Government of **Western Australia**
School Curriculum and Standards Authority

ATAR course examination, 2018

Question/Answer booklet

ENGINEERING STUDIES

Please place your student identification label in this box

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: 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.

Ref: 18-024

2018/64266
Web version of 2018/55838

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	68	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 2018*. 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.

Section One: Core content **40% (68 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 items listed below would be the **least** damaging to the environment if disposed in land fill?

(a) an old mobile phone battery that contains nickel/cadmium
(b) empty fruit, biscuit and chocolate tins that contain iron
(c) an old computer screen that contains lead
(d) a fluorescent tube that contains mercury

2. A mining company wishes to lay an underground gas pipeline between the towns of Newman and Karratha. Which of the following would be the first step the engineering consultant would need to consider in the planning process?

(a) test different types of pipeline materials to select a preferred option
(b) conduct staff training sessions on how to lay a pipeline
(c) perform an environmental and Indigenous heritage impact study on the proposed area the pipeline may affect
(d) produce a detailed construction application to submit to the Shire of East Pilbara and City of Karratha

3. An engineer wrote up a design specification for a mobile phone tower to be used on an offshore gas platform. The **most** important design consideration would be

(a) appearance.
(b) cost of materials.
(c) physical size.
(d) structural safety.

4. Which of the following metals is an alloy that **always** contains zinc?

(a) solder
(b) cast iron
(c) brass
(d) stainless steel

5. Trays for cooking cakes can be made from a silicone rubber. They are flexible, available in a wide range of colours and unaffected by the required cooking temperatures. What physical property of silicone rubber makes it suitable for this application?

(a) high melting point
(b) easily moulded
(c) low thermal conductivity
(d) easily coloured

6. Which of the following methods of energy production has the **least** impact on the local environment when used as a means of generating electrical energy?

(a) hydroelectric
(b) burning of hydrocarbons
(c) nuclear
(d) photovoltaic

7. Dimensional information used by designers so that products will suit the target population is sourced from the study of

(a) ergonomics.
(b) anthropometrics.
(c) economics.
(d) demographics.

8. The electrical energy used to determine the cost for electricity in industry and households is measured in which of the following units?

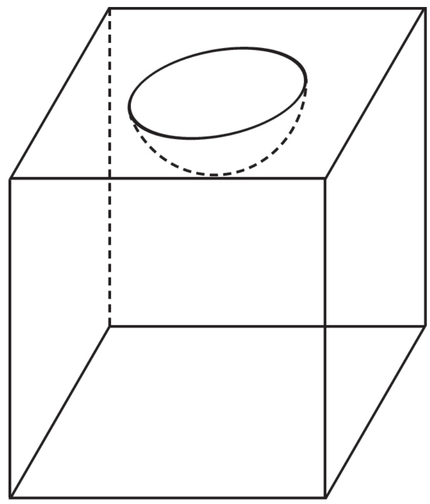
(a) kilojoules
(b) kilowatts
(c) kilojoule hours
(d) kilowatt hours

9. Most soft drink cans are made from aluminium. Which of the following is the **best** example of recycling aluminium cans from their manufacture to their disposal?

(a) melting the used aluminium cans and making new products from this material
(b) flattening them into aluminium sheets that are stored for later use
(c) collecting and storing all offcuts when manufacturing aluminium cans
(d) designing a manufacturing process for aluminium cans that uses the minimum of material and energy

10. An ornamental concrete pot consists of a cube with side lengths of 4r and a hemispherical hole with a radius of r in the top. Which of the equations below represents the volume of concrete required to cast the pot?

(a) $r^3(64 - \pi)$
(b) $r^3(64 - \frac{2}{3}\pi)$
(c) $(4r)^3 - 4\pi r^2$
(d) $(16r^3 - \pi r^3)$



Section One: Core content

Part B: Extended answer **30% (58 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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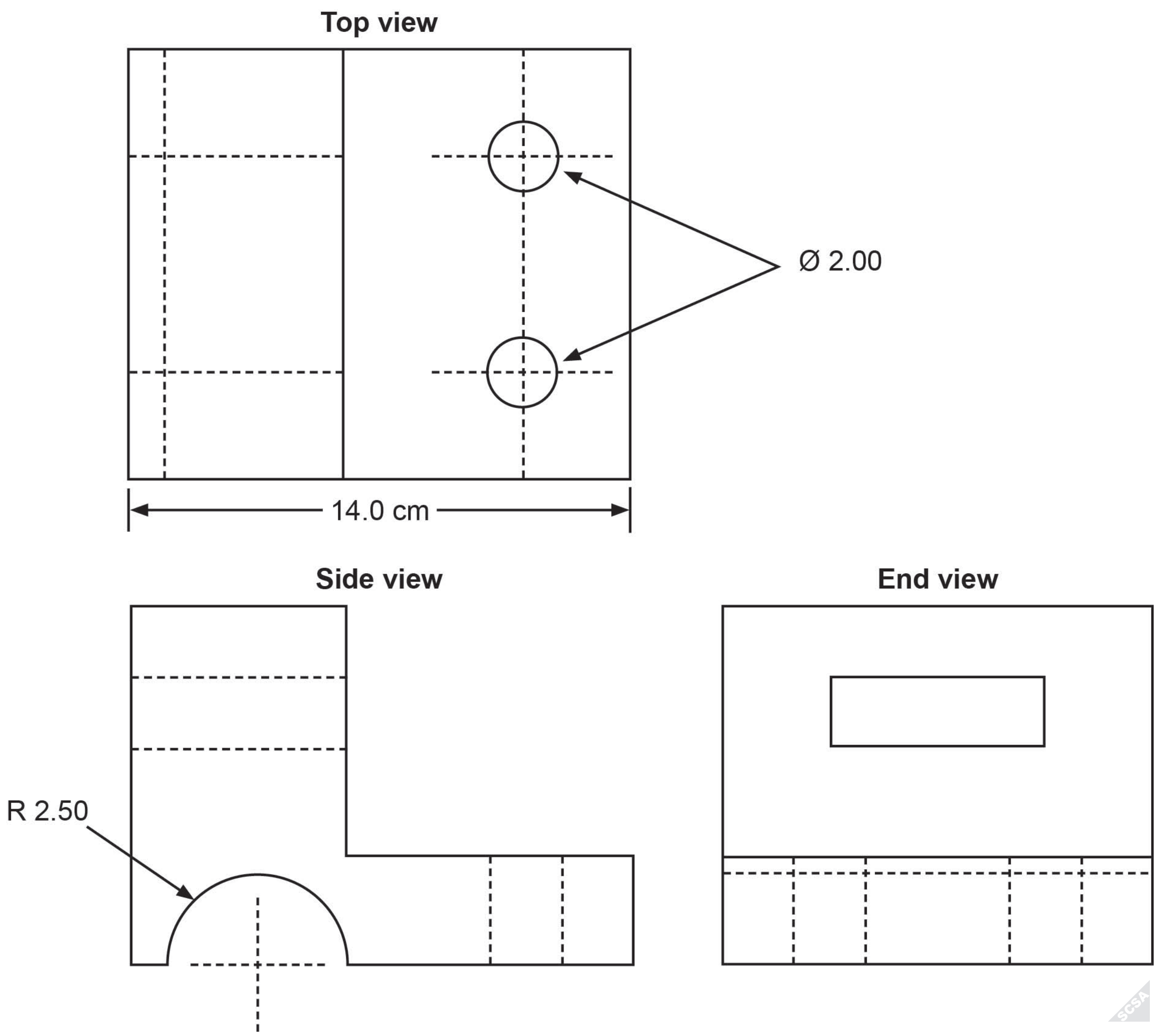
Question 11 **(15 marks)**

Below is a partially-dimensioned orthographic drawing of a plastic clamp manufactured on a 3D printer and drawn to a scale of 1:2. By using the information contained on this drawing and making the necessary measurements, you are required to draw a neat and accurately dimensioned pictorial drawing of the clamp as seen from the end view shown in the drawing. You must include a minimum of **four** correct external dimensions excluding any dimensions given. The grid is provided to assist. All measurements are in cm.



