Centre Number

Student Number

**2023** HIGHER SCHOOL CERTIFICATE EXAMINATION

# Engineering Studies

**General Instructions**
- Reading time – 5 minutes
- Working time – 3 hours
- Write using black pen
- Draw diagrams using pencil
- Calculators approved by NESA may be used
- A formulae sheet is provided at the back of this paper
- Write your Centre Number and Student Number at the top of this page

**Total marks: 100**

**Section I – 20 marks** (pages 2–10)
- Attempt Questions 1–20
- Allow about 30 minutes for this section

**Section II – 80 marks** (pages 13–40)
- Attempt Questions 21–27
- Allow about 2 hours and 30 minutes for this section

2070

## Section I

**20 marks**
**Attempt Questions 1–20**
**Allow about 30 minutes for this section**

Use the multiple-choice answer sheet for Questions 1–20.

**1** Which of the following is a recognised impact test?

    A.    Brinell

    B.    Erichsen

    C.    Notch

    D.    Punch

**2** Why did steel replace cast iron in bridges built after 1850?

    A.    It is lighter in weight.

    B.    It is easier to produce.

    C.    It has greater tensile strength.

    D.    It has greater compressive strength.

**3** Why is pure copper preferred over a copper alloy in telecommunications applications?

    A.    It has higher stiffness.

    B.    It has better conductivity.

    C.    It can be precipitation hardened.

    D.    It has a better strength to weight ratio.

**4**   Four types of lines are shown.

| 1 | 2 | 3 | 4 |
|---|---|---|---|
| ———— | - - - - - - - - | —·——·——·— | —⋀— |

Which row of the table correctly identifies the typical application of each line type according to AS 1100?

|   | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| A. | Outline | Concealed | Centre | Break |
| B. | Solid | Hidden detail | Chain | End |
| C. | Outline | Hidden detail | Centre | Break |
| D. | Development | Stitch line | Reference | Section |

**5**   Why does signal loss occur in optical glass fibres?

A.   Flaws in the glass fibres scatter the light.

B.   Twisted cables affect the transmission of light.

C.   External electromagnetic noise affects signal quality.

D.   Pressure affects signal transmission in submarine cables.

**6**   The landing gear on an aircraft uses a hydraulic braking system. A force of 60 N is applied at the master cylinder with a piston diameter of 12 mm.

What is the force at the brake calliper with a piston diameter of 42 mm?

A.   4.9 N

B.   17.14 N

C.   210 N

D.   735 N

**7**   Why is cast iron preferred to steel when used as a heavy machine base?

A.   It is less brittle.

B.   It is more malleable.

C.   It has a lower damping capacity.

D.   It has a higher damping capacity.

**8** Why were steam trains replaced with electric trains in underground rail systems?

    A.    Electric trains are faster than steam trains.

    B.    Electric trains have better traction than steam trains.

    C.    Electric trains produce less emissions than steam trains.

    D.    Electric trains require less infrastructure than steam trains.


**9** In the process of manufacturing a concrete slab, cables are placed in ducting. After the concrete is poured and cured, the cables are stretched, anchored and released.

What type of concrete slab is this?

    A.    Meshed

    B.    Reinforced

    C.    Pre-tensioned

    D.    Post-tensioned


**10** A bogie pin is shown.
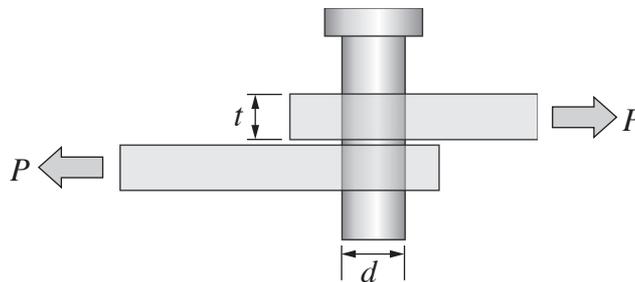


What is the expression for the shear stress in the pin?

    A.   $\dfrac{4P}{\pi \times d}$

    B.   $\dfrac{4P}{\pi \div d}$

    C.   $\dfrac{4P}{\pi \times d^2}$

    D.   $\dfrac{4P}{\pi \div d^2}$

**11** Which manufacturing process is used to make soft drink bottles out of polyethylene terephthalate (PET)?

    A.    Stamping

    B.    Extrusion

    C.    Blow moulding

    D.    Rotational moulding

**12** A rail switch lever is shown.
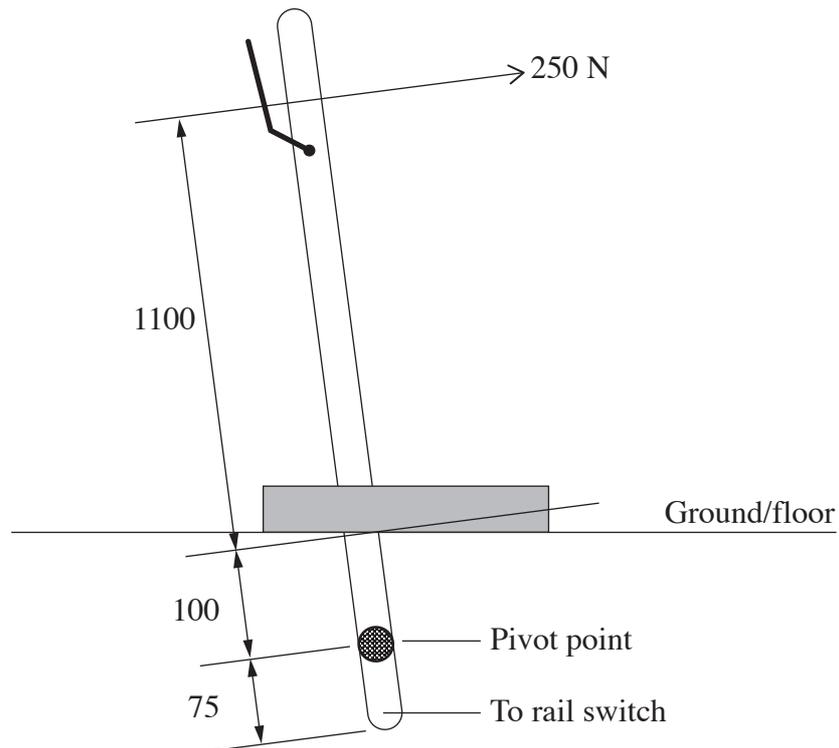


What is the calculated mechanical advantage when operating this rail switch lever?

    A.    3.7

    B.    6.3

    C.    14.7

    D.    16.0

**13**   Which mechanical property describes an object that is under load and follows Hooke's Law?

   A.   Ductility

   B.   Elasticity

   C.   Malleability

   D.   Plasticity


**14**   A piece of 0.8% C steel is heated to above its recrystallisation temperature and then normalised.

   In what medium is this piece of steel cooled?

