NSW Education Standards Authority

2018 **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 2–10)

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

Section II – 80 marks (pages 13–36)

- 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.

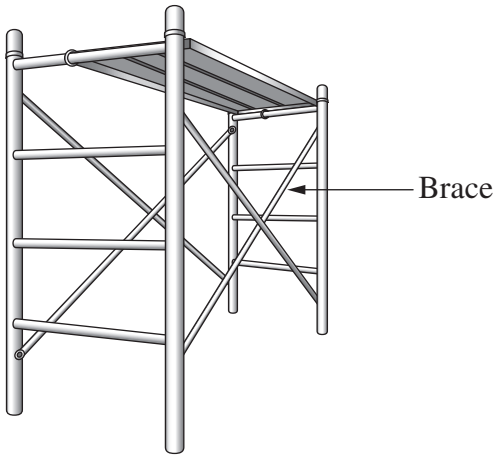
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1 An engineer has been asked to investigate and report on the failure of a component.

Which row of the table correctly identifies what the engineer would need to do before finalising the report?

	Investigate the component's material	*Redesign the component*	*Conduct a simulation of the operational use of the component*	*Prepare an initial draft of the report*
A.	No	Yes	Yes	Yes
B.	Yes	No	Yes	Yes
C.	Yes	Yes	No	Yes
D.	Yes	Yes	Yes	No

2 The diagram shows a scaffold with diagonal braces.



When loaded, the diagonal braces are typically subjected to which pair of forces?

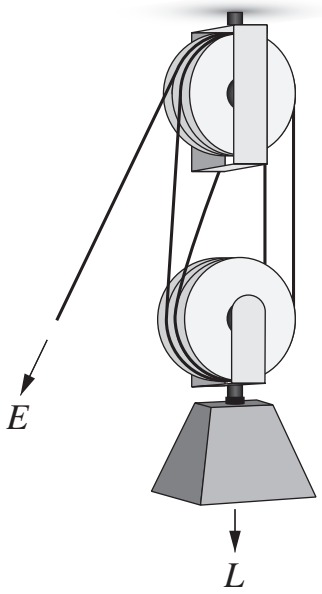
A. Torsion and shear

B. Torsion and tension

C. Compression and shear

D. Compression and tension

3 A pulley system is shown.



© Cesar Rincon, 7 August 2004

What is the mechanical advantage of this pulley system?

A. 2

B. 3

C. 4

D. 5

4 A line specified in AS 1100 is shown.

Which feature is this line typically used to indicate?

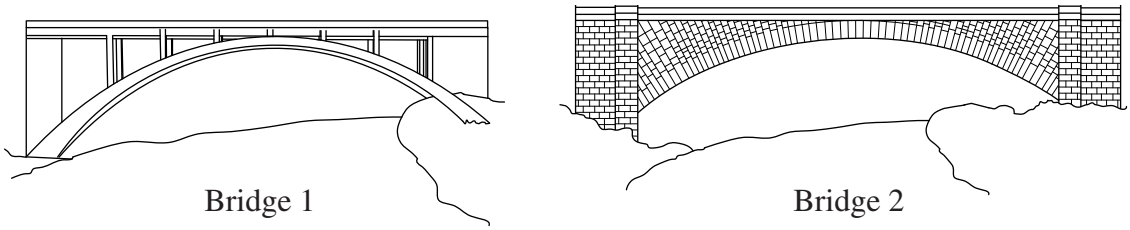
A. Centre-line

B. Cutting plane

C. Hidden feature

D. Fictitious outline

5 Two types of bridge are shown.



Bridge 1 Bridge 2

What are the two types of bridge design shown?

A. Suspension bridge and masonry arch

B. Suspension bridge and masonry beam

C. Reinforced concrete arch and masonry arch

D. Reinforced concrete arch and masonry beam

6 Which device is used to measure the airspeed of an aircraft in flight?

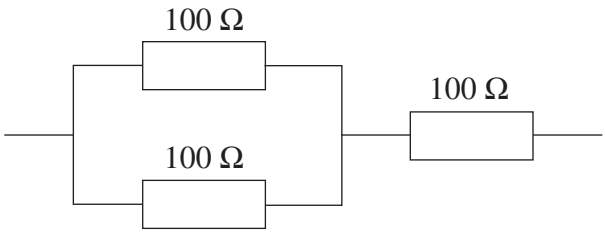
A. Altimeter

B. Pitot tube

C. Wind gauge

D. Potentiometer

7 An arrangement of resistors is shown.



What is the total resistance of this arrangement of resistors?

A. 33 Ω

B. 50 Ω

C. 150 Ω

D. 300 Ω

8 In which of the following do all of the processes require plastic deformation to achieve a final shape?

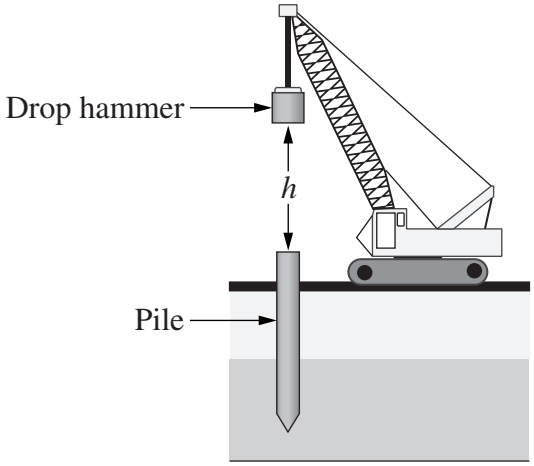
A. Brazing, casting, rolling

B. Brazing, soldering, welding

C. Extruding, casting, forging

D. Extruding, pressing, rolling

9 The diagram shows a drop hammer being used to drive a pile into the ground.



'Driven Piling' image provided courtesy of TransLink, Queensland Department of Transport and Main Roads (June 2013). This image has been adapted from the original by NSW Education Standards Authority.

