SUPERVISOR TO ATTACH PROCESSING LABEL HERE

Letter

STUDENT NUMBER

SYSTEMS ENGINEERING
Written examination

Monday 15 November 2021

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	18	18	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 25 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.

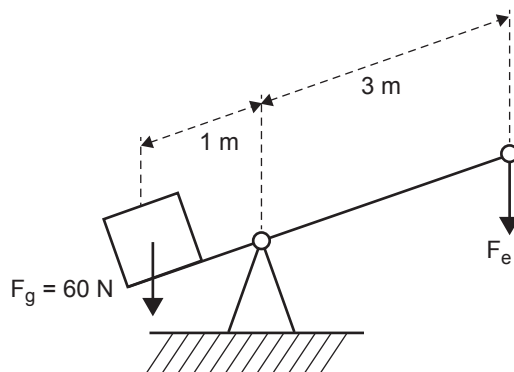A correct answer scores 1; an incorrect answer scores 0.

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.
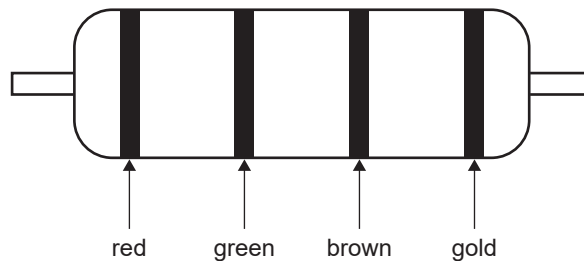
Question 1

The lever in the diagram below is used to lift a load of 60 N.

The effort force, F_e, required to lift the load is

A.   20 N

B.   60 N

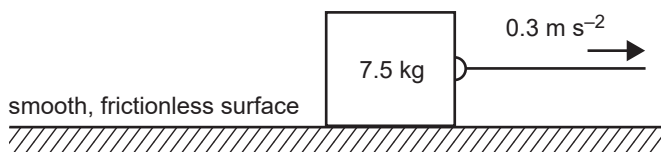**C.**   180 N

D.   240 N

Question 2

Which of the following gives the resistance and the tolerance of the resistor shown above?

A.   251 Ω, 5%

B.   251 Ω, 10%

C.   250 Ω, 5%

D.   250 Ω, 10%

Question 3

A 7.5 kg mass that is attached to a rigid cable is accelerated horizontally to the right at 0.3 m s^{-2} on a smooth, frictionless surface, as shown in the diagram below. Ignore the mass of the cable.
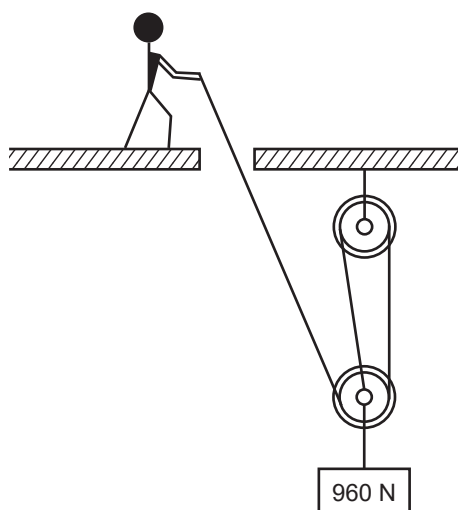

The tension in the cable is closest to

A.   0.04 N

B.   2.3 N

C.   23 N

D.   75 N

Question 4

The diagram below shows an ideal pulley system being used to raise a load of 960 N vertically upwards.
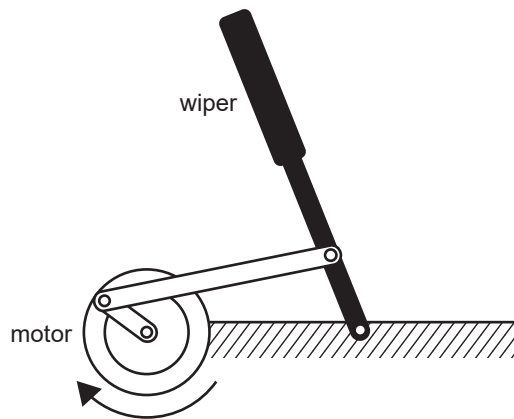

