

Engineering Studies

General Instructions

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

Total marks: 100

Section I – 20 marks (pages 2–9)

- 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

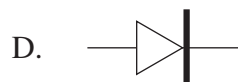
Attempt Questions 1–20

Allow about 30 minutes for this section

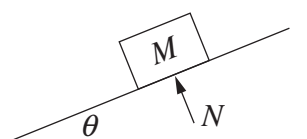
Use the multiple-choice answer sheet for Questions 1–20.

- 1 Which of the following describes the primary responsibility of an engineer?
- A. To read the latest engineering research
 - B. To explain engineering decisions to local media
 - C. To manage successful delivery of engineering projects
 - D. To ensure workplace compliance with work health and safety (WHS) requirements

- 2 Which of the following is the circuit symbol for a diode?



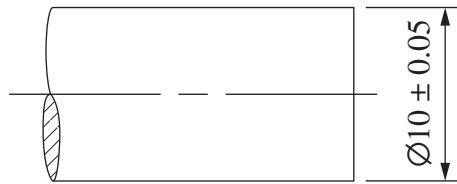
- 3 A mass M sits on a plane inclined at θ° to the horizontal.



What expression is used to calculate the normal reaction N ?

- A. Mg
- B. $Mg \cos \theta$
- C. $Mg \sin \theta$
- D. $Mg \tan \theta$

- 4 Specifications for a $\varnothing 10$ steel bar require it to have a tolerance of ± 0.05 mm.



What is the permitted range of diameters for this bar?

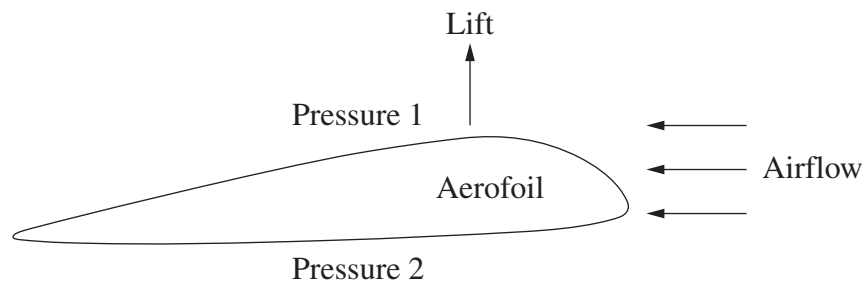
- A. 9.90–10.00 mm
 - B. 9.95–10.00 mm
 - C. 9.95–10.05 mm
 - D. 10.00–10.05 mm
- 5 The image shows the microstructure of brass.



What type of grain structure does this image represent?

- A. Deformed
- B. Dendritic
- C. Equiaxed
- D. Stressed

- 6 The diagram shows an aerofoil.



Which condition needs to be achieved for lift to occur?

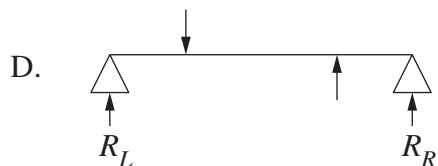
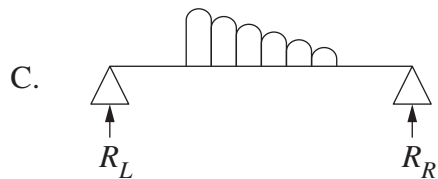
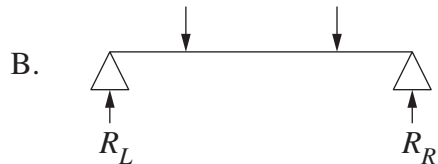
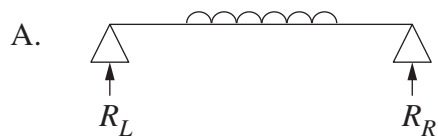
- A. Pressure 1 < Pressure 2
 - B. Pressure 1 = Pressure 2
 - C. Pressure 1 > Pressure 2
 - D. Pressure 1 + Pressure 2 = 0
- 7 Wireless networks operate in two distinct frequency bands: 2.4 GHz and 5 GHz.

Which of the following statements is correct?

- A. 5 GHz waves experience lower attenuation and have a lower bandwidth
 - B. 5 GHz waves experience higher attenuation and have a higher bandwidth
 - C. 2.4 GHz waves experience lower attenuation and have a higher bandwidth
 - D. 2.4 GHz waves experience higher attenuation and have a lower bandwidth
- 8 Which row of the table correctly identifies how the properties of a cold worked metal are changed after annealing?

	<i>Hardness</i>	<i>Ductility</i>	<i>Internal residual stress</i>
A.	Reduction	Decrease	Increase
B.	Reduction	Increase	Decrease
C.	Increase	Decrease	Increase
D.	Increase	Increase	Decrease

9 Which free-body diagram shows a beam subjected to a uniformly distributed load?



10 Which of the following statements describes Hooke's Law?

- A. Pressure acting on an object varies proportionally with depth.
- B. Pressure acting on an object in a confined fluid is uniform in all directions.
- C. Force induced in an object by stretching it is initially proportional to its extension.
- D. Force acting on an object is equal to the stress divided by the cross-sectional area.

