BOARD OF STUDIES
NEW SOUTH WALES

2005

HIGHER SCHOOL CERTIFICATE EXAMINATION

Engineering Studies

General Instructions

- Reading time – 5 minutes
- Working time – 3 hours
- Write using black or blue pen
- 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 9, 11, 15, 17, 19, 23, 27 and 31

Total marks – 100

Section I Pages 2–6

10 marks

- Attempt Questions 1–10
- Allow about 20 minutes for this section

Section II Pages 9–26

70 marks

- Attempt Questions 11–16
- Allow about 2 hours for this section

Section III Pages 27–34

20 marks

- Attempt Questions 17–18
- Allow about 40 minutes for this section

Section I

10 marks
Attempt Questions 1–10
Allow about 20 minutes for this section

Use the multiple-choice answer sheet.

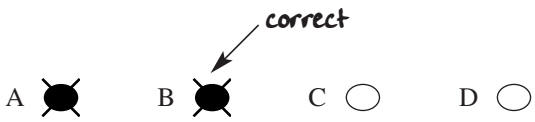
Select the alternative A, B, C or D that best answers the question. Fill in the response oval completely.

Sample: 2 + 4 = (A) 2 (B) 6 (C) 8 (D) 9

A ○ B ● C ○ D ○

If you think you have made a mistake, put a cross through the incorrect answer and fill in the new answer.

If you change your mind and have crossed out what you consider to be the correct answer, then indicate the correct answer by writing the word **correct** and drawing an arrow as follows.



1 What method is used to manufacture the outer shell of an industrial hard hat?

(A) Blow moulding

(B) Die casting

(C) Injection moulding

(D) Shell forming

2 A 20 kg crate is at rest on a horizontal surface. The coefficient of friction between the crate and surface is 0.5.

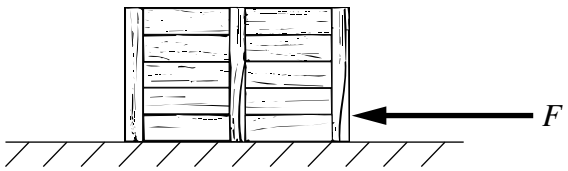
What is the minimum horizontal force (F) required to start the box sliding?

(A) 10 N

(B) 20 N

(C) 100 N

(D) 200 N



3 Aluminium–silicon alloys are often chosen for pressure die-casting processes.

Which of the following characteristics of aluminium–silicon alloys justifies this choice?

(A) They have high melting points.

(B) They have low density and superior machinability.

(C) They are more suitable to produce thick-walled castings.

(D) They have high fluidity and a low coefficient of expansion.

4 Which of the following is an essential property of the fluid used in hydraulic applications?

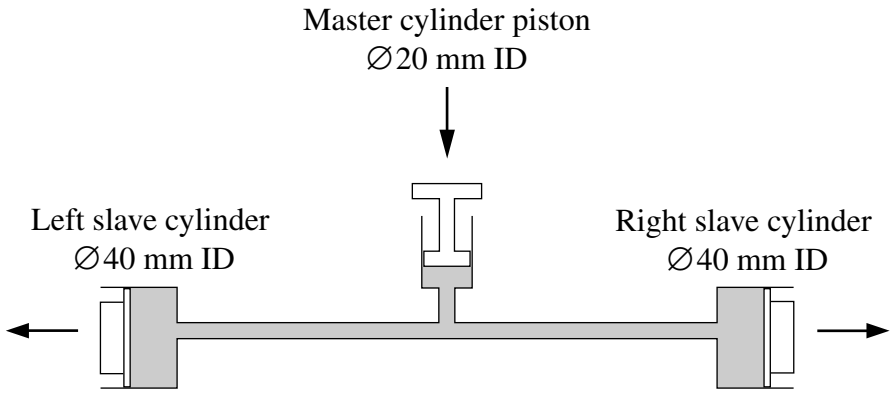
(A) High viscosity

(B) Low compressibility

(C) Low toxicity

(D) Self-sealing ability

5 The front disc brakes of a car are arranged according to the master/slave cylinder system shown.



When the brakes are not in use, the distance between the brake pad and the brake disc is 1 mm.

How far, in mm, must the master cylinder piston move to bring the brake pad into contact with the brake disc?

(A) 1

(B) 4

(C) 8

(D) 16

6 Why are high voltages used to transmit electrical power over long distances?

(A) Less electrical power is lost in transmission lines.

