STUDENT NUMBER

CENTRE NUMBER

BOARD OF STUDIES
NEW SOUTH WALES

HIGHER SCHOOL CERTIFICATE EXAMINATION

1997
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

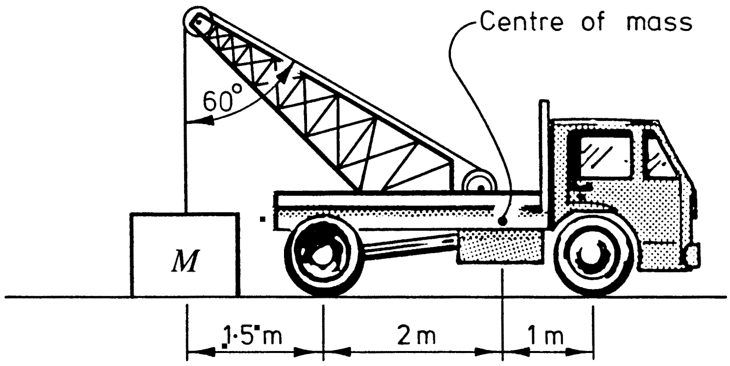
- Write your Student Number and Centre Number at the top right-hand corner of this page.
- Allow approximately 90 minutes for this Section.
- Attempt ALL questions.
- Answer the questions in the spaces provided in this paper. Set out your working clearly and neatly. Emphasis will be placed on that working 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.
- A Formulae Sheet is provided on page 33.
- The Formulae sheet 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) Details of a tow truck of mass 3 tonnes are shown on the diagram. **4**



'Introduction to Engineering Mechanics', Schlenker & McKern, John Wiley & Sons 1976, p182.

(i) Determine the maximum load, *M*, that could be safely lifted by this tow truck.

Maximum load *M* .... t

(ii) For a different set of conditions, the cable uniformly accelerates a load of 1500 kg upward from rest at 0·3 m/s^2. Determine the maximum tension in the cable that occurs during this acceleration.

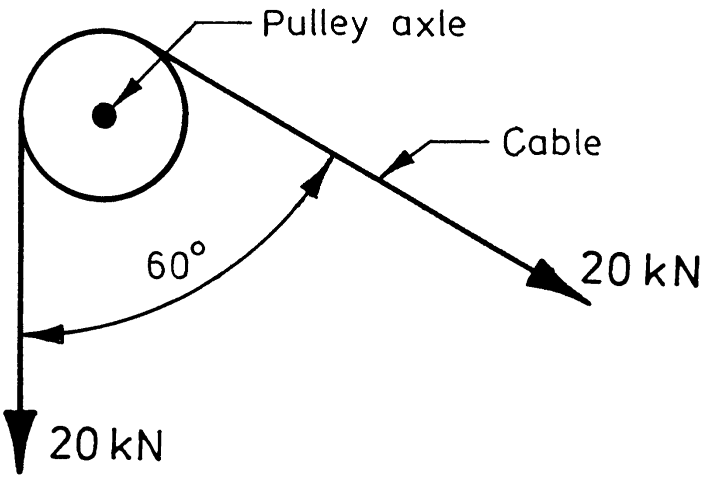
Maximum tension .... kN

QUESTION 1. (Continued) **Marks**

(b) An axle is used to support the pulley as shown on the diagram. **4**

(i) For a different set of circumstances, the tension in the cable is 20 kN.

Determine the reactive force exerted by the pulley axle.



Reactive force ....kN

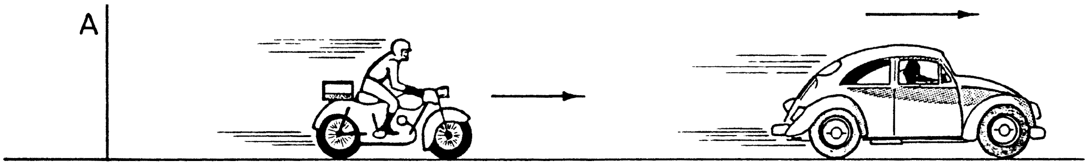
Direction.............................

(ii) For a different set of circumstances, the force on the pulley axle is 50 kN. Determine the minimum diameter of the axle if the maximum shear stress in the axle is 70 MPa. Assume that the axle is supported on both sides of the pulley.

Minimum diameter .... mm

QUESTION 2 **Marks**

(a) A car, speeding at a constant velocity of 100 km/h, passes point *A* where a police motorcyclist is stationary. Two seconds later the motorcycle accelerates at a constant rate of 6 m/s^2 until it reaches 120 km/h. It then travels at this constant velocity. **6**



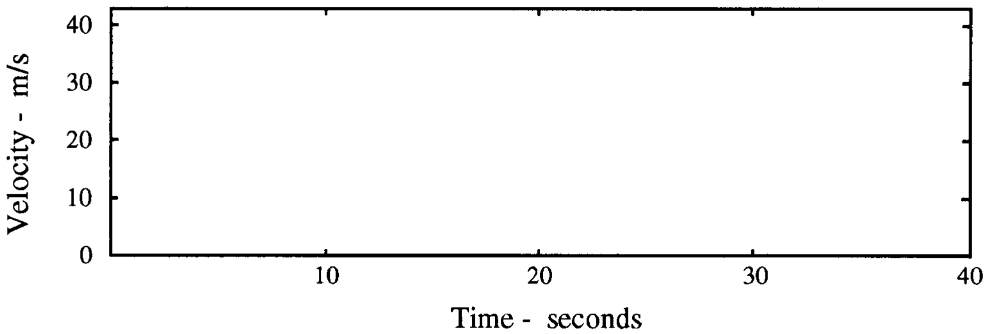
'Introduction to Engineering Mechanics', Schlenker & McKern, John Wiley & Sons 1976, p273.

'Engineering Mechanics', 2nd ed, Meriam & Kraige, John Wiley 1987, p218.

(i) Determine the time taken for the motorcycle to reach 120 km/h.