Which formula gives the height h required for the drop hammer to impact the pile at a pre-determined velocity v?

A. $h = \frac{v^2}{2g}$

B. $h = \frac{2g}{v^2}$

C. $h = \frac{v}{2g}$

D. $h = \frac{2g}{v}$

10 In a ductile material, which two stresses are used to calculate the factor of safety (FOS)?

A. Working and yield

B. Working and compressive

C. Bending and yield

D. Bending and compressive

11 What is the most appropriate propulsion system for a long-haul commuter aircraft?

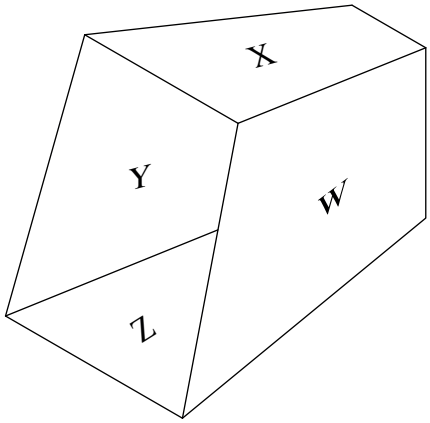
A. Ramjet

B. Scramjet

C. Turbofan

D. Turboprop

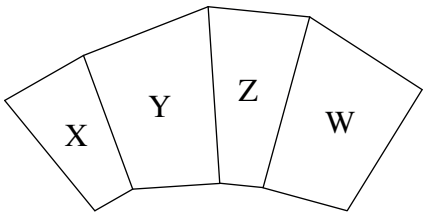
12 A transition piece is shown.



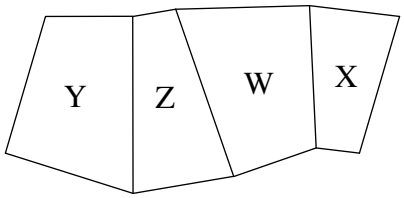
Scale 2:1

Which of the following correctly represents the development of the transition piece?

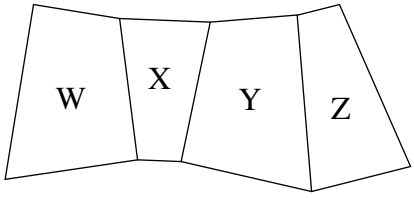
A.



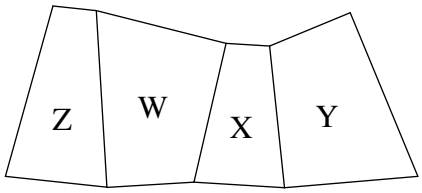
B.



C.



D.



13 Which statement best describes modulation?

A. The addition of information to a carrier wave.

B. The attenuation of information in a carrier wave.

C. The removal of quantised information from a carrier wave.

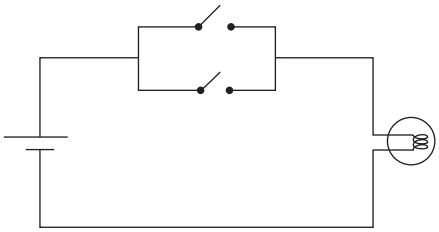
D. The filtering of unnecessary information from a carrier wave.

14 Which row of the table correctly describes the property changes that occur after tempering quench-hardened steel?

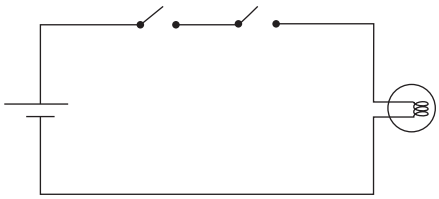
	Toughness	*Hardness*
A.	Increased	Minimal loss
B.	Minimal loss	Increased
C.	Increased	Increased
D.	Minimal loss	Minimal loss

15 Which of the following electronic circuits functions as a NAND logic gate?

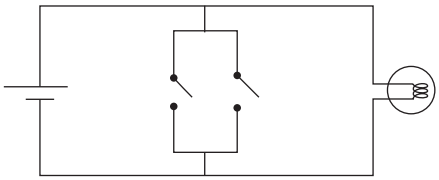
A.



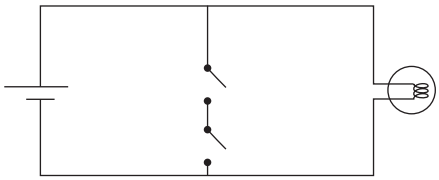
B.



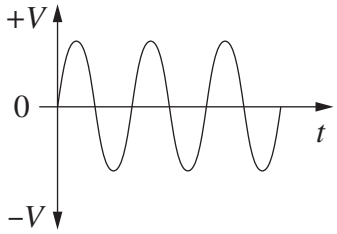
C.



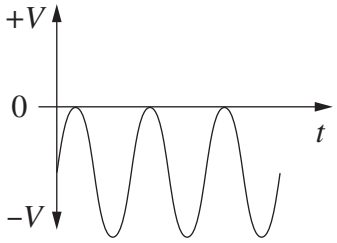
D.



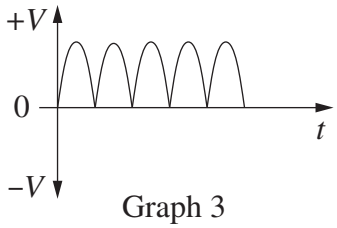
16 Four output graphs from an oscilloscope are shown.



