



ATAR course sample examination

Question/Answer booklet

ENGINEERING STUDIES

Please place your student identification label in this box

WA student number: In figures

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In words

Time allowed for this paper

Reading time before commencing work: ten minutes
Working time: three hours

Place a tick (✓) in one of the following boxes to indicate your specialist field.

Mechanical

Mechatronics

Materials required/recommended for this paper

To be provided by the supervisor

This Question/Answer booklet
Data Book

Number of additional answer booklets used (if applicable):

To be provided by the candidate

Standard items: pens (blue/black preferred), pencils (including coloured), sharpener, correction fluid/tape, eraser, ruler, highlighters

Special items: up to three calculators, which do not have the capacity to create or store programmes or text, are permitted in this ATAR course examination

Important note to candidates

No other items may be taken into the examination room. It is **your** responsibility to ensure that you do not have any unauthorised material. If you have any unauthorised material with you, hand it to the supervisor **before** reading any further.

Structure of this paper

Section	Number of questions available	Number of questions to be answered	Suggested working time (minutes)	Marks available	Percentage of examination
Section One Core content					
Part A	8	8	90	19	10
Part B	5	5		71	40
Section Two Mechanical					
Part A	5	5	90	12	10
Part B	4	4		86	40
Section Two Mechatronics					
Part A	6	6	90	12	10
Part B	4	4		86	40
				Total	100

Instructions to candidates

- The rules for the conduct of the Western Australian external examinations are detailed in the *Year 12 Information Handbook 2024: Part II Examinations*. Sitting this examination implies that you agree to abide by these rules.
- Section One: You must answer all questions.
Section Two: You must choose to answer only one of the specialist fields. In the specialist field you have chosen, answer all questions.

In both Section One and Section Two, answer the questions according to the following instructions.

Part A
Answer all questions. Write your answers in the spaces provided in this Question/Answer booklet preferably using a blue/black pen. Do not use erasable or gel pens.

When calculating answers, show all your working clearly. Your working should be in sufficient detail to allow your answers to be checked readily and for marks to be awarded for reasoning. In final answers, include appropriate units where applicable.

Part B
Answer all questions. Write your answers in the spaces provided in this Question/Answer booklet preferably using a blue/black pen. Do not use erasable or gel pens.

When calculating answers, show all your working clearly. Your working should be in sufficient detail to allow your answers to be checked readily and for marks to be awarded for reasoning. In final answers, include appropriate units where applicable.
- You must be careful to confine your answers to the specific questions asked and to follow any instructions that are specific to a particular question.
- Supplementary pages for planning/continuing your answers to questions are provided at the end of this Question/Answer booklet. If you use these pages to continue an answer, indicate at the original answer where the answer is continued, i.e. give the page number.
- The Data Book is not to be handed in with your Question/Answer booklet.

See next page

Section One: Core content**50% (90 Marks)**

This section has **two** parts.

Part A: Answer **all** questions

Part B: Answer **all** questions

Suggested working time: 90 minutes.

Part A:**10% (19 Marks)**

This section has **eight** questions. Answer **all** questions. Write your answers in the spaces provided.

When calculating answers, show all of your working clearly. Your working should be in sufficient detail to allow your answers to be checked readily and for marks to be awarded for reasoning. In final answers, include appropriate units where applicable.

Supplementary pages for planning/continuing your answers to questions are provided at the end of this Question/Answer booklet. If you use these pages to continue an answer, indicate at the original answer where the answer is continued, i.e. give the page number.

Question 1**(2 marks)**

You have been asked to design a child's toy. One of the requirements of the brief is that the toy must be able to move independently, without any external force being applied. Name **two** suitable energy sources that could be used.

One: _____

Two: _____

Question 2

(2 marks)

State why steel, stainless steel and cast iron can be classified as a ferrous alloy.

Question 3

(3 marks)

Automotive windshields are made by layering sheets of glass and plastic. Identify and describe the type of material used for a windshield.

Type of material: _____

Description of material: _____

Question 4

(2 marks)

A 6 m long square hollow section structural steel tube has external dimensions of 100 mm x 100 mm. Calculate the mass of the steel tube if the thickness of its walls is 5 mm.

Mass (kg) = _____

Question 5

(3 marks)

In an Engineering design process, state **three** types of activities that could be considered as 'investigating'.

One: _____

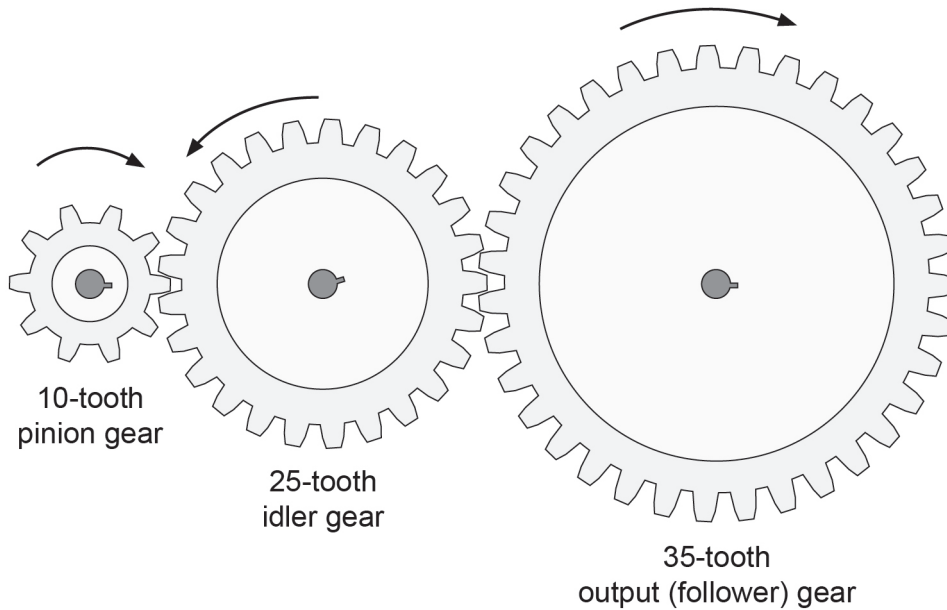
Two: _____

Three: _____

Question 6

(3 marks)

In a simple gear train, a 10-tooth pinion gear drives a 25-tooth idler gear, which in turn drives a 35-tooth output (follower) gear. State the velocity ratio (VR) formula between the input and output gear and calculate the final VR .



Formula = _____

VR = _____

See next page

Question 7

(2 marks)

A force of 500 N is required to slide a pallet of goods across the floor of a warehouse. Calculate how much power is required to slide the pallet a distance of 4 m in 3 seconds.

Power required (W) = _____

Question 8

(2 marks)

State **two** reasons why a manufacturer of an engineered product may conduct a life cycle analysis of one or a group of their products.

One: _____

Two: _____

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See next page

Part B:

40% (71 Marks)

This section has **five** questions. Answer **all** questions. Write your answers in the spaces provided.

When calculating answers, show all of your working clearly. Your working should be in sufficient detail to allow your answers to be checked readily and for marks to be awarded for reasoning. In final answers, include appropriate units where applicable.

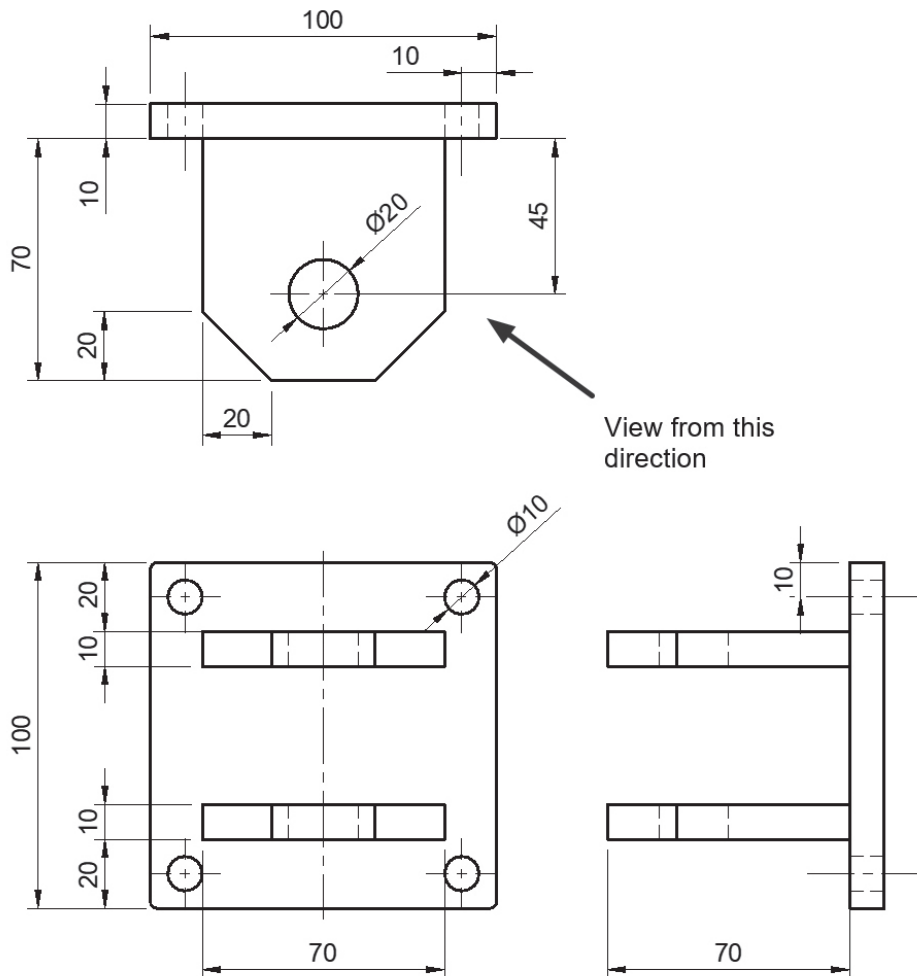
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Question 9

