STUDENT NUMBER

CENTRE NUMBER

BOARD OF STUDIES
NEW SOUTH WALES

HIGHER SCHOOL CERTIFICATE EXAMINATION

1997
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 21–2.
- The Formulae 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	

Marks

SECTION I

(20 Marks)

Attempt BOTH questions.
Each question is worth 10 marks.

QUESTION 1

(a) A 1 metre diameter flywheel accelerates uniformly from 10 r.p.m. to 2000 r.p.m. in 5 seconds. **6**

(i) Determine the angular acceleration.

Angular acceleration .... rad/s^2

(ii) Determine how many revolutions the flywheel makes in attaining its speed of 2000 r.p.m.

Revolutions .... revs

(iii) Consider a point on the rim of the flywheel 0·25 seconds after the flywheel began accelerating from 10 r.p.m.

1. Determine the linear velocity of the point.

Linear velocity .... m/s

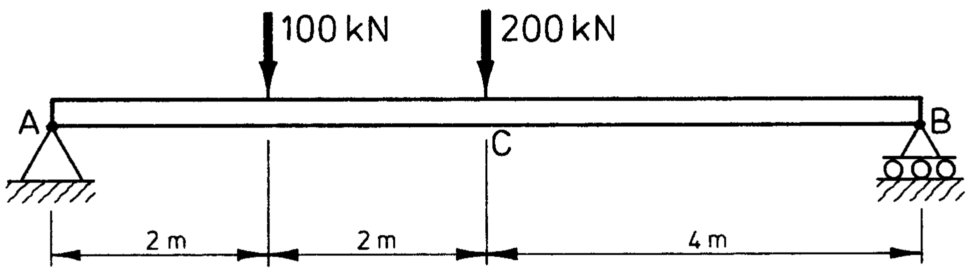
2. Determine both the magnitude and the direction of the resultant linear acceleration of the point. Consider both the tangential and normal accelerations.

Linear acceleration .... m/s^2

Angle to the normal .... °

QUESTION 1. (Continued) **Marks**

(b) A laminated beam 250 mm wide, 500 mm deep, and 8 m long is simply supported at *A* and at *B* as shown below. Neglect the mass of the beam. **4**

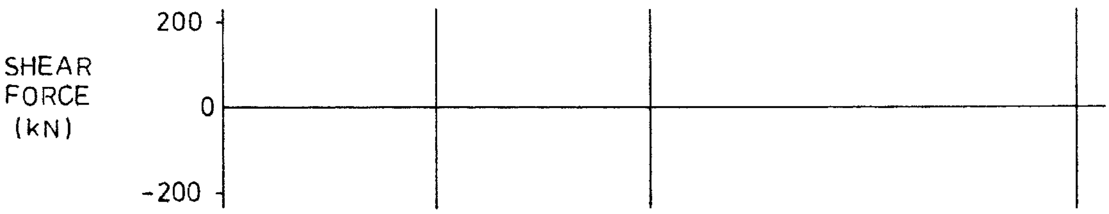


(i) Calculate the reactions at *A* and at *B*.

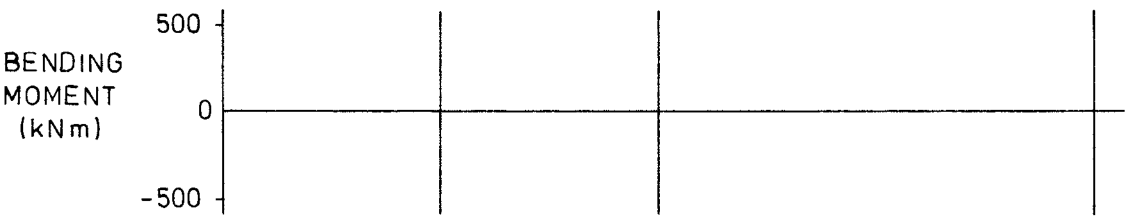
Reaction at *A* .... kN

Reaction at *B* .... kN

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



(iii) Draw the bending moment diagram for the beam.

