ATAR course examination, 2020

Question/Answer booklet

ENGINEERING STUDIES

Please place your student identification label in this box

WA student number: In figures

In words

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

Mechanical

Mechatronics

Number of additional answer booklets used (if applicable):

Time allowed for this paper
Reading time before commencing work: ten minutes
Working time: three hours

Materials required/recommended for this paper
To be provided by the supervisor
This Question/Answer booklet
Multiple-choice answer sheet
Data Book

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: Multiple-choice	10	10	70	85	10
Part B: Extended answer	4	4			30
Section Two **Mechanical** Part A: Multiple-choice	10	10	110	110	10
Part B: Extended answer	6	6			50
Section Two **Mechatronics** Part A: Multiple-choice	10	10	110	110	10
Part B: Extended answer	6	6			50
				Total	100

Instructions to candidates

1. The rules for the conduct of the Western Australian external examinations are detailed in the *Year 12 Information Handbook 2020: Part II Examinations*. Sitting this examination implies that you agree to abide by these rules.

2. 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. Do not use erasable or gel pens. 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.

3. 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.

4. 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.

5. The Data Book is not to be handed in with your Question/Answer booklet.

See next page

Section One: Core content 40% (85 Marks)

This section has **two** 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. Do not use erasable or gel pens. 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.

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1. Which of the following design criteria is the **most** important for a searchlight used by rescue or security services?

    (a) light output
    (b) cost
    (c) durability
    (d) energy efficiency

2. Which of the following is a composite material?

    (a) brass
    (b) polycarbonate
    (c) concrete
    (d) cast iron

3. The bending and twisting of metal wire to form a coat hanger like that shown below relies on the construction material's

    (a) malleability.
    (b) toughness.
    (c) elasticity.
    (d) plasticity.

4. When an engineering design task is set up, it is usually done so with a timeline. The purpose of the timeline is to

    (a) provide the date when the task must be completed.
    (b) calculate the hours for which employees will need to be paid.
    (c) record the time it takes to acquire the materials and resources.
    (d) provide completion dates for each phase of the task.

See next page

5.   Used car batteries can be taken to waste stations, where they are stockpiled. The **most** likely reason for doing this is to

    (a)   reduce the volume of waste in landfill.
    (b)   recycle the components of the battery.
    (c)   recharge them and then resell them.
    (d)   bury them later in the landfill site.

6.   Which of the following is the **most** important design criterion for a car baby seat?

    (a)   comfort for the baby
    (b)   cost for the parent
    (c)   secure fitting to the car
    (d)   appearance and colour

7.   Reinforced concrete is used for the floors of multistorey buildings. The difference between a slab of non-reinforced concrete and a slab of reinforced concrete is that the reinforced concrete

    (a)   has a framework of metal rods within its structure.
    (b)   contains more cement per cubic metre.
    (c)   has more rocks in its structure per cubic metre.
    (d)   is always thicker than non-reinforced concrete.

8.   Which of the following pairs of forms of energy are non-polluting during the period that they are used to generate electricity?

    (a)   gas and photovoltaic
    (b)   wind and fuel oil
    (c)   biomass and tidal
    (d)   nuclear and geothermal

9.   Aluminium, an excellent conductor of electricity, is commonly used for multi-core high voltage electrical transmission cables. Which of the following properties make aluminium an excellent choice for this application?

    I   aluminium is corrosion resistant
    II   aluminium has a low density compared to other metals
    III   aluminium is very malleable
    IV   aluminium is very ductile
    V   aluminium has a high thermal conductivity

    (a)   I, III and IV
    (b)   I, II and IV
    (c)   I and III
    (d)   I, III and V

10.　Which of the formulae below would enable you to calculate the external surface area of a cylinder of height h and diameter d that is sealed at one end with a circular disc and at the other end with a hemisphere?

(a)　$5\pi r^2 + 2\pi dh$
(b)　$3\pi r^2 + \pi dh$
(c)　$4\pi r^2 + 2\pi rh$
(d)　$2\pi r^2 + \pi dh$

Part B: Extended answer **30% (75 Marks)**

This section has **four** 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 11 **(21 marks)**

Below is a dimensioned isometric drawing of a bracket that is to be machined from a block of metal. Dimensions are in millimetres.

Note: The surface marked by an **X** refers to part (d) of this question.
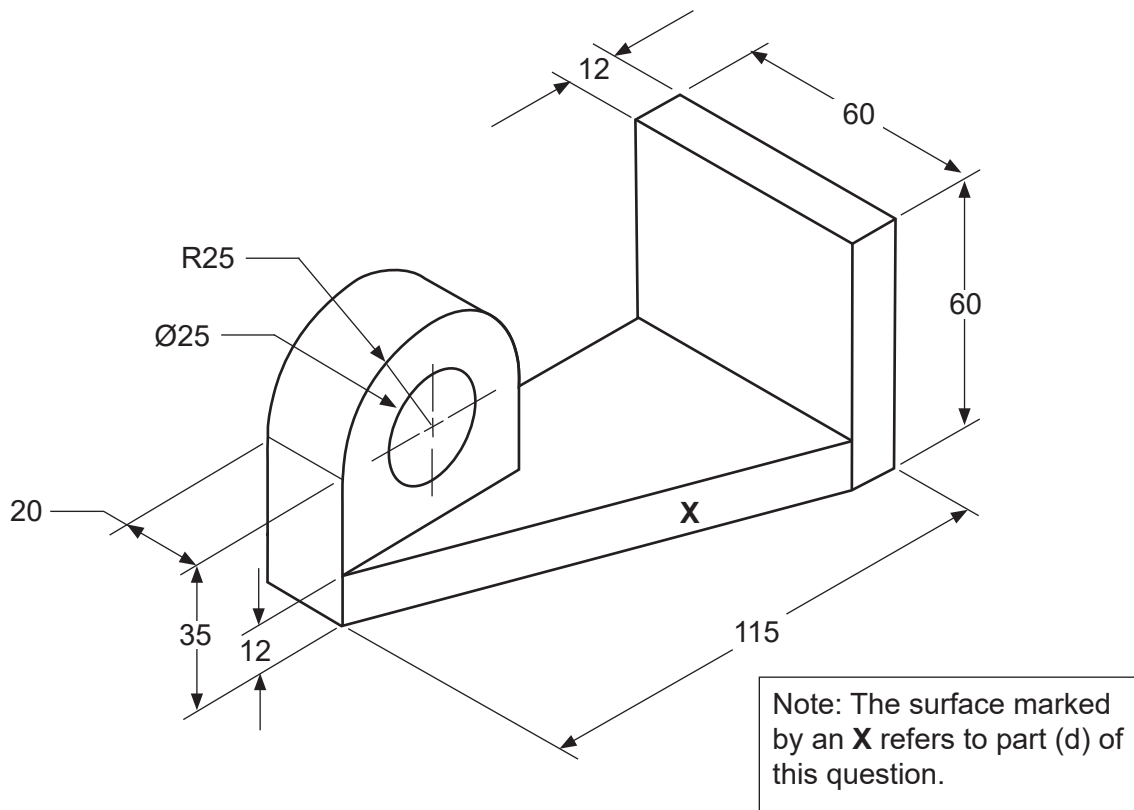
(a)   Use the grid provided on page 7 to produce a full-sized and labelled 3rd angle orthographic projection of this fitting, showing the front and top views using the correct conventions for line types. You are also required to dimension both views fully. Plan the positioning of the views carefully, as these will fit by keeping the page in its vertical orientation. Use a ruler for straight lines and use a compass or freehand for the circular features. **(10 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.

See next page

Question 11 (continued)

(b)   Using calculations, demonstrate that the volume of material in the bracket is very close to 125 500 mm³.   (5 marks)

The mass of the bracket is approximately 1100 grams and it is made from an alloy listed on page five of the Data Book.

(c)   Use calculations to identify the alloy. If you were unable to obtain a value for part (b), use 125 500 mm³.   (4 marks)

(d)   Calculate the area in mm² of the surface indicated by an **X** on the isometric drawing on page 6.   (2 marks)

Question 12 **(17 marks)**
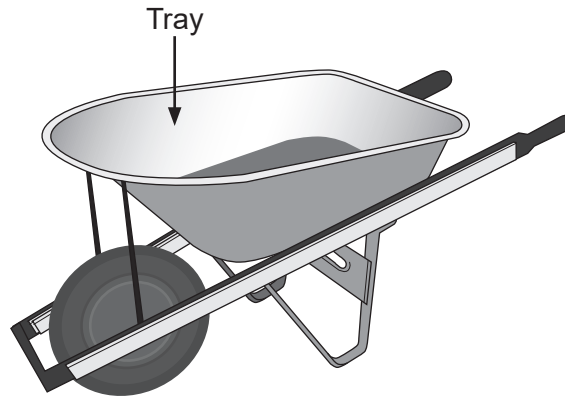
Tray

Wheelbarrows are commonly used by builders, landscapers and gardeners. The tray of a wheelbarrow is typically made from steel (a ferrous alloy) or high-density polyethylene (the same material used for bins provided by local councils for rubbish collection and recycling).

(a) What is meant by the term 'alloy' and how is a 'ferrous alloy' different from a 'non-ferrous alloy'? (3 marks)

_____

_____

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_____

_____

_____

High-density polyethylene is classed as a polymer.

(b) Define the term 'polymer'. (2 marks)

_____

_____

_____

_____

See next page

Question 12 (continued)

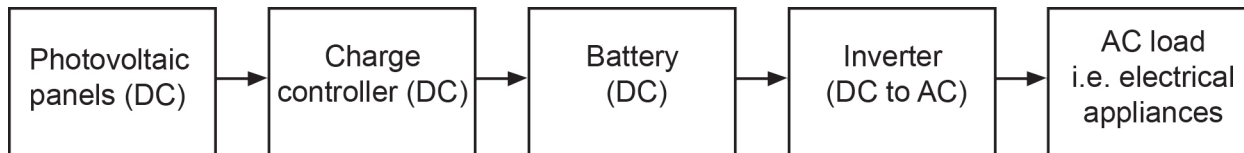The types of loads that are placed in the tray of a wheelbarrow include soil, mulch, plants, rocks (small and large) and rolls of lawn.

