BOARD OF STUDIES
NEW SOUTH WALES

STUDENT NUMBER

CENTRE NUMBER

HIGHER SCHOOL CERTIFICATE EXAMINATION

1999

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

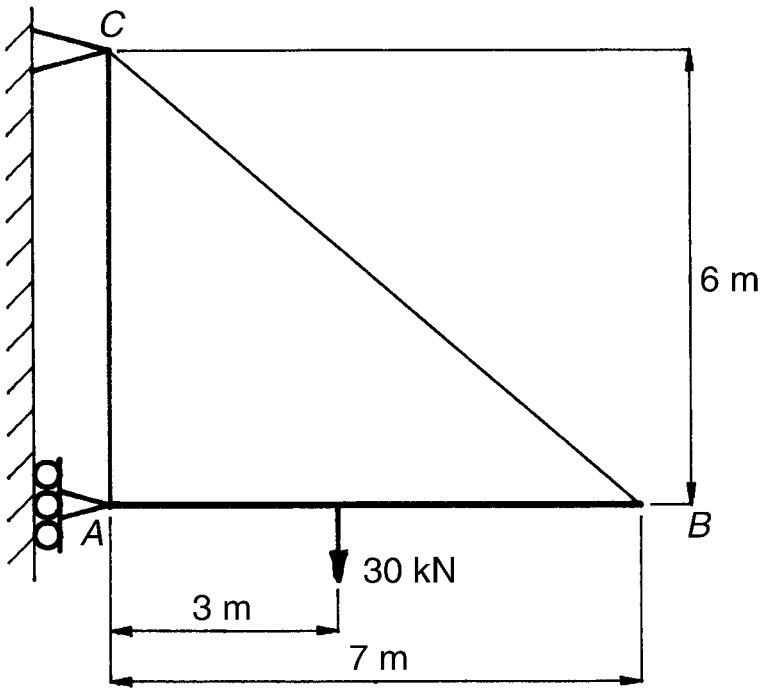
- Remove the staple to separate Section I and Section II.
- Write your Student Number and Centre Number at the top right-hand corner of this page and page 17.
- Allow approximately 90 minutes for this Section.
- Attempt ALL questions.
- Answer the questions in the spaces provided in this paper. Set out 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 (page 34) 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**

A simple jib-crane truss is shown in the figure below. The crane assembly is connected to a vertical wall by a pin support at *C* and a roller support at *A*. The beam *AB* has a mass of 50 kg/m acting through the centre of the beam. Members *AC* and *BC* are relatively light, round cables and their mass should be ignored.



(a) For one set of conditions, a vertical load of 30 kN is applied to the beam *AB* at a point 3 metres to the right of *A*. **4½**

(i) Determine the reactions at the supports *A* and *C*.

Magnitude of reaction at *A* ..... kN. Direction .....

Magnitude of reaction at *C* ..... kN. Direction .....

QUESTION 1 (Continued) **Marks**

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

Axial force in member *BC* ..... kN

Nature of axial force in member *BC* .....

(b) The 30 kN force is moved to joint *B*. Select the most appropriate term: *increase*, *decrease* or *remain the same*, to complete the following sentences. **1**

(i) The axial force in member *BC* would .....

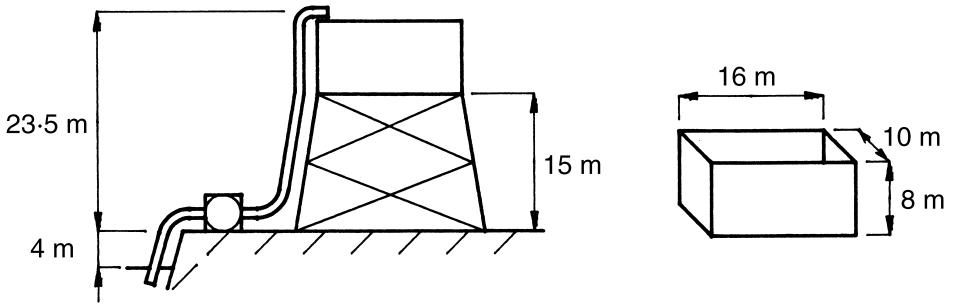
(ii) The horizontal component of the reaction at *A* would .....

(c) For another set of conditions, the maximum working axial force in the diagonal member *BC* is 53 kN. The steel used in the member has a yield stress of 300 MPa. Using a factor of safety of 1·5, determine the minimum diameter of member *BC*. **2$\frac{1}{2}$**

Minimum diameter of *BC* ..... mm

QUESTION 2 **Marks**

(a) A pumping system and water tank are shown below. (The dimensions of the water tank are also given.) The pump draws water from the river and supplies the tank. The tank sits on a frame 15 m above the ground. **4**



(i) Determine the work done to pump the water from the river to half-fill the tank. (1 cubic metre of water has a mass of 1000 kg.)

Work done ..... MJ

(ii) The tank is to be half-filled with water in 25 minutes. Determine the power required of the pumping system if it has an efficiency of 70%.

Power required ..... kW

QUESTION 2 (Continued) **Marks**

(b) Ball *A* is released from rest at a height of 12 metres from the ground. At the same time, a second ball *B* is thrown vertically upwards from a height of 1 metre above the ground. The balls pass one another at a height of 6 metres from the ground. **$2\frac{1}{2}$**

(i) Draw a free-body diagram representing the situation.

