



# Western Australian Certificate of Education Examination, 2010

## Question/Answer Booklet

### ENGINEERING STUDIES

#### Stage 2

Please place your student identification label in this box

Student Number: In figures

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In words

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#### 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

Document Booklet

Data Book

##### *To be provided by the candidate*

Standard items: pens, pencils, eraser, correction fluid/tape, ruler, highlighters

Special items: non-programmable calculators satisfying the conditions set by the Curriculum Council for this course, measuring and drawing instruments

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

Systems and Control

Mechanical

Electronic/Electrical

#### Important note to candidates

No other items may be taken into the examination room. It is **your** responsibility to ensure that you do not have any unauthorised notes or other items of a non-personal nature in the examination room. If you have any unauthorised material with you, hand it to the supervisor **before** reading any further.

## Structure of this paper

Section	Number of questions available	Number of questions to be answered	Suggested working time (minutes)	Marks available	Percentage of exam
Section One: <b>Core content</b>					
Part A: Multiple-choice	10	10	10	10	10
Part B: Extended answer	4	3	50	45	25
Section Two: <b>Systems and Control</b>					
Part A: Multiple-choice	10	10	10	10	10
Part B: Extended answer	3	3	110	105	55
Section Two: <b>Mechanical</b>					
Part A: Multiple-choice	10	10	10	10	10
Part B: Extended answer	4	4	110	105	55
Section Two: <b>Electronic/Electrical</b>					
Part A: Multiple-choice	10	10	10	10	10
Part B: Extended answer	3	3	110	105	55
<b>Total</b>					100

## Instructions to candidates

- The rules for the conduct of Western Australian external examinations are detailed in the *Year 12 Information Handbook 2010*. Sitting this examination implies that you agree to abide by these rules.
- Answer the questions according to the following instructions.

Sections One and Two, Part A:

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, do not erase or use correction fluid, and shade your new answer. Marks will not be deducted for incorrect answers. No marks will be given if more than one answer is completed for any question.

Section One, Part B:

Write answers in this Question/Answer Booklet. Answer only **three (3)** questions.

Section Two, Part B:

You must choose to answer only **one (1)** of the specialist sections.

Write answers in this Question/Answer Booklet. **All** questions must be answered.

- You must be careful to confine your responses to the specific questions asked and to follow any instructions that are specific to a particular question.
- Spare pages are included at the end of this booklet. They can be used for planning your responses and/or as additional space if required to continue an answer.
  - Planning: If you use the spare pages for planning, indicate this clearly at the top of the page.
  - Continuing an answer: If you need to use the space to continue an answer, indicate in the original answer space where the answer is continued, i.e. give the page number. Fill in the number of the question(s) that you are continuing to answer at the top of the page.

**See next page**

**Section One: Core content****35% (55 Marks)**

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

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

Part B: Extended answer      Answer **three (3)** questions

Suggested working time: 60 minutes.

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

This part has **ten (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, do not erase or use correction fluid, and shade your new answer. Marks will not be deducted for incorrect answers. No marks will be given if more than one answer is completed for any question.

Suggested working time: 10 minutes.

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1. Dimensional information used by designers so that products will suit the target population is sourced from the study of
  - (a) anthropometrics.
  - (b) ergonomics.
  - (c) economics.
  - (d) demographics.
  
2. When designing the interior of a motor vehicle, the placement of controls such as switches or buttons should be informed by anthropometric data. In general, the distance from the driver's location to a control should fit the
  - (a) 95th percentile so that 95% of drivers can reach the control.
  - (b) 95th percentile so that 5% of drivers can reach the control.
  - (c) 5th percentile so that 95% of drivers can reach the control.
  - (d) 5th percentile so that 5% of drivers can reach the control.
  
3. Checking that a design performs as expected and making suggestions for improvement best describes
  - (a) testing.
  - (b) specification.
  - (c) maintenance.
  - (d) evaluation.
  
4. The designer of a new ladder must consider a number of factors that affect the final design. The most important factor in the following list is
  - (a) the vertical distance between the steps.
  - (b) the material of which the ladder will be made.
  - (c) the method by which the steps will be secured to the ladder posts.
  - (d) the maximum weight that the ladder is expected to support.

**See next page**

5. Which one of the following is **not** a type of 3D pictorial drawing?
- oblique
  - isometric
  - orthogonal
  - perspective
6. A  $\text{Ø } 10 \text{ mm}$  hole must meet a tolerance of  $\pm 0.1 \text{ mm}$ . Which one of the following meets this tolerance?
- $\text{Ø } 10.05 \text{ mm}$
  - $\text{Ø } 9.9 \text{ mm}$
  - neither (a) or (b)
  - both (a) and (b)
7. An engineering drawing includes a feature labelled  $\text{M5} \times 10 \text{ deep}$ . This most likely refers to
- a 10 mm deep threaded hole tapped with metric 5 thread.
  - a metric 5 bolt 10 mm long.
  - a metric 5 nut 10 mm thick.
  - a 10 mm deep hole of diameter 5 mm.

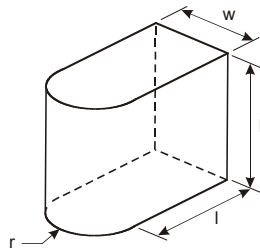
8. Examine the diagram shown below. Which formula could be used to calculate the area of its top surface?

(a)  $\frac{\pi \cdot r^2}{2} + hw$

(b)  $\frac{\pi \cdot r^2}{2} + L \cdot w$

(c)  $\frac{\pi \cdot r}{2} + h \cdot w$

(d)  $\frac{\pi \cdot r}{2} + L \cdot w$



9. The energy required to operate an electric motor is measured in units called
- newtons.
  - joules.
  - volts.
  - watts.
10. Which one of the following is an example of recycling?
- melting used aluminium cans and making new products from this material
  - melting used aluminium cans and making ingots that are stored for later use
  - collecting and storing all off-cuts when manufacturing aluminium cans
  - designing a manufacturing process for aluminium cans that uses the minimum of material and energy

Section One: Core content

Part B: Extended answer

25% (45 Marks)

This section has **four (4)** questions. Answer **only three (3)** 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.
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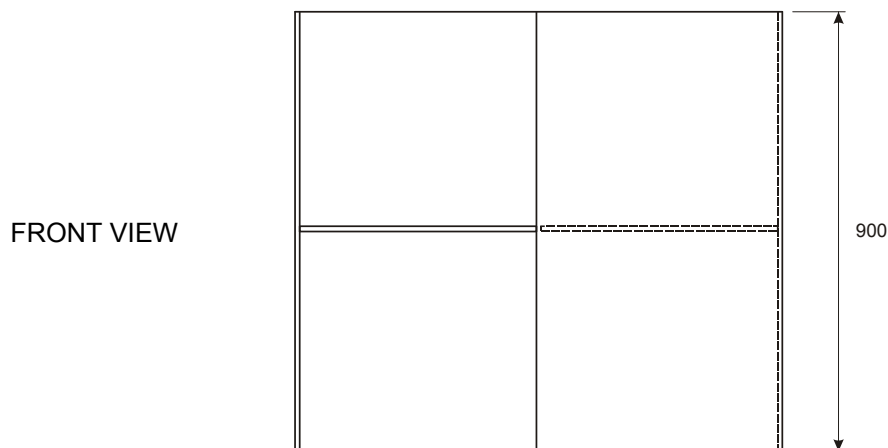
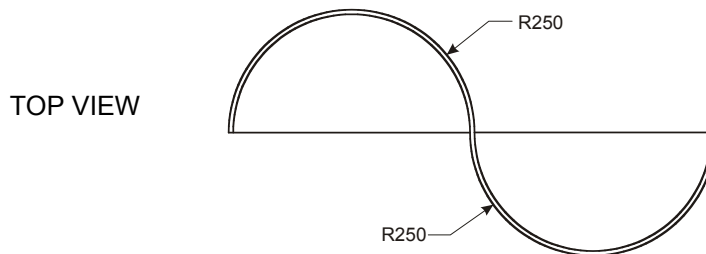
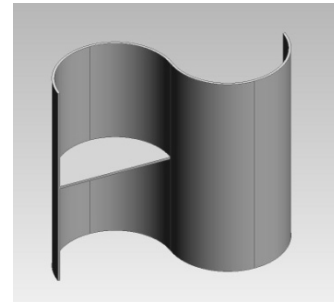
Suggested working time: 50 minutes.

Question 11

(15 marks)

A park bench is designed to accommodate two people facing in opposite directions but they can easily talk to each other by turning their heads slightly.