   A.   Air

   B.   Brine

   C.   Sand

   D.   Water


**15**   What is the primary benefit of placing a satellite in a low earth orbit rather than a higher earth orbit?

   A.   Longer lifespan

   B.   Less atmospheric drag

   C.   Faster data transmission

   D.   Cover larger areas on Earth

**16** An aircraft weighing 3 tonne is ascending as shown. The lift to drag ratio is 11:1.



Mass

3T

6°
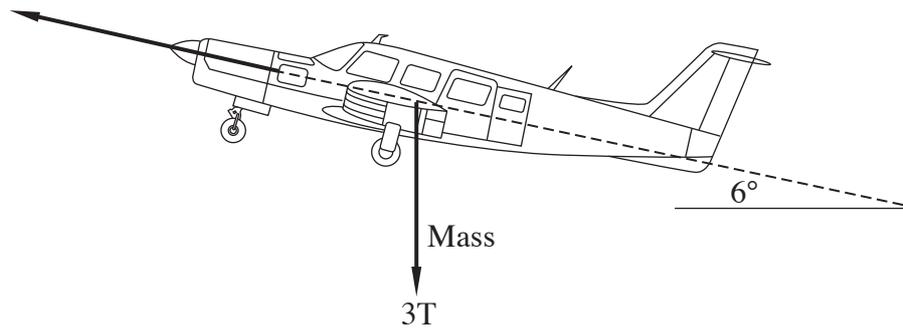
Which row of the table correctly identifies the lift, drag and thrust values for the aircraft?

|  | Lift | Drag | Thrust |
|---|---|---|---|
| A. | 29.8 kN | 2.7 kN | 5.8 kN |
| B. | 29.8 kN | 2.7 kN | 3.1 kN |
| C. | 2.7 kN | 3.1 kN | 5.8 kN |
| D. | 2.7 kN | 3.1 kN | 29.8 kN |

**17** Three machined parts drawn to AS 1100 are shown.



1                    2                    3
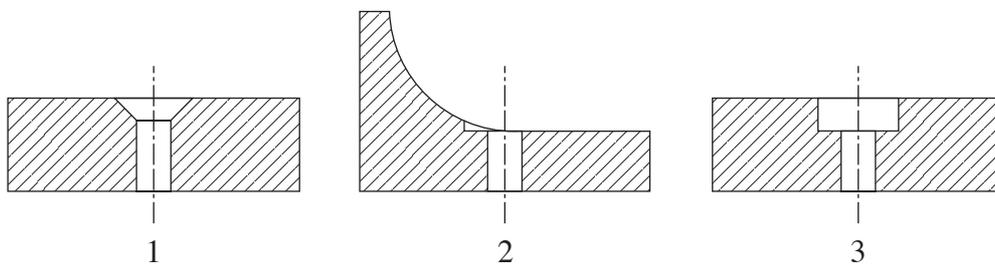
Which row of the table correctly identifies the AS 1100 standard representations?

|  | 1 | 2 | 3 |
|---|---|---|---|
| A. | Counterbore | Spotface | Countersink |
| B. | Spotface | Countersink | Counterbore |
| C. | Countersink | Spotface | Counterbore |
| D. | Countersink | Counterbore | Spotface |

**18** A diagram of a block being pulled by a rope up an inclined plane is shown.
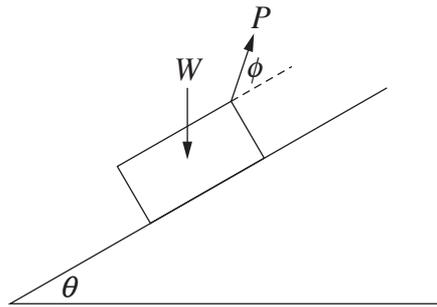


Which free body diagram correctly represents the diagram given?

A.



B.



C.



D.
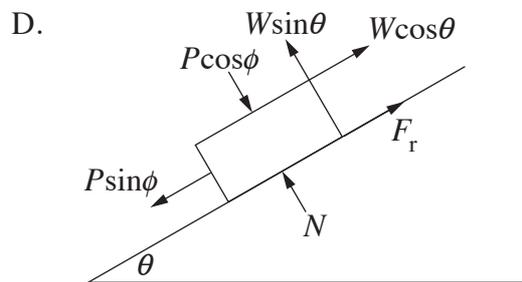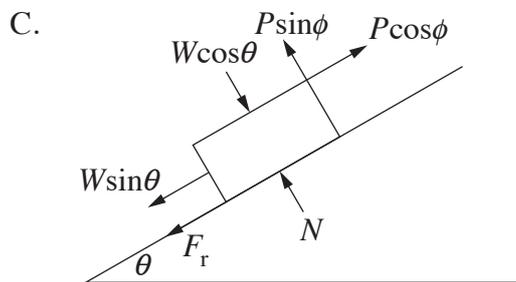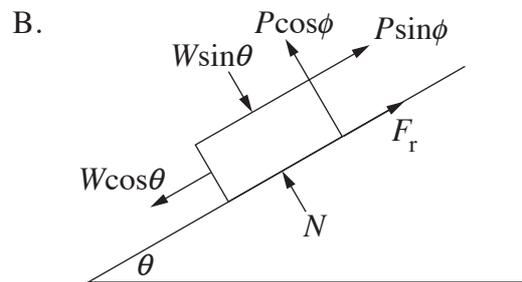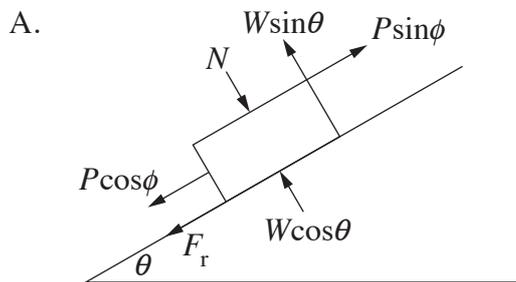
**19**   A loaded truss is shown.
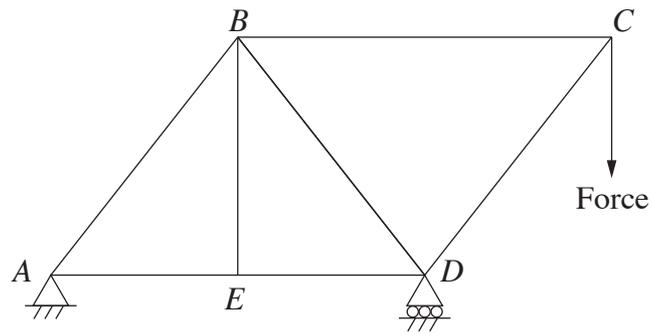


Which of the following is the redundant member?