(B) Electrical power is consumed at these high voltages.

(C) It is easier to store electrical power in large quantities.

(D) All electrical power is generated at these high voltages.

7 Why is hydro-electric power generation useful as a component of an electrical power supply grid?

(A) It costs less to construct than other types of 'green' power generators.

(B) It can be turned on and off relatively quickly to match supply and demand.

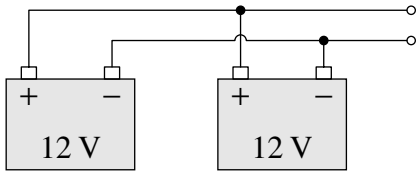
(C) It is usually situated close to where the electrical power is being consumed.

(D) It is more efficient in converting mechanical power to electrical power than other generating systems.

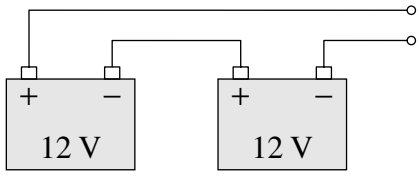
8 In a forklift's electrical system, two batteries are required to supply a large amount of current at 12 volts.

Which of the following electrical connections would achieve this?

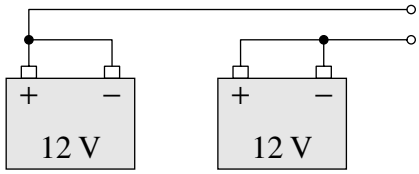
(A)



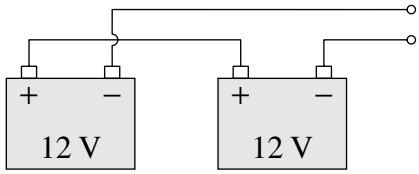
(B)



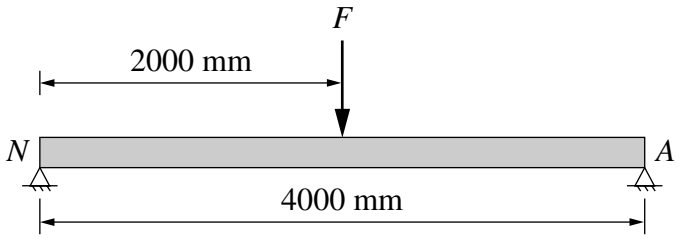
(C)



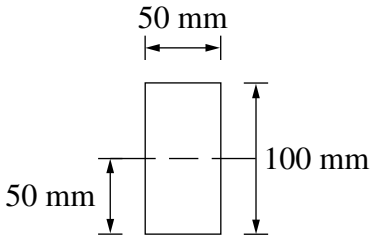
(D)



9 A four-metre beam is loaded as shown.



Cross-section of beam



The Second Moment of Area (I) for the rectangular beam shown is 4.17×10^6 mm^4.

If the maximum bending stress on the bottom edge of the beam is not to exceed 42 MPa, what is the maximum magnitude of the force, *F*?

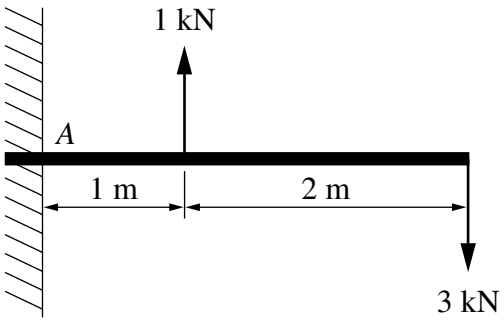
(A) 3.5 MN

(B) 87.6 kN

(C) 875.7 N

(D) 1751.4 N

10 A cantilevered beam is loaded as shown.



What is the force/couple acting at point *A*?

(A) 2 kN vertically up, 5 kNm clockwise

(B) 2 kN vertically down, 8 kNm clockwise

(C) 4 kN vertically down, 5 kNm anticlockwise

(D) 4 kN vertically up, 8 kNm anticlockwise

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Engineering Studies

Centre Number

Section II

Student Number

70 marks
Attempt Questions 11–16
Allow about 2 hours for this section

Answer the questions in the spaces provided.

Marks

Question 11 — Historical and Societal Influences, and the Scope of the Profession (10 marks)

(a) During the design of a new public telephone booth, a telecommunication engineer needs to consult with other professional and interest groups.

