VICTORIAN CURRICULUM AND ASSESSMENT AUTHORITY

Victorian Certificate of Education 2023

SUPERVISOR TO ATTACH PROCESSING LABEL HERE

STUDENT NUMBER | | | | | | | | | | Letter |

SYSTEMS ENGINEERING

Written examination

Tuesday 14 November 2023

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

Section	*Number of questions*	*Number of questions to be answered*	*Number of marks*
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 29 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.

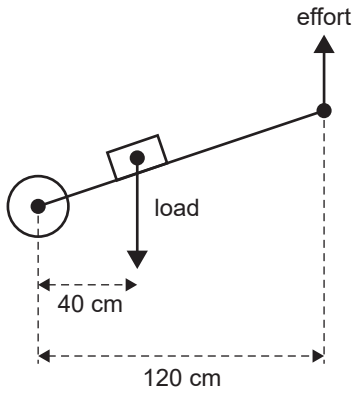
Students are NOT permitted to bring mobile phones and/or any other unauthorised electronic devices into the examination room.

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.

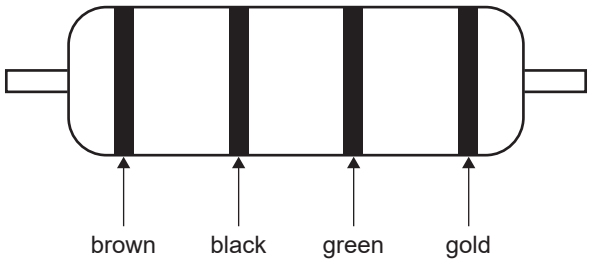
Question 1



The effort required to hold a 24 kg load in the wheelbarrow represented above is (g = 10 m s^{-2})

A. 24 N
B. 80 N
C. 120 N
D. 240 N

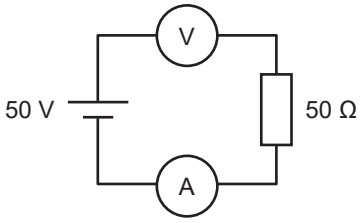
Question 2



The resistance and tolerance of the resistor in the figure above is

A. 105 Ω, 5%
B. 105 Ω, 10%
C. 1 MΩ, 5%
D. 1 MΩ, 10%

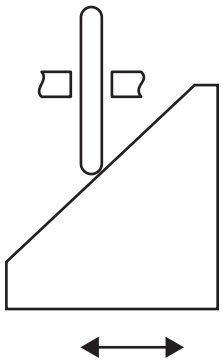
Question 3



The voltage displayed by the voltmeter V and the current displayed by the ammeter A in the figure above are

A. 0 V, 0 A
B. 0 V, 1 A
C. 50 V, 0 A
D. 50 V, 1 A

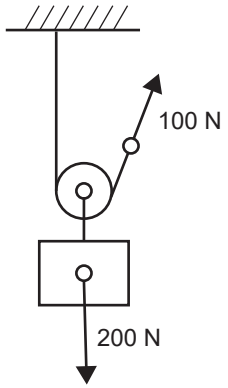
Question 4



The cam in the cam and follower mechanism above is a

A. radial cam.
B. wedge cam.
C. spherical cam.
D. cylindrical cam.

Question 5



The mechanical advantage of the pulley above is

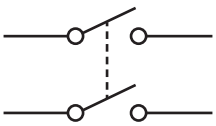
A. 2
B. 4
C. 100
D. 200

Question 6

Which one of the following is the most important personal protection item to be worn while arc welding?

A. earmuffs
B. earplugs
C. face shield
D. rubber boots

Question 7



The device shown above is best described as

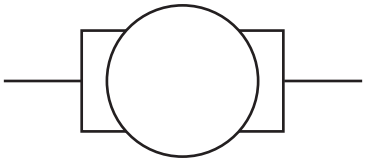
A. an open single-pole single-throw switch.
B. an open double-pole single-throw switch.
C. a closed single-pole double-throw switch.
D. a closed double-pole double-throw switch.

Question 8

What is the effect of friction on a load sliding down an inclined plane?

A. There is no effect.
B. Friction slows down or stops the load.
C. The sliding speed of the load will increase.
D. Friction will cause the load to move up the inclined plane.

Question 9



The device shown in the diagram above is

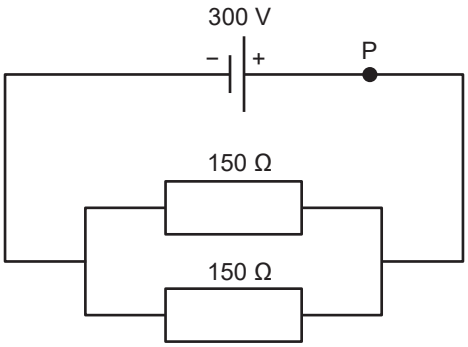
A. a relay.

