BOARD OF STUDIES
NEW SOUTH WALES

HIGHER SCHOOL CERTIFICATE EXAMINATION

2000

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.

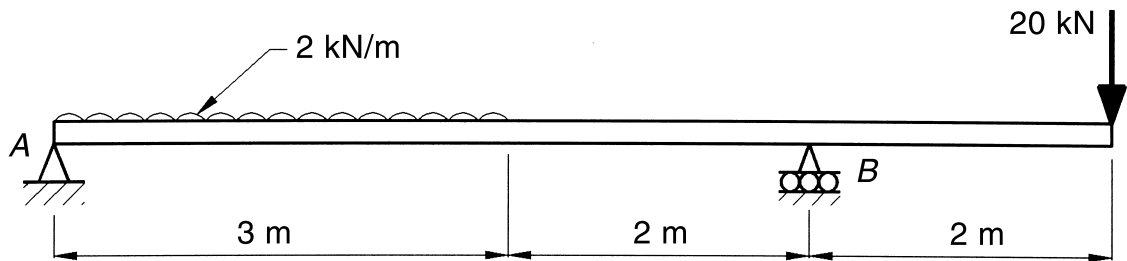- The Formulae sheet will not be collected.

329

SECTION I

(20 Marks)

Attempt BOTH questions.

Each question is worth 10 marks.

QUESTION 1

(a)   A small steel box girder is loaded as shown. The girder is simply supported at   **7**
A and B. The box girder has a mass of 60 kg/m.

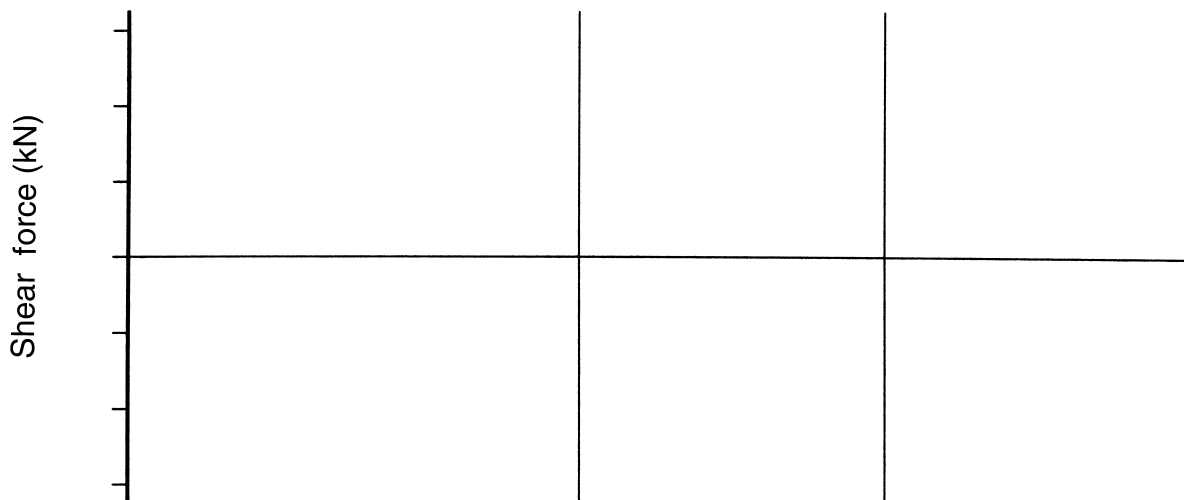(i)   Determine the reactions at A and B.

Reaction at A .... kN Sense ....

Reaction at B .... kN Sense ....

(ii)   Draw and label the shear force diagram for the girder.
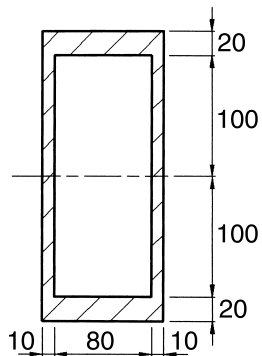
QUESTION 1 (Continued)   **Marks**

    (iii)   Determine the maximum bending moment for the girder.

               Maximum bending moment .... kN m

    (iv)   For another loading condition, the maximum bending moment in the girder is calculated to be 100 kN m. Determine the maximum bending stress developed in the cross-section.