Time .... s

(ii) On the axes shown below, plot and label the velocity–time graph for both the car and motorcycle for 40 seconds after the car passes point *A*.



(iii) Determine the distance travelled by the motorcycle in reaching 120 km/h.

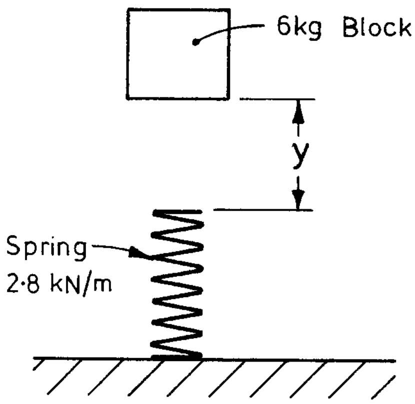
Distance travelled .... m

QUESTION 2. (Continued) **Marks**

(iv) Determine the distance between the motorcycle and the car, 10 seconds after the car has passed point A.

Distance .... m

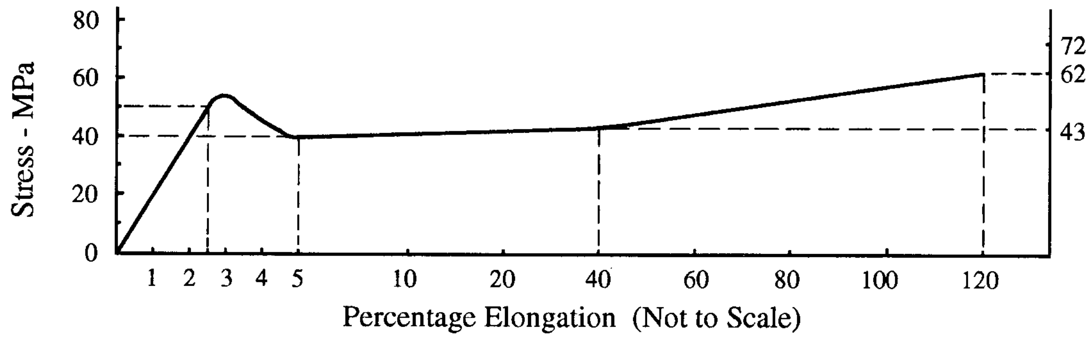
(b) A 6 kg block shown in the diagram below is released from rest and falls through a vertical distance ***y***. The block strikes the spring, compressing it by 100 mm. The spring constant is 2·8 kN/m. Determine the distance ***y***. **2**



Distance ***y*** .... mm

QUESTION 3 **Marks**

(a) Data from a tensile test on a polycarbonate sample are plotted on the stress and percentage elongation axes shown below. **$4\frac{1}{2}$**



(i) Determine the strain at the elastic limit.

Strain at the elastic limit ....

(ii) Data from a tensile test on a 10% glass-filled polycarbonate sample are listed below. On the stress–percentage elongation axes shown above, draw a possible curve from the given data for the 10% glass-filled polycarbonate sample.

- UTS, 72 MPa
- Percentage elongation at fracture, 10%
- Modulus of elasticity, 3·1 GPa
- Stress at the elastic limit, 64 MPa

(iii) Polycarbonate and 10% glass-filled polycarbonate are both used in the manufacture of components for bicycle safety helmets.

The visor is tough and transparent, while the helmet is highly rigid and has good dimensional stability.

Determine which material would be used for the visor, and which material would be used for the helmet. Justify your answer, using the relevant data from the tensile tests and your knowledge of materials.

Visor material ....

Justification ....

....

Helmet material ....

Justification ....

....

QUESTION 3. (Continued) **Marks**

(b) (i) Define thermopolymer **1**

....

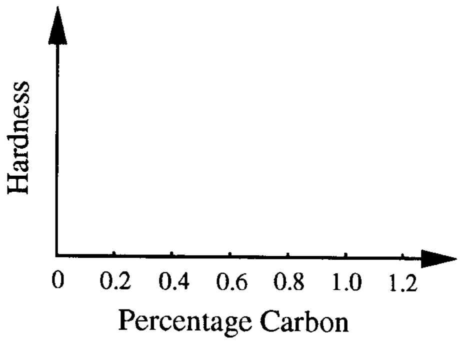
(ii) Define condensation polymerisation ....

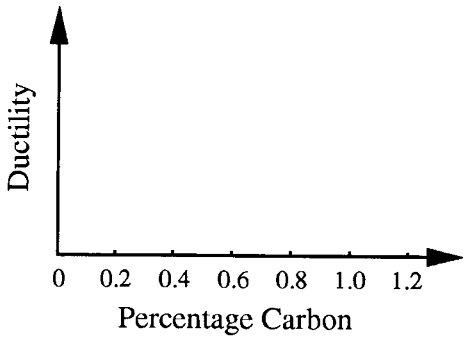
....

(c) Draw and label the macrostructure of reinforced concrete. **$1\frac{1}{2}$**

REINFORCED CONCRETE

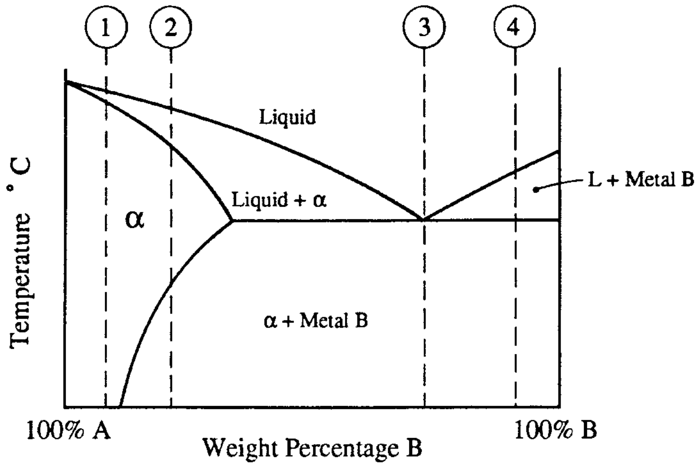
(d) The carbon content of steel in the annealed state affects the hardness and ductility of the steel. On the axes provided, graph the effect of increasing carbon content on hardness and ductility. **1**



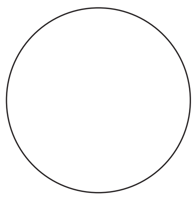


QUESTION 4 **Marks**

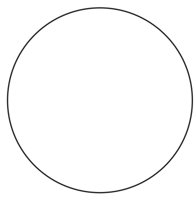
(a) The phase diagram for a binary alloy of metal *A* and metal *B* is given below. **4**



(i) Alloy 2 and alloy 3 are cooled under equilibrium conditions to room temperature. Draw and label the resulting microstructures.