A.   *AB*

B.   *BD*

C.   *BE*

D.   *CD*

**Please turn over**

**20**  A transition duct is shown.



Top view



Front view
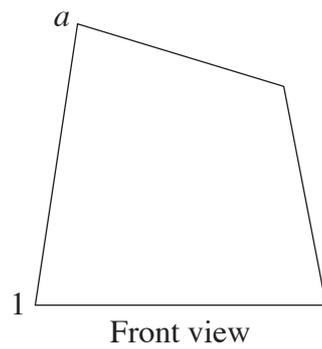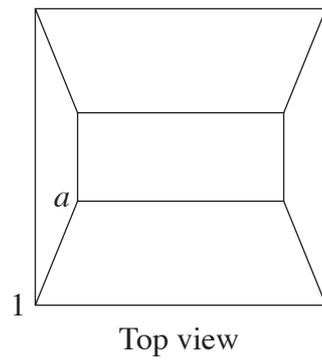
What is the true angle of the line 1–*a* to the horizontal plane?

A.  69°

B.  81°

C.  90°

D.  101°

BLANK PAGE

BLANK PAGE

Centre Number

Student Number

# Engineering Studies

## Section II Answer Booklet

**80 marks**
**Attempt Questions 21–27**
**Allow about 2 hours and 30 minutes for this section**

**Instructions**
- Write your Centre Number and Student Number at the top of this page.

- Answer the questions in the spaces provided. These spaces provide guidance for the expected length of response.

- Show all relevant working in questions involving calculations.

- Extra writing space is provided at the back of this booklet. If you use this space, clearly indicate which question you are answering.

**Please turn over**

**Question 21** (11 marks)

(a) How can computer graphics be utilised as a tool in aeronautical engineering?  **2**

.......................................................................................................................................

.......................................................................................................................................

.......................................................................................................................................

.......................................................................................................................................

(b) You are part of a team of engineers working collaboratively on the design of a new aircraft.  **3**

Explain the benefits of collaboration when completing the engineering report.

.......................................................................................................................................

.......................................................................................................................................

.......................................................................................................................................

.......................................................................................................................................

.......................................................................................................................................

.......................................................................................................................................

1530310429

Do NOT write in this area.

(c)   An orthogonal view of a rib in an aircraft wing is shown.                    **3**
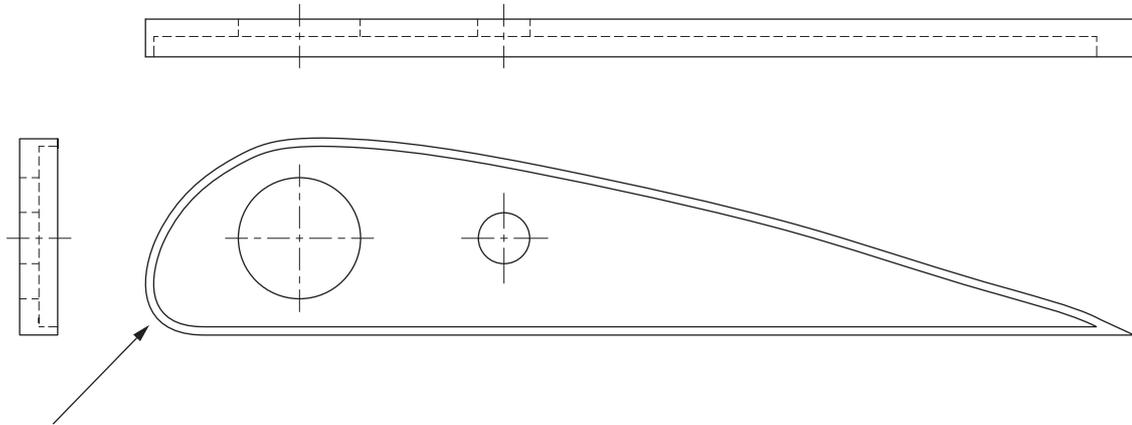


Construct a freehand isometric sketch of the wing rib as viewed in the direction of the arrow.
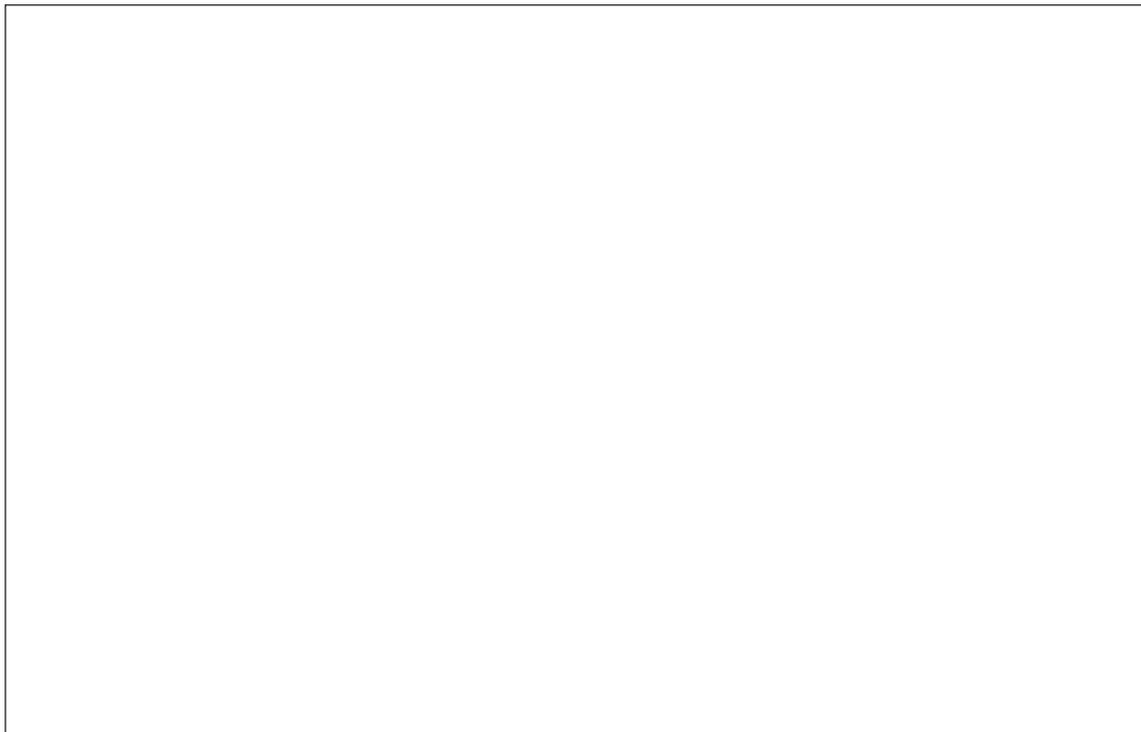


**Question 21 continues on page 16**

Office Use Only – Do NOT write anything, or make any marks below this line.

0398310420

Question 21 (continued)

(d)    Draw, label and describe the microstructure of a thermosetting polymer.        **3**

.......................................................................................................................................

.......................................................................................................................................

.......................................................................................................................................

.......................................................................................................................................