               Maximum bending stress .... MPa

QUESTION 1 (Continued)   **Marks**

(b)   Determine the change in height, h, of a conical pendulum when its speed   **3**
      increases from 75 rpm to 100 rpm. The sphere rotates in a horizontal plane.
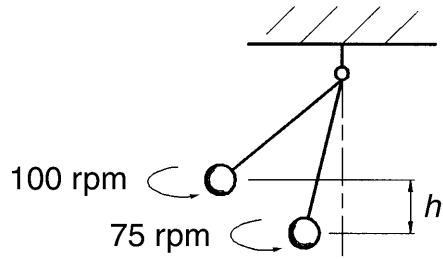
Change in height, h .... mm

QUESTION 2   **Marks**

The table of standard electrode potentials is to be used in answering parts (a) and (b) of this question.

Electrode reaction	Standard electrode potential
$Al \rightarrow Al^{3+} + 3e^-$	$+1 \cdot 67$
$Zn \rightarrow Zn^{2+} + 2e^-$	$+0 \cdot 762$
$Cr \rightarrow Cr^{3+} + 3e^-$	$+0 \cdot 71$
$Fe \rightarrow Fe^{2+} + 2e^-$	$+0 \cdot 440$
$Cd \rightarrow Cd^{2+} + 2e^-$	$+0 \cdot 402$
$Sn \rightarrow Sn^{2+} + 2e^-$	$+0 \cdot 136$
$Cu \rightarrow Cu^{2+} + 2e^-$	$-0 \cdot 337$
$2H_2O \rightarrow O_2 + 4H^+ + 4e^-$	$-1 \cdot 229$

(a)   A zinc plate is placed in a solution of zinc sulfate ($ZnSO_4$).   **5**

    (i)   State the oxidation reaction.

        ....

    (ii)   State the reduction reaction.

        ....

    (iii)   Calculate the electrical potential developed between chromium and steel.

        ....

        ....

    (iv)   A sample of steel is coated with cadmium. A break in the coating and immersion in fresh water would establish a galvanic cell. Label the cathodic and anodic areas on the diagram.

Coating of cadmium
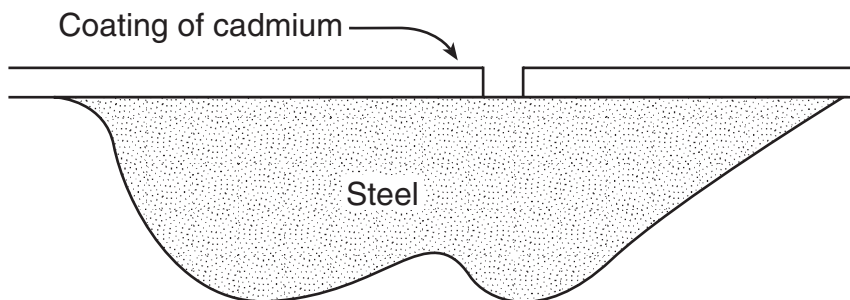
Steel

Question 2 continues on page 6

QUESTION 2 (Continued)   **Marks**

     (v) Without a protective coating, steel undergoes corrosion. State TWO characteristics of steel that would enable corrosion to take place.

        Characteristic 1 ....

        ....

        Characteristic 2 ....

        ....

(b) In two separate tests, steel is coupled with each of the metals chromium and zinc, and immersed in fresh water.   **2**

- Test piece 1:   Steel and chromium
- Test piece 2:   Steel and zinc

     (i) Explain why Test piece 1 exhibits greater corrosion protection than Test piece 2.

        ....

     (ii) Explain how chromium in alloy steels provides atmospheric corrosion resistance.

        ....

        ....