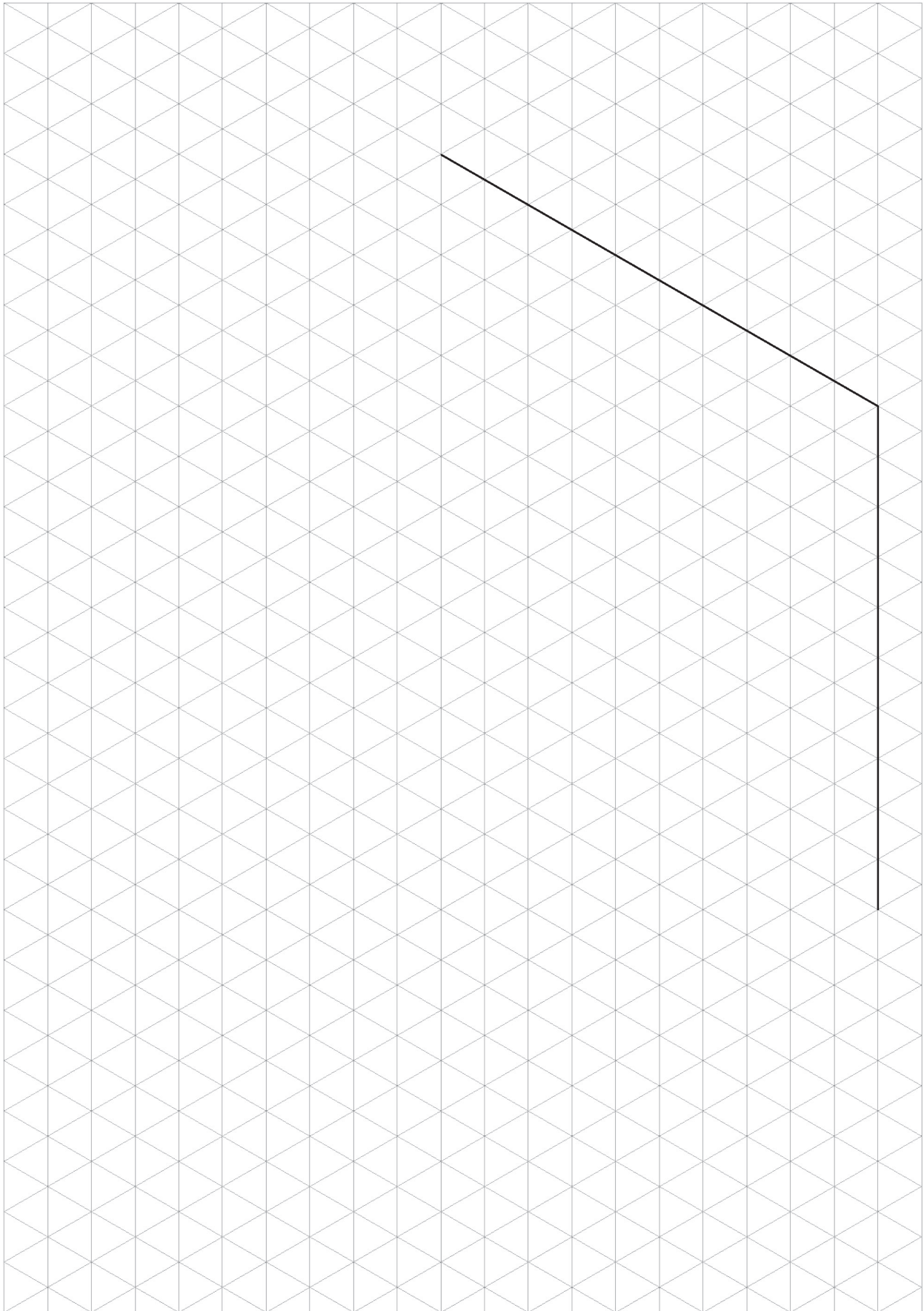
(20 marks)

The orthogonal picture below shows a towing bracket designed for a small tractor. The customer has difficulty understanding the orthogonal drawing and has asked that an isometric view be produced for clarity of the design.

- (a) When viewed from the direction indicated below, create the isometric view on the isometric grid provided on page 9. Dimensions are not required on the drawing, but an accurate scale must be used. (7 marks)



See next page



A spare grid is provided at the end of this Question/Answer booklet. If you need to use it, cross out this attempt and indicate that you have redrawn it on the spare grid.

See next page

Question 9 (continued)

The towing bracket is to be mounted on a tractor that is used to pull boats and trailers out of the ocean and to a boat ramp across the beach. In such harsh marine environments, stainless steel is often used to manufacture brackets and fittings.

- (b) State the **four** main components of stainless steel. (4 marks)

One: _____

Two: _____

Three: _____

Four: _____

The manufacturer produces the brackets in batches of 100 units and packages them in boxes containing 20 units.

- (c) Calculate the mass of **one** bracket. Ignore the small amount of material that is removed by the radius on the corners of the back plate. (9 marks)

Mass (kg) = _____

Question 10**(12 marks)**

Copper wire is used to make electrical cable because it is a very good conductor. Copper is also malleable and ductile.

- (a) Using the definitions of malleability and ductility, explain which of these properties is required in the manufacture of copper wire. (3 marks)

Brass is considered a non-ferrous alloy.

- (b) (i) Define the term 'non-ferrous'. (1 mark)

- (ii) State what an alloy is. (1 mark)

- (iii) State the main components of brass. (1 mark)

Question 10 (continued)

The properties of a material for a propeller on a large boat are being evaluated.

- (c) State **three** main properties that would influence the choice of material for a propeller on a large boat and outline how these properties are relevant in this application. (6 marks)

Property: _____

Relevance: _____

Property: _____

Relevance: _____

Property: _____

Relevance: _____

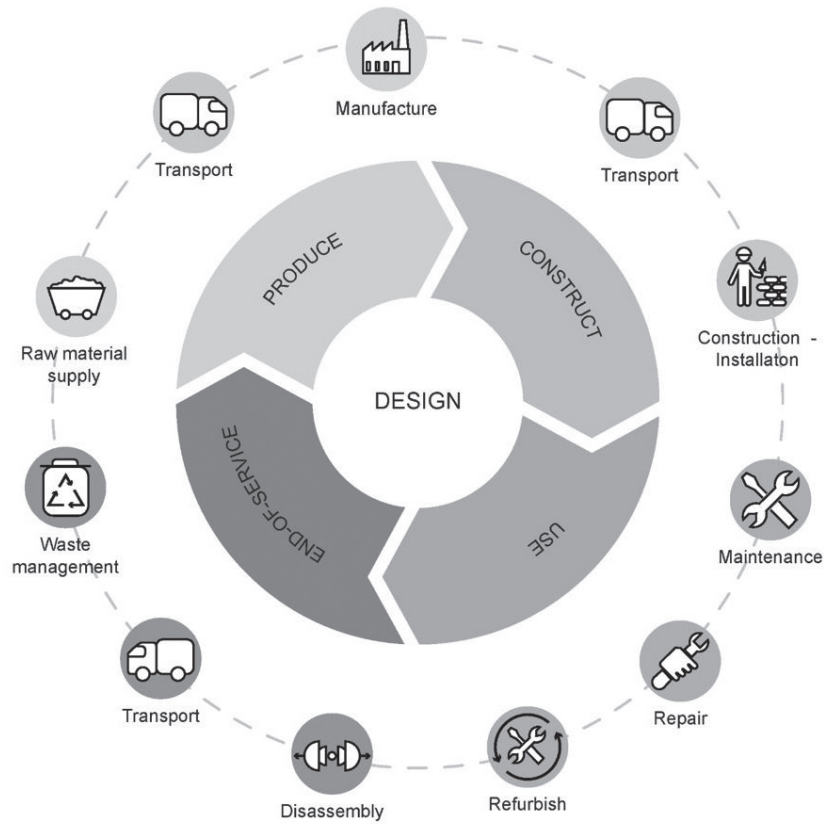
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See next page

Question 11

(10 marks)

The Life Cycle Analysis (LCA) diagram below represents the life cycle of a building, such as a residential house.



- (a) When used, the maintenance, repair and refurbish activities may be repeated many times before the house comes to the end of its useful life and is demolished. Explain the importance of these activities in relation to the overall emission of CO₂ in the life of the building. (3 marks)

- (b) Transport is identified at key points in the LCA diagram (construction, end of service, production) but transport affects every stage of the LCA. Outline **four** ways transport impacts CO₂ production while the building is in use. (4 marks)

One: _____

Two: _____

Three: _____

Four: _____

As shown in the LCA diagram on page 14, after disassembly, materials are transported into waste management with a path back to raw material supply.

- (c) State **three** activities or materials from the building that could be involved in 'waste management' and would lead back to 'raw material supply'. (3 marks)

One: _____

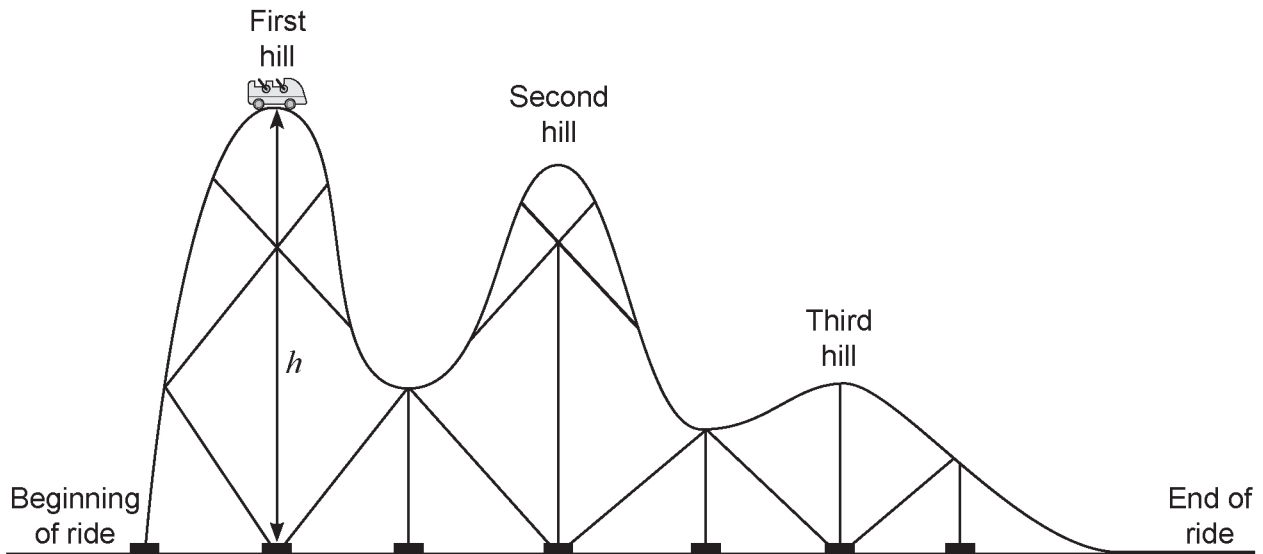
Two: _____

Three: _____

Question 12

(15 marks)

A roller coaster at a local fun park is represented in the diagram below. The roller coaster car has a mass of 1100 kg including the passengers.



