VICTORIAN CURRICULUM AND ASSESSMENT AUTHORITY

Victorian Certificate of Education 2018

SUPERVISOR TO ATTACH PROCESSING LABEL HERE

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

SYSTEMS ENGINEERING

Written examination

Monday 19 November 2018

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	9	9	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 24 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 term 'torque' refers to

A. a type of force.
B. the power generated by a motor.
C. the amount of twist on an object.
D. the amount of energy produced by a motor.

Question 2

Gears are used for a range of reasons, including to change the direction of rotation and to increase torque or speed in various machines. In most cases, the driven gear can become the driver gear when a machine is slowing down.

In which of the following gear sets can the driven gear not become the driver gear?

A. crown wheel and pinion gear
B. worm and wheel gear
C. rack and pinion gear
D. internal gears

Question 3

Under the *Occupational Health and Safety Act 2004*, who is authorised to operate a piece of equipment with a 'defective' tag on it?

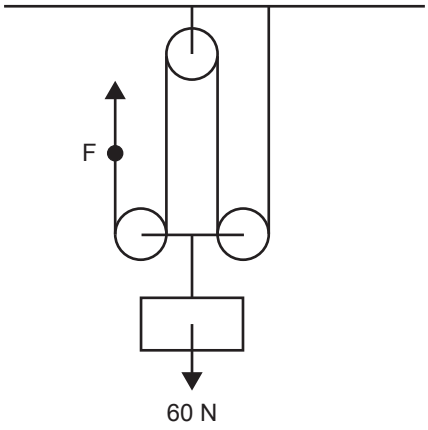
A. any person designated or instructed by the employer to do so
B. any person who has been trained to operate the machine
C. anyone who has a 'test and tag' certificate
D. no-one but the repairer

Question 4

Which one of the following statements about energy is true?

A. Energy can be created.
B. Energy can be transformed.
C. Potential energy can be destroyed.
D. Kinetic energy can be easily stored.

Question 5



In the diagram shown above, the force F required to keep the weight in place is

A. 60 N
B. 30 N
C. 20 N
D. 15 N

Question 6

A 300 mm diameter car wheel has a torque of 200 N m.
What is the driving force of the wheel on the road surface?

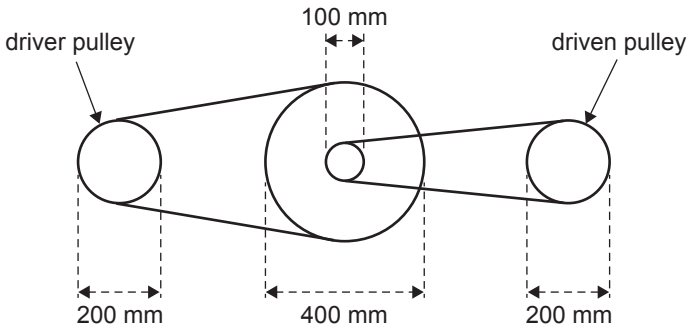
A. 30 N
B. 60 N
C. 30 kN
D. 60 kN

Question 7

If a motor produces 12 000 J of energy in four minutes, the power of the motor would be

A. 48 kW
B. 3000 W
C. 500 W
D. 50 W

Question 8



The pulley ratio of the system shown above is

A. 1:8

B. 1:4

C. 1:2

D. 1:1

Question 9

The thread pitch of a bolt is 2 mm. The bolt is tightened 90° after first contact with the parts to be fastened. How much stretch has been applied to the bolt shank?

A. 0 mm

B. 0.25 mm

C. 0.5 mm

D. 1 mm

Question 10

The number 314 159 written in engineering notation and correct to four significant figures is

A. 3.141×10^5

B. 3.142×10^5

C. 314.1×10^3

D. 314.2×10^3

Question 11

The term 'watt' refers to the

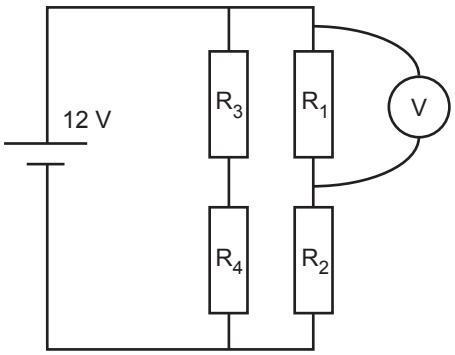
A. rate of doing work.

