



NSW Education Standards Authority

2021 HIGHER SCHOOL CERTIFICATE EXAMINATION

Engineering Studies

**General
Instructions**

- Reading time – 5 minutes
- Working time – 3 hours
- Write using black pen
- Draw diagrams using pencil
- Calculators approved by NESA may be used
- A formulae sheet is provided at the back of this paper

**Total marks:
100**

Section I – 20 marks (pages 2–12)

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

Section II – 80 marks (pages 13–28)

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

Section I

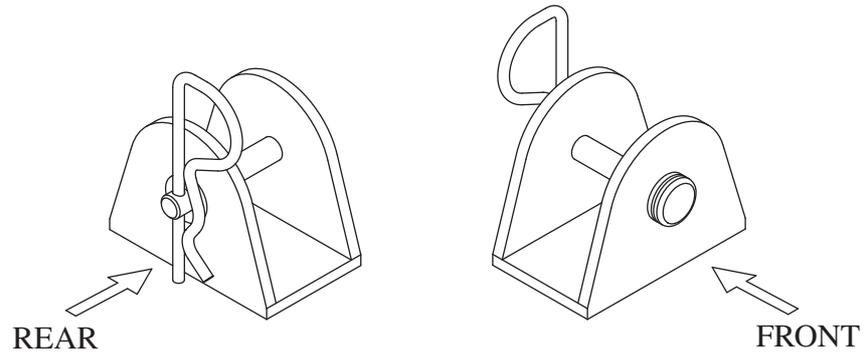
20 marks

Attempt Questions 1–20

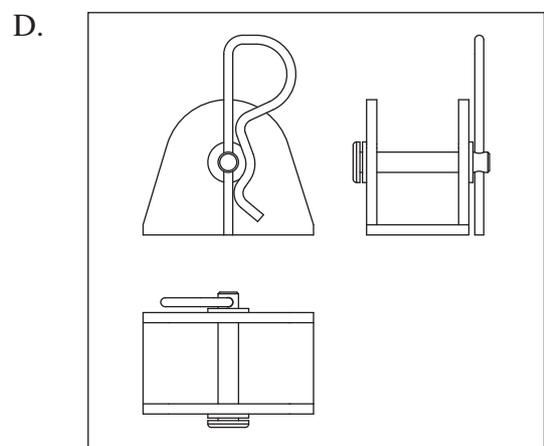
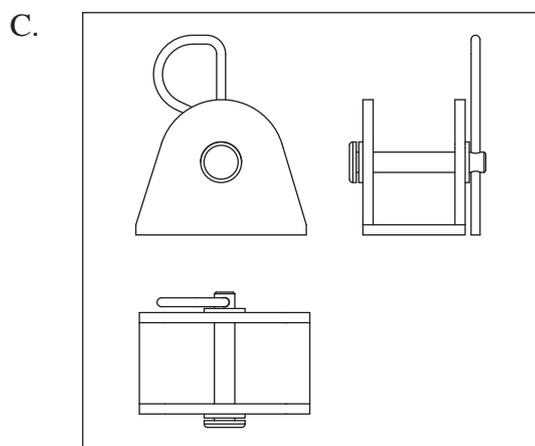
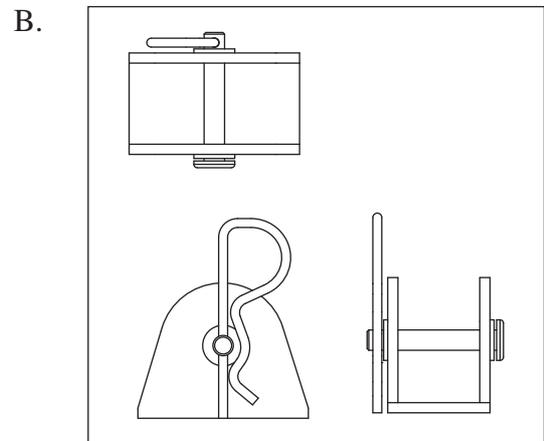
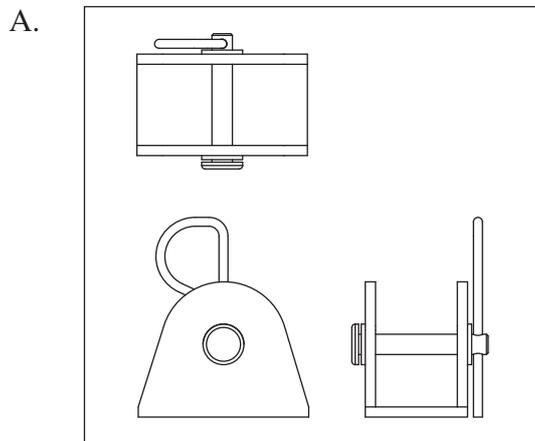
Allow about 30 minutes for this section

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

1 The diagram shows the rear and front views of a bracket.



Which of the following shows the bracket in third angle projection?