The roller coaster car is raised to the top of the first hill by an electric motor and track chain. An electric motor with an input power rating of 35 kW runs continuously for 15 seconds to move the car from the bottom to the top of the first hill. The motor and associated track chain lifting mechanism is only 40% efficient.

- (a) Calculate the vertical change in height (h) from the bottom, where the ride begins, to the top of the first hill. (4 marks)

Vertical change in height (m) = _____

See next page

- (b) Assuming no energy is lost to friction or wind, calculate the speed of the roller coaster at the top of the third hill if it is 10 m high. If you could not calculate an answer for part (a), use 20 metres. (5 marks)

Speed of the roller coaster (m s^{-1}) = _____

The fun park management is hoping to run the roller coaster ride from solar panels, placed on the roof of the gift shop, that will charge a bank of batteries to smooth out delivery of power. Each solar panel generates on average 120 watts for the 8 hours of useable daylight each day.

- (c) If the ride cycles around the track five times per hour for 12 hours per day, determine how many solar panels will be needed to make the ride sustainable without additional power being required. (6 marks)

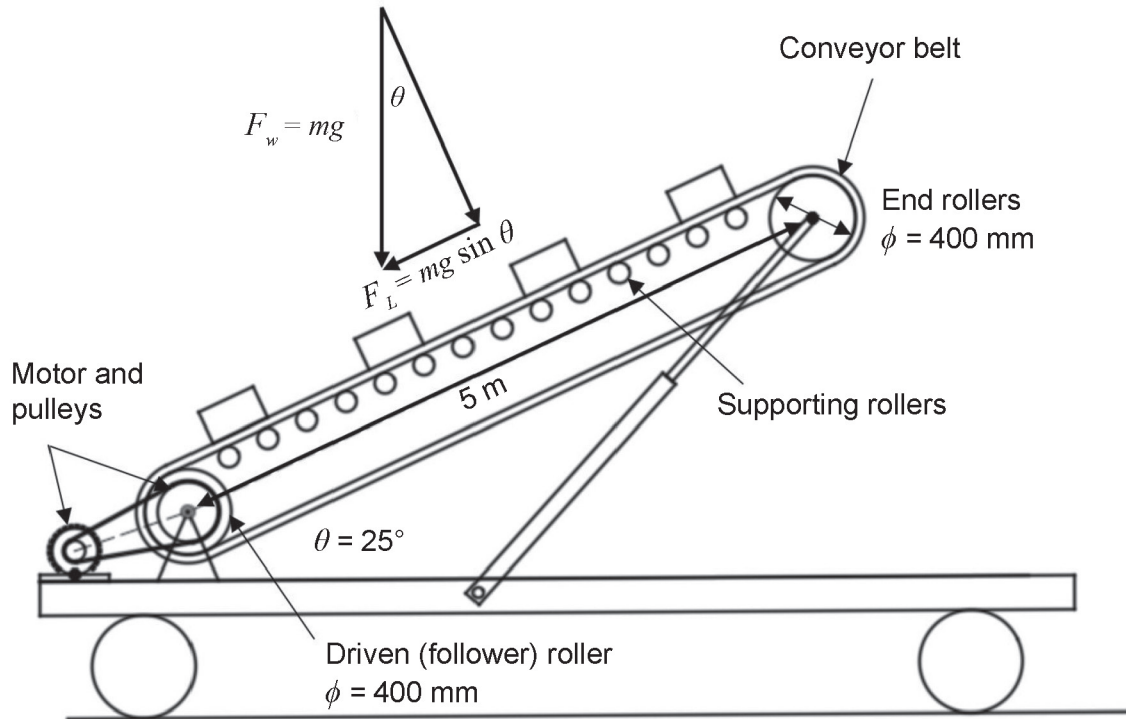
Number of solar panels = _____

See next page

Question 13

(14 marks)

A conveyor belt is used to load boxes and luggage onto a plane, as indicated in the diagram below. The boxes are spaced evenly on the belt with four boxes on the belt at any time. The usable centre to centre length of the belt is 5 m.



- (a) The conveyor belt needs to be able to load 240 items onto the plane in 12 minutes. Calculate the speed of the conveyor belt (in m s^{-1}) to achieve this objective. Ignore the small amount of time required for the first box to travel the length of the conveyor belt. (3 marks)

Speed of conveyor belt (m s^{-1}) = _____

- (b) Determine the angular velocity (in rpm) of the end rollers of the conveyor when the belt is travelling at this speed. If you could not calculate an answer to part (a), use 0.5 m s^{-1} .
(2 marks)

Angular velocity (rpm) = _____

- (c) The force (F_L) that the boxes exert parallel to the belt due to gravity can be calculated using $F_L = mg \sin \theta$. If the average mass of each item is 20 kg, prove by calculation that the force parallel to the belt when it is fully loaded with 4 boxes is close to 330 N. (1 mark)

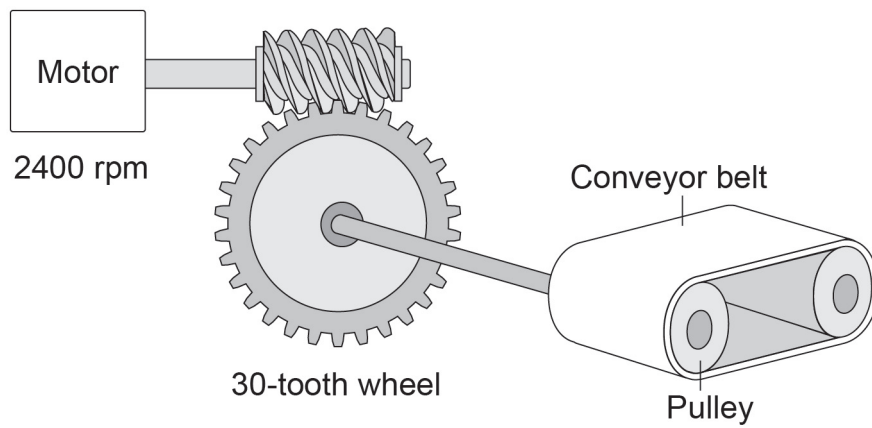
- (d) Calculate the torque on the driven (follower) roller when the conveyor belt is fully loaded, given that it has a diameter of 400 mm. (1 mark)

Torque (N m) = _____

Question 13 (continued)

- (e) The conveyor belt is driven by a 24 V DC motor that draws 20 A. Determine the efficiency of the conveyor belt's mechanical system. (3 marks)

- (f) The motor rotates at 2400 rpm and drives a 30-tooth single start worm drive gearbox. The output shaft of the gearbox has a pulley which moves the conveyor belt at 0.55 m s^{-1} . Calculate the diameter of the pulley. (4 marks)



Diameter of the pulley (m) = _____

End of Section One

See next page

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Section Two: Specialist fields**50% (98 Marks)**

Candidates are required to choose **one** of the following options, according to which specialist field they studied.

Tick **one** of the boxes below to indicate your choice of option.

Specialist field	✓	Question numbers	Pages
Mechanical	<input type="checkbox"/>	14–22	24–42
Mechatronics	<input type="checkbox"/>	23–32	44–62

Now turn to the relevant pages and answer the questions for the specialist field you have selected.

Section Two: Specialist field – Mechanical

50% (98 Marks)

This section has **two** parts.

Part A: Answer **all** questions

Part B: Answer **all** questions

Suggested working time: 90 minutes.

Part A:

10% (12 Marks)

This section has **five** questions. Answer **all** questions. Write your answers in the spaces provided.

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Question 14

(2 marks)

Mass produced cars use cast engine blocks, but a growing number of race cars use engine blocks that are machined from a single billet of material. Outline **one** advantage and **one** disadvantage of using a cast engine block.

Advantage: _____

Disadvantage: _____

Question 15

(3 marks)

A structural steel lifting hook has a cross-sectional area of 50 mm^2 and is rated to a safe working load of 11.75 kN. Determine the factor of safety (FS) of the hook.

$FS =$ _____

See next page

Question 16**(3 marks)**

A square solid beam has a I_{xx} of 520 833.4 mm⁴. Calculate the cross-section height and width of the square beam.

Cross-section height and width (mm) = _____

Question 17**(3 marks)**

A 6 m long aluminium rod with a diameter of 5 mm is subjected to a force of 20 N. Determine the change in length of the rod with this force applied.

Change in length (mm) = _____

Question 18**(1 mark)**

State the condition for rotational equilibrium.

See next page

Part B:

40% (86 Marks)

This section has **four** questions. Answer **all** questions. Write your answers in the spaces provided.

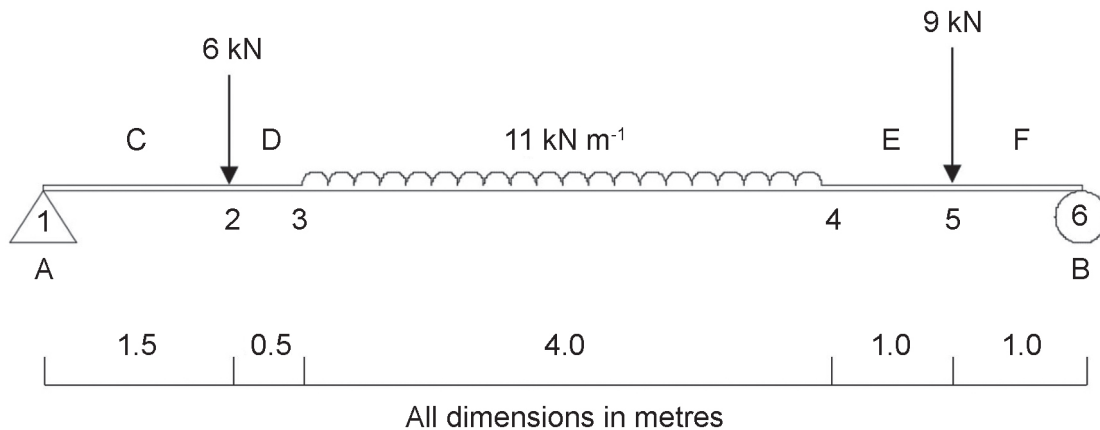
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Question 19

(25 marks)

The diagram below shows a simply supported structural steel beam in a state of static equilibrium, supported at Points A and B.



