

B O A R D O F S T U D I E S
NEW SOUTH WALES

2013

**HIGHER SCHOOL CERTIFICATE
EXAMINATION**

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, 15, 19, 23, 25, 27 and 31

Total marks – 100

Section I Pages 2–11

20 marks

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

Section II Pages 13–33

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.

- 1 The image shows a structural concrete slab under construction.



Acknowledgement: <http://www.tallbridgeguy.com/2009/03/13/kansas-post-tensioned-slabs/>

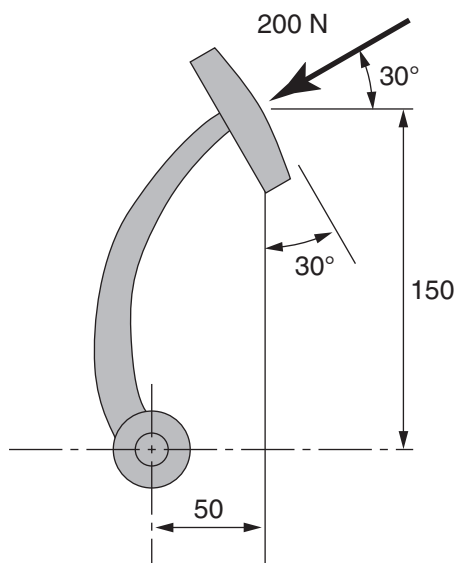
What is the main load bearing type of concrete construction illustrated?

- (A) Post-tensioned
 - (B) Pre-tensioned
 - (C) Reinforced
 - (D) Spalling
- 2 Which of the following control surfaces on an aircraft is used to control the pitching moment?
- (A) Aileron
 - (B) Elevator
 - (C) Flap
 - (D) Rudder

3 Which principal element is alloyed with aluminium to aid fluidity in casting?

- (A) Copper
- (B) Manganese
- (C) Silicon
- (D) Zinc

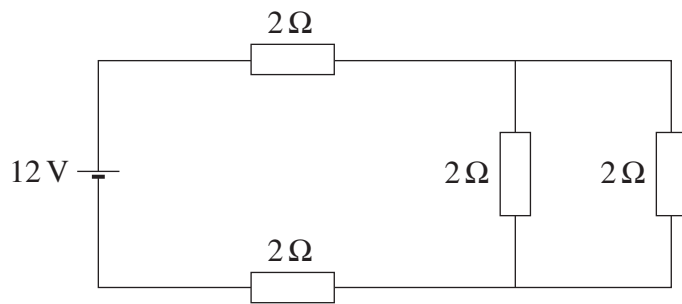
4 A brake pedal is loaded as shown.



What is the moment applied to the pivot?

- (A) 21 Nm
- (B) 26 Nm
- (C) 30 Nm
- (D) 31 Nm

- 5 A simple electric circuit is shown.



What is the total current in the loaded circuit?

- (A) 1.5 A
(B) 2.4 A
(C) 3.0 A
(D) 6.0 A
- 6 The truth table represents the basic operation of a two-input logic gate.

<i>Input X</i>	<i>Input Y</i>	<i>Output Z</i>
0	0	1
0	1	1
1	0	1
1	1	0

What is the logic gate?

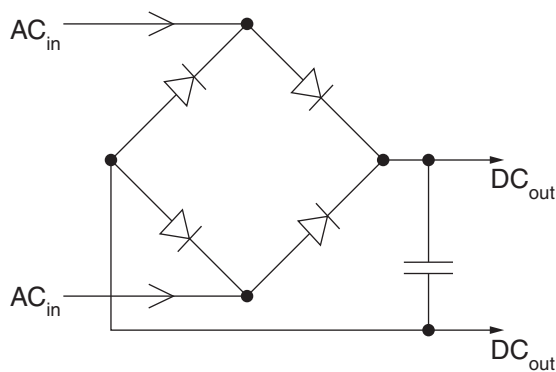
- (A) OR gate
(B) NOR gate
(C) AND gate
(D) NAND gate

- 7 The hydraulic cylinder of a lift truck has a rated capacity of 1.5 tonnes. The diameter of the cylinder piston is 150 mm.

What is the oil pressure in the cylinder at maximum rated capacity?