(i) Describe ONE social issue that the telecommunication engineer would need to consult on. Identify an interest group that should be consulted on this issue. **2**

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Question 11 continues on page 10

Marks

Question 11 (continued)

(ii) Describe ONE technical issue that the telecommunication engineer would need to consult on. Identify another type of engineering field that should be consulted on this issue. **2**

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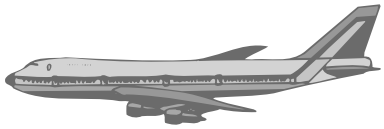
(b) Older commercial aircraft, such as the Boeing 747 shown, often undergo mid-life upgrades to take advantage of evolving technologies. **3**



Identify an example of a technological upgrade, and explain the role that an aeronautical engineer would have during the upgrading process.

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(c) Discuss an ethical issue that aeronautical engineers might need to consider in their work. **3**

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End of Question 11

Marks

Question 12 — Civil Structures (10 marks)

(a) Prefabricated reinforced concrete is increasingly being used for walls in buildings.

(i) Outline characteristics or properties of prefabricated reinforced concrete construction that make it suitable for assembly, and in service as a finished wall. **2**

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Question 12 continues on page 12

Question 12 (continued)

(ii) Walls can be prefabricated OFF the building site, or walls can be produced ON the building site. **3**

Discuss the advantages of producing a wall on-site AND off-site.

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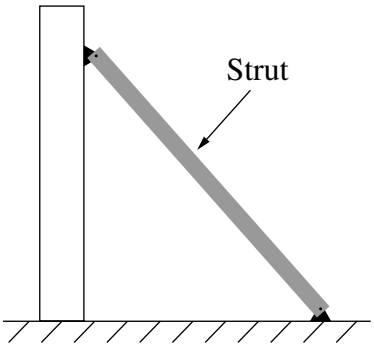
(b) (i) A strut is supporting a concrete wall panel. **2**

Calculate the compressive stress in the strut when the axial load is 30 kN and the cross-sectional area of the strut is 250 mm^2.



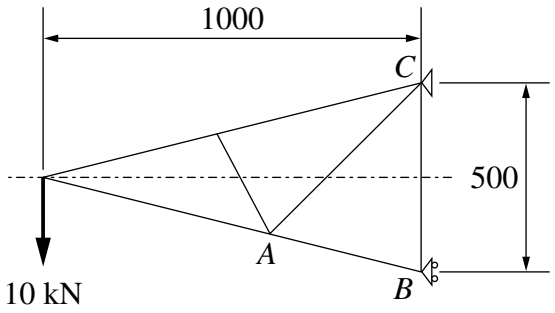
Stress in the strut = ...

Question 12 continues on page 13

Question 12 (continued)

(ii) A crane is used to lift the wall into position. The end of the crane jib is shown in the scale drawing below. **3**

Determine the magnitude and nature of the force in member *A*–*B*.



Magnitude of the force = ... kN

Nature of the force (tension/compression) = ...

End of Question 12

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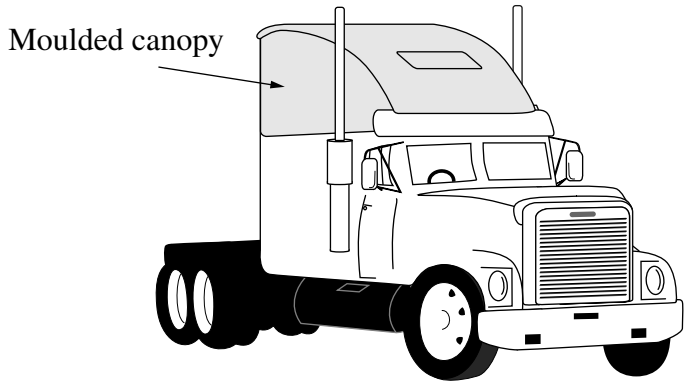
Marks

Question 13 — Personal and Public Transport (10 marks)

(a) A truck has a moulded canopy mounted above the cab, as shown.