The effort applied by the worker is closest to

A.   160 N

B.   240 N

C.   320 N

D.   480 N

Question 5

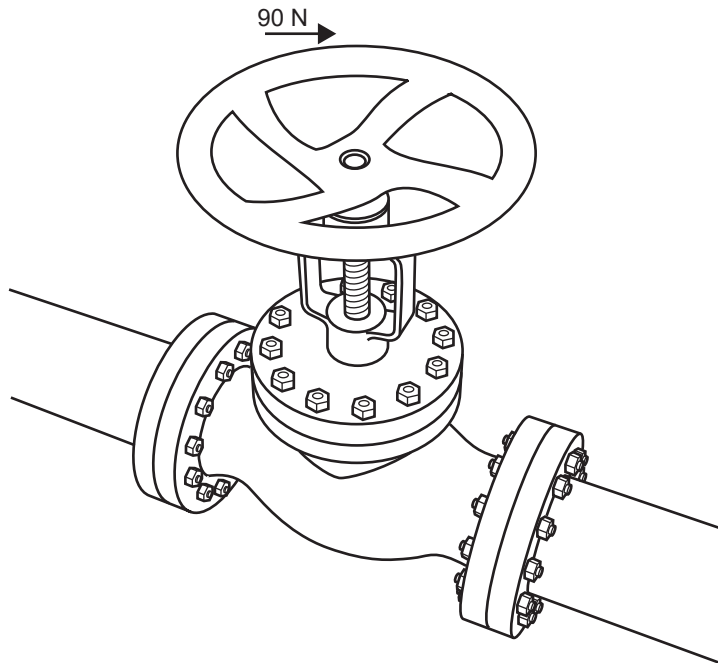The diagram below shows a linkage mechanism that is connected to a motor.

When the motor rotates clockwise, the motion produced by the wiper is

A.   rotary.

B.   linear.

C.   oscillating.

D.   reciprocating.

Question 6

A wheel is used to open the valve shown below. The valve requires 18 N m to open. The operator can apply a total force of 90 N on the wheel.
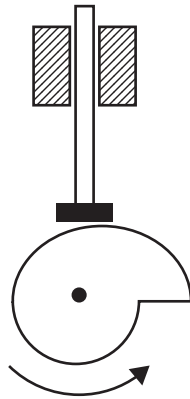

In order for the operator to open the valve, which wheel diameter is required?

A.   10 cm

B.   20 cm

C.   30 cm

D.   40 cm

Question 7

A cam and follower mechanism is shown in the diagram below.

The two types of motion produced by the mechanism are

A. oscillating and linear.

B. oscillating and rotary.

C. rotary and reciprocating.

D. oscillating and reciprocating.

Question 8

A lifting device with a mechanical advantage of 6.5 elevates an object of mass 52 kg.

Taking acceleration due to gravity to be 10 m s^{-2}, the input force of this system is closest to

A.   8 N
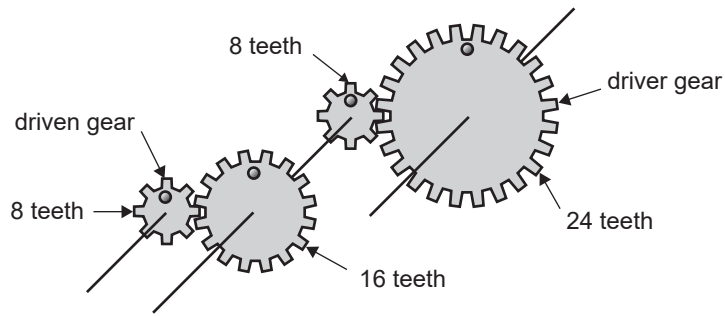
B.   80 N

C.   338 N

D.   3380 N

Question 9

A conveyor belt uses 2000 J of electrical energy in one minute. During this time, it was measured to produce 200 J in sound energy and 500 J in heat energy throughout the system.

Which one of the following gives the mechanical energy of the conveyor belt?

A.   300 J

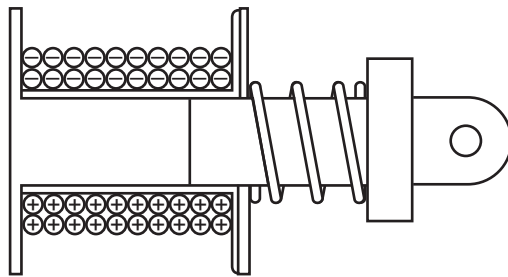**B.**   700 J

C.   1300 J

D.   2000 J

Question 10

The gear ratio of the compound gears shown above is
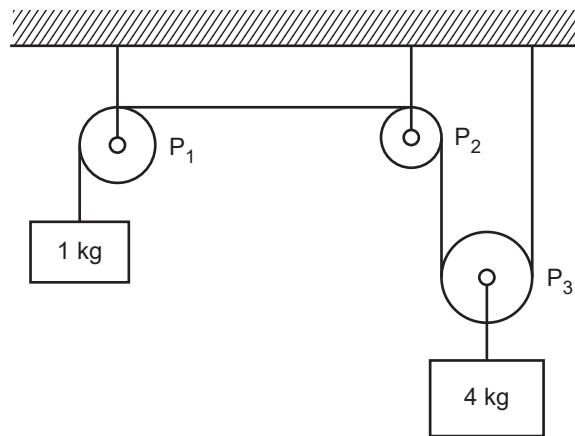
A. 1:3
B. 1:6
C. 3:1
D. 6:1

Question 11

Which one of the following gives the name of the component shown above?

