Curriculum Council
Government of Western Australia

WACE
Western Australian Certificate of Education

Western Australian Certificate of Education
Course Examination, 2008 Sample

Question/Answer Booklet

ENGINEERING STUDIES

STAGE 2

Please place your student identification label in this box

Student Number: In figures | | | | | | | | |

In words _____

_____

Time allowed for this paper

Reading time before commencing work: Ten minutes
Working time for paper: Three hours

Material required/recommended for this paper

To be provided by the supervisor

This Question/Answer Booklet
Document Booklet
Engineering Studies Data Book for whole examination

To be provided by the candidate

Standard items: Pens, pencils, eraser or correction fluid, ruler, highlighter, printed English language dictionary and/or bilingual dictionary (non-electronic and not a thesaurus).
Special items: Appropriate plotting and measuring instruments, and calculators satisfying the conditions set by the Curriculum Council for this course.

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 attempted	Marks available
SECTION 1: Core Engineering, all candidates			
Part A Multiple-Choice	10	10	10
Part B Written	3	3	60
SECTION 2: Specialised fields Candidates choose from **ONE** of the following fields. • *Systems and Control* • *Materials, Structures and Mechanical Systems* • *Electronic/Electrical* Each field contains:			
Part A Multiple-Choice	10	10	10
Part B Written			
• *Systems and Control*	3	3	90
• *Materials, Structures and Mechanical Systems*	4	4	90
• *Electronic/Electrical*	3	3	90
		Total marks	170

Instructions to candidates

1. The rules for the conduct of Western Australian external examinations are detailed in the *TEE/WACE Handbook*. Sitting this examination implies that you agree to abide by these rules.

2. **SECTION 1:** You must answer all questions from Part A and Part B.

3. **SECTION 2:** You must answer all questions from Part A and Part B for **one** of the following three fields:
   Systems and Control,
   OR
   Materials, Structures and Mechanical Systems,
   OR
   Electronic/Electrical.

4. For Part A questions, you must use a blue or black pen or a B or 2B pencil to record your answers for the multiple-choice questions.

   For Part B questions, you must write all your answers in the Question/Answer Booklet. A blue or black ballpoint or ink pen should be used. The space provided for each question in the Question/Answer Booklet is an indication of the length of answer required. Spare answer pages are provided at the end of this booklet. If you need to use them, indicate in the original answer space where the answer is continued (e.g. write "continued on page 31").

5. Where appropriate, use sketches to illustrate your answer. Do not sketch in ink. All dimensions are to be shown in millimetres.

6. (Note about significant figure requirements)

7. (Note about need to show working)

SEE NEXT PAGE

SECTION ONE: CORE ENGINEERING (70 Marks)

This section consists of **two** parts.

Both parts are to be answered by **all** candidates.

Part A (10 marks)

For Part A multiple-choice questions, you must use a blue or black pen or a B or 2B pencil to record your answer. Circle (a), (b), (c) or (d) to indicate your response. There are **ten** questions in this section. You must answer all ten questions. Each question is worth one mark. Marks are not deducted for incorrect answers. If you wish to change an answer, make sure you indicate clearly your final answer.

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1. A company wishes to produce an electric drill for home handyman use. The first step that the company should take is to

(1 mark)

(a) purchase and test the most expensive rival manufacturer's product.
(b) engage an industrial designer to sketch some ideas.
(c) develop a prototype based on the product specification.
(d) review the range of similar products currently in the market.

2. A child's toy has been designed for a manufacturer who wants to mass produce the product. The most important design objective is its

(1 mark)

(a) function.
(b) ergonomics.
(c) safety.
(d) finish.

3. The Australian Standard symbol for showing a radius on an engineering drawing is

(1 mark)

(a) ∅
(b) R
(c) r
(d) Rad.

4. A designer is working on a new mobile phone. One of the activities the designer undertakes is to make an initial working version of the design. This activity in the design process is formally called

(1 mark)

(a) prototyping.
(b) modelling.
(c) manufacturing.
(d) specification analysis.

5. A 1.00m diameter pulley attached to a large motor is rotating at 240.0 rpm. The velocity at the pulley's outer surface is closest to

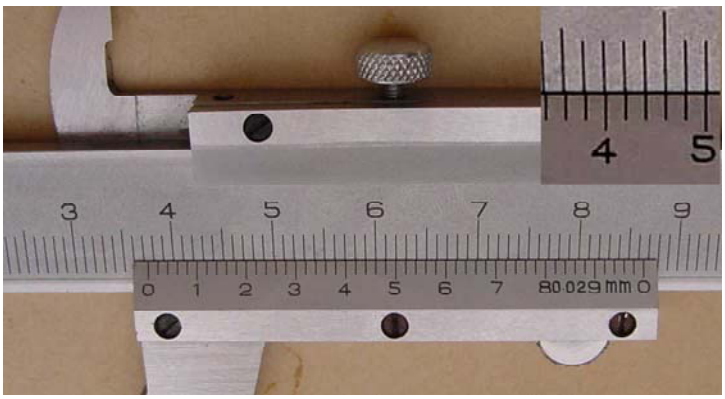
(1 mark)

(a) 6 $m\ s^{-1}$
(b) 12 $m\ s^{-1}$
(c) 720 $m\ s^{-1}$
(d) 240 $m\ s^{-1}$

6. The reading shown on the vernier callipers is

(1 mark)

(a) 37.46 mm.
(b) 34.46 mm.
(c) 60.40 mm.
(d) 37.60 mm.



[From: Buffler, A. 2003]

7. A waste product from a manufacturing plant is said to be biodegradable if it

(1 mark)

(a) is reduced to harmless natural materials in the presence of living organisms.
(b) is disposed of in a land fill reclamation site which is used for new housing.
(c) is burnt to ashes in a high temperature furnace and the ashes used for garden soil enrichment.
(d) is sold to a waste disposal company that recycles the product.

8. The surfaces of some components in a computer are coated with gold. The purpose of this to

(1 mark)

(a) make the computers look attractive.
(b) add value to the computers.
(c) reduce the chances of surface corrosion on the components.
(d) enable the components to be exchanged in the field.

SEE NEXT PAGE

9. Anthropometric data results from the study of

(1 mark)

(a) human movement.
(b) ergonomic design.
(c) average human limb measurements.
(d) workshop output.

10. The graph below shows the forward voltage in response to temperature for a special type of silicon diode.

For copyright reasons this graph cannot be reproduced in the online version of this document, but may be viewed at http://www.omega.com/Temperature/pdf/CY7.pdf

[Graph adapted from: Omega.com]

The diode is **most** sensitive to temperature in the range

(1 mark)

(a) 5 to 15 Kelvin.
(b) 15 to 30 Kelvin.
(c) 30 to 70 Kelvin.
(d) 5 to 70 Kelvin.

SECTION ONE

Part B (60 marks)

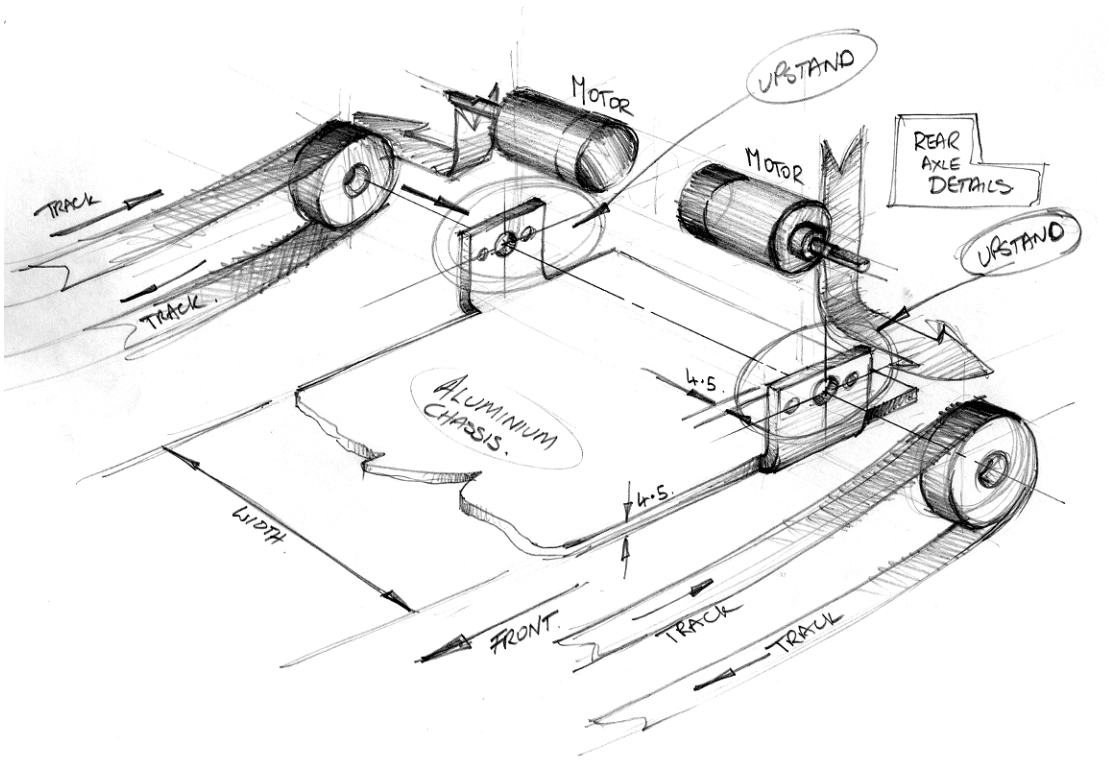
This part contains four questions, that require written responses in this Question/Answer Booklet. Each question is worth 20 marks. You must answer only **three** of the four questions.

