



ATAR course examination, 2019

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
Multiple-choice answer sheet
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: 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	83	10
Part A: Multiple-choice Part B: Extended answer	4	4			30
Section Two Mechanical	10	10	110	113	10
Part A: Multiple-choice Part B: Extended answer	6	6			50
Section Two Mechatronics	10	10	110	113	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 external examinations are detailed in the *Year 12 Information Handbook 2019*. 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. 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.

- 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**40% (83 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.

1. Which of the following statements **best** describes the physical property of toughness?
The ability of a material to
 - (a) not degrade when exposed to the elements.
 - (b) absorb energy without fracture or failure.
 - (c) retain its shape and dimension when under load.
 - (d) resist scratching or indentation.

2. Which of the following sources of energy production does **not** have the sun as its primary source?
 - (a) wind
 - (b) waves
 - (c) tidal
 - (d) biomass

3. Cast iron is classified as a
 - (a) ferrous alloy.
 - (b) pure metal.
 - (c) composite material.
 - (d) non-ferrous alloy.

4. Some children's toys are rejected by Australian Government authorities for importation. The main reason for this would be
 - (a) functionality.
 - (b) safety.
 - (c) ergonomics.
 - (d) finish.

See next page

5. Single-use plastic bags have recently been banned from sale in Western Australia as they are not biodegradable when disposed of in waste. Which of the following **best** describes a biodegradable material?
- (a) can be resold for recycling and remanufacture
 - (b) can be easily disposed of in a landfill site
 - (c) breaks down in a high-temperature furnace
 - (d) living organisms can break it down into harmless products
6. A malleable material would be used when the product needs to be
- (a) resistant to corrosion.
 - (b) rolled into a thin sheet.
 - (c) drawn through a die to produce wire.
 - (d) flexed back and forth like a hinge.
7. Household electricity is charged for on the basis of the number of kilowatt-hours used. Another unit that could be used to measure electricity usage is
- (a) kilojoule-seconds.
 - (b) amps per second.
 - (c) megajoules.
 - (d) watts per second.
8. The discussions between the client and the engineer that result in the creation and documentation of a design brief belong to which phase of the engineering design process?
- (a) investigating
 - (b) evaluating
 - (c) devising
 - (d) producing
9. Which of the following lists contains only polymers?
- (a) brass, solder, cast iron and stainless steel
 - (b) nylon, acrylic, concrete and polypropylene
 - (c) nylon, acrylic, polycarbonate and stainless steel
 - (d) polypropylene, polycarbonate, acrylic and nylon
10. Which of the following equations could be used to calculate the volume of a solid that is a cylindrical body of height 'h' and radius 'r', with a hemisphere on one end and a flat base on the other?
- (a) $2\pi r(r^2/3 + h)$
 - (b) $2\pi(r^3/3 + 2rh)$
 - (c) $\pi r^2(2r/3 + h)$
 - (d) $4\pi r^3/3 + \pi r^2 h$

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See next page

Part B: Extended answer

30% (73 Marks)

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

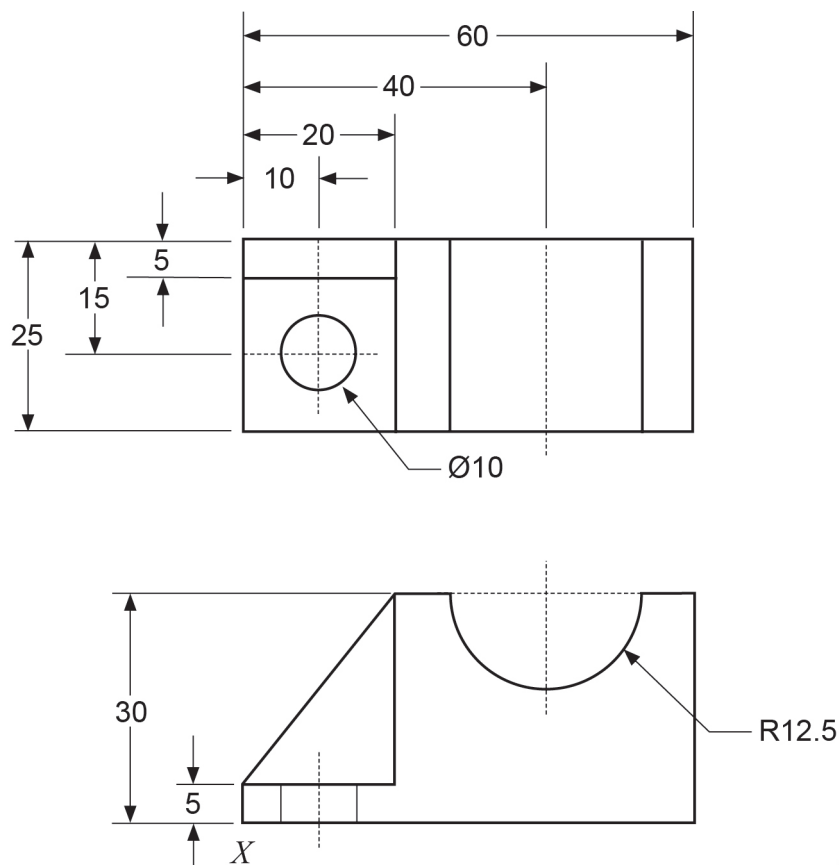
When calculating answers show all of your working clearly. Your working should be in sufficient detail to allow your answers to be checked readily and for marks to be awarded for reasoning. In final answers, include appropriate units where applicable.

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Question 11

(17 marks)

The following question relates to the orthographic drawing given below.

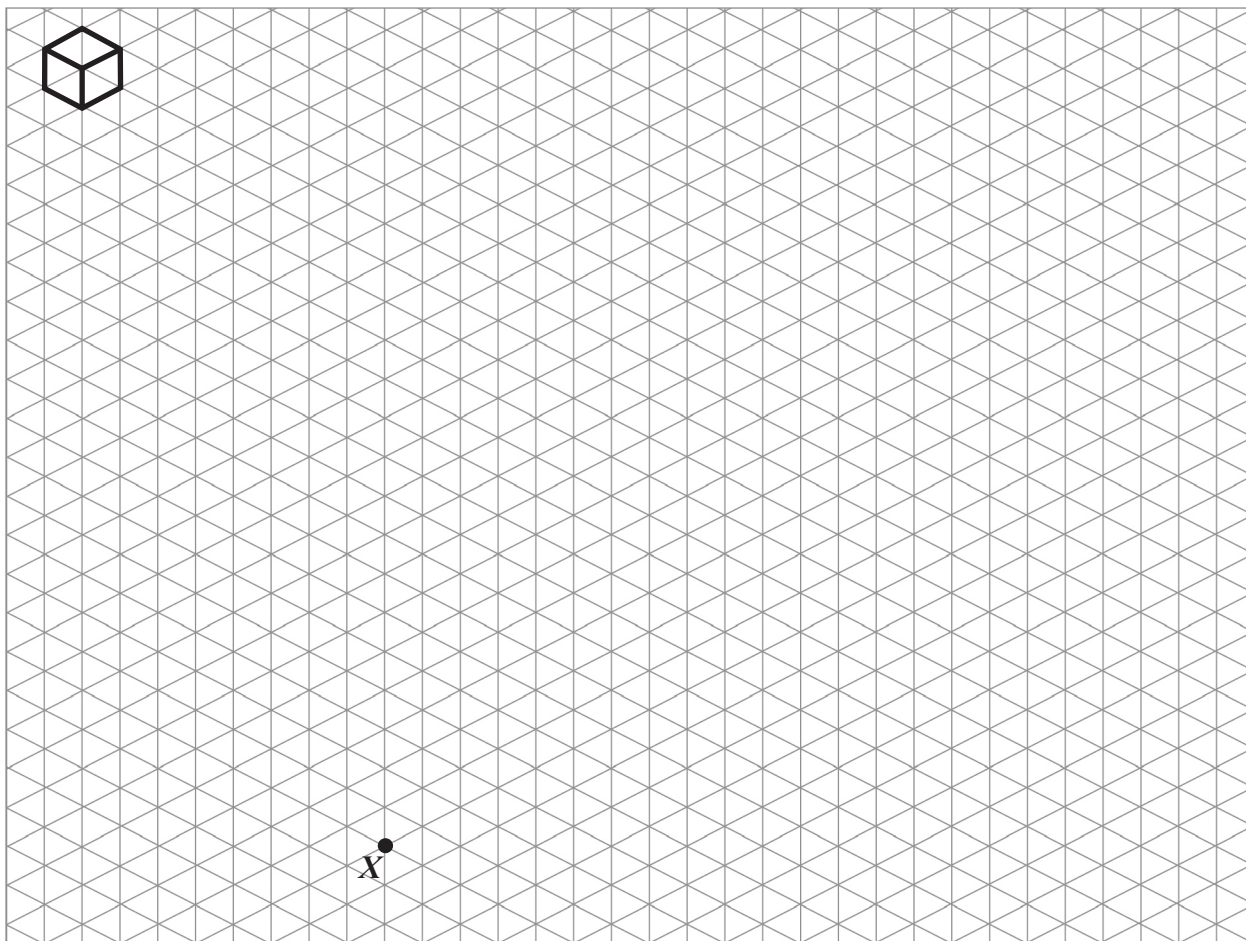


This drawing gives the top and front views of a solid brass bracket.