(i) Identify a physical function of this canopy, and give TWO reasons why fibre-reinforced composite materials are ideal for this application. **3**

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(ii) Identify TWO properties of the canopy's surface finish that are important for this application. **2**

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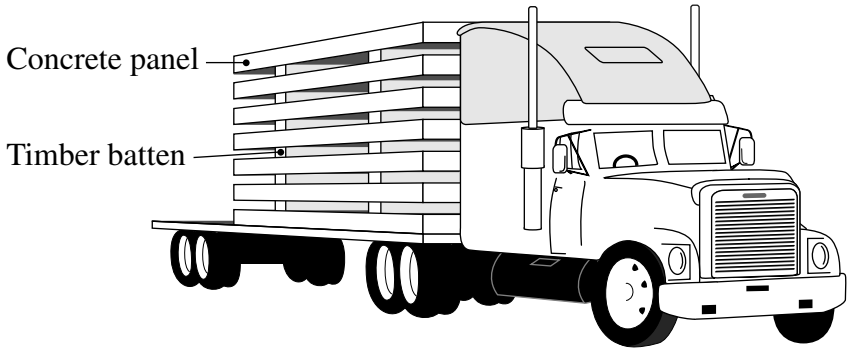
Question 13 continues on page 16

Question 13 (continued)

(b) (i) A truck with a total hauling power of 400 kW is used to deliver precast panels to a construction site. The truck and trailer have a mass of 10 tonnes, and each panel has a mass of 7.5 tonnes. **3**



The truck is to climb a 100 m long access road with a grade of 1 in 5 (11.3°), in 20 seconds, at constant velocity.

Calculate the number of panels the truck can carry. Show all working. (Neglect the mass of the timber battens and frictional rolling resistance.)

Number of panels = ...

(ii) Precast panels are stacked flat on the trailer of the truck, separated by timber battens placed at carefully chosen spacings. **2**

Explain why the choice of spacing is important.

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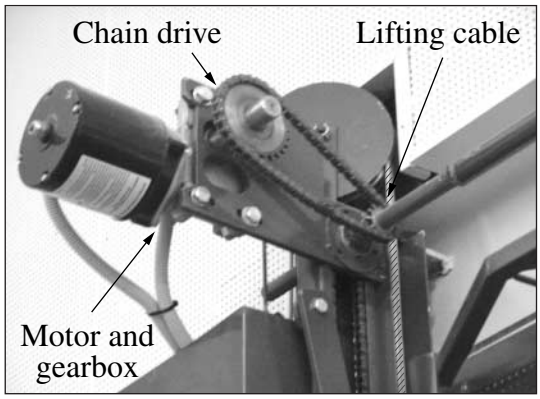
End of Question 13

Marks

Question 14 — Lifting Devices (10 marks)

An electric motor drives a gearbox and chain drive that opens and closes a door, as shown in the photograph.



(a) (i) The electric motor drives a gearbox with a Velocity Ratio (VR) of 100 : 1, which then drives a chain drive of VR 1 : 4. **1**

Find the total Velocity Ratio.

Total Velocity Ratio = ...

(ii) Two lifting cables, one for each side, are required to lift a 400 kg door. The steel lifting cables are each 5 m long and each has a cross-sectional area of 27 mm^2. The Modulus of Elasticity of the steel in the cables is 230 GPa. **3**

Calculate the extension of each cable.

Extension = ...

Question 14 continues on page 18

Marks

Question 14 (continued)

(b) (i) An induction motor is chosen for this door-lifting mechanism. **2**

Outline TWO reasons for the choice of this type of electric motor.

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(ii) The gears in the gearbox can be manufactured by powder forming. **2**

Outline TWO reasons for the choice of this manufacturing method.

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(c) Three of the safety features in this lifting system are 'fail safe': **2**

- the clutch in the gearbox;
- an automatic door-reversing switch;
- an electrical overload switch.

Explain how TWO of these features lead to improved safe operation of the door.

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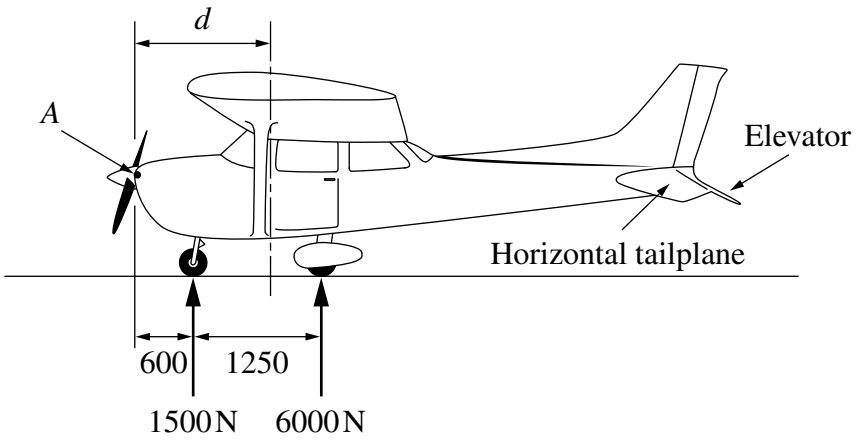
End of Question 14

Marks

Question 15 — Aeronautical Engineering (15 marks)

(a) A diagram of a light plane is shown.