B. a Zener diode.

C. a phototransistor.

D. an electrical motor.

Question 10



The circuit above is made up of two resistors of resistance 150 Ω each and a battery that provides a voltage of 300 V.

What is the current at point P in the circuit?

A. 2 A

B. 3 A

C. 4 A

D. 8 A

Question 11

Which one of the following is an example of a renewable source of energy?

A. wind

B. petrol

C. natural gas

D. nuclear energy

Question 12

Compression springs are coil springs that store mechanical energy when they are in a compressed state.

Which one of the following uses the principle of compression springs for its operation?

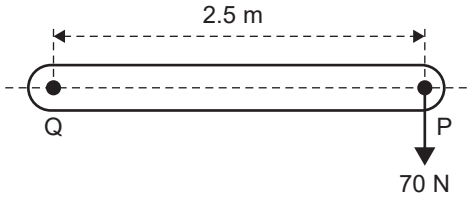
A. a car seat

B. a solar panel

C. a trampoline

D. a garage door

Question 13



A 70 N vertical force is applied to the end of a lever which is attached to a shaft at Q.

The moment of the force at point Q is

A. 30.0 N m

B. 67.8 N m

C. 151.5 N m

D. 175.0 N m

Question 14

On Earth, which of the following objects experiences the most gravitational force?

A. an umbrella

B. a cricket ball

C. an adult person

D. a train carriage

Question 15

When the power transmission shaft on a motor and gearbox is twisted about its axis, it is subjected to loads that result in torsion.

A shaft is said to be in torsion if

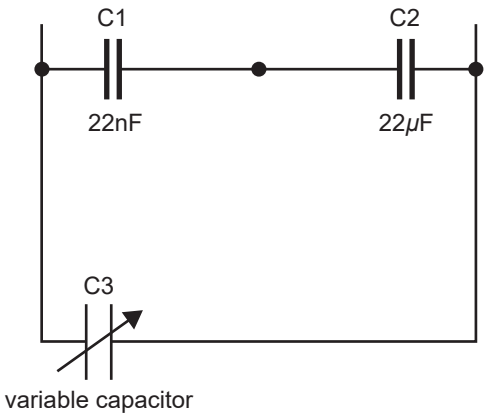
A. a bending load is applied to the shaft.

B. two opposite turning moments are applied to the shaft.

C. the turning force is applied at one end and the other end is not fixed.

D. the turning moment is applied to one end and the other end is not fixed.

Question 16



The circuit above is a noise-suppression network.

Calculate the value of the capacitance of C3 so that the total capacitance of the circuit is 0.1 μF

A. 22 nF

B. 78 nF

C. 100 nF

D. 22 μF

Question 17

An appropriate workstation must be maintained when soldering electronic components on a circuit board.

Which one of the following must be used for safety in this situation?

A. a heat sink clamp

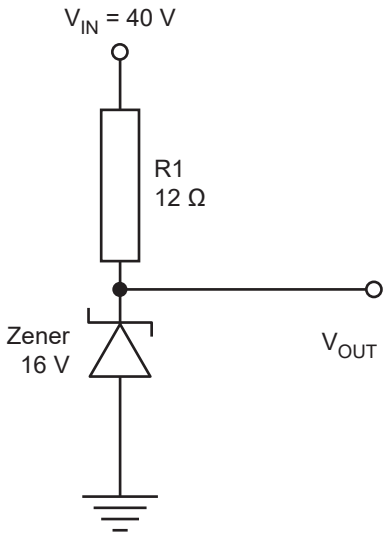
B. the correct flux type

C. a fume extraction system

D. the correct temperature for the solder

Question 18

A simple voltage regulator circuit is shown below.



The current through the resistor R1 in the circuit is

A. 2 A

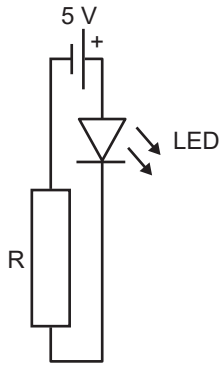
B. 5 A

C. 12 A

D. 16 A

Question 19

In the circuit below, the specifications for a light-emitting diode, LED, state that, for continuous operation, a voltage drop of 2.7 V and a current of 20 mA are required.



The smallest value of the resistance of R that would satisfy these conditions is

A. 115 Ω

B. 135 Ω

C. 250 Ω

D. 270 Ω

Question 20

Which one of the following is a suitable application for a mercury switch?

