

STUDENT NUMBER Letter

SYSTEMS ENGINEERING

Written examination

Monday 14 November 2022

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	15	15	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.

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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.

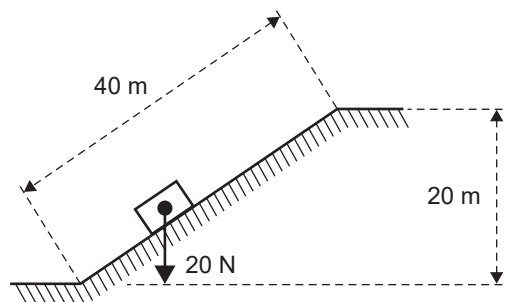
Marks will **not** be deducted for incorrect answers.

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

The diagram below shows a box on an inclined plane.

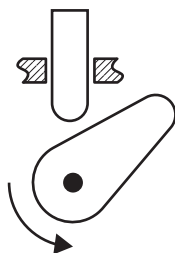


The mechanical advantage of the inclined plane is

- A. 0.5
- B. 2
- C. 400
- D. 800

Question 2

The diagram below shows a cam and follower mechanism.



The cam in the mechanism is

- A. radial.
- B. a wedge.
- C. spherical.
- D. cylindrical.

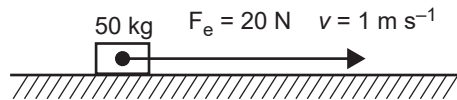
Question 3

Which one of the following energy sources is renewable?

- A. coal
- B. solar
- C. petrol
- D. natural gas

Question 4

The 50 kg load in the diagram below moves with a constant speed of 1 m s^{-1} .



The friction between the load and the ground is

- A. 0 N
- B. 20 N
- C. 50 N
- D. 500 N

Question 5

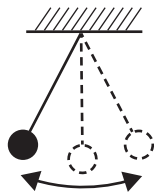
A tool using a 20 W electrical motor delivers 800 J of mechanical work in 50 s.

The efficiency of the energy conversion is

- A. 16%
- B. 40%
- C. 60%
- D. 80%

Question 6

The diagram below shows a moving object.

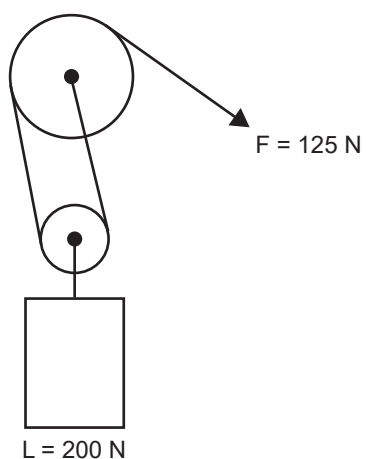


The motion of the object is

- A. linear.
- B. rotary.
- C. circular.
- D. oscillating.

Question 7

The diagram below shows a non-ideal pulley system.



Based on the information in the diagram, what is the mechanical advantage of the pulley system?

- A. 0.625
- B. 1.6
- C. 2
- D. 4

Question 8

The diagram below shows a gear system.



Source: Borshch Filipp/Shutterstock.com

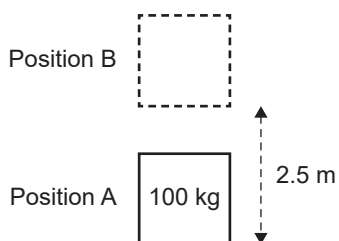
The part indicated by the arrow is called a

- A. bevel.
- B. worm.
- C. pinion.
- D. crown wheel.

Question 9

Which one of the following best represents the useful energy conversions that take place in a loudspeaker?

- A. kinetic \rightarrow kinetic \rightarrow sound
- B. electrical \rightarrow kinetic \rightarrow sound
- C. sound \rightarrow electrical \rightarrow kinetic
- D. chemical \rightarrow kinetic \rightarrow electrical

Question 10

Using the information in the diagram above, what is the work done to lift the 100 kg box from Position A to Position B? Use $g = 10 \text{ m s}^{-2}$.

- A. 25 J
- B. 250 J
- C. 1000 J
- D. 2500 J

Question 11

Cradle-to-cradle design is becoming more relevant in society.

One of the advantages of a cradle-to-cradle design is that it

- A. reduces exploration of different concepts.
- B. allows for the use of resources only once and for a limited time.
- C. is a limited exploration of different concepts, processes or materials.
- D. allows for the re-use of components and the recycling of the materials used.