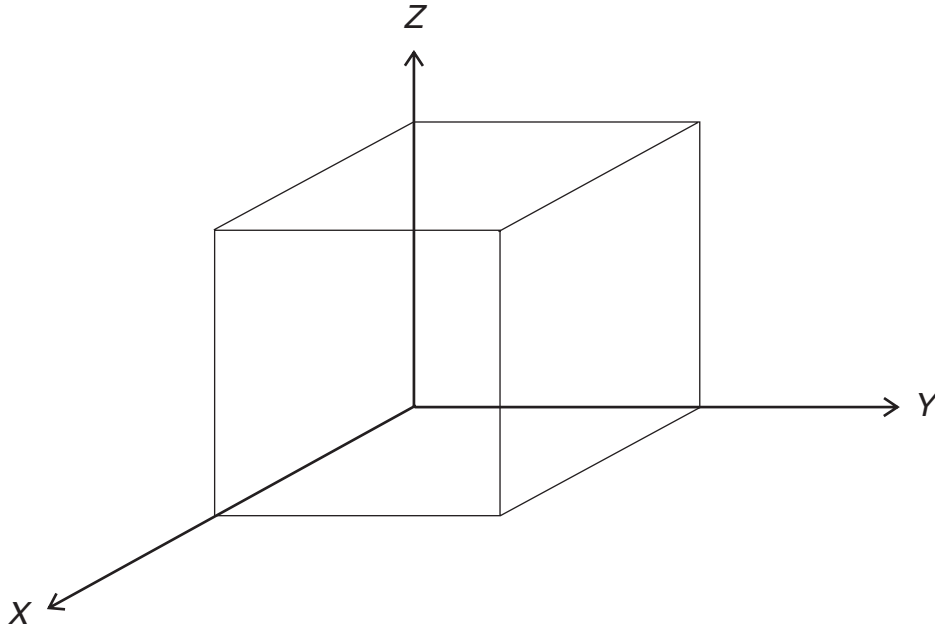QUESTION 2 (Continued)   **Marks**

(c)   The diagram below shows a unit cell.   **3**

   (i)   On this diagram, draw a plane on which slip is likely to occur in a face-centre cubic (FCC) metal.

   (ii)   State the Miller Indices for the set of planes with the same form as the plane you have drawn in part (i) above.

   Miller Indices ....

   (iii) For an FCC metal, the atomic radius is 110×10^{-12} metres. Calculate the lattice parameter of the unit cell.

Lattice parameter .... m

SECTION II

(15 Marks)
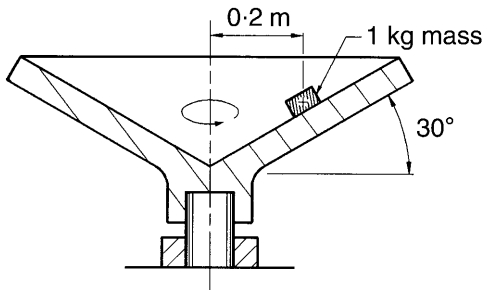
Attempt THREE questions.

Each question is worth 5 marks

QUESTION 3

A small object, of mass 1 kg, is placed on the inner surface of a conical dish at a radius of 0·2 m, as shown.

5

The coefficient of static friction between the object and the surface is 0·4.

The conical dish is accelerated from rest at a rate of 0·2 rad s^{-2}.

(a)   Determine the number of revolutions required for the conical dish to reach an angular velocity of 5 rad s^{-1}, when it started from rest.

Number of revolutions ....

(b)   Determine the angular velocity of the conical dish at the instant when the object starts to move up the surface.

Angular velocity .... rad s^{-1}

QUESTION 4   **Marks**

A rigid bar is supported horizontally by two wires, Wire 1 and Wire 2, as shown.   **5**
A force of 500 N is applied to the bar, d metres from the left-hand end.

Wire 1 has a cross-sectional area of $2 \cdot 84 \times 10^{-6} \text{ m}^2$ and Wire 2 has a cross-sectional
area of $7 \cdot 26 \times 10^{-7} \text{ m}^2$. The modulus of elasticity for each wire is 230 GPa.