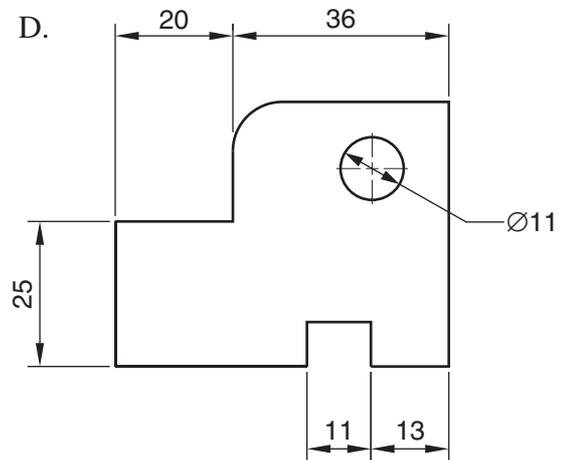
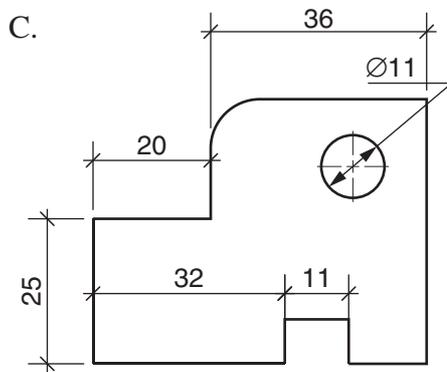
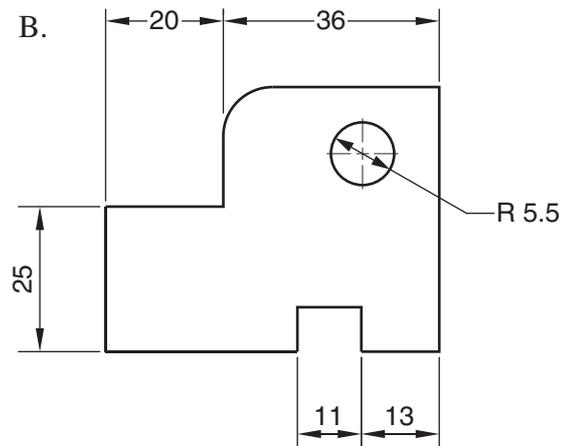
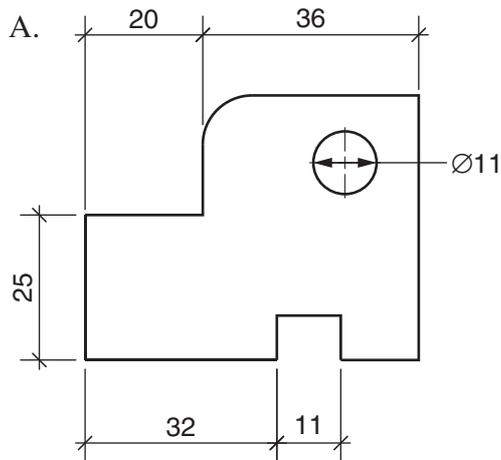


- 2 The flight recorder, commonly known as the 'black box', was developed in Australia in the 1950s to assist in air crash investigations.

How does a black box assist in an air crash investigation?

- A. It contains aircraft maintenance history.
 - B. It holds passenger details and conversations.
 - C. It keeps details of flight data and cockpit conversations.
 - D. It retains details of baggage weight and flight crew rosters.
- 3 Which of the following is used to transmit data in a fibre optic cable?
- A. Air pressure
 - B. Infrared light
 - C. Plasma radiation
 - D. Electrical voltage

4 Which engineering drawing shows a bracket correctly dimensioned to AS 1100 drawing standards?



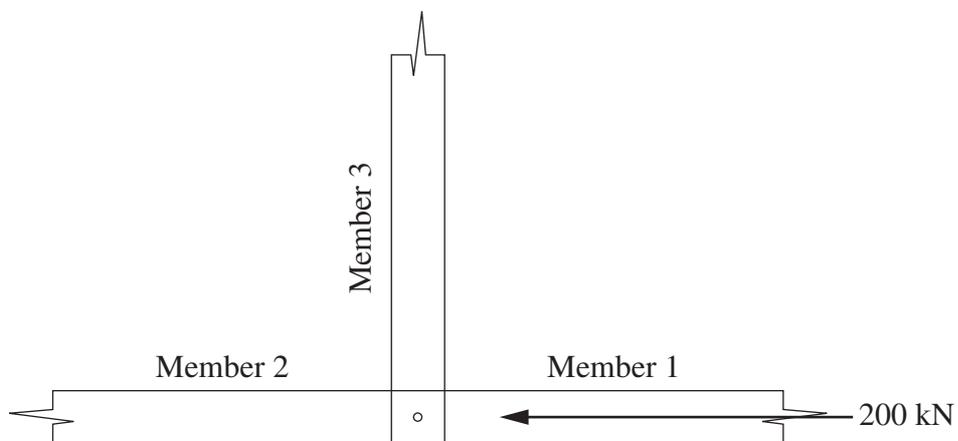
5 One of the key responsibilities of a qualified professional aeronautical engineer is to ensure that

- A. flight schedules at an airport are optimised.
- B. airport runways are constructed to standard.
- C. baggage carousels undergo routine maintenance.
- D. aircraft design minimises the noise heard at ground level.

- 6 A train has a total mass of 400 tonnes. It accelerates from rest to a speed of 25 m/s.