.......................................................................................................................................
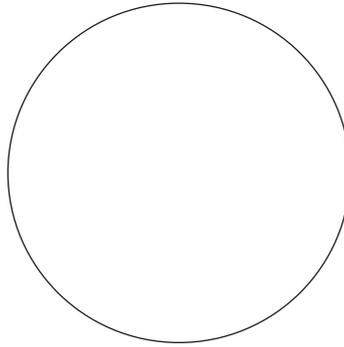
**End of Question 21**

**Question 22** (11 marks)

(a) Previously, children's playground structures were constructed from 'treated pine' logs. The logs were treated with a copper chromium arsenate (CCA) solution which resisted fungi, insect attack and decay.

(i) Outline why new materials are being used to replace CCA treated logs in children's playground structures.

**2**

..............................................................................................................................

..............................................................................................................................

..............................................................................................................................

..............................................................................................................................

..............................................................................................................................

(ii) Justify a suitable material to use for a playground structure which will be exposed to the weather at all times.

**3**

..............................................................................................................................

..............................................................................................................................

..............................................................................................................................

..............................................................................................................................

..............................................................................................................................

..............................................................................................................................

..............................................................................................................................

..............................................................................................................................

9777310420

Question 22 (continued)

(b)   The diagram shows a child with a mass of 45 kg hanging 2 metres from the left end of a structure, and an adult with a mass of 85 kg hanging 1 metre from the right end.
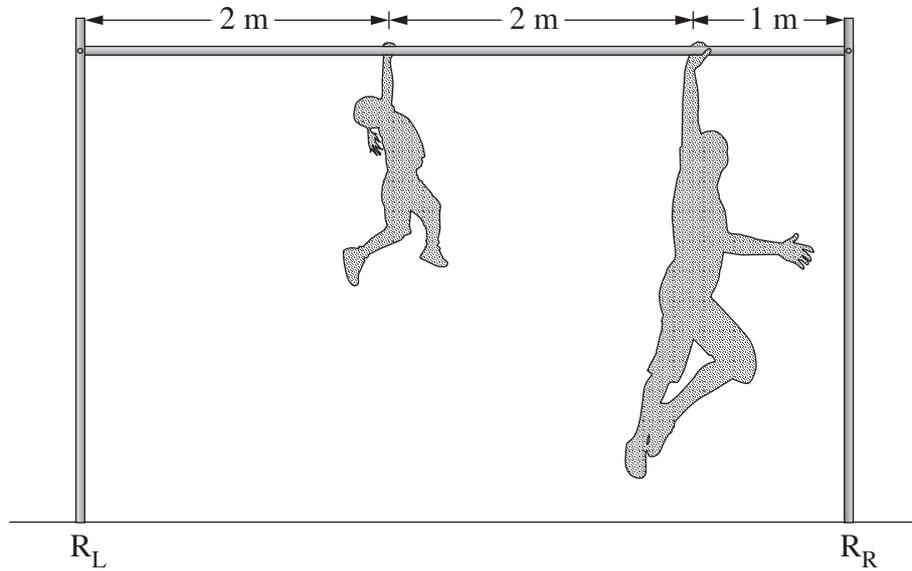


(i)   Calculate the reactions at $R_L$ and $R_R$.                    **3**

$R_L$ = .................................... N        Direction ................................

$R_R$ = .................................... N        Direction ................................

3556310429

(ii) Complete the shear force and bending moment diagrams of the scenario described on the previous page.    **3**
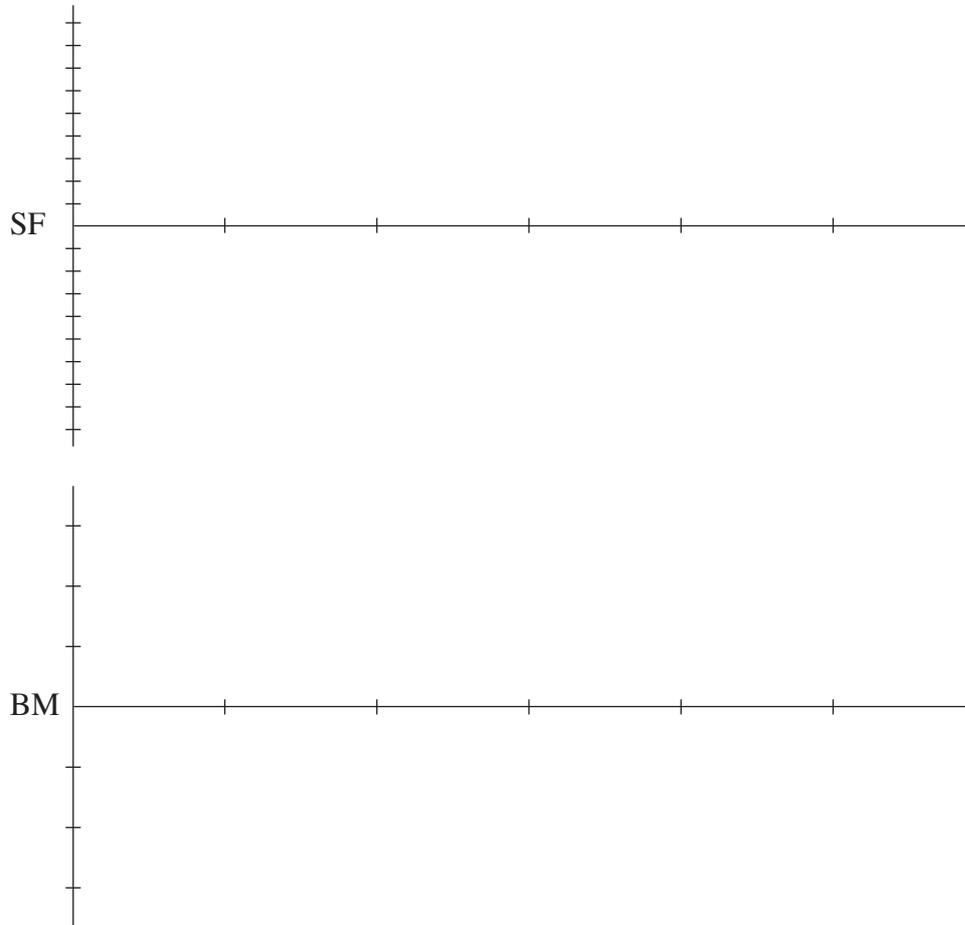
**End of Question 22**

Do NOT write in this area.

**Question 23** (12 marks)

(a) Draw the symbols which match the electronic components named in the table. **3**

| Component | Symbol |
|---|---|
| Open switch | |
| Power cell | |
| Light emitting diode | |
| Resistor | |
| Light dependent resistor | |
| NPN transistor | |
| Capacitor | |

5775310424

Do NOT write in this area.

Question 23 (continued)

(b) Describe the responsibilities of the engineer when considering security issues of telecommunications devices.  **3**

..........................................................................................................................

..........................................................................................................................

..........................................................................................................................

..........................................................................................................................

..........................................................................................................................

..........................................................................................................................

..........................................................................................................................

..........................................................................................................................

(c) How are insulating materials used in the telecommunications industry? Include an example in your answer.  **3**

..........................................................................................................................

..........................................................................................................................

..........................................................................................................................

..........................................................................................................................

..........................................................................................................................

..........................................................................................................................