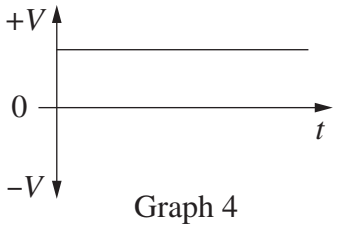
Graph 1



Graph 2



Graph 3



Graph 4

Which graph(s) represent direct current (DC)?

A. Graph 4 only

B. Graphs 3 and 4 only

C. Graphs 2, 3 and 4 only

D. Graphs 1, 2 and 3 only

17 Aircraft skins can be constructed using either fibre metal laminate (FML) or sheet aircraft-grade aluminium alloy.

FML is preferred in this application because it has

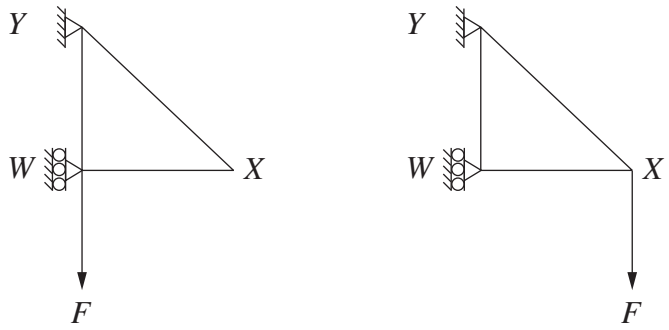
A. higher density and lower Young's modulus.

B. higher density and improved fatigue resistance.

C. higher strength-to-weight ratio and lower Young's modulus.

D. higher strength-to-weight ratio and improved fatigue resistance.

18 The force *F* is moved from joint *W* to joint *X*, as shown.



Which row of the table correctly describes the changes in the internal force in member *XY* and the reaction force at *W* as a result of force *F* moving from *W* to *X*?

	Internal force in member XY	*Reaction force at W*
A.	Decreases	Decreases
B.	Increases	Increases
C.	Increases	Decreases
D.	Decreases	Increases

19 Which heat-treated metal is used for contact springs in electrical switches?

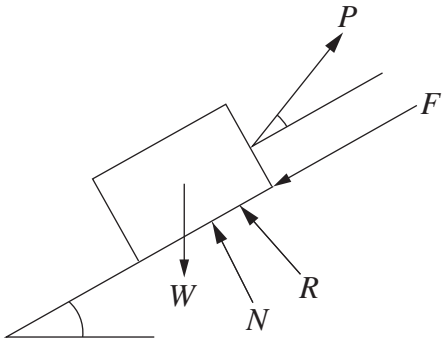
A. OFHC copper

B. Phosphor bronze

C. Copper beryllium

D. Tough pitched copper

20 A box with weight W and subject to a friction force F is being pulled up an inclined plane by a force P.



The force R is the resultant of which two forces?

A. P and W

B. P and N

C. F and W

D. F and N

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2018 HIGHER SCHOOL CERTIFICATE EXAMINATION

Centre Number

Student Number

Engineering Studies

Section II Answer Booklet

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.
- Extra writing space is provided at the back of this booklet. If you use this space, clearly indicate which question you are answering.

Please turn over

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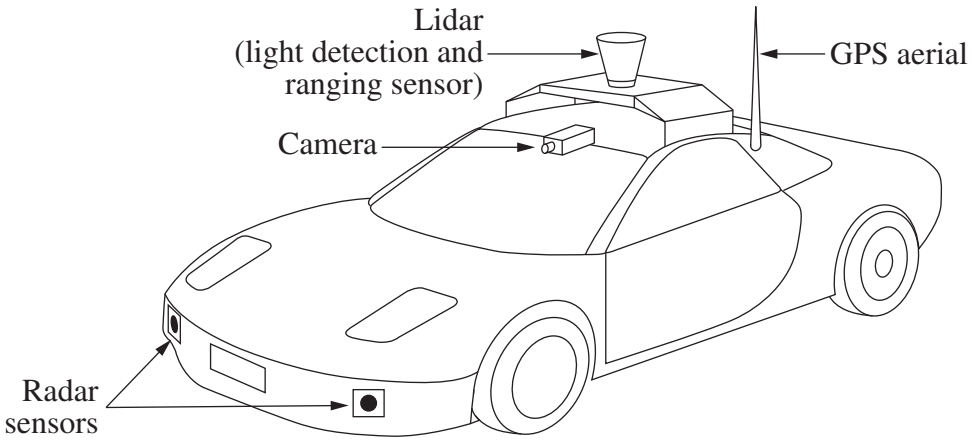
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Question 21 (12 marks)

The diagram shows a self-driving electric vehicle.



(a) Innovations in global positioning systems (GPS) and sensor technologies are used in the operation of this vehicle. **3**

Describe how both of these innovations are used in the control of the vehicle.

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Question 21 continues on page 15

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Question 21 (continued)

(b) Outline the benefits of using electric motors to power self-driving vehicles. **3**

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(c) The self-driving vehicle has a mass of 1.5 tonnes and is travelling at 60 km/h. **3**

Calculate its kinetic energy.

