BOARD OF STUDIES
NEW SOUTH WALES

STUDENT NUMBER

CENTRE NUMBER

HIGHER SCHOOL CERTIFICATE EXAMINATION

1996

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

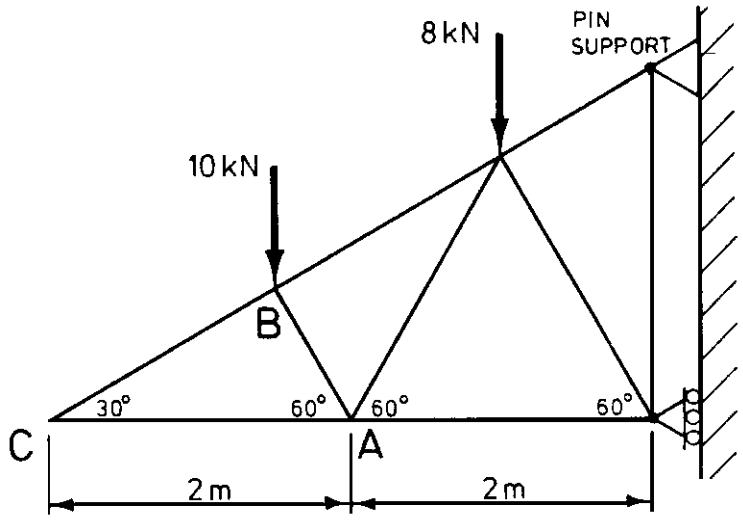
- Write your Student Number and Centre Number at the top right-hand corner of this page.
- Allow approximately 90 minutes for this Section.
- Attempt ALL questions.
- Answer the questions in the spaces provided in this paper. Set out your working clearly and neatly. Emphasis will be placed on that working when marks are allocated.
- 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.
- The Data and Rough Work Sheet will not be collected.

EXAMINER'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**

(a) The pin-jointed truss drawn below is loaded by an 8 kN force and a 10 kN force as shown. **5**



(i) Determine the magnitude and sense of the horizontal and vertical components of the reaction at the pin support.

Reaction: *horizontal* component ..... kN Sense .....

vertical component ..... kN Sense .....

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

Magnitude of force in *AB* …… kN

Nature of force in *AB* ……

QUESTION 1. (Continued) **Marks**

(b) A baseball batter hits a ball directly towards a fielder standing 100 m away. The ball leaves the bat with a velocity having horizontal and upward vertical components each of 20 m/s. The fielder starts to run towards the ball at the instant it is hit. The ball is caught at the same height above the ground that it was initially hit. **3**

(i) Determine the time that the ball is in the air.

Time …… s

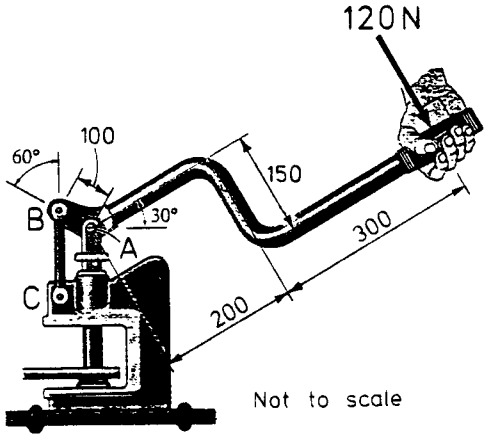
(ii) Determine the distance moved by the fielder to catch the ball.

Distance …… m

QUESTION 2 **Marks**

(a) A hand-operated punch, fixed to a bench, is shown below. A force of 120 N is applied perpendicular to the handle. **3**

(i) Determine the force in the link *BC*.



Force in *BC* …… N

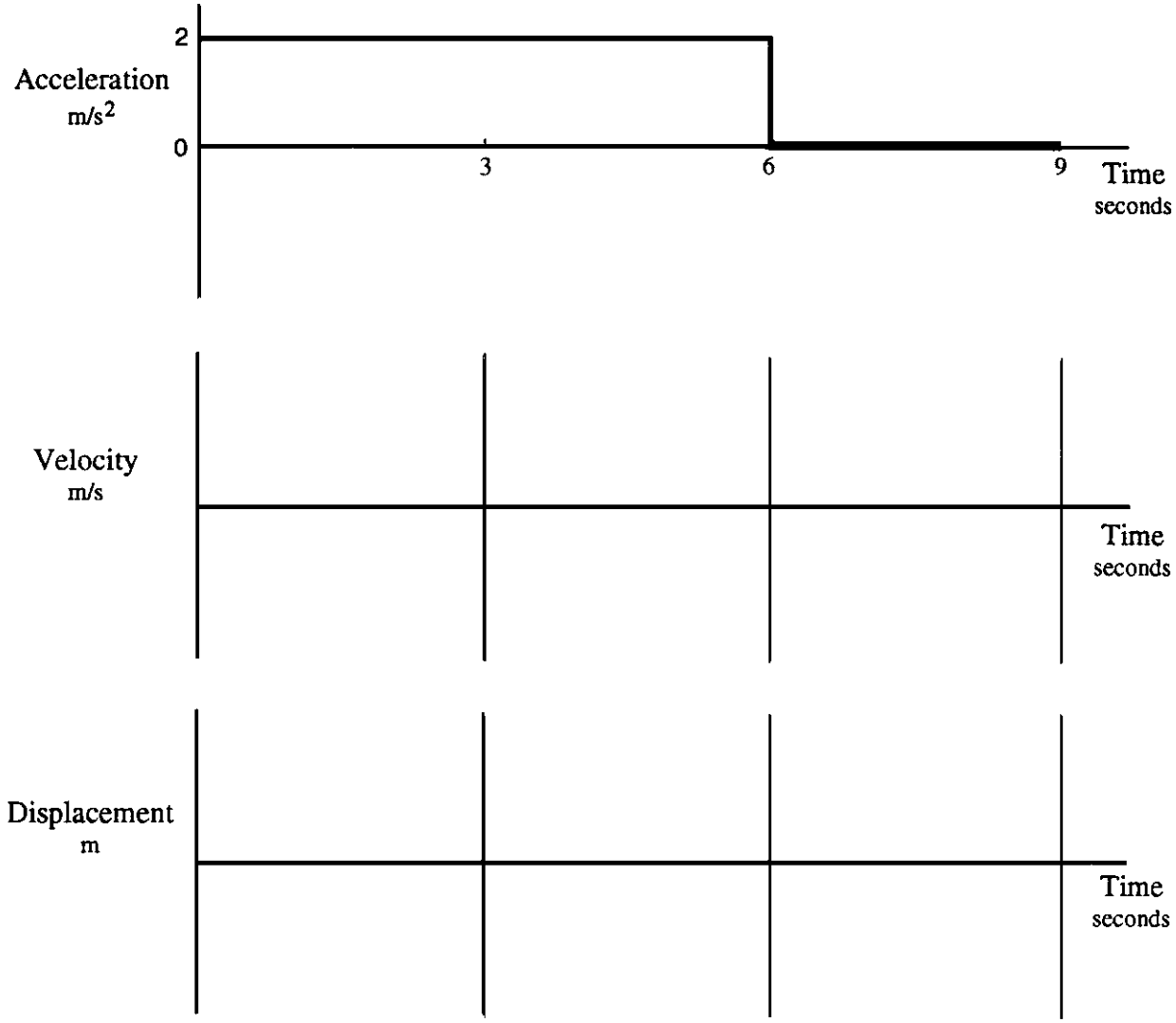
(ii) If the link *BC* has a diameter of 6 mm, determine the axial stress in the link.

