STUDENT NUMBER

CENTRE NUMBER

BOARD OF STUDIES
NEW SOUTH WALES

HIGHER SCHOOL CERTIFICATE EXAMINATION

1995
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

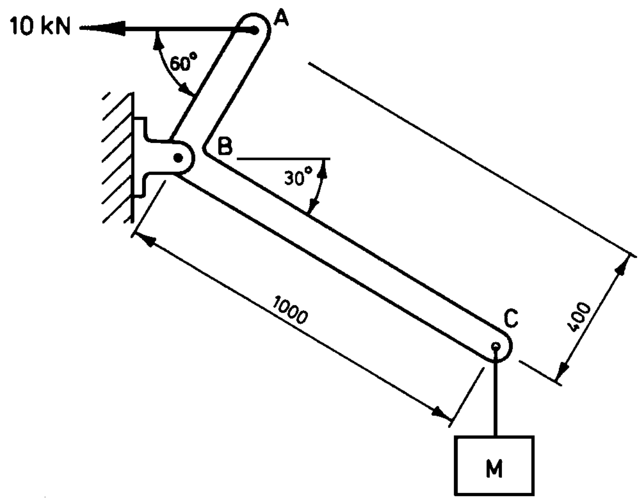
- Write your Student Number and Centre Number at the top right-hand corner of this page.
- Allow approximately 90 minutes for this Section.
- Attempt ALL questions.
- Answer the questions in the spaces provided in this paper. Set out your working clearly and neatly. Emphasis will be placed on that working 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) A mass *M* is hanging from a crank *ABC* as shown. The crank is supported by a frictionless hinge at *B* and a horizontal force of 10 kN applied at *A*. **3**



(i) Determine the mass *M*.

(ii) Determine the magnitude and direction of the reaction at *B*.

Mass .... kg

Magnitude of reaction .... kN

Direction of reaction ....

QUESTION 1. (Continued) **Marks**

(b) A test is conducted on a nail gun by firing a nail at a 60 mm thick timber plank. The nail strikes the plank with a velocity of 300 m/s and emerges from the other side with a velocity of 200 m/s. **$2\frac{1}{2}$**

(i) Determine the loss in kinetic energy if the nail has a mass of 10 g.

Energy loss .... J

(ii) Determine the average resistance to motion.

Average resistance to motion .... N

(iii) Determine the maximum penetration of a nail in a block of the same timber having a thickness of 120 mm. Note that the nail is identical to that in part (i) above and fired at a velocity of 300 m/s.

Penetration .... mm

(c) A train *A* is travelling at a constant velocity of 12 m/s. A second train *B* is travelling at 30 m/s in the same direction. Train *B* starts decelerating at a constant rate when it is 2 km behind train *A*. **$2\frac{1}{2}$**

Determine the minimum deceleration to avoid a collision.

Minimum deceleration .... m/s^2

QUESTION 2 **Marks**

(a) An aeroplane is flying with an airspeed of 500 km/h in a direction 10° west of north. A strong wind is blowing from the south-west. The plane arrives at a destination 400 km due north without altering course or velocity. **3**

(i) Determine the wind velocity.

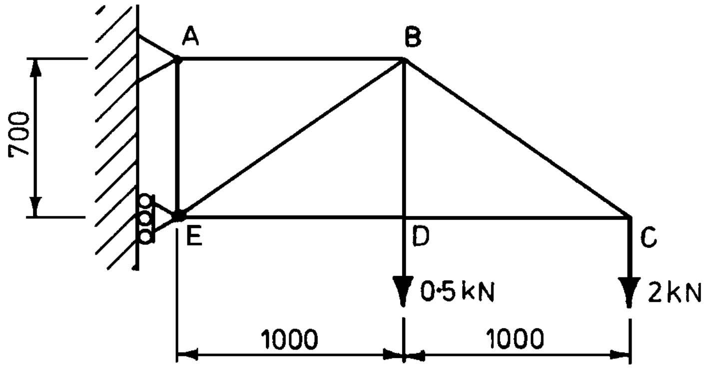
Magnitude of wind velocity .... km/h

(ii) Determine the time taken for the plane to reach its destination.

Time taken .... hours

QUESTION 2. (Continued) **Marks**

(b) A pin-jointed truss is loaded as shown below. **5**



(i) Determine the magnitude and nature (tension or compression) of the force in member *BC*.

Force in *BC* .... kN. Nature ....

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

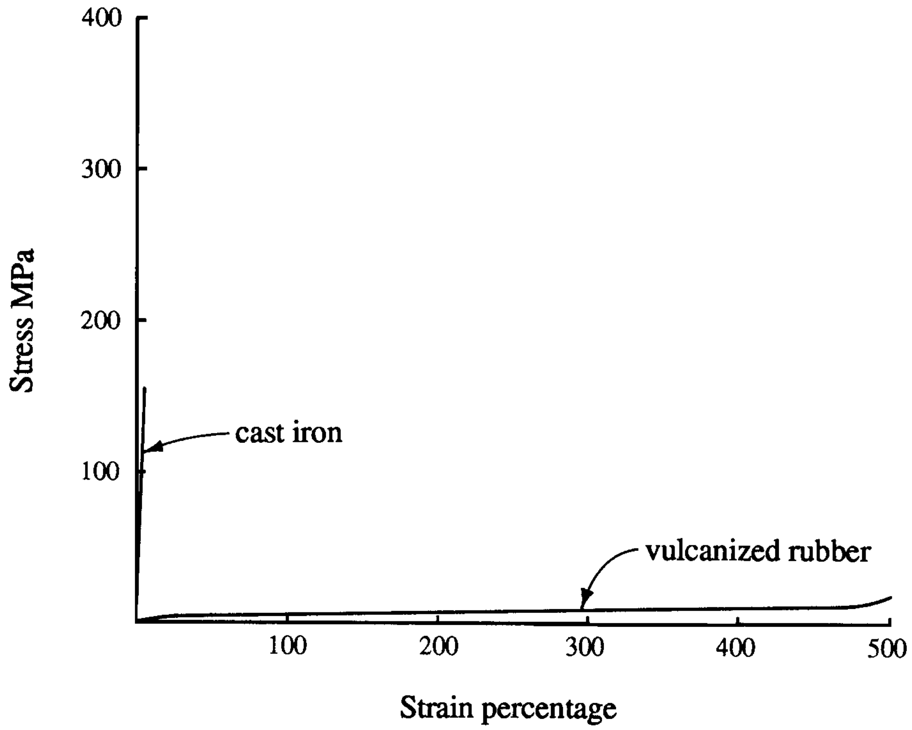
Force in *AB* .... kN. Nature ....

