BOARD OF STUDIES
NEW SOUTH WALES

STUDENT NUMBER

CENTRE NUMBER

HIGHER SCHOOL CERTIFICATE EXAMINATION

1999

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

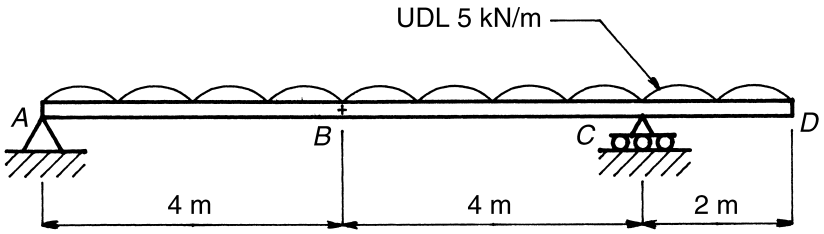
(20 Marks)

Attempt BOTH questions.

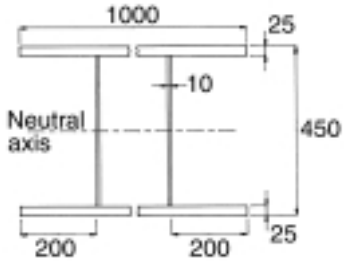
Each question is worth 10 marks.

QUESTION 1

(a) A small steel box girder is to be used as a footbridge, as shown in the diagram below. The girder is simply supported at *A* and *C*. The cross-section of the girder is also given. The steel used in the box girder has a density of 7800 kg/m^3. The bridge has a uniformly distributed load of 5 kN/m applied. **7**



(i) Determine the weight of the box girder.



Weight ..... N

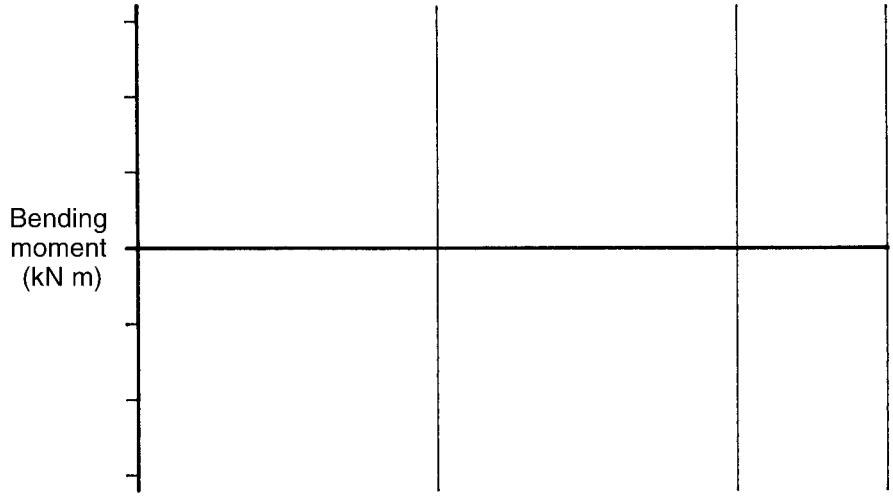
(ii) Determine the reactions at *A* and *C*.

Reaction at *A* ..... kN

Reaction at *C* ..... kN

QUESTION 1 (Continued) **Marks**

(iii) Draw the bending moment diagram for the bridge. Label the values at points *B* and *C*.



(iv) The maximum bending stress (225 mm from the neutral axis) is limited to 150 MPa. Determine the maximum bending moment that can be applied to the girder.