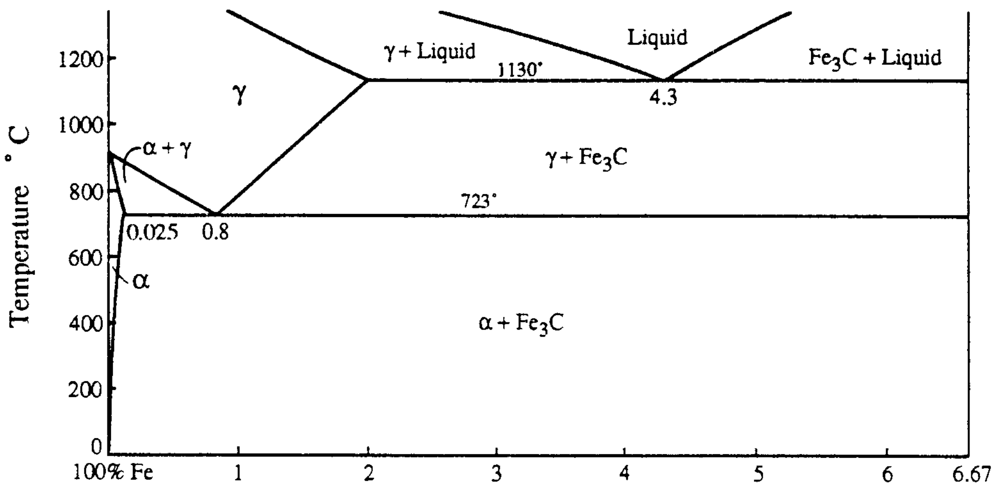


(iv) Determine the maximum bending stress at point *C*.

Bending stress .... MPa

QUESTION 2 **Marks**

(a) A portion of the iron–carbon phase diagram is given below. A 0·6% carbon steel is cooled under equilibrium conditions to room temperature. **6**



(i) Determine the relative amounts of ferrite and cementite at room temperature.

Relative amount of ferrite .... %

Relative amount of cementite .... %

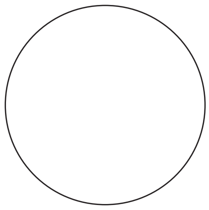
(ii) Determine the relative amount of pearlite at room temperature.

Relative amount of pearlite .... %

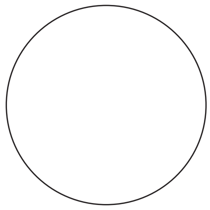
QUESTION 2. (Continued) **Marks**

(iii) A 0·6% carbon steel and a 1·3% carbon steel are cooled under equilibrium conditions to room temperature.

1. Draw and label the resultant microstructure for each steel.



0·6% CARBON STEEL



1·3% CARBON STEEL

2. Compare the properties of ductility and hardness of the two steels, explaining the differences in terms of their microstructures.

Ductility ……………………………………………………………

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Hardness ……………………………………………………………

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(iv) Cementite is an interstitial compound of iron and 6·67% carbon. Its formula is Fe_3C.

1. Define *interstitial compound.*

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2. Explain the relationship between the structure and the properties of cementite.

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(v) Annealing and tempering of glass involves different cooling rates. Describe how these different cooling rates produce different properties.