A. relay switch
B. pull solenoid
C. hydraulic cylinder
D. pneumatic actuator

Question 12

The diagram below shows a pulley system.

Which of the following gives the motion of the pulleys P_1 and P_2?

	P_1	P_2
A.	clockwise	clockwise
B.	anticlockwise	clockwise
C.	clockwise	anticlockwise
D.	anticlockwise	anticlockwise

Question 13

Which one of the following components would be best suited to act as a simple voltage regulator?

A. resistor
B. capacitor
C. light globe
D. Zener diode

Question 14

Which one of the following is a passive component whose resistance varies with respect to receiving light on its surface?

A. light globe
B. neon lamp
C. light-emitting diode
D. light-dependent resistor

Question 15

Which of the following gives the characteristics of a polarised capacitor?

	Voltage range	Type of current	Capacitance range	Cost
A.	200–1600 V	AC and DC	0.001 μF to 10 μF	low
B.	50–30 000 V	AC and DC	100 pF to 1 μF	high
C.	100–1000 V	AC and DC	47 pF to 3000 pF	high
D.	3–600 V	DC	1 μF to 47 000 μF	high

Question 16

A counterweight is often used in machines, such as the crane shown in the diagram below, to make lifting a heavy load safer and more efficient.
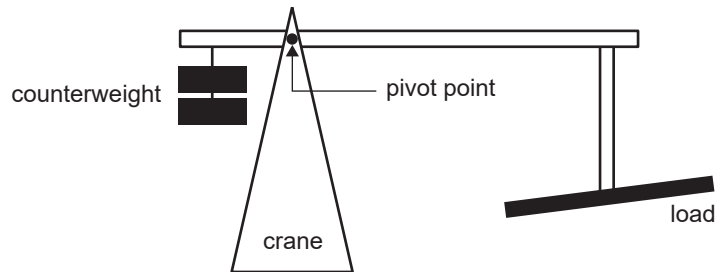
Which one of the following forces acting on the crane is responsible for the counterweight providing the mechanical stability of the crane?

A.   tension
B.   friction
C.   compression
D.   gravitational

Question 17

A microphone is a type of transducer, converting one type of energy into another.

Which of the following gives the correct type of input energy and output energy for a microphone?

	Input energy	Output energy
A.	mechanical energy	sound energy
B.	sound energy	electrical energy
C.	sound energy	mechanical energy
D.	electrical energy	sound energy

Question 18

Torsion can be best described as a force that

A. bends.

B. twists.

C. shears.

D. compresses.

Question 19

The power of a DC motor that draws a current of 30 mA and is operated on a 12 V power supply is

A. 0.36 W

B. 2.5 W

C. 3.6 W

D. 360 W

Question 20

The process of risk assessment has four common steps that should be carried out in sequential order.

Which of the following gives the correct order in which to carry out the steps of risk assessment?

A. identify hazards → assess/evaluate risks → implement controls → review

B. assess/evaluate risks → review → identify hazards → implement controls

C. review → implement controls → identify hazards → assess/evaluate risks

D. implement controls → review → assess/evaluate risks → identify hazards

END OF SECTION A
TURN OVER

SECTION B

<div style="border:1px solid black">

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.

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Question 1 (4 marks)

The speed of a car can be controlled by two processes:

- Process 1 increases the speed of the car.
- Process 2 decreases the speed of the car.

Complete the input-process-output (IPO) diagrams for Process 1 and Process 2 by writing appropriate information in the boxes provided.