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

Question 12 **(12 marks)**

Complete the table below by naming the material you have studied this year that is **most** suitable for each of the given applications and give **one** reason why that material is fit for that purpose.

Application	Material	Fitness for purpose
frames and supports for solar panels		
tubing on the panels of solar hot water systems		
fibre optic cable		
lenses in protective glasses		
metal coating the surface of structural steel		
3D printer filament		

Question 13 **(17 marks)**

This question relates to the cable car shown in the picture to the left that crosses the valley above the rapids at Niagara Falls.

The cable car can carry 35 standing passengers and travels on six supporting steel cables each with a diameter of 25 mm. Each supporting cable spans between two terminals 540 m apart situated on either side of a deep valley. Each supporting cable has an overall length of 560 m. When the cable car is at either terminal, assume the length between terminals of each supporting cable is 540 m with the remainder attached to counterweights either side. The cable car is supported by two sets of double rollers per cable.

(a) Calculate the volume of metal in one of these cables. (3 marks)

(b) Determine the total mass of steel in all six cables. (3 marks)

Question 13 (continued)

At the start and end of each trip, the cables are 73 m above the water and when the cable car is midway between the terminals the cables are 60 m above the water. Assume there is no sag in the cables when the cable car is at either terminal.

(c) Calculate the length of each cable between the terminals when the cable car is centrally located across the gap. A diagram is required in your answer. (5 marks)

The cable car has a maximum weight of 7.00 tonnes when fully laden. It is hauled across the valley at an average speed of 7 km hr^{-1} using a 57 kW electric motor.

The six supporting cables are not fixed but connected to a 10 tonne steel counterweight at each end. This means that the tension in each supporting cable is constant regardless of the position of the cable car as the counterweights rise and fall as the cable car's position changes.

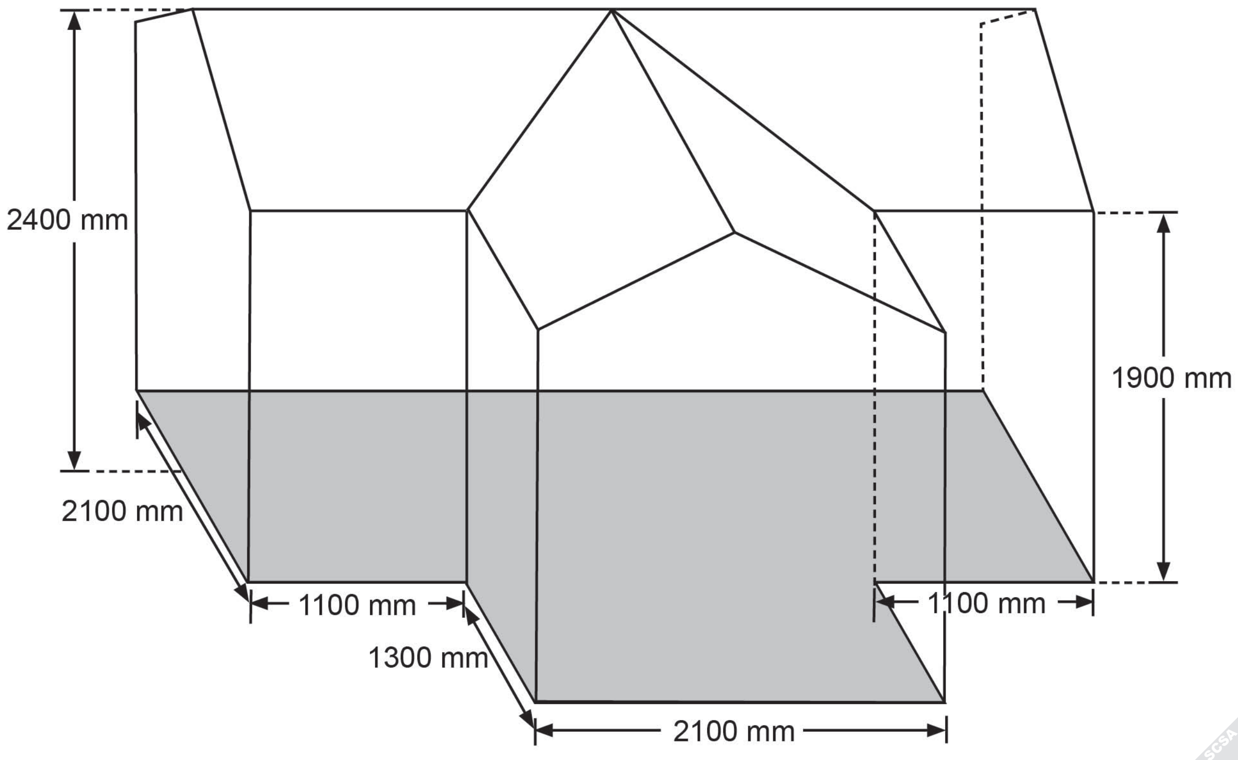
(d) Explain, including a relevant calculation, why each counterweight has a mass of 10 tonnes. (3 marks)

It takes the cable car 4.7 minutes to travel from one side of the valley to the other and the system is 75% efficient.

(e) Calculate the energy expended per round trip in joules. (3 marks)

Question 14 **(14 marks)**

A greenhouse is a building designed for growing plants. It is usually made of glass and supported by an aluminium frame.



wall height = 1900 mm
roof height = 2400 mm

(a) The glass and aluminium greenhouse is being set onto a 75 mm thick concrete pad which is the exact size of the footprint of the greenhouse. Calculate the volume of concrete required in cubic metres. (3 marks)

To secure the greenhouse in windy conditions it is tied down by a 5 mm diameter steel cable slung over each of the three gable ends.

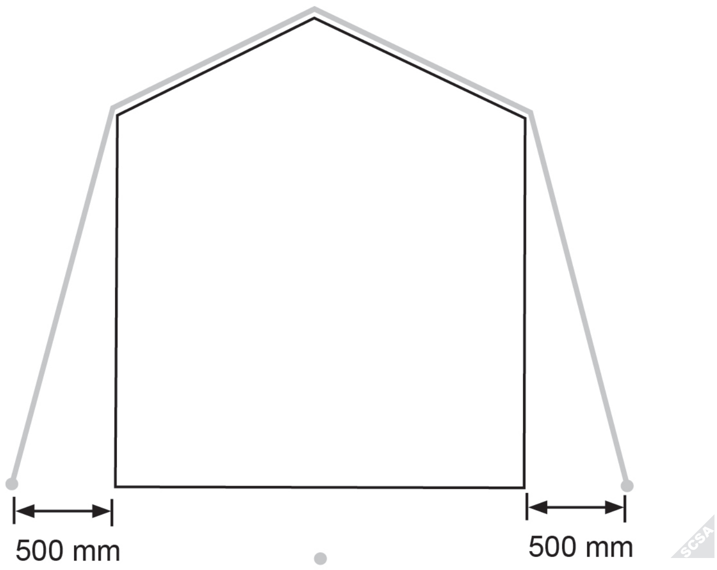
(b) Give **two** reasons why steel is the preferred material for securing the greenhouse. (2 marks)

One: ______________________________

____

Two: ______________________________

____



The cables are tied to pegs in the ground 500 mm from the base of the greenhouse.

(c) Calculate the total length of cable required for all three gable ends assuming that each cable needs an extra 100 mm in length to tie it to a peg on either side. (5 marks)

Question 14 (continued)

(d) When the greenhouse is no longer required state how the following materials can be disposed of and what happens to them if they are recycled.

(i) Glass (2 marks)

Disposal: ______________________________

____

Recycled: ______________________________

____

(ii) Concrete pad (2 marks)

Disposal: ______________________________

____

Recycled: ______________________________

____

End of Section One

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 2018.

