Student Number

Centre Number

BOARD OF STUDIES
NEW SOUTH WALES

HIGHER SCHOOL CERTIFICATE EXAMINATION

1996
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.
- The Data Sheet will not be collected.

Examiner's Use Only

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

SECTION I

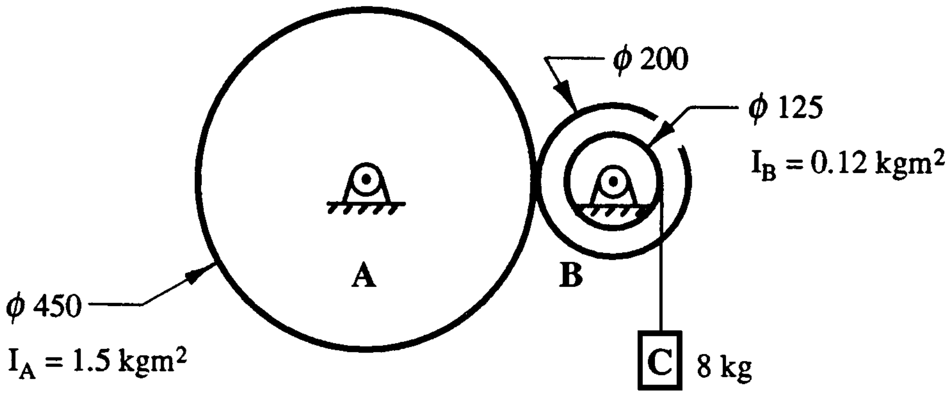
(20 Marks)

Attempt BOTH questions.

Each question is worth 10 marks.

QUESTION 1

(a) Block *C* in the diagram below is connected to a cord which is wrapped around the hub of compound pulley *B*. The contact between the pulleys *A* and *B* is such that there is no slip. **4**



(i) A torque is applied to pulley *A*, resulting in block *C* descending with an acceleration of $1 \cdot 5$ m/s^2. Determine the corresponding angular acceleration of pulley *A*.

Angular acceleration .... rad/s^2

QUESTION 1. (Continued)

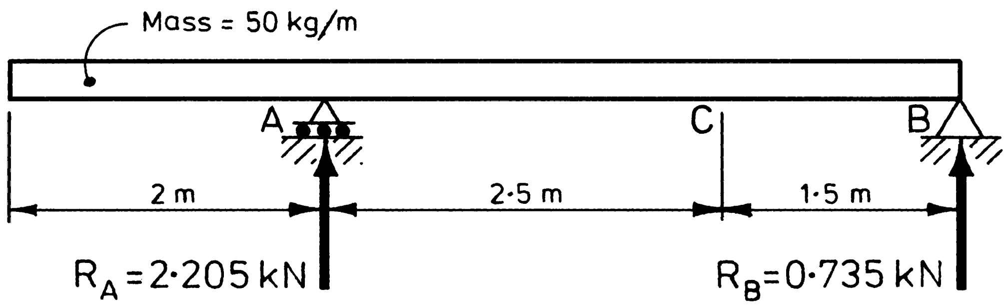
(ii) Determine the tangential contact force between pulley *A* and pulley *B* that results from the motion described in part (i).

Force ………………… N

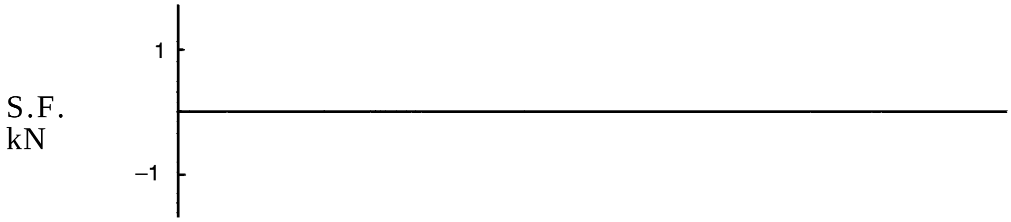
Question 1 continues on page 4

QUESTION 1. (Continued)

(b) A hardwood beam, 150 mm wide, 250 mm deep, and 6 m long, has a mass of 50 kg per metre. The beam is supported at *A* and at *B* as shown below. The reactions are given. **6**



(i) Draw the shear force diagram for the beam.