A. an automatic fertiliser system that provides nutrients

B. a detection of liquid mercury leaks in laboratory settings

C. a magnetic detection of a model train, to avoid collisions

D. an alarm to indicate that a ramp is too steep for a wheelchair

END OF SECTION A
TURN OVER

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 (7 marks)

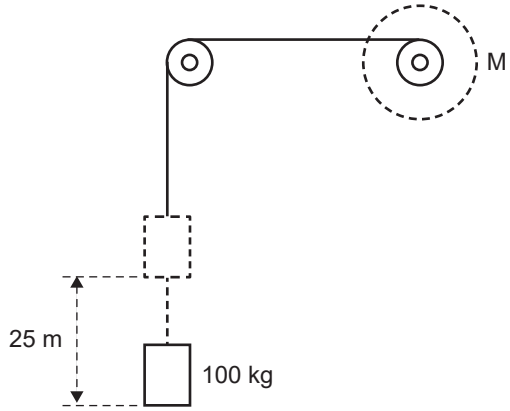


Figure 1

An electrical motor uses 500 W to lift a load of 100 kg a height of 25 m in 60 seconds.

a. Calculate the mechanical work required to lift the load if $g = 9.8$ m s^{-2}. Show your working. 3 marks

b. Calculate the electrical energy used by the motor to lift the load. Show your working. 2 marks

c. Calculate the efficiency of this system. Show your working. Round to the nearest 1%. 2 marks

Question 2 (6 marks)

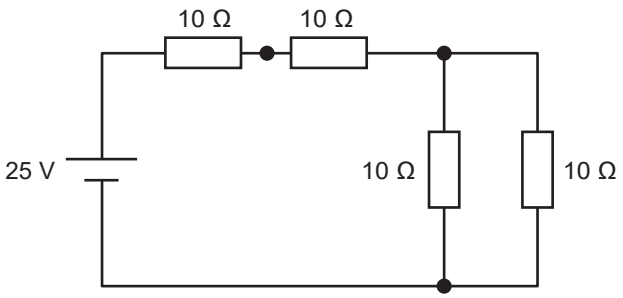


Figure 2

Figure 2 shows a small electrical circuit consisting of four 10 Ω resistors.

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

b. Calculate the current provided to the circuit by the power supply. 1 mark

c. Calculate the power provided to the circuit by the power supply. 1 mark

Question 3 (7 marks)

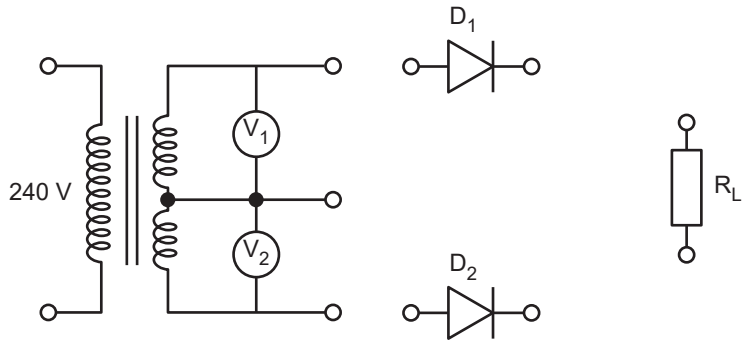


Figure 3

Figure 3 shows a small electrical circuit. It includes an ideal transformer with 1000 turns in the primary and a secondary with two windings of 250 turns each. The circuit also includes two diodes, D_1 and D_2, and a resistor load, R_L. The RMS voltage across the primary of the transformer is 240 V.

a. Identify the RMS voltages displayed on the voltmeters V_1 and V_2. 2 marks

b. On Figure 3, complete the circuit so that a DC voltage is produced across R_L. 3 marks

c. Name the component that can be included in the circuit to smooth the output voltage. 1 mark

d. State where in the circuit the component identified in **part c.** should be positioned. 1 mark

Question 4 (7 marks)

Some caravan owners want to install solar panels on their caravan. To operate as designed, the lighting of the caravan requires a total power of 20 W and the fridge requires a power of 100 W.

a. Calculate the total amount of energy required per day if the caravan lighting is used for 6 hours per day and the fridge for 2 hours per day. Show all working. 3 marks

b. On a typical sunny day each solar panel can provide 100 W h of energy.

How many solar panels are required to produce the energy needed for the caravan lights and fridge? 1 mark

c. The owners of the caravan want to ensure they have energy if there is no sunshine for three days. They intend to use batteries to store the energy produced by the solar panels. The battery specifications are 12 V, 100 A h.