Determine the distance, d, from the left-hand end for the 500 N force, if the bar is to
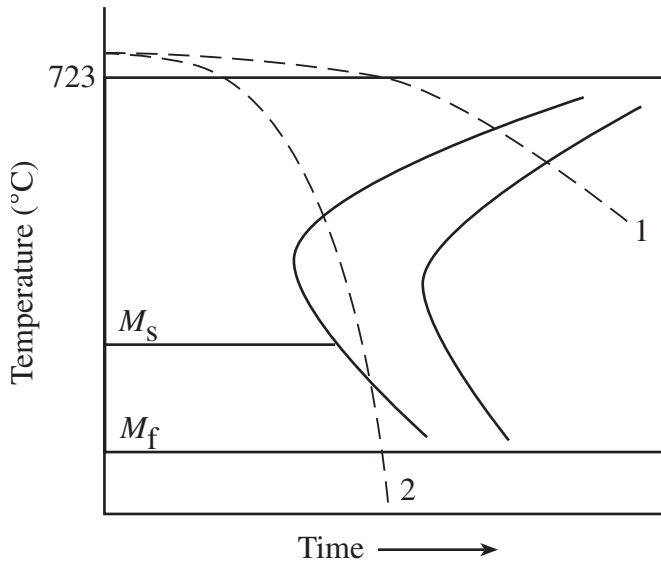remain horizontal.

Wire 1   Wire 2

500 N

1 m   3 m

d

3 m

Diagram NOT to scale
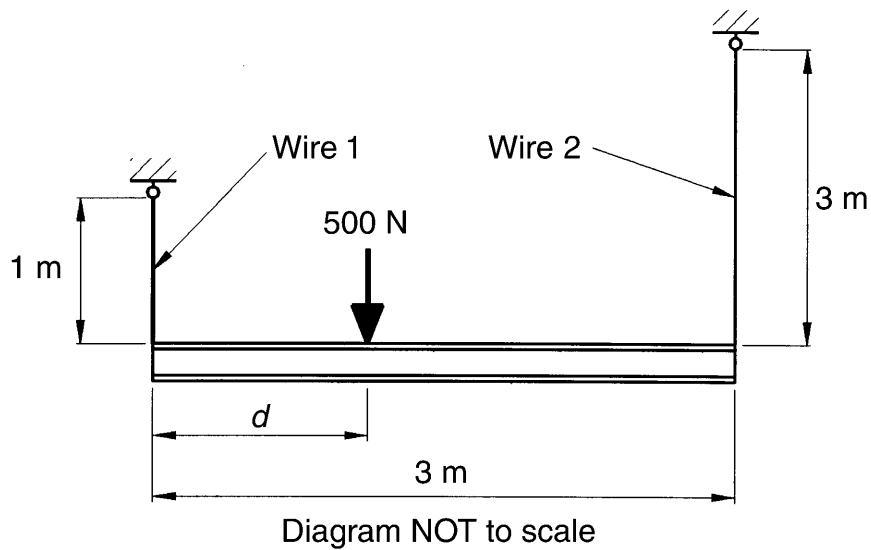
Distance, d .... m

QUESTION 5

A time-temperature-transformation (TTT) diagram for a eutectoid steel is given, indicating two cooling rates.

5

(a)   (i)   On the TTT diagram, sketch and label the slowest possible uninterrupted quenching rate that will result in a fully martensitic structure.

(ii)   Sketch and label the microstructure for the eutectoid steel cooled at rate 1, at room temperature.
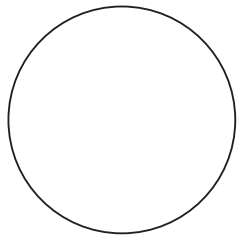
(iii)   Describe the structural transformations that occur during cooling rate 2 for the eutectoid steel.

....

....

....

(iv)   Explain the purpose of martempering of eutectoid steels.

....

....

....

QUESTION 5 (Continued)   **Marks**

(b)   (i)   On the TTT diagram, sketch and label the cooling rate that would
            represent austempering.

      (ii)   Describe the resultant microstructure at room temperature.

            ....

            ....