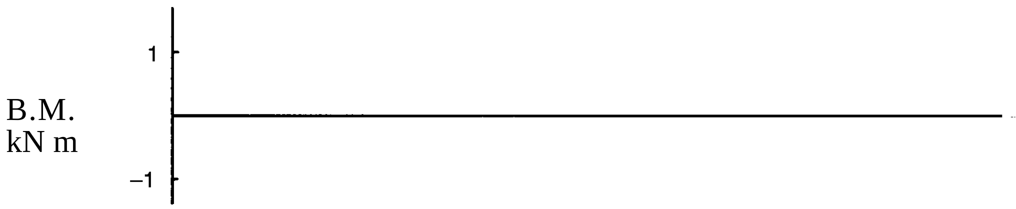
(ii) Determine the bending moment at point *C*, 1·5 m from *B*.

Bending moment .... kN m

(iii) The maximum bending moment of 0·98 kN m occurs at *A*. Determine the maximum bending stress in the beam.

Bending stress .... MPa

(iv) Using the bending moments from part (ii) and part (iii) above, sketch the shape of the bending moment diagram.

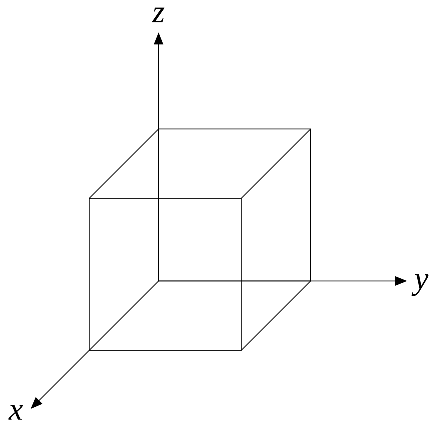


BLANK PAGE

QUESTION 2

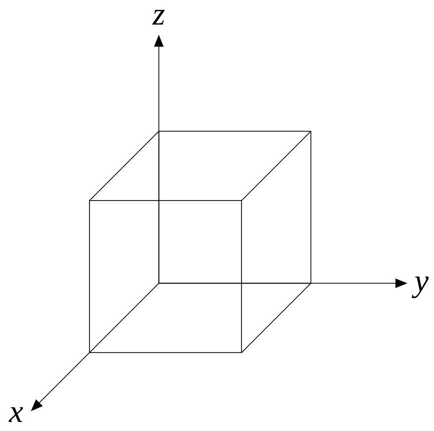
(a) Lead has a face-centred cubic lattice structure. **2**

(i) On the unit cell for lead, shown below, draw a plane which has the highest atomic density. Indicate the Miller indices for that plane.



(ii) State the coordination number of lead. ………………………………….

(iii) Draw on the diagram below, the plane that has Miller indices of (121).