(c) (i) Name **three** properties of steel that make it a good choice of material for the tray of the wheelbarrow. For each property, provide a reason for its inclusion. (6 marks)

Property of steel	Reason for inclusion
One: _____	_____
Two: _____	_____
Three: _____	_____

(ii) Name **three** properties of polyethylene that would make it a good choice of material for the tray of the wheelbarrow. For each property, provide a reason for its inclusion. When answering this question, you must **not** repeat a property that was used previously in part (c)(i). (6 marks)

Property of polyethylene	Reason for inclusion
One: _____	_____
Two: _____	_____
Three: _____	_____

Question 13 **(20 marks)**

A house owner makes enquiries regarding the installation of 6.6 kW of solar panels on the roof of their house, coupled with a battery storage system next to the house and an inverter to convert DC (direct current) from the battery to AC (alternating current). This system is illustrated below as a block diagram.

| Photovoltaic panels (DC) | → | Charge controller (DC) | → | Battery (DC) | → | Inverter (DC to AC) | → | AC load i.e. electrical appliances |

The information below is supplied regarding the panels:
- require 20 x 330 W panels with a nominal voltage of 24 V per panel
- each panel has dimensions of 1650 mm x 990 mm x 50 mm and a mass of 18 kg
- the mounting hardware for the panels has a mass of 7 kg m^{-2} of panel area covered.

(a) Calculate the total area of roof covered by these panels. Give your answer in m^2.

(3 marks)

(b) Calculate the mass per square metre of the panels and mounting hardware on the roof. If you were unable to obtain a value for part (a), use 34.4 m^2. (3 marks)

(c) Calculate the output current from the solar panels on a day when the maximum efficiency of the panels is 65%. Note: Power = Voltage × Current (3 marks)

Question 13 (continued)

The information below is provided about the Lithium-ion battery storage system and the coupled inverter.

I	AC output = 240 V, 50 Hz single phase
II	AC output energy available = 13.2 kWh
III	Peak power available on discharge = 7 kW for 10 seconds
IV	Efficiency of inverter (DC power in to AC power out) = 89%
V	Battery dimensions = 115 cm x 75.5 cm x 15.5 cm
VI	Mass of battery = 122 kg

(d)   Calculate the average density of the battery in units of kg m^{-3}.   (3 marks)

(e)   Calculate the AC output current when the output power is 7 kW.
       Note: Power = Voltage × Current   (2 marks)

(f)   Calculate the maximum energy input from the battery to the inverter in MJ if the efficiency of the inverter is taken into consideration.   (3 marks)

(g)   Calculate the total energy provided by the battery in kWh if it operates at peak power for the allowed maximum time of 10 seconds.   (3 marks)

See next page

Question 14   **(17 marks)**

The life cycle analysis of an engineered product includes investigation of how the item is packaged. Consider the packaging materials used for many engineered products. These typically include cardboard, foam (e.g. beads, sheets or moulds) and plastic film. Often all three materials are used in the one package to protect the product, make it easier to transport and allow it to be displayed.

The use of each of these materials is often linked to negative impacts on the environment. These may be linked directly to the discarded material or indirectly to its manufacture. Furthermore, the impact is not immediately evident but often will have long-term effects that are not always initially obvious.

(a)   For each material, identify and provide a description of an immediate and a related long-term problem that can result from either the disposal or manufacture of the packaging material. Note: do **not** repeat the same answer for any of the three materials.

　　　　(i)   Cardboard   (4 marks)

　　　　　　　　　　Disposal   or   Manufacture   (circle **one** only)

　　　　　　　　Immediate problem: _____

　　　　　　　　_____

　　　　　　　　_____

　　　　　　　　_____

　　　　　　　　Long-term problem: _____

　　　　　　　　_____

　　　　　　　　_____

　　　　　　　　_____

    (ii)   Foam (e.g. beads, sheets or moulds)   (4 marks)

        Disposal   or   Manufacture   (circle **one** only)

Immediate problem: _____

_____

_____

_____

Long-term problem: _____

_____

_____

_____

    (iii)   Plastic film   (4 marks)

        Disposal   or   Manufacture   (circle **one** only)

Immediate problem: _____

_____

_____

_____

Long-term problem: _____

_____

_____

_____

See next page

Question 14 (continued)

A reduction in environmental problems associated with packaging of engineered products would be beneficial for both the environment and society.

(b)   Choose **one** packaging material and for this material identify and describe a potential strategy that could be implemented to reduce its negative effects on the environment. In addition, provide **two** suggestions that would increase the likelihood that the strategy will be effective. (5 marks)

Cardboard   Foam   Plastic film   (circle **one** only)

_____

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_____

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_____

_____

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 2020.

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

Specialist field	✓	Question numbers	Pages
Mechanical	☐	15–30	18–37
Mechatronics	☐	31–46	38–54

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

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

This section has **two** 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. Do not use erasable or gel pens. 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.

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15.   A vehicle's tyres are partly deflated before driving through soft sand. The reasoning behind this is

   (a)   pressure on the sand is reduced because the tyres have a greater area.
   (b)   force on the sand is reduced because the tyres have a greater area.
   (c)   smaller diameter wheels travel more easily through sand.
   (d)   a very common misconception that has no scientific backing.

16.   The Working Load Limit indicated on a lifting coupling is 300 kg and the standard governing its design requires a safety factor of 2. What will the test load on the part be for certification purposes?

   (a)   600 kg
   (b)   150 kg
   (c)   150 N
   (d)   600 N

17.   The **most** common advantage of casting steel over forging steel is

   (a)   increased toughness.
   (b)   increased strength.
   (c)   more reliable properties.
   (d)   cheaper to manufacture.

18.   kN mm^{-2} is a unit of

   (a)   acceleration.
   (b)   strain.
   (c)   stress.
   (d)   toughness.

See next page

19. A 1 kg mass of each of the following items is dropped from the same height in a vacuum; steel cube, steel sheet, polyethylene cube, polyethylene sheet. In what order, from first to last, will they hit the ground?

    (a) there is not enough information
    (b) they will all land at the same time
    (c) steel cube, steel sheet, polyethylene cube, polyethylene sheet
    (d) steel cube, polyethylene cube, steel sheet, polyethylene sheet

20. The small diameter piston of a closed hydraulic pump is pushed down with a force of F Newtons over a distance of d metres. Which of the following statements is **true** about the large diameter piston of the pump?

    (a) the large diameter piston will be displaced further than the small diameter piston
    (b) the small diameter piston will be displaced further than the large diameter piston
    (c) the pistons will travel the same distance (d metres)
    (d) the large diameter piston will travel ($F \times d$) metres

21. What is the approximate resilience of Material X in the graph below?

Material X
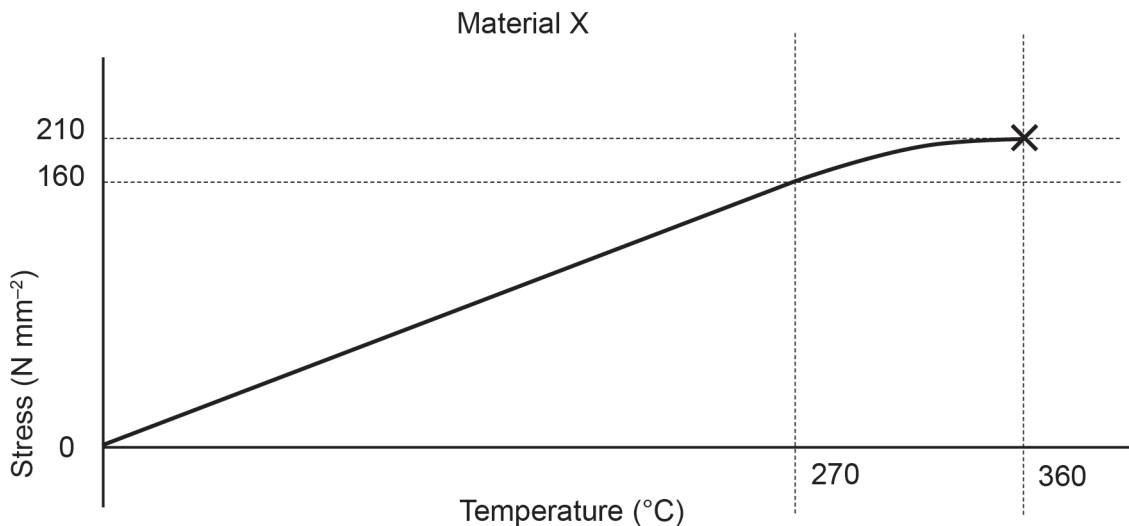
    (a) there is not enough information
    (b) 28 350 J m^{-3}
    (c) 28 350 N mm^{-2}
    (d) 37 800 N mm^{-2}

22. What is the power utilised to move an object at a constant velocity of 1 m s^{-1} using a force of 1 N?

    (a) you cannot calculate power without the mass of the object
    (b) 1 J s^{-1}
    (c) you cannot calculate the power without the time it is acting over
    (d) 1 Nm

See next page

23. Two equal forces F are applied to the box along the directions x and y at the same time. What is the work done when the box arrives at point P?
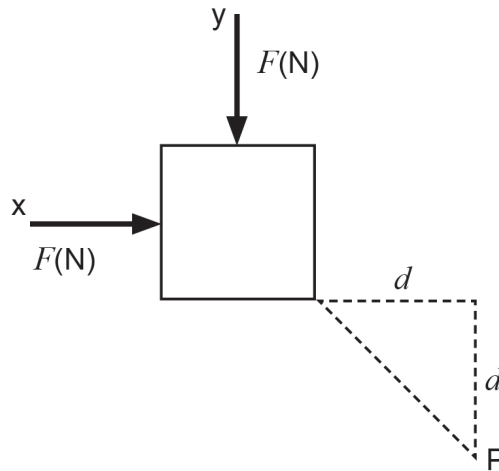
    (a) $4Fd$

    (b) $2F\sqrt{(2d^2)}$

    (c) $\sqrt{(2F^2)}\sqrt{(2d^2)}$

    (d) $4d\sqrt{(2F^2)}$

24. A ball is shot directly into the sky from rest and then falls directly back down and comes to rest again at exactly the same position from which it started. The journey takes two seconds. What can be correctly said about the resultant acceleration the ball experiences on its journey?

