STUDENT NUMBER

CENTRE NUMBER

BOARD OF STUDIES
NEW SOUTH WALES

HIGHER SCHOOL CERTIFICATE EXAMINATION

1998
ENGINEERING SCIENCE
3 UNIT (ADDITIONAL)

(50 Marks)

Time allowed—One hour and a half
(Plus 5 minutes reading time)

DIRECTIONS TO CANDIDATES

- Write your Student Number and Centre Number at the top right-hand corner of this page.
- Attempt EIGHT questions.
- **Section I** (20 marks) Attempt BOTH questions.
  Section II (15 marks) Attempt THREE questions.
  Section III (15 marks) Attempt THREE questions.
- All questions in Sections II and III are of equal value.
- Answer the questions in the spaces provided in this paper.
- Set out your working clearly and neatly. Emphasis will be placed on that working when marks are allocated.
- Diagrams in this paper are drawn to scale, unless otherwise stated.
- Drawing instruments and Board-approved calculators may be used.
- A Formulae sheet is provided on pages 21–22.
- The Formulae sheet will not be collected.

MARKER'S USE ONLY

Question	Marks Awarded	Mark Checked
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
TOTAL	Max. 50	

SECTION I

Marks

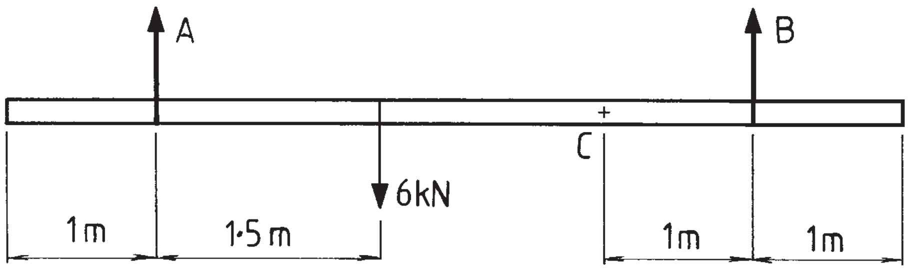
(20 Marks)

Attempt BOTH questions.

Each question is worth 10 marks.

QUESTION 1

(a) Details of a 6 m long steel beam are shown below. The beam is suspended by two steel cables, A and B. The beam has a mass of 50 kg/m. **7**

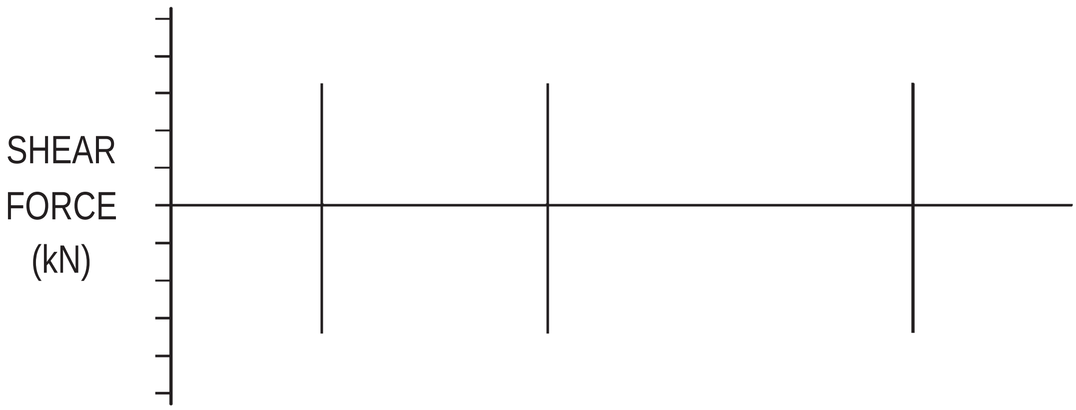


(i) Determine the forces in cables A and B.

Force in cable A .... kN

Force in cable B .... kN

(ii) Draw and label the shear force diagram for the beam.

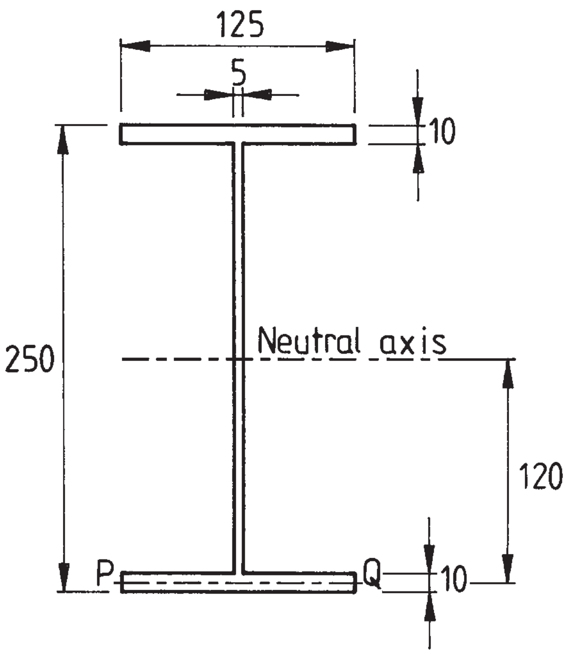


QUESTION 1 (Continued) **Marks**

(iii) Determine the bending moment at point C, 2 m from the right-hand end.