Question 1 (20 marks)

A designer has sourced an electric motor from a popular Perth components supplier to power a small robotic buggy. The designer has chosen to use two of the motors to provide the drive and steerage to a pair of axles. The buggy will be rubber caterpillar-tracked and skid-steer driven.

The complete specification of the available motors is included in the provided Document Booklet. The initial motor selection is the 1271-12-21 model code.

The chassis is made from 4.5 mm thick flat aluminium plate. The initial design sketch of part of the buggy chassis as produced by the designer is shown below.



Use the information in the Document Booklet, and the designer's initial design sketch, to answer the following questions.

(a) What should be the minimum height above the chassis for the centre of the central hole in the upstands used to mount the motor? Justify your answer.

(2 marks)

(b) What should be the diameter of the central hole drilled in the upstand used to mount the motor? Justify your answer.

(2 marks)

(c) What would be the best width of the drive wheel to be attached to the motor shaft? Justify your answer, and explain why the width should not be greater or less than this value.

(4 marks)

(d) What should be the minimum width of the chassis that would allow both motors to be fitted after the two upstands have been formed? Justify your answer.

(4 marks)

(e) After further design consideration, it was suggested that a second buggy could be manufactured using the same chassis. A base model would have a total torque of 5.0 Ncm, and a deluxe model would have a total torque of 16.0 Ncm with both models running off a 12 V power supply. What design changes to the dimensions of the chassis would be required?

(3 marks)

(f) Considering the specifications of the two different motors referred to in (e), describe **one** major problem that will require resolution before this design option could be implemented. Suggest **one** method for solving this problem.

(5 marks)

Question 2 (20 marks)

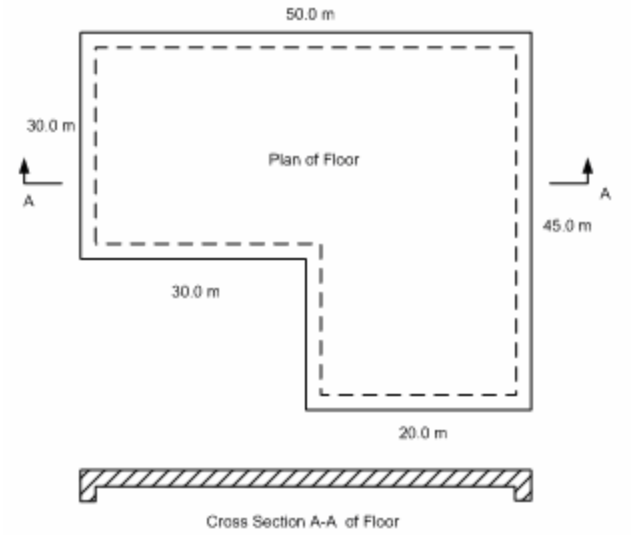
You are an engineer working for a company which makes aluminium hull recreational motor boats of less than 7 m length. Your workshop includes metal fabrication equipment, a machine shop, an electrical/electronics shop, a paint finishing shop, an assembly area and an office. Your company's business has out-grown its existing premises and your specific task is to design a new workshop.

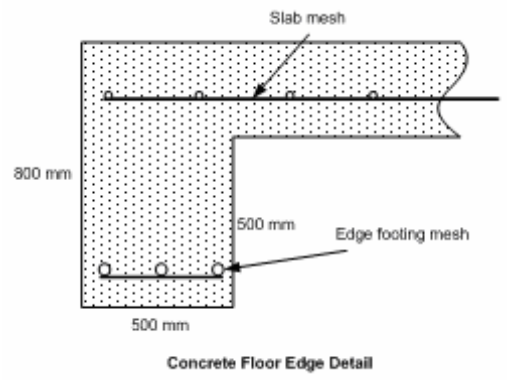
(a) The following key design factors have been identified for this design. For each design factor add a short justification that could be used to help convince your boss that the new workshop design should address these factors.

Design Outcome	**Justification**
Materials handling	
Lighting in workshop	
Ventilation and air extraction	
Sound levels	
Waste disposal and recycling	

(5 marks)

The floor of the new workshop will be made from steel reinforced concrete and has the following 'L'-shaped plan. The whole floor plan is to be reinforced with a steel slab mesh, and the whole length of the edge footing will be covered by an additional steel footing mesh.





(b) Demonstrate that the total volume of concrete that would be required to complete the floor and footings is approximately 587 m^3.

(5 marks)

(c) If the cost of the steel slab mesh is $20 per sqm, and the cost of the steel footing mesh is $10 per linear metre, what is the total cost of the steel reinforcing? To simplify the calculations assume that the slab reinforcing mesh goes right to the edge of the slab and that the footing mesh fully overlaps at each corner.

(5 marks)

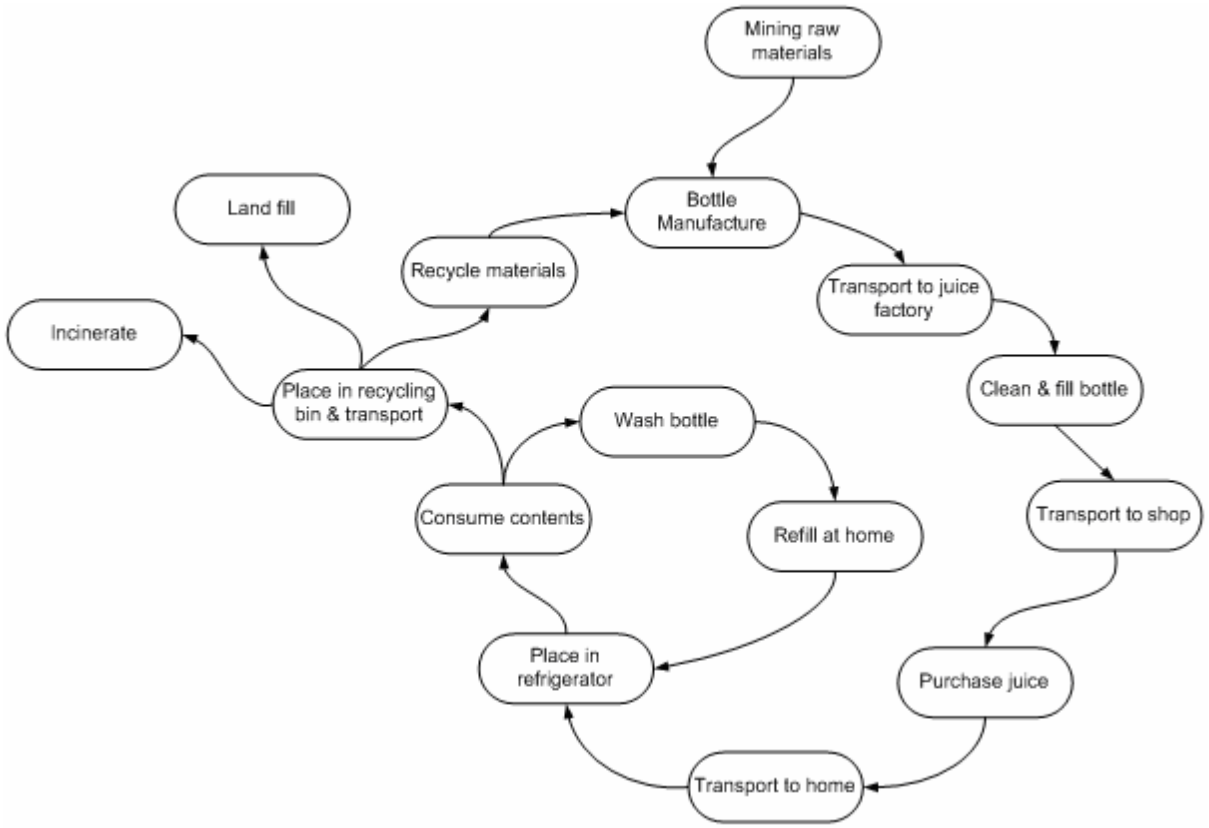
(d) The concrete is delivered to the site by trucks. Concrete delivery trucks come in two sizes: 5 m^3 and 3 m^3. The price for concrete is $200 per m^3 when delivered in the larger capacity trucks and $300 per m^3 when delivered in the smaller trucks. Trucks can only be ordered with a full capacity. Calculate the cheapest cost for the supply of concrete to complete the slab and footings, and compute the required number of deliveries of each truck size.

(5 marks)

SEE NEXT PAGE

Question 3 (20 marks)

The following diagram shows the simplified life-cycle of a plastic bottle of the type used for fruit juice as commonly sold in a supermarket.



Each 'node' (labelled activity) in the diagram represents some action that is performed in the lifecycle of the plastic bottle. A 'pathway' shows the movement of the bottles between nodes. Each action may require energy inputs, and may generate energy outputs as well as waste and pollutants (solids, liquids and gases).

(a) Identify **three** nodes where different types of energy sources would be required and state the **type** of energy source required.

(6 marks)

(b) Identify **three** nodes where you would expect different types of pollution to be generated and describe the **type** of pollutant expected.

(6 marks)

(c) Identify **two** pathways in the life-cycle diagram that can reduce the amount of raw materials required to maintain the supply of plastic bottles. Explain your reasons.

(4 marks)

(d) A product life-cycle must be carefully managed if it is to be effectively used to minimise energy use as well as production of pollutants. In the above life-cycle diagram, which node should be targeted for particularly careful management? Justify your answer.

(2 marks)

(e) If the incinerator could be managed to reduce the potential gaseous pollutants to an absolute minimum, with the resulting heat energy being available for use in some way, suggest **two** ways this energy might be used in the above life-cycle diagram to reduce the total required energy inputs.

(2 marks)

SEE NEXT PAGE

Question 4 (20 marks)

Information required for parts (a) to (e) of this question is included in the attached Document Booklet under the title '**Queensland Government Marketplace'**. This information is a printout of a page on the web. You should read this information carefully before responding to parts (a) to (e) of this question.