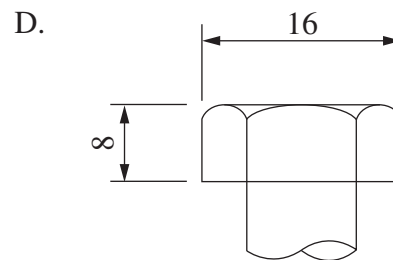
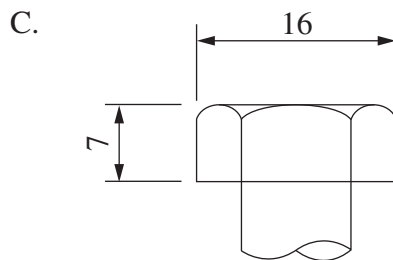
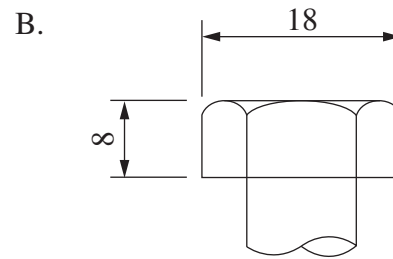
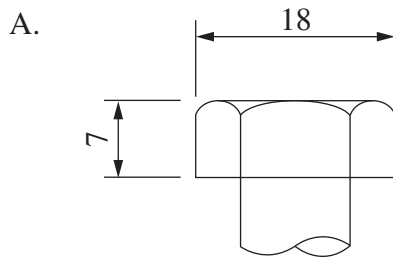
11 The properties of some aluminium-magnesium-silicon alloys can be altered using the following procedure.

Solution treating  Quenching  Reheating

What type of hardening process is this?

- A. Case hardening
- B. Flame hardening
- C. Induction hardening
- D. Precipitation hardening

- 12 Which drawing shows the correct AS 1100 standard representation of a $\varnothing 10$ non-structural bolt head?



NOT TO SCALE

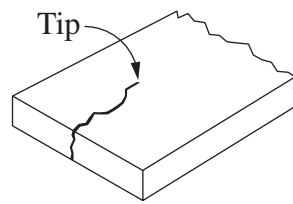
- 13 An image of an Allen truss bridge is shown.



Which of the following correctly identifies the loading conditions of an Allen truss bridge?

- A. Timber members in shear and steel members in torsion
- B. Timber members in torsion and steel members in shear
- C. Timber members in tension and steel members in compression
- D. Timber members in compression and steel members in tension

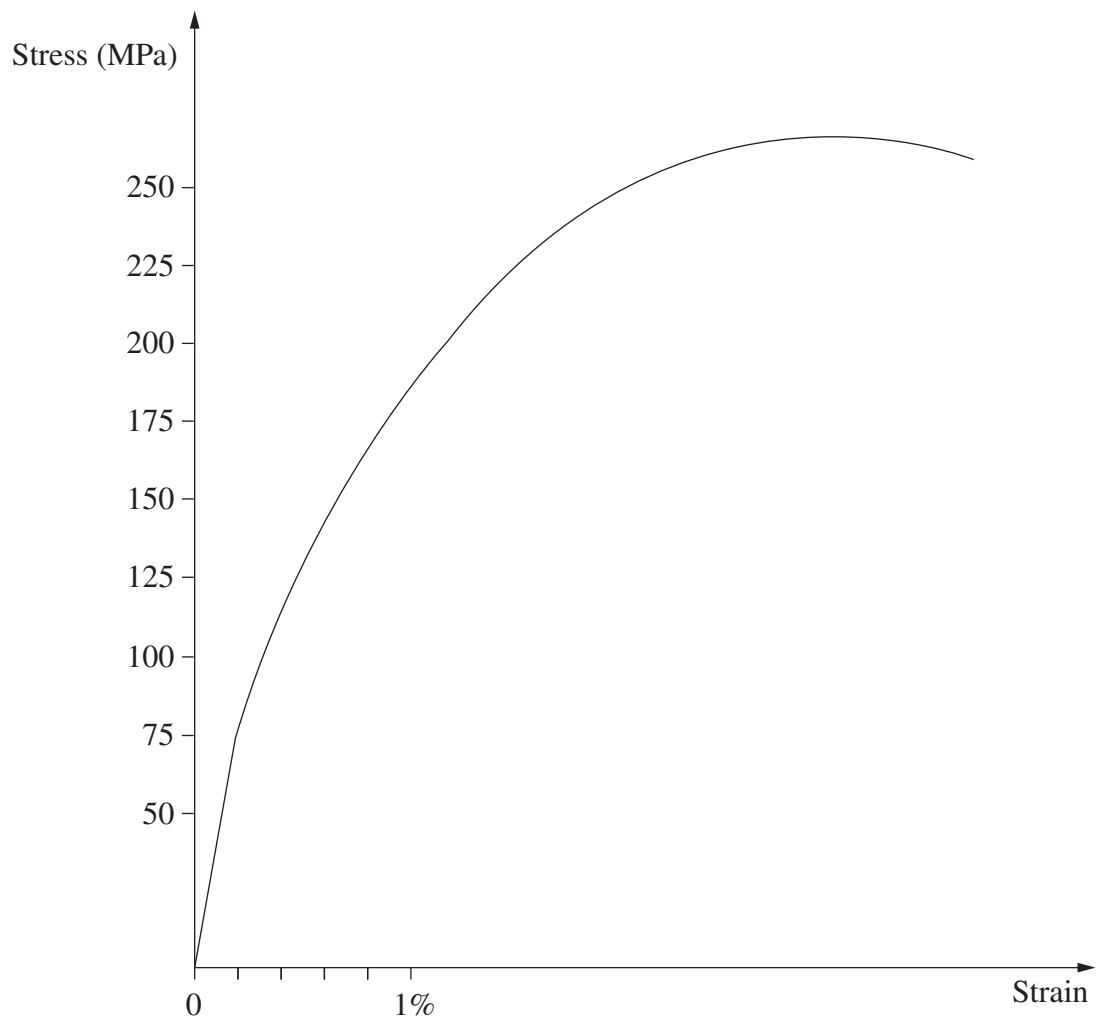
- 14** A highly stressed steel plate develops a fatigue crack while in service.