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

Specialist field	✓	Question numbers	Pages
Mechanical	☐	15–30	**16–33**
Mechatronics	☐	31–46	**34–50**

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: 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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15. The energy absorbed by a material within the elastic range up to the yield point as measured by the area under the stress strain graph, is known as

    (a) yield energy.
    (b) elasticity.
    (c) toughness.
    (d) resilience.

16. When steel alloys are heated until they are molten and then poured into moulds, the process is known as

    (a) casting.
    (b) forging.
    (c) pressing.
    (d) drawing.

17. When a vehicle is being driven on a flat road, a force must be applied to overcome both air and rolling resistance. The system is said to be in equilibrium when the vehicle is

    (a) uniformly decelerating.
    (b) travelling at a constant velocity.
    (c) applying a force equivalent to its mass.
    (d) rolling with no force being applied.

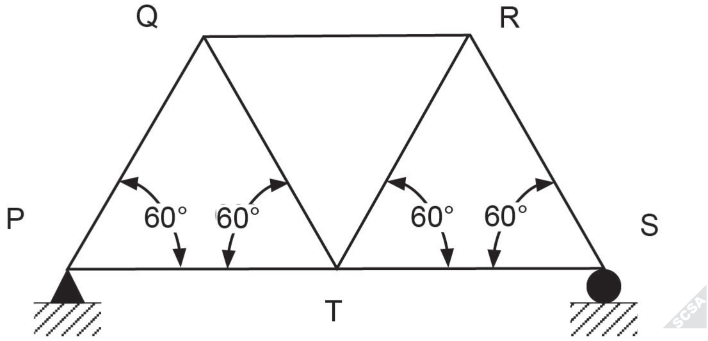
18. The ultimate tensile strength of a material is equivalent to its

    (a) breaking point.
    (b) toughness.
    (c) maximum stress.
    (d) stress strain graph slope.

19. The diagram below is a structural representation of a railway bridge crossing over a main road. All beams are of equal length and all angles are 60°.

Which of the sectional beams listed below under compression has the **least** compressive force when a train crossing the bridge is at the midpoint of the base of the bridge?

(a) PQ
(b) TS
(c) QR
(d) QT



20. You have four identically-dimensioned solid triangular prisms each made of one of the following materials:

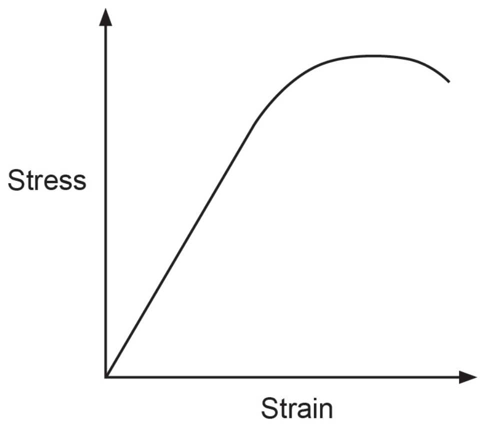
copper
polypropylene
zinc
polycarbonate.

Determine the material used to make the prism with the **least** weight.

(a) copper
(b) polypropylene
(c) zinc
(d) polycarbonate

21. The graph below represents the stress versus strain for a particular material under increasing tension. The behaviour of this material when an increasing load is applied varies greatly in two regions. Which of the following statements **best** describes these two regions?

(a) extension region followed by a failure region
(b) elastic region followed by a plastic region
(c) stress region followed by a strain region
(d) plastic region followed by an elastic region



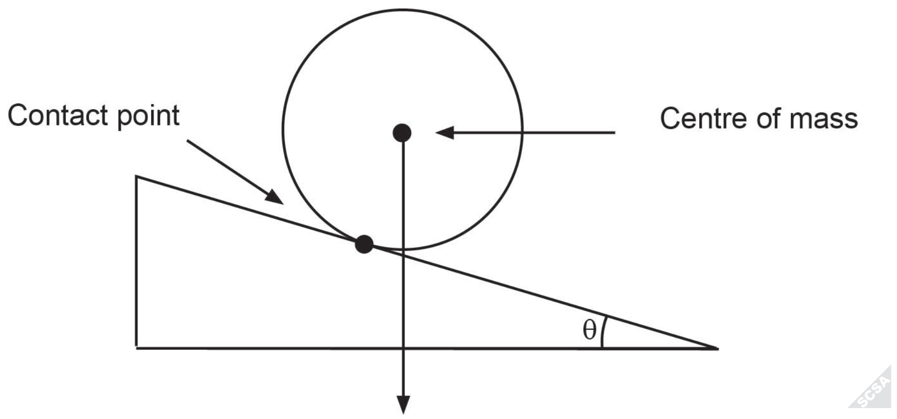
22. A manufacturer of metal rods receives an order for rods with a specified hardness. The hardness of a test sample of these rods can be determined by

(a) the depth of the indent made when it is hit with a sharp metal punch.
(b) the amount of energy absorbed when the sample is fractured.
(c) how ductile it is when it is drawn into a wire.
(d) its increase in length when a known stress is applied along its length.

23. A machining process is used by a precision engineering company to manufacture high-tensile stainless steel bolts with a nominal diameter of 25.0 mm. The accepted tolerance for their diameter is 0.02 mm. What does the term 'tolerance' mean in this situation?

(a) This is the most the diameter of these bolts can change when heated or cooled.
(b) Any bolt outside of the range 24.98 mm to 25.02 mm will need to be re-machined to correct the error.
(c) Any nut to be fitted to a bolt outside of the range 24.98 mm to 25.02 mm must be out of tolerance by the same amount.
(d) Any bolt with a diameter outside of the range 24.98 mm to 25.02 mm will be rejected.

24.



The torque about the point where a roller with mass m and radius r touches the ramp is equivalent to

(a) mgr.
(b) mgCosθ.
(c) mgr/Cosθ.
(d) mgrSinθ.

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.

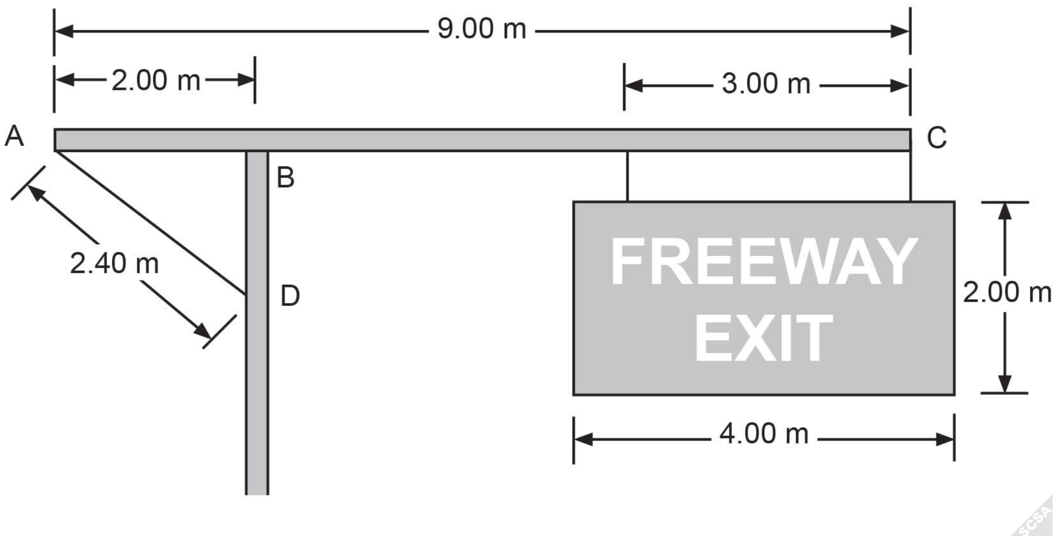
Supplementary pages for planning/continuing your answers to questions are provided at the end of this Question/Answer booklet. If you use these pages to continue an answer, indicate at the original answer where the answer is continued, i.e. give the page number.

Question 25 **(22 marks)**

The diagram below is of a large sign of an exit lane from a freeway. The sign is painted on a zincalume steel sheet which is strengthened by a steel frame constructed from galvanised tube steel attached to the rear side. The centre of mass of the sign and frame is in the centre of the sign.

