BOARD OF STUDIES
NEW SOUTH WALES

STUDENT NUMBER

CENTRE NUMBER

HIGHER SCHOOL CERTIFICATE EXAMINATION

2000

ENGINEERING SCIENCE

2/3 UNIT (COMMON)

SECTION I

(48 Marks)

Total time allowed for Sections I and II—Three hours
(Plus 5 minutes reading time)

DIRECTIONS TO CANDIDATES

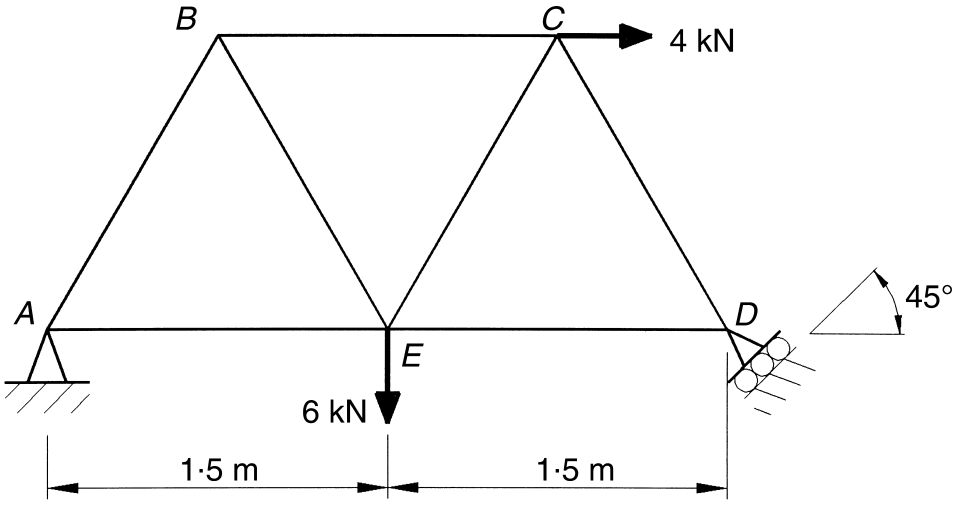
- Remove the staple to separate Section I and Section II.
- Write your Student Number and Centre Number at the top right-hand corner of this page and page 21.
- Allow approximately 90 minutes for this Section.
- Attempt ALL questions.
- Answer the questions in the spaces provided in this paper. Set out your working clearly and neatly. Emphasis will be placed on that working when marks are allocated.
- All questions are of equal value.
- Diagrams throughout this paper are to scale, unless otherwise stated.
- Drawing instruments and Board-approved calculators may be used.
- A Formulae sheet is provided on page 37.
- The Formulae sheet and Rough Work sheet (page 38) will not be collected.

MARKER'S USE ONLY

Question	Max. Marks	Marks Awarded	Marks Checked
1	8		
2	8		
3	8		
4	8		
5	8		
6	8		
TOTAL	Max. 48		

QUESTION 1 **Marks**

The details of a steel truss, loaded by a 6 kN force and a 4 kN force, are given on the diagram. All members of the truss are made from solid round steel rod, and are 1·5 metres in length.



(a) (i) Determine the magnitude and sense of the reactions at the supports *A* and *D*. **5**

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

Reaction at *D* ..... kN Sense .....

(ii) Determine the magnitude and nature of the force in member *CE*.

Magnitude of force in *CE* ..... kN

Nature of force in *CE* .....

QUESTION 1 (Continued) **Marks**

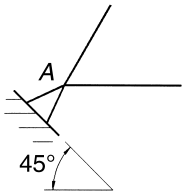
(b) Select the most appropriate term: *increase*, *decrease*, or *remain the same*, to complete the following sentences. **1**

(i) If the force at joint *C* is increased to 5 kN, the reaction at support *D* will

.....

(ii) If the fixed support at *A* is rotated 45° as shown, the reaction at *A* will

.....

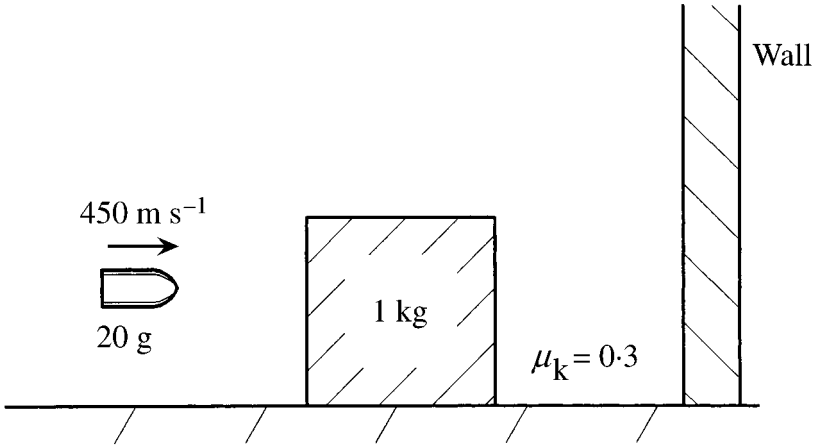


(c) For a different set of conditions, the force in member *CD* was found to be 13·5 kN. Determine the minimum diameter of the round steel rod if the maximum allowable stress for the steel is 120 MPa. **2**

Minimum diameter of *CD* ..... mm

QUESTION 2 **Marks**

(a) A 20 gram projectile with a velocity of 450 m s^{-1} impacted with a block of mass 1 kg, as shown. The impact was elastic. The coefficient of kinetic friction between the block and the floor is 0·3. **4**



(i) Determine the velocity of the combined block and projectile immediately after the impact.

Velocity ..... m s^{-1}

QUESTION 2 (Continued) **Marks**

(ii) For a different set of conditions, the velocity of the combined block and projectile was found to be $13\ m\ s^{-1}$ before striking the wall. Immediately after striking the wall, the combined block and projectile had a velocity of $5{\cdot}5\ m\ s^{-1}$ in the opposite direction.

1 Determine the energy loss due to the impact.

Energy loss ..... J

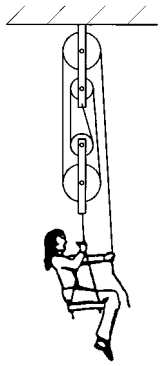
2 Determine the distance the block and projectile rebound from the wall.