    (a)   Gravity is always 9.81 m s^{-2} so the ball's acceleration is always this value.

    (b)   It can be calculated and is at 0 m s^{-2}. This is because its initial and final velocities are 0 m s^{-1} and time is known.

    (c)   Its magnitude must be greater than 0 N kg^{-1} and act in the opposite direction to gravity at some point on its journey.

    (d)   It must be greater in magnitude than 9.81 m s^{-2} at some point on its journey to overcome gravity.

See next page

Part B: Extended answer 50% (100 Marks)

This section has **six** 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.

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 25 **(14 marks)**

A building has a ground floor and three upper levels as shown in the diagram below. The elevator weighs 1000 kg (not counting passengers). Dimensions are in millimetres.
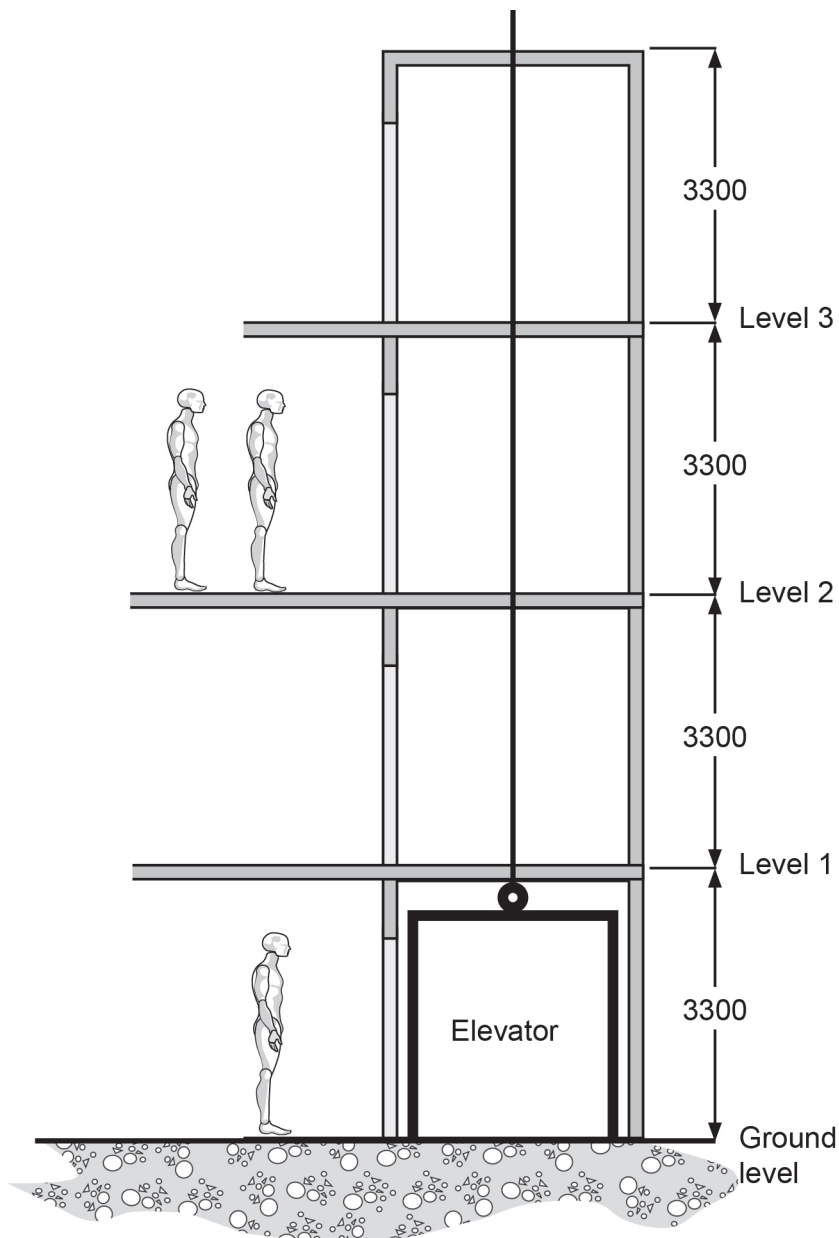
See next page

Question 25 (continued)

(a)   Calculate the potential energy of the elevator when the first passenger weighing 100 kg
steps on at ground level. (1 mark)

(b)   Calculate the potential energy of the system when the elevator reaches Level 2 with the
first passenger still in the lift but before anyone else boards. (4 marks)

The elevator, still at Level 2, picks up two additional people weighing 90 kg each and then continues to Level 3.

(c)   Calculate the minimum electrical mains energy the motors running the lift have used over the whole trip, assuming 95% efficiency.   (5 marks)

See next page

Question 25 (continued)

(d)   All the passengers disembark at Level 3. There was then a catastrophic failure of the elevator cable and redundancy systems, calculate the velocity with which the elevator hits the ground. (4 marks)

Question 26 **(10 marks)**

A ball is thrown horizontally from a height of 1.8 m on the moon. Its initial horizontal velocity is 10 m s^{-1}. Gravity on the moon is 1.62 m s^{-2} and there is no atmosphere. Note: Ignore any effects from the curvature of the moon.

(a)   Calculate the vertical component of the ball's velocity and then use Pythagoras' theorem to solve the resultant velocity of the ball when it hits the ground. (8 marks)

(b)   Calculate how many seconds it takes for the ball to hit the ground after it is thrown.

(2 marks)

See next page

Question 27 **(24 marks)**

Consider the following diagram. Dimensions are in millimetres.
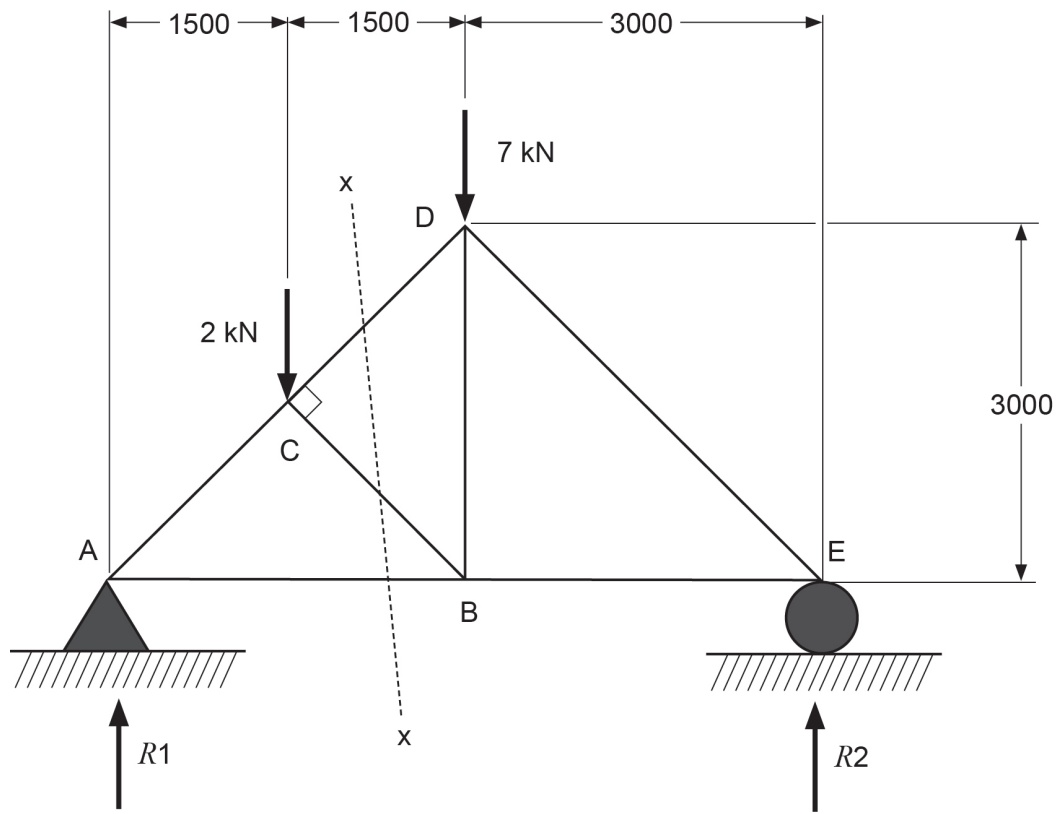
(a)   Find the length of segment CB. (1 mark)

See next page

(b)   Calculate the reaction forces $R1$ and $R2$.   (8 marks)

Question 27 (continued)

