BOARD OF STUDIES
NEW SOUTH WALES

STUDENT NUMBER

CENTRE NUMBER

HIGHER SCHOOL CERTIFICATE EXAMINATION

1995
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

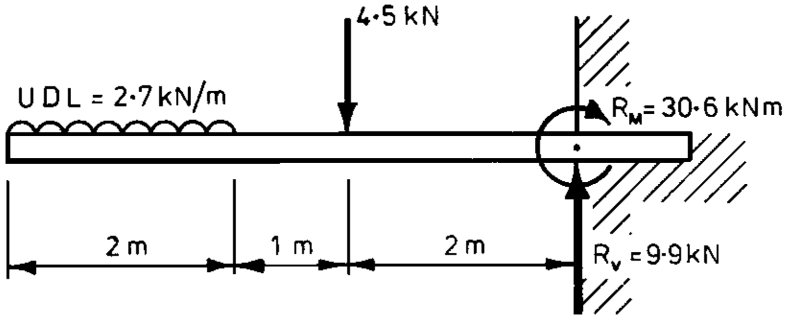
(20 Marks)

Attempt BOTH questions.
Each question is worth 10 marks.

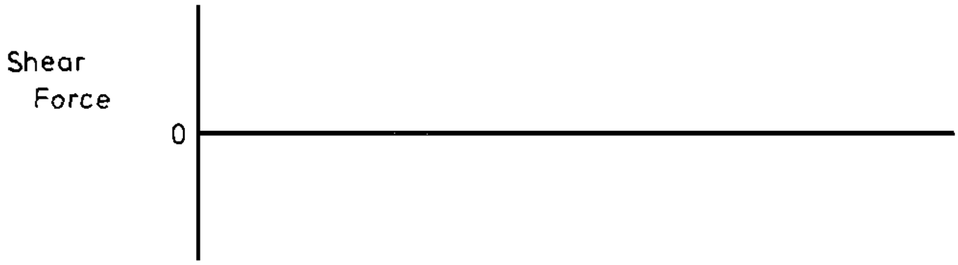
Marks

QUESTION 1

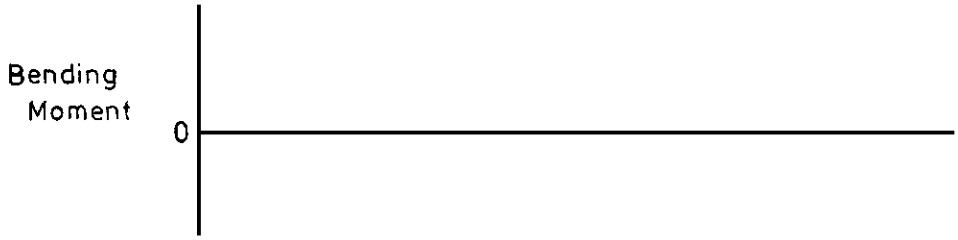
(a) A hollow cylindrical cantilever beam is loaded as shown below. The magnitude and direction of the reaction force and reaction moment at the wall are also shown. **5**



(i) Draw and fully label the shear-force diagram.

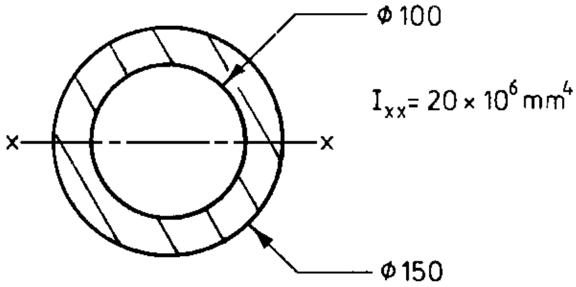


(ii) Draw and fully label the bending-moment diagram.



QUESTION 1. (Continued) **Marks**

(iii) A cross-section of the hollow beam is shown below.



