BOARD OF STUDIES
NEW SOUTH WALES

2007

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, 19, 23, 27, 31 and 35

Total marks – 100

Section I Pages 2–6

10 marks

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

Section II Pages 9–30

70 marks

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

Section III Pages 31–37

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 for Questions 1–10.

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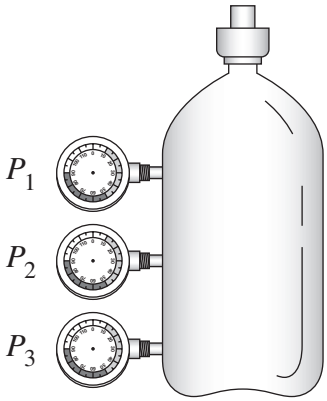
1 Which row best identifies the relative changes in the properties of a hardened medium carbon steel after it has been tempered?

	Hardness	*Toughness*
(A)	Same	Lower
(B)	Lower	Same
(C)	Lower	Higher
(D)	Higher	Higher

2 A gas bottle is pressurised. Gas pressure readings at the three levels shown are P_1, P_2, and P_3.



Which statement is correct?

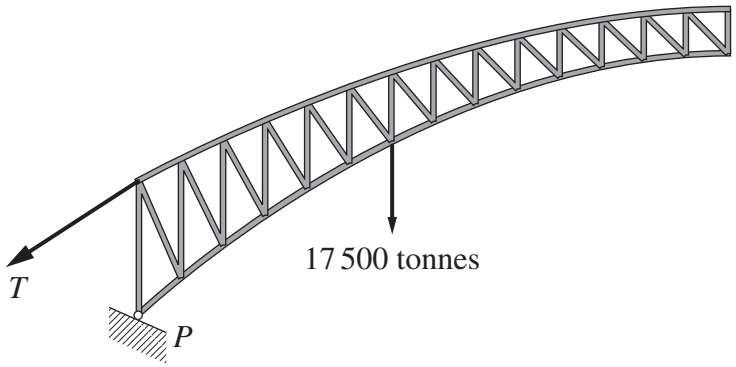
(A) $P_1 = P_2 = P_3$

(B) $P_1 > P_2 > P_3$

(C) $P_1 < P_2 < P_3$

(D) $P_1 > P_2,\ P_3 > P_2$

3 During the construction of an arch bridge, each half arch was supported on a pin joint (P) and with cables (T) as shown.



TO SCALE

At what direction to the horizontal would the force at P act?

(A) 25°

(B) 35°

(C) 50°

(D) 90°

4 The diagram shows a ceramic insulator.

Why do ceramic insulators have this design?

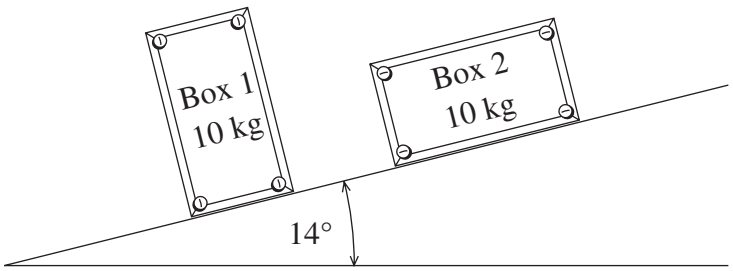
(A) This shape can be extruded.

(B) Weight is kept to a minimum.

(C) Holes are easily drilled in ceramics.

(D) Ceramics are strong in compression.

5 Two 10 kg boxes are positioned on a ramp which has a 14° slope. The coefficient of friction between the boxes and the ramp is 0.2.



Which statement correctly describes the state of the boxes on the ramp?

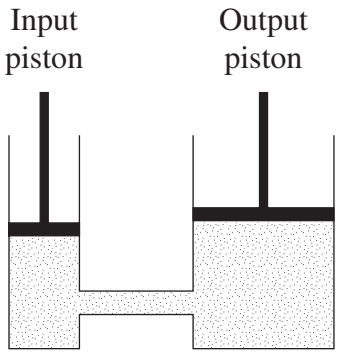
(A) Both boxes are stationary

(B) Both boxes are sliding

(C) Box 1 is sliding, Box 2 is stationary

(D) Box 2 is sliding, Box 1 is stationary

6 In the hydraulic system below, if the ∅12 mm input piston moves a distance of 16 mm, how far will the ∅24 mm output piston move?