(ii) Determine the velocity at which ball *B* is thrown upwards.

Velocity ..... m/s

(c) A girl runs along a wharf to jump onto her boat that has started to drift. The boat is drifting with a velocity of 1 m/s in the same direction that she is running. The boat has a mass of 300 kg. **$1\frac{1}{2}$**

Determine the combined velocity of the girl and boat if the girl's weight is 65 kg and her velocity is 3·5 m/s when she jumps onto the boat.

Combined velocity ..... m/s

QUESTION 3 **Marks**

(a) Four ceramic products are given in the table below. Complete the table by stating the most suitable forming process for each product. **2**

Product	*Manufacturing process*
Toilet bowl	
Glass bottle	
Quality sheet glass	
Clay house-brick	

(b) (i) The following items are manufactured from various polymers. **$2\frac{1}{2}$**

- Plastic food wrap
- Bicycle brake block
- Inflatable inner tube

Three polymeric structures are shown below. Write the name of the item below the diagram that best represents its polymeric structure.

....

(ii) Cross-linking is evident in one or more of the structures shown above. Name and describe a process used to achieve cross-linking.

Name .....

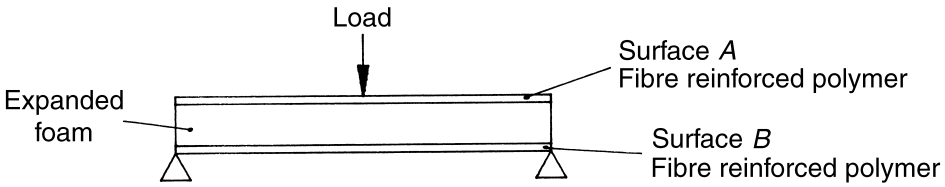
Description .....

.....

.....

QUESTION 3 (Continued) **Marks**

(c) A cross-section through the wall of a structural component used in the marine and aircraft industry is shown below. **$2\frac{1}{2}$**



(i) The panel is loaded as shown. State the surface (*A* or *B*) that will require the greater number of fibres.

.....

(ii) State ONE reason for the use of the foam.

.....

(iii) Name a suitable material for the expanded foam.

.....

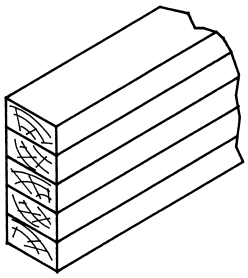
(iv) State the purpose of the fibre in the reinforced polymer.

.....

(v) Name a suitable material for the fibre in the reinforced polymer.

.....

(d) Structural beams are often laminated, as shown below, rather than cut from solid timber. **1**



State TWO structural advantages of using laminated beams for long spans in building structures.

Advantage 1 .....

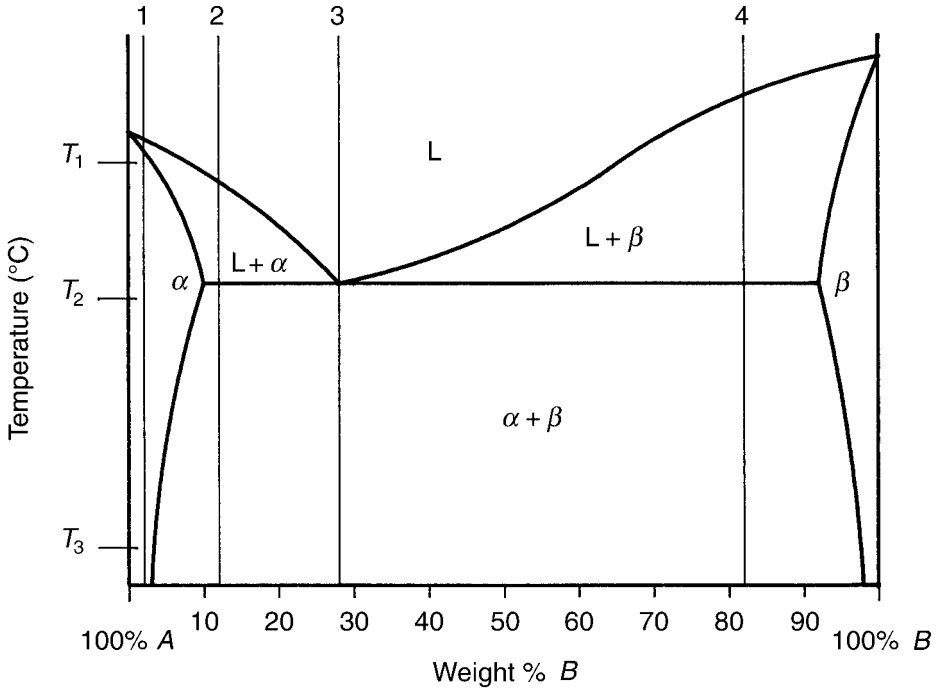
.....

Advantage 2 .....

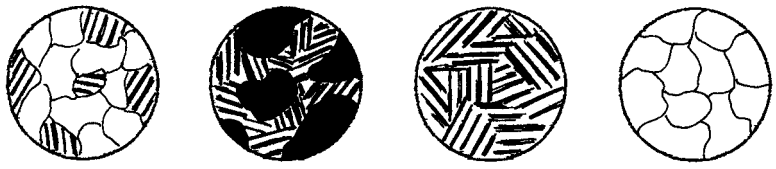
.....