How many batteries are required to supply electricity to the caravan for three days of no sunshine? Show your working. 3 marks

Question 5 (6 marks)

A circuit diagram is shown in Figure 4.

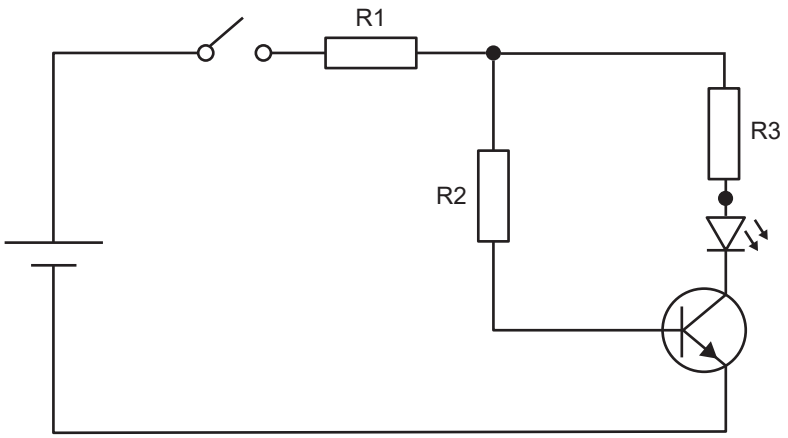


Figure 4

Figure 5 shows a printed circuit board, PCB, with components.

On Figure 5, draw the PCB artwork diagram for the circuit in Figure 4.

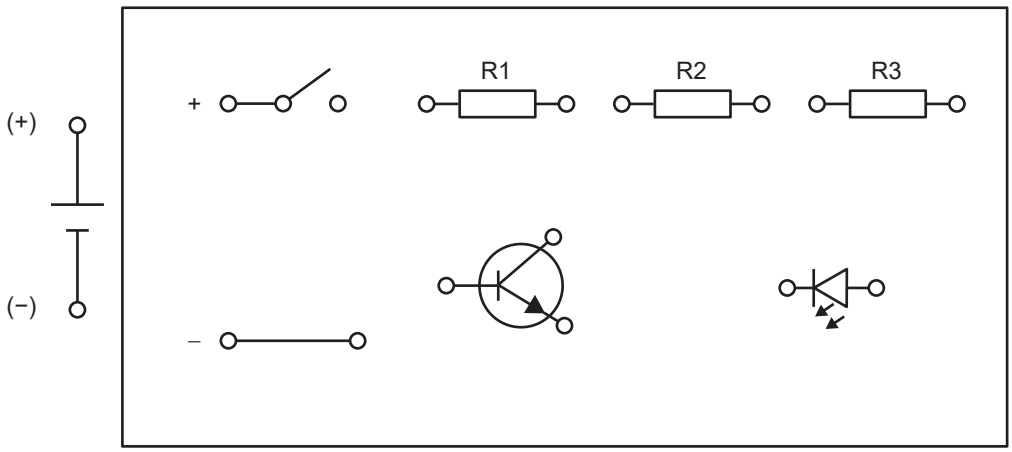


Figure 5

Question 6 (7 marks)

Certain systems or devices can function either as an open- or closed-loop system according to the desired output requirements.

a. Identify a system or device that can function either as an open- or closed-loop system. 1 mark

b. Describe **one** open-loop and **one** closed-loop system that are used in the system or device identified in **part a.** 2 marks

c. Explain two advantages of a closed-loop system when compared to an open-loop system in relation to the system or device identified in **part a.** 4 marks

Advantage 1

Advantage 2

Question 7 (7 marks)

Hydraulic systems can be used to lift cars. A simple hydraulic system is shown in Figure 6.
A force F_1 is applied to the piston of the small-diameter cylinder in order for a second piston, with a larger-diameter cylinder, to apply a force F_2. The pressure of the fluid in the pipe between the two pistons remains constant.

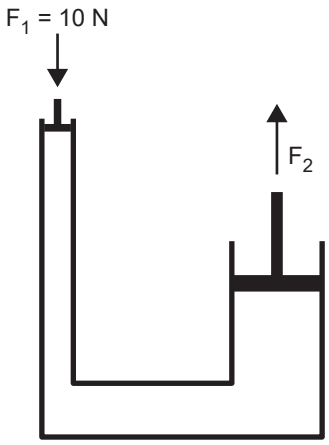


Figure 6

a. Calculate the area of the piston of the small cylinder if the pressure is 2632 Pa and the force F_1 is 10 N. Show your working. 1 mark

b. If the piston at the large cylinder has a surface area of 0.5 m^2, what force is applied by this piston? Show your working. 1 mark

c. State why the applied force is typically on the smaller cylinder. 1 mark

Figure 7 shows a hydraulic system used to lift a car of mass 2800 kg. A force F_1 is applied to the piston P_1 of the small cylinder. The system supports the weight of the car that is on a platform on the piston P_2 of the large cylinder.