Axial stress …… MPa

(b) A person of mass 60 kg jumps down from a dock onto a raft of mass 130 kg. The raft is initially at rest in the water. At the point of impact with the raft, the person has a velocity of 2·4 m/s at 30° to the horizontal. Determine the horizontal velocity of the raft immediately after the person lands on it. **2**

QUESTION 2. (Continued) **Marks**

(c) A car moves in a straight line with an acceleration–time relationship as shown below. Complete the velocity–time and displacement–time diagrams. Label the relevant values. The initial velocity of the car is zero. **3**



QUESTION 3 **Marks**

(a) Complete the following table. **1**

Mechanical test	*Property determined*
Charpy test	
	Ductility
Transverse test	
Rockwell test	

(b) (i) Describe the production process for domestic window glass. **5**

……

……

……

……

(ii) Describe the method of manufacture of toughened glass for use in sliding doors.

……

……

……

……

(iii) Toughened glass fractures when struck by a stone. Draw and label the macrostructure showing the fracture.

(iv) Draw and label the macrostructure showing the fracture of laminated glass.

QUESTION 3. (Continued) **Marks**

(c) With reference to bonding, explain why a specimen of MgO has a brittle fracture under tensile loading. **1**

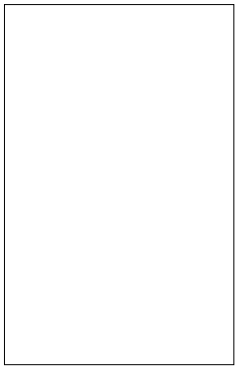
……

……

……

……

(d) A concrete specimen is tested to destruction in a compression test. Draw and label the type of failure that would occur. **1**



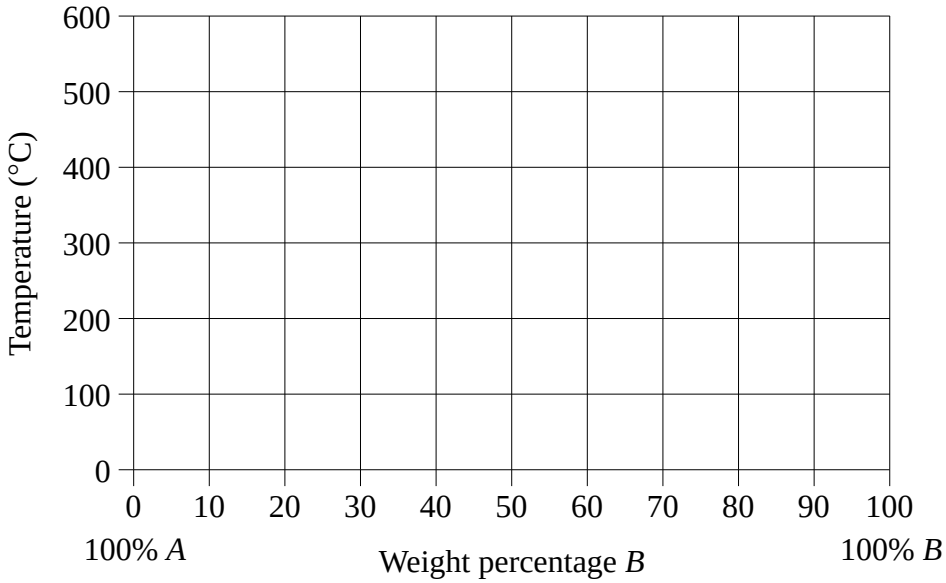
CONCRETE SPECIMEN

QUESTION 4 **Marks**

(a) The following data relate to the equilibrium diagram for two metals, *A* and *B*. **3**