..........................................................................................................................

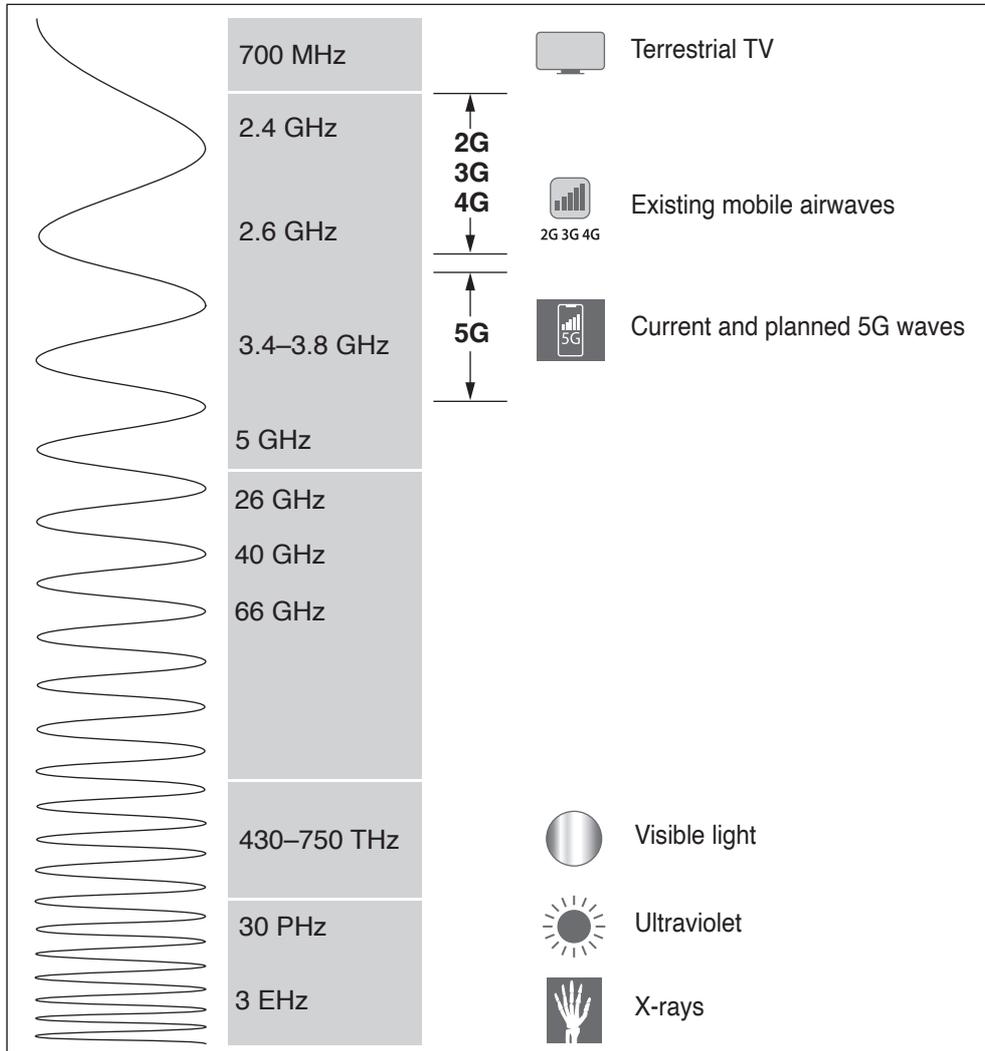..........................................................................................................................

**Question 23 continues on page 22**

(d)   The diagram shows the relative placement of 4G and 5G telecommunication   **3**
      bands within the electromagnetic spectrum.



With reference to the diagram, explain why 5G networks need more cellular
antennae and closer positioning of antennae than 4G networks.

..............................................................................................................................

..............................................................................................................................

..............................................................................................................................

..............................................................................................................................

..............................................................................................................................

..............................................................................................................................

..............................................................................................................................

..............................................................................................................................

**End of Question 23**

Office Use Only – Do NOT write anything, or make any marks below this line.

0915310425

**Question 24** (12 marks)

(a)   Roller coaster support structures can be made from either timber or steel.   **2**





Compare the properties of the two materials in roller coaster support structures.
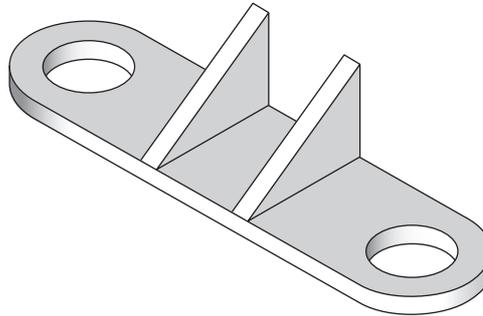
.......................................................................................................................................

.......................................................................................................................................

.......................................................................................................................................

.......................................................................................................................................

.......................................................................................................................................
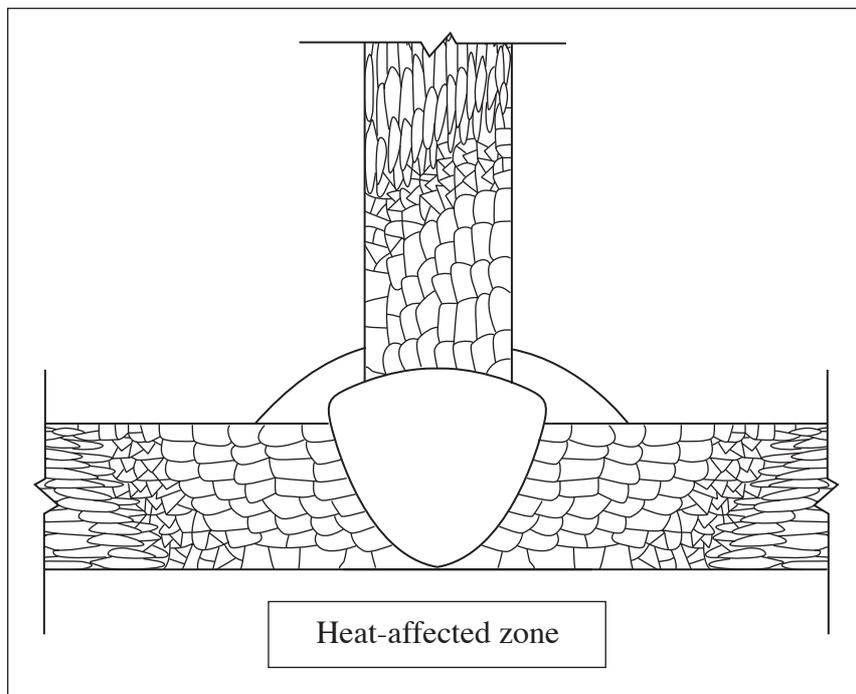
2248310426

Question 24 (continued)

(b)   A roller coaster component is fabricated using cold rolled steel. Two webs are     **2**
      welded onto a base plate as shown.