      (iii) Describe the changes in TWO mechanical properties of the austempered
            steel compared with a martensitic steel.
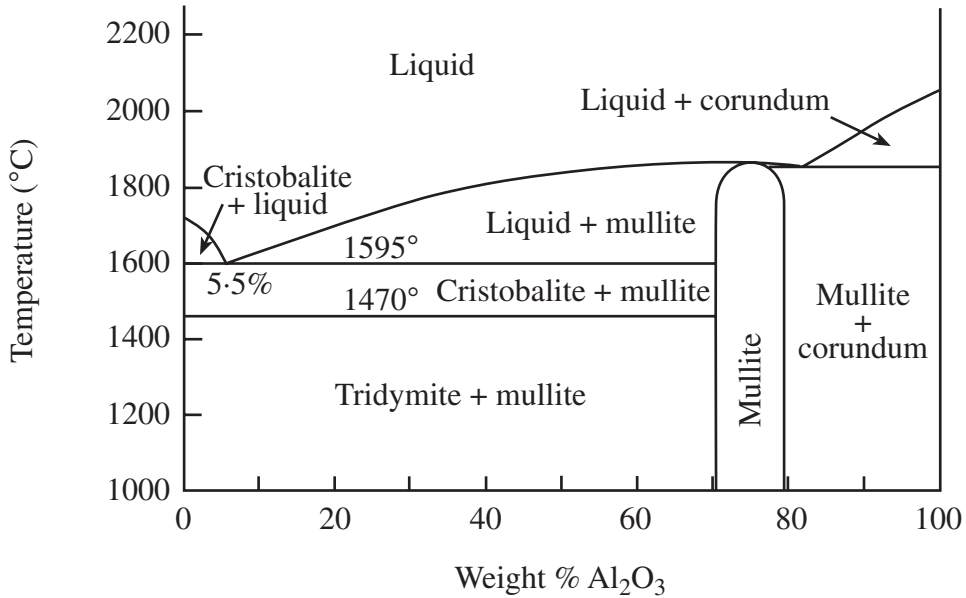
            Mechanical property 1 ....

            ....

            Mechanical property 2 ....

            ....

                                Please turn over

QUESTION 6   **Marks**

The $SiO_2 - Al_2O_3$ equilibrium (phase) diagram is given below.   **5**

Cristobalite   — SiO_2
Tridymite   — SiO_2
Corundum   — Al_2O_3
Mullite   — $Al_6Si_2O_{13}$

(a)   (i)   Determine the composition of the solid formed at 1900°C for the 10% SiO_2 – 90% Al_2O_3 alloy cooled under equilibrium conditions.

Composition of solid ....

(ii)   Determine the relative amount of proeutectic mullite for the 70% SiO_2 – 30% Al_2O_3 alloy cooled under equilibrium conditions to 1000°C.

Relative amount of proeutectic mullite ....

QUESTION 6 (Continued)   **Marks**

    (iii)   Sketch and label the microstructure of the 70% SiO_2 – 30% Al_2O_3 ceramic, at 1200° when cooled under equilibrium conditions.
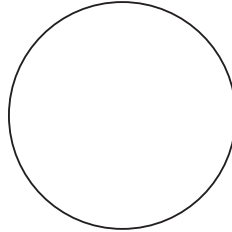
    (iv)   Describe the solid state allotropic transformation that occurs in the cooling of the 70% SiO_2 – 30% Al_2O_3 alloy to 1200°C.
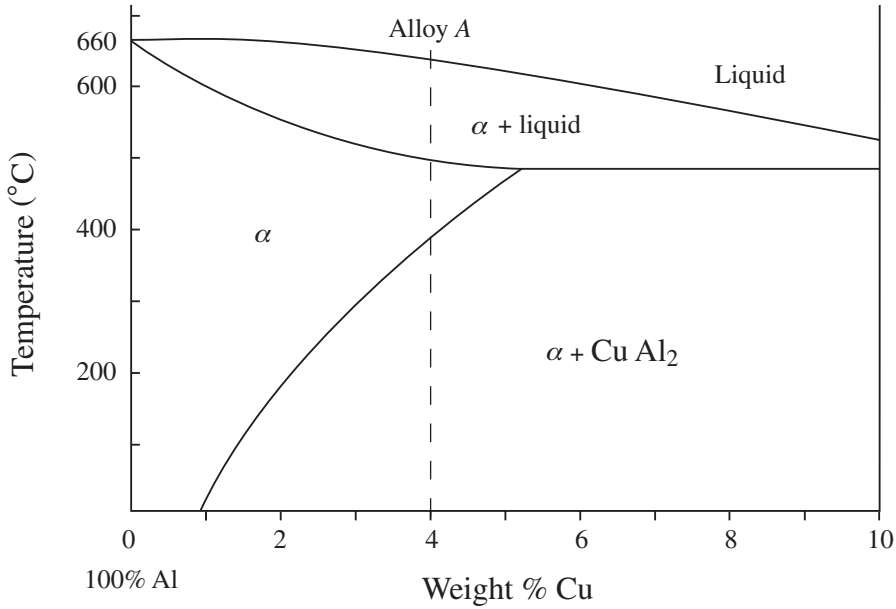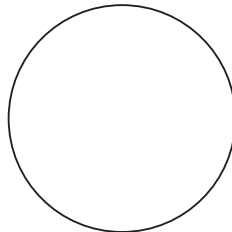
....

