

**Victorian Certificate of Education  
2019**

SUPERVISOR TO ATTACH PROCESSING LABEL HERE

STUDENT NUMBER           Letter

# SYSTEMS ENGINEERING

## Written examination

**Monday 18 November 2019**

**Reading time: 9.00 am to 9.15 am (15 minutes)**

**Writing time: 9.15 am to 10.45 am (1 hour 30 minutes)**

## QUESTION AND ANSWER BOOK

### Structure of book

<i>Section</i>	<i>Number of questions</i>	<i>Number of questions to be answered</i>	<i>Number of marks</i>
A	20	20	20
B	14	14	80
			Total 100

- Students are permitted to bring into the examination room: pens, pencils, highlighters, erasers, sharpeners, rulers and one scientific calculator.
- Students are NOT permitted to bring into the examination room: blank sheets of paper and/or correction fluid/tape.

#### Materials supplied

- Question and answer book of 27 pages
- Detachable insert of miscellaneous formulas in the centrefold
- Answer sheet for multiple-choice questions

#### Instructions

- Write your **student number** in the space provided above on this page.
- Check that your **name** and **student number** as printed on your answer sheet for multiple-choice questions are correct, **and** sign your name in the space provided to verify this.
- Unless otherwise indicated, the diagrams in this book are **not** drawn to scale.
- All written responses must be in English.

#### At the end of the examination

- Place the answer sheet for multiple-choice questions inside the front cover of this book.
- You may keep the detached insert.

**Students are NOT permitted to bring mobile phones and/or any other unauthorised electronic devices into the examination room.**

**SECTION A – Multiple-choice questions****Instructions for Section A**

Answer **all** questions in pencil on the answer sheet provided for multiple-choice questions.

Choose the response that is **correct** or that **best answers** the question.

A correct answer scores 1; an incorrect answer scores 0.

Marks will **not** be deducted for incorrect answers.

No marks will be given if more than one answer is completed for any question.

Unless otherwise indicated, the diagrams in this book are **not** drawn to scale.

**Question 1**

A relay

- A. operates by using a semiconductor.
- B. operates by using a magnetic field.
- C. converts an AC signal to a DC signal.
- D. converts a DC signal to an AC signal.

**Question 2**

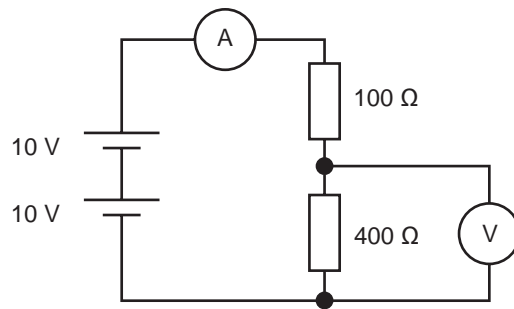
The component represented in the diagram shown above is a

- A. single-pole single-throw switch.
- B. single-pole double-throw switch.
- C. double-pole single-throw switch.
- D. double-pole double-throw switch.

**Question 3**

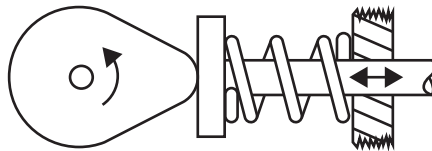
A dynamo converts mechanical energy into electrical energy with the aid of a

- A. commutator.
- B. pair of slip rings.
- C. rotary converter.
- D. semiconductor rectifier.

**Question 4**

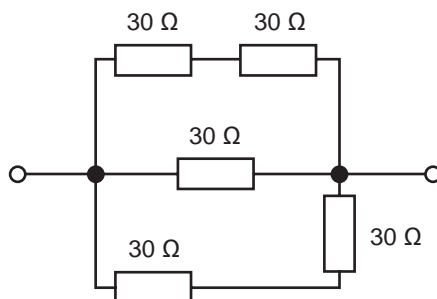
The readings of the voltmeter and the ammeter in the diagram shown above would be respectively

- A. 8 V and 40 mA
- B. 10 V and 20 mA
- C. 10 V and 40 mA
- D. 16 V and 40 mA

**Question 5**

Which one of the following best describes the system in the diagram shown above?