Answer: ..... kJ

Question 21 continues on page 16

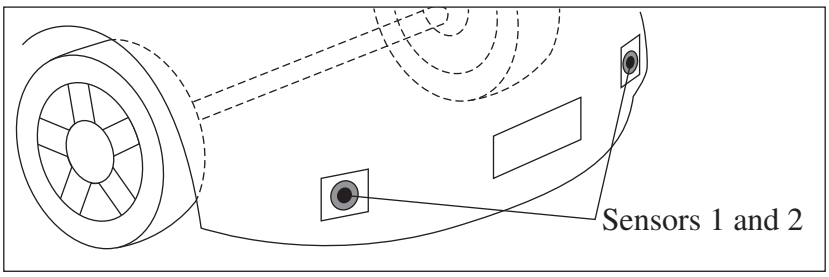
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Question 21 (continued)

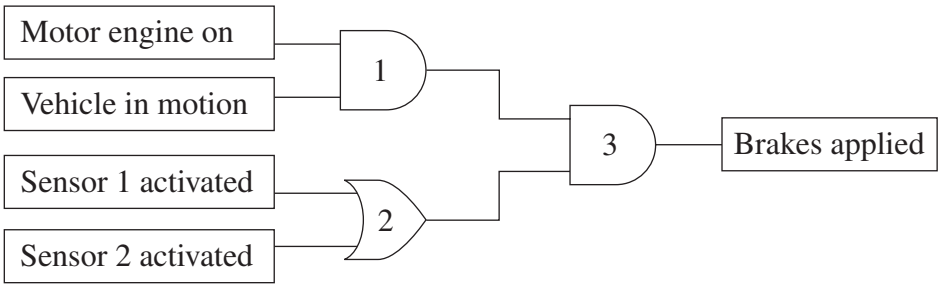
(d) Digital logic controls the vehicle's brakes. **3**



Brakes will be applied when all of the following conditions are met:

- the motor is on
- the vehicle is in motion
- either sensor 1 or sensor 2 is activated.

Explain how the logic gates, labelled 1, 2 and 3 in the circuit below, control the vehicle's brakes.



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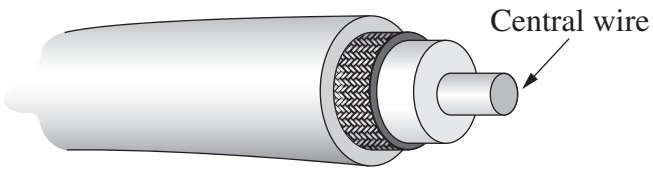
End of Question 21

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Question 22 (11 marks)

(a) Telecommunication signals can be carried by a variety of transmission media. A common form of connection between a television set and an antenna is a coaxial cable. **2**



Coaxial cable

Why is copper-coated steel used for the central wire?

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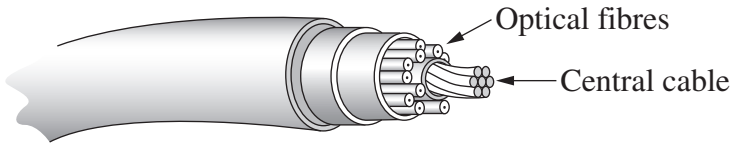
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(b) Explain why optical fibre is used in preference to traditional copper cable in telecommunication networks. **2**



Optical cable

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Question 22 continues on page 18

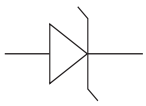
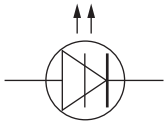
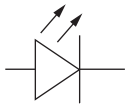
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Question 22 (continued)

(c) The following three types of diode are used in telecommunication circuits. **4**

		
Zener diode	Laser diode	Light emitting diode

Describe the function of each diode in telecommunication circuits.

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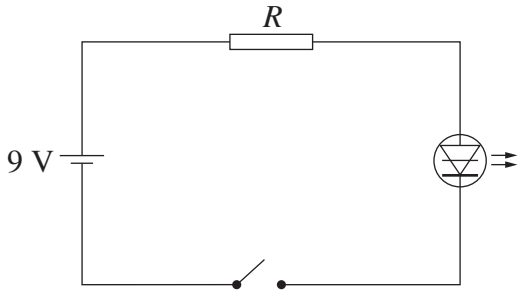
Question 22 continues on page 19

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Question 22 (continued)

(d) To operate successfully, a laser diode requires 2.3 V while drawing a current of 25 mA. **3**



For the circuit shown, calculate the required resistor value *R* needed to produce the correct operating voltage.

Answer: ..... Ohms

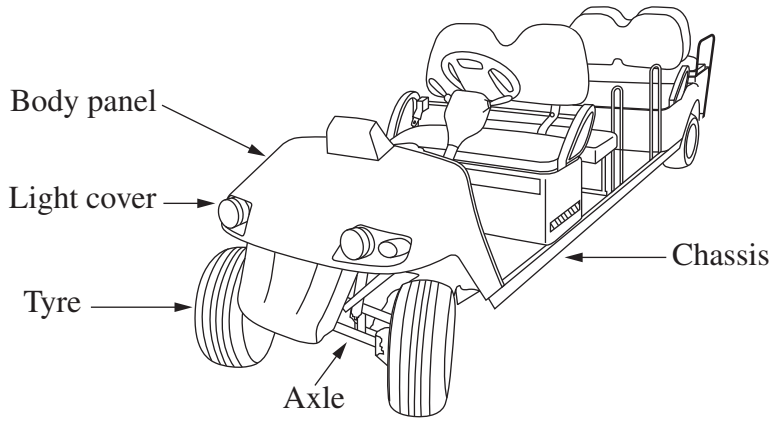
End of Question 22

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Question 23 (12 marks)

A people-mover vehicle is assembled using a variety of parts.