Process 1

input   process (increases the speed)   output

Process 2

input   process (decreases the speed)   output
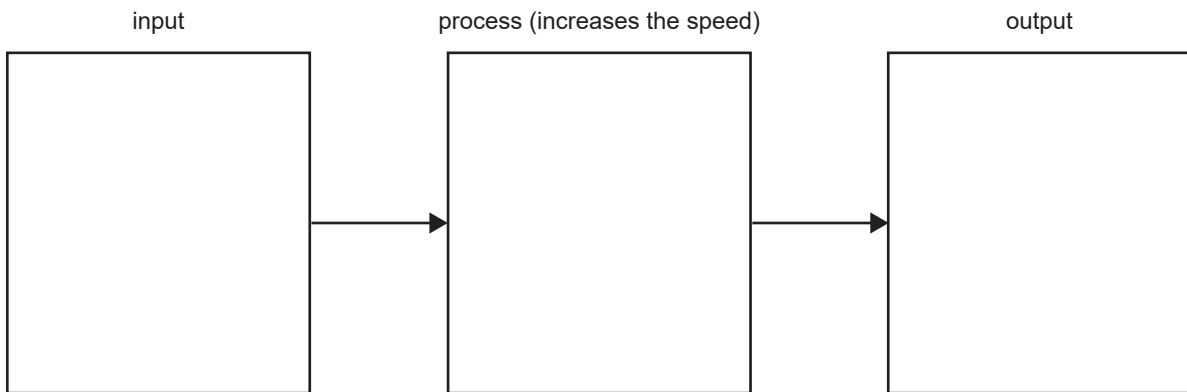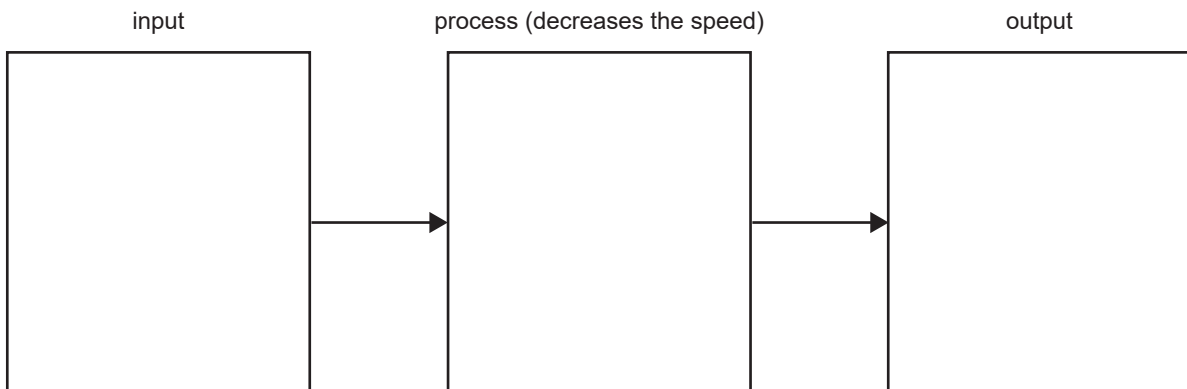
Question 2 (4 marks)

Figure 1 below represents a small electrical circuit. The circuit has two switches, S_1 and S_2. Depending on the state of the switches S_1 and S_2, the currents I_1, I_2 and I_3 have different values.
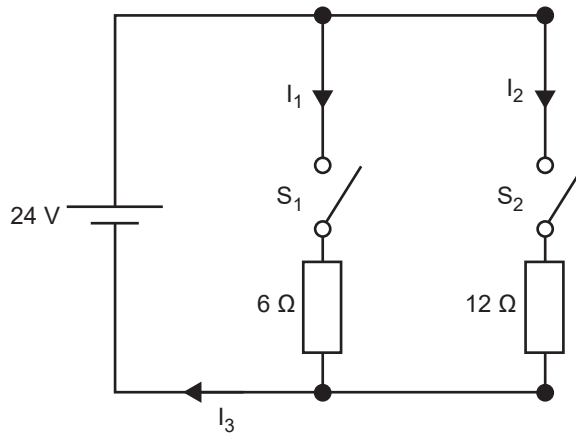
Figure 1

Complete the table below with the values of the currents I_1, I_2 and I_3 based on the given states of the switches S_1 and S_2. All values must be in amperes (A). The state 'OFF' occurs when the switch is open and the state 'ON' occurs when the switch is closed.

S_1	S_2	I_1 (A)	I_2 (A)	I_3 (A)
OFF	OFF			
ON	OFF			
OFF	ON			
ON	ON			

Question 3 (4 marks)

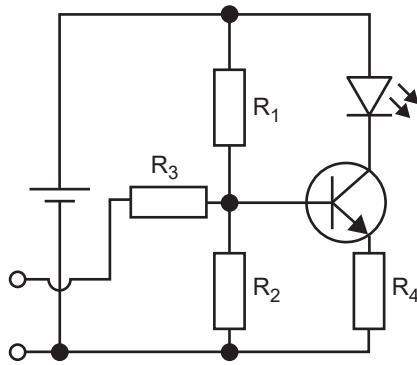Figure 2 shows a schematic circuit diagram for a small electronic circuit.

