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

WACE
Western Australian Certificate of Education

Western Australian Certificate of Education Examination, 2013

Question/Answer Booklet

ENGINEERING STUDIES

Stage 3

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.

Systems and Control ☐

Mechanical ☐

Electronic/Electrical ☐

Number of additional answer booklets used (if applicable): ☐

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

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.

Ref: 13-044

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 Part B: Extended answer	10 3	10 3	70	10 45	10 30
Section Two: **Systems and Control**					
Part A: Multiple-choice Part B: Extended answer	10 5	10 5	110	10 100	10 50
Section Two: **Mechanical**					
Part A: Multiple-choice Part B: Extended answer	10 5	10 5	110	10 100	10 50
Section Two: **Electronic/Electrical**					
Part A: Multiple-choice Part B: Extended answer	10 6	10 6	110	10 100	10 50
				Total	100

Instructions to candidates

1. The rules for the conduct of Western Australian external examinations are detailed in the *Year 12 Information Handbook 2013*. 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 (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.
3. 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.
4. 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.
5. The Data Book is **not** 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.

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1. Brass and solder (lead/tin) are most appropriately classified as

   (a) pure metals.
   (b) ferrous alloys.
   (c) non-ferrous alloys.
   (d) composites.

2. A system has an input of 265 kW and an efficiency of 74%. The output of this system would be

   (a) 198.75 kW.
   (b) 196.1 kW.
   (c) 358.1 kW.
   (d) 3.58 kW.

3. Global mobile phone ownership continues to increase, while the average life span of a mobile phone decreases. Manufacturers are under pressure to take greater responsibility for which one of the following stages of the mobile phone life cycle?

   (a) materials acquisition
   (b) processing materials
   (c) manufacture
   (d) reuse/recycle/disposal

See next page

4. The maximum volume of water able to be stored in a cylindrical water tank with an internal radius of 1 metre and internal height of 2 metres is

   (a) 62.8 m^3.
   (b) 6.28 m^3.
   (c) 12.56 m^3.
   (d) 1.256 m^3.

5. When producing an orthographic drawing of a new product/design, the primary objective is to

   (a) produce an attractive image suitable for the marketing of the product.
   (b) produce as many drawings as required to show every surface of the product.
   (c) clearly show all the essential dimensions/details of the product such that a third party could successfully manufacture it.
   (d) allow for the accurate costing of the materials required.

6. A timeline used in project planning can be

   (a) a line on an assembly drawing showing the order in which the assembly of items takes place.
   (b) a sequence of dates in the project plan showing when each phase of the project will be completed.
   (c) a line drawn on the face of an office clock showing when work is to cease for the day.
   (d) the date at which the project must be complete.

7. The source of energy in a coal-fired power station is

   (a) fossil fuel.
   (b) geothermal energy.
   (c) kinetic energy.
   (d) biomass fuel.

8. A ductile material would be used when it needs to be

   (a) welded for fabrication.
   (b) resistant to corrosion.
   (c) deformed during fabrication
   (d) hardened to resist abrasion.

See next page

9. The surface area (A) of a cylindrical tank with a diameter of D and a height of H, including the top and bottom, is given by which one of the following?

(a) $A = \pi D^2 H + \frac{\pi D}{2}$

(b) $A = \pi D H^2 + 2 \pi D^2$

(c) $A = \pi D H + 2 \pi D$

(d) $A = \pi D H + \frac{\pi D^2}{2}$

10. A life cycle for a product to be manufactured will come to an end when the product

(a) design is fully specified.
(b) is manufactured for the first time.
(c) is sent to the recycling station.
(d) returns a profit to the manufacturer.

See next page

Section One: Core content

Part B: Extended answer **30% (45 Marks)**

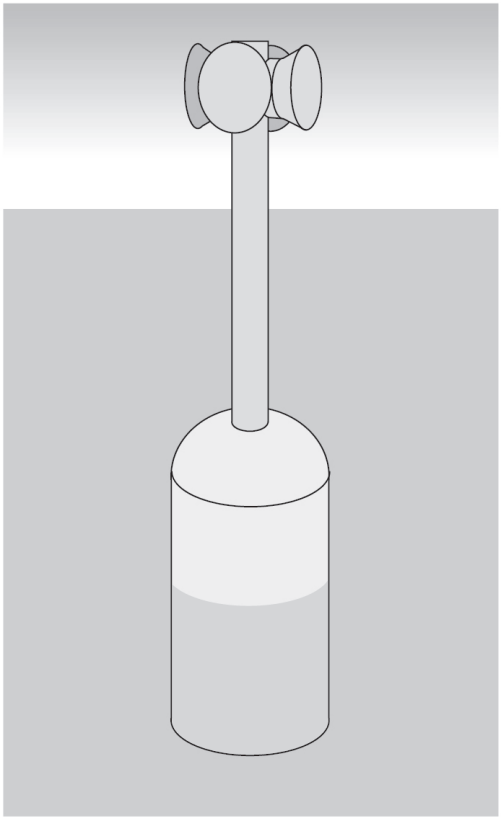
This section has **three (3)** questions. Answer **all** questions. Write your answers in the spaces provided.

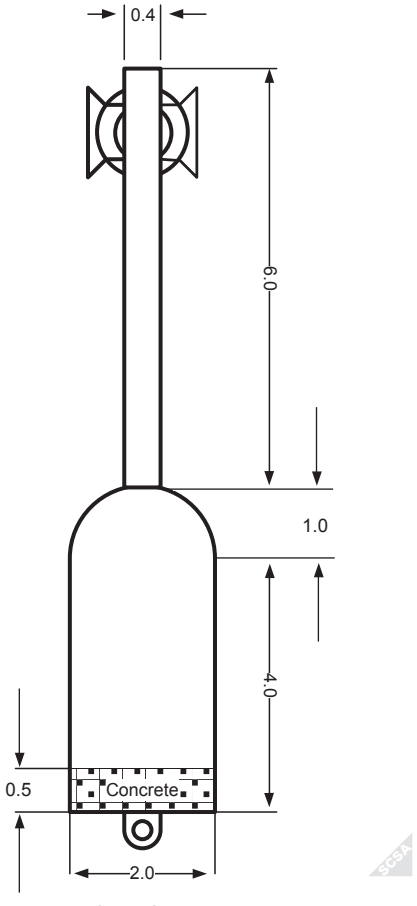
Spare pages are included at the end of this booklet. They can be used for planning your responses and/or as additional space if required to continue an answer.

- 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 **(15 marks)**

The following drawings show a marine buoy of the type that is often used to mark navigation channels in the ocean. The buoy has a cylindrical body section with a hemispherical cap. It is topped by a cylindrical post on which four navigation lights are mounted. The buoy is held in position by an anchor chain connected to the lug at the bottom. To ensure that the buoy floats in an upright position it is partially filled with concrete.





Cross Section

The buoy is made from 8 mm thick stainless steel. Each of the navigation lights (and the associated electronics) weighs 300 kg. The anchoring lug weights 20 kg. All dimensions are in metres.

Show **all** workings.

(a) Show that the surface area of the buoy and post is close to 42.2 m^2 (exclude the lug and the lights). (7 marks)

See next page

Question 11 (continued)

(b) Using the surface area from (a) show that the total weight of the buoy, including all its parts, is approximately 7500 kg. (5 marks)

(c) If the buoy was floating in calm water, how far would it sink into the water? The buoy will displace an amount of water equal to its own weight (Archimedes' principle). (3 marks)

See next page

Question 12 **(15 marks)**

(a) Smart phones are becoming an essential communication tool in the modern world. The designers of the current generation of smart phones work with a long list of criteria for the phones they develop. Provide a brief description of four realistic criteria that you would expect to see used in the development of a new smart phone design, indicating how each criterion would contribute to the quality of the design. (4 marks)

Criterion One: _____

_____

Criterion's contribution: _____

_____

Criterion Two: _____

_____

Criterion's contribution: _____

_____

Criterion Three: _____

_____

Criterion's contribution: _____

_____

Criterion Four: _____

_____

Criterion's contribution: _____

_____

See next page

Question 12 (continued)

(b) Smart phone chassis, casings and circuitry are often made using a combination of plastic, stainless steel and aluminium. In the following table describe a property of each of these materials that makes them a popular choice for this application.
Note: the chassis is the internal structural support (backbone) of the phone. (3 marks)

Material	Property of material
Plastic	
Stainless steel	
Aluminium	

(c) The following diagram shows an orthographic drawing of an after-market smart phone protector casing, i.e. a casing that can protect the phone from minor abrasions and normal wear and tear.

Using the drawing on page 11, determine the following dimensions:

(3 marks)

the distance from the top of the casing to the centre of the lower hole

_____

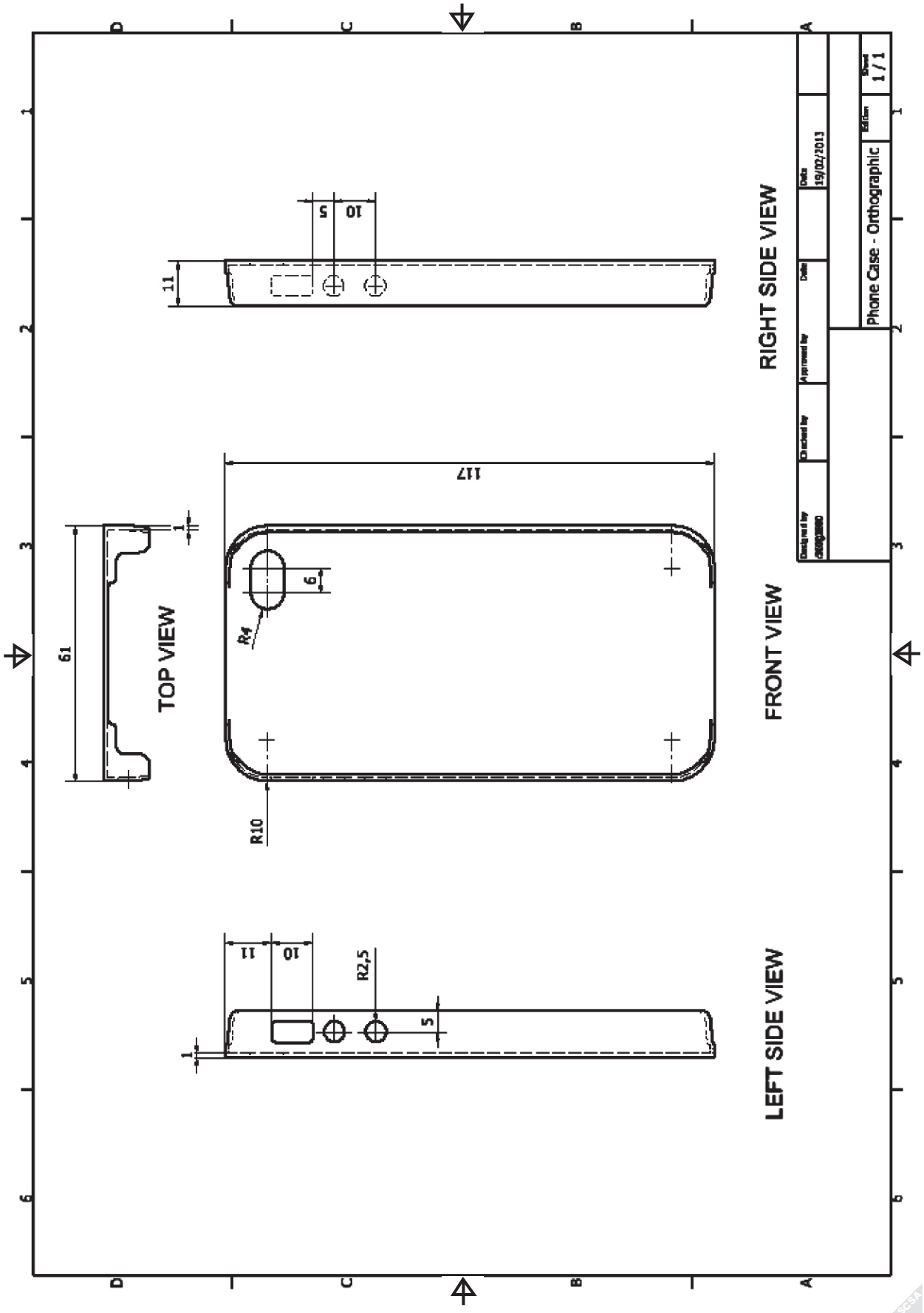
the diameter of each of the circular holes