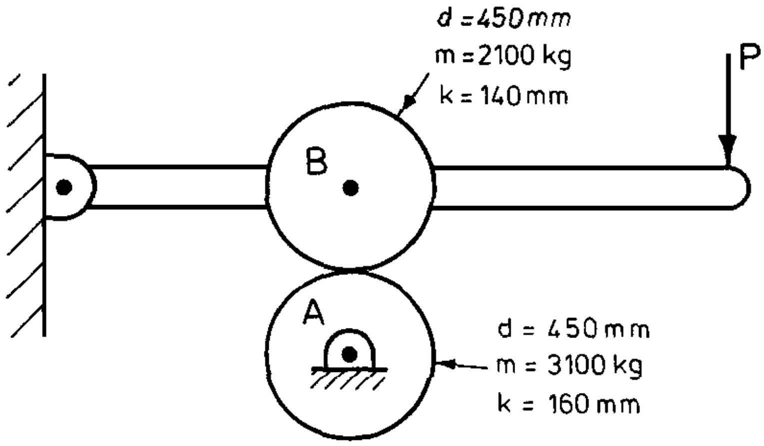
Determine the maximum tensile stress on the inner surface of the hollow beam due to bending at the wall.

Tensile stress .... MPa

Question 1 continues on page 4

QUESTION 1. (Continued) **Marks**

(b) Two rollers *A* and *B* are shown below. Initially the rollers are not in contact and *A* is rotating at 300 r.p.m., while *B* is stationary. Roller *A* has a mass of 3100 kg, a diameter of 450 mm, and a radius of gyration of 160 mm. Roller *B* has a mass of 2100 kg, a diameter of 450 mm, and a radius of gyration of 140 mm. The coefficient of friction between the rollers is 0·5. **5**



A force *P* is applied to bring the rollers together, so that a normal force of 20 kN is acting between the rollers.

(i) Determine the angular acceleration of each roller during the initial slipping.

Angular acceleration *A* .... rad/s^2

Angular acceleration *B* .... rad/s^2

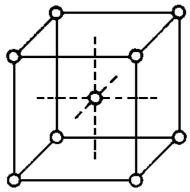
QUESTION 1. (Continued) **Marks**

(ii) Determine the common angular velocity of the rollers after slipping has ceased.

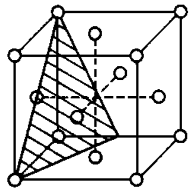
Common angular velocity .... rad/s

QUESTION 2 **Marks**

(a) Sketches of body-centred cubic and face-centred cubic unit cells are given below. One plane has been shaded on the FCC unit cell. **$3\frac{1}{2}$**



BCC UNIT CELL



FCC UNIT CELL

(i) Determine the number of atoms that lie on the (110) plane of the BCC unit cell.

Number of atoms ....

(ii) Determine the Miller indices for the plane that has been shaded on the FCC unit cell.

Miller indices ....

(iii) Nickel has a FCC structure and an atomic diameter of 2·49 Å. Determine the lattice parameters of the unit cell.

Lattice parameters ....

(iv) The radius ratio contributes to determining whether atoms occupy interstitial or substitutional sites in the lattice structure of binary alloys. Explain this contribution.

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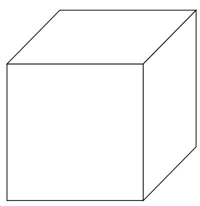
(b) The unit cell of the NaCl lattice structure is simple cubic. NaCl has a coordination number of 6. **1**

(i) On the sketch provided below, draw the position of four sodium ions and three chloride ions. Clearly label each ion.



(ii) Explain in terms of structure why NaCl is brittle.

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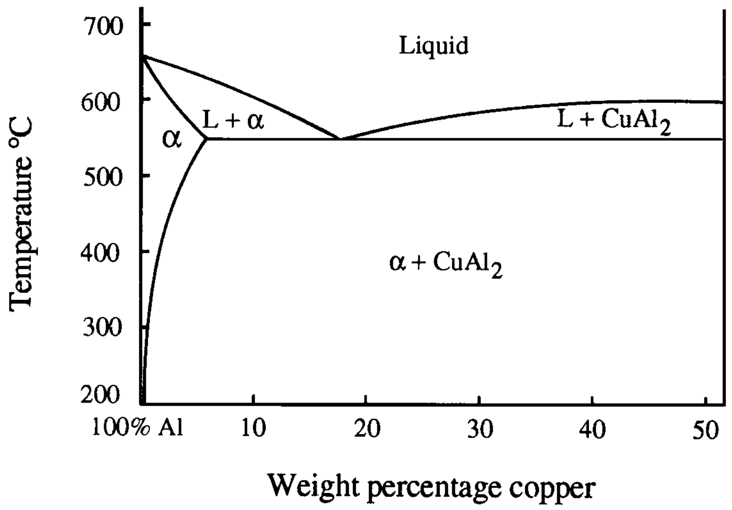
QUESTION 2. (Continued) **Marks**