What is the kinetic energy of the train at the speed of 25 m/s?

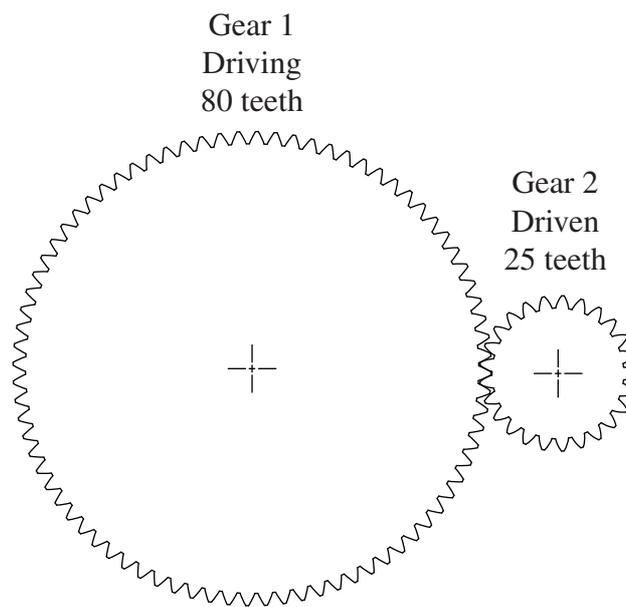
- A. 125×10^3 J
 B. 250×10^3 J
 C. 125×10^6 J
 D. 250×10^6 J
- 7 The diagram shows a section of a pin jointed truss in equilibrium. The force in Member 1 is 200 kN in compression.



Which row of the table identifies the magnitude and nature of the forces in Member 2 and Member 3?

	<i>Force in Member 2</i>	<i>Force in Member 3</i>
A.	200 kN (compression)	0 kN
B.	200 kN (tension)	0 kN
C.	100 kN (compression)	100 kN (tension)
D.	100 kN (tension)	100 kN (compression)

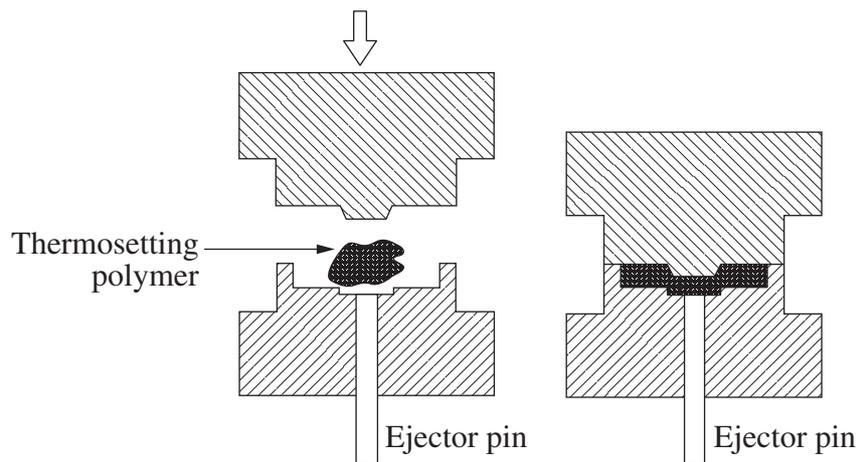
- 8 A gear system is shown.



What is the velocity ratio of this gear system?

- A. 0.3125
 - B. 0.320
 - C. 3.125
 - D. 3.20
- 9 A pitot tube supplies two pressure readings, total pressure and static pressure.
- These pressure readings are then used to determine the
- A. sealed pressure.
 - B. dynamic pressure.
 - C. standard pressure.
 - D. hydrostatic pressure.

10 The diagram illustrates a method of forming a thermosetting polymer.



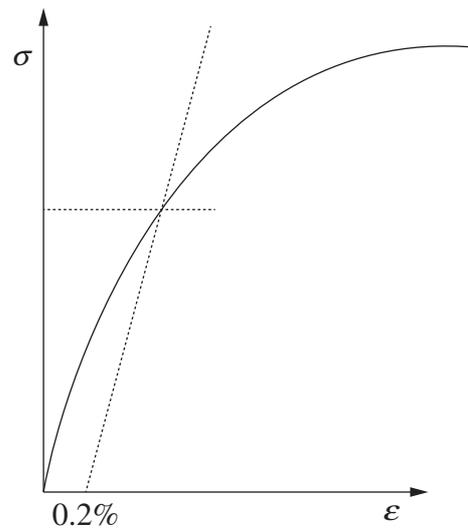
Which method is illustrated?

- A. Extrusion
- B. Calendering
- C. Injection moulding
- D. Compression moulding

11 Which radio transmission method is most likely to have static interference?

- A. Amplitude modulation (AM)
- B. Frequency modulation (FM)
- C. Digital audio broadcast (DAB)
- D. Pulse width modulation (PWM)

- 12 The stress–strain diagram shown is being used to calculate a material property.