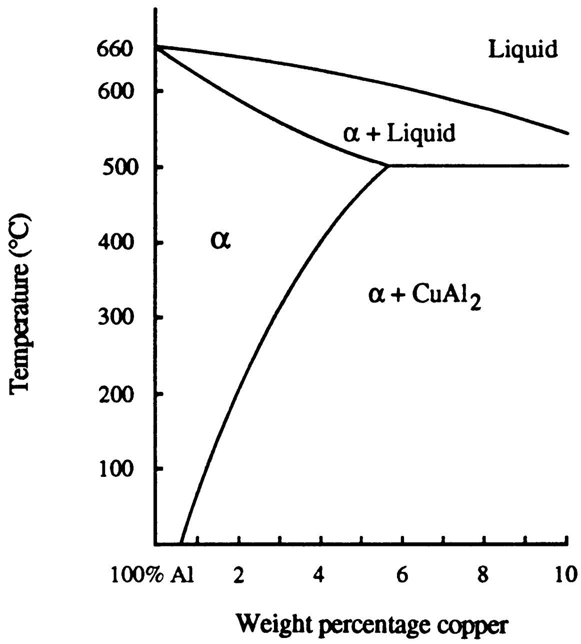


(b) Chromium has a body-centred cubic lattice structure, and has an atomic diameter of 2·49 Å. Determine the maximum atomic diameter of a solute atom that would fit interstitially into the chromium lattice without causing the lattice to distort. **1**

Atomic diameter ………………… Å

QUESTION 2. (Continued)

(c) A portion of the aluminium–copper phase diagram is shown below. **2 ½**



(i) Name and describe a heat-treatment process used to harden an alloy of 96% Al – 4% Cu.

Name of process ....

Description of process ....

....

....

....

....

....

....

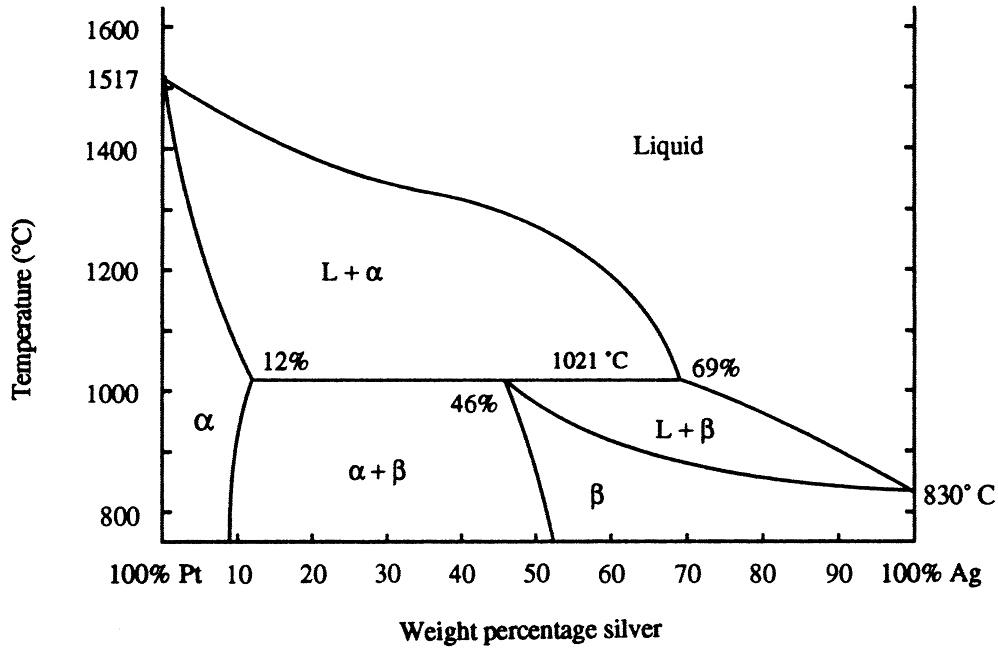
(ii) Name a hardening process that could be used for the 99·5% Al – 0·5% Cu alloy.

Name of process ....

Question 2 continues on page 8

QUESTION 2. (Continued)

(d) A portion of the platinum–silver phase diagram is given below. The following questions relate to equilibrium cooling of various platinum–silver alloys. **4 $\frac{1}{2}$**



(i) On the above phase diagram, clearly indicate the solidus line.

(ii) Determine the composition of the liquid present for the 40% Pt – 60% Ag alloy at 1100°C.

....

(iii) Determine the percentage of the liquid phase present for the 40% Pt – 60% Ag alloy at 1022°C.

....

(iv) Determine the percentage of the β phase present for the 40% Pt – 60% Ag alloy at 1020°C.

....