(i) A static-weight and balance test is carried out on the light plane to determine the position of the centre of gravity. **2**

A reaction force of 1500 N is measured at the nose wheel, and a total of 6000 N is measured at the main wheels.

Calculate the horizontal distance, d, from point A to the centre of gravity.

Distance d = ... mm

Question 15 continues on page 20

Marks

Question 15 (continued)

(ii) During level flight a vertical force on the horizontal tailplane is usually required to maintain stability. **2**

Explain the aerodynamic features of the tailplane that allow a stabilising force to be produced.

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(iii) The elevator could be controlled by: **3**

- an electric pump/hydraulic ram system;
- a cable/pulley system; or
- an electric motor/gear system.

Explain why electric pump/hydraulic ram systems are more common than other control systems on larger, heavier aircraft, such as the Boeing 747.

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Question 15 continues on page 21

Marks

Question 15 (continued)

(b) (i) Explain reasons why a crack might develop in an aircraft frame after it has been in service for several years. **2**

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(ii) As part of regular inspections, non-destructive tests are carried out on sections of the aircraft frame to detect structural faults. **2**

Name a suitable non-destructive test method, and explain the testing process.

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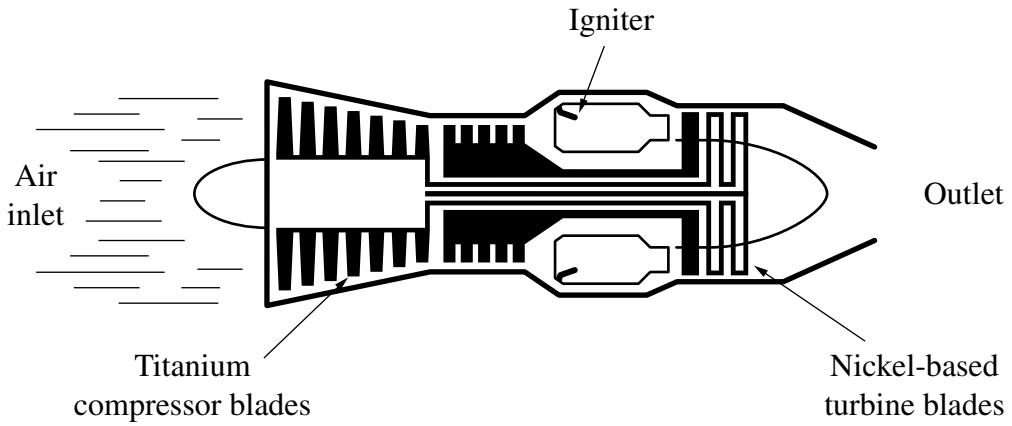
Question 15 continues on page 22

Question 15 (continued)

(c) A diagram of a turbojet engine is shown.



(i) Explain the purpose of compressing the air in the first stage of the engine. **2**

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(ii) Turbine blades are cast from a nickel-based alloy. **2**

Explain TWO essential engineering properties that the nickel-based alloy must have in this situation.

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End of Question 15

Marks

Question 16 — Telecommunication (15 marks)

(a) A headphone device is being chosen to allow someone to listen to a home sound system without disturbing other people in their house. Three options are:

- cable-connected headphones;
- infrared-linked 'wireless' headphones with a wavelength of 940 nm;
- 'wireless' headphones having a radio link with a longer wavelength (frequency 433 MHz).

(i) Describe ONE characteristic of the cable-connected headphones, and explain how this limits functionality. **2**

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(ii) If the headphones with a wireless link were chosen, the carrier signal would have to be modulated with the information signal (audio). **2**

Explain why this process is needed.

