



Western Australian Certificate of Education ATAR course examination, 2016

Question/Answer booklet

ENGINEERING STUDIES

Please place your student identification label in this box

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	<input type="checkbox"/>
Mechatronics	<input type="checkbox"/>

Materials required/recommended for this paper

To be provided by the supervisor

This Question/Answer booklet
Multiple-choice answer sheet
Data book

Number of additional answer booklets used (if applicable):	<input type="text"/>
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To be provided by the candidate

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

Special items: non-programmable calculators approved for use in this 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	10	10	70	70	10
Part A: Multiple-choice Part B: Extended answer	4	4			30
Section Two Mechanical	10	10	110	110	10
Part A: Multiple-choice Part B: Extended answer	7	7			50
Section Two Mechatronics	10	10	110	110	10
Part A: Multiple-choice Part B: Extended answer	6	6			50
Total					100

Instructions to candidates

- The rules for the conduct of the Western Australian Certificate of Education ATAR course examinations are detailed in the *Year 12 Information Handbook 2016*. 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: Multiple-choice

Answer all questions on the separate Multiple-choice answer sheet provided. For each question, shade the box to indicate your answer. Use only a blue or black pen to shade the boxes. If you make a mistake, place a cross through that square, then shade your new answer. Do not erase or use correction fluid/tape. Marks will not be deducted for incorrect answers. No marks will be given if more than one answer is completed for any question.

Part B: Extended answer

Answer all questions. Write your answers in the spaces provided in this Question/Answer booklet.

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.
- Additional working space pages at the end of this Question/Answer booklet are for planning or continuing an answer. If you use these pages, indicate at the original answer, the page number it is planned/continued on and write the question number being planned/continued on the additional working space page.
- The Data book is not to be handed in with your Question/Answer booklet.

See next page

Section One: Core content**40% (70 Marks)**

This section has **two (2)** parts.

Part A: Multiple-choice Answer **all** questions

Part B: Extended answer Answer **all** questions

Suggested working time: 70 minutes.

Part A: Multiple-choice**10% (10 Marks)**

This part has **10** questions. Answer **all** questions on the separate Multiple-choice answer sheet provided. For each question, shade the box to indicate your answer. Use only a blue or black pen to shade the boxes. If you make a mistake, place a cross through that square, then shade your new answer. Do not erase or use correction fluid/tape. Marks will not be deducted for incorrect answers. No marks will be given if more than one answer is completed for any question.

1. An engineer wishes to design a pumping system to pump water from an underground well. The **most** important design consideration is
 - (a) the technical data supplied to him.
 - (b) the function the pump is to perform.
 - (c) the cost of the finished product.
 - (d) what the system will look like when it is finished.

2. The unit 'watt' is used when measuring
 - (a) work done per second.
 - (b) friction per metre.
 - (c) mechanical resistance.
 - (d) heat energy dissipated.

3. From the list of materials below choose the one that is an alloy.
 - (a) iron
 - (b) copper
 - (c) brass
 - (d) nickel

4. A design brief is intended to
 - (a) specify the requirements of the client.
 - (b) specify the materials to be used in manufacture.
 - (c) set the production time line.
 - (d) summarise the marketing strategy for the product.

See next page

5. A designer is working on a new robotic machine. His first task is to make a working version of the design. What is the name given to the process of making this working version?
- (a) modelling
 - (b) marketing
 - (c) producing
 - (d) prototyping
6. A solid sphere is cut in half. Which of the formulae below could be used to calculate the surface area of one of the halves?
- (a) $2\pi r^2$
 - (b) $3\pi r^2$
 - (c) $4\pi r^2$
 - (d) $5\pi r^2$
7. Which of the following is **not** an example of a renewable energy system?
- (a) methane recovery from animal waste
 - (b) production of biofuels from grain crops
 - (c) production of alcohol fuel additives by fermentation of cereal produce
 - (d) distillation of crude oil
8. Orthographic drawings have specific information that must be included on the drawing. Which of the following is **not** a requirement in orthographic drawings?
- (a) They must show all internal as well as external structures.
 - (b) All dimensions must be drawn to scale.
 - (c) The area of all surfaces must be stated on the drawing.
 - (d) All dimensions and units must be shown on the drawing.
9. In designing an adventure playground, the **most** important consideration is the
- (a) appearance of the installation.
 - (b) enjoyment of the users.
 - (c) safety of the equipment.
 - (d) cost of the equipment and installation.
10. A cone has a diameter D , a vertical height H and a slanted side of length S . Which of the following formulae could be used to calculate the height?
- (a) $H = \sqrt{S^2 - D^2}$
 - (b) $H = \sqrt{S^2 - \frac{D^2}{4}}$
 - (c) $H = \sqrt{S^2 + \frac{D^2}{2}}$
 - (d) $H = \sqrt{\frac{D^2}{2} - S^2}$

See next page

Section One: Core content**Part B: Extended answer****30% (60 Marks)**

This section has **four (4)** questions. Answer **all** questions. Write your answers in the spaces provided.

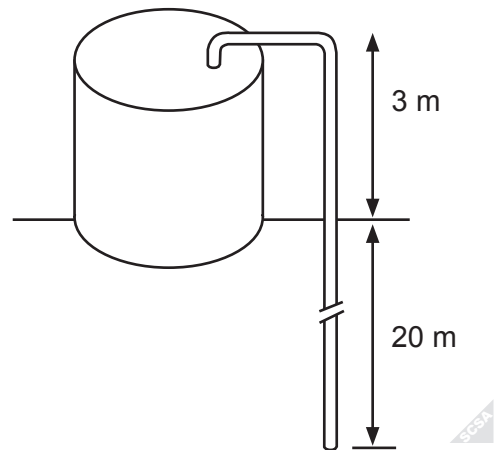
When calculating answers, show all your working clearly. Your working should be in sufficient detail to allow your answers to be checked readily and for marks to be awarded for reasoning. In final answers, include appropriate units where applicable.

Additional working space pages at the end of this Question/Answer booklet are for planning or continuing an answer. If you use these pages, indicate at the original answer, the page number it is planned/continued on and write the question number being planned/continued on the additional working space page.

Question 11**(14 marks)**

The diagram on the right shows a system that pumps water from a 20 m deep underground well into the top of an above-ground cylindrical tank.

The 20 m³ tank is 3 m high and is made of heavy-duty ultraviolet resistant plastic.



- (a) Calculate the internal radius of the tank, given that its internal height is 3 m. (3 marks)

- (b) State the energy changes in the
- (i) pump when its electric motor is operating. (2 marks)

- (ii) water as it is lifted from the bottom of the well to the tank. (1 mark)

The pump is controlled electronically using two sensors inside the tank. The upper sensor stops the pump when the water reaches a certain height and the lower sensor starts it again when the water falls to a set level. The height difference between the upper and lower sensors is 2.8 m.

- (c) Calculate the mass of water added when the tank refills from the bottom sensor to the top sensor. Note that 1 m^3 of water has a mass of 10^3 kg . (2 marks)

- (d) The work required to lift enough water to fill the tank is 4.207 MJ. If the pump is rated at 750 W and is 85% efficient, how long will it take to refill the tank? (3 marks)

- (e) How many kilowatt hours of electricity does the pump use to refill the tank five times? (2 marks)

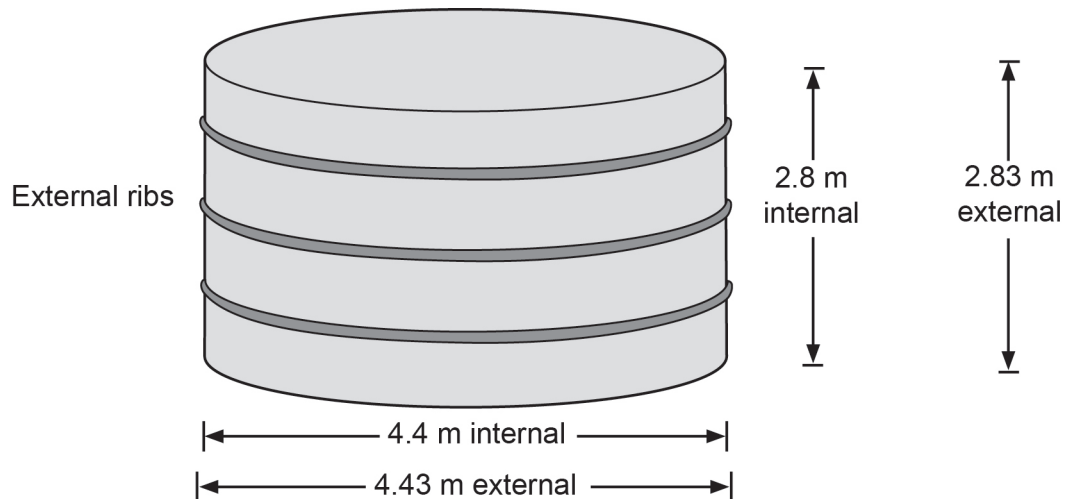
- (f) Given that the efficiency of the electric pump is 85%, what happens to most of the other 15% of the energy provided to the pump? (1 mark)

Question 12

(10 marks)

A farmer has a cylindrical polycarbonate tank with an internal height of 2.8 m and an internal radius of 2.2 m. Its wall and base are 1.5 cm thick. The flat top, also 1.5 cm thick, has a diameter of 4.43 m and rests on the tank walls.