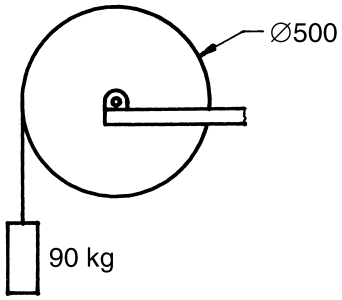
Maximum bending moment ..... kN m

Question 1 continues on page 4

QUESTION 1 (Continued) **Marks**

(b) The pulley shown in the diagram below is used to raise a mass of 90 kg. The pulley has a moment of inertia of 14 kg m^2. **3**

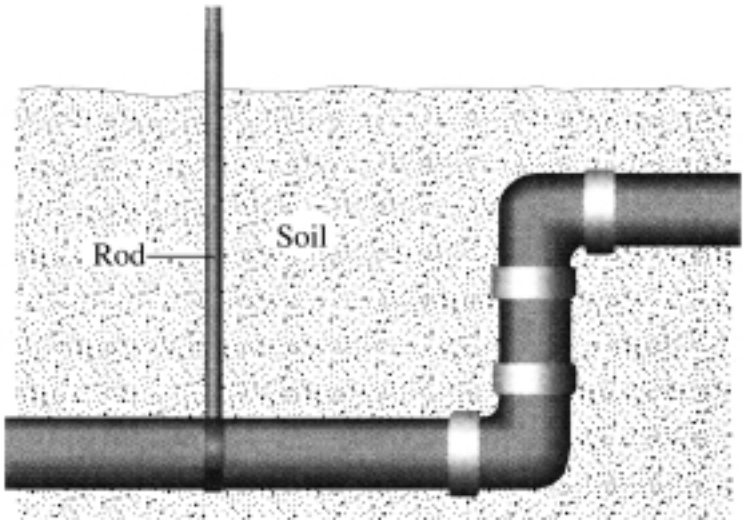
Determine the energy required to accelerate the load from rest to a velocity of 6 m/s in a distance of 10 m.



Energy ..... MJ

QUESTION 2 **Marks**

(a) To prevent corrosion of an underground iron pipe, a rod is connected to the pipe as shown in the diagram below. **4**



(i) Using the standard electrode potentials provided, state the most suitable metal for the rod.

Electrode potentials	
$Ag^+ + e^- \rightarrow Ag$	+ 0·80 V
$Cu^{2+} + 2e^- \rightarrow Cu$	+ 0·35 V
$Mn^{2+} + 2e^- \rightarrow Mn$	– 1·05 V
$Fe^{2+} + 2e^- \rightarrow Fe$	– 0·41 V
$Mg^{2+} + 2e^- \rightarrow Mg$	– 2·36 V

Name of metal .....

(ii) Name and describe the process by which the rod aids in the prevention of corrosion.

Name .....

Description .....

.....

(iii) Pure aluminium is another metal that could have been used for this purpose. In practice it is not recommended. State the reason.

Reason .....

.....

Question 2 continues on page 6

QUESTION 2 (Continued) **Marks**

(iv) Name and describe TWO other preventative measures that could be used to reduce corrosion of the iron pipe.

Method 1

Name .....

Description .....

.....

Method 2

Name .....

Description .....

.....

(b) (i) Explain the term *intergranular corrosion*. **2**

.....

.....

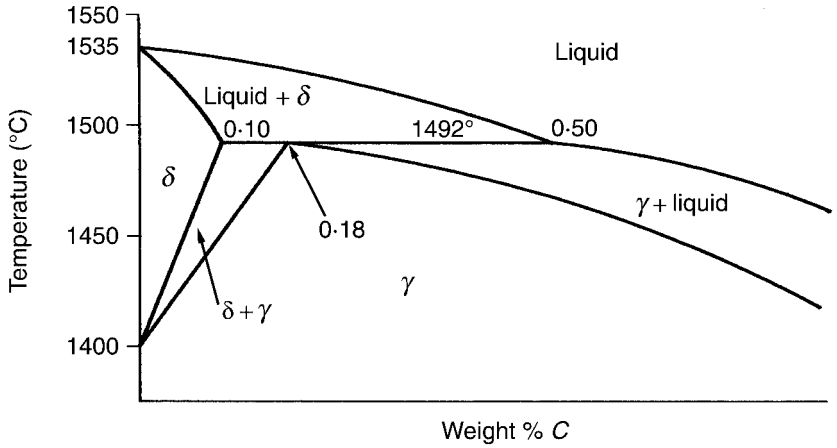
(ii) List TWO causes for this type of corrosion.