B. size of small engines.

C. amount of energy used in steam engines.

D. amount of energy used in electrical devices.

Question 12



The voltage displayed on the voltmeter shown above is 12 V.
Which one of the following options is most likely correct?

A. R_1 is shorted.
B. R_2 is shorted.
C. R_2 is open circuit.
D. R_3 or R_4 is open circuit.

Question 13

The four-band colour code for a 1 MΩ 5% resistor is

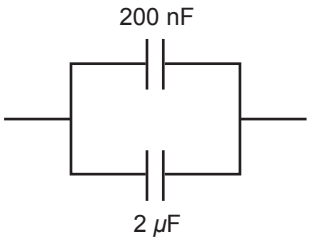
A. brown, blue, black, gold.
B. brown, black, blue, gold.
C. brown, black, green, gold.
D. brown, black, black, yellow.

Question 14

The function of a Zener diode in a circuit is to

A. provide a voltage reference.
B. rectify an AC voltage.
C. detect light.
D. emit light.

Question 15



The total capacitance of the circuit shown above is

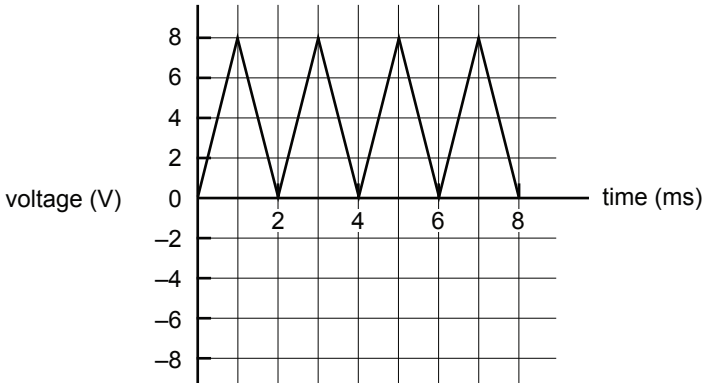
A. 0.5 nF

B. 181 nF

C. 202 nF

D. 2200 nF

Question 16



The waveform shown in the diagram above can be described as

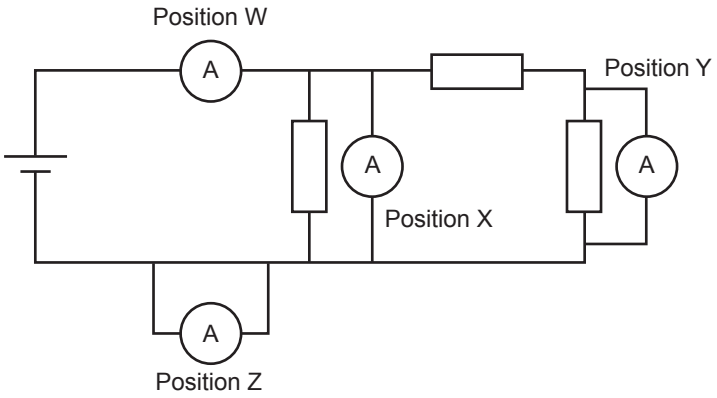
A. digital.

B. a sine wave.

C. a direct current.

D. an alternating current.

Question 17



An ammeter is used to measure the current from the battery supplying the entire circuit shown above.
In which position should the ammeter be placed?