Bending moment at C .... kN m

(iv) For a different loading, the bending moment at point C is 3·65 kN m. A cross-section of the beam at point C is shown below. Determine the stress in plane PQ.



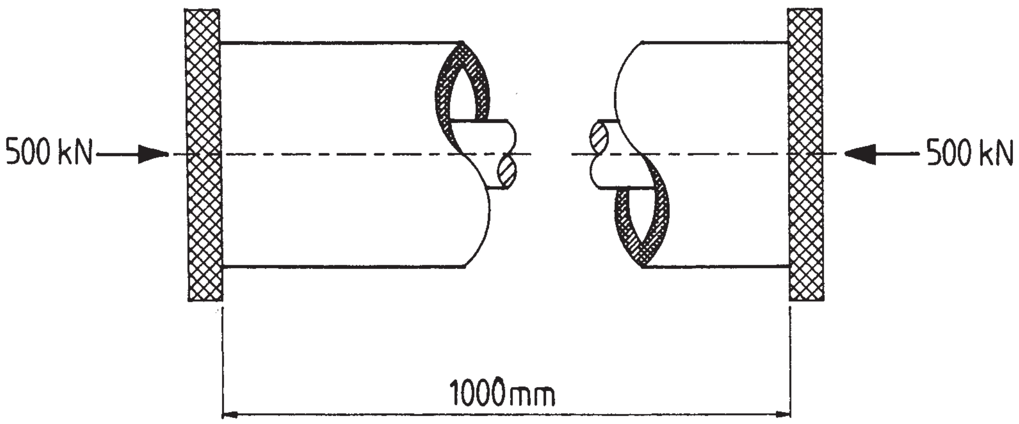
Stress in plane PQ ....MPa

QUESTION 1. (Continued) **Marks**

(b) An aluminium tube and a solid steel bar, as shown below, are compressed by a force of 500 kN. **3**

$E_{aluminium}$ = 70 GPa Cross-sectional area$_{aluminium}$ = 700 mm^2

E_{steel} = 200 GPa Cross-sectional area$_{steel}$ = 180 mm^2



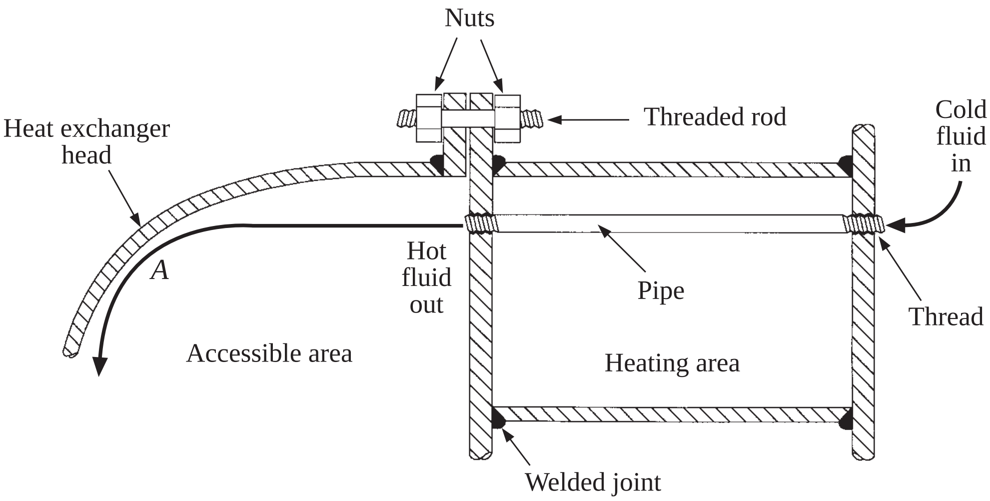
Determine the forces in the tube and the bar.

Force in tube .... kN

Force in bar .... kN

QUESTION 2 **Marks**

(a) A simplified heat exchanger, made from low-carbon steel, is shown below. A fluid flows through the pipe at high velocity. The fluid strikes the heat exchanger head, at point *A*, which redirects the flow. The heat exchanger operates under high pressure and temperature. **6**



(i) Corrosion occurs at point *A* on the heat exchanger head.