- (A) 8.49 Pa
 - (B) 84.9 Pa
 - (C) 84.9 kPa
 - (D) 849 kPa
- 8 Which of the following copper alloys, when fully heat-treated and then cold-worked, is the hardest and strongest?
- (A) Copper beryllium
 - (B) Copper tin (bronze)
 - (C) Copper zinc (brass)
 - (D) Electrolytic tough pitched copper

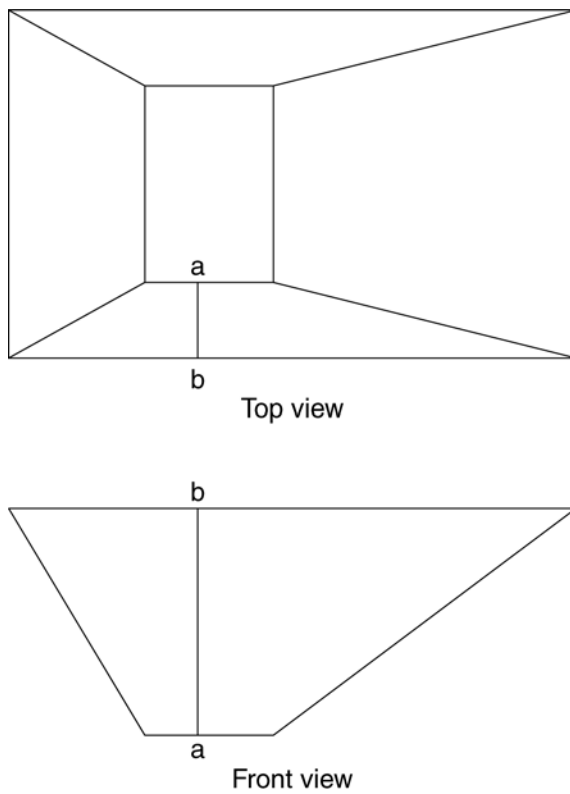
- 9 An electronic circuit is shown.



What is the function of the circuit?

- (A) Inversion
- (B) Modulation
- (C) Rectification
- (D) Transformation

- 10 The top and front views of a transition piece are drawn to scale, as shown.



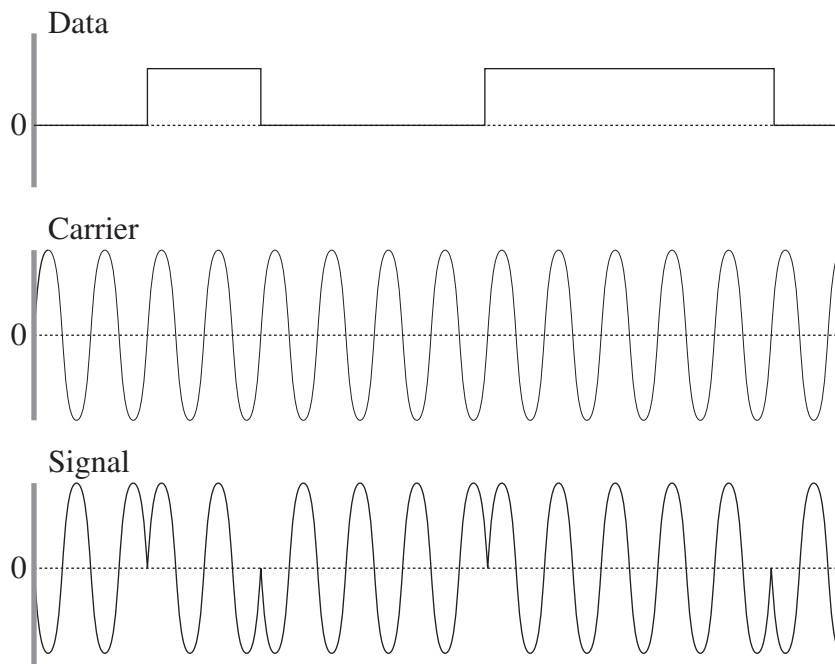
What is the true length of seam ab?

- (A) 10 mm
 - (B) 30 mm
 - (C) 32 mm
 - (D) 41 mm
- 11 A 0.8% eutectoid plain-carbon steel is heated and then water quenched to achieve maximum hardness.

What will the final microstructure be?