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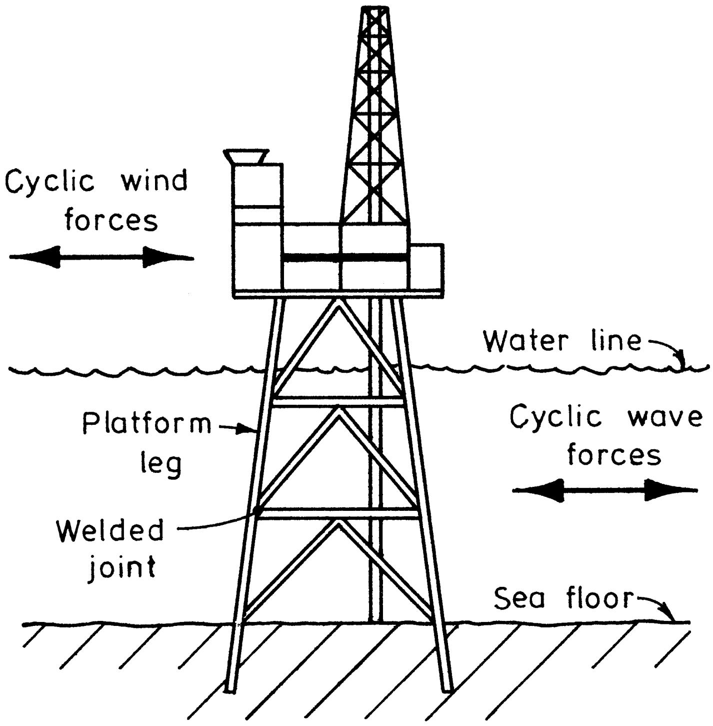
Question 2 continues on page 6

QUESTION 2. (Continued) **Marks**

(b) The offshore structure shown below is subjected to cyclic loads from both wind and waves throughout its life. The platform legs are constructed of structural steel, free from impurities. The welded joints on the platform legs have developed cracks, as observed by divers during routine inspections. **4**



NOT TO SCALE

(i) Name and describe the type of corrosion that would occur at the cracked welded joints.

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(ii) Name and describe one type of corrosion that may occur on the platform legs.

....

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(iii) Name and describe TWO preventative measures that could be used to reduce corrosion on the platform legs.

Method 1 ....

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Method 2 ....

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Section II commences on page 8

Marks

SECTION II

(15 Marks)

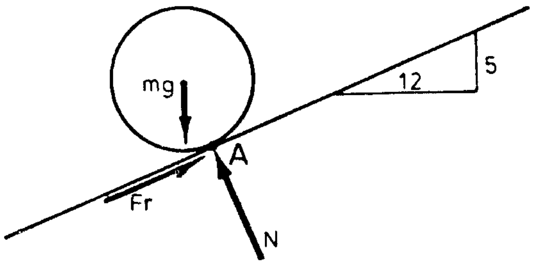
Attempt THREE questions.

Each question is worth 5 marks.

QUESTION 3

The 30 kg wheel has a diameter of 500 mm and a radius of gyration of 300 mm about point *A*, the instantaneous point of contact between the wheel and the incline. The forces acting on the wheel as it accelerates down the incline without slipping, are shown in the diagram. **5**

(a) (i) Determine the sum of the moments about point A.



Moments ……. N m

(ii) Determine the moment of inertia about point A.

Moment of inertia .... kg m^2

(iii) Determine the angular acceleration of the wheel as it rolls down the incline.

Angular acceleration ....rad/s^2

QUESTION 3. (Continued) **Marks**

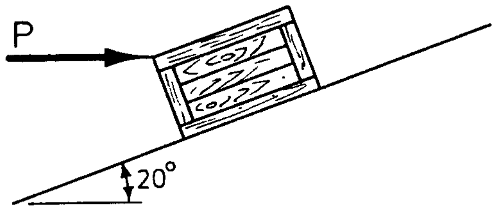
(b) Determine the frictional force acting on the wheel during its downhill roll.

Frictional force .... N

QUESTION 4 **Marks**

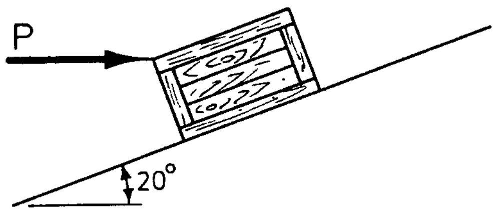
The crate shown in the diagrams below has a mass of 120 kg. The plane is inclined at an angle of 20° to the horizontal. A horizontal force *P* is applied as shown. **5**

(a) Determine the minimum value of force *P* required to hold the crate on the plane. The coefficient of static friction between the crate and the plane is 0·15.



Force *P* ………………… N

(b) Determine the magnitude of the force *P* required to maintain a constant acceleration of 0·4 m/s^2 up the plane. The coefficient of dynamic friction between the crate and the plane is 0·12.