(a) Complete the table. **3**

Part	*Material*	*Engineering property*	*Manufacturing method*
Tyre		Flexibility and high coefficient of friction	Compression moulding
Axle	Alloy steel		Machined
Light cover	Acrylic	Transparency	
Chassis	Mild steel		Rolled
Body panels		Resilience	Hand lay-up
Electrical wire	Copper	Electrical conductivity	

Question 23 continues on page 21

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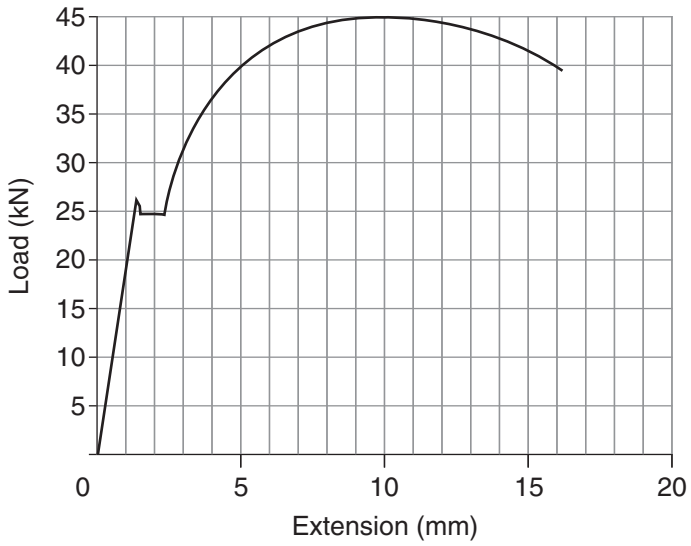
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Question 23 (continued)

(b) The steel used in the chassis members was tested.

The load–extension graph represents the data collected during the testing of a specimen of the steel.



Before testing, the specimen was 1020 mm long with a cross-sectional area of 100 mm^2.

(i) Calculate Young's modulus for this steel. **4**

Answer: ..... GPa

Question 23 continues on page 22

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Question 23 (continued)

(ii) Describe the physical changes that occur in the specimen tested in part (i) when a 20 kN load is applied and then removed, compared to when a 30 kN load is applied and then removed. **2**

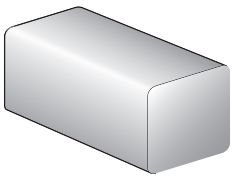
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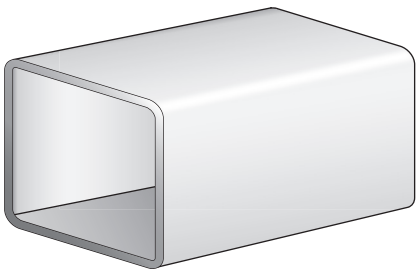
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(c) The chassis for the vehicle could be made from a solid steel bar or hollow steel tube. Both the bar and the tube have the same mass and cost per metre. **3**



Solid steel bar



Hollow steel tube

Justify why a hollow tube would be used in preference to a solid bar to build the vehicle chassis.

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End of Question 23

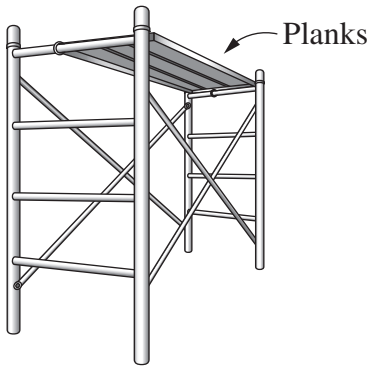
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Question 24 (11 marks)

(a) The diagram shows a scaffold supporting planks. The planks can be made from laminated timber, aluminium alloy or galvanised steel. **3**



Outline an in-service advantage of each of these materials when used as a scaffold plank.

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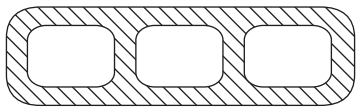
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(b) The cross-section of an extruded aluminium alloy plank is shown. **2**



Outline the steps of the extrusion process.

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Question 24 continues on page 24

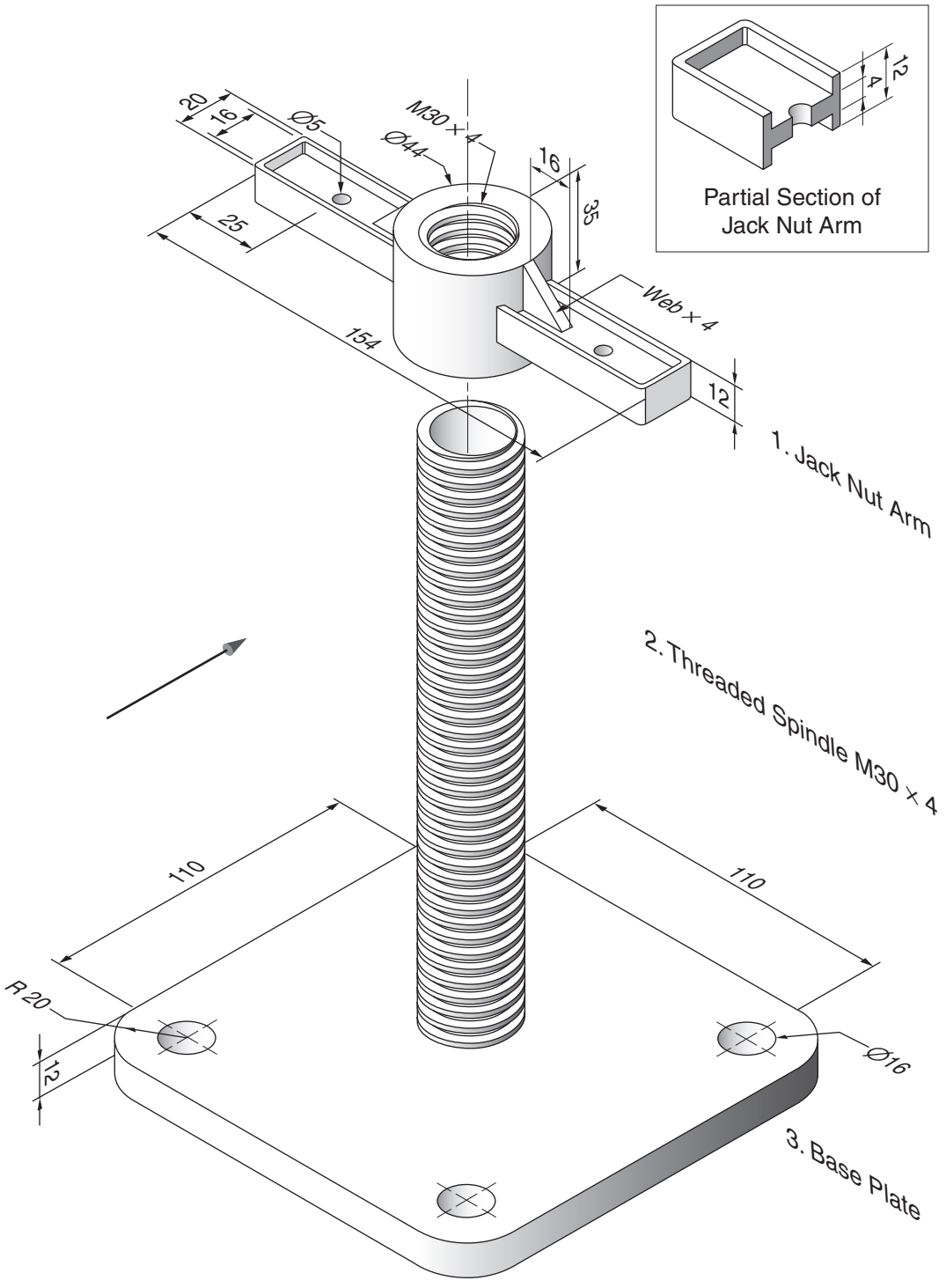
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Question 24 (continued)