- (a) Use the grid on page 7 to produce a pictorial drawing of the bracket. This three-dimensional representation must be accurately proportioned. To assist with this, each grid represents 5 mm in each direction. (A 5 mm x 5 mm x 5 mm cube has been drawn in the top left-hand corner of the grid to illustrate how to use the grid). Use a ruler for straight lines and freehand for the circular and semi-circular features.

The corner X , indicated on the drawing above, is also marked on the grid with a small labelled dot to act as the starting point. No dimensioning is required. (8 marks)

See next page



A spare grid is provided on page 56 of this Question/Answer booklet. If you need to use it, cross out the attempt on this page.

- (b) Calculate the volume of material in the bracket. Give your answer in units of mm^3 .
(6 marks)
- (c) With reference to information in the Data Book, calculate the mass of the bracket. If you were unable to obtain a value for part (b), use $25\,500\text{ mm}^3$.
(3 marks)

Question 12

(16 marks)

A bicycle frame is an example of an engineered product for which materials selection is crucial to enabling the design to perform its functions and reach its anticipated service life. A frequently-used material for bicycle frames is aluminium alloy.



Name **four** important physical properties that the construction material (aluminium alloy) must exhibit if it is to be suitable for a bicycle frame. The focus must be on fitness for purpose and **not** how the frame is manufactured. Define each property and justify why each is a requirement of the material used in a bicycle frame.

Property one

Name: _____

Definition: _____

Justification: _____

Property two

Name: _____

Definition: _____

Justification: _____

Property three

Name: _____

Definition: _____

Justification: _____

Property four

Name: _____

Definition: _____

Justification: _____

Question 13

(22 marks)

Electricity is produced by many processes in different parts of the world, depending on the availability and cost of resources. In Australia, the most common large-scale electricity generation systems use the energy released from the burning of fossil fuels.

South-eastern Australia and Tasmania supplement their energy needs with the production of hydroelectricity using water stored in large water catchments.

Wind farms, in which a number of wind generators are coupled together, are also widely used, particularly in localised country areas.

South Australia has recently established several large-scale photovoltaic farms that are connected to the State grid. The initial phase of one of these, the Solar River Project, comprises a 220 MW panel array and a 120 MWh lithium-ion battery. This photovoltaic farm has 628 000 panels and during the day these track the sun from east to west to improve efficiency.

New Zealand meets a large proportion of its electricity needs using geothermal steam and other countries, such as France and Japan, use the heat energy released from controlled nuclear reactions to produce the steam required to drive the generators.

- (a) Name a renewable energy source that is not mentioned in the text above. (1 mark)

- (b) Name the energy generation system mentioned in the text you would consider has the **least** environmental impact during its construction, operation and demolition? Explain the reason for your choice. (2 marks)

Energy generation system: _____

Explanation: _____

- (c) Name the energy generation system mentioned in the text you would consider has the **greatest** atmospheric environmental impact during its operation? Explain the reason for your choice. (3 marks)

Energy generation system: _____

Explanation: _____

Every form of energy generation has its advantages and disadvantages.

- (d) Circle **one** of the following methods of energy generation and outline briefly **two** advantages and **two** disadvantages of this method. (4 marks)

Hydroelectric

Wind farm

Nuclear

(circle **one** only)

Advantage one: _____

Advantage two: _____

Disadvantage one: _____

Disadvantage two: _____

Consider the Solar River Project in South Australia.

- (e) (i) Explain why this project requires the coupling of the photovoltaic panels to battery storage. (3 marks)

- (ii) In units of kilojoules (kJ), calculate the energy available from the energy storage system when it is fully charged. (2 marks)

Question 13 (continued)

- (iii) Given each panel in the solar farm has an area of 1.94 m^2 and an efficiency of 20%, calculate the total power being produced at a time when the solar irradiance is 0.88 kW m^{-2} . Answer in units of megawatts (MW). (4 marks)
- (iv) On a particular evening, after the solar panels had stopped functioning, the battery storage went from fully charged to quarter charged in a five-hour period. Calculate the power being supplied by the storage system if it was constant over this five-hour period. Answer in units of megawatts (MW). (3 marks)

Question 14

(18 marks)

Australia imports all new family cars from overseas as it no longer has car manufacturing facilities. They are transported from the countries of manufacture to ports in Australia by ships and distributed for sale to cities and towns from the port of arrival by specialised trucks.

A life cycle analysis of family cars should include the analysis of their transportation. This would focus on issues of the energy and materials associated with the modes of transporting the vehicles, plus environmental impacts. This analysis could also relate indirectly to the mode of transport, e.g. necessary infrastructure for it to achieve its task of collecting, transporting and delivering the cars.

Consider the transport phase that requires ships. Energy will be required by the ship to propel it across the ocean to its destination. Energy will also be required for the working and living quarters of the crew.

- (a) (i) For the propulsion of the ship and working and living quarters of the crew, identify the form of energy required and describe the relevant energy conversions. (6 marks)

Form of energy (propulsion): _____

Description: _____

Form of energy (working and living quarters): _____

Description: _____

- (ii) Name **two** types of environmental impact that are likely to occur during this transport phase. For each impact, provide a brief description that includes **two** specific examples. (6 marks)

Environmental impact one: _____

Examples: _____

Question 14 (continued)

Environmental impact two: _____

Examples: _____

Now consider the transport phase that requires specialised trucks.

- (b) Name **two** environmental impacts that result directly from the delivery truck in transit, and **one** indirect environmental impact associated with the infrastructure required for the truck to get from the port to the point of sale. Outline each of these environmental impacts. (6 marks)

Direct impact one: _____

Description: _____

Direct impact two: _____

Description: _____

Indirect impact: _____

Description: _____

Section Two: Specialist fields**60% (113 Marks)**

Candidates are required to choose one of the following options, according to which specialist field they studied in 2019.

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

Specialist field	✓	Question numbers	Pages
Mechanical	<input type="checkbox"/>	15–30	16–33
Mechatronics	<input type="checkbox"/>	31–46	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% (113 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.

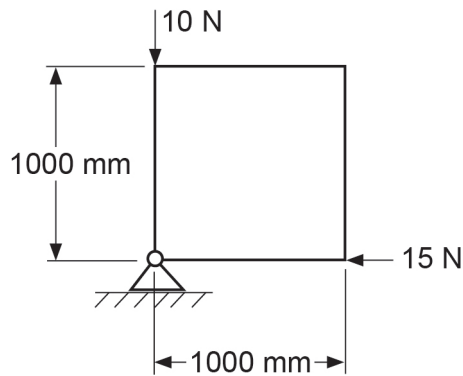
Part A: Multiple-choice**10% (10 Marks)**

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.

15. Factor of safety is defined as the ratio of
- (a) ultimate failure stress to safe working stress.
 - (b) elastic limit to safe working stress.
 - (c) toughness to safe working stress.
 - (d) ultimate tensile strength to ultimate failure stress.
16. The units of strain are
- (a) N mm^{-2} .
 - (b) $\text{mm}^2 \text{N}^{-1}$.
 - (c) stress dependent.
 - (d) dimensionless.
17. Potential energy and kinetic energy can be defined respectively as energy of the
- (a) earth and energy of motion.
 - (b) mass and energy of acceleration.
 - (c) position or state and energy of motion.
 - (d) mass and energy of motion.
18. 320 N mm^{-2} is equivalent to
- (a) 320 kPa.
 - (b) 320 MPa.
 - (c) 320 GPa.
 - (d) 320 kN m^{-2} .

See next page

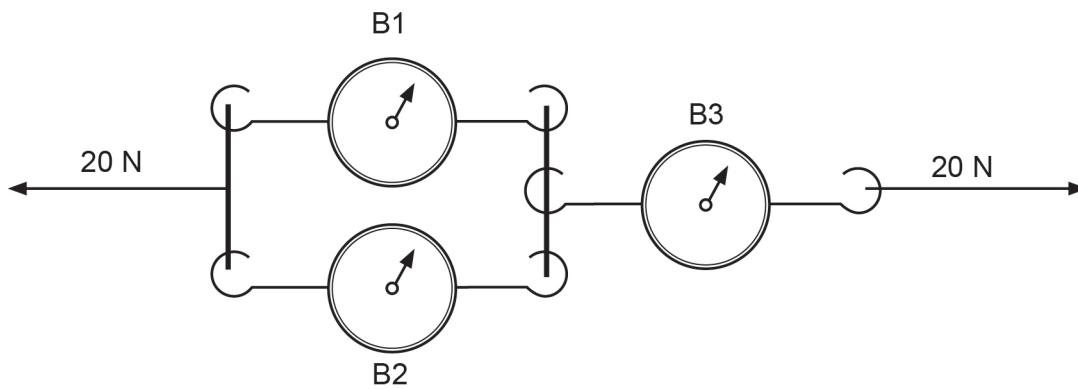
19. A body initially at rest is **not** in static equilibrium. Which of the following would be a **true** statement concerning that body?
- This is not possible; a body must always be in static equilibrium.
 - All forces on the body must be equal.
 - There must not be any forces acting on the body.
 - The body begins to accelerate.
20. Bright drawn steel is manufactured by
- melting the steel and pouring it into a cavity.
 - machining down the steel to an accurate size.
 - pushing the steel through a die.
 - pushing stainless steel through a die.