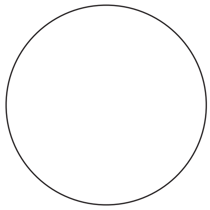


Magnitude of force *P* ………………… N

QUESTION 5 **Marks**

Two samples of 0·5% carbon steel were heated to 50°C above their upper critical temperature (UCT), soaked, then quenched to room temperature at a rate exceeding their critical cooling rate. **5**

(a) Sketch and label the resultant microstructure.



QUENCHED 0·5% CARBON STEEL

(b) Briefly describe the mechanical properties of the quenched 0·5% carbon steel.

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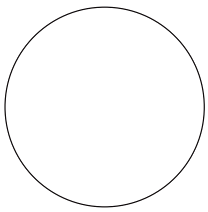
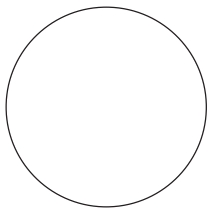
(c) Sample 1 was reheated to 220°C, soaked for 45 minutes, then cooled to room temperature.

Sample 2 was reheated to 670°C, soaked for 45 minutes, then cooled to room temperature.

(i) Sketch and label the final microstructure of each sample.



SAMPLE 1



SAMPLE 2

(ii) Explain, in terms of structure, the difference in mechanical properties of the two heat-treated samples.

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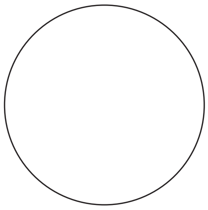
Question 5 continues on page 12

QUESTION 5. (Continued) **Marks**

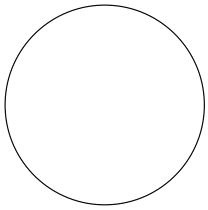
(d) Sample 1 was reheated to 800°C, soaked for 45 minutes, then very slowly furnace cooled to room temperature.

Sample 2 was reheated to 800°C, soaked for 45 minutes, then air cooled to room temperature.

(i) Sketch and label the final microstructure of each sample.



SAMPLE 1



SAMPLE 2

(ii) Explain, in terms of structure, the difference in mechanical properties of the two heat-treated samples.

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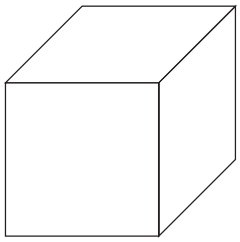
QUESTION 6 **Marks**

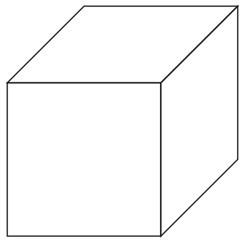
(a) Copper has a face-centred cubic structure. **2**

(i) On the sketches given below, draw the (111) plane and the (110) plane.

(ii) Indicate, on the sketches given below, the position of the centres of all the copper atoms that lie on *each* of these planes.



(111) PLANE



(110) PLANE

(iii) Explain why slip occurs more readily on the (111) planes of copper than on the (110) planes.

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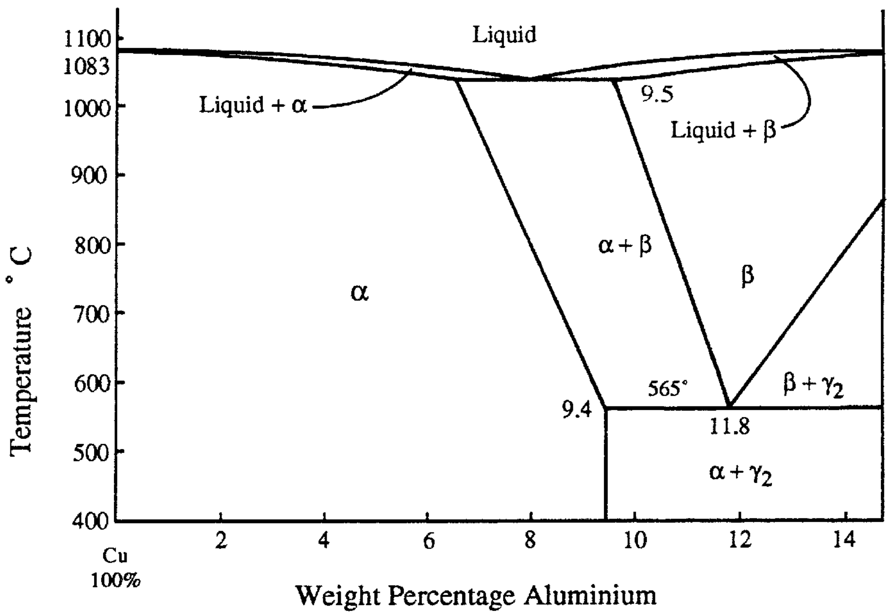
(b) Aluminium has an atomic radius of 1·431 Å and a face-centred cubic structure. Determine the size of the unit cell. **1**