The diagram on page 26 has been reproduced to answer Question 27 parts (c) to (e).
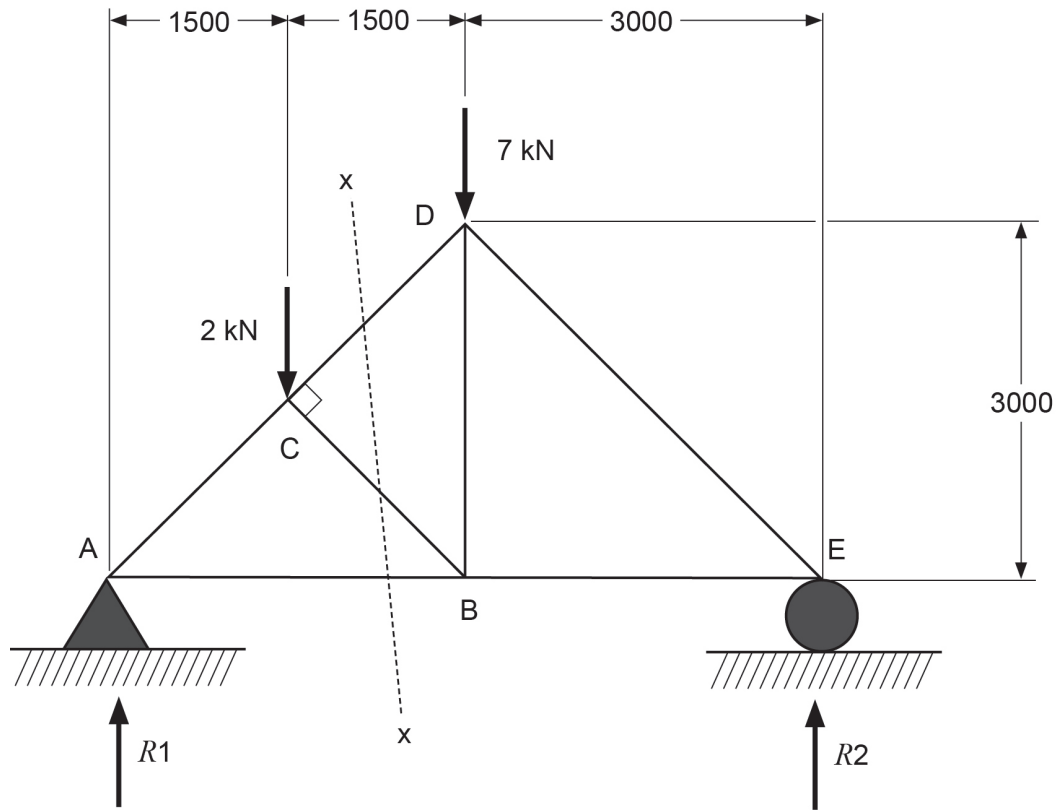
(c)   Using the method of sections at x-x, calculate the force in the member CD and state if it is in compression or tension. (5 marks)

See next page

(d)   Using the method of sections at x-x, calculate the force in the member AB and state if it is in compression or tension.   (5 marks)

(e)   Using the method of sections at x-x, calculate the force in the member CB and state if it is in compression or tension.   (5 marks)

Question 28   **(22 marks)**

A hollow beam is attached to a fixed support at one end.
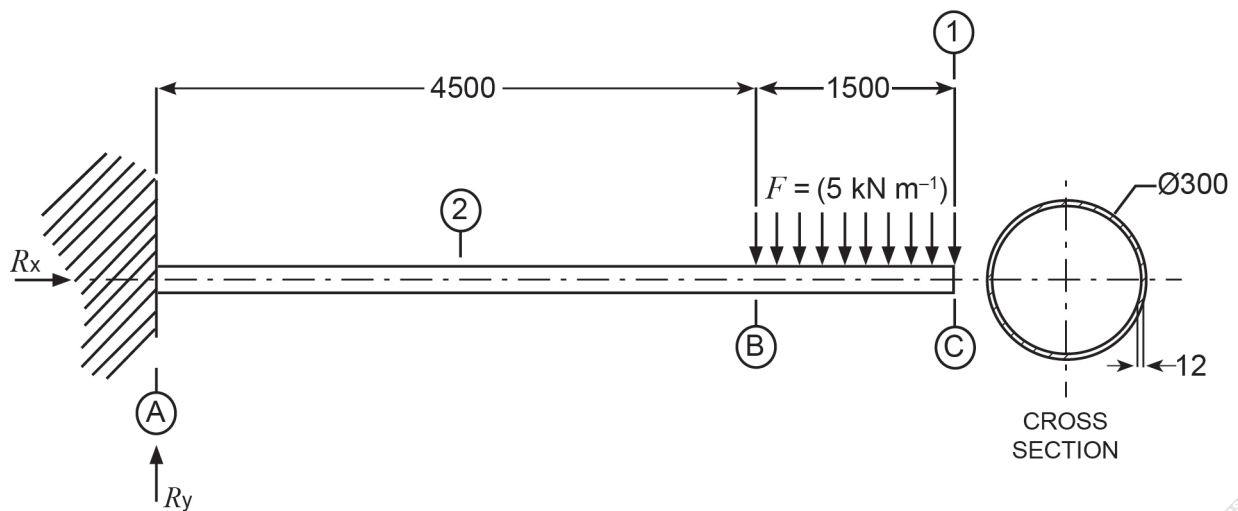
In the above beam diagram, ignoring self-weight, R_y equals 7.5 kN. Dimensions are in millimetres.

(a)   Calculate the reaction moment at the support.   (3 marks)

(b)   Draw a shear force diagram for this beam on the graph paper provided on page 33. In the space below, show all calculations undertaken at reference points 1 and 2 on the beam diagram that are used to construct the shear force diagram. (7 marks)

Question 28 (continued)

(c)   Draw a bending moment diagram for this beam on the graph paper provided on page 33 under the shear force diagram. In the space below, show all calculations undertaken at reference points A, B and C on the beam diagram that are used to construct the bending moment diagram. (12 marks)
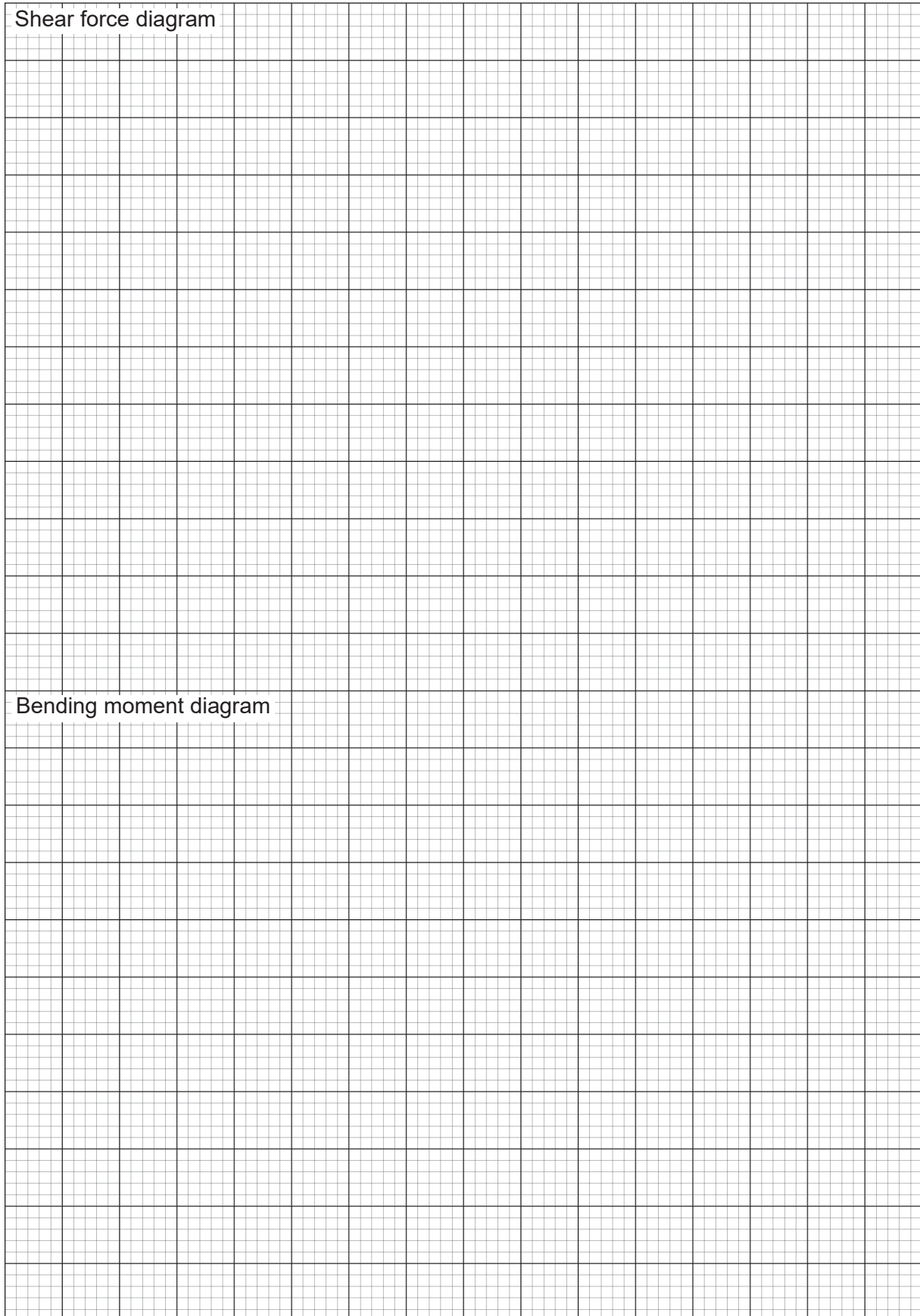
Shear force diagram