(c) An exploded view of an adjustable scaffold foot is shown. **6**



On the next page, complete a half-sectioned front view of the scaffold foot with the jack nut arm. The arrow indicates the direction of viewing.

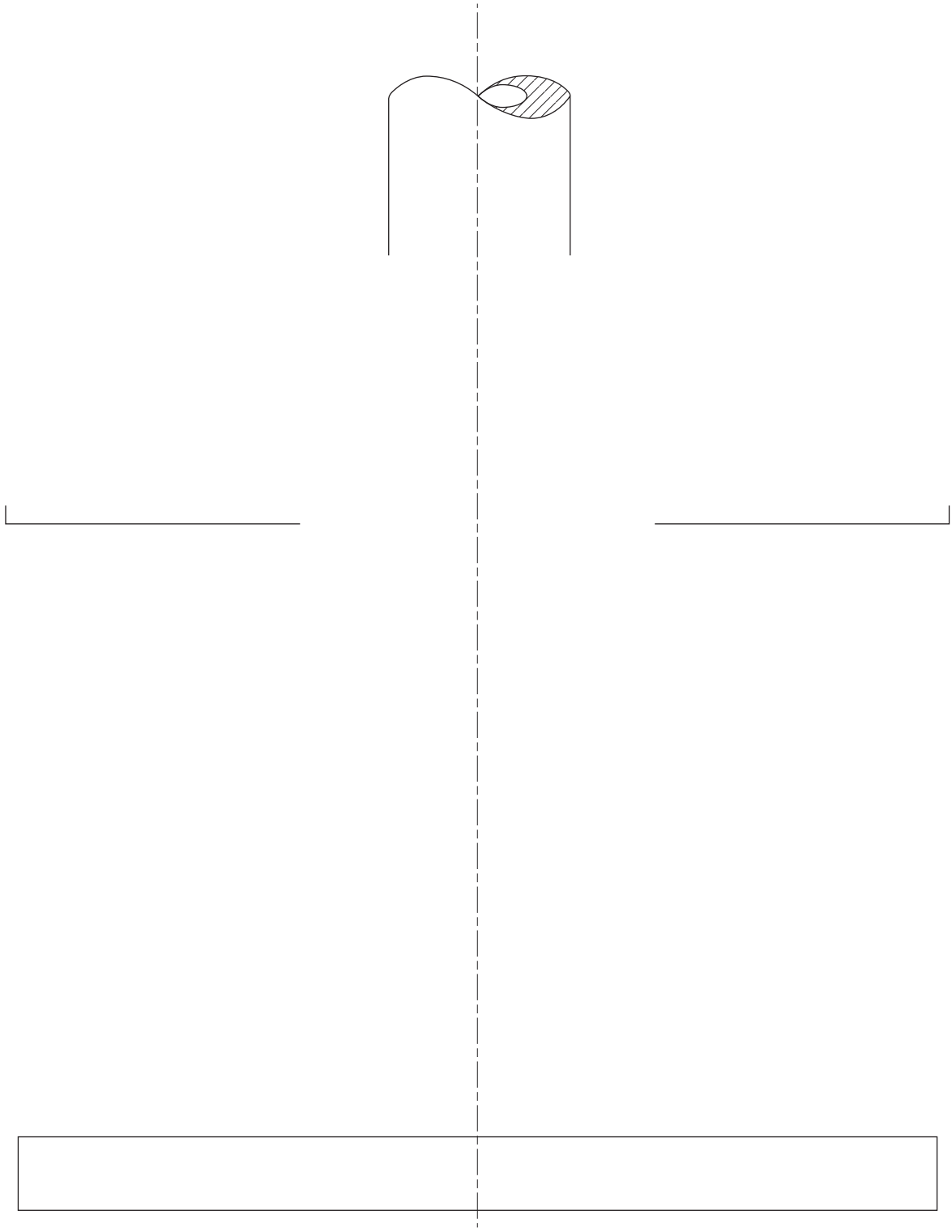
Question 24 continues on page 25

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Question 24 (continued)