QUESTION 4 **Marks**

(a) The phase diagram for a binary alloy system of metal *A* and metal *B* is given below. Four alloy compositions are also indicated on the diagram. **4**



(i) Match each of the microstructures shown below with the alloys 1, 2, 3 or 4, shown in the phase diagram. Assume that each alloy was cooled under equilibrium conditions.



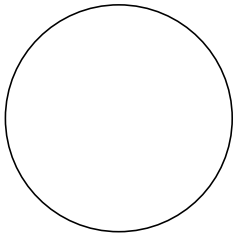
Alloy..... Alloy..... Alloy..... Alloy.....

QUESTION 4 (Continued) **Marks**

(ii) Determine the composition of the liquid at temperature T_1 for a 20% *A*–80% *B* alloy under equilibrium conditions.

Composition of liquid .....

(iii) Describe the changes to the microstructure of a 92% *A*–8% *B* alloy as it cools from temperature T_2 to T_3, under equilibrium conditions. Draw and label the microstructure of the alloy at temperature T_3.



.....

.....

.....

.....

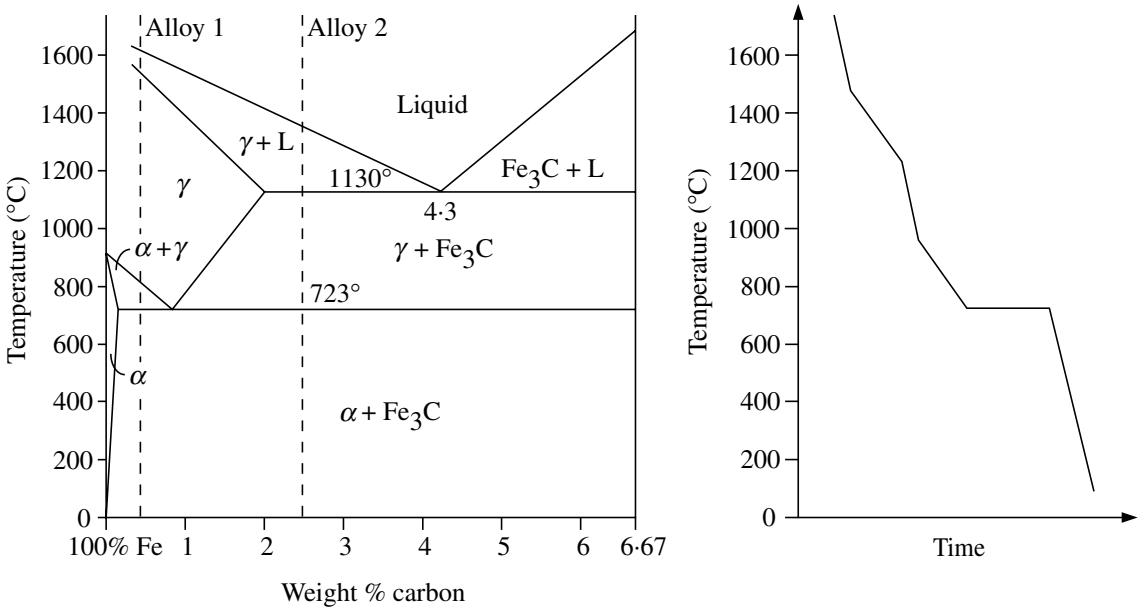
.....

.....

Question 4 continues on page 10

QUESTION 4 (Continued) **Marks**

(b) A portion of the iron–carbon phase diagram is given below. A cooling curve for a particular alloy is also given. **4**



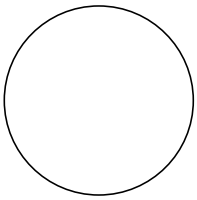
(i) Determine the composition of the alloy represented by the cooling curve shown above.

Composition .....% carbon

QUESTION 4 (Continued) **Marks**

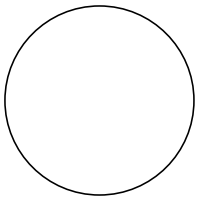
(ii) Alloy 1 (0·4% carbon in iron) and alloy 2 (2·5% carbon in iron) are cooled, under equilibrium conditions, to room temperature. Draw and label the microstructure of each alloy.

Alloy 1



0·4% carbon alloy

Alloy 2



2·5% carbon alloy

(iii) Alloy 1 is relatively soft while alloy 2 is relatively hard. State ONE reason for this difference in mechanical properties.

.....

.....

(iv) Determine which alloy, 1 or 2, has the lower casting temperature.

