

# Engineering Studies

## General Instructions

- Reading time – 5 minutes
- Working time – 3 hours
- Write using black or blue pen  
Black pen is preferred
- Draw diagrams using pencil
- Board-approved calculators may be used
- A formulae sheet is provided at the back of this paper
- Write your Centre Number and Student Number at the top of pages 13, 17, 21, 25, 29, 31 and 35

## Total marks – 100

### **Section I** Pages 2–11

#### **20 marks**

- Attempt Questions 1–20
- Allow about 30 minutes for this section

### **Section II** Pages 13–37

#### **80 marks**

- Attempt Questions 21–27
- Allow about 2 hours and 30 minutes for this section

## Section I

**20 marks**

**Attempt Questions 1–20**

**Allow about 30 minutes for this section**

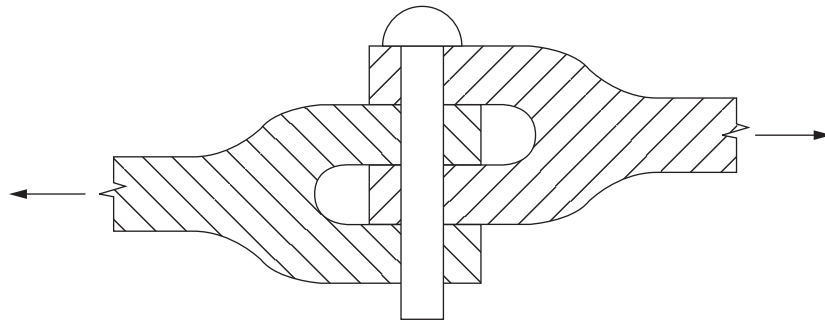
Use the multiple-choice answer sheet for Questions 1–20.

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**1** Which of the following is a test performed on a batch of concrete to test its workability?

- (A) Compression
- (B) Proving
- (C) Slump
- (D) Tensile

**2** The diagram shows couplings experiencing a tensile load.



What type of shear stress is on the pin under the tensile load?

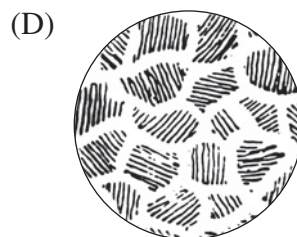
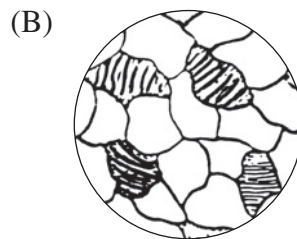
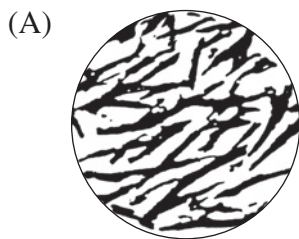
- (A) Single
- (B) Double
- (C) Triple
- (D) Quadruple

- 3 Engineers suspect that there is a flaw in the centre of a large concrete pylon used in a building structure.

Which of the following techniques could be used to find the flaw without damaging the pylon?

- (A) Bend test
  - (B) Radiography
  - (C) Eddy current inspection
  - (D) Dye penetrant inspection
- 4 Which of the following control surfaces on an aircraft is used to control yawing?
- (A) Aileron
  - (B) Elevator
  - (C) Flap
  - (D) Rudder

- 5 Which of the following microstructures shows a water quenched high carbon steel?



- 6 An engineer has designed a warning system to alert ferry masters so that a ferry can only depart when the boarding ramp is on board and the passengers are seated.

The following statements are represented by a 1 if true, or a 0 if false:

**A** – the boarding ramp is on board

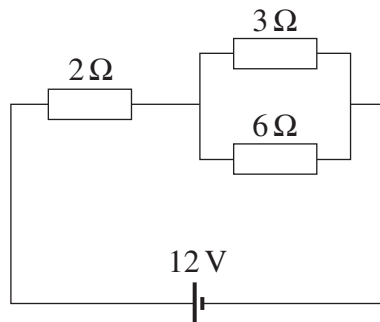
**B** – the passengers are seated

**X** – the ferry can depart.

Which row of the table represents the situation where the passengers are not seated even though the boarding ramp is on board?

	<b>A</b>	<b>B</b>	<b>X</b>
(A)	0	1	1
(B)	0	1	0
(C)	1	0	1
(D)	1	0	0

- 7 The diagram shows an electrical circuit.



Which of the following correctly calculates the total resistance for this electrical circuit?

(A)  $\left( \frac{1}{\frac{1}{3} + \frac{1}{6}} \right) + 2$

(B)  $\left( \frac{1}{3} + \frac{1}{6} \right) + 2$

(C)  $\left( \frac{1}{3} + \frac{1}{6} \right) + \frac{1}{2}$

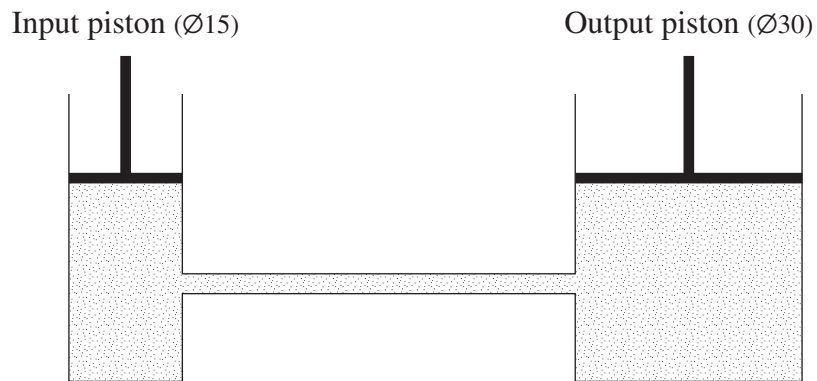
(D)  $(3 + 6) + 2$

- 8 An insulated conductor has 2000 volts placed across it.