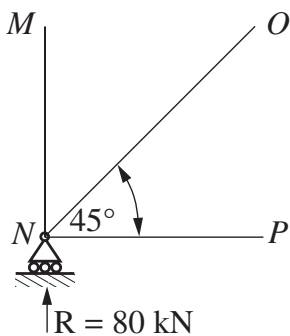
- (A) Austenite
- (B) Cementite
- (C) Martensite
- (D) Pearlite

- 12 A data signal wave has been modulated onto a carrier wave to produce a signal wave.



What type of modulation is shown?

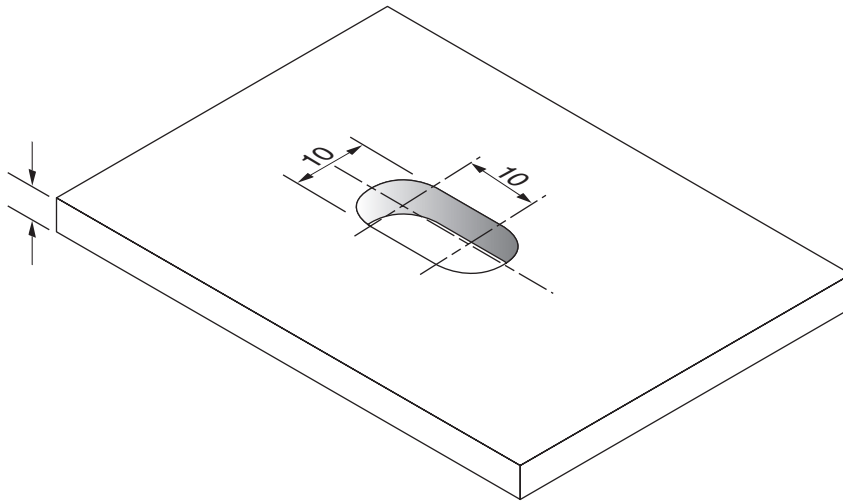
- (A) Demodulation
 - (B) Phase modulation
 - (C) Frequency modulation
 - (D) Amplitude modulation
- 13 When analysing roller joint N , the reaction is 80 kN vertically upwards and the force in member NP is 20 kN in compression.



What is the magnitude of the force in member MN ?

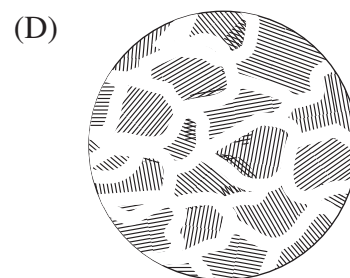
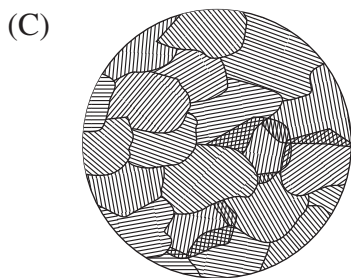
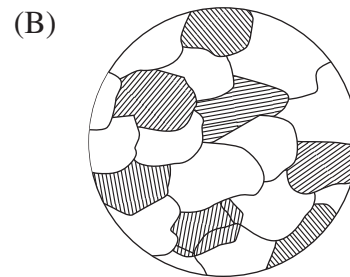
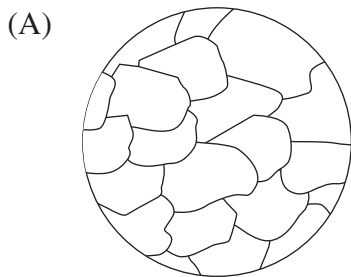
- (A) 20 kN
- (B) 60 kN
- (C) 80 kN
- (D) 100 kN

- 14 A metal plate is 4 mm thick and has an ultimate shear stress of 600 MPa. A hole is punched through the plate as shown.

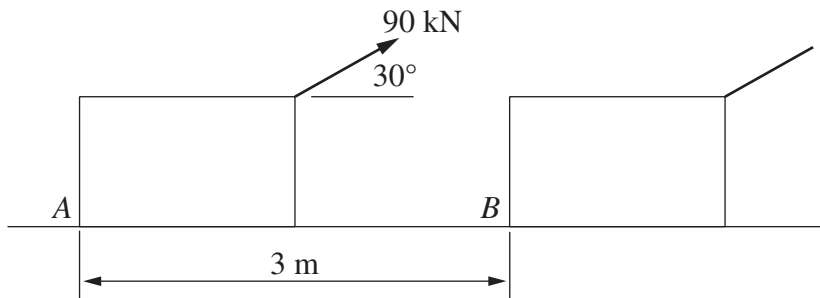


What is the force required to punch the hole?