There are several circular ribs around the tank, as shown in the diagram.



- (a) Calculate the mass of polycarbonate in the tank, including the base and the top. Ignore the circular ribs. (5 marks)

The tank has several circular ribs around its circumference as shown in the diagram on page 8.

- (b) What is the purpose of these ribs? (1 mark)

The farmer finds that a flat circular lid lacks strength and sags in the middle.

- (c) Suggest a shape for the lid that would give it extra strength. (1 mark)

- (d) State an advantage of using polycarbonate to manufacture such a tank, and state a property of polycarbonate that gives this advantage. (2 marks)

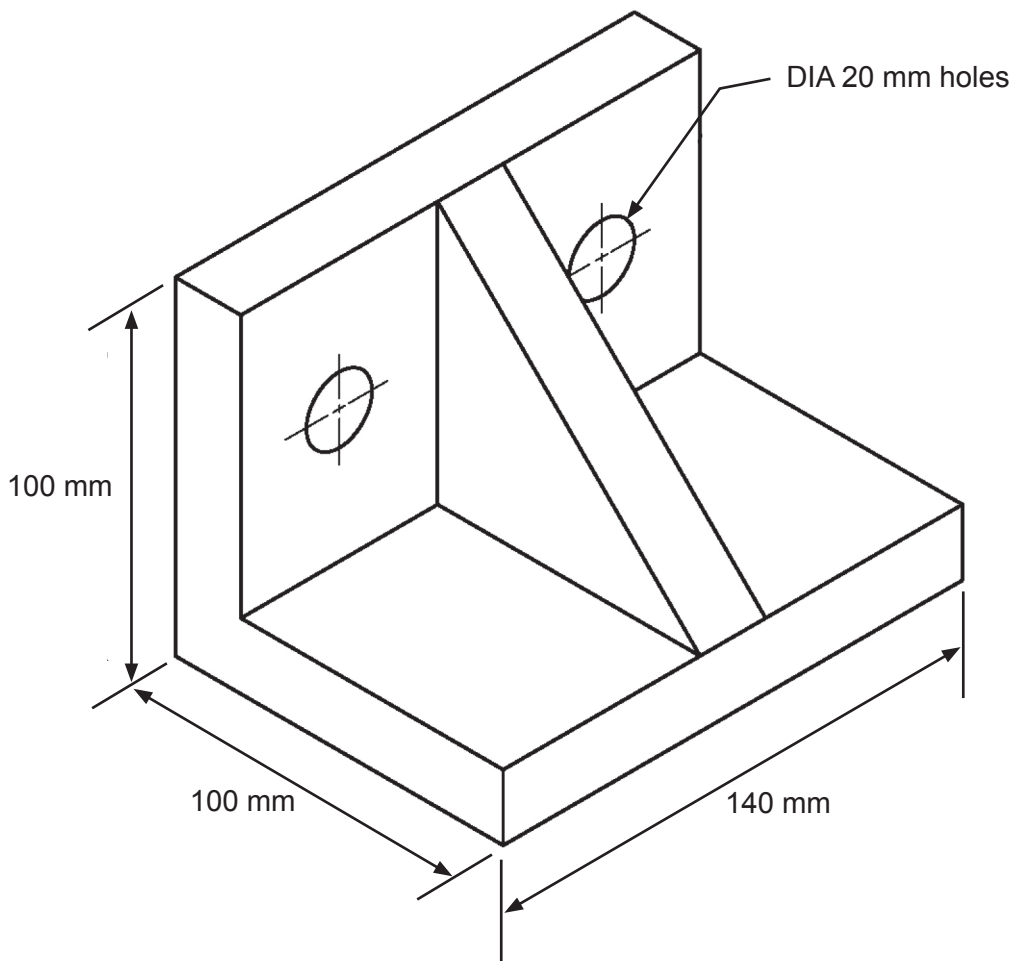
- (e) The manufacturers incorporated an ultraviolet-resistant additive in the polycarbonate used to make the tank. What problem would arise if this was **not** added to the polycarbonate? (1 mark)

Question 13

(17 marks)

The diagram below shows a bracket that is to be manufactured from 20 mm steel plate. The bracket is 100 mm high, 140 mm long and has a 100 mm wide base. It will be used to connect a vertical steel column to an existing concrete footing.

The triangular rib is centrally located. The bracket is fixed to the column using two bolts that pass through 20 mm diameter holes located centrally as shown. The base will be chemically grouted to the concrete footing.



Note: all plate 20 mm thick

Using the grid provided on page 11, produce fully-dimensioned scaled orthographic drawings (front and side views) to enable a workshop to manufacture the bracket.

(a) You must ensure:

- your projections are neat and labelled. (4 marks)
- you have chosen a suitable scale and stated it. (2 marks)
- the correct relationship between the two views is shown. (1 mark)
- all hidden edges are shown correctly. (1 mark)
- all dimensions are shown correctly. (3 marks)

See next page

Question 13 (continued)

(b) (i) Calculate the volume of this metal bracket, ignoring the holes. (3 marks)

(ii) The bracket is to be made of stainless steel. Calculate its mass. (2 marks)
(If you did not obtain an answer for (i) above, use a volume of $6.5 \times 10^{-5} \text{ m}^3$.)

(c) Using your Data book, state a possible advantage of using stainless steel rather than structural steel to make this bracket. (1 mark)

See next page

Question 14

(19 marks)

The photograph below shows wind farms on the coast, south-west of Albany.



The footing for each tower is a reinforced concrete pad of circular section, 15.4 m in diameter and 2.6 m deep.

The base of each tower is a structural steel cylinder with walls 36 mm thick and 2 m high, and an outside diameter of 4.2 m. The base is lifted into place before the concrete is poured, embedding the base in the footing. After the base is embedded, the 64 m high tower is mounted onto it.

- (a) Explain why reinforced concrete is used to construct the footings for the towers rather than concrete that is **not** reinforced. (2 marks)

- (b) Explain why each concrete footing is significantly wider than the base of the tower it supports. (2 marks)

Question 14 (continued)

- (c) Including the base of the tower, 40% of the volume of each footing is structural steel. Calculate the mass of **one** such footing. (3 marks)
- (d) Calculate the volume of steel in the cylindrical steel base that supports the upper part of each tower. (4 marks)

Each blade is made of fibreglass (epoxy resin), has a radial length of 35.5 m and turns in a clockwise direction at a rotational speed of between 6 and 21.5 rpm. The blades require a start-up wind speed of 54 km hr^{-1} and have a cut-out wind speed of 120 km hr^{-1} .

- (e) The tip of each blade rotates in a circular path.
- (i) Calculate the circumference of this path. (2 marks)

- (ii) Calculate the speed in metres per second of the tip of each blade when it is rotating at 21.5 rpm. (3 marks)
- (f) One wind farm has six generators, each with a maximum electrical output of 2300 kW. If each generator produces 40% of its maximum output in a year, how many kilowatt hours of electricity would the farm produce in that time? (2 marks)
- (g) What major environmental advantage does wind generation have over the use of fossil fuels to generate electricity? (1 mark)

End of Section One

See next page

Section Two: Specialist fields**60% (110 Marks)**

Candidates are required to choose one of the following options, according to which specialist field they studied in 2016.

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

Specialist field	✓	Question numbers	Pages
Mechanical	<input type="checkbox"/>	15–31	17–33
Mechatronics	<input type="checkbox"/>	32–47	34–50

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

See next page

Section Two: Specialist field—Mechanical**60% (110 Marks)**

This section has **two (2)** parts.

Part A: Multiple-choice Answer **all** questions

Part B: Extended answer Answer **all** questions

Suggested working time: 110 minutes.