Distance ..... m

Question 2 continues on page 6

QUESTION 2 (Continued) **Marks**

(b) A bosun's chair is used to hoist a person of mass 75 kg, as shown in the diagram. The efficiency of the system is 85%. **4**



(i) Determine the mechanical advantage for the system.

Mechanical advantage .....

(ii) For a different system, with a different efficiency, the mechanical advantage is 3·75. Determine the effort required to hold the person stationary.

Effort ..... N

(iii) Determine the effort required to cause the person to accelerate upward at 0·8 m s^{-2}.

Effort ..... N

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QUESTION 3 **Marks**

(a) (i) Four ceramic products are given in the table below. Complete the table by selecting from the list below, the most suitable forming process for mass production of each product. **4**

Processes

- Blow and blow
- Slip casting
- Jiggering
- Calendering
- Float process
- Crown process

Product	*Mass production process*
Mirror glass	
Coffee mug	
Science laboratory test tube	
Bathroom handbasin	

(ii) State TWO purposes for applying a glaze to a hand-thrown ceramic dinner plate.

Purpose 1 .....

Purpose 2 .....

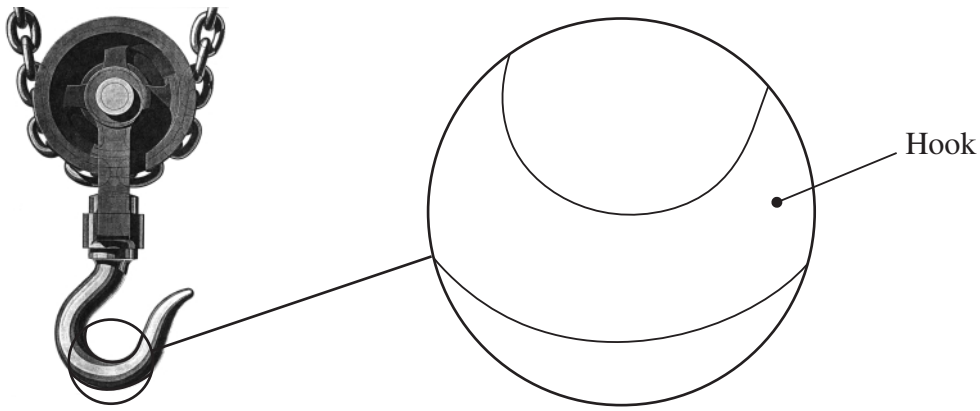
(iii) Porcelain is fired at a slightly higher temperature than stoneware. State the effect that the firing temperature has with respect to the following properties:

Opacity .....

Porosity .....

QUESTION 3 (Continued) **Marks**

(b) A crane hook and chain assembly is shown. The hook is to be manufactured from steel by sand casting. **4**



(i) On the enlarged section of the hook, sketch and label the typical grain structure of the steel after solidification.

(ii) A similar hook is to be forged from steel. State ONE advantage to be gained by drop forging as opposed to casting the steel.

.....

(iii) After a period of use it is necessary to inspect the cast hook for flaws. State TWO methods of non-destructive testing that could be used to detect microscopic flaws.

Method 1 .....

Method 2 .....

(iv) The hook is repeatedly loaded to below its elastic limit over an extended period of time. Name the type of failure that may occur as a result of this loading.

.....

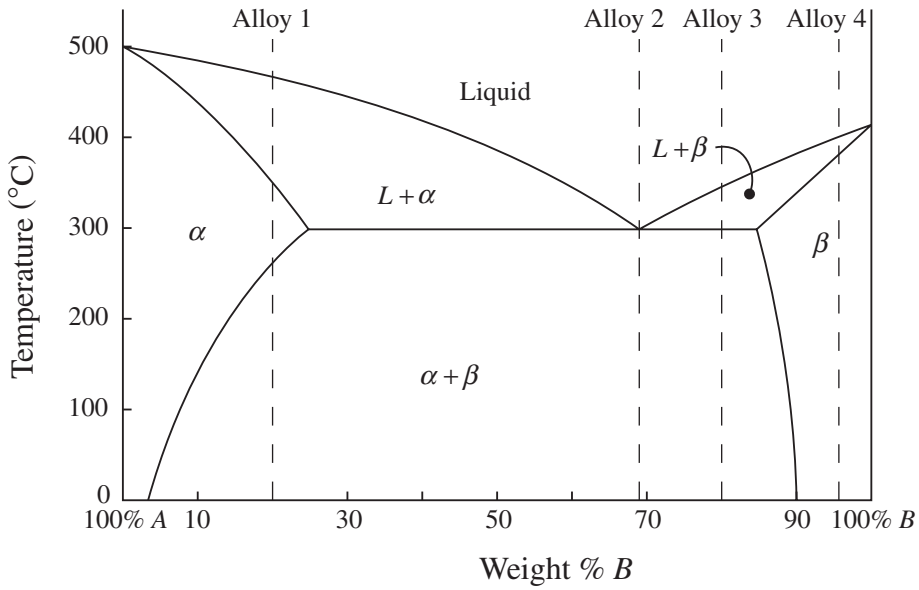
(v) Each link of the supporting chain is formed from cold-drawn steel rod. The join in each link is welded. Describe the effect the welding process has on the strength of the link around the join.

.....

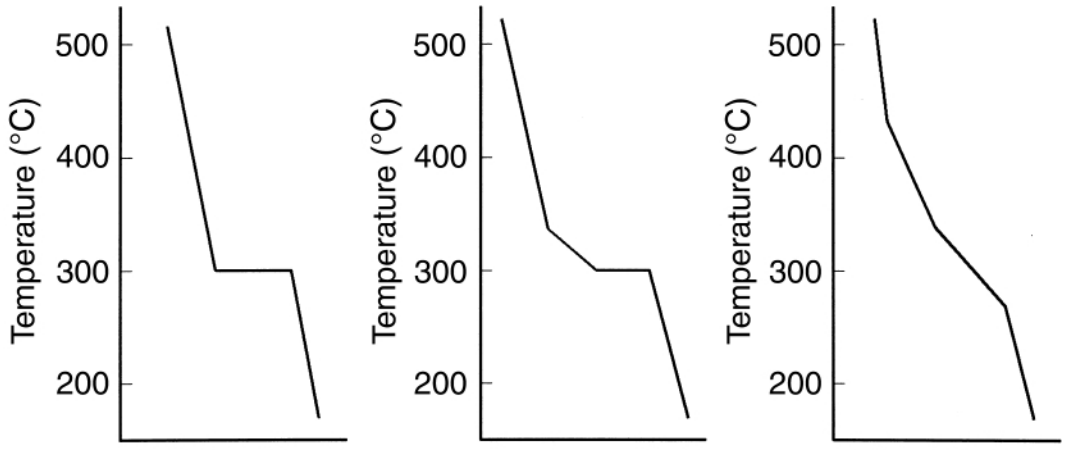
.....