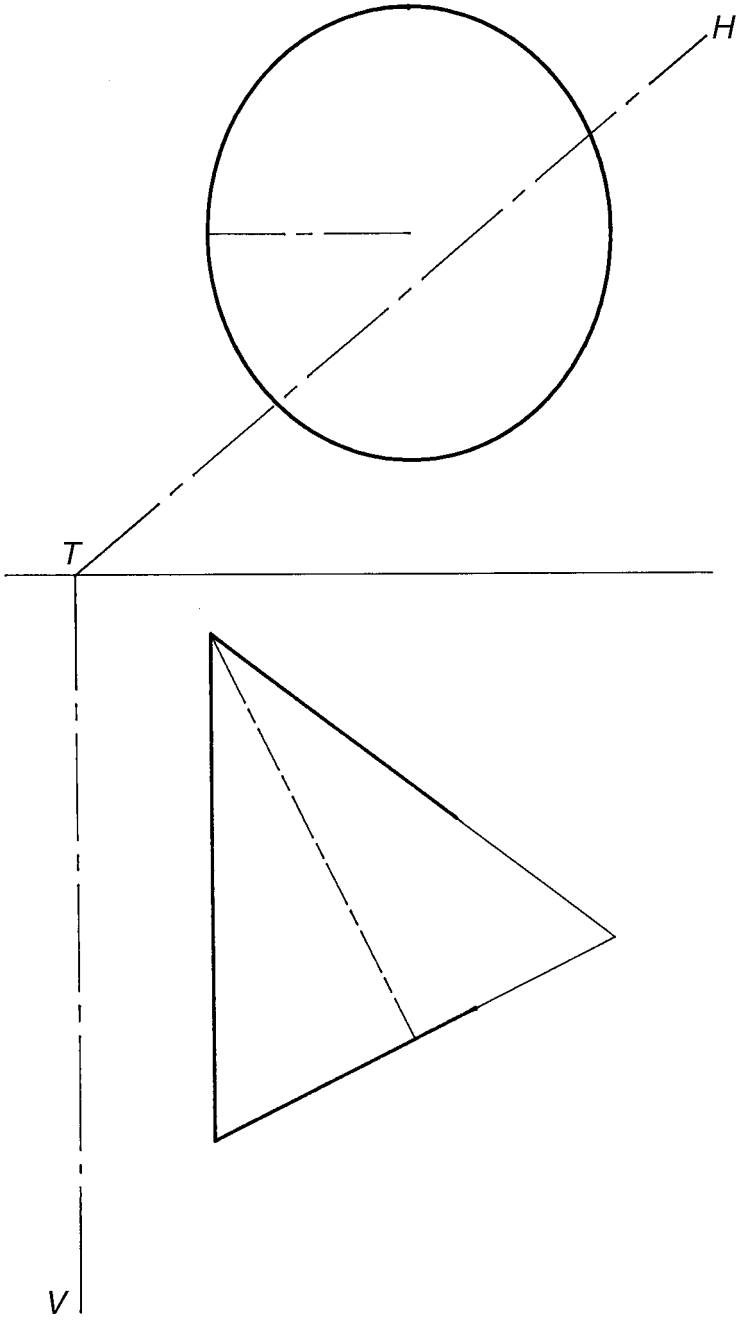
Alloy .....

QUESTION 5 **Marks**

(a) The top view and incomplete sectional front view of a cone inclined to the horizontal plane are shown below in third-angle projection. **4**

The cone is cut by a vertical section plane as shown.

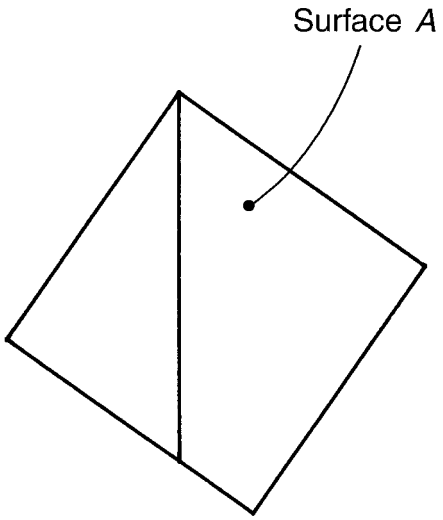
Complete the sectional front view.

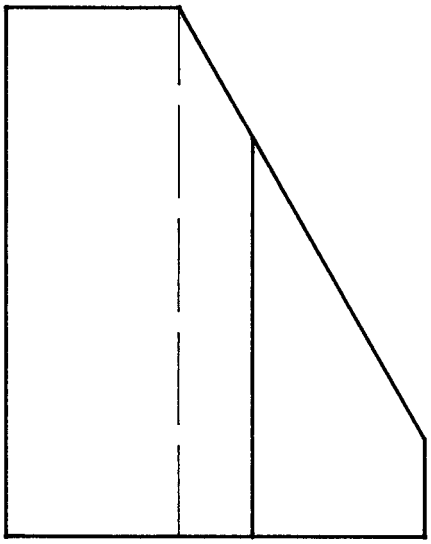


QUESTION 5 (Continued) **Marks**

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

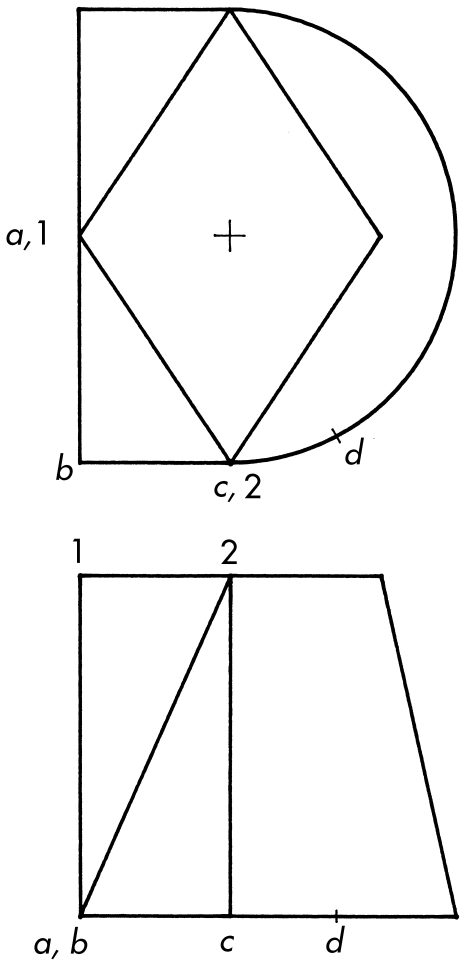
Project a right-side view of the prism so that surface *A* is seen as the true shape. Show visible and hidden outline.