QUESTION 2. (Continued)

(v) Describe, in detail, the equilibrium cooling of the 40% Pt – 60% Ag alloy from 1100°C to 1000°C.

…………………………………………………………………………………

…………………………………………………………………………………

…………………………………………………………………………………

…………………………………………………………………………………

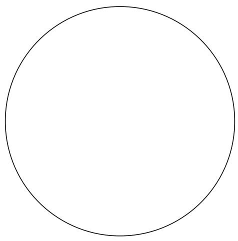
…………………………………………………………………………………

…………………………………………………………………………………

…………………………………………………………………………………

…………………………………………………………………………………

(vi) Draw and label the microstructure of the 50% Pt – 50% Ag alloy at 800°C.



50% Pt – 50% Ag

SECTION II

(15 Marks)

Attempt THREE questions.

Each question is worth 5 marks.

QUESTION 3

A merry-go-round has an inner radius of 4·5 m and an outer radius of 8·1 m. The mass of the merry-go-round is 1130 kg and the radius of gyration is 6·6 m. The merry-go-round is coasting at 6 r.p.m. when a 100 kg person is standing on the inner edge. **5**

(a) The person walks from the inner edge to the outer edge. Determine the angular velocity of the merry-go-round when the person reaches the outer edge.

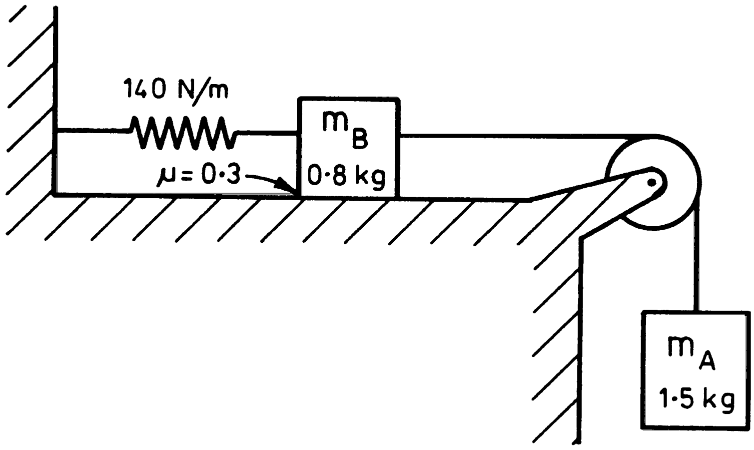
Angular velocity .... rad/s

(b) The person remains at the outer edge. Determine the torque required to return the speed of the merry-go-round to 6 r.p.m. in 2 s.

Torque .... N m

QUESTION 4

Two masses are connected by a rope passing over a frictionless pulley, as shown below. The 0·8 kg mass is acted upon by a spring of stiffness 140 N/m. The coefficient of friction between the 0·8 kg mass and the horizontal surface is 0·3. At the instant that the 1·5 kg mass is moving downward with a velocity of 5 m/s, the spring has an extension of 0·2 m from its unstretched position. **5**



(a) Determine the kinetic energy of the system at the instant that the 1·5 kg mass is moving downward at 5 m/s.

Kinetic energy .... N m

(b) Determine the velocity of the 0·8 kg mass after the 1·5 kg mass has moved downward a further 400 mm.

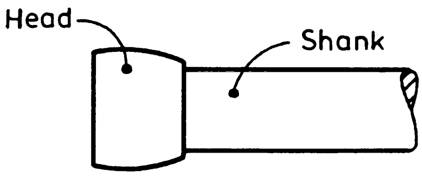
Velocity .... m/s

QUESTION 5

(a) A low-carbon-steel nail is immersed in an aqueous solution. **1**

(i) On the given diagram:

- indicate the area where corrosion is most likely to occur;
- show the anodic and cathodic areas.



(ii) Explain the reason for this corrosion occurring.

....

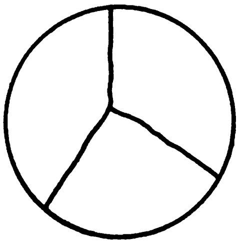
....