- A. crank and piston
- B. cam and follower
- C. piston and cylinder
- D. crankshaft and piston

**Question 6**

The total resistance of the circuit in the diagram shown above is

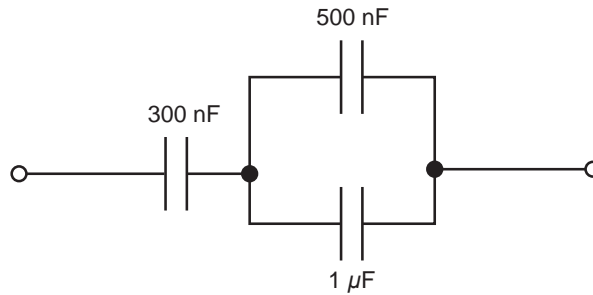
- A. 105 Ω
- B. 45 Ω
- C. 30 Ω
- D. 15 Ω

**Question 7**

An input transducer transforms

- A. an analog signal into a digital signal.
- B. a digital signal into an analog signal.
- C. a physical quantity into an electrical signal.
- D. an electrical signal into a physical quantity.

**Question 8**



The total capacitance of the circuit in the diagram shown above is

- A. 200 nF
- B. 250 nF
- C. 633 nF
- D. 1800 nF

**Question 9**

Which one of the following symbols represents a phototransistor?

- A.
- B.
- C.
- D.

**Question 10**

The four-band colour code for a  $250\ \Omega$  10% resistor is

- A. red, green, brown, silver.
- B. red, green, black, silver.
- C. red, black, brown, gold.
- D. red, green, black, gold.

**Question 11**

What is one common application of a variable capacitor?

- A. optic device
- B. voltage divider
- C. tuning a radio set
- D. changing the volume on a radio set

**Question 12**

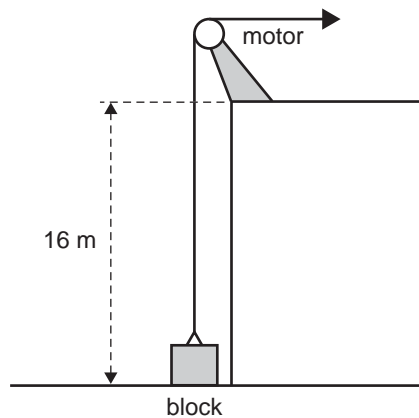
An AC power supply has a peak voltage of 540 V. It supplies a  $100\ \Omega$  resistor.

The average power dissipated by the resistor is closest to

- A. 54 000 W
- B. 45 000 W
- C. 2920 W
- D. 1460 W

**Question 13**

A motor is used to lift a 1200 N concrete block with a cable. The motor lifts the concrete block 16 m vertically, as shown in the diagram below.

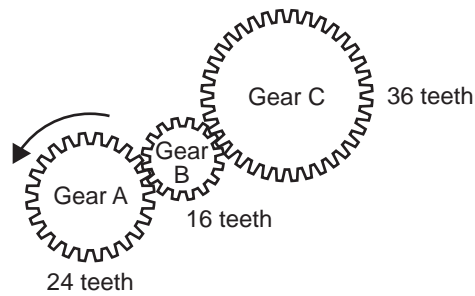


The work done on the concrete block by the attached cable is

- A. 75 J
- B. 75 kJ
- C. 19.2 J
- D. 19.2 kJ

**Question 14**

Gear A is attached to the shaft of a motor and rotates in a counterclockwise direction, as shown in the diagram below.

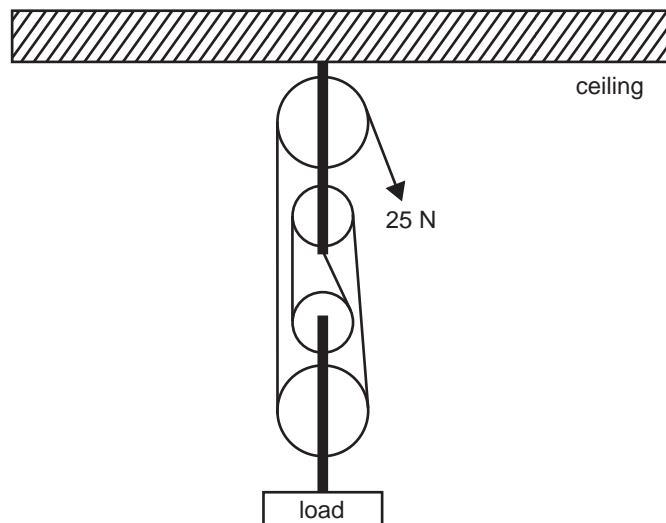


Gear C will rotate

- A. slower than Gear A and in a counterclockwise direction.
- B. faster than Gear A and in a counterclockwise direction.
- C. slower than Gear A and in a clockwise direction.
- D. faster than Gear A and in a clockwise direction.

**Question 15**

An ideal pulley system hanging from a ceiling is shown in the diagram below, with an unknown load attached.