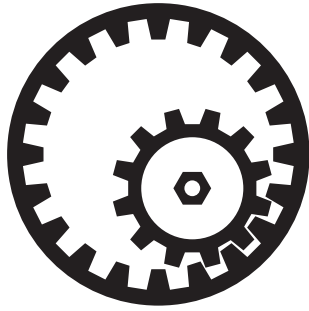
Question 12

Which one of the following must be worn when soldering to ensure safe work practices are followed?

- A. helmet
- B. leather gloves
- C. protective glasses
- D. steel-capped boots

Question 13

The diagram below shows an internal spur gear.

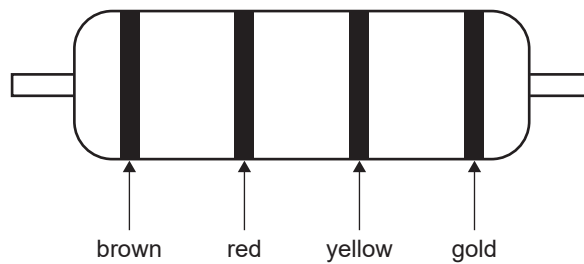


An internal spur gear is useful in a system in which

- A. using a large amount of space is acceptable.
- B. the input and output shafts rotate in the same direction.
- C. the input and output shafts rotate in opposite directions.
- D. the gears have teeth cut on the outside surface of the mating cylindrical wheels.

Question 14

The diagram below shows a resistor.

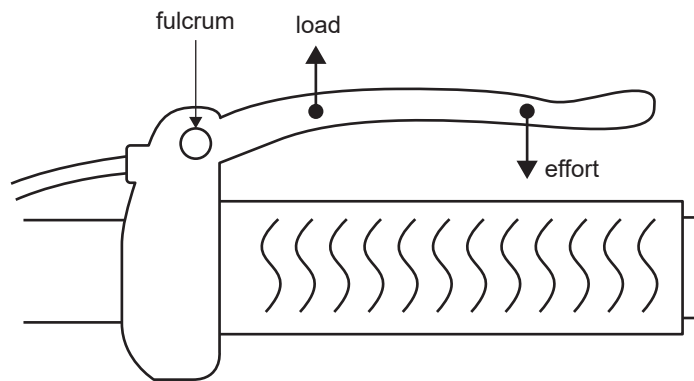


Which one of the following values would be considered to be within the tolerance of the resistor?

- A. 120 Ω
- B. 1.2 k Ω
- C. 115 k Ω
- D. 130 k Ω

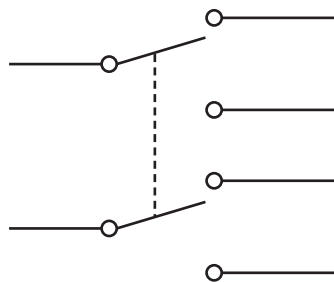
Question 15

The diagram below shows a lever often used on a bicycle handle.



The application of the lever in this simple machine will

- A. multiply force.
- B. multiply speed.
- C. reduce mechanical advantage.
- D. multiply both force and speed.

Question 16

The symbol above represents a

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

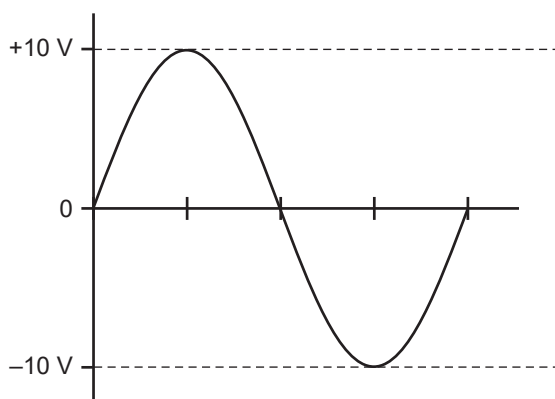
Question 17

In a magnetic induction (moving coil) microphone, sound moves a cone attached to a magnet inside a coil. Which one of the following gives the correct order of the useful energy conversions that occur when this microphone is used as an input transducer?

- A. sound → electrical → elastic → magnetic
- B. electrical → magnetic → elastic → kinetic
- C. sound → magnetic → elastic → electrical
- D. sound → magnetic → thermal → electrical

Question 18

When tested using an oscilloscope, a signal generator produces the following graph.