There are three parts to the bench. The main support structure is a single 'S' shaped piece of 5 mm thick mild steel. The seating places are semicircular shapes, also 5 mm thick. They are simply welded to the support structure at mid-height and do not require any special slots or brackets.



See next page

- (a) Calculate the mass of the mild steel used to construct the park bench. (8 marks)

Note 1: Mass is volume of material  $\times$  density. Use the appropriate formula from the Data Book to calculate the volume of material.

Note 2: The density of mild steel is  $7850 \text{ kg m}^{-3}$

Note 3: No allowance is required for welds

Total mass of mild steel \_\_\_\_\_

- (b) The park bench will require painting to protect it from the elements. An estimate must be made of how much paint to purchase. To make the estimate, it is first necessary to calculate the surface area of the park bench.

Calculate the total surface area of the park bench.

(7 marks)

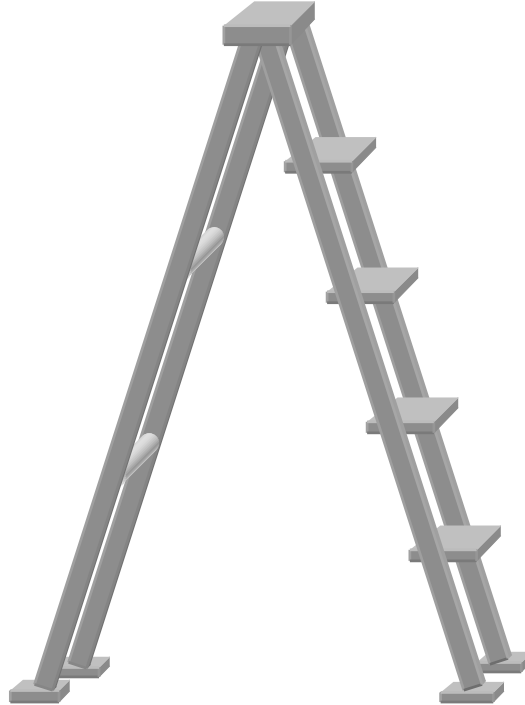
Note: All edges can be ignored when calculating the surface area.

Total surface area (ignoring edges) \_\_\_\_\_

**Question 12**

**(15 marks)**

A significant number of injuries, particularly of elderly people, can be connected to accidents involving ladders. Consider the 'A' frame ladder shown below. The safety of this ladder could be improved by supplying a locking mechanism to hold it in the desired position.



- (a) Draw a 3D sketch of a suitable locking mechanism for the ladder shown, indicating how the locking mechanism is attached to the ladder. Your sketch must be clear and appropriately labelled. Your design must be workable and simple to use. (7 marks)



(b) Explain how your design will help to make the ladder safer to use. (2 marks)

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(c) Comment on your design with regard to:

Demand (2 marks)

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Environment (2 marks)

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Ergonomics (2 marks)

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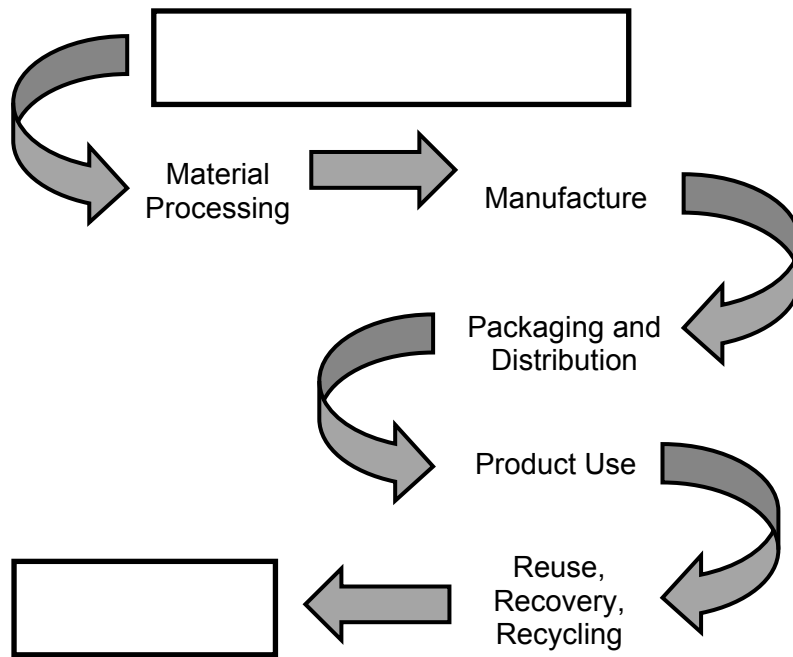
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Question 13

(15 marks)

(a) Name the missing stages from the Life Cycle Analysis diagram below.

(2 marks)



(b) Explain what occurs at the Reuse, Recovery, Recycling stage of the Life Cycle Analysis. (3 marks)

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(c) Describe two examples in stages of the Life Cycle that substantially reduce energy consumption and impact on the environment.

(i) \_\_\_\_\_

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(2 marks)

(ii) \_\_\_\_\_

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(2 marks)

(d) Name a significant engineering invention and explain its influence on society. Comment on how it is beneficial, i.e. the impact on people's lives, and how it has further enhanced engineering technologies and understandings. List any new discoveries made as a result of your chosen invention. (6 marks)

Handwriting lines for the answer.

**Question 14**

**(15 marks)**

The following question refers to information provided in the **Document Booklet**.

Grey water is the waste water generated in the bathroom, kitchen and laundry. Grey water is therefore those components of domestic waste water that have not originated from the toilet. Grey water can be reused to irrigate gardens. This will reduce the demand on quality ground and surface water supplies. Considering the dry environment in many parts of Western Australia and the sometimes-limited supply of water available, it is important that water be used efficiently and conserved wherever possible. Reuse of grey water is therefore supported and encouraged by the government to help conserve water.

- (a) Name three factors affecting the characteristics of grey water. (3 marks)

Factor one: \_\_\_\_\_

Factor two: \_\_\_\_\_

Factor three: \_\_\_\_\_

- (b) What percentage of water usage in the average home is derived from the use of taps? (1 mark)

\_\_\_\_\_

- (c) What range is recorded in the typical composition table (1.3(b)) against sodium in mg/L for both grey water and raw sewage? (2 marks)

grey water: \_\_\_\_\_

raw sewage: \_\_\_\_\_

- (d) Calculate the average daily grey water flow generated by a household with four occupants. (1 mark)

- (e) If a household of four occupants wishes to reuse bathroom and laundry grey water only, what tank capacity is required? (2 marks)

(f) For a household with four occupants, a subsoil trench is dug 0.3 m deep × 0.3 m wide. Calculate the length of the trench required for the following two substrates.

(i) Soil – Alternating system (3 marks)

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(ii) Gravel – Alternating system (3 marks)

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**End of Section One**

**See next page**

**Section Two: Specialist fields**

**65% (115 Marks)**

Candidates are required to choose one of the following options, according to which specialist field they studied in 2010.

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

Specialist field	✓	Question numbers	Pages
Systems and Control	<input type="checkbox"/>	15–27	<b>15–29</b>
Mechanical	<input type="checkbox"/>	28–41	<b>30–45</b>
Electronic/Electrical	<input type="checkbox"/>	42–54	<b>46–56</b>

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

**Section Two: Specialist field—Systems and Control****65% (115 Marks)**

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

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

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

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.

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Suggested working time: 120 minutes.

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**Part A: Multiple-choice****(10 marks)**

This part has **ten (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, do not erase or use correction fluid, and shade your new answer. Marks will not be deducted for incorrect answers. No marks will be given if more than one answer is completed for any question.

Suggested working time: 10 minutes.

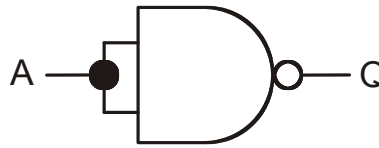
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15. Which one of the following produces a digital signal?
- (a) variable resistor
  - (b) limit switch
  - (c) thermistor
  - (d) LDR
16. Which one of the following situations will require a sensor that responds to an analogue input signal?
- (a) detecting a change in temperature only
  - (b) detecting a change in colour only
  - (c) detecting a change in moisture only
  - (d) detecting a change in any of temperature, colour or moisture
17. How many of the four possible input combinations for a 2 input XOR gate will result in an output?
- (a) 1
  - (b) 2
  - (c) 3
  - (d) 4

**See next page**

18. Which one of the following is the equivalent logic function for the diagram shown below?

- (a) NOT gate
- (b) NOR gate
- (c) NAND gate
- (d) AND gate



19. A 12 V electric motor draws 120 mA of current. Its power is

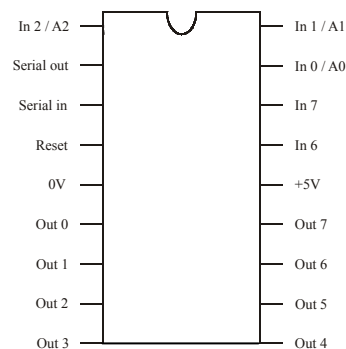
- (a) 1.44 W.
- (b) 10.0 W.
- (c) 14.4 W.
- (d) 1440 W.