The diagram shows a partially completed microstructure of the parent and weld metals.



Heat-affected zone

Complete the microstructure by drawing and labelling the following grain types in the heat-affected zone for ONE of the webs:

• chill crystals

• equi-axed grains

• columnar grains.

Question 24 (continued)

(c)  A roller coaster car is at rest at point *A* as shown.                                              **3**
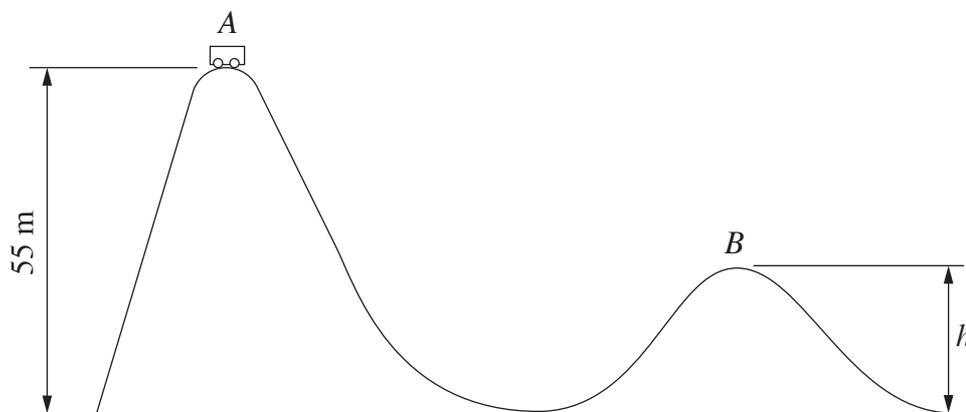


Determine the height, $h$, of the roller coaster at point *B* if it is travelling at 30 m/s at that point. Assume no energy losses.

Height of roller coaster at point *B* =  ................ m

**Question 24 continues on page 26**

Office Use Only – Do NOT write anything, or make any marks below this line.

6077310420

Question 24 (continued)

(d)   One of several fail-safe systems incorporated into a roller coaster design uses the following safety protocol.
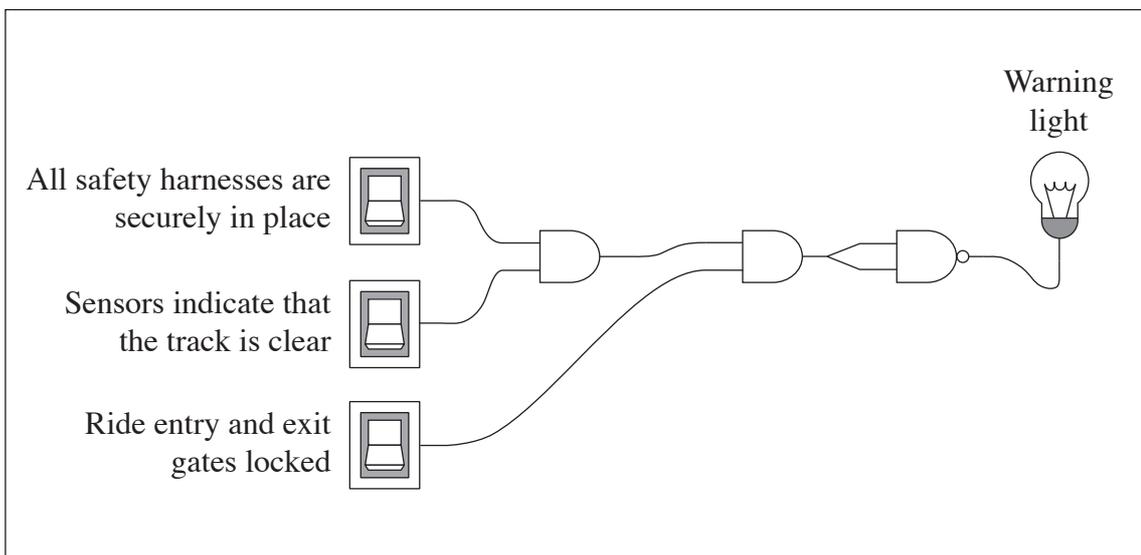
Before a roller coaster car brake can be released to allow the roller coaster to commence its ride, ALL of the following conditions must be met:

- passenger safety harnesses must be secured into place
- the sensors must indicate the track is clear of obstructions
- the ride entry and exit gates are locked.

A logic gate schematic is shown.



(i)   What is the purpose of the NAND gate in this schematic?   **2**

....................................................................................................................

....................................................................................................................

....................................................................................................................

....................................................................................................................

**Question 24 continues on page 27**

9725310423

(ii) Complete the truth table for the logic gate schematic. **3**

| Safety harnesses secure | Track is clear | Ride gates are locked | Operator warning light |
|---|---|---|---|
| 0 | 0 | 0 | |
| 0 | | | 1 |
| 0 | 1 | 0 | 1 |
| 0 | | | |
| 1 | 0 | 0 | 1 |
| 1 | | | 1 |
| 1 | | | 1 |
| 1 | 1 | 1 | |

**End of Question 24**

**Question 25** (12 marks)

(a) Describe the process of compression moulding when used to manufacture aircraft components.

**3**

..............................................................................................................................

..............................................................................................................................

..............................................................................................................................

..............................................................................................................................

..............................................................................................................................

..............................................................................................................................

..............................................................................................................................

(b) Explain the functions of a transistor in an electrical circuit.

**3**

..............................................................................................................................

..............................................................................................................................

..............................................................................................................................

..............................................................................................................................

..............................................................................................................................

..............................................................................................................................

..............................................................................................................................

(c) Outline how GPS satellites determine a position on the planet.

**2**

..............................................................................................................................

..............................................................................................................................

..............................................................................................................................

..............................................................................................................................
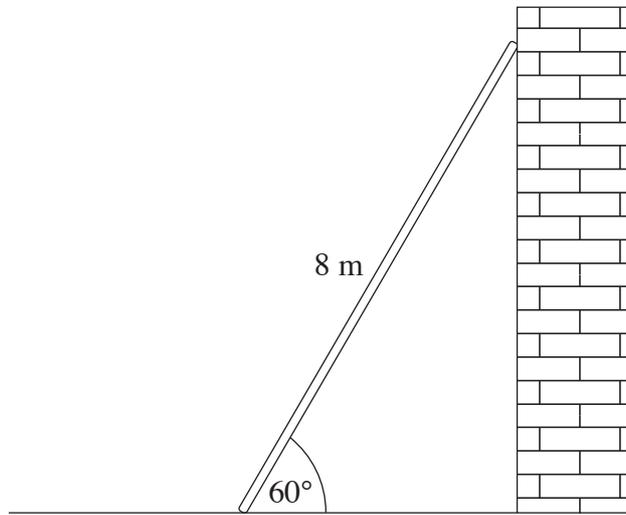
**Question 25 continues on page 29**

0896310423

Question 25 (continued)

(d)  A uniform 8-metre ladder with a mass of 12 kg has been placed against a smooth      **4**
     wall.