Size of the unit cell .... Å

Question 6 continues on page 14

QUESTION 6. (Continued) **Marks**

(c) The copper rich portion of the copper–aluminium equilibrium diagram is given below. **1**



The maximum solubility of aluminium in copper is 9·4% and occurs at 565°C. The eutectoid composition is 88·2% Cu–11·8% Al and the eutectoid temperature is 565°C.

(i) Explain the significance, if any, of the above data with reference to the heat treatment of aluminium–bronze alloys.

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(ii) Briefly describe the method of hardening aluminium–bronze alloys by heat treatment.

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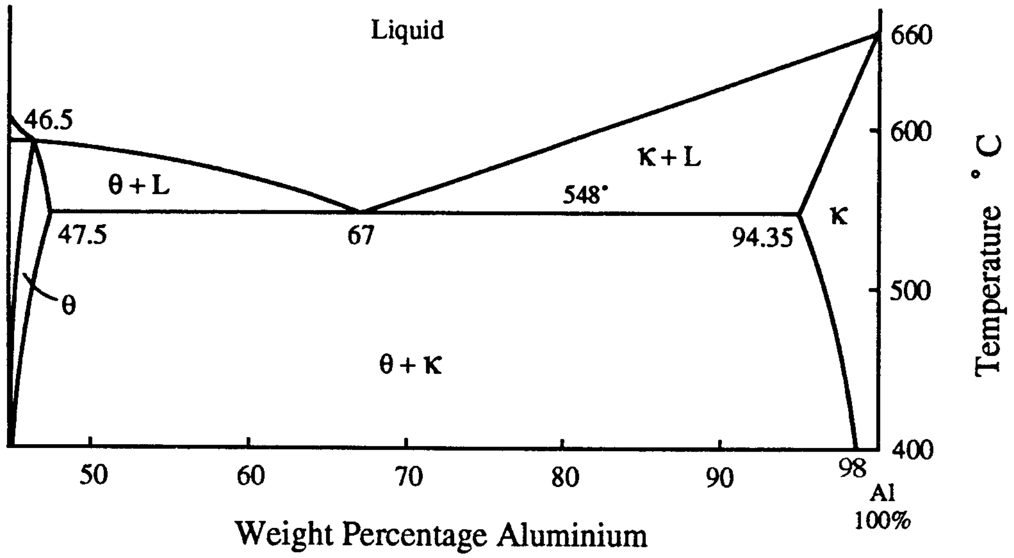
QUESTION 6. (Continued) **Marks**

(d) The aluminium-rich portion of the copper–aluminium equilibrium diagram is given below. **1**



The maximum solubility of copper in aluminium is 5·65% and occurs at 548°C. The eutectic composition is 67% Al–33% Cu and the eutectic temperature is 548°C.

(i) Explain the significance, if any, of the above data with reference to the heat treatment of duralumin.

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(ii) Briefly describe the method of heat-treating duralumin.