1. Name and describe this type of corrosion.

....

....

2. Suggest a possible method of reducing corrosion at point *A*. (The fluid velocity cannot be reduced.)

....

....

(ii) State TWO other types of corrosion that can occur in the heat exchanger. Give reasons for your answers.

1. ....

....

2. ....

....

(iii) State a method used to reduce corrosion within the heating area.

....

QUESTION 2. (Continued) **Marks**

(iv) A silver and zinc galvanic cell, with respective electrode potentials shown below, is connected to a voltmeter.

Electrode potentials	
$Ag \rightarrow Ag^{+} + e^{-}$	–0·800 V
$Zn \rightarrow Zn^{2+} + 2e^{-}$	+0·762 V

1. Determine the value, in volts, shown on the voltmeter.

.... V

2. Which of the two metals will act as the anode? Explain your answer.

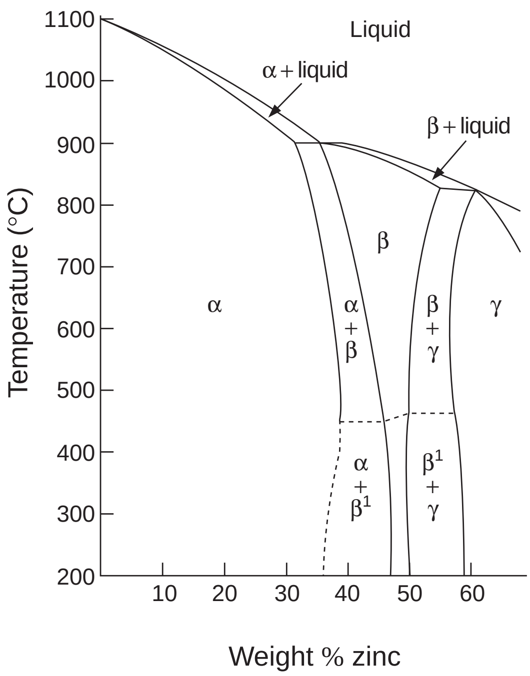
Metal ....

Explanation ....

....

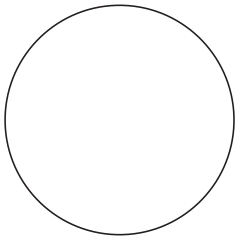
....

(b) The copper-rich portion of the copper–zinc phase diagram is given below. **4**

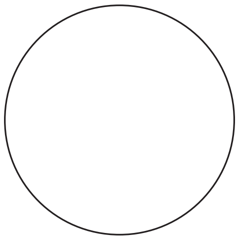


QUESTION 2. (Continued) **Marks**

(i) An alloy of 60% Cu–40% Zn is cooled under equilibrium conditions to room temperature. In the spaces provided, sketch and label the microstructure of this alloy at 850°C and 500°C.



850°C



500°C

(ii) During equilibrium cooling of an alloy of 60% Cu–40% Zn, β phase occurs in the microstructure. Explain the effect of this phase on the properties of the alloy at room temperature.

(iii) Alloys of 70% Cu–30% Zn are readily cold-worked, while alloys of 60% Cu–40% Zn often require hot-working, during manufacturing processes. Explain the reason for this, in terms of phases present.

SECTION II

Marks

(15 Marks)

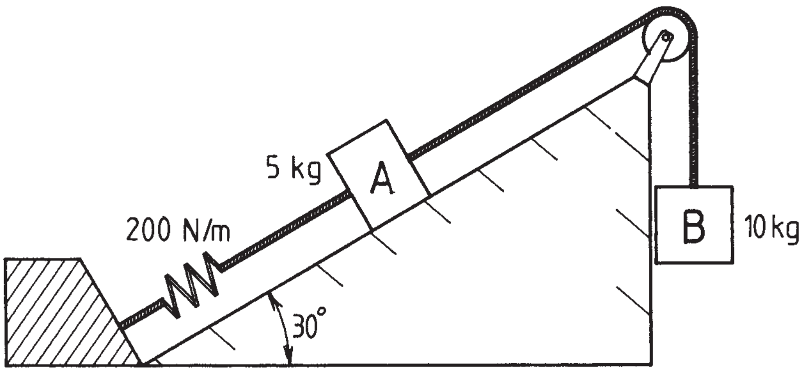
Attempt THREE questions.

Each question is worth 5 marks.