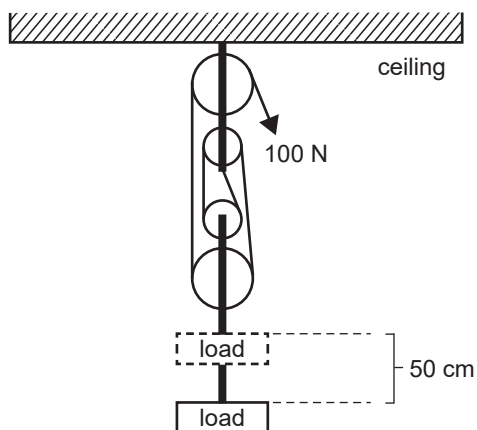


If the same signal generator is tested using an analogue voltmeter, which one of the following settings could be used on the voltmeter?

- A. 5 V DC
- B. 5 V AC
- C. 15 V DC
- D. 15 V AC

Question 19

A pulley system is arranged as shown in the diagram below. All mechanical elements are ideal.



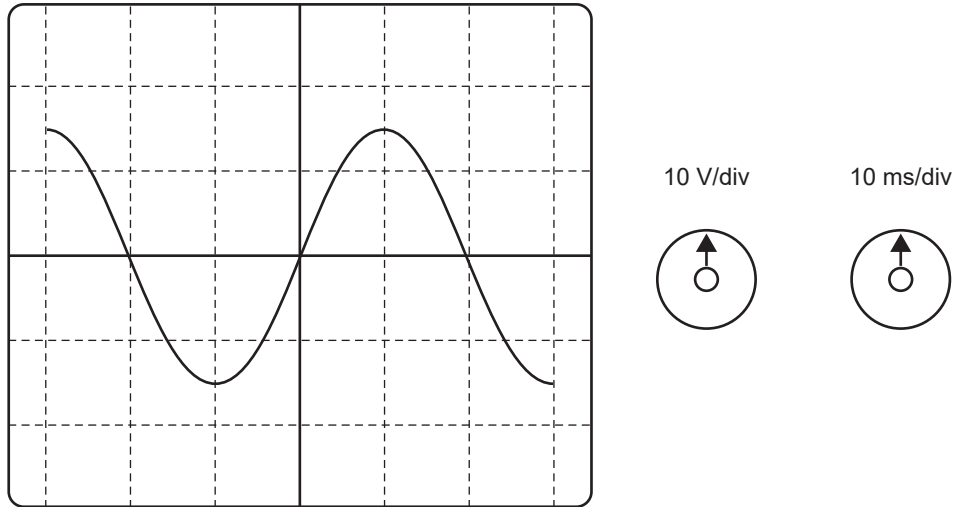
A constant force of 100 N is applied as shown above, raising the load 50 cm in 25 s.

The mechanical power of the system is closest to

- A. 2 W
- B. 8 W
- C. 0.2 kW
- D. 1.25 kW

Question 20

The diagram below shows a signal on an oscilloscope and some of the controls on the oscilloscope. The controls have been set to 10 V/div and 10 ms/div.



The frequency of this signal is

- A. 25 Hz
- B. 200 Hz
- C. 500 Hz
- D. 2000 Hz

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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.