....

....

....

(b) A copper specimen is polished, then etched. The microstructure is shown below. **1**



EQUIAXED GRAINS OF Cu

Explain the reason for corrosion occurring during the etching.

....

....

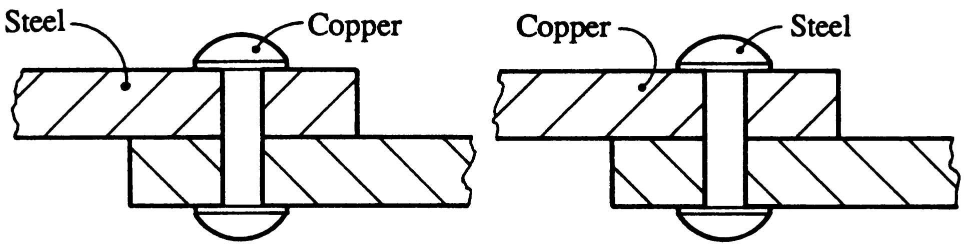
....

....

....

QUESTION 5. (Continued)

(c) Two structures, one of steel with copper rivets, the other of copper with steel rivets, are shown below. **1**



STRUCTURE 1 STRUCTURE 2

(i) Indicate the structure that would tend to have the longer life.

....

(ii) Explain the reason for the longer life of the structure.

....

....

....

(d) Specimens of four different materials undergo various heat treatments. Draw and label the resultant microstructures. **2**

(i) Copper is cold-worked, then annealed.

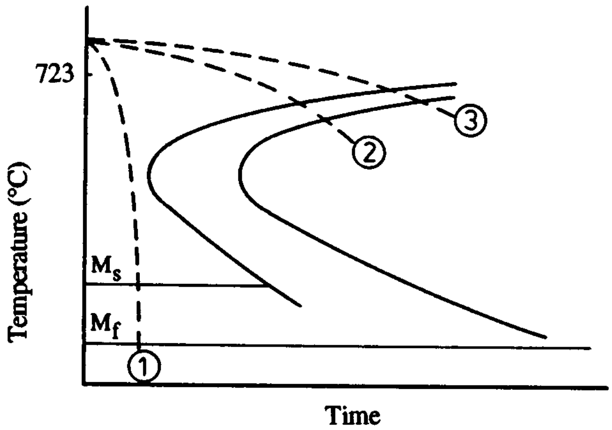
(ii) An alloy of 90% Cu – 10% Al is homogenised, then quenched.

(iii) An alloy of 96% Al – 4% Cu is solution-treated.

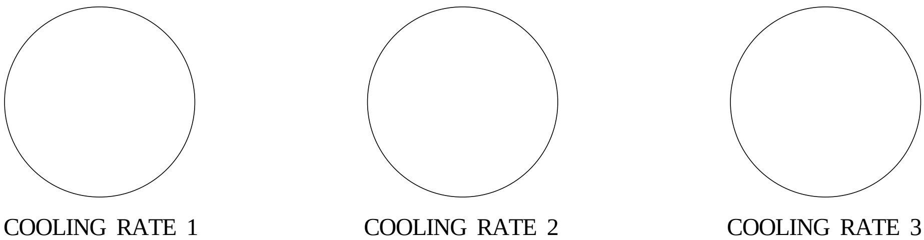
(iv) Aluminium is cold-worked, annealed, and then again cold-worked.

QUESTION 6

(a) A time–temperature–transformation diagram for a eutectoid steel is given below. Three cooling rates, numbered 1, 2, and 3, are shown on the diagram. **4**



(i) Draw and label the resultant microstructure for *each* of the cooling rates.



(ii) Shrinkage cracking occurs in components with large cross-sectional areas when they are cooled at rate 1.

Name and describe a heat-treatment process that is used to prevent shrinkage, but still produces the same microstructure as rate 1.

Name ....