QUESTION 3

Two masses, A and B, are connected by a rope passing over a frictionless pulley as shown below. Mass A, resting on a frictionless inclined plane, is acted upon by a spring of stiffness 200 N/m. Mass B is initially held stationary such that the spring has an extension of 0·75 m from its unstretched position. **5**

Ignore extension of the rope.



(a) Determine the instantaneous acceleration of the masses when the 10 kg mass is released.

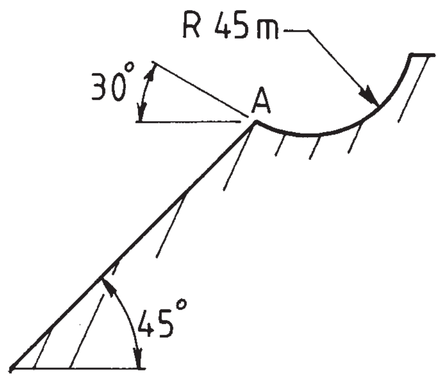
acceleration .... m/s^2

(b) What will be the extension of the spring once the masses have come to rest?

extension .... mm

QUESTION 4 **Marks**

Details of a ski jump are given below on the diagram. A skier has a mass of 80 kg, and attains a linear velocity, at the take-off position A, of 25 m/s, upward at an angle of 30° to the horizontal. **5**



(a) Determine the magnitude of the normal force exerted by the ski jump on the skier at point A.

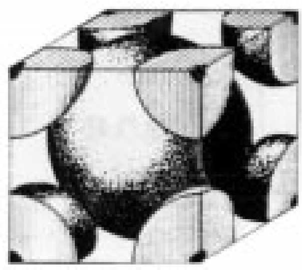
Normal force .... kN

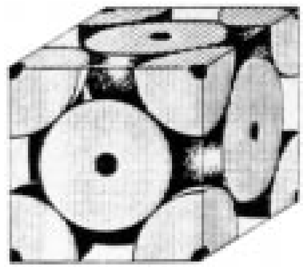
(b) Determine the distance down the slope, from point A, where the skier will land.

Distance .... m

QUESTION 5 **Marks**

(a) The schematic drawings of the lattice structures of metal *A* and metal *B* are given below. **2**





Introduction to material science, Jacaranda Wiley, ISBN 0 701 621 818, p 38. Reproduced with permission of Jacaranda Wiley Australia Ltd

METAL *A* METAL *B*

(i) With reference to the structures given, explain why metal *B* is softer and more ductile than metal *A*.

....

....

....

....

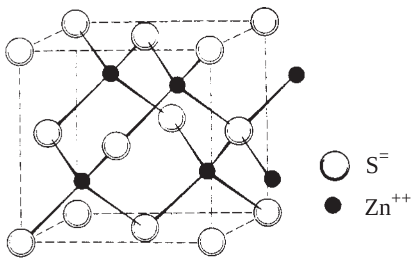
(ii) Determine the coordination number for each of the above structures.

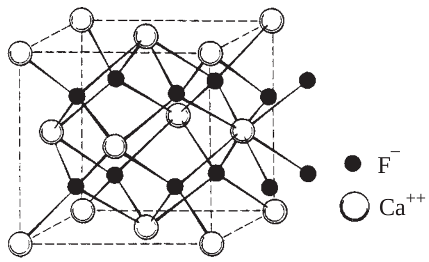
Metal *A* ....

Metal *B* ....

QUESTION 5. (Continued) **Marks**

(b) The unit cells of the crystal structures of zinc blende, ZnS, and fluorite, CaF_2, are shown below. The interstitial sites of the basic unit cells are occupied by cations in the zinc blende structure and by anions in the fluorite structure. **2**





Introduction to material science, Jacaranda Wiley, ISBN 0 701 621 818, p 29809. Reprinted with permission of Jacaranda Wiley Australia Ltd

(i) Explain why double the number of interstitial sites are occupied in the fluorite structure compared to the zinc blende structure.

....

....

....

(ii) The anions in the zinc blende and the cations in the fluorite have the same lattice arrangement. Name the lattice arrangement.

....

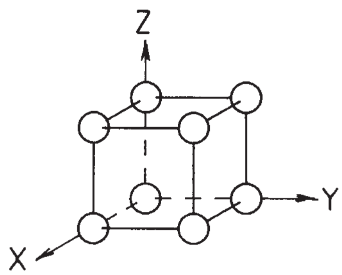
(iii) Give one reason why zinc blende is hard and brittle.

....

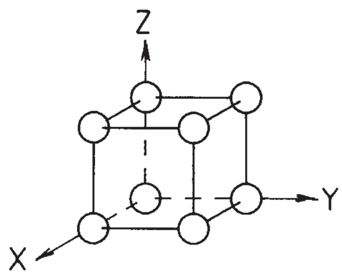
....