Part A: Multiple-choice**10% (10 Marks)**

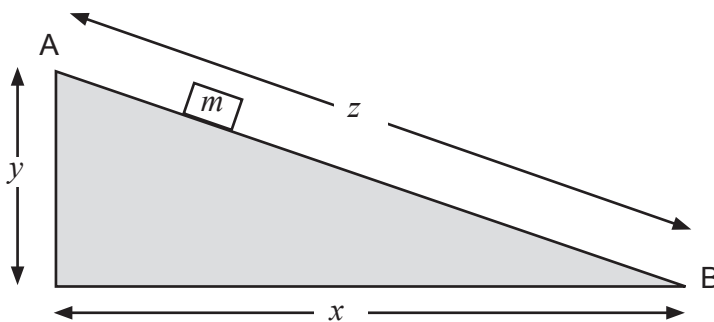
This part has **10** questions. Answer **all** questions on the separate Multiple-choice answer sheet provided. For each question, shade the box to indicate your answer. Use only a blue or black pen to shade the boxes. If you make a mistake, place a cross through that square, then shade your new answer. Do not erase or use correction fluid/tape. Marks will not be deducted for incorrect answers. No marks will be given if more than one answer is completed for any question.

15. Which is the **most** suitable method for producing steel bars of consistent cylindrical shape with accurate dimensions?
- (a) forging
 - (b) cold drawing
 - (c) pressing
 - (d) casting
16. An electrical wire consists of a copper core coated with polypropylene insulation. Each material has the same cross-sectional area. When the wire is subjected to increasing tension, the
- (a) copper will snap first because of its higher ultimate tensile strength.
 - (b) polypropylene will snap first because of its lower ultimate tensile strength.
 - (c) copper will snap first because of its higher Young's modulus.
 - (d) polypropylene will snap first because of its lower Young's modulus.
17. Which of the following is an alternative unit for kilopascals (kPa)?
- (a) N m^{-2}
 - (b) N mm^{-2}
 - (c) kN m^{-2}
 - (d) kN mm^{-2}
18. Which of the following formulae can be used to calculate power?
- (a) $mv^2/2t$
 - (b) mgt/h
 - (c) mv^2/t
 - (d) mg/t

See next page

19. The factor of safety of a floor in a building changes when its approved usage changes from an office to a dance floor (disco). This is mainly to account for the
- (a) dynamic movement of humans.
 - (b) resonance of the music.
 - (c) increased weight of sound insulation.
 - (d) movement of office furniture.
20. The factor of safety for a passenger lift is 20 and its rated safe working load is 1800 kg. The lift has to be designed to take a maximum load of
- (a) 90 kg.
 - (b) 1800 kg.
 - (c) 18 000 kg.
 - (d) 36 000 kg.
21. An object moving in a straight line with constant positive acceleration has
- (a) constant velocity.
 - (b) decreasing velocity.
 - (c) increasing velocity.
 - (d) zero velocity.
22. In which of the following situations does the potential energy of an object **decrease**?
- (a) slowing down while travelling horizontally
 - (b) free falling under the influence of gravity
 - (c) accelerating with a constant horizontal acceleration
 - (d) accelerating vertically upward

23. In the diagram, a mass m is moved a distance z up an incline from B to A.



The work that m does against gravity is

- (a) $mg(x + y)$.
- (b) mgx .
- (c) mgz .
- (d) $mg y$.

24. The efficiency of a mechanical system can be defined as the ratio of the
- (a) load lifted to the weight of the load.
 - (b) factor of safety to the safe working stress.
 - (c) toughness of the system to its resilience.
 - (d) useful work done to the energy supplied.

Part B: Extended answer**50% (100 Marks)**

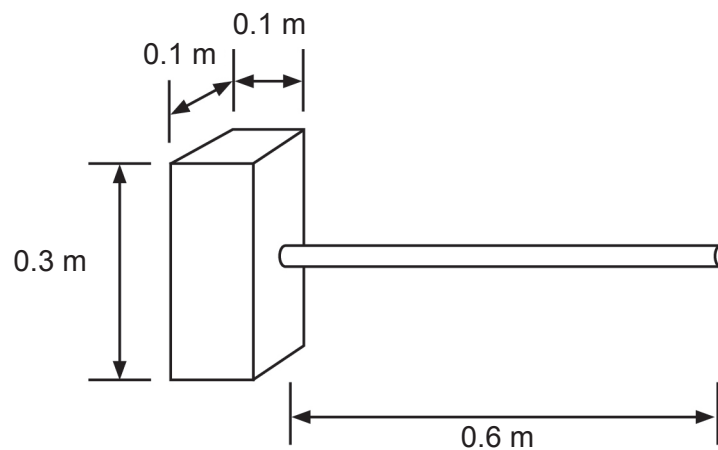
This part has **seven (7)** questions. Answer **all** questions. Write your answers in the spaces provided.

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.

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Question 25**(10 marks)**

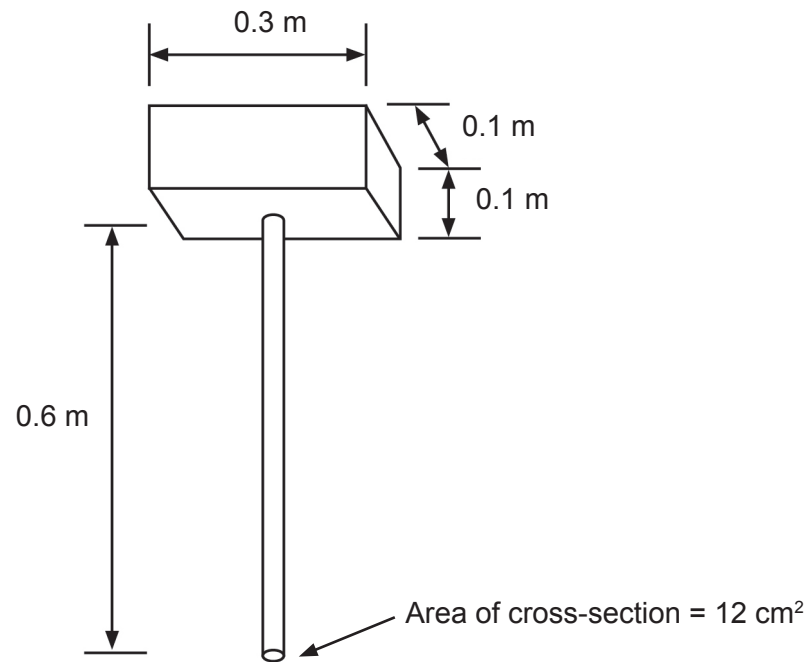
A hammer is made of brass, with dimensions as shown below.



- (a) Show that the weight of the hammer head is 256.96 N.

(3 marks)

Hint: density = $\frac{\text{mass}}{\text{volume}}$

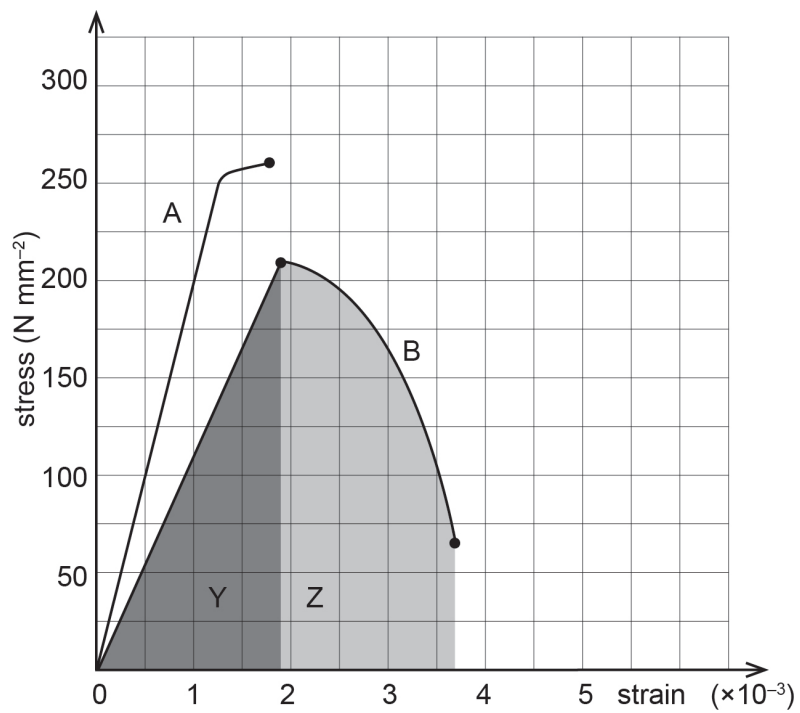


- (b) When the hammer is balanced on the end of its handle as shown above, the weight of the head compresses the handle and reduces its length. Show by calculation that this change in length is close to zero. Assume that only the weight of the head affects the length of the handle. (7 marks)

Question 26

(10 marks)

The stress/strain graph below shows two very different materials.