(iii) Determine the reactive force at the support *A*.

Reactive force .... kN. Direction ....

QUESTION 3 **Marks**

Tensile tests are conducted on grey cast iron and lightly vulcanized rubber specimens. The stress–strain curve for each is plotted on the diagram below.



(a) Explain in terms of properties why the curve for cast iron is steeper than the curve for lightly vulcanized rubber. **½**

....

....

....

(b) Explain in terms of structure why the curve for lightly vulcanized rubber changes direction as it nears the fracture point. **½**

....

....

....

(c) On the diagram given above, draw the stress–strain curve for another material that exhibits all of the following characteristics during a tensile test. **1**

- A yield stress of 300 MPa.
- A distinct yield point.
- A breaking stress that is lower than the ultimate tensile strength.
- A maximum strain of 300%.

QUESTION 3. (Continued) **Marks**

(d) Complete the following table for the composite materials. **$\frac{1}{2}$**

Composite	*Binder*	*Other component*
Glass-reinforced polymer		Glass fibre
Asphalt	Bitumen	
	Urea formaldehyde	Wood veneers

(e) The raw material used for making bottle glass contains silica, soda ash, and limestone. **1**

(i) State the main purpose of the silica.

....

....

(ii) Why is it necessary to have a flux?

....

....

(f) Annealing affects the toughness of glass containers. **1**

(i) Describe how glass containers are annealed.

....

....

(ii) Why is the toughness of the glass container affected by annealing?

....

....

Question 3 continues on page 8

QUESTION 3. (Continued) **Marks**

(g) Glass containers may be formed by blow-moulding. Aluminium oxide crucibles may be formed by slip casting followed by sintering. **$3\frac{1}{2}$**

(i) State the principal difference between the structure of glass and the structure of aluminium oxide.

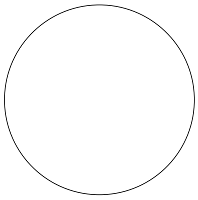
....

....

(ii) List the FOUR major steps in the slip-casting process.

1. ....
2. ....
3. ....
4. ....

(iii) Draw and label the macrostructure of sintered aluminium oxide.

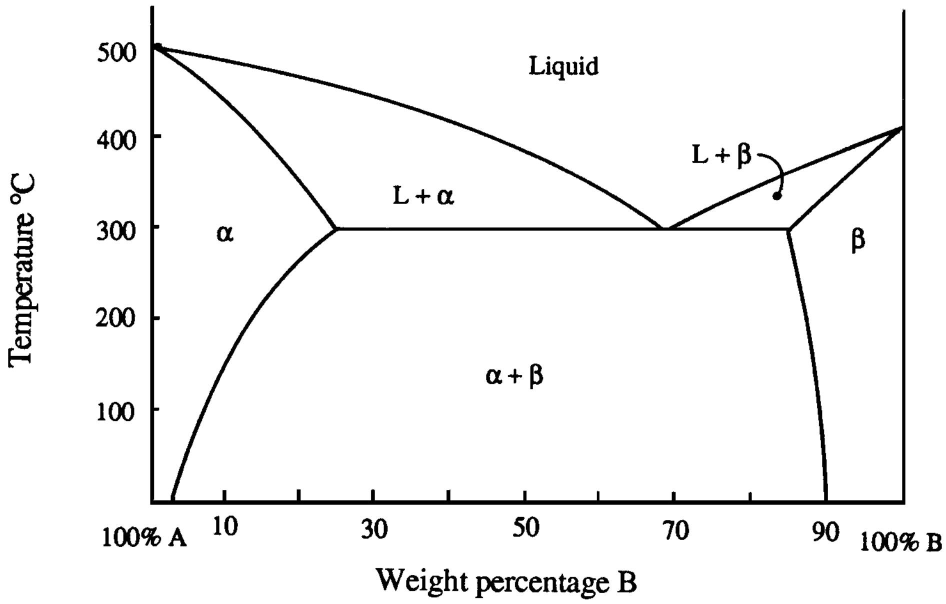


MACROSTRUCTURE OF SINTERED ALUMINIUM OXIDE

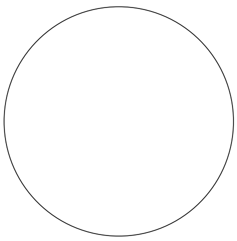
BLANK PAGE

QUESTION 4 **Marks**

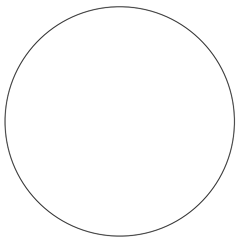
(a) The phase diagram for a binary alloy of metal *A* and metal *B* is given below. **4**



(i) Alloys of 90% *A* – 10% *B* and 5% *A* – 95% *B* are cooled under equilibrium conditions to room temperature. Draw and label the resulting microstructures.