_____

the wall thickness of the phone casing.

_____

See next page



See next page

Question 12 (continued)

(d) In the blank space below, draw a dimensioned pictorial view of the phone casing. Present the casing using a view/orientation of your choice in order to best display all of its features. Include only major dimensions (length, width and depth). (5 marks)

See next page

Question 13 **(15 marks)**

It is important to keep in mind that motor vehicles have an impact on the environment through their carbon dioxide (CO_2) emissions and their life cycle.

According to the 2012 Motor Vehicle Census by Australian Bureau of Statistics, there were 16.7 million vehicles registered in Australia as at 31 January 2012. Among these, 13.6 million vehicles were registered with a fuel type of petrol, 2.7 million vehicles with diesel fuel, and a much lower number with LPG fuel.

Table A presents an indicative guide on the amount of CO_2 emitted from the exhaust for each litre of a particular fuel.

Table A: CO_2 Emissions per litre of fuel consumed

Fuel type	CO_2 emissions (kg/L)
Petrol	2.3
Diesel	2.7
LPG	1.6

Table B shows an indicative guide on the fuel consumption and the CO_2 emissions for a particular type of petrol vehicle.

Table B: Fuel consumption and CO_2 emissions from various types of petrol vehicles

Vehicle type	Fuel consumption (L/100 km)	CO_2 emissions (g/km)
Small	6	138
Medium	8	184
Large	10	230
4WD	12	276

See next page

Question 13 (continued)

(a) Based on the statistics presented in Table A, state whether the following statement is true or false, and provide a reason: (2 marks)

'For the same distance travelled, an LPG vehicle will always produce less CO_2 emissions than an equivalent petrol or diesel vehicle.'

The statement is (true or false): _____

Reason: _____

(b) Calculate the fuel efficiency, in terms of kilometres per litre, of a 4WD petrol vehicle. Show **all** workings. (2 marks)

(c) Given that the price of petrol is 150 cents per litre, calculate the annual cost of petrol in dollars and the annual emission of CO_2 in kg for a medium-sized petrol vehicle that has travelled 15 000 km in a year. Show **all** workings. (4 marks)

Annual petrol cost ($):

Annual CO_2 emission (kg):

See next page

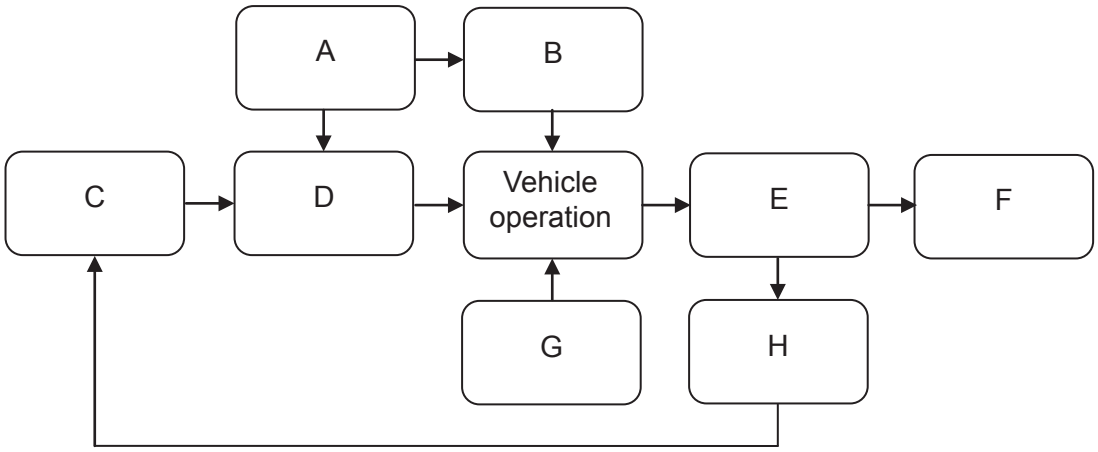
(d) Suppose a driver of a medium-sized petrol vehicle has learned to drive more efficiently, resulting in a drop of fuel consumption from 8 L/100 km to 7 L/100 km, and also manages to reduce their distance driven from 15 000 km to 10 000 km per year. Determine the annual CO_2 emission, in kg, as a result of this. Show **all** workings. (3 marks)

See next page

Question 13 (continued)

(e) Complete the simplified life cycle diagram of a vehicle as shown below by matching the following labels (1-8) to the boxes (A-H). (4 marks)

Label 1 – Recycling
Label 2 – Raw materials
Label 3 – Waste products
Label 4 – Fuel production
Label 5 – Landfill and emissions
Label 6 – Vehicle production
Label 7 – Energy sources
Label 8 – Vehicle maintenance



Use the above diagram (with pencil and eraser) to develop your answer and once complete show your answers below by writing the label number next to each box label.

Box A: _____
Box B: _____
Box C: _____
Box D: _____
Box E: _____
Box F: _____
Box G: _____
Box H: _____

End of Section One

See next page

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

Candidates are required to choose one of the following options, according to which specialist field they studied in 2013.

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

Specialist field	✓	Question numbers	Pages
Systems and control	☐	14–28	**18–35**
Mechanical	☐	29–43	**36–54**
Electronic/Electrical	☐	44–59	**55–75**

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.

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14. You are required to connect a digital signal that has voltage values of 0 V or 10 V (to indicate LOW and HIGH signals) to the digital input of a microprocessor. A suitable conditioning circuit for this would consist of only

    (a) resistors.
    (b) a transistor and resistors.
    (c) resistors and diodes.
    (d) resistors and capacitors.

15. Is it possible to replace all the gates in a logic circuit with only NAND gates to create an equivalent circuit?

    (a) only when there is an even number of gates
    (b) only when there are no XOR gates present
    (c) yes, always
    (d) no, never

16. A fixed resistor placed in series with an LED will **always**

    (a) control the brightness of the LED.
    (b) change the colour of the LED.
    (c) change the voltage at which the LED turns on.
    (d) limit the current flowing through the LED.

See next page

17. A repetition loop in a program in a microprocessor is intended to terminate when

(a) the reset button is pushed.
(b) the number of iterations reaches the limit matching the microprocessor's word size.
(c) some logic condition is satisfied in the program.
(d) the power is switched off.

18. The term 'PWM', which is often associated with controlling the speed of motors, means

(a) Pulse Width Modulation.
(b) Power Wide Management.
(c) Programmed With Microprocessor.
(d) Pulsed Wired Mode.

19. A Darlington array would be used in a driver circuit to

(a) filter a signal.
(b) reduce the noise on a signal.
(c) amplify a signal.
(d) invert a signal.

20. The name of the device used for comparing the output with the input in a closed loop system in order to control an action is

(a) error detector.
(b) feedback sensor.
(c) input conditioner.
(d) output actuator.

21. A rack and pinion geared mechanism would be used to

(a) convert clockwise rotation into anticlockwise rotation.
(b) convert a rotational movement into a translational movement.
(c) change the speed of rotation but not the direction.
(d) increase the mechanical advantage to lift a heavy object.

22. You would use a solenoid-based device to

(a) limit the current flowing through a LED.
(b) open and close a valve in a water supply.
(c) determine if a limit switch is tripped.
(d) determine if water is flowing in a pipe.

See next page

23. You may choose to use a limit switch to operate an actuator being controlled by a microprocessor because it

(a) provides an easy way of setting the operational limits of the actuator by simply reprogramming the microprocessor.
(b) provides a convenient way of setting the operational limits of the actuator without reprogramming the microprocessor.
(c) can be used to find out the actual position of the actuator at any time in its range of movement.
(d) can be used to set accurately the position of the actuator an any valid position within its range of movement.

See next page

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

This part has **five (5)** 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 24 **(32 marks)**

A thermostat is a device that controls the temperature of an object. Your task involves designing a microprocessor-based thermostat for a portable refrigerator, of the type that you might use when camping. For the design you have

- a portable refrigerator, that is driven from a 12 VDC supply, with no thermostat.
- a microcontroller that you can program. It has four digital input/output pins (D0, D1, D2, D3) and two 10-bit voltage (0 V to 5 V) analogue input pins (A0, A1).
- a 12 V relay that is capable of switching the power supply to the refrigerator unit on and off. The relay requires 200 mA from its input signal to operate.
- one type K thermocouple device. These temperature-sensitive sensors produce a voltage that is proportional to the temperature to which they are exposed. They operate according to the formula:

  $$T = 22.5 \times V$$

  Where T is the temperature (ºC) and V is the DC voltage output (volts) produced by the thermocouple device. The range of voltage of the output from the thermocouple is 0 V to 5 V. This thermocouple device comes with its own 12 V power supply.
- a variable resistor that will be used to set the required temperature for the refrigerator (the set point) to a value in the range of 0 to 10 ºC.