QUESTION 6 **Marks**

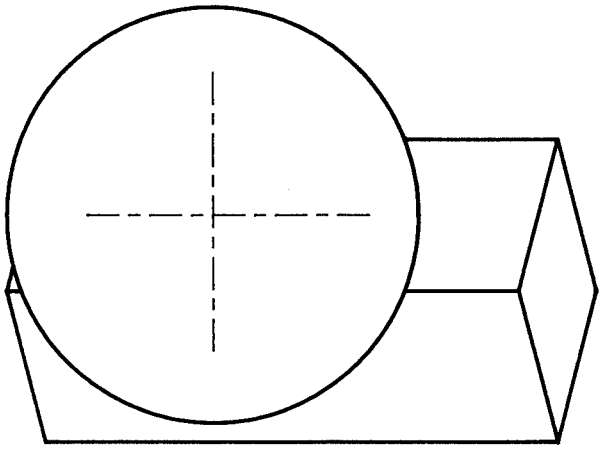
(a) The top view and front view of a transition piece are shown below in third-angle projection. Complete a pattern of the surface *abcd*21. The starting position for the seam 1*a* is given. **4**

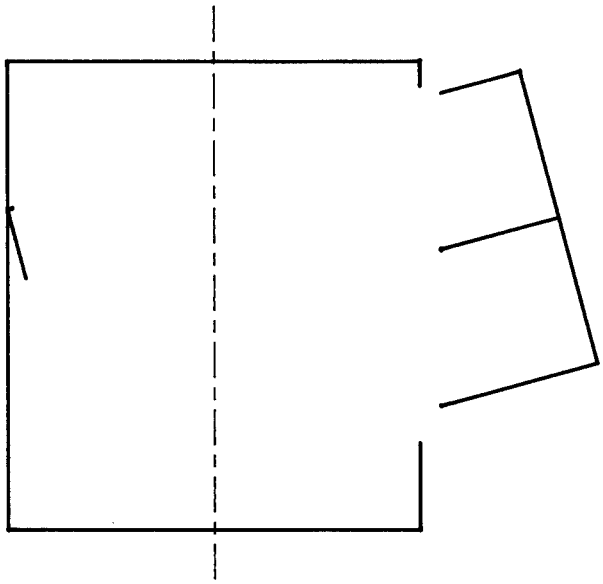


QUESTION 6 (Continued) **Marks**

(b) The top view and incomplete front view of a cylinder intersecting with a square prism are given below in third-angle projection. **4**

Complete the front view, showing only visible outline.





BLANK PAGE

BOARD OF STUDIES
NEW SOUTH WALES

STUDENT NUMBER

CENTRE NUMBER

HIGHER SCHOOL CERTIFICATE EXAMINATION

1999

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

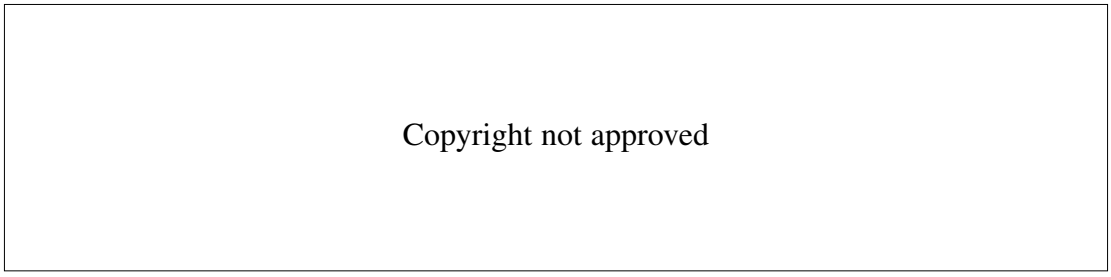
- Write your Student Number and Centre Number at the top right-hand corner of this page.
- Allow approximately 90 minutes for this Section.
- Attempt ALL questions.
- Answer the questions in the spaces provided in this paper. Set out your working clearly and neatly. Emphasis will be placed on that working 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**

The design of modern-day bicycles has developed over a short period of time, from a Tourer to BMX to a Mountain bike.