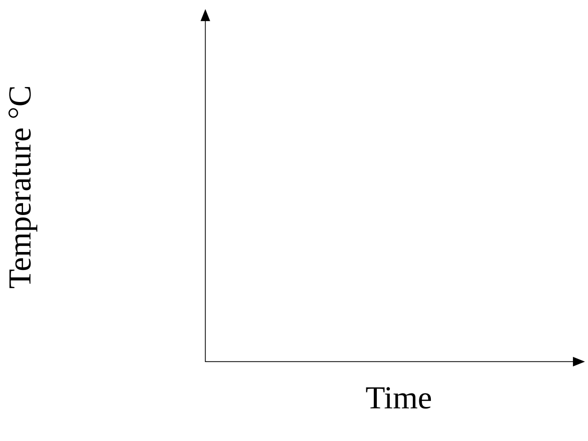


90% *A* – 10% *B*

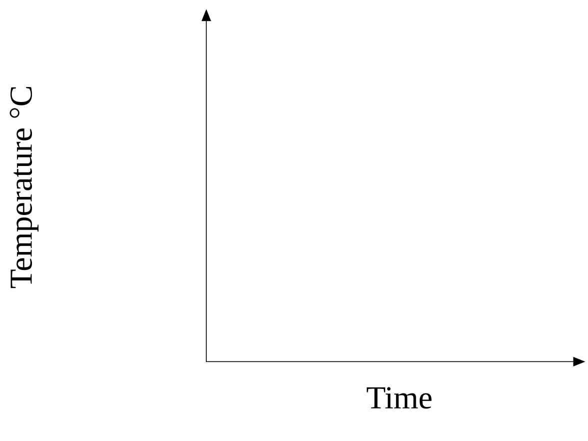


5% *A* – 95% *B*

(ii) On the diagram below, draw and fully label the cooling curves for alloys 90% *A* – 10% *B* and 5% *A* – 95% *B* respectively. Show all relevant temperatures and phases.



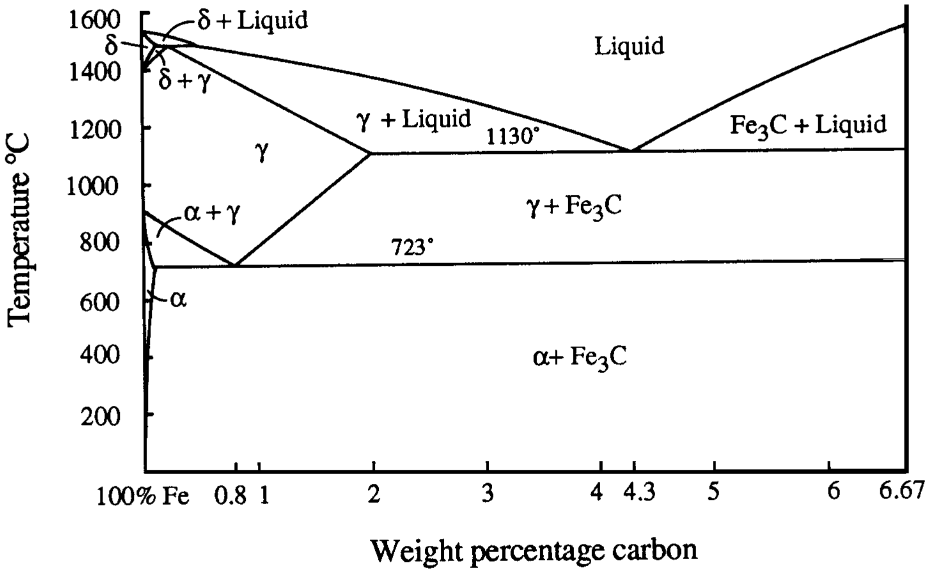
90% *A* – 10% *B*



5% *A* – 95% *B*

QUESTION 4. (Continued) **Marks**

(b) **4**



(i) From the given iron–carbon phase diagram, write the carbon content of each of the following.

1. The eutectic composition .... % C

2. The eutectoid composition .... % C

3. The composition of the interstitial compound .... % C

(ii) A 0·4% carbon steel is used to manufacture gearwheels for an engine.

There are two phases that would be found in this steel at room temperature when cooled under equilibrium conditions.

Name the TWO phases and state TWO mechanical properties for each of these phases.

	Mechanical property 1	*Mechanical property 2*
Phase 1		
Phase 2		

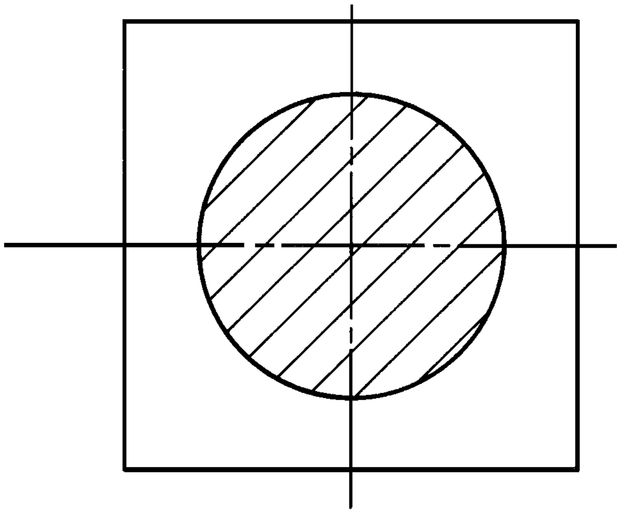
(iii) A beam of 0·4% carbon steel is hot-rolled. Draw and label the resulting microstructure.

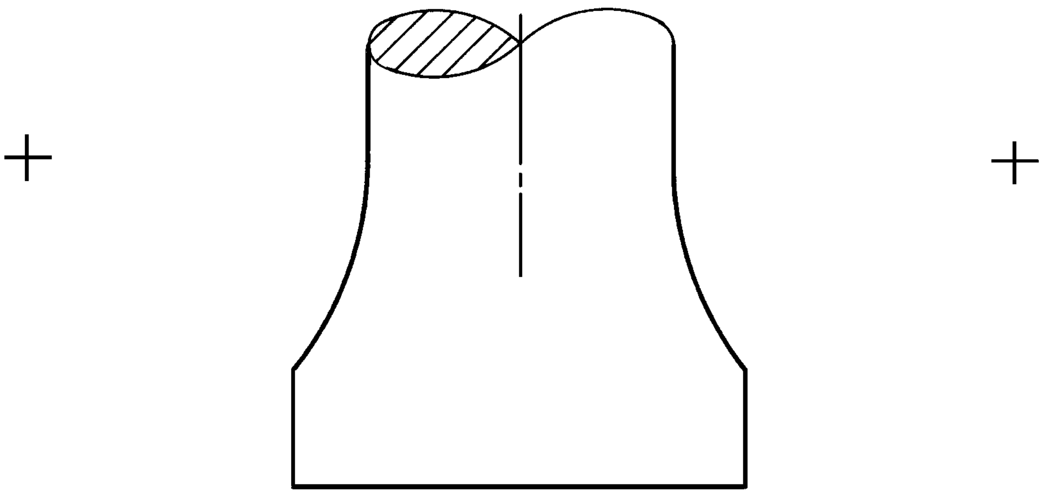
MICROSTRUCTURE FOR HOT-ROLLED 0·4%C STEEL

QUESTION 5 **Marks**

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

Complete the front view.