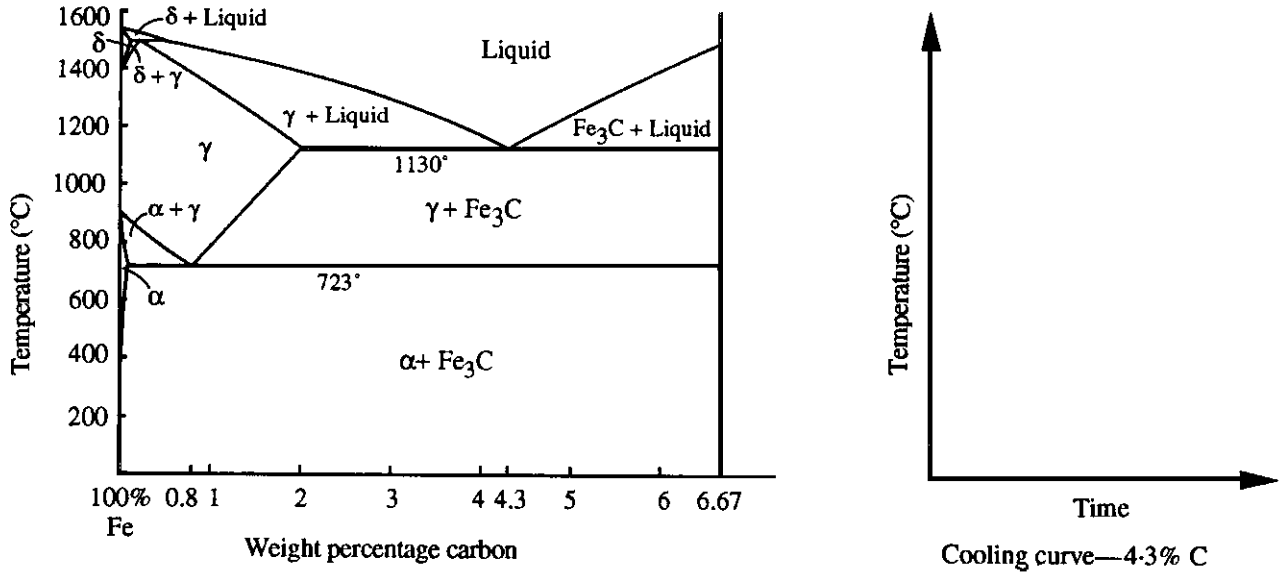
- *A* and *B* are completely soluble in the liquid state.
- The melting-point of metal *A* is 500°C.
- The melting-point of metal *B* is 400°C.
- The eutectic temperature is 300°C.
- The eutectic composition is 40% *A* – 60% *B*.
- The solubility of *A* in *B* at 300°C is 20%.
- The solubility of *A* in *B* at 50°C is 5%.
- *B* is insoluble in *A* in the solid state.

Draw the equilibrium diagram for metals *A* and *B* on the grid provided below. Label *all* the phase areas of the diagram.



QUESTION 4. (Continued) **Marks**

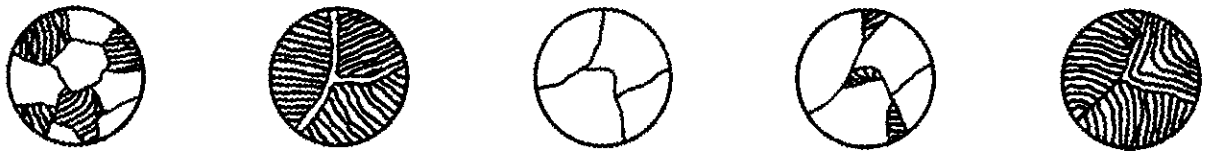
(b) A portion of the iron–carbon phase diagram is given below. **5**



(i) On the given axes to the right of the phase diagram, draw the cooling curve for a specimen of 4·3% carbon. The specimen is cooled under equilibrium conditions from 1500°C to 100°C. Label the phases.

(ii) Five numbered microstructures are shown below. Equilibrium cooling of a 1·2% carbon steel, a 0·4% carbon steel, and a 0·1% carbon steel produces THREE of the numbered microstructures. Identify these THREE microstructures by labelling the relevant carbon content on the lines provided.

1 2 3 4 5



…… …… …… …… ……

(iii) The phases in the above five numbered microstructures are either ferrite or cementite. Write the number corresponding to:

- the microstructure representing the most brittle material ……
- the microstructure representing the most ductile material ……
- the microstructure representing the eutectoid composition ……

QUESTION 5 **Marks**

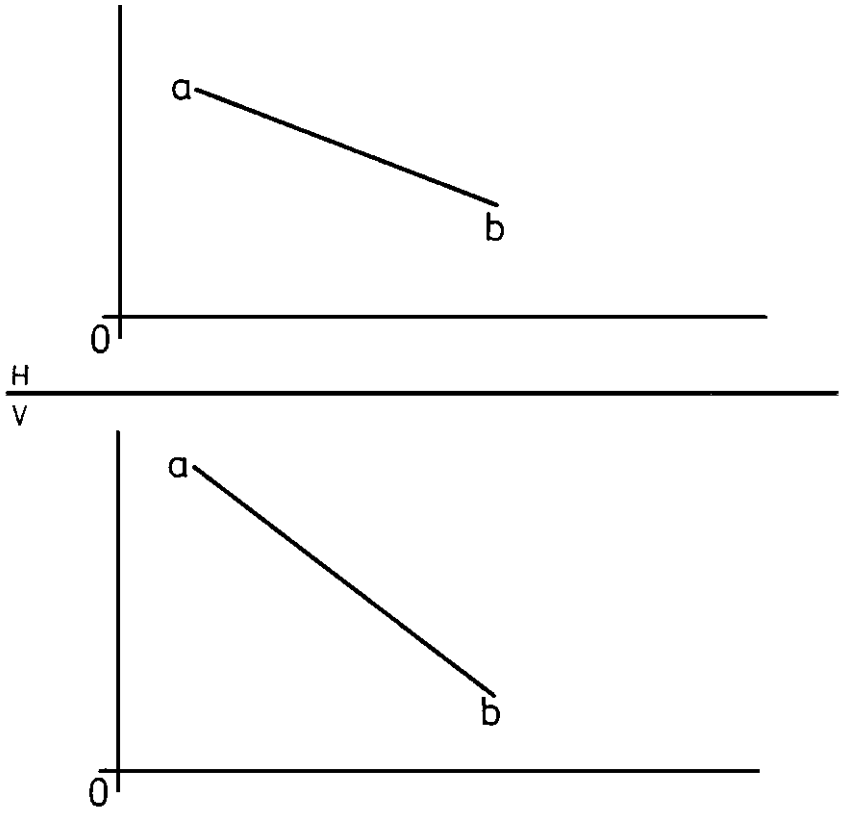
(a) The top and front views of a line *AB* are drawn below. **4**