End of Question 24

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Question 25 (13 marks)

(a) Describe the basic operational principles of jet propulsion. Use a labelled sketch to support your answer. **3**

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(b) Explain how the angle of attack of an aircraft in flight influences the lift generated by the wings. Use a labelled sketch to support your answer. **3**

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Question 25 continues on page 27

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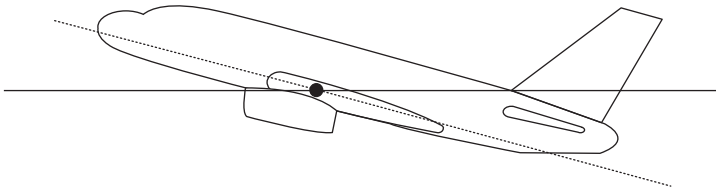
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Question 25 (continued)

(c) A two-engine aircraft with mass 330 tonnes is climbing at 15°. Each engine produces 510 kN of thrust. The aircraft maintains a constant velocity.

(i) Complete the space diagram by indicating the four key forces of flight for this situation. **2**



(ii) Determine the induced drag force for this situation. **3**

Drag: ..... kN

(d) Identify factors that contribute to stress corrosion cracking in aluminium alloy aircraft components. **2**

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End of Question 25

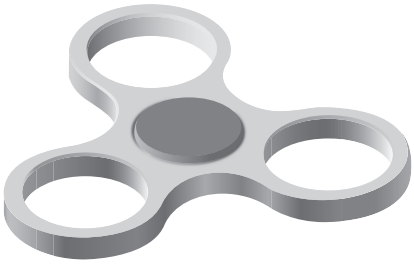
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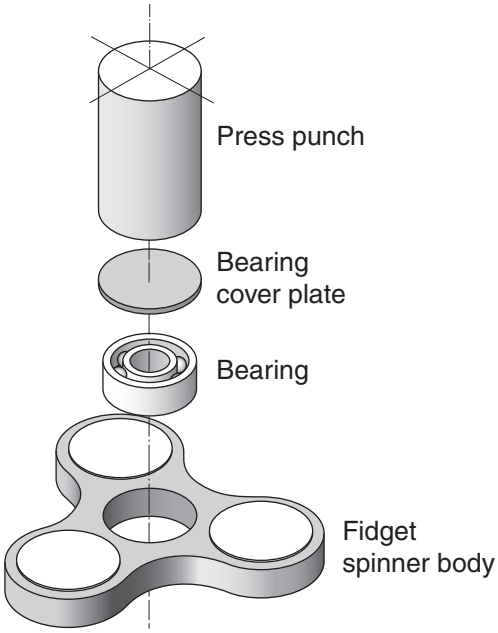
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Question 26 (11 marks)

A fidget spinner is shown. It is a toy that contains a ball bearing in its centre and is designed to spin on its axis with little effort.



The central components of a fidget spinner are press fitted together using a press punch.



(a) The press punch diameter is 21 mm. The force applied by the press punch to the bearing is 17.3 N. **2**

Calculate the compressive stress in the press punch.

Stress: ..... Pa

Question 26 continues on page 29

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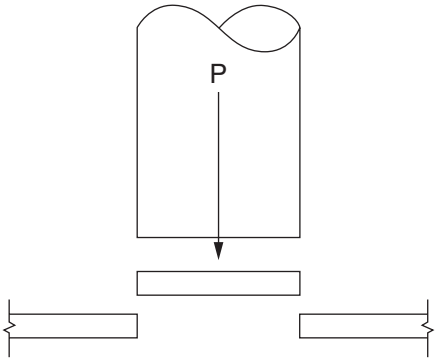
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Question 26 (continued)

(b) The body of the fidget spinner is made from polypropylene. The bearing is made from steel. **2**

When the force P applied by the press punch is 16 N, the bearing slides into position.



Calculate the normal force (N) acting on the bearing walls if the coefficient of friction between polypropylene and steel is 0.20.

Answer: ..... N

Question 26 continues on page 30

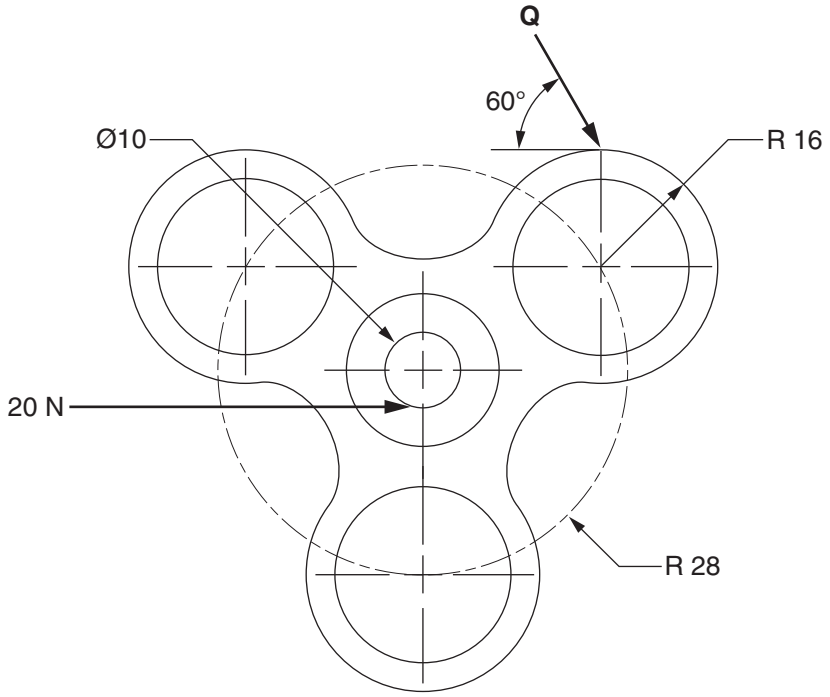
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Question 26 (continued)

(c) The top view of a fidget spinner is shown. **3**



DRAWN TO SCALE

What force **Q** is required to overcome the 20 N resistance force shown?