A. Position W
B. Position X
C. Position Y
D. Position Z

Question 18

A hydrogen cell, or fuel cell, works by

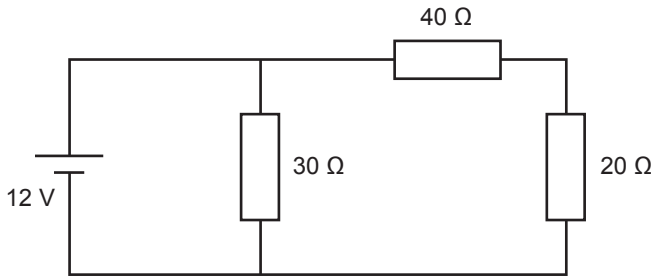
A. burning hydrogen and oxygen together to produce water and electricity.
B. combining hydrogen and oxygen with a membrane catalyst to produce water and electricity.
C. converting water to hydrogen and oxygen, and then burning the oxygen to produce electricity.
D. converting water to hydrogen and oxygen, and then burning the hydrogen to produce electricity.

Question 19

Biofuel is best described as energy produced from

A. a hydrogen cell.
B. burning coal.
C. plant matter.
D. crude oil.

Question 20



The total current in the circuit shown above is

A. 600 mA
B. 400 mA
C. 200 mA
D. 133 mA

END OF SECTION A

SECTION B

Instructions for Section B

Answer **all** questions in the spaces provided.

All calculations must show appropriate formulas and working.

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

Emma is constructing a new house as shown in Figure 1 and she wants it to operate independently of any inputs, apart from those in the immediate environment. This type of house is known as an autonomous house.

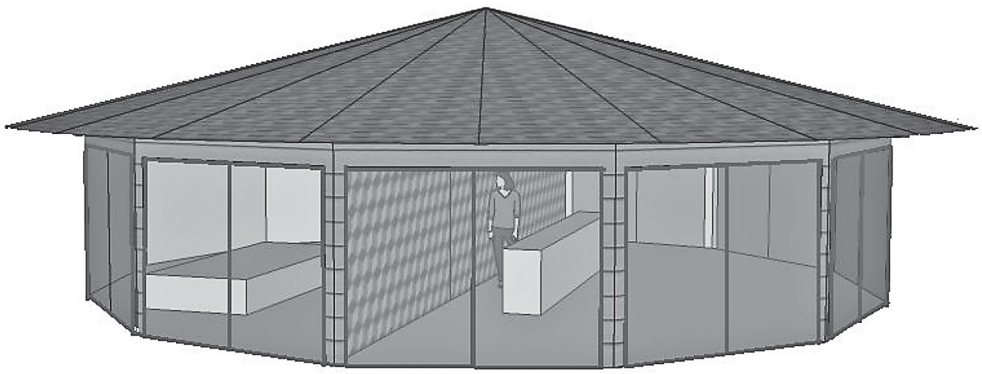


Figure 1

Question 1 (5 marks)

a. Apart from electrical solar panels to generate electricity, give **two** ways in which energy could be harnessed from the sun for this autonomous house. 2 marks

b. How will heat energy be stored in this autonomous house? 1 mark

c. Identify **two** environmental considerations that should be taken into account when designing any engineering system. 2 marks

Question 2 (14 marks)

The house needs a supply of water. Emma has a water tank, but the water needs to be pumped from the tank to be able to use it. Emma's initial idea is to use a hand pump, as shown in Figure 2.