Which of the following is the most effective temporary method to slow or stop the crack's growth?

- A. Weld the crack as it is
 - B. Drill a hole ahead of the tip of the crack
 - C. Drill a hole through the start of the crack
 - D. Weld a small steel plate over the tip of the crack
- 15** What can be used to minimise significant losses in electrical power transmission cables?
- A. Very high current
 - B. Very high voltage
 - C. Very high resistance
 - D. Very high capacitance
- 16** Television programs that show high levels of activity often have lower picture quality.
- This is because television signals are transmitted using
- A. digital modulation at low compression levels.
 - B. digital modulation at high compression levels.
 - C. analogue modulation at low compression levels.
 - D. analogue modulation at high compression levels.
- 17** In which of the following does an impervious oxide surface layer provide corrosion resistance for the base metal?
- A. Zinc coating of steel in underground applications
 - B. Carbon fibre panels in automotive body applications
 - C. Powder coating of steel structures in marine applications
 - D. Nickel-based alloys in high temperature aeronautical applications

- 18 The following graph shows the results of a tensile test on a metal sample.

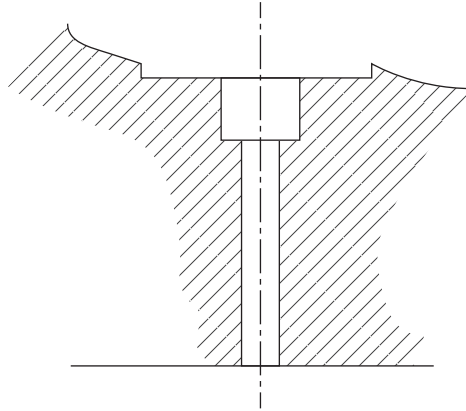


What is the approximate 0.2% proof stress for this metal sample?

- A. 70 MPa
- B. 80 MPa
- C. 140 MPa
- D. 260 MPa

19 An engineering component is required to have the following features:

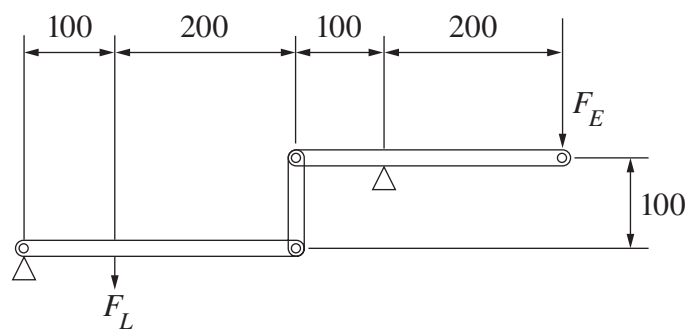
- 30 mm spotface
- 10 mm counterbore, 8 deep
- 6 mm through.



Which of the following shows the correct dimensioning?

- A. $\varnothing 6 \sqcup \varnothing 10 \times \nabla 8 \varnothing 30 \text{ SF}$
- B. $\varnothing 6 \sqcup \varnothing 8 \times \nabla 10 \sqcup \varnothing 30$
- C. $\varnothing 6 \varnothing 10 \times 8 \nabla \varnothing 30 \text{ SF}$
- D. $\varnothing 8 \varnothing 6 \times 10 \nabla \varnothing 30 \text{ SF}$

20 A compound lever system is shown.



What is the velocity ratio of this lever system?