1 .....

2 .....

QUESTION 2 (Continued) **Marks**

(c) Part of the iron–carbon equilibrium diagram is shown below. An alloy of 0·15% carbon is cooled under equilibrium conditions from 1550°C to 1400°C. **4**

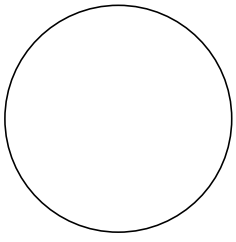


(i) Name the phases present and determine the proportion of these phases for this alloy at 1500°C.

Name of phase 1 ..... Proportion ..... %

Name of phase 2 ..... Proportion ..... %

(ii) In the space provided, draw and label the microstructure of the alloy at a temperature of 1490°C.



(iii) Name and describe the reaction that occurs at 1492°C.

Name .....

Description .....

.....

.....

SECTION II

Marks

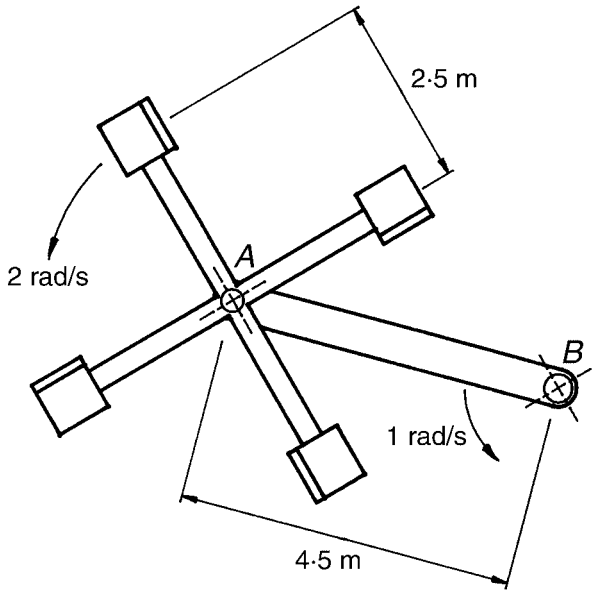
(15 Marks)

Attempt THREE questions.

Each question is worth 5 marks.

QUESTION 3

The seats on an amusement park ride, shown below, rotate in the vertical plane. The arm rotates around axle *B* with a constant angular velocity of 1 rad/s. The minor arm rotates around axle *A* with a constant angular velocity of 2 rad/s. **5**



(a) Determine the maximum centrifugal force that an 80 kg person will experience during the ride.

Centrifugal force ..... N

QUESTION 3 (Continued) **Marks**

(b) Determine the maximum linear velocity that the person will experience.

Linear velocity ..... m/s

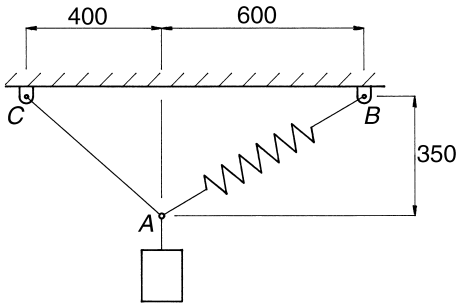
(c) Determine the maximum *g* force experienced by the person during the ride.

g force ..... *g*

QUESTION 4 **Marks**

(a) An object is suspended from a beam by a non-elastic cable (*AC*) and a spring (*AB*), as shown in the diagram below. The unstretched length of spring *AB* is 660 mm. The spring stiffness is 475 N/m. **2**

Determine the mass of the suspended object.