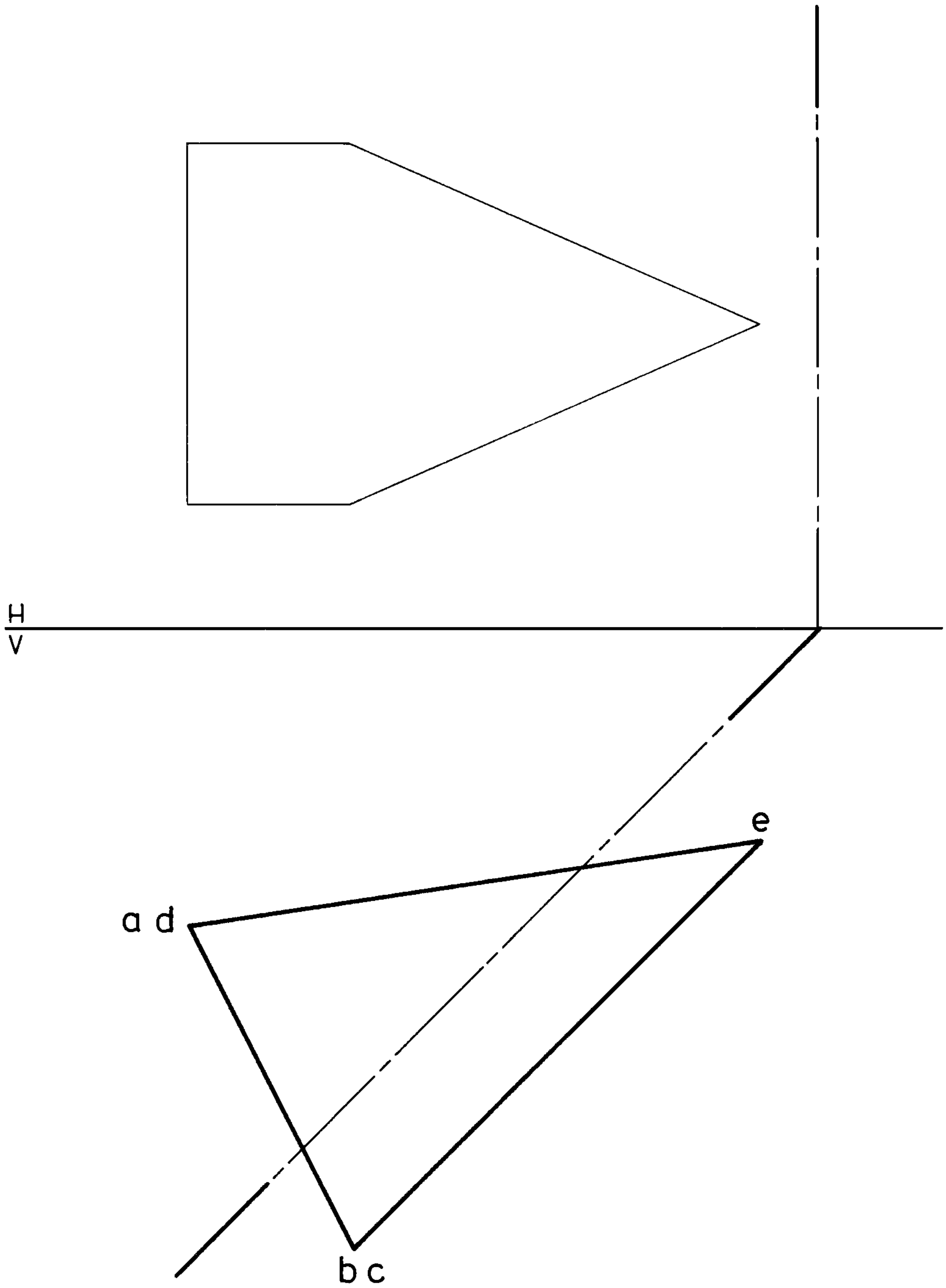


QUESTION 5. (Continued) **Marks**

(b) The front view and partly completed sectional top view of a square pyramid are shown below. The pyramid is positioned so that its lowest base edge, ***bc***, is horizontal and at 90° to the principal vertical plane. The triangular face, ***bce***, is inclined at 45° to the horizontal. **4**

The pyramid is cut by an inclined section plane, as shown in the front view.

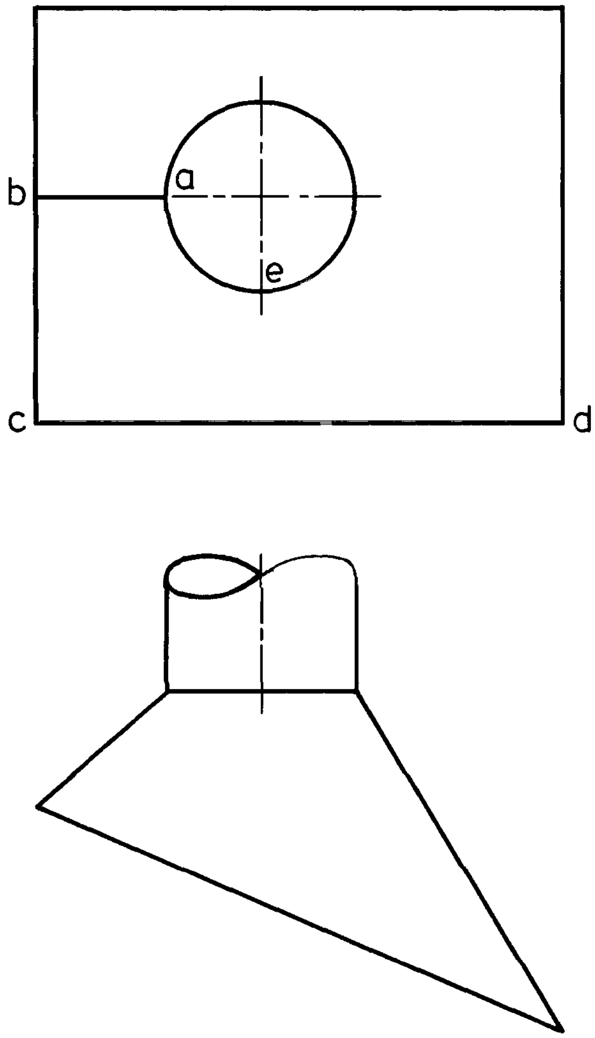
Complete the sectional top view, clearly showing all visible and hidden outline.