20. Which of the following is **not** a closed loop system?

- (a) thermostat
- (b) black line following robot
- (c) electric kettle
- (d) volume control for a public address speaker system

21. Shown here is the pin-out diagram for an 18 pin microcontroller. The pins used to download instructions via the download socket are

- (a) serial out.
- (b) serial in.
- (c) serial out and serial in.
- (d) serial out, serial in and reset.



22. Which one of the following mechanical systems is most prone to slipping under a heavy load?

- (a) pulley
- (b) chain and sprocket
- (c) gear
- (d) rack and pinion

23. The use of an idler gear in a mechanical system

- (a) increases output speed.
- (b) decreases output speed.
- (c) makes no difference to output speed.
- (d) puts the system into neutral.



24. Pneumatic systems make use of 5/2 valves. These are used to control
- (a) single acting cylinders (SAC).
  - (b) double acting cylinders (DAC).
  - (c) air pressure.
  - (d) piston speed.

**This space has been left blank intentionally**

Part B: Extended answer

(105 marks)

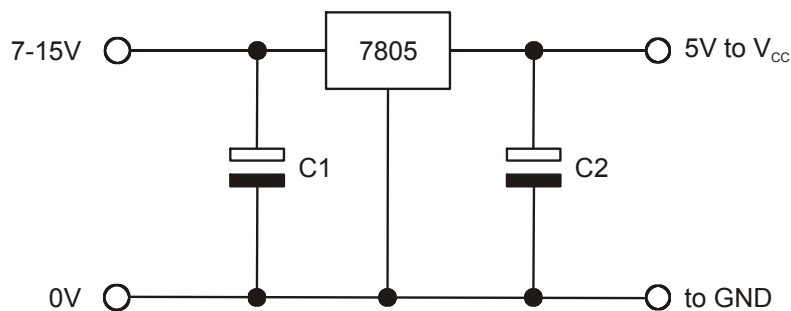
This part has **three (3)** questions. Answer **all** questions. Write your answers in the spaces provided.

Suggested working time: 110 minutes.

Question 25

(30 marks)

- (a) For logic ICs, the voltage supplied must be 5 V. This is often achieved by using the circuit shown below. What are the names of the components labelled C1 and C2 and what is the purpose of each? (6 marks)



C1 name: \_\_\_\_\_

C1 purpose: \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

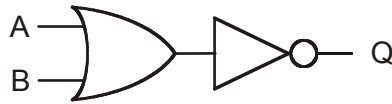
C2 name: \_\_\_\_\_

C2 purpose: \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

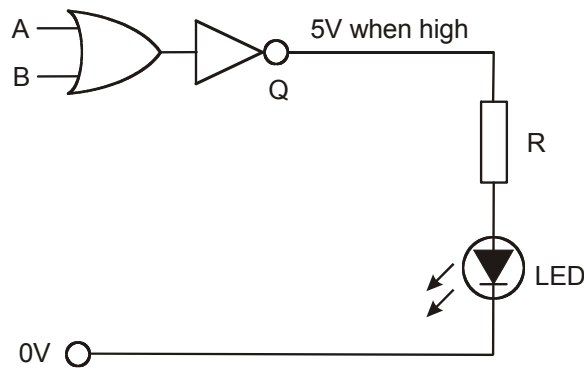
(b) Examine the combination of logic gates shown below.



(i) The truth table for this system is shown below. Complete it by placing a 0 or 1 in each row of the B and Q columns. (8 marks)

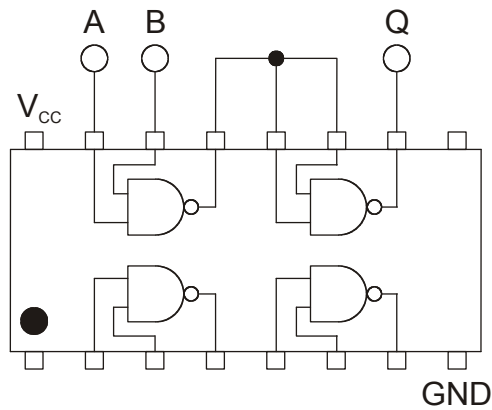
A	B	Q
0		
0		
1		
1		

(ii) An LED (light emitting diode) is used as the output for the logic circuit. This is shown in the diagram below. The forward voltage of the LED is 2 V and the current flowing through it is 11 mA.



Calculate the ideal value for the series resistor that would be used with the LED. (4 marks)

(c) The following diagram shows a 'Quad 2-Input NAND gate integrated circuit' (IC).



(i) How many inputs are there on the **entire** Quad 2-input NAND gate IC? (2 marks)

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(ii) The partially completed truth table for the system shown in the diagram above is provided below. Complete the table by placing a 0 or 1 in each row of the Q column. (8 marks)

A	B	Q
0	0	
0	1	
1	0	
1	1	

(iii) What type of logic gate has resulted from this combination of NAND gates? (2 marks)

## Question 26

(35 marks)

An automated control system is used for watering the garden and lawn in a small backyard. To conserve water, a number of factors are considered before the pump will turn on. These factors are:

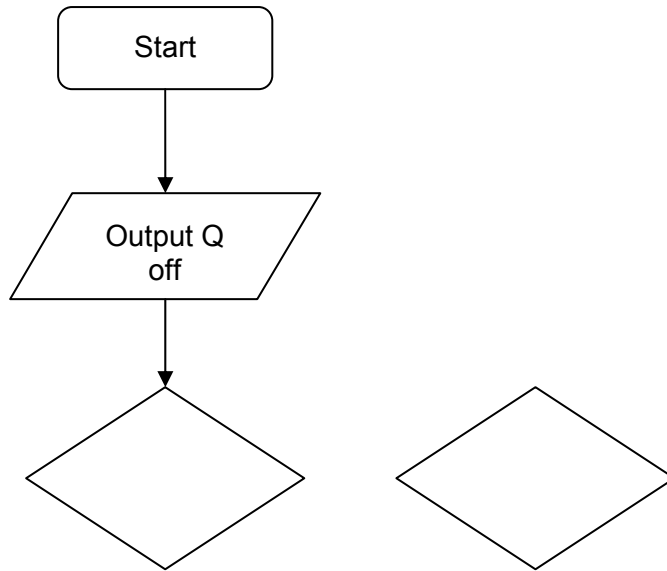
- (A) **If** it is a designated watering day i.e. Sunday **or**
  - (B) Thursday, **and**
  - (C) it is 5.00 a.m., **and**
  - (D) a moisture sensor detects that the soil is dry, **then**
  - (Q) the pump will turn on
- (a) In the space below sketch the logic diagram for the system described above. (7 marks)

- (b) There are 16 possible combinations available for the system described in part (a). For the purpose of this question, only 10 of these are shown below in the truth table. Complete the table by placing a 0 or 1 in each row of the Q column. (10 marks)

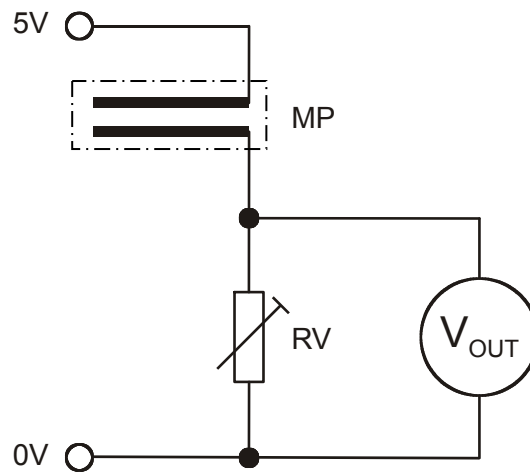
A	B	C	D	Q
0	1	1	0	
0	1	1	1	
1	0	0	0	
1	0	0	1	
1	0	1	0	
1	0	1	1	
1	1	0	0	
1	1	0	1	
1	1	1	0	
1	1	1	1	

- (c) Rather than use logic ICs to create the automatic watering system a microcontroller will be used instead. In the space below complete the flow chart that satisfies the specifications outlined for question 26.