Determine the minimum coefficient of static friction between the ground and the
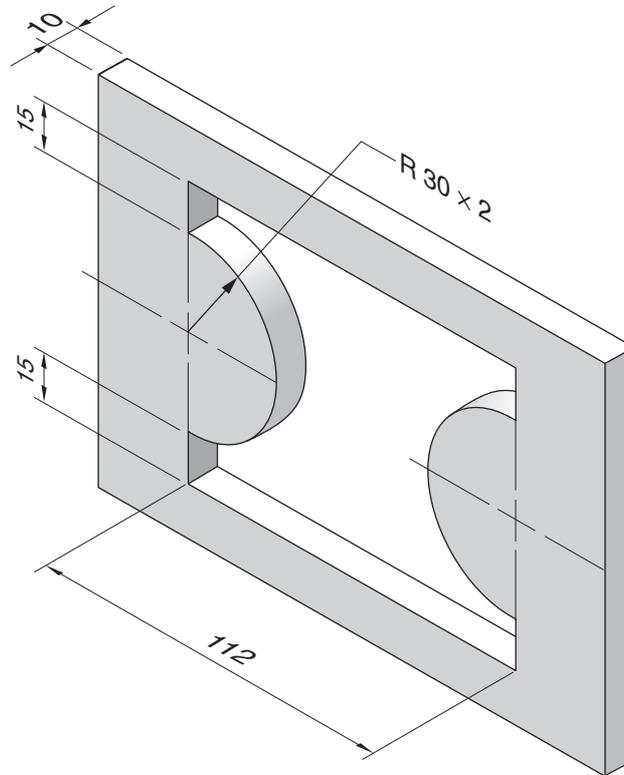ladder. Assume there is no friction between the ladder and the wall.

Minimum coefficient of static friction:  ..................................

**End of Question 25**

**Question 26** (12 marks)

(a)   A component of a roller coaster car bogie is to be punched out from a 10 mm       **3**
      thick rectangular plate of mild steel as shown.



Calculate the shear force of the punching die if the shear stress is 345 MPa.

Shear force:  ................................. kN

**Question 26 continues on page 31**

Office Use Only – Do NOT write anything, or make any marks below this line.

2503310420

Question 26 (continued)

(b) A team of engineers is working together to develop a new aeronautical device for a company. An engineer takes the design and produces the device without permission. **3**

Describe the implications for the individual engineer and the company.
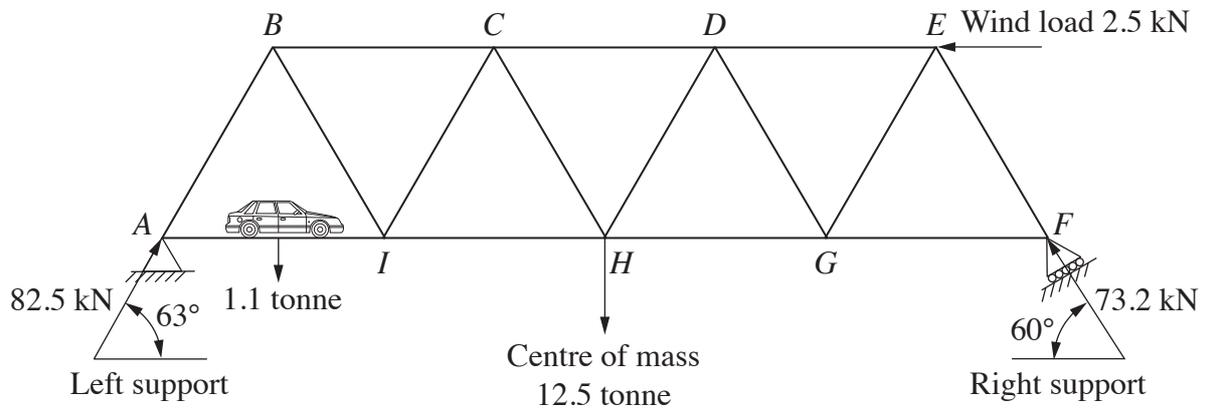
......................................................................................................................

......................................................................................................................

......................................................................................................................

......................................................................................................................

......................................................................................................................

......................................................................................................................

......................................................................................................................

5460310425

(c)    A truss is loaded as shown.                                                                    **6**



Complete the table.

| | *Magnitude* (kN) | *Nature of force* (T or C) |
|---|---|---|
| Internal reaction of member *EF* | | |
| Internal reaction of *CH* | | |

Use the space provided below and on page 33 for working.

**Question 26 continues on page 33**

1538310427

**End of Question 26**

BLANK PAGE

7955310426

**Question 27** (10 marks)

(a)  Discuss the use of composite materials in aircraft construction. Support your answer with specific examples.

**4**
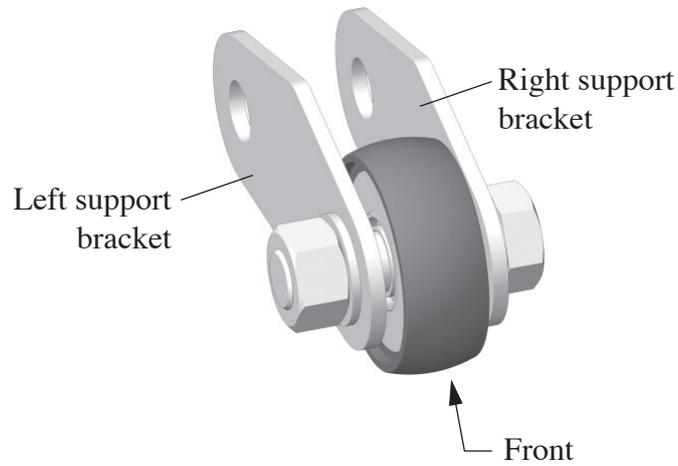
..........................................................................................................................

..........................................................................................................................

..........................................................................................................................

..........................................................................................................................

..........................................................................................................................

..........................................................................................................................

..........................................................................................................................

..........................................................................................................................

..........................................................................................................................

..........................................................................................................................