Figure 2

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

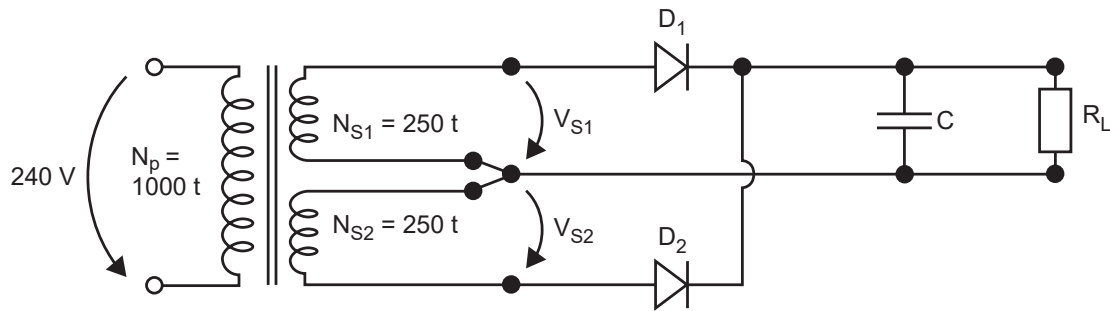On Figure 3, draw the missing connections that are required to complete the PCB layout.

Figure 3

Question 4 (4 marks)

Figure 4 represents an electric circuit supplied with mains power. The voltage of the primary is 240 V. The winding of the primary has 1000 turns. The secondary has two windings with an equal number of turns, $N_{S1} = N_{S2} = 250$ turns.

Figure 4

a. What is the name of the component labelled C in the electric circuit and what is its role in the circuit? 2 marks

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b. Calculate the secondary voltages, V_{S1} and V_{S2}. Show your working. 2 marks

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V_{S1} [   ] V V_{S2} [   ] V

Question 5 (2 marks)

A test is conducted to determine the efficiency of the solar panel shown in Figure 5. The panel is illuminated with a 200 W lamp. The readings for the voltage and the current produced are V = 10 V and I = 15 A.

solar panel
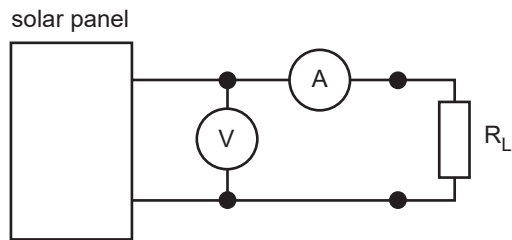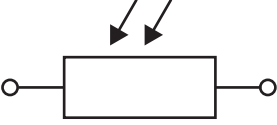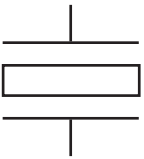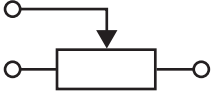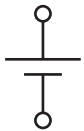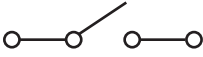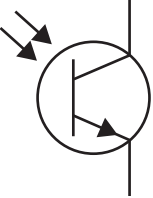
Figure 5

Calculate the efficiency of the panel. Show your working.

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Question 6 (6 marks)

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

Component	Name

Question 7 (5 marks)

A Victorian coastal town has a growing population and an increasing demand for electricity.

The town council is considering different sources of energy that the town could use to meet this demand.

How might the town council justify a decision to use wind energy in this situation? In your answer, refer to cradle-to-cradle analysis.

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Question 8 (6 marks)

Figure 6 shows a hand-operated aluminium soft drink can crusher.
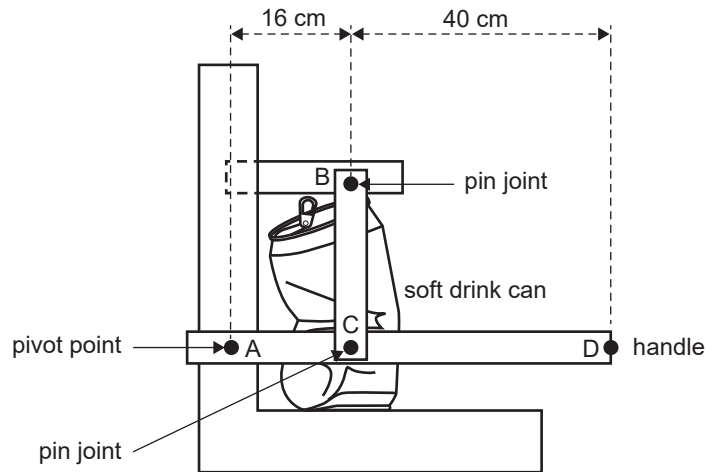
Figure 6

a. What type of lever is the soft drink can crusher? Explain your answer.   2 marks