Two lengths of the same galvanised tube steel are an equal distance from each end of the sign and 3.00 m apart. They are welded to both the frame and the horizontal support beam to support the sign, as shown in the diagram below. The total mass of the sign and its support frame is 60.0 kg. The left-hand side of the horizontal steel beam is supported by a 2.40 m long stainless steel cable attached to the vertical support pole and the end of the horizontal beam.

The horizontal support beam is uniform and is made from a 9.00 m length of solid rectangular structural steel. It has a mass of 148 kg and its cross-sectional dimensions are 70.0 mm high and 30.0 mm wide. The vertical support is 100 mm steel square tube.



Question 25 (continued)

(a) How far from the top of the vertical support is the stainless steel cable AD attached? (2 marks)

(b) Calculate the second moment of area for this horizontal beam. (3 marks)

(c) Calculate the maximum bending moment of the beam at B before the sign is attached. (Assume the section AB remains horizontal and there is no significant bending in the vertical support.) (4 marks)

(d) Calculate the maximum deflection of the beam at C before the sign is attached. (Assume the section AB remains horizontal and there is no significant bending in the vertical support.) (4 marks)

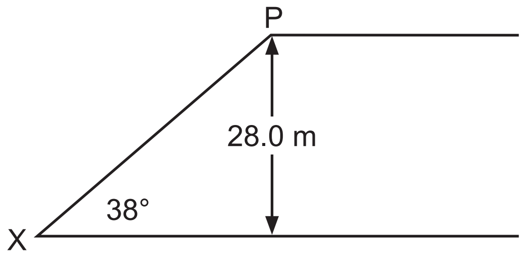
Consider the sign as a point load acting on the horizontal beam at a point directly above its centre of mass.

(e) Calculate the maximum deflection of the beam at C when the sign is attached. (Assume the section AB remains horizontal and there is no significant bending in the vertical support.) If you were unable to obtain a value for part (d), use 0.0500 m. (4 marks)

(f) Calculate the tension in the cable AD assuming the beam AC is horizontal. (5 marks)

Question 26 **(15 marks)**

The diagram below shows the ramp XP on which a roller-coaster car is moved. The starting platform of the ride begins at the point P, 28.0 m above the ground. To reach the starting platform at P the car of the roller-coaster is driven up the ramp XP at a constant velocity of 0.720 m s^{-1} using an electric motor, gears and steel cables. The ramp XP makes an angle of 38° to the horizontal.



(a) Calculate the length of the ramp XP. (2 marks)

(b) Calculate the time it takes for the roller-coaster car to travel from X to P? (2 marks)

(c) A person in the roller-coaster car when stationary at point P dropped a 150 g chocolate bar. How long would the chocolate bar take to hit the ground, assuming that it fell from the person's hand when it was 28.5 m above the ground? (Ignore air resistance.) (3 marks)

The mass of the roller-coaster car and passengers is 1600 kg and the frictional force between the track and the car is 15% of the weight.

(d) Calculate the frictional force between the track and the car. (2 marks)

The force needed to move the car up the slope at a constant velocity is the sum of the force against gravity and the frictional force. The force against gravity is calculated using the formula below.

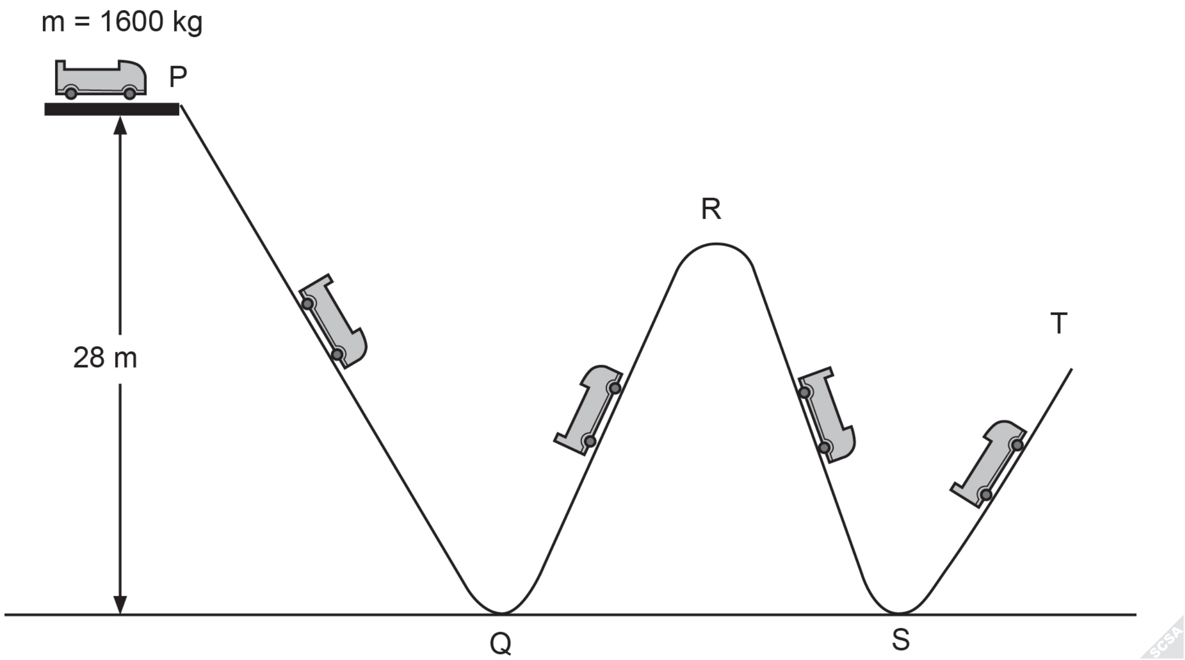
$$F = mg\text{Sin}\theta, \text{ where } \theta \text{ is angle of the ramp.}$$

(e) Using this information calculate the force the motor must apply to the car to move it up this slope at a constant velocity. (4 marks)

(f) Determine the power rating of the motor used to achieve this task, if it is 80% efficient. If you were unable to obtain a value for part (e), use 11 000 N. (2 marks)

Question 27 **(18 marks)**

The diagram below shows the path of the roller-coaster car for the initial part of the track. After the car is released from its stationary position at P, it has no mechanism driving it.



(a) Indicate the direction of the acceleration on the roller-coaster car in each of the following regions by circling the correct answer either up or down. (2 marks)

R to S	up	down
S to T	up	down

(b) Explain the reasoning you used to choose your answer for the region S to T in part (a) above. (2 marks)

(c) Calculate the speed of the roller-coaster car at point Q, assuming there is no energy losses between P and Q and PQ is a straight line. (3 marks)

(d) Calculate the amount of energy ‘lost’ by the roller-coaster car between P and Q if its actual speed at Q is 20.6 m s^{-1}. (2 marks)

(e) With regard to this ‘lost’ energy:

(i) state the form of energy into which most of it is transformed. (1 mark)

(ii) state where this transformed energy immediately goes. (1 mark)

(f) Determine the proportion of the roller-coaster car’s potential energy ‘lost’ by the time it reaches point Q? (4 marks)

(g) If this same proportion of energy is ‘lost’ as kinetic energy between Q and R, determine the maximum height of R above Q. If you were unable to obtain a value for part (f), use 25%. (3 marks)