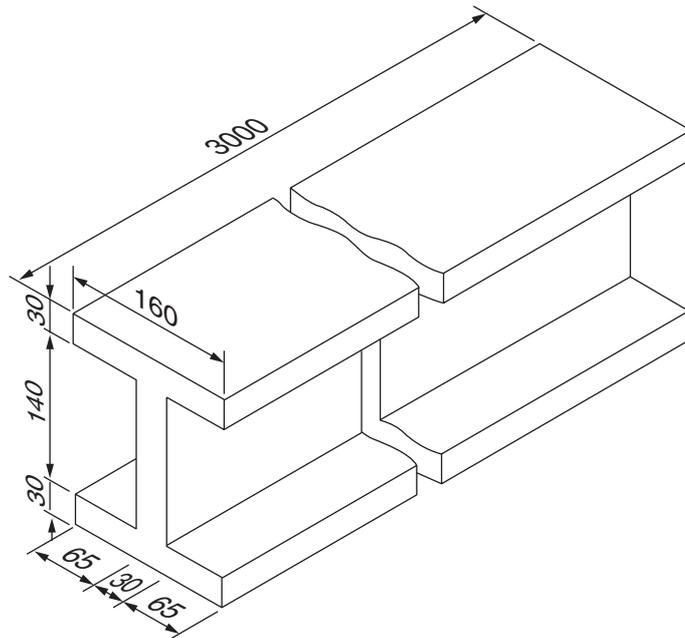
What material property can be calculated by using the dotted lines shown in this diagram?

- A. Hardness
 - B. Toughness
 - C. Proof stress
 - D. Ultimate tensile stress
- 13 Two identical aircraft, Q and R , are travelling at 500 km per hour. Aircraft Q is at an altitude of 1000 m and aircraft R is at an altitude of 10 000 m.

Compared to aircraft Q , aircraft R generates

- A. less lift and less drag.
- B. less lift and more drag.
- C. more lift and less drag.
- D. more lift and more drag.

14 The diagram shows a beam.

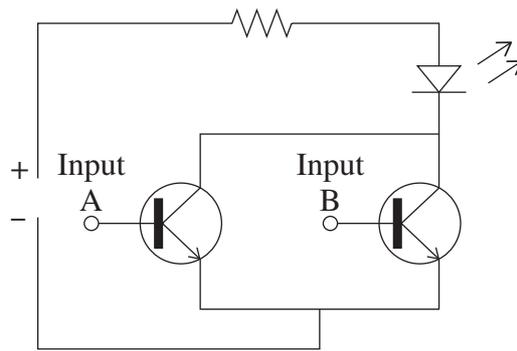


The beam's second moment of area is $76.96 \times 10^6 \text{ mm}^4$. It is subjected to a maximum bending moment of 250 kNm.

What is the maximum bending stress of the beam?

- A. 227.4 MPa
 - B. 324.8 MPa
 - C. 649.7 MPa
 - D. 9745.3 MPa
- 15 Which of the following would be the most suitable material to use for a spring in a telecommunication component?
- A. Annealed copper zinc alloy
 - B. Electrolytic tough pitch copper
 - C. Age hardened aluminium silicon alloy
 - D. Age hardened copper–beryllium alloy

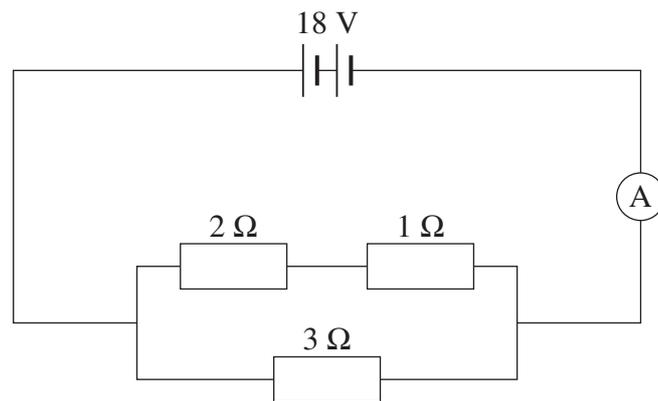
- 16 The circuit diagram shown includes two transistors in its configuration.



What type of logic gate has the same function as this pair of transistors in the circuit?

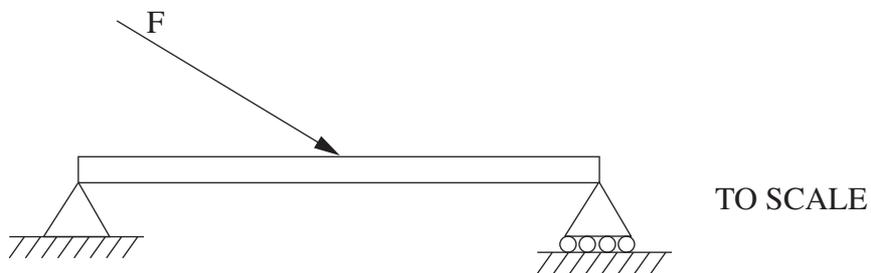
- A. OR gate
 - B. NOR gate
 - C. AND gate
 - D. NAND gate
- 17 Which of the following is a specialised test used to determine the compressive strength of cured concrete?
- A. Slump test
 - B. Janka hardness test
 - C. Shore hardness test
 - D. Rebound hammer test

- 18 The diagram shows a simplified circuit of an electric scooter.



What would be the reading of the ammeter in this circuit?