(a) Which of the microprocessor pins would you use to connect to the thermocouple? Explain your answer. (2 marks)

Pin: _____

Explanation: _____

_____

_____

_____

_____

_____

See next page

Question 24 (continued)

(b) State which microprocessor pin you would use to connect to the relay. Explain your choice. (2 marks)

Pin: _____

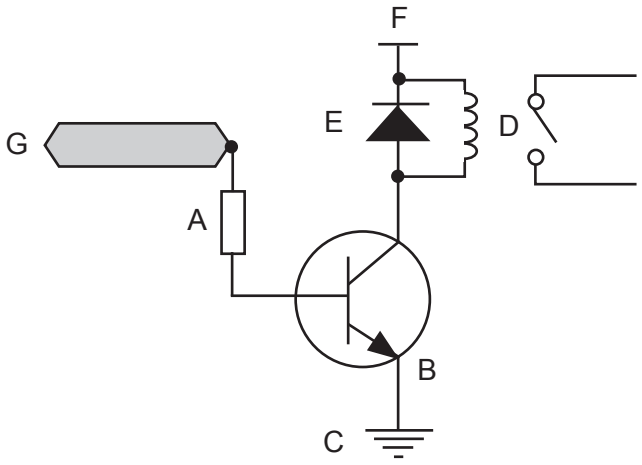
Explanation: _____

_____

_____

_____

(c) The circuit shown below allowed the microprocessor to turn the relay ON or OFF when it was provided with a 5 V or 0 V signal from the microprocessor. Each component is labelled from 'A' to 'G'. Name each component, and explain the operation of this circuit. (11 marks)



A: _____ E: _____

B: _____ F: _____

C: _____ G: _____

D: _____

Explanation: _____

_____

_____

_____

_____

_____

(d) Draw a circuit to show how you would connect the variable resistor to the microcontroller so that you could provide a voltage in the range 0 to 5 V to indicate a temperature in the range 0 to 10 ºC. You have a 12 V power supply available but you are required to limit the current drawn by this circuit to 20 mA. Calculate the electrical values of all the required components. (8 marks)

See next page

Question 24 (continued)

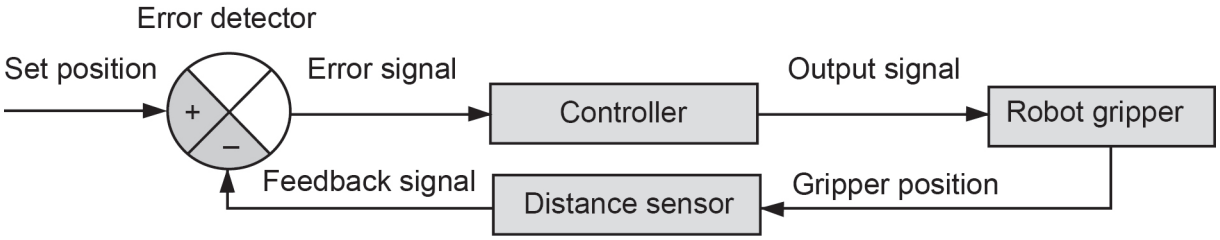
(e) To operate effectively, i.e. to maintain the temperature at some chosen value (the set point), it is necessary to define a range of temperatures so that the refrigerator is not turning on and off at short intervals. This range is T±1 ºC, where T is the required set point temperature in the range 0 to 10 ºC.

Draw a flow chart that describes correctly the operation of a thermostat system that could be used. (9 marks)

See next page

Question 25 **(16 marks)**

You have been asked to advise on the design of a control system for a robot gripper (the part of the robot that actually grasps the objects to be picked up and moved). The gripper is initially closed. The following control diagram, using proportional control, has been proposed:



In this diagram each system component is shown as a block labelled with an appropriate name to describe its function, and the connecting arrows are labelled to indicated the type of information that is being passed between the system blocks.

(a) Give a brief description of the function of each system block. Explain how the input signals are used and describe the output signals in each case. (8 marks)

Error detector: _____

_____

_____

Controller: _____

_____

_____

Robot gripper: _____

_____

_____

Distance sensor: _____

_____

_____

See next page

Question 25 (continued)

(b) Explain how proportional control would operate with the system shown on page 25. (4 marks)

(c) A colleague has suggested to you that such a complex control system is not really necessary. All you need to do is to send a single instruction to the gripper to change its gap to the required value.

Provide an explanation to your colleague that describes why this alternative approach may **not** prove to be satisfactory in practice. (4 marks)

See next page

Question 26 **(14 marks)**

Most modern motor vehicles have warning signals to indicate if any doors are not closed fully. You have been asked to design a logic system for a new vehicle to operate as follows:

- The car has two doors, each with an open/close detector that will give a HIGH signal if the door is closed fully.
- There will be a visual display for the driver that will indicate when either of the doors is open. This display will have a separate display segment for each door so that the driver can see immediately which door is not closed.
- These displays will operate all the time, even when the engine is not running.
- When the engine is running (the ignition is ON), if either of the doors is not closed fully a buzzer will sound to alert the driver.

The system you are required to design has:

- three input signals:
  - D1 and D2 – the signals for each door: HIGH means closed, LOW means open
  - Ignition – the signal from the ignition switch: HIGH means the engine is running, LOW means it is not.

- three output signals:
  - W1 and W2 – the signals to turn ON/OFF the warning light displays for each door when the door is open
  - Buzzer – the signal to active the buzzer, ON/OFF, to turn on when any of the doors is OPEN and the ignition is ON.

See next page

Question 26 (continued)

(a) Draw and label a suitable logic diagram that will meet these requirements, using a combination of discrete logic gates. Each gate should be drawn using the standard symbols or labelled to indicate its type clearly. Each input and output signal must be labelled clearly to match the signals described on page 27. (9 marks)

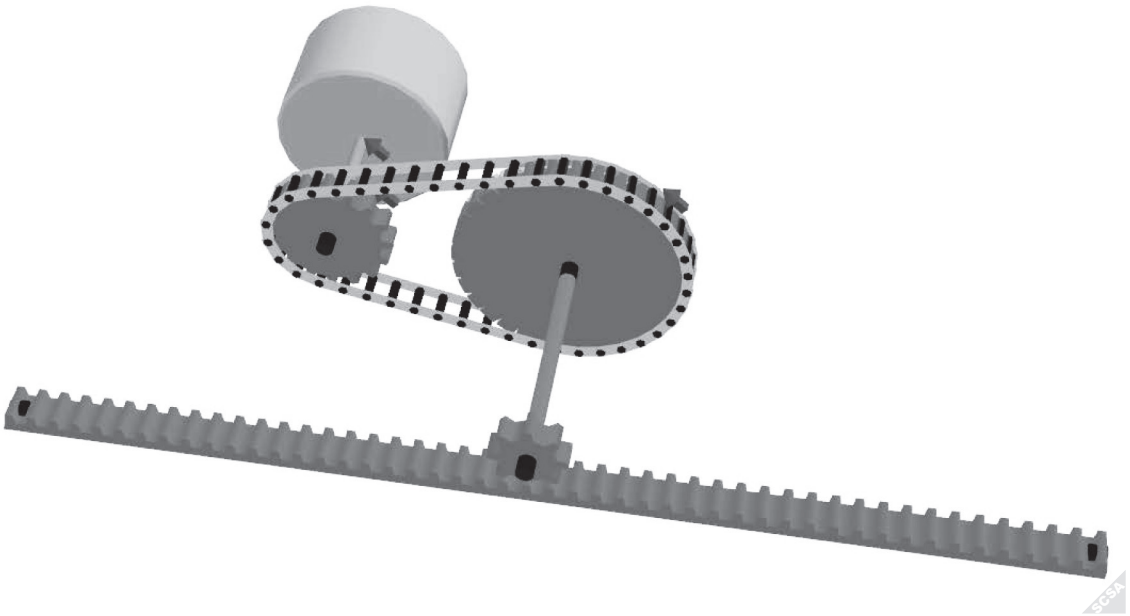
See next page

(b) Construct a Boolean logic expression to represent the operation of the buzzer in the warning system as a function of the three input signals. (5 marks)

See next page

Question 27 **(17 marks)**

The diagram below shows a schematic representation of a rack and pinion system being driven by an electric motor through a reduction gear system.



The gears are described below:

- The drive motor shaft has 16 teeth.
- The intermediate gear has 32 teeth.
- The pinion has 8 teeth.
- The rack has 48 teeth and has a gear pitch of 10.0 mm.

The motor rotates at 400 rpm in either direction.

Show **all** workings.

(a) Show that the speed of rotation of the intermediate gear is 200 rpm. (2 marks)

See next page

(b) Show that it will take about 1.5 s for the rack to translate a distance of 400 mm. (4 marks)

(c) If you wished to double the time taken to translate the rack a distance of 400 mm, what change in the design of this gear system (using the same motor) would you suggest? Why? (3 marks)

Change: _____

Explanation: _____

(d) Describe the operation of new components that might be added to this drive system to ensure that the rack was not driven beyond its length in either direction. Draw a system block diagram showing how these new components would be connected to the drive system. (5 marks)

See next page

Question 27 (continued)

(e) The motor is replaced with a stepper motor so that the position of the rack can be controlled more accurately. The stepper motor has an angular step size of 18º. Calculate the number of steps required to translate the rack 100 mm. (3 marks)

See next page

Question 28 **(21 marks)**

To use an analogue signal (say in the range 0 to 12 VDC) in a microprocessor it is necessary to convert this signal into a digital value. The device used for this purpose is an ADC (analogue digital converter). For many microprocessors this capability is already built into the device, so no additional hardware is required.

The task you have involves controlling the temperature of beer being brewed in a large vat so that the heating system can be managed to maintain the temperature to an accuracy of ±0.1 ºC in the range 20 ºC to 60 ºC. The required temperature can vary according to the type of beer being brewed.

The temperature sensor provides an analogue signal in the range 0 to 12 VDC that is linearly proportional to its design temperature range, i.e. from 0 ºC to 100 ºC.

The ADC on the selected microprocessor has an 8 bit resolution.