QUESTION 4 **Marks**

(a) The equilibrium (phase) diagram for a binary alloy system of metal *A* and metal *B* is given. Four alloy compositions are indicated. **5**



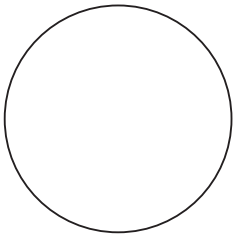
(i) The cooling curves for three of these alloys are shown. Identify each cooling curve, using the appropriate alloy number.



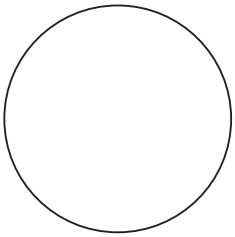
Alloy ..... Alloy ..... Alloy .....

QUESTION 4 (Continued) **Marks**

(ii) Sketch and label the room temperature microstructures for Alloy 1 and Alloy 3.



Alloy 1



Alloy 3

(iii) Alloy 2 at room temperature exhibits strength properties that are vastly different from those of Alloy 4. State the reason for the differences in these properties.

.....

.....

.....

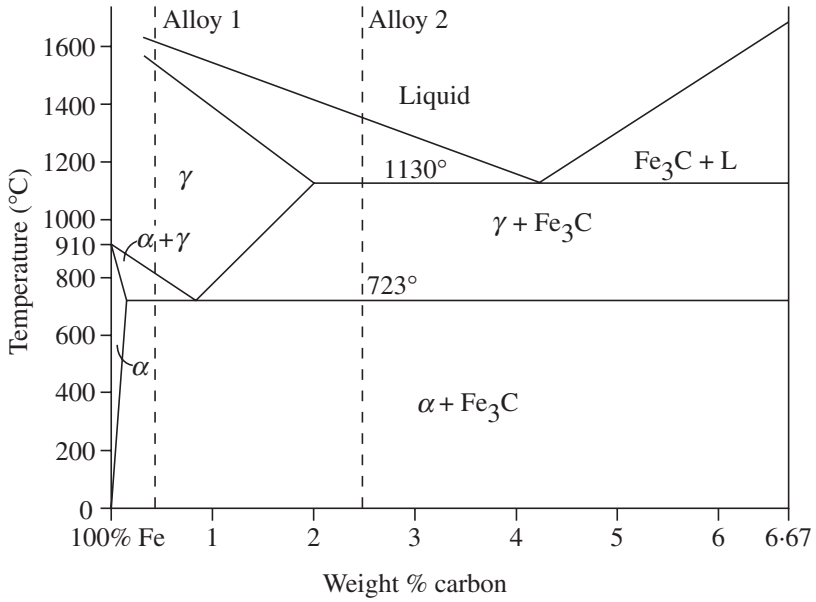
(iv) Write the equation for the reaction that occurs at 300°C during the cooling of Alloy 2.

.....

Question 4 continues on page 12

QUESTION 4 (Continued) **Marks**

(b) A portion of the iron–carbon equilibrium (phase) diagram is given below. **3**

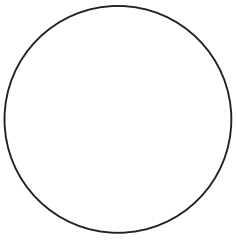


(i) Alloy 2 (2·5% carbon in iron) is indicated on the diagram. Name the TWO phases present at 1200°C.

Name of phase 1 .....

Name of phase 2 .....

(ii) Alloy 1 (0·4% carbon in iron) is cooled under equilibrium conditions to room temperature. This alloy is then used in the production of a cold-drawn spring. Sketch the microstructure of the cold-drawn spring at room temperature.



Cold-drawn spring

(iii) Describe the structural change that occurs in pure iron at 910°C during cooling.

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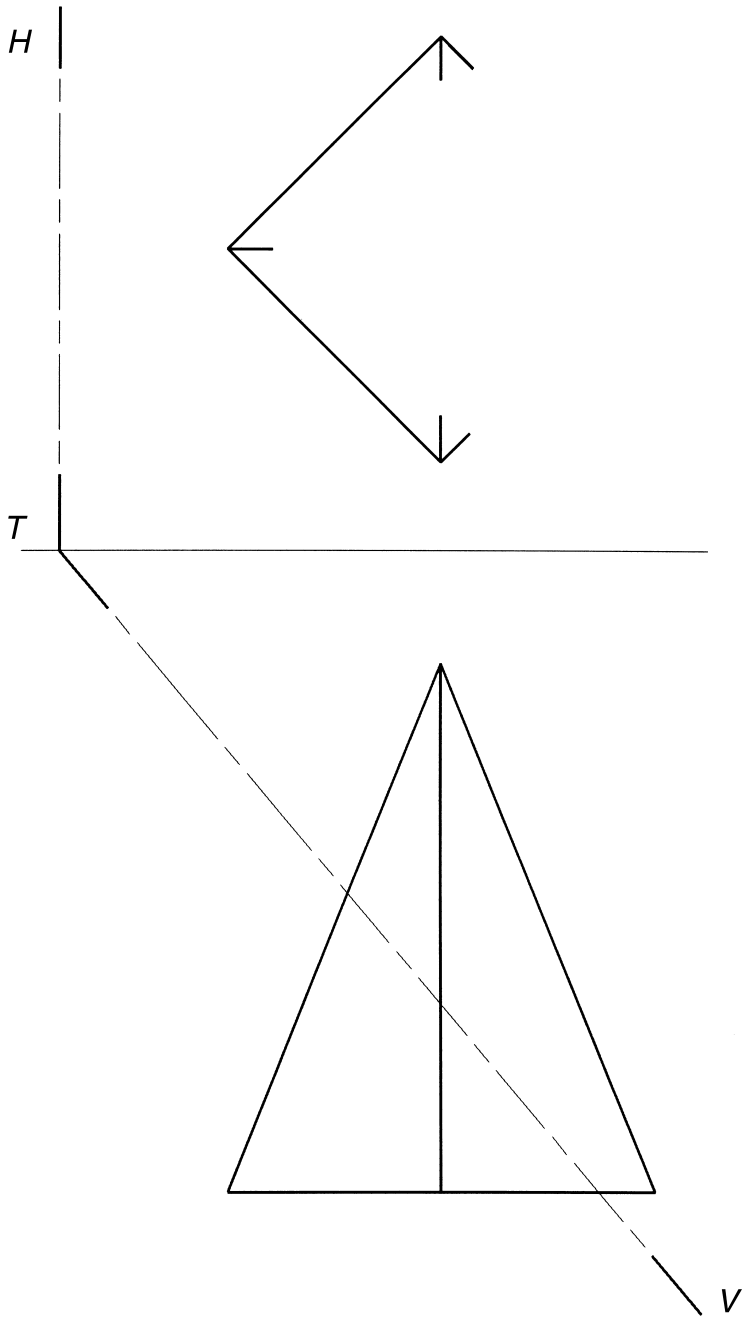
QUESTION 5 **Marks**