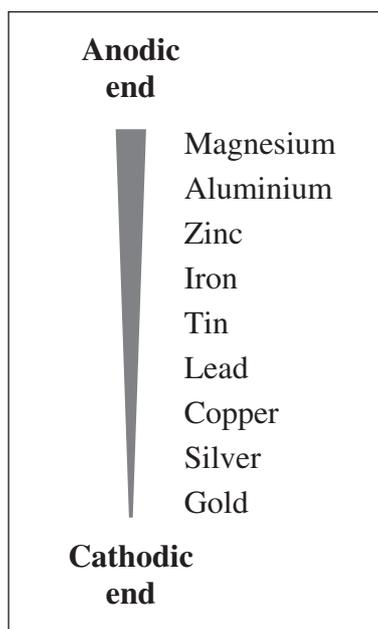
- A. 3.0 A
 - B. 6.0 A
 - C. 12.0 A
 - D. 26.9 A
- 19 The diagram shows a simply supported beam in equilibrium. It is loaded with a single force (F) as shown.



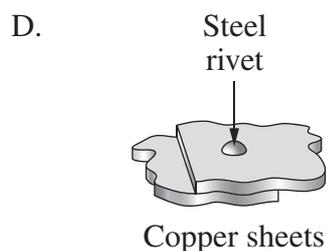
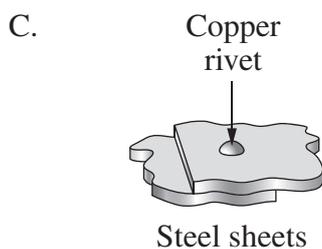
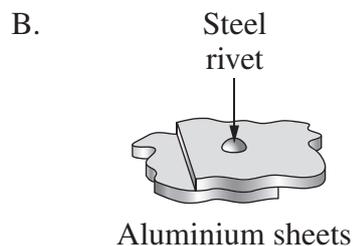
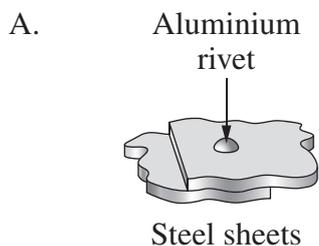
Which of the following angles is closest to the angle of the reaction force to the horizontal at the fixed bearing?

- A. 7°
- B. 14°
- C. 31°
- D. 90°

- 20 The galvanic table below shows the relative corrosion potential of a metal when it is in contact with another metal in an aqueous environment.



In which of the following situations is the steel component likely to corrode in the shortest amount of time?



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Centre Number

Engineering Studies

Section II Answer Booklet

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Student Number

80 marks

Attempt Questions 21–27

Allow about 2 hours and 30 minutes for this section

Instructions

- Write your Centre Number and Student Number at the top of this page.
- Answer the questions in the spaces provided. These spaces provide guidance for the expected length of response.
- Show all relevant working in questions involving calculations.

Please turn over

Question 21 (11 marks)

- (a) Some large cities, such as Sydney, have bridges which span large bodies of water. **2**

Outline TWO ways in which the construction of such bridges affects society.

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- (b) A 100 mm long M16 × 2 bolt is used in the concrete decking of a bridge. The bolt has a thread length of 50 mm. **3**
- (i) Draw an orthogonal view, to AS 1100, to show the length of the bolt. Use the centreline provided and do NOT dimension the drawing. Use a scale of 1 : 1.

Question 21 continues on page 15

Do NOT write in this area.

Question 21 (continued)

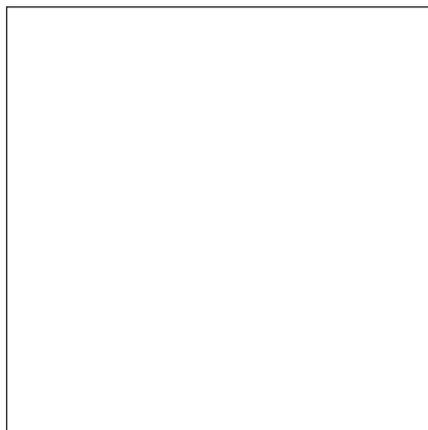
- (ii) The yield stress of the bolt is 476 MPa and the diameter is 16 mm. 3

Calculate the maximum load that the bolt can resist, assuming a Factor of Safety of 2.

Answer: kN

- (c) Reinforced concrete is a composite material. 3

In the box below sketch and label the components of the macrostructure of reinforced concrete.



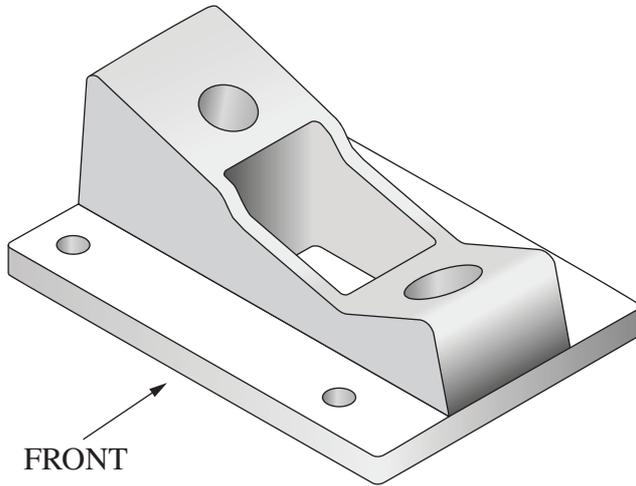
End of Question 21

Question 22 (12 marks)

- (a) A baseplate used to support the wheels under a trolley is shown in pictorial view.