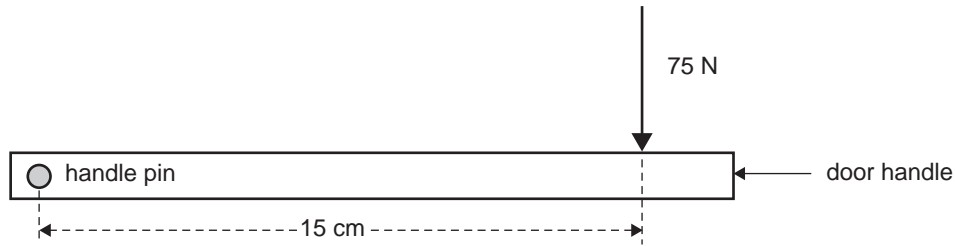


If an effort of 25 N is required just to keep the load stabilised, then the weight of the unknown load would be closest to

- A. 67 N
- B. 80 N
- C. 100 N
- D. 133 N

**Question 16**

A force of 75 N is applied perpendicular to a door handle, as shown in the diagram below.

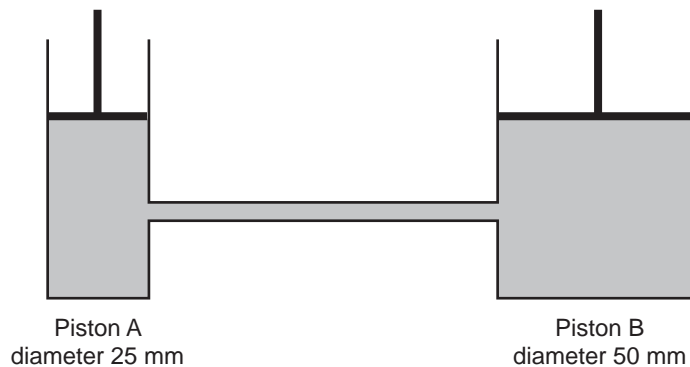


If the applied force is located 15 cm from the handle pin, then the resulting torque will be closest to

- A. 1130 N m
- B. 500 N m
- C. 75.2 N m
- D. 11.3 N m

**Question 17**

The diagram below shows an ideal hydraulic system. Both pistons have a circular cross-section, with Piston A having a diameter of 25 mm and Piston B having a diameter of 50 mm.



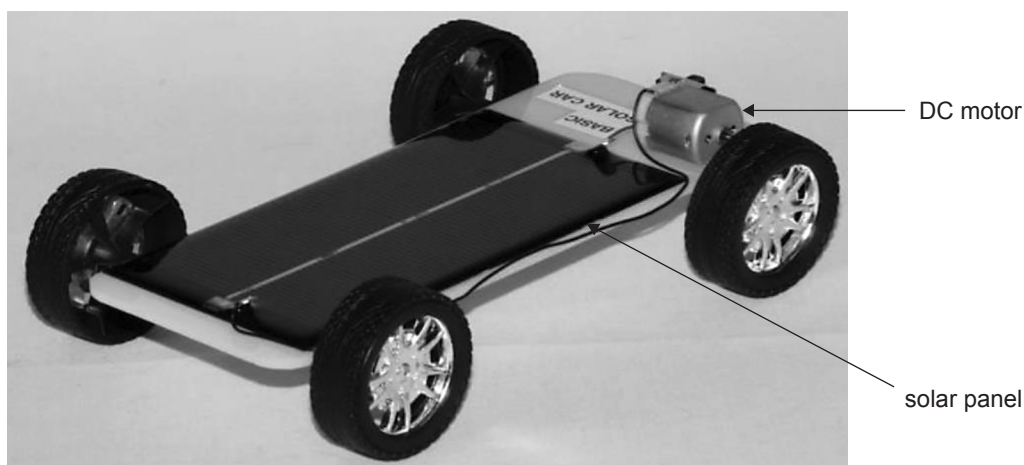
An unknown downward force is applied to Piston A.

How far will Piston B move if Piston A moves a distance of 20 mm?

- A. 2 mm
- B. 5 mm
- C. 10 mm
- D. 25 mm

**Question 18**

A student has constructed a model solar-powered car, as shown in the diagram below, with the solar panel connected to a DC motor. The shaft from the DC motor is connected to one of the rear wheels via a system of gears.



Source: Scorpio Technology, <[www.scorpiontechnology.com.au/](http://www.scorpiontechnology.com.au/)>; reproduced by kind permission of Scorpio Technology

The student tests the solar-powered car by shining a bright light onto the solar panel.

Which one of the following best represents the order of the energy conversions taking place during this test?

- A. light → thermal → mechanical
- B. light → mechanical → thermal
- C. light → mechanical → electrical
- D. light → electrical → mechanical

**Question 19**

A new bus running on biofuel made from coffee grounds is being tested in Melbourne. The bus produces 0.24 J of energy in the form of motion for every joule of energy provided by the biofuel.