(a) The incomplete sectional top view and front view of a square pyramid are shown in third-angle projection. **4**

The square pyramid is cut by a section plane inclined at 50° to the horizontal plane.

(i) Complete the sectional top view.

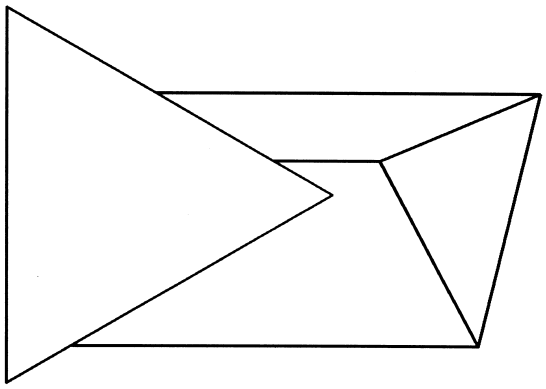
(ii) Construct and label a true shape of the cut surface.

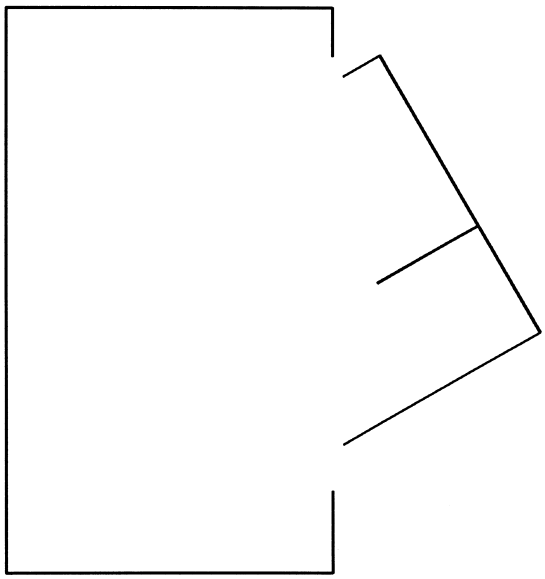


QUESTION 5 (Continued) **Marks**

(b) The top view and incomplete front view of two intersecting triangular prisms drawn in third-angle projection are given. **4**

Complete the front view, showing visible and hidden outlines.