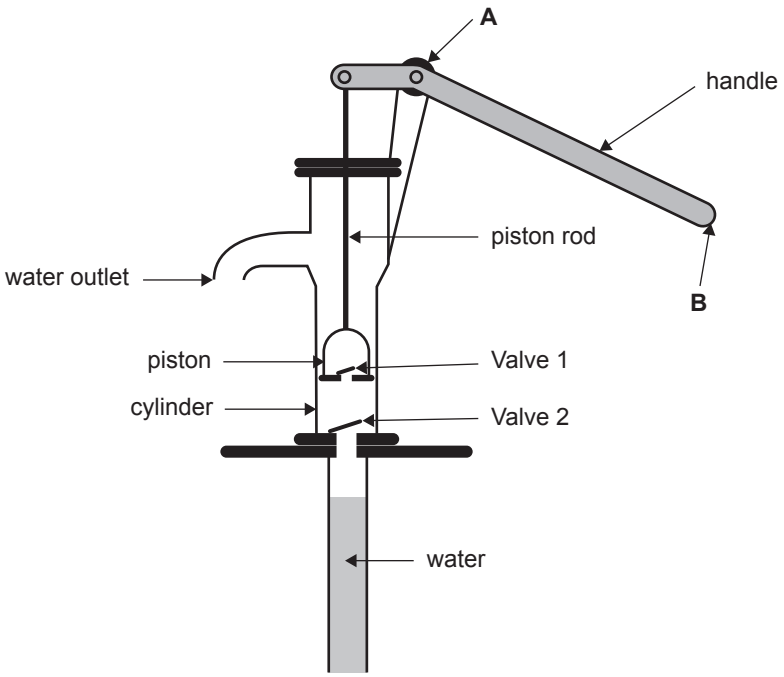


Figure 2

a. Using the options provided below, identify the parts labelled A and B in Figure 2. 2 marks

effort fulcrum load

A _____

B _____

b. Name the type of motion the hand pump's piston uses in its operation. 1 mark

_____

c. Name the class of lever used to operate the hand pump. 1 mark

_____

d. Explain how the hand pump operates. Refer to the components Valve 1, Valve 2, cylinder and piston rod in your response. 3 marks

_____

_____

_____

_____

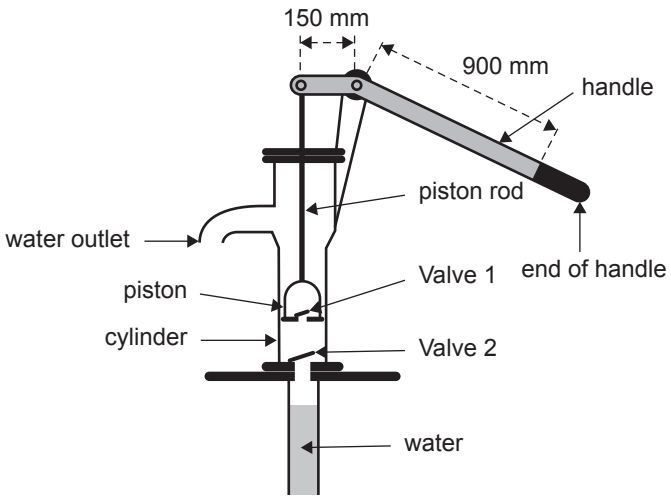


Figure 3

e. With reference to Figure 3, calculate the mechanical advantage of the handle. Show your working. 2 marks

f. If the piston moves 100 mm, calculate the approximate distance that the end of the handle will move. Show your working. 2 marks

mm

g. Calculate the pressure applied to the water if an upward force of 10 N is applied at the end of the lever and the cylinder's diameter is 50 mm. Show your working. 3 marks

N m^{-2}

Question 3 (9 marks)

Emma found that the flow of water from the pump was not constant, so she decided to use a pump that operates on both strokes of the piston. Figure 4 shows the pump without valves.