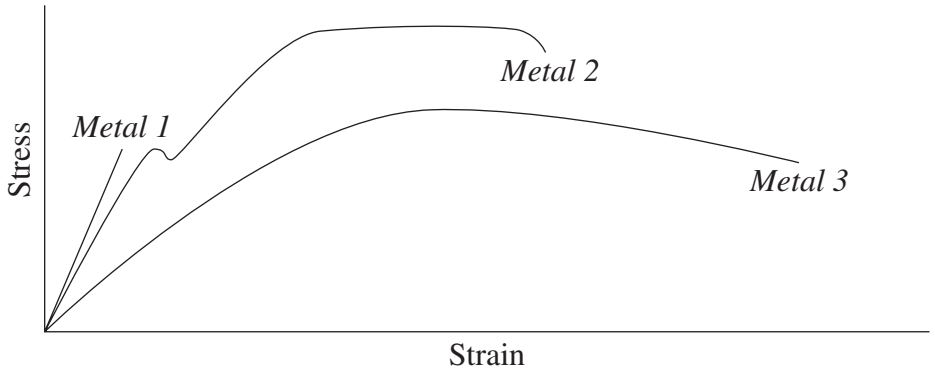
(A) 4 mm

(B) 8 mm

(C) 16 mm

(D) 32 mm

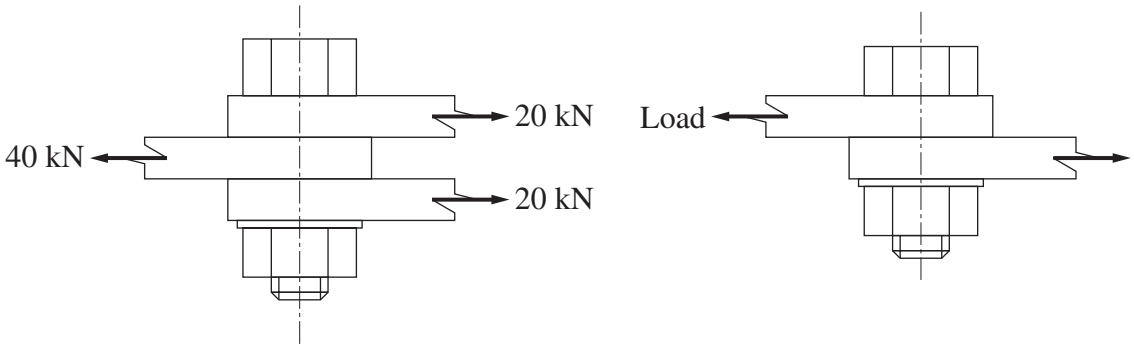
7 The stress–strain graph indicates typical results for tensile tests on three different metals.



Which row correctly identifies metals 1, 2 and 3?

	Metal 1	*Metal 2*	*Metal 3*
(A)	Steel	Cast iron	Copper
(B)	Cast iron	Copper	Steel
(C)	Copper	Steel	Cast iron
(D)	Cast iron	Steel	Copper

8 The diagrams show ∅10 mm steel bolts in double and single shear.



Double shear Single shear

The bolt in double shear supports a maximum load of 40 kN.

What maximum load would the bolt in single shear support?

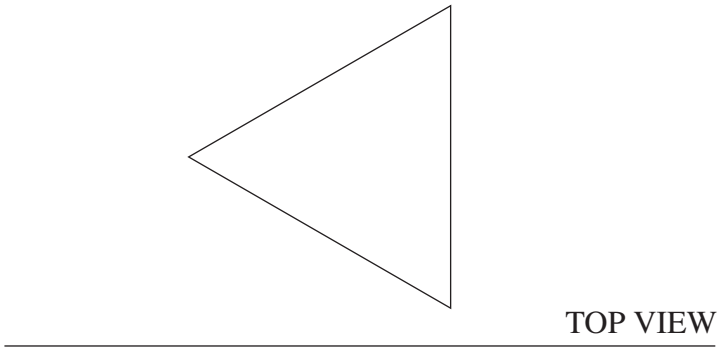
(A) 10 kN

(B) 20 kN

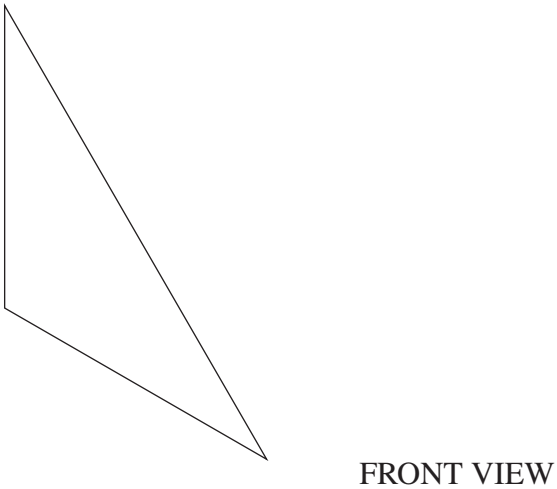
(C) 40 kN

(D) 80 kN

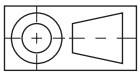
9 Two views of a triangular pyramid are shown.



TOP VIEW



FRONT VIEW



How many lines are shown as true length in these views?

(A) One

(B) Two

(C) Three

(D) Four

10 A mild steel test piece for a civil structure was made to $\frac{1}{4}$ scale, and tested in tension to destruction. The force required to destroy the test piece was 200 kN.

At what minimum force would you expect the full-size component to fail?

(A) 200 kN

(B) 400 kN

(C) 800 kN

(D) 3200 kN

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2007 HIGHER SCHOOL CERTIFICATE EXAMINATION

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) Old and modern rescue vehicles are shown.