- A. 1:1
- B. 2:1
- C. 4:1
- D. 6:1

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HIGHER SCHOOL CERTIFICATE
EXAMINATION

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Centre Number

Engineering Studies

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Student Number

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

Question 21 (13 marks)

- (a) Using examples, explain why gears are used in the design of vehicles.

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- (b) Gears used in automotive engines can be manufactured using ferrous alloys.

- (i) Sand casting and powder metallurgy are methods that can be used.

4

Compare the properties of the gears manufactured by each method.

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- (ii) After manufacture the gears are case hardened.

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Describe how case hardening produces the required structure–property relationships for this application.

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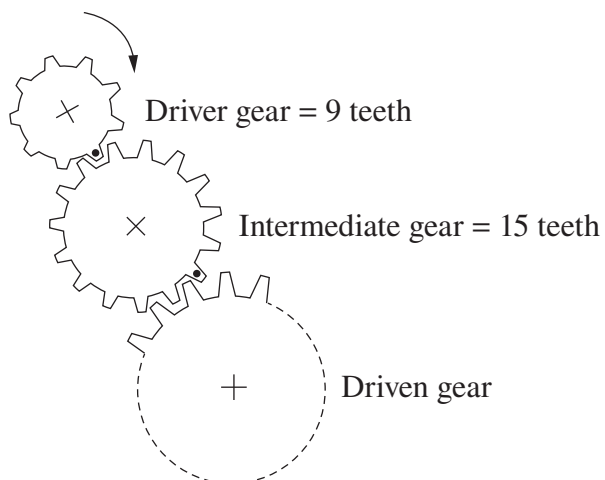
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Question 21 continues on page 15

Question 21 (continued)

- (c) The diagram shows a gear train.

3



The mechanical advantage of the gear train is 1.6 : 1 with an efficiency of 80%.

Calculate the number of teeth on the driven gear.

Answer:

End of Question 21

Question 22 (11 marks)

Carbon fibre was originally developed to produce aircraft bodies and high performance vehicles. Carbon fibre is now used in a wide range of applications, including the manufacture of the type of bicycle frame shown.



- (a) Outline the advantages of carbon fibre bicycle frames over steel bicycle frames. **3**

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- (b) Explain how a carbon fibre bicycle frame is manufactured. **3**

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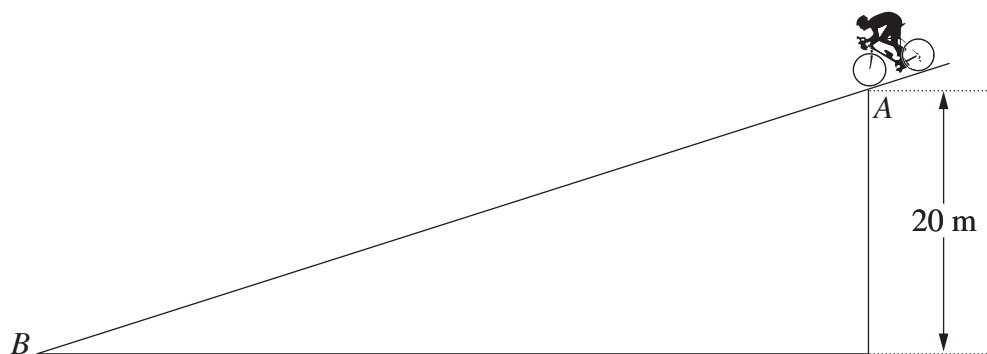
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Question 22 continues on page 17

Question 22 (continued)

- (c) A bike with a rider rolls down a hill without braking from a standing start at point A.

2



The combined weight of the bike and the rider is 100 kg.

Calculate the speed of the rider at point B. (Assume no wind resistance and 100% efficiency.)

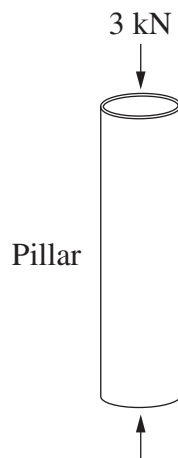
Answer:

Question 22 continues on page 18

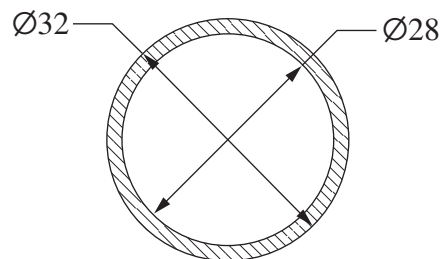
Question 22 (continued)

- (d) When a bike goes over a bump, there is a vertical force of 3 kN exerted axially on the main pillar.

3



The cross-section of the pillar is shown.



All dimensions
in millimetres

Calculate the compressive stress acting in the pillar.