Note: The pump will turn off when the moisture sensor detects sufficient water has penetrated the soil. (13 marks)



(d) The circuit diagram for the moisture sensor is shown below.



(i) Calculate the output voltage ( $V_{OUT}$ ). Assume the resistance of MP (moisture probe) is  $50\text{ k}\Omega$  and RV is set to  $12\text{ k}\Omega$ . (3 marks)

(ii) Is the output signal,  $V_{OUT}$ , a digital or analogue signal? Explain why. (2 marks)

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Question 27

(40 marks)

- (a) The architecture inside a microcontroller contains a number of features. Three of these are listed below.

State the name and briefly describe the purpose for each of the following. (9 marks)

ROM name: \_\_\_\_\_

ROM purpose: \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

I/O name: \_\_\_\_\_

I/O purpose: \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

ADC name: \_\_\_\_\_

ADC purpose: \_\_\_\_\_

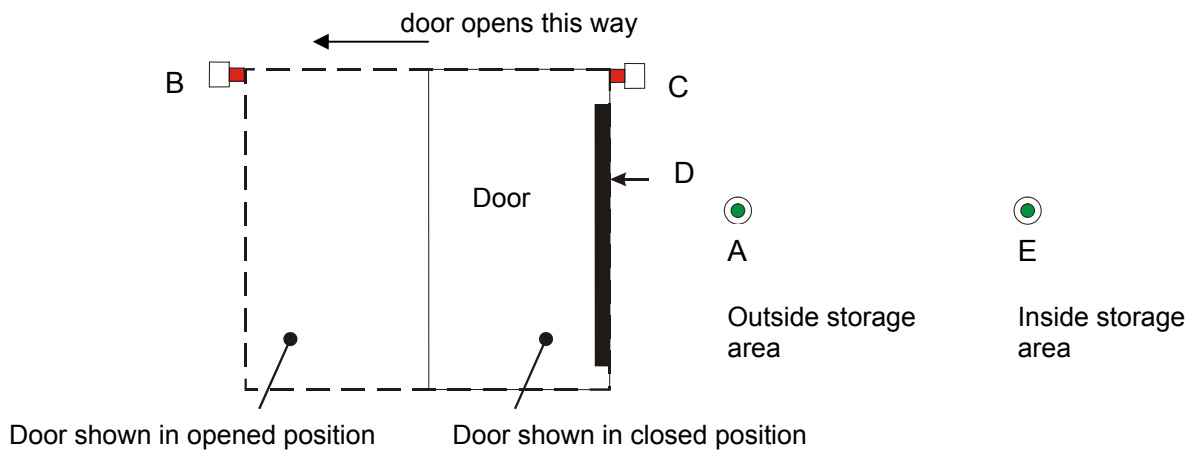
\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

Automated sliding doors and gates are found in many locations, including shopping centres, factories, trains and homes. For parts (b) and (c) of this question, the example is an automated sliding door at the entrance to a storage area in a factory. The system includes the following:

- Inputs
- (A) Switch outside the storage area that signals for the door to be opened
  - (B) Limit switch that detects when the door is fully opened and, if it is, will halt the motor for 5 seconds before it begins to close
  - (C) Limit switch that detects when the door is fully closed
  - (D) Switch incorporated into the leading edge of the door that detects any obstructions when the door is closing and if there are, will reopen the door
  - (E) Switch inside the storage area that signals for the door to be opened
- Outputs
- (F) Signals the motorised gearbox to open the door
  - (G) Signals the motorised gearbox to close the door



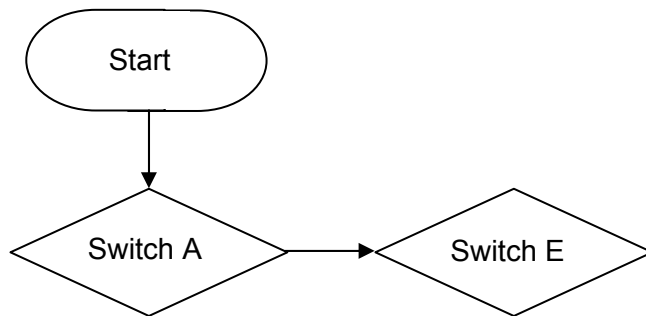
Door shown in opened position

Door shown in closed position

Motorised gearbox controlled by F and G.

**Note:** The above diagram has been simplified by omitting most structural and mechanical parts. The motorised gearbox is not in its final position and input E would actually be in a similar position to input A, but inside the storage area.

- (b) In the space below, sketch a flow chart that would control the sliding door and incorporate all the specified inputs and outputs. Some of the commands have been supplied. (20 marks)



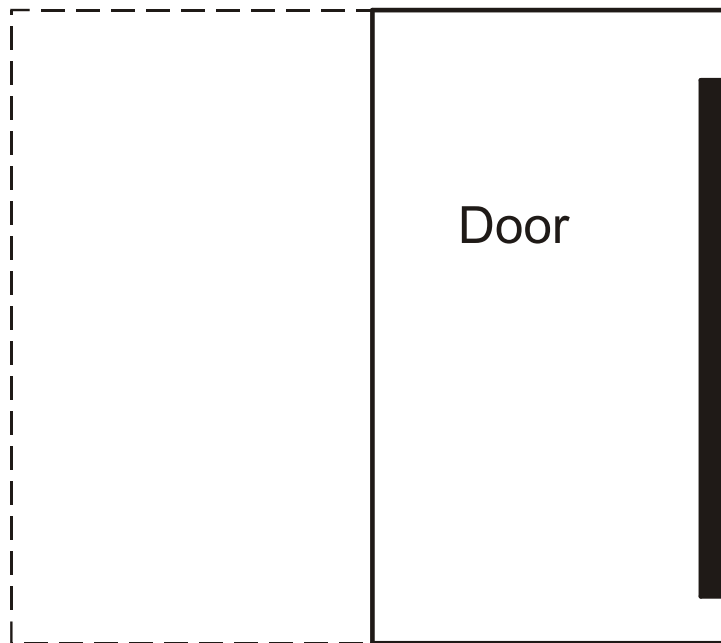
(c) To cause the sliding door to open and close, a suitable mechanical system must be driven by the output shaft of the motorised gearbox.

(i) In the space below, sketch a mechanical system, including the motorised gearbox, that could operate the door and guide it as it opens and closes.

(5 marks)

Note 1: There is no need to show any details of the switches used by the control system.

Note 2: Marks will be awarded for neatness of the sketch and for brief notes that describe key features of the mechanical system.



- (ii) When moving the door, the power exerted by the motor is 1200 W and it draws 5 A. Calculate the supply voltage. (3 marks)

- (iii) Calculate the velocity at which the door moves when opening or closing, given that the force applied to the door via the mechanical system is 6000 N. (3 marks)

Note 1:  $P = Fv$ , where  $P$  = power (W),  $F$  = force (N) and  $v$  = velocity ( $\text{m s}^{-1}$ )

Note 2: Assume that the door moves at a constant velocity

Note 3: Losses due to friction can be ignored

Section Two: Specialist field—Mechanical

65% (115 Marks)

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

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

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

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Suggested working time: 120 minutes.

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**Part A: Multiple-choice**

**(10 marks)**

This part has **ten (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, do not erase or use correction fluid, and shade your new answer. Marks will not be deducted for incorrect answers. No marks will be given if more than one answer is completed for any question.

Suggested working time: 10 minutes.

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28. Consider four spheres, each of diameter 10 mm, and each made of a different metal; cast iron, brass, stainless steel and copper. Use the **Data Book** to determine that the heaviest sphere is made of
- (a) cast iron.
  - (b) brass.
  - (c) stainless steel.
  - (d) copper.
29. A cutting tool accelerates from  $50 \text{ mm s}^{-1}$  to  $150 \text{ mm s}^{-1}$  in 0.2 seconds. The average acceleration of the tool is
- (a)  $500 \text{ m s}^{-2}$ .
  - (b)  $1 \text{ m s}^{-2}$ .
  - (c)  $20 \text{ m s}^{-2}$ .
  - (d)  $0.5 \text{ m s}^{-2}$ .
30. 'Pressure' is defined as
- (a) force acting on an accelerated body.
  - (b) force per unit area acting on a surface.
  - (c) stress over strain.
  - (d) area divided by force acting on a surface.

See next page

31. The ability of a metal to be stretched or drawn into wire by a tensile force without fracturing is called

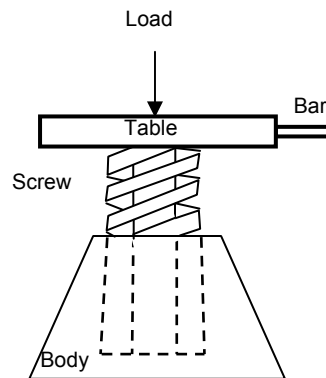
- (a) ductility.
- (b) malleability.
- (c) elasticity.
- (d) plasticity.