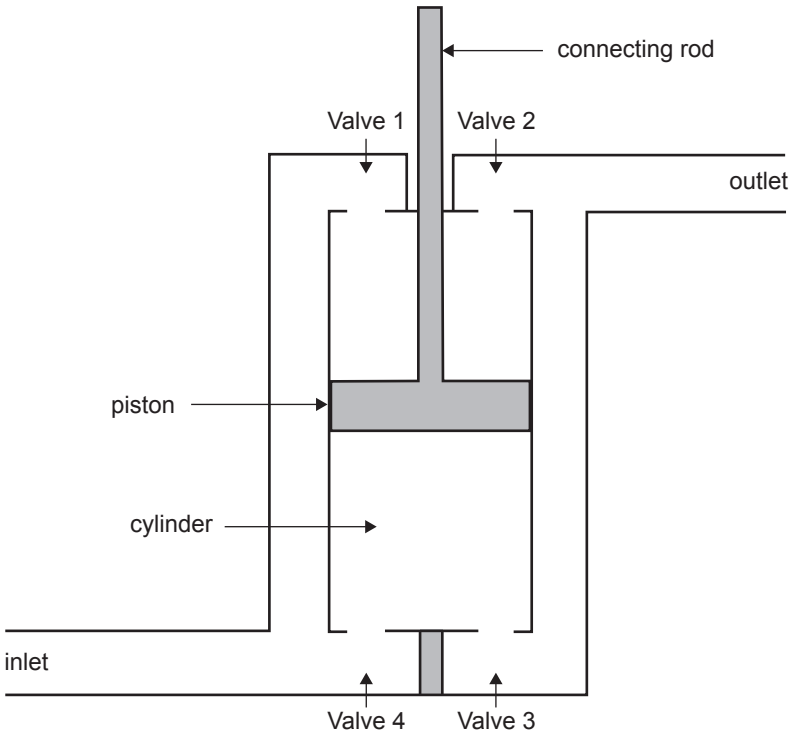


Figure 4

a. On Figure 4, correctly draw the four valves, where indicated by the labels Valve 1, Valve 2, Valve 3 and Valve 4, that will let the water flow from the inlet to the outlet on each stroke. 2 marks

b. In the table below, give the state of each valve (open or closed) as the piston is moving up. 2 marks

Direction of piston	Valve 1	Valve 2	Valve 3	Valve 4
moving up				

c. Calculate the volume of water that goes through the pump in one minute if the piston has a diameter of 50 mm, the stroke of the piston is 50 mm and the pump runs at 40 strokes per minute. Show your working. 2 marks

mm^3

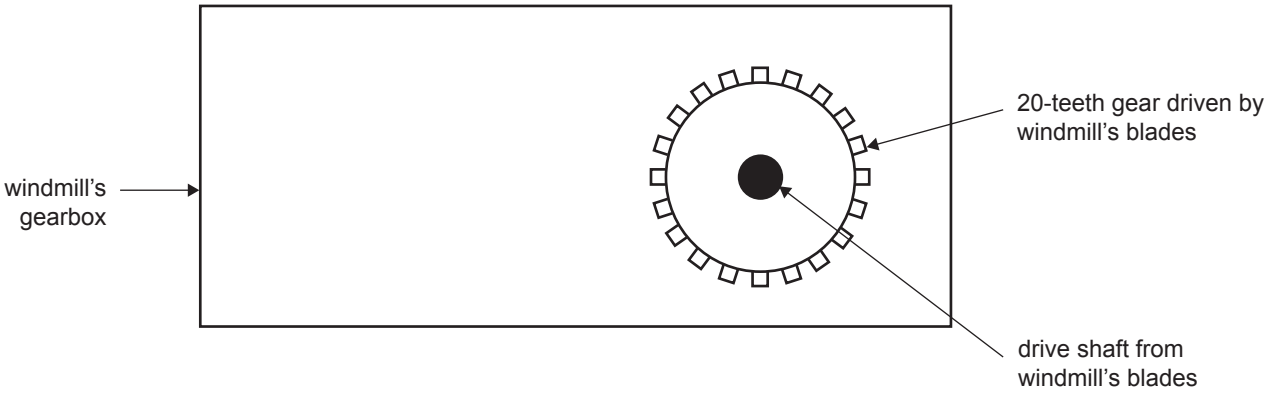
d. Calculate the pressure in the cylinder if the force of the downward stroke on the piston is 50 N. Show your working. 3 marks