(a) Draw and label a suitable interfacing circuit using a voltage divider that could be used to connect the output of the temperature sensor to an ADC pin on the microprocessor.
(4 marks)

See next page

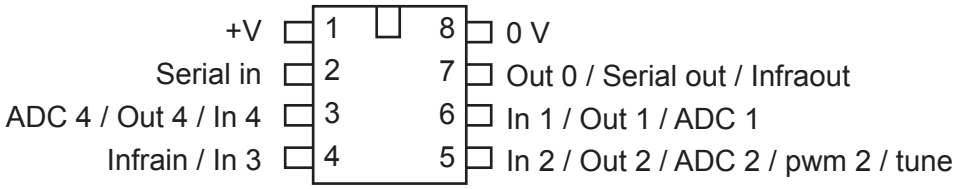
Question 28 (continued)

(b) If one of the ADC inputs on the microprocessor was used to connect to the temperature input circuit, calculate the accuracy of the temperature value available in the microprocessor for computations in the control task. Would this accuracy be acceptable if the required accuracy is ± 0.1 °C? Why? Show **all** workings. (4 marks)

(c) Calculate the digital values that will be observed in the microprocessor for the expected low and high values at temperatures of 20.0 ºC to 60.0 ºC respectively. Show **all** workings. (4 marks)

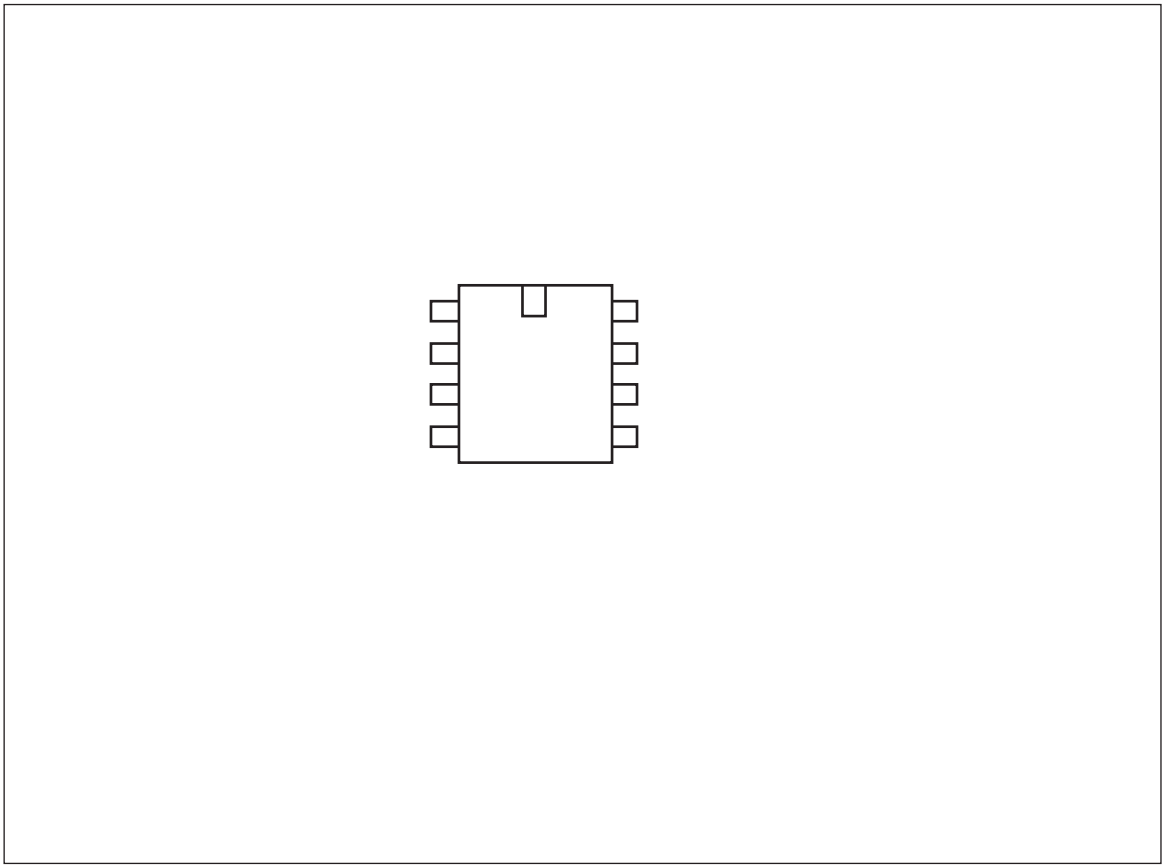
See next page

(d) If the temperature goes outside the range of 20 ºC to 60 ºC, the brewing process may become unstable and some alarm signals should be generated. If the temperature goes below 20 ºC, a 'too low alarm' should be triggered and if it goes above 60 ºC a 'too high alarm' should be triggered. A suitable microprocessor is shown below.



Draw and label the following on the schematic diagram of the microprocessor:

- the two alarm devices and their connection to the appropriate pins on the microprocessor and the direction of the signal for each connection
- the temperature sensor and its connection to the microprocessor and the direction of the signal for this connection
- the 5 VDC supply voltage and ground connections. (9 marks)



End of Section Two: Systems and Control

See next page

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

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

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

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

Suggested working time: 110 minutes.

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

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

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29. 'Work' can be defined as

    (a) a measure of the energy expended by a force in moving an object a certain distance.
    (b) power × time.
    (c) force × distance.
    (d) all of the above.

30. The maximum bending moment experienced within a cantilevered beam that has a single load at its unsupported end will occur

    (a) at the beam's midpoint.
    (b) at the point where the beam extends from its supporting structure.
    (c) at the end of the beam where the external load is applied.
    (d) evenly throughout the beam.

31. The process of forging would be used to manufacture a machine component in preference to the process of casting when

    (a) a highly complex shape needs to be produced.
    (b) the part will not be subjected to high-stress-inducing loads.
    (c) the part will be routinely subjected to a variety of high-stress-inducing loads.
    (d) the grain formation/direction within the part is not important.

See next page

32. A 10 kg sandbag is dropped from a hot air balloon on a windless day from a height of 330 m. Neglecting aerodynamic friction, what would be the kinetic energy of the bag immediately before impact?

(a) 3300 joules
(b) 32.34 kilojoules
(c) 80.42 kilojoules
(d) 3.23×10^6 joules

33. Which one of the following is the most appropriate alternative unit that can be exchanged directly for megapascals (MPa)?

(a) $N\ m^{-2}$
(b) $N\ mm^{-2}$
(c) $kN\ mm^{-2}$
(d) $MN\ mm^{-2}$

34. Structural steel has an ultimate tensile stress of 400 $N\ mm^{-2}$. If a factor of safety of 2 was used for a particular application, would the steel contained in the part continue to behave elastically when experiencing its maximum safe working stress?

(a) Yes, because the safe working stress remains below the material's yield stress.
(b) No, the material would deform permanently as this would exceed the yield stress.
(c) Yes, because the safe working stress remains below the material's ultimate tensile stress.
(d) No, the material would fail as this would exceed the ultimate tensile stress.

35. When comparing the shear force diagram and bending moment diagram of a centrally loaded beam that is simply supported at each end, the point of maximum bending moment corresponds with the point where

(a) the shear force diagram crosses the X axis.
(b) the bending moment diagram crosses the X axis.
(c) shear force is at its maximum value.
(d) shear force is at its minimum value.

36. When comparing stress-strain curves of two different materials, the material with the higher gradient within the proportional section of its graph will have a higher

(a) yield stress value.
(b) ultimate tensile stress value.
(c) elastic limit.
(d) Young's modulus value.

See next page

37. A horizontal beam is simply supported at both ends and is loaded centrally. Which of the following **best** describes the resulting forces within the beam?

(a) The beam will experience tensile forces above its neutral axis and compressive forces below the neutral axis.
(b) The beam will experience no forces along its neutral axis and only compressive forces elsewhere.
(c) The beam will experience no forces along its neutral axis and only tensile forces elsewhere.
(d) The beam will experience compressive forces above its neutral axis and tensile forces below its neutral axis.

38. Within a loaded pin-jointed truss, the members will be either in tension or compression (axial loads). The common name for a truss member that is in compression is a

(a) tie.
(b) reaction member.
(c) strut.
(d) moment arm.

See next page

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

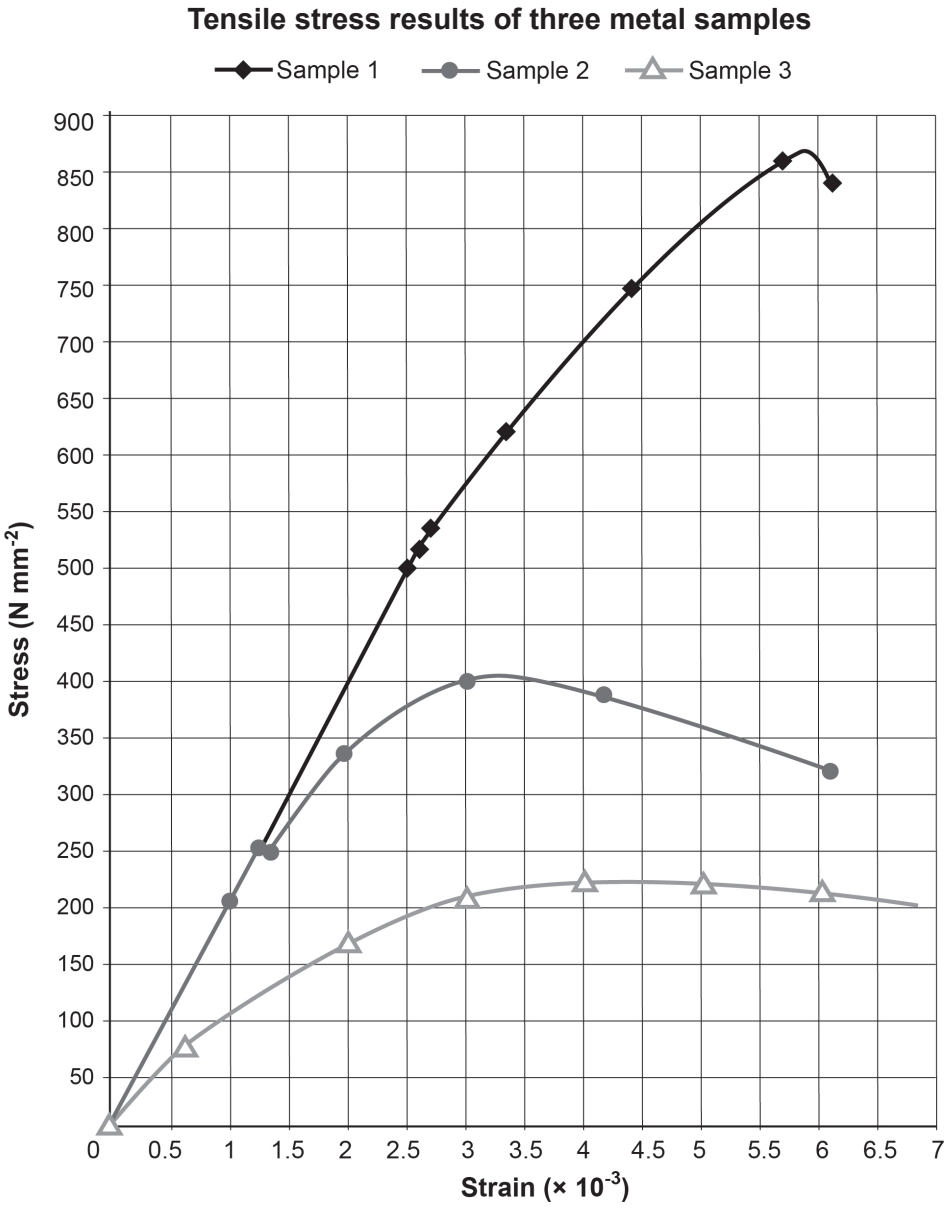
This part has **five (5)** questions. Answer **all** questions. Write your answers in the spaces provided.

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 39 **(20 marks)**

Below is a stress/strain graph containing the resulting curves produced by three metal samples when they were each subjected to a tensile test.