(a) Calculate an estimate for the unit cost of electricity in Queensland for Government agencies in $/kWh.

(3 marks)

(b) Describe why the use of natural light will save energy use in buildings, and describe **three** ways in which saving can be made by using appropriate lighting management techniques.

(4 marks)

(c) What strategy has been suggested to encourage agencies to reduce their energy usage?

(2 marks)

(d) In the Norman Park State School, what device has been used to reduce the need for artificial lighting, and how was it designed?

(3 marks)

(e) For the Norman Park State School, some special features were designed to treat sunlight falling on the western facing windows. Describe what these design features are, and what advantages they offer.

(4 marks)

(f) Consider the following information:

- A medium sized car with a petrol engine produces 0.34 kg of CO_2 per km travelled.
- The production of the electricity produces 0.94 kg of CO_2 per kWh.
- The average computer consumes 300 W of power when it is turned on.

Using this information, is it reasonable to claim that a car driving from Sydney to Perth (3, 600 km) generates about the same quantity of CO_2 as a computer left turned on for 12 hours overnight for every day of the year? Justify your answer.

(4 marks)

END OF SECTION A

SEE NEXT PAGE

For the remainder of this examination, you must answer questions **only** related to the field you have studied in detail (Systems and Control; Materials, Structures and Mechanical Systems; or Electronic/Electrical).

- Systems and Control context questions begin on this page.
- Materials, Structures and Mechanical Systems context questions begin on page 31.
- Electronic/Electrical context questions begin on page 42.

SECTION TWO: SYSTEMS AND CONTROL FIELD (100 Marks)

Only candidates who have studied the Systems and Control field should answer these questions.

This section consists of **two** parts. **All** questions from each part are to be answered.

Part A (10 marks)

For Part A multiple-choice questions, you must use a blue or black pen or a B or 2B pencil to record your answers. Circle (a), (b), (c) or (d) to indicate your response. There are **ten** questions in this section. You must answer all ten questions. Each question is worth one mark. Marks are not deducted for incorrect answers. If you wish to change an answer, make sure you clearly indicate your final answer.

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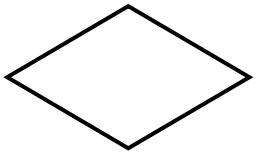
1. The flow chart symbol on the right represents

(1 mark)



(a) an output operation.
(b) a branch in the flow of computation.
(c) a clock.
(d) a counter.

2. In a circuit containing digital devices the term ‘ADC’ means

(1 mark)

(a) Advanced Digital Conversion
(b) Analogue and Digital Combination
(c) Analogue to Digital Converter
(d) Approximate Digital Code.

3. Feedback in a control circuit is used to

(1 mark)

(a) provide power to a device.
(b) allow a device to shut down gracefully.
(c) switch signals between two or more devices.
(d) adjust the inputs to a device depending on its outputs.

4. A program loop is

(1 mark)

(a) a set of program instructions that are executed one after the other.
(b) a branch in the flow of execution that allows alternative execution paths to be executed.
(c) a set of instructions that are repeatedly executed a set number of times.
(d) a part of a program that can be used from different parts of the program.

SEE NEXT PAGE

5. An actuator is a device that

(1 mark)

(a) determines which command in a program is to be executed next.
(b) senses the state of a physical switch.
(c) detects the speed of a motor.
(d) allows a computer to open and close a control valve.

6. An example of an analogue component that can be used to sense the angle of rotation of a rotating shaft is

(1 mark)

(a) a reed switch.
(b) a potentiometer.
(c) an LDR.
(d) a thermistor.

7. Which one of the following devices can be used as a sensor in a control system?

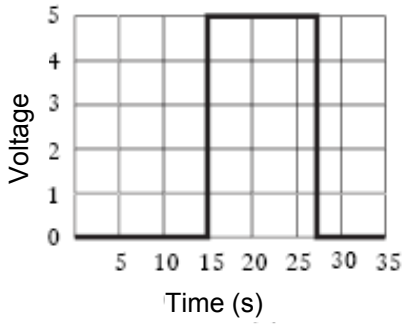
(1 mark)

(a) a double acting pneumatic cylinder
(b) a light dependent resistor
(c) a light emitting diode
(d) a solenoid.

8. The signal shown at the right is **not**

(1 mark)

(a) a pulsed signal.
(b) a digital signal.
(c) the ouput from an AND gate.
(d) an analogue signal.



[From: SQA, n.d.]

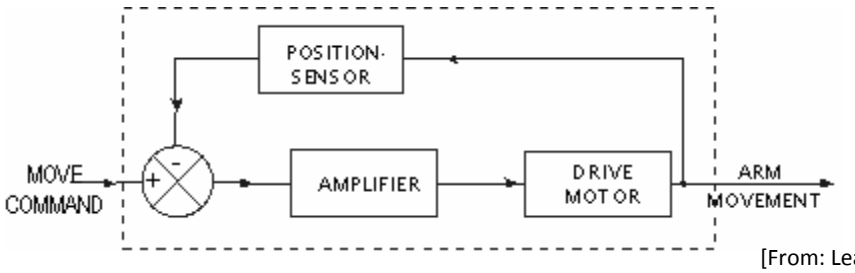
9. A fuse would be placed in a control circuit t

(1 mark)

(a) limit the current through the circuit.
(b) indicate when the power was switched on.
(c) prevent an incorrect voltage polarity being applied to the circuit.
(d) limit the voltage applied to the circuit.

10. The diagram shown below represents

(1 mark)



[From: LTS, 1999]

[From: Learning and Teaching Scotland]

(a) an open loop system.
(b) a logic circuit diagram.
(c) a closed loop system.
(d) an interface diagram.

SEE NEXT PAGE

SECTION TWO: SYSTEMS AND CONTROL FIELD

Only candidates who have studied the Systems and Control field should answer these questions.

Part B (90 marks)

This part contains three questions requiring written responses in this Question/Answer Booklet. Each question is worth 30 marks. You must answer **all** questions.

Question 1 (30 marks)

(a) What are the types of the four logic gates (G1, G2, G3 and G4) in the logic circuit diagram shown in Figure 1?

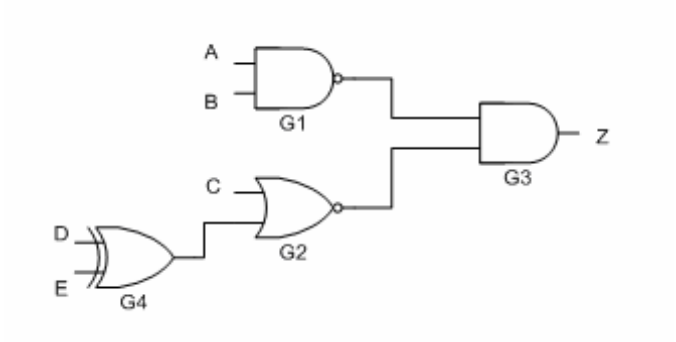


Figure 1: A Logic Circuit Diagram

(4 marks)

(b) What is a truth table? Explain what it can be used for.

(4 marks)

(c) If a truth table was provided for the above circuit, in Figure 1, what would it tell you about the output Z, given some set of inputs for A, B, C, D and E?

(4 marks)

(d) The circuit shown above, in Figure 1, must be modified so that the output Z is the inverse of that in the existing design for all possible input values. Suggest two (2) ways of achieving this. Draw the logic diagram for each solution.

(6 marks)

(e) Construct a truth table for the logic circuit diagram shown in Figure 2. A, B and C are inputs and Z is the output.

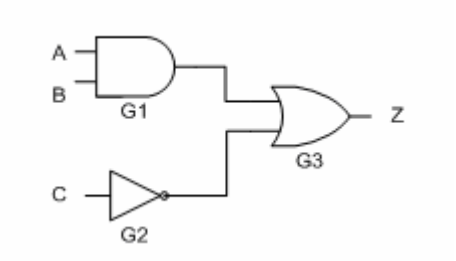


Figure 2: A Logic Diagram

(8 marks)

(f) If a single IC package device could be found, or manufactured, to match the circuit in Figure 1 from part (a), describe **two** advantages of using such a device rather than using the discrete devices as in the circuit diagram.

(4 marks)

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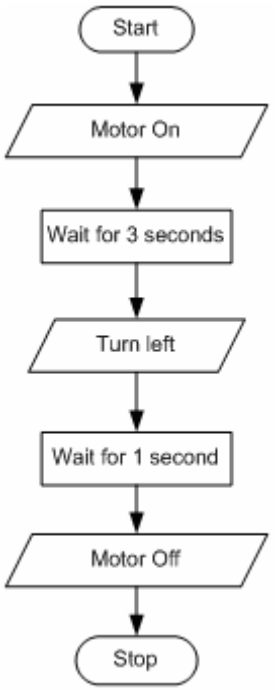
Question 2 (30 marks) [From: Learning and Teaching Scotland]

The flow chart for the movement of a robot buggy is shown below. For this buggy the available operations are:

- Start (and power on)
- Motor On (and move forward at a constant speed)
- Motor Off (buggy stops moving)
- Stop (and power off)
- Turn left (90deg)
- Turn right (90deg)
- Wait (the program waits for a number of seconds before executing the next instruction)

The buggy travels at a constant speed of 0.25 m/sec on a smooth and level surface. **Note that the buggy will continue to move until the Motor Off instruction is performed.**



(a) Draw a fully dimensioned sketch of the path you would expect the robot buggy to take. Assume speed is constant.

(2 marks)

(b) Redraw the flow chart on the previous page, inserting an execution loop to ensure that the two commands (“Turn left” and “Wait for 1 second”) are repeated a pre-determined number of times.