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SECTION III

(15 Marks)

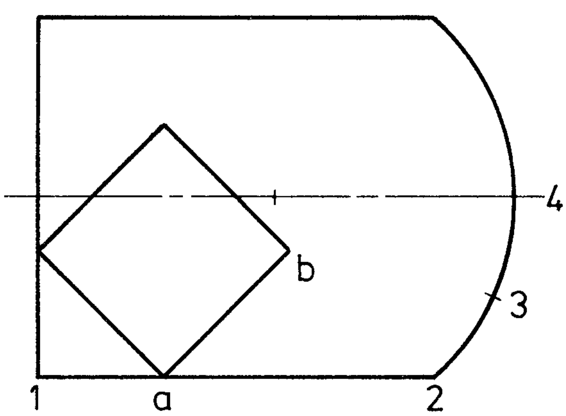
Attempt THREE questions.

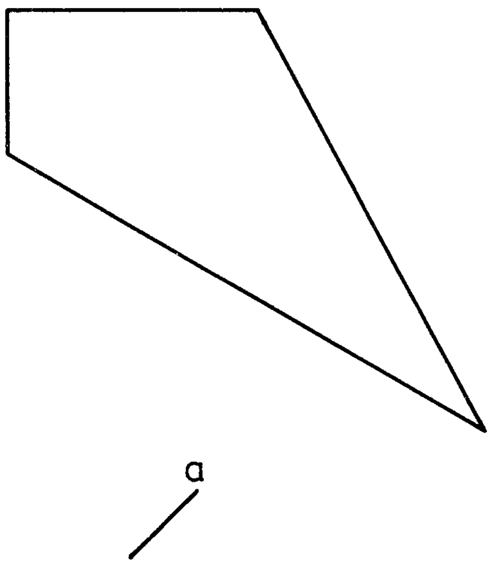
Each question is worth 5 marks.

Marks

QUESTION 7

The top view and front view of a transition piece are shown below in third-angle projection. Draw a pattern for the surface *a1234b*. The starting position for *a1* is indicated below. **5**

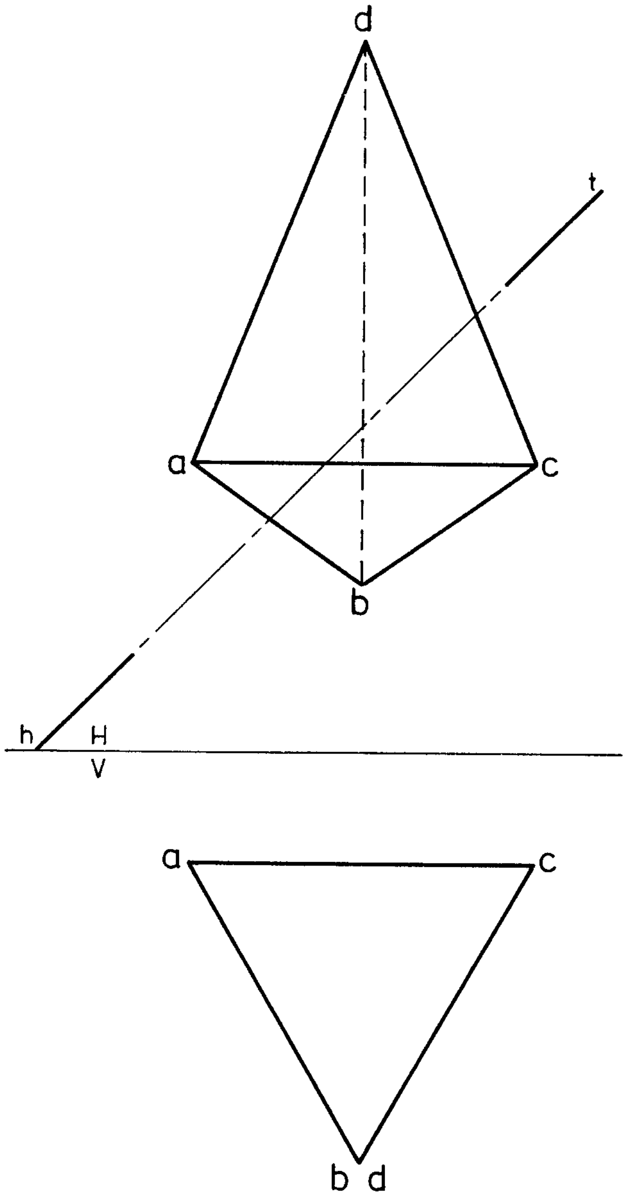




QUESTION 8 **Marks**

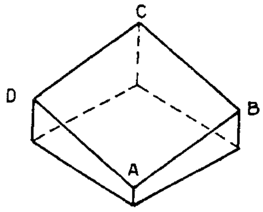
The top view and front view of a triangular pyramid are shown below in third-angle projection. A vertical cutting plane is positioned as shown in the top view. **5**