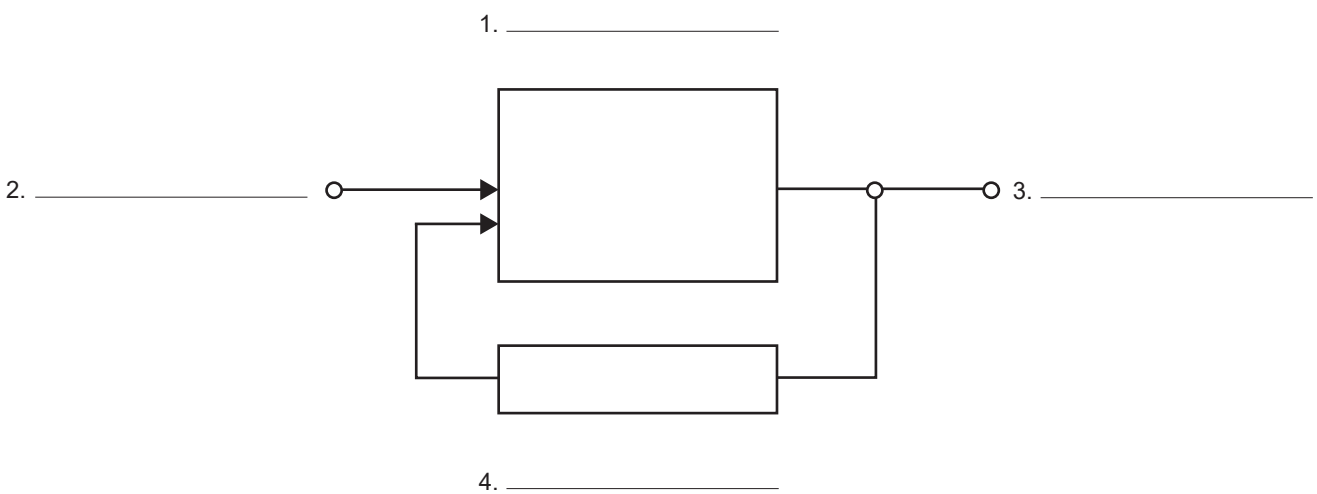
Where an answer box is provided, write your final answer in the box.

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 (4 marks)

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

**Figure 1**

Using the list of terms below, complete the block diagram by writing the correct term on each of the lines numbered 1 to 4.

transducer output input controlled process

Question 2 (7 marks)

Figure 2 shows a small electrical circuit.

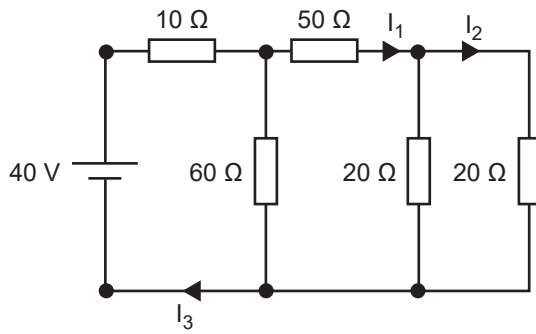


Figure 2

- a. Calculate the total resistance of the circuit. Show your working. 4 marks

Ω

- b. Calculate the currents I_1 , I_2 and I_3 . Show your working. 3 marks

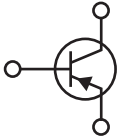
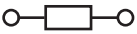




I_1 A

I_2 A

I_3 A

Question 3 (3 marks)

Write the name of each component shown in the table below.

Component	Name
	
	
	
	
	
	

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Question 4 (6 marks)

Figure 3 shows a small electrical circuit. After a period of time, one of the components in the circuit becomes faulty.

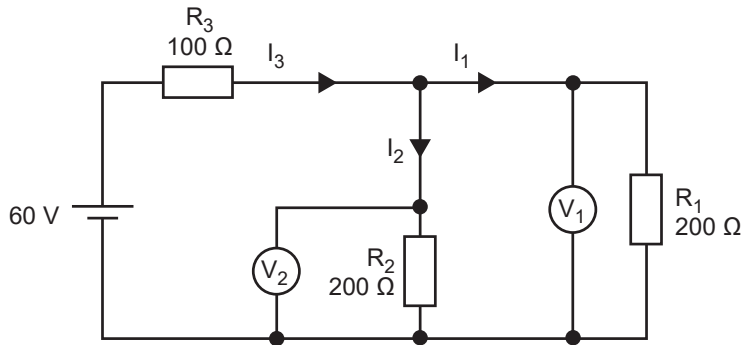


Figure 3

The currents in the circuit have the following values:

- $I_3 = 200 \text{ mA}$
- $I_2 = 200 \text{ mA}$
- $I_1 = 0 \text{ A}$

a. Determine the total current of the faulty circuit.

1 mark

mA

b. Calculate the power supplied by the battery. Show your working.

2 marks

W

c. Identify the fault that caused the current I_1 to have a value of 0 A.

1 mark

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- d. Calculate the voltages measured by the voltmeters V_1 and V_2 in the faulty circuit. Show your working.

2 marks

V_1 V

V_2 V

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Question 5 (5 marks)

Figure 4 shows a cylinder containing air at atmospheric pressure.