- (a) Calculate the Young's modulus of Material B from the graph.

(4 marks)

(b) Using the information from your Data book, answer the following questions relating to this graph.

(i) Which material is likely to be copper? (1 mark)

(ii) Give **three** reasons for your answer. (3 marks)

(c) The area under the graph of Material B is divided into sections labelled 'Y' and 'Z'. What material properties do the following represent?

(i) Area Y: (1 mark)

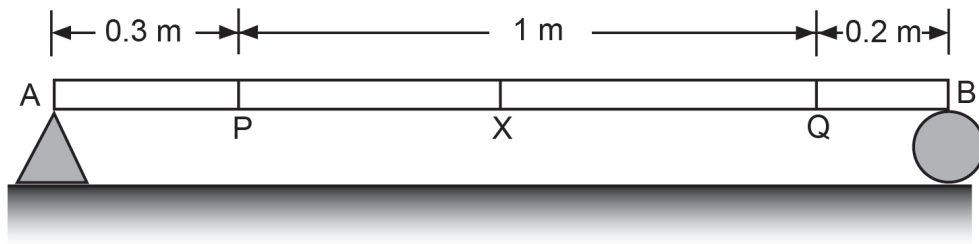
(ii) Area Y + Area Z: (1 mark)

Question 27

(21 marks)

The diagram below shows a uniform horizontal steel beam AB simply supported at both ends. This beam is in static equilibrium.

A 150 kg load (that includes the mass of the bar) is distributed evenly over a 1 m length between P, 0.3 m from A, and Q, 0.2 m from B, as indicated in the diagram. Point X is the midpoint of the beam.



(a) Calculate R_A , the reaction force at A.

(4 marks)

(b) Calculate R_B , the reaction force at B.

(2 marks)

- (c) (i) Describe how to calculate the shear force at Point X, the midpoint of the beam. (3 marks)

- (ii) Calculate the bending moment at Point X, using the equation below. (3 marks)

$$M = R_A \times L_{AX} - \frac{1}{2} W (L_{AX} - L_{AP})^2$$

where M = the bending moment

R_A = reaction force at A

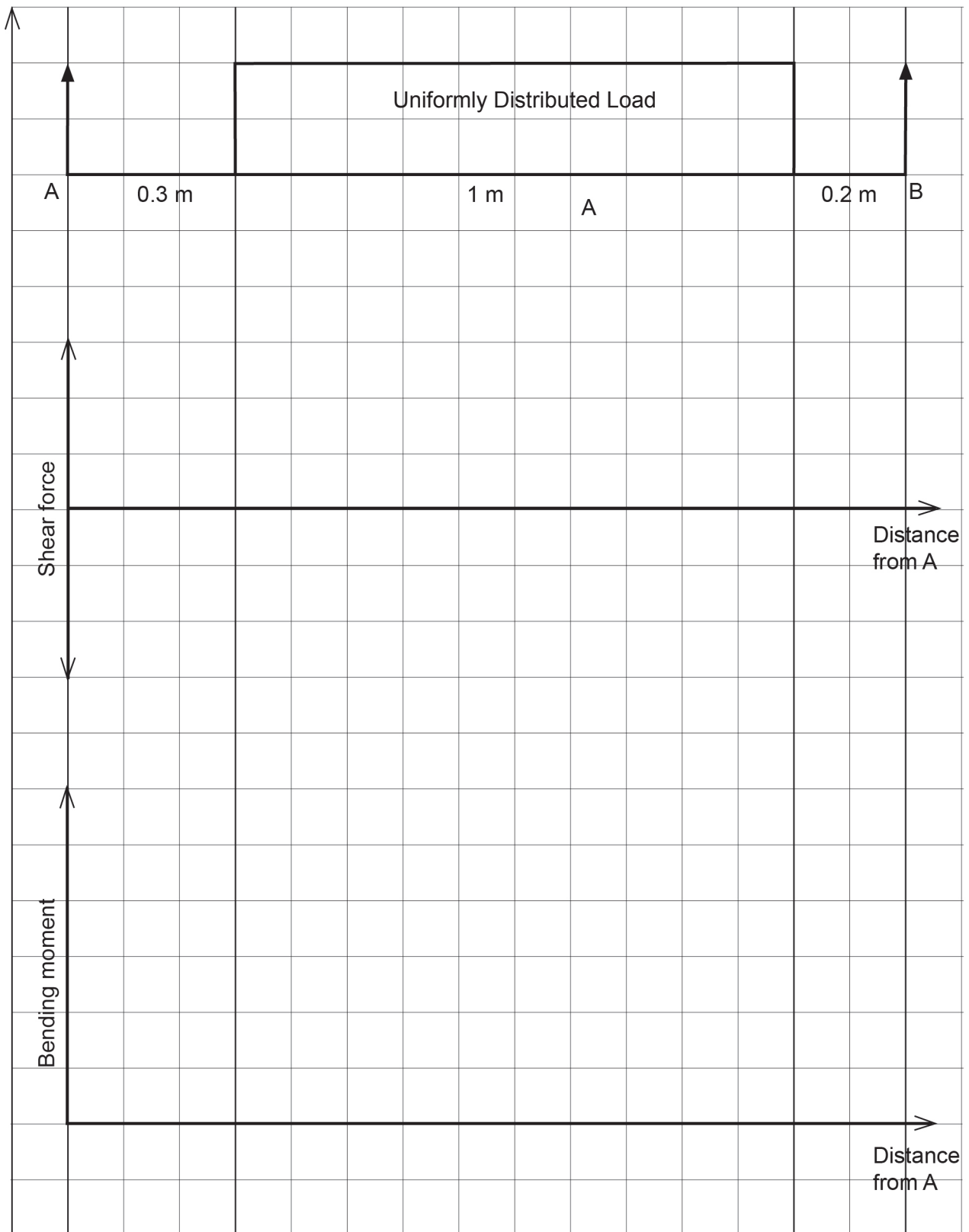
L_{AX} = length of AX

W = force per metre in the loaded part of the beam

L_{AP} = length of AP

Question 27 (continued)

- (d) Using the grid below and taking into account all relevant forces, construct a shear force diagram and a bending moment diagram for the beam. On the bending moment diagram indicate clearly the point of maximum bending moment. (9 marks)



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

See next page

Question 28**(10 marks)**

An elastic ball of mass 125 g is dropped from a height of 3 m onto the ground below.

Ignore air resistance in your calculations.

- (a) Using an appropriate formula from the Data book, show by calculation that the instantaneous velocity at the moment of impact with the ground is 7.668 m s^{-1} . (3 marks)

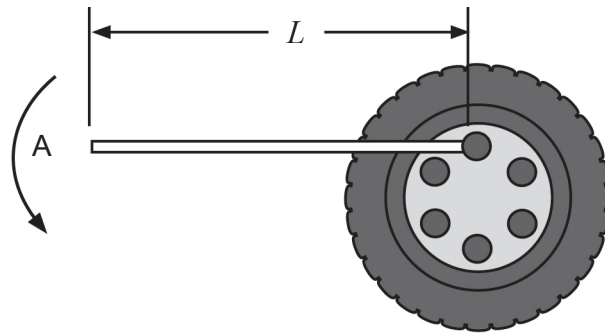
- (b) Would the instantaneous velocity at the moment of impact change if the mass of the ball was increased to 250 g? Explain your answer, with reference to relevant equations. (4 marks)

- (c) After impact with the ground, the elastic ball rebounds to a height of 2.15 m. Calculate the percentage of the ball's initial energy that remains on rebound. (3 marks)

Question 29

(19 marks)

The diagram shows a truck wheel and an attempt to loosen one nut with a wheel brace.



The nut requires 700 N m of torque to loosen it.

Assume the wheel brace is made from a solid structural steel rod with a circular cross-section of diameter 2.5 cm.