Which instrument should be used to measure the insulation resistance of the conductor?

- (A) Ammeter
- (B) Megohmmeter
- (C) Multimeter
- (D) Voltmeter

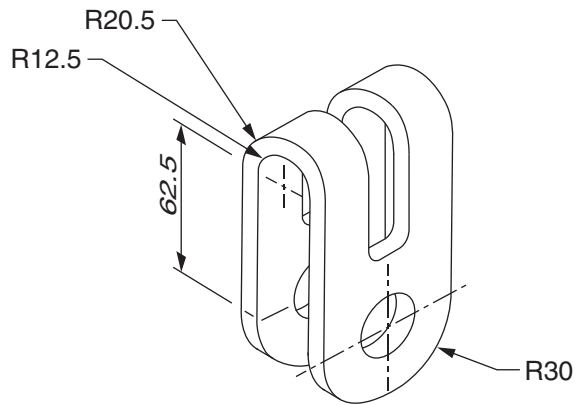
- 9 The diagram shows a hydraulic system.



How far will the output piston move if the input piston moves a distance of 20 mm?

- (A) 5 mm
- (B) 10 mm
- (C) 20 mm
- (D) 40 mm

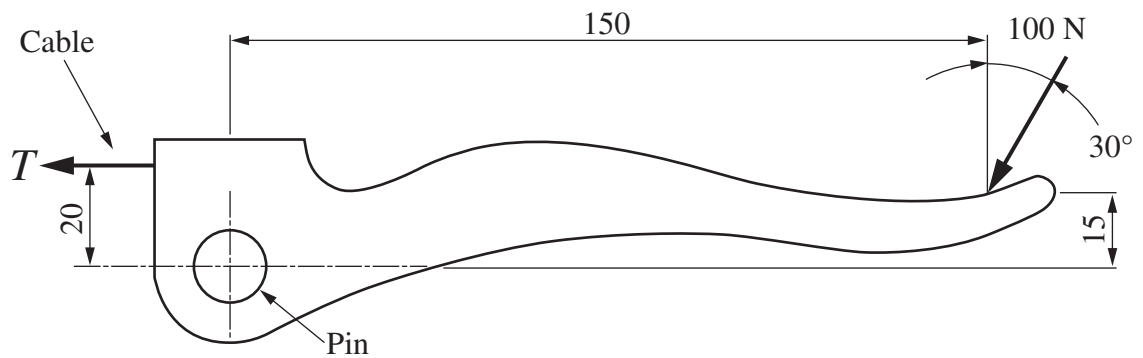
- 10 The diagram shows a bracket folded from a single strip of stainless steel.



If the measurement is taken along the neutral axis, what are the two radii needed to calculate the length of strip required to make the bracket?

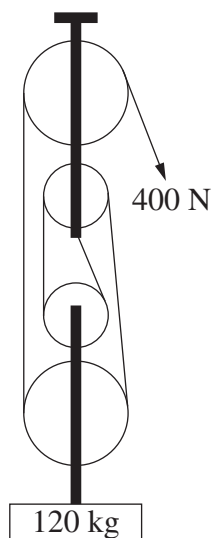
- (A) 12.5 and 30
  - (B) 16.5 and 30
  - (C) 20.5 and 30
  - (D) 30 and 30
- 11 Which of the following electrical components does NOT contain a semiconductor?
- (A) Diode
  - (B) Rectifier
  - (C) Resistor
  - (D) Transistor

- 12 The diagram, drawn to scale, shows a handle with a force of 100 N applied.



What is the tension  $T$  in the cable?

- (A) 612 N
  - (B) 650 N
  - (C) 687 N
  - (D) 750 N
- 13 The diagram shows a pulley system.



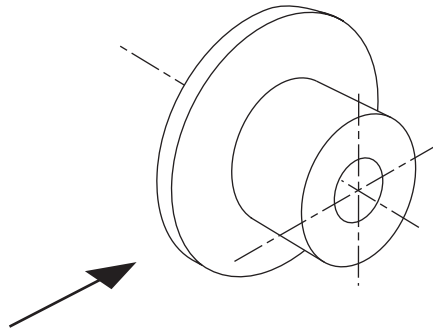
NOT TO  
SCALE

A 400 N effort is needed to lift the 120 kg load.

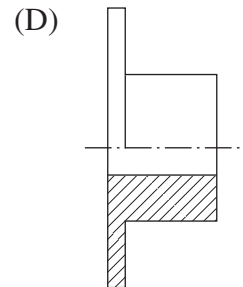
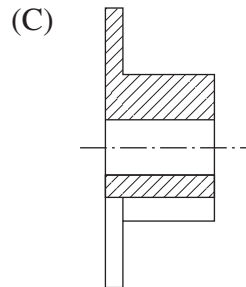
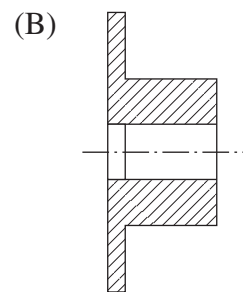
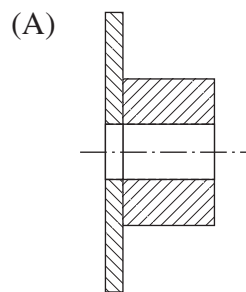
What is the efficiency of the pulley system?