Answer: ..... N

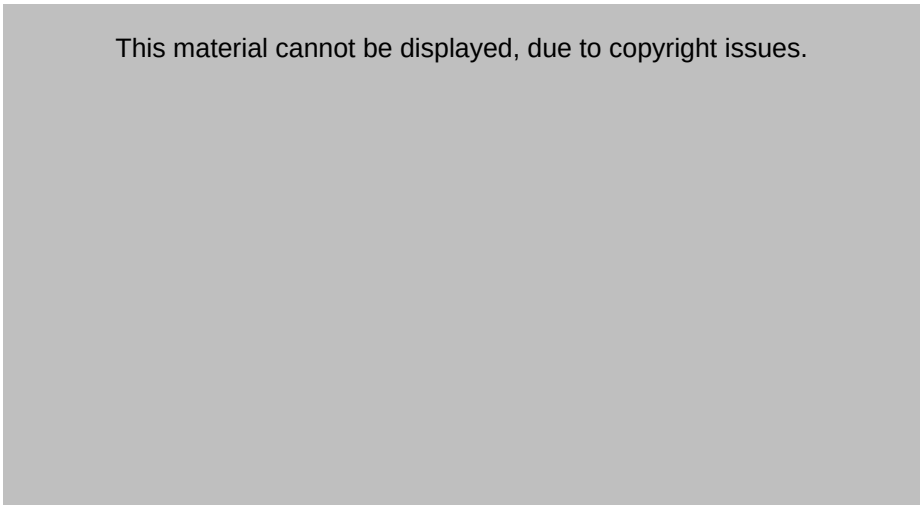
Question 26 continues on page 31

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(d) The components of the bearing assembly used in the fidget spinner are shown. **4**



The retainer can be made from either glass fibre-reinforced nylon or stainless steel.

Compare the in-service properties of these materials for use in the retainer.

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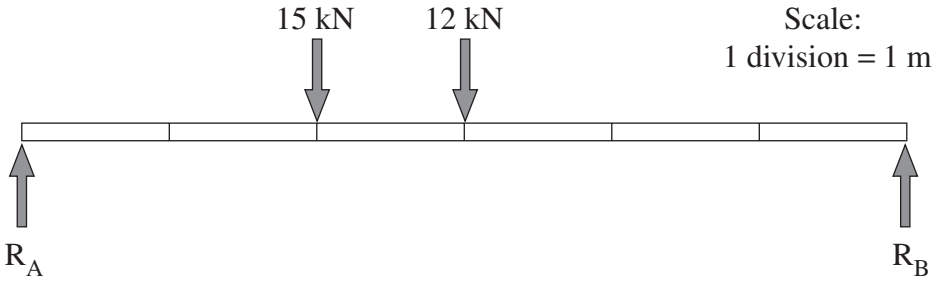
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Question 27 (10 marks)

(a) A 6-metre beam is loaded as shown. **6**



On the following page, draw the shear force and bending moment diagrams. Support your answer with relevant calculations. Ignore the weight of the beam.

Space for calculations is provided below.

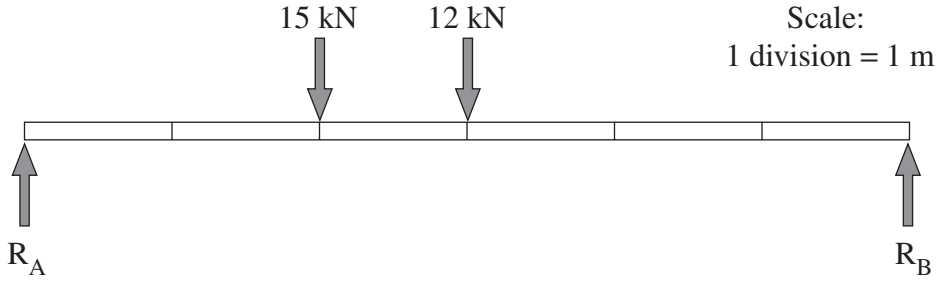
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Question 27 (continued)



Shear force diagram



Bending moment diagram



Question 27 continues on page 34

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Question 27 (continued)

(b) Why would an engineer refer to shear force diagrams and bending moment diagrams when determining the effects of loads on a beam? **4**

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Engineering Studies

FORMULAE SHEET

Force, Moments

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

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

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

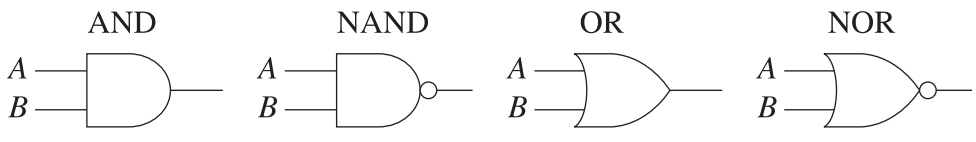
$\sigma = \frac{F}{A}$; $\quad \varepsilon = \frac{e}{L}$; $\quad E = \frac{\sigma}{\varepsilon}$; $\quad \sigma = \frac{My}{I}$

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

Machines

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

Digital Electronics



Electricity, Electronics

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

Series $\quad R_t = R_1 + R_2 + R_3 + R_4 + \cdots + R_n$

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

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