- (a) The wheel nut can be just loosened when the brace is horizontal and a person of mass 75 kg stands on it at end A. Show that the length L of the brace is 95.2 cm. Ignore the mass of the wheel brace in your calculation. (3 marks)

- (b) Using appropriate equations from your Data book, calculate the maximum deflection of the tip of the wheel brace as the nut starts to loosen when the 75 kg person stands on end A. Ignore the mass of the wheel brace in your calculation. (7 marks)

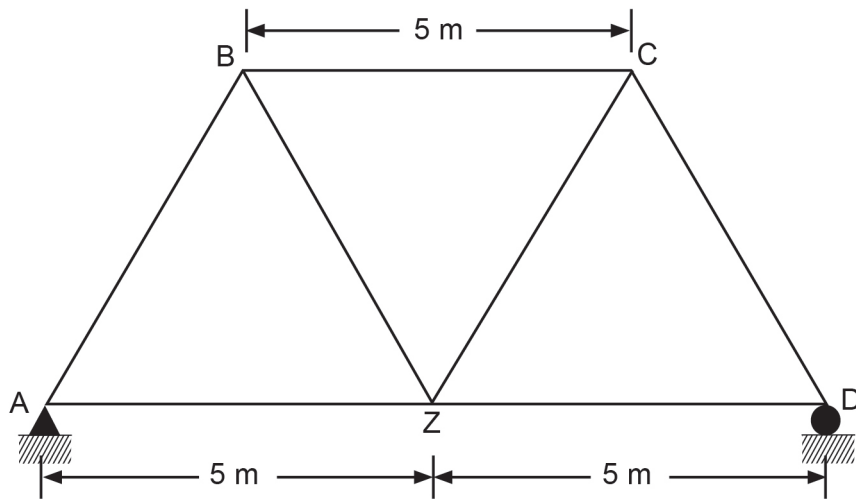
- (c) A second wheel brace of the same length is a solid rod of rectangular section of height 3 cm and width 2 cm. Using appropriate equations from your Data book, calculate the maximum deflection of the tip of this wheel brace when the same 75 kg person stands on end A. Ignore the mass of the wheel brace in your calculation. (7 marks)

- (d) If you did **not** ignore the mass of the wheel brace in part (c), would the new calculated deflection increase, decrease or stay the same? Give a reason for your answer. (2 marks)

See next page

Question 30

(14 marks)



Consider the diagram above. Strut BC has a uniformly distributed load of 1.35 kN m^{-1} and a point load of 15 kN acting vertically downward at C. Assume all other struts (AB, BZ, CZ and CD) are stiff and lightweight. All triangles are equilateral with sides of 5 m, making the distance between A and D 10 m.

- (a) Calculate the vertical reaction force at D. (5 marks)

(b) Calculate the vertical reaction force at A. (4 marks)

(c) (i) Calculate the force in the strut AB. (4 marks)

(ii) Is AB under compression or under tension? Circle the answer below. (1 mark)

compression

tension

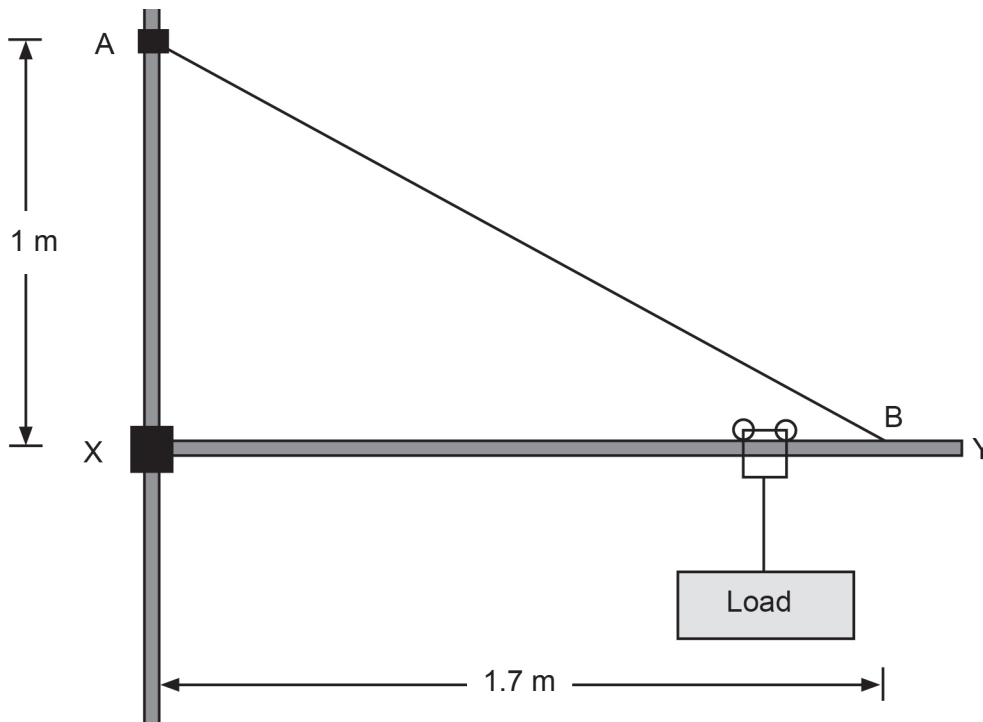
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Question 31

(16 marks)

The diagram below is of a workshop crane. It consists of a uniform 60 kg, 2 m long horizontal beam XY attached at right angles to a vertical pole at X and supported by a steel cable attached to the beam at B, 0.3 m from end Y. The steel cable is attached to the vertical pole at A, 1 m from X. The angle ABX is 30.47° .

A generator of mass 760 kg is being lifted from the back of a truck by the crane in order to be positioned on the workshop floor. When the load is lifted initially it is 0.5 m from Y.



- (a) Calculate the tension in the cable when the load is lifted initially from the back of the truck. (5 marks)

(b) Calculate the horizontal component of the reaction force that the beam exerts on the vertical support at X when the load is lifted initially from the back of the truck. (3 marks)

(c) Calculate the vertical component of the reaction force that the beam exerts on the vertical support at X when the load is lifted initially from the back of the truck. (5 marks)

After being lifted off the truck, the load is moved toward X.

(d) What will happen to the vertical component of the reaction force at X as this occurs? Explain. (3 marks)

Section Two: Specialist field—Mechatronics**60% (110 Marks)**

This section has **two (2)** parts.

Part A: Multiple-choice Answer **all** questions

Part B: Extended answer Answer **all** questions

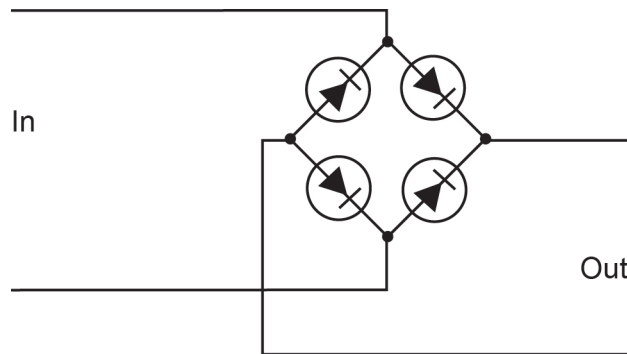
Suggested working time: 110 minutes.

Part A: Multiple-choice**10% (10 Marks)**

This part has **10** questions. Answer **all** questions on the separate Multiple-choice answer sheet provided. For each question, shade the box to indicate your answer. Use only a blue or black pen to shade the boxes. If you make a mistake, place a cross through that square, then shade your new answer. Do not erase or use correction fluid/tape. Marks will not be deducted for incorrect answers. No marks will be given if more than one answer is completed for any question.

32. An engineer is required to redesign a circuit in order to allow for the flow of AC but block the flow of DC. Which of the following components would he choose to do this?
- (a) a diode
 - (b) a capacitor
 - (c) a resistor
 - (d) a relay
33. A telescope mount has an electric motor coupled to a mechanical drive system. It is designed to move the telescope to allow for the rotation of the Earth (one revolution every 24 hours). Which of the following mechanical drive systems would be the most suitable for this application?
- (a) a belt and pulley
 - (b) a chain and sprocket
 - (c) a worm and worm wheel
 - (d) a rack and pinion
34. The number of combinations ($2^n - 1$) in a 12 bit ADC is
- (a) 4095.
 - (b) 1024.
 - (c) 2048.
 - (d) 255.

35. Four electronic components are configured as in the diagram below.



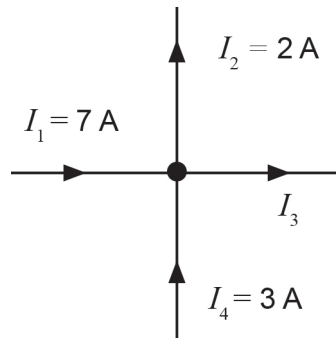
The purpose of this circuit is to

- (a) produce a sine wave output.
 - (b) change the direction of the input current.
 - (c) protect from reverse polarity.
 - (d) produce a DC output.
36. Three resistors are connected in parallel. The first has a value of $R \Omega$, the second has a value of $2R \Omega$ and the third a value of $3R \Omega$. The total resistance is **closest** to
- (a) $0.5R \Omega$.
 - (b) $6R \Omega$.
 - (c) $0.17R \Omega$.
 - (d) $12R \Omega$.
37. A thermistor is described as having a negative temperature coefficient (NTC). This means that as the temperature of the thermistor increases, the electrical resistance will
- (a) decrease.
 - (b) become positive.
 - (c) increase.
 - (d) remain the same.
38. In a rack and pinion gear system, a rack has a length of 120 cm and the pinion gear has a diameter of 1 cm. If the pinion is rotated 10 times, the rack will move a distance of
- (a) 12 cm.
 - (b) 31.4 cm.
 - (c) 3.18 cm.
 - (d) 10 cm.
39. To measure the supply voltage of an electric circuit, the voltmeter **must** be connected in
- (a) parallel with the power supply.
 - (b) parallel with the load.
 - (c) series with the power supply.
 - (d) series with the load.