32. The gradient of a stress versus strain curve indicates

- (a) yield stress.
- (b) energy absorbed.
- (c) Young's modulus.
- (d) ultimate tensile strength.

33. If the velocity ratio of a screw jack is 50 and its efficiency is 40%, the effort to lift a load of  $3.6 \times 10^6$  N is

- (a) 2.88 kN.
- (b)  $2.88 \times 10^4$  N.
- (c) 180 kN.
- (d) 72 kN.



34. 'Kinetic energy' is defined as

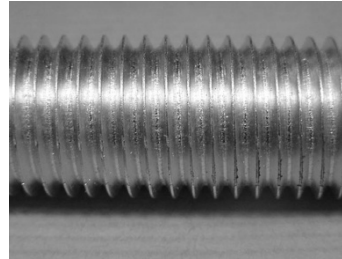
- (a) a form of mechanical energy possessed by a solid body by virtue of its motion.
- (b) the work required to lift an object with a mass by a constant speed.
- (c) a solid body that has the potential to generate energy.
- (d) a form of mechanical energy possessed by a solid body due to its elevation above some datum.

35. What is the main difference between normalising and annealing?

- (a) normalised metals are quenched in water from red heat but annealed metals are cooled in air from below red heat
- (b) annealed metals are cooled in air from below red heat but normalised metals are cooled in air from red heat
- (c) annealed metals are quenched from red heat but normalised metals are cooled in air from red heat
- (d) annealing produces metals with smaller grains than normalising

36. Torque can be defined as a
- (a) force per second.
  - (b) force acting on a wheel.
  - (c) force per metre.
  - (d) force that produces a rotation.
37. Which one of the following is the minimum cross-sectional area a mild steel bolt should have to withstand a load of 600 kN, if the steel has a yield stress of 300 MPa and the factor of safety is to be 4?

- (a)  $4 \times 10^{-3} \text{ m}^2$
- (b)  $8 \times 10^{-3} \text{ m}^2$
- (c)  $12 \times 10^{-3} \text{ m}^2$
- (d)  $0.72 \text{ m}^2$





## Part B: Extended answer

(105 marks)

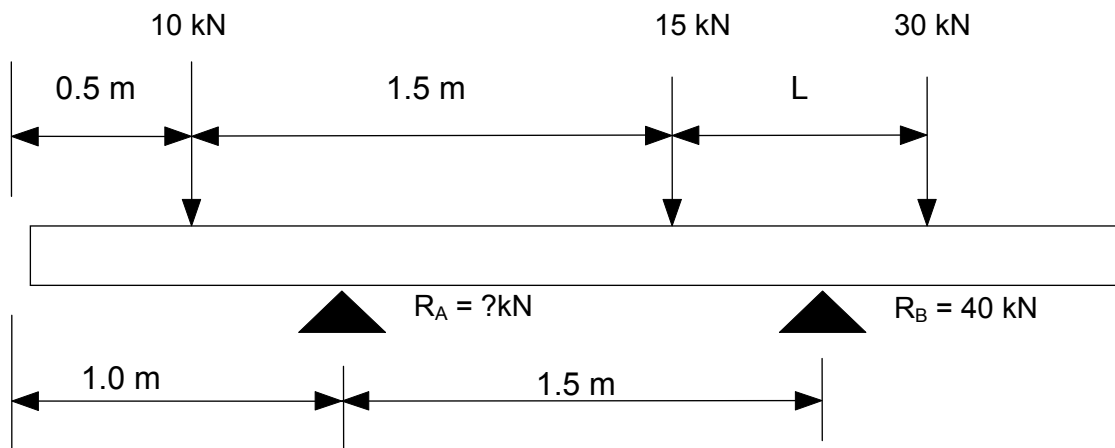
This part has **four (4)** questions. Answer **all** questions. Write your answers in the spaces provided.

Suggested working time: 110 minutes.

## Question 38

(27 marks)

A uniform horizontal beam weighs 5.0 kN and is 3.5 m long. The beam is loaded as shown below and is supported at two points, where the reaction forces are  $R_A$  and  $R_B$  respectively.



(a) Calculate the force  $R_A$ :

(3 marks)

$R_A =$  \_\_\_\_\_ N

(b) (i) Redraw the beam in the space below, showing **all** of the forces acting on the beam, and showing all the distances as measured from the left hand end of the beam. (4 marks)

- (ii) By taking moments about the left hand end, calculate the location of the 30 kN force and hence determine the distance L. (5 marks)

L = \_\_\_\_\_ m

- (c) If the distance L is increased so that the 30 kN force moves to the extreme right of the beam, what effect will this have on the magnitudes of  $R_A$  and  $R_B$ ? Circle the correct answers. (2 marks)

$R_A$  will:            increase                      decrease                      remain the same

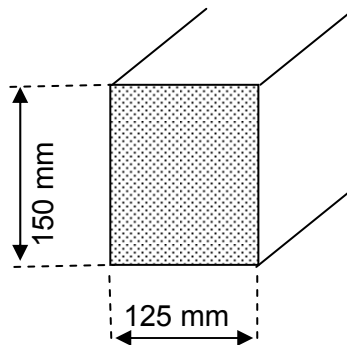
$R_B$  will:            increase                      decrease                      remain the same

- (d) The same beam has the vertical loads removed, and is subjected to a tension load. The beam deforms elastically, resulting in a temporary change of length.

- (i) Does the length increase or decrease? Circle the correct answer. (1 mark)

                  increase                      decrease

- (ii) The dimensions of the beam are shown below. The tension load has a magnitude of 600 kN, and is directed along the long axis of the beam. Calculate the stress this causes in the beam. (4 marks)



stress = \_\_\_\_\_

- (iii) The beam is made of structural steel. Use the calculated stress from (ii) above and the elastic (Young's) modulus of structural steel from the **Data Book** to calculate the strain in the beam. (5 marks)

strain = \_\_\_\_\_

- (iv) Hence, determine the change in length of the beam. (3 marks)

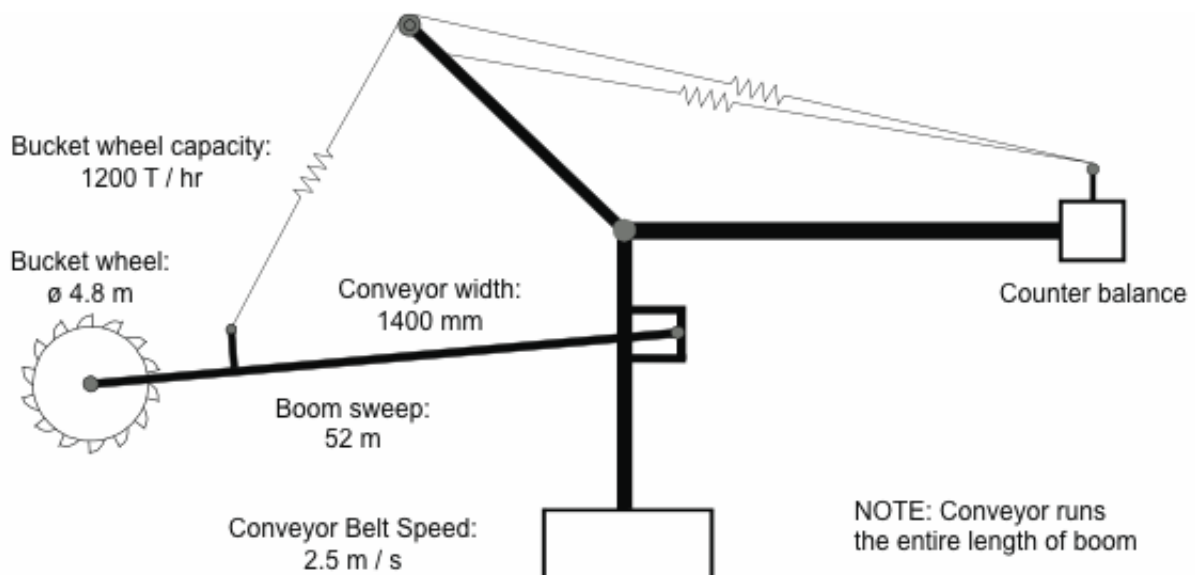
change in length = \_\_\_\_\_

See next page

Question 39

(23 marks)

Bucket wheel reclaimers are designed to rapidly move stockpiles of crushed ore. The wheel mechanism at the end of the boom is made up of a series of scoops (buckets) that carry the crushed ore up and over the wheel and onto a moving conveyor belt located on the boom. Crushed ore is then poured onto the infeed conveyor leading to the port facility where it is loaded onto a bulk carrier for transport overseas.