- (A) 300%
- (B) 100%
- (C) 75%
- (D) 33%

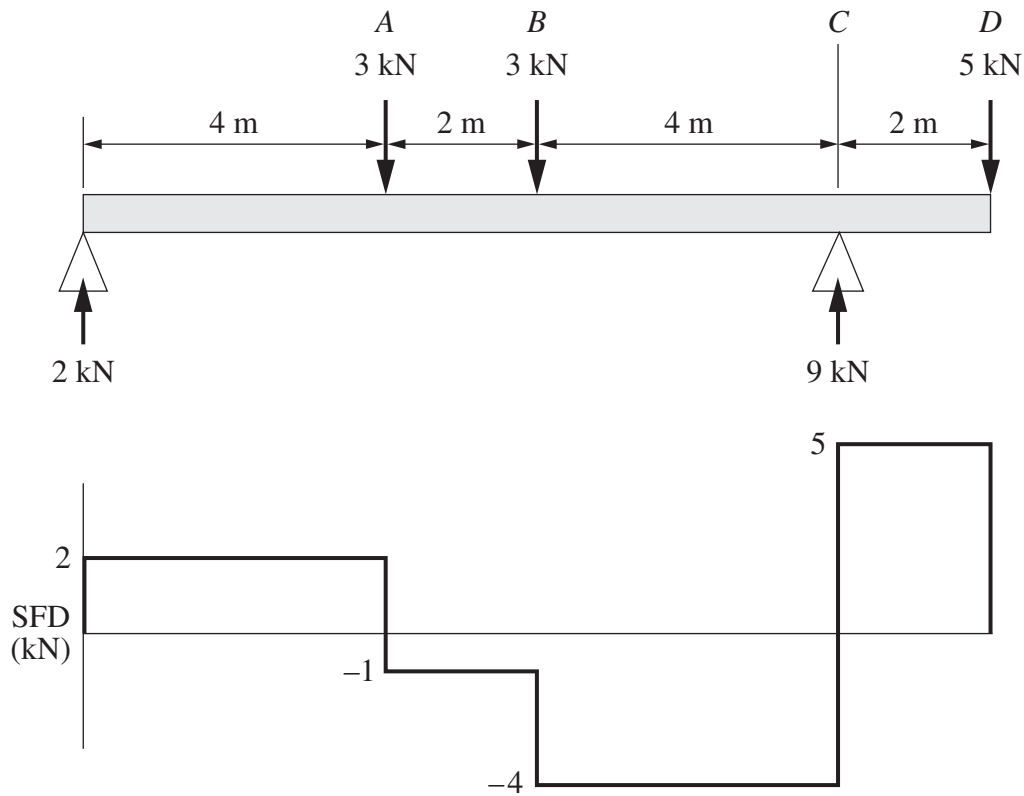
- 14 A pictorial drawing of an inlet valve is shown.



Which of the following sectional front views of the valve complies with AS1100?



- 15 The diagram shows a loaded 12 metre beam and the corresponding shear force diagram.



What is the position of the maximum bending moment?

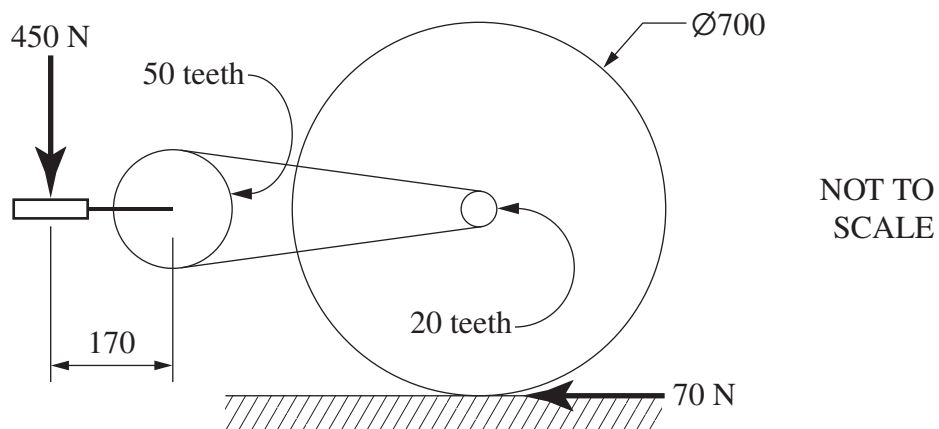
- (A) *A*
  - (B) *B*
  - (C) *C*
  - (D) *D*
- 16 Ceramics are good insulators because their structure has
- (A) covalent and secondary bonds.
  - (B) ionic bonds with no free electrons.
  - (C) dipole attraction with the molecules.
  - (D) metallic bonds with some free electrons.

- 17 A 2 tonne vehicle is stationary at the top of a  $40^\circ$  slope that is 20 metres long. The vehicle is allowed to roll down the slope.

Ignoring friction, what is the velocity of the vehicle at the bottom of the slope?

- (A) 57.7 m/s
- (B) 20.0 m/s
- (C) 17.5 m/s
- (D) 16.0 m/s

- 18 The diagram shows a bicycle drive mechanism.



What is the velocity ratio of the mechanism?