ALLOY 2



ALLOY 3

(ii) Alloy 1 and alloy 4 are cooled under equilibrium conditions to room temperature. Alloy 1 has a lower tensile strength than alloy 4. Explain, in terms of structure, the reason for this lower tensile strength.

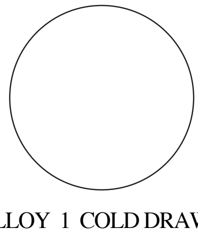
....

....

(iii) Alloy 1 is used for the manufacture of cold-drawn wire. State a mechanical property, other than suitable tensile strength, that enables it to be used for cold-drawn wire.

....

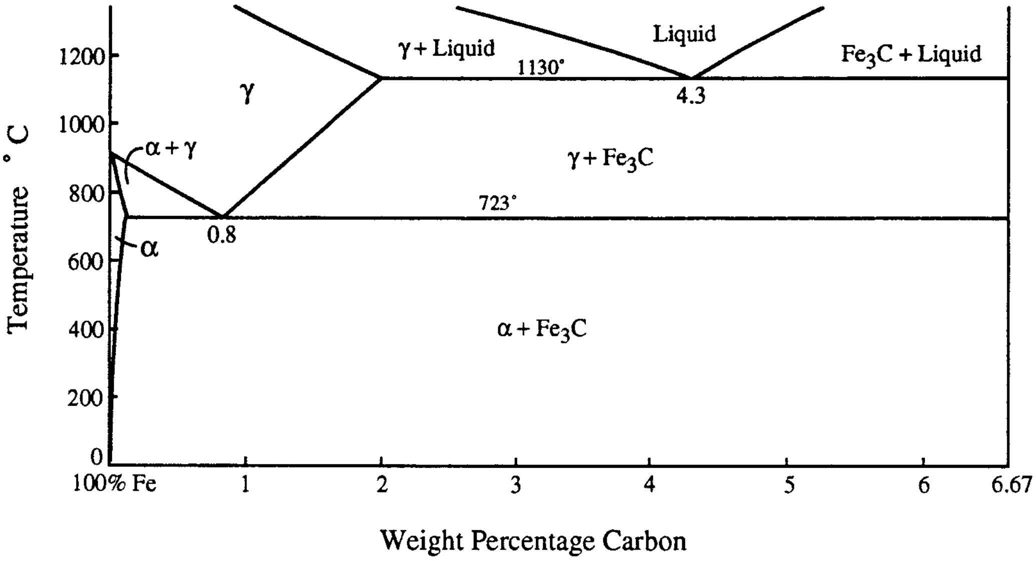
(iv) Draw and label the microstructure of alloy 1, following the cold-drawing process.



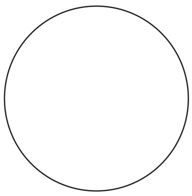
ALLOY 1 COLD DRAWN

QUESTION 4. (Continued) **Marks**

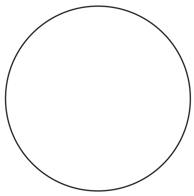
(b) Part of the iron–carbon phase diagram is given below. **2**



A sample containing 0·4% carbon is cooled under equilibrium conditions from 900°C to room temperature. Draw and label the microstructure at 750°C, and the microstructure at room temperature.

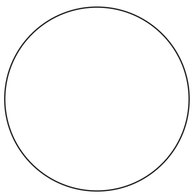


750°C



ROOM TEMPERATURE

(c) (i) Draw and label the microstructure of grey cast iron. **2**



GREY CAST IRON

(ii) Explain, in terms of structure, why grey cast iron is weak in tension but much stronger in compression.

....

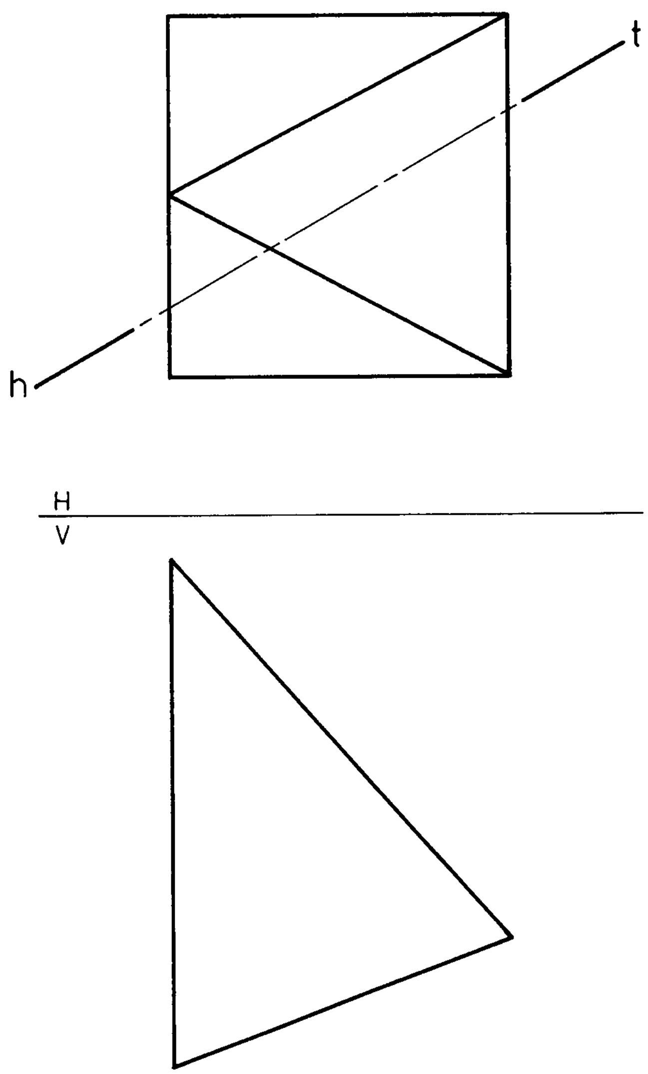
....