- (a) Each bucket on the bucket wheel reclaimer has a capacity of 500 kg of crushed ore. Calculate the maximum rise in potential energy of a single bucket as the wheel rotates. (3 marks)

Energy = \_\_\_\_\_ J

- (b) (i) Given that the density of the crushed ore is  $2100 \text{ kg m}^{-3}$ , calculate the volume of crushed ore moved in one hour. (4 marks)

Note that density =  $\frac{\text{mass}}{\text{volume}}$

Volume = \_\_\_\_\_  $\text{m}^3$

- (ii) Calculate how long it takes for the conveyor to move a piece of ore from one end of the boom to the other.

Note that speed =  $\frac{\text{distance travelled}}{\text{time taken}}$  (4 marks)

Time taken = \_\_\_\_\_ s

See next page

- (iii) Explain the purpose of the counterbalance. (4 marks)

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- (c) Given that each of the fourteen buckets on the bucket wheel has the capacity to hold 500 kg of crushed ore, find:

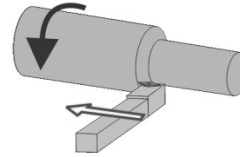
- (i) the period of rotation (in seconds) of the bucket if the bucket wheel reclaimer moves 1200 tonnes of ore per hour. (4 marks)

- (ii) the maximum torque generated in the shaft as a result of the weight of a single bucket's load. (4 marks)

Torque = \_\_\_\_\_ Nm

**Question 40****(27 marks)**

A  $\varnothing$  50 mm aluminium tie-rod, 600 mm long, is turned down to  $\varnothing$  40 mm over 200 mm of its length. The rod is then subjected to a 30 kN tensile force.



- (a) Determine the stress in the  $\varnothing$  50 mm section of the rod.

**(4 marks)**

$$\sigma = \text{_____ MPa}$$

- (b) Determine the stress in the  $\varnothing$  40 mm section of the rod.

**(4 marks)**

$$\sigma = \text{_____ MPa}$$

**See next page**

- (c) Determine the strain in the  $\varnothing$  50 mm section of the rod. **Refer to the Data Book.** (4 marks)

$$\varepsilon = \underline{\hspace{10cm}}$$

- (d) Determine the strain in the  $\varnothing$  40 mm section of the rod. (4 marks)

$$\varepsilon = \underline{\hspace{10cm}}$$

- (e) Calculate the total change in length of the tie-rod. (4 marks)

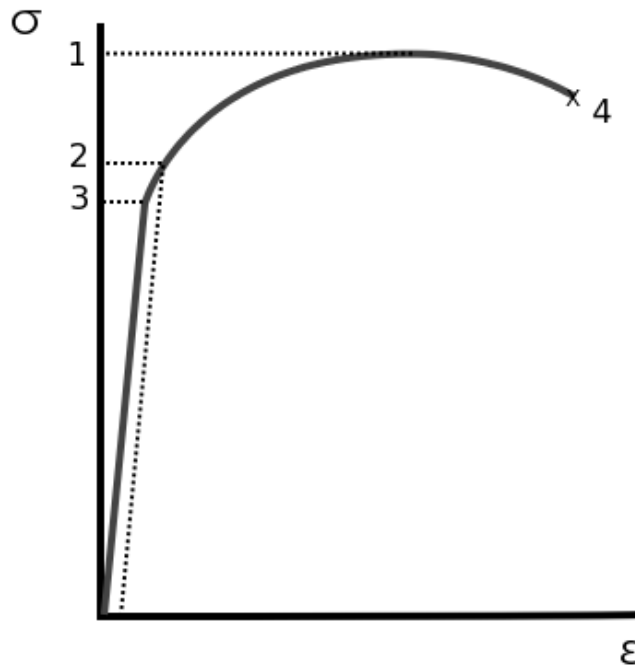
$$\Delta L_{\text{TOTAL}} = \underline{\hspace{10cm}}$$

**See next page**



- (f) Calculate the factor of safety of the tie-rod. Base your answer on the maximum stress in the material, which occurs in the reduced section of the tie-rod. **Refer to the Data Book.** (3 marks)

Factor of Safety = \_\_\_\_\_



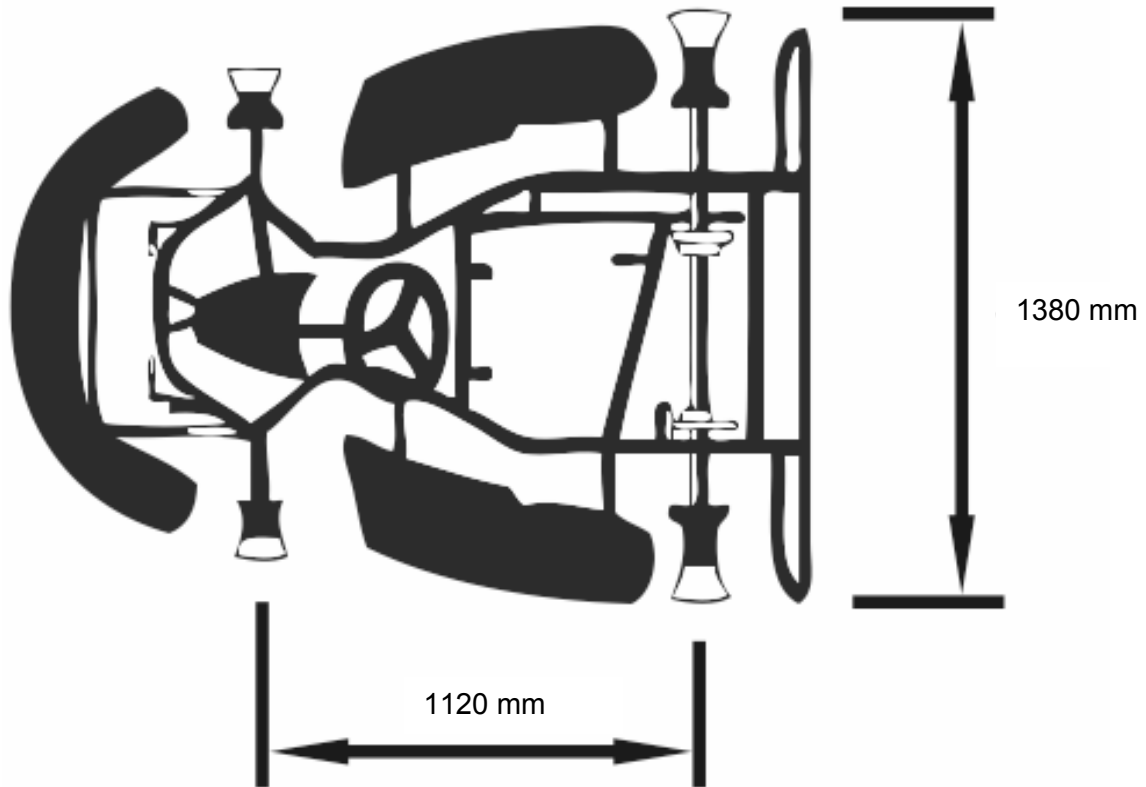
- (g) During a tensile test of the aluminium tie-rod, a stress-strain graph was plotted similar to the one shown above. Identifiable regions and/or points on a stress-strain graph include the following: fracture; elastic deformation; plastic deformation; proportional limit; tensile strength; yield strength. Use this list and your Engineering knowledge to name the numbered points on the graph. (4 marks)

- 1. \_\_\_\_\_
- 2. \_\_\_\_\_
- 3. \_\_\_\_\_
- 4. \_\_\_\_\_

Question 41

(28 marks)

Engineers from the local university are developing the design of a go-kart chassis. Shown below is a top view of the go-kart chassis, with dimensioning indicating wheelbase (distance between axles) and total width.



- (a) The tyres on the go-kart have an outside diameter of 460 mm. This makes the ratio of the rear axle height to width equal to 6:1.

Explain why the designer has made this ratio so high.

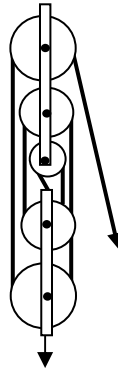
(4 marks)

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- (b) A block and tackle pulley mechanism, similar to the one illustrated above, is used to lift the go-kart chassis off the ground when attaching the tyres. A pulley system magnifies the user's effort. Find the velocity ratio of this system. (3 marks)

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- (c) One group of engineers has examined the drive train of the go-kart. The gear attached to the motor has 12 teeth and the gear mounted to the wheel has 82 teeth. The tyres have an outside diameter of 460 mm.