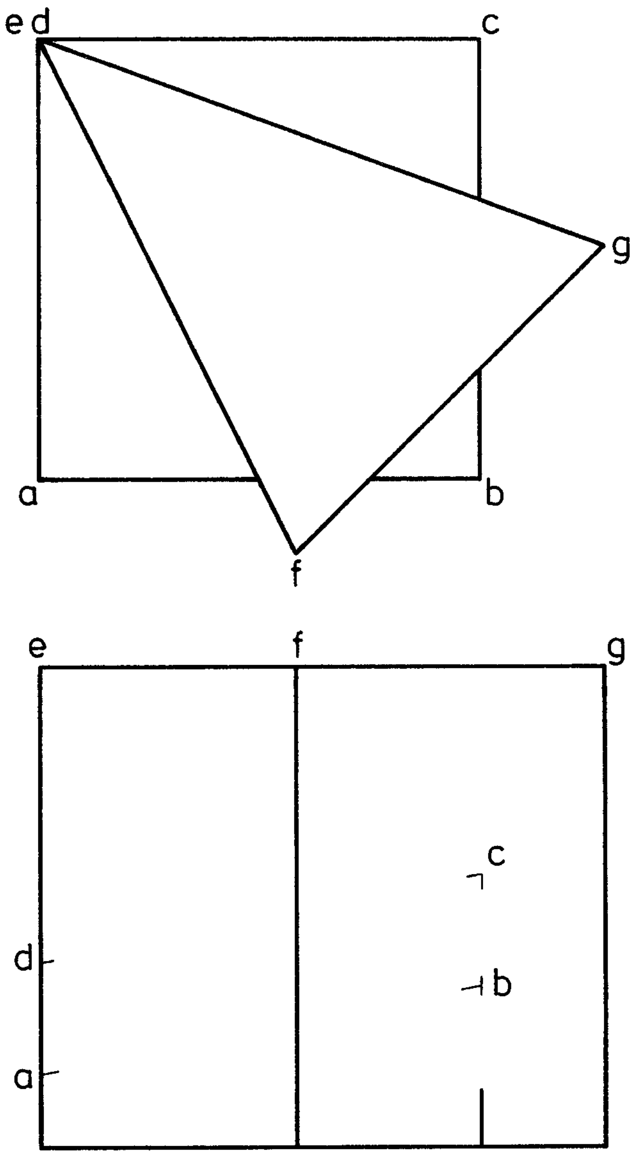
Project from the top view a sectional front view of the pyramid if the slant edge *bd* remains horizontal and the base edge *ac* makes an angle of 45° to the principal vertical plane. The apex is behind and to the right of the centre of the base.



QUESTION 9 **Marks**

The top view and incomplete front view of a triangular prism intersecting a truncated square prism are given below in third-angle projection. A pictorial drawing of the truncated square prism is given to assist visualisation. Complete the front view. **5**