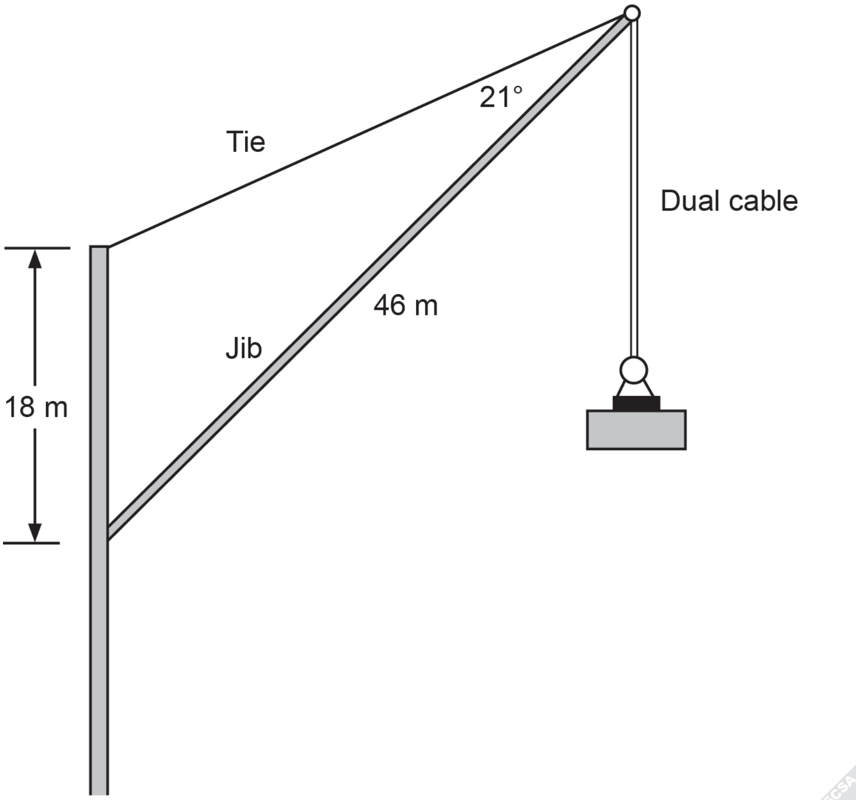
Question 28 **(17 marks)**

The picture on the right shows a jib crane used to lift sea containers between a wharf and container ships.

The containers are lifted using a steel clamp assembly attached to a pulley with two lifting cables. The clamp assembly is locked securely onto the container before it is lifted.

The containers lifted by the crane have dimensions of 6.00 m long, 2.45 m high and 2.40 m wide. They each have a mass of 2300 kg empty and a maximum load capacity of 25 000 kg.

The diagram below is a simplified representation of this jib crane and is to be used in answering this question.



The jib is uniform, weighs 4500 kg and is 46.0 m long. The tie is a steel cable and is connected to the vertical 18.0 m above the connection of the jib, as shown in the diagram above. The angle between the tie and the jib is 21°.

(a) Name the structural part of this crane that will be under compression. (1 mark)

____

(b) Determine the minimum radius of each of the steel lifting cables needed to lift a container filled with its maximum weight just before each cable undergoes plastic deformation.
(6 marks)

(c) Using 540 mm^2 as the cross-sectional area for each steel lifting cable, determine the mass of the load that would need to be attached to cause these cables to break if an attempt was made to lift the container. (4 marks)

Question 28 (continued)

A factor of safety of 10 is required in the lifting cables, making their actual diameter 83 mm when not under load.

(d) State **two** situations that could arise in lifting a load requiring a factor of safety to be applied to the steel lifting cables. (2 marks)

One: ______________________________

Two: ______________________________

A container with a total weight of 176 000 N was attached to the clamp on the end of these 83 mm diameter cables and all slack in the cables was taken up prior to beginning the lift. At this point, each of the steel lifting cables was tight but not under tension and each was 40.0 m long.

(e) Calculate the increase in length of each steel lifting cable under this load at the point the container just started to rise from the wharf. (4 marks)

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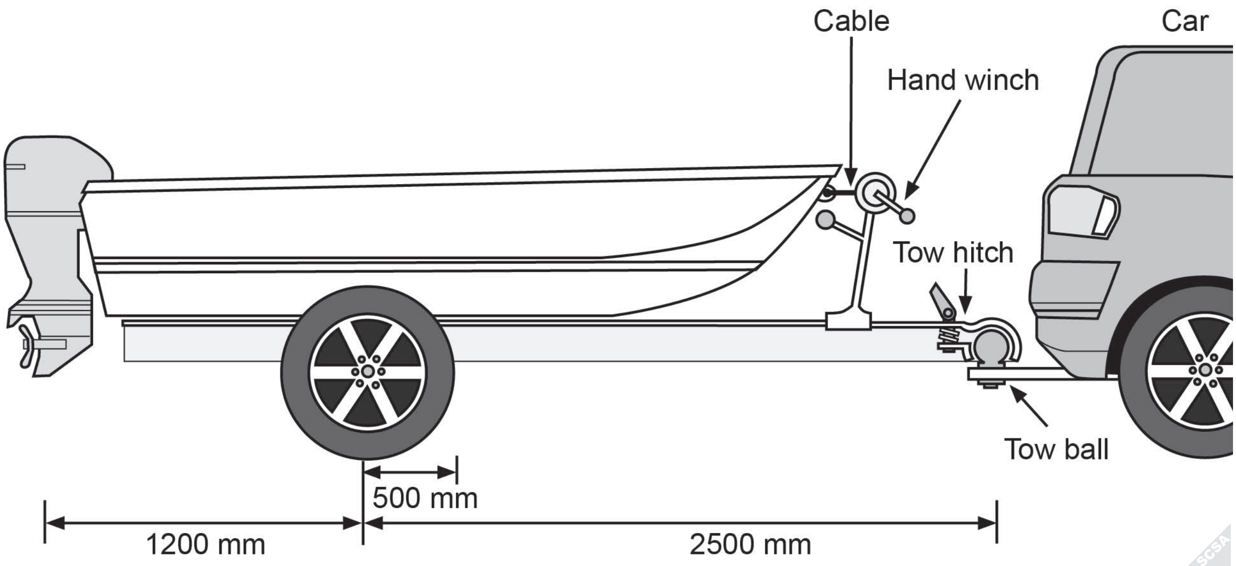
Question 29 **(12 marks)**

A trailer is designed to transport a small boat behind a car. The trailer must be able to withstand being partially submerged while the boat is being launched and retrieved from the water.



The centre of mass of the boat motor is 1.20 m behind the centre of the wheel.
The centre of mass of the boat and trailer alone is 0.500 m in front of the centre of the wheel.
The mass of the boat is 400 kg.
The mass of the trailer is 140 kg.
The mass of the motor is 112 kg.

The front of the trailer that connects to the tow ball of the car is 2.50 m in front of the centre of the wheel.

(a) Calculate the downward force on the tow ball of the car when the trailer with boat and motor are attached to the car. The tow ball is the contact point between the boat trailer and the car. (4 marks)

(b) The power output of a boat motor is almost exclusively measured using the unit of Horsepower (Hp). Given the power of this motor is 60 Hp, convert this into kilowatts given 1 Hp = 746 W. (1 mark)

Answer ______________________ kW

The boat is pulled onto the trailer using a cable attached to a hand winch at the front of the trailer.

The boat trailer is at an incline of 20° to the horizontal and the cable is parallel to the trailer.

(c) Calculate the tension in the cable when it is parallel to the trailer. You are required to give the correct units in your answer. (4 marks)

(d) Suggest a suitable material for construction of the trailer. Give **two** reasons why this material was chosen. (3 marks)

Material selected: ____

One: ____

____

Two: ____

____

Question 30 **(16 marks)**

A drone is an unmanned aircraft guided by remote control. Most common drones have downward-facing propellers that enable the craft to hover or move in any direction.

A commercially-available drone used for photography has the following specifications:

- four motors with propellers
- mass 734 g
- maximum ascent speed 5.0 m s^{-1}
- maximum controlled descent speed 3.0 m s^{-1}
- maximum horizontal speed 65 km hr^{-1}
- maximum flight time 27 minutes
- maximum range 13 km
- battery capacity 3830 mAh, 43.6 Wh
- camera field of view angle 78.8°.