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(iii) Describe ONE limitation of the performance of EACH of the two wireless headphones. **2**

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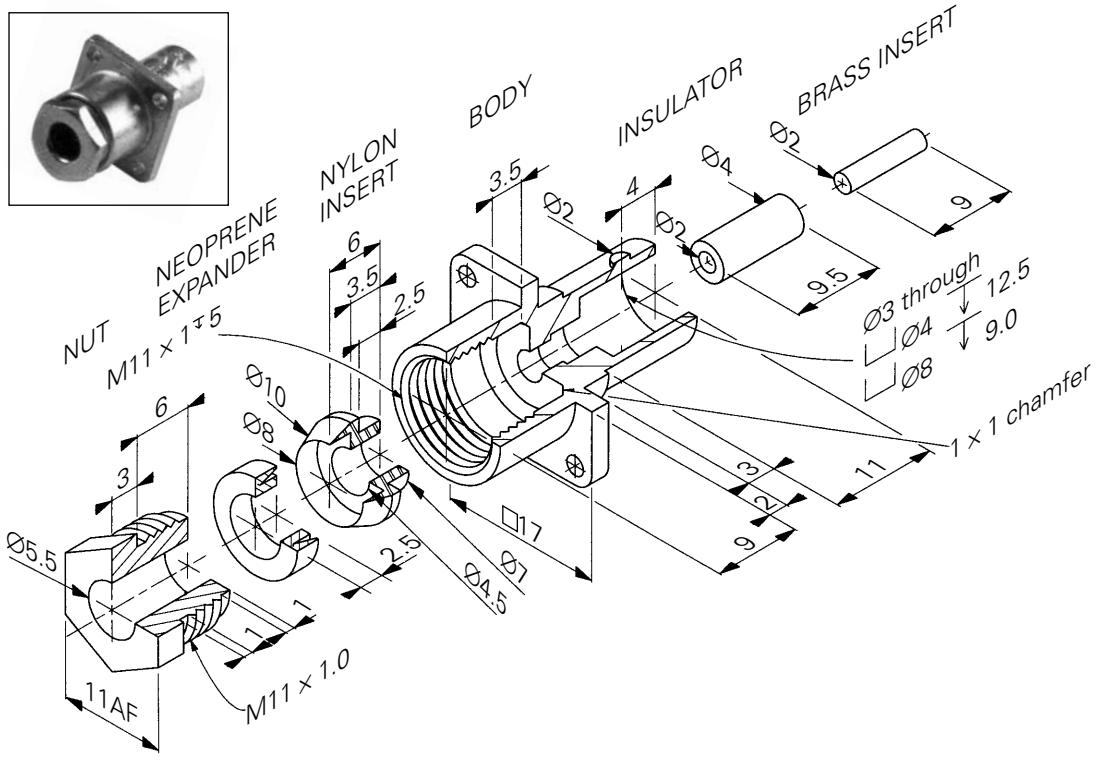
Question 16 continues on page 24

Question 16 (continued)

(b) Details of a BNC connector for a coaxial cable are given.



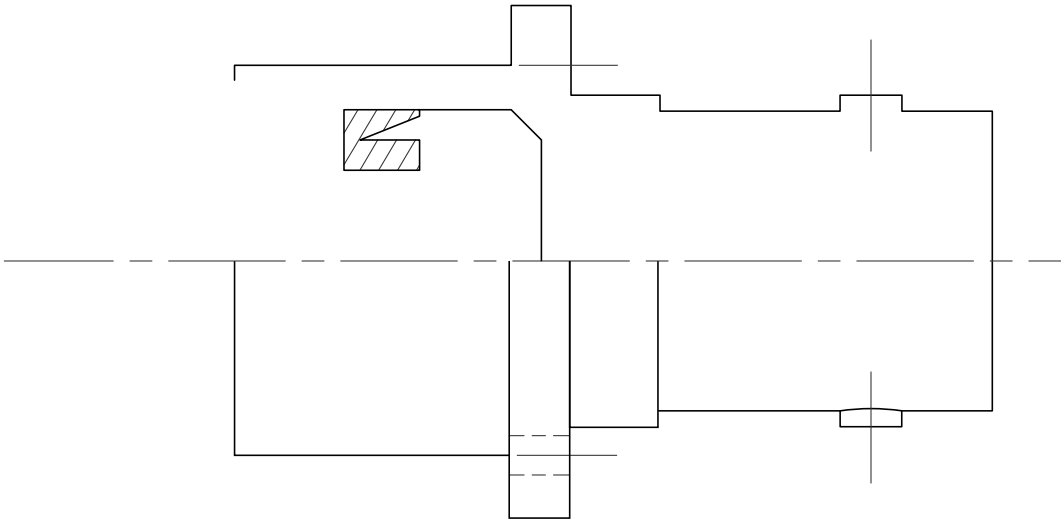
Question 16 continues on page 25

Marks

Question 16 (continued)

(i) A partially completed sketch of the assembly is shown, half-sectioned. The sketch is drawn to a scale of 4 : 1. **5**

Complete the assembly in the space provided. OMIT the brass insert. Apply AS1100 drawing standards where appropriate. Do NOT show hidden detail. Do NOT dimension.