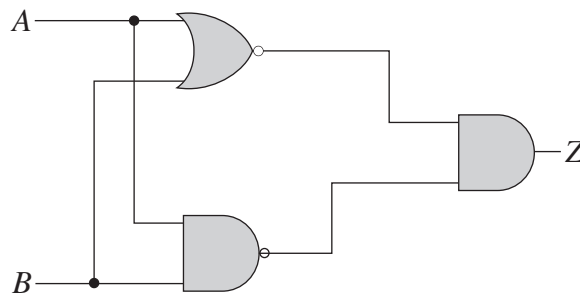
Answer:

End of Question 22

Question 23 (11 marks)

- (a) A digital TV receiver circuit uses logic gates as shown.

2



Complete the truth table for this logic circuit.

<i>A</i>	<i>B</i>	<i>Z</i>
0	0	
0	1	
1	0	
1	1	

- (b) The digital TV receiver uses zener diodes.

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Compare the operation of zener diodes with common diodes used in electrical circuits.

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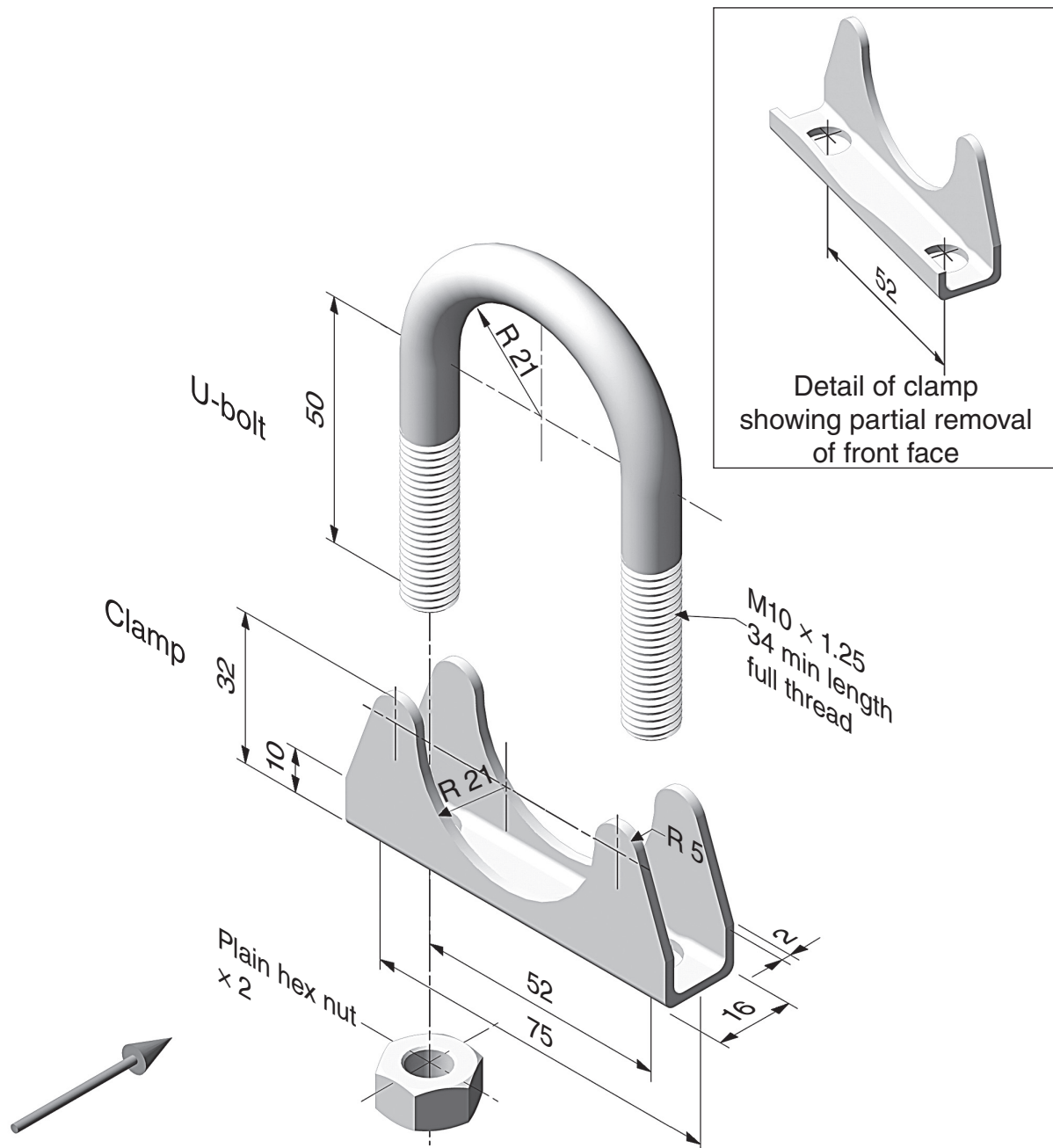
Question 23 continues on page 20

Question 23 (continued)

- (c) The U-bolt clamp shown is used to hold a $\varnothing 42$ digital TV aerial pipe in place. 6