6954310424

Question 27 (continued)

(b)    A portion of a roller coaster wheel sub-assembly is shown.                     **6**



Right support bracket

Left support bracket

Front

An exploded pictorial of the wheel sub-assembly is shown.
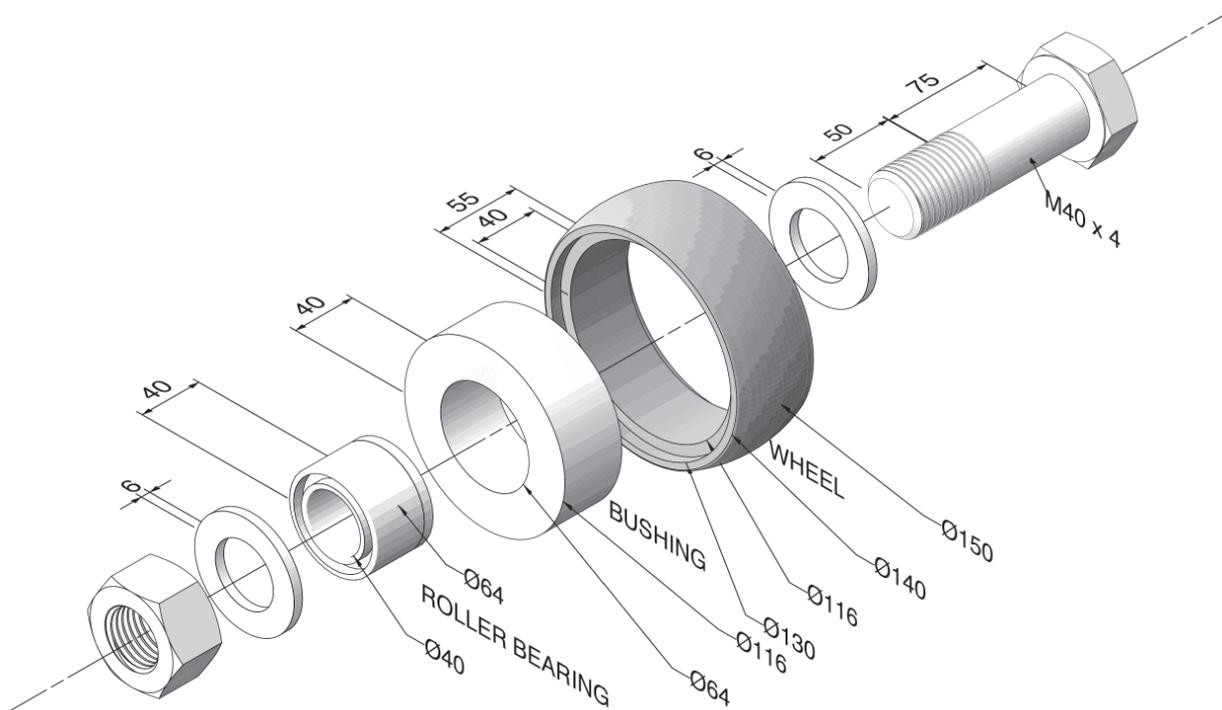
– 36 –

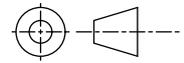Office Use Only – Do NOT write anything, or make any marks below this line.

2230310427

Complete an assembled sectioned front view of the wheel sub-assembly at scale 1:2. Apply AS 1100 drawing standards. Do NOT add dimensions.

A

PARTIAL LEFT VIEW

Left support bracket

Right support bracket
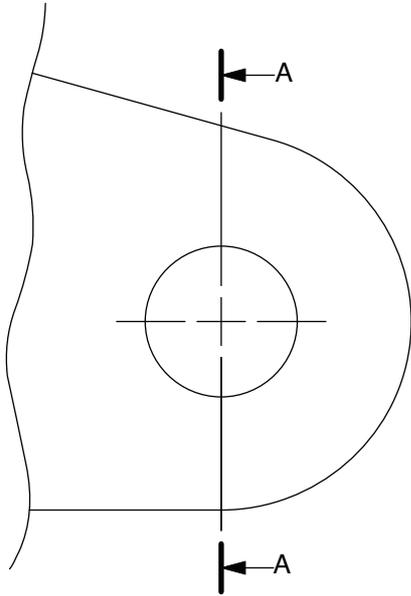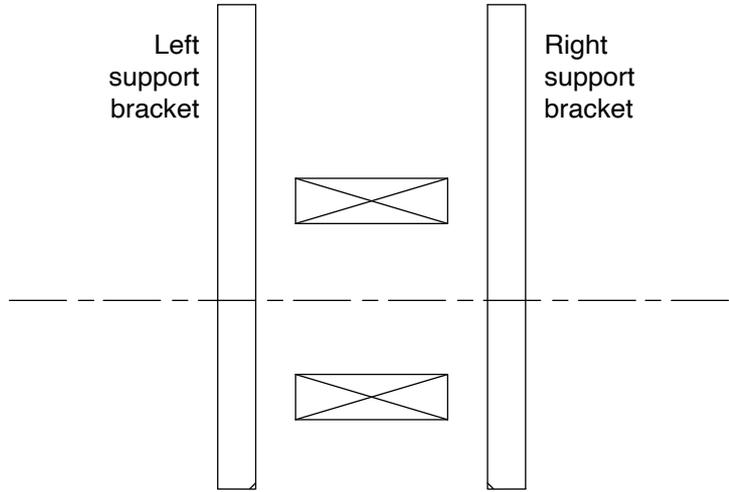
SECTION A–A

Scale 1:2

**End of paper**

# Section II extra writing space

**If you use this space, clearly indicate which question you are answering.**

9913310422

**Section II extra writing space**

**If you use this space, clearly indicate which question you are answering.**

3914310427

# Section II extra writing space

**If you use this space, clearly indicate which question you are answering.**

# Engineering Studies

## FORMULAE SHEET

### Force, Moments

$F = ma$;    $M = Fd$

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

### Friction

$F = \mu N$;    $\mu = \tan \phi$

### Energy, Work, Power

$KE = \frac{1}{2}mv^2$;    $PE = mgh$;    $W = Fs = \Delta PE + \Delta KE$;    $P = \dfrac{W}{t}$;    $P = \dfrac{Fs}{t}$;    $P = Fv$

### Pressure

$P = \dfrac{F}{A}$;    $P = P_o + \rho gh$

### Stress and Strain

$\sigma = \dfrac{F}{A}$;    $\varepsilon = \dfrac{e}{L}$;    $E = \dfrac{\sigma}{\varepsilon}$;    $\sigma = \dfrac{My}{I}$

$\sigma_{\text{allowable}} = \dfrac{\sigma_{yield}}{F \text{ of } S}$ (Ductile);      $\sigma_{\text{allowable}} = \dfrac{\sigma_{UTS}}{F \text{ of } S}$ (Brittle)

### Machines

$MA = \dfrac{L}{E}$;    $VR = \dfrac{d_E}{d_L}$;    $\eta = \dfrac{MA}{VR}$

### Digital Electronics
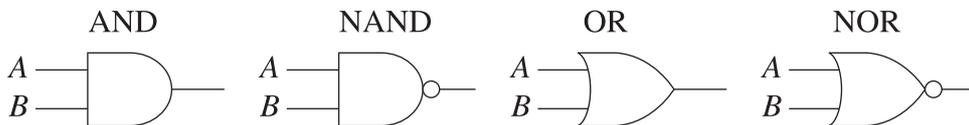


### Electricity, Electronics

$E = IR$          $P = I^2 R$

Series     $R_t = R_1 + R_2 + R_3 + R_4 + \cdots + R_n$

Parallel    $\dfrac{1}{R_t} = \dfrac{1}{R_1} + \dfrac{1}{R_2} + \dfrac{1}{R_3} + \dfrac{1}{R_4} + \cdots + \dfrac{1}{R_n}$

BLANK PAGE