(c) The aluminium-rich portion of the aluminium–copper equilibrium diagram is given below. **2**



(i) An alloy of 96% Al – 4% Cu is a heat-treatable alloy. Describe the heat treatment process used to harden the alloy.

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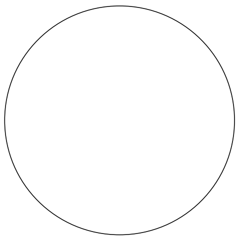
(ii) Draw and label the resultant microstructure of the heat-treated alloy.

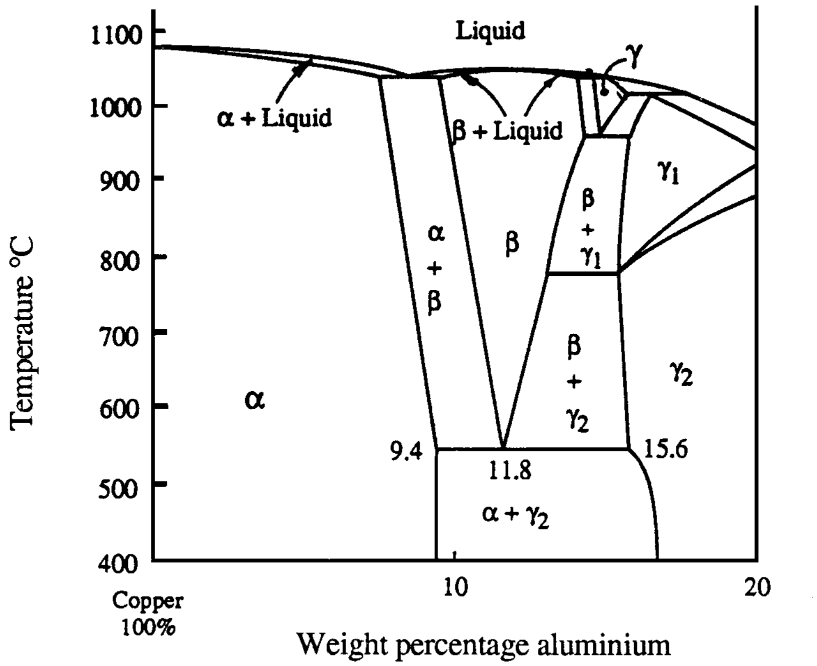


MICROSTRUCTURE OF HEAT-TREATED ALLOY

Question 2 continues on page 8

QUESTION 2. (Continued) **Marks**

(d) The copper-rich portion of the copper–aluminium equilibrium diagram is given below. **$3\frac{1}{2}$**



The following parts relate to an alloy of 90% Cu – 10% Al.

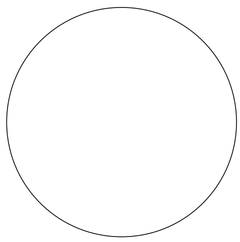
(i) Name the phase that is first to solidify during the equilibrium cooling of the alloy from the liquid state.

Phase ....

(ii) Determine the percentage of the alpha phase present in the alloy when it is cooled under equilibrium conditions to 600°C.

Percentage of alpha phase ....

(iii) The alloy is cooled to 600°C under equilibrium conditions. The resulting microstructure exhibits a Widmanstatten structure. Draw and label the microstructure.



90% Cu – 10% Al at 600°C

(iv) The alloy is heated to 1000°C, soaked, then quenched. Describe the structure of the quenched alloy.