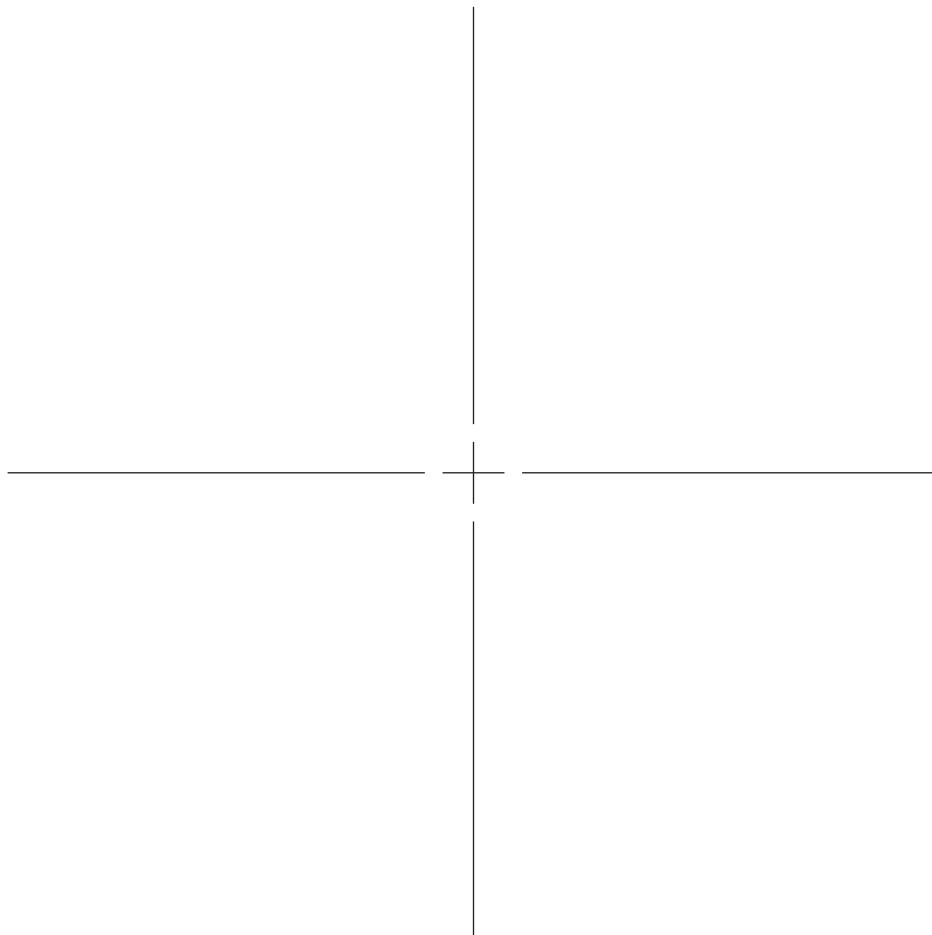
On the next page, draw an assembled half-sectional front view of this U-bolt clamp to AS 1100 standards. The front is indicated by the direction of the arrow.

Use a scale of 2 : 1 and place the half section on the right-hand side.



Question 23 continues on page 21

Question 23 (continued)



End of Question 23

– 21 –

Question 24 (11 marks)

- (a) Sleds are used to slide loads over soft surfaces such as grass, sand and snow. They can be made using polypropylene.



- (i) Explain how the properties of polypropylene make it a suitable material for this application. **3**

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- (ii) Describe a suitable manufacturing method to make a sled from polypropylene. **3**

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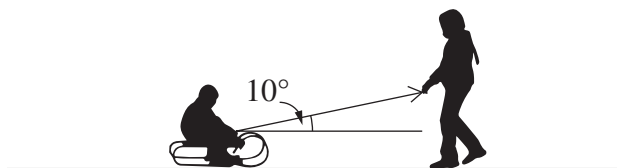
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Question 24 continues on page 23

Question 24 (continued)

- (b) A child and sled with a combined mass of 23 kg are being pulled along a horizontal snow-covered surface using a rope.



The coefficient of static friction between the sled and the snow is 0.14.

- (i) Draw a free-body diagram that indicates the forces acting on the sled. Label the diagram. 2
- (ii) Calculate the tension in the rope immediately before the point at which the sled and child begin to move. 3

Answer:

End of Question 24

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Question 25 (continued)

- (i) Determine the magnitude and direction of the reactions at A and B .

4

Reaction at A = Direction

Reaction at B = Direction

Question 25 continues on page 26

Question 25 (continued)

- (ii) Determine the magnitude and nature of the force in member *C*.

2

Magnitude = kN

Nature =

- (iii) Explain why concrete would be a suitable material to support the roadside sign around point *D*.

