



Western Australian Certificate of Education Examination, 2014

Question/Answer Booklet

ENGINEERING STUDIES

Stage 3

Please place your student identification label in this box

Student Number: In figures

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In words

Time allowed for this paper

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

Materials required/recommended for this paper

To be provided by the supervisor

This Question/Answer Booklet
Multiple-choice Answer Sheet
Data Book

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

Systems and Control	<input type="checkbox"/>
Mechanical	<input type="checkbox"/>
Electronic/Electrical	<input type="checkbox"/>

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 the WACE examinations

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 notes or other items of a non-personal nature in the examination room. 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 exam
Section One: Core content					
Part A: Multiple-choice	10	10	70	10	10
Part B: Extended answer	3	3		45	30
Section Two: Systems and control					
Part A: Multiple-choice	10	10	110	10	10
Part B: Extended answer	4	4		100	50
Section Two: Mechanical					
Part A: Multiple-choice	10	10	110	10	10
Part B: Extended answer	4	4		100	50
Section Two: Electronic/electrical					
Part A: Multiple-choice	10	10	110	10	10
Part B: Extended answer	4	4		100	50
				Total	100

Instructions to candidates

- The rules for the conduct of Western Australian external examinations are detailed in the *Year 12 Information Handbook 2014*. 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 (1)** of the specialist fields. In the specialist field you have chosen, answer **all** questions.
In both Section One and Section Two, answer the questions according to the following instructions.
Part A: Multiple-choice
Answer **all** questions on the separate Multiple-choice Answer Sheet provided. For each question, shade the box to indicate your answer. Use only a blue or black pen to shade the boxes. If you make a mistake, place a cross through that square, then shade your new answer. Do not erase or use correction fluid/tape. Marks will not be deducted for incorrect answers. No marks will be given if more than one answer is completed for any question.
Part B: Extended answer
Answer **all** questions. Write your answers in the spaces provided in this Question/Answer Booklet.
- You must be careful to confine your responses to the specific questions asked and to follow any instructions that are specific to a particular question.
- Spare pages are included at the end of this booklet. They can be used for planning your responses and/or as additional space if required to continue an answer.
 - Planning: If you use the spare pages for planning, indicate this clearly at the top of the page.
 - Continuing an answer: If you need to use the space to continue an answer, indicate in the original answer space where the answer is continued, i.e. give the page number. Fill in the number of the question that you are continuing to answer at the top of the page.
- The Data Book is **not** to be handed in with your Question/Answer Booklet.

See next page

Section One: Core content**40% (55 Marks)**

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

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

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

Suggested working time: 70 minutes.

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

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

1. A motor has a power input of 1875 W. If the output power is 1.8 kW, what is the efficiency of the motor?
 - (a) 9.6%
 - (b) 104%
 - (c) 4%
 - (d) 96%

2. A fully enclosed cylindrical drum has a radius of r and a height of h . Which of the following equations should be used for determining the surface area of the drum?
 - (a) $4\pi r^2 + 2\pi rh$
 - (b) $2\pi r(r+h)$
 - (c) $\pi r^2 h$
 - (d) $\pi r(r+h)$

3. A television set has a standby power consumption of 0.4 W. If it was in stand-by mode continuously for 365 days, approximately how much energy would it have consumed?
 - (a) 12.6 MJ
 - (b) 3.504 kJ
 - (c) 146 J
 - (d) 912.5 J

4. The purpose of a parts list is to
 - (a) control costs of materials.
 - (b) select suitable materials.
 - (c) ensure every component is produced before assembling.
 - (d) ensure safety in the manufacturing of components.

See next page

5. The **most** critical aspect of material choice in manufacturing a product is
- (a) durability.
 - (b) safety.
 - (c) attractiveness.
 - (d) ease of colouring.
6. Fibreglass (glass fibres layered and held together by plastic resin) is **most** appropriately classified as
- (a) a pure metal.
 - (b) an alloy.
 - (c) a polymer.
 - (d) a composite.
7. Many small towns in Western Australia have banned the use of plastic bags. The primary reason is that plastic bags are
- (a) difficult to recycle or biodegrade.
 - (b) unsightly.
 - (c) easily torn when in use.
 - (d) a high cost to the consumer.
8. Mobile phones have, over the years, changed significantly in form, size and weight. One of the primary reasons is ergonomics. Which one of the following aspects of the design of a mobile phone does **not** take into account ergonomics?
- (a) width of the mobile phone
 - (b) weight of the mobile phone
 - (c) battery life of the mobile phone
 - (d) screen size of the mobile phone
9. In the devising stage, when producing an annotated orthographic drawing of design ideas, which of the following is the **least** critical?
- (a) all considerations of the shape of the product
 - (b) all hidden dimensions of the product
 - (c) all explanations of the function of the product
 - (d) all considerations of the form of the product
10. When doing the final testing on a designed product, what should **not** be on the checklist?
- (a) future criteria
 - (b) finish criteria
 - (c) design brief criteria
 - (d) safety criteria

Section One: Core content**Part B: Extended answer****30% (45 Marks)**

This section has **three (3)** questions. Answer **all** questions. Write your answers in the spaces provided.

Spare pages are included at the end of this booklet. They can be used for planning your responses and/or as additional space if required to continue an answer.

- Planning: If you use the spare pages for planning, indicate this clearly at the top of the page.
- Continuing an answer: If you need to use the space to continue an answer, indicate in the original answer space where the answer is continued, i.e. give the page number. Fill in the number of the question that you are continuing to answer at the top of the page.

Question 11**(13 marks)**

Australian consumers spend over a billion dollars each year on coffee and coffee-related products. For every seven cups of coffee consumed, one is a takeaway. Takeaway coffee cups are typically for single use only and the large number of cups consumed results in significant waste.

Your engineering firm has been asked by EcoCupCo to develop a takeaway coffee cup that has a lid and is both functional and environmentally friendly. Before your team begins the design of the cup you have been asked to develop the design brief for it.

- (a) List **two** design criteria that ensure the functionality of the cup and describe how each criterion contributes to this. (4 marks)

One: _____

Contribution: _____

Two: _____

Contribution: _____

Question 11 (continued)

- (b) Your design team has narrowed down the material choice for the cup to polypropylene and stainless steel. Considering the physical properties of the two materials, list and explain **one** advantage and **one** disadvantage of using polypropylene over stainless steel. (4 marks)

Advantage: _____

Explanation: _____

Disadvantage: _____

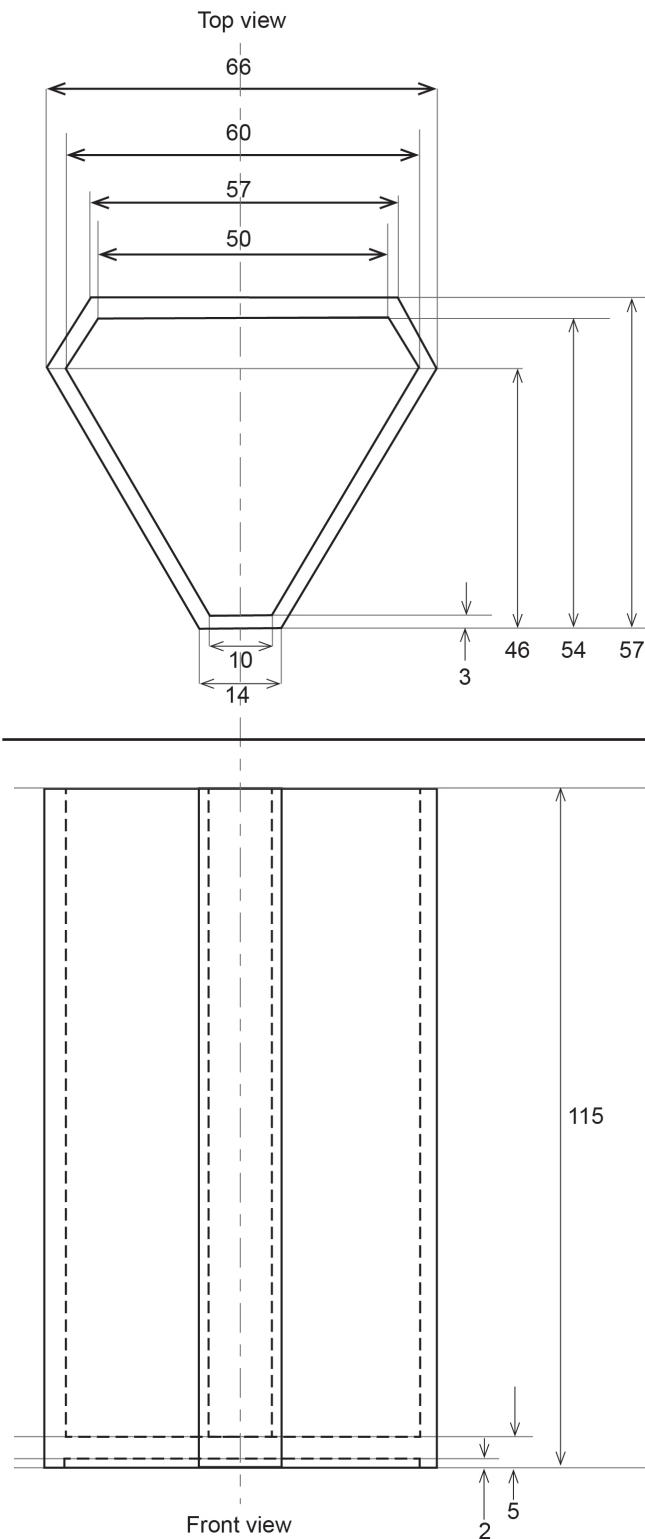
Explanation: _____

Question 12

(21 marks)

The orthographic drawing shows an aluminium coffee. All dimensions shown are in millimetres.