See next page

Question 39 (continued)

(a) Identify each of the three metal samples that produced the graphed data on page 39 and state the identifying values you used. You may need to refer to information provided in the **Data Book** to assist with this identification. (6 marks)

Sample 1: _____

Identified by: _____

_____

Sample 2: _____

Identified by: _____

_____

Sample 3: _____

Identified by: _____

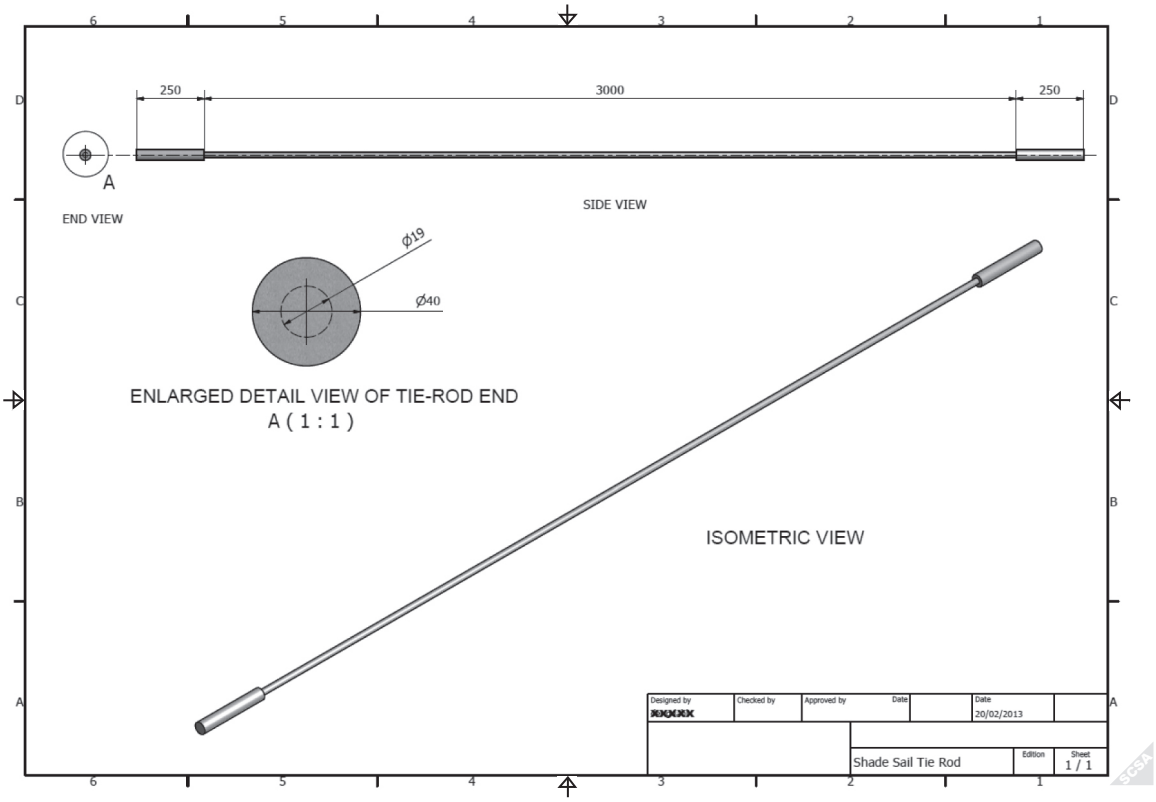
_____

(b) The following image shows a part of a playground shade structure.

This playground shade sail structure is located in a coastal area. It has tensile members made of stainless steel to brace each support post in order to prevent excessive bending moments being generated during extreme wind events, such as cyclones.

See next page

The main (central) section of the tie-rod has a diameter of 19 mm and is 3 m long. At each end of the rod, leading to the attachment points, the bar increases to a diameter of 40 mm for a length of 0.25 m as shown in the following drawing:



(i) During a recent storm with strong westerly winds, an elongation of 0.19 mm was measured in the 3 m span of one of the supporting tie-rods. Show that the force required to produce this degree of elongation in the 19 mm diameter section is close to 3.6 kN. (5 marks)

See next page

Question 39 (continued)

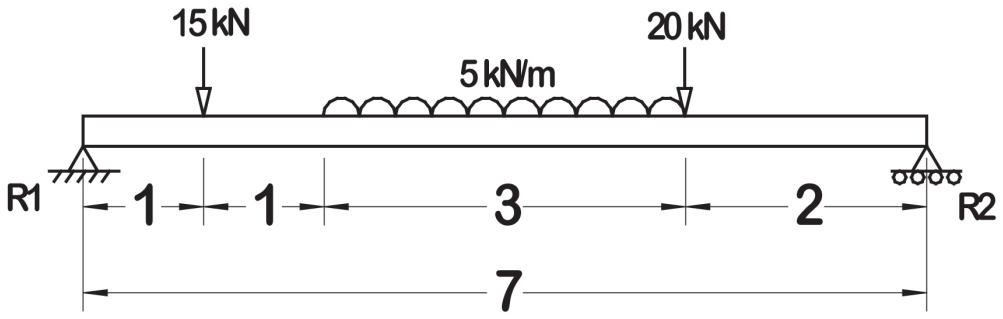
(ii) When subjected to this peak force, what is the total elongation experienced by the whole rod including the two 0.25 m long, 40 mm diameter rod end sections? (6 marks)

(c) If the rod was secured to its footing at an angle of 55°, calculate the minimum mass required for the concrete footing (where the tie-rod attaches to the ground) to ensure that it does not lift out of the ground in this scenario where an axial load of 3589 N is applied to the tie rod. (3 marks)

See next page

Question 40 **(23 marks)**

The following questions relate to the simply supported beam shown below.



(a) Use the condition of equilibrium, ΣCWM = ΣACWM, to prove that the reaction force at R1 is about 26 kN. Show **all** workings. (4 marks)

(b) Use a condition of equilibrium of your choice to show that the reaction force at R2 is about 24 kN. Show **all** workings. (4 marks)

See next page

Question 40 (continued)

(c) Demonstrate through calculation that the position of maximum bending moment in the beam is close to 4.2 m from the left-hand end of the beam. (3 marks)

(d) Demonstrate through calculation that the maximum bending moment in the beam is close to 49 kN m. (3 marks)

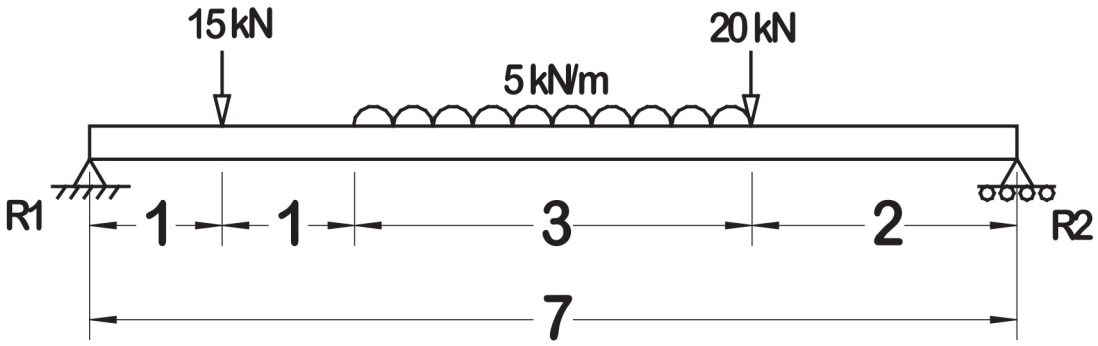
See next page

(e) On the two sets of axes provided below:

(i) Draw a graph of the shear force diagram for the beam. (4 marks)

(ii) Draw a graph of the bending moment diagram for the beam including the maximum. (5 marks)

Note: You must include an appropriate scale with correct units on both the X and Y axis of each graph and clearly show the correct values on the key points in each diagram.

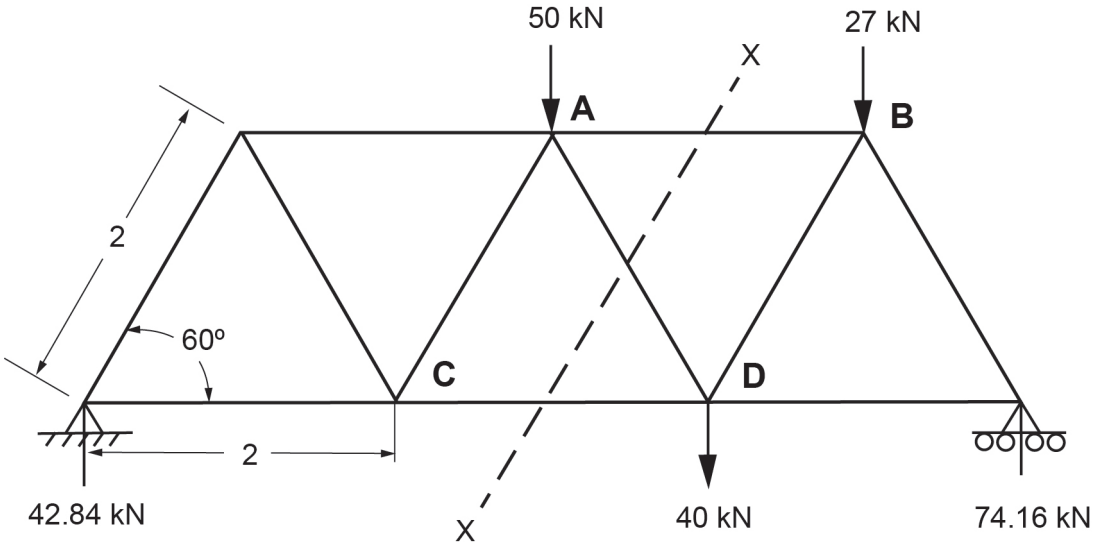


SF

BM

See next page

Question 41 **(12 marks)**



Find the forces in the truss members cut by the section line X-X using the Method of Sections. The members in question are CD, AB, and AD.

In each case indicate whether the members are either in tension or compression (circle the correct option) and explain why.

Show **all** workings.