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b. Calculate the force applied to the soft drink can at point B, if the operator applies a force of 120 N on the handle at point D. Show your working.   2 marks

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_____

_____

_____

_____

N

c. Explain the effect of using a longer lever while keeping the pivot point A at the same location.   2 marks

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Question 9 (3 marks)

An electrical generator is a machine that is used to convert mechanical energy into electrical energy. Figure 7 shows the internal components of an AC generator.

In each box provided on Figure 7, state the name of the part indicated, using the following list:

copper slip ring   carbon brush   armature coil   magnetic poles
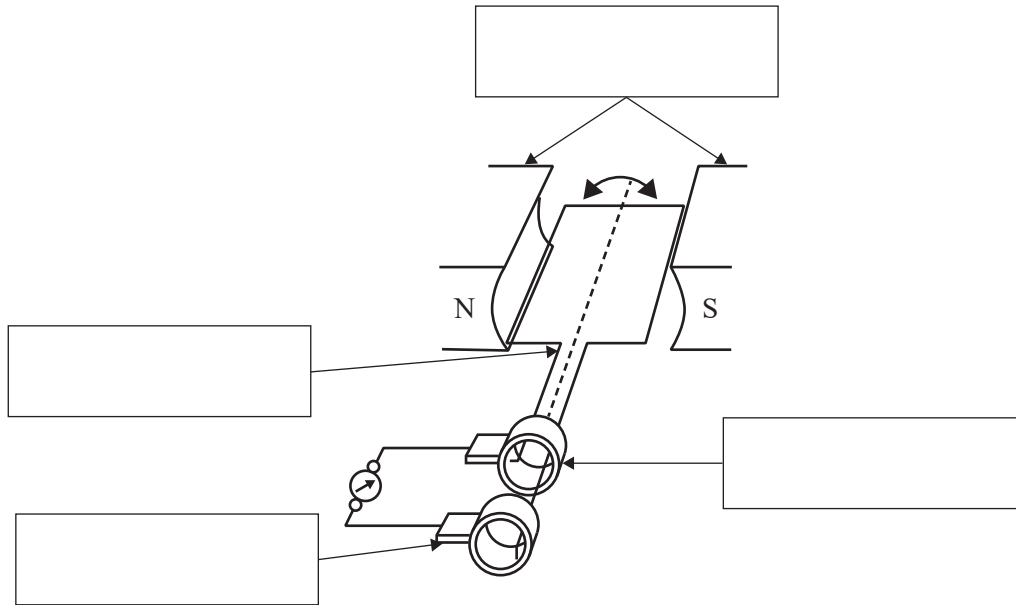
Figure 7

Question 10 (5 marks)

Coal-fired electricity generation is a large component of Australia's total electricity generation.

a. Describe how energy from coal is transformed during each stage of the life cycle of power supply, from when the coal is in the ground to when coal-fired electricity is used in homes.   2 marks

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_____

b. Describe **one** technological development in coal-fired power stations and explain how this technological development reduced the environmental impact of coal-fired electricity generation.   3 marks

_____

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Question 11 (4 marks)

The hydraulic jack system shown in Figure 8 is filled with an incompressible oil.

Piston B
area 0.5 m^2
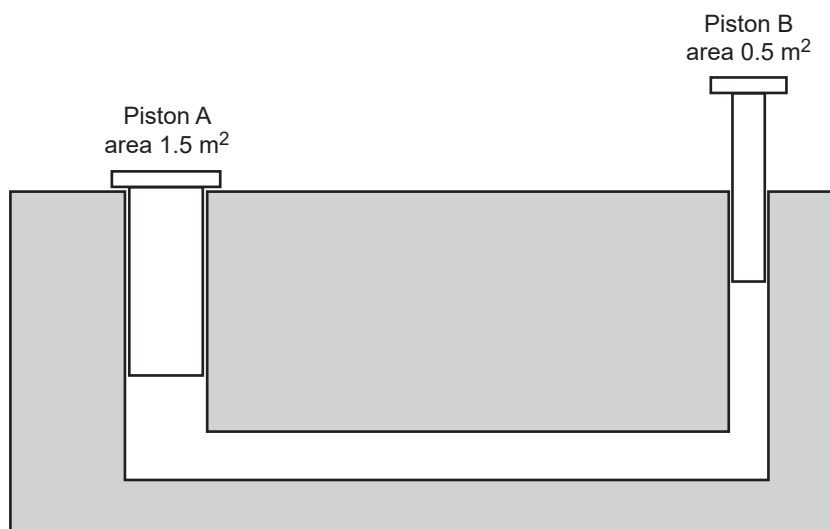
Piston A
area 1.5 m^2

Figure 8

a. A downward force of 600 N is applied to Piston B.