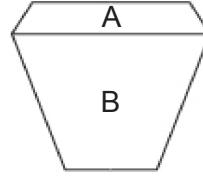
- (a) Draw a right side view of the coffee cup. The drawing must be full size and show all dimensions and hidden detail. (6 marks)



See next page

- (b) Use the dimensions from the drawing to calculate the maximum volume of liquid capable of being held by the coffee cup. Show **all** workings. (6 marks)

Hint: you can work out the area of the base by dividing the base into sections, such as that shown:



- (c) Calculate the volume of aluminium in the coffee cup. Show **all** workings. (6 marks)

Question 12 (continued)

- (d) Assuming that the density of coffee is the same as the density of pure water, calculate the total mass of the aluminium coffee cup when it contains the maximum volume of coffee. Show **all** workings. (3 marks)

Question 13

(11 marks)

As the world's population grows, so does the demand for electricity. The adverse environmental impacts of the generation of electricity, such as global warming and air pollution, are well known. Electricity can be supplied from a number of different energy sources.

- (a) Explain why wind energy and wave energy are often considered as other forms of solar energy. (4 marks)

Wind energy:

Wave energy:

(b) The disadvantages of using nuclear energy for electricity generation have been widely publicised. However, nuclear power also has a number of significant advantages.

(i) State **one** major advantage that nuclear power plants have over fossil fuelled power plants. (1 mark)

(ii) State **one** major advantage that nuclear power plants have over wind power plants. This answer must be different to that given in (i) above. (1 mark)

(iii) State **one** major advantage that nuclear power plants have over wave power plants. This answer must be different to those given in (i) and (ii) above. (1 mark)

(c) Describe briefly how hydro-electricity is generated, and state **two** main disadvantages of hydro power. (4 marks)

Description: _____

One: _____

Two: _____

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 the specialist field they studied in 2014.

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

Specialist field	✓	Question numbers	Pages
Systems and control	<input type="checkbox"/>	14–27	13–30
Mechanical	<input type="checkbox"/>	28–41	31–45
Electronic/electrical	<input type="checkbox"/>	42–55	46–63

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

See next page

Section Two: Specialist field—Systems and Control

60% (110 Marks)

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

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

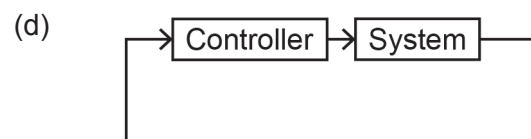
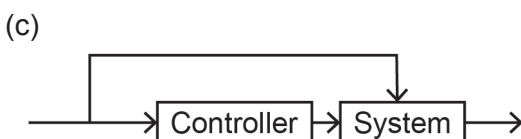
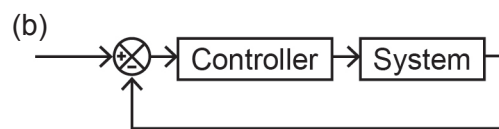
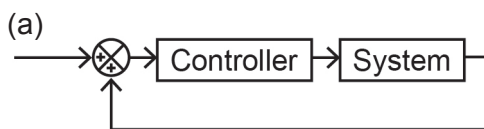
Part B: Extended answer Answer **all** questions

Suggested working time: 110 minutes.

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

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

14. A NAND gate can be built from NOT gates and an AND gate by placing the NOT gate
- on one input to the AND gate and a NOT gate on the output to the AND gate.
 - on one of the inputs to the AND gate.
 - after the AND gate.
 - on all of the inputs and outputs of the AND gate.
15. Pulse width modulation is used in motor control to
- convert the analogue signals supplied to the digital motor controller.
 - control the electrical energy supplied to the motor.
 - amplify the electrical energy supplied to the motor.
 - change the pulse width of the motor controller.
16. In the control diagrams shown below, which of the circuits can **best** be described as using closed loop control with negative feedback?

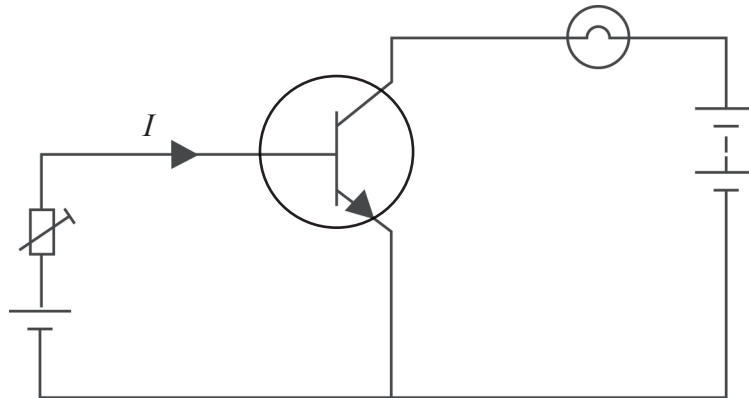


See next page

17. A relay is **best** used for which of the following applications?

- (a) implementing a Boolean logic circuit
- (b) converting electrical energy to mechanical energy
- (c) acting as a surge protector
- (d) amplifying electrical current

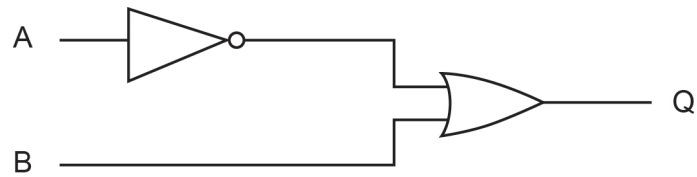
18. In the lighting circuit shown below, the current I is more than sufficient to saturate the transistor and for the bulb to light up.



If the current I is now increased, the

- (a) bulb will turn off.
 - (b) brightness of the bulb decreases as I increases.
 - (c) brightness of the bulb increases as I increases.
 - (d) magnitude of I does not affect the brightness of the bulb.
19. A stepper motor is **best** used to control
- (a) a treadmill.
 - (b) the gearbox of an automatic car.
 - (c) the speed of a remotely controlled car.
 - (d) the direction of a satellite receiver dish.
20. Cams and followers are typically selected for machine design because they
- (a) increase the torque output of the system.
 - (b) convert rotational movement into linear movement.
 - (c) increase the energy output of the system.
 - (d) change the direction of rotation.

Questions 21 and 22 refer to the logic diagram below.



21. Which of the following logic expressions describes the resultant action at Q?

- (a) $Q = \bar{A} + B$
- (b) $Q = A + \bar{B}$
- (c) $Q = A \cdot \bar{B}$
- (d) $Q = (A \cdot B)$

22. Select the correct truth table for the logic diagram above:

(a)

A	B	Q
0	0	1
1	0	0
0	1	1
1	1	1

(b)

A	B	Q
0	0	1
1	0	0
0	1	0
1	1	0

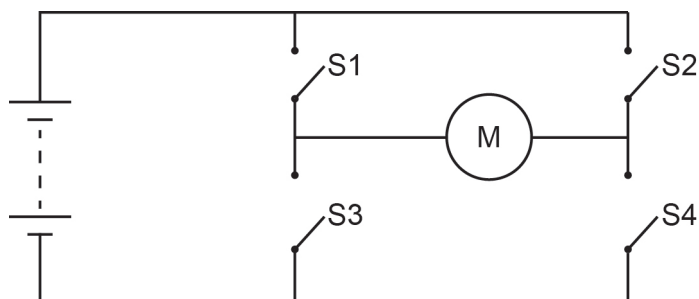
(c)

A	B	Q
0	0	0
1	0	0
0	1	1
1	1	0

(d)

A	B	Q
0	0	0
1	0	1
0	1	0
1	1	0

23. The H bridge shown in the diagram is used to control the rotation of the motor. When Switch 1 and Switch 4 (S1 and S4) are closed and Switches 2 and 3 (S2 and S3) are open, the motor shaft spins in a clockwise direction and reaches a constant speed. S1 and S4 are now open and S2 and S3 are closed. What will be the final effect on the motor shaft?