The efficiency of the biofuel is closest to

- A. 2.4%
- B. 7.6%
- C. 24%
- D. 76%

**Question 20**

A student has designed an integrated and controlled system. As part of the design stage of the systems engineering process, the student uses an open-source simulation software program.

The **main** benefit provided by the simulation software program is that it allows the student to model the control system in order to

- A. trial and conduct testing of the system prior to construction.
- B. test and analyse the system's performance once the project has been completed.
- C. trial and conduct testing of the system after it has been integrated and produced.
- D. evaluate and report on the system once the system has been produced and processes used.



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**SECTION B**

**Instructions for Section B**

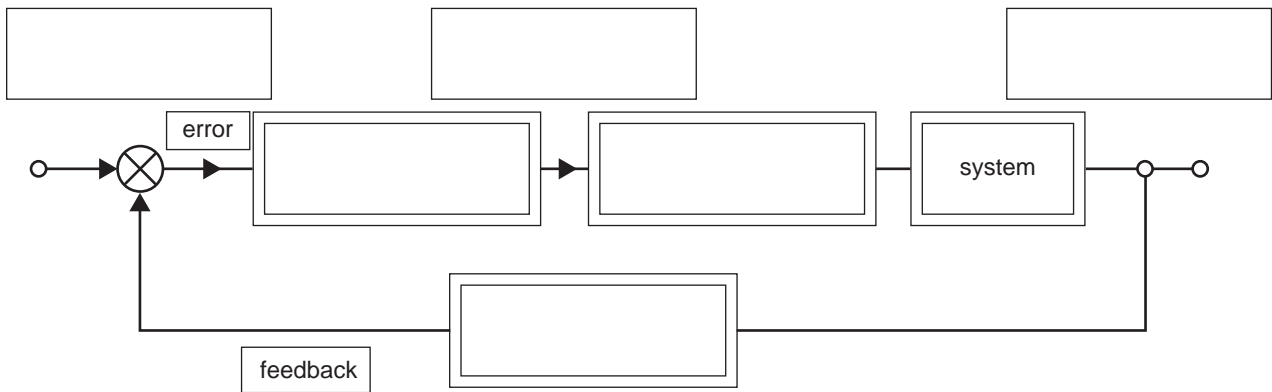
Answer **all** questions in the spaces provided.  
 All calculations must show appropriate formulas and working.  
 Where an answer box is provided, write your final answer in the box.  
 If an answer box has a unit printed in it, give your answer in that unit.  
 Unless otherwise indicated, the diagrams in this book are **not** drawn to scale.

**Question 1** (3 marks)

Figure 1 is an incomplete block diagram for an automated and controlled system.

Complete the block diagram by entering the following terms for the missing components in the spaces provided.

output    input    commands    actuator    decision device    transducer



**Figure 1**

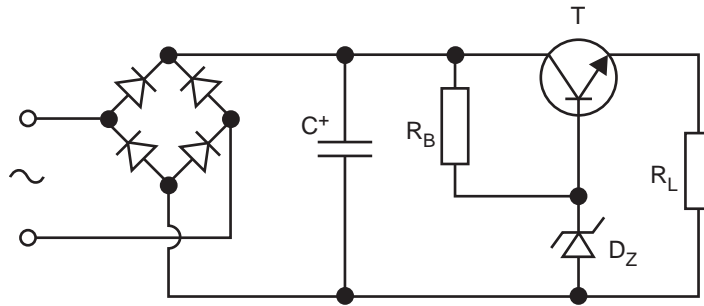
**Question 2** (4 marks)

List the four steps that **must** be taken to control the health and safety risks of a hazard.

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

**Question 3** (3 marks)

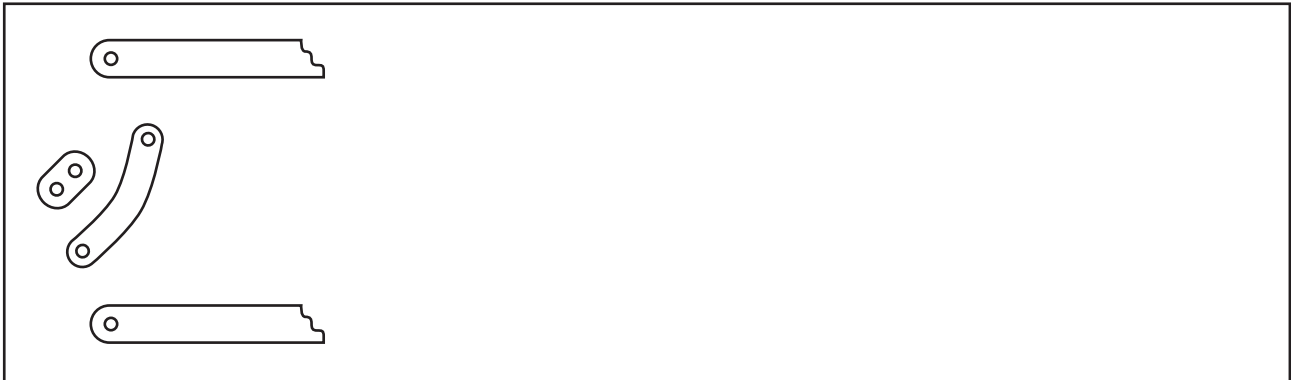
Figure 2 shows a schematic circuit diagram for a small electronic circuit.