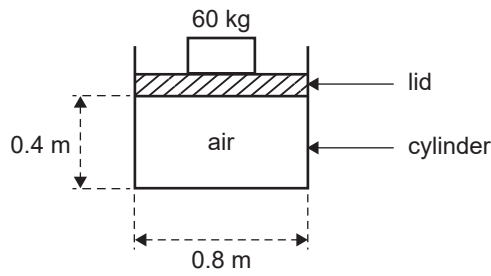


Figure 4

The lid is made of light material with negligible mass. A 60 kg object is placed on the lid. The air within the cylinder is compressed as the lid moves down.

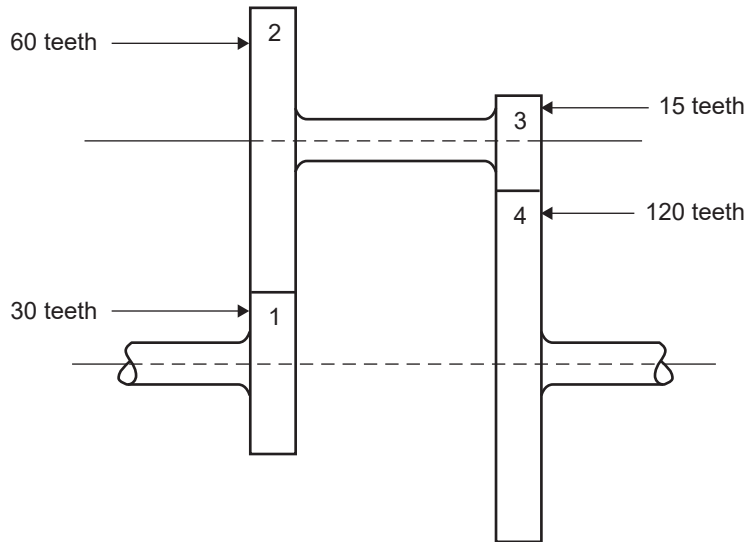
- a. Calculate the pressure produced by the 60 kg object. Use $g = 10 \text{ m s}^{-2}$ and include units in your answer. Show your working. 4 marks

- b. State the condition under which the compression of the air will stop. 1 mark

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Question 6 (6 marks)

Figure 5 shows a gearbox used to drive a small lathe. The gears are numbered 1 to 4 and the number of teeth on each gear is shown. The input to the gearbox is connected to gear 1.

**Figure 5**

- a. Calculate the total gear ratio for the gearbox. Show your working. 4 marks

Total gear ratio

- b. State the mechanical advantage of this gearbox. 1 mark

- c. State whether the gearbox increases the torque or the speed of the output. 1 mark

Question 7 (6 marks)

Throughout history, water has been our most-used renewable energy source. The sites on which hydro-electric power plants are built require certain features.

- a. State **two** important physical and/or environmental features of a suitable site to build a hydro-electric power plant. 2 marks

- b. Discuss the advantages and disadvantages of hydro-electricity. 4 marks

Question 8 (4 marks)

A group of students was asked to build the electronic circuit shown in Figure 6.

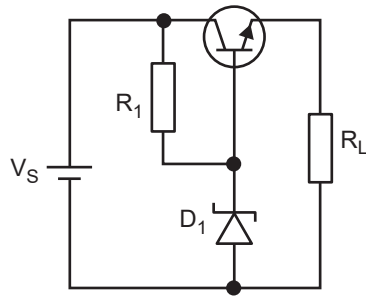


Figure 6

The specifications for the components to be used in the circuit are as follows:

- $V_S = 20\text{ V}$
- $R_1 = 150\ \Omega, 2\text{ W}$
- $R_L = 200\ \Omega, 2\text{ W}$
- $D_1 = 5\text{ V Zener diode}$

When collecting the required components, the students noticed that there were no $150\ \Omega, 2\text{ W}$ resistors or 5 V Zener diodes available. Instead, they used a $150\ \Omega, 1\text{ W}$ resistor as R_1 and a standard diode as the Zener diode. They connected the cathode of the standard diode to the negative terminal of the power supply, V_S .

Explain what effect, if any, the replacement of the $150\ \Omega, 2\text{ W}$ resistor and 5 V Zener diode will have on each of the following.

- The functioning of the circuit _____

- The voltage across the resistor R_L _____

Question 9 (5 marks)

Biomass energy is an important form of renewable energy.

- a. List the three main forms of energy in the production and use of biomass. 3 marks

- b. What are the two main effects of the process of photosynthesis that have the biggest impact on the environment? 2 marks

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Question 10 (2 marks)

Workshop safety is everyone's responsibility. In a workshop, a student intends to cut a square shape from a piece of metal. The student starts by assessing the hazards of the cutting process.