(a) Calculate the upward force required by each motor to enable the drone to hover at a constant height. Assume the drone does not lose any power during the flight and there are no external wind factors. (3 marks)

(b) Using the maximum ascent, controlled descent and flight times, calculate the maximum height to which the drone can fly. Ignore any acceleration or deceleration effects. (4 marks)

(c) Calculate the total time that the drone would take to ascend to 100 m, fly to the maximum range, return and perform a controlled descent to the ground, all at maximum speed. (Assume maximum speed is reached immediately on lift-off.) (6 marks)

(d) The drone's camera is pointed vertically downward and takes square photographs. Calculate the surface area of land that it could photograph at a height of 100 m, given that a field of view of 78.8° means the angle of view to the vertical is 39.4°. (3 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. A 3 pin IC marked with the symbol 7805 is a

(a) microcontroller chip.
(b) 5V voltage regulator.
(c) NPN transistor.
(d) 7805 Ω variable resistor.

32. Which of the following is used for temperature sensing?

(a) ultrasonic device
(b) thermistor
(c) LDR
(d) buzzer

33. What would be the **best** way to drive a 10 A DC load in a microcontroller-based control system?

(a) relay
(b) directly from the microcontroller’s output
(c) NPN transistor
(d) resistor

34. What does ‘ALU’ stand for?

(a) adding logic unit
(b) all logic unit
(c) arithmetic logic unit
(d) action logic unit.

35. What is the **best** method of transmitting power from one shaft to another when their axes are at 90° to each other?

(a) belt drive
(b) chain drive
(c) crank and slider
(d) gear drive

36. In which of the following types of capacitors does the orientation in the circuit matter?

(a) ceramic
(b) mica
(c) electrolytic
(d) vacuum

37. What is the gear ratio of a two-stage gearbox with a X:1 stage one and a Y:1 stage two?

(a) XY:1
(b) $\frac{1}{X} + \frac{1}{Y}$:1
(c) $\frac{Y}{X}$:1
(d) X + Y:1

38. Which of the following is **best** for converting rotary motion into reciprocating motion?

(a) crank and slider
(b) worm gear and worm wheel
(c) compound gear drive
(d) chain and sprockets

39. If a 5 V and 10 V battery are mistakenly connected in parallel and a voltmeter is used to measure the voltage a short time later, it will show

(a) the sum of the two voltages.
(b) the difference of the two voltages.
(c) a voltage in between the two voltages.
(d) just under 10 V.

40. What is the smallest change in voltage a 16-bit ADC chip with an input voltage ranging from 0 V to 10 V will detect?

(a) 0.03906 V
(b) 0.62500 V
(c) 0.00244 V
(d) 0.00015 V

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

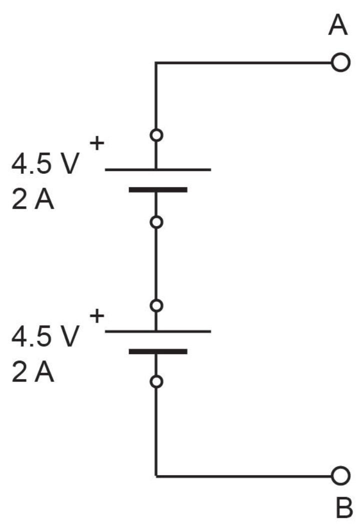
This section has **six** questions. Answer **all** questions. Write your answers in the spaces provided.

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 **(13 marks)**

The circuit below is that of a battery pack made from two 4.5 V cells.

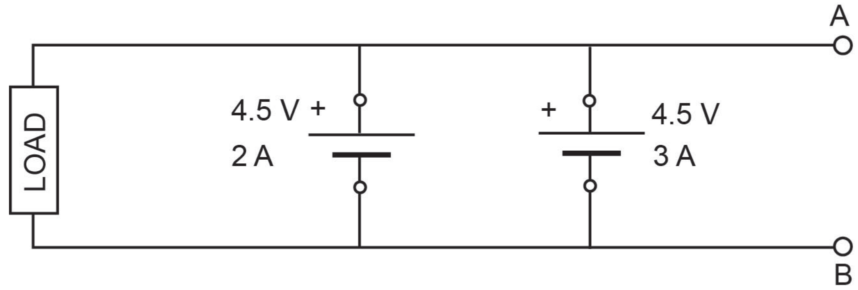


(a) Calculate the voltage and the current capacity of this battery pack at the outputs AB. (2 marks)

Voltage

Current

A second battery pack is made using three cells. Two of these are 4.5 V cells, with a third cell to be added between the points A and B as shown below.



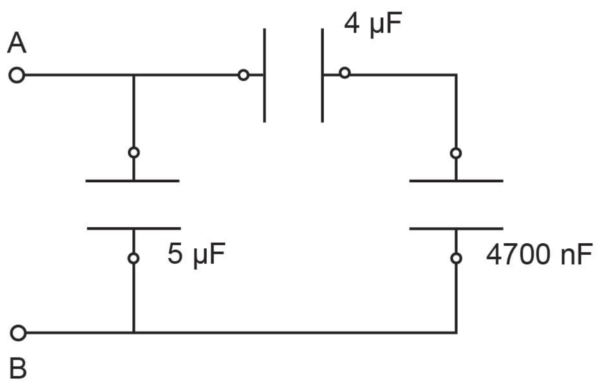
(b) Determine the voltage and current capacity this cell would need to have so that this battery pack could supply 6 A at 4.5 V to the load? (2 marks)

In the parallel circuit diagram of the battery pack above, one cell is rated at 50 Ah and the other at 30 Ah. The load needs to operate for 100 hours, drawing a continuous current of 1.2 A with an 80% duty cycle.

(c) Calculate the minimum Ah that the third cell connected between A and B must have to achieve this. (4 marks)

Question 41 (continued)

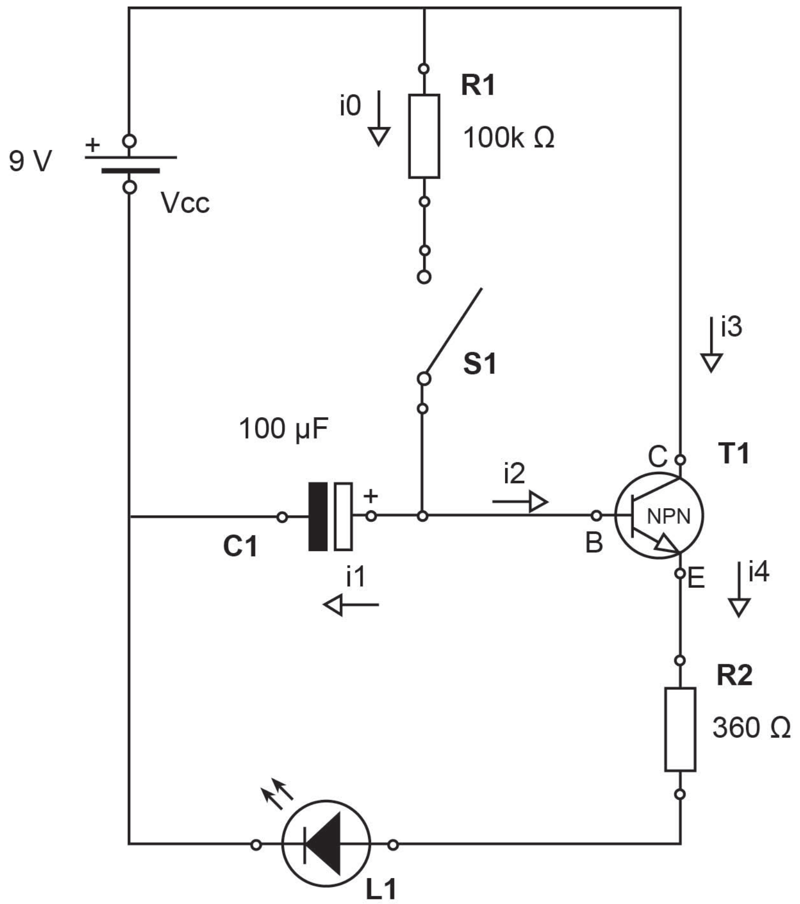
(d) Calculate the total capacitance across AB in the circuit below. (3 marks)



(e) Calculate the value of the capacitor required to bring the total capacitance between A and B in the circuit above to 10 μF and correctly draw it into the circuit in part (d). (2 marks)

Question 42 **(15 marks)**

This question refers to the circuit below. The circuit is initially in the state pictured.