The coordinates for the points *A* and *B* and a point *C* are given.

	X	*Y*	*Z*
A	10	30	40
B	50	15	10
C	80	50	20

(i) Complete the top and front views of triangle *ABC*.

(ii) Determine the true angle of inclination of edge *AB* to the horizontal.

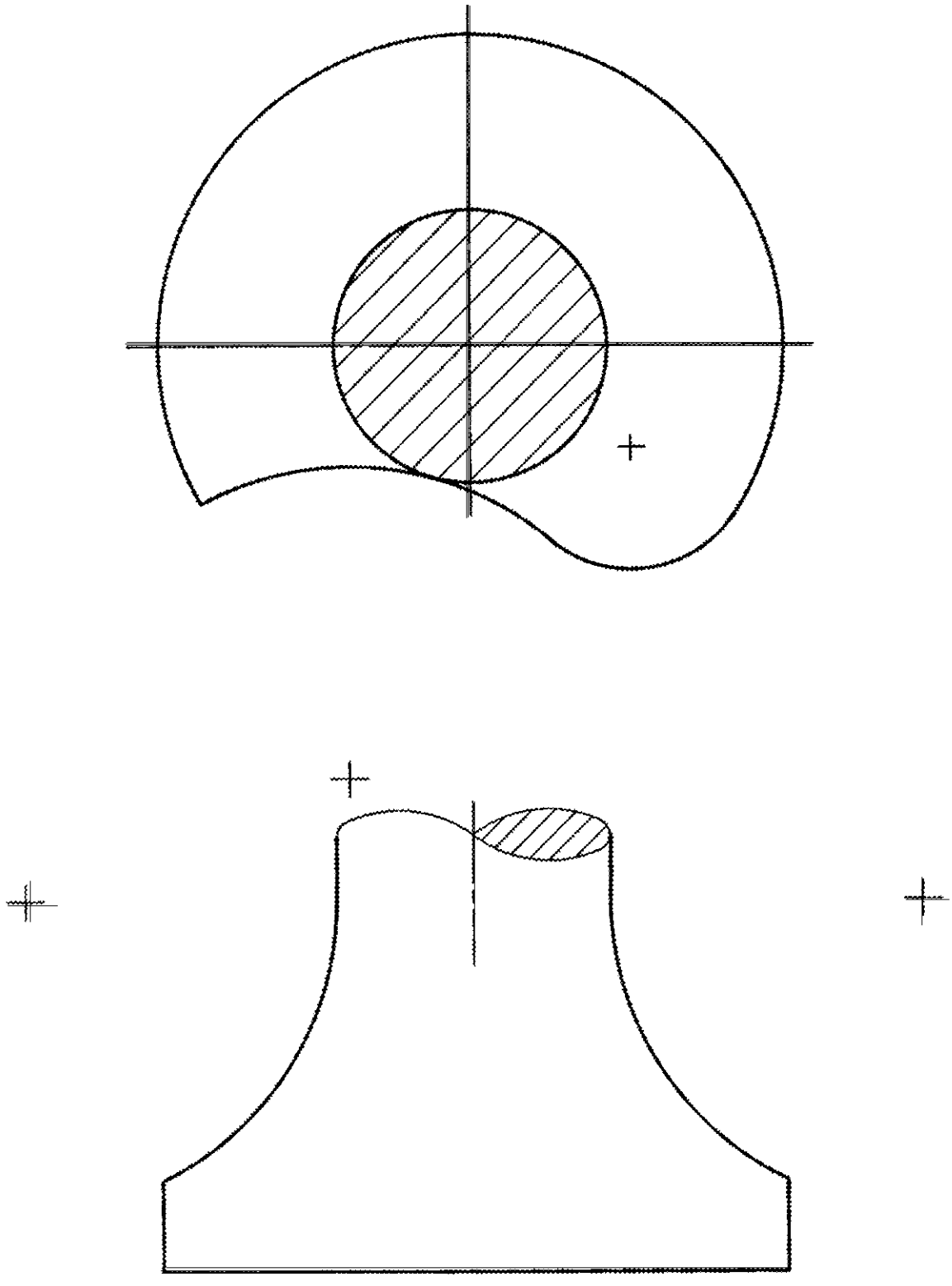


True inclination of *AB* to horizontal ……

QUESTION 5. (Continued) **Marks**

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

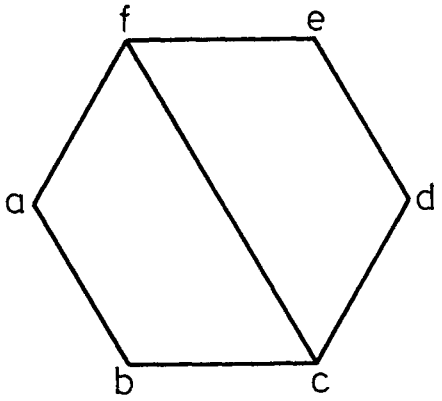
Complete the front view.