21. In the diagram above, the moment being generated by the forces displayed about the pivot equals
- 0 Nm.
 - 10 Nm.
 - 15 Nm.
 - 25 Nm.
22. Consider a solid square cantilever beam with a force applied at one end. Which of the following would cause the greatest increase in the deflection of the beam?
- doubling the force on the end of the beam
 - selecting a new material with half the Young's modulus
 - doubling the area of the square section
 - doubling the length of the beam
23. A force of 10 N is being applied to a mass of 2 kg resting on a table with the intention of moving it 1 m. Due to friction forces the mass does not move. What can be said about the work done?
- The work done is 10 J.
 - There is no work done.
 - The work done depends on the size of the friction force.
 - The work done is 19.62 J.

See next page

24. A spring balance is a device that displays force applied to it. What will be the reading on each of the three spring balances shown in the diagram below?



	B1	B2	B3
(a)	0 N	0 N	0 N
(b)	10 N	10 N	0 N
(c)	10 N	10 N	20 N
(d)	20 N	20 N	40 N

Part B: Extended answer

50% (103 Marks)

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

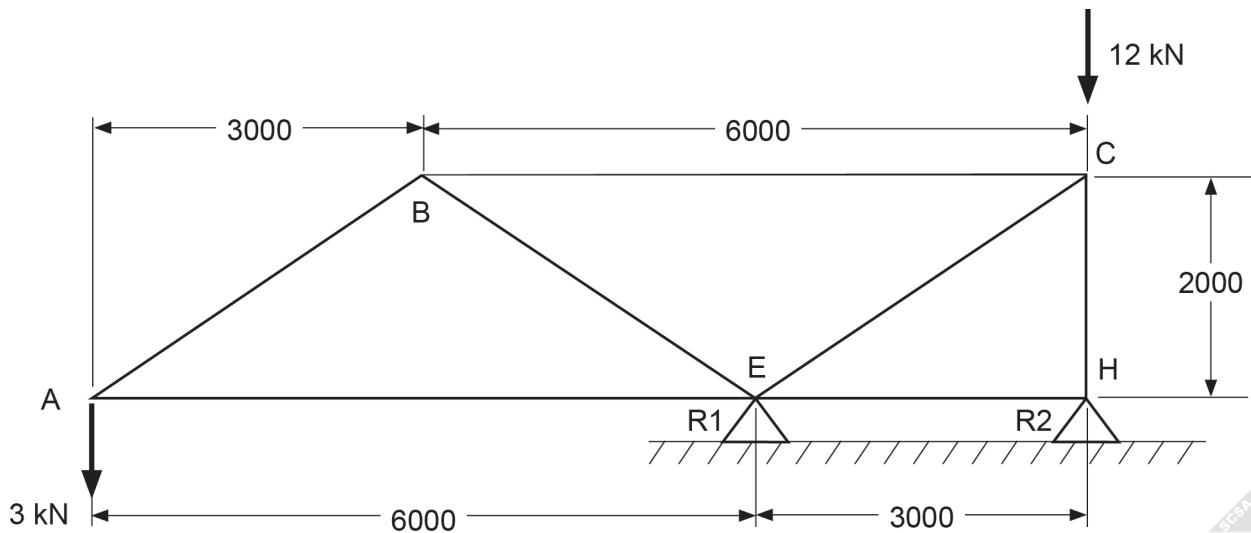
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Question 25

(21 marks)

A hoist truss loaded as shown in the diagram below is connected at two supports R1 and R2.



(a) Find the reaction forces at the two supports.

(4 marks)

Question 25 (continued)

- (b) Apply the method of sections and draw a free body diagram of the remaining part of the truss that can be used to determine the forces through members AE, BC and BE. Include the cut line and label the forces F_{AE} , F_{BC} and F_{BE} on the diagram on page 19. (5 marks)

- (c) Use the method of sections to determine the force in members AE, BC and BE. Circle to show whether each member is in tension or compression.

- (i) Member AE (3 marks)

tension compression

- (ii) Member BC (3 marks)

tension compression

(iii) Member BE

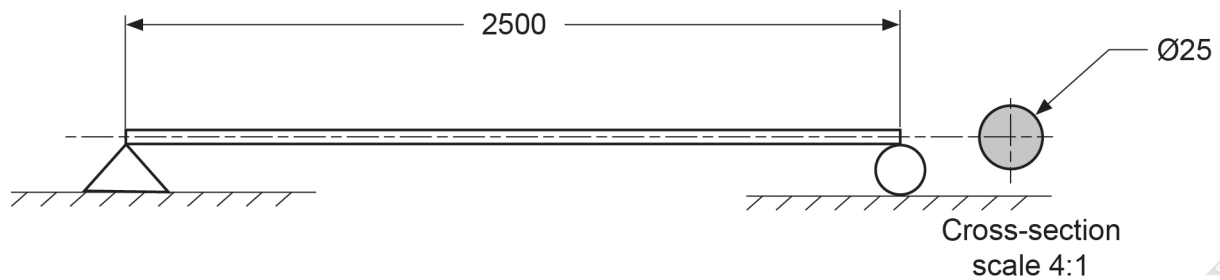
(6 marks)

tension compression

Question 26

(13 marks)

A round, solid-steel beam is supported at either end as shown in the diagram below. The self-weight of the beam is producing a distributed load of 37.55 N m^{-1} .



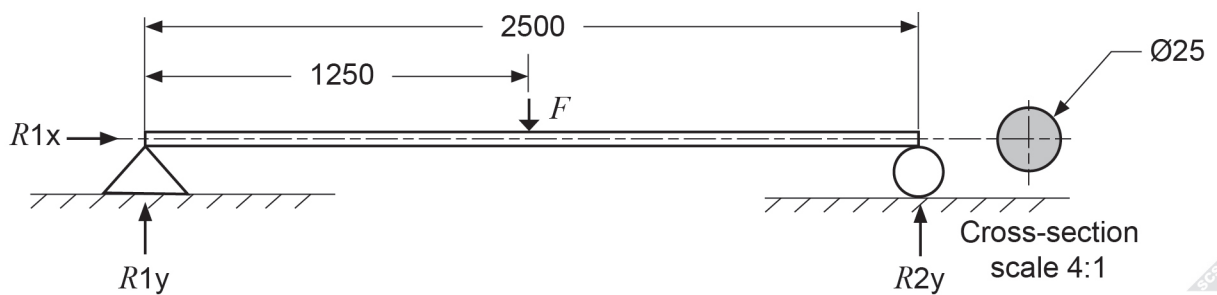
Use the following values if you fail to calculate them but need them to continue:

Item	Value	Description
I_{xx}	$19\,000 \text{ mm}^4$	Second moment of area of the beam
$Y1$	5 mm	Deflection of the beam due to self-weight

- (a) Calculate the second moment of area I_{xx} for the cross-section. (2 marks)
- (b) Calculate the dimension of a solid square steel bar with the same I_{xx} as the round, solid-steel beam, but still has the same resistance to deflection under equivalent forces. (4 marks)

- (c) Calculate Y_1 , the deflection of the round beam at its centre due to self-weight only.
(3 marks)

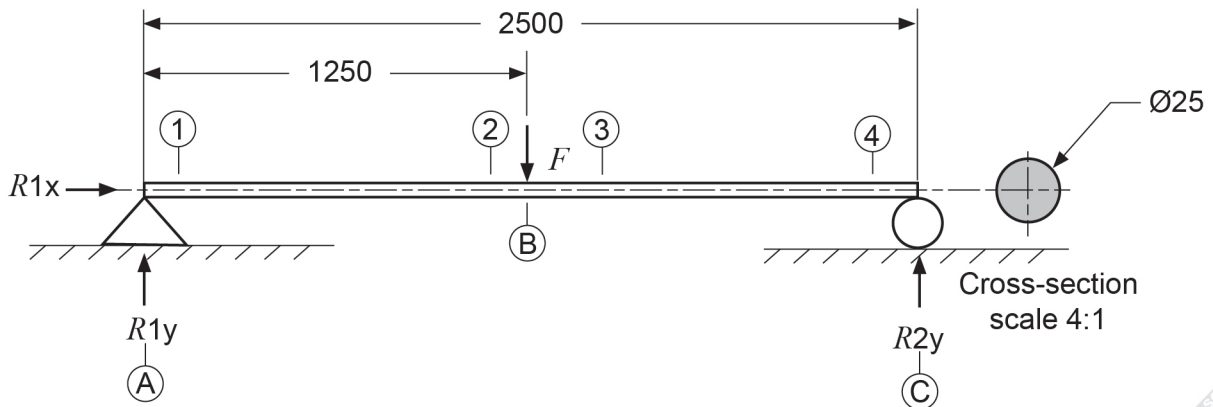
A force F of 306.125 N is now applied to the round, solid-steel beam as shown in the diagram below.