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Marks

SECTION II

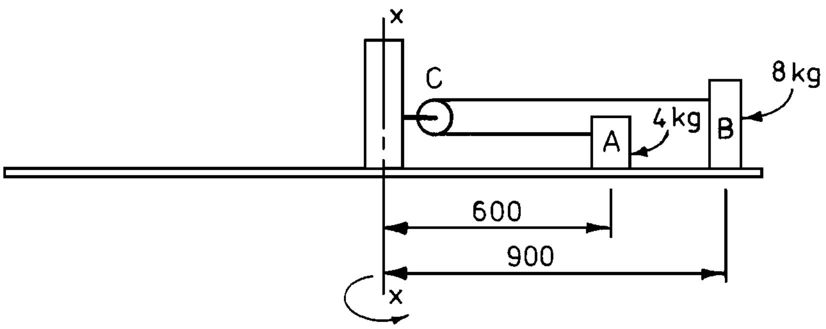
(15 Marks)

Attempt THREE questions.

Each question is worth 5 marks.

QUESTION 3

A platform rotates about a vertical axis *X*–*X* as shown below. Two masses *A* and *B* rest on the platform and are joined by a cord passing over a frictionless pulley *C*. The coefficient of friction between each block and the platform is 0·3.



(a) Draw a free-body diagram of the forces acting on blocks *A* and *B* when they are on the point of sliding. $\frac{1}{2}$

QUESTION 3. (Continued) **Marks**

(b) Determine the angular velocity of the platform at which the blocks start to slide radially. **2**

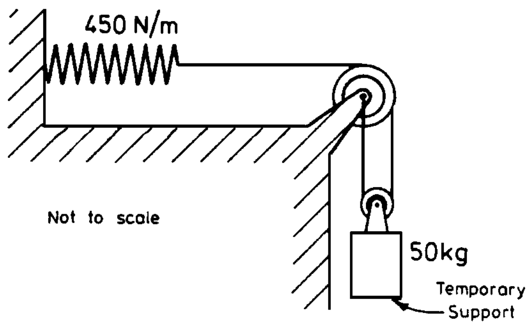
Angular velocity .... rad/s

(c) For the radial positions shown, determine the mass that block *A* would have to be for no sliding to occur at any angular velocity. Block *B* still has a mass of 8 kg. $\mathbf{2\frac{1}{2}}$

Mass of block *A* .... kg

QUESTION 4 **Marks**

A cylinder of mass 50 kg is attached to a spring by a rope passing over pulleys as shown in the diagram below. The spring stiffness is 450 N/m. Initially the spring is under a tension of 45 N and the cylinder is held at rest in the position shown.



(a) Determine the initial energy stored in the spring. **1**

Energy in spring .... J

(b) The cylinder is released from rest. **4**

(i) Determine the velocity of the cylinder after it has fallen 150 mm.

Velocity of cylinder .... m/s

(ii) Determine the maximum downward displacement of the cylinder.

Maximum displacement .... mm

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QUESTION 5 **Marks**

(a) The data given in the table below may be used to assist in answering parts of this question. **3**

Electrode reaction	*Standard electrode potential (V)*
$K^+ + e^- \rightarrow K$	–2·922
$Mg^{2+} + 2e^- \rightarrow Mg$	–2·340
$Al^{3+} + 3e^- \rightarrow Al$	–1·662
$Ti^{2+} + 2e^- \rightarrow Ti$	–1·630
$Zn^{2+} + 2e^- \rightarrow Zn$	–0·762
$Fe^{2+} + 2e^- \rightarrow Fe$	–0·440
$Cd^{2+} + 2e^- \rightarrow Cd$	–0·402
$Ni^{2+} + 2e^- \rightarrow Ni$	–0·250
$2H^+ + 2e^- \rightarrow H_2$	0
$Cu^{2+} + 2e^- \rightarrow Cu$	0·337
$O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$	0·401

(i) A cell consists of a copper electrode in copper sulfate solution and a zinc electrode in zinc sulfate solution. If the concentration of zinc sulfate in the zinc half-cell is increased, will the cell voltage increase or decrease? Justify your answer.

Cell voltage ....

Justification ....

....

(ii) A 'Nicad' battery consists of nickel and cadmium electrodes in aqueous electrolytes containing nickel and cadmium ions respectively.

Write the electrochemical half-cell equation for the anode of the Nicad battery.

Anode equation ....

(iii) Calculate the standard cell voltage for the Nicad battery.