- (A) 30.8 kN
(B) 48.0 kN
(C) 60.0 kN
(D) 123.4 kN
- 15 Which of the following plain carbon steel microstructures would be best for the manufacture of gears and shafts?

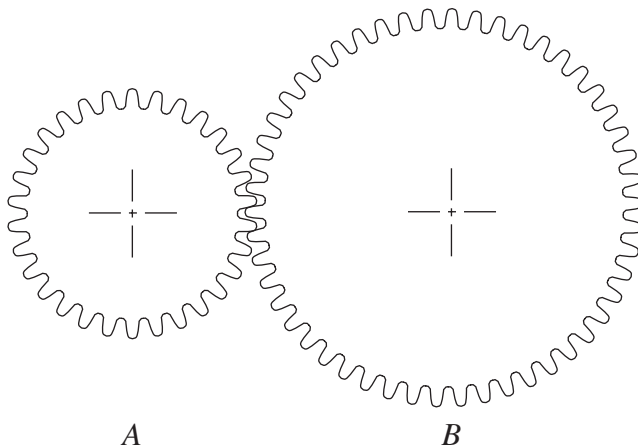


- 16 A block is moved on a rough surface with a resistance of 30 kN. A 90 kN force is used to move the block from position *A* to position *B*.



How much work is done on the block to move its position?

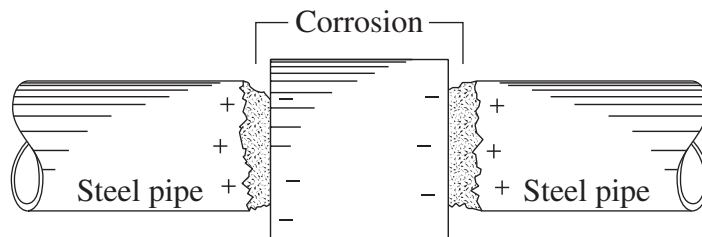
- (A) 90.0 kJ
(B) 143.8 kJ
(C) 180.0 kJ
(D) 233.8 kJ
- 17 In a simple gear train system, the driving gear *A* has 30 teeth and the driven gear *B* has 50 teeth. The gear train efficiency is 85%.



What is the mechanical advantage of the system?

- (A) 0.51:1
(B) 0.60:1
(C) 1.42:1
(D) 1.67:1

- 18 A metal sleeve was used to join two mild steel pipes. After some time, the pipes corroded, as shown.

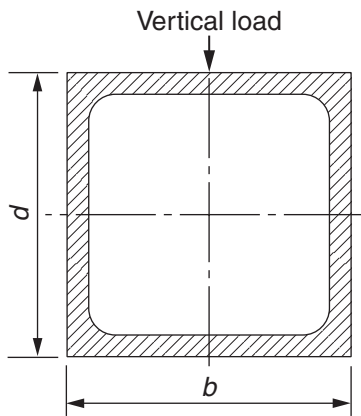


Galvanic Series	
Magnesium	Anode ↑ ↓ Cathode
Zinc	
Aluminium	
Mild Steel	
Cast Iron	
Tin	
Copper	

Using the Galvanic Series table above, which of the following metals could have been used for the sleeve to ensure minimal corrosion of the pipes?

- (A) Aluminium
- (B) Cast iron
- (C) Tin
- (D) Zinc

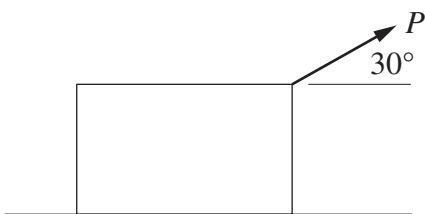
19 A cross-section of a structural beam is shown.



How could this cross-section be redesigned to most efficiently increase its resistance to bending?

- (A) Increase b by 20%
- (B) Increase d by 20%
- (C) Rotate the cross-section by 45°
- (D) Fill in the void with the same material as the cross-section

20 A 23 kg block rests on a surface which has a coefficient of friction of 0.4.



What will be the value of the inclined force, P , when the block is just on the point of sliding?