Pre 1940

Post 2000

(i) Describe ONE development in materials that has enabled a material to be used in the modern vehicle that was not available for use in the older vehicle. **2**

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(ii) Outline an engineering system used in the modern vehicle that was not available when the older vehicle was produced. **2**

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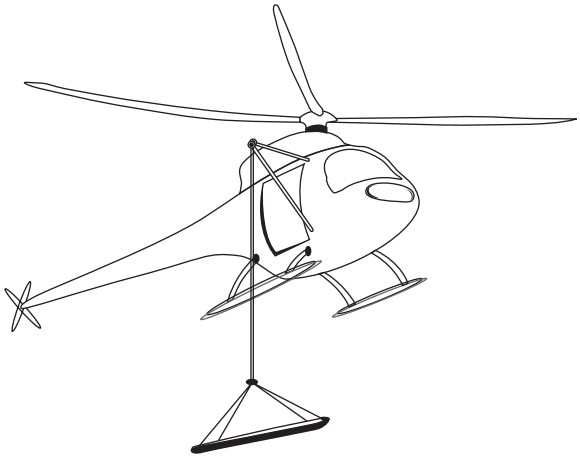
Question 11 continues on page 10

Question 11 (continued)

(b) An engineering project involves designing a rescue winch system that is to be attached to the side of a helicopter, as shown.



(i) Explain the role an engineer would perform in this project to ensure the helicopter and rescue winch operate safely when in service. **3**

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(ii) After a number of winch systems have been manufactured and installed on helicopters, an engineer has concerns about the safe operation of the system. **3**

Propose actions the engineer should take to resolve the situation.

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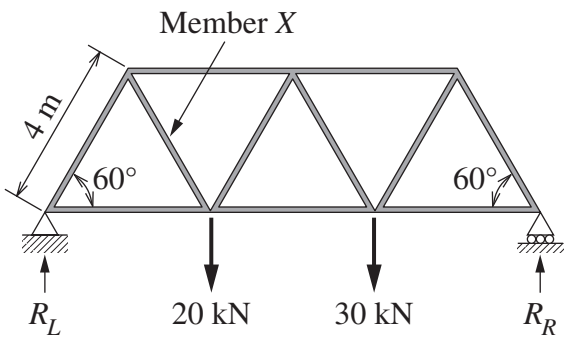
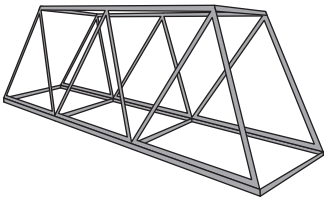
End of Question 11

Marks

Question 12 — Civil Structures (10 marks)

(a) A temporary bridge is constructed using pin-jointed trusses and beams.





(i) Calculate the magnitude of the reaction at R_L. **1**

Magnitude of the reaction at R_L = ... kN

(ii) Calculate the tensile force in truss member X. **2**

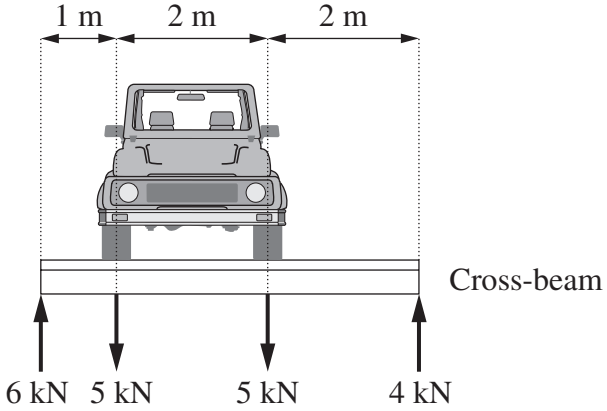
Tensile force in truss member X = ... kN

Question 12 continues on page 12

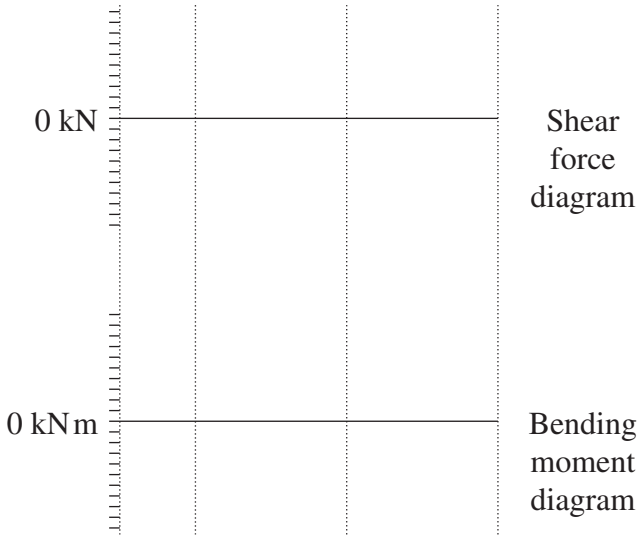
Marks

Question 12 (continued)

(b) A beam on the bridge is loaded as shown below.