(10 marks)

SEE NEXT PAGE

(c) Draw a dimensioned sketch of the path taken by the buggy if the loop in the flow chart in part (b) is executed **three** times.

(4 marks)

(d) For how long is the robot buggy moving, and what is the total distance travelled for the flow chart in part (b) if the loop is executed **five** times?

(4 marks)

(e) If the initial direction of the robot is North, then in what direction will it be facing if the loop is executed **five** times.

(4 marks)

(f) Because of its design, the buggy can only determine the distance travelled by using a clock timer together with knowledge of its travel speed. In some applications this might cause problems resulting in inaccurate travel distances. Describe **two** situations that might cause such problems.

_____

_____

_____

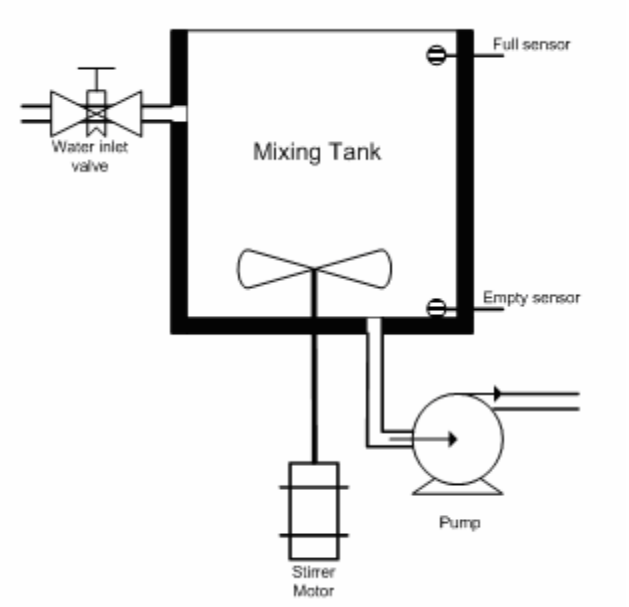
_____

_____

(6 marks)

Question 3 (30 marks) [Adapted from: Scottish Qualifications Authority]

A food manufacturer uses a micro-controller to control the mixing of the ingredients in the following mixing tank.



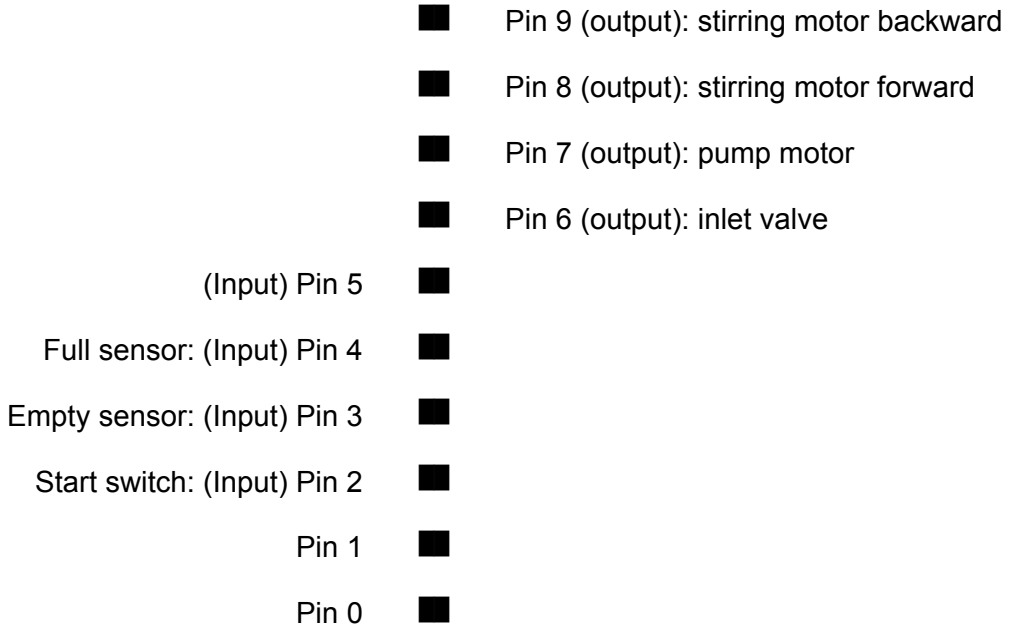
The mixing process is described as follows.

Event	Operator Action	Control Activity	Note
1	Weigh the solid ingredients into mixing tank	None	
2	Press Start switch	Sequence commences	
3	Nil	Open water inlet valve fully until full sensor output is high (output = 1), then close valve.	Fill subroutine
4	Nil	Switch on stirrer for 10 secs forward then 8 secs backward. Repeat 20 times.	Mix subroutine
5	Nil	Switch on pump motor until empty sensor output is low (output = 0), then switch off.	Empty subroutine
6	Nil	Go back to start of program	

The process is controlled by a microprocessor that has **four** digital input signals and **four** digital output signals and is wired as follows:

SEE NEXT PAGE

Microcontroller Wiring Diagram



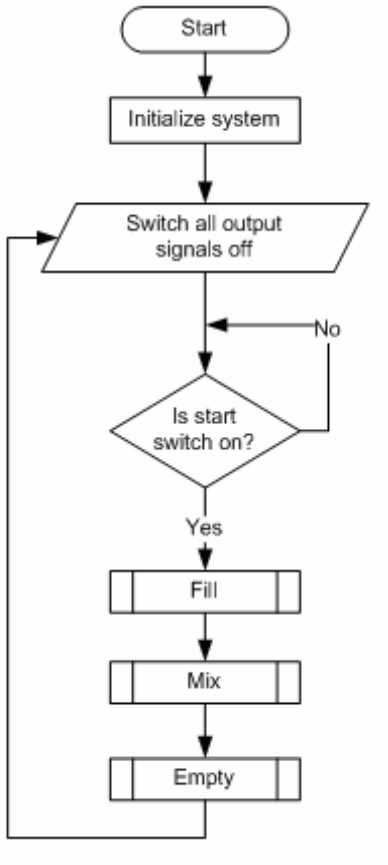
(a) In the microcontroller wiring diagram (above), **two** pins (Pin 0 and Pin 1) are unlabeled. Describe what these **two** pins are most likely to be used for to make the microcontroller fully operational.

_____

_____

(2 marks)

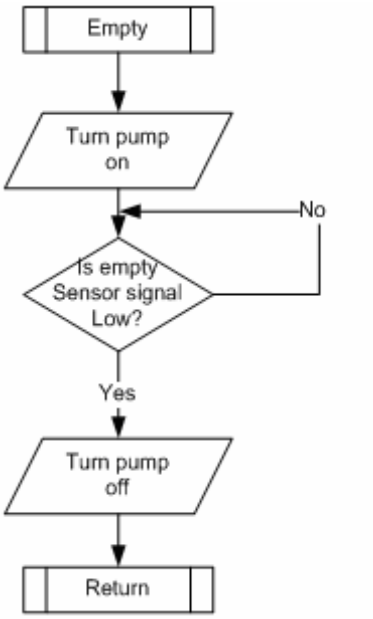
(b) The following flow chart has been created to describe the major steps in the microcontroller program. It shows the **three** detailed operations (Fill, Mix and Empty) as subroutines.



What is a 'subroutine' and how does a subroutine operate in a program? Give **two** reasons why subroutines may be used effectively in this program application.

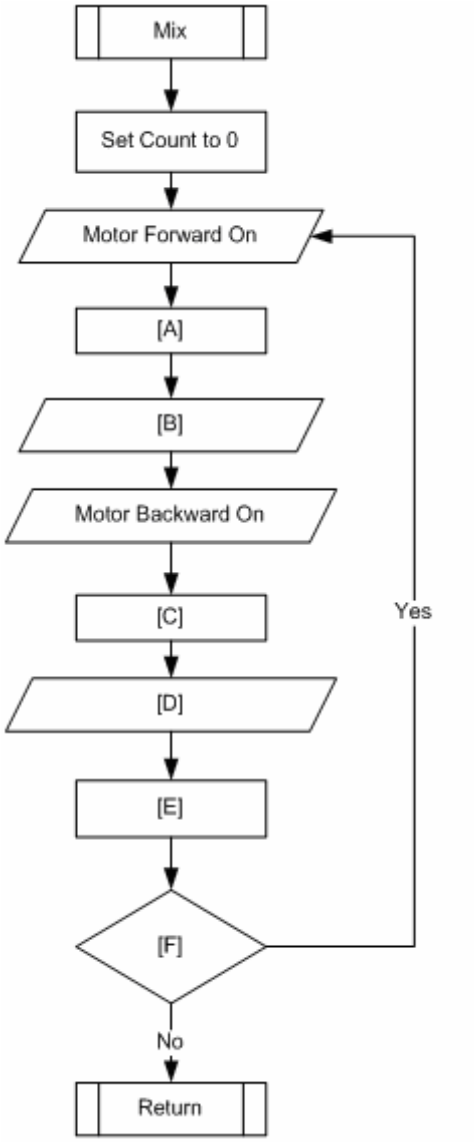
(8 marks)

(c) If the following flow chart describes the Empty subroutine, create a flow chart for the Fill subroutine.



(8 marks)

(d) The following flow chart has been created for the Mix subroutine.



Define the appropriate text descriptions for the flowchart symbols with the missing labels [A] through to [F] in the above diagram.

(12 marks)

This is the end of the examination, for candidates studying the Systems and Control field of Engineering Studies.

SEE NEXT PAGE

SECTION TWO: MATERIALS, STRUCTURES AND MECHANICAL SYSTEMS FIELD
(100 Marks)

Only candidates who have studied the Materials, Structures and Mechanical Systems field should answer these questions.

This section consists of **two** parts. **All** questions from each part are to be answered.