- (d) Calculate the new total deflection due to both the self-weight and the applied force F in the middle of the beam.
(4 marks)

Question 27

(20 marks)



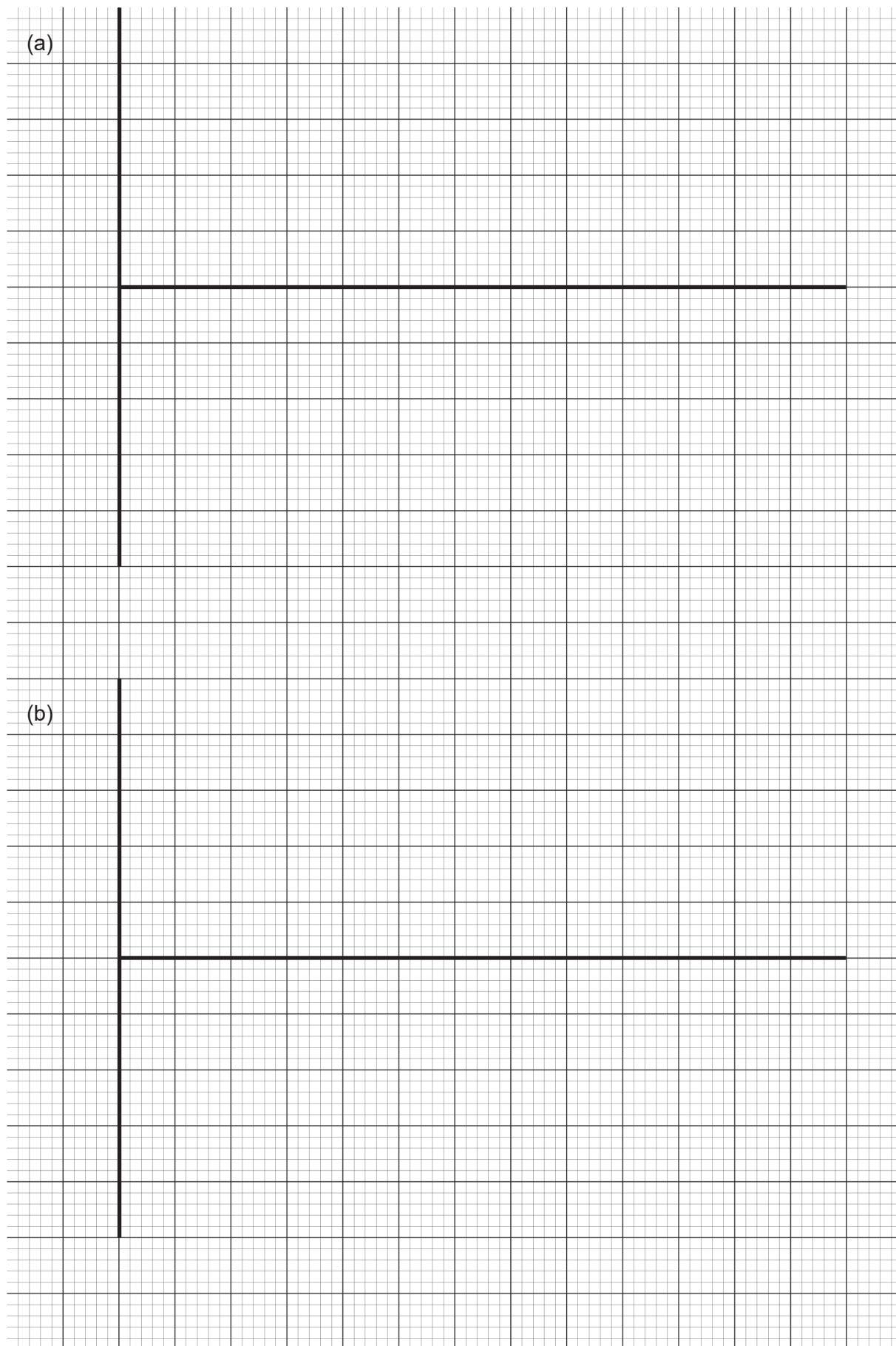
This question uses the same beam as in Question 26, (reproduced above) with all the same forces and reactions (F is equal to 306.125 N, R_{2y} is equal to 200 N and a self-weight distributed load equal to 37.55 N m^{-1} .)

- (a) Using points 1, 2, 3 and 4 labelled in the diagram above, construct a shear force diagram on the axes on the **top** half of the grid provided on page 26. In the space below, show all calculations undertaken to construct this diagram. (12 marks)

(Use the space at the top of the next page to continue your working.)

See next page

- (b) Using points A, B and C labelled on the diagram on page 24, construct a bending moment diagram on the axes on the **bottom** half of the grid provided on page 26. Make sure you show clearly the maximum bending moment and its location. In the space below, show all calculations undertaken to construct this diagram. (8 marks)



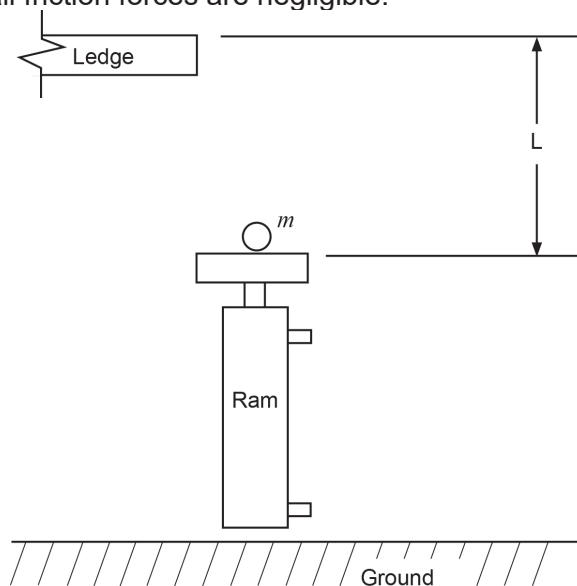
A spare grid is provided on page 57 of this Question/Answer booklet. If you need to use it, cross out the attempt on this page.

See next page

Question 28

(20 marks)

In the diagram below, the pressure in the hydraulic ram supplies a constant force of 500 N. There is a 30 kg mass (m) fixed securely on top of the piston that must be lifted directly upward over the entire 100 mm stroke of the piston (L) to bring it in line with the ledge. Assume that the weight of the piston and all friction forces are negligible.



- (a) Calculate the acceleration (a) of the mass (m) going up. (4 marks)

If you were unable to obtain a value in part (a), use 7.00 m s^{-2} for parts (b), (c) and (d).

- (b) Calculate the final velocity of the mass (m) just before the piston hits its limit going up. (3 marks)
- (c) Calculate the displacement of the mass (m) after 0.1 seconds going up from rest. (3 marks)

Question 28 (continued)

The equation for time (t) in seconds taken for an object starting from rest to move a distance (s) in metres with a constant acceleration (a) is given below.

$$t = \sqrt{\frac{s}{0.5 a}}$$

- (d) Calculate the time taken for the piston to reach full extension. (2 marks)
- (e) Calculate the power used by the piston in one full extension. (2 marks)
- (f) Calculate the energy required for the piston to lift the securely-fixed mass (m) in line with the ledge. (2 marks)

Assume that the mass (m) is **not** fixed to the top of the piston. At its highest point, the piston retracts and the mass continues rising. The mass starts to fall and keeps gaining velocity until it reaches the top of the piston at the point at which it initially started.

- (g) Explain the relationship between conservation of energy and gravity during the mass's journey described above. (Ignore air resistance). (3 marks)

- (h) State what happens to the E_k when the ball hits the top of the piston on its downward journey. (1 mark)

See next page

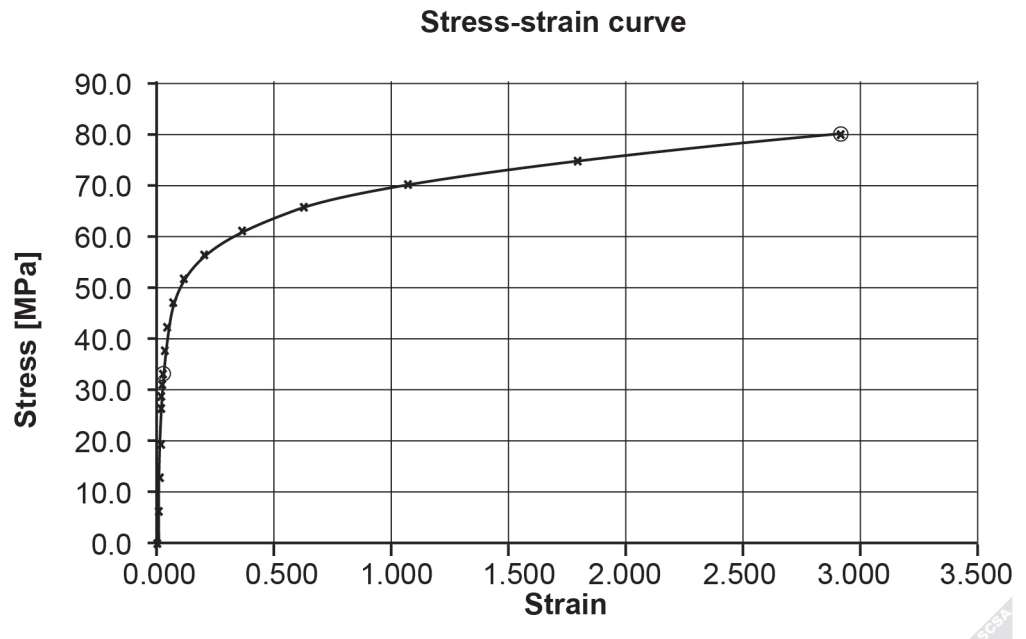
Question 29

(20 marks)

A company that manufactures emergency equipment was testing different types of materials to be used as multi-strand safety cable. Three materials X, Y and Z were tested for suitability. Below and on page 30 are the stress-strain curves and testing data of these three materials.