Calculate the upward force provided by Piston A. Ignore the mass of the pistons. Show your working. 2 marks

N

b. Explain the effect the presence of air bubbles would have in this hydraulic jack system. 2 marks

Question 12 (4 marks)

Global warming can be defined as the long-term increase in Earth's surface temperature. One cause of the increase is the burning of fossil fuels.

a. Name **two** commonly used fossil fuels. 2 marks

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_____

_____

b. List **two** alternative energy sources, excluding geothermal energy, that are being used to replace the fossil fuels named in **part a.** 2 marks

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Question 13 (5 marks)

Geothermal energy is used to generate electricity in some countries, but Australia is still exploring how it can be used in a commercial setting.

a. Describe how geothermal electricity is generated. 2 marks

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b. Describe **one** challenge of geothermal electricity production in Australia. 2 marks

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c. Identify **one** other use of geothermal energy, aside from electricity production. 1 mark

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Question 14 (5 marks)

Figure 9 shows an entry gate system for a household driveway. When entry is granted, the motor drives the gear system shown for a specific amount of time, which allows the gate to slide open horizontally.
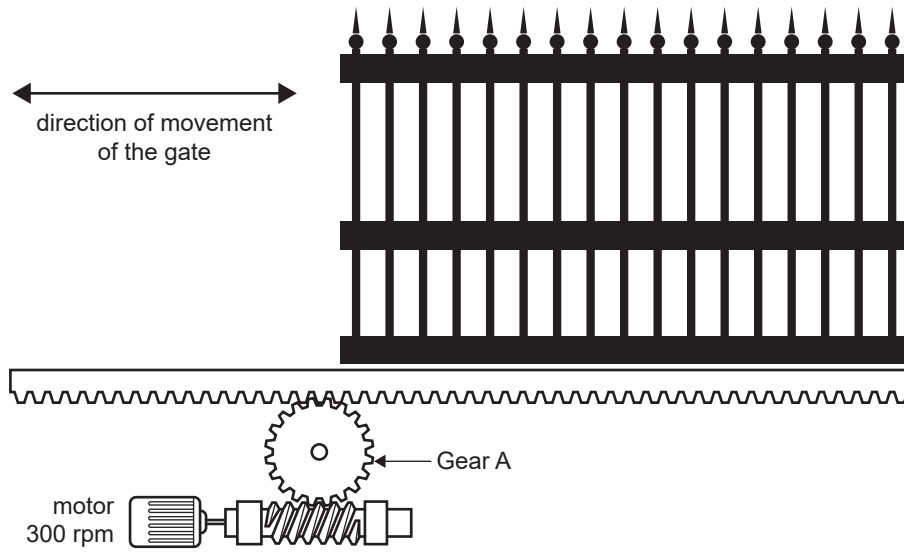
Figure 9

a.   Name Gear A.   1 mark

_____

_____

b.   State **two** advantages of using this type of system to control the entry gate.   2 marks

_____

_____

c.   The motor attached to Gear A rotates at a speed of 300 rpm and the gate slides at a rate of 5 mm per tooth on the rack.

Calculate the amount of time the motor must run to slide the gate through 1 m. Show your working.   2 marks

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Question 15 (5 marks)

A switch is used to turn an air extraction system on and off. The extraction system is made up of a fan circuit and a light-emitting diode (LED) circuit. The LED operates with a 3 V supply and the extraction fan requires 9 V to operate. The fan and the LED must turn on and off at the same time.

a. Identify the best switch to use in the circuit so that both the fan and the LED turn on and off at the same time. 1 mark

b. The LED is in series with a 20 Ω resistor.

In the space provided below, sketch the air extraction system circuit. 4 marks

Question 16 (6 marks)

The systems engineering process represents the stages in creating a system.

a. List the six stages in creating a system.   2 marks

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b. Describe the purpose of applying the systems engineering process to create a system.   2 marks

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c. Two factors that should be considered when creating a system are function and cost.