....

....

Question 6 continues on page 14

QUESTION 6 (Continued)   **Marks**

(b)   A portion of the aluminium-copper equilibrium (phase) diagram is shown
      below.

(i)   Draw and fully label the room temperature microstructure of alloy *A*
       after age hardening.

(ii)   The aircraft industry uses rivets manufactured from duralumin. Other
       than the ability to be strengthened through age hardening, state TWO
       reasons why duralumin is used for these rivets.

       Reason 1 ....

       ....

       Reason 2 ....

       ....
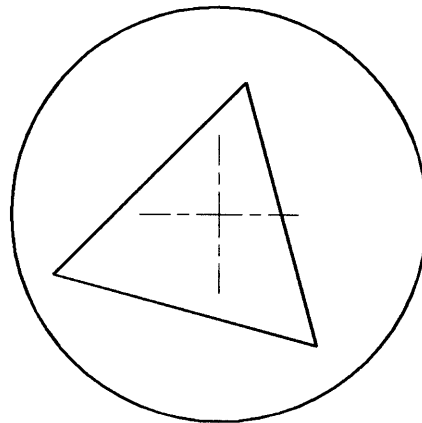
SECTION III

(15 Marks)

Attempt THREE questions.

Each question is worth 5 marks

QUESTION 7

The top view and incomplete front and left-side views of a triangular prism intersecting an oblique cone are given.

5

Complete the front view and left-side view.
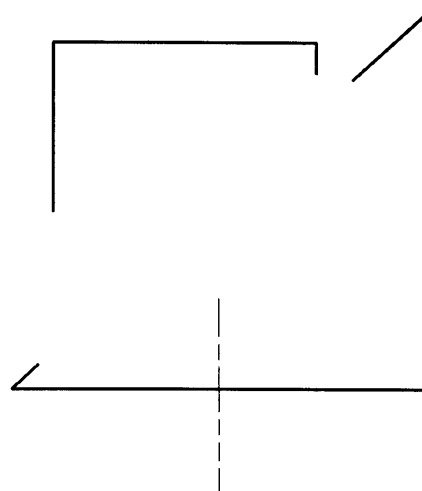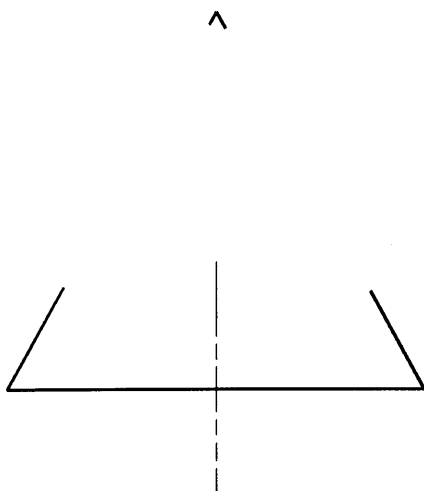
QUESTION 8