(a) Complete the table below identifying the components in the circuit. (6 marks)

Diagram label	Component
Vcc	
T1	
C1	
L1	
R1	
S1	

Question 42 (continued)

(b) Determine the initial value of the current i0 with S1 open. (1 mark)

(c) Explain what happens to the current i1 and i2 over time when the switch S1 is closed. (2 marks)

(d) Explain what happens to the mode of T1 when the switch S1 is closed? (2 marks)

(e) If C1 was reduced, what effect would this have on L1? State the reason for your answer. (2 marks)

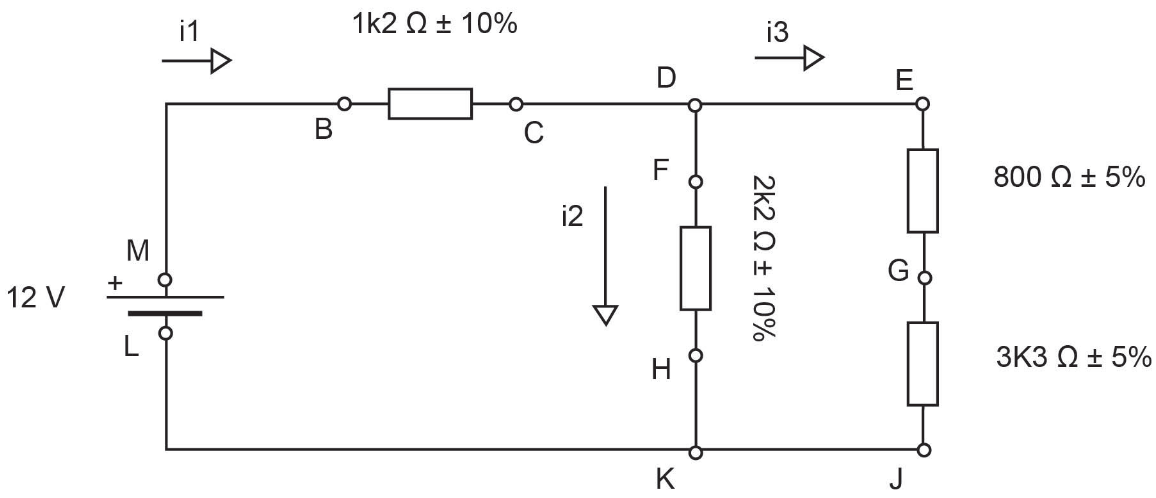
Effect:

Reason:

(f) With reference to voltages V_E, V_B and V_C, how can we determine that T1 cannot go into saturation mode? (2 marks)

Question 43 **(19 marks)**

This question refers to the circuit below.



(a) Explain how you would measure the current flowing from the voltage source into the 1k2 Ω resistor. (3 marks)

Question 43 (continued)

(b) Calculate the **maximum** possible total resistance of the circuit. (7 marks)

(c) Calculate the **minimum** possible total resistance of the circuit. (7 marks)

(d) Calculate the **maximum** possible current flowing at i1. If you were unable to obtain an answer for part (c), use $R_{T\ MIN}$ = 2 600 Ω. (1 mark)

(e) Calculate the **maximum** possible power dissipated by the 1k2 Ω resistor. If you were unable to obtain an answer for part (d), use $i1_{MAX}$ = 4.6 mA. (1 mark)

Question 44 **(12 marks)**

(a) Name **one** advantage and **one** disadvantage of an open loop control system. (2 marks)

Advantage: ___

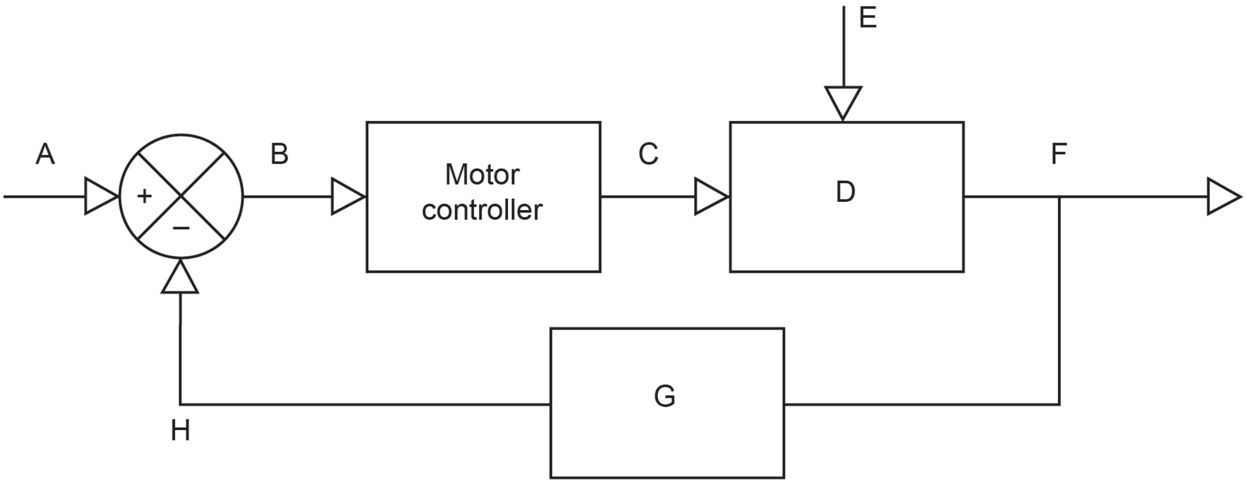
Disadvantage: ___

(b) Name **one** advantage and **one** disadvantage of a closed loop control system. (2 marks)

Advantage: ___

Disadvantage: ___

Below is a diagram of a control system for a DC motor that must run at a desired input speed.



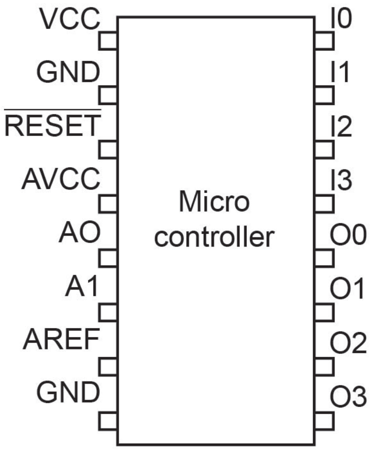
(c) Complete the table below by identifying what should be at each of the labelled locations of the control system above. (8 marks)

Diagram label	Description
A	
B	
C	
D	
E	
F	
G	
H	

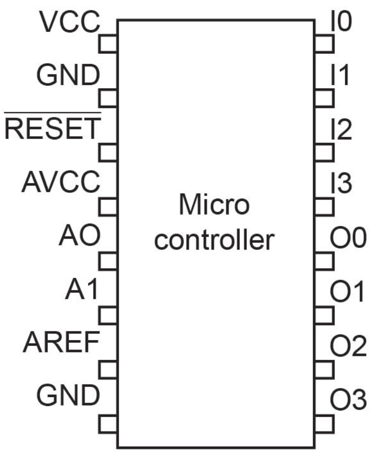
Question 45 **(27 marks)**

The following question uses a standard microcontroller chip diagram with common pins displayed. Communication pins have been removed for clarity. In each part you will need to complete the wiring diagram that would give your system the required functionality.