TOURER 1960 BMX 1980 MOUNTAIN 1990

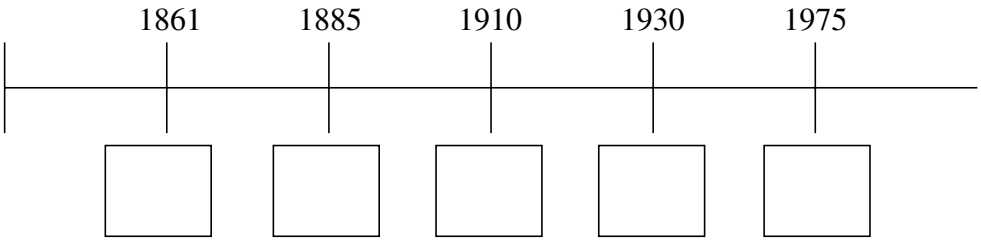
(a) Complete the table below by filling in a statement next to each point. **3**

	Tourer	*BMX*	*Mountain*
Purpose of the design	• 'on road' design • cheap transport to work	• for racing, jumps and general rugged 'off road' use • built for younger age groups	• .... • ....
Features of speed mechanism design	• large wheels • 3 speed hub, single cable	• small wheels • had little or no design for speed	• .... • ....
Features of frame and components	• .... •	• aluminium alloy frame • small rugged frame • high-strength wheels • gusset construction for frame	• carbon fibre, alloy steel and aluminium • large strong frame • light weight • hydraulic brakes and suspension

QUESTION 7 (Continued) **Marks**

(b) Social values, events and materials development have played an important part in the evolution of bicycle design. **2**

Write the number of each statement in the correct box on the time line.



1 Mass production techniques reduce costs, leading to greater demand for the bicycle.

2 Society sees the importance of fitness and a reduction in pollution.

3 Rover Safety with pneumatic tyres provides a safer, more comfortable ride.

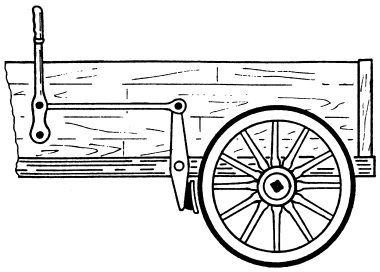
4 The bicycle increased in popularity at this stage of its development, due to its use as cheap transport to work.

5 The Velocipede had a sprung frame, 2 cart wheels and a simple string-operated brake.

Question 7 continues on page 20

QUESTION 7 (Continued) **Marks**

(c) A variety of materials have been used as the friction components in the development of brake systems, as shown in the diagrams below. Give TWO reasons for the use of each material. **3**

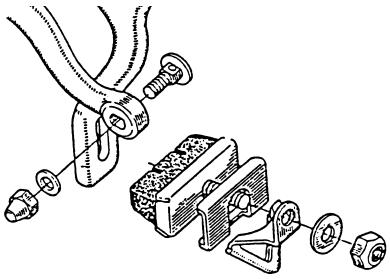


Curved wooden brake shoe

Reason

1 .....

2 .....

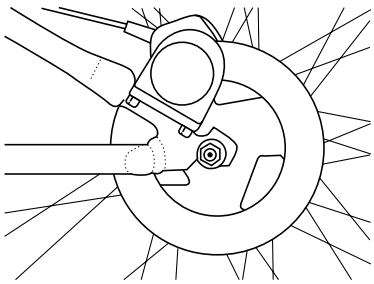


Brake block (rubber)

Reason

1 .....

2 .....



Disc pad (cermet composite)

Reason

1 .....

2 .....

QUESTION 8 **Marks**

(a) A bicycle and rider start from rest and roll down a slope of 1 : 2. The bicycle and rider have a combined mass of 105 kg. After a period of 12 seconds the bicycle and rider reach a maximum velocity of 30 km/h. **4**

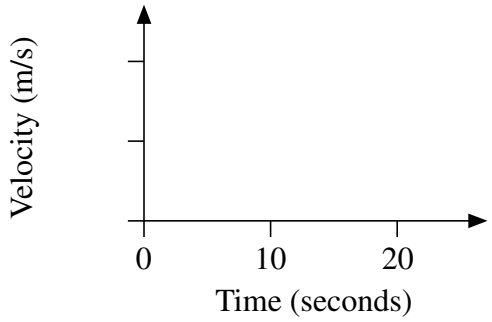
(i) Determine the acceleration of the rider down the slope.

Acceleration ..... m/s^2

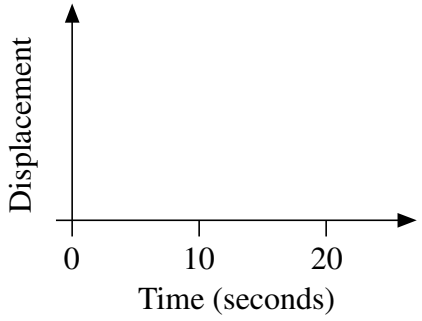
(ii) Determine the resistance to motion when the rider is travelling at 30 km/h.

..... N

(iii) On the axes provided below, plot a velocity–time graph that represents the rider's journey for the first 20 seconds.



(iv) On the axes provided below, sketch the displacement–time graph for the first 20 seconds.



Question 8 continues on page 22

QUESTION 8 (Continued) **Marks**

(b) (i) For the same rider, now travelling on a level road at 25 km/h, the resistance to motion is 275 N. The rider must exert an average force of 350 N on the pedal to maintain this speed. **$2\frac{1}{2}$**

Determine the mechanical advantage of the system.

Mechanical advantage .....

(ii) While travelling at a speed of 25 km/h the rider suddenly increases the average pedal force to 500 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.