Part A (10 marks)

For Part A multiple-choice questions, you must use a blue or black pen or a B or 2B pencil to record your answers. Circle (a), (b), (c) or (d) to indicate your response. There are **ten** questions in this section. You must answer all ten questions. Each question is worth one mark. Marks are not deducted for incorrect answers. If you wish to change an answer, make sure you clearly indicate your final answer.

---

1. Bending moments are measured in

(1 mark)

(a) newton metres.
(b) kilograms.
(c) pascals per millimetre.
(d) newtons.

2. Shown opposite is an example of

(1 mark)

(a) a stub axle assembly.
(b) a taper roller bearing.
(c) an axle oil seal.
(d) a stainless steel test blank.

[From: Silberwolf, 2006]

3. A material is subjected to a tensional load, as a result of which it increases in length by a microscopic amount. When the load is released, it returns to its original length. This behaviour shows that the material is

(1 mark)

(a) ductile.
(b) loaded within its brittle limit.
(c) highly malleable.
(d) loaded within its elastic limit.

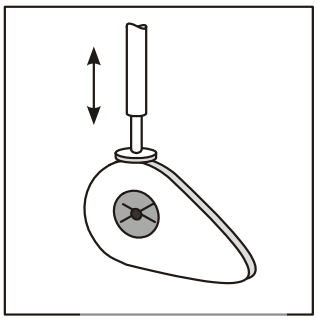
4. Which of the materials below is a non-ferrous alloy?

(1 mark)

(a) copper
(b) steel
(c) brass
(d) nylon

5. The name of the mechanism shown opposite is a

(1 mark)



[From: LTS, 2001]

(a) ratchet and pawl.
(b) worm and wheel.
(c) compound gear.
(d) cam and follower.

6. Galvanising is the

(1 mark)

(a) quenching of steel heated to 300°C in oil.
(b) plating of steel with zinc.
(c) coating iron carbon alloy with minimum 10.5% chromium.
(d) quenching of steel in tepid water.

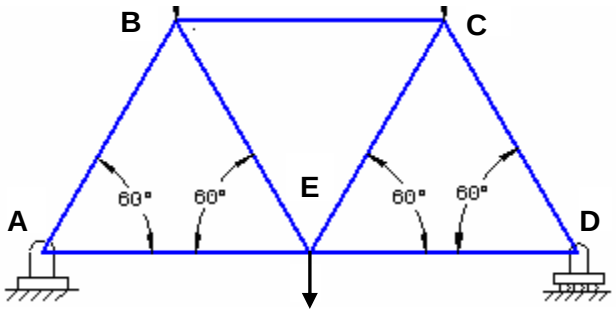
7. A material that deforms before it fails under load is described as

(1 mark)

(a) brittle.
(b) ductile.
(c) weak.
(d) tough.

8. A load is applied to the structure below, acting downwards at point E. Assuming that all of the members in the structure are of equal length, which one of those listed below is in compression?

(1 mark)



[From: LTS, 2003]

(a) AE
(b) ED
(c) BC

SEE NEXT PAGE

(d) BE

9. Stainless steel is often used in applications where

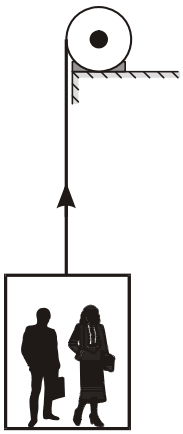
(1 mark)

(a) cost is not important.
(b) high thermal conductivity is necessary.
(c) corrosion resistance is required.
(d) a polished surface is required.

10. A winch raises a lift with a total mass of 1000 kg to a height of 20 m. The minimum amount of work that must be done by the winch is

(1 mark)

(a) 196 000 J
(b) 2 000 J
(c) 2 041 J
(d) 20 000 J.



[From: LTS, 2003]

SECTION TWO: MATERIALS, STRUCTURES AND MECHANICAL SYSTEMS FIELD

Only candidates who have studied the Materials, Structures and Mechanical Systems field should answer these questions.

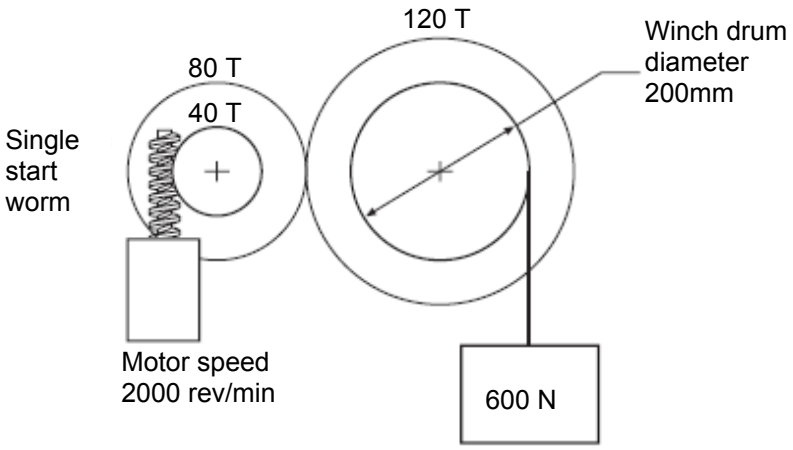
Part B (90 marks)

This part contains **four** questions requiring written responses in this Question/Answer Booklet. You must answer **all** questions.

Question 1 (20 marks)

[Adapted from: SQA, 2002]

Details of a motorised winch system are shown below.



(a) Demonstrate through calculations that the speed of rotation of the drum is 33 1/3 rpm.

(6 marks)

(b) Calculate the distance that the 600 N load is raised in 50 seconds.

(6 marks)

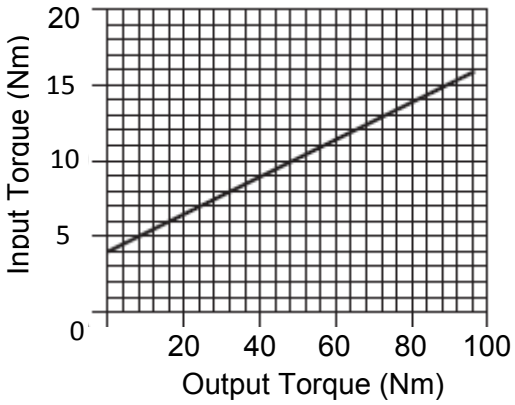
(c) Explain what is meant by ‘torque’.

(2 marks)

(d) Calculate the torque on the winch drum caused by the 600 N load. Ignore the thickness of the rope.

(2 marks)

(e) The graph below shows the input/output torque relationship of the winch system.



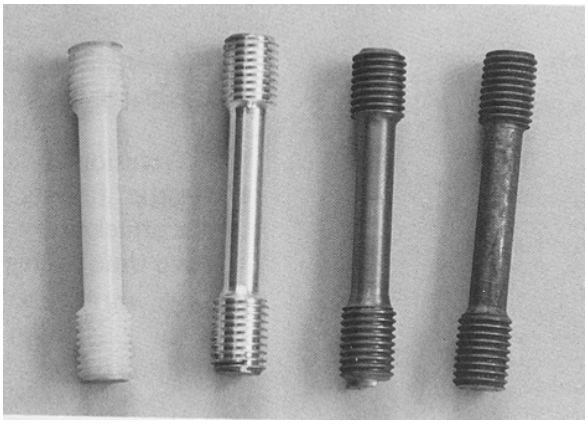
[From: SQA, 2002]

Use the graph to estimate the torque that the motor must deliver to hold the 600N load off the ground.

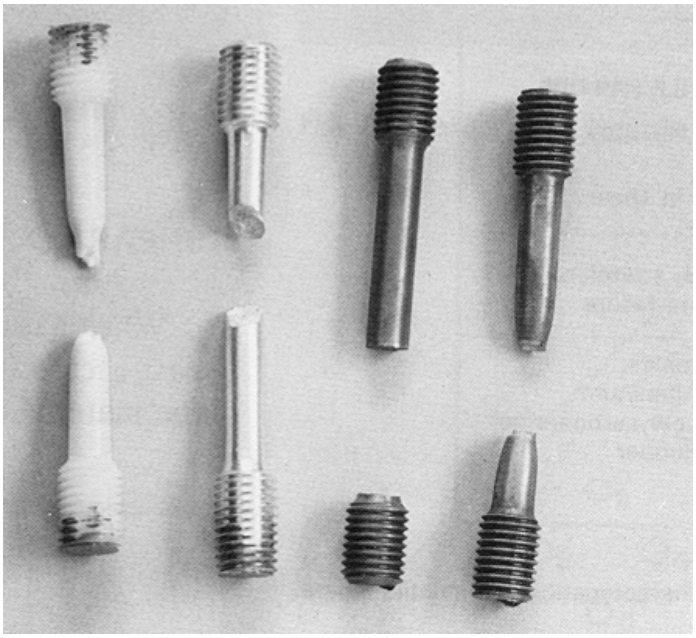
(4 marks)

Question 2 (18 marks)

Four material samples as shown below were subject to a test to determine their properties when placed in tension. Each material sample had the same length, diameter and general configuration before testing.



After the testing was complete, the samples were laid out as shown below.



(a) Name and describe the test being carried out, and the processes followed to complete it.