- (a) It will stop rotating.
- (b) It will spin faster in a clockwise direction.
- (c) It will spin in an anticlockwise direction.
- (d) It will spin slower in a clockwise direction.

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

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

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Question 24**(20 marks)**

Louise designed a power source that had a voltage output of between 0 and 12 VDC. To test her design she recorded the voltage output of the power source using a microprocessor.

- (a) Design a voltage divider circuit that can connect the power supply to the ADC pin of the microprocessor. Assuming that the maximum current drawn by the circuit is 15 mA and that the maximum voltage supplied to the analogue pin is 3 V, calculate suitable resistance values. Show **all** workings. (8 marks)

Drawings	Calculations

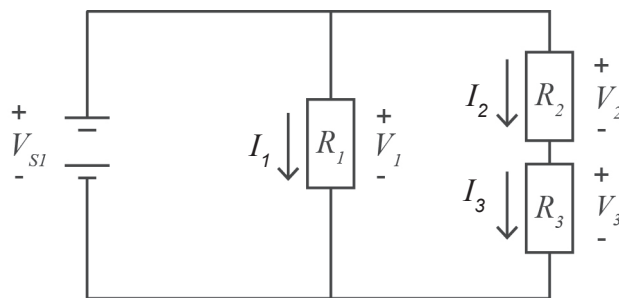
See next page

Question 24 (continued)

- (b) Explain why an analogue to digital converter (ADC) is needed for the microprocessor to read the input voltage from the power source. (2 marks)

- (c) If the ADC has 8 bit resolution, calculate the accuracy to which the microprocessor can measure the 12 VDC output of the power source. (2 marks)

Once Louise had confirmed the voltage output of the power source, she connected it to three resistors. The resulting circuit is shown below where $V_{SI} = 12\text{ V}$, $R_1 = 4\ \Omega$, $R_2 = 2\ \Omega$ and $R_3 = 4\ \Omega$.



- (d) Show by calculation that the total resistance of the circuit is $2.4\ \Omega$. (3 marks)

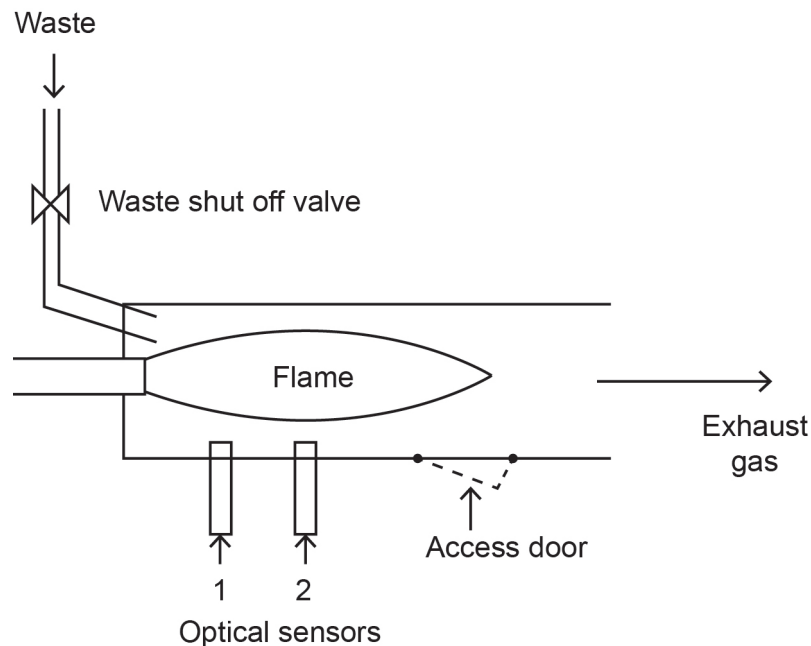
- (e) Using the resistance value of 2.4Ω , calculate the maximum power drawn by the circuit. Show **all** workings. (2 marks)

- (f) Calculate V_3 , the voltage across R_3 . Show **all** workings. (3 marks)

Question 25

(27 marks)

Incinerators are used in hospitals to burn medical waste that is potentially infected by toxins such as bacteria and viruses. A typical layout of an incinerator is shown in the diagram below.



If the incinerator flame is alight, it is safe to feed in waste, as it will be completely burnt and the dangerous toxins destroyed. If the flame is extinguished, waste must no longer be fed into the incinerator, as it poses a health risk.

The waste shut off valve can only be open (Output Q = True) if the following conditions have been met:

- the incinerator access door is not open (Input A = False)
- the master switch is activated (Input B = True)
- a flame is detected by at least one of Optical Sensor 1 (Input C = True) and Optical Sensor 2 (Input D = True), or both.

- (a) Complete the truth table below for the output Q. Use T or 1 to indicate True/ON and F or 0 to indicate False/OFF. (5 marks)

A	B	C	D	Q
T	T	T	T	
T	T		F	F
T	T	F	T	F
T	T	F	F	F
T	F	T	T	F
T	F	T	F	
T	F	F	T	F
T	F	F	F	F
F	T	T	T	T
F	T		F	T
F	T	F	T	
F	T	F	F	F
F	F	T	T	F
F	F	T	F	F
F	F	F	T	F
F	F	F	F	F

Question 25 (continued)

- (b) Draw a logic gate diagram that shows how the input signals A, B, C and D can be connected to achieve the desired output Q. Label each signal and each logic gate with its type. (9 marks)

- (c) Convert the logic circuit to a NAND logic circuit. (9 marks)

- (d) After trialling the system, an engineer decided to set the condition that both optical sensors must detect light (Input C = T and Input D = T) in order for the waste to be fed to the incinerator.

List and explain **one** advantage and **one** disadvantage of this approach. (4 marks)

Advantage: _____

Explanation: _____

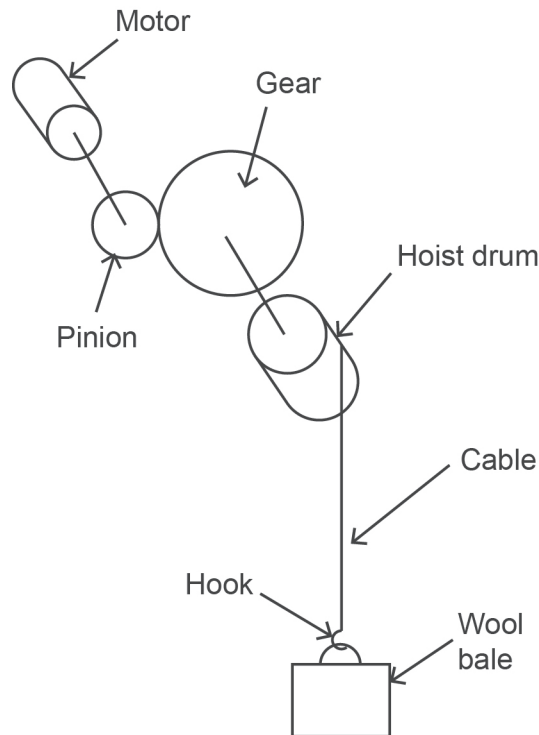
Disadvantage: _____

Explanation: _____

Question 26

(17 marks)

You have been approached by an engineering consultant to design an electric hoist system to lift bales of wool onto the upper floor of a warehouse. The consultant's sketch of the basic layout of the system is shown in the diagram below.



The hoist system comprises the motor control system, electric motor, pinion, gear, hoisting drum and cable. The bales of wool are attached via a hook to the bottom of the cable. Once the bales of wool are connected, the operator presses a button on the control panel and the bales are lifted from the warehouse floor to the upper floor.