QUESTION 5 **Marks**

(a) The top view and incomplete sectional front view of a square pyramid, cut by a vertical section plane, are given below in third-angle projection. **4**

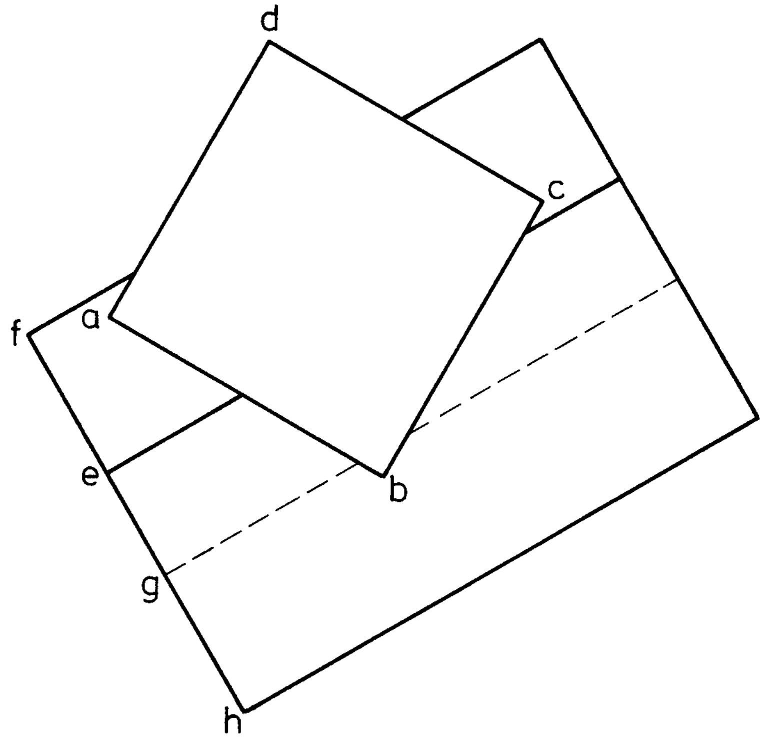
(i) Complete the sectional front view.

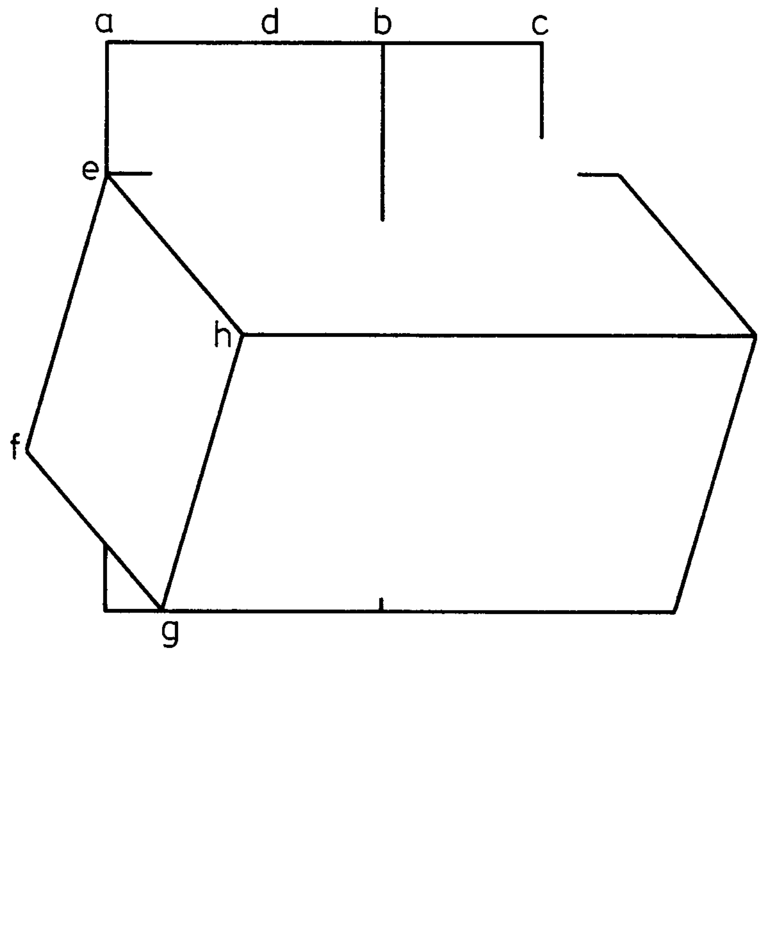
(ii) Draw the true shape of section.