(i) Plot both the shear force diagram and the bending moment diagram on the axes given below. **3**



Question 12 continues on page 13

Marks

Question 12 (continued)

(ii) The diagrams show two steel beams that have equal cross-sectional areas. **2**

Explain why an engineer would use the hollow beam rather than the solid beam.

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(c) Explain why reinforced concrete is typically used for foundations in civil structures. **2**

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End of Question 12

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Centre Number

Section II (continued)

Student Number

Marks

Question 13 — Personal and Public Transport (10 marks)

A 5.3 tonne vehicle has been designed to transport personnel and equipment in emergency situations. The side windows of the vehicle are made from toughened glass. A ladder is fixed to the side of the vehicle.

(a) Explain how the process of producing toughened glass changes the characteristics of the glass. **3**

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Question 13 continues on page 16

Marks

Question 13 (continued)

(b) Compare aluminium alloy with mild steel as the construction material for the ladder fixed to the side of the vehicle. Consider both the fabrication and use of the ladder. **3**

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Question 13 continues on page 17

Marks

Question 13 (continued)

(c) (i) The vehicle travels at a constant velocity for 1 kilometre on a level road. The time taken for the journey is 60 seconds. The power required to maintain this velocity is 300 kW. **2**

Calculate the resistance to motion.

Resistance force = ... kN

(ii) The same vehicle is travelling at 7 m/s up a 5° slope when the engine is disengaged and the vehicle is allowed to coast to a stop. **2**

Calculate how far up the slope it will coast before stopping.

Distance = ... m

End of Question 13

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Engineering Studies

Centre Number

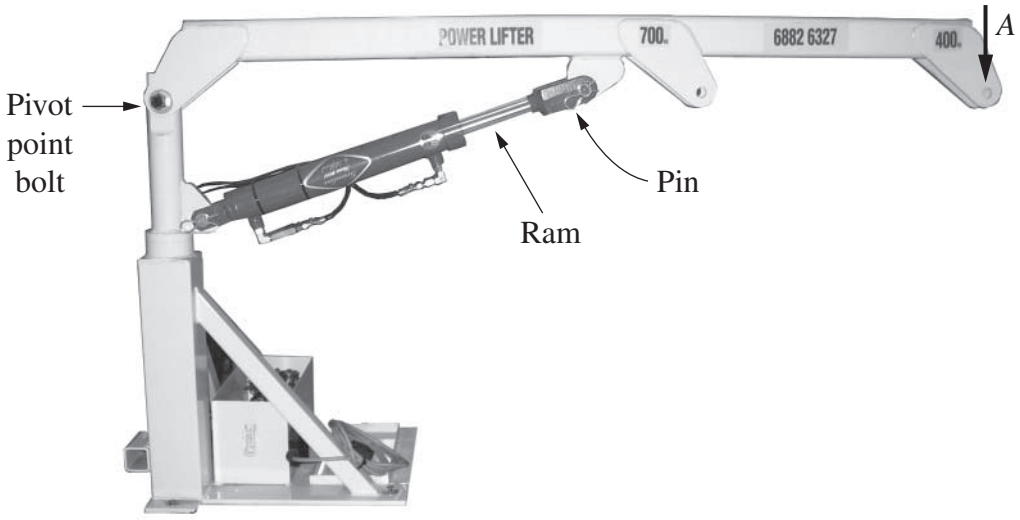
Section II (continued)

Student Number

Marks

Question 14 — Lifting Devices (10 marks)

The electrically-controlled hydraulic lifting arm shown below is used to load and unload equipment from transport vehicles.



(a) (i) Calculate the force in the ram when the arm is vertically loaded with a 240 kg mass at position *A*. Measurements can be taken from the diagram. **3**

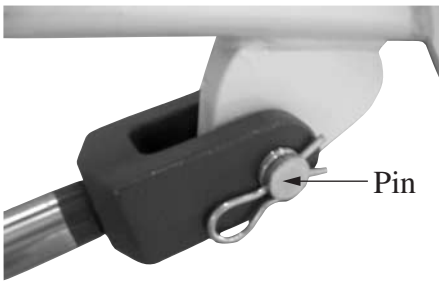
Force = ... kN

Question 14 continues on page 20

Marks

Question 14 (continued)

(ii) A high tensile steel pin with a cross-sectional area of 110 mm^2 holds the ram in place as shown. The ultimate shear stress for the steel is 880 MPa and a factor of safety of 4 is to be used. **3**



Calculate the maximum shear force the pin can support.

Force = ... kN

Question 14 continues on page 21

Marks

Question 14 (continued)

(b) The high tensile steel pivot point bolt is produced from round bar. **2**

Describe a suitable process to manufacture:

- the bolt head;

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- the thread.