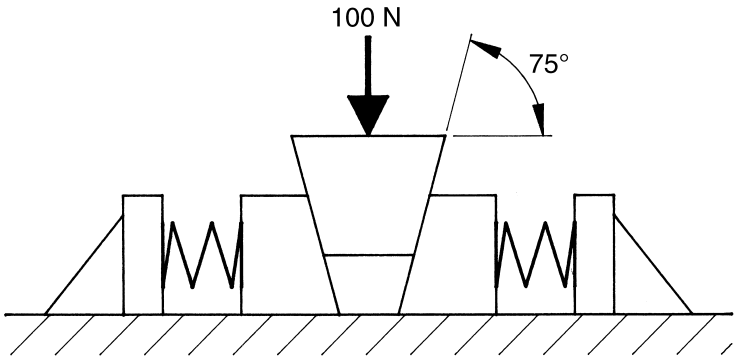
Mass ..... kg

QUESTION 4 (Continued) **Marks**

(b) A system of wedges and springs is used to support a load of 100 N, as shown in the diagram. **3**

Determine the minimum spring constant for the springs used, necessary to prevent the load from moving down.

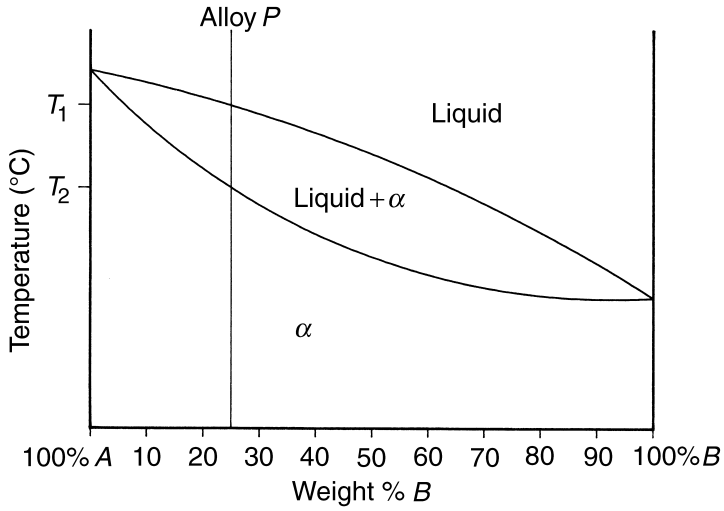
Neglect the mass of the blocks. The coefficient of static friction for all surfaces is 0·18.

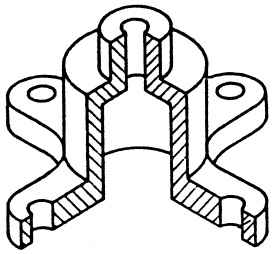


Spring constant ..... N/m

QUESTION 5 **Marks**

(a) The thermal-equilibrium diagram of the alloy system for pure metals *A* and *B* is shown below. Alloy P is used to produce the die casting as shown below. The die casting is cooled under non-equilibrium conditions. **3**



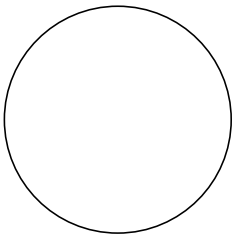


(i) On the thermal-equilibrium diagram, sketch the change in shape of the solidus for alloy *P*.

(ii) State the name given to the type of grain structure resultant in alloy *P*.

.....

(iii) Sketch the cross-section of a grain of alloy *P* at room temperature. Fully label your sketch.



(iv) The die casting is homogenised to alter the grain structure. Describe the effect that this process has at the atomic level of the grains.

.....

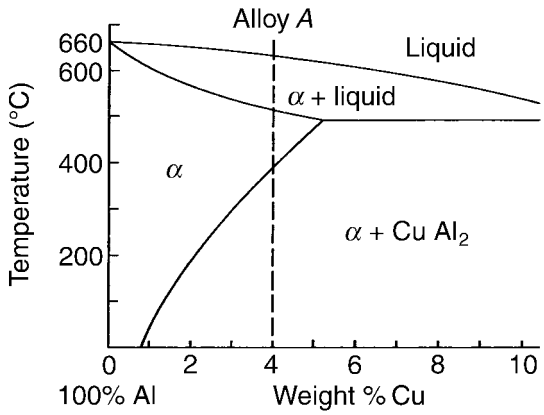
.....