QUESTION 5. (Continued) **Marks**

(b) The top view and incomplete front view of two intersecting square prisms are given below in third-angle projection. Complete the front view, showing only visible outline. **4**





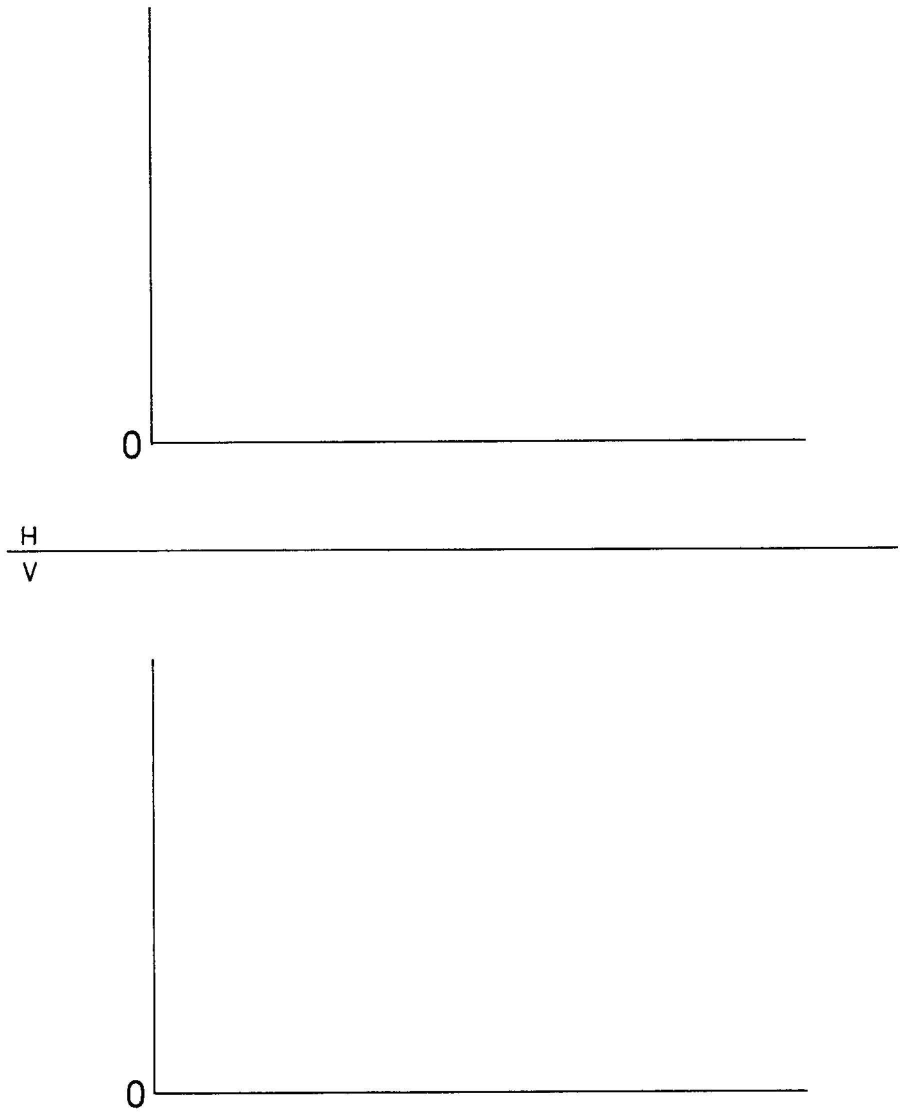
QUESTION 6 **Marks**

(a) The coordinates for the corners of a triangle ***ABC*** are given below. **4**

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

(i) Draw the front view and top view of the triangle ***ABC***.

(ii) Determine and state the true angle ***BAC***.

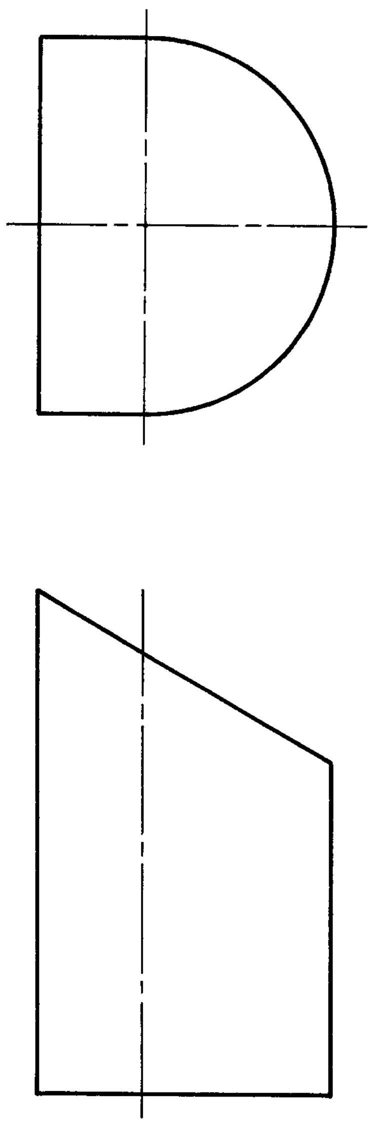


True angle ***BAC*** = ...°

QUESTION 6. (Continued) **Marks**

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

Draw a half-pattern for the downpipe.



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STUDENT NUMBER

CENTRE NUMBER

BOARD OF STUDIES
NEW SOUTH WALES

HIGHER SCHOOL CERTIFICATE EXAMINATION

1997
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.

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

(a) The components listed below were manufactured in 1947 and the manufacturing process used for each is given. State the material used, and give reasons, other than cost, *why* the manufacturing process was appropriate. **3**

(i) Bicycle frame.

Manufacturing process: brazed lug construction.

Material: ....

Reasons: ....

....

(ii) Domestic push-mower handle.

Manufacturing process: cut and shape.

Material: ....

Reasons: ....

....

(iii) Brake drum.

Manufacturing process: sand casting.

Material: ....

Reasons: ....

....