- (a) While a bale of wool is being lifted it applies a maximum force of 200 N to the cable. If the drum has a 50 cm diameter, determine the maximum torque applied to the drum by a bale of wool. Show **all** workings. (3 marks)

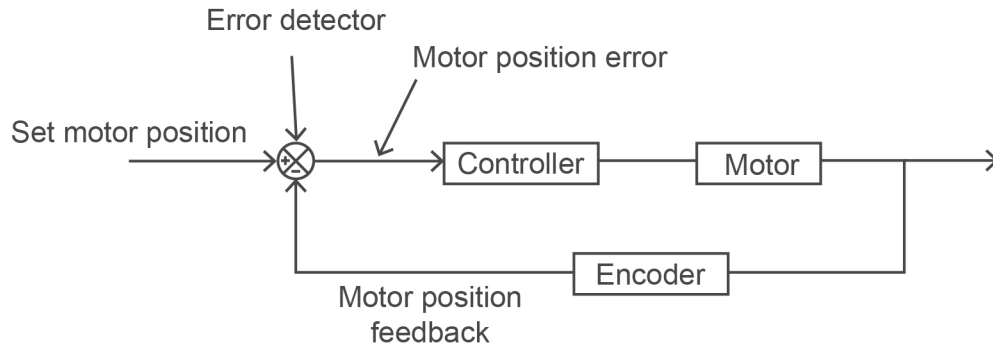
- (b) If the pinion completes five rotations for every one rotation of the gear, calculate the maximum torque that the motor must apply to lift a bale of wool. Assume that the system has 100% efficiency. Show **all** workings. (3 marks)

- (c) Explain how reducing gearbox efficiency affects the mechanical advantage of the gearbox. (2 marks)

- (d) What effect would doubling the diameter of the pinion have on the speed of rotation of the hoist drum? (2 marks)

Question 26 (continued)

Your design team has decided to use a servo motor to control the position of the motor. The control diagram for the servo motor is shown below.



- (e) Explain in detail how negative feedback is used to control the position of the motor. (3 marks)

- (f) List and describe **two** factors that need to be considered when selecting a servo motor for position control. (4 marks)

One: _____

Consideration: _____

Two: _____

Consideration: _____

Question 27

(36 marks)

After experiencing several break-ins, Bill decided to protect his business by fitting a burglar alarm system. The alarm monitors the status of the front and rear doors and a side window. If either of the doors or the windows is opened while the alarm system is on, a siren will sound.

A switch is used to turn the alarm on and off. When the switch is off, the alarm system is deactivated and when the switch is on, the alarm system is activated. An LED is used to display the status of the alarm system. When the alarm system is activated, the LED is illuminated and when the alarm is deactivated, the LED is not illuminated.

The inputs to the alarm system are as follows:

D1, D2, W1 are the signals from the two doors and the side window. They produce a HIGH signal when the doors or window are open and a LOW signal when they are closed.

S1 is the signal from the switch. It produces a HIGH signal when the alarm system is activated and a LOW signal when the alarm system is deactivated.

The outputs to the alarm system are as follows:

A1 is the signal that sounds the siren. It produces a HIGH signal when either door or the window is open while the alarm system is activated. At all other times it produces a LOW signal.

L1 is the signal used to illuminate the LED. It produces a HIGH signal when the alarm system is activated and a LOW signal when the alarm system is deactivated.

- (a) Construct a Boolean logic expression to represent the operation of the siren in the alarm system, given the four inputs. (6 marks)

- (b) Draw a flow chart for the alarm system. Use the standard flow chart symbols shown in the **Data Book**. (14 marks)

Question 27 (continued)

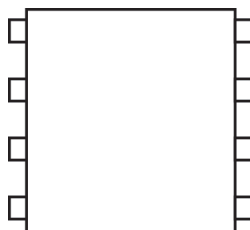
- (c) Draw and label a logic diagram for the alarm system. You must use a combination of discrete logic gates and each gate should be drawn using the standard symbols or labelled to indicate clearly its type. Each input and output signal must be labelled clearly to match the signals described in the question. (8 marks)

- (d) An infrared motion sensor is added to upgrade the alarm system. If motion is detected, an LED is switched on to illuminate the room and a siren is triggered. The motion sensor produces a 3 V digital pulse when motion is detected and a 0.5 V digital pulse when no motion is detected.

A suitable microprocessor for reading the infrared sensor and controlling the LED and siren is shown below. Refer to the **Data Book** for details.

On the schematic diagram of the microprocessor, draw and label all inputs and outputs and their connection to the appropriate pins.

You must also indicate the direction of the signal for each connection, the 5 VDC supply voltage and the ground connections. (8 marks)



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

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

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

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

Suggested working time: 110 minutes.

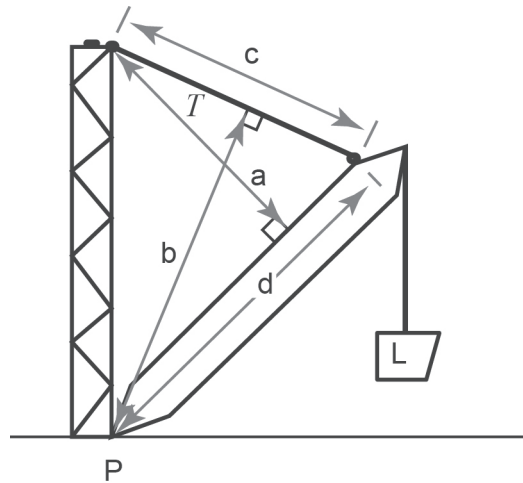
Part A: Multiple-choice**10% (10 Marks)**

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

28. A screw of mass 5 g was thrown off a building site from a height of 50 m. Neglecting air resistance, what would be the kinetic energy of the screw immediately before impact on the footpath?
- (a) 2.45 J
 - (b) 2.45 kJ
 - (c) 24.5 J
 - (d) 2.45×10^{-2} J
29. The safe working load of an office lift is 12 persons or 960 kg. Designing to a factor of safety of 2.5, the capacity (force) of the cable holding up the lift should be
- (a) 2400 N.
 - (b) 2945 N.
 - (c) 23.52 kN.
 - (d) 29.45 kN.
30. Which of the following statements is true?
- (a) A safety factor is just another way of over-engineering, and it costs the client more.
 - (b) I will need additional servicing on a machine that has experienced extreme working conditions and not rely on safety factors for safe machine operation.
 - (c) I can overload a machine by the safety factor to make the best use of available resources.
 - (d) I can ignore servicing dates and rely on the safety factor to prevent machine failure.

31. If it is found that Material A has a higher elastic (Young's) modulus than Material B, Material A can be described as being
- (a) more flexible.
 - (b) less ductile.
 - (c) more dense.
 - (d) less elastic.
32. The SI unit for Young's modulus is
- (a) none, because it is a ratio.
 - (b) none, because the units for stress and strain cancel each other out.
 - (c) the same as strain, because stress has no units.
 - (d) the same as stress, because strain has no units.
33. A fishing rod with a uniform cross-section that has a fish on the end of the line can be simplified as a cantilevered beam with a single load at its unsupported end. Which of the following **best** describes the resulting forces on the rod (beam)?
- (a) The rod will experience no forces below the neutral axis and only tensile forces above the neutral axis.
 - (b) The rod will experience no forces above the neutral axis and only tensile forces above the neutral axis.
 - (c) The rod will experience compressive forces above the neutral axis and only tensile forces below the neutral axis.
 - (d) The rod will experience compressive forces below the neutral axis and only tensile forces above the neutral axis.
34. The head of a hammer is formed by casting rather than by other methods. This is because of
- (a) the highly detailed design of the hammer head.
 - (b) its increased ability to handle compression stress with little deformation.
 - (c) its increased ability to handle tensile stress with little deformation.
 - (d) its increased ability to handle repeated cycles of tensile and compression stresses.

35. The following diagram shows a tension force (T) acting along a cable holding up a boom of a crane.



- The moment of the tension force (T) about point P is **best** described by
- (a) $T \times a$
 - (b) $T \times b$
 - (c) $T \times c$
 - (d) $T \times d$
36. The relationship between the second moment of area of a beam (I_{xx}) and its maximum deflection is **best** described by which sentence?
- (a) There is absolutely no relationship between I_{xx} and maximum deflection.
 - (b) The larger the I_{xx} the larger the maximum deflection.
 - (c) The larger the I_{xx} , the smaller the maximum deflection.
 - (d) The relationship depends upon the type of loading, point or uniform.
37. Which of the following statements does **not** need to hold true for equilibrium to occur?
- (a) The sum of energy is zero.
 - (b) The sum of all moments is zero.
 - (c) The sum of all forces in the horizontal plane is zero.
 - (d) The sum of all forces in the vertical plane is zero.

Part B: Extended answer

50% (100 Marks)

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

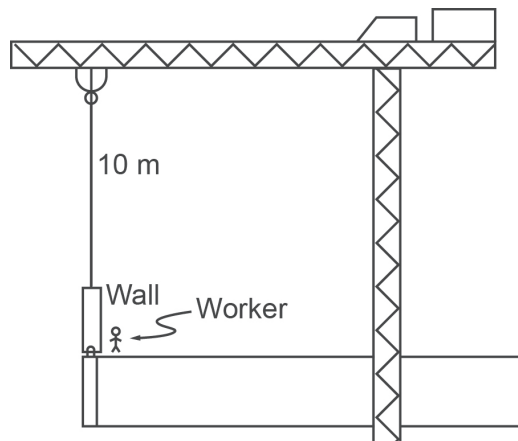
Spare pages are included at the end of this booklet. They can be used for planning your responses and/or as additional space if required to continue an answer.