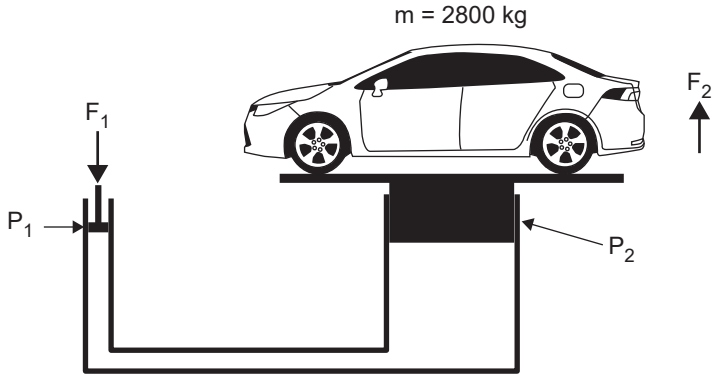


Figure 7

d. Find F_1 when the mass of the car is 2800 kg, the area of the small piston is 0.6 m^2 and the area of the large piston is 3.6 m^2. Use $g = 9.8$ m s^{-2}. Show your working. 4 marks

Question 8 (8 marks)

An off-grid solar power system is a system that is not connected to the regular power grid supplying a community. To operate, the off-grid power system requires a battery inverter, a battery bank and an AC generator for backup. A typical off-grid power system is shown in Figure 8.

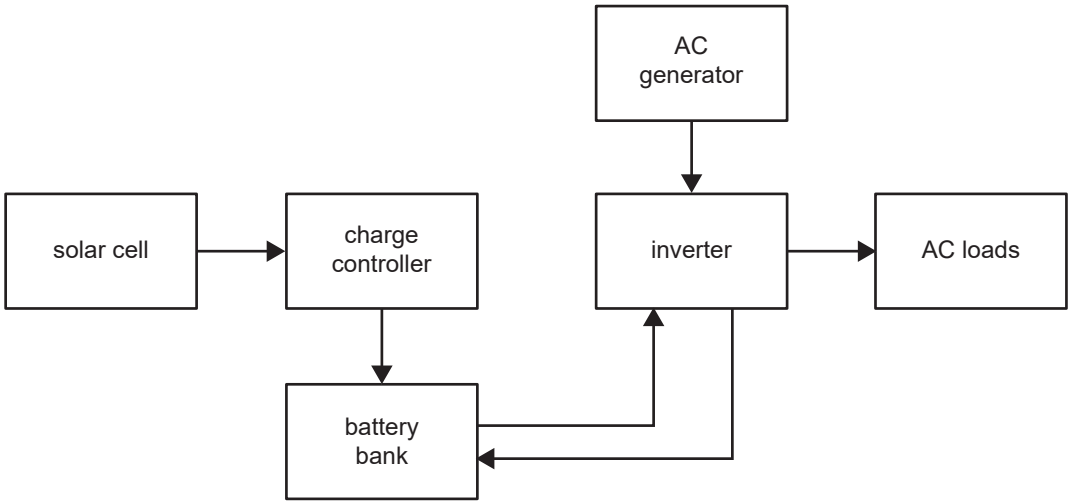


Figure 8

a. Identify the function of an AC generator. 1 mark

b. State the role of an AC generator in an off-grid solar power system. 1 mark

c. The structure of a typical AC generator is shown Figure 9.

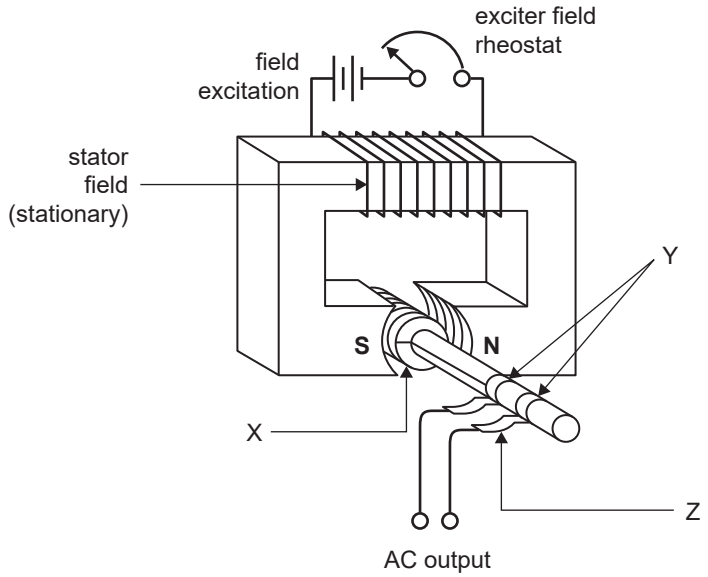


Figure 9

Complete the table below, identifying the parts X, Y, and Z of the generator in Figure 9 and stating their functions. 6 marks

	Part	**Function**
X		
Y		
Z		

Question 9 (2 marks)

The output of an AC generator is alternating electrical power in the form of alternating voltage and current.