(b) The components listed below were manufactured in 1997, each using different materials. Name each of the materials used. **$1\frac{1}{2}$**

Component	*Material*
Racing-bicycle frame	
Domestic rotary-mower baseplate	
Disk brake callipers for high-performance car	

QUESTION 7. (Continued)

(c) In 1947 asbestos was used in brake lining material. Explain why asbestos is no longer used. $\frac{1}{2}$

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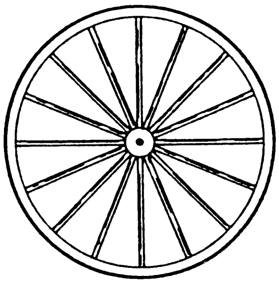
(d) For each of the bicycle wheels shown below, explain how the design was influenced by the materials and technology available. **3**

(i)



MACMILLAN 1839
Wrought iron rim on
wooden wheel

………………………………………

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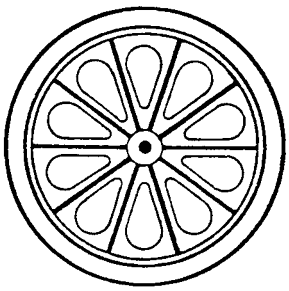
………………………………………

(ii)



BMX 1980
Vulcanised rubber tyre on a
glass-filled, high density
polyethylene wheel

………………………………………

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QUESTION 8

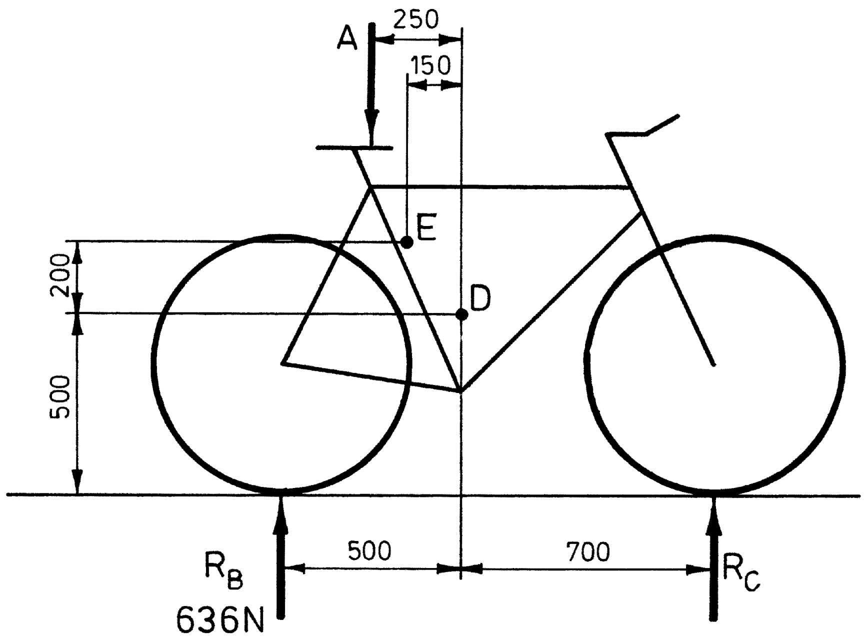
(a) Details of a bicycle are given below. The centre of mass of the bicycle, point *D*, and the combined centre of mass of the bicycle and rider, point *E*, are shown on the diagram. The mass of the bicycle is 10 kg. **5**

The bicycle accelerates on a level road due to an out-of-balance horizontal force of 81·5 N at point *E*. During this acceleration the vertical reaction R_B, at the rear wheel, is 636 N.

NOTE. Disregard the force on the handlebars and on the pedals.

(i) Determine the vertical downward force of the rider at point *A*.

(ii) Determine the vertical reaction R_C at the front wheel.



Force at *A* = ... N

Reaction R_C = ... N

QUESTION 8. (Continued)

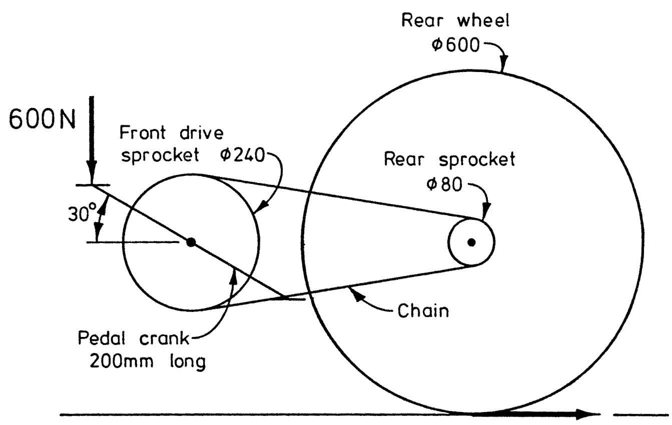
(b) A 1·5 m steel cable, with a Young's modulus of 210 GPa, is used in the bicycle braking system. The maximum cable extension is 0·34 mm for a braking force in the cable of 150 N. **3**

Determine the minimum cable diameter required.

Diameter .... mm

QUESTION 9

(a) Details of the drive mechanism of a bicycle are given below. **5**



NOT TO SCALE

At a given instant, the pedals are at an angle of 30° to the horizontal, and a vertical force of 600 N is applied to the pedal as shown. Assume 100% efficiency.

(i) Determine the force applied to the chain by the front drive sprocket.

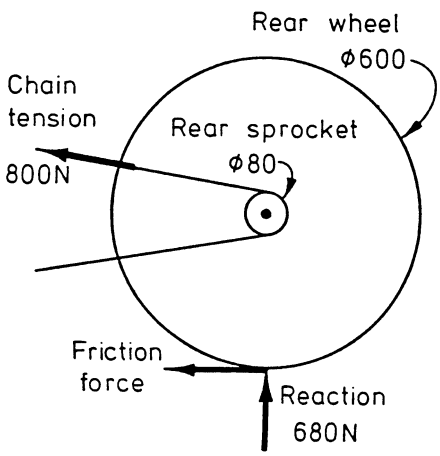
Force .... N

(ii) Determine the velocity ratio of the drive mechanism.

Velocity ratio ....

QUESTION 9. (Continued)

(iii) For a different set of conditions, the tension in the chain is 800 N and the vertical reaction at the rear wheel is 680 N. The bicycle is travelling at a constant velocity. Determine the coefficient of friction between the bicycle tyre and the road surface.



NOT TO SCALE

Coefficient of friction ....

(b) A bicycle is travelling at a constant velocity of 30 km/h against a resistance of 80 N for a distance of 1·5 km. **3**

(i) Determine the work done in travelling a distance of 1·5 km.