- Planning: If you use the spare pages for planning, indicate this clearly at the top of the page.
- Continuing an answer: If you need to use the space to continue an answer, indicate in the original answer space where the answer is continued, i.e. give the page number. Fill in the number of the question that you are continuing to answer at the top of the page.

Question 38

(19 marks)

A crane is moving precast walls into place. Each wall weighs 1.5 tonnes. The structural steel cable has an equivalent diameter of 15 mm. In the following calculations, ignore the size of the walls.

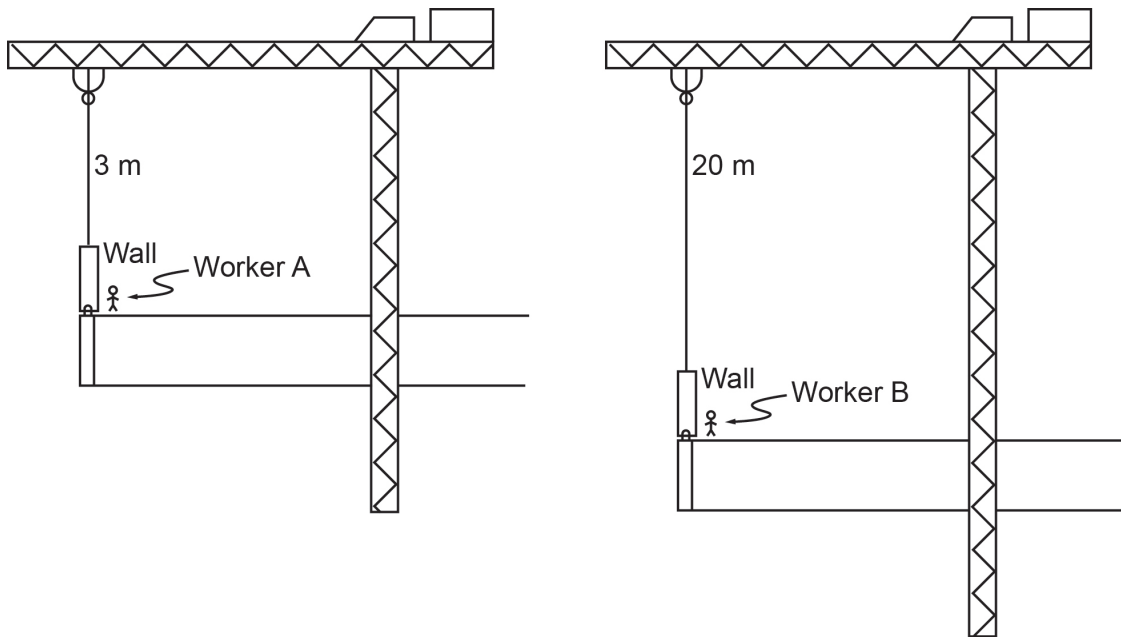


- (a) Calculate the strain in the cable while lifting a precast wall. Show **all** workings. (6 marks)

- (b) Show that a force of 44.175 kN is required to bring the cable to its elastic limit (yield stress). (3 marks)
- (c) Calculate the extension in the 10 m cable while lifting the wall. Show **all** workings. (4 marks)
- (d) If the crane is operating with a safety factor of 2, calculate the safe working load. Show **all** workings. (2 marks)

Question 38 (continued)

(e)



Both Worker A and Worker B must move the precast wall into place by pushing it horizontally. Which worker will exert the **lesser** force to do this? Circle the correct answer, and explain your reasoning. No calculations are required. (4 marks)

Worker A

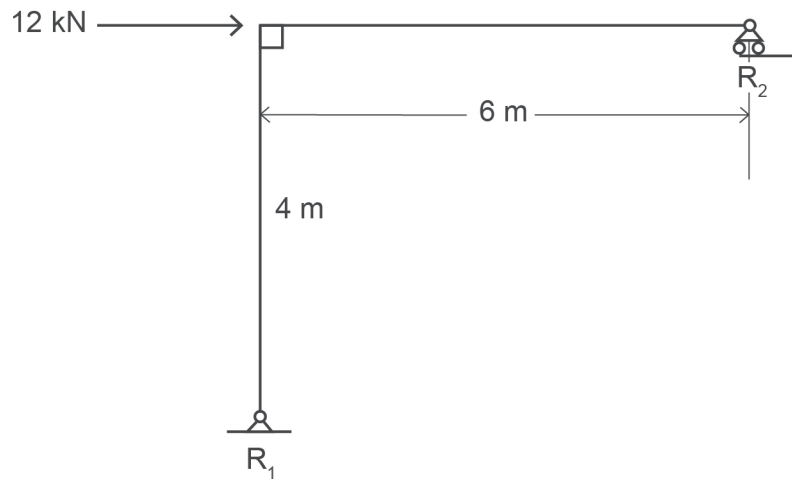
Worker B

Explanation: _____

Question 39

(28 marks)

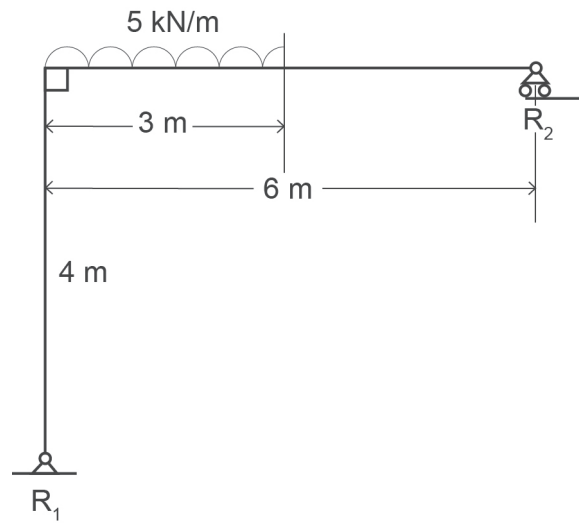
The following questions relate to the uniform L-shaped member supported as shown below. Ignore the weight of the member itself in the following calculations.



- (a) Using moments about R_1 , prove that the reaction force at R_2 is about 8 kN (upward). (2 marks)
- (b) Using the equilibrium of forces, prove that the reaction force at R_1 is about 8 kN (downward) and 12 kN to the left. (4 marks)

Question 39 (continued)

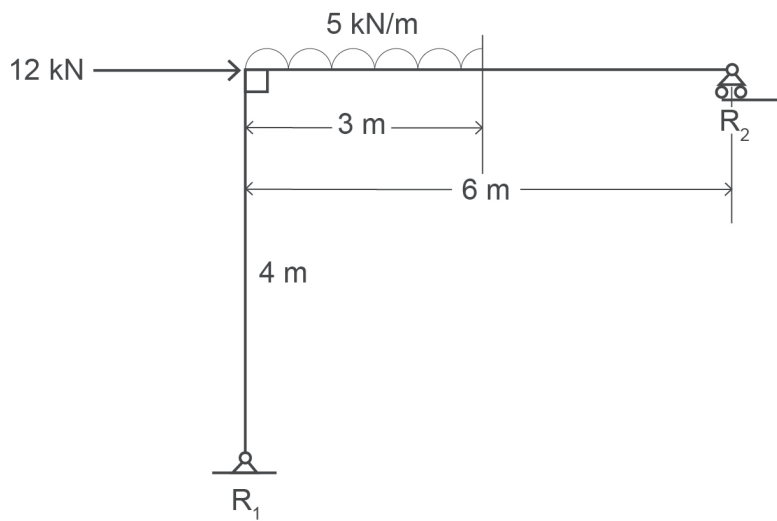
The 12 kN point load is removed, and a uniformly distributed load is added as shown below.



(c) Prove that the reaction force at R_1 is 11.25 kN (upward). (2 marks)

(d) Prove that the reaction force at R_2 is 3.75 kN (upward). (2 marks)

The two forces are combined as shown in the drawing below.