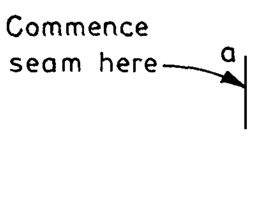


QUESTION 6 **Marks**

(a) The top view and front view of a fume-extraction hood are shown below in third-angle projection. **4**

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

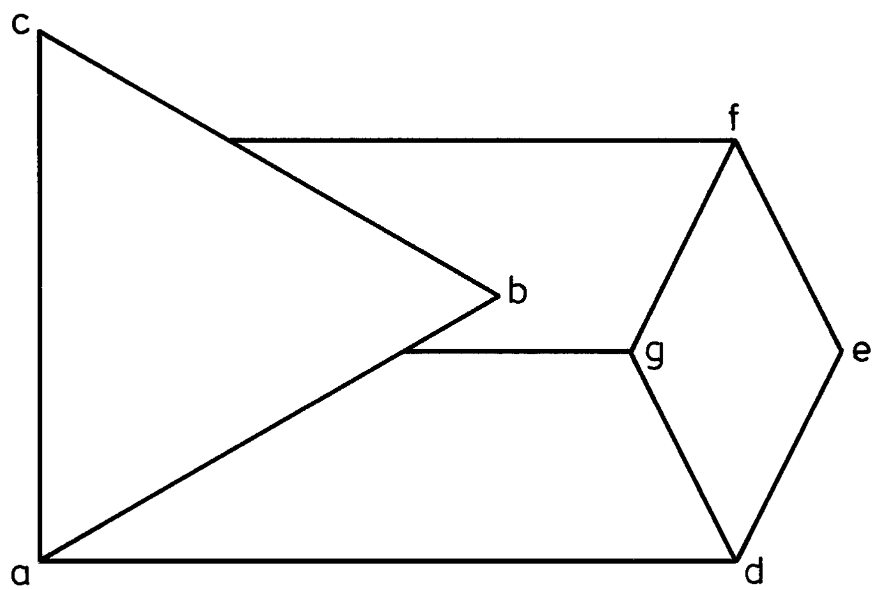


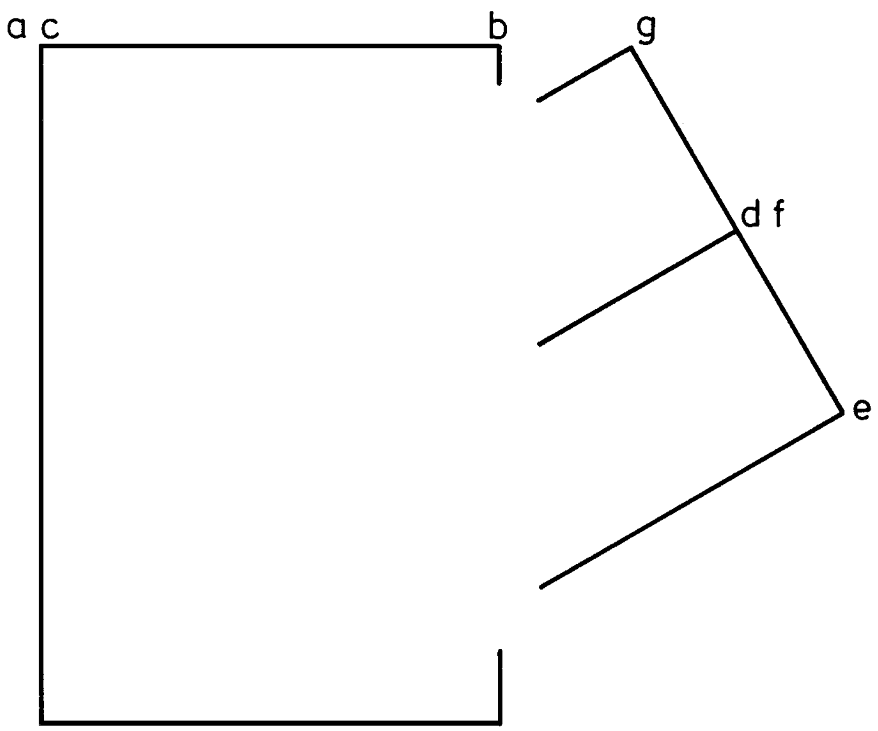


QUESTION 6. (Continued) **Marks**

(b) The top view and partly completed front view of an inclined square prism intersecting an equilateral triangular prism are shown below in third-angle projection. **4**

Complete the front view.





BLANK PAGE

STUDENT NUMBER

CENTRE NUMBER

BOARD OF STUDIES
NEW SOUTH WALES

HIGHER SCHOOL CERTIFICATE EXAMINATION

1995
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.
- The Data and Rough Work Sheet will not be collected.

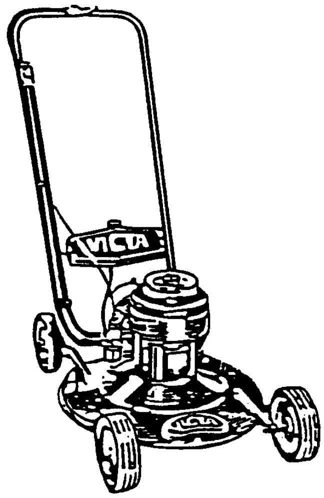
EXAMINER'S USE ONLY

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**

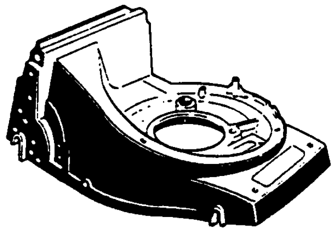
The illustrations below show a push mower, a 1950s Victa 2-stroke mower, and a baseplate deck from a 1980s mower.