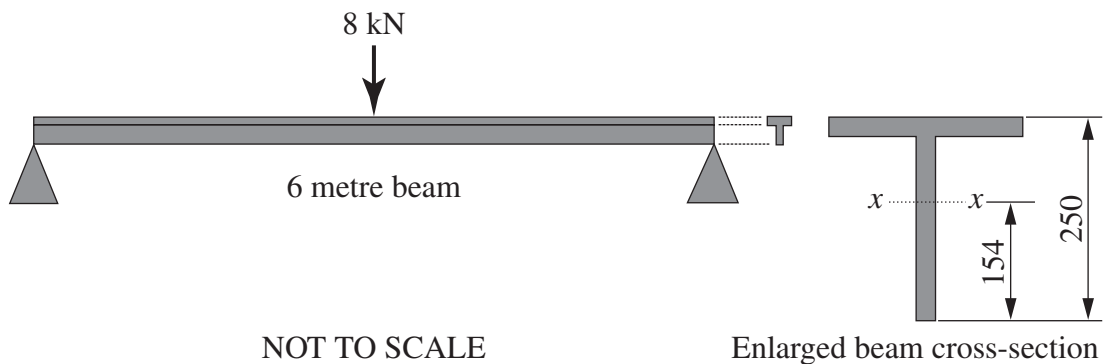
- (A) 0.16
- (B) 0.19
- (C) 0.40
- (D) 0.48

19 Aluminium copper alloys can be strengthened by a heat treatment process.

Which of the following statements best describes the stages of this process?

- (A) Heat to red heat, slowly cool to room temperature.
- (B) Heat to about 150°C, quench to room temperature, reheat to slightly above 100°C.
- (C) Heat to form a uniform structure, quench to room temperature, reheat to a slightly elevated temperature.
- (D) Heat to recrystallisation temperature, cool to room temperature, reheat to slightly below recrystallisation temperature.

20 The diagram shows a 6 metre beam and its cross-section.



The beam is loaded at its midpoint. The cross-sectional area of the beam is 110 mm<sup>2</sup>. The second moment of area  $I_{xx} = 102 \times 10^6 \text{ mm}^4$ .

What is the maximum compressive stress in the beam?

- (A) 11.3 MPa
- (B) 18.1 MPa
- (C) 22.6 MPa
- (D) 29.4 MPa

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Centre Number

Section II

80 marks

Attempt Questions 21–27

Allow about 2 hours and 30 minutes for this section

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Student Number

Answer the questions in the spaces provided. These spaces provide guidance for the expected length of response.

Question 21 (12 marks)

- (a) The photographs show a large single hull ferry and a smaller twin hull ferry. 3



Single Hull



Twin Hull

Contrast how these ferries are used to provide public transport.

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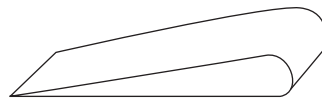
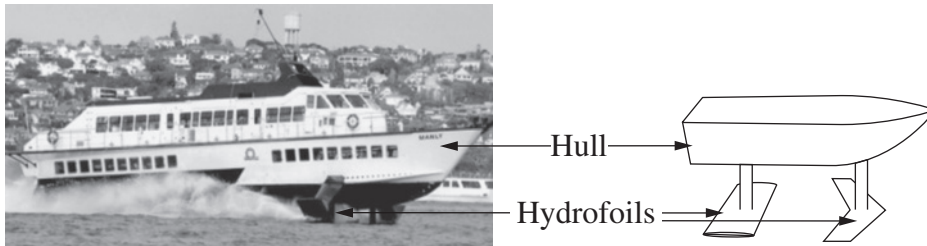
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Question 21 continues on page 14

Question 21 (continued)

- (b) A photograph of hydrofoils in operation on a ferry and the detail of hydrofoil geometry are shown.

3



Detail of Hydrofoil Geometry

Using the information provided, describe how a hydrofoil operates.

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**Question 21 continues on page 15**

Question 21 (continued)

- (c) Outline factors that an engineer needs to consider when designing a ferry wharf. **3**

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- (d) Modern wharves, such as the one shown, often use steel structures to support the decking. **3**



Describe a method, other than applying a protective coating, that could be used to protect the steel from corrosion.

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**End of Question 21**

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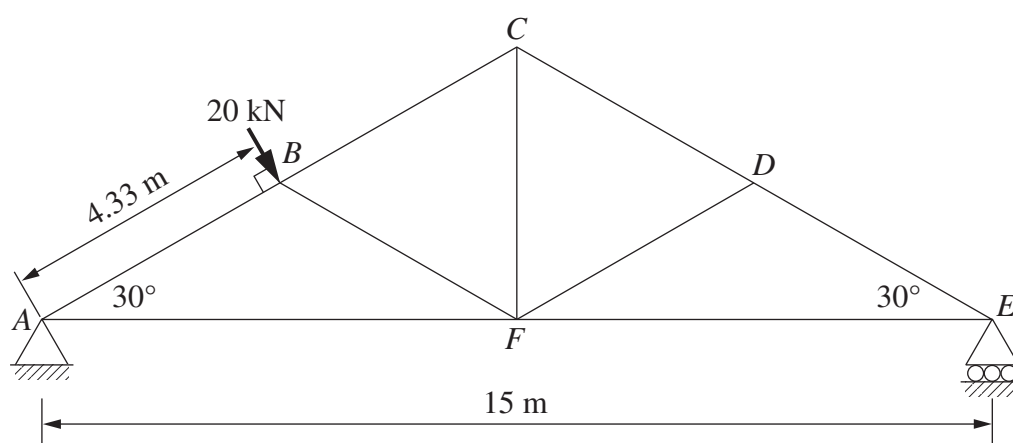
## Section II (continued)

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Student Number

## Question 22 (12 marks)

- (a) The diagram shows a roof truss supported at each end.