.....

.....

QUESTION 5 (Continued) **Marks**

(b) A portion of the aluminium–copper phase diagram is shown below. **2**



The process of age-hardening an alloy consists of two stages: solution treatment and ageing.

Describe each of these stages. Draw and fully label the microstructure of alloy *A* after each stage.

Solution treatment

.....

.....

.....

.....

Ageing

.....

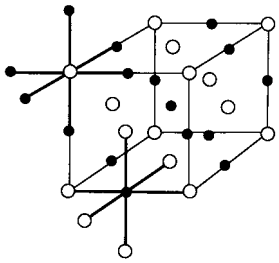
.....

.....

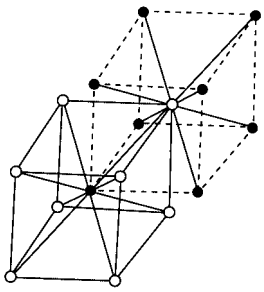
.....

QUESTION 6 **Marks**

(a) The unit cells of sodium chloride and caesium chloride are shown below. **$1\frac{1}{2}$**



Sodium chloride (NaCl)
(● Na, ○ Cl)



Caesium chloride (CsCl)
(● Cs, ○ Cl)

(i) Name and describe the type of bond that exists between sodium and chlorine.

Name of bond .....

Description of bond .....

.....

.....

(ii) Determine the coordination numbers of the caesium chloride structure and the sodium chloride structure.

Caesium chloride structure .....

Sodium chloride structure .....

(iii) The coordination numbers of sodium chloride and caesium chloride differ. State a reason for this difference.

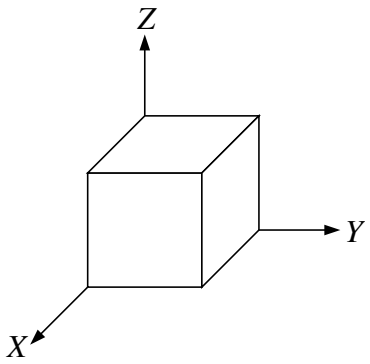
Reason .....

.....

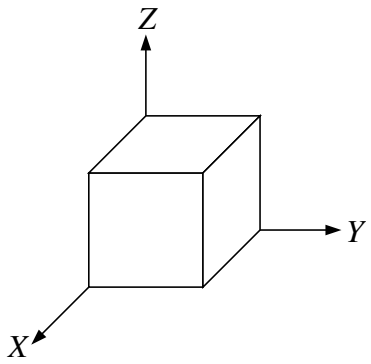
.....

QUESTION 6 (Continued) **Marks**

(b) (i) On the sketches below, draw the (112) plane and the (010) plane. **2**



(112) plane



(010) plane

(ii) State the Miller indices of the plane on which slip is more likely to occur in a body centred cubic structure. State a reason for your choice.

Miller indices .....

Reason .....

(c) The atomic radius of an iron atom is 0·124 nm. Iron crystallises as BCC. Calculate the lattice parameter of the unit cell. **$1\frac{1}{2}$**

Lattice parameter .....nm

SECTION III

Marks

(15 Marks)

Attempt THREE questions.

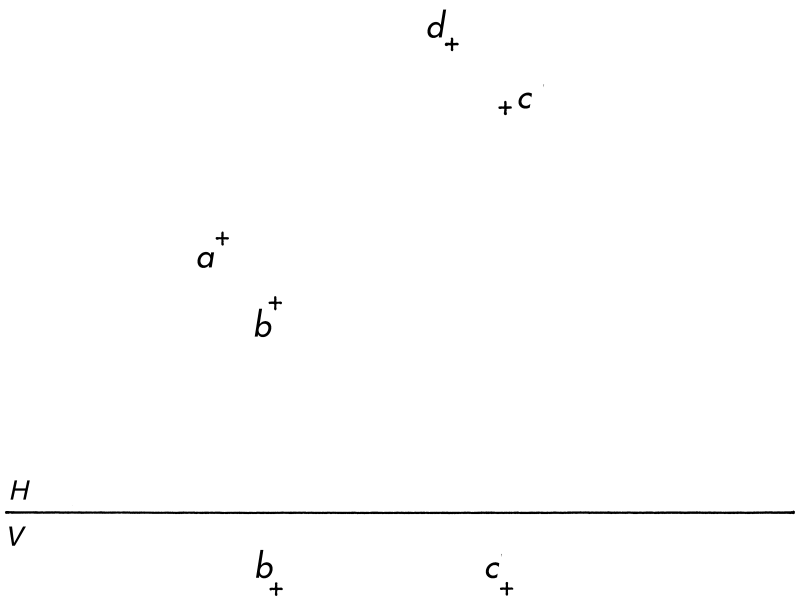
Each question is worth 5 marks.