(ii) Identify an appropriate manufacturing technique for the brass insert. **1**

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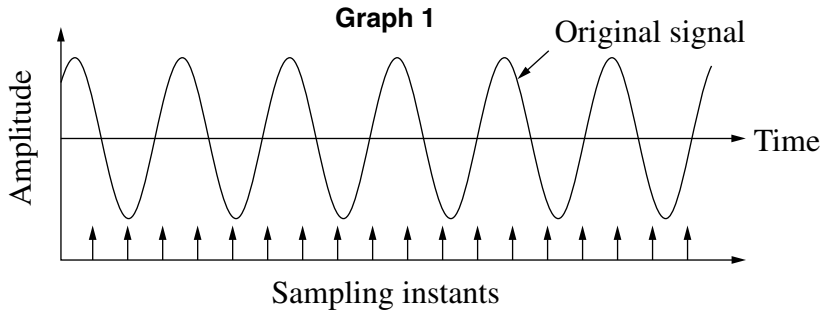
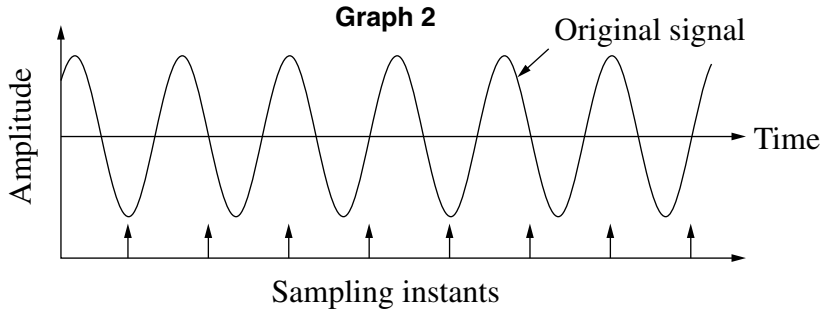
Question 16 continues on page 26

Question 16 (continued)

(c) Graphs 1 and 2 both show an original audio signal of 16 kHz.





The original signal in graph 1 has been sampled at three (3) times the signal frequency. In graph 2 the original signal has been sampled at one and one third ($1\frac{1}{3}$) times the signal frequency.

(i) Explain why the sampling rate of graph 1 will allow the reproduction of the original signal and the sampling rate of graph 2 will not. **2**

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(ii) Sketch below the signal that you would reconstruct if sampling is done at exactly the frequency of the original signal. **1**

End of Question 16

Engineering Studies

Centre Number

Section III

Student Number

20 marks
Attempt Questions 17–18
Allow about 40 minutes for this section

Answer the questions in the spaces provided.

Marks

Question 17 — Engineering and the Engineering Report (10 marks)

Use the photographs below to answer Question 17.

(a) (i) Stainless steel was chosen for the panels on the vertical column of a telephone booth. **2**

Outline TWO reasons for the choice of stainless steel for this application.

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Question 17 continues on page 28

Marks

Question 17 (continued)

(ii) The roof of the booth is made from a polymer. **2**

What properties would this polymer require during manufacture and when in service?

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(b) (i) Bolts are embedded in the concrete slab as anchor points for the booth. **2**

Explain TWO mechanical requirements of these bolts.

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(ii) The anchoring system for the booth would need to be corrosion resistant in order to maintain the structure's design strength. **2**

Describe methods to allow this to be achieved.

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Question 17 continues on page 29

Question 17 (continued)

(c) The booth design chosen was based on a single column rather than an enclosed booth. **2**

Discuss the advantages of the single-column design.

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End of Question 17

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Question 18 — Engineering and the Engineering Report (10 marks)

Please turn over

Question 18 — Engineering and the Engineering Report (10 marks)

Use the information below to answer Question 18.

A grab handle on a public transport seat designed ten years ago is shown in the photograph. It is manufactured from powder-coated aluminium, and is fixed with two ∅ 6 mm screws.

The shape of the handle and the construction material used were considered satisfactory when the seat was first put into service, having been approved by transport authorities.