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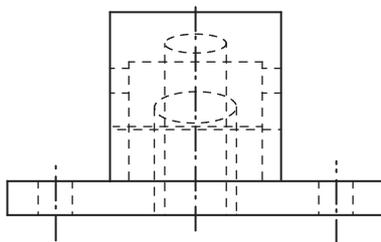
Construct, within the dashed-line box provided, a top view of the baseplate. Do NOT dimension.



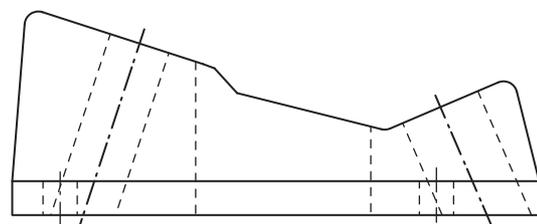
FRONT



TOP VIEW



SIDE VIEW



FRONT VIEW

Question 22 continues on page 17

Do NOT write in this area.

Question 22 (continued)

- (b) The baseplate is to be cast. 2

What are the advantages of pressure die casting over sand casting?

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- (c) An electric skateboard battery is rated at 0.078 watts at an operating voltage of 48 volts. 3

Calculate the capacity of the battery in amp hours, if it fully discharges in one hour of use. The power (P) is given by the formula $P = VI$.

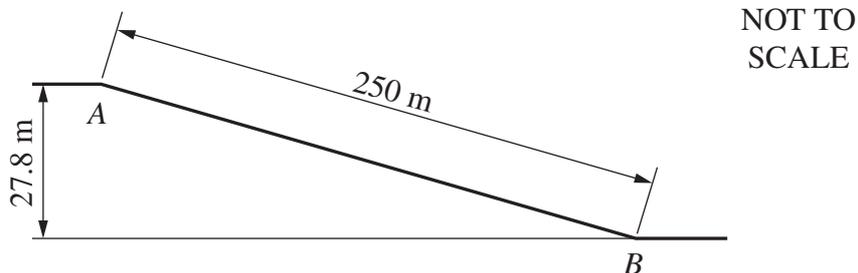
Battery capacity: Ah

Question 22 continues on page 18

Question 22 (continued)

- (d) A skateboard rider is at rest at the top of a slope, indicated by point *A* in the diagram.

4



The combined mass of the rider and skateboard is 80 kg.

Calculate the speed of the rider, in metres per second, at point *B* if the average work done by friction against the skateboard is 55 N.

Speed of rider at point *B*: m/s

End of Question 22

Do NOT write in this area.

Question 23 (12 marks)

- (a) Due to a reduction in air travel, an airline company has had to store some of its unused aircraft. **3**

Explain why the desert is a suitable place to store the unused aircraft.

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- (b) How has the work of aeronautical engineers helped to improve aircraft safety? **3**

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Question 23 continues on page 20

Question 23 (continued)

- (c) A 3000 kg aircraft is flying in level flight at constant speed. 3

Using a free-body diagram, calculate the thrust on the plane if the lift to drag ratio of the aircraft is 11 : 1.

..... kN

- (d) Carbon fibre epoxy is an example of a composite material used in aircraft construction. 3

Describe the benefits of using this composite in aircraft construction in terms of both its manufacturing properties and its in-service properties.

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End of Question 23

Do NOT write in this area.

Question 24 (13 marks)

- (a) A telecommunications engineer is designing a Wi-Fi network that will use either a 2.4 GHz or 5 GHz signal in a client's local area network. 2

How do the 2.4 GHz and 5 GHz signals differ in performance?

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- (b) Outline how voltage can be tested in a circuit. 2

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- (c) Describe the basic principles of low orbit satellite telecommunication systems. 3