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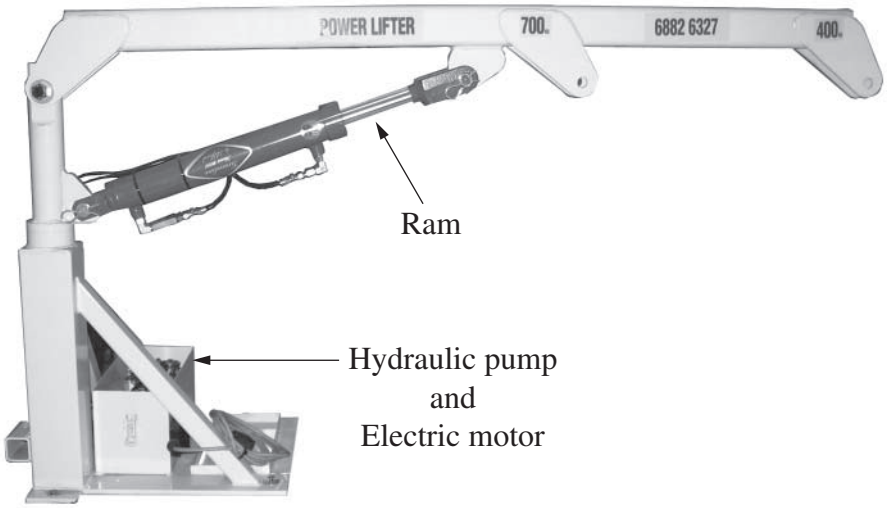
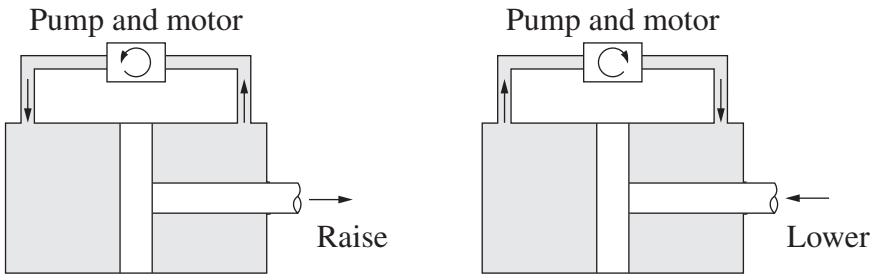
Question 14 continues on page 22

Question 14 (continued)

(c) Raising and lowering the lifting arm is achieved by hydraulic action which is controlled by an electrical system. **2**





The hydraulic pump is attached to an electric motor. The direction of the hydraulic oil flow when raising or lowering the arm is shown.

Why is an electrical system used to control the direction of the arm?

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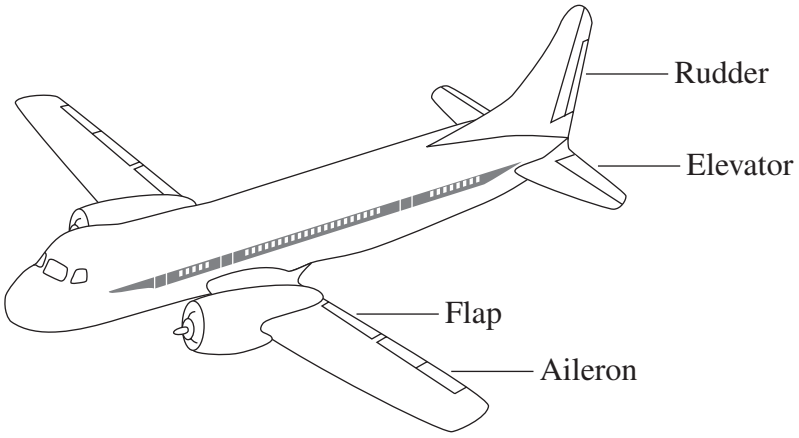
End of Question 14

Marks

Question 15 — Aeronautical Engineering (15 marks)

(a) As an aircraft comes in to land, its velocity is decreased. **2**

What adjustments would the pilot make to the aerodynamics of the aircraft in order to compensate for this reduced velocity?



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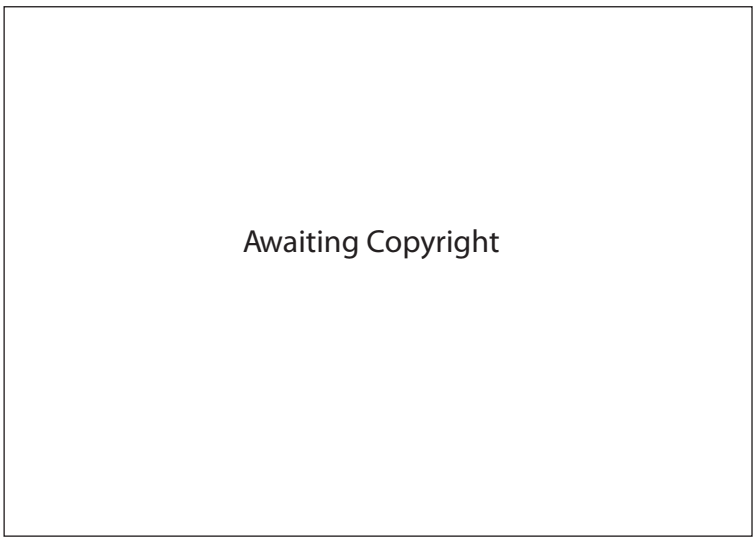
Question 15 continues on page 24

Marks

Question 15 (continued)

(b) The diagram shows defects found in an aircraft panel during a routine visual inspection.