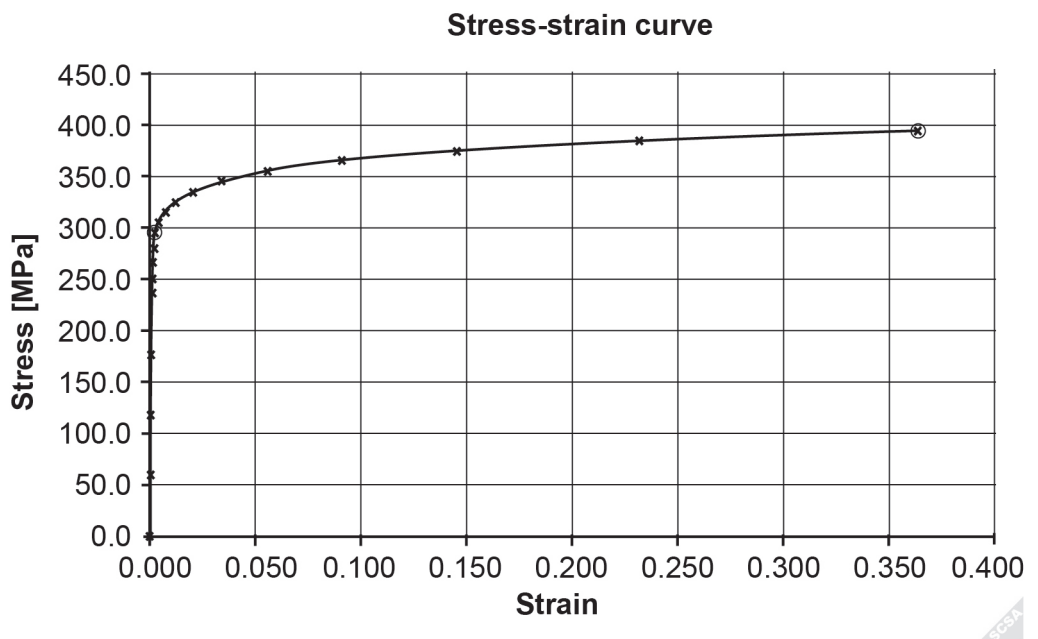
Material X

σ (MPa)	ϵ
0.0	0.00000
6.6	0.00448
13.1	0.00896
19.7	0.01346
26.2	0.01823
27.9	0.01956
29.5	0.02099
31.2	0.02258
32.8	0.02439
37.5	0.03156
42.2	0.04446
46.9	0.06914
51.6	0.11629
56.3	0.20377
60.9	0.36013
65.6	0.62922
70.3	1.07624
75.0	1.79549
79.7	2.92000



Material Y

σ (MPa)	ϵ
0.0	0.00000
59.0	0.00030
118.0	0.00059
177.0	0.00089
236.0	0.00122
250.8	0.00136
265.5	0.00163
280.3	0.00220
295.0	0.00348
305.0	0.00515
315.0	0.00801
325.0	0.01286
335.0	0.02095
345.0	0.03428
355.0	0.05594
365.0	0.09068
375.0	0.14571
385.0	0.23181
395.0	0.36500

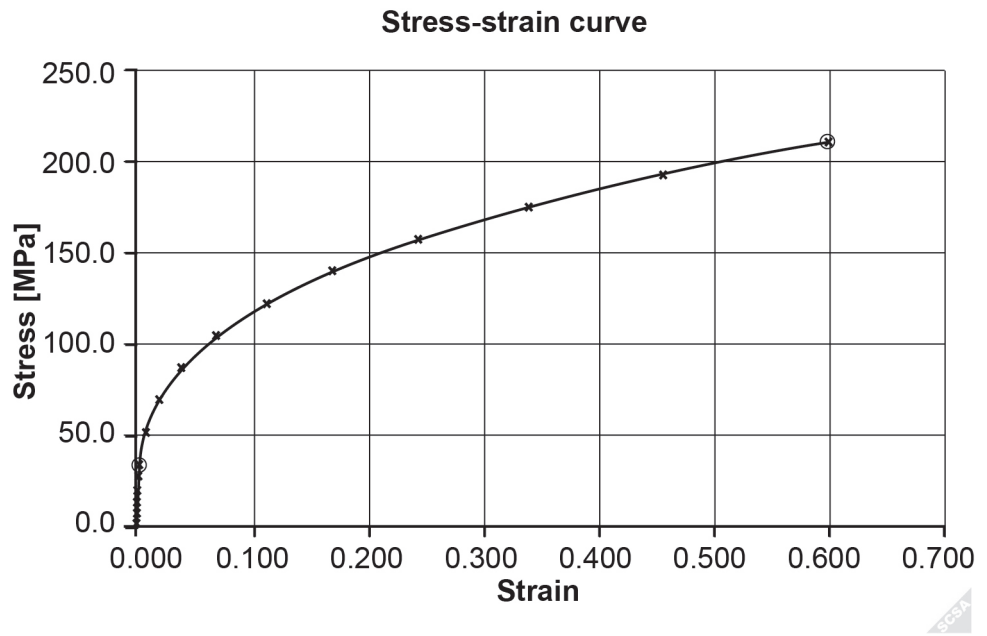


See next page

Question 29 (continued)

Material Z

σ (MPa)	ϵ
0.0	0.00000
6.7	0.00007
13.3	0.00024
20.0	0.00059
26.6	0.00124
28.3	0.00147
30.0	0.00172
31.6	0.00199
33.3	0.00230
51.0	0.00793
68.6	0.01939
86.3	0.03893
104.0	0.06883
121.7	0.11146
139.3	0.16919
157.0	0.24445
174.7	0.33969
192.3	0.45737
210.0	0.60000



(a) Name the material that is toughest and state why. (2 marks)

(b) Name the material that has the highest resilience and state why. (2 marks)

You are told that the three materials are copper, mild steel and polypropylene.

(c) Circle which of these is Material Y and justify your selection. (2 marks)

Copper Mild Steel Polypropylene

- (d) Circle which of these materials you believe would be best suited for this application as safety cable and justify your selection. (2 marks)

Copper Mild Steel Polypropylene

- (e) Derive Young's modulus for the selected material in part (d) using the stress-strain curves and testing data provided. (3 marks)

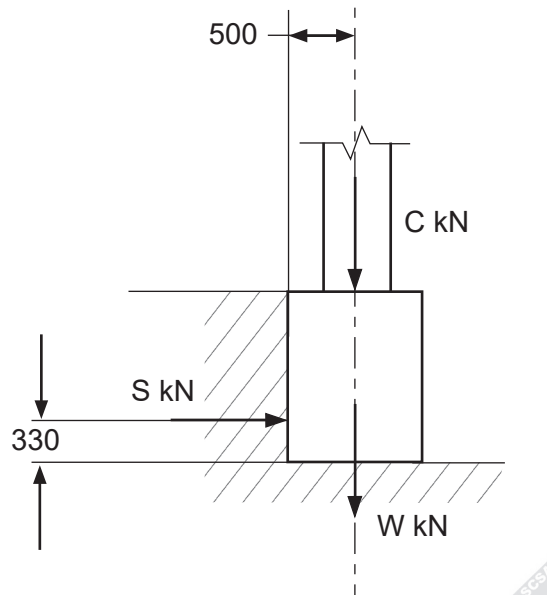
- (f) Calculate the elongation in the cable selected in part (d) above after it is loaded with 2000 N if prior to loading it was 1 m long with a cross-sectional area of 78.5 mm^2 . If you were unable to obtain a value for part (e), use 1700 N mm^2 . (2 marks)

- (g) This cable will need to safely hold 120 kg. If a factor of safety of 2 is required, calculate the smallest cable diameter allowable. (7 marks)

Question 30

(9 marks)

Below is a cross-section of a retaining wall. Soil pressure exerts a horizontal force (S) of 80 kN on the wall 330 mm above the base. The weight of the wall (W) is 200 kN. A column (C) stands on top of the wall and exerts a vertical force of 35 kN centrally.



- (a) Calculate the magnitude and angle to the horizontal of the resultant force. (5 marks)

Magnitude: _____

Angle to horizontal: _____

- (b) Calculate the turning moment about the centre of the base of the retaining wall due to the soil pressure. (2 marks)

Turning moment: _____

See next page

- (c) Calculate the perpendicular distance from the resultant to the centre of the base of the retaining wall. If you were unable to obtain a value for part (a), use 250 kN acting at an angle of 70° to the horizontal. If you were unable to obtain a value for part (b), use 30 kN m.

(2 marks)

Distance from vertical midline: _____

Section Two: Specialist field – Mechatronics

60% (113 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.

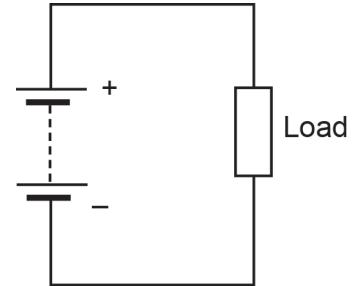
31. Which of the following components is **not** polarity sensitive?
- (a) light-dependent resistor
 - (b) semiconductor diode
 - (c) electrolytic capacitor
 - (d) light emitting diode
32. A capacitor is labelled 333. Its capacitance is
- (a) 33 μF .
 - (b) 33 000 nF.
 - (c) 0.033 μF .
 - (d) 33 pF.
33. When two capacitors of unequal value are connected in series, the total capacitance is
- (a) the addition of the two values.
 - (b) half of the larger value.
 - (c) greater than the larger value.
 - (d) less than the smaller value.
34. When an NPN transistor is operating in its forward-active region, an increase of the base current will cause
- (a) an increase in the voltage across the collector-emitter.
 - (b) a decrease in the voltage across the collector-emitter.
 - (c) a decrease in the voltage across the base-emitter.
 - (d) a decrease in the collector current.

See next page

35. When measuring voltage, the probes of a voltmeter are placed such that the voltmeter is in
- series with the component and with the power to the circuit turned on.
 - parallel with the component and with the power to the circuit turned on.
 - series with the component and with the power to the circuit turned off.
 - parallel with the component and with the power to the circuit turned off.