**Figure 2**

A partially completed printed circuit board (PCB) for the circuit is shown in Figure 3.

On Figure 3, draw the 11 missing connections that are required to complete the PCB layout.

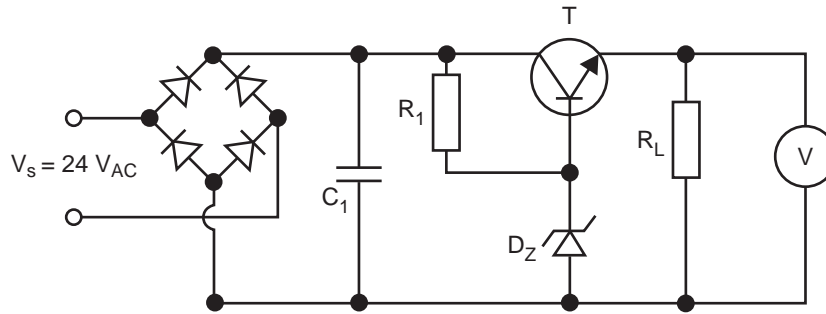


**Figure 3**

**Question 4** (9 marks)

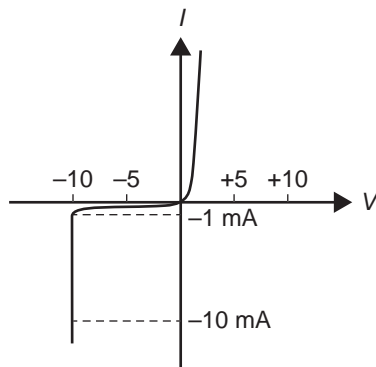
The circuit in Figure 4 was designed using components with the following characteristics:

$V_S = 24 \text{ V}_{AC}$ ,  $C_1 = 100 \mu\text{F} / 5 \text{ V}$ ,  $R_1 = 50 \text{ k}\Omega$ ,  $R_L = 300 \Omega$ .



**Figure 4**

The current–voltage characteristic of the Zener diode  $D_Z$  is represented in Figure 5 below.



**Figure 5**

- a. i. Provide the name/function of the circuit in Figure 4. 1 mark

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- ii. What is the expected reading of the voltmeter V? 1 mark

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- b. The voltage displayed by the voltmeter V was  $5 \text{ V}_{DC}$ .  
Identify the mistake in the design of the circuit that led to that reading. Show your working. 3 marks

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- c.** Explain how the mistake identified in **part b.** can be addressed. Show your working. 2 marks

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- d.** Identify another mistake in the design of the circuit and outline how it can be fixed. 2 marks

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**Question 5** (9 marks)

The owner of a factory wants to reduce the amount of electrical energy that the factory consumes from the grid. The owner decides to install solar panels. The total power consumed by the factory is 10 000 W for an average of seven hours a day. After researching the solar panel market, the owner decides to choose between two brands of solar panels: Brand A and Brand B. Some of the characteristics of the solar panels being considered are given below.

	<b>Brand A</b>	<b>Brand B</b>
<b>V<sub>output</sub></b> <b>I<sub>output</sub></b>	V <sub>output</sub> = 24 V I <sub>output</sub> = 1 A	V <sub>output</sub> = 36 V I <sub>output</sub> = 0.5 A
<b>Efficiency</b>	90%	95%
<b>Cost per panel</b>	\$200	\$175

- a. Identify which brand of solar panel – Brand A or Brand B – would be the more economical choice. Show your working. 2 marks

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- b. Solar panels produce electricity for an average of nine hours a day at their nominal power. For the brand of solar panel identified in **part a.**, calculate how many solar panels the factory will need to cover 40% of its energy consumption. Show your working. 2 marks

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- c. i. What other subsystem has to be introduced into the solar panel system to supply the 240 V<sub>AC</sub> needed to power the factory's machines? 1 mark