Bending moment diagram

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 29 **(11 marks)**

The diagram below is of a tension wire roof where the tension is supplied by a hanging mass (m) of 100 kg that is free to move vertically on a supporting metal pole. At points P1 and P2, assume there are frictionless pulleys of negligible diameter and points A, B and C are fixed connection points. The structure is in static equilibrium. Assume the columns do not deflect or change length.
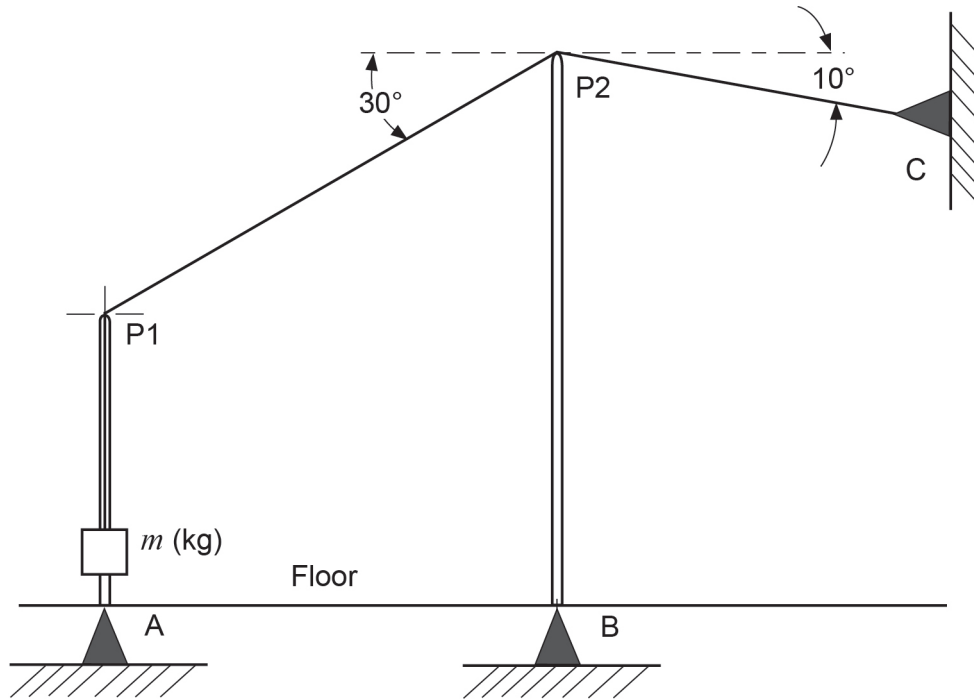
(a)   Calculate the tensile forces in the two wire segments P1 to P2 and P2 to C.   (2 marks)

See next page

(b) Graphically solve the resultant force acting on the axis of the pulley P1 and draw in the reaction force R on the axis pin, including its angle. (6 marks)
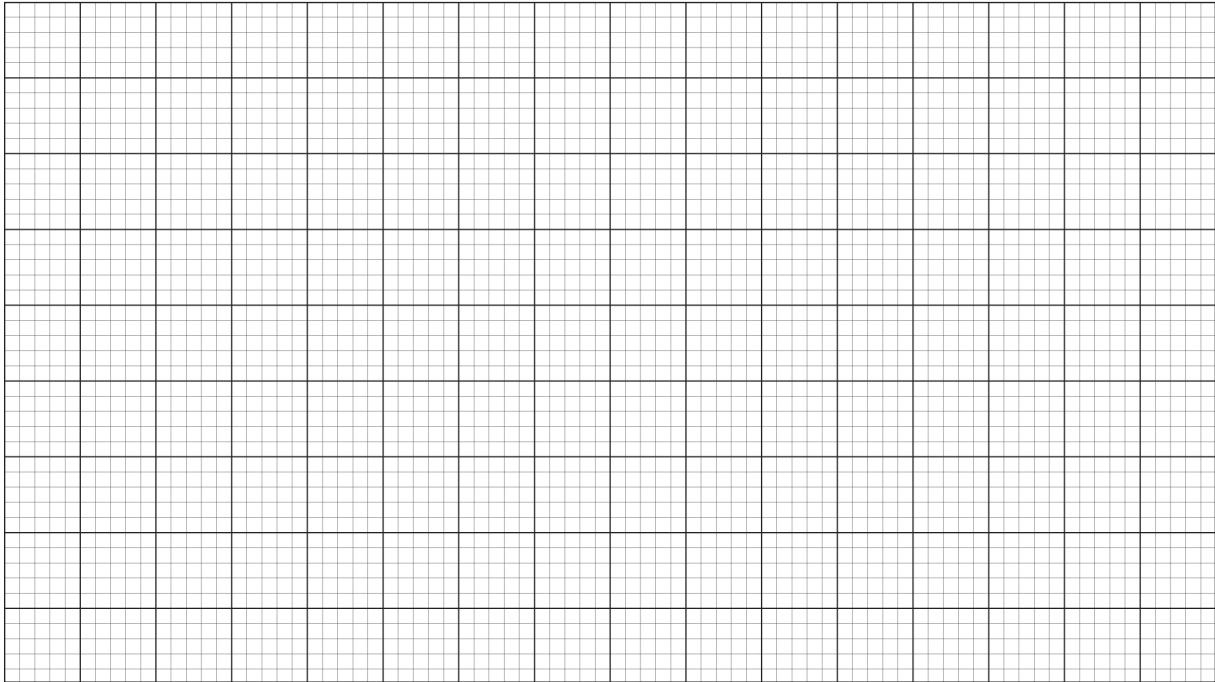
A spare grid is provided at the end of this Question/Answer booklet. If you need to use it, cross out this attempt and indicate that you have redrawn it on the spare grid.

(c) If the pulleys at points P1 and P2 are increased to a diameter of 100 mm and remain frictionless, explain the effect this will have on the resultant force at the axis. Justify your answer. (3 marks)

See next page

Question 30 **(19 marks)**

Below is the same tension wire roof as in Question 29, with a modified tension weight that has been attached but not released. On release it drops 350 mm to the floor

The designer of this system has decided the mass must rest on the ground with a resultant force of 1500 N after supplying the cable tension force of 1000 N. The designer also wants the thinnest wire possible from available materials for aesthetic reasons.
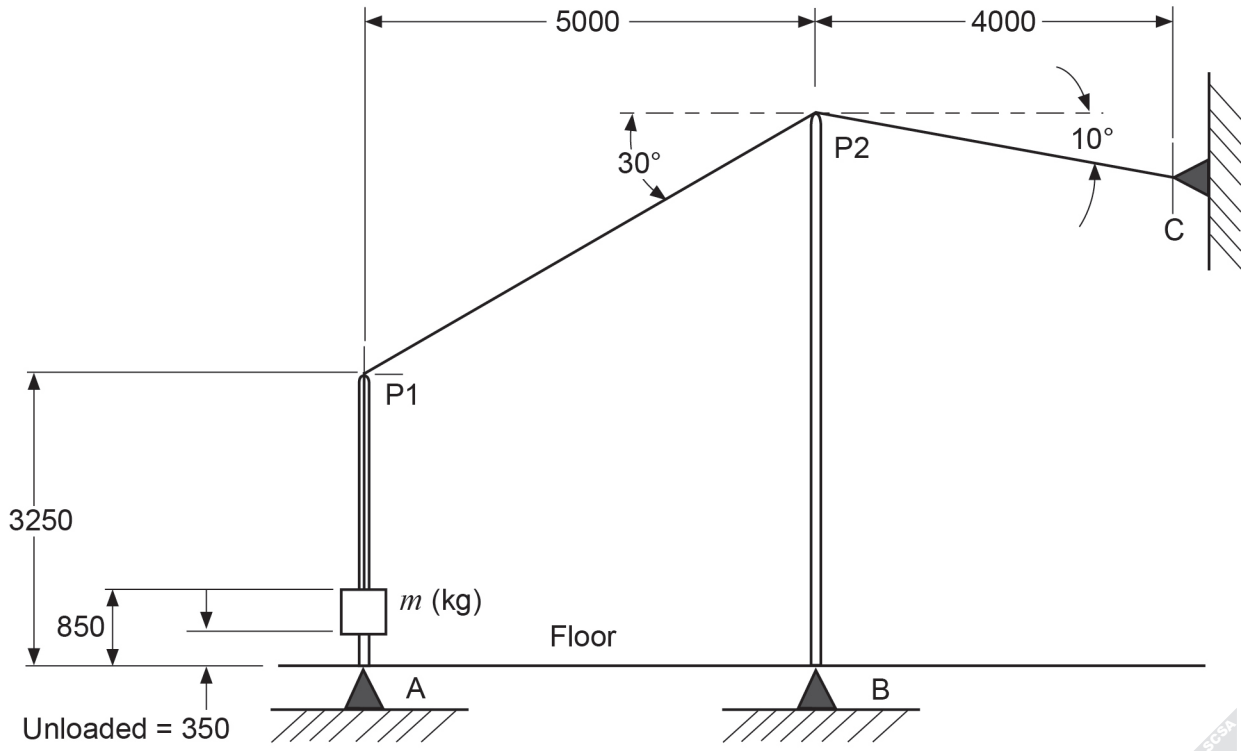
(a)   Calculate the mass m (kg) required. (3 marks)

(b)   What is the total unloaded wire length? (4 marks)

See next page

(c)   Which of the following three materials would you select for this tension wire considering the design requirements? Circle and then justify your selection.   (3 marks)

Polypropylene   Copper   Mildsteel

(d)   Calculate the diameter of the material you selected for the wire. If you were unable to calculate a value for part (b), use 12 m. With reference to the Data Book, comment on the suitability of this wire.   (9 marks)

End of Mechanical Section

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

This section has **two** 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. Do not use erasable or gel pens. 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.

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31.   Which of the following components will be damaged if the polarity of its power supply is reversed?

   (a)   resistor
   (b)   diode
   (c)   electrolytic capacitor
   (d)   LED

32.   With reference to the circuit shown to the right, when conditions become cooler the

   (a)   voltage across NTC will decrease.
   (b)   current through RV will decrease.
   (c)   resistance of RV will decrease.
   (d)   current through NTC will increase.