- (i) What is the velocity ratio (VR) of this system? (3 marks)

- (ii) Determine the acceleration of the go-kart, if the top speed of  $40 \text{ km h}^{-1}$  is reached in 8.0 seconds. (4 marks)

(iii) Calculate the distance travelled to reach top speed.

If you could not calculate the acceleration in (ii) above, use  $2.00 \text{ m s}^{-2}$ .

(3 marks)

(iv) Determine the rpm of the gear mounted to the wheel at  $40 \text{ km h}^{-1}$ .

(3 marks)

(v) Calculate the revolutions of the gear attached to the motor over a distance of 100 m.

(4 marks)

- (d) Another group of engineers is concerned with the go-kart's turning circle. These engineers developed a formula that, given steering angle ( $\theta$ ), will calculate the turning circle diameter. The formula, using the rear track of the go-kart, is

$$\text{Turning circle diameter} = 2 \times \frac{\text{wheelbase}}{\sin \theta} + \text{Distance from axle centreline to outside of tyre}$$

Given that the steering angle is  $35^\circ$ , calculate the go-kart's turning circle. (4 marks)

Section Two: Specialist field—Electronic/Electrical

65% (115 Marks)

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

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

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

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(s) that you are continuing to answer at the top of the page.

Suggested working time: 120 minutes.

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**Part A: Multiple-choice**

**(10 marks)**

This part has **ten (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, do not erase or use correction fluid, and shade your new answer. Marks will not be deducted for incorrect answers. No marks will be given if more than one answer is completed for any question.

Suggested working time: 10 minutes.

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42. When two parallel resistors each with a value of  $R \Omega$ , are placed in series with a single resistor of  $R \Omega$ , the total resistance is

- (a)  $\frac{5}{2} R \Omega$ .
- (b)  $4 R \Omega$ .
- (c)  $3 R \Omega$ .
- (d)  $\frac{3}{2} R \Omega$ .

43. Ten  $100 \mu\text{F}$  capacitors placed in parallel will have a combined total capacitance of

- (a)  $10 \text{ pF}$ .
- (b)  $100 \mu\text{F}$ .
- (c)  $10 \mu\text{F}$ .
- (d)  $1 \text{ mF}$ .

44. A  $240 \text{ V}$  transformer for a mobile phone has an output of  $7.2 \text{ V}$ . Which one of the following is the primary to secondary turns ratio for the transformer?

- (a)  $100:3$
- (b)  $100:7$
- (c)  $240:12$
- (d)  $3:100$

See next page

45. A simple solenoid will act to
- (a) amplify current.
  - (b) change voltage.
  - (c) change current.
  - (d) switch current.
46. An electricity meter measures electrical energy. The units used by the meter are
- (a) volts.
  - (b) amperes.
  - (c) watts.
  - (d) kilowatt hours.
47. A set of Christmas tree lights has twelve LEDs connected in a parallel circuit. One of the LEDs becomes disconnected as a leg breaks. Assuming that each LED acts as a resistor, we can predict that the remaining LEDs will
- (a) glow more brightly.
  - (b) glow less brightly.
  - (c) remain unchanged.
  - (d) all go out.
48. A current of 1  $\mu\text{A}$  flows through a 1  $\text{k}\Omega$  resistor. The voltage across the resistor is equal to
- (a) 1 millivolt.
  - (b) 1 microvolt.
  - (c) 1 megavolt.
  - (d) 1 picovolt.
49. The biased voltage across the base/emitter of an NPN transistor is equal to
- (a) 12 volts.
  - (b) 0.5 volts.
  - (c) -0.5 volts.
  - (d) 0.7 volts.
50. The purpose of a full wave rectifier in a power supply is to
- (a) produce a DC output from an AC supply.
  - (b) reverse the flow of current.
  - (c) produce a sine wave supply.
  - (d) produce an AC output from a DC supply.
51. An electric motor is quoted as being 96% efficient. This means that the ratio of output power to input power is equal to
- (a) 96.
  - (b) 0.01.
  - (c) 0.96.
  - (d) 1.03.

Part B: Extended answer

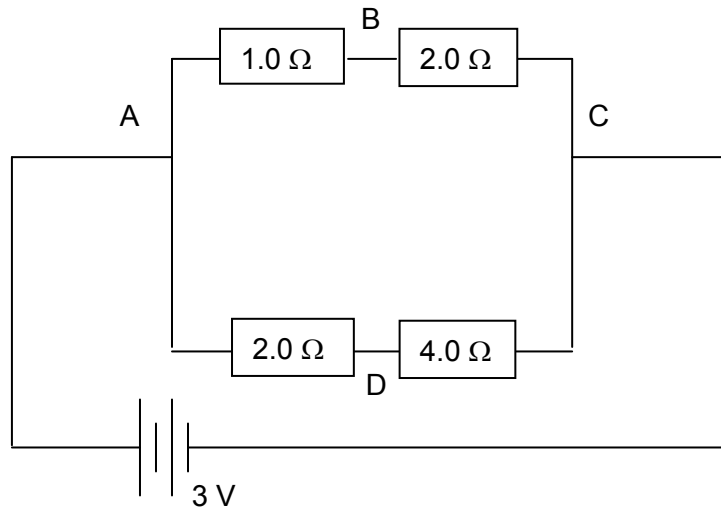
(105 marks)

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

Suggested working time: 110 minutes.

Question 52

(35 marks)



(a) (i) Find the resistance between A and C. (3 marks)

(ii) Find the current  $I_{ABC}$ . (3 marks)

(iii) Find the current  $I_{ADC}$ . (3 marks)



(iv) Find  $V_{AB}$ . (3 marks)

(v) Find  $V_{AD}$ . (3 marks)

(vi) Find the potential difference between B and D. (2 marks)

(vii) If a multimeter was placed between B and D, would it register a current? (1 mark)

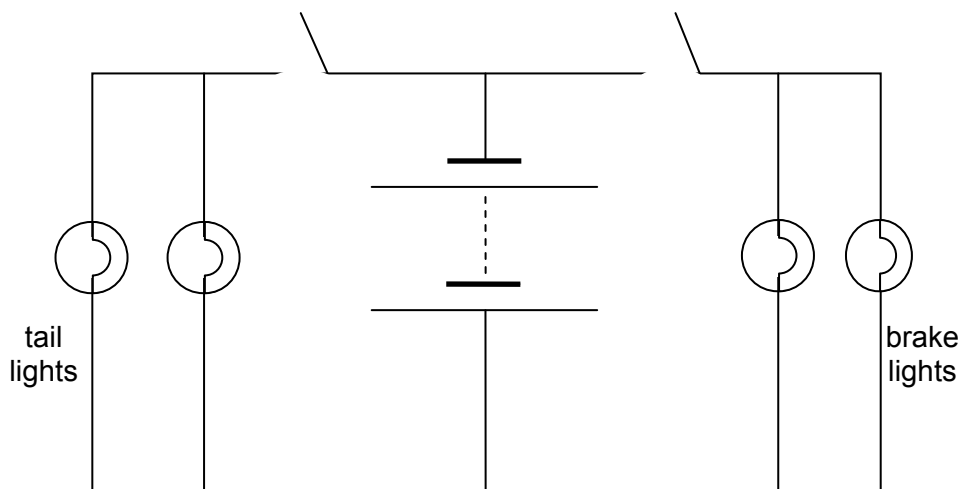
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All cars have two sets of lights at the back. One set, the brake lights, includes a red light on each side. This set lights up when the brakes are applied, to warn following motorists that the car is slowing down. The rear of a car also has indicators, which consist of an orange flashing light on each side to show which direction the car intends to turn. A single twelve-volt battery powers the electrical system in a car.

The red brake light has two filaments in the same globe: one is a 21 watt tail light filament, which comes on when the headlights are switched on; and the second is a 35 watt filament, which is the actual brake light.

- (b) The brakes of a car usually have a normally open momentary switch under the brake pedal. When the brakes are applied, the brake lights switch on.

The circuit diagram shows how the two brake lights are connected.