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- ii. What is the power of the subsystem identified in **part c.i.**? 1 mark

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kW
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- d.** Identify an optional subsystem that could be included in the solar panel system to improve the efficiency of the system. 1 mark

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- e.** How could the energy produced by the solar panel system be used even when the factory's machines are not operating? Give **two** possible options. 2 marks

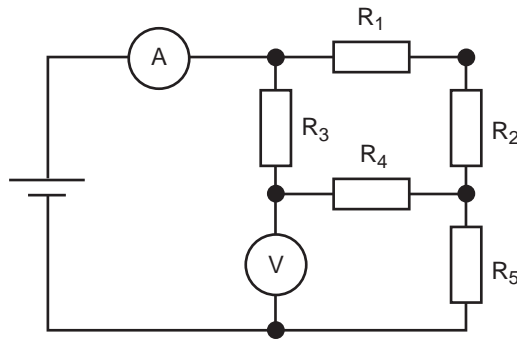
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**Question 6** (7 marks)

The circuit in Figure 6 is supplied with  $30\text{ V}_{\text{DC}}$ . The circuit consists of five identical  $20\ \Omega$  resistors. The current and the voltage in different sections of the circuit are measured with an ammeter and a voltmeter, as shown in Figure 6.



**Figure 6**

- a. Calculate the total resistance of the circuit. Show your working. 2 marks

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$\Omega$
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- b. Calculate the current displayed by the ammeter and the voltage displayed by the voltmeter. Show your working. 2 marks

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Ammeter	A	Voltmeter	V
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- c. Calculate the power dissipated by the resistor  $R_2$ . Show your working. 2 marks

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$\text{W}$
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d. Calculate the total power supplied to the circuit.

1 mark

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W
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**Question 7** (7 marks)

A student has designed and developed an electric hybrid bicycle that features a 14.8 V, 200 W brushless DC electric motor powered by a 14.8 V lithium-ion battery.

- a. At what stage of the systems engineering process would the student identify the constraints for their project? 1 mark

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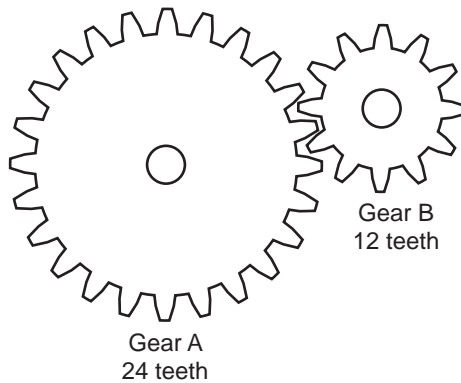
- b. Why would the student have chosen to use a brushless DC electric motor rather than a brushed DC electric motor? 2 marks

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- c. A simple system of gears is used to drive the rear wheel of the bicycle, as shown in Figure 7. Gear A is attached to the motor's shaft and has a maximum of 1000 revolutions per minute (rpm).



**Figure 7**

- What is the maximum rpm of Gear B? 1 mark

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- d.** The 14.8 V lithium-ion battery is rated at 10 Ah.

Calculate how far the electric hybrid bicycle will travel on level ground if a constant speed of 8 km/h is maintained under battery power only. Show your working.

3 marks

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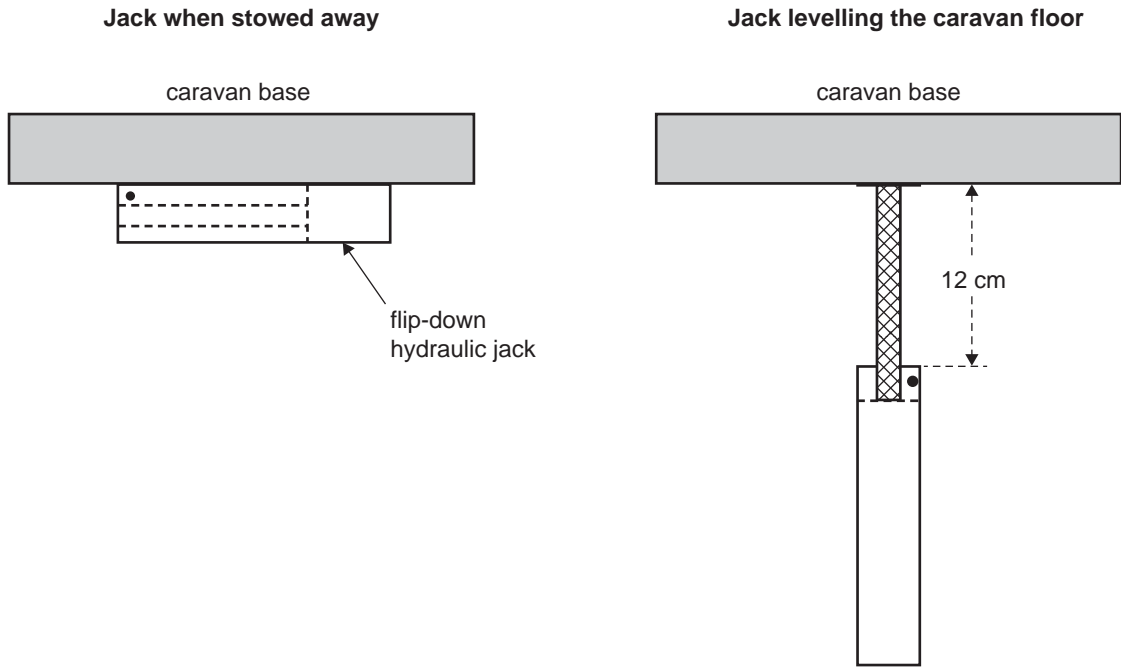
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km
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**Question 8** (5 marks)