Cell voltage .... volts

QUESTION 5. (Continued) **Marks**

(iv) A steel pipe is to be cathodically protected by attached zinc electrodes and then painted. The supervisor is undecided whether the anodes should be painted. Make a recommendation and support your decision.

Recommendation ....

Reason ....

....

(v) Brass screws used in a marine environment often appear a reddish colour after some years in service. Explain in terms of corrosion why this occurs.

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(b) Two gearwheels are to be manufactured. **2**

- Gear *A*—0·4% C steel which is to be flame-hardened to obtain the required service properties.
- Gear *B*—0·15% C steel.

(i) State TWO service properties for the flame-hardened gear *A*.

Property 1 ....

Property 2 ....

(ii) Describe the flame-hardening process.

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(iii) Gear *B* is to have its properties modified so that it has similar properties to those of the flame-hardened gear *A*. Describe a process that could be used to treat gear *B*.

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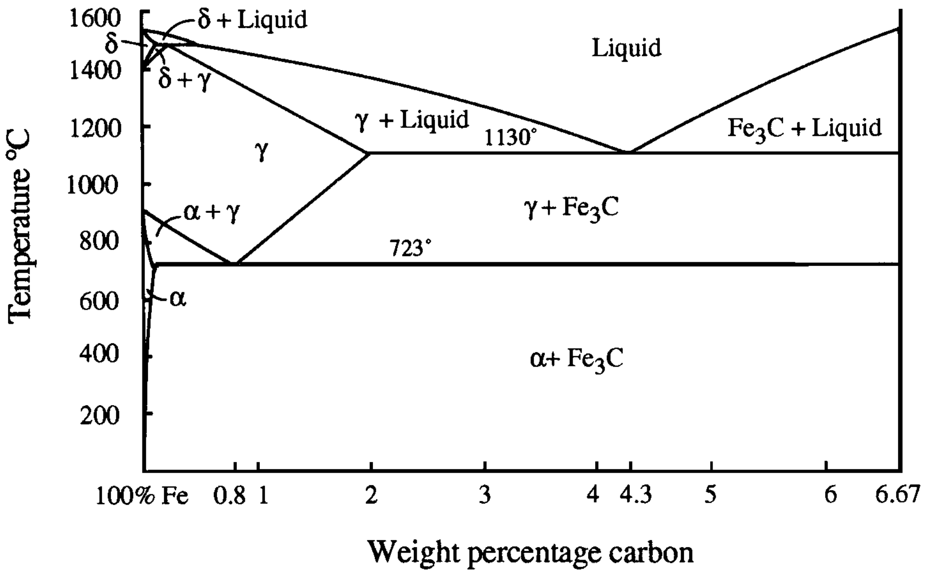
Marks

QUESTION 6

A portion of the iron–carbon phase diagram is given below.



(a) State why austenite is an important phase in the heat treatment of steel. **1**

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(b) Two samples, *A* and *B*, of 0·8% carbon steel are heated to a uniform temperature of 800°C. Each sample requires further heat treatment to achieve its final structure. **2**

(i) Describe the next stage in the heat-treatment process to achieve fine pearlite in sample *A*.

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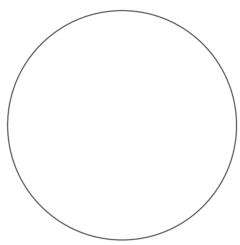
....

(ii) Draw the microstructure of fine pearlite.



FINE PEARLITE

QUESTION 6. (Continued) **Marks**

(iii) Describe the next stage in the heat-treatment process to achieve tempered martensite in sample *B*.

....

....

(iv) Draw the microstructure of tempered martensite.

TEMPERED MARTENSITE

(c) A sample of soda–lime glass is heated to 700°C, then the surface is rapidly cooled. **1**

State the effect on the bending strength of the glass. Explain, in terms of structure, the reason for this effect.

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(d) Electrical copper wire is formed by severe cold drawing. Glass bottles are formed by the blow-and-blow process. Both require heat treatment to obtain specific service properties. **1**

Describe the required heat treatment for:

(i) electrical copper wire;

....

....

....

(ii) glass bottles.

....