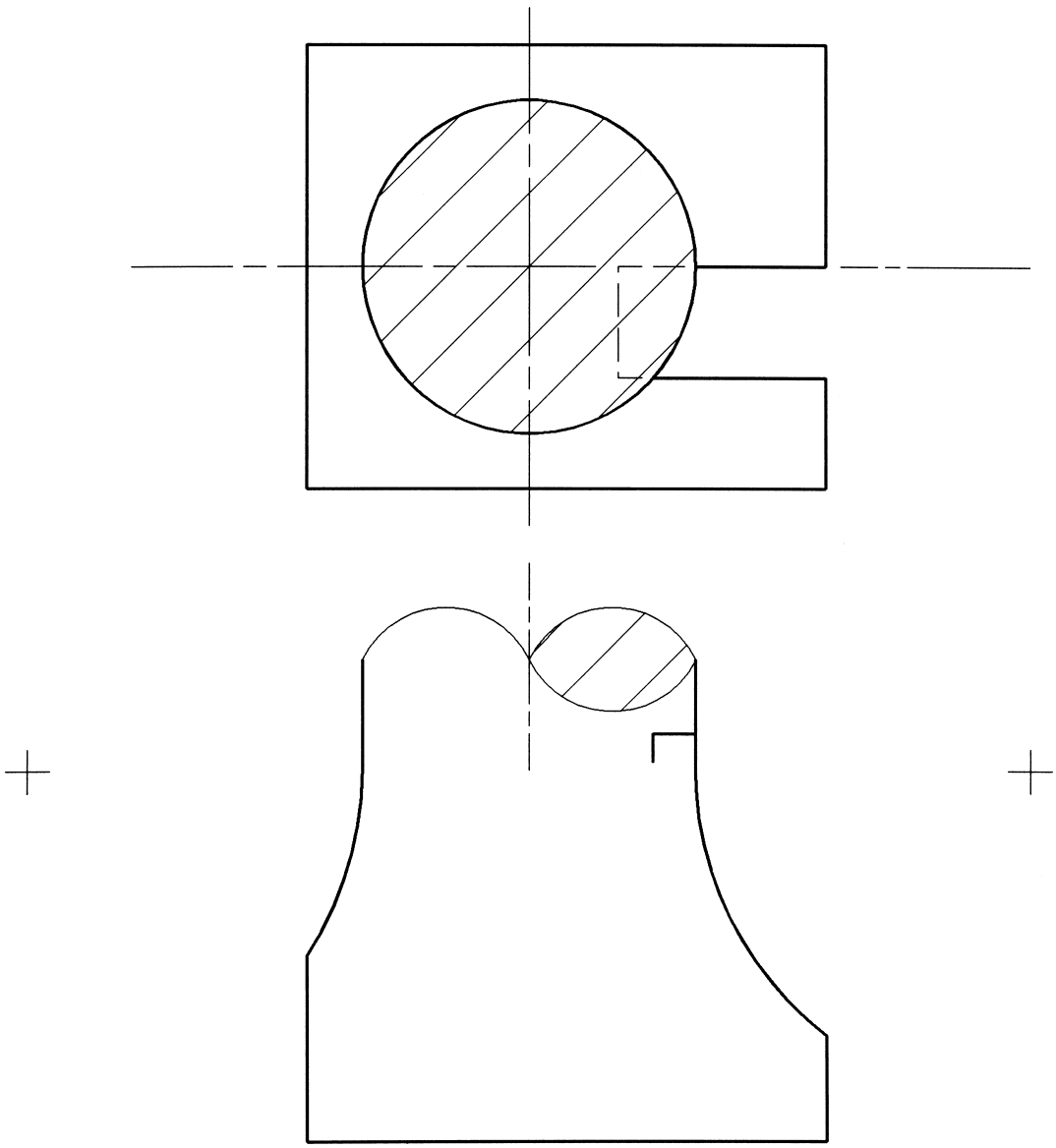


QUESTION 6 **Marks**

(a) The top view and incomplete front view of a rod end are given in third-angle projection. **4**

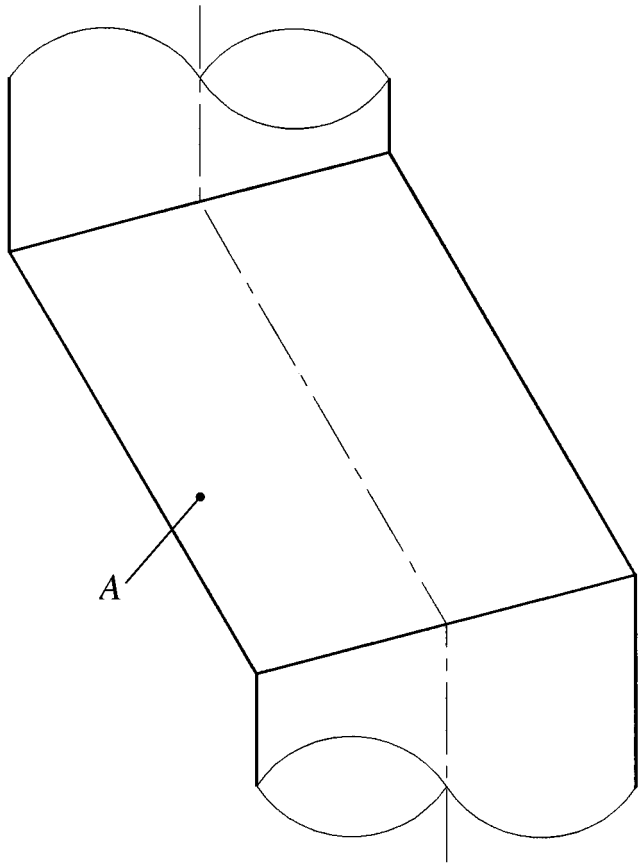
A vertical slot has been removed from the rod end.

Complete the front view, showing visible outline only.



QUESTION 6 (Continued) **Marks**

(b) Three cylindrical sheet metal pipes of equal diameter are joined to form part of a house stormwater downpipe. The front view of the downpipe is given. Complete a half-pattern of the central pipe, marked *A*. **4**



End of Section I

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BOARD OF STUDIES
NEW SOUTH WALES

STUDENT NUMBER

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HIGHER SCHOOL CERTIFICATE EXAMINATION

2000

ENGINEERING SCIENCE

2/3 UNIT (COMMON)

SECTION II

(52 Marks)

Total time allowed for Sections I and II—Three hours
(Plus 5 minutes reading time)

DIRECTIONS TO CANDIDATES

- Write your Student Number and Centre Number at the top right-hand corner of this page.
- Allow approximately 90 minutes for this Section.
- Attempt ALL questions.
- 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 throughout this paper are to scale, unless otherwise stated.
- Drawing instruments and Board-approved calculators may be used.

MARKER'S USE ONLY

Question	Max. Marks	Marks Awarded	Marks Checked
7	8		
8	8		
9	8		
10	8		
11	8		
12	12		
TOTAL	Max. 52		

QUESTION 7 **Marks**

Five stages in the evolution of braking systems are represented in the diagrams A–E in Figure 1.

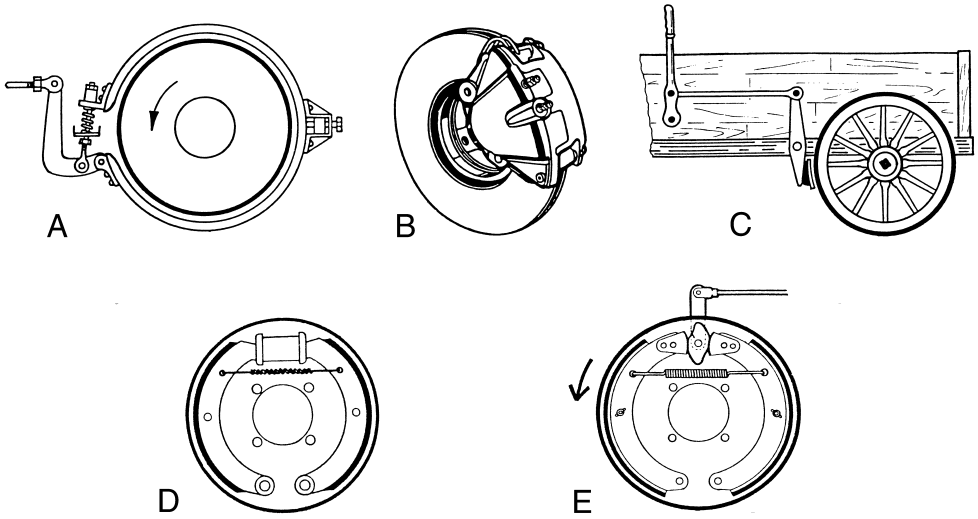
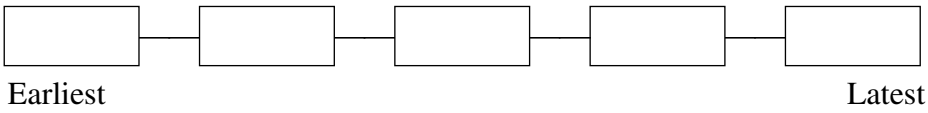


FIG. 1

(a) (i) Indicate the historical sequence of the braking systems by placing the appropriate letters (A–E) in the relevant boxes on the time line provided. **4**



(ii) The braking system shown in Figure 3 improved the maintenance and performance characteristics of the braking system shown in Figure 2. Describe ONE performance improvement and ONE maintenance improvement resulting from the design changes.