36. Suppose an identical extra battery is added in parallel to the circuit shown below. This will result in an increase in which of the following?

- voltage held across the load
- power dissipated by the load
- current through the load
- current capacity of the supply



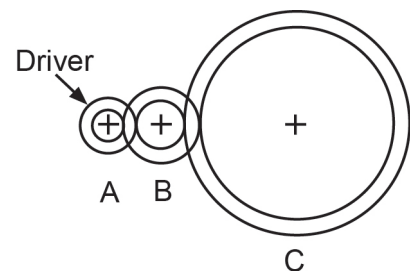
37. Which of the following types of memory is only temporary storage which is lost when the power is turned off?

- ROM
- RAM
- EEPROM
- Flash

38. If a pulse width modulation signal is designed to have a frequency of 50 Hz and a duty cycle of 70%, then the duration of each **high** pulse is

- 0.02 s.
- 0.035 s.
- 0.014 s.
- 0.006 s.

39. A gear-drive system contains three meshed gears A, B and C, each on a separate shaft. If the system is modified by replacing the original middle gear B with a larger one with more teeth, and the shafts are relocated to enable correct meshing, then



- gear C will now rotate more quickly.
- gear C will now rotate more slowly.
- the speed of rotation of gear C is not affected.
- the mechanical advantage of gear C is increased.

40. Which of the following is an example of a closed-loop system?

- a kettle that switches off when the water boils
- street lights that turn on at dusk and off at dawn
- an automated sliding door that opens and closes between two limit switches
- the cruise control of a car that maintains vehicle speed in varying conditions

See next page

Part B: Extended answer

50% (103 Marks)

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

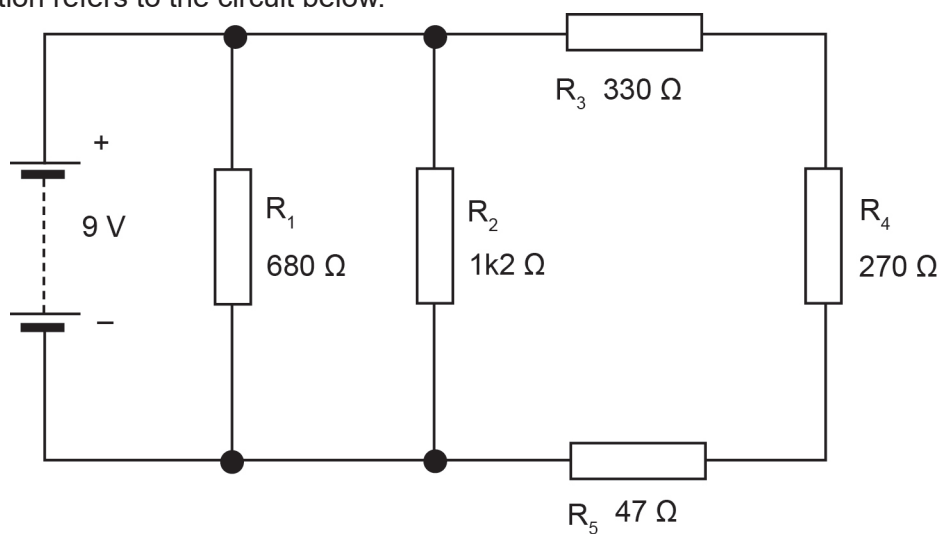
When calculating answers, show all your working clearly. Your working should be in sufficient detail to allow your answers to be checked readily and for marks to be awarded for reasoning. In final answers, include appropriate units where applicable.

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

(20 marks)

This question refers to the circuit below.



(a) Calculate the current through R_2 .

(3 marks)

(b) Calculate the current being supplied to the circuit by the battery.

(6 marks)

See next page

(c) Calculate the voltage held across R_4 .

(7 marks)

Suppose the resistance of R_1 is not the ideal value shown on the diagram on page 36.

(d) If its tolerance band is gold, calculate the maximum possible power R_1 will dissipate.

(4 marks)

Question 42

(17 marks)

A circuit containing a microcontroller will use a potentiometer to control the rotation of the horn mounted on a 6 V servo (see picture).

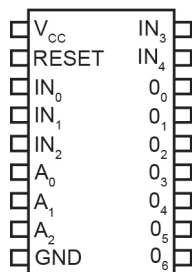
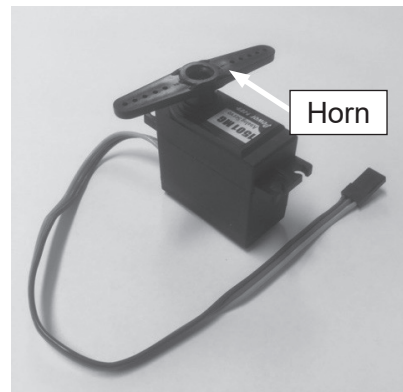
A servo has three connections: signal, positive and ground. For this question, use the servo symbol given in the Data Book.

The servo will require a 6 V battery to power it. A SPDT switch is used to make and break the connection of the positive terminal of the battery to the servo.

Additionally, an LED with current-limiting resistor will indicate when the servo is powered up.

Below is a diagram of a simplified microcontroller.

- (a) Using labelled circuit symbols, complete the circuit diagram described above, i.e. add the potentiometer, servo, 6 V battery, switch, LED and resistor. (11 marks)



A spare copy of this microcontroller is provided on page 58 of the Question/Answer booklet. If you need to use it, cross out the attempt on this page.

See next page

The following parameters are associated with the LED that indicates when the servo has been powered up:

Voltage supply = 6 V, forward voltage of LED = 2.1 V and $R = 330 \Omega$.

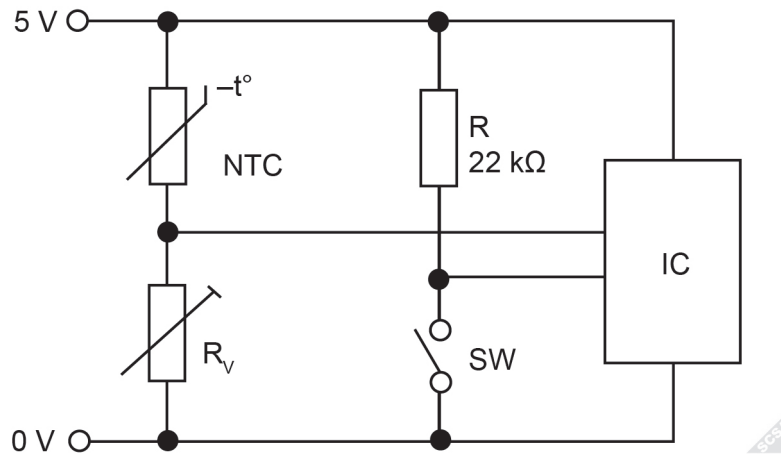
(b) (i) Calculate the current that flows through the LED. (3 marks)

(ii) Calculate the power dissipated by the resistor. (3 marks)

Question 43

(16 marks)

The diagram below has two forms of input connected to a microcontroller (IC). One will be a digital input and the other an analogue input.



Consider the input that results from the arrangement of components R and SW.

- (a) If SW is left in open circuit will the input detected by the microcontroller be *high* (5 V) or *low* (0 V)? Support your answer with relevant calculations. (4 marks)

The input will be _____

Now consider the input that results from the arrangement of components R_v and NTC.

- (b) If the temperature detected by NTC rises, then will the voltage detected by the microcontroller increase or decrease? Explain your reasoning. (4 marks)

Suppose the temperature being sensed by NTC causes its resistance to be $12\,500\ \Omega$.

- (c) Calculate the value of the resistance R_v needed so that the voltage being detected by the microcontroller is $3.25\ \text{V}$. (4 marks)

The voltage output from the temperature sensor is connected to an ADC pin on the microcontroller.

- (d) What does ADC mean and, if its resolution is 10-bit, what will be its value when the voltage being detected is $3.25\ \text{V}$? Present a calculation to show how you determined the 10-bit value. (4 marks)

ADC means _____

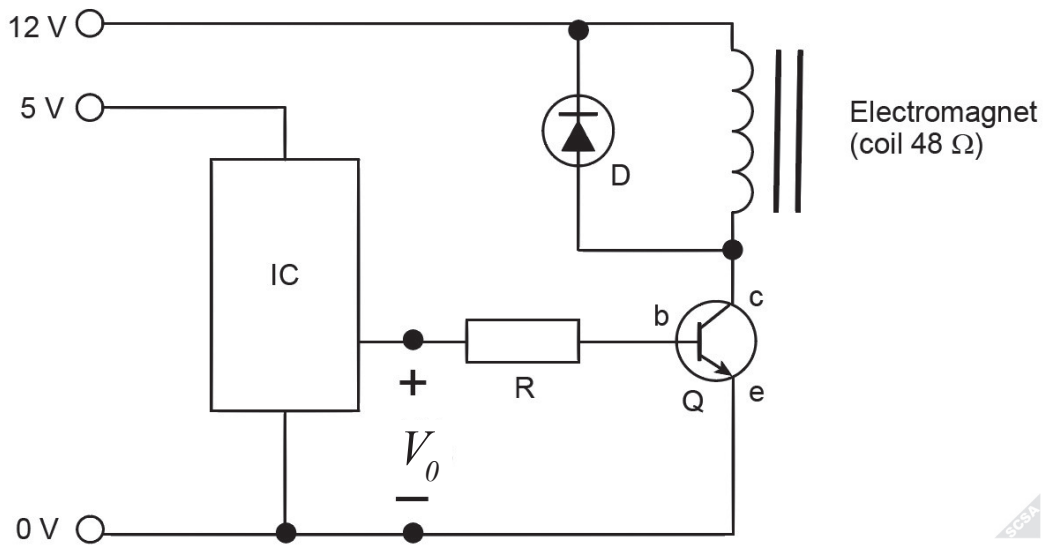
Question 44

(21 marks)

This question refers to the circuit below. It features an electromagnet that is driven by a transistor. The electromagnet is a coil that behaves the same as the coil in a relay, i.e. when a current is passed through it, a magnetic field is emitted and this can be used to attract ferrous materials.