Identify one possible hazard of this cutting process and provide an appropriate control measure for that hazard.

Hazard	Control measure

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Question 11 (4 marks)

The systems engineering process represents the stages in creating a system. One stage in the systems engineering process is to ‘identify and document the problem, need, opportunity or situation’.

- a. Describe what is documented in this stage of the process. 2 marks

- b. Describe how the ‘evaluate and report on the system produced and processes used’ stage of the systems engineering process is related to the ‘identify and document the problem, need, opportunity or situation’ stage of the systems engineering process. 2 marks

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Question 12 (5 marks)

Figure 7 shows a circuit diagram for a light-sensitive electronic circuit.

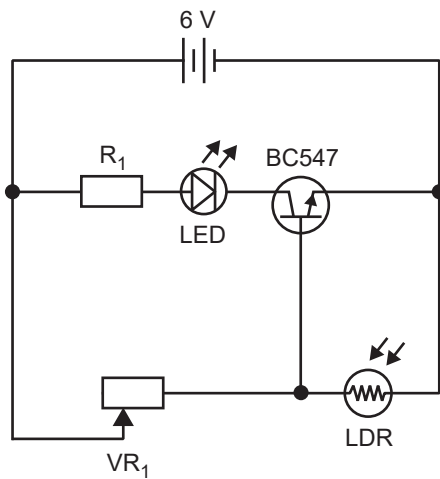


Figure 7

Figure 8 shows a partially completed printed circuit board (PCB) for the light-sensitive electronic circuit.

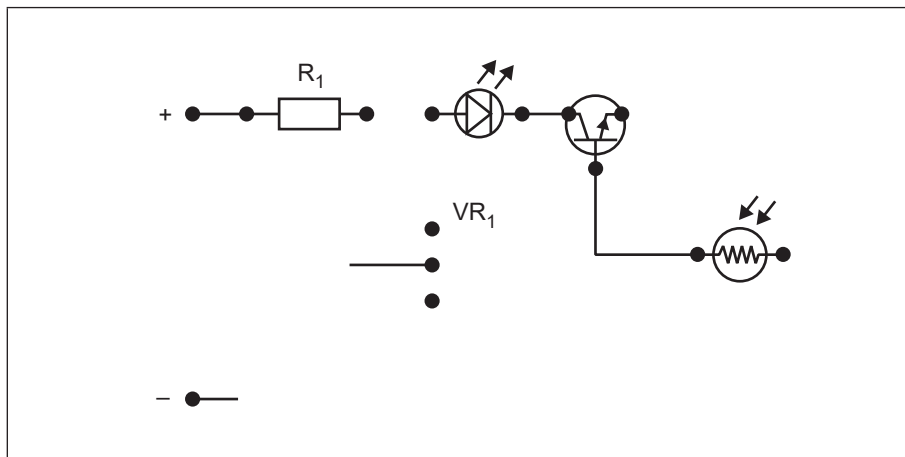
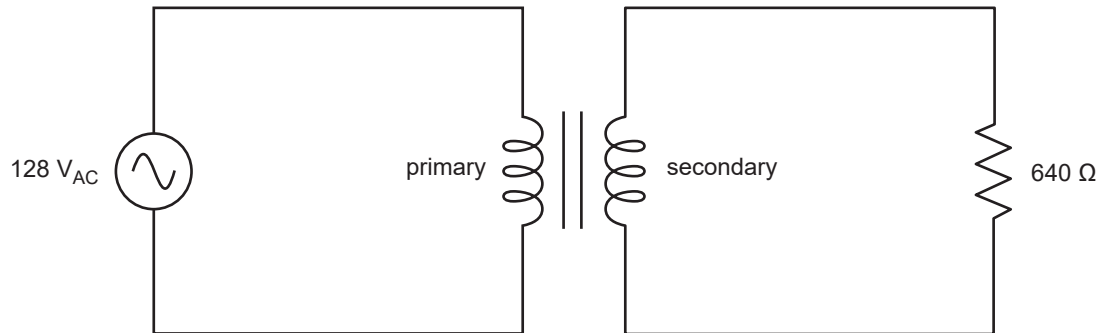


Figure 8

On Figure 8, draw the missing tracks and connections required to complete the PCB.