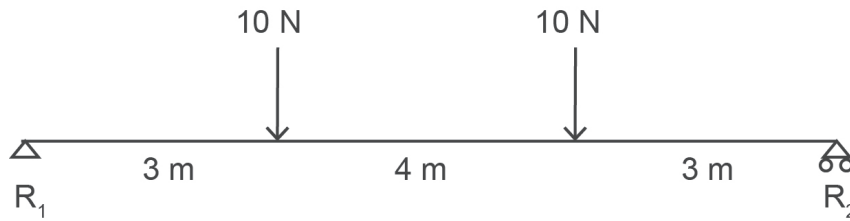
(e) Prove that the reaction force at R_2 is about 11.75 kN upward. (2 marks)

(f) Calculate the magnitude of the resultant reaction force at R_1 . Show **all** workings. (4 marks)

Question 39 (continued)

- (g) On the two sets of axes provided below, draw the shear force and bending moment diagrams. (12 marks)

Note: Use the same horizontal scale as the diagram provided, label all axes, and show clearly key values in each diagram. Show **all** workings.

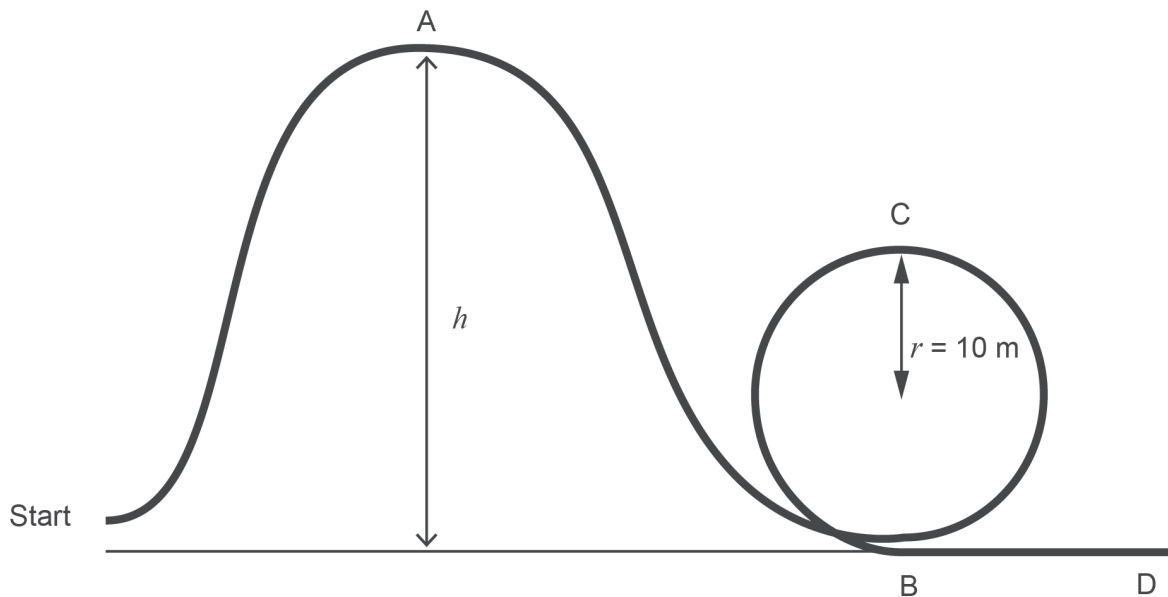


Workings:

Question 40

(19 marks)

The following question relates to the single loop roller-coaster track shown below. Ignore friction unless otherwise instructed.



- (a) The work done in lifting the roller-coaster car against gravity is 784 kJ. Calculate the average force acting on the roller-coaster car during the journey upward from start to Point A, assuming that the distance travelled is 60 m. Show **all** workings and give your answer to four significant figures. (3 marks)
- (b) Assume that it takes 30 s to transport a roller-coaster car from start to Point A. Determine the minimum design power output of the roller-coaster transportation system if it is only 65% efficient. Show **all** workings. (4 marks)

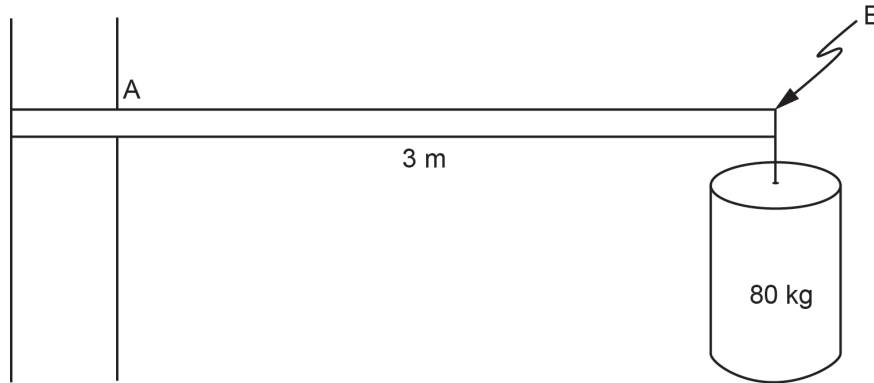
Question 40 (continued)

- (c) The loop has a 10 m radius. The roller-coaster car, with a mass of 2 tonnes, travels with a velocity of 19.8 m s^{-1} at Point C, the top of the loop. Prove that the vertical distance h is approximately 40 m. (6 marks)
- (d) The roller-coaster car has a speed of 25 m s^{-1} when it reaches Point D. Calculate the percentage of its energy lost due to friction as the car travels from Point A to Point D. Show **all** workings. (6 marks)

Question 41

(34 marks)

The diagram below shows a punching bag suspended from the end of a structural steel cantilever. The mass of the punching bag is 80 kg and the density of structural steel is as stated in the **Data Book**. The cantilever has a solid square cross-section of 5 cm × 5 cm.



(a) Calculate the cantilever's second moment of area. Show **all** workings. (3 marks)

(b) Calculate the beam's maximum deflection at Point B. Show **all** workings. (9 marks)

Question 41 (continued)

- (c) Calculate the beam's maximum bending moment at Point A. Show **all** workings. (7 marks)

The square cross-section beam is replaced by a solid circular beam of equal cross-sectional area.

- (d) Calculate the circular beam's second moment of area. Show **all** workings. (4 marks)

- (e) Calculate the circular beam's maximum deflection at Point B. Show **all** workings. (5 marks)

- (f) Judging from your calculations, would a hollow circular beam of equal cross-sectional area deflect more or less than the solid circular beam? Explain. (3 marks)

Circle your answer: More Less

Explain your choice:

- (g) Would the circular beam's maximum bending moment at Point A differ from that of the square beam? Explain. (3 marks)

Circle your answer: Yes No

Explain your choice:

End of Section Two: Mechanical

See next page

Section Two: Specialist field—Electronic/Electrical

60% (110 Marks)

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

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

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

Suggested working time: 110 minutes.

Part A: Multiple-choice

10% (10 Marks)

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

42. 100 000 μA is the same as

- (a) 1×10^{-6} A.
- (b) 100 kA.
- (c) 0.1 mA.
- (d) 100 000 000 000 pA.

43. One of the main applications of a capacitor is to

- (a) pass DC and block AC.
- (b) block DC and pass AC.
- (c) block both DC and AC.
- (d) pass both DC and AC.

44. A ceramic disk capacitor with a three digit label of 220 has a capacitance of

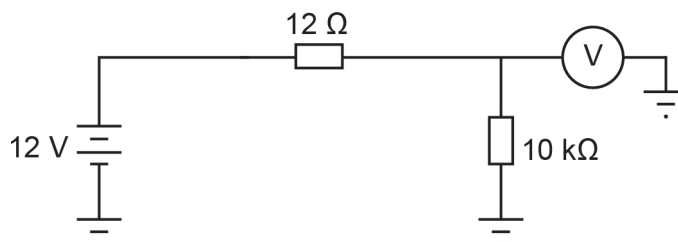
- (a) 200 pF.
- (b) 200 μF .
- (c) 22 nF.
- (d) 22 pF.

45. A motor drives a pump via a gearbox. The motor and the gearbox are each 80% efficient. The electric power input to the motor is 2400 W. The power delivered to the pump is

- (a) 1536 W.
- (b) 1920 W.
- (c) 2400 W.
- (d) 3000 W.

46. Given that the cost of electricity is 25 cents per kWh, the energy cost for a 1100 W swimming pool pump that runs continuously for 7 days would be
- (a) \$44.00.
 - (b) \$46.20.
 - (c) \$19.25.
 - (d) \$23.10.
47. Which type of capacitor can explode and cause injury if the polarity of the voltage across its plates is incorrect?
- (a) ceramic
 - (b) mica
 - (c) electrolytic
 - (d) variable
48. If the charge stored in a 5 μF capacitor is 90 μC , then the voltage across the capacitor equals
- (a) 0.0555 V.
 - (b) 18 V.
 - (c) 95 V.
 - (d) 450 V.
49. The resistance of a wire can be calculated using $R = \frac{\rho \ell}{A}$ where ρ is the resistivity of the wire material, ℓ is the length of the wire, and A is the circular cross-sectional area of the wire. The resistivity of copper is $1.725 \times 10^{-8} \Omega \text{ m}$. The resistance of a 20 m long copper wire having cross-sectional area 3.142 mm^2 is
- (a) $109.8 \times 10^{-9} \Omega$.
 - (b) $109.8 \times 10^{-15} \Omega$.
 - (c) $109.8 \times 10^{-3} \Omega$.
 - (d) $109.8 \times 10^{-6} \Omega$.
50. The work done in moving a unit charge between two points is a measure of
- (a) resistance.
 - (b) current.
 - (c) potential difference.
 - (d) capacitance.