The gain, also called β , of the transistor is 55.

The resistor, R, is connected to an output pin of a microcontroller, IC. When this output pin is *low*, $V_o = 0\text{ V}$ and when it is *high*, $V_o = 5\text{ V}$.



- (a) Describe the purposes of the resistor R and the diode D. (4 marks)

Resistor: _____

Diode: _____

Suppose R is a $1\text{k}\Omega$ resistor, the output pin is *high* and the transistor is operating in its forward-active region.

(b) (i) Calculate I_B the base current of the transistor. (3 marks)

(ii) Calculate I_C the collector current of the transistor. If you could not obtain a value for part (b) (i), use 0.0045 A. (3 marks)

(iii) Calculate V_{CE} the voltage across the collector-emitter of the transistor. If you could not obtain a value for part (b) (ii), use 0.22 A. (3 marks)

Question 44 (continued)

To deliver maximum efficiency, the transistor needs to operate in its saturation region.

- (c) (i) At the transition point between forward-active and saturation, the transistor will still operate in forward-active but $V_{CE} = 0$ V. Calculate R , the ideal value for the resistor, so that this condition is achieved. (6 marks)

- (ii) Specify the **maximum** E12 preferred value resistor that would be used for a practical circuit such that the transistor will be forced into saturation and, assuming a tolerance of $\pm 5\%$, list its 4-band colour code. (2 marks)

E 12 preferred value resistor: _____

Colour code: _____

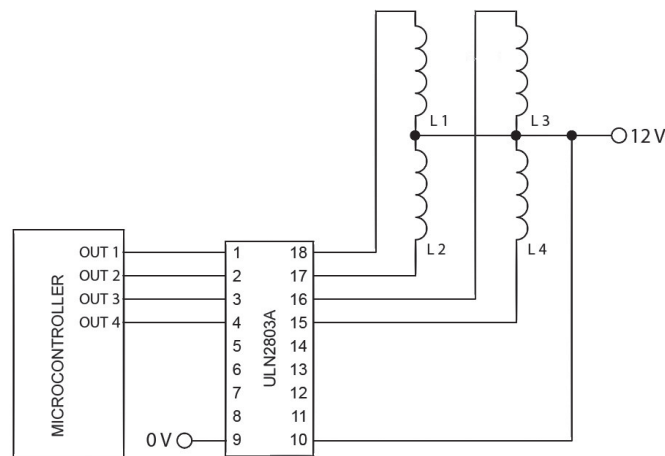
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Question 45

(16 marks)

The circuit diagram for controlling a unipolar stepper motor via a ULN 2803A Darlington driver integrated circuit is given below. Four outputs from a microcontroller are used to turn four coils on or off in a sequence of four steps that will cause it to rotate (see table below). This sequence is repeated to keep the stepper motor rotating e.g. for clockwise rotation, step 1 then 2 then 3 then 4, then return to 1 then 2 and so on. Forty-eight steps are required for one full rotation.

Step	L 1 OUT 1	L 2 OUT 2	L 3 OUT 3	L 4 OUT 4	Rotation	
					CW	ACW
1	1	0	1	0		
2	1	0	0	1		
3	0	1	0	1		
4	0	1	1	0		



- (a) Calculate the period of time that each step needs to be activated so that the speed of rotation is 50 revolutions per minute. Answer in milliseconds. (3 marks)
- (b) On page 47, use labelled flow chart symbols to design a system to control the stepper motor that meets the following specifications: (13 marks)
- when the program is started, all coils of the stepper motor are *low*
 - the condition of a switch, SW, is checked
 - if SW is not pressed, then all coils of the stepper motor remain *low*
 - if SW is **pressed** and then **released**, the stepper motor rotates **anticlockwise** at 50 rpm through an angle of 120°
 - the stepper motor will then switch off (all coils *low*)
 - a subroutine must be included in the flow chart to control the sequence of the four steps
 - the system must loop.

See next page

Start

Subroutine

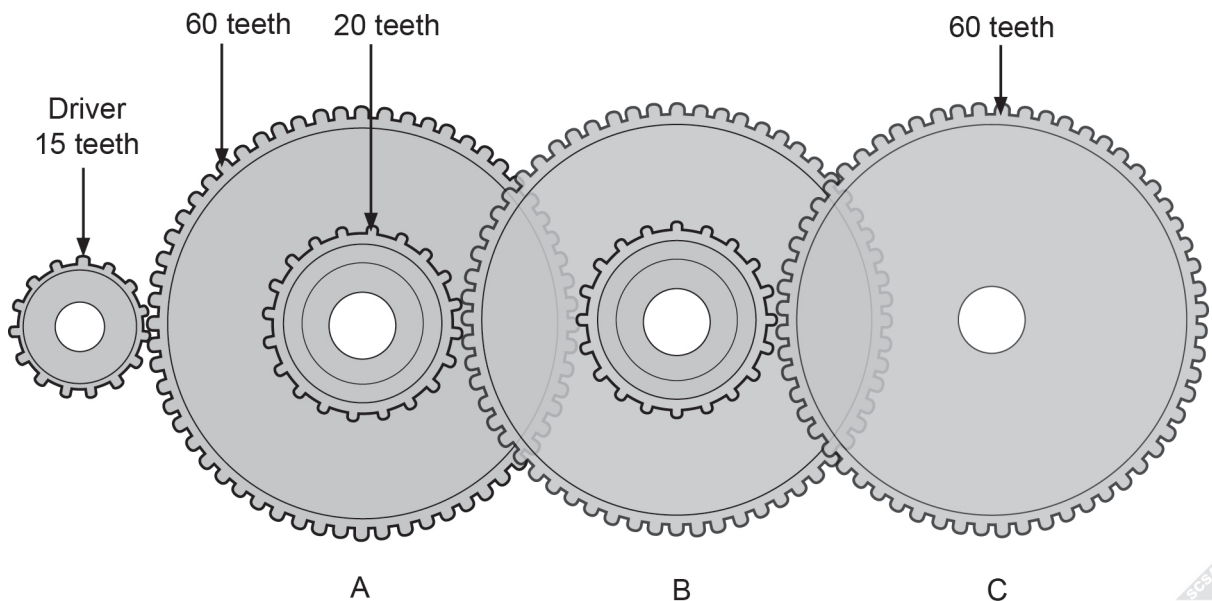
A spare copy of this diagram is provided on page 59 of this Question/Answer booklet. If you need to use it, cross out the attempt on this page.

See next page

Question 46

(13 marks)

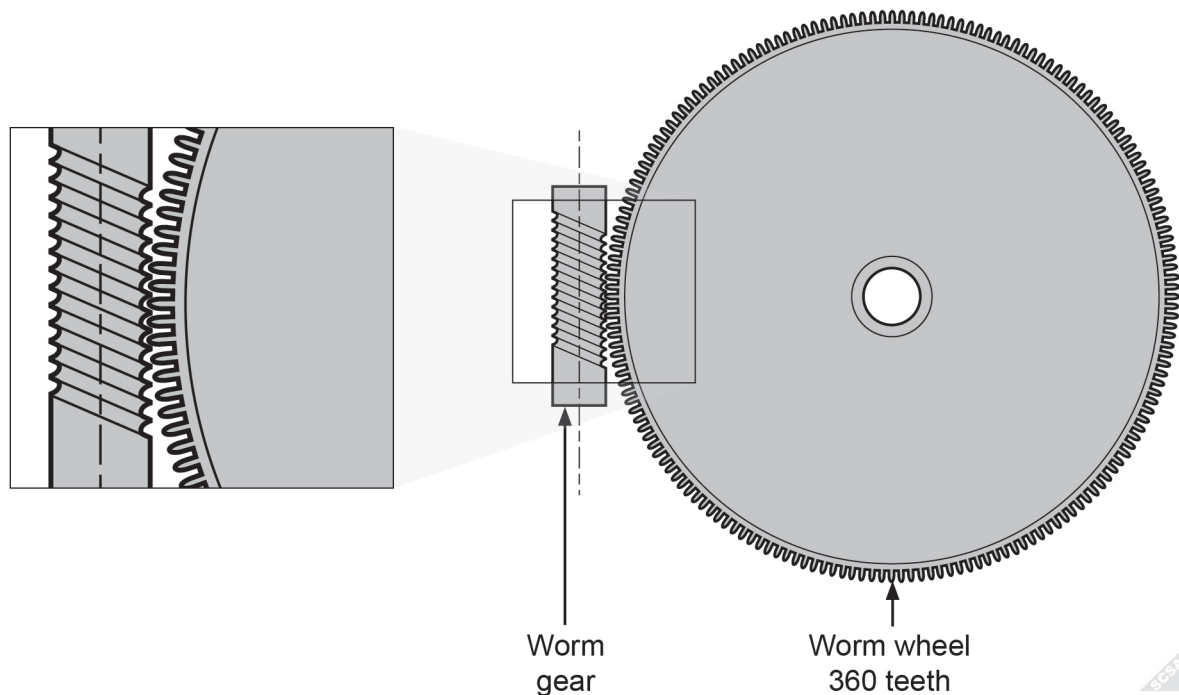
The rotating mount for a telescope requires a smooth and very slow-moving mechanism. To achieve this, an electric DC motor is connected to a compound gear drive that rotates a worm gear and then the worm wheel. The diagram below illustrates the compound gear drive system.