(c) The simple cubic lattice structure is shown below. **1**

(i) Sketch and clearly label, on the given diagram, the plane that has Miller indices of (211).

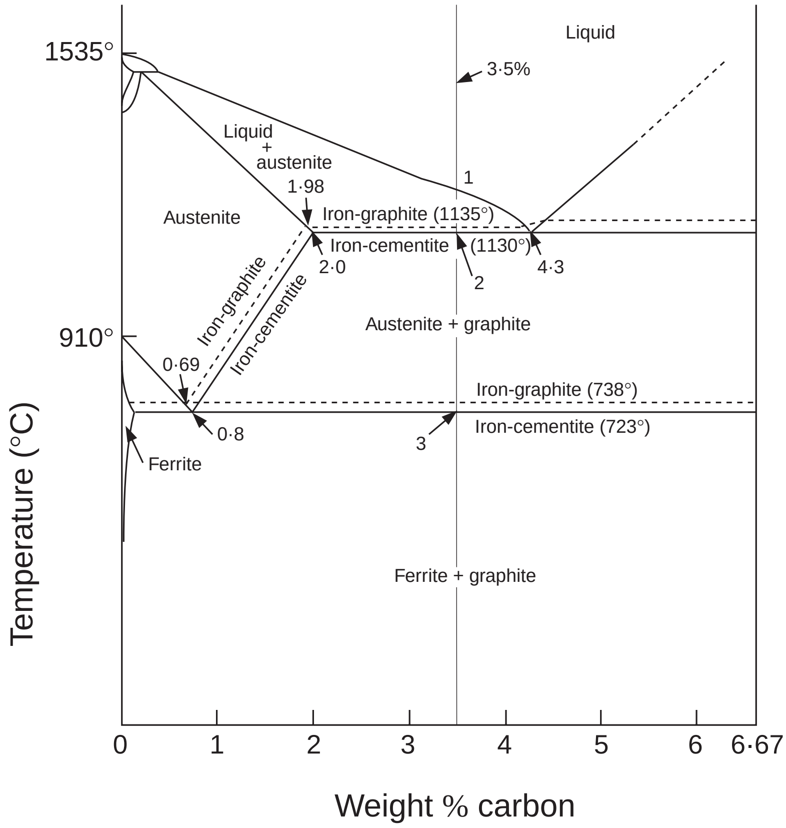


(ii) Sketch and clearly label on the given diagram, the (011) direction.



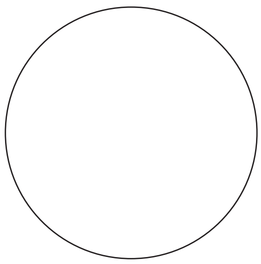
QUESTION 6 **Marks**

(a) The iron–graphite phase diagram is given below. **2**



An alloy of 3·5% carbon in iron is cooled to produce white cast iron. The casting is then annealed at 850ºC for 48 hours, and then furnace cooled to room temperature.

(i) Sketch and label the microstructure resulting from this heat treatment process.



3·5% CARBON

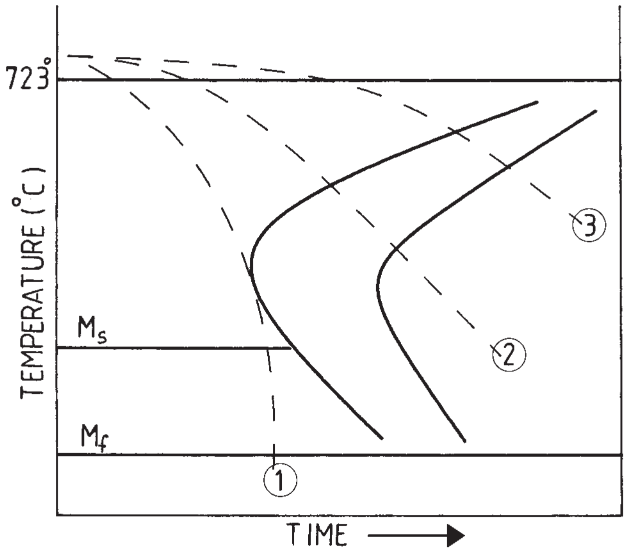
(ii) White cast iron is generally very hard and brittle. Briefly describe the change in mechanical properties that results from the heat treatment described above.

....

....

QUESTION 6. (Continued) **Marks**

(b) A time–temperature transformation diagram for a eutectoid steel is shown below, indicating three cooling rates. **3**



(i) Explain the significance of cooling rate ① to the resultant microstructure.

....

....

....

....