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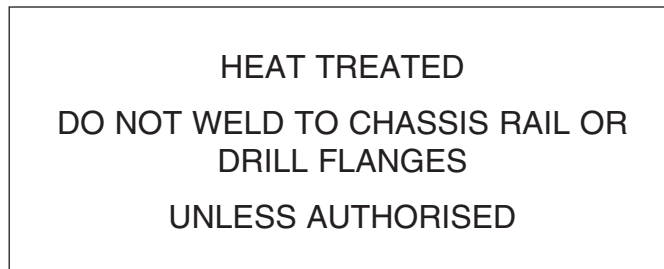
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Question 25 continues on page 27

Question 25 (continued)

- (b) A small truck chassis rail has been made from rectangular hollow section (RHS) steel. The RHS has been cold formed from an alloy steel with a yield strength of 500 MPa. A manufacturer's sign on the chassis rail is shown below.



- (i) Explain why the chassis rail should normally not be drilled or welded.

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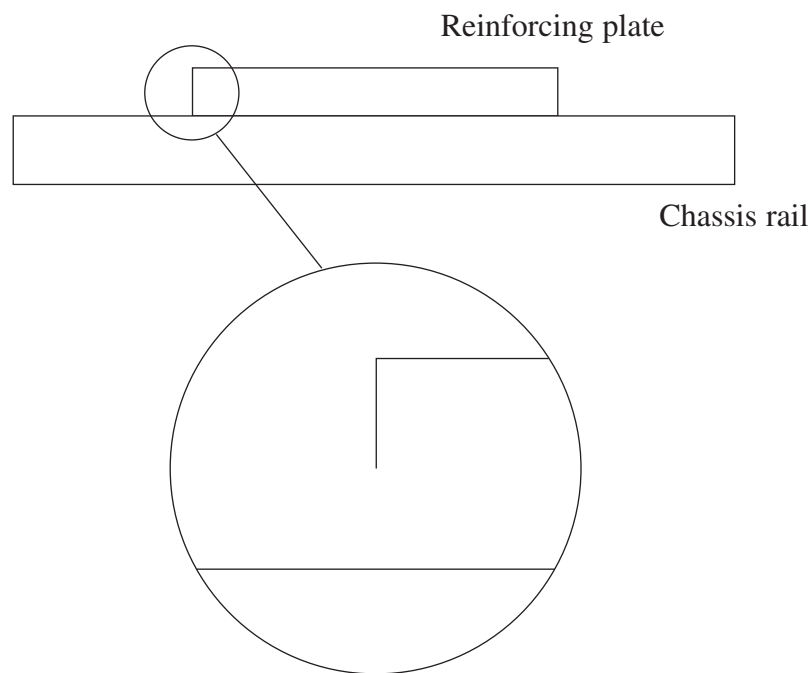
Question 25 continues on page 28

Question 25 (continued)

- (ii) A large reinforcing plate that supports a new attachment is to be welded onto the chassis rail according to the manufacturer's specifications.

2

Use the diagram below to draw and label the macrostructure of the weld area, including the surrounding chassis rail and reinforcing plate.

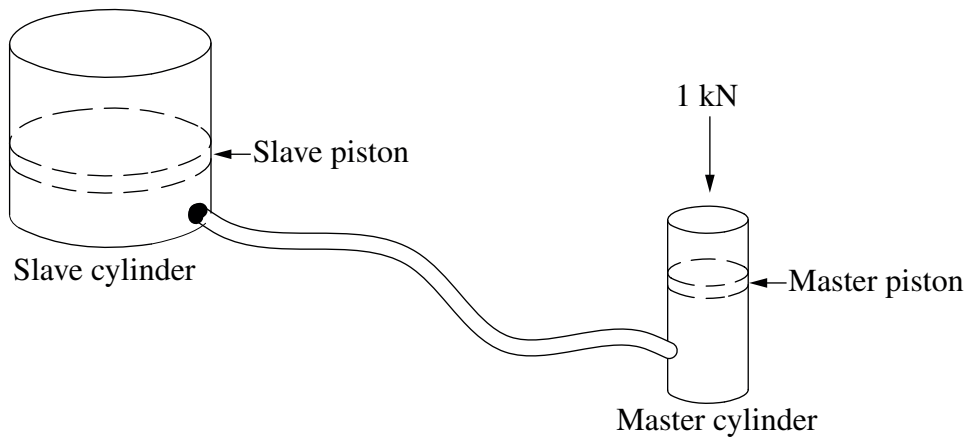


End of Question 25

Question 26 (13 marks)

- (a) The flaps of an executive jet are controlled using a hydraulic system. A force of 1 kN acts on the 40 mm diameter master piston.