DRAWN TO SCALE

- (i) A force of 20 kN is applied at joint *B*.

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Determine the magnitude and direction of the reaction at the pin joint *A*.

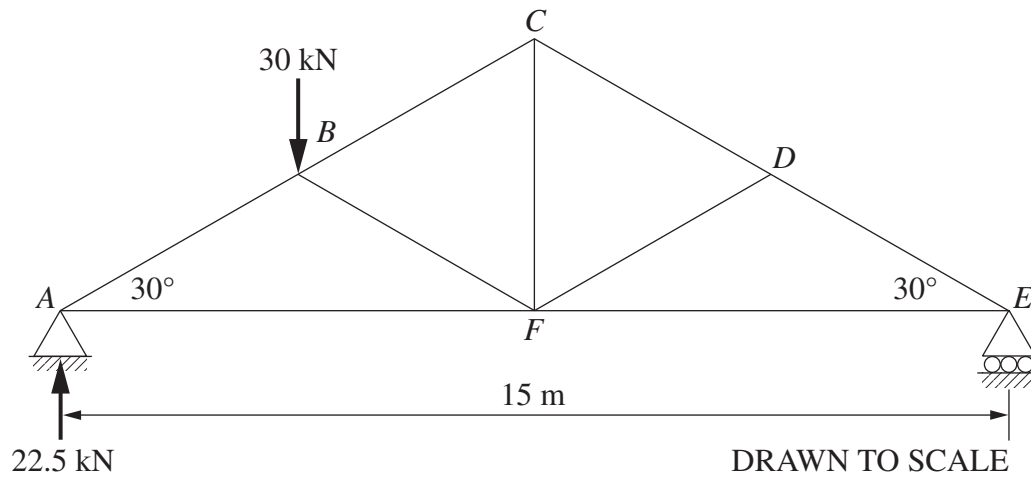
Force ..... kN    Direction .....

Question 22 continues on page 18

Question 22 (continued)

- (ii) For a different loading, a 30 kN vertical force is applied at joint  $B$  and the reaction at the pin joint  $A$  is 22.5 kN vertically upwards.

3



Determine the magnitude and nature of the forces in the members  $BC$  and  $DF$ .

Force in  $BC$  ..... kN Nature .....

Force in  $DF$  ..... kN Nature .....

Question 22 continues on page 19

Question 22 (continued)

- (iii) For a different loading, the force in member  $CF$  is 29 kN.  $CF$  is a solid circular member. **2**

Determine the diameter of member  $CF$  if the yield stress for steel is 272 MPa, and a factor of safety of 1.6 is used.

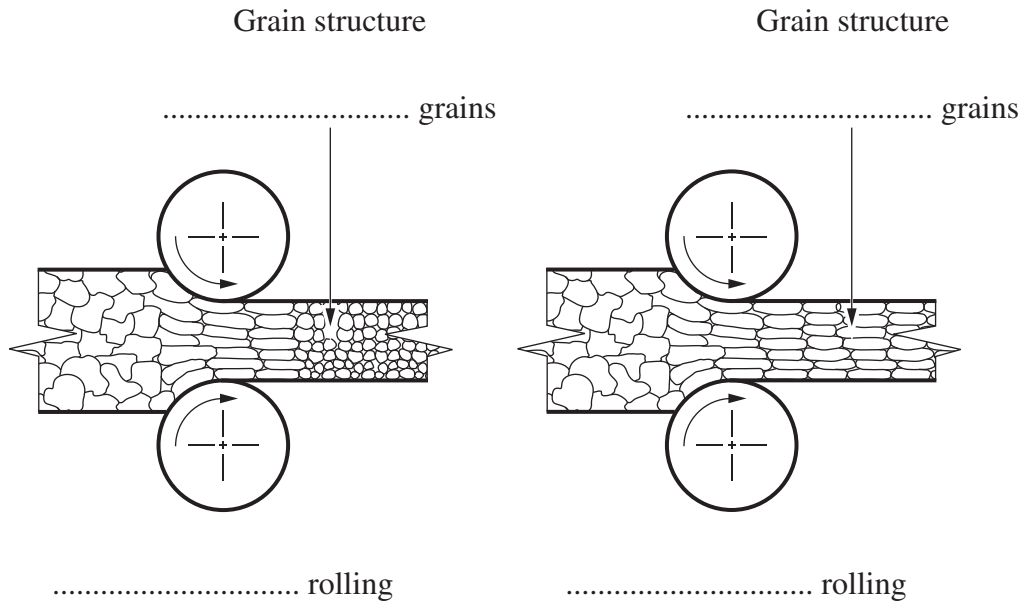
Diameter ..... mm

**Question 22 continues on page 20**

Question 22 (continued)

- (b) Flat steel members used for roof trusses could be produced by hot rolling or cold rolling.

- (i) Complete the diagrams by naming each process and labelling the grain structure produced. 2



- (ii) Choose one of the processes named in part (i). 2

Explain how the change in grain structure caused by this process has affected TWO different mechanical properties of the steel.

Name of process .....

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**End of Question 22**

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Centre Number

Section II (continued)

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Student Number

**Question 23** (12 marks)

- (a) Outline advantages of polymer roof guttering compared to metal roof guttering. **3**

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- (b) In the box below, name a polymer that is suitable for roof guttering. Describe the extrusion process for the named polymer. A labelled diagram may be included. **3**

Name of polymer .....
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**Question 23 continues on page 22**

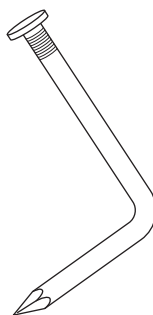
Question 23 (continued)

- (c) The sketch shows a bent mild steel nail which has become severely corroded after lying in a polymer gutter.