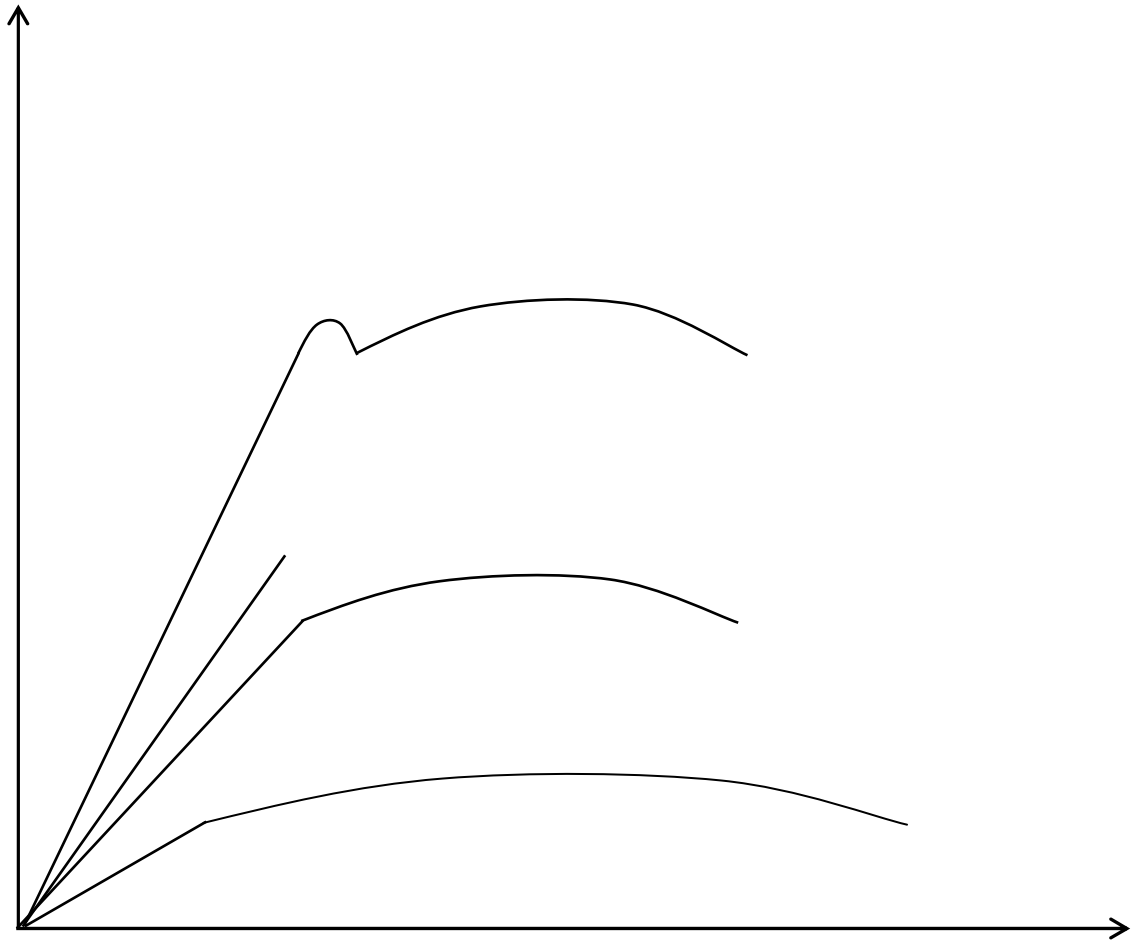
(4 marks)

(b) The materials shown above are (from left to right) nylon, aluminium, cast iron and mild steel. The graph below shows the stress-strain graphs for each of these tests.

(i) Label the axes. (2 marks)

(ii) Label each graph with the correct sample type. (8 marks)

(iii) Identify the major features of each graph. (10 marks)



(c) A material sample with a cross-sectional area of 0.2 m^2 has a stress of 40 kN applied to it, resulting in a strain of 0.003. Calculate the Young's Modulus of the material.

(4 marks)

Question 3 (24 marks)

When the Apollo 11 astronauts left the moon, they were travelling in a spacecraft with a total mass of 4550kg (of which 2275kg was fuel). Their rocket engine could produce 16kN of thrust. They had to overcome the acceleration due to the moon's gravity ($g = 1.62$ m/s^2; about 1/6th of that experienced on earth) and rendezvous with their colleague in another spacecraft in orbit around the moon. Note that there is no atmosphere on the moon, so there are no drag forces to consider. You may neglect the curvature of the moon's surface.

(a) Draw a free body diagram of their spacecraft at the moment it left the moon's surface, travelling vertically upwards. Note that $g = 1.62$ m/s^2 on the moon.

(3 marks)

(b) Show by calculation that the maximum acceleration of the spacecraft at launch is 1.90 m/s^2, and find the height and velocity of the craft after 10 seconds.

(9 marks)

SEE NEXT PAGE

(c) Assuming constant acceleration vertically away from the moon's surface, calculate the velocity of the spacecraft at the point when its fuel runs out, 7 minutes 14 seconds after launch. Explain why this is a gross underestimate of the final velocity.

(4 marks)

(d) Once the spacecraft reached a true orbit around the moon, it was 308 km away from the launch site. Estimate the work done by the rocket motor.

(3 marks)

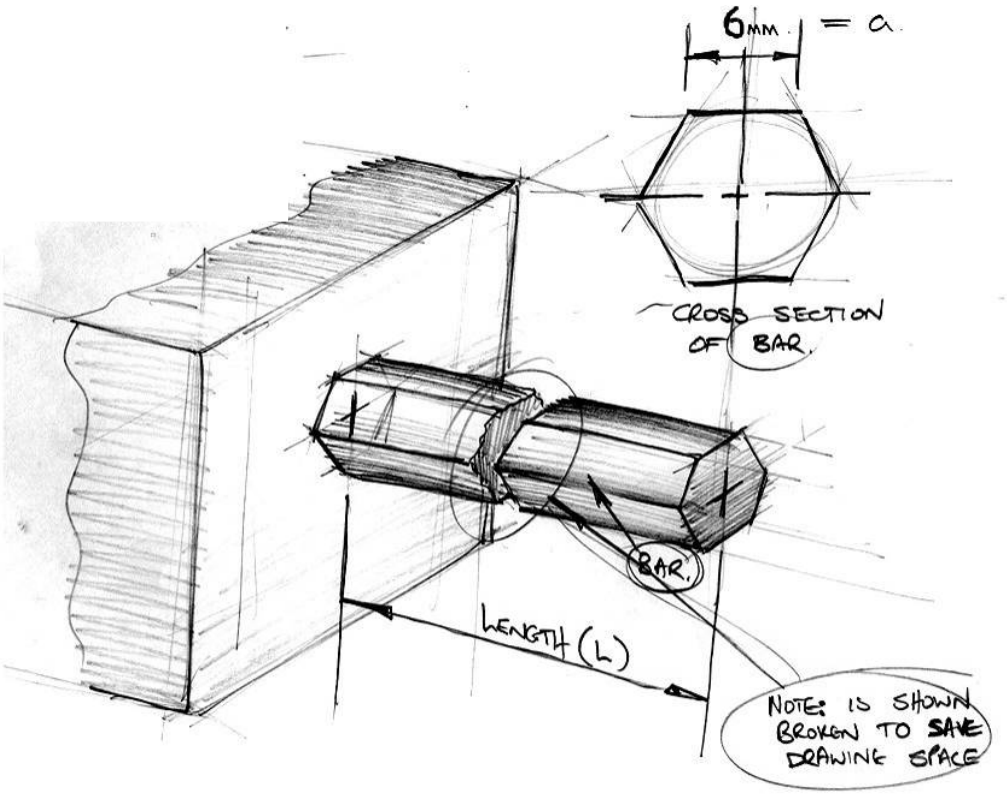
(e) When the Apollo astronauts re-entered the earth's atmosphere in the Command Module capsule, they were travelling at 11 032 m/s. When the capsule landed in the Pacific Ocean, it was travelling at 9.5 m/s. If the command module had a mass of 5568 kg, how much kinetic energy was dissipated during the descent to the ocean?

(5 marks)

SEE NEXT PAGE

Question 4 (18 marks)

The chief designer of a multi-part machine proposes that certain parts of the final assembly can be slid together and located (and slid apart for maintenance) using bars made of hexagonal cross-section brass. At a meeting of the design team, one of the senior engineers suggests that the bars are too long, and that they will droop under their own weight, preventing various parts of the machine from aligning correctly. You have been assigned the task of calculating the deflection of the longest of the brass rods, and reporting your findings to the next design team meeting.



The Figure above shows the bar projecting horizontally from a rigid mount in a vertical panel. The unsupported length of the bar L = 745 mm. When viewed in cross-section, the hexagonal bar has equal faces of length a = 6 mm.

Note:

- The area of a hexagon is given by $(3/2)\sqrt{3}.\ a^2$.
- The end deflection δ of a cantilevered beam with a uniformly distributed load is given by $\delta = \omega L^4/8EI$;
  where ω is the load per unit length in N/m;
  E is the elastic Modulus of the material, and
  I is the second moment of area.
- The second moment of area of the bar is $1.386 \times 10^{-10}\ m^4$.

SEE NEXT PAGE

(a) Show by calculation that the mass per unit length of the bar is 0.817 kg/m, and hence the load per unit length ω = 8.0 N/m.

(6 marks)

(b) Calculate δ, the end deflection of the bar in mm.

(6 marks)

(c) If the design team decide that this deflection is too large, suggest and briefly explain **three** ways in which the deflection could be reduced.

(6 marks)

This is the end of the examination for candidates studying the Materials, Structures and Mechanical Systems field of Engineering Studies.

SEE NEXT PAGE

SECTION TWO: ELECTRONIC/ELECTRICAL (100 Marks)

Only candidates who have studied the Electronic/Electrical field should answer these questions.

This section consists of **two** parts. **All** questions from each part are to be answered.

Part A (10 marks)

For Part A multiple-choice questions, you must use a blue or black pen or a B or 2B pencil to record your answers. Circle (a), (b), (c) or (d) to indicate your response. There are **ten** questions in this section. You must answer all ten questions. Each question is worth one mark. Marks are not deducted for incorrect answers. If you wish to change an answer, make sure you clearly indicate your final answer.

---

1. Voltage is the measurement of

(1 mark)

(a) potential difference across a power supply or component.
(b) current through a power supply or component.
(c) resistance of a power supply or component.
(d) the difference of current across components.