PUSH MOWER



1950s VICTA 2-STROKE

Victa manual, 1955.
Reproduced with permission of Universal Press.



1980s BASEPLATE DECK

Victa manual, 1982.
Reproduced with permission of Universal Press.

(a) (i) Describe the cutting-system first used in the Victa 2-stroke mower. **2**

....

....

(ii) Describe a cutting-system used prior to the Victa 2-stroke mower.

....

....

(b) Developments in materials and manufacturing processes have influenced the design of baseplate decks. **3**

(i) State the material used and describe the manufacturing process of the 1950s baseplate deck.

Material ....

Manufacturing process ....

....

....

....

(ii) The shape of the 1980s baseplate deck has design advantages over that of the 1950s baseplate deck. State TWO design advantages.

1. ....

2. ....

QUESTION 7. (Continued) **Marks**

(c) Developments in materials and manufacturing technologies have affected the design of bicycles. **3**

(i) State a specific development in materials used in bicycles that has occurred over the past fifty years.

....

....

(ii) Explain how the stated development from part (i) above has affected the design of the bicycle.

....

....

....

(iii) State a specific development in the manufacturing process of the bicycle frame that has occurred over the past fifty years.

....

....

(iv) Explain how the stated development from part (iii) above has affected the design of the bicycle frame.

....

....

....

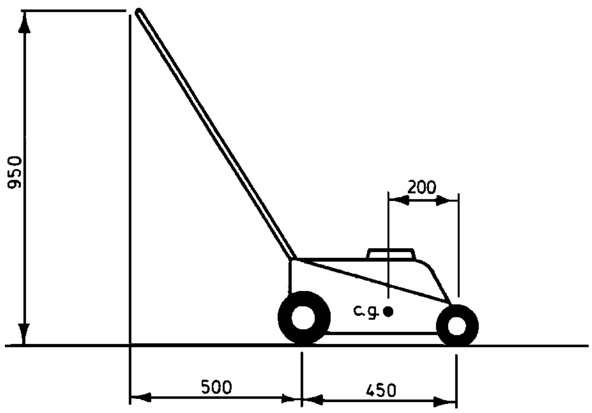
(v) State TWO social factors that have influenced the use of bicycles over the past fifty years.

1. ....

2. ....

QUESTION 8 **Marks**

(a) The lawnmower shown below has a mass of 15 kg. $3\frac{1}{2}$



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

(ii) Determine the magnitude of the reaction at each of the rear wheels. Assume that each rear wheel supports an equal mass.

Reaction at rear wheel .... N

(iii) Each of the rear wheels of the lawnmower is supported by a 10 mm diameter axle. Determine the shear stress in the axle of one of the rear wheels.

Shear stress .... MPa

(iv) The resistance to motion between the wheels and the ground is 30% of the normal reaction. Determine the horizontal force that must be applied at the top of the handle to just move the lawnmower forward.

Force .... N

QUESTION 8. (Continued) **Marks**

(b) The following data were determined from tensile testing of a material used for lawnmower blades. **3**

- Original cross-sectional area = 40 mm^2.
- Original gauge length = 120 mm.
- Load at elastic limit = 12 kN.
- Extension at elastic limit = 0·19 mm.
- Maximum load = 14 kN.

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

Young's modulus .... GPa

(ii) Determine the UTS.

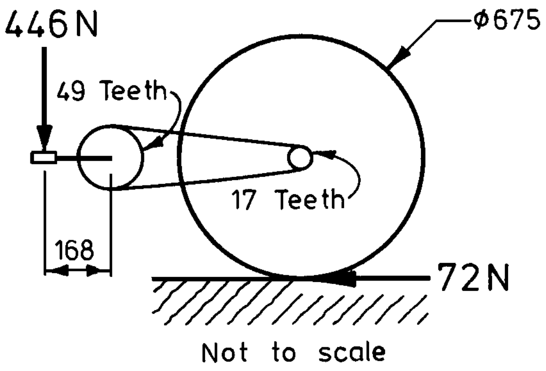
UTS .... MPa

(c) The motor of a self-propelled mower develops a power of 190 W. The efficiency of the drive mechanism is 94%. Determine the total resistance to motion when the velocity of the mower is 1·8 m/s. **$1\frac{1}{2}$**

Resistance to motion .... N

QUESTION 9 **Marks**

(a) The diagram below shows the drive mechanism for a bicycle. When the pedal crank is horizontal, a vertical downward force of 446 N just rotates the rear wheel against a resistance of 72 N. **$4\frac{1}{2}$**



(i) Determine the mechanical advantage for the drive mechanism.

Mechanical advantage ....

(ii) Determine the number of revolutions the rear wheel makes when the crank rotates one revolution.

Number of revolutions ....

(iii) Determine the distance the bicycle moves during one rotation of the wheel. Assume no slipping occurs.

Distance moved .... m

(iv) Determine the velocity ratio for the drive mechanism.

Velocity ratio ....

(v) Determine the efficiency of the drive mechanism.

Efficiency .... %

QUESTION 9. (Continued) **Marks**

(b) The bicycle and rider have a combined mass of 105 kg. When the bicycle is ridden at 20 km/h, the brakes are applied and the velocity reduced to 5 km/h. **$3\frac{1}{2}$**

(i) Determine the impulse.

Impulse .... N s

(ii) If the reduction in velocity takes place over 3 seconds, determine the average braking force between the rear tyre and the road.

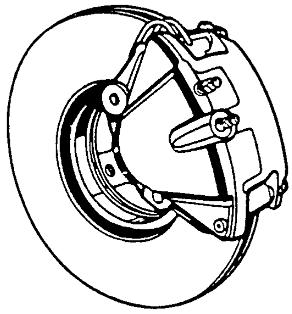
Average braking force .... N

(iii) Determine the average braking power required.

Average braking power .... W

QUESTION 10 **Marks**

The disk brake shown below uses normalized 1·0% carbon steel for the high tensile spring, annealed 0·1% carbon steel for the rivets, and grey cast iron for the disk.