(a) The control system below will use a N/O switch S1 as an input that will later be programmed to turn on a motor. It will also have a N/C switch S2 connected as an input that will be programmed to be used for directional control of a motor. Draw the wiring diagram for this below. The input pins have internal pull up resistors that can be assumed to have been programmed to be on. (4 marks)



(b) The control system below will use an output to turn on a LED L1 with a resistor R1 in series. This will later be programmed to turn on when the motor is running. Draw the wiring diagram for this below. (4 marks)

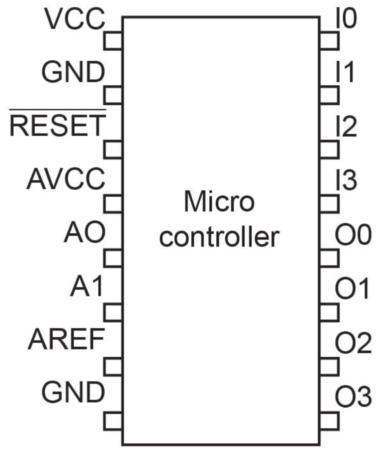


A spare standard microcontroller chip diagram is provided at the end of the Question/Answer booklet. If you need to use it, cross out the attempt above.

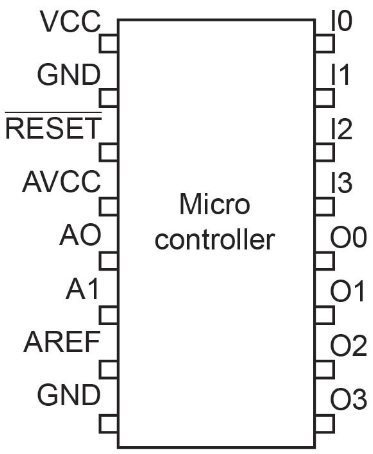
Question 45 (continued)

The voltage regulator data sheet is to be used to answer Question 45 part (c).

(c) Use the diagram below to draw a voltage regulator circuit to take a 9 V battery and provide the microcontroller with the 5 V supply it requires. (7 marks)



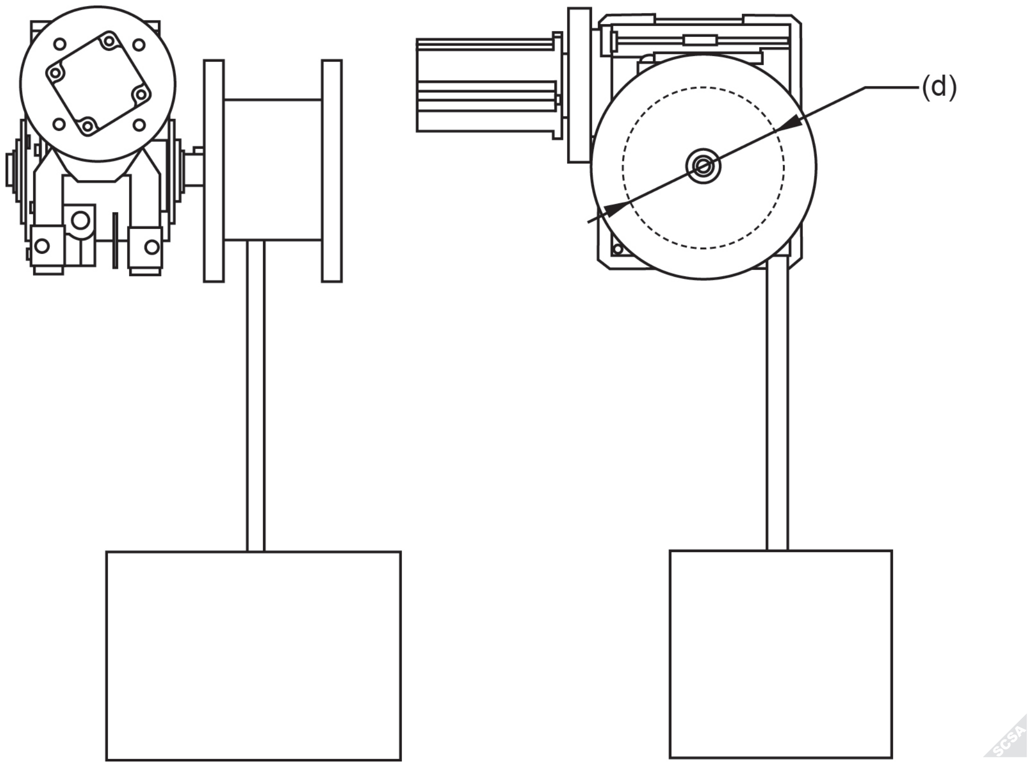
(d) The controller will use an output for a DPDT relay Y1, which will be used as a H bridge that will drive a motor M1 from a separate 10 A 24 V DC source. It will also use a SPDT relay Y2 triggered by an output to turn the motor power off and on. Draw this configuration, using the diagram below. (12 marks)



A spare standard microcontroller chip diagram is provided at the end of the Question/Answer booklet. If you need to use it, cross out the attempt above.

Question 46 **(14 marks)**

An electric motor drives a gearbox connected to a winch that is being used to lift the weight pictured below. The gearbox has a ratio of 35:1 and the effective diameter of the winch (d) is 0.20 m. Assume there are no losses in the system.



(a) When the motor is rotating at 300 rpm, how fast is the winch rotating? (1 mark)

(b) If the motor is rotating at 300 rpm, how fast is the weight rising? If you did not get an answer for part (a), use 9 rpm. (3 marks)

(c) At what rate does the motor need to spin for the weight to rise at 0.10 m s^{-1}? (3 marks)

(d) For what period of time does the motor need to spin at 300 rpm for the weight to have risen 1.20 m? If you did not get an answer for part (b), use 95 mm s^{-1}. (3 marks)

Question 46 (continued)

(e) If the velocity ratio is 1.01 and the distance moved by the load is 1.30 m, calculate the distance moved by the effort. (1 mark)

(f) If the effective diameter of the output shaft of the gearbox is 20 mm does the winch or the gearbox have greater mechanical advantage in this system? Circle either winch or gearbox and then explain your answer. (3 marks)

winch or gearbox

Explanation: ____________________

____

____

____

____

End of Mechatronics Section

End of questions

Supplementary page

Question number: ____________

Supplementary page

Question number:

Supplementary page

Question number: ________________

Supplementary page

Question number: ____________

Supplementary page

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Supplementary page

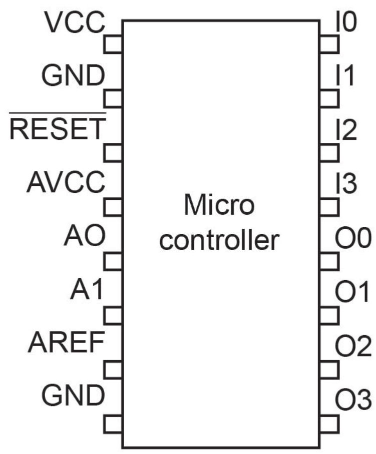
Question number: __________

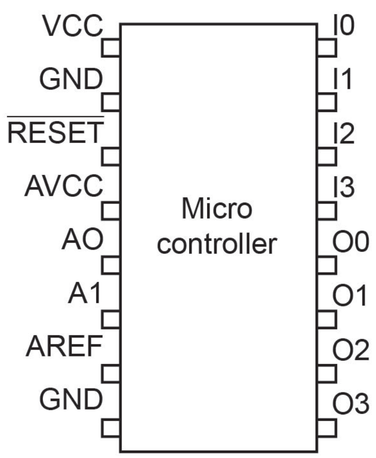
Supplementary page

Question number: ____________________

Spare grid

Spare standard microcontroller chips





ACKNOWLEDGEMENTS

Question 13	Photographs by courtesy of member of examining panel. Cable car information from: Whirlpool Aero Car. (2017). In *Wikipedia*. Retrieved May, 2018, from https://en.wikipedia.org/wiki/Whirlpool_Aero_Car Used under Creative Commons Attribution-ShareAlike 3.0 Unported licence.
Question 28	Photograph by courtesy of member of examining panel.
Question 45(c)	Data sheet adapted from: Fairchild Semiconductor. (2001). *MC78XX/LM78XX/MC78XXA 3-terminal 1A positive voltage regulator* (fig. 5, fig. 9, p. 10, p. 5, p. 2). Retrieved May, 2018, from http://uk.rs-online.com/webdocs/0f85/0900766b80f85ea6.pdf

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