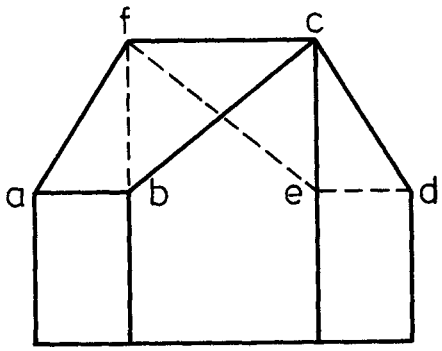


QUESTION 6 **Marks**

(a) The top view and front view of a hexagonal block are given below in third-angle projection. **3**

Project from the front view a right-side view.

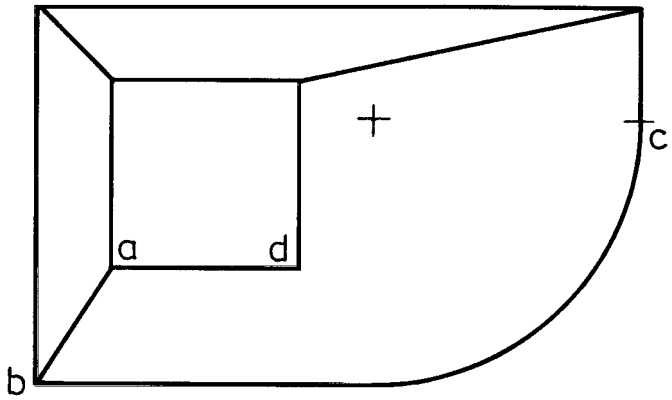


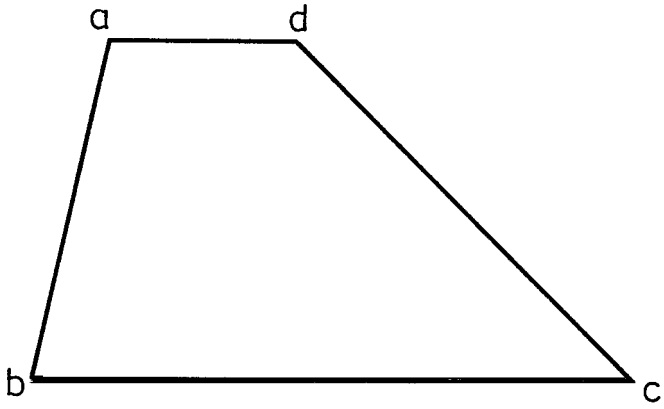


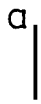
QUESTION 6. (Continued) **Marks**

(b) The top view and front view of part of an air-conditioning duct are shown below in third-angle projection. **5**

Complete a pattern for surface ***abcd***. The starting position for the seam ***ab*** is given below.







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1996

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.
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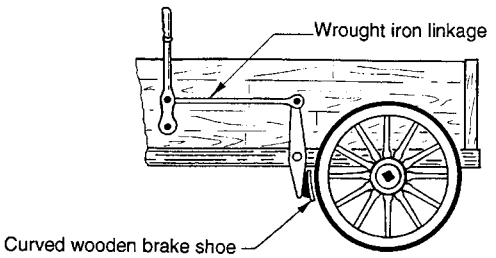
EXAMINER'S USE ONLY

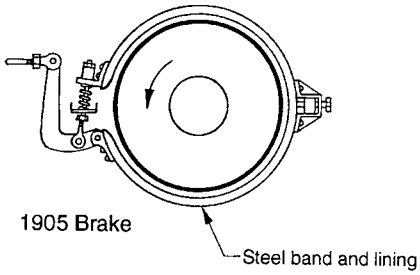
Question	Max. Marks	Marks Awarded	Marks Checked
7	8		
8	8		
9	8		
10	8		
11	8		
12	12		
TOTAL	Max. 52		

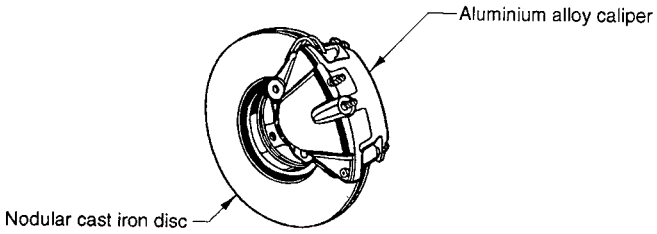
QUESTION 7 **Marks**

The brake systems shown below were appropriate for the vehicles on which they were used.



1850 Brake





1980 Brake

(a) For the 1850 brake system: **$2\frac{1}{2}$**

(i) State TWO major reasons why this system was appropriate for stopping the vehicle.

1. ……

2. ……

(ii) Wrought iron was the material used to construct the brake linkage. State TWO reasons for its use.

1. ……

2. ……

(iii) Name the manufacturing method used in the production of the brake linkage.

……

QUESTION 7. (Continued) **Marks**

(b) For the 1905 brake system: **$2\frac{1}{2}$**

(i) State TWO major reasons why this system was appropriate for stopping the vehicle.

1. ……

2. ……

(ii) State why the lining was included in this system.

……

……

……

(iii) State a major disadvantage of the design of this system.

……

……

(c) For the 1980 brake system: **$2\frac{1}{2}$**

(i) State TWO major reasons why this system was appropriate for stopping the vehicle.