2

Identify the type of corrosion most likely to have occurred, and on the sketch show the areas of corrosion indicating the anode and cathode regions.

Type of corrosion .....

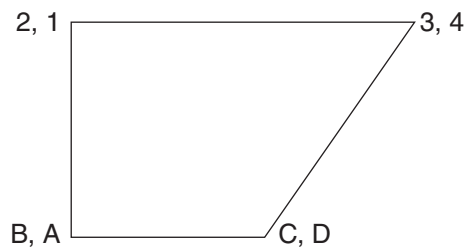
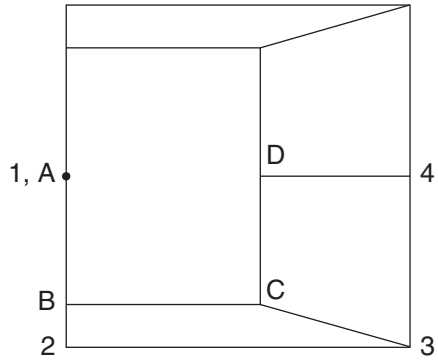


**Question 23 continues on page 23**

Question 23 (continued)

- (d) A transition piece is used to allow water to flow from a gutter to a downpipe. The top view and front view of the transition piece are drawn in third-angle projection.

4



Complete a half development of the transition piece. The starting position for the seam 1–A is given.

1 •

End of Question 23

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Centre Number

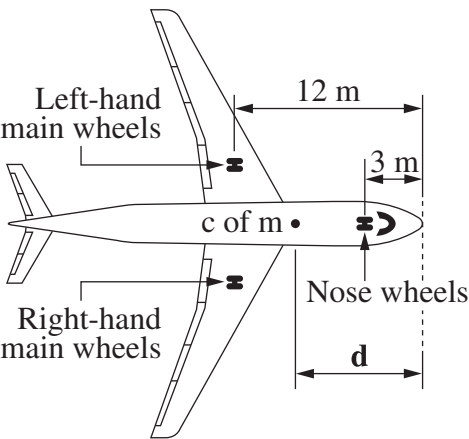
## Section II (continued)

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Student Number

## Question 24 (12 marks)

- (a) The table shows data obtained by placing an aircraft on three scales, one under each set of wheels. 2

	<i>Scale position</i>	<i>Scale reading</i>
	Under nose wheels	550 kg
	Under right-hand main wheels	1400 kg
	Under left-hand main wheels	1400 kg

Calculate the distance (**d**) between the centre of mass (c of m) and the front of the aircraft.

**d** = ..... m

Question 24 continues on page 26

Question 24 (continued)

- (b) Outline how a pitot tube operates in flight. **2**

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- (c) Describe the function of winglets on modern aircraft. **2**

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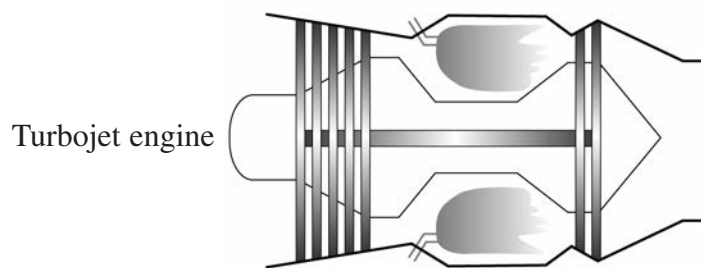
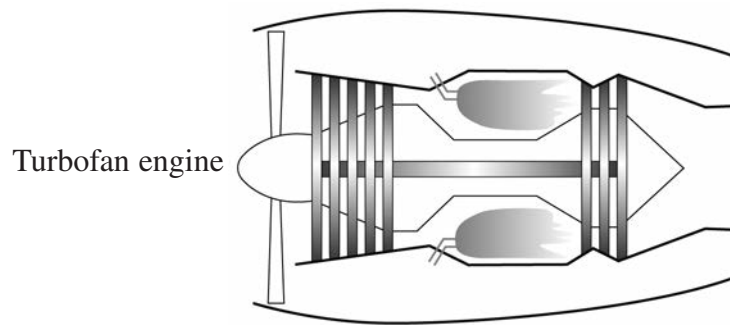
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**Question 24 continues on page 27**

Question 24 (continued)

- (d) The diagrams show a turbofan engine and a turbojet engine.

6



Explain how thrust created by airflow affects the main operations of the two engines. You may add relevant information to the diagrams to support your answer.

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**End of Question 24**

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Centre Number

Section II (continued)

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Student Number

**Question 25** (12 marks)

- (a) Outline TWO control technologies used to make modern cars safer. **3**

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- (b) A car with a petrol engine has a 12 volt DC electrical system. **3**

How is the electricity generated, stored and then changed to a different voltage system within the car?

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**Question 25 continues on page 30**

Question 25 (continued)

- (c) Outline the advantages of using fibre optics in telecommunications.

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- (d) Explain how a global positioning system (GPS) uses multiple satellites for navigation.