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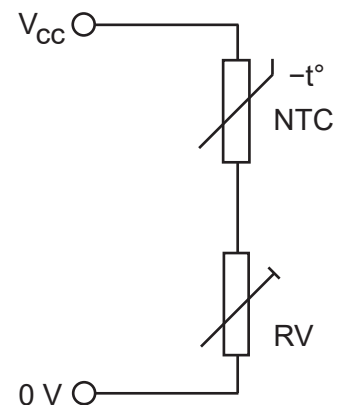
33. The circular cam shown in the diagram below is 150 mm in diameter and the follower is 160 mm long. The follower slides up and down inside the fixed sleeve as the cam rotates around the centre of the camshaft. The minimum height possible for the top of the follower above the top of the fixed sleeve is

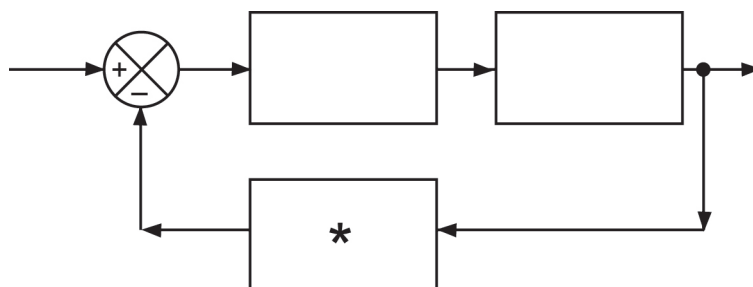   (a) 10 mm.
    (b) 20 mm.
    (c) 30 mm.
    (d) 50 mm.
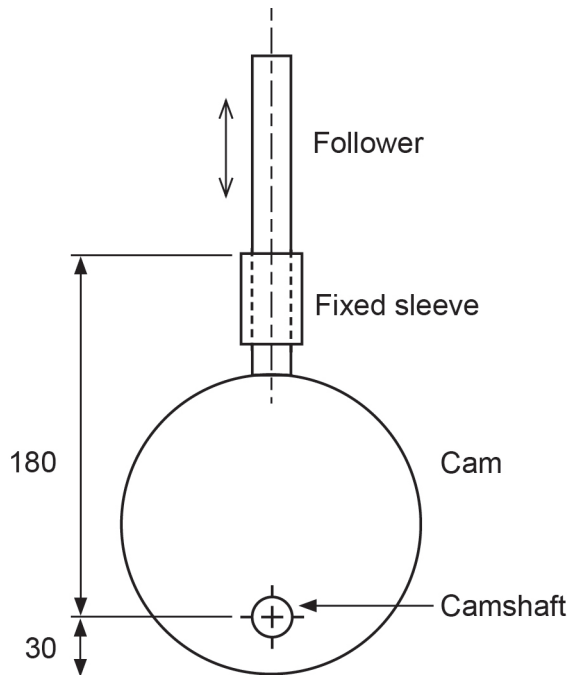
34. A pulse width modulation signal has a duty cycle of 60% and the duration of the time it is *low* is 0.015 seconds. The frequency of the signal is

    (a) 26.67 Hz.
    (b) 44.44 Hz.
    (c) 66.67 Hz.
    (d) 266.67 Hz.

35. The part of the control diagram that has been identified with an ✱ is the

    (a) error detector.
    (b) set point.
    (c) output sensor.
    (d) controller.

36. The maximum number of circuits with no common pathways that can be connected and disconnected by a DPDT switch is

    (a) 1.
    (b) 2.
    (c) 4.
    (d) 6.

See next page

37. The RAM of a microcontroller is used to

    (a)   permanently store information.
    (b)   perform mathematical functions.
    (c)   route all messages.
    (d)   temporarily store information.

38. The velocity ratio of a mechanism where the distance moved by the effort is equal to the distance moved by the load is

    (a)   <1.
    (b)   1.
    (c)   >1.
    (d)   not possible.

39. Which of the following statements is true for the pulley system shown in the diagram?

    (a)   The belt has the same tension at all points around its perimeter.
    (b)   The linear velocity of the belt is faster around the larger pulley.
    (c)   The speed of rotation of the smaller pulley is slower than that of the larger pulley.
    (d)   The shaft of the larger pulley has the greater turning force of the two pulleys.
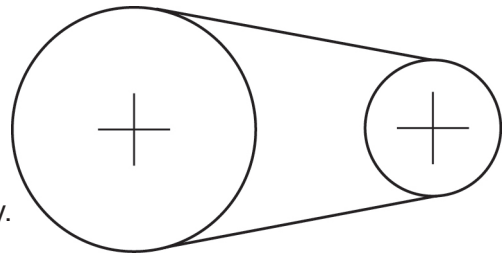
40. What is the velocity ratio of the gear drive shown in the diagram?

    (a)   0.5:1
    (b)   0.66:1
    (c)   1.5:1
    (d)   2:1
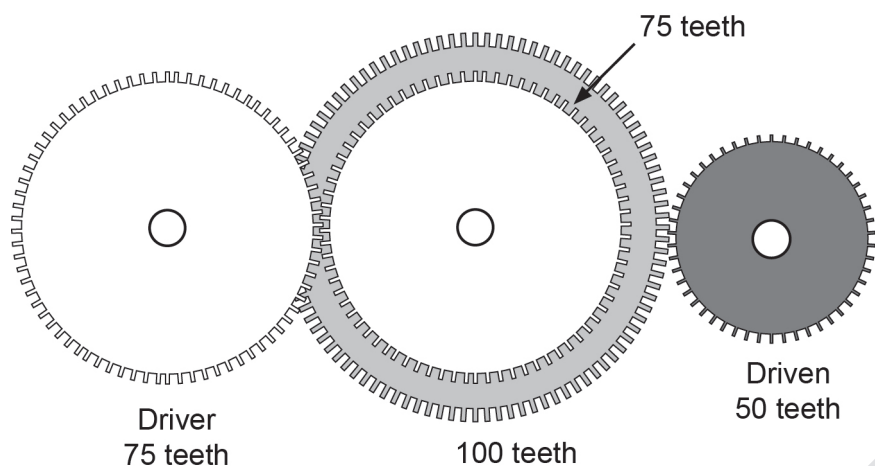
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Part B: Extended answer **50% (100 Marks)**

This section has **six** 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.

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 41 **(24 marks)**
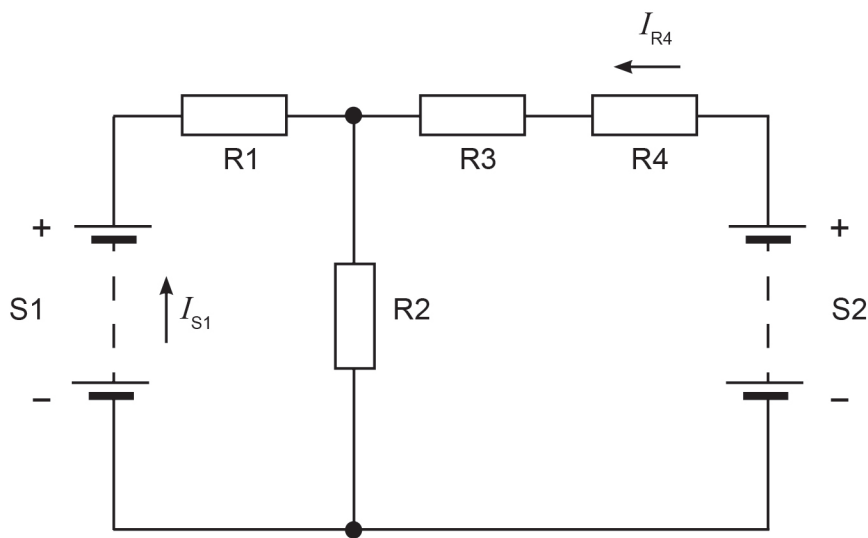
The circuit shown above has the following parameters: R1 = 1 kΩ, R3 = 330 Ω, R4 = 270 Ω, S2 = 6 V, I_{S1} = 7.5 mA and I_{R4} = 7.5 mA.

(a) Calculate V_{R2}, the voltage across R2. (4 marks)

See next page

Question 41 (continued)

(b)   Calculate R_2, the resistance of R2.   (4 marks)

(c)   Calculate P_{S1}, the power supplied by S1.   (4 marks)
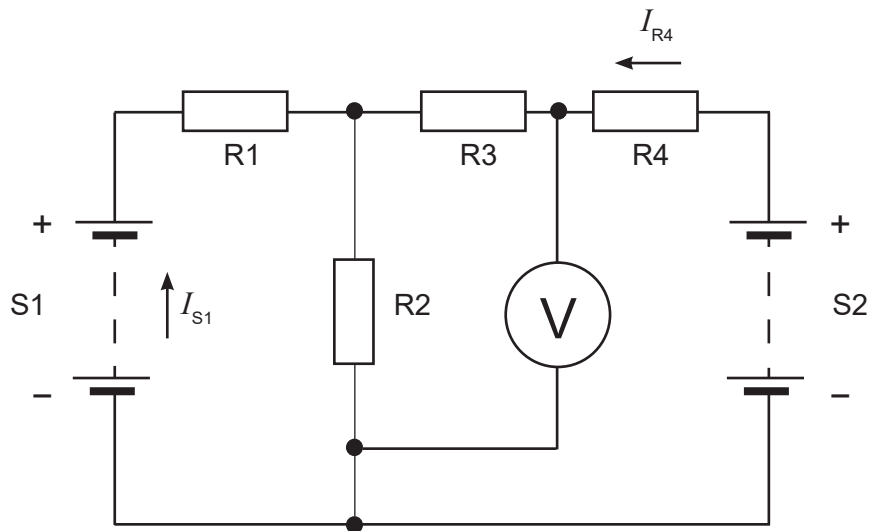
(d) A voltmeter is connected to the circuit as shown in the above diagram. Using calculations, determine its reading. (3 marks)

See next page

Question 41 (continued)
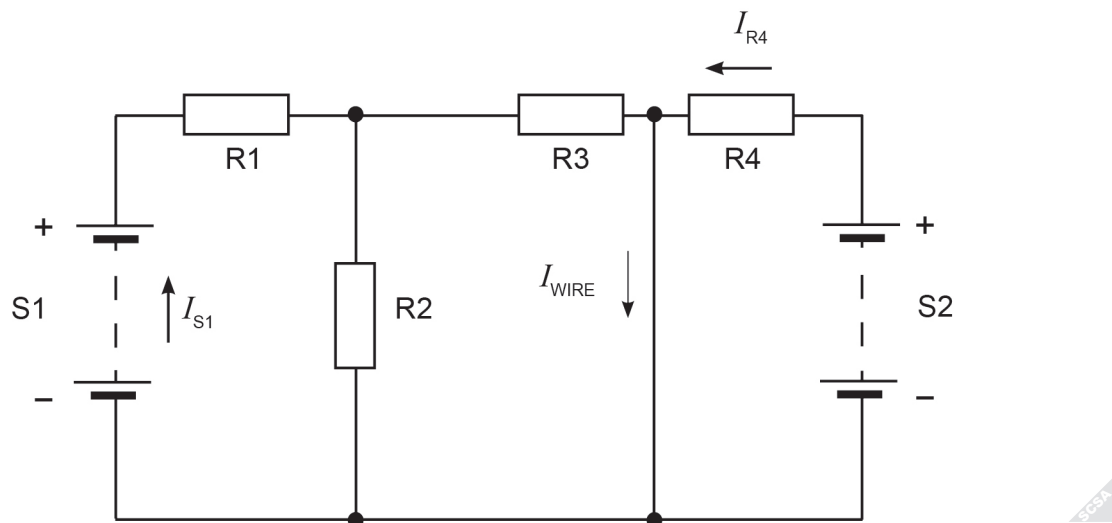
Suppose a wire with negligible resistance is connected to the circuit as shown in the above diagram.