On the grid in Figure 10, draw the signal generated by an AC generator when it is producing a peak voltage of 40 V at a frequency of 25 Hz. Show at least **two** complete cycles.

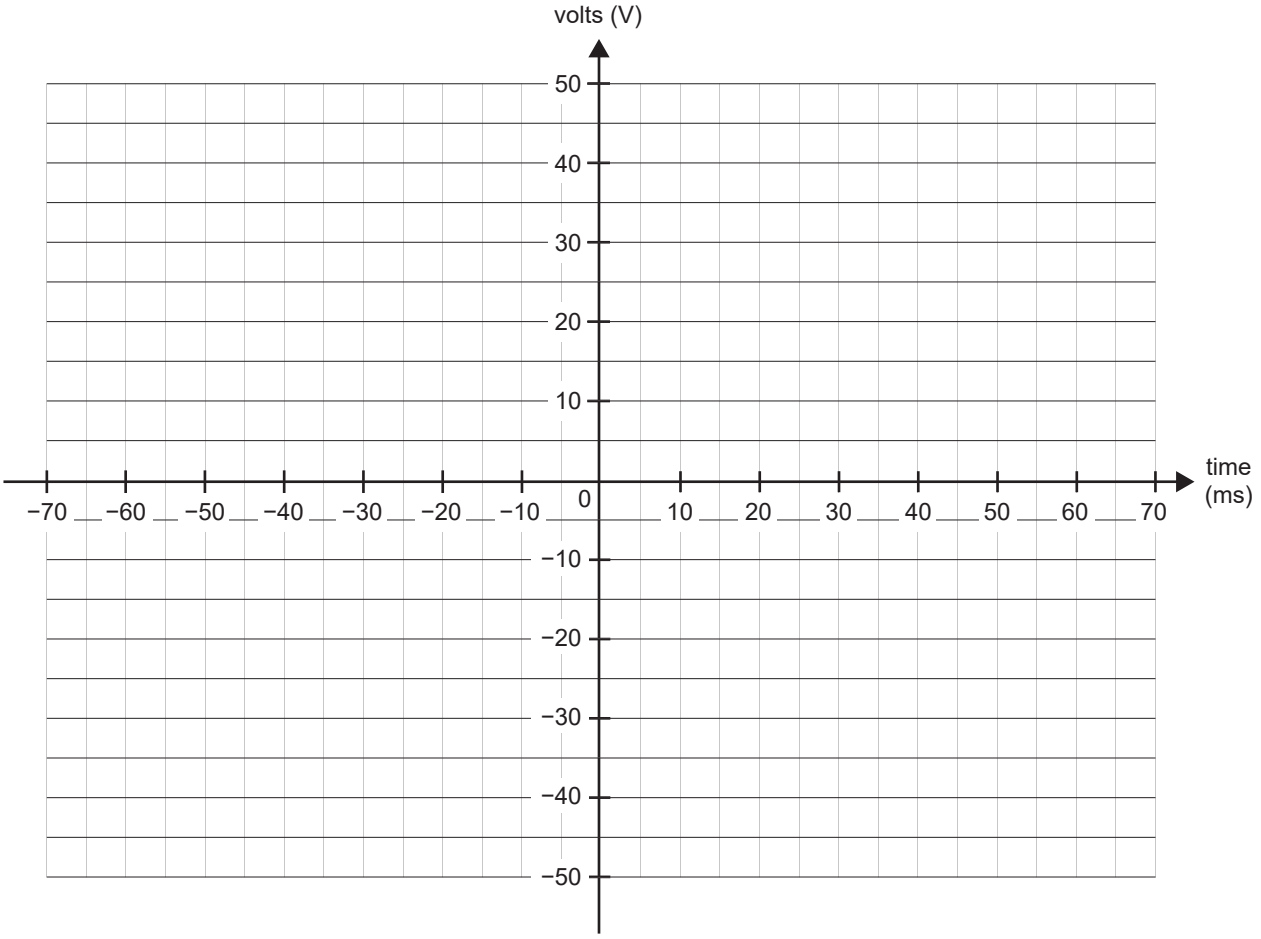


Figure 10

Question 10 (3 marks)

Using the components listed below, design a circuit that will provide a variable DC output between 2.5 V and 5 V.