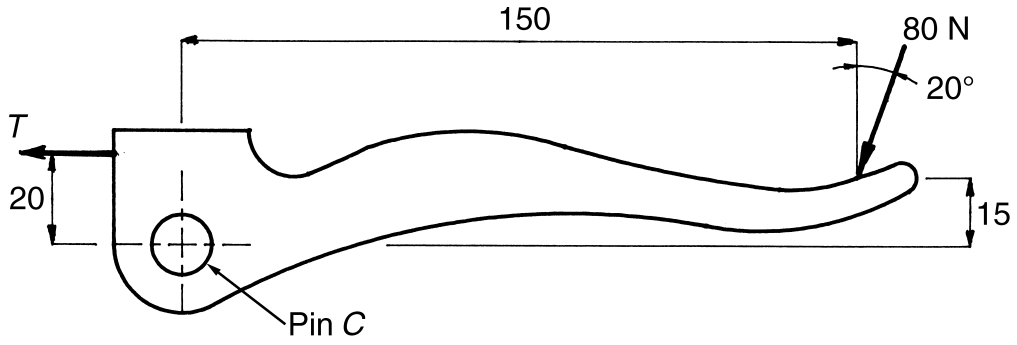
Acceleration ..... m/s^2

(c) For another set of conditions, the rider's velocity is 30 km/h. The brakes are then applied for 6 seconds, reducing the velocity to 5 km/h. Determine the energy absorbed by the brakes. Assume that the energy lost is due to the application of the brakes only. **$1\frac{1}{2}$**

Energy absorbed ..... J

QUESTION 9 **Marks**

(a) Details of a handle used in a bicycle brake system are shown in the diagram. **2**



(i) Determine the tension T in the cable if a load of 80 N is applied to the handle as shown in the diagram.

Tension T ..... N

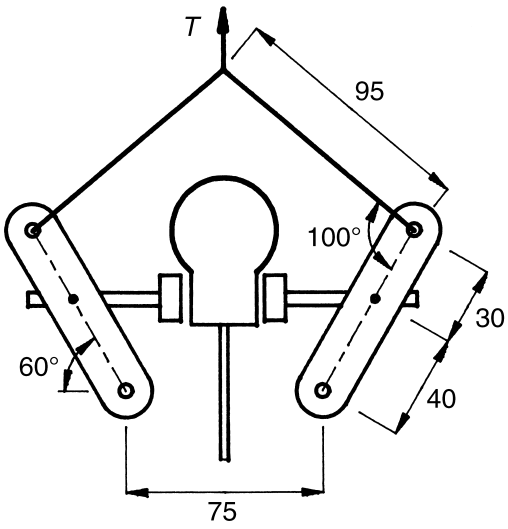
(ii) Determine the resultant shear force acting on Pin C.

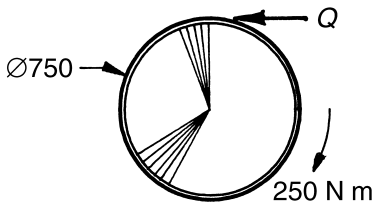
Shear force ..... N

Question 9 continues on page 24

QUESTION 9 (Continued) **Marks**

(b) Details of a centre-pull bicycle brake system, and a bicycle wheel are given in the diagrams. The wheel is held stationary by the brake system while a 250 N m torque is applied to the wheel. The coefficient of friction between the brake block and the wheel rim is 0·75. **6**





(i) Determine the tangential friction force Q required to prevent the rotation of the wheel.

Q ..... N

(ii) For a different set of conditions the tangential friction force is 800 N. Determine the tension T in the brake cable required to produce the 800 N force.

Tension T ..... N

QUESTION 9 (Continued) **Marks**

(iii) For a different set of conditions, the tension in the brake cable is 1·2 kN. The cable has a gauge length of 300 mm and a diameter of 1·5 mm. The steel used in the cable has a modulus of elasticity of 210 MPa.

Determine the extension of the cable.

Extension ..... mm

QUESTION 10 **Marks**

(a) Lugs are used in the joining of a bicycle frame. **$3\frac{1}{2}$**

(i) 1 Name a method used to join the lug to the frame.

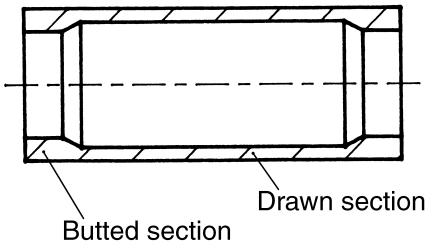
.....

2 List TWO reasons for the use of this lug joining method.

(I) .....

(II) .....

(ii) The following steel tube has been cold drawn to form butted ends by using a combination of cold-drawing processes.



1 What is the main advantage of butting the tube ends?

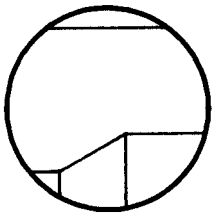
.....

.....

2 If 0·3%C seamless steel tube is used to form the butted tube, state a change in mechanical properties caused by this process.

.....

3 Draw the grain structure of the tube wall at the butted section.



QUESTION 10 (Continued) **Marks**

(b) The cowling of a lawnmower is produced by injection moulding a 10% glass-filled nylon composite. **$2\frac{1}{2}$**

(i) If injection moulding is used with glass fibre and a granulated form of nylon, give TWO reasons for the use of injection moulding.

1 .....