1. ……

2. ……

(ii) Aluminium alloy was the material used to construct the brake caliper. State TWO reasons for its use.

1. ……

2. ……

(iii) Name the manufacturing method used in the production of the brake caliper.

……

(d) State a change which occurred to brake pad materials to improve the diffusion of heat. **$\frac{1}{2}$**

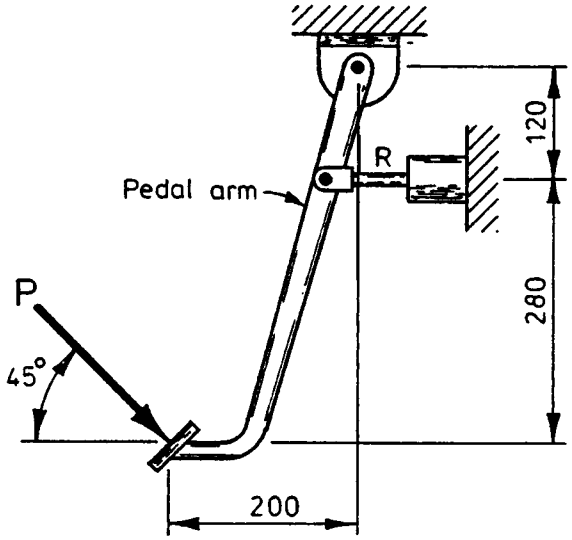
……

……

……

QUESTION 8 **Marks**

(a) A force *P* acts on a brake pedal at an angle of 45° to the horizontal as shown. A horizontal force of 800 N is transmitted to the push rod at *R*. **5**

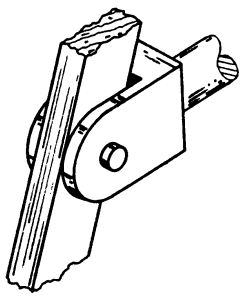


(i) On the above diagram, show all the forces acting on the pedal arm.

(ii) Determine the magnitude of the force *P*.

Force *P* …… N

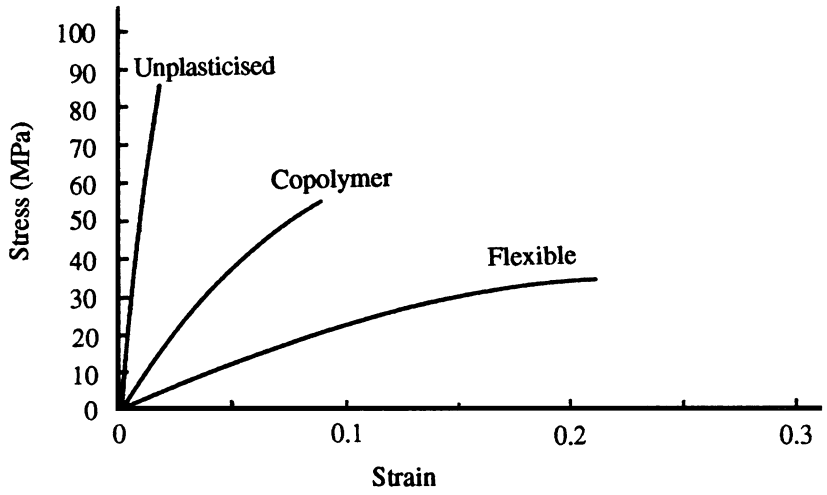
(iii) The push rod is connected to the pedal arm as shown in the pictorial drawing. Determine the minimum diameter of the pin required to connect the push rod to the pedal arm. The maximum shear stress in the pin is to be 75 MPa.



Minimum diameter …… mm

QUESTION 8. (Continued) **Marks**

(b) A rod, of length 125 mm and diameter 5 mm, is required to support a maximum tensile load of 900 N in a bicycle component. The extension of the rod is to be limited to 6 mm. **3**



Using the information from the above stress–strain curves, determine which material would best satisfy the rod specifications given above.

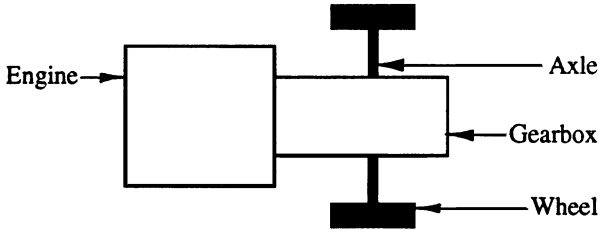
Prove by calculation that your selection is correct.

Material selected ……

QUESTION 9 **Marks**

(a) (i) The crankshaft of an engine in a ride-on mower is connected through a gearbox to the driving axle. The overall gear ratio between the engine and the axle is 25 : 1. **4**

If the axle drives a wheel 200 mm in diameter, determine the speed of the mower when the engine is turning at 1700 r.p.m.



SCHEMATIC DIAGRAM

Speed …… m/s

(ii) When moving at a constant velocity of 5 km/h, the resistance to motion of the mower is 140 N. The power developed by the engine is 220 W.

Determine the overall efficiency of the drive.

Efficiency …… %

QUESTION 9. (Continued) **Marks**

(b) A bicycle and rider have a total mass of 95 kg. The rider is able to coast down a 5° incline at a constant speed of 10 km/h without pedalling. **4**

(i) Determine the resistance to motion when the rider is travelling at 10 km/h.

Resistance to motion …… N

(ii) On a level road, the rider must exert an average force of 400 N on the pedals to maintain a speed of 10 km/h. Determine the mechanical advantage of the system.

Mechanical advantage ……

(iii) While travelling at a speed of 10 km/h, the rider suddenly increases the average pedal force to 550 N. The tractive force at the rear wheel increases in proportion to the increase in pedal force.