Components:

- a 5 V battery
- a 100 Ω resistor
- a 100 Ω potentiometer

Question 11 (6 marks)

Cars can be designed to be fuelled by biodiesel, petrol or Li-ion batteries. The fuel type will influence the design of the car and the infrastructure required to transport and store the fuel.

Following is some information about the three types of fuel when used to operate a car, in relation to:

- energy density in units of energy per volume of material
- specific energy in units of energy per mass of the material
- efficiency

Energy density (energy per volume of material)

Biodiesel	Petrol	Li-ion battery
42.2 MJ/L	34.2 MJ/L	2.6 MJ/L

Specific energy (energy per kilogram of material)

Biodiesel	Petrol	Li-ion battery
33 MJ/kg	46.4 MJ/kg	0.9 MJ/kg

Vehicle efficiency

Biodiesel	Petrol	Li-ion battery
33%	25%	50%

a. The volume of fuel used by the car will affect the design of the size of the car.

Using the information provided above, describe a design consideration when designing electric cars and biodiesel cars. Use calculations to support your answer. 4 marks

b. Discuss the basic infrastructure needed for both transportation and storage of energy for electric vehicles compared with petrol vehicles. 2 marks

Question 12 (4 marks).

A community group would like to monitor a body of water to check the effects of a new road on a nearby lake.

The monitoring system should be small enough to be carried by one person. It will be used to sample water in the middle of the lake to a depth of 500 mm and then return to shore with collected data.

The group is interested in collecting information about the cloudiness of the water that is caused by oils washing from the road into the lake. Cloudiness reduces the amount of light passing through the water.

Describe a feasible design for the sampling system. Clearly identify the components of your design and how these components will be used to address the brief.

The following components may be used as part of the design.

- servo motor
- stepper motor
- solenoid
- pump
- piston
- microcontroller
- light-dependent resistor (LDR)
- photodiode
- phototransistor

CONTINUES OVER PAGE

Question 13 (4 marks)

A steering-rack mechanism is shown in Figure 11.

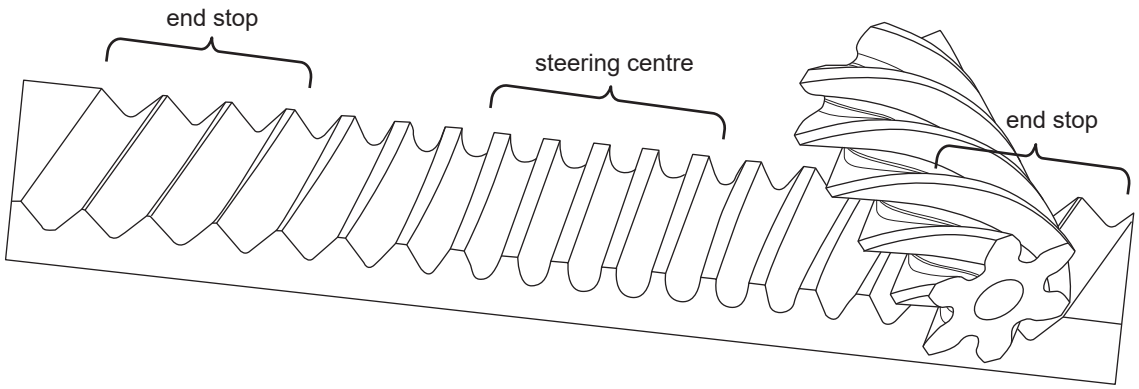


Figure 11

The teeth in the steering-centre section of the rack are equally spaced.

The teeth in the end-stop sections of the rack are machined so that they are increasingly further apart.

a. State how the rate of steering change varies from the engagement with the steering centre of the rack to engagement with the end stops. 1 mark

Figure 12 shows a gearbox that contains four gears A–D. The input gear is gear A; the output gear is gear D.