Marks

The coordinates of two points *A* and *B* and the centre of a 40 mm diameter sphere are given in the table.
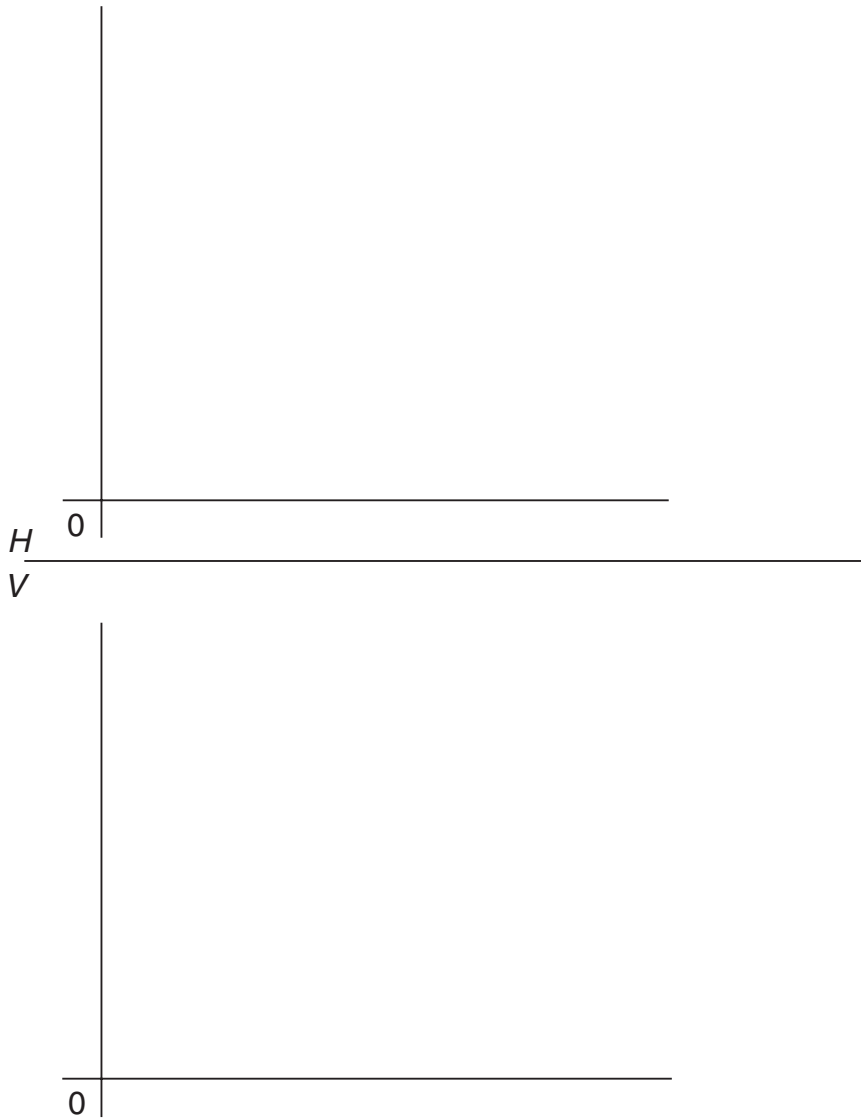
5

	X	*Y*	*Z*
A	22	60	51
B	57	8	33
Centre of sphere	31	27	28

Draw the top view and the front view of the line *AB* and the sphere on the axes given.

Clearly indicate the points where the line and the surface of the sphere intersect.

Show visible and hidden outlines. Do NOT include that part of the line inside the sphere.

H
V

0

0

QUESTION 9   **Marks**

The top view and front view of a triangular pyramid are drawn in third-angle   **5**
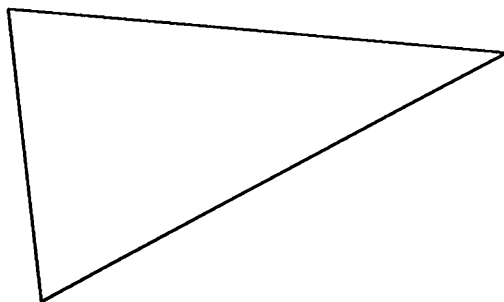projection.

Project from the top view an auxiliary view of the pyramid if its slant edge, *AD*, is to
remain at the same inclination to the Horizontal Plane, and is at an angle of 45° to the
Principal Vertical Plane.