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**End of Question 25**

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Centre Number

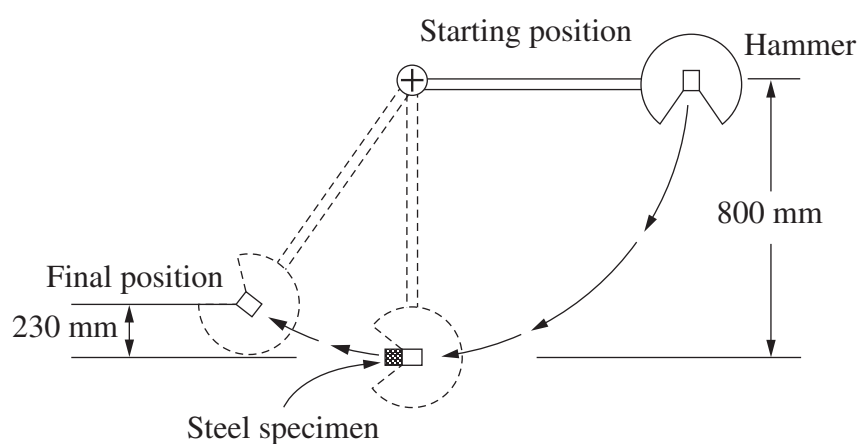
## Section II (continued)

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Student Number

## Question 26 (12 marks)

- (a) The diagram shows a notched bar test. A hammer of mass 11 kg is released from a height of 800 mm. The hammer strikes and fractures the steel specimen at the bottom of the arc, and then continues its swing to a height of 230 mm.



- (i) Determine the energy lost by the hammer in fracturing the steel specimen. Assume there is no friction loss in the test machine.

2

Energy lost ..... J

Question 26 continues on page 32

Question 26 (continued)

- (ii) Complete the table for a type of notched bar impact test.

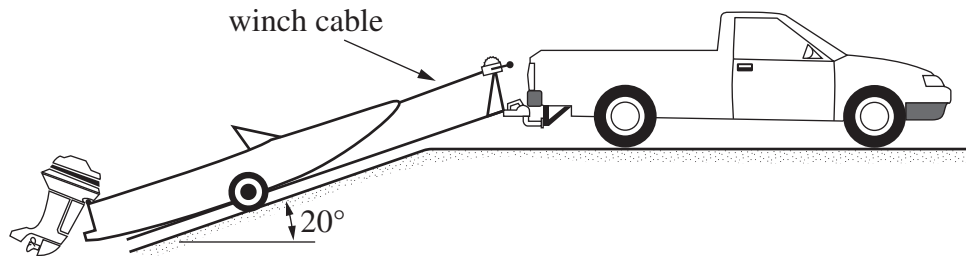
4

Name of notched bar impact test .....
Sketch how the specimen is held. Indicate on your sketch the position of the notch relative to the striker.
Mechanical property determined .....

**Question 26 continues on page 33**

Question 26 (continued)

- (b) A 1.3 tonne boat rests on a trailer inclined at  $20^\circ$  to the horizontal plane. The coefficient of friction between the boat and the trailer is 0.3 and the winch cable is parallel to the trailer boat supports.



- (i) Calculate the minimum force required in the winch cable to just prevent the boat from slipping back down the trailer.

3

Force in cable ..... kN

Question 26 continues on page 34

Question 26 (continued)

- (ii) An electric motor drives a winch to pull the 1.3 tonne boat in part (i) up onto the trailer at a constant velocity of 0.7 m/s. The coefficient of friction between the boat and the trailer is 0.3. **3**

Calculate the power required if the efficiency of the motor is 77%.

Power ..... kW

**End of Question 26**

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Centre Number

Section II (continued)

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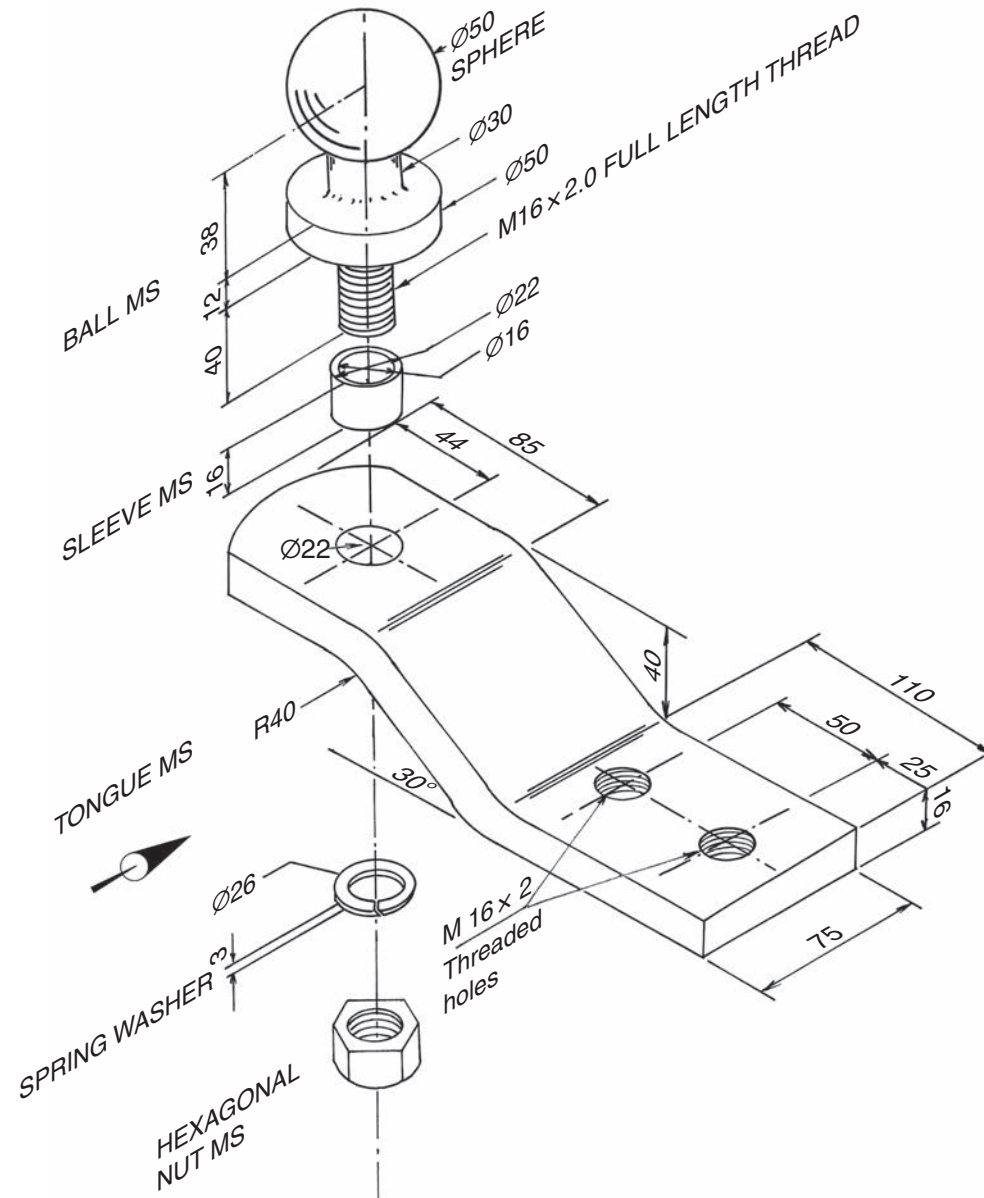
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Question 27 (8 marks)