Discuss why these two factors should be considered when creating a system.   2 marks

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Question 17 (6 marks)

Maya has created a prototype emergency mountain shelter for her Systems Engineering project.
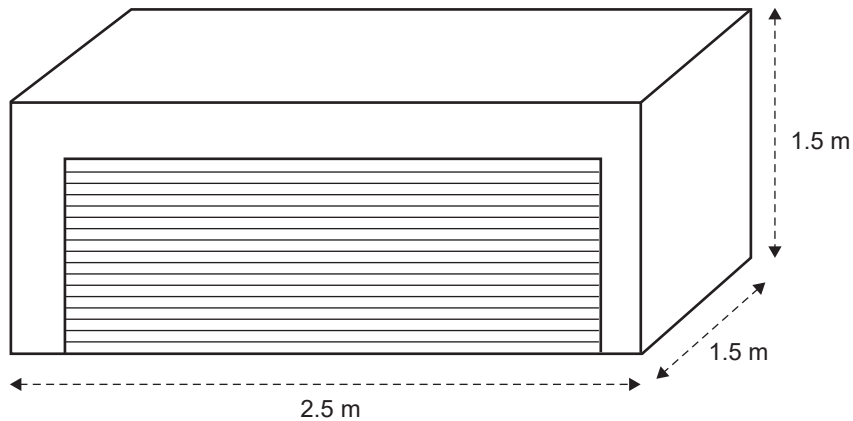A simplified version is shown in Figure 10 with approximate dimensions.

Figure 10

The shelter provides an individual with protection from the environment. Entry is via a roller door.
Lighting and ventilation are provided within the shelter.

a. Suggest **one** suitable lighting option that could be included within the shelter. Give your reasoning. 2 marks

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One power source that Maya is considering is photovoltaic solar panels.

b. Identify **two** advantages of using photovoltaic solar panels. 2 marks

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c.   Explain **one** issue that would need to be addressed about the use of photovoltaic solar panels.   2 marks

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Question 18 (2 marks)

A 500 N load is being pulled up along a 21 m length of slope to a height of 7 m. This is shown in Figure 11. Ignore friction between the surface of the slope and the load.
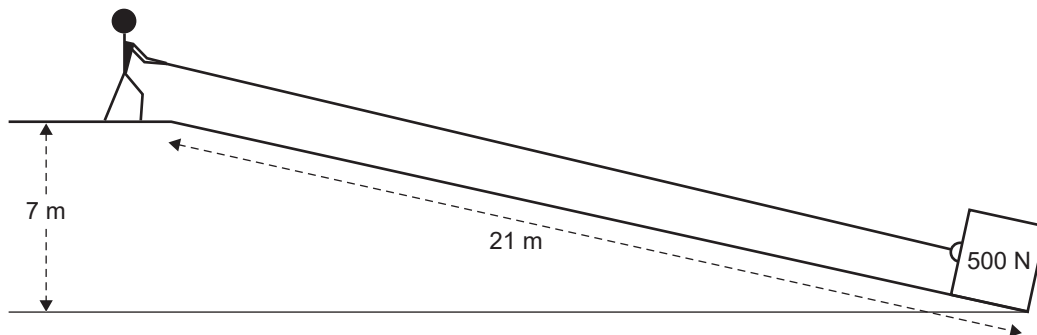

Figure 11

Calculate the effort required to move the load along the 21 m length of slope to a height of 7 m. Show your working.

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N

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.

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Systems Engineering formulas

gear ratio final = gear ratio 1 × gear ratio 2	efficiency = $\dfrac{\text{output energy}}{\text{input energy}} \times 100\%$
gear ratio = $\dfrac{\text{number of teeth on driven gear}}{\text{number of teeth on driver gear}}$	$\text{efficiency}_{\text{Total}} = \text{efficiency}_1 \times \text{efficiency}_2$
$\dfrac{\text{gear A rpm}}{\text{gear B rpm}} = \dfrac{\text{number of teeth gear B}}{\text{number of teeth gear A}}$	mechanical advantage = $\dfrac{\text{load}}{\text{effort}}$
$\dfrac{\text{pulley A rpm}}{\text{pulley B rpm}} = \dfrac{\text{radius of pulley B}}{\text{radius of pulley A}}$	force = pressure × area
voltage = current × resistance	torque = force × distance
power = voltage × current	frequency = $\dfrac{1}{\text{period}}$
area of circle = πr^2 ($\pi = 3.14$)	speed = $\dfrac{\text{distance}}{\text{time}}$
circumference of circle = $2\pi r$	

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

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%

END OF FORMULA SHEET