(e)   Using calculations, determine I_{WIRE}, the current that flows through the wire. If you were unable to obtain a value in part (b), use 90 Ω. If you were unable to obtain a value for V_{S1} in part (c), use 10 V.   (9 marks)

See next page

Question 42   **(12 marks)**
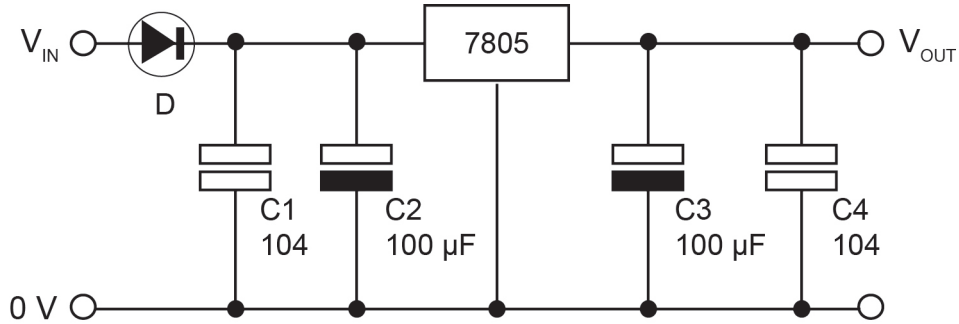
The above circuit includes a diode, capacitors and a 5 V voltage regulator. This type of circuit typically is used to supply power to a microcontroller.

(a)   Calculate the total capacitance of the arrangement of C1 and C2 only. Answer in units of nanofarads (nF).   (3 marks)

(b)   What is the purpose of the capacitors in this circuit? Describe how these components perform the required function and explain why this is necessary, given that the voltage regulator circuit will supply power to a microcontroller.   (5 marks)

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See next page

Question 42 (continued)

(c)   Although the diode is not always included in voltage regulator circuits it is a very useful
        addition. What is its purpose and how does it perform its function?   (4 marks)

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Question 43 **(20 marks)**
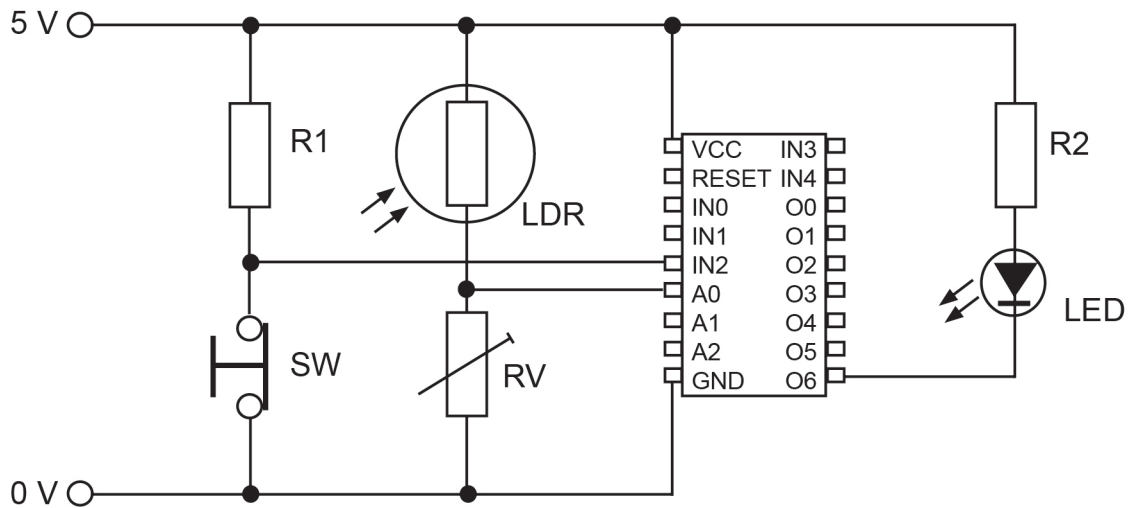
The above circuit diagram incorporates a microcontroller and three interfacing circuits.

(a) Explain the behaviour of the digital input when the switch is operated. (6 marks)

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Question 43 (continued)

(b)   Explain why the output of the sensor that incorporates an LDR will increase when
        conditions become brighter.   (4 marks)

Suppose the light-detecting sensor is connected to an ADC that has 8-bit resolution and the
reading being produced by the ADC is 153. Also suppose that the current through the
light-detecting sensor is 300 µA.

(c)   Calculate the resistance of the LDR.   (4 marks)

(d)   When the microcontroller pin is *low*, the LED glows and when it goes *high*, the LED stops
        glowing. Explain why this occurs.   (6 marks)

See next page

Question 44 **(17 marks)**
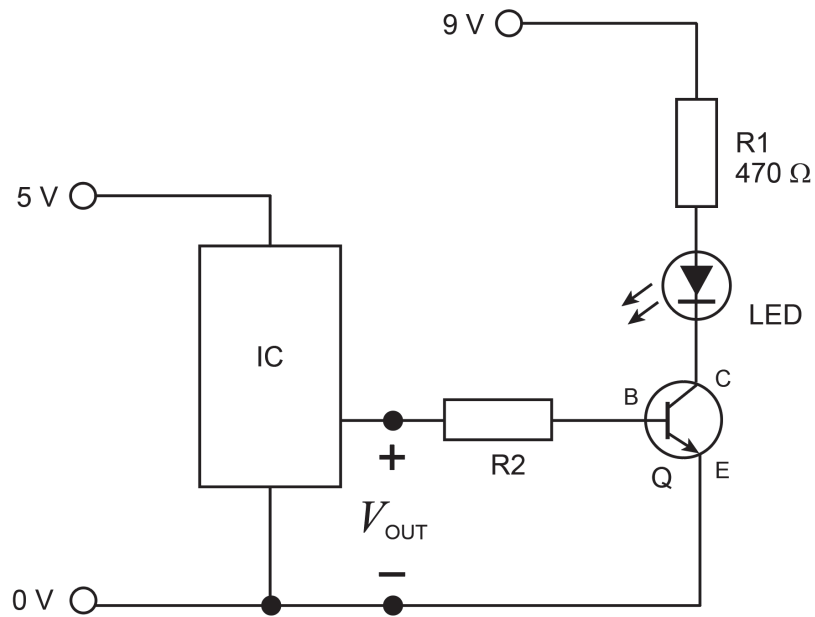
The circuit shown above includes a microcontroller, IC, and a transistor, Q. It has the following parameters: $V_{OUT,LOW}$ = 0 V, $V_{OUT,HIGH}$ = 5 V, transistor gain β = 25 and $V_{LED,ON}$ = 2.1 V.

Suppose the output pin is *high*. This causes V_{CE} to be 1.85 V.

(a) (i) Calculate I_C, the collector current of the transistor. (5 marks)

Question 44 (a) (continued)

    (ii)   Calculate the resistance of R2. If you were unable to obtain a value for part (i), use 0.01 A. (5 marks)

(b)   Suppose R2 is replaced with a 2k2 Ω resistor. When the microcontroller output pin is *high*, will the transistor operate in its forward-active or saturation region? Explain your answer by providing supporting calculations. (7 marks)

        Forward-active   Saturation   (circle **one** only)

Question 45 **(13 marks)**

A vent in a greenhouse has a fan driven by a DC electric motor that is powered by a 12 V battery. The vent can expel air from the greenhouse or pull in fresh air from outside.

Switches at either end can switch the fan motor on or off. Switches are wired in such a way that a person can turn the fan motor on or off without having to adjust the position of the other switch. These switches are SW1 and SW2.

The reversing of the motor that enables the fan to either expel or pull in air is achieved using a third switch. This switch is SW3.

(a)   In the space below, use appropriate circuit symbols to draw a neat, labelled circuit diagram that meets the needs of the system described above.   (10 marks)

(b)   The electric motor draws a current of 2.5 A and is operated for three hours and 45 minutes. Calculate the quantity of energy transferred from the battery to the motor. Answer in units of kilojoules. Note: 1 W = 1 J s^{-1}.   (3 marks)

Question 46 **(14 marks)**

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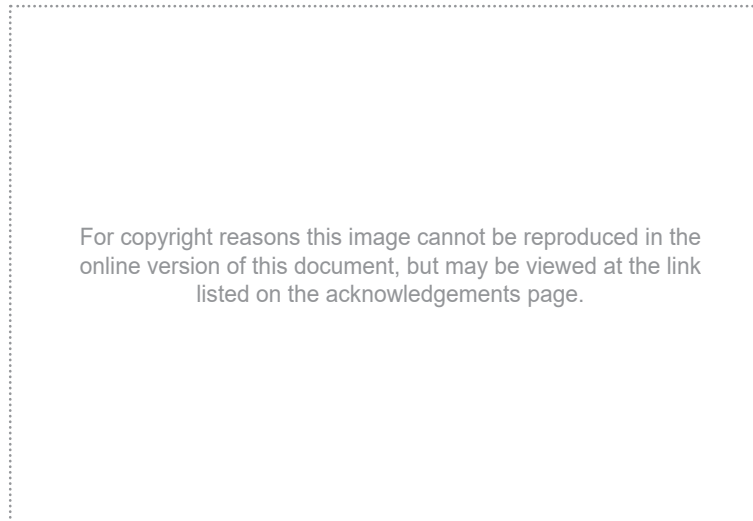
A headlamp has three ultra-bright LEDs controlled by a microcontroller. These are identified as LED1, LED2 and LED3. Power to the headlamp is controlled by one switch and there is a second switch, SW, that can be used to produce a digital signal. SW is a push-to-make switch that produces a normally *low* signal and when pressed will produce a *high* signal. There is a light sensor (LS) that produces a 10-bit analogue signal.