Determine the acceleration of the bicycle and rider.

Acceleration …… m/s^2

QUESTION 10 **Marks**

A pictorial drawing of a carburettor assembly for a lawnmower is shown below.

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(a) The carburettor body is manufactured by injection moulding from a 15% glass-filled polyester composite. **1**

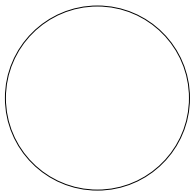
List ONE manufacturing property and ONE service property that the glass filler provides to the composite.

(i) Manufacturing property ……

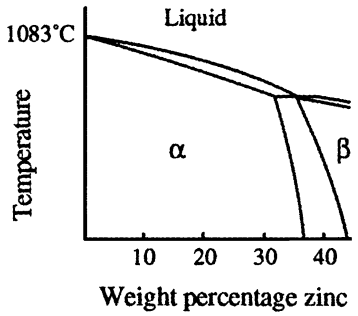
(ii) Service property ……

(b) The jet is machined from a cold-drawn rod of 70–30 brass. **1**

Draw and label the microstructure of the cold-drawn 70–30 brass. A schematic drawing of the Cu–Zn equilibrium diagram is given to assist in your answer.



COLD-DRAWN 70–30 BRASS



Cu–Zn EQUILIBRIUM DIAGRAM

(c) Nitrile, a synthetic rubber made by *addition polymerisation*, is used to manufacture the priming bulb. **1½**

(i) Define *addition polymerisation*. ……

……

(ii) State TWO major service properties of the nitrile used for the priming bulb.

1. ……

2. ……

QUESTION 10. (Continued) **Marks**

(d) Most rubbers, despite *vulcanisation*, are still *unsaturated polymers*. **1**

(i) Define the term *unsaturated polymer*. ……

……

(ii) Explain the term *vulcanisation.* ……

……

(e) The fuel tank on a mower is mass produced in two parts from high-density polyethylene (HDPE) by injection moulding. **2**

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(i) Describe the process of injection moulding.

……

……

……

……

(ii) 70% of HDPE contains crystallites; the remaining 30% is amorphous. Explain the term *crystallites.*

……

……

……

Question 10 continues on page 26

QUESTION 10. (Continued) **Marks**

(f) $\mathbf{1\frac{1}{2}}$

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(i) Neoprene, a synthetic rubber made by addition copolymerisation, is used to manufacture the cover for the spark plug lead.

Define *copolymerisation*. ……

……

……

(ii) The cylinder head is manufactured by pressure die casting from an aluminium alloy.

List ONE manufacturing property and ONE service property of the aluminium alloy.

(i) Manufacturing property ……

(ii) Service property ……

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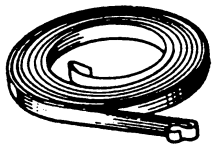
QUESTION 11 **Marks**

(a) The recoil spring shown below is shaped from cold-rolled 0·25% carbon steel. The ends are annealed and then bent. **1**

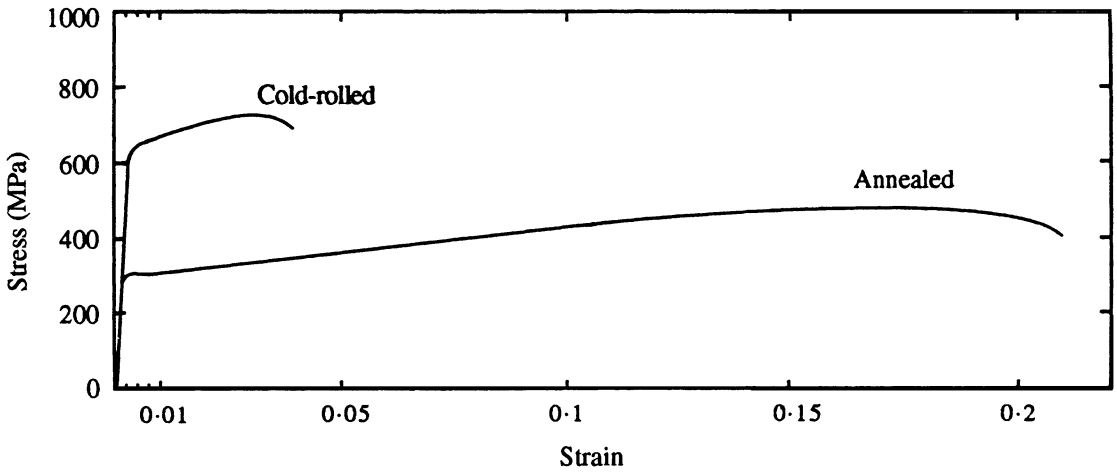
Draw and label the microstructure of the annealed portion of the 0·25% carbon steel spring.



RECOIL SPRING

ANNEALED 0·25% CARBON STEEL

(b) Stress–strain curves for 0·25% carbon steel in the annealed condition and in the cold-rolled condition are shown below. **3**



(i) Use the data from the diagram to determine the following:

1. The UTS for the steel in the cold-rolled condition. ..... MPa

2. The yield stress for the steel in the annealed condition. ..... MPa

(ii) Calculate, showing full working, the modulus of elasticity for the steel.