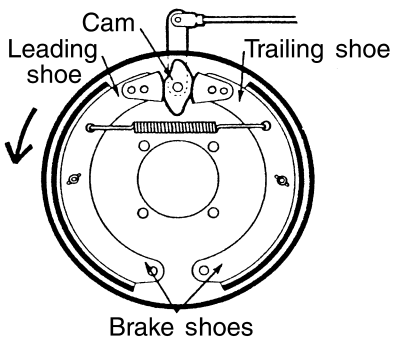


FIG. 2

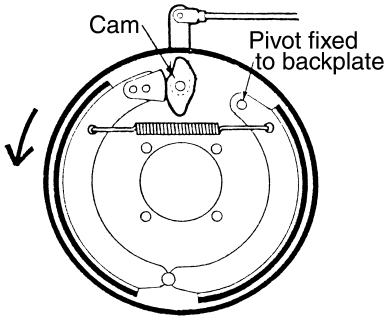


FIG. 3

Performance .....

.....

Maintenance .....

.....

QUESTION 7 (Continued) **Marks**

(b) Heat generated during the application of drum brakes causes a loss of effectiveness. Describe TWO reasons for this loss of effectiveness due to heat. **2**

Reason 1 .....

.....

.....

Reason 2 .....

.....

.....

(c) State TWO advantages of hydraulic braking systems over mechanical braking systems. **1**

Advantage 1 .....

Advantage 2 .....

(d) Describe how the introduction of the ABS (Anti-lock Braking System) has improved the effectiveness of braking safety in motor vehicles. **1**

.....

.....

.....

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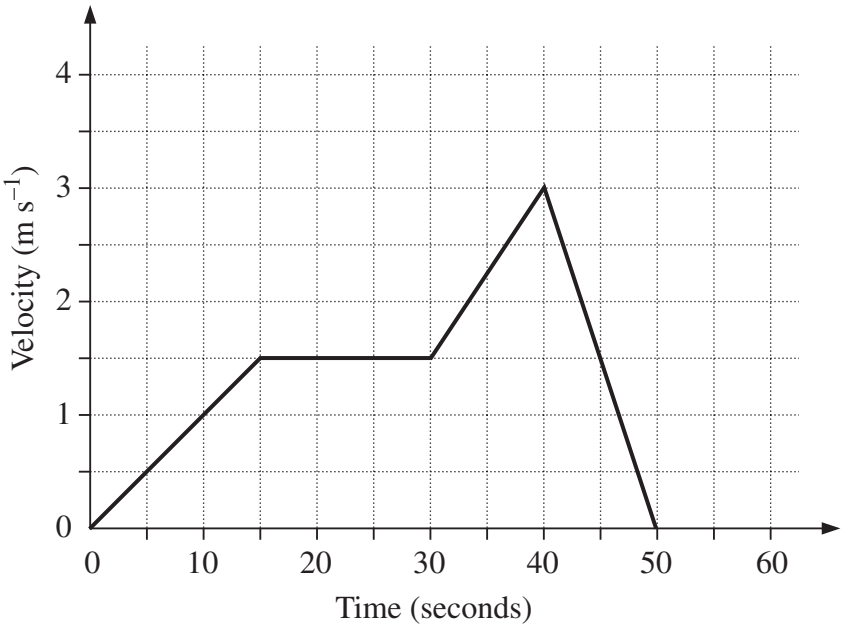
QUESTION 8 **Marks**

(a) A velocity–time graph of a bicycle and rider is plotted. **5**



(i) Complete the table by inserting the values obtained from the velocity–time graph.

Velocity (m s^{-1})	0			3·0	
Time (s)	0	15	35		50

(ii) Describe the motion between the twenty-fifth (25th) and the thirty-fifth (35th) seconds.

.....

.....

(iii) Determine the total distance travelled by the rider between the thirtieth (30th) and fiftieth (50th) seconds.

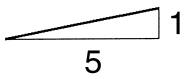
Distance travelled ..... m

QUESTION 8 (Continued) **Marks**

(iv) Determine the time taken to travel the first 20 metres.

Time taken ..... s

(b) The bicycle and rider have a combined mass of 110 kg. The rider pedals up a hill of gradient of 1 : 5 with a constant velocity of 10 km/h. The frictional resistance to motion is 15 N per kg mass. **3**



(i) Determine the driving force of the rider.

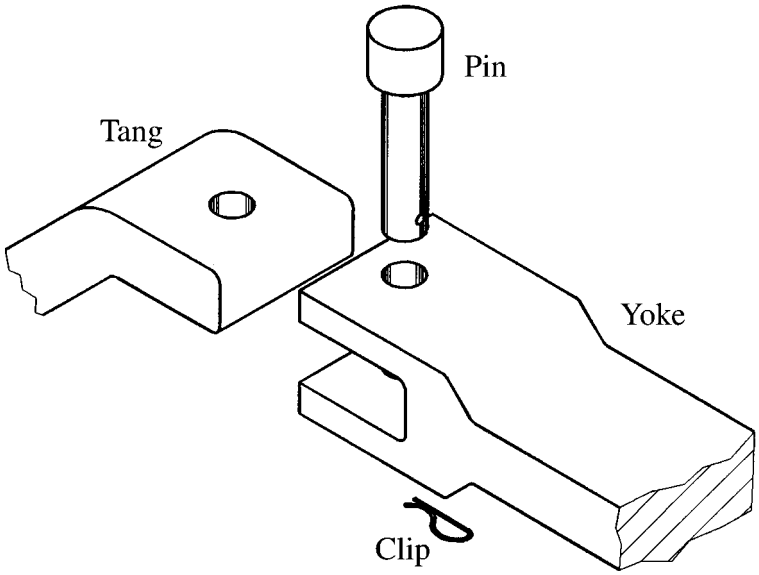
Driving force ..... N

(ii) Determine the power developed by the rider.