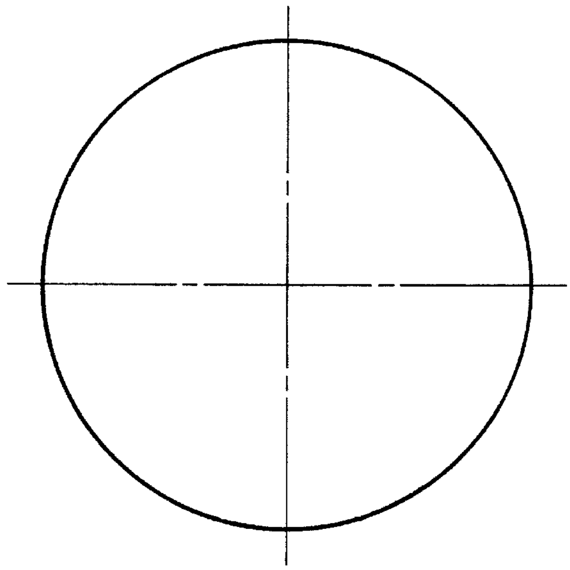


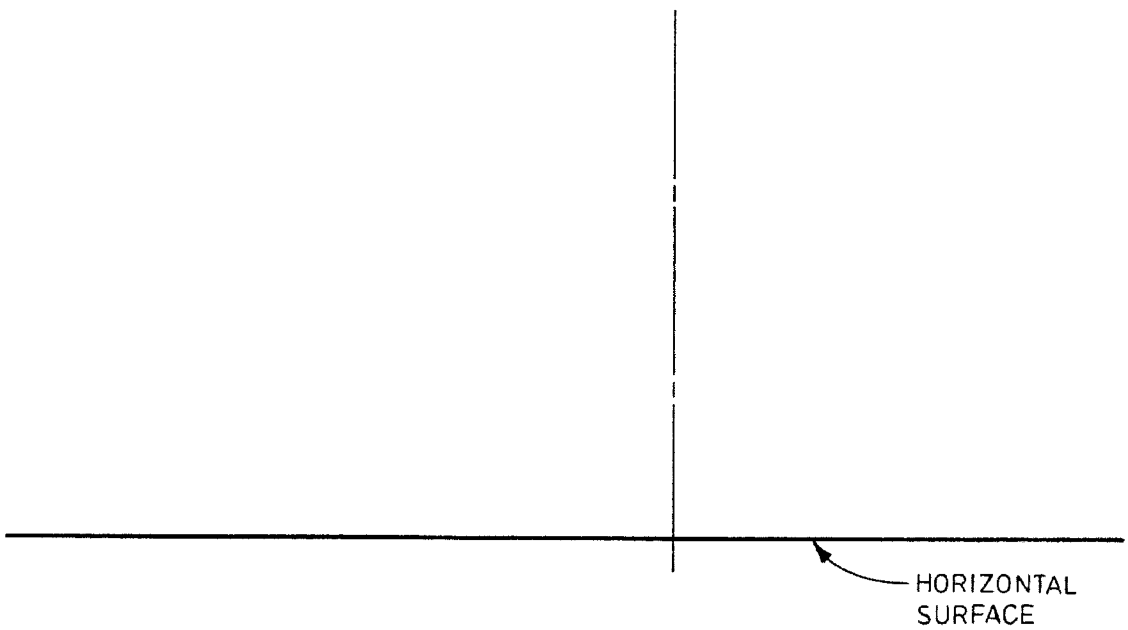
QUESTION 10 **Marks**

The top view of a sphere is given below. The sphere rests on a horizontal surface. A cylinder, diameter 40 mm and length 70 mm, stands on its end on the horizontal surface and touches the sphere. The centre of the cylinder is to the left and 15 mm behind the centre of the sphere. **5**

A second sphere, diameter 30 mm, also rests on the horizontal surface, touching both the sphere and cylinder. It is in front of both the cylinder and the sphere.

Complete, in third-angle projection, the top view and front view of the cylinder and the spheres.





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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

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

Strength of materials

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

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

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

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

Area of circle

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

Circumference of circle

$C = \pi d$

Formulae continue on page 22

FORMULAE

(Continued)

Dynamics

$v = u + at$

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

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

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

$s = r\theta$

$v = r\omega$

$a = r\alpha$

$F = \mu N$

$F = ma$

$Ft = m(v - u)$

$M = mv$

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

$PE = mgh$

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

$F = kx$

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

$W = Fs$

$\omega = \omega_0 + \alpha t$

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

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

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

$\sum M = T = I\alpha$

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

$P = T\omega$

$M = I\omega$

$I = mk^2$

$W = T\theta$

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

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