- (a) Using an equilibrium condition of your choice, prove by calculation that the reaction force at Point B is close to 31 kN. (4 marks)

- (b) Using an equilibrium condition of your choice, prove by calculation that the reaction force at Point A is close to 28 kN. (2 marks)

- (c) Calculate the shear forces at the sections along the length of the beam, indicated by letters C, D, E, F. (4 marks)

$$SF_C \text{ (kN)} = \underline{\hspace{10cm}}$$

$$SF_D \text{ (kN)} = \underline{\hspace{10cm}}$$

$$SF_E \text{ (kN)} = \underline{\hspace{10cm}}$$

$$SF_F \text{ (kN)} = \underline{\hspace{10cm}}$$

Question 19 (continued)

- (d) Calculate the bending moments at Points 1 to 6 along the length of the beam. (6 marks)

BM_1 (kN m): _____

BM_2 (kN m): _____

BM_3 (kN m): _____

BM_4 (kN m): _____

BM_5 (kN m): _____

BM_6 (kN m): _____

See next page

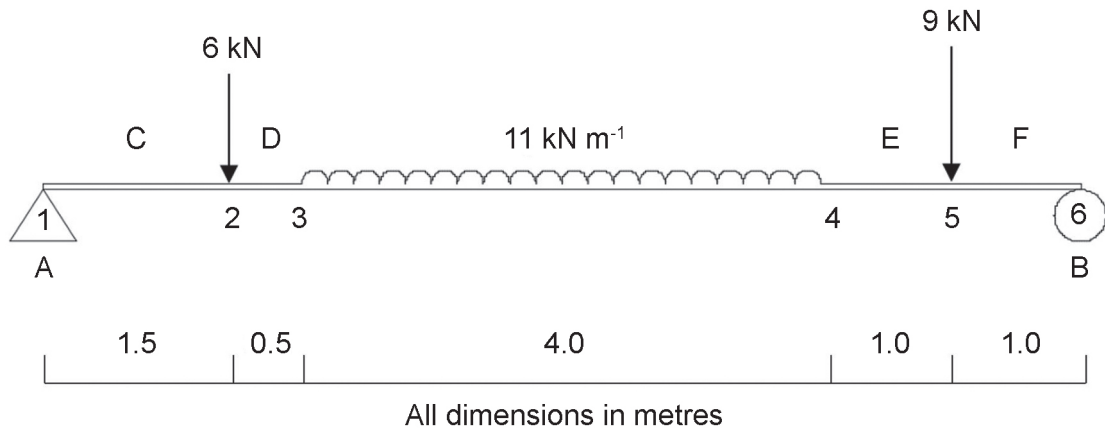
- (e) Determine the position and value of the maximum bending moment. (3 marks)

Position of the maximum bending moment = _____

Value of maximum bending moment (kN m) = _____

Question 19 (continued)

- (f) On the diagram on page 31, construct shear force and bending moment diagrams for the beam, labelling a suitable scale and all key features. (6 marks)



A spare diagram is provided at the end of this Question/Answer booklet. If you need to use it, cross out this attempt and indicate that you have redrawn it on the spare diagram.

Question 20

(18 marks)

An Airbus A380 plane has a fully laden mass of 560 tonnes on take-off. To become airborne, the plane needs to reach a speed of 300 km h^{-1} , requiring a minimum runway length of 3000 m.

- (a) Calculate the average acceleration of the plane as it travels along the runway from rest to take-off speed. (3 marks)

Average acceleration (m s^{-1}) = _____

- (b) Calculate the time that has elapsed when travelling from rest to take-off speed. (2 marks)

Time elapsed (s) = _____

- (c) The plane takes off at 300 km h^{-1} and continues to accelerate at 1.2 m s^{-2} . Calculate the time it will take for the plane to reach its cruising speed of 900 km h^{-1} . (3 marks)

Time to cruising speed (s) = _____

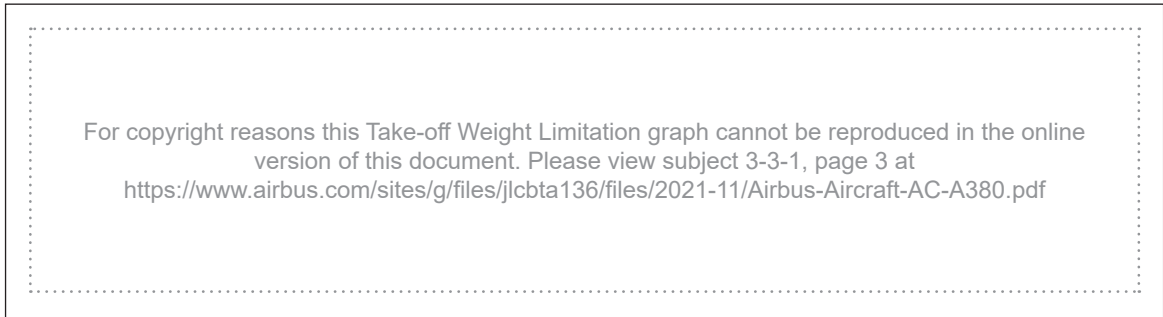
See next page

- (d) The plane has four engines, all producing an equal amount of thrust. Calculate the thrust provided by each engine when the plane begins to accelerate along the runway.(2 marks)

Thrust (kN) = _____

Question 20 (continued)

- (e) Using the table below, determine the runway length required if the fully loaded plane was leaving from an airstrip that was 4000 ft above sea level. (1 mark)



Length: _____

The Airbus A380 plane holds approximately 323 000 litres of fuel for a long-haul flight. The density of jet fuel is 0.78 kg L^{-1} . On its return, the plane has used 80% of the available fuel before approaching the runway to land.

- (f) Calculate the weight of the plane as it is about to land. (3 marks)

Landing weight (kg) = _____

As the plane is landing, it touches the runway at a speed of 260 km h^{-1} . The brakes on the wheels perform 80% of the braking effort with the remainder performed by wind spoilers and engine thrusters.

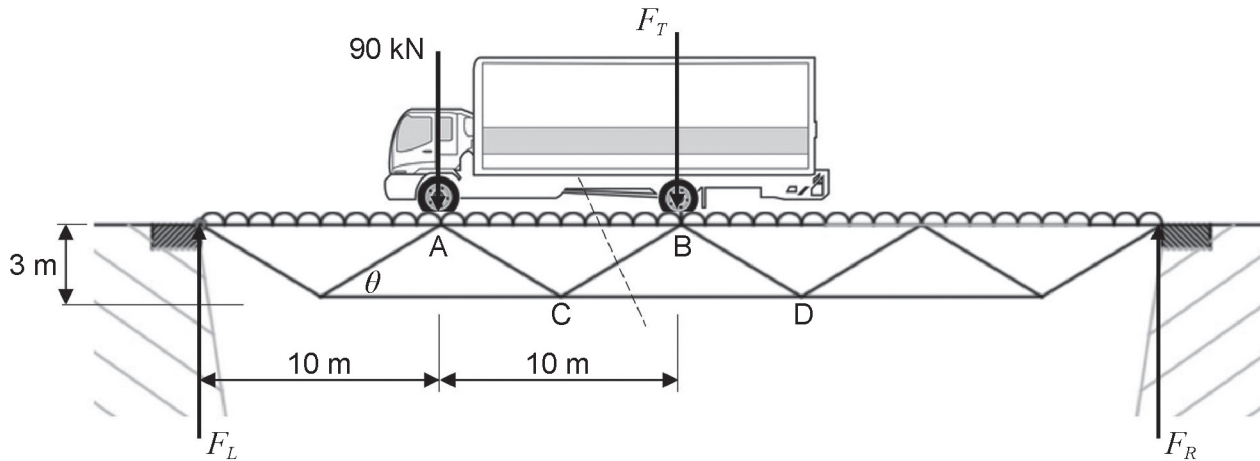
- (g) Calculate how much work is done by the brakes on each of the 22 landing wheels to bring the plane to rest. (4 marks)

Brakes on each wheel (MJ) = _____

Question 21

(23 marks)

The diagram below shows a simply supported, single, parallel chord truss spanning a ravine. The top of the truss supports a uniformly distributed load (UDL) in the form of a road. The UDL has a load rate of 12 kN m^{-1} . The truss is also supporting a truck, weighing a total of 20 T, imposing forces on the truss at Points A and B, which can each be considered as point loads.



- (a) Using the conditions of equilibrium, prove by calculation that the reaction forces at F_L and F_R are close to 360 kN and 315 kN respectively, due to the UDL and the loads imposed by the truck. Ignore the mass of the truss. (6 marks)

Question 21 (continued)

- (b) The truss has a section line running through AB, BC and CD. Neatly draw a free body diagram of the bridge to the right of the section line and indicate the assumed direction of the forces in the cut members of the truss. (4 marks)

- (c) Using moments around a suitable point in the truss, determine F_{AB} , the force in member AB, and state if it is in tension or compression. (5 marks)

$$F_{AB} \text{ (kN)} = \underline{\hspace{15em}}$$

$$\text{Tension or compression} = \underline{\hspace{15em}}$$

See next page

- (d) Using moments around a suitable point in the truss, determine F_{CD} , the force in member CD, and state if it is in tension or compression. (4 marks)

$$F_{CD} \text{ (kN)} = \underline{\hspace{10cm}}$$

$$\text{Tension or compression} = \underline{\hspace{10cm}}$$

- (e) Using any of the conditions of equilibrium, determine F_{BC} , the force in member BC, and state if it is in tension or compression. (4 marks)

$$F_{BC} \text{ (kN)} = \underline{\hspace{10cm}}$$

$$\text{Tension or compression} = \underline{\hspace{10cm}}$$

See next page

Question 22

(20 marks)

An unknown material specimen was given a tensile test and the following results were obtained:

Material original diameter = 2 mm. Original sample length = 70 mm.