Power developed ..... kW

QUESTION 9 **Marks**

The clevis-pin linkage shown is used to connect a small trailer to a bicycle.



(a) (i) The loaded trailer requires a horizontal force of 800 N to keep moving at a constant velocity of $6\ m\ s^{-1}$. Determine the maximum shear stress in the pin if it has a diameter of 8 mm. **3**

Shear stress ..... MPa

(ii) In a linkage such as this, it is preferable for the pin to be made from a softer material than either the yoke or the tang. State a reason for this.

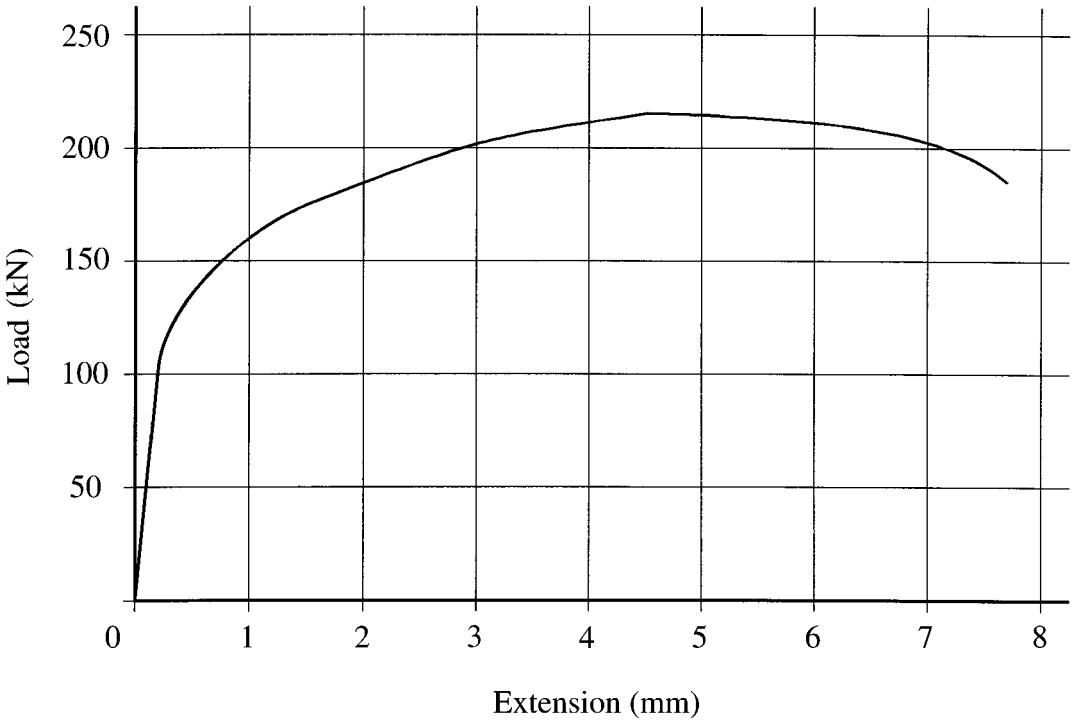
.....

.....

.....

QUESTION 9 (Continued) **Marks**

(b) The load-extension graph shown was obtained from a tensile test of a material used to produce the tang and the yoke. The test piece had a gauge length of 60 mm and a cross-sectional area of 100 mm^2. **5**



(i) Determine the strain at the proportional limit.

Strain .....

(ii) The stress at the elastic limit is slightly higher than the stress at the proportional limit. Describe how the elastic limit for a material is determined.

.....

.....

.....

Question 9 continues on page 28

QUESTION 9 (Continued) **Marks**

(iii) Determine the Young's modulus for the material.

Young's modulus ..... GPa

(iv) Determine the ultimate tensile strength (UTS) of the material.

UTS ..... MPa

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QUESTION 10 **Marks**

(a) A lawnmower fuel tank is to be manufactured from high density polyethylene (HDPE). **4**

(i) Name and describe a suitable manufacturing process for the fuel tank.

Name .....

Description .....

.....

.....

(ii) State TWO service properties required for the fuel tank.

Property 1 .....

Property 2 .....

(iii) The structure of the high density polyethylene has a degree of cross-linking. Explain the need for the presence of cross-linking in this structure.

.....

.....

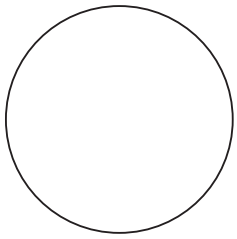
QUESTION 10 (Continued) **Marks**

(b) A modern grasscatcher is to be manufactured from a glass-filled polymer composite. **4**

(i) State the purpose of the addition of the glass fibres.

.....

(ii) Sketch and label a macrostructure of the glass-filled polymer.



(iii) An alternative method of manufacturing the grasscatcher is by rotational moulding. Describe this process.

.....

.....

.....

.....

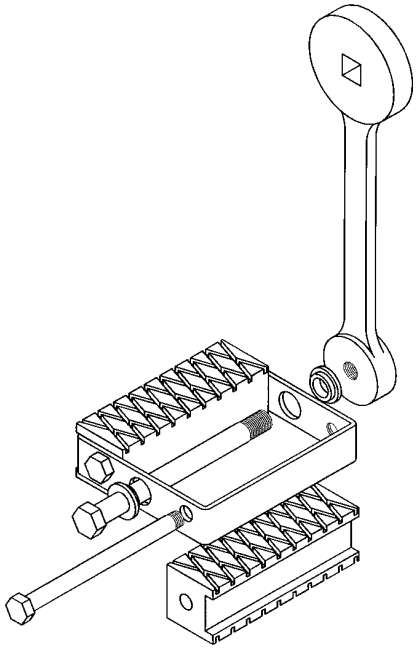
(iv) Early grasscatchers were manufactured using canvas. Canvas was replaced by pressed low-carbon steel, which was later replaced by a polymer. State ONE reason why each of these earlier grasscatchers was superseded.