Please turn over

**Question 27** (8 marks)

A pictorial drawing of a towbar is shown.



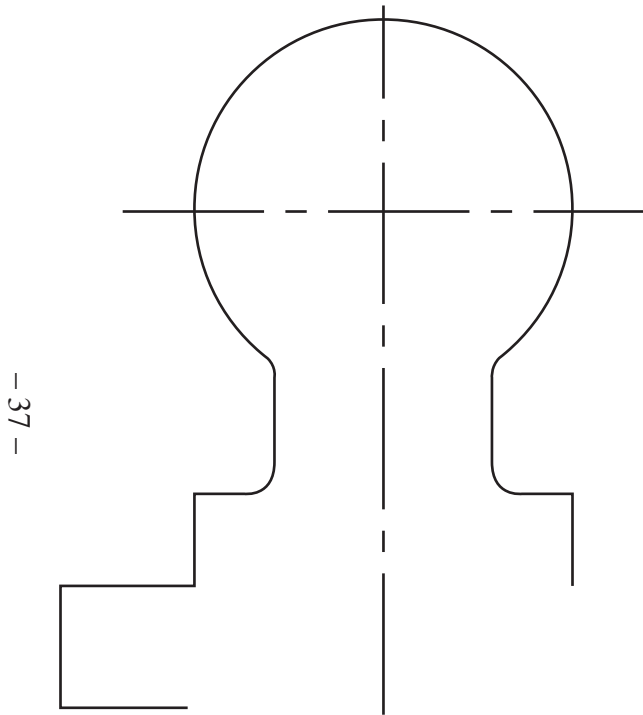
Question 27 continues on page 37

Question 27 (continued)

Draw a full sectional view of the fully assembled towbar when viewed from the direction of the arrow.

The section plane is to pass through the centre line containing the M16 threaded holes and  $\text{Ø}22$  hole in the towbar. Dimension the overall length of the tongue and the diameter of the ball.

8



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## FORMULAE SHEET

**Force, Moments**

$$F = ma; \quad M = Fd$$

If a body is in equilibrium, then  $\sum F_x = 0$ ;  $\sum F_y = 0$ ;  $\sum M = 0$

**Friction**

$$F = \mu N; \quad \mu = \tan \phi$$

**Energy, Work, Power**

$$KE = \frac{1}{2}mv^2; \quad PE = mgh; \quad W = Fs = \Delta PE + \Delta KE; \quad P = \frac{W}{t}; \quad P = \frac{Fs}{t}; \quad P = Fv$$

**Pressure**

$$P = \frac{F}{A}; \quad P = P_o + \rho gh$$

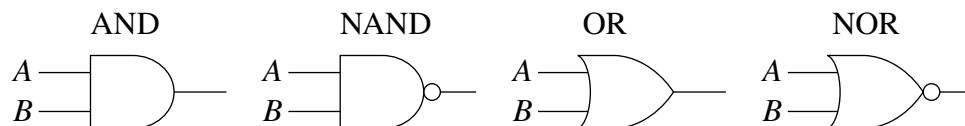
**Stress and Strain**

$$\sigma = \frac{F}{A}; \quad \epsilon = \frac{e}{L}; \quad E = \frac{\sigma}{\epsilon}; \quad \sigma = \frac{My}{I}$$

$$\sigma_{\text{allowable}} = \frac{\sigma_{\text{yield}}}{F \text{ of } S} \text{ (Ductile); } \quad \sigma_{\text{allowable}} = \frac{\sigma_{UTS}}{F \text{ of } S} \text{ (Brittle)}$$

**Machines**

$$MA = \frac{L}{E}; \quad VR = \frac{d_E}{d_L}; \quad \eta = \frac{MA}{VR}$$

**Digital Electronics****Electricity, Electronics**

$$E = IR \quad P = I^2 R$$

Series  $R_t = R_1 + R_2 + R_3 + R_4 + \dots + R_n$

Parallel  $\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4} + \dots + \frac{1}{R_n}$

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