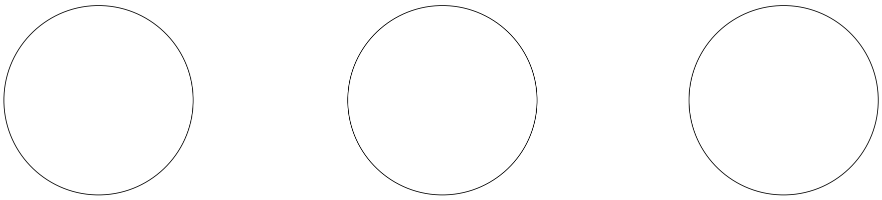


(a) Draw the microstructure of each of the following materials: **3**

(i) normalized 1·0% carbon steel;

(ii) annealed 0·1% carbon steel;

(iii) grey cast iron.



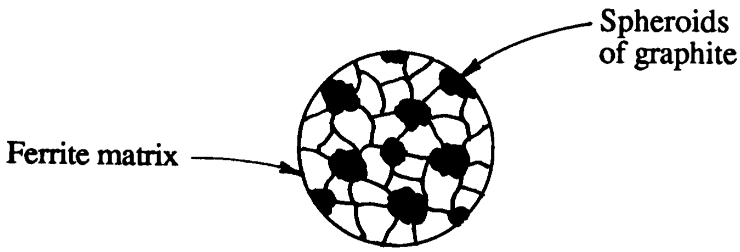
NORMALIZED 1·0 % CARBON STEEL | ANNEALED 0·1 % CARBON STEEL | GREY CAST IRON

(b) Grey cast iron is weak in tension. Explain the reason for this in terms of microstructure. **$\frac{1}{2}$**

....

....

(c) Spheroidal graphite cast iron is used to cast the callipers. The microstructure is given below. **1**



List TWO mechanical properties that make spheroidal graphite cast iron suitable for use in disk-brake callipers.

(i) ....

(ii) ....

QUESTION 10. (Continued) **Marks**

(d) Copper has replaced the 0·1% carbon steel used in the manufacture of the rivets. The copper is severely cold worked, then annealed. **2**

(i) Describe the recrystallization process of the cold-worked copper during the annealing process.

....

....

....

(ii) Draw the microstructure of the annealed cold-worked copper.

(e) (i) The high tensile spring is normalized during production. Explain why this process is used. **1½**

....

....

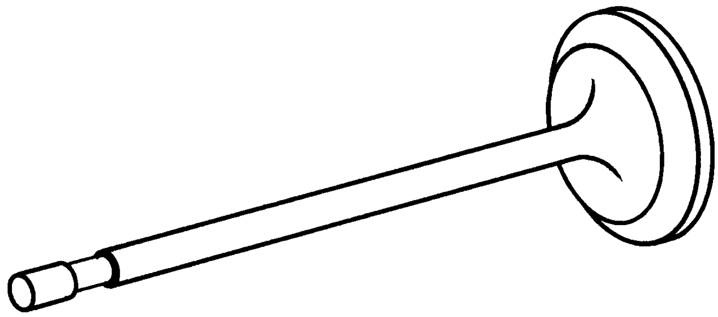
(ii) State TWO mechanical properties which are improved as a result of normalizing.

1. ....

2. ....

QUESTION 11 **Marks**

(a) The lawnmower-engine valve shown below is hot-forged, then machined from 0·4% carbon steel. $2\frac{1}{2}$



(i) Name and describe a non-destructive test, other than visual examination, used to locate surface defects in the lawnmower-engine valve.

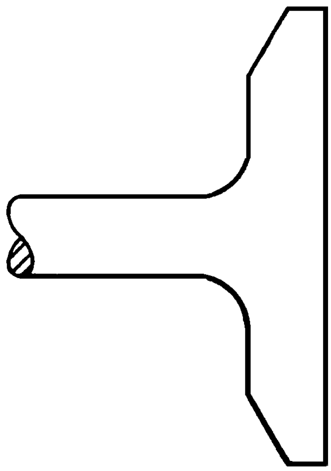
Name of test ....

Description of test...

....

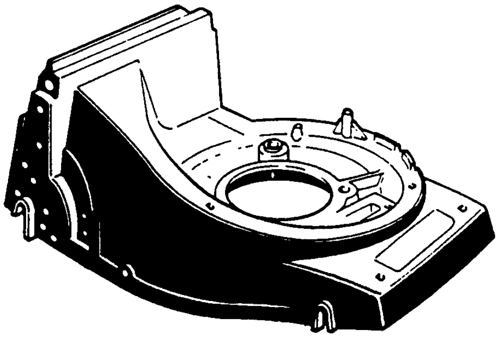
....

(ii) On the cross-section of the valve head shown below, sketch the grainflow resulting from hot forging.



QUESTION 11. (Continued) **Marks**

(b) A material is to be selected for the manufacture of the lawnmower baseplate deck shown below. **2½**



Victa manual, 1982.
Reproduced with permission of Universal Press.

LAWNMOWER BASEPLATE DECK

(i) State a mechanical property required for the service conditions of the baseplate.

....

(ii) State a chemical property required for the service conditions of the baseplate.

....

(iii) Describe a manufacturing process that would be suitable for forming the baseplate deck.

....

....

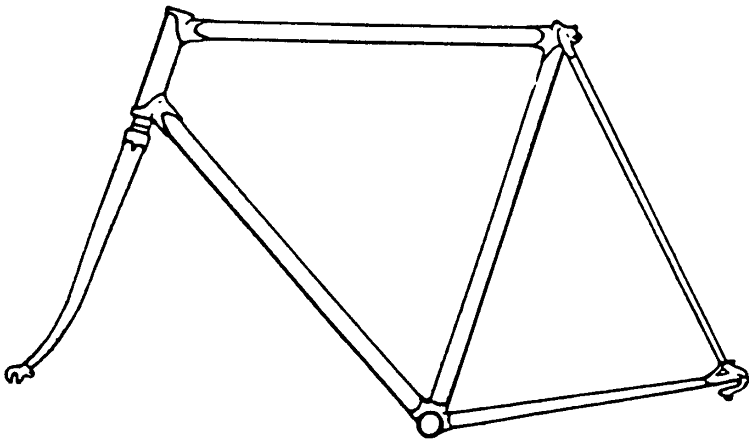
....

....