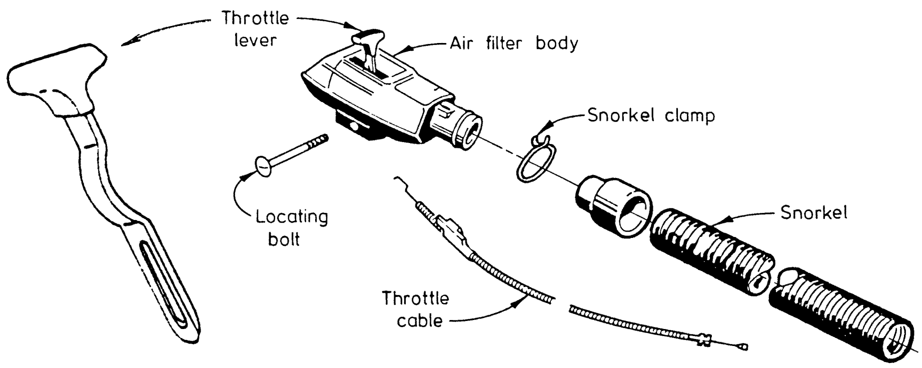
Work done ....kJ

(ii) Determine the power transferred by the cyclist.

Power ....W

QUESTION 10

A pictorial drawing of a lawnmower air filter system is shown below. **4**



'Victa Rotary Mowers', 1955-84 Service & Repair Manual, Gregory's Sci Publ No 220 1984 p24.

(a) The air filter body is made from high-density polyethylene.

(i) Name a suitable manufacturing process for the air filter body.

....

(ii) The throttle cable cover is manufactured by extrusion. Describe the extrusion process.

....

....

(iii) The throttle lever is made from cold rolled 0·2% carbon steel. Name a manufacturing process that may be used to form the curved section, and a manufacturing process used to form the elongated hole.

Curved section ....

Elongated hole ....

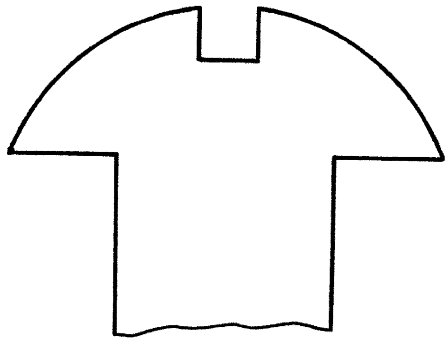
(iv) State a manufacturing property and a service property for the components in the table below.

Component	*Materials*	*Manufacturing property*	*Service property*
Throttle lever	0·2% carbon steel		
Snorkel clamp	0·5% carbon steel		
Snorkel	Low-density polyethylene		

QUESTION 10. (Continued)

(b) The locating bolt is made from 0·35% carbon steel. The head is hot formed by upsetting. The slot is machined at a later stage. **2**

(i) Sketch the grainflow of the finished bolt.



(ii) The bolt has been coated to prevent corrosion. Name a suitable metal used to coat the bolt.

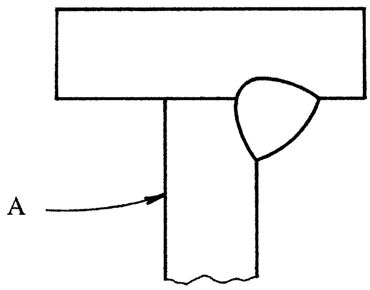
. . . .

(iii) State ONE advantage of forming a screw thread by cold rolling.

. . . .

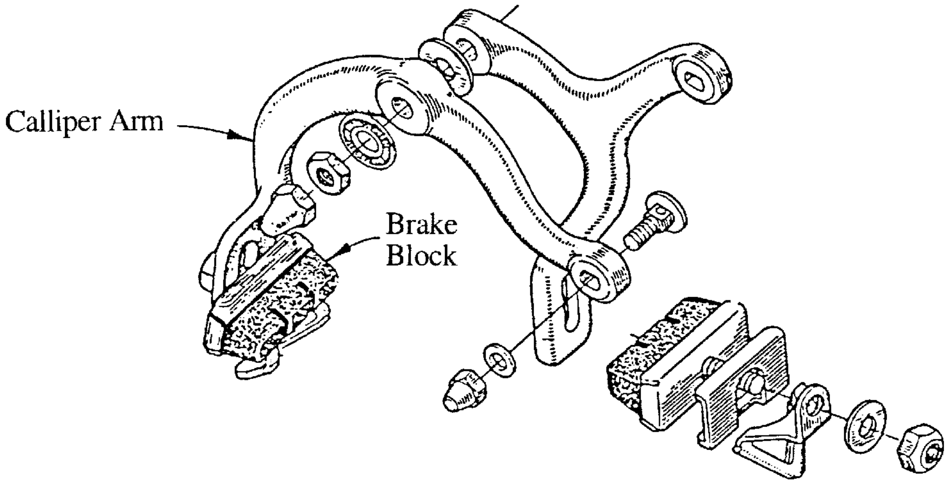
(c) The top portion of the throttle lever is welded on one side using a single run weld. A sectioned view of part of the welded lever is shown below. **2**

Draw and label the resultant grain structure of the parent metal of part A.



QUESTION 11

The drawing below shows parts of a bicycle side-pull brake calliper. **4**



(a) The brake block is a composite material. It is composed of neoprene rubber, 10% glass fibre, and carbon black. The neoprene is 10% vulcanised with sulfur.

(i) Briefly explain the mechanism of vulcanisation.

....

....

....

(ii) The batched material is formed and cured using compression moulding. Briefly describe this process.

....

....

....

(iii) For each of the materials listed, write one specific service property that the material contributes to the composite material in the brake block.

Neoprene rubber ....