QUESTION 7

The top view of the corners of the base of a regular square pyramid, A, B, C and D, is given below. The front view of the corners B and C of the same square pyramid is also given below. **5**

The pyramid has been inclined to both the horizontal plane and vertical plane. The length of the axis is 55 mm.

Complete the top view and the front view of the pyramid.



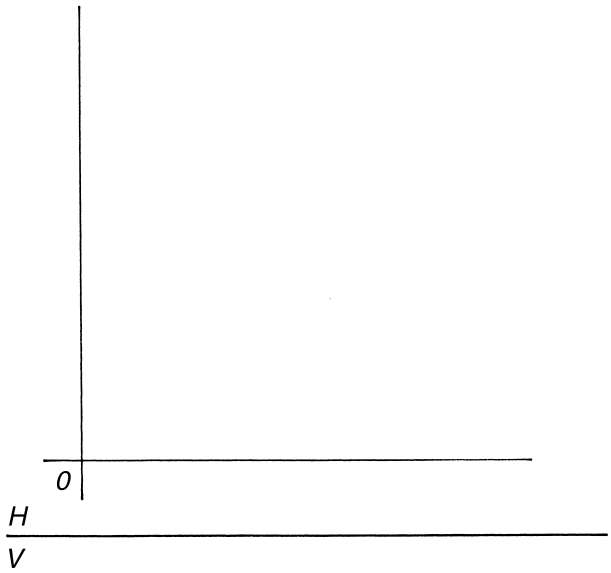
QUESTION 8 **Marks**

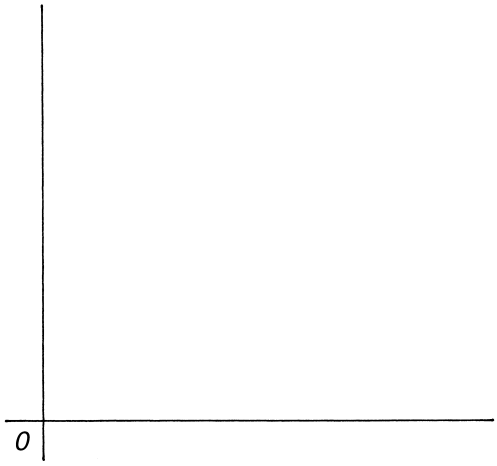
The coordinates of four points *A*, *B*, *C* and D are given in the table below. **5**

	X	*Y*	*Z*
A	5	15	15
B	50	50	25
C	10	40	25
D	50	20	45

Draw the top view and the front view of the two lines *AB* and *CD* on the axes given below.

Graphically determine the shortest distance between the two lines *AB* and *CD*.