A couple has purchased a caravan for the purpose of travelling around the country. To improve their living space, the couple modifies the caravan by adding a hydraulic levelling system. This system consists of four flip-down hydraulic jacks, one at each corner of the caravan. Figure 8 shows the jack when stowed away and when used to level the floor of the caravan.



**Figure 8**

Each jack can raise the floor of the caravan by up to 12 cm and has a maximum rated capacity of 3000 N.

- a. If it takes 20 s to raise the caravan floor by 12 cm, calculate the maximum power required by each hydraulic jack. Assume that each jack is 100% efficient. Show your working. Use the following formulas. 2 marks

$$\text{work done} = \text{force} \times \text{distance} \qquad \text{power} = \frac{\text{work done}}{\text{time}}$$

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W
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- b. The diameter of each hydraulic jack's cylinder piston is 30 mm.

What is the oil pressure in the cylinder at the maximum rated capacity? Show your working. 3 marks

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MPa

**Question 9** (3 marks)

A pulley system with a mechanical advantage of 4.0 requires a force of 15 N to lift a load of 50 N.

Calculate the efficiency of this pulley system. Show your working.

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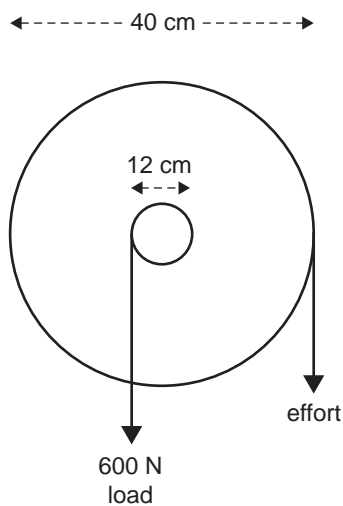


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**Question 10** (4 marks)

A wheel and axle system has been set up to lift a 600 N load, as shown in Figure 9.



**Figure 9**

- a. On Figure 9, clearly label the wheel and the axle. 2 marks
- b. Determine the mechanical advantage of this system. Show your working. 2 marks

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**Question 11** (5 marks)

A town council is considering two options for the generation of electricity to service the community:

- Option 1 – A small-scale wind farm consisting of 12 wind turbines
  - Option 2 – Accessing a geothermal energy source nearby
- a. The wind turbines on the wind farm in Option 1 would supply the community with 19 MW of electricity.

Identify **two** potential environmental impacts that would have to be considered if Option 1 were selected.

2 marks

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- b. Explain how the geothermal energy in Option 2 could be harnessed.

2 marks

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- c. Ignoring environmental impacts, why could geothermal energy be considered a better option than wind power?

1 mark

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**Question 12** (7 marks)

For his integrated and controlled systems project, Ethan has designed and built an automated hatch door for a chicken incubator.

Two of the subsystems used in this project are:

1. a simple mechanical pulley mechanism
2. an electronic subsystem to control the pulley mechanism, featuring a purpose-built PCB.

Ethan is currently testing the functionality of these two subsystems.