51. In the circuit below, the voltmeter reads exactly 12 V.



Which of the following scenarios would cause this?

	12 Ω resistor	10 kΩ resistor
(a)	shorted	open
(b)	open	shorted
(c)	open	open
(d)	working normally	shorted

Part B: Extended answer

50% (100 Marks)

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

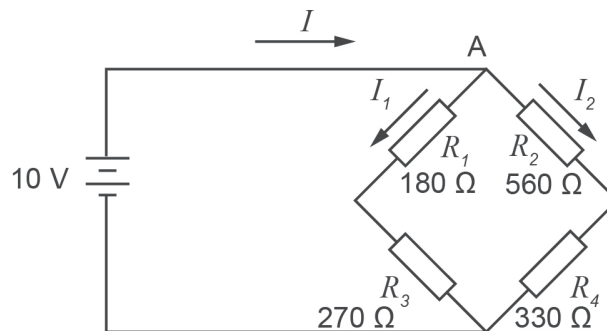
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Question 52

(24 marks)

A circuit is constructed as shown below with a 10 V battery and four resistors: $R_1 = 180 \Omega$, $R_2 = 560 \Omega$, $R_3 = 270 \Omega$ and $R_4 = 330 \Omega$.



- (a) Calculate the total resistance of the circuit. Show **all** workings.

(3 marks)

Question 52 (continued)

(b) Calculate the currents I , I_1 and I_2 , and verify that Kirchhoff's current law applies at Node A. Show **all** workings.

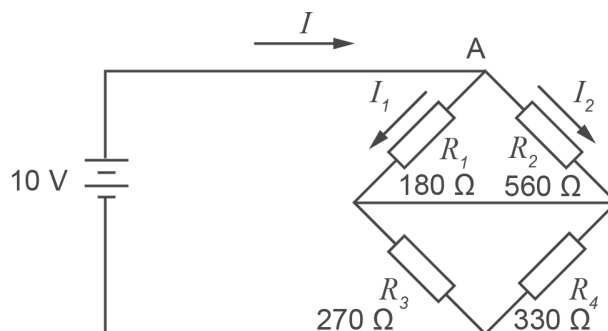
(i) Current I : (2 marks)

(ii) Current I_1 : (2 marks)

(iii) Current I_2 : (2 marks)

(iv) Verify that Kirchhoff's current law applies at Node A. (2 marks)

- (c) Suppose a short is added to the circuit as shown below. Calculate the total resistance of the circuit and the currents I_1 and I_2 . Show **all** workings. (9 marks)



Total resistance:

Current I_1 :

Current I_2 :

Question 52 (continued)

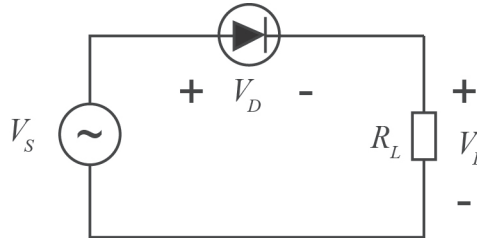
(d) State the colour codes for the resistors R_1 , R_2 , R_3 and R_4 in the table below. (4 marks)

Resistor	Band 1	Band 2	Band 3	Tolerance band
$R_1 = 180 \Omega$				Ignore
$R_2 = 560 \Omega$				Ignore
$R_3 = 270 \Omega$				Ignore
$R_4 = 330 \Omega$				Ignore

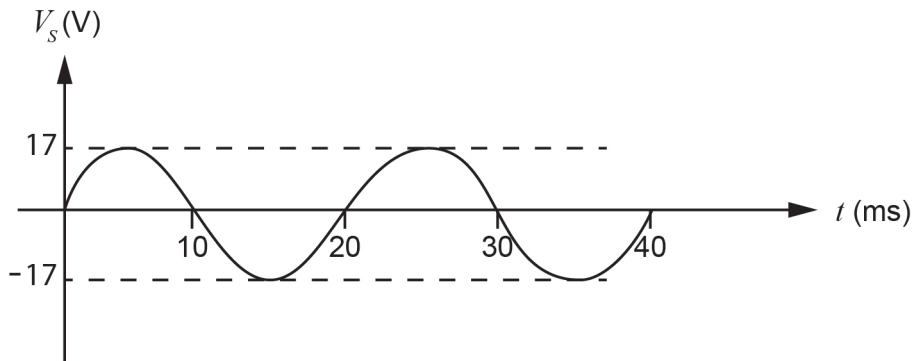
Question 53

(24 marks)

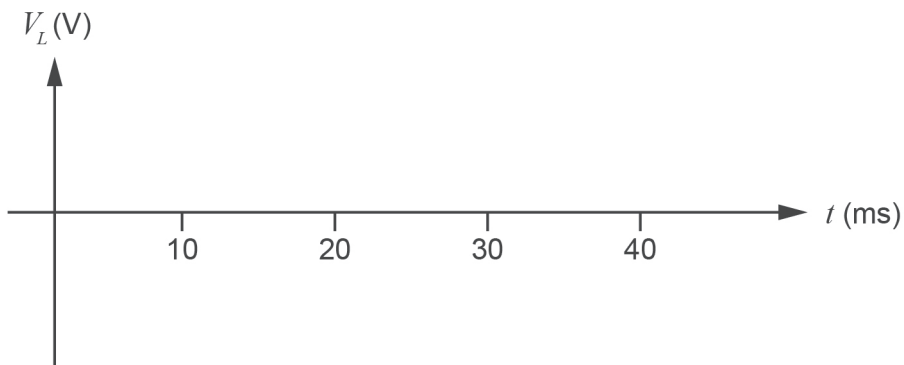
A half-wave rectifier circuit with a voltage source V_S and a load resistor R_L is shown below. Assume that the diode has a forward voltage of 0.6 V.



Suppose the source voltage V_S is AC as depicted below.



- (a) Sketch clearly the voltage waveform V_L , and state its maximum and minimum voltage values as well as its frequency. (5 marks)



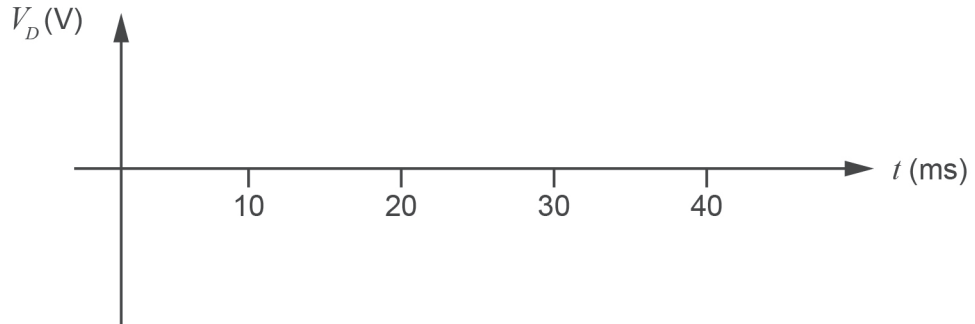
Maximum value: _____

Minimum value: _____

Frequency: _____

Question 53 (continued)

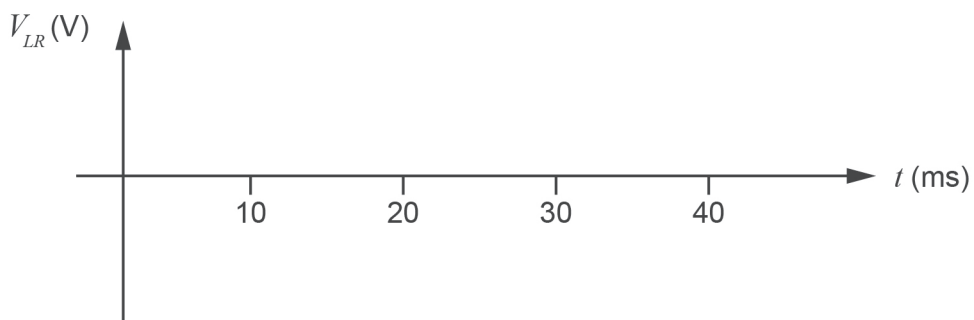
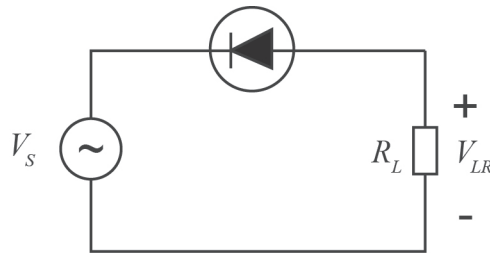
- (b) Sketch clearly the voltage waveform V_D , and state its maximum and minimum voltage values. (4 marks)