(a) Find the force in member CD. (4 marks)

F_{CD} = _____ kN in tension/compression because _____

See next page

(b) Find the force in member AB. (4 marks)

F_{AB} = _____ kN in tension/compression because _____

(c) Find the force in member AD. (4 marks)

F_{AD} = _____ kN in tension/compression because _____

See next page

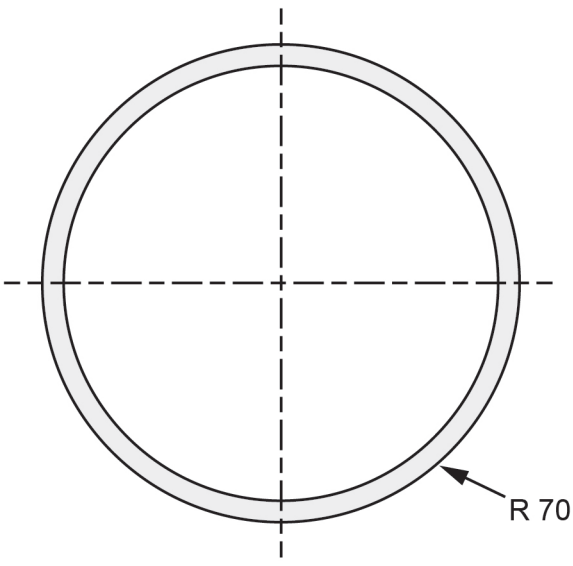
Question 42 **(22 marks)**

A playground located in a sheltered (medium wind level) area has the outer corners of its shade sails supported by (near) vertical posts as shown in Image A. They are made from structural steel using circular tube section with an outside diameter of 140 mm. The post shown in detail in Image B (below) is located on one of the corners of the playground. It has no extra support (e.g. tie-rods) and therefore the post acts as a cantilever, relying entirely on its concrete footing to counteract the moments applied. It is 3 m high and has a single horizontal attachment at the top of the post for the shade sail.

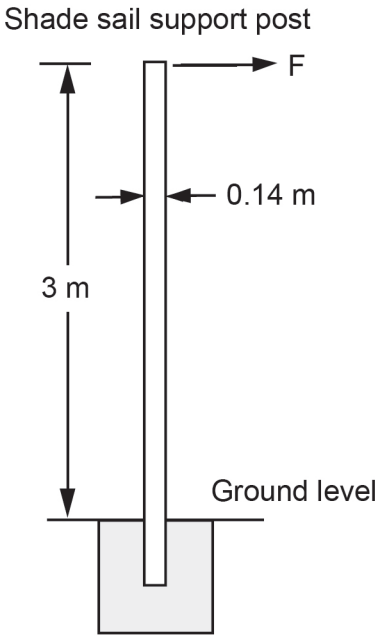
Image A

Image B

See drawings below for details of the post.



Cross section of shade sail post
(structural steel)



Concrete footing

See next page

(a) Given that the second moment of area (I_{xx}) of the circular tube support post is 5 387 832 mm^4, prove, through calculation using the formula from the **Data Book**, that the wall thickness (t) of the tube section is 5 mm. Show **all** workings. (4 marks)

(b) The support post deflects 4.35 mm at its tip (sail attachment point 'F') due to the static tensile force in the cable holding the shade sail. Calculate the magnitude of this force. Show **all** workings. (5 marks)

(c) Over winter, the shade sails were removed by the local council and put into storage to reduce the chance of potential storm damage. A very strong gust during a winter storm created a uniform distributed load (UDL) on the 3 m length of exposed post. The UDL generated by the wind caused the top of the post to momentarily deflect 0.094 mm.

Calculate the force per metre on the 3 m post caused by the wind. Show **all** workings. (6 marks)

See next page

Question 42 (continued)

(d) In a different scenario, the tension on the cable at the top of the post becomes 1 kN and simultaneously, a universally distributed load applies a force of 20 newtons per metre to the full 3 m length of the post in the same direction as the cable. Calculate the moment generated at the base of the post. Show **all** workings. (5 marks)

(e) Give **two** reasons why a circular tube section of structural steel, 140 mm in diameter and 5 mm thick, is an appropriate choice in this application. (2 marks)

One:

Two:

Question 43 **(23 marks)**

An Australian team is preparing to make an attempt on the world land speed record. They have designed and developed a rocket powered car to eclipse the current world record of 1228 km h^{-1} by travelling at over 1610 km h^{-1}.

Note 1: Critically, the car needs to accelerate and decelerate at no more than 31 m s^{-2} in order to maintain wheel traction and, therefore, control.

Note 2: A world record attempt is based on the time taken to cover a distance of 1609 m (a 'measured mile'), that is the average speed over the course and not the peak speed that may need to be considerably greater.

(a) Given that the car's rocket engine produces 275 kN of thrust and the car has a fully loaded mass of 9.163 tonnes, would its initial rate of acceleration be safe (allowing traction to be maintained) if the rocket was fired giving immediate full thrust? Show **all** workings. (3 marks)

See next page

Question 43 (continued)

(b) In a hypothetical scenario, the rocket car's record attempt has three phases.

Acceleration phase: from a standing start, the car accelerates at a constant 30 m s^{-2} until it reaches 1580 km h^{-1}.

Course phase: the car enters the 1609 m course at a speed of 1580 km h^{-1}, and its acceleration decreases immediately to a lesser, but still positive and constant, value. The car reaches a peak speed of 1640 km h^{-1} just as it exits the course.

Deceleration phase: On leaving the course at 1640 km h^{-1}, the car decelerates at a constant rate taking 14.69 s to come to a complete stop.

Calculate the total distance travelled by the car in completing this hypothetical record attempt. Show **all** workings. (10 marks)

See next page

(c) If the 9163 kg rocket car was reconfigured to launch vertically as a space-bound rocket, show that the available 275 kN of thrust would be enough to launch the rocket car, and determine its initial rate of acceleration.

Justify your answer and show **all** workings. (5 marks)

(d) The rocket consumes 112 kg of fuel and liquid oxygen per second as it attempts the land speed record of 1640 km h^{-1}. Identify and describe **two** significant factors that have a major influence on the acceleration and/or top speed of the car. (2 marks)

One:

Two:

See next page

Question 43 (continued)

(e) If the car maintained a constant velocity 455.56 m s^{-1} over the timed course of 1609 m and the force generated by the rocket engine remains constant at 275 kN, calculate the power produced during this part of the run. (3 marks)

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.

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44. In a semiconductor diode, the two bias conditions are

    (a) open and closed.
    (b) blocking and non-blocking.
    (c) positive and reverse.
    (d) forward and reverse.

45. When the voltage across a capacitor is doubled, the stored charge

    (a) stays the same.
    (b) is halved.
    (c) increases by four.
    (d) is doubled.

46. A capacitance of 0.05 μF is larger than

    (a) 6000 pF.
    (b) 0.00005 mF.
    (c) 490 nF.
    (d) 5.1×10^{-7} F

47. The term ‘pole’ as it relates to switches is defined as the

    (a) number of closed contact positions that the switch has.
    (b) number of completely isolated circuits that can be controlled by the switch.
    (c) number of connecting terminals the switch has.
    (d) voltage polarity of the switch.

See next page

48. For a typical transistor, which one of the following statements is correct?

(a) The current I_B is approximately equal to the current I_E.
(b) The current I_B is approximately equal to the current I_C.
(c) The current I_C is approximately equal to the current I_E.
(d) The sum of the current I_C and I_E is approximately equal to the current I_B.

49. If a thermistor has a negative temperature coefficient, its resistance

(a) increases with a decrease in operating temperature.
(b) decreases with a decrease in operating temperature.
(c) is unaffected by its operating temperature.
(d) is unaffected when the operating tempersature is above 0 °C.

50. Voltage loading is usually a problem when measuring voltages in

(a) parallel circuits.
(b) high resistance circuits.
(c) low resistance circuits.
(d) a series circuit with low resistance values.

51. Battery cells are connected in parallel to

(a) increase the current capacity.
(b) increase the voltage output.
(c) decrease the current capacity.
(d) decrease the voltage output.

52. Which of the following statements about the Darlington Pair is correct?

(a) An emitter of the first transistor feeds current to the collector of the second transistor.
(b) Applying sufficient base-emitter voltage to turn on the first transistor will automatically turn on the second transistor.
(c) Both (a) and (b) are correct.
(d) Neither (a) nor (b) is correct.

53. LEDs are based on the principle of

(a) forward bias.
(b) photon sensitivity.
(c) electroluminescence.
(d) electron-hole recombination.

See next page

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

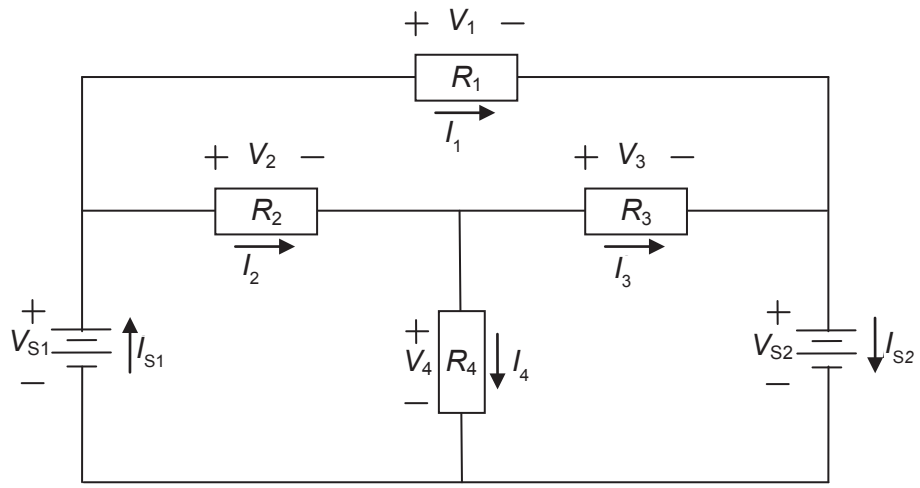
This part has **six (6)** questions. Answer **all** questions. Write your answers in the spaces provided.

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 54 **(19 marks)**

A circuit is constructed as shown below with four resistors and two batteries.