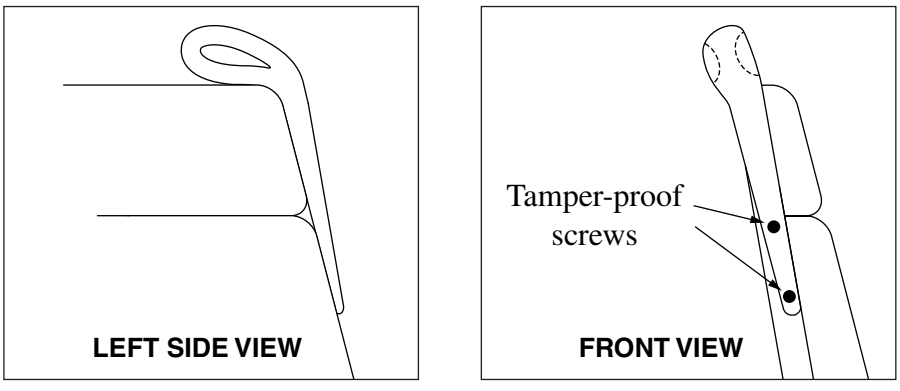
A recent engineering report has identified three safety concerns with the handle.

The handle:

- presents a hazard to falling passengers;
- could break a passenger's arm if their hand slipped through the handle as the vehicle lurched;
- is prone to damage by vandals.

The report recommends that the handle be replaced with a redesigned model, using the existing fixing points.

A design sketch of the redesigned shape of the handle is shown below.



Question 18 continues on page 33

Marks

Question 18 (continued)

(a) Three material choices have been identified: **4**

- cast and powder-coated aluminium
- steel-reinforced polyurethane
- glass-reinforced nylon.

Choose ONE of these materials to use in the redesigned handle.

Choice: .....

Discuss how the form or shape of the redesigned handle, combined with your material choice, addresses the three safety concerns identified in the report.

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(b) Explain why engineering designs can be rejected some time after their initial acceptance. **3**

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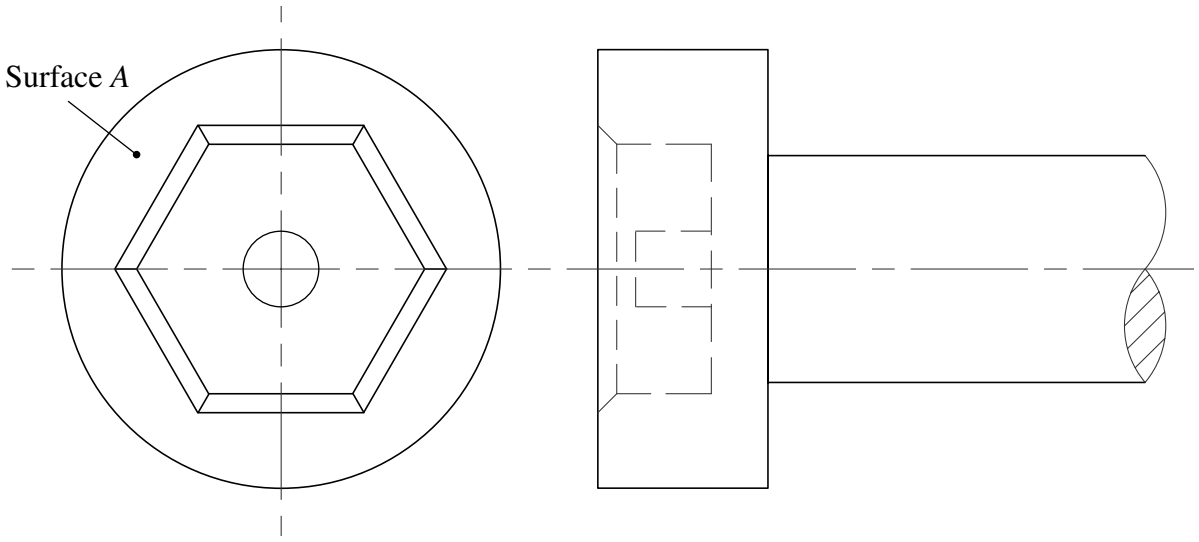
Question 18 continues on page 34

Question 18 (continued)

(c) The orthogonal drawing gives details of the ∅6 tamper-proof screws for the grab handle. The scale of the orthogonal drawing is 5 : 1. **3**



Taking sizes from the orthogonal drawing, sketch a pictorial view of the screw so that surface *A* can be seen.

End of paper

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

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

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

Machines

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

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