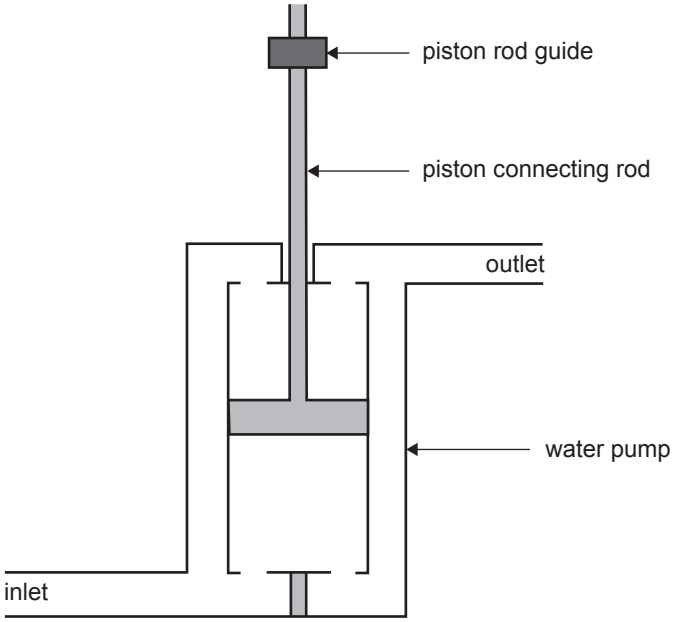
kPa

Question 4 (5 marks)

Emma considers using a windmill to drive the water pump.

On the diagrams provided below, design a mechanism to convert four rotations of motion from the blades of the windmill to one cycle of the piston connecting rod moving up and down. Clearly label all components and dimensions.





Question 5 (6 marks)

Emma decides to make the windmill and water pump system herself.

The table below lists the stages of the Systems Engineering Process.

Letter	Stage of the Systems Engineering Process
A	Test and diagnose/analyse performance.
B	Design and model the system.
C	Re-evaluate, modify and document.
D	Evaluate and report on system produced and processes used.
E	Research feasibility and alternatives.
F	Plan, build and fabricate/integrate subsystems.
G	Identify and document problem/need/opportunity/situation.

Select the most appropriate stage of the Systems Engineering Process for each task given below and write the appropriate letter for that stage next to the task. Only one stage per task is allowed.

Task	Letter for stage
Find out the volume of water and the height that the water needs to be raised.	
Cost a windmill and water pump.	
Trial the operation of the water pump.	
Generate a parts list and formulate a timeline.	
Test the operation of the windmill and water pump.	
Assess the final operation of the windmill against the design criteria.	

Question 6 (16 marks)

Emma decides to use low-voltage DC to provide power to her house. In making her decision, Emma explores the implications of using a 12 V rail or a 24 V rail. One factor in her decision is the resistance of the wire used.

Different areas of the house have separate circuits. Emma decides to put all of the 10 living room lights on one circuit. Emma investigates using a 12 V supply and 12 V light globes. When all of the living room lights are on, the circuit draws 20 A. Emma initially considers using wire rated with a maximum constant current flow of 20 A and a resistance of 0.005 Ω/m.

a. Give **two** variables that affect the resistance of a wire. 2 marks

b. If the resistance of the living room wire is 0.15 Ω, calculate the length of wire used for the living room circuit. 1 mark

m

c. What is the voltage drop across the wire when all of the living room lights are turned on? Show your working. 2 marks

V

d. Calculate the voltage drop across the light globes when all of the living room lights are turned on. 1 mark

V

e. Emma performed an experiment to check her calculations. She connected a 12 V light globe and a 12 V supply using wire with a resistance of 0.15 Ω in a circuit. This resulted in a voltage drop of 11.85 V across the light globe and a current of 1 A through the circuit.

Why is this voltage drop different from your answer in **part d.**? Use calculations to justify your response. 3 marks

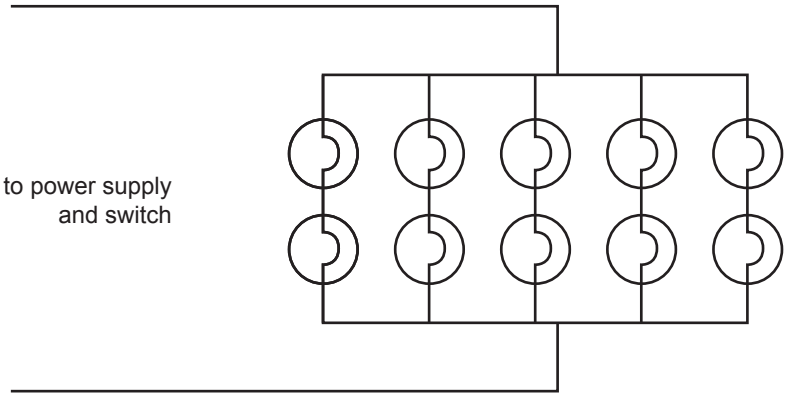


Figure 5

f. Emma considers using a 24 V supply. She connects pairs of the 12 V light globes in the living room in series, as shown in Figure 5.