- (A) 86.3 N
- (B) 92.0 N
- (C) 106.2 N
- (D) 138.1 N

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Engineering Studies

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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) Describe how the development of a specific material has changed bicycle frames. In your answer, identify the specific material. **3**

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- (b) Identify a material used in early bicycle mudguards and a different material used in modern bicycle mudguards. Contrast the in-service properties of these materials. **4**

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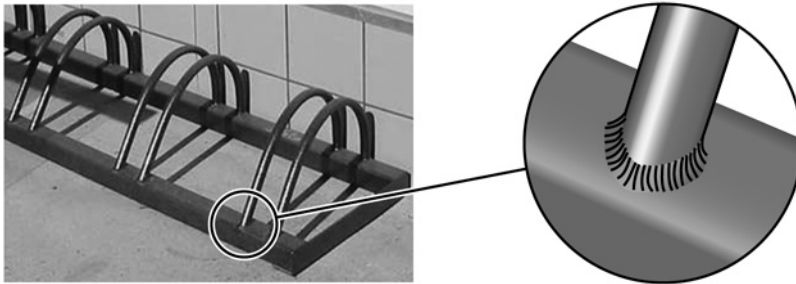
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Question 21 continues on page 14

Question 21 (continued)

- (c) Some bicycle racks made from mild steel are manufactured by welding members together. 2



Why are the welded areas, as shown in the detail above, more likely to corrode than other sections of the rack?

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- (d) How have social and environmental issues influenced the planning of urban infrastructure for bicycles? 3

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End of Question 21

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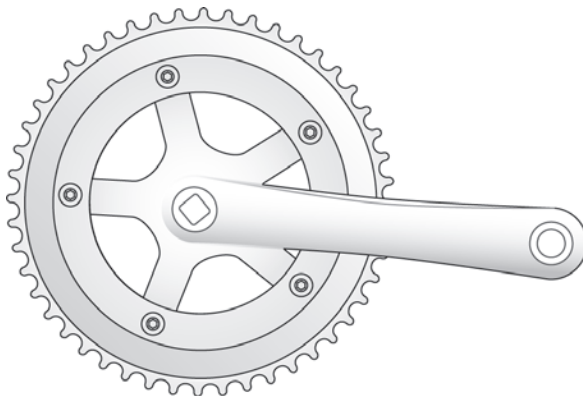
Section II (continued)

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Student Number

Question 22 (12 marks)

(a) A pedal crank is shown.



Why are pedal cranks manufactured by drop-forging in preference to sand casting?

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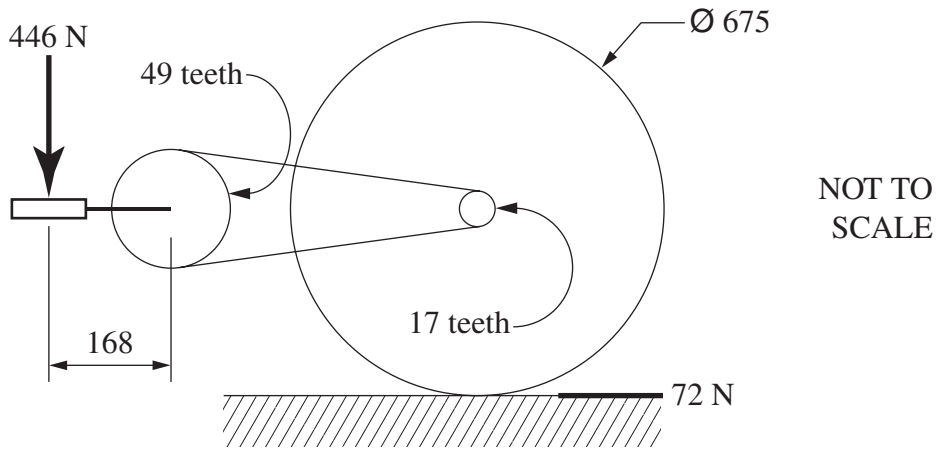
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Question 22 continues on page 16

Question 22 (continued)

- (b) The diagram shows the drive mechanism for a bicycle. When the pedal crank is horizontal, a vertical downward force of 446 N just rotates the rear wheel against a resistance of 72 N.

3



Calculate the efficiency of the drive mechanism.

Efficiency %

Question 22 continues on page 17

Question 22 (continued)

(c) Electric hybrid bicycles have been developed to assist the rider in hilly areas. They are commonly powered by a brushless DC electric motor powered by lithium-ion batteries.