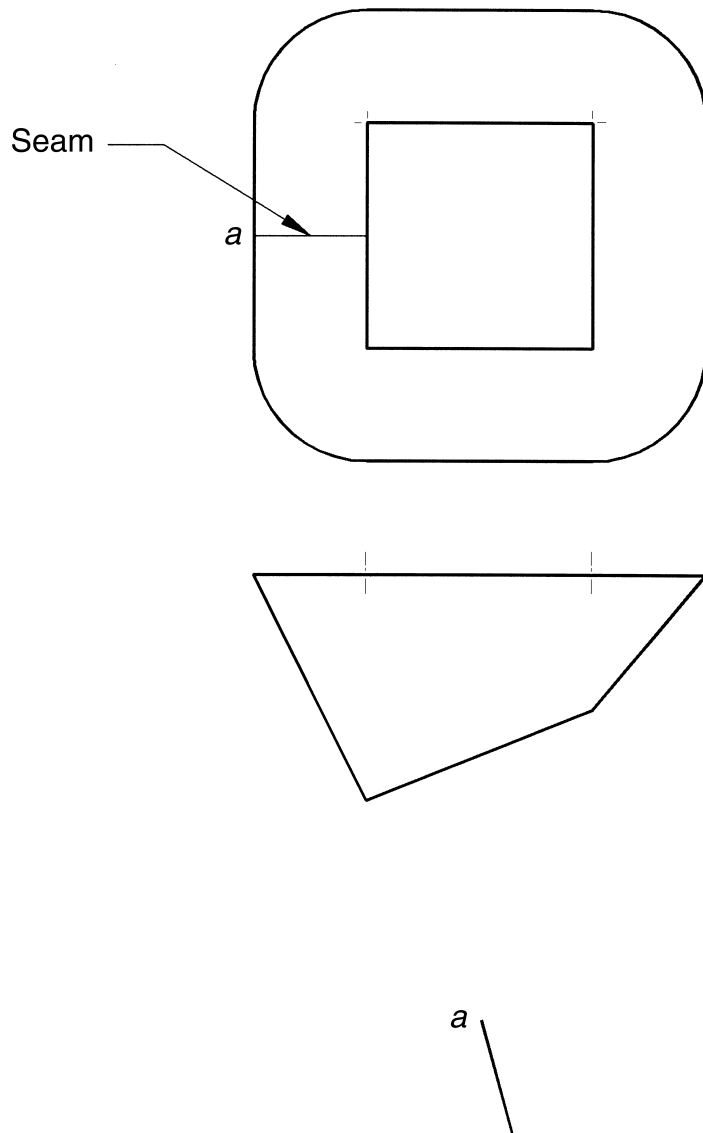The apex *D* is to be to the right, and in front of the centre of the base.
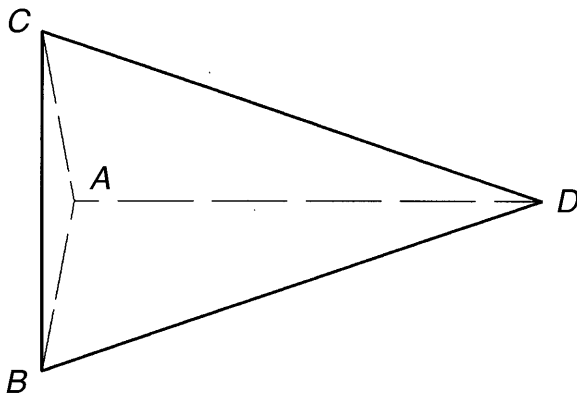
QUESTION 10   **Marks**

The top view and front view of a transition piece are drawn in third-angle projection.   **5**

Complete a half-pattern of the surface.

The starting position for the seam is given.

Seam

a

a

End of paper

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2000
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

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

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

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

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

Area of circle

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

Circumference of circle

$$C = \pi d$$

FORMULAE

(Continued)

Dynamics

$v = u + at$

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

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

$W = Fs$

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

$\omega = \omega_0 + \alpha t$

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

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

$s = r\theta$

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

$v = r\omega$

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

$a = r\alpha$

$\sum M = T = I\alpha$

$F = \mu N$

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

$F = ma$

$P = T\omega$

$Ft = m(v - u)$

$M = I\omega$

$M = mv$

$I = mk^2$

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

$W = T\theta$

$PE = mgh$

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

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

$F = kx$