- a.** Identify a suitable diagnostic testing instrument that Ethan could use for the purpose of fault-finding in the electronic subsystem. 1 mark

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- b.** How will the instrument identified in **part a.** allow Ethan to check for faults in the electronic subsystem? 2 marks

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- c.** Identify two potential issues that need to be considered as part of testing the mechanical pulley mechanism and describe how each issue could be addressed. 4 marks

Issue 1 \_\_\_\_\_

Description \_\_\_\_\_

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Issue 2 \_\_\_\_\_

Description \_\_\_\_\_

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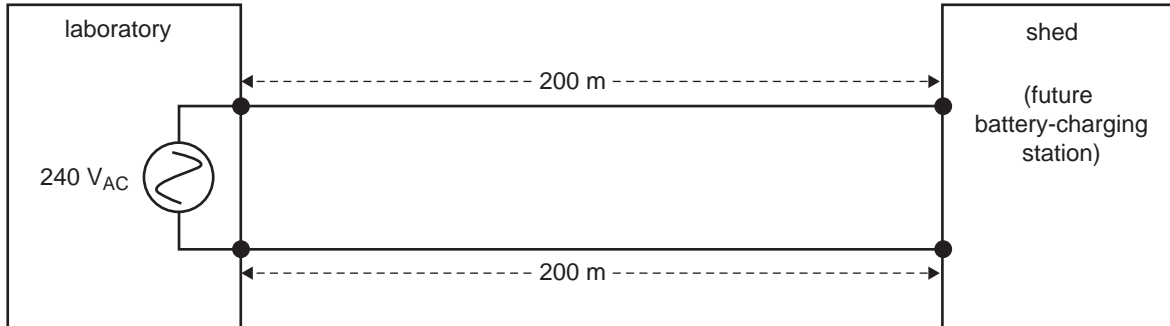


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**Question 13** (9 marks)

A group of students is building a charging station for an electric car. The students want to connect a  $240\text{ V}_{AC}$  power source in their school laboratory to a shed (future battery-charging station) located on the opposite side of the school, using a long extension cord.

The initial design of the system is shown in Figure 10.



**Figure 10**

- a. Identify **one** electrical safety issue with the arrangement of the transmission line shown in the initial design in Figure 10. Give your reasoning. 2 marks

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- b. Suggest a workable solution for the electrical safety issue identified in **part a**. 2 marks

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- c. The students have purchased an extension cord with an electrical resistance of  $0.08\ \Omega/\text{m}$ . They measure the required length of the extension cord. The total minimum length required is 400 m.

Calculate the minimum total resistance of the wire in the extension cord.

1 mark

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$\Omega$
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- d. The batteries to be charged by the future battery-charging station have a nominal voltage of 12 V.

Identify the additional circuit required for the system to be able to charge the batteries. Give your reasoning.

2 marks

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- e. The students discover that there is insufficient power supplied to the shed to charge the batteries.

One of the students suggests replacing the existing wire in the transmission line with a better-quality wire.

What characteristic of the wire will improve the efficiency of the transmission of electricity to the shed? Give your reasoning.

2 marks

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**Question 14** (5 marks)

A manufacturing business has implemented additional automation processes in its production line. The introduction of this new technology can have both positive and negative impacts.

Discuss the possible impacts of introducing additional automation processes in a manufacturing business, giving examples to support your response.

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# **SYSTEMS ENGINEERING**

## **Written examination**

### **FORMULA SHEET**

#### **Instructions**

Please remove from the centre of this book during reading time.  
This formula sheet is provided for your reference.

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## Systems Engineering formulas

gear ratio final = gear ratio 1 $\times$ gear ratio 2	efficiency = $\frac{\text{output energy}}{\text{input energy}} \times 100\%$		
gear ratio = $\frac{\text{number of teeth on driven gear}}{\text{number of teeth on driver gear}}$	efficiency <sub>Total</sub> = efficiency <sub>1</sub> $\times$ efficiency <sub>2</sub>		
$\frac{\text{gear A rpm}}{\text{gear B rpm}} = \frac{\text{number of teeth gear B}}{\text{number of teeth gear A}}$	mechanical advantage = $\frac{\text{load}}{\text{effort}}$		
$\frac{\text{pulley A rpm}}{\text{pulley B rpm}} = \frac{\text{radius of pulley B}}{\text{radius of pulley A}}$	force = pressure $\times$ area		
voltage = current $\times$ resistance	torque = force $\times$ distance		
power = voltage $\times$ current	frequency = $\frac{1}{\text{period}}$		
area of circle = $\pi r^2$ ( $\pi = 3.14$ )	speed = $\frac{\text{distance}}{\text{time}}$		
circumference of circle = $2\pi r$			
resistors in series	$R_t = R_1 + R_2 + R_3 + \dots$	capacitors in series	$\frac{1}{C_t} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} \dots$
resistors in parallel	$\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \dots$	capacitors in parallel	$C_t = C_1 + C_2 + C_3 + \dots$
two resistors in parallel	$R_t = \frac{R_1 \times R_2}{R_1 + R_2}$		

### Colour codes

Colour	Value	Colour	Value
black	0	blue	6
brown	1	violet	7
red	2	grey	8
orange	3	white	9
yellow	4	gold	5%
green	5	silver	10%