(i) Contrast the operation of a brushless DC electric motor with the operation of a brushed DC electric motor. **2**

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(ii) Describe how regenerative braking charges the battery. **2**

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(iii) The lithium-ion 24 volt battery is rated at 40 ampere hours. The power of the DC electric motor is 200 watts. **3**

Calculate how far the bicycle will travel at an average speed of 8 km/h under battery power only.

Distance km

End of Question 22

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Centre Number

Section II (continued)

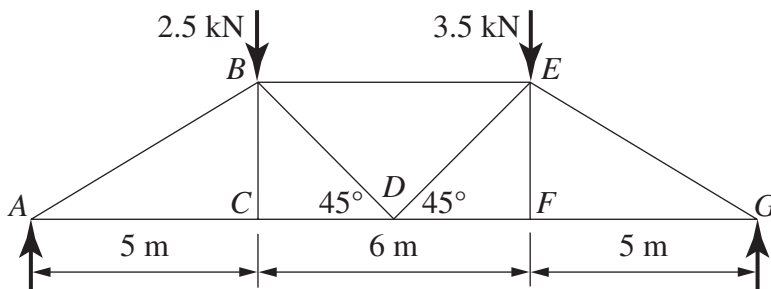
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Student Number

Question 23 (12 marks)

(a) A roof truss is supported at each end and carries loads as indicated.

4



Determine the magnitude AND nature of the forces in the members *BC* and *BD*.

Force in *BC*: kN

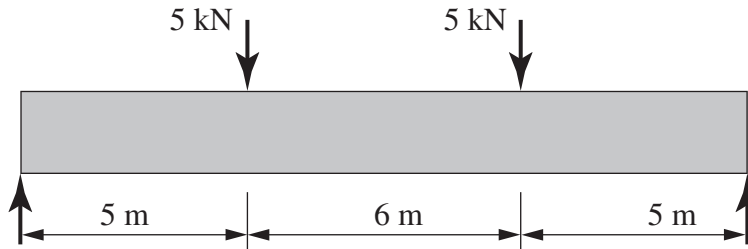
Force in *BD*: kN

Question 23 continues on page 20

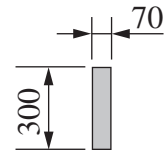
Question 23 (continued)

- (b) The truss is replaced by a laminated beam 70 mm wide, 300 mm deep and 16 m long. This beam is simply supported at each end and loaded as shown.

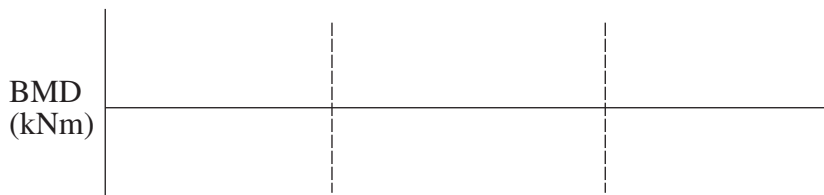
NOT TO SCALE



Cross-section of beam



- (i) Draw the shear force diagram AND bending moment diagram for the beam. Label the values on your diagrams. 3



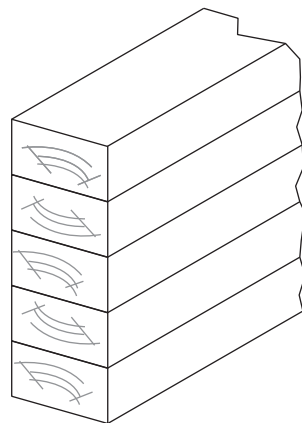
Question 23 continues on page 21

Question 23 (continued)

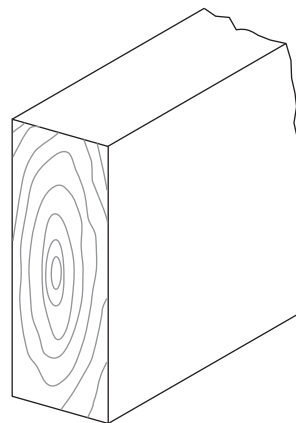
- (ii) If the second moment of area, I , is $157.5 \times 10^6 \text{ mm}^4$, determine the maximum bending stress in the beam. Neglect the mass of the beam. **3**

Maximum bending stress = MPa

- (c) Structural timber beams are often laminated rather than being one piece of solid timber. **2**



Laminated beam



Solid timber beam

Outline TWO structural advantages of using laminated beams for long spans in building structures.