Description ....

....

....

....

(b) The theoretical value of the force required to cause slip in a single crystal is much higher than the actual value. **1**

Explain the reason for the difference in these values.

Reason ....

....

....

....

SECTION III

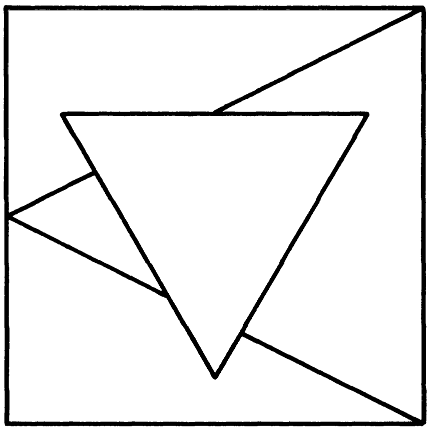
(15 Marks)

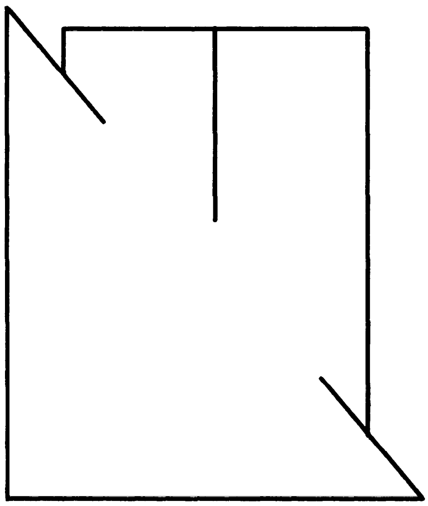
Attempt THREE questions.
Each question is worth 5 marks.

QUESTION 7

The top view and partly completed front view of an equilateral triangular prism intersecting an oblique square pyramid are shown below in third-angle projection. **5**

Complete the front view.