Question 54 (continued)

(a) Given V_{s1} = 24 V, V_{s2} = 12 V and V_2 = 8 V, use Kirchhoff's voltage law to determine the value for the voltages V_1, V_3 and V_4. Show **all** workings. (3 marks)

Voltage V_1

Voltage V_3

Voltage V_4

(b) Given I_{s1} = 3 mA, I_{s2} = 2 mA and I_2 = 2 mA, use Kirchhoff's current law to determine the value for the currents I_1, I_3 and I_4. Show **all** workings. (3 marks)

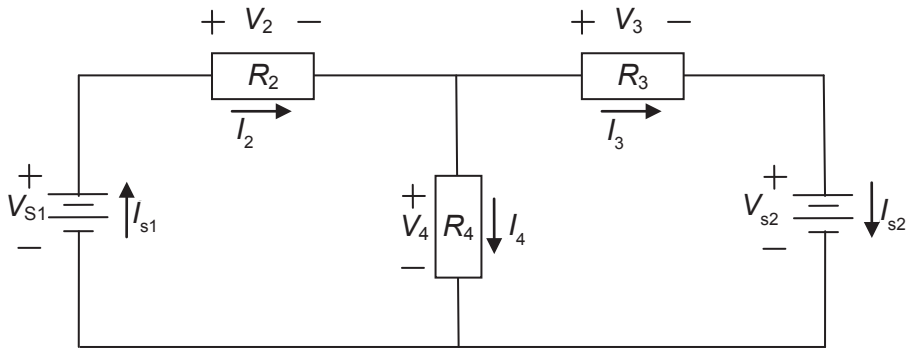
Current I_1

Current I_3

Current I_4

See next page

(c) Suppose the resistor R_1 is removed to create a new circuit as shown below, where V_{s1} = 24 V, V_{s2} = 12 V, V_2 = 8 V, R_2 = 4 kΩ, and R_3 = 4 kΩ. Calculate the current I_{s2} and the resistor R_4. Show **all** workings. (5 marks)

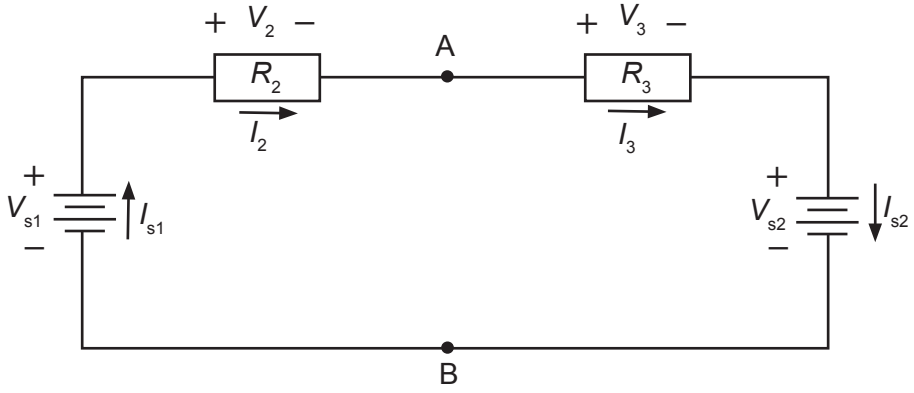


Current I_{s2}

Resistor R_4

Question 54 (continued)

(d) Suppose the resistor R_4 is now removed, resulting in another new circuit as shown below, where V_{s1} = 24 V, V_{s2} = 12 V, R_2 = 4 kΩ, and R_3 = 4 kΩ.



(i) Show that the power supplied by the battery labelled V_{s1} is 36 mW. (3 marks)

(ii) Determine the expected reading of an ideal voltmeter if its red probe (which indicates positive reference) is connected to Point A while its black probe is on Point B of the circuit. Show **all** workings. (3 marks)

See next page

(iii) The circuit on page 60 can be represented by an equivalent circuit that consists of one battery and one resistor. Calculate the equivalent battery voltage and the equivalent overall resistance. Show **all** workings. (2 marks)

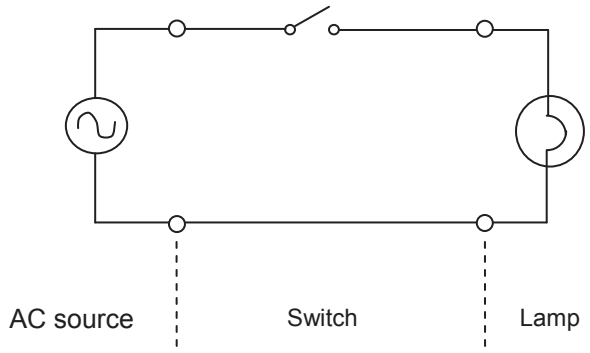
Equivalent battery voltage:

Equivalent overall resistance:

See next page

Question 55 **(16 marks)**

A basic lighting circuit, which consists of an AC source, a switch and a lamp, is shown below.

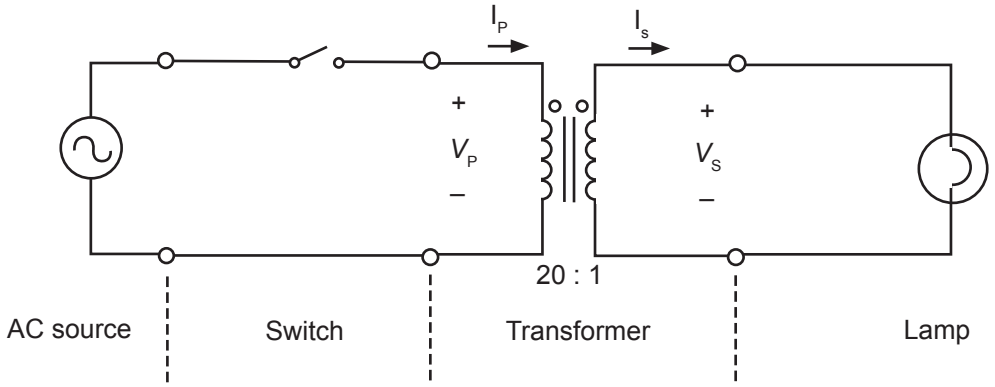


(a) Suppose a 240 V, 50 W halogen lamp is used, and it has been switched on continuously for seven days. Calculate the energy consumption in kWh, and the electricity cost in dollars, assuming that the electricity is charged at a rate of 30 cents per kWh. Show **all** workings. (4 marks)

Energy consumption in kWh:

Electricity cost in dollars:

(b) Suppose, as shown below, an ideal transformer with turns ratio $\frac{N_p}{N_s} = 20$ is added to the lighting circuit so that it can operate a low voltage 50 W halogen lamp.



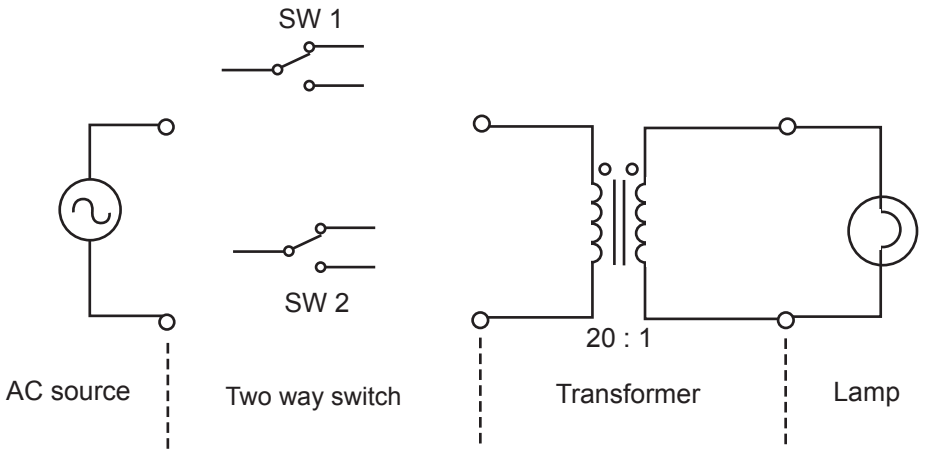
Knowing that the AC source is 240 VAC, calculate the secondary voltage V_s, the secondary current I_s , and the primary current I_p in the case when the switch is open and also in the case when the switch is closed. Place your answers in the table below. Show **all** workings. (6 marks)

Switch	V_S (in VAC)	I_S (in AAC)	I_P (in AAC)
OPEN			
CLOSED			

See next page

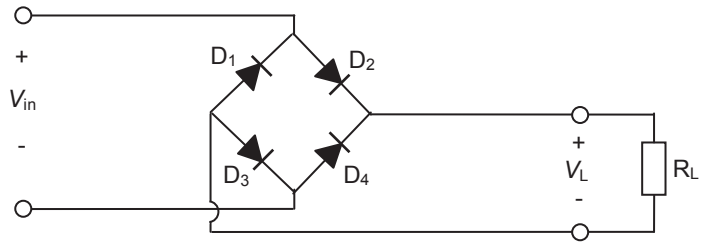
Question 55 (continued)

(c) Suppose the light is to be used in a stairwell with a switch (SW1) at the top and another switch (SW2) at the bottom of the stairs. Complete the circuit diagram below to clearly illustrate how the two SPDT switches are to be connected to the rest of the lighting circuit so that the lamp can be turned on or off by either of the two switches. (6 marks)



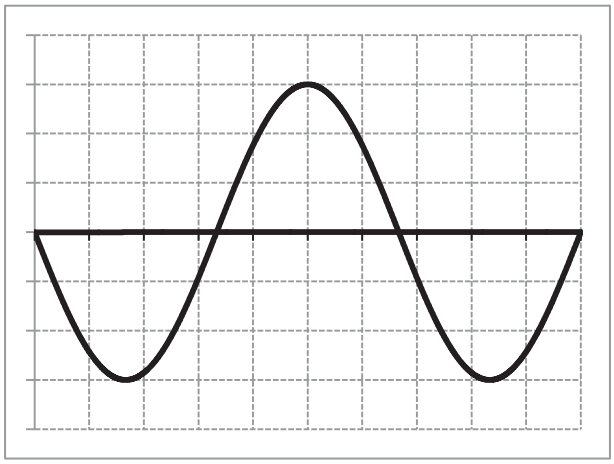
Question 56 **(24 marks)**

A diode-bridge full-wave rectifier with a load resistor is shown below. Assume that each diode has a forward voltage of 0.6 V.



Suppose the input voltage V_{in} is a sinusoid and the oscilloscope display of this waveform is depicted below. The oscilloscope is set to DC mode, with the amplitude setting at 5 V per division, the time base setting at 2 ms per division, and the zero voltage reference line as indicated in the display.

Input voltage V_{in}



See next page

Question 56 (continued)

(a) Based on the trace of V_{in}, on page 65, determine its frequency as accurately as possible by avoiding approximation. Also, determine its peak-to-peak voltage value. (3 marks)

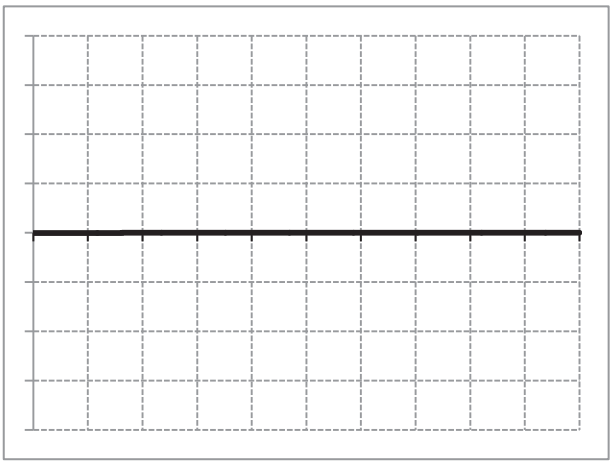
Frequency:

Peak-to-peak voltage value:

See next page

(b) Sketch clearly the load voltage, V_L, waveform in the oscilloscope display grid below. Assume the same oscilloscope settings as before. Also, determine the maximum and minimum voltage values as well as the frequency. (6 marks)

Load voltage V_L



Maximum value:

Minimum value:

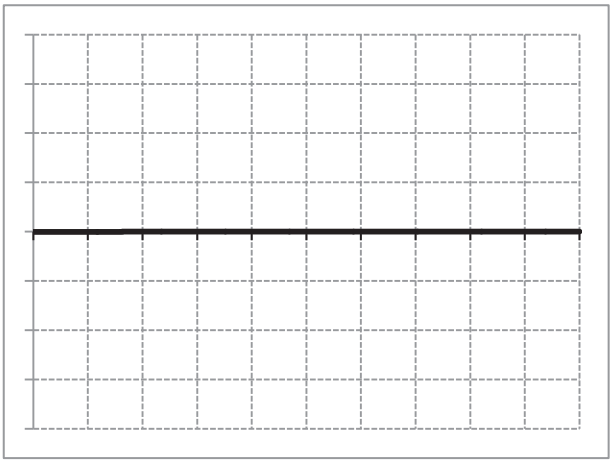
Frequency:

See next page

Question 56 (continued)

(c) Suppose that as a result of poor soldering, the diodes D_2 and D_3 have loose connections and behave like an open circuit. How would this affect the load voltage V_L? Clearly sketch the waveform in the grid below. Assume the same oscilloscope settings as before. Also, determine the maximum and minimum voltage values as well as frequency. (6 marks)

Load voltage V_L in the presence of faulty diode connections



Maximum value:

Minimum value:

Frequency:

(d) A capacitor is normally added in parallel to the load resistor to smooth out the pulsations of the rectified voltage.