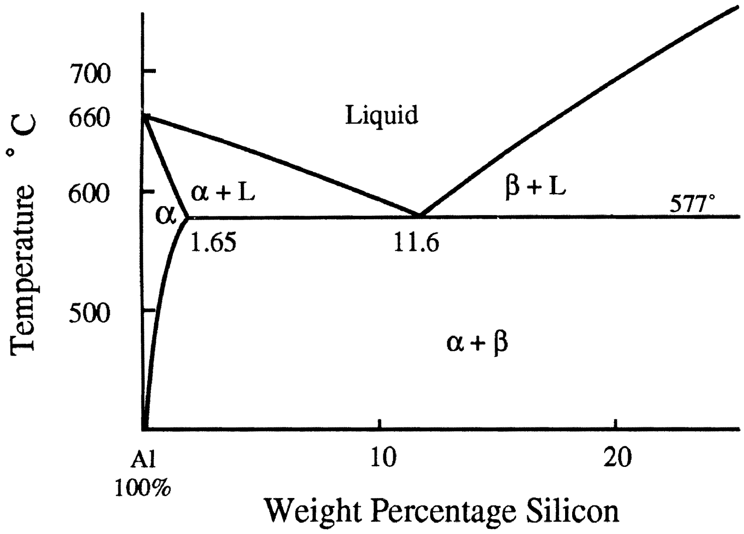
Carbon black ....

Glass fibre ....

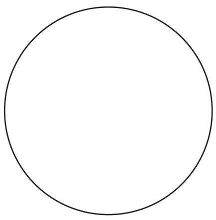
Sulfur ....

QUESTION 11. (Continued)

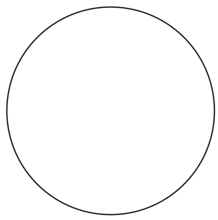
(b) A portion of the aluminium–silicon phase equilibrium diagram is given below. **4**



(i) Two alloys, a 95% aluminium–5% silicon alloy, and an 88·4% aluminium–11·6% silicon alloy, are cooled under equilibrium conditions to room temperature. Draw and label the resultant microstructure for each of the alloys.



95% ALUMINIUM–5% SILICON



88·4% ALUMINIUM–11·6% SILICON

(ii) Explain, in terms of the microstructures, why the 5% silicon alloy is softer and more ductile than the 11·6% silicon alloy.

....

....

....

(iii) A die-cast aluminium alloy, containing 5% silicon, is used to manufacture the calliper arms. Describe the die-cast process.

....

....

....

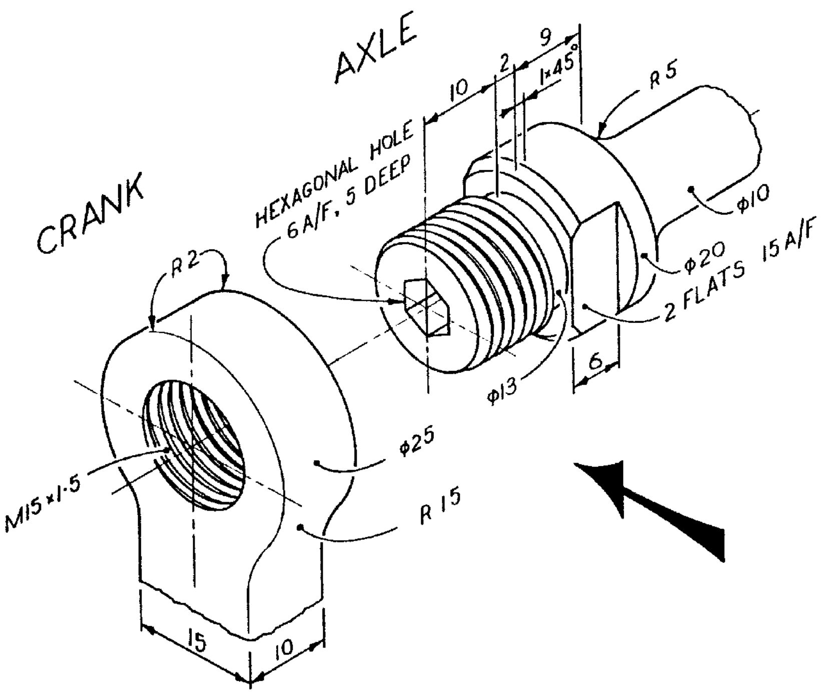
QUESTION 12

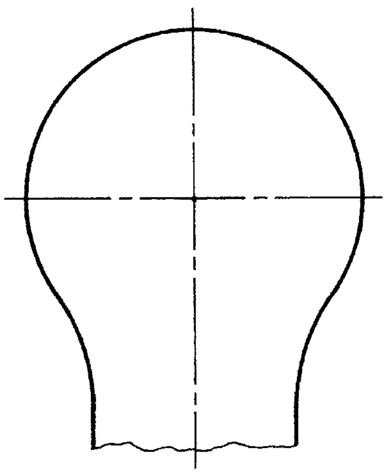
Shape and size details of part of a bicycle pedal crank and part of an axle are given in the exploded pictorial drawing. **12**

(a) Using a scale of 2:1, complete the left-side view of the assembled crank and axle. Do NOT show hidden outline.

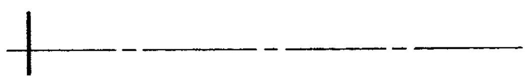
(b) Project a part-sectional front view of the assembled crank and axle, when viewed in the direction of the arrow.

- The crank is to be part-sectioned to show the axle as visible outline.
- The axle is also to be part-sectioned to show the hexagonal hole as visible outline.





LEFT SIDE VIEW



FRONT VIEW

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1997
HIGHER SCHOOL CERTIFICATE EXAMINATION
ENGINEERING SCIENCE
2/3 UNIT (COMMON)

Not to be collected at the conclusion of the examination.

FORMULAE

Dynamics

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

Statics

If a body is in equilibrium, then: $\sum F_x = 0$; $\sum F_y = 0$; $\sum M = 0$

$M = Fd$; $F = \mu N$

Machines

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

Strength of materials

$\sigma = \frac{P}{A}$; $\varepsilon = \frac{e}{L}$; $E = \frac{\sigma}{\varepsilon}$; $\% RA = \frac{A_0 - A}{A_0} \times 100$

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.