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End of Question 23

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Centre Number

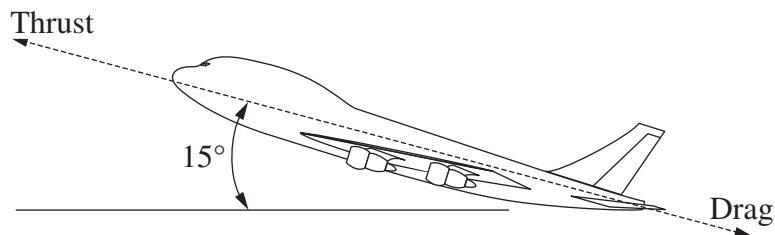
Section II (continued)

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Student Number

Question 24 (12 marks)

- (a) An aircraft of mass 260 tonnes develops a thrust of 987 kN to maintain constant velocity at an incline of 15° . 3



Determine the lift to drag ratio.

Lift to Drag Ratio =

Question 24 continues on page 24

Question 24 (continued)

- (b) How do the airspeed and the angle of attack affect drag during flight? **3**

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- (c) Describe the steps involved in the heat treatment of duralumin (an aluminium-copper alloy) to achieve its maximum strength. **3**

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- (d) Describe the basic operation of the instrument that allows a pilot to determine the altitude of an aircraft. **3**

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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 **THREE** benefits of digital television signals compared to analogue television signals. **3**

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- (b) LED, LCD and plasma systems use different display technologies. **3**

Contrast how these technologies light a television screen.

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Question 25 continues on page 26

Question 25 (continued)

- (c) List the main elements of satellite television communication systems. In your answer, specify the type of satellite. **3**

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- (d) A satellite orbiting Earth at a mean height of 170 km has an orbital speed of 27 250 km/h. If the weight of the satellite is 5 kN, calculate its kinetic energy. **3**

(Note: $g = 9.2 \text{ m/s}^2$ at 170 km above Earth's surface)

Kinetic Energy = GJ

End of Question 25

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Centre Number

Section II (continued)

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Student Number

Question 26 (12 marks)

- (a) A standard hexagonal nut is to be made to suit an $M25 \times 2$ bolt. **4**

Sketch a pictorial view of the nut blank (hole drilled but no thread) at twice full size. Appropriately dimension the distance across the flats, the thickness of the nut and the diameter of the drilled hole.

Question 26 continues on page 28

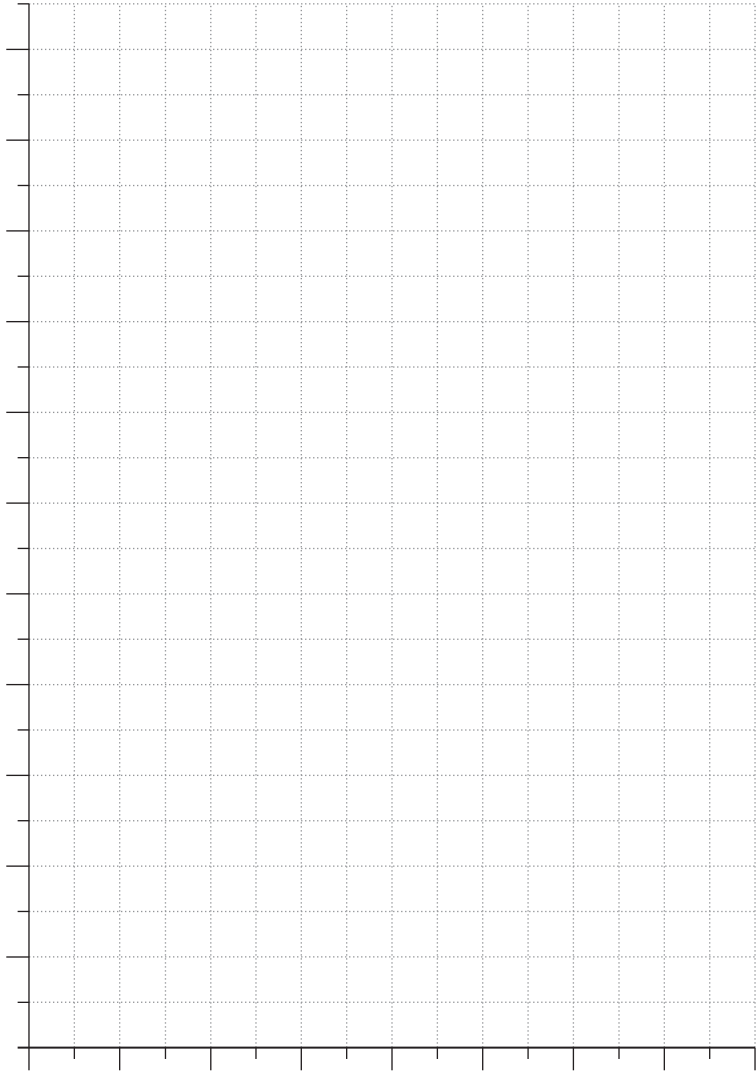
Question 26 (continued)