Force (N)	173	298	440	471	455 (Failure)
Stress (N mm⁻²)					
Extension (mm)	0.055	0.095	0.210	0.280	0.420
Strain					

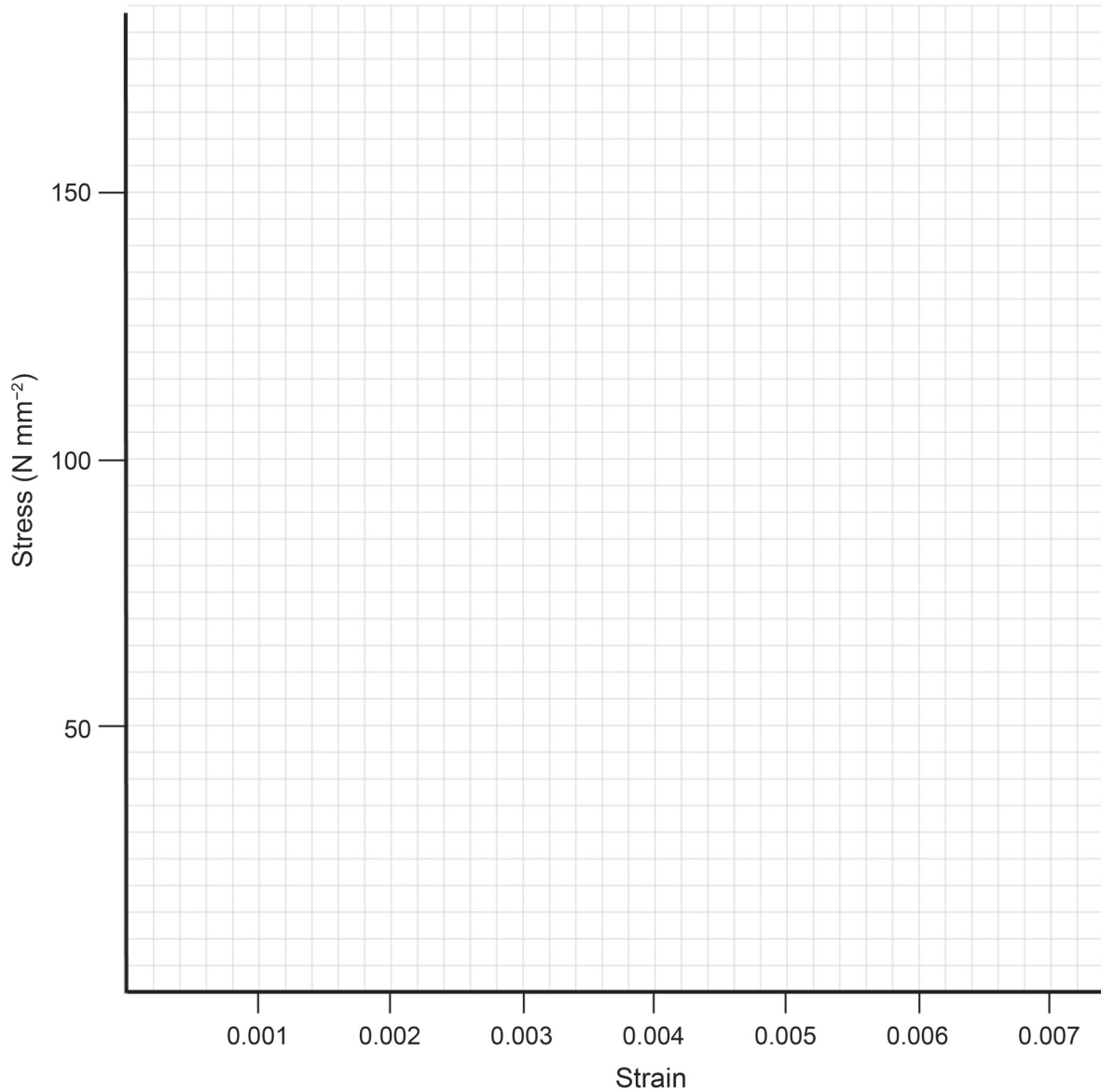
(a) Determine the stress and strain values in the table above.

(5 marks)

(b) On the grid below, graph the tensile test results, draw the curve of best fit and label the following:

- (i) elastic limit
- (ii) yield point
- (iii) part of the line where permanent plastic deformation is occurring
- (iv) ultimate tensile strength (UTS).

(6 marks)



A spare grid is provided at the end of this Question/Answer booklet. If you need to use it, cross out this attempt and indicate that you have redrawn it on the spare grid.

Question 22 (continued)

- (c) Determine Young's modulus for the material using the stress-strain graph in part (b) on page 41. (2 marks)

- (d) Identify the material based on the data collected. Justify your answer. (3 marks)

Material: _____

Justification: _____

- (e) Show the part of the graph that indicates the toughness of the material. (1 mark)

- (f) Show the part of the graph that indicates the resilience of the material. (1 mark)

- (g) Identify whether the material exhibits ductile **or** brittle behaviour. Justify your answer. (2 marks)

Ductile **or** brittle behaviour: _____

Justification: _____

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See next page

Section Three: Specialist field – Mechatronics

50% (98 Marks)

This section has **two** parts.

Part A: Answer **all** questions

Part B: Answer **all** questions

Suggested working time: 90 minutes.

Part A:

10% (12 Marks)

This section has **six** questions. Answer **all** questions. Write your answers in the spaces provided.

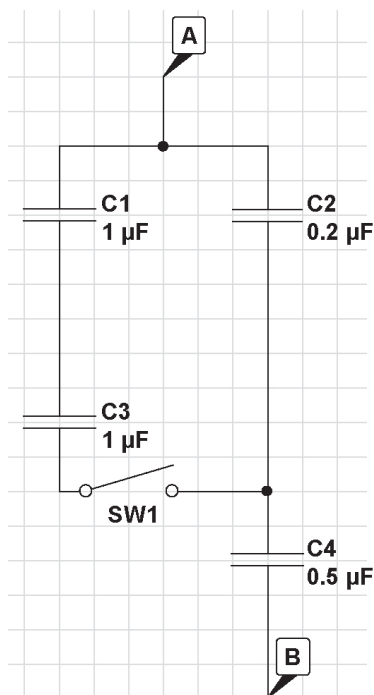
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Question 23

(2 marks)

Determine the capacitance between nodes A and B when the switch is open.



Capacitance (μF) = _____

See next page

Question 24**(2 marks)**

A USB umbilical can supply a maximum current of 90 mA. Calculate the charge (in C) it can supply a device in every hour of use.

Charge (C) = _____

Question 25**(2 marks)**

A ceramic capacitor has 155K stamped on its side. State the capacitance of this capacitor in nF.

Capacitance (nF) = _____

Question 26**(2 marks)**

An E12 resistor is required for a circuit to have a resistance of 4.7 k Ω and a tolerance of 2%. State the colours of the four bands.

Band one: _____

Band two: _____

Band three: _____

Band four: _____

Question 27

(2 marks)

A bipolar NPN transistor has a DC current gain, β value, of 200. Calculate the minimum base current (I_B) required to place the transistor into saturation mode when a collecting current of 4 mA is applied.

Current (A) = _____

Question 28

(2 marks)

Describe the likely consequence of using two 100 Ω resistors, each with a power rating of 0.5 W, arranged in parallel that are being supplied by a 6 V DC cell.

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See next page

Part B:

40% (86 Marks)

This section has **four** questions. Answer **all** questions. Write your answers in the spaces provided.

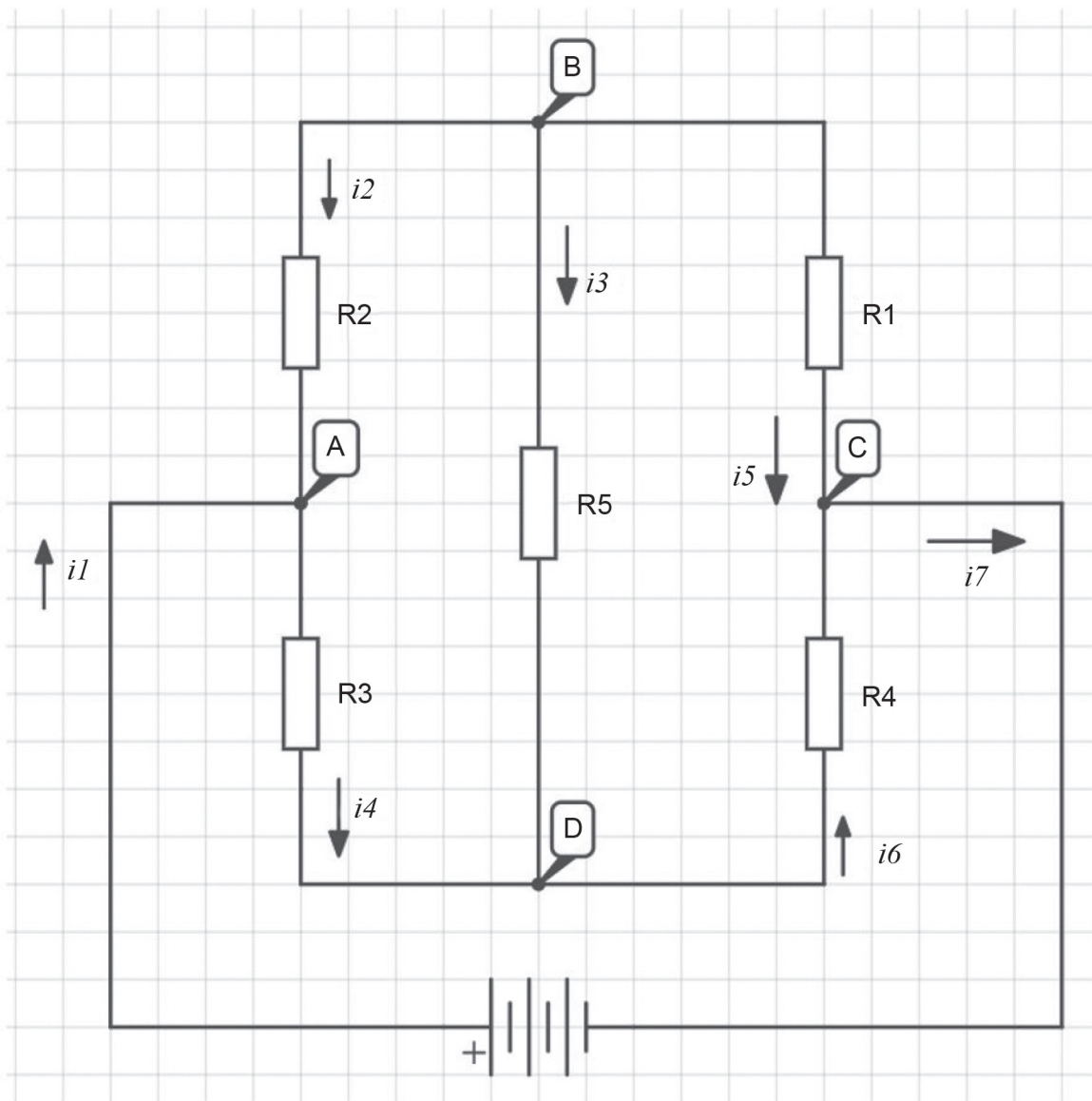
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Question 29

(14 marks)

Part (a) refers to the circuit below.