Question 11 continues on page 28

QUESTION 11. (Continued) **Marks**

(c) A bicycle frame is manufactured from tubular 0·25% carbon steel. **3**



(i) The tubular sections of the bicycle frame shown above are hot-formed by rotary tube piercing. Describe this process.

....

....

....

....

(ii) State TWO mechanical properties of the 0·25% carbon steel that are altered by the hot-working process of rotary tube piercing.

1. ....

2. ....

(iii) Name TWO methods used to join bicycle-frame members.

1. ....

2. ....

QUESTION 12 **Marks**

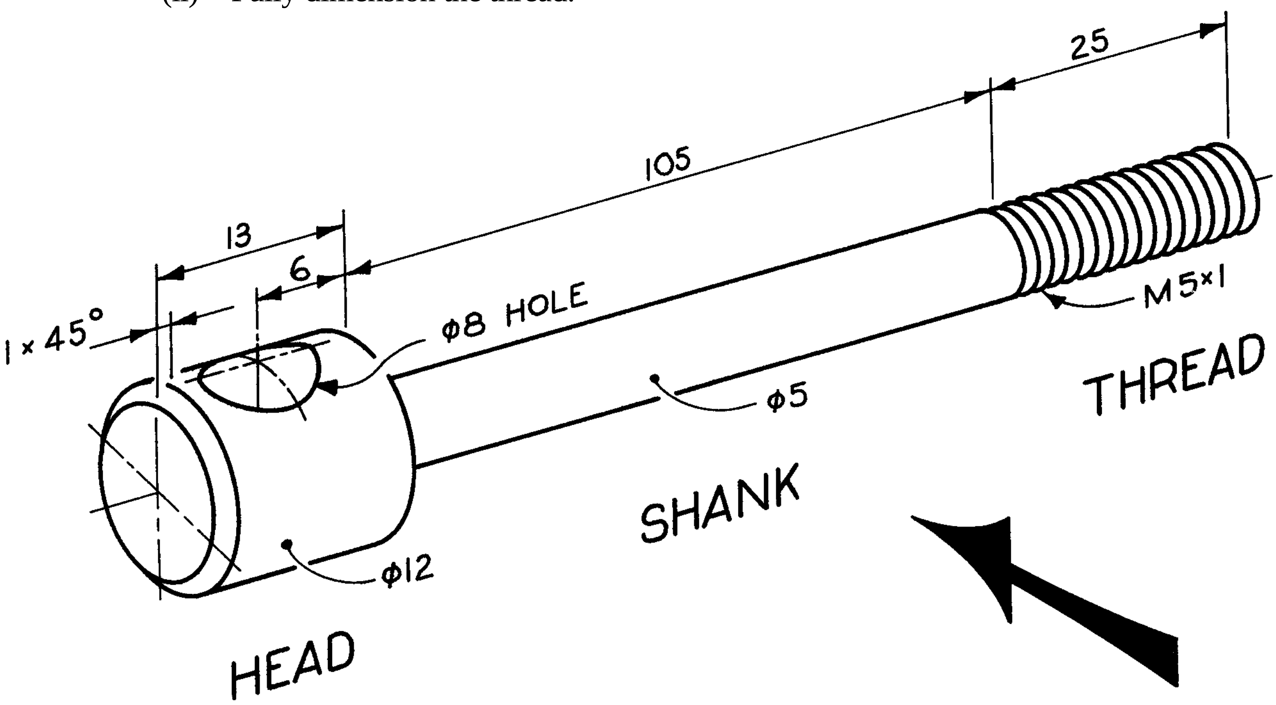
Shape and size details for a hub skewer from a quick-release mechanism on a bicycle wheel are shown below.

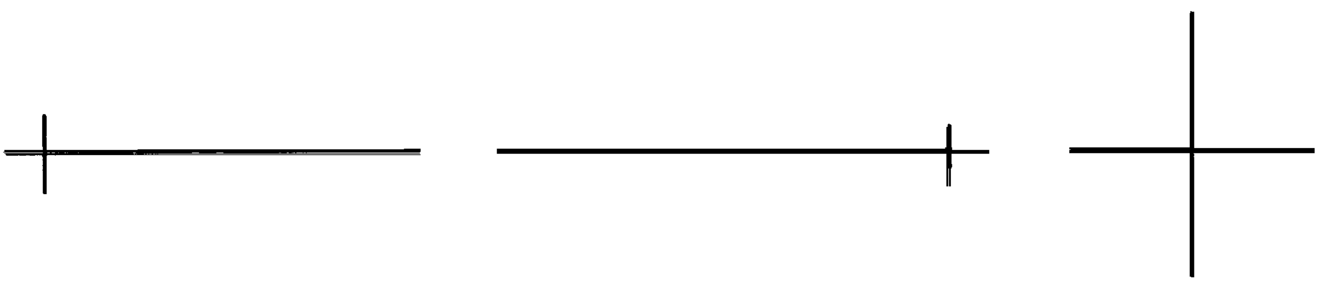
(a) A front view of the skewer is commenced below, showing a centre line and both ends of the skewer. Complete the front view of the hub skewer using a scale of 2 : 1. The direction of viewing is indicated by the arrow. AS1100 drawing standards must be used to show a break in the shaft to allow the view to fit in the space provided. **8**

(b) Project from the front view, using third-angle projection, a right side view. **1**

(c) (i) Fully dimension the skewer head. **3**

(ii) Fully dimension the thread.





FRONT VIEW

RIGHT SIDE VIEW

BLANK PAGE

BLANK PAGE

BLANK PAGE

1995
HIGHER SCHOOL CERTIFICATE EXAMINATION
ENGINEERING SCIENCE
2/3 UNIT (COMMON)

Not to be collected at the conclusion of the examination.

FORMULAE

Dynamics

$v = u + at$	$\mathrm{KE} = \frac{1}{2}mv^2$
$s = ut + \frac{1}{2}at^2$	$\mathrm{PE} = mgh$
$s = \left(\frac{u+v}{2}\right)t$	$\mathrm{SE} = \frac{1}{2}kx^2$
$v^2 = u^2 + 2as$	$F = kx$
$F = ma$	$P = \frac{W}{t}$
$I = Ft = m(v - u)$	$W = Fs$
$M = mv$	

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

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

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.