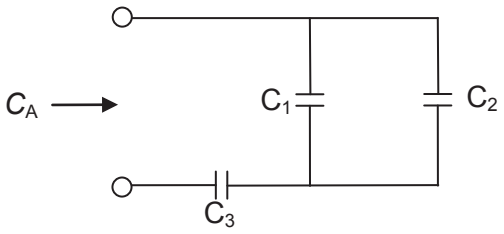
This capacitor is more effective when its capacitance value is (circle the correct answer): (2 marks)

large small

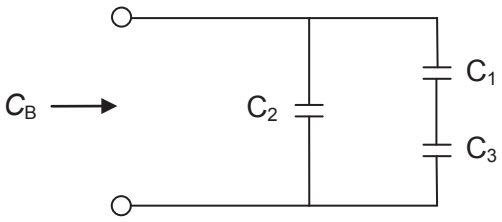
Explain your reasoning.

See next page

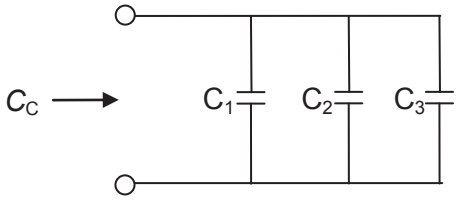
(e) Given that C_1 = 400 µF, C_2 = 500 µF and C_3 = 600 µF, determine which of the following three capacitor networks has the smallest overall capacitance value, and provide justification. Show **all** workings. (7 marks)



Network A



Network B



Network C

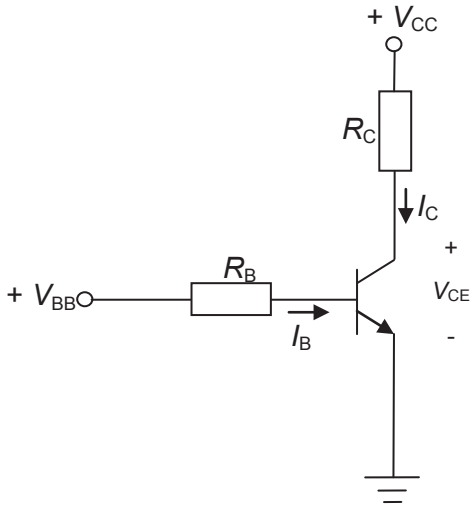
The network with the smallest overall capacitance is (circle the correct answer)

Network A Network B Network C

See next page

Question 57 **(12 marks)**

A transistor circuit and its parameter are shown below.



Parameters	
Collector supply voltage V_{CC}	10 V
Base resistor R_B	39 kΩ
Collector resistor R_C	1 kΩ
Transistor on-voltage $V_{BE,on}$	0.7 V
Transistor saturation voltage $V_{CE,sat}$	0 V
Transistor current gain β	200

(a) Supposing that V_{BB} = 0 V, calculate the voltage V_{CE} and the current I_C. Show **all** workings. (2 marks)

Voltage V_{CE}

Current I_C

(b) Calculate the minimum current I_B required to saturate this transistor. Show **all** workings. (4 marks)

See next page

(c) Supposing that V_{BB} = 2 V, calculate the currents I_B and I_C, and the voltage V_{CE}. Show **all** workings. (6 marks)

Current I_B

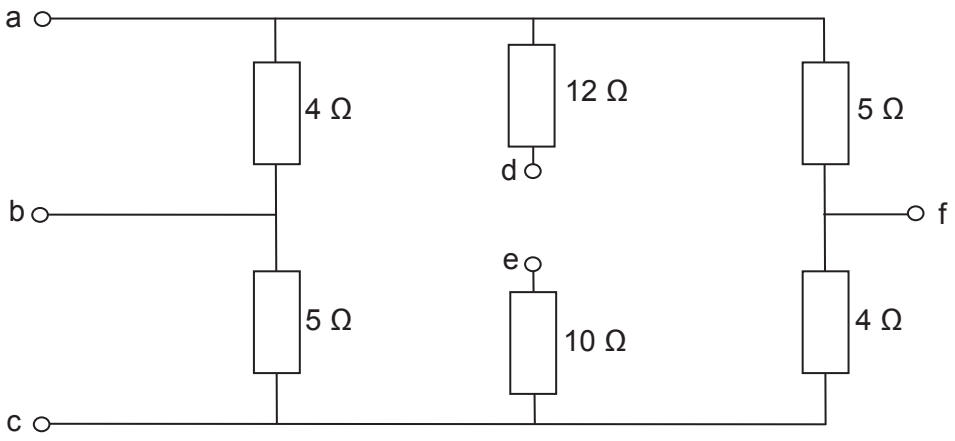
Current I_C

Voltage V_{CE}

See next page

Question 58 **(16 marks)**

A resistor network circuit with six terminals (from a to f) is constructed as shown below.



(a) Calculate the resistance between the following sets of terminals. In each case, show **all** workings. (8 marks)

R_{ab} (i.e. the resistance between terminals a and b)

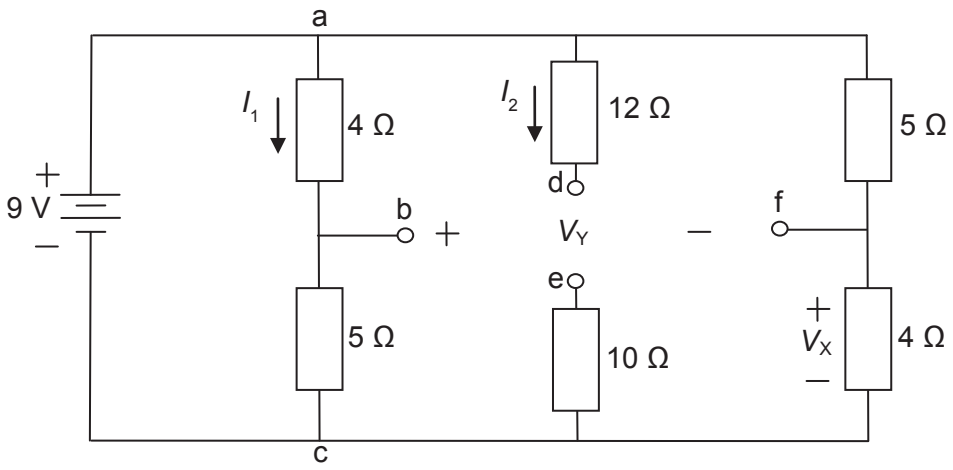
R_{bf}

R_{de}

R_{bd}

See next page

(b) If a 9 V battery is placed across terminals a and c, calculate the currents I_1 and I_2 and the voltages V_X and V_Y as defined in the circuit diagram below. Note that the voltage V_Y is across terminals b and f. In each case, show **all** workings. (8 marks)



Current I_1

Current I_2

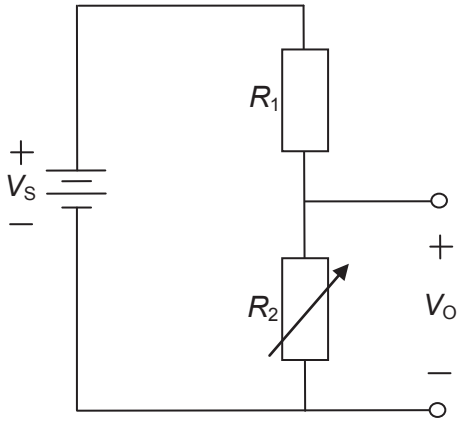
Voltage V_X

Voltage V_Y (between b and f).

See next page

Question 59 **(13 marks)**

A voltage divider circuit, which uses a fixed resistor R_1 and a variable resistor R_2, is shown below.



(a) If V_S = 12 V and R_1 = 47 Ω, calculate the resistance value R_2 such that the output voltage V_O = 9 V. Show **all** workings. (3 marks)

See next page

(b) Suppose a load as represented by a 2 kΩ resistor is connected to the output terminals of the voltage divider circuit on page 74, where V_S = 12 V, R_1 = 390 Ω, and the variable resistor R_2 is set to 390 Ω. Calculate the voltage across, and the current through, this load. Show **all** workings. (6 marks)

Load voltage:

Load current:

(c) Suppose a 4-band colour coded resistor is used to implement R_1. If the colour (starting from Band 1) is blue-grey-red-red, determine the range of possible resistance values that can be expected from this resistor. Show **all** workings. (4 marks)

The minimum resistance value is _____

The maximum resistance value is _____

End of Section Two: Electronic/Electrical

End of questions

Additional working space

Additional working space

Additional working space

Additional working space

Additional working space

Additional working space

Additional working space

Additional working space

ACKNOWLEDGEMENTS

Section One

Question 13

Text adapted from: Australian Bureau of Statistics. (2012). *9309.0–Motor vehicle census, Australia, 31 Jan 2012*. Retrieved March, 2013, from www.abs.gov.au/ausstats/abs@.nsf/mf/9309.0/. Used under the Creative Commons attribution 2.5 Australia licence http://creativecommons.org/licenses/by/2.5/au/

Table A adapted from: Department of Sustainability, Environment, Water, Population and Communities. (2008). *CO2 Tailpipe emissions/Litre of fuel consumed*. Retrieved March, 2013, from www.environment.gov.au/settlements/transport/fuelguide/environment.html

Table B adapted from: Department of Sustainability, Environment, Water, Population and Communities. (2008). *CO2 Tailpipe emissions from petrol vehicles*. Retrieved March, 2013, from www.environment.gov.au/settlements/transport/fuelguide/environment.html

Published by the School Curriculum and Standards Authority of Western Australia
27 Walters Drive
OSBORNE PARK WA 6017