(ii) Each of the cooling rates is started from a temperature above the eutectoid isotherm. Explain why this is necessary in the formation of martensite.

....

....

....

....

(iii) Name the cooling processes indicated by cooling rates ② and ③.

Cooling rate ② ....

Cooling rate ③ ....

(iv) On the time–temperature transformation diagram, clearly sketch the martempering cooling rate.

Marks

SECTION III

(15 Marks)

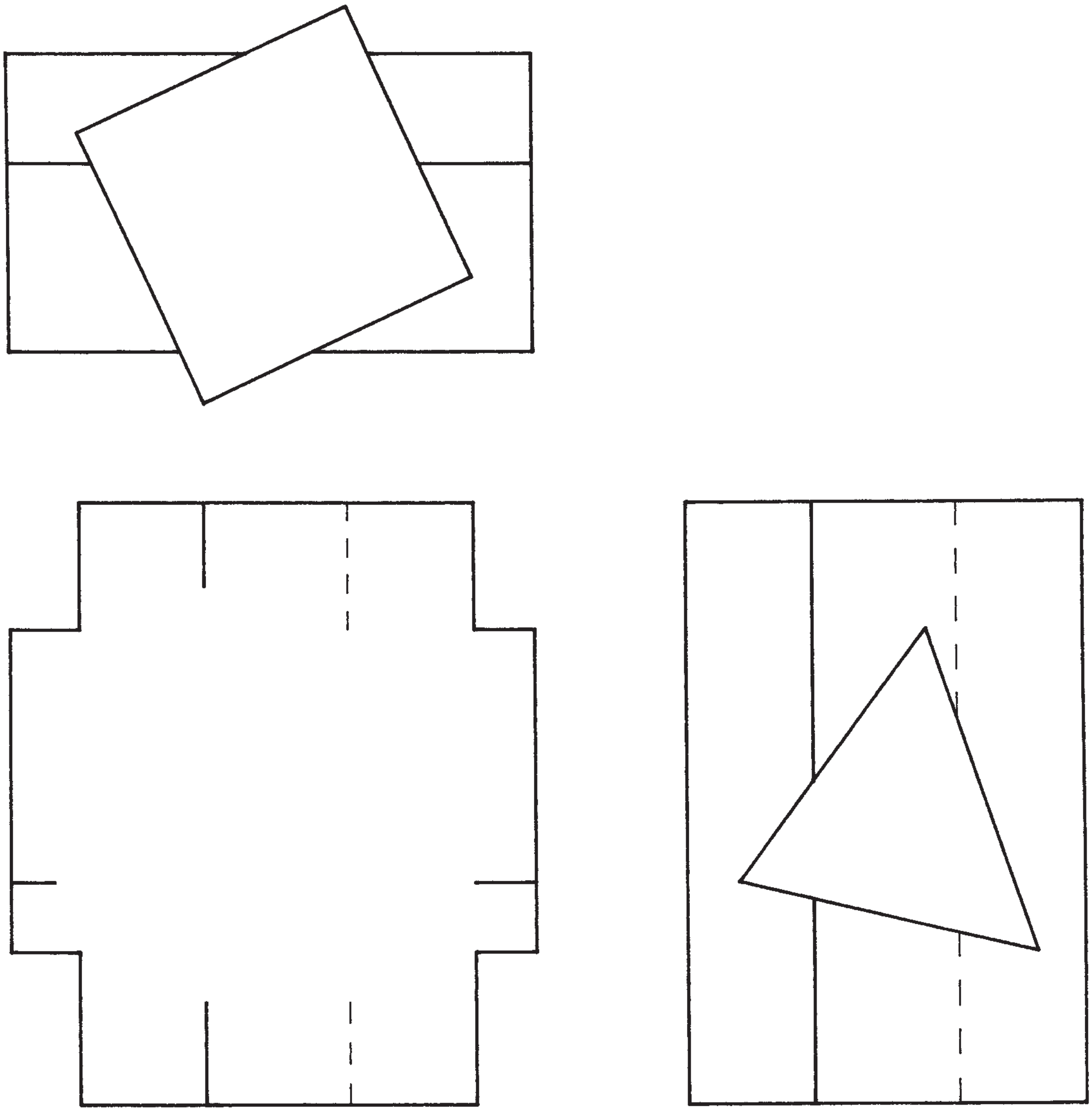
Attempt THREE questions.

Each question is worth 5 marks.