Canvas .....

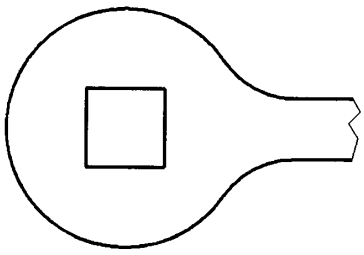
Low-carbon steel .....

QUESTION 11 **Marks**

A bicycle pedal and crank assembly is shown.



(a) (i) The crank is formed by hot forging. A round hole is formed during forging and is later machined square. Sketch the grain flow on the portion of the crank shown. **3 1/2**



(ii) Hot working is carried out above a particular temperature. State the name given to this temperature.

.....

(iii) State TWO factors that control the grain size of a hot-worked metal.

Factor 1 .....

Factor 2 .....

QUESTION 11 (Continued) **Marks**

(iv) Hot-worked steels often undergo a small amount of cold working during final stages of manufacture. State TWO advantages gained by this cold working.

Advantage 1 .....

Advantage 2 .....

(v) The finished crank is surface coated with chromium. Name this process.

.....

(b) A bolt is used to attach the pedal to the crank. **$1\frac{1}{2}$**

(i) Describe ONE method of mass-producing the thread on the bolt.

.....

.....

(ii) During use, there is sometimes a tendency for one of the bolts to work loose, due to the direction of rotation. State ONE method of preventing the bolt from working loose.

.....

(c) Low-carbon steel bolts are used to secure the pedal blocks to the pedal frame. **3**

(i) Describe a forming process used to shape the bolt heads.

.....

.....

(ii) The rubber pedal blocks are manufactured with deeply grooved surfaces and a central hole for the bolt. Briefly describe a manufacturing method that could achieve these features in one process.

.....

.....

(iii) The frame of the pedal assembly is manufactured from cold-rolled 0·2% carbon steel. Name ONE mass production method, other than drilling, that could be used for the holes in the frame.

.....

QUESTION 12 **Marks**

Shape and size details of a push-rod assembly are shown. **12**

The centre line for the position of the hole through the yoke has been given. The centre line for the right-side view is also given.

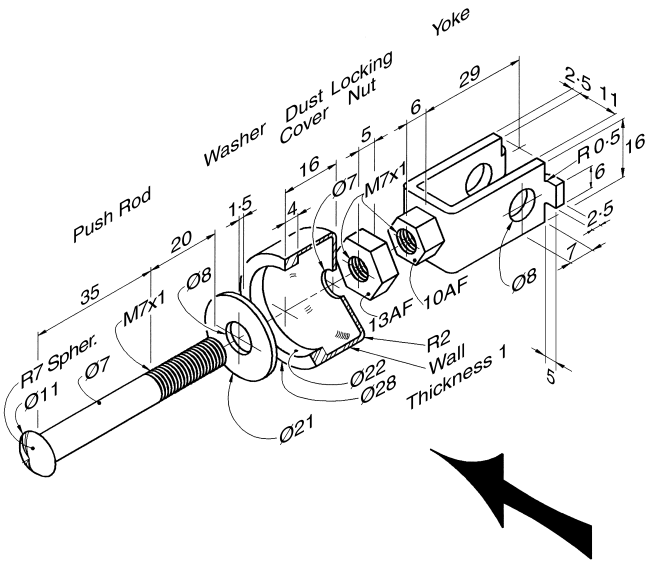
The threaded end of the push-rod should extend 5 mm through the yoke.

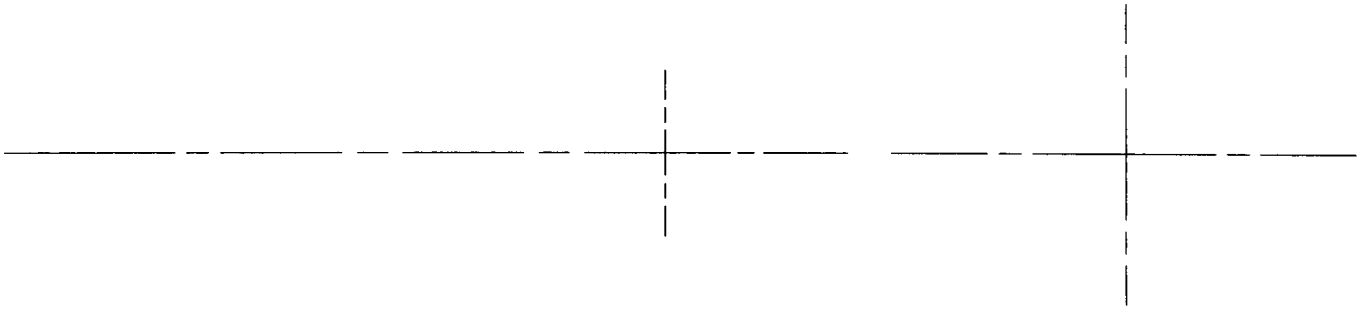
Using a scale of 2 : 1,

(a) complete the front view of the yoke assembly when viewed in the direction of the arrow. AS1100 drawing standards must be used to show a break in the shaft of the push-rod 28 mm from the right hand end;

(b) complete the right-side view of the yoke assembly. Do NOT include hidden outline.

The washer and dust cover are not to be included in either view.





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2000
HIGHER SCHOOL CERTIFICATE EXAMINATION
ENGINEERING SCIENCE
2/3 UNIT (COMMON)

Not to be collected at the conclusion of the examination.

FORMULAE

Dynamics

$v = u + at$

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

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

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

$F = ma$

$I = Ft = m(v-u)$

$M = mv$

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

$PE = mgh$

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

$F = kx$

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

$W = Fs$

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

$\sigma = \frac{P}{A}; \quad \varepsilon = \frac{e}{L}; \quad E = \frac{\sigma}{\varepsilon}; \quad \%RA = \frac{A_0 - A}{A_0} \times 100; \quad FS = \frac{\sigma_{\text{yield}}}{\sigma_{\text{working}}}$

Area of circle

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

Circumference of circle

$C = \pi d$

ROUGH WORK SHEET

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