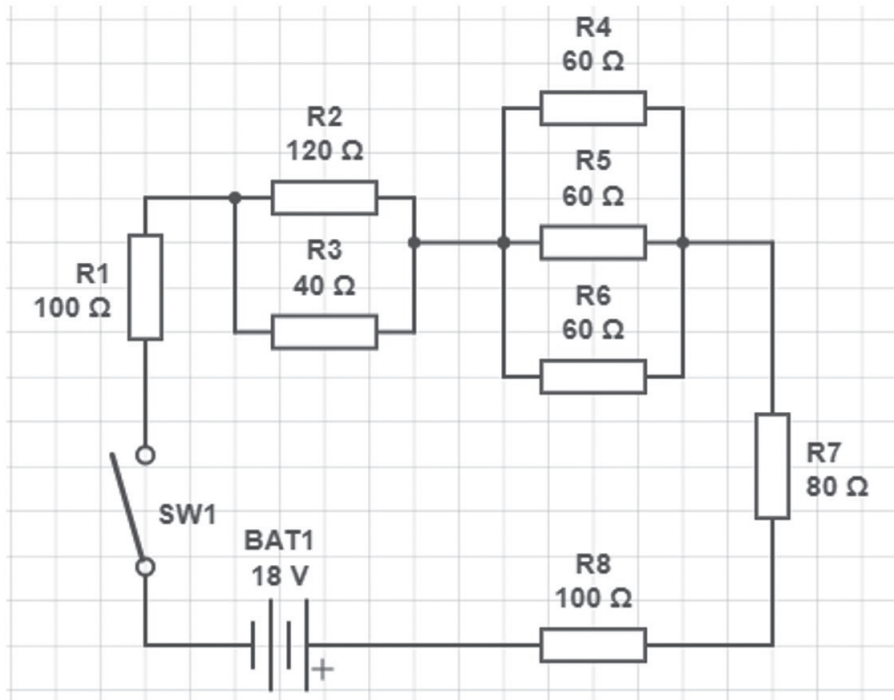
See next page

- (a) For the circuit on page 48, use Kirchhoff's Current Law (KCL) to complete the table by determining the current for i_3 , i_4 , i_6 and i_7 . The values for i_1 , i_2 and i_5 are given in the table below. (4 marks)

	Current (A)	Working
i_1	10 A	
i_2	-6 A	
i_3		
i_4		
i_5	4 A	
i_6		
i_7		

Question 29 (continued)

- (b) An 18 V battery is connected to a circuit as shown below and the switch (SW1) is then closed.



- (i) Prove by calculation that the total resistance of the circuit is 330 Ω. (2 marks)

- (ii) Calculate the maximum current in the circuit if there is a 10% fluctuation in the battery voltage. (2 marks)

Maximum current (mA) = _____

See next page

(iii) A multimeter used to determine the current through the $60\ \Omega$ resistor (R4) displayed 18.2 mA. Prove by calculation that this reading is correct. (2 marks)

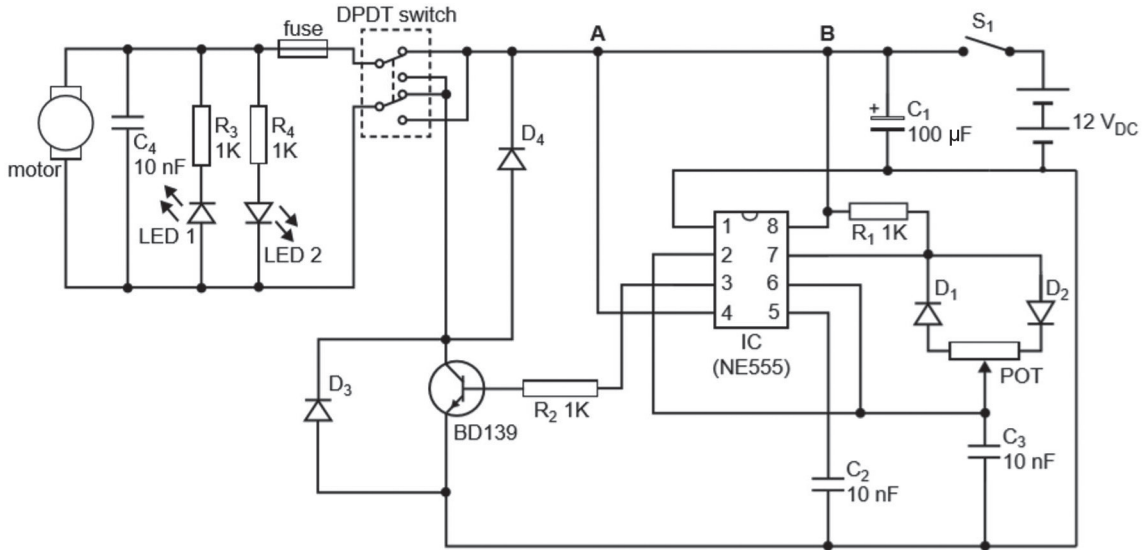
(iv) Each of the $60\ \Omega$ resistors are tungsten filament globes. Determine the power dissipated in each globe. (2 marks)

(v) If R4 blows, describe the effect on the other two globes, R5 and R6. (2 marks)

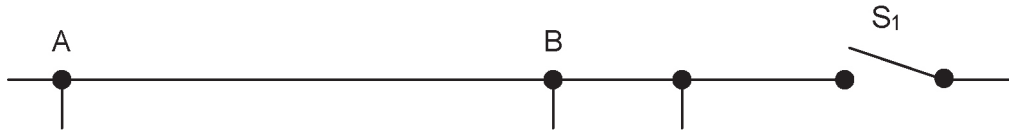
Question 30

(19 marks)

To control the speed of a motor, a 12 V DC motor and an electronic speed controller are used as shown by the circuit diagram below.



- (a) On the excerpt below, from the above diagram, show the direction of conventional current between Points A and B when switch S_1 is closed. (1 mark)



- (b) State what the abbreviation 'DPDT' stands for and the function of the DPDT switch in the circuit above. (2 marks)

DPDT stands for: _____

Function: _____

A digital multimeter set on DC volts is used to measure the voltage across two selected pins of the integrated circuit (IC).

- (c) State the value expected to be seen on the multimeter display for each of the following selected pairs of pins as the motor operates. (2 marks)

Pins 1 and 8: _____

Pins 2 and 6: _____

- (d) State **two** possible consequences if C_4 was short circuited (2 marks)

One: _____

Two: _____

During testing, capacitor C_2 is found to be faulty and needs to be replaced. There are only 5 nF or 20 nF capacitors available, and only two of each. There are **two** possible solutions that use the available capacitors.

- (e) For each of the **two** solutions, draw circuit diagrams and show appropriate calculations of how 5 nF or 20 nF capacitors could be used to take the place of the 10 nF capacitor. (4 marks)

Question 30 (continued)

When the transistor with a gain of 50 is operating in its saturation mode, the motor consumes 2.4 W of power.

(f) (i) Prove by calculation that the current through the motor is 0.2 A. (2 marks)

(ii) Prove by calculation that the current through R_4 is 0.01 A if the LED consumes 2 V. (2 marks)

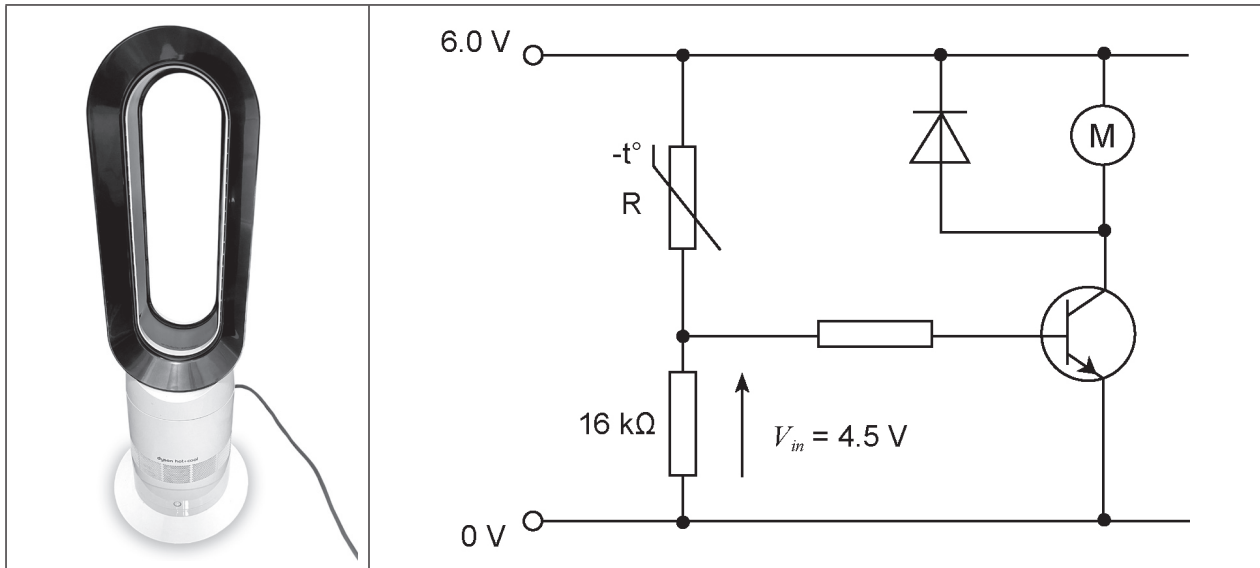
(iii) Prove by calculation that the collector current of the transistor is 0.21 A. (1 mark)

(iv) With 5 V out of Pin 3, prove by calculation that the transistor is in saturation mode. (3 marks)

Question 31

(21 marks)

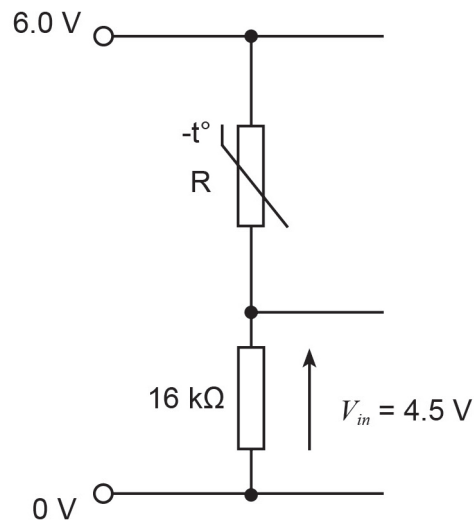
A desktop fan like the one pictured has a circuit arrangement to control the operation of the fan's motor, as indicated by the circuit diagram.