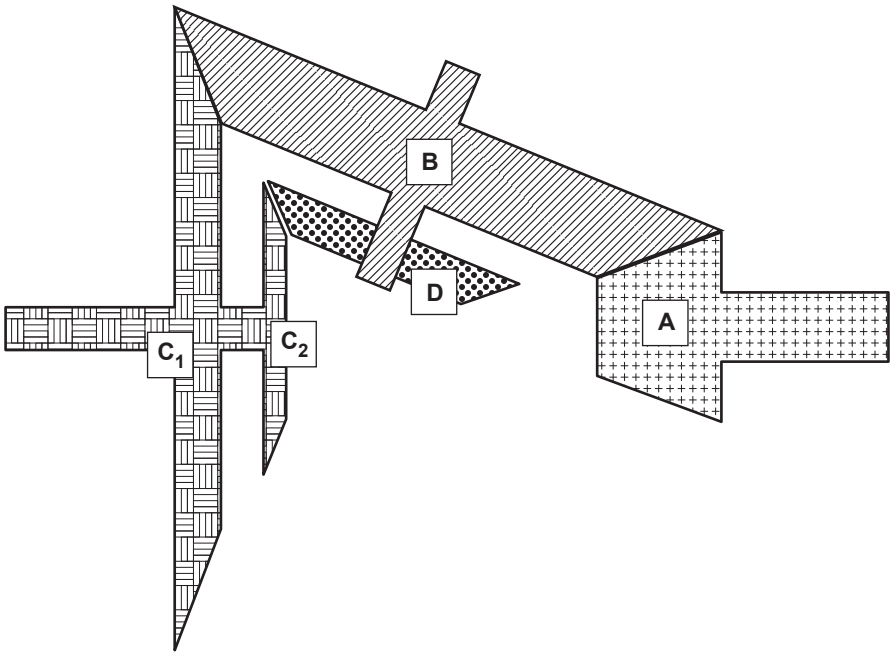


Figure 12

The components C_1 and C_2 are fixed together to make a compound gear, gear C.
Gear D rotates independently on an axle that is fixed to gear B.
The number of teeth for each component is given in the following table.

Gear	Number of teeth
A	24
B	120
C_1	150
C_2	60
D	60

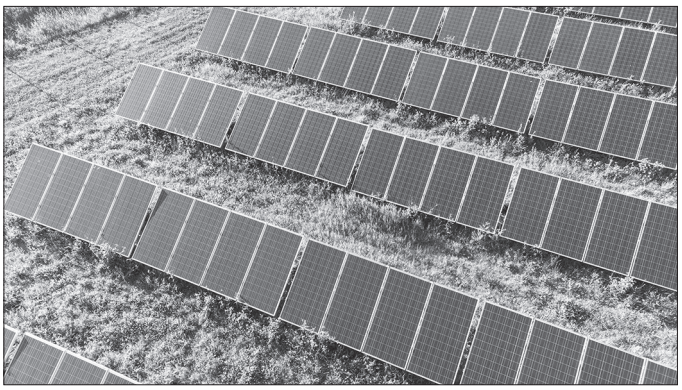
b. Calculate the number of rotations that gear A must complete so that gear D rotates four turns. 3 marks

Question 14 (6 marks)

Wind and solar energy are renewable energies that may be used to supplement energy in the power grid. Figure 13 shows a typical wind turbine installation and Figure 14 shows a typical solar installation.

Source: Phubadee Na Songkhla/Shutterstock.com

Figure 13



Source: francesco de marco/Shutterstock.com

Figure 14

a. Describe two environmental factors that should be considered when selecting a site for a wind-turbine farm that will be connected to the power grid. 2 marks

Environmental factor 1 _____

_____

Environmental factor 2 _____

_____

b. Evaluate wind-farm generation and solar-farm generation as renewable sources of energy that contribute to the power grid. 4 marks

END OF QUESTION AND ANSWER BOOK

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
$F_1 d_1 = F_2 d_2$	$P = \frac{F}{A}$
$\text{speed} = \frac{\text{distance}}{\text{time}}$	$\text{mechanical advantage} = \frac{\text{load}}{\text{effort}}$
gear ratio final = gear ratio 1 $\times$ gear ratio 2	$\text{gear or pulley ratio} = \frac{\text{speed of driver (rpm)}}{\text{speed of driven (rpm)}}$
$\frac{\text{Gear A rpm}}{\text{Gear B rpm}} = \frac{\text{Gear B number of teeth}}{\text{Gear A number of teeth}}$	$\frac{\text{Pulley A rpm}}{\text{Pulley B rpm}} = \frac{\text{diameter of Pulley B}}{\text{diameter of Pulley A}}$
$\text{velocity ratio} = \frac{\text{distance moved by effort}}{\text{distance moved by load}}$	

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	$R_t = R_1 + R_2 + R_3 + \ldots$	resistors in parallel	$\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots$
two resistors in parallel	$R_t = \frac{R_1 \times R_2}{R_1 + R_2}$	capacitors in series	$\frac{1}{C_t} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \ldots$
capacitors in parallel	$C_t = C_1 + C_2 + C_3 + \ldots$		

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		

END OF FORMULA SHEET