(i) Identify ONE of these defects. Describe the conditions that would have led to this defect, and suggest a suitable way of preventing this type of defect occurring in the future. **3**

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(ii) Name and describe ONE test that would identify a defect that is not able to be detected by a regular visual inspection. **2**

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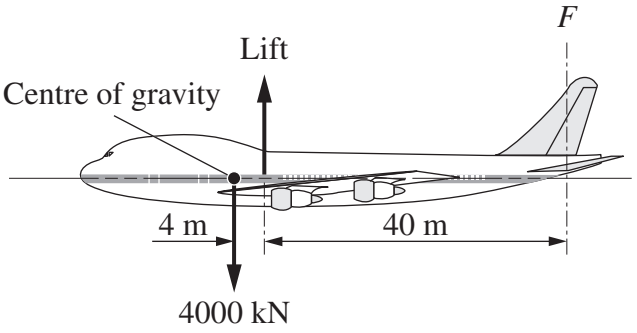
Question 15 continues on page 25

Marks

Question 15 (continued)

(c) The diagram shows the vertical force system for an aircraft in level flight.



(i) Calculate the magnitude of the force (F) required at the horizontal stabiliser/elevator to ensure that the aircraft stays trimmed level. **1**

Magnitude of the force = ... kN

(ii) Why are aluminium–copper (duralumin) alloys preferred for airframe construction over pure aluminium? **3**

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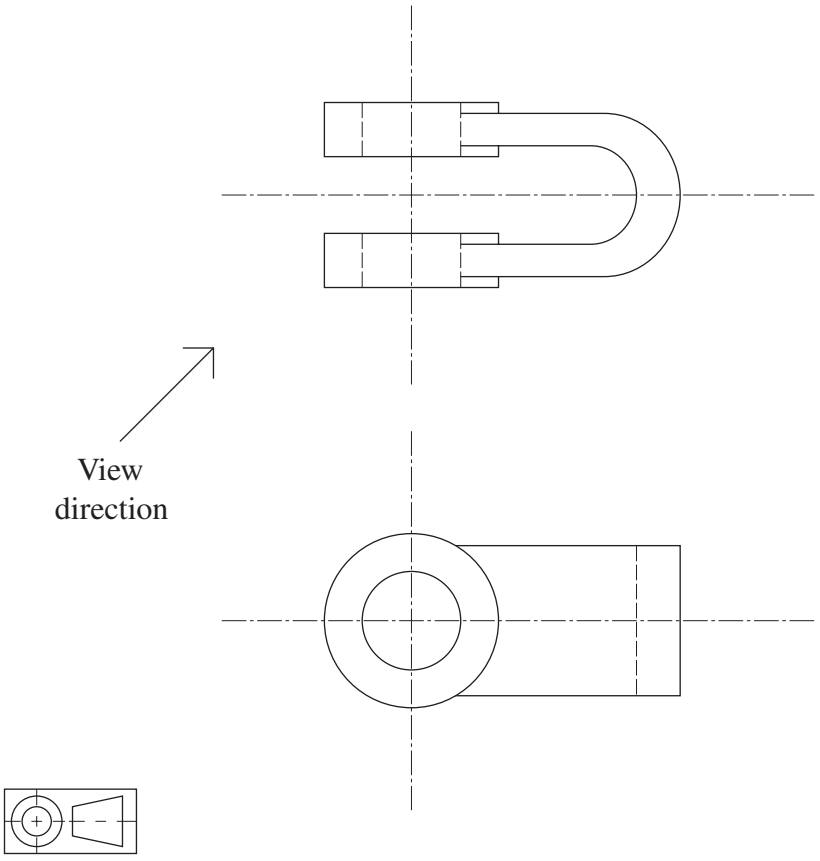
Question 15 continues on page 26

Marks

Question 15 (continued)

(d) The top and front views of a guide are shown below. **4**

Sketch a freehand pictorial drawing of this guide to the same scale.



End of Question 15

Engineering Studies

Centre Number

Section II (continued)

Student Number

Marks

Question 16 — Telecommunication (15 marks)

(a) (i) Modulation is used in the wireless transmission of low frequency signals such as voice. Give reasons for the use of modulation. **2**

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(ii) Explain the process of amplitude modulation (AM) of a signal. **2**