3



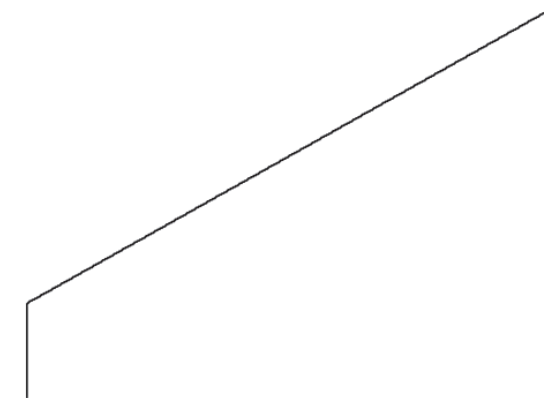
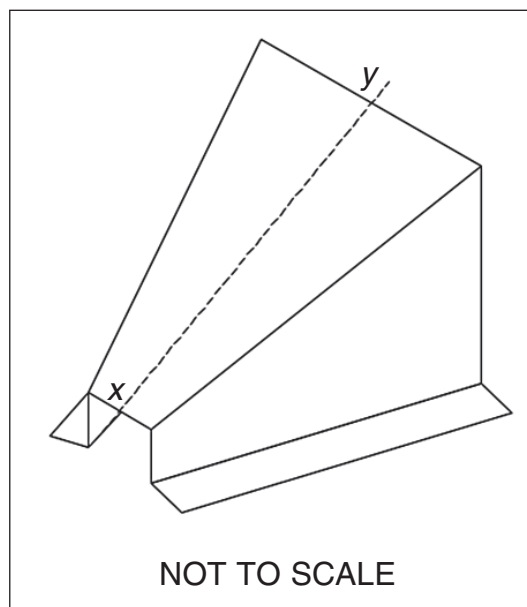
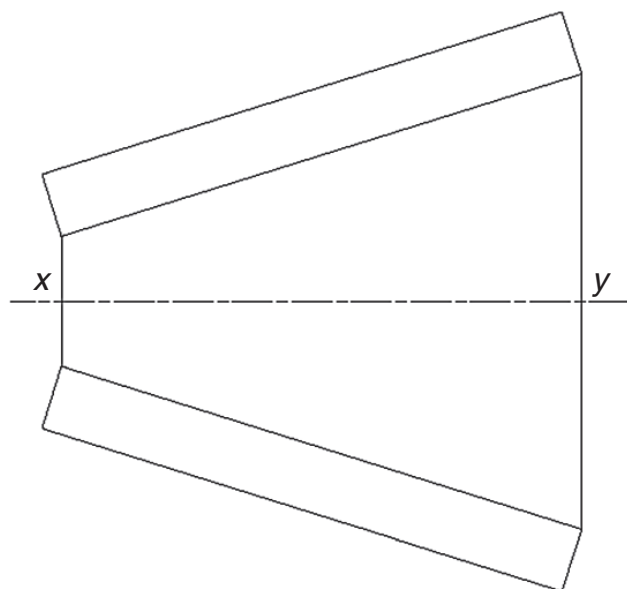
What force would need to be developed to move the flap if the slave piston has a diameter of 100 mm?

Answer:

Question 26 continues on page 30

Question 26 (continued)

- (b) Orthogonal and pictorial drawings of a sheet metal electrical cable cover are given below.



Question 26 continues on page 31

Question 26 (continued)

- (i) Draw a half-development of the electrical cable cover. Use the centre line to position the development.

4



Question 26 continues on page 32

Question 26 (continued)

- (ii) A 20 mm diameter hole is to be punched through the top of the electrical cable cover before folding.

3

The ultimate shear stress of the material used to manufacture the cover is 110 MPa.

Calculate the force required to punch out the hole if the thickness of the sheet metal is 0.5 mm.

Answer:

Question 26 continues on page 33

Question 26 (continued)

- (c) In modern aircraft, the external skin is riveted to the frame using solution treated and quenched aluminium 4% copper alloy rivets. These rivets are used immediately to attach the external skin of the aircraft to the frame.

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Describe the changes that occur to the structure and properties of these rivets after installation.

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End of Question 26

Please turn over

Question 27 (8 marks)

- (a) Why is the routine testing of engineering components important during service?

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- (b) An engineering team has been contracted to design a multi-function lifting device for a coastal container wharf.

6

The table shows some of the engineering design elements for this lifting device.

<i>Engineering element</i>	<i>Criterion</i>
Mechanical efficiency	Minimum efficiency required = 75%
Working environment	Withstand lateral wind speeds of 150 kph
Materials	Corrosive resistant metals
Load	Lift and transport containers up to 30 t

Explain how the lifting device can be tested and evaluated to determine if the criteria for the listed engineering elements are met.

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Question 27 continues on page 35

Question 27 (continued)

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Section II extra writing space

If you use this space, clearly indicate which question you are answering.

Do NOT write in this area.

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

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

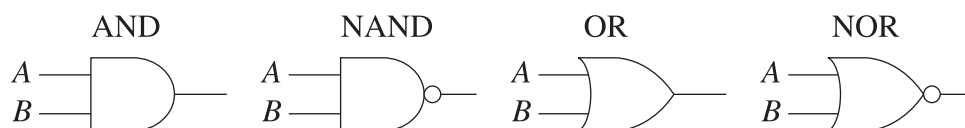
Stress and Strain

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

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

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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