QUESTION 7

The top view, right-side view and partly completed front view of a square prism intersecting with an irregular triangle prism are shown below in third-angle projection. **5**

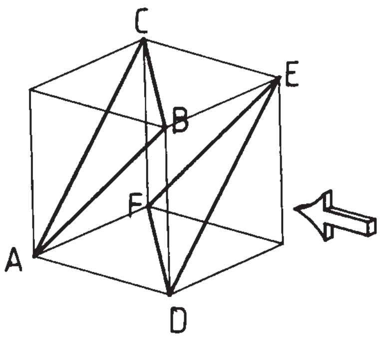
Complete the front view.

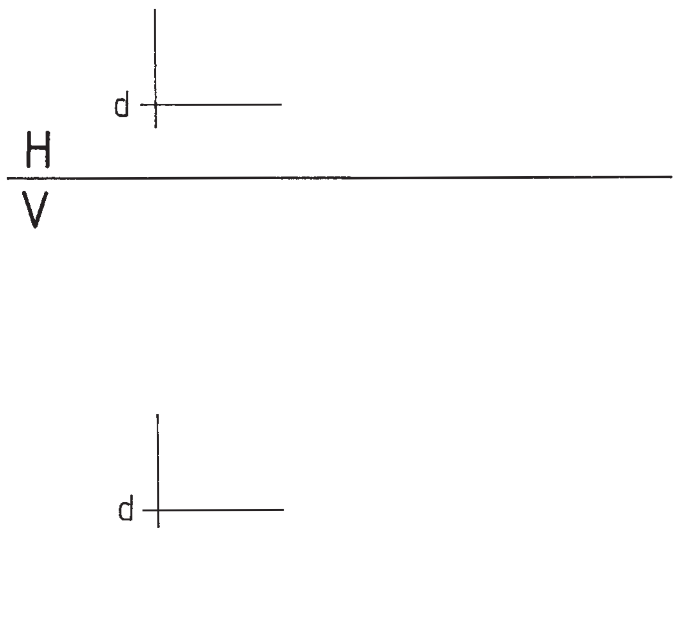


QUESTION 8 **Marks**

A pictorial drawing of a cube is shown below. Planes ABC and DEF are given. The cube has edges of length 35 mm. The top view and front view of point, d, are drawn below in third-angle projection. Complete the top view and front view of the cube, and the planes, when viewed in the direction of the arrow. **5**

Graphically determine the shortest distance between the planes ABC and DEF.

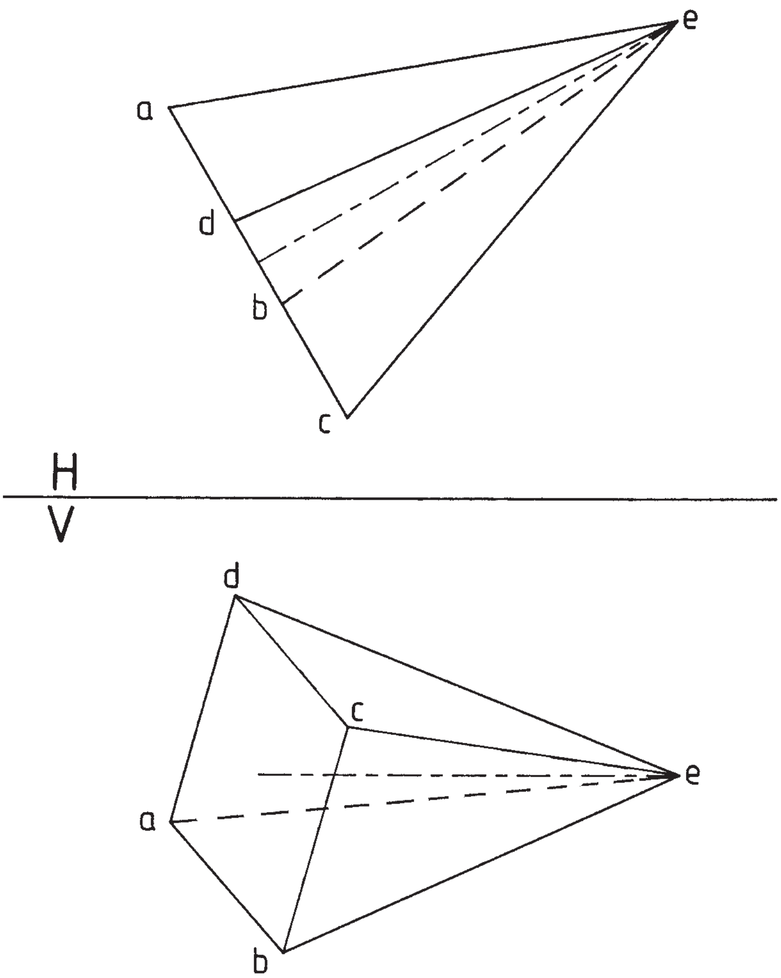




QUESTION 9 **Marks**

The top view and front view of a square pyramid are drawn below in third-angle projection. Project from the front view an auxiliary view of the pyramid if slant edge, de, is to remain at the same angle to the principal vertical plane and is inclined at 45° to the horizontal. **5**

The apex, e, is to be to the left and in front of the centre of the base.