Question 13 (8 marks)

Figure 9 shows a schematic of an ideal transformer used to deliver 410 W to a $640\ \Omega$ resistor. The transformer has 400 windings in the secondary coil and the input of the transformer is $128\ V_{AC}$.

**Figure 9**

- a. Calculate the current in the secondary coil of the transformer. Show your working and include a unit in your answer. 4 marks

- b. Calculate the voltage of the secondary coil of the transformer. Show your working and include a unit in your answer. 2 marks

- c. Calculate the number of windings in the primary coil. Show your working. 2 marks

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Question 14 (9 marks)

Energy storage is a key requirement in optimising the use of renewable energy to meet energy demands. Energy can be stored in many forms, including mechanical, electrical and thermal.

- a. Identify a technology for the storage of mechanical energy. Explain how this energy may be stored and released for use. 3 marks

- b. Identify a technology for the storage of electrical energy. Explain how this energy may be stored and released for use. 3 marks

- c. Identify a technology for the storage of thermal energy. Explain how this energy may be stored and released for use. 3 marks

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Question 15 (6 marks)

A community organisation works with people with disability, connecting them with engineers, industrial designers and health professionals. Together, they design and build products that respond to the complex needs of individuals to improve their everyday lives.

An opportunity has emerged to develop a robotic arm for a person with limited arm mobility. The robotic arm is designed to be anchored to a wheelchair and would be used to move cutlery, dishes and glasses from a kitchen table to a dishwasher. The integrated and controlled system must be able to handle fragile items safely.

Modelling employs a range of activities to respond to design briefs. These include prototyping, virtual modelling, simulations, calculations and scale modelling.

For each of the following, state two different types of modelling activities and describe the benefit of each.

- The mechanical aspect of the integrated and controlled system

1. Type _____

Benefit _____

2. Type _____

Benefit _____

- The electrotechnological aspect of the integrated and controlled system

1. Type _____

Benefit _____

2. Type _____

Benefit _____

- The general performance of the integrated and controlled system

1. Type _____

Benefit _____

2. Type _____

Benefit _____

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.

Systems Engineering formulas

Mechanical

$\text{efficiency} = \frac{\text{useful energy output}}{\text{total energy input}} \times 100\%$	$\text{efficiency}_{\text{total}} = \text{efficiency}_1 \times \text{efficiency}_2$
$F = ma$	force due to gravity = mass \times acceleration due to gravity
$P = \frac{W}{t}$	work done = force in direction moved \times distance
torque = twisting force \times perpendicular distance to pivot point	moment = force \times perpendicular distance to pivot point
$F_1 d_1 = F_2 d_2$	$P = \frac{F}{A}$
speed = $\frac{\text{distance}}{\text{time}}$	mechanical advantage = $\frac{\text{load}}{\text{effort}}$
gear ratio final = gear ratio 1 \times gear ratio 2	gear or pulley ratio = $\frac{\text{speed of driver (rpm)}}{\text{speed of driven (rpm)}}$
$\frac{\text{Gear A rpm}}{\text{Gear B rpm}} = \frac{\text{Gear B number of teeth}}{\text{Gear A number of teeth}}$	$\frac{\text{Pulley A rpm}}{\text{Pulley B rpm}} = \frac{\text{diameter of Pulley B}}{\text{diameter of Pulley A}}$
velocity ratio = $\frac{\text{distance moved by effort}}{\text{distance moved by load}}$	

Electrical

electrical energy efficiency $= \frac{\text{useful energy output}}{\text{total energy input}} \times 100\%$	$I = \frac{V}{R}$		
$P = VI$	$P = \frac{E}{t}$		
$f = \frac{1}{T}$	$V_x = \frac{R_x}{R_{\text{total}}} \times V_{\text{supply}}$		
$\frac{N_1}{N_2} = \frac{V_1}{V_2} = \frac{I_2}{I_1}$	$V_{\text{peak}} = \sqrt{2} V_{\text{RMS}}$		
resistors in series	$R_t = R_1 + R_2 + R_3 + \dots$	resistors in parallel	$\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots$
two resistors in parallel	$R_t = \frac{R_1 \times R_2}{R_1 + R_2}$	capacitors in series	$\frac{1}{C_t} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \dots$
capacitors in parallel	$C_t = C_1 + C_2 + C_3 + \dots$		

General

area of circle = πr^2 ($\pi = 3.14$)
circumference of circle = $2\pi r$

Resistor colour codes

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