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SECTION III

(15 Marks)

Attempt THREE questions.
Each question is worth 5 marks.

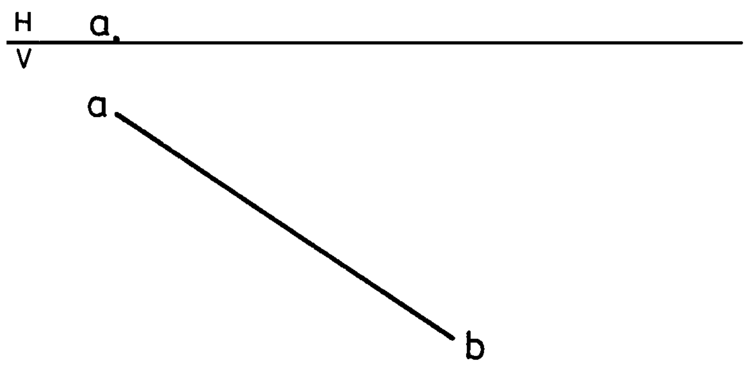
Marks

QUESTION 7

(a) The front view of a line ***ab*** and the top view of point ***a*** is given below in third-angle projection. The true length of the line is 60 mm. **$1\frac{1}{2}$**

(i) Project the top view of ***ab***.

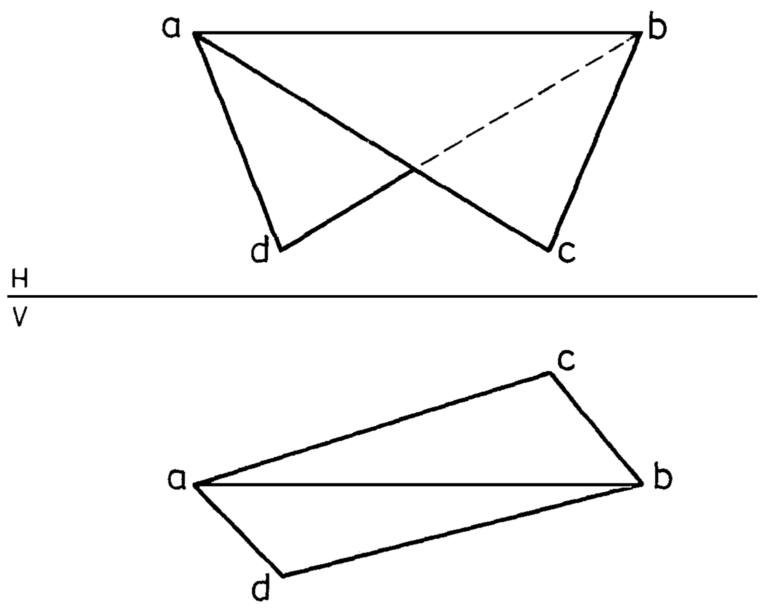
(ii) Determine and state the true angle of ***ab*** to the horizontal.



True angle of ***ab*** to the horizontal .... °

QUESTION 7. (Continued) **Marks**

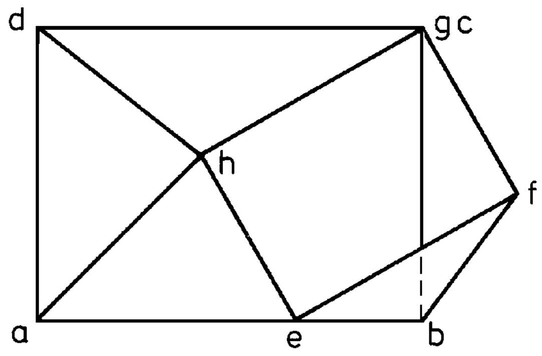
(b) The top view and front view of two triangular surfaces ***abc*** and ***abd*** are given below in third-angle projection. Determine and state the true angle between the two triangular surfaces. Draw the true shape of the surface ***abc***. $3\frac{1}{2}$