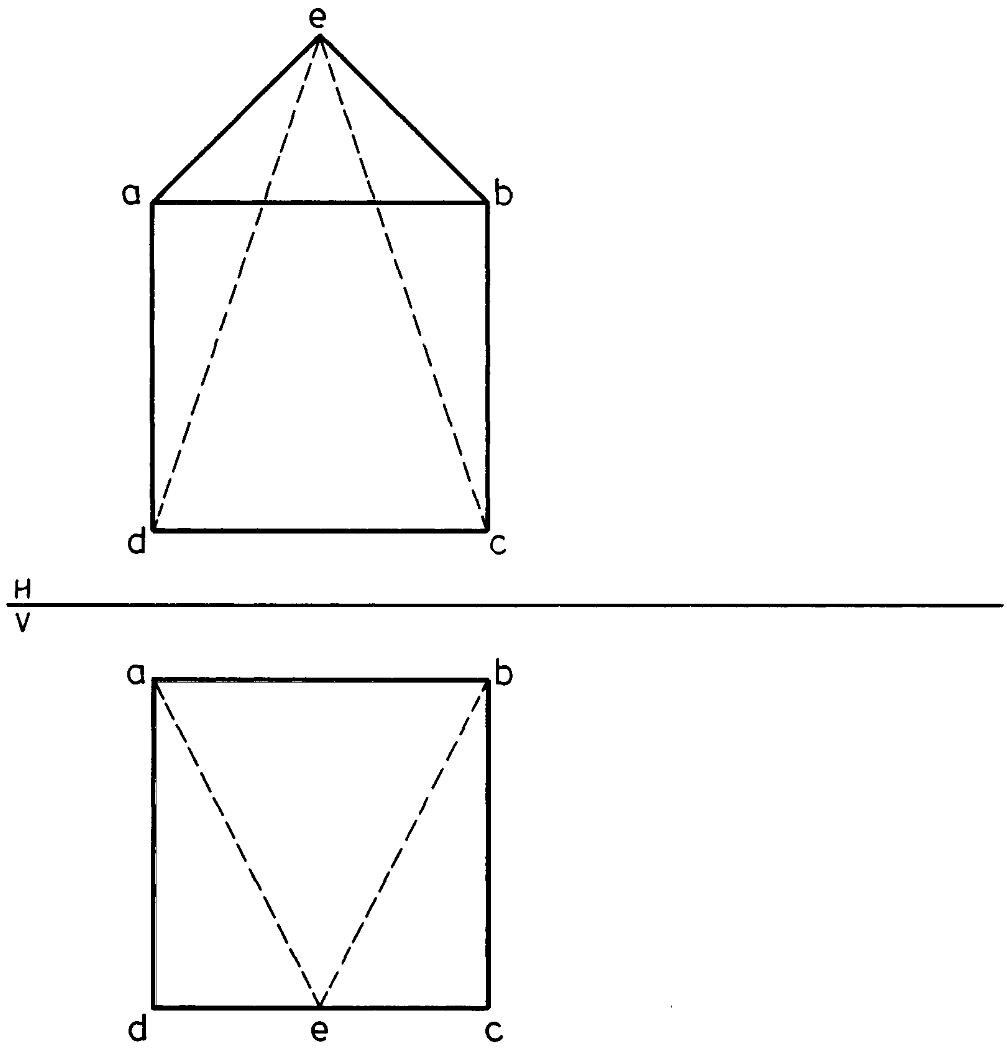




QUESTION 8

The top view and front view of an oblique rectangular pyramid are shown below in third-angle projection. **5**

Draw the top view and front view of the pyramid if the face ***cde*** remains horizontal, the base edge ***cb*** makes an angle of 30° to the principal vertical plane, and the apex is behind and to the right of the centre of the base.

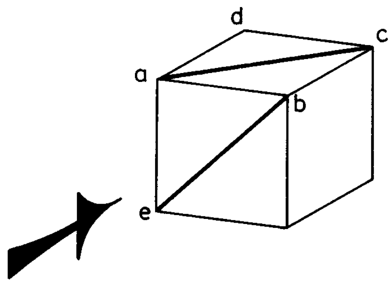


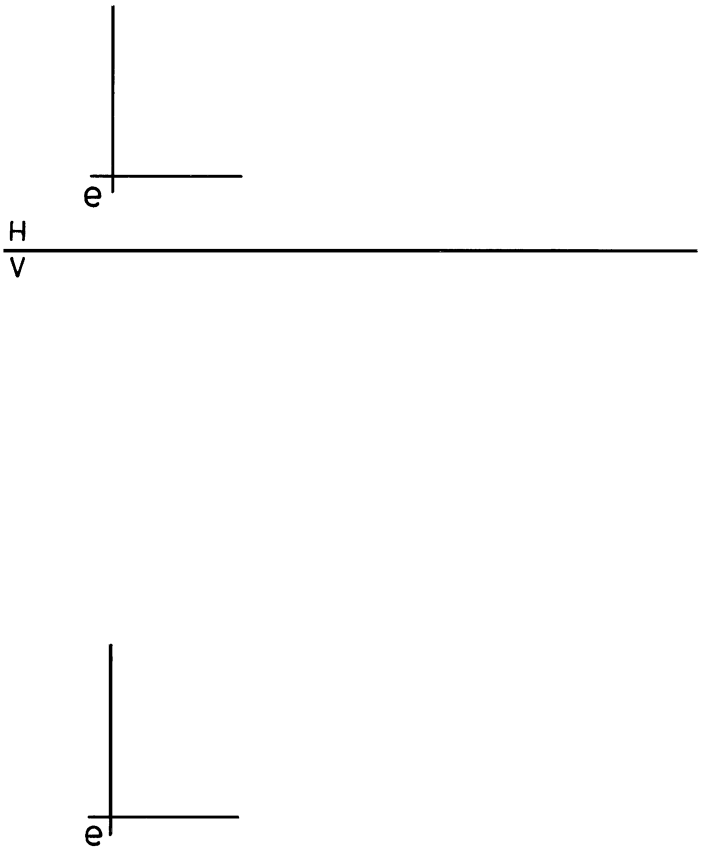
QUESTION 9

A pictorial drawing of a cube is shown below. Diagonals ***ac*** and ***eb*** are given. The cube has edges of length 60 mm. **5**

The top view and front view of the corner ***e*** of the cube are drawn below in third-angle projection. Complete the top view and front view of the cube, and the diagonals, when viewed in the direction of the arrow.