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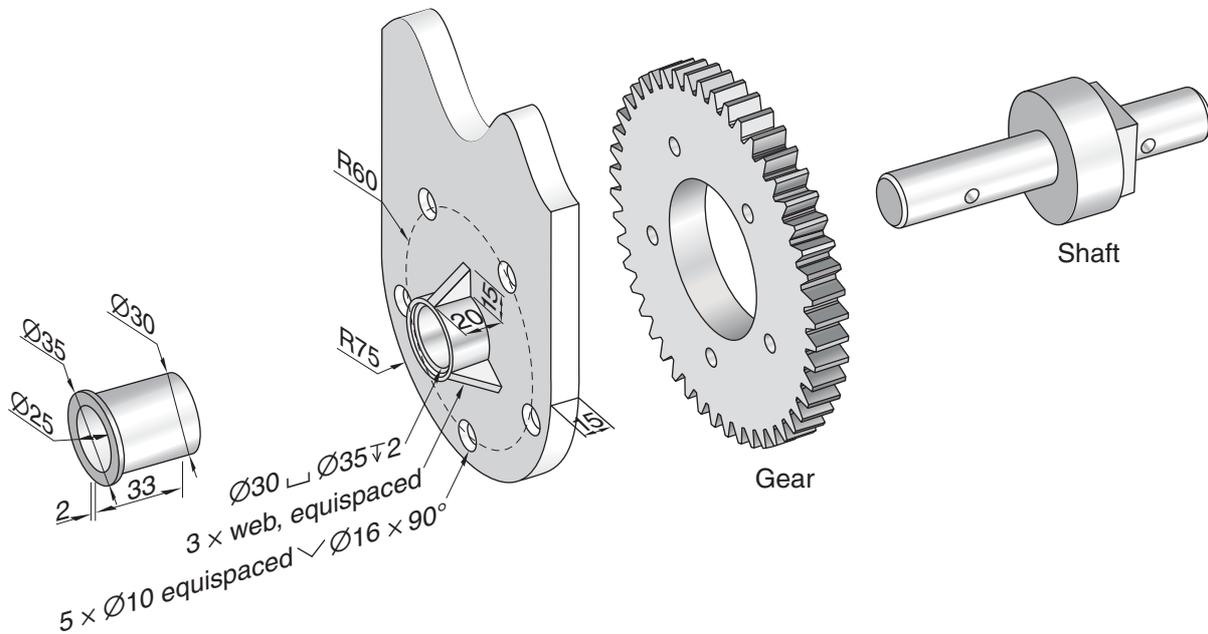
Question 24 continues on page 22

Question 24 (continued)

- (d) A drive mechanism used to control the satellite dish of a mobile TV transmission van is shown.

6

Key dimensions of components are given.



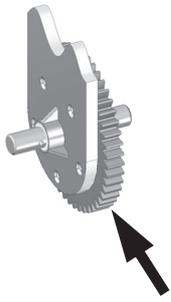
The dimensions of each of the five holes in the gear are $\varnothing 10 \sphericalangle \varnothing 16 \times 90^\circ$ on one side.

A partially sectioned drawing of the gear and shaft is provided on the following page.

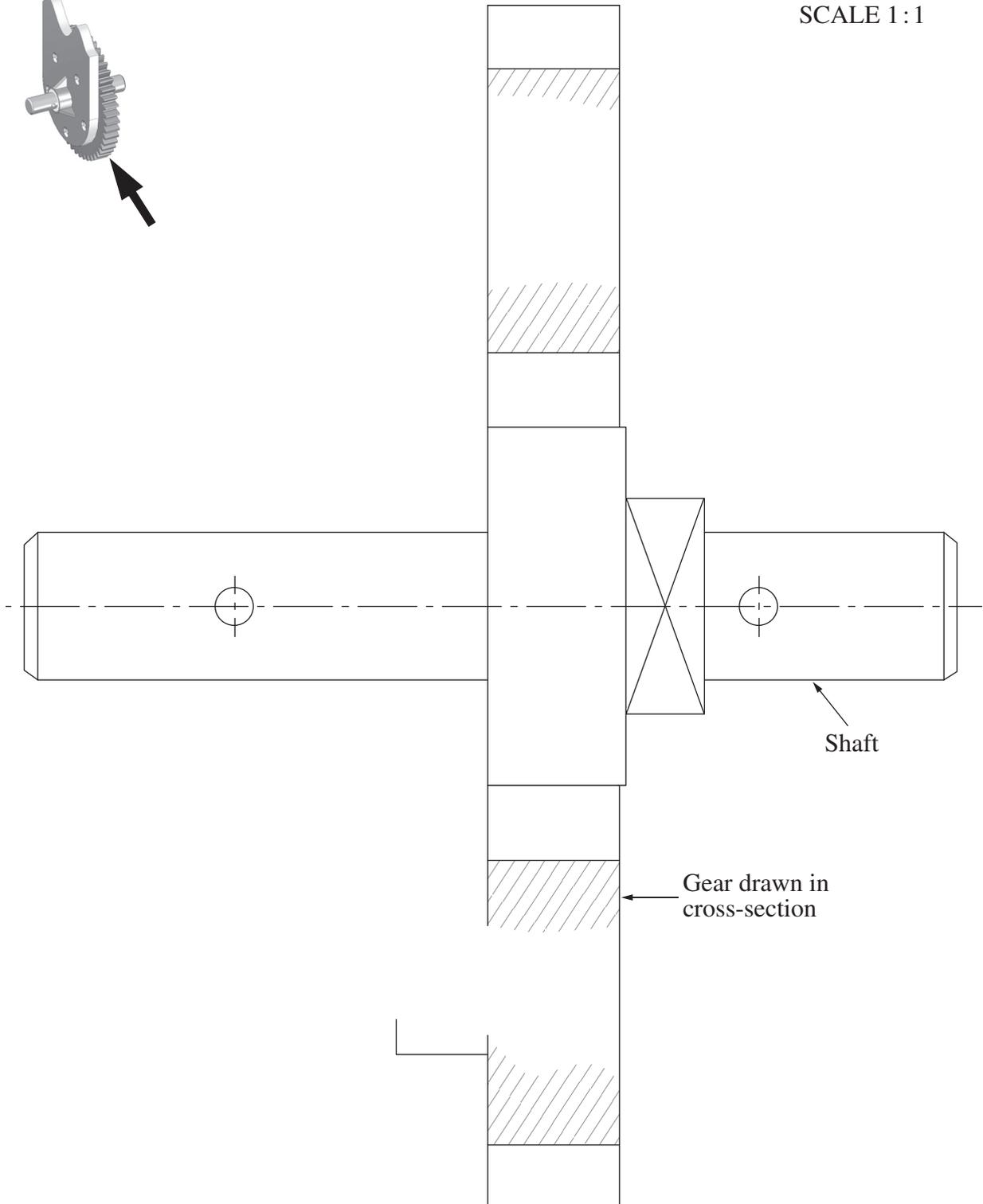
Question 24 continues on page 23

Question 24 (continued)