2. The most common voltage used by electronic digital control circuits is

(1 mark)

(a) 24 V
(b) 5 V
(c) 240 V
(d) 250 VAC

3. A variable resistor is placed in series with an LDR or thermistor to

(1 mark)

(a) protect the component from surges.
(b) divide the current across the components.
(c) control the voltage through the components.
(d) adjust the voltage across the components.

4. A fuse in an electrical circuit is designed to

(1 mark)

(a) create an open circuit if the circuit current is too large.
(b) create a short circuit if the circuit current is too large.
(c) create an open circuit if the circuit voltage is too large.
(d) create a short circuit if the circuit voltage is too large.

5. Which of the following is **not** a transistor?

(1 mark)

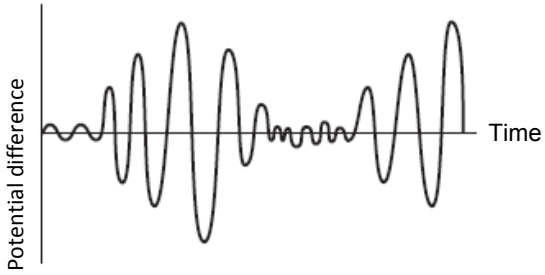
(a) NPN
(b) FET
(c) LDR
(d) PNP

SEE NEXT PAGE

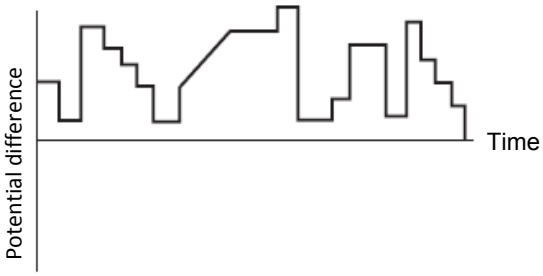
6. Which of the following graphs represents a digital signal for a control circuit?

(1 mark)

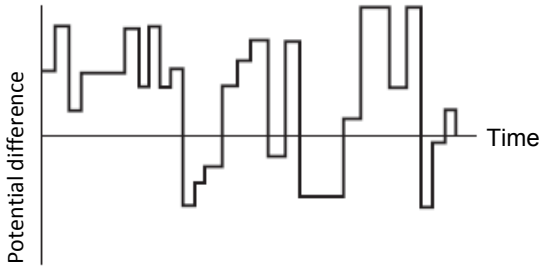
(a)



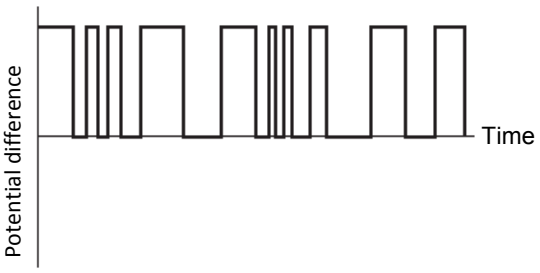
(c)



(b)



(d)



7. A diode is a device that

(1 mark)

(a) protects components from voltage surges.
(b) protects components from current flowing in the wrong direction.
(c) controls the amount of voltage across other components.
(d) enables transistors to switch on.

8. Three 12 V batteries are connected in parallel between two points. Their total voltage between those two points is

(1 mark)

(a) 36 V
(b) 24 V
(c) 12 V
(d) 4 V

9. A 24 μf, a 12 μf and a 6 μf capacitor are connected in parallel between two points. Their total capacitance is

(1 mark)

(a) 3.43 μf
(b) 14 μf
(c) 27.50 μf
(d) 42 μf

10. A 24 Ω, a 12 Ω and a 6 Ω resistor are connected in parallel between two points. Their total resistance is

(1 mark)

(a) 3.43 Ω
(b) 27.50 Ω
(c) 42 Ω
(d) 14 Ω

SEE NEXT PAGE

SECTION TWO: ELECTRONIC/ELECTRICAL

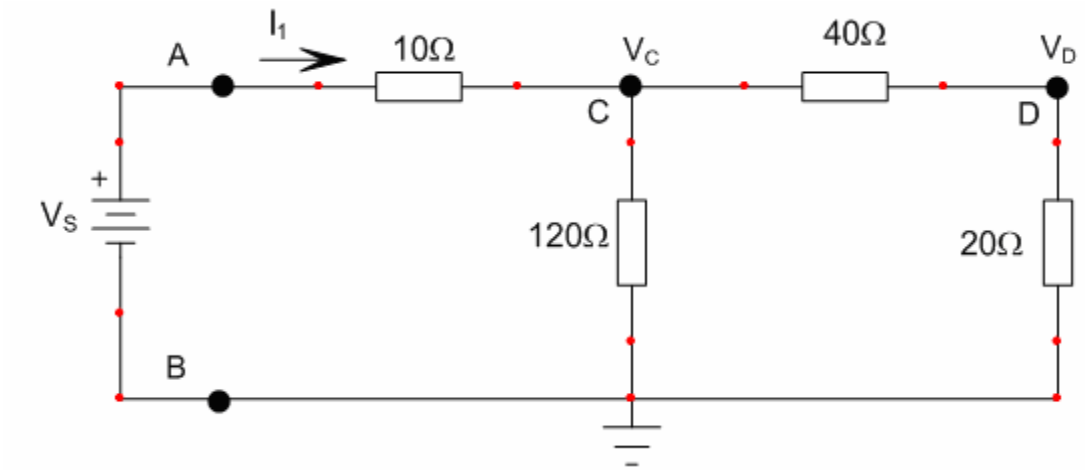
Only candidates who have studied the Electronic/Electrical field should answer these questions.

Part B (90 marks)

This part contains **three** questions requiring written responses in this Question/Answer Booklet. Each question is worth 30 marks. You must answer **all** questions.

Question 1 (30 marks)

This question refers to the figure shown below.



Note that node voltage V_C is the voltage drop from node C to the ground node; node voltage V_D is the voltage drop from node D to the ground node.

(a) Determine R_{AB}, which is the equivalent resistance between the battery terminals A and B.

(8 marks)

(b) A measurement of the node voltage V_D is 2 V. Find:

(i) the current flowing through the 20 Ω resistor.

(2 marks)

(ii) the power dissipated in the 20 Ω resistor.

(2 marks)

(iii) the node voltage V_C.

(2 marks)

(iv) the current I_1.

(3 marks)

(v) the unknown source voltage V_S.

(3 marks)

(c) The source voltage V_S is now set at 24 V. The 120 Ω resistor may be faulty. To check on the possible effects of a faulty resistor, find the node voltage V_D, and justify your answer when

(i) the 120 Ω resistor is replaced by a short-circuit.

(4 marks)

(ii) the 120 Ω resistor is replaced by an open circuit.

(4 marks)

(d) Kirchhoff's current law states:

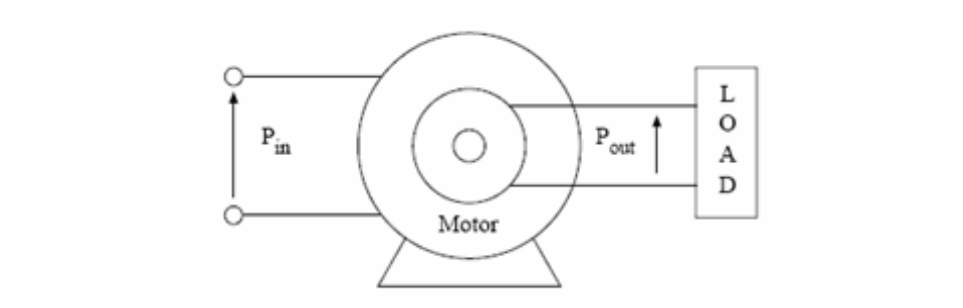
$$\sum I = 0$$

Explain what Kirchhoff's law means in relation to node C. Use a diagram to explain your answer.

(2 marks)

Question 2 (30 marks)

(a) The electric motor shown below has an output power of 100kW and operates at an efficiency of 80%.



Determine

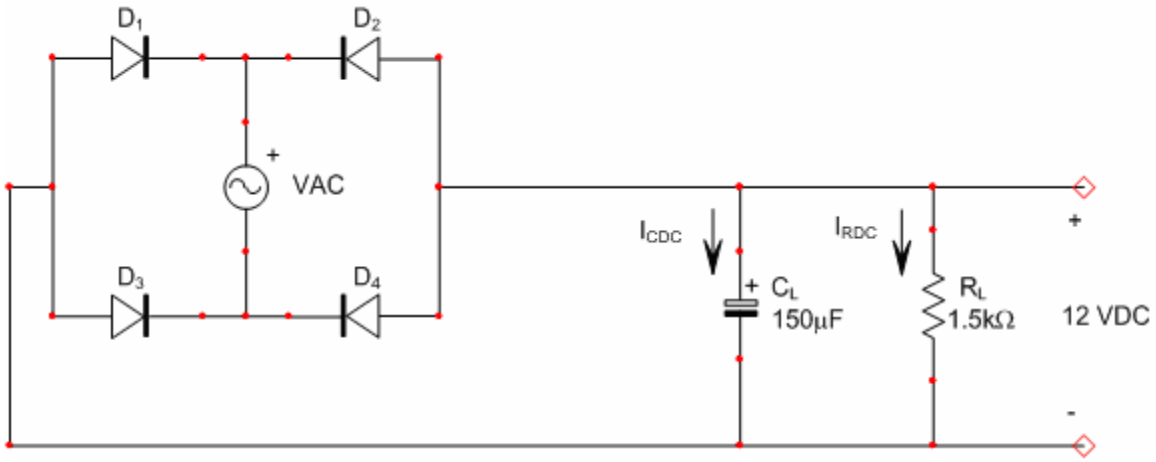
(i) the electrical energy in joules delivered to the motor in 15 minutes.