- (a) Explain the operation of the circuit shown above as the temperature in the room increases. Include reference to the resistance of the thermistor and the voltage V_{in} as the temperature increases. (4 marks)

Question 31 (continued)

The input sensing circuit of the fan is shown below.

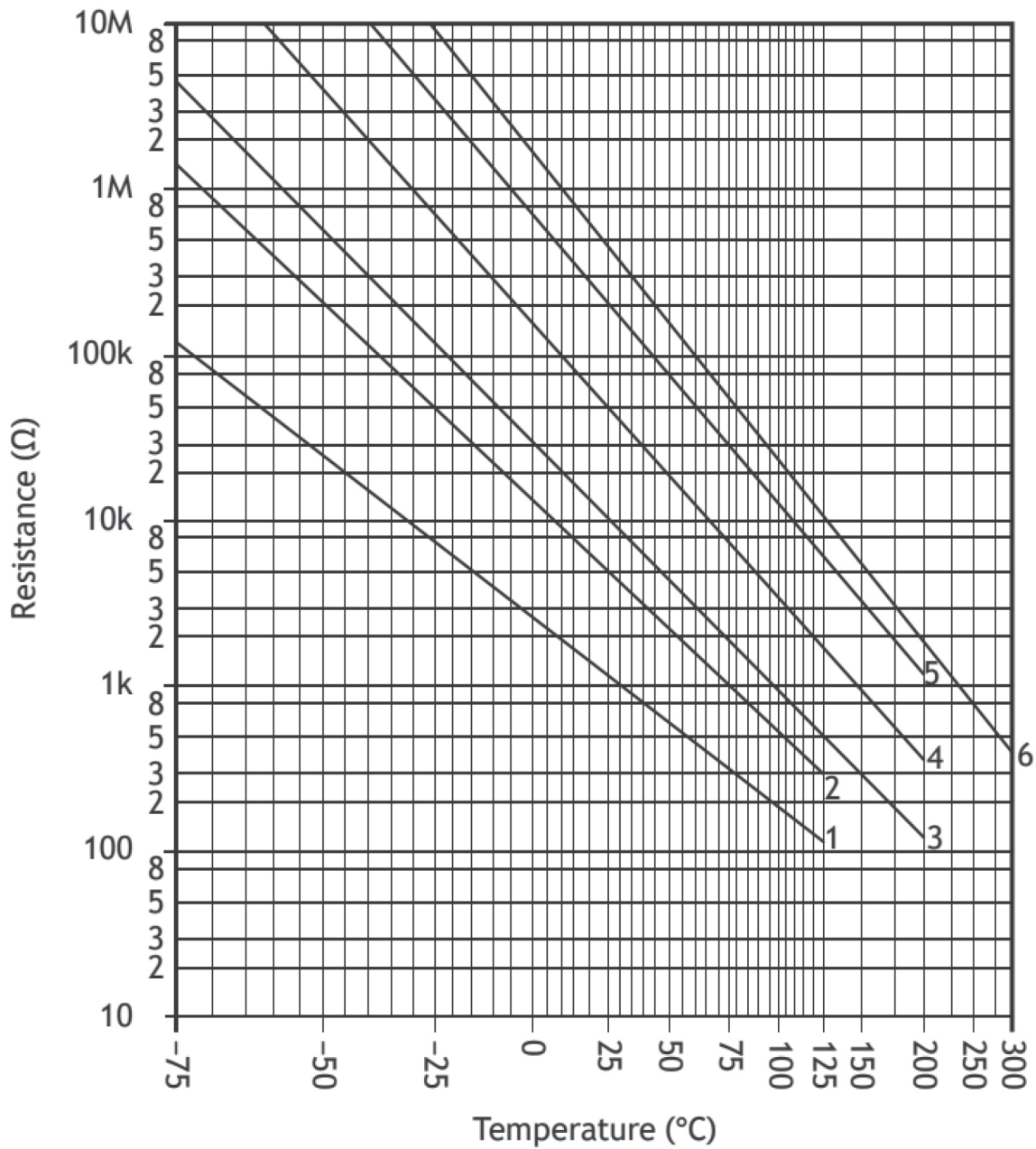


- (b) Calculate the resistance R when V_{in} is 4.5 V . (3 marks)

Resistance (Ω) = _____

- (c) State how the input sensing circuit could be easily altered to allow the operator to set the temperature at which the fan motor switches on. (1 mark)

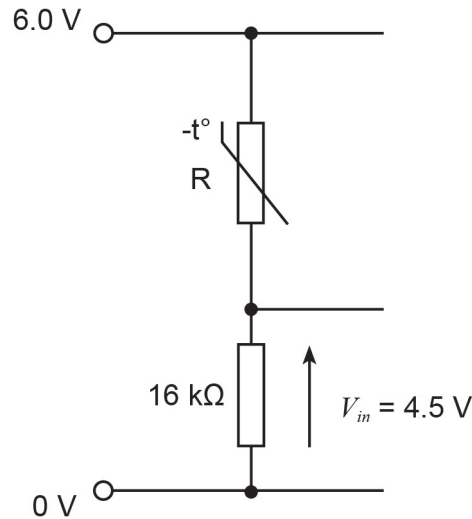
The graph below shows the behaviour of a range of thermistors (Types 1, 2, 3, 4, 5 and 6) that can be used in heating/cooling systems.



- (d) Using a Type 4 thermistor, show on the graph that: (2 marks)
- (i) the resistance at $-20\text{ }^{\circ}\text{C}$ is $500\text{ k}\Omega$
 - (ii) the temperature that gives $3\text{ k}\Omega$ of resistance is $110\text{ }^{\circ}\text{C}$.

Question 31 (continued)

This voltage dividing circuit, using a Type 4 thermistor, can be connected to a 8-bit microcontroller that will accept a V_{MAX} of 6 V and a V_{MIN} of 0 V. Consider the maximum range of the sensor to be between $-20\text{ }^{\circ}\text{C}$ and $110\text{ }^{\circ}\text{C}$.



- (e) Show that the maximum and minimum expected V_{in} are approximately 5 V and 0.2 V, respectively. (4 marks)

- (f) Determine, to the nearest mV, the digital resolution voltage of the analogue to digital converter (ADC). (3 marks)

Digital resolution voltage (mV): _____

- (g) Calculate the decimal digital output of the analogue to digital converter (ADC) when the input is: (4 marks)
- (i) 0.2 V
 - (ii) 5 V.

$$\text{Digital resolution voltage} = \frac{\text{Full Scale Range } (V_{MAX} - V_{MIN})}{\text{Bit resolution } (2^n)} = \frac{\text{Analogue voltage measured}}{\text{Digital Output from ADC}}$$

Minimum output voltage (V) = _____

Maximum output voltage (V) = _____

Question 32

(32 marks)

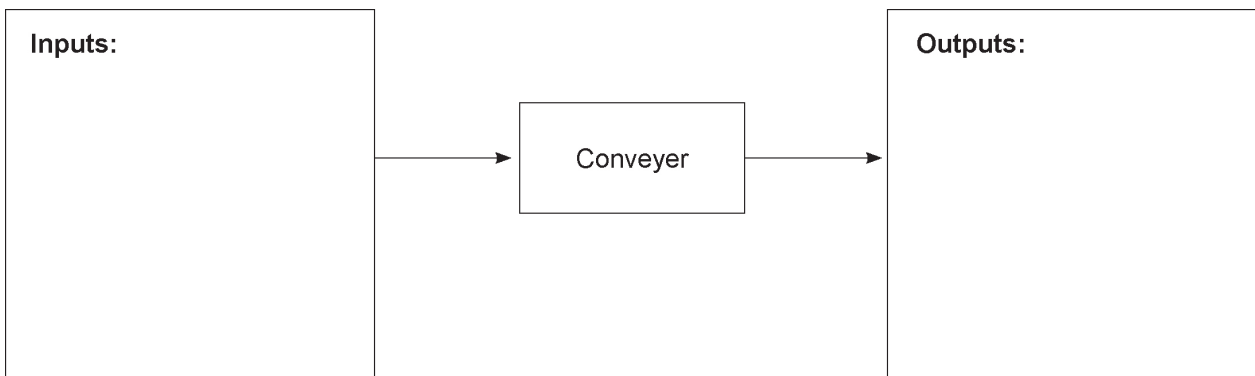
At the supermarket, the conveyer belt is still being used to assist checkout attendants to move customers' groceries into place for them to scan the item, place them in a bag and return the bagged groceries to the customer. While self-checkouts are becoming more common, the conveyors are still preferred by shoppers who have a large number of grocery items.

Many of the conveyor systems will only engage the motor that turns the conveyor when a sensor at the end – the far sensor – detects a grocery item. It will move that item forward at a constant speed until a second sensor – the near sensor located close to the attendant – stops the motor, preventing the conveyor from moving. When the near sensor detects no items and the far sensor still detects an item, then the conveyor belt will move. There is an override button that the attendant can push to disengage the motor at any time. It is located on the floor and engaged using their foot.