40. The most suitable power supply for a microcontroller chip would be a

- (a) 12 V battery.
- (b) 5 V AC transformer.
- (c) 7805 voltage regulator circuit.
- (d) rectified 12 V transformer.

41. The current I_3 in the following circuit is



- (a) -8 A .
- (b) 2 A .
- (c) -2 A .
- (d) 8 A .

Part B: Extended answer**50% (100 Marks)**

This part has **six (6)** questions. Answer **all** questions. Write your answers in the spaces provided.

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.

Additional working space pages at the end of this Question/Answer booklet are for planning or continuing an answer. If you use these pages, indicate at the original answer, the page number it is planned/continued on and write the question number being planned/continued on the additional working space page.

Question 42**(21 marks)**

(a) The speed of a DC electric motor can be controlled using the following methods. Explain the method of operation and give an advantage and disadvantage of each.

(i) Pulse width modulation (4 marks)

Method of operation: _____

Advantage: _____

Disadvantage: _____

(ii) Variable resistor (4 marks)

Method of operation: _____

Advantage: _____

Disadvantage: _____

Question 42 (continued)

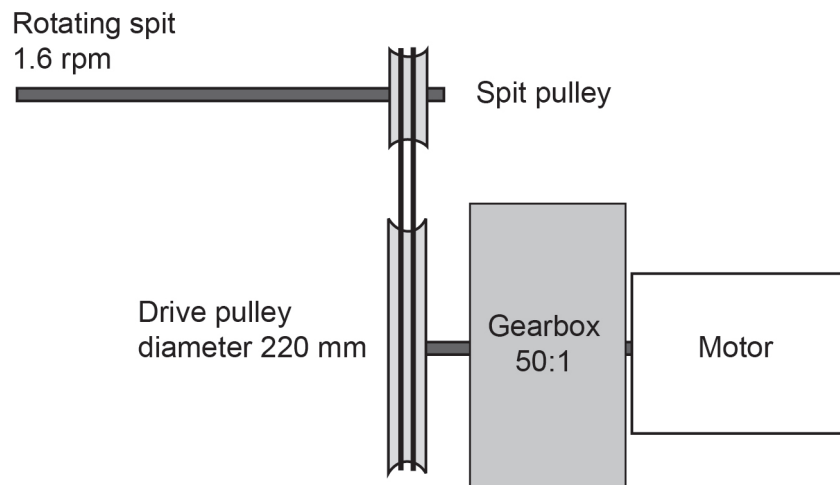
- (iii) Increasing or decreasing the number of cells in the power supply battery. (4 marks)

Method of operation: _____

Advantage: _____

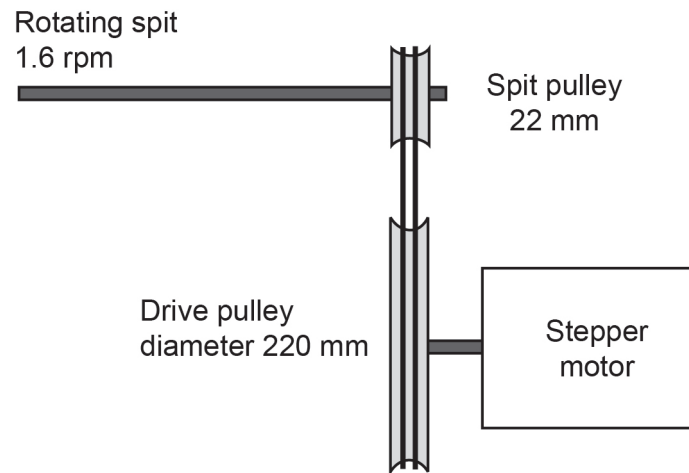
Disadvantage: _____

- (b) A windscreen wiper motor and incorporated gearbox are used to rotate a spit on a homemade barbecue. The required rotation rate of the spit is 1.6 rpm.



- (i) Calculate the motor rpm given that the drive pulley has a rotational speed of 44 rpm and the gearbox ratio is 50:1. (1 mark)
- (ii) Calculate the diameter of the spit pulley required to keep the spit rotating at 1.6 rpm if the motor speed is reduced to 1600 rpm. (4 marks)

The windscreen motor and incorporated gearbox proved difficult to mount and it was decided to replace both with a large stepper motor connected directly to the drive pulley. A new spit pulley with a diameter of 22 mm was used.



- (iii) Determine the degrees/step for the stepper motor if the stepper motor is stepped 40 times to achieve one rotation. (1 mark)
- (iv) How many steps should occur in one minute to ensure that the spit still rotates at 1.6 rpm? (3 marks)

Question 43**(17 marks)**

(a) Complete the following table of component functions.

(7 marks)

Component	Function
Light dependent resistor (LDR)	
Fuse	
Transistor (NPN)	
Thermistor (NTC)	
Servo	
Rectifier diode	
Polarised capacitor	

(b) Complete the following table of resistor and capacitor values and units.

(2 marks)

Component	Marking	Value	Unit
Fixed value resistor	Yellow, violet, green.		
Polyester capacitor (greencap)	223		

See next page

- (c) (i) Complete the table below for a 68 Ω , 5% tolerance, 1 W resistor. (2 marks)

Band 1 colour	Band 2 colour	Band 3 colour	Band 4 colour

- (ii) Determine the maximum and minimum values this resistor can have. (1 mark)

- (d) What would be a label on a 150 pF polyester capacitor? (1 mark)

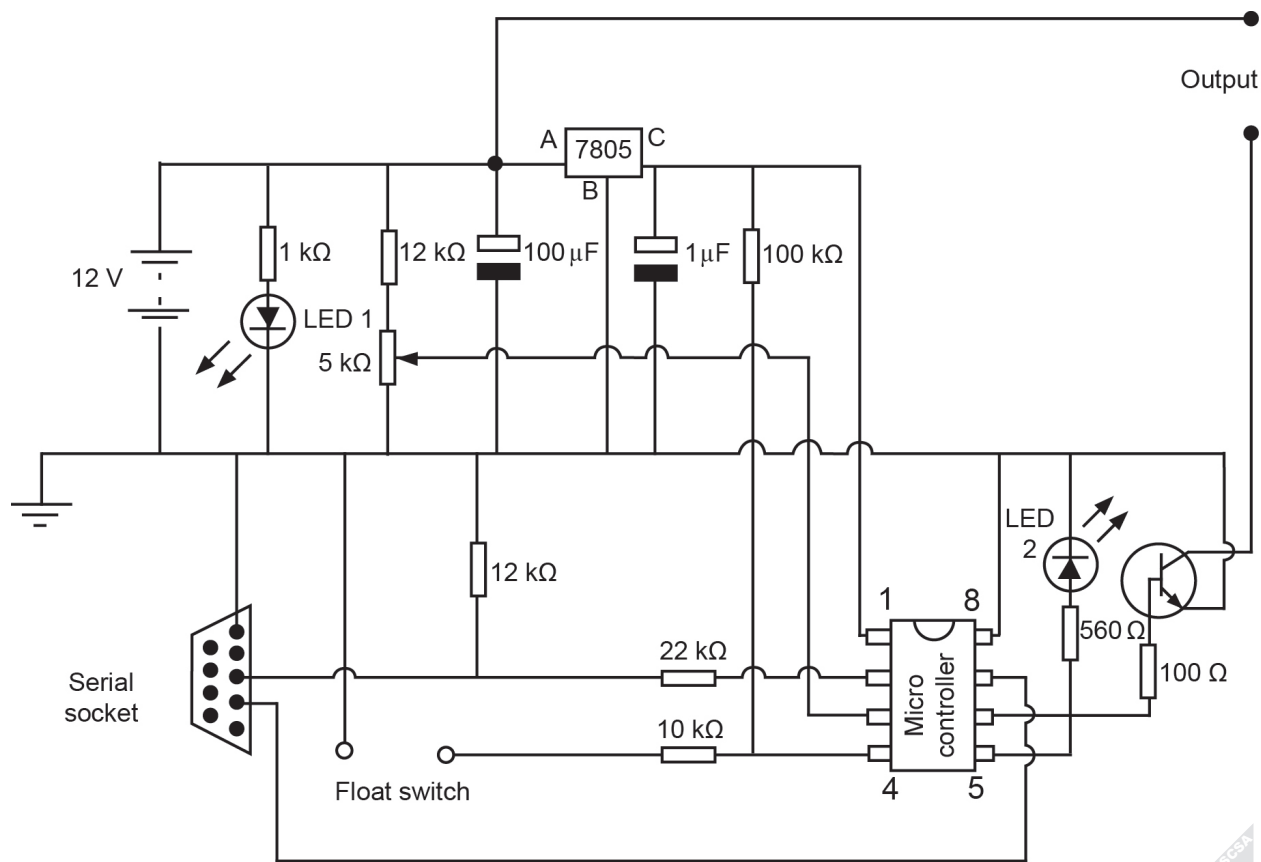
- (e) Complete the following table for each component. (4 marks)