(7 marks)

(ii) the electrical energy in kWh delivered to the motor in 7 hours.

(3 marks)

(b) A diode bridge and capacitor are used to create a constant DC supply from an AC source, as shown in the figure below. ***Note that two of the diodes are pointing in the wrong direction.*** The value of the DC supply is set at 12V, with the top terminal more positive than the bottom terminal, as shown in the figure.



(i) Which two diodes are pointing in the wrong direction?

(4 marks)

(ii) What is the value of the DC current flowing through the 1.5 kΩ resistor?

(1 mark)

(iii) What is the value of the DC current flowing through the 150 μF capacitor?

(1 mark)

(iv) What is the power delivered to the 1.5 kΩ resistor?

(1 mark)

SEE NEXT PAGE

(v) Assuming that the diodes are ideal, what is the power supplied by the AC source?

(1 mark)

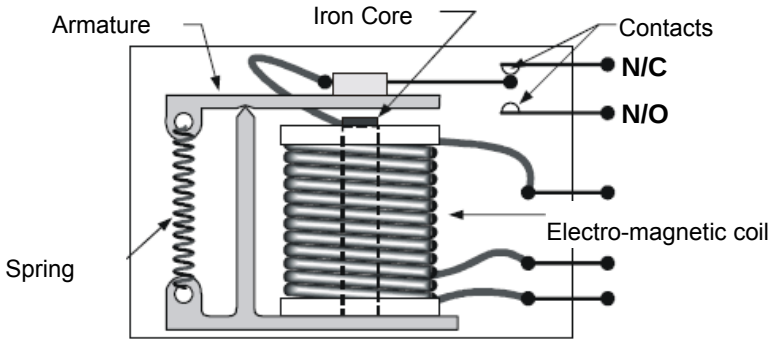
(vi) An individual 150 μF capacitor is not available, but there are plenty of 100 μF capacitors. Sketch a network made up of only 100 μF capacitors that is equivalent to a single 150 μF capacitor.

(4 marks)

(vii) A 1.5 kΩ resistor is not available, but there are plenty of 1 kΩ resistors. Sketch a network made up of only 1 kΩ resistors that is equivalent to a single 1.5 kΩ resistor.

(4 marks)

(c) A diagram of a relay is shown below.



Relay

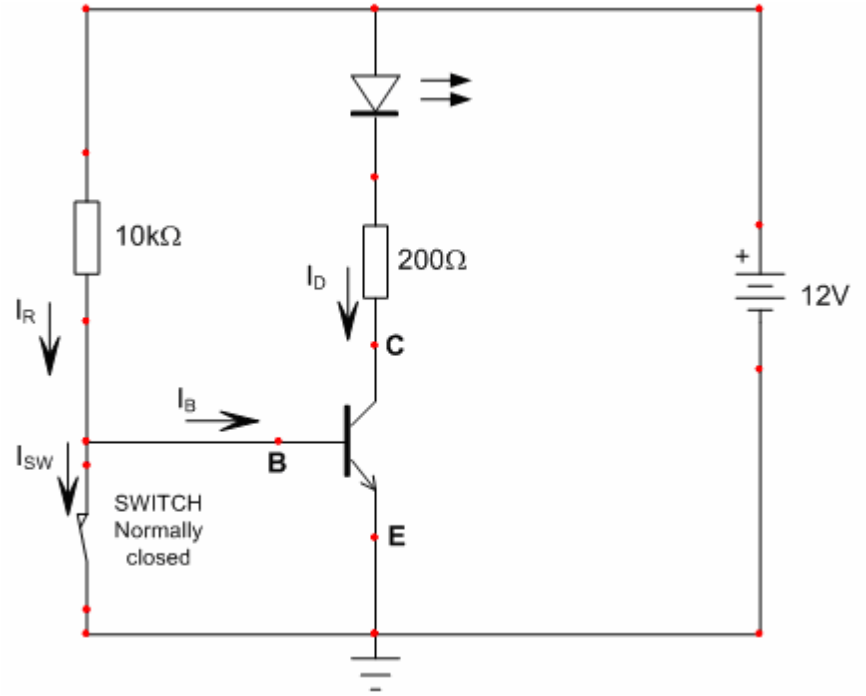
Explain how the parts interact to make the relay function.

(4 marks)

Question 3 (30 marks)

In the circuit shown below, the transistor has a base-emitter on-voltage of 0.7 V and a collector-emitter saturation voltage of 0 V. The light-emitting diode (LED) has an on-voltage of 2.0 V. The circuit is used as an open-door detector: when the contacts represented by the switch are open, then the LED turns on.

(*NOTE: It is usually desirable to have only small currents flowing through the switch. By using the transistor, the current that flows through the switch will be much smaller than the current that flows through the LED.*)



(a) When the switch is **closed**, calculate the currents I_R, I_{SW}, I_B and I_D.

(10 marks)

(b) When the switch is open, calculate the currents I_R, I_{SW}, I_B and I_D.

(11 marks)

(c) By re-positioning the LED and the 200 Ω resistor, re-design the circuit so that the LED is on when the switch is closed. Sketch your design, clearly labelling all components and component values.

(6 marks)

(d) The only available light-emitting diode has a maximum allowed current of only 20 mA. What is the smallest value for resistor R_D that could be used in this circuit?

(3 marks)

END OF SECTION TWO PART A

This is the end of the examination for candidates studying the Electronic/Electrical field of Engineering Studies.

ACKNOWLEDGEMENTS

SECTION ONE: Core Engineering

Part A (Multiple-Choice)

Question 6: Diagram from: Buffler, A. (2003). *Using the vernier calipers and micrometer screw gauge* (fig. 4). Retrieved May, 2007, from University of Cape Town website: http://www.phy.uct.ac.za/courses/c1lab/vernier1.html.

Question 10: Graph adapted from: Omega.com. (n.d.). *Cryogenic Temperature Sensors CY7 Series Silicon Diodes.* Retrieved May, 2008, from: *ttp://www.omega.com/Temperature/pdf/CY7.pdf*

SECTION TWO: Systems and Control Field

Part A (Multiple-Choice)

Question 8: Diagram from: Scottish Qualifications Authority. (n.d.). *Standard Grade Technological Studies: General level specimen question paper* (p.6). Retrieved May, 2007, from http://www.sqa.org.uk/files_ccc/SG_Tech%20stds%20g%20spec.pdf.

Question 10: Diagram from: Learning and Teaching Scotland. (1999). *Technological Studies: Systems and Control: Students' notes: Intermediate 2* (outcome 1, p. 20). Retrieved May, 2007, from http://www.ltscotland.org.uk/nq/images/5718det2_tcm4-124136.pdf.

Part B (Written)

Question 2: Flowchart from: Learning and Teaching Scotland. (1999). *Technological Studies: Systems and Control: Students' notes: Intermediate 2* (outcome 4, p. 6). Retrieved May, 2007, from http://www.ltscotland.org.uk/nq/images/5718det2_tcm4-124136.pdf.

Question 3: Adapted from: Scottish Qualifications Authority. (n.d.). *Standard Grade Technological Studies: Credit level specimen question paper* (q. 12). Retrieved May, 2007, from http://www.sqa.org.uk/files_ccc/SG_Tech%20stds%20c%20spec.pdf.

SECTION TWO: Materials, Structures and Mechanical Systems Field

Part A (Multiple-Choice)

Question 2: Silberwolf. (2006). *Tapered-roller-bearing din720*. Retrieved May, 2008, from: http://commons.wikimedia.org/wiki/Image:Tapered-roller-bearing_din720_ex.png

Question 5: Diagram from: Learning and Teaching Scotland. (2001). *Mechanical Systems—Homework* (p. 91). Retrieved May, 2007, from http://www.ltscotland.org.uk/nq/images/mechanical_systems_3_tcm4-118273.doc.

Question 8: Learning and Teaching Scotland. (2003). *Concurrent force systems—Components of a force* (p. 6, homework 2.3). Retrieved May, 2007, from http://www.ltscotland.org.uk/nq/images/structures_homework_questions_tcm4-118205.doc.

Question 10: Diagram from: Learning and Teaching Scotland. (2001). *Energy 'losses' during transformations* (p. 56). Retrieved May, 2007, from http://www.ltscotland.org.uk/nq/images/energy_2_tcm4-118345.doc.

Part B (Written)

Question 1 (a) – (e): Adapted from: Scottish Qualifications Authority. (2002). *Standard Grade Technological Studies: Credit level specimen question paper* (q. 5). Retrieved May, 2007, from http://www.sqa.org.uk/files_ccc/SG_Tech%20stds%20c%20spec.pdf.

Question 2: Photographs from: Brandt, D.A. (1992). *Metallurgy fundamentals*. Chicago: Goodheart-Willcox

SECTION TWO: Electronic/Electrical

Part A

Question 6: Board of Studies New South Wales. (2003). *Engineering Studies: 2003 Higher School Certificate Examination* (q. 2). Retrieved May, 2007, from http://www.boardofstudies.nsw.edu.au/hsc_exams/hsc2003exams/pdf_doc/engineer_studies_03.pdf.

Part B

Question 2(a): Scottish Qualifications Authority. (n.d.). *Intermediate 2 Electronic and Electrical Fundamentals: Specimen question paper* (q. 3). Retrieved May, 2007, from http://www.sqa.org.uk/files/nq/c02511_sqp.pdf.

Question 2(c): Diagram from: Learning and Teaching Scotland. (1999). *Technological Studies: Systems and Control: Students' notes: Intermediate 2* (outcome 2, p. 13). Retrieved May, 2007, from http://www.ltscotland.org.uk/nq/images/5718det2_tcm4-124136.pdf

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