(a) On page 53, use labelled flowchart symbols to design a system to control the headlamp to meet the specifications below. (8 marks)

- There are three lighting combinations. In order, these are:
  Combination 1 – LED1 on   LED2 off   LED3 off
  Combination 2 – LED1 off   LED2 on   LED3 on
  Combination 3 – LED1 on   LED2 on   LED3 on
  Then loop back to Combination 1.
- When the headlamp is powered up, Combination 1 is activated.
- To progress one combination at a time, it is necessary to hold SW down for at least one second. If SW is pressed for less than one second, then the program does not progress to the next combination (i.e. it remains on its current combination).
- Once the program has advanced to the next combination, SW must be released within one second or else the program will continue to progress to each successive lighting combination until released.

See next page

Start

A spare flowchart 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 flow chart.

See next page

Question 46 (continued)

Rather than using SW to scroll through the different lighting sequences, a new program needs to be designed that will make use of the level of available light in the surroundings to determine how many of the LEDs are turned on. The light level of the surroundings is detected by the light sensor, LS, and this is converted by the microcontroller's ADC into a 10-bit value.

(b)   In the space below, use labelled flowchart symbols to design a new system to control the headlamp that meets the following specifications.   (6 marks)

- When the headlamp is powered up, LED1 only turns on.
- If LS detects a light level for the surroundings that produces a 10-bit value greater than or equal to 800, then LED1 only will remain on.
- However, if the 10-bit value being produced is less than 800, then LED1 turns off and LEDs 2 and 3 turn on.
- Should the 10-bit value fall below 650, then all three LEDs will be on.
- The program must constantly monitor conditions and ensure that the correct number of LEDs is on at the specified light levels.

Start

End of Mechatronics Section

Supplementary page

Question number: _____

Supplementary page

Question number: _____

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Question number: _____

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Question number: _____

Spare grid

Spare grid

Shear force diagram

Bending moment diagram
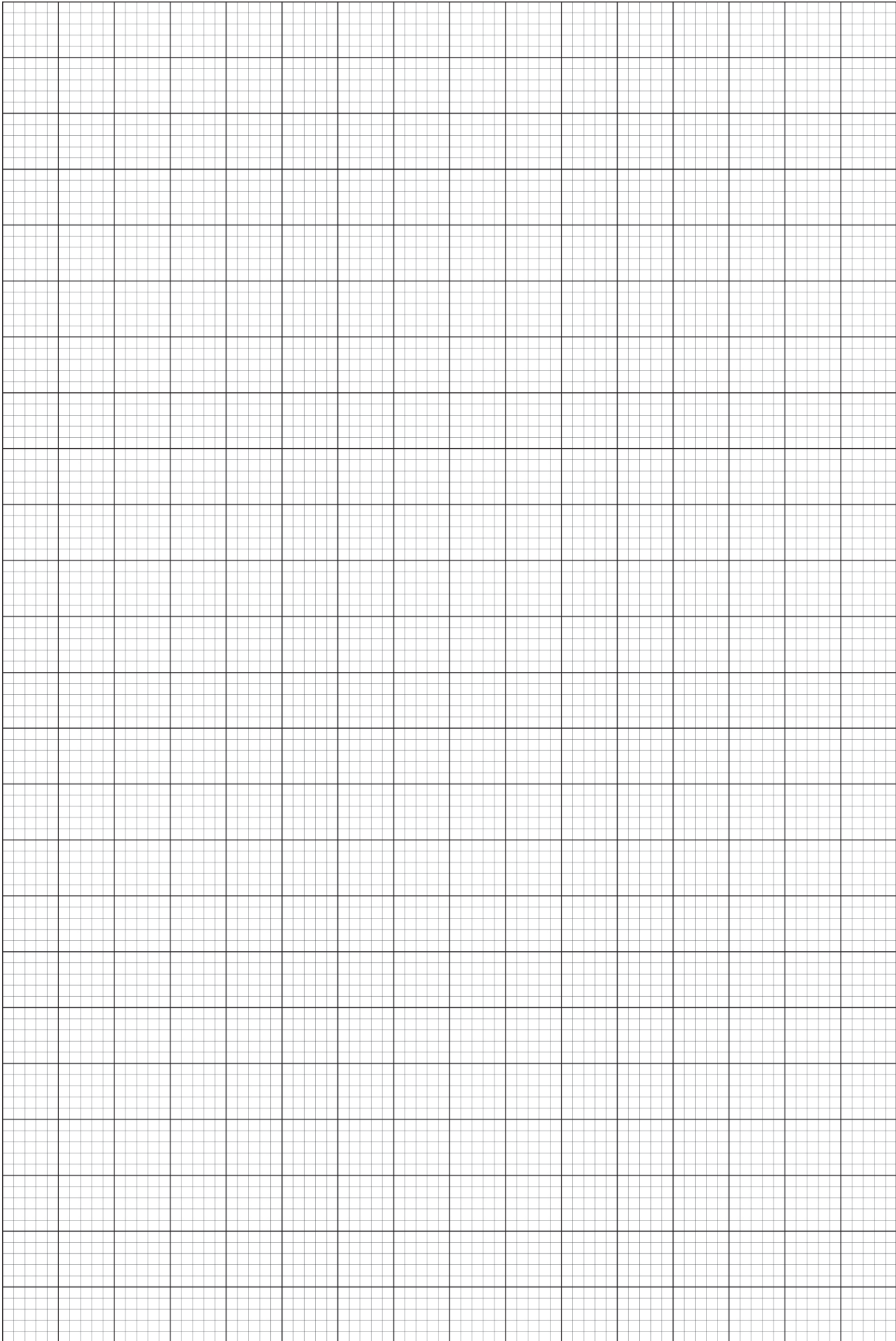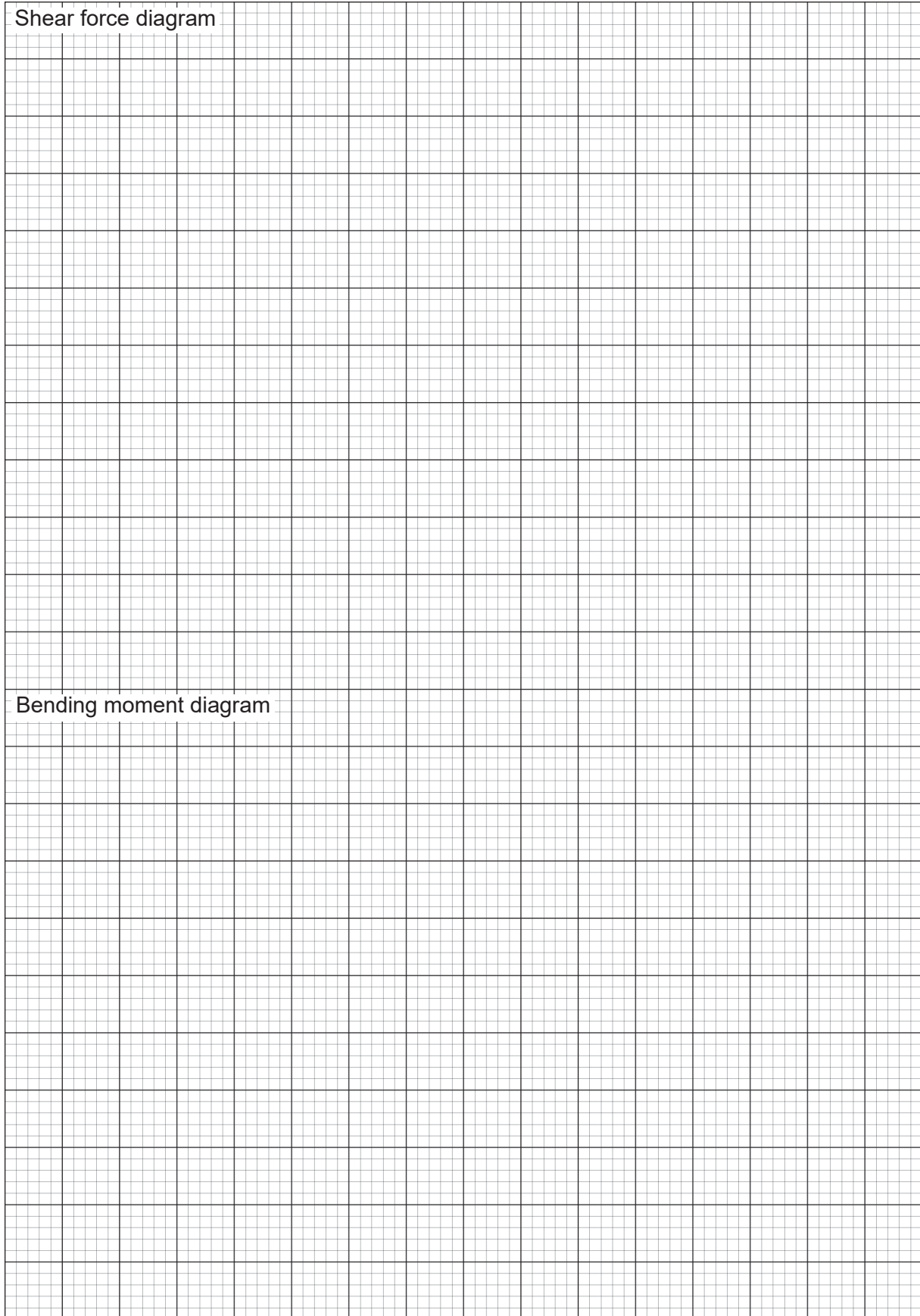
Spare grid

Spare flowchart

Start

ACKNOWLEDGEMENTS