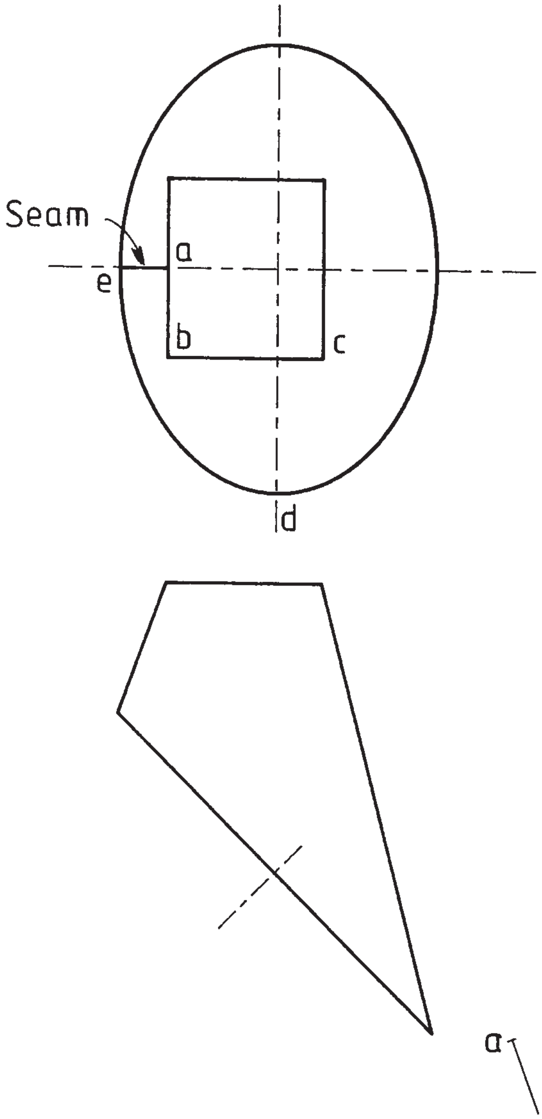


QUESTION 10 **Marks**

The top view and front view of a transition piece, used to join rectangular ducting to circular ducting, are shown below in third-angle projection. **5**

Draw a pattern for the surface, abcde.

The starting position for the seam, ae, is indicated below.



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Not to be collected at the conclusion of the examination.

FORMULAE

Statics

If a body is in equilibrium, then :

$\sum F_x = 0; \quad \sum F_y = 0; \quad \sum M = 0$

$M = Fd; \quad F = \mu N$

Machines

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

Strength of materials

$$\sigma = \frac{P}{A}; \quad \varepsilon = \frac{e}{L}; \quad E = \frac{\sigma}{\varepsilon}$$

$$SE \text{ per unit volume } = \frac{\sigma^2}{2E}$$

$$I = \frac{bd^3}{12}; \quad I = \frac{\pi D^4}{64}; \quad I = \frac{\pi\left(D^4 - d^4\right)}{64}$$

$$\sigma = \frac{My}{I}; \quad FS = \frac{\sigma_{\text{yield}}}{\sigma_{\text{working}}}$$

Area of circle

$$A = \frac{\pi}{4}d^2$$

Circumference of circle

$$C = \pi d$$

FORMULAE

(Continued)

Dynamics

$v = u + at$

$s = ut + \tfrac{1}{2}at^2$

$s = \left(\dfrac{u + v}{2}\right)t$

$v^2 = u^2 + 2as$

$s = r\theta$

$v = r\omega$

$a = r\alpha$

$F = \mu N$

$F = ma$

$Ft = m(v - u)$

$M = mv$

$KE = \tfrac{1}{2}mv^2$

$PE = mgh$

$SE = \tfrac{1}{2}kx^2$

$F = kx$

$P = \dfrac{W}{t}$

$W = Fs$

$\omega = \omega_0 + \alpha t$

$\theta = \omega_0 t + \tfrac{1}{2}\alpha t^2$

$\theta = \left(\dfrac{\omega_0 + \omega}{2}\right)t$

$\omega^2 = \omega_0{}^2 + 2\alpha\theta$

$\sum M = T = I\alpha$

$KE = \tfrac{1}{2}I\omega^2$

$P = T\omega$

$M = I\omega$

$I = mk^2$

$W = T\theta$

$F_c = \dfrac{mv^2}{r} m\omega^2 r$