Component	Power	Voltage	Current	Resistance
Component 1	4.4 mW			1.2 Ω
Component 2	20 kW	440 V		

Question 44

(14 marks)

Refer to the circuit to answer the questions that follow.



- (a) Calculate the voltage applied to pin four of the microcontroller when the float switch is closed. (3 marks)

- (b) Calculate the minimum and maximum current that could be supplied to pin three of the microcontroller. (3 marks)

Minimum current

Maximum current

- (c) The circuit has two LEDs. Explain the purpose of each. (2 marks)

Purpose of LED 1

Purpose of LED 2

- (d) Why does each LED have a different value resistor in series with it? (1 mark)

- (e) An ideal multimeter is connected across the pins of the voltage regulator. State the reading that you would see across: (3 marks)

A to B _____

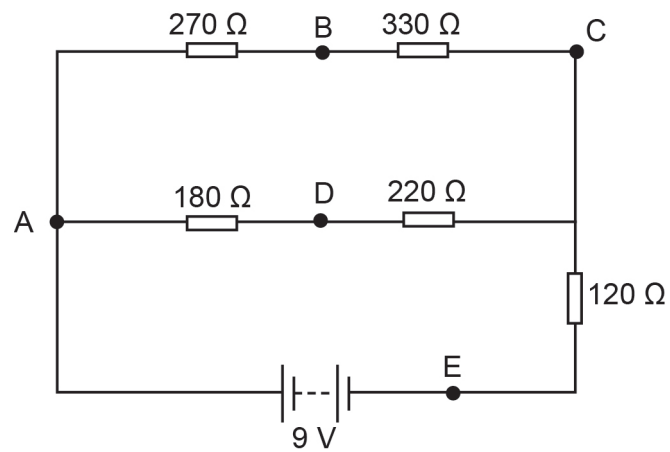
B to C _____

A to C _____

- (f) Calculate the base current of the transistor, given that the collector current is 400 mA and the h_{FE} is 300. (2 marks)

Question 45

(16 marks)



(a) Calculate the resistance between A and C in the circuit above. (3 marks)

(b) Calculate the total resistance of the circuit. (2 marks)

(c) Find the current at E (the total current in the circuit). (2 marks)

(d) Find the current through the 270 Ω resistor. (2 marks)

(e) Find the current through the 220 Ω resistor. (2 marks)

(f) Find the power dissipated in the 330 Ω resistor. (2 marks)

(g) Find the potential difference between B and D (V_{BD}). (3 marks)

Question 46**(13 marks)**

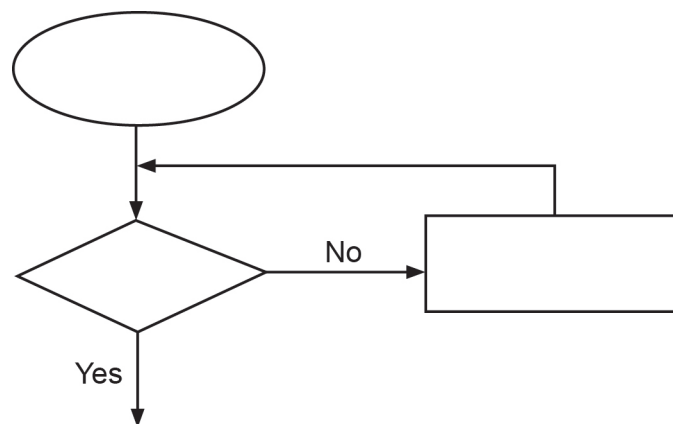
A spray-painting booth is a climate controlled room used to provide optimum conditions for spray-painting cars. Compressed air to spray the paint is produced by an electric motor connected to a compressor.

The compressor motor will only operate if certain conditions exist. These must be met and checked in the order given below.

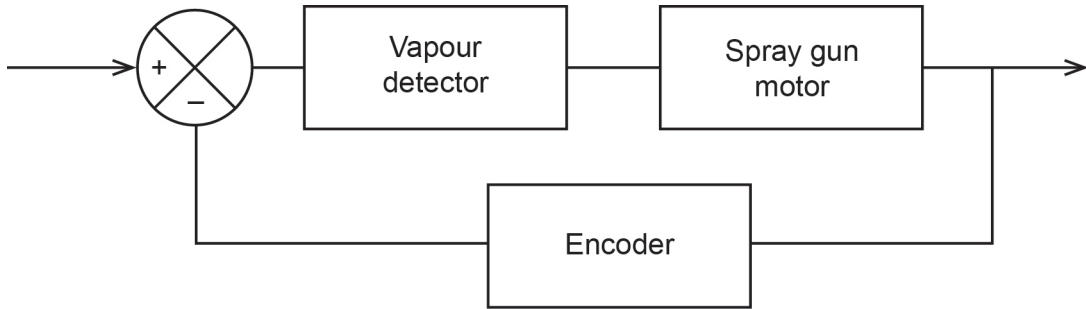
- The temperature of the booth must not be below 35°.
- The exhaust ventilation fan and lights must be on.
- The door to the booth must be closed.
- Every five minutes a check must be made of all conditions.

- (a) Using the standard flow chart symbols shown in the Data book, complete the flow chart below for this spray-painting booth. (9 marks)

All relevant feedback loops for this operation must be shown.



- (b) Due to occupational safety and health requirements the negative feedback loop below must be added to increase the safety features of this booth.



- (i) How does this safety system operate? (2 marks)

- (ii) State **two** other components of the booth that could be controlled by this feedback loop to further improve safety. (2 marks)

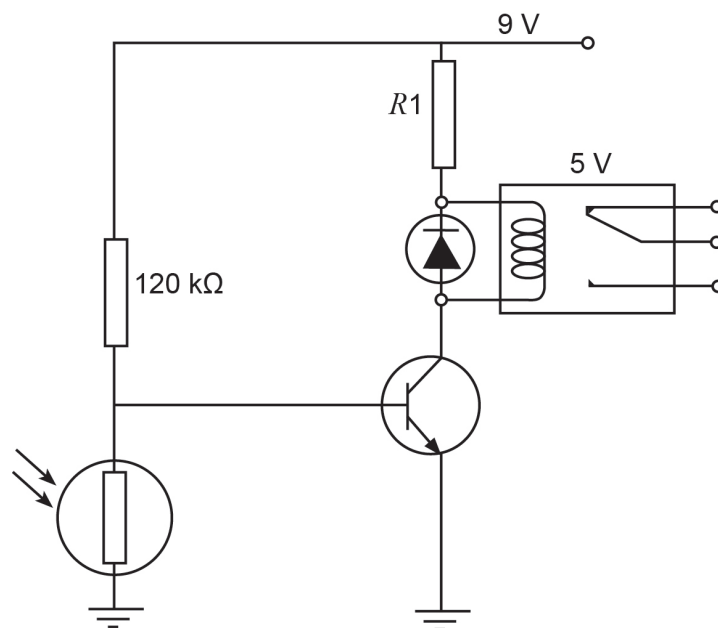
Question 47

(19 marks)

The security door in a building can be switched on manually or by using a relay triggered by a light dependent resistor (LDR). The door is automatically raised when there is sufficient sunlight on the LDR to activate the 5 V/100 Ω relay, which then switches on the motor used to raise the door.

The LDR has a resistance of 10.5 k Ω when the light incident on it is just sufficient to trigger the relay. It has near 150 Ω resistance when in full daylight.

The switching circuit for the relay is given below.



