&gt; AND2 =&gt; safety brake operation [1 mark]</li> <li>– gear =&gt; NOT =&gt; AND1 =&gt; AND2 =&gt; safety brake operation [1 mark]</li> <li>– engine =&gt; AND2 =&gt; safety brake operation [1 mark]</li> </ul> </li> <li>• correctly labels left and right motion sensor inputs [1 mark]</li> <li>• correctly labels gear input [1 mark]</li> <li>• correctly labels engine input [1 mark]</li> <li>• correctly labels intermediary inputs/outputs E, F and G [1 mark]</li> <li>• correctly labels safety brake output [1 mark]</li> </ul>

**Method 2**

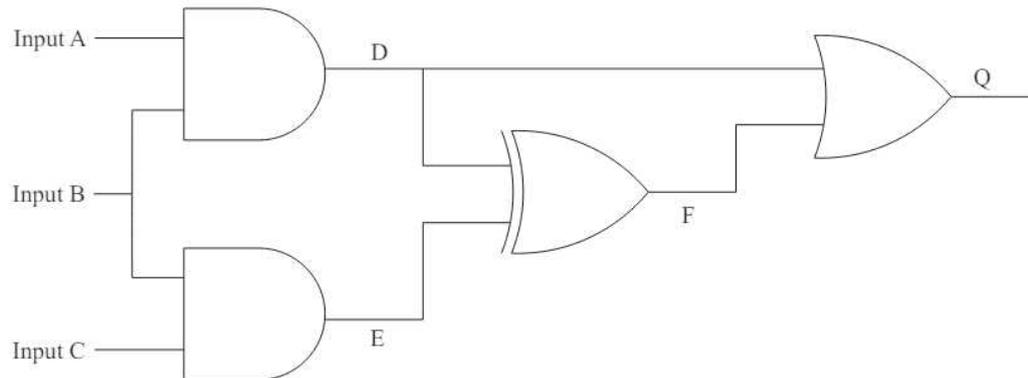


- provides a correctly applied logic gate circuit including
  - left motion sensor and right motion sensor => OR => AND2 => safety brake operation [1 mark]
  - gear => NOT => AND1 => AND2 => safety brake operation [1 mark]
  - engine => AND1 => AND2 => safety brake operation [1 mark]
- correctly labels left and right motion sensor inputs [1 mark]
- correctly labels gear input [1 mark]
- correctly labels engine input [1 mark]
- correctly labels intermediary inputs/outputs E, F and G [1 mark]
- correctly labels safety brake output [1 mark]

**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"> <li>• uses wording indicating that when all three inputs are on                             <ul style="list-style-type: none"> <li>– the solar panel drives the electric motor [1 mark]</li> <li>– the XOR gate will not allow the wind turbine to drive the motor [1 mark]</li> </ul> </li> <li>• uses wording indicating that when                             <ul style="list-style-type: none"> <li>– 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]</li> <li>– 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]</li> </ul> </li> </ul>

<b>2022</b> <b>Paper 1</b> <b>Section 2</b> <b>Question 13</b>  <b>Machine control</b>	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> </tr> <tr> <th>Input</th> <th>Input</th> <th>Output</th> </tr> </thead> <tbody> <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			Input	Input	Output	0	0	1	0	1	1	1	0	1	1	1	0	<table border="1"> <thead> <tr> <th>The response</th> </tr> </thead> <tbody> <tr> <td> <ul style="list-style-type: none"> <li>appropriately describes NAND gate function using wording that indicates the               <ul style="list-style-type: none"> <li>output is 0 when all inputs are 1 [1 mark]</li> <li>output is 1 when all inputs are not 1 [1 mark]</li> </ul> </li> <li>provides a truth table with               <ul style="list-style-type: none"> <li>one column correct [1 mark]</li> <li>a second column correct [1 mark]</li> <li>a third column correct [1 mark]</li> </ul> </li> </ul> </td> </tr> </tbody> </table>	The response
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Input	Input	Output																			
0	0	1																			
0	1	1																			
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<b>2022</b> <b>Paper 1</b> <b>Section 2</b> <b>Question 16</b>  <b>Machine control</b>	<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"> <li>provides a correctly applied logic circuit including               <ul style="list-style-type: none"> <li>clearly identified swipe card input [1 mark]</li> <li>clearly identified temperature input with temperature requirement &gt;25 [1 mark]</li> <li>clearly identified one-hour timer input [1 mark]</li> <li>clearly identified movement sensor input [1 mark]</li> <li>clearly identified ceiling fan operation output [1 mark]</li> </ul> </li> <li>swipe card and temp sensor =&gt; AND1 [1 mark]</li> <li>condition 1 and condition 2 =&gt; AND2 =&gt; ceiling fan operation [1 mark]</li> <li>one-hour timer =&gt; XOR =&gt; AND2 =&gt; ceiling fan operation [1 mark]</li> <li>one-hour timer =&gt; NOT =&gt; AND3 =&gt; XOR =&gt; AND2 =&gt; ceiling fan operation [1 mark]</li> <li>movement sensor =&gt; AND3 =&gt; XOR =&gt; AND2 =&gt; ceiling fan operation [1 mark]</li> </ul> </td> </tr> </tbody> </table>	Sample response	The response	
Sample response	The response			
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**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.

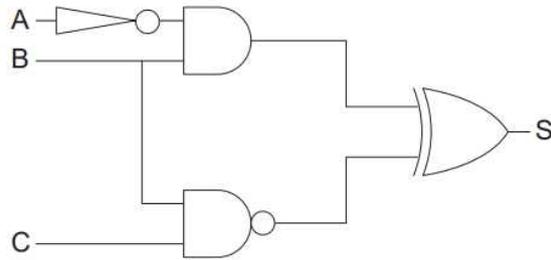
Clearly annotate all logic gate inputs and outputs and label all sensors. [6 marks]

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

Sample response	The response
<p>The diagram shows a logic circuit with four inputs: P, S, C, and M. P and S are connected to an AND gate. C and M are connected to another AND gate, with a NOT gate in series with M. The outputs of these two AND gates are connected to a final AND gate.</p>	<ul style="list-style-type: none"> <li>provides an appropriately annotated logic gate showing <ul style="list-style-type: none"> <li>inputs and outputs to produce a logic circuit 1 output [1 mark]</li> <li>correct sensor labels for logic circuit inputs [1 mark]</li> </ul> </li> <li>includes use of the <ul style="list-style-type: none"> <li>AND gate for P and S sensors [1 mark]</li> <li>NOT gate for M sensor prior to AND gate [1 mark]</li> <li>AND gate for C and M sensors [1 mark]</li> <li>AND gate linked to an AND gate and an AND gate to acknowledge the two conditions of machine operation [1 mark]</li> </ul> </li> </ul>

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