The DC motor is connected to a 15-tooth driver gear that meshes with Gear A. Gears A and B are identical and are both compound gears.

- (a) Calculate VR , the velocity ratio, of the compound gear drive. (3 marks)

Shown below is the worm gear and worm wheel section of the drive system. The worm gear is fitted to the shaft of Gear C of the compound gear drive. The worm wheel is fitted directly to the telescope and as it rotates, so too does the telescope.

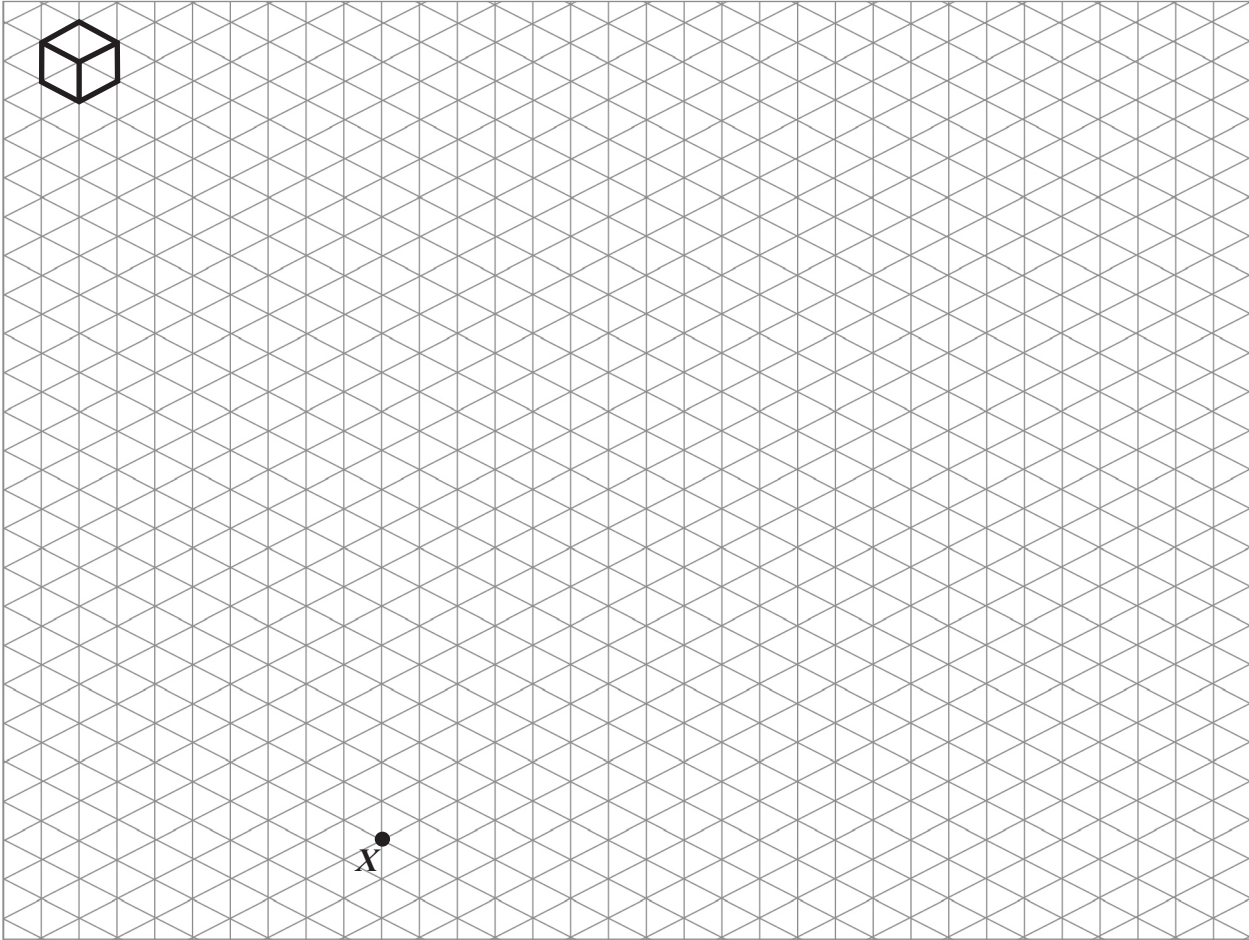


- (b) The input speed of the motor that is connected to the driver gear of the compound gear drive is 500 rpm. Calculate the output speed of the worm wheel. Assume 100% efficiency. If you were unable to obtain a value for part (a), use 42. (4 marks)
- (c) Calculate the time it takes for the telescope to rotate through 180° . If you were unable to obtain a value for part (b), use 0.06 rpm. Give your answer in seconds. (4 marks)

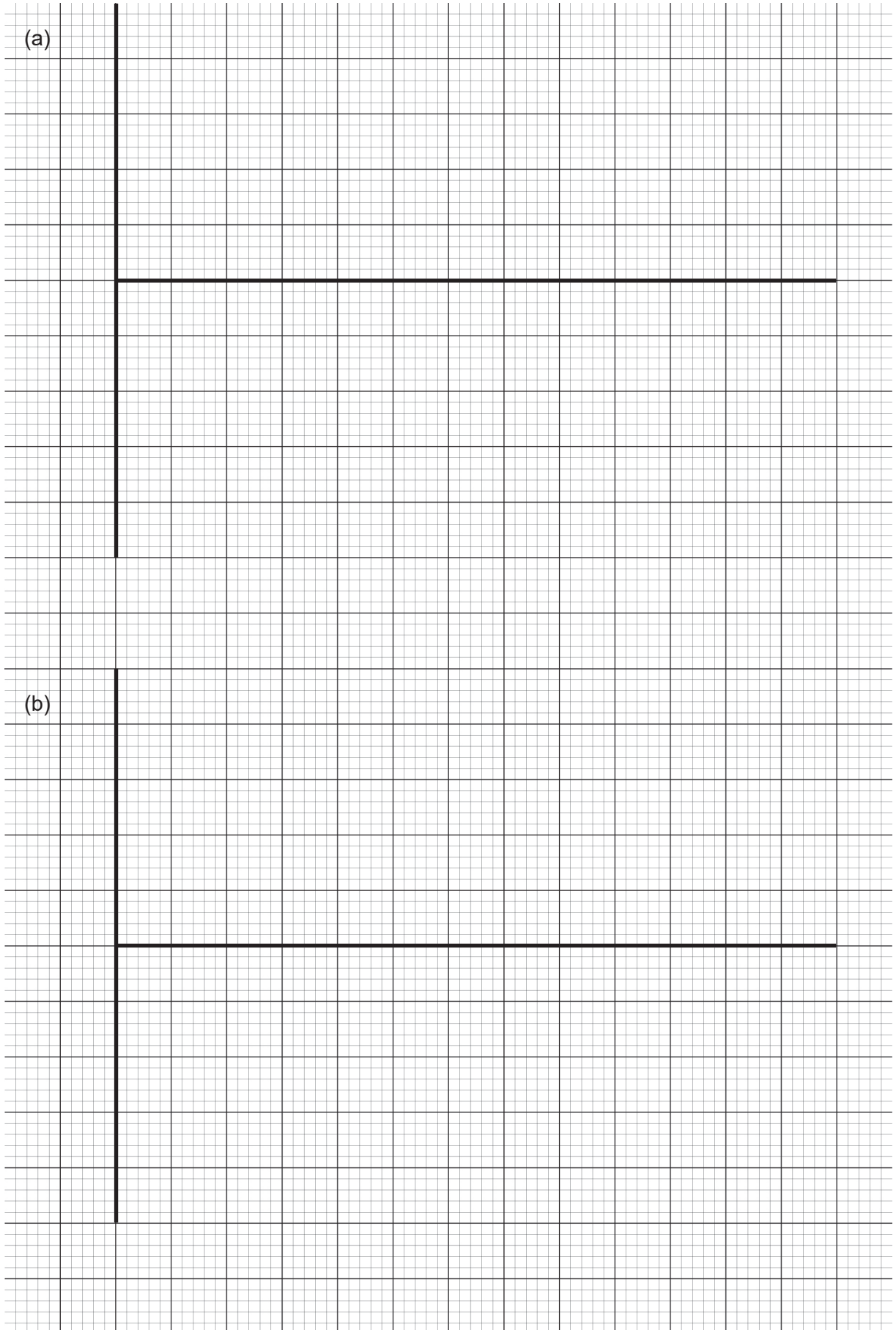
Question 46 (continued)

- (d) Can the worm wheel be used to rotate the worm gear? Explain your reasoning. (2 marks)

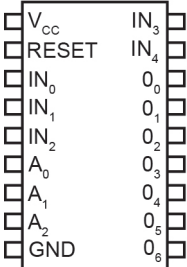
Spare grid



Spare grid



Spare microcontroller



Spare diagram

Start

Subroutine

ACKNOWLEDGEMENTS

Question 42

Photograph by courtesy of member of the examining panel.

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