- (a) Calculate the voltage across the 120 k Ω resistor when the relay is activated. (2 marks)

(b) Calculate the power dissipated in the $120\text{ k}\Omega$ resistor when the relay is activated. (2 marks)

(c) Determine the current required to operate the relay. (2 marks)

(d) Calculate the required value for resistor $R1$. (3 marks)

Question 47 (continued)

The security door has a mass of 140 kg and is lifted by a rack and pinion gear system driven by a 240 V motor operating at 3000 rpm with a 40:1 reduction gear set.

(Assume there is no friction in this system.)

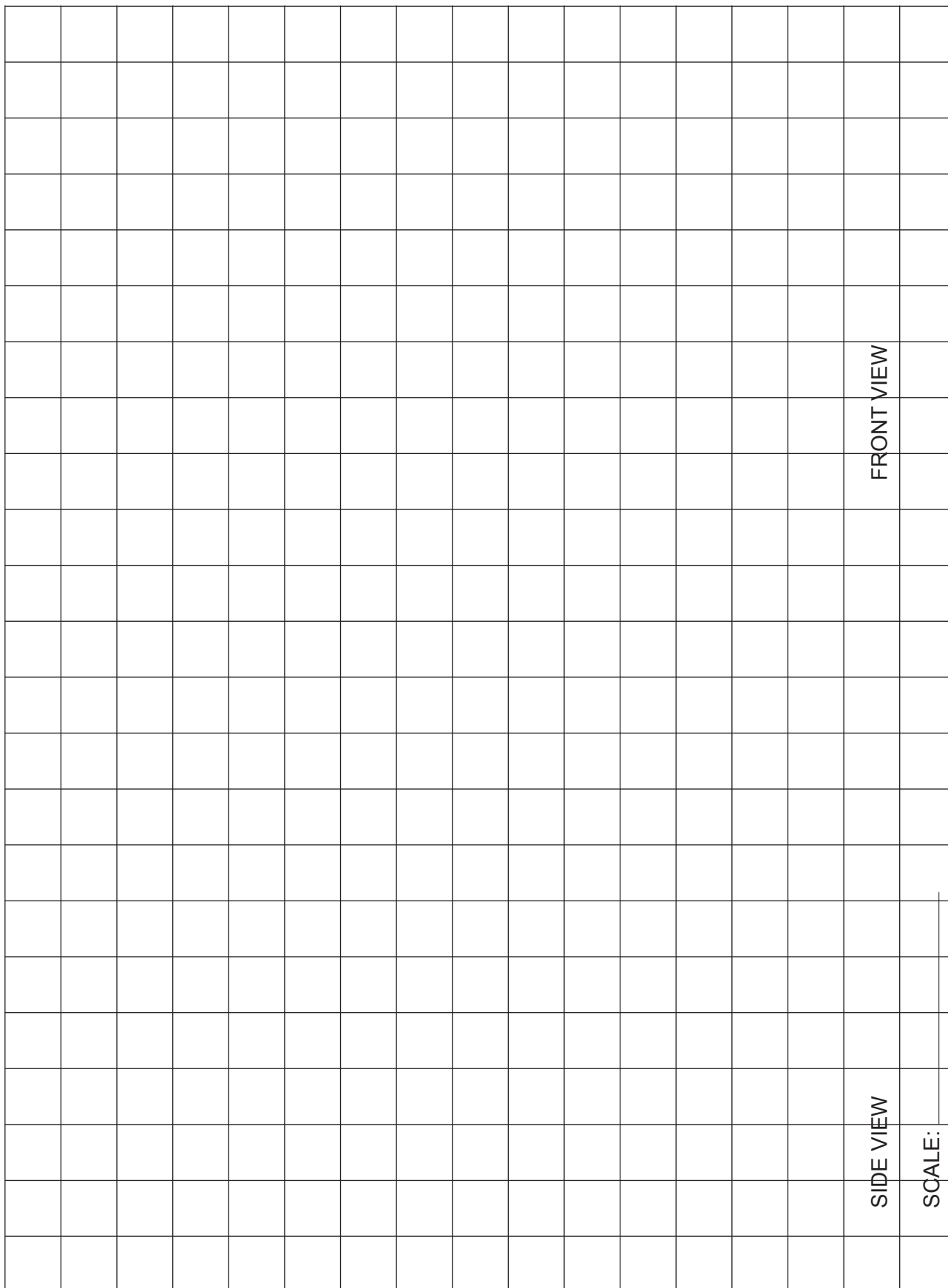
- (e) (i) Calculate the time taken to raise the door to a height of 3 m, given that the pinion gear has a radius of 3 cm. (5 marks)

- (ii) Calculate the power required to raise the door in this time. (2 marks)

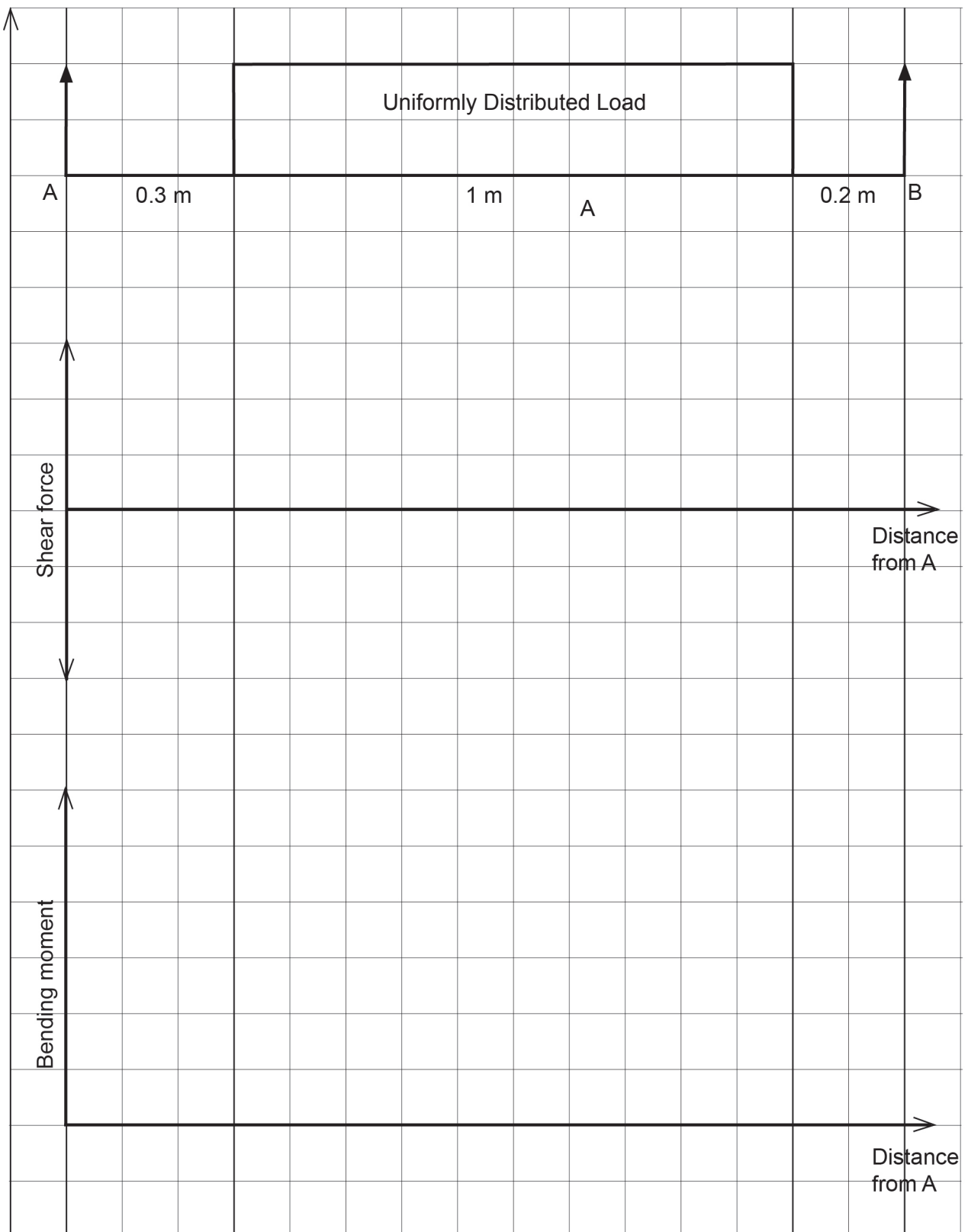
- (f) Given that the motor is 80% efficient, calculate the current drawn by the motor while lifting the door. (3 marks)

End of questions

Question 13



Question 27



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