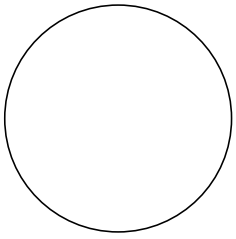
2 .....

(ii) At what stage is the glass fibre added to the composite in the manufacture of the cowling?

.....

.....

(iii) Draw and label a macrostructure of 10% glass-filled nylon.



(c) Brake drums are often made from grey cast iron. **2**

(i) List THREE reasons for the use of cast iron in the brake drum.

1 .....

2 .....

3 .....

(ii) Name the most appropriate type of casting used to make the brake drums.

Name .....

QUESTION 11 **Marks**

A lawnmower assembly bolt is manufactured from cold drawn 0·2% carbon steel. The head and thread are formed by cold-working processes.

(a) Both the cold-drawn stock and the finished bolt are to be tested to examine properties and detect faults. Name and describe a different non-destructive test that could be used for each situation. **3**

(i) Cold-drawn stock

Name of test .....

Description of test .....

.....

.....

(ii) Finished bolt

Name of test .....

Description of test .....

.....

.....

(b) State TWO advantages that cold rolling of the thread has over machining of the thread. **1**

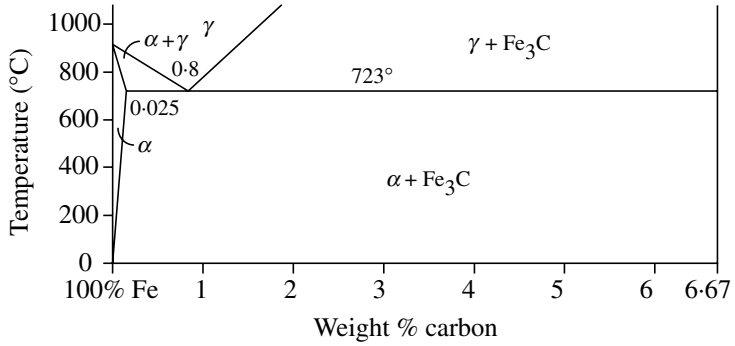
Advantage 1 .....

Advantage 2 .....

QUESTION 11 (Continued) **Marks**

(c) Two samples of cold-drawn 0·2% carbon steel stock are to be prepared for microscopic examination. One sample was process annealed. The second sample was normalised. **4**

(i) With reference to the partial iron–carbon diagram, describe in detail the procedure used for each heat treatment process.



1 Process annealing

.....

.....

.....

2 Normalising

.....

.....

.....

(ii) Draw and label the microstructure resulting from the normalising process.

(iii) Normalising and process annealing result in different mechanical properties. State which heat treatment process results in:

1 higher strength .....

2 higher hardness .....

QUESTION 12 **Marks**

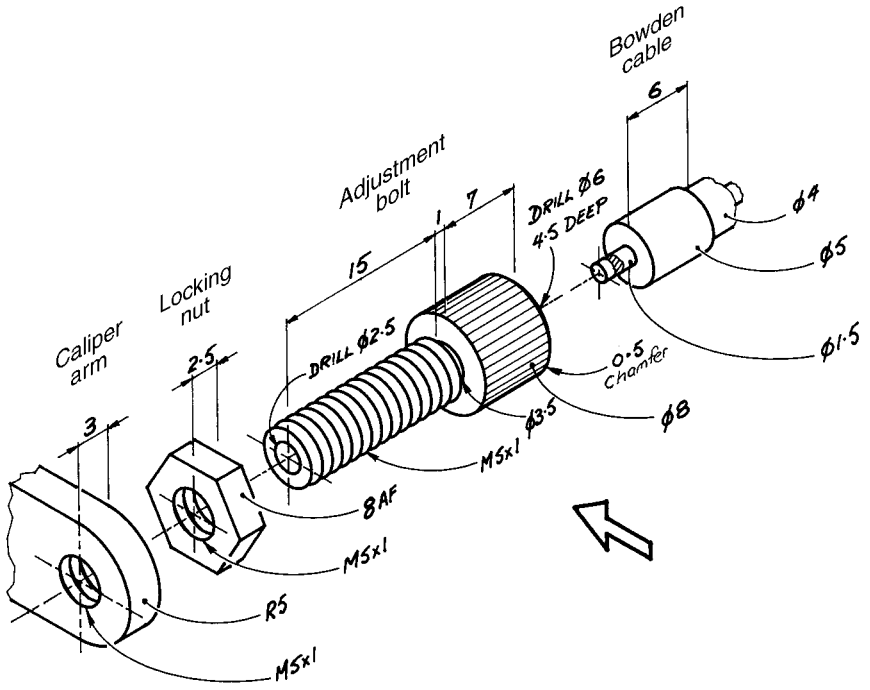
Shape and size details of a brake-cable tensioning assembly for a bicycle are given below in the exploded pictorial drawing. **12**

The head of the adjustment bolt is 5 mm from the caliper arm.

The centre cable of the Bowden cable should extend 1 mm beyond the end of the adjustment bolt.

The position of the left end of the adjustment bolt has been given.

Complete, using a scale of 5 : 1, a half-sectioned front view of the assembled parts when viewed in the direction of the arrow.



End of paper

BLANK PAGE

BLANK PAGE

1999
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

Not to be collected at the conclusion of the examination.