(b) The results of a tension test on a sample of normalised medium carbon steel are provided in the table. The test piece was 200 mm long and 25 mm in diameter. The original cross-sectional area of the test piece was 491 mm².

Load (kN)	0	50	100	110	150	175	200	215	220	215	205
Extension (mm)	0	0.1	0.2	0.25	0.75	1.5	2.9	4.5	6.2	7.0	7.7

(i) Construct an appropriate diagram using the information given in the table. Label the axes.

2



Question 26 continues on page 29

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Engineering Studies

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Centre Number

Section II (continued)

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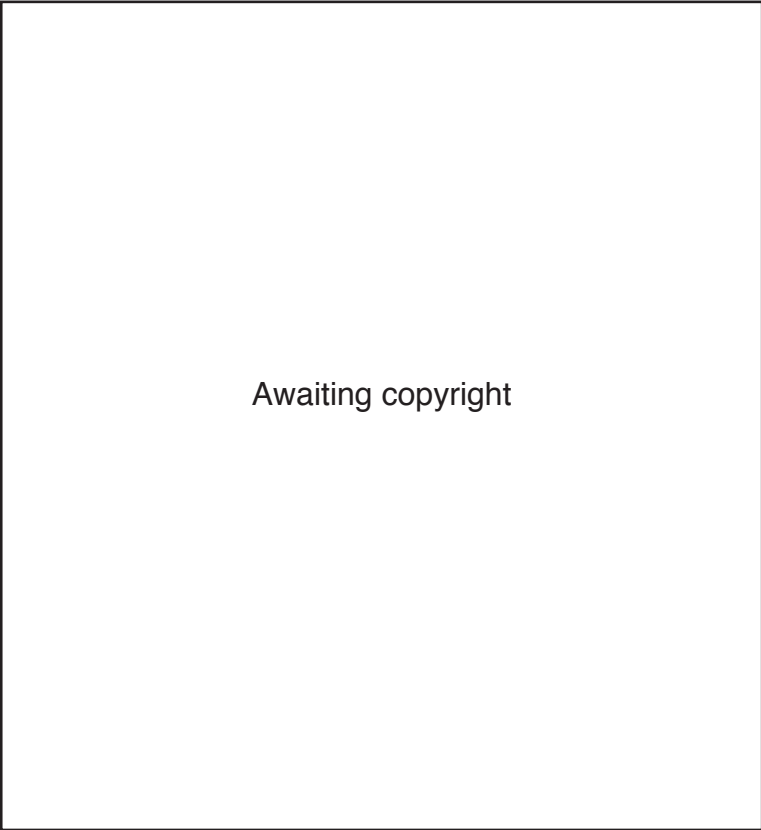
Student Number

Question 27 (8 marks)

Please turn over

Question 27 (continued)

A pictorial drawing of a component is shown.



(a) What do the labels of 92 PCD and $3 \times 45^\circ$ indicate?

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Question 27 continues on page 33

Question 27 (continued)

- (b) Draw to AS1100 standards a full size half-sectional front view of the component when viewed in the direction of the arrow. Use the centre line provided. **6**

NO dimensioning is required.



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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

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

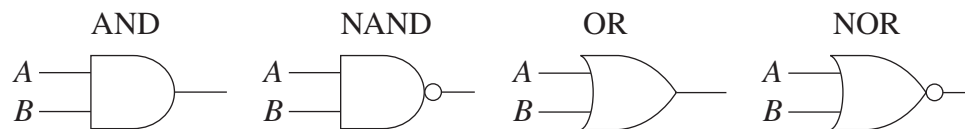
Stress and Strain

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

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

Machines

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

Digital Electronics**Electricity, Electronics**

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

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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