Maximum value: _____

Minimum value: _____

- (c) Suppose that the rectifier diode was accidentally mounted on the printed circuit board in an opposite direction as depicted below. How would this affect the load voltage V_{LR} ? Sketch the voltage waveform V_{LR} , and state the maximum and minimum values of V_{LR} . (4 marks)



Maximum value: _____

Minimum value: _____

- (d) A full-wave rectifier is needed instead of a half-wave rectifier. Sketch clearly a circuit diagram below showing a diode-bridge full-wave rectifier with its input connected to a voltage source V_S and its output to a load resistor R_L . Also, given that V_S has a peak-to-peak voltage of 34 V, calculate the peak-to-peak voltage that would appear across R_L . Assume all diodes have a forward voltage of 0.6 V. Show **all** workings. (7 marks)

Peak-to-peak voltage across R_L :

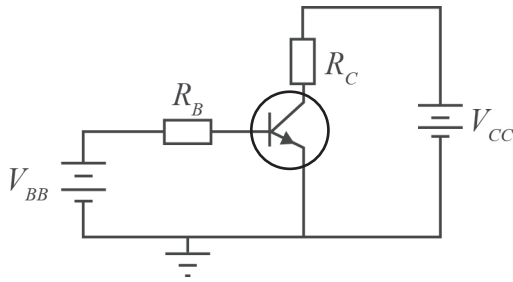
- (e) The rectifier is supplied from the household mains by a transformer. Sketch clearly a circuit diagram below showing a transformer that has a primary voltage of 240 VAC and a secondary voltage of 12 VAC. State the required turns ratio. (4 marks)

Turns ratio: _____

Question 54

(28 marks)

A transistor circuit and its parameter are shown below.

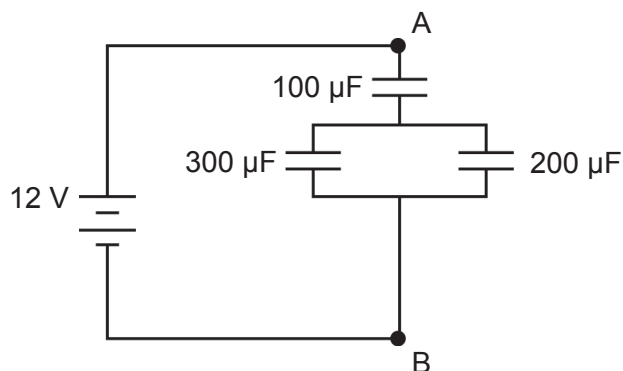


Parameters	
Collector supply voltage V_{CC}	10 V
Base resistor R_B	80 k Ω
Collector resistor R_C	2 k Ω
Transistor on-voltage $V_{BE,on}$	0.7 V
Transistor saturation voltage $V_{CE,sat}$	0 V
Transistor current gain h_{FE}	100

- (a) Calculate the minimum base current I_B required to saturate the transistor. Show **all** workings. (4 marks)

- (b) Calculate the minimum base supply voltage V_{BB} required to saturate the transistor. Show **all** workings. (2 marks)

(c) Consider the circuit below:

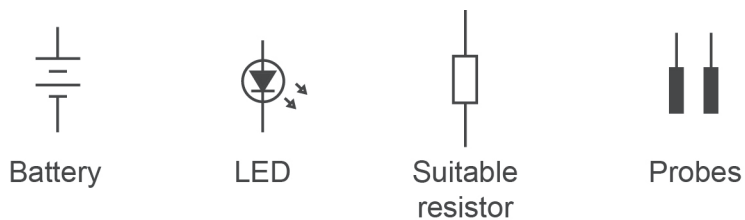


(i) Calculate the overall capacitance of this network. Show **all** workings. (3 marks)

(ii) This capacitor network can discharge its stored charge Q by creating a discharge current I over a time t . This can be represented as $Q=It$. Calculate the current if the network discharge time is 1 ms. Show **all** workings. (3 marks)

Question 54 (continued)

- (d) Design a simple tool for testing a PCB for any broken tracks. Your tool should light up when an unbroken connection is tested. Using the components shown below, draw a circuit diagram of your own design, and explain how it works and the purpose of the resistor. (5 marks)



Explanation:

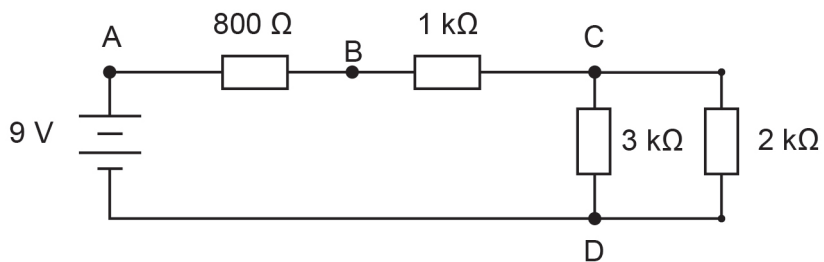
- (e) Suppose the battery is 9 V and the LED operates at a forward voltage of 2.5 V and a current of 13 mA. Calculate the required resistor value R that will make the circuit in part (d) work. Also, determine the closest E12 preferred value resistor that should be used for R . Show **all** workings. (3 marks)

Required resistor value R :

The closest E12 preferred value resistor that should be used for R :

Question 54 (continued)

A resistive circuit is constructed as shown below.



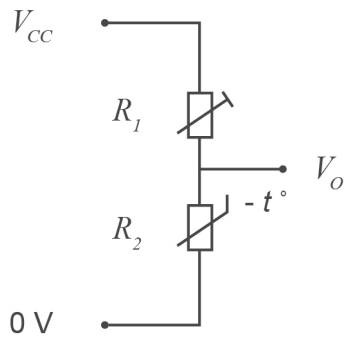
- (f) Calculate the voltage and the current of each resistor. Provide your final answers in the table below. Show **all** workings. (8 marks)

Resistor (Ω)	Voltage (V)	Current (mA)
800 Ω		
1 k Ω		
3 k Ω		
2 k Ω		

Question 55

(24 marks)

A voltage divider circuit that uses a variable resistor R_1 and a thermistor R_2 is shown, together with a thermistor characteristic table. The supply voltage V_{CC} is permanently set to 9 V.



Thermistor characteristic	
Temperature ($^{\circ}\text{C}$)	Resistance ($\text{k}\Omega$)
-20	80
-10	50
0	30
10	18
20	12
30	6

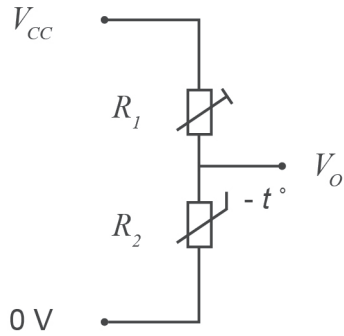
- (a) Explain the general function of a NTC thermistor. (2 marks)

- (b) By using the voltage division principle, write a mathematical expression for the output voltage V_o in terms of R_1 , R_2 and V_{CC} . Also show that V_o swings from 4 V to 0.51 V as R_1 is set at 100 k Ω and the temperature changes from -20°C to 30°C . Show **all** workings. (5 marks)

Question 55 (continued)

- (c) Calculate the minimum and the maximum current flowing through the thermistor as R_T is set at $100\text{ k}\Omega$ and the temperature changes from $-20\text{ }^\circ\text{C}$ to $30\text{ }^\circ\text{C}$. Show **all** workings. (5 marks)

- (d) Calculate R_T such that $V_o = 1\text{ V}$ when the temperature is $10\text{ }^\circ\text{C}$. Show **all** workings. (3 marks)



(e) If you modify the voltage divider shown above and add a Darlington pair, the resulting circuit can switch on a motor when the temperature rises above a certain level. Draw the circuit diagram for the modified circuit described. (7 marks)

(f) State the **main** advantage and the **main** disadvantage of using a Darlington pair over a single NPN transistor. (2 marks)

Advantage: _____

Disadvantage: _____

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