- (i) Calculate the current drawn by one tail-light. (4 marks)

- (ii) Calculate the current drawn by one brake light. (4 marks)

- (c) Give **two (2)** advantages of replacing incandescent globes with LED lights in tail-lights. (4 marks)

Advantage one

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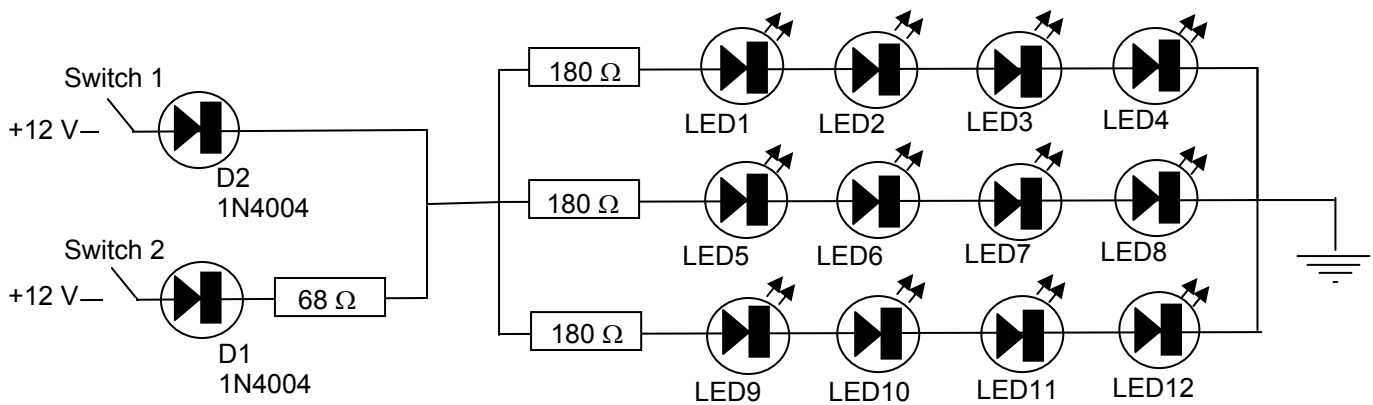
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Advantage two

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- (d) The LED tail/brake light combination light must emulate the incandescent globe with two filaments. The circuit diagram below is for a tail and brake function LED light. Explain how the LED light set is made to glow at two different light levels, bright for the brake and duller for the tail-light. In your explanation, state which switch fulfils which function. (5 marks)



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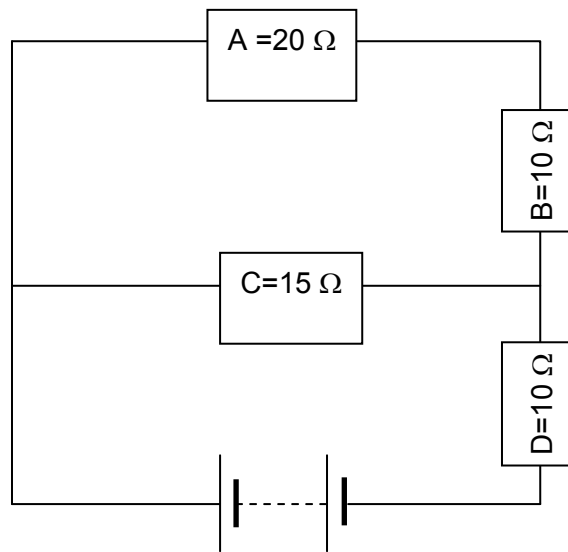
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Question 53

(44 marks)

(a) Refer to the circuit below and complete the following table.

(20 marks)



Resistor	Resistance ( $\Omega$ )	Voltage (volts)	Current (milliamps)
A	20 $\Omega$		100 mA
B	10 $\Omega$		
C	15 $\Omega$		
D	10 $\Omega$		
Total circuit			

As a result of generous government rebates, home solar power supplies that are connected to the electricity grid are becoming increasingly popular. These turn the electricity meter of the house backward when more electricity is being supplied by the solar array than is being used in the house.

The solar array is usually installed so that it faces north to collect the maximum sunlight.

A solar array on the roof of a house is rated at 1.2 kW. It is made up of six 24 V panels connected in series. The panels produce a DC supply, which is fed into an inverter. The inverter puts out a 240 V AC supply, which is fed into the electricity grid from the house. After the government rebate, the system costs the homeowner \$6000.



- (b) (i) Calculate the total voltage of the array. (2 marks)
- (ii) Calculate the current produced by the array. (2 marks)
- (c) The value 1.2 kW refers to the power produced by the array before the inverter. If the inverter is rated at 94% efficient, calculate the power of the AC supply. (4 marks)

(d) (i) In Australia we can expect to receive an average of 5.5 hours of useable sunlight each day. Calculate the energy output from the inverter per year (365 days) in the units of kilowatt hours (kWh). (4 marks)

(ii) One unit (1 kWh) of electricity from the grid costs \$0.16. At this price, calculate the value in dollars of the electricity output of the system in one year. (2 marks)

(iii) Calculate the time that it would take for the system to generate enough electricity to pay off the \$6000 original outlay. Assume that you will use 80% of the electricity generated, and that you can sell the remaining 20% back to the grid at \$0.40 per unit. (3 marks)

(e) (i) On a sunny winter's day, the array is producing a 5.0 A current. The total resistance of the wire between the array and the inverter is 0.5  $\Omega$ . Calculate the power loss in the wire. (3 marks)

(ii) Describe **two (2)** changes that you could make to the system to decrease the power loss. (4 marks)

Change one

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Change two

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## Question 54

(26 marks)

A UHF Remote Mains Switch Receiver is a device that is able to switch on and off any device that is powered by 240 V mains power and is commonly used to change channels and volume on TV sets.

The circuit diagram for the device can be found in the **Document Booklet**.

- (a) Explain the purpose of the series of components D1 – D4. (3 marks)

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- (b) Explain the purpose of the component RLY 1. (3 marks)

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- (c) (i) The component T1 has an input of 240 V and an output of 12.6 V. Calculate the primary to secondary turns ratio of the component. (3 marks)

- (ii) For each of the following components, state whether the current is AC or DC. (3 marks)

Component	AC or DC
T1 input	
T1 output	
D1 – D4 output	

See next page

(iii) Calculate the change in the value of the current between the input and output of the component T1. (2 marks)

(d) State the purpose of the 100  $\mu$ F and 470  $\mu$ F on the input side of the components Reg 1 and Reg 2. (2 marks)

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(e) (i) State the purpose of the component Q1 BC337. (2 marks)

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(ii) Explain how the component Q1 BC337 operates. (4 marks)

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(f) Many of the components in electronic circuits have a prefix to the units. State the name and number value of the following unit prefixes. (4 marks)

Prefix	Name	Number value
n	nano	$10^{-9}$
p		
$\mu$		
m		
k		









## ACKNOWLEDGEMENTS

### Section Two: Specialist field—Mechanical

- Question 37** Image adapted from: Plbcr. (2007). *ISO metric thread M20*. Retrieved August, 2010, from:  
[http://upload.wikimedia.org/wikipedia/commons/f/f6/ISO\\_metric\\_thread\\_M20.JPG](http://upload.wikimedia.org/wikipedia/commons/f/f6/ISO_metric_thread_M20.JPG)
- Question 39** Photograph adapted from: Gordon Kneale Brooke. (2006). *Drax Power Station Bucket wheel machine*. Retrieved August, 2010, from  
[http://commons.wikimedia.org/wiki/File:Drax\\_Power\\_Station\\_Bucket\\_Wheel\\_Machine\\_-\\_geograph.org.uk\\_-\\_190557.jpg](http://commons.wikimedia.org/wiki/File:Drax_Power_Station_Bucket_Wheel_Machine_-_geograph.org.uk_-_190557.jpg)
- Question 40(a)** Photograph from: Dschwen. (2006). *Zirconium rod*. Retrieved August, 2010, from  
[http://upload.wikimedia.org/wikipedia/commons/d/d3/Zirconium\\_rod.jpg](http://upload.wikimedia.org/wikipedia/commons/d/d3/Zirconium_rod.jpg).  
  
Image adapted from: Rainer. (2007). *Laengsrunddrehe*. Retrieved August, 2010, from  
<http://upload.wikimedia.org/wikipedia/commons/e/e8/Laengsrunddrehen.jpg>.
- Question 40(f)** Image adapted from : Maksim. (2006). *Stress v strain Aluminum*. Retrieved August, 2010, from  
[http://upload.wikimedia.org/wikipedia/commons/0/0c/Stress\\_v\\_strain\\_Aluminum\\_2.png](http://upload.wikimedia.org/wikipedia/commons/0/0c/Stress_v_strain_Aluminum_2.png).
- Question 53** Photograph adapted from: Duncan. (n.d.). *Photovoltaic systems at no cost*. Retrieved August, 2010, from <http://www.ecologiae.com/impianto-fotovoltaico-costo-zero-provincia-gorizia/16485/>.

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