Determine the shortest distance between the diagonals ***ac*** and ***eb***.



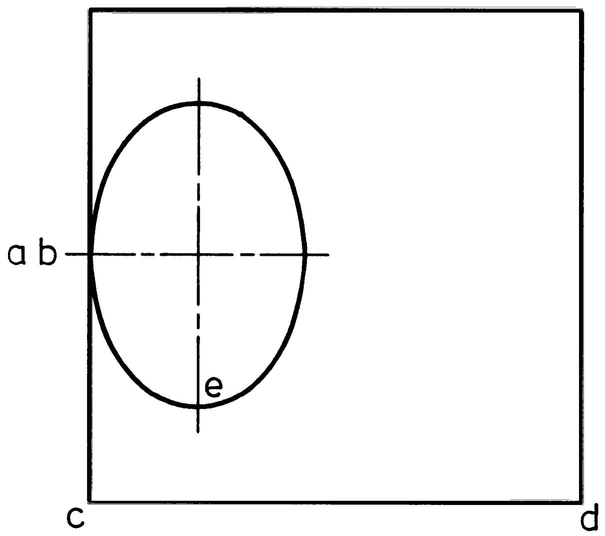


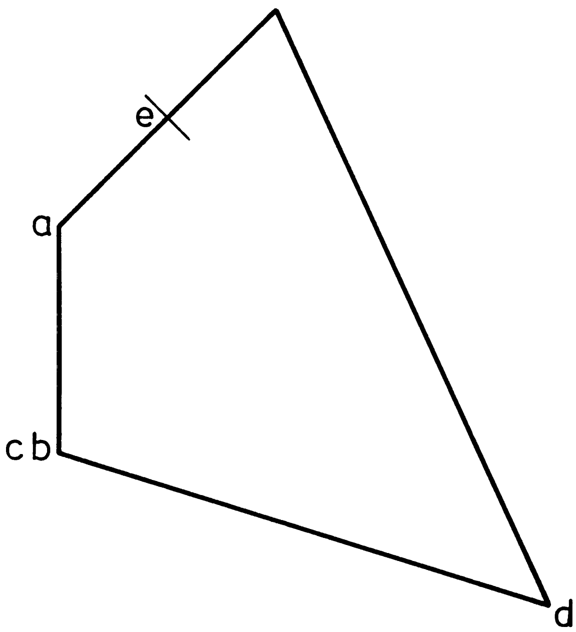
QUESTION 10

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

Draw a pattern for the surface ***abcde***.

The starting position for the seam ***ab*** is indicated below.





BLANK PAGE

BLANK PAGE

1996
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: $\sum F_x = 0$; $\sum F_y = 0$; $\sum M = 0$.

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

Machines

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

Strength of materials

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

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

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

$$\sigma = \frac{My}{I}$$

Area of circle

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

Circumference of circle

$$C = \pi d$$

Please turn over

FORMULAE

(Continued)

Dynamics

$v = u + at$

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

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

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

$s = r\theta$

$v = r\omega$

$a = r\alpha$

$F = \mu N$

$F = ma$

$Ft = m(v - u)$

$M = mv$

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

$\text{PE} = mgh$

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

$F = kx$

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

$W = Fs$

$\omega = \omega_0 + \alpha t$

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

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

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

$\sum M = T = I\alpha$

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

$P = T\omega$

$M = I\omega$

$I = mk^2$

$W = T\theta$

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