Using a toggle switch, the conveyor belt can be operated in either 'Auto Mode', where the sensors control the movement of the conveyor, or in 'Manual Mode', where the motor is controlled by the operator manually pushing a foot pedal to start and stop the conveyor belt.

When each item is scanned, the unique identifying code is checked against the store's database of items and, when accepted, it will sound a high-pitched beep and a green light will appear. When the item is not identified, it will sound a low-pitched beep and a red light will be illuminated. The conveyor is stopped when a low-pitched beep is sounded and restarted when a high-pitched beep is produced.

- (a) Using a universal system block diagram for only the conveyor, list the components of the checkout system operating in 'Auto Mode' and 'Manual Mode'. This should include all the real-world inputs and outputs that are processed or produced by the conveyor. (6 marks)



- (b) Draw a flow chart for the checkout conveyor and scanning when operating in both modes. Use the standard flow chart symbols shown in the Data Book. (14 marks)

Question 32 (continued)

- (c) Use this specific application to describe and give an example of both an open-loop and a closed-loop system. (4 marks)

Open-loop: _____

Closed-loop: _____

The conveyor system uses a relay operated motor control circuit to drive the motor. The relay and any associated electronics operate at 5 V. The motor requires an operating voltage of 36 V when turned on. The motor can be isolated from the 36 V supply using an SPST switch to prevent accidental operation. The motor operates in one direction only. No bidirectional operation is required.

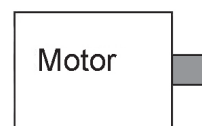
- (d) Design a control circuit which meets the brief listed above. (8 marks)

5 V

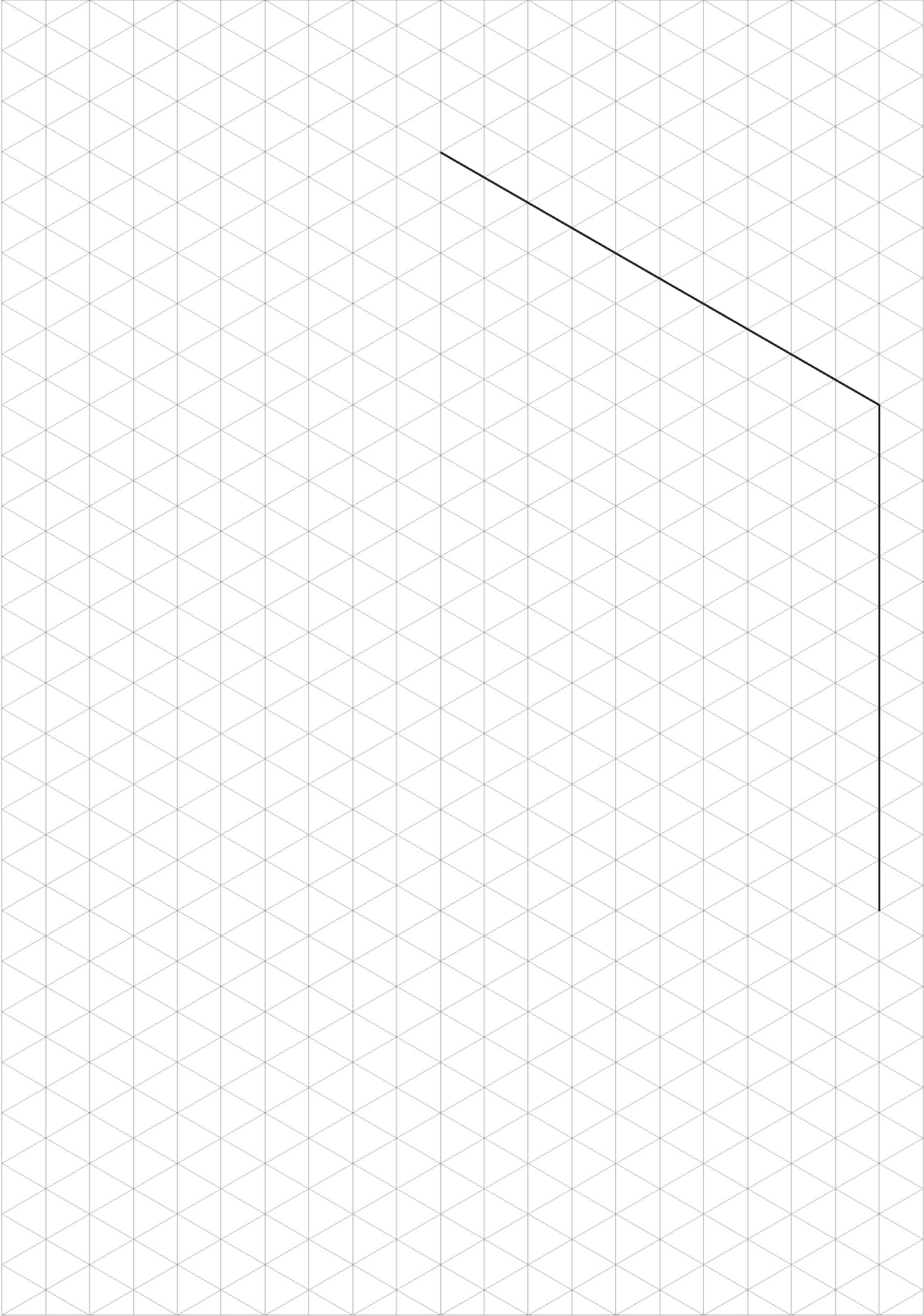
36 V

Output from microcontroller

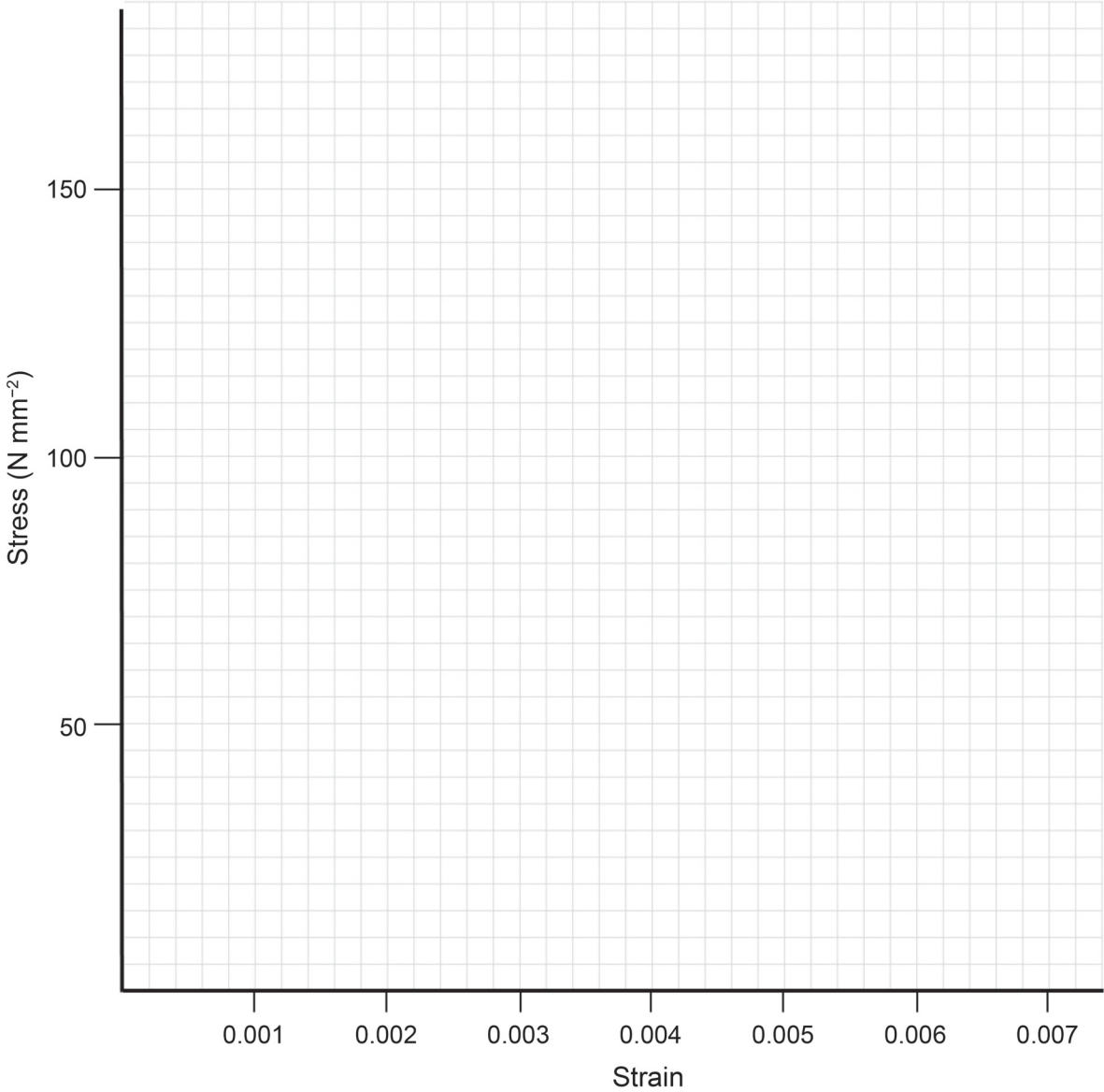
0 V



Spare grid for Question 9(a)



Spare grid for Question 22(b)



ACKNOWLEDGEMENTS

- Question 11** TU Delft OpenCourseWare. (n.d.). *3.1.2 Life-Cycle of a Building* [Diagram]. Retrieved June, 2024, from <https://ocw.tudelft.nl/course-readings/3-1-2-life-cycle-of-a-building/>
Used under Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International licence.
- Question 20(e)** Airbus. (2020). Take-Off Weight Limitation ISA Conditions - GP 7200 Engine FIGURE-3-3-1-991-008-A01 [Graph]. *A380: Aircraft Characteristics Airport and Maintenance Planning* (Subject 3-3-1, p. 3). Retrieved June, 2024, from <https://www.airbus.com/sites/g/files/jlcbta136/files/2021-11/Airbus-Aircraft-AC-A380.pdf>