Modulus of elasticity ..... GPa

QUESTION 11. (Continued) **Marks**

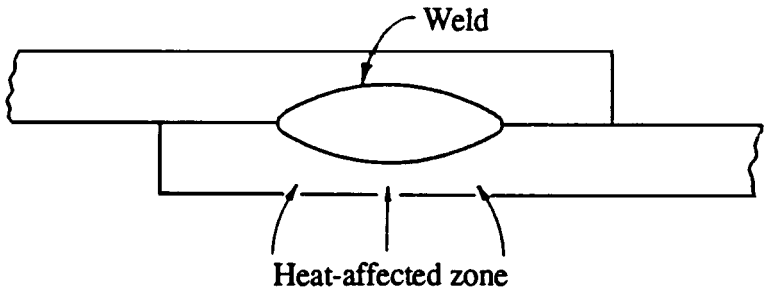
(iii) With reference to the given diagram, comment on the toughness of the steel in the annealed condition, compared to the toughness of the steel in the cold-rolled condition.

……

……

(c) The steel flap of a mower is made from cold-rolled 0·1% carbon steel. The clip is spot welded to the flap. **2**

(i) Draw and label the macrostructure of the weld.



(ii) Describe the grain structure in the heat-affected zone.

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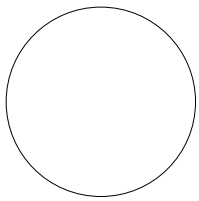
……

……

(d) The piston rings in a lawnmower engine are manufactured from grey cast iron. **2**

(i) Draw and label the microstructure for grey cast iron.



(ii) State TWO service properties for the grey cast iron piston rings.

1. ……

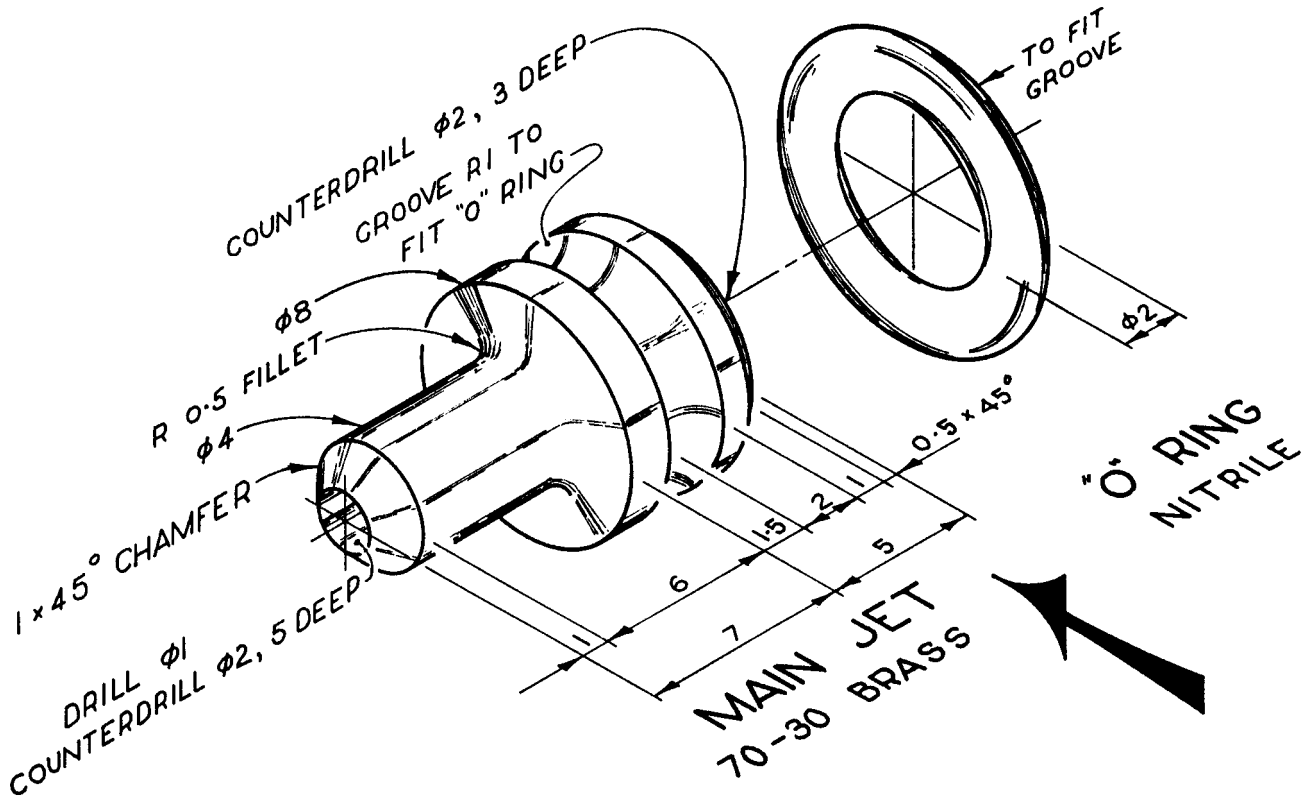
2. ……

QUESTION 12 **Marks**

Shape and size details of a main jet and 'O' ring from a lawnmower carburettor are given below in the exploded pictorial drawing. **12**

(a) Draw, to a scale of 10 : 1, a half-sectional front view of the assembled parts when viewed from the direction of the arrow. The main centreline is given for the drawing.

(b) Dimension a chamfer, the fillet, and the overall length.



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1996
HIGHER SCHOOL CERTIFICATE EXAMINATION
ENGINEERING SCIENCE
2/3 UNIT (COMMON)

Not to be collected at the conclusion of the examination.

FORMULAE

Dynamics

$v = u + at$

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

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

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

$F = ma$

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

$M = mv$

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

$\text{PE} = mgh$

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

$F = kx$

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

$W = Fs$

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

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

Strength of materials

$\sigma = F/A; \quad \varepsilon = e/L; \quad E = \sigma/\varepsilon; \quad \%RA = \frac{A_0 \pm A}{A_0} \times 100$

Area of circle

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

Circumference of circle

$C = \pi d$

ROUGH WORK SHEET

Not to be collected at the conclusion of the examination.