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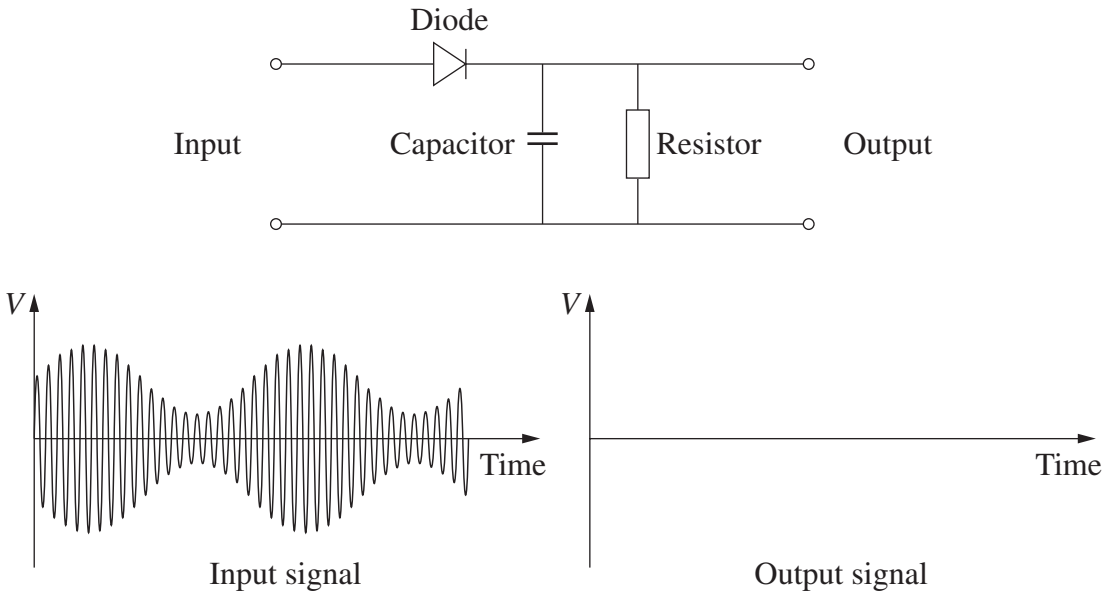
Question 16 continues on page 28

Marks

Question 16 (continued)

(iii) The electronic circuit shown can be used to demodulate an amplitude modulated (AM) signal. Given the input signal, draw the expected output signal of this circuit. **2**



(b) Describe a geosynchronous satellite orbit. **1**

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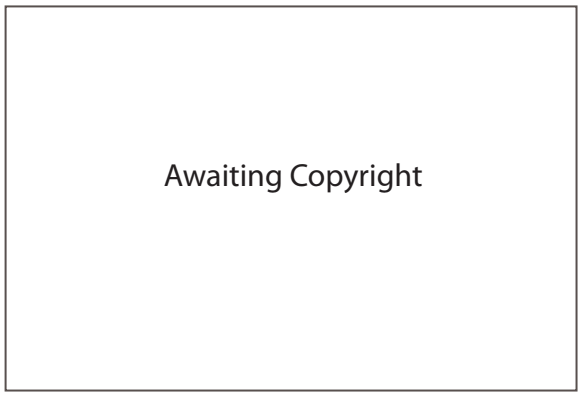
(c) Suggest the most appropriate cable type to be used for communication over the distances and frequency ranges given in the table below. Cost is a major component in the selection. **2**

Frequency	*Distance*	*Cable type*
200 kHz	0.5 km	
20 MHz	5.0 km	
900 GHz	40.0 km	

Question 16 continues on page 29

Question 16 (continued)

(d) The diagram shows an Emergency Position Indicating Radio Beacon (EPIRB) that needs to be protected by a weather- and impact-resistant case. **1**



Identify a suitable material and a suitable method of manufacturing the EPIRB case.

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Question 16 continues on page 30

Marks

Question 16 (continued)

(e) Draw a fully sectioned orthogonal front view of the 'cable tensioner' parts shown when viewed from direction *A*. **5**

The parts are to be fully assembled and drawn to a scale of 3 : 1.

End of Question 16

2007 HIGHER SCHOOL CERTIFICATE EXAMINATION

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.

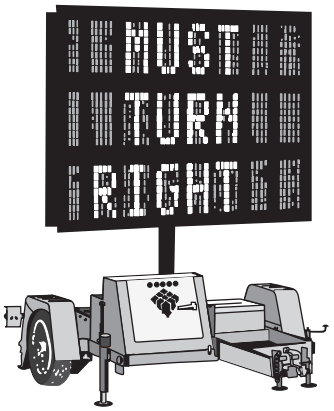
Question 17 — Engineering and the Engineering Report (10 marks)

Please turn over

Marks

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

A transportable road safety sign is shown.



(a) Three systems for recharging the battery bank 'on-site' are being considered by an engineer. The alternative systems are solar cells, a wind turbine, or a petrol engine generator. **3**

Identify FIVE criteria that could be used to evaluate the best system to recharge the battery bank for this application, and explain why each criteria is relevant.

(i) .....

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(ii) .....

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(iii) .....

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(iv) .....

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(v) .....