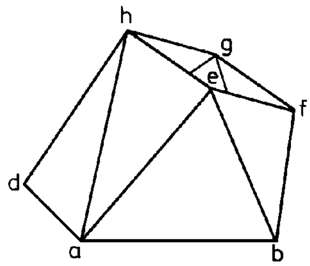


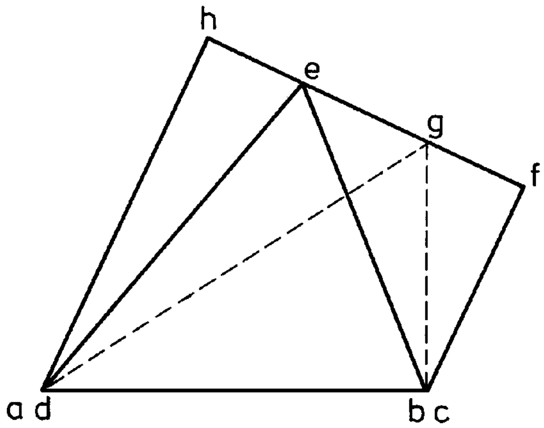
True angle between surfaces .... °

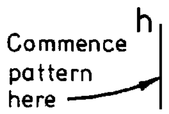
QUESTION 8 **Marks**

The top view and front view of a transition piece used to join two rectangular ducts are given below in third-angle projection. A pictorial drawing of the transition piece is also given. Draw a pattern for the surface ***abfeh***. The starting position for the edge ***ah*** is indicated below. **5**



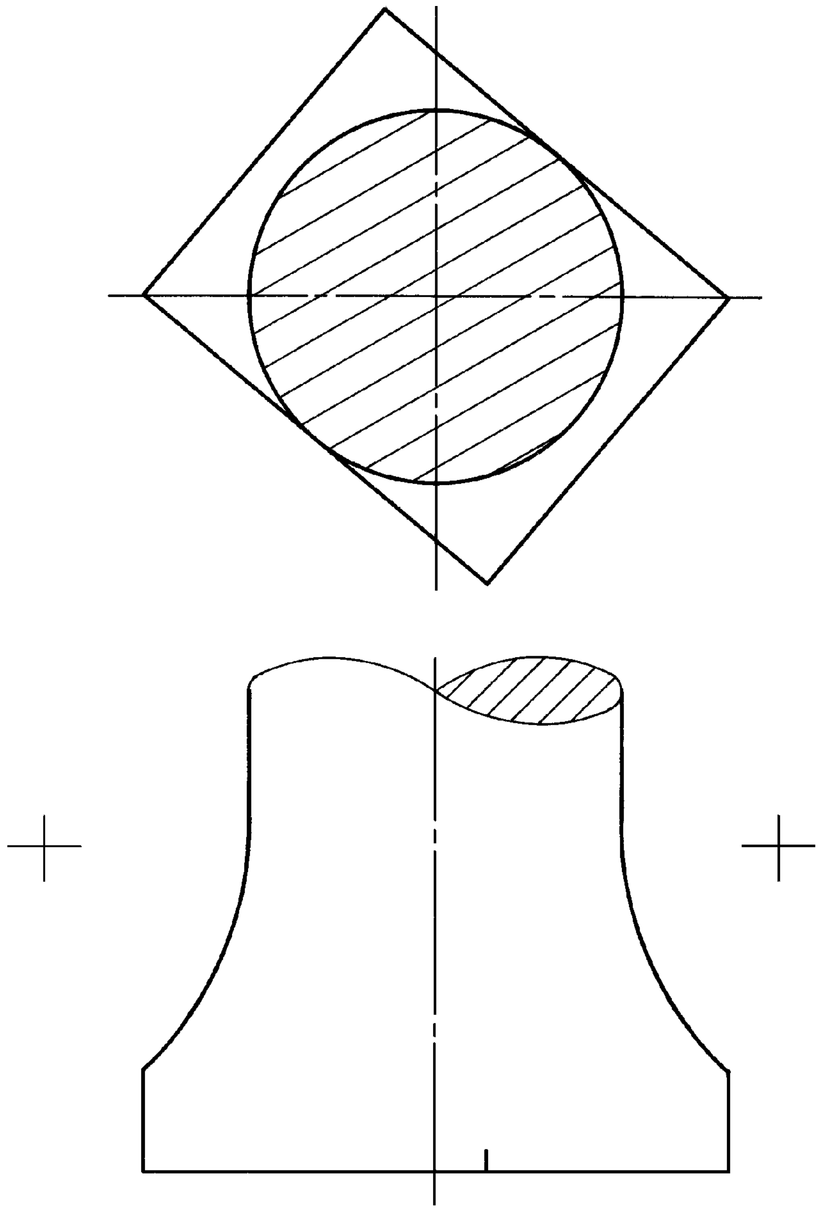






QUESTION 9 **Marks**

The top view and partly completed front view of a rod end are given below in third-angle projection. Complete the front view. Do not show hidden outline. **5**