Assuming the rest of the wiring from the power supply to the switch is the same, calculate

i. the current through the new circuit 1 mark

A

ii. the voltage across each light globe. Show your working. 2 marks

V

g. Calculate the efficiency of a circuit that has a 12 V supply and 11.85 V across the load. Show your working. 2 marks

h. Calculate the total power used by the 12 V circuit. Show your working. 2 marks

W

Question 7 (7 marks)

Emma wants to install a hall light that can be turned on or off by two separate switches. Table 1 shows how the hall light changes with various settings of Switch A and Switch B.

Table 1

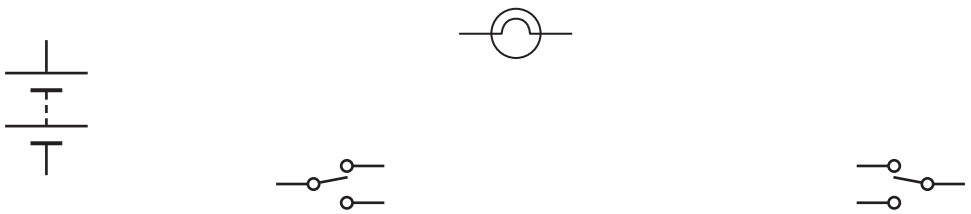
Switch A	Switch B	Light
open	open	off
open	closed	on
closed	open	on
closed	closed	off

a. What logic gate would the information given in Table 1 represent? 1 mark

_____

b. Sketch the symbol for the logic gate in **part a.** 1 mark

c. In the space below, draw a circuit in which Emma could use either of the two single-pole double-throw switches to turn the hall light on and off. 2 marks



d. Write a program or draw a flow chart that uses the state of Switch A and Switch B to represent turning the hall light on and off. 3 marks

Question 8 (13 marks)

Emma has some appliances that operate at 240 V AC. She wants to operate these appliances using electricity generated by solar panels.

A systems diagram is given in Figure 6 below.

Figure 6

a. Why is Figure 6 an open-loop system? 1 mark

b. What is the name of the subsystem Block A? 1 mark

c. Write the purpose of each subsystem in the table below. 3 marks

Subsystem	Purpose
solar panels	
batteries	
Block A	

d. Emma uses a 240 V, 1 kW vacuum cleaner for 30 minutes.

How much energy does she use? Show your working. 2 marks

kWh

e. The solar panels have an efficiency of 80%, the batteries are 90% efficient and the components in Block A are 45% efficient.

Calculate the total efficiency of the system. Show your working. 2 marks

%

f. Emma needs to produce an average of 12 kWh of energy per day.

If the sun shines for an average of six hours per day and there are 10 solar panels, calculate the power rating of each solar panel for an average day. Show your working. 2 marks

kW

g. The batteries have a nominal voltage of 12 V and a capacity of 250 Ah.

How many of these batteries are required to store 12 kWh of energy? Show your working. 2 marks

Question 9 (5 marks)

Facial recognition is a software application that is capable of identifying or verifying a person's identity using key facial features. The technology is used in passports and device security, among other things.

Apart from the applications mentioned above, describe **one** possible application of facial recognition systems and the possible implications of this application for society.

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 = $\frac{\text{output energy}}{\text{input energy}} \times 100\%$	
gear ratio = $\frac{\text{number of teeth on driven gear}}{\text{number of teeth on driver gear}}$		$\text{efficiency}_{\text{Total}} = \text{efficiency}_1 \times \text{efficiency