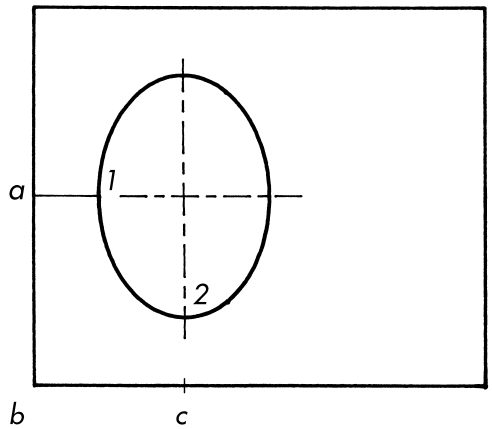


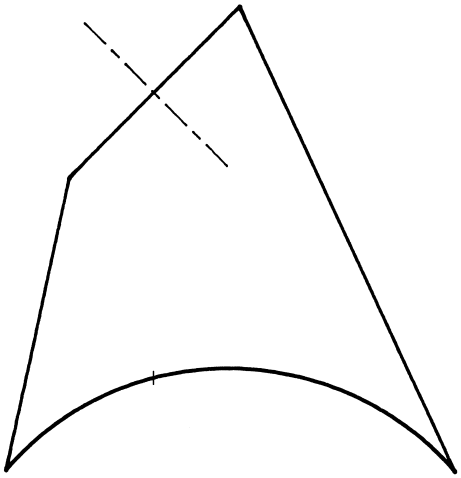


QUESTION 9 **Marks** 5

The top view and front view of a transition piece are shown below in third-angle projection. Draw a pattern for the surface *abc*21.

The starting position for the seam *a*1 is indicated below.

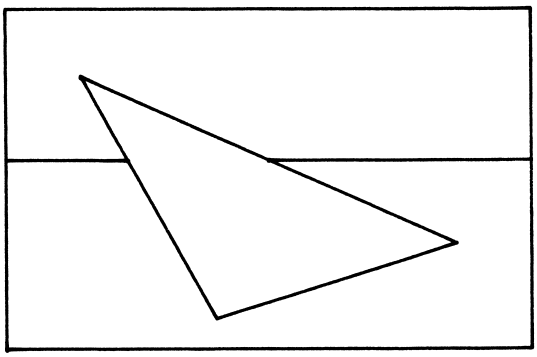


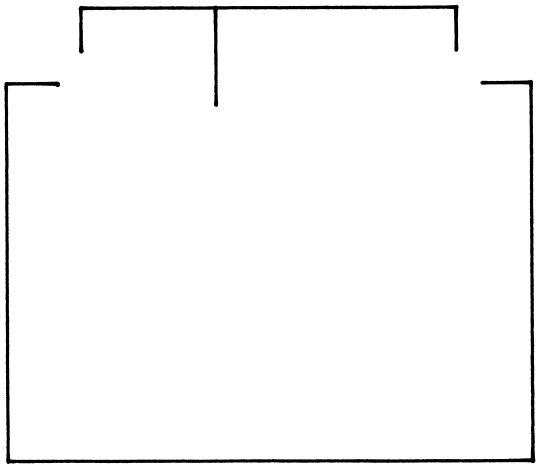


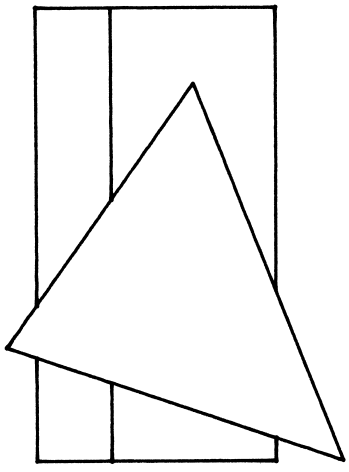
QUESTION 10 **Marks** 5

The top view, right-side view and incomplete front view of two intersecting triangular prisms are given below in third-angle projection.

Complete the front view, showing both visible and hidden outline.







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1999
HIGHER SCHOOL CERTIFICATE EXAMINATION
ENGINEERING SCIENCE
3 UNIT (ADDITIONAL)

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

$v = u + at$

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

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

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

$s = r\theta$

$v = r\omega$

$a = r\alpha$

$F = \mu N$

$F = ma$

$Ft = m(v-u)$

$M = mv$

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

$PE = mgh$

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

$F = kx$

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

$W = Fs$

$\omega = \omega_0 + \alpha t$

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

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

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

$\sum M = T = I\alpha$

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

$P = T\omega$

$M = I\omega$

$I = mk^2$

$W = T\theta$

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