Complete the sectioned assembly of this drive mechanism to AS 1100 from the direction indicated by the arrow. Include break lines where appropriate.



SCALE 1:1



Do NOT write in this area.

End of Question 24

Question 25 (12 marks)

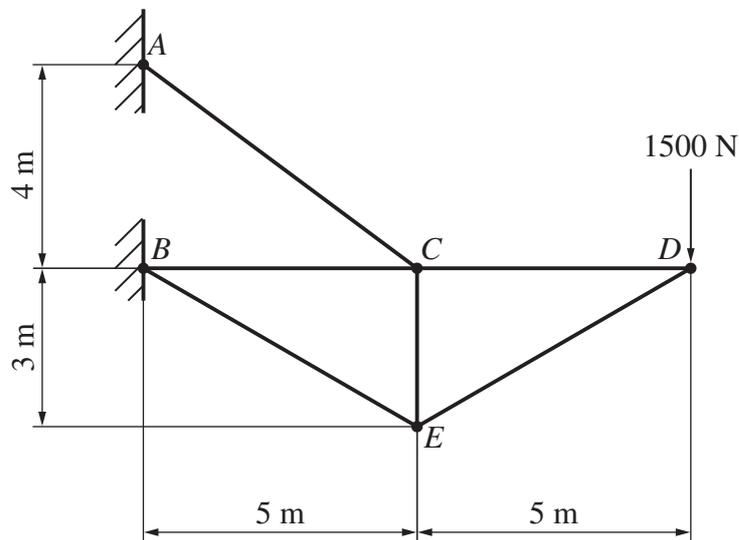
- (a) Control technologies are used in modern vehicles.

2

Outline the basic principle behind the operation of ONE of these technologies.

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- (b) A truss is fixed to a wall at A and B as shown. Ignore the mass of the truss.



- (i) Determine the horizontal reaction at A.

2

Horizontal reaction at A: kN

Question 25 continues on page 25

Question 25 (continued)

- (ii) Determine, using method of joints, the internal reaction in member *AC*. 3
Indicate the nature of the force in the member.

Internal reaction in *AC*: kN

Nature of force:

- (iii) Determine, using method of sections, the internal reaction in member *CE*. Indicate the nature of the force. 3

Internal reaction in *CE*: kN

Nature of force:

- (c) The pins in the truss joints are made from normalised mild steel. 2

How does the process of normalising affect the material properties of these pins?

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End of Question 25

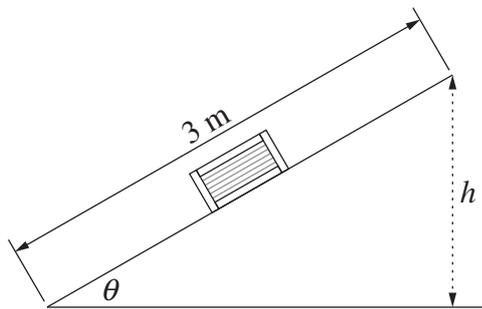
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Question 26 (12 marks)

- (a) Outline a change in technology that has led to improved fuel efficiency in cars. **2**

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- (b) The diagram shows a box which is at rest on an inclined ramp. The length of the ramp is 3 m and one end is raised h metres off the ground. **3**



The coefficient of friction between the ramp and the box is 0.5.

To what height (h) must the ramp be raised for the box to just begin to slide?

Height: m

Question 26 continues on page 27

Question 26 (continued)

- (c) Explain how a mobile phone maintains a communication link with the network as the user moves location while making a call. 3

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- (d) Compare multimode optical fibre and single mode optical fibre in terms of light paths taken and materials used. Drawings may be included to support your answer. 4

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Do NOT write in this area.

End of Question 26

Please turn over

Engineering Studies

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

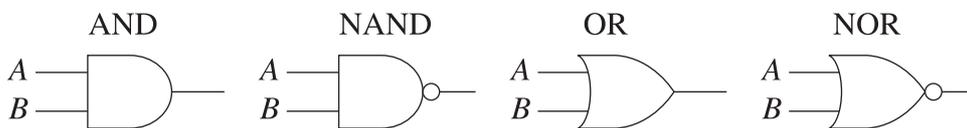
$$\sigma = \frac{F}{A}; \quad \epsilon = \frac{e}{L}; \quad E = \frac{\sigma}{\epsilon}; \quad \sigma = \frac{My}{I}$$

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

Machines

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

Digital Electronics



Electricity, Electronics

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

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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