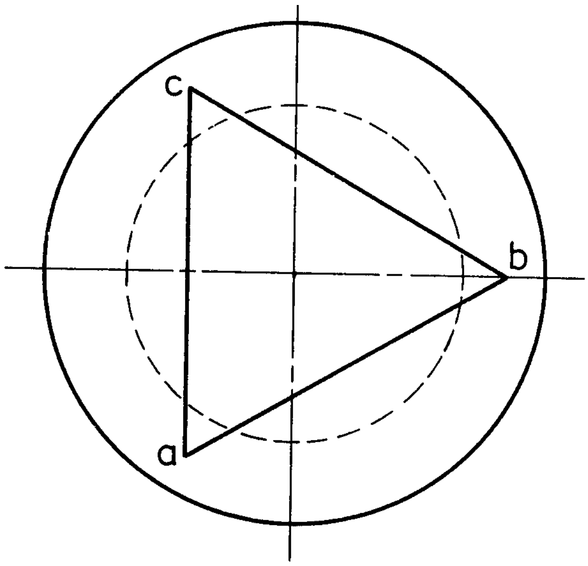
QUESTION 10 **Marks**

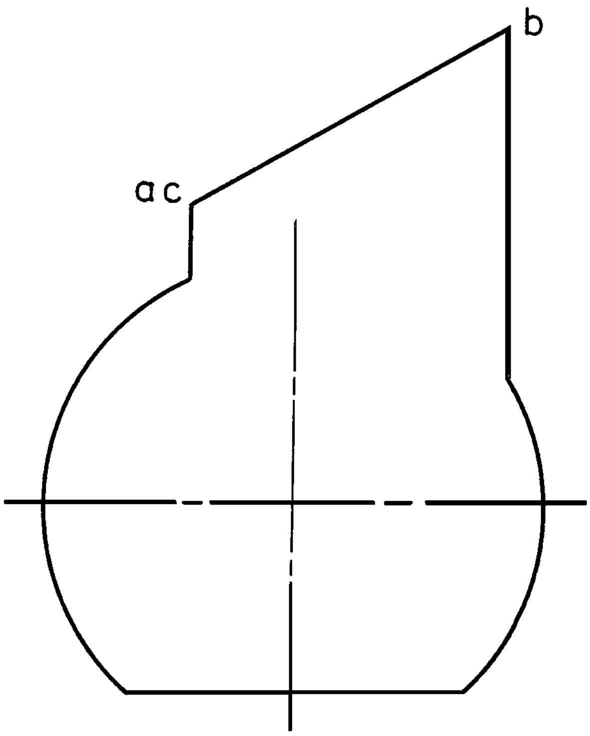
The top view and partly completed front view of a tennis trophy are shown below in third-angle projection drawn to a scale of 1 : 2. The trophy consists of an equilateral triangular prism intersecting a spherically shaped base.

(a) Complete the front view. **$3\frac{1}{2}$**

(b) A brass plate ***abc*** is positioned on top of the prism as shown. **$1\frac{1}{2}$**

Determine and indicate the true angle between edges ***ab*** and ***ac***.





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1995
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

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

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

$$C = \pi d$$

FORMULAE

(Continued)

Dynamics

$v = u + at$

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

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

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

$s = r\theta$

$v = r\omega$

$a = r\alpha$

$F = \mu N$

$F = ma$

$Ft = m(v-u)$

$M = mv$

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

$\text{PE} = mgh$

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

$F = kx$

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

$W = Fs$

$\omega = \omega_0 + \alpha t$

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

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

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

$\sum M = T = I\alpha$

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

$P = T\omega$

$M = I\omega$

$I = mk^2$

$W = T\theta$

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