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Question 17 continues on page 33

Question 17 (continued)

(b) Identify a specific process for manufacturing each of the trailer parts, and give a reason for your choice. **3**

Mudguard

Mudguard (mild steel)

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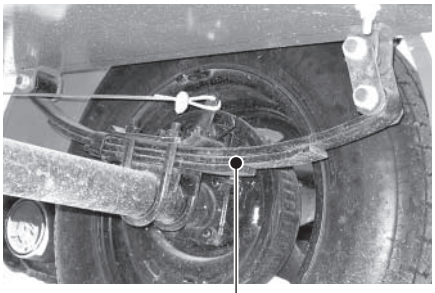

Suspension spring

Suspension spring (medium carbon steel)

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Light cover

Brake and turn indicator light cover (PVC)

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Question 17 continues on page 34

Marks

Question 17 (continued)

(c) What occupational health and safety (OHS) issues should have been considered in the design of the trailer for safe use? **2**

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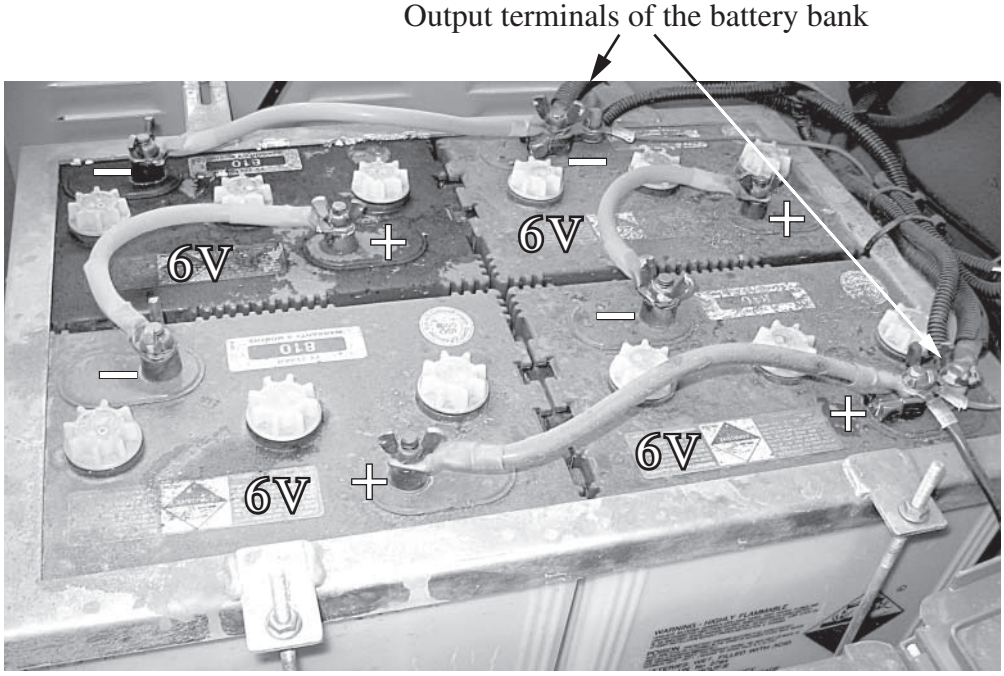
(d) Identify the arrangement of the electrical connections of the batteries within the battery bank shown below, and determine the output voltage. **2**



The battery bank

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End of Question 17

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

Please turn over

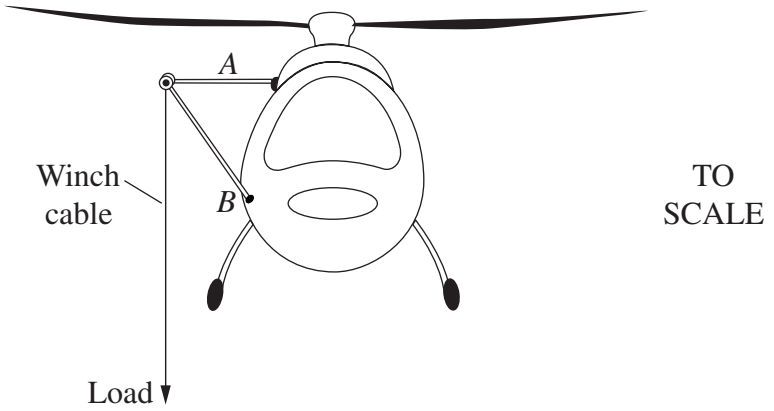
Marks

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

(a) (i) The diagram shows the front view of a helicopter and its rescue winch system. **2**

The force in the top horizontal member of the winch system, *A*, caused by the rescue load, is 900 N.

Calculate the magnitude, direction and sense of the reaction at *B*. Measurements can be taken from the diagram.



Magnitude, direction and sense = ...

Question 18 continues on page 37

Marks

Question 18 (continued)

(ii) In another situation, the load on the winch cable is 1100 N. The cross-sectional area of the cable material is 37 mm^2 and the Young's Modulus of the material is 210 GPa. **2**

Calculate the extension that would occur in a 10 metre length of cable material.

Extension = ... mm

(b) What data does a tensile test provide, and how could this data aid in the selection of an appropriate material for the horizontal member *A*? **3**

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(c) The rotor blade of the helicopter is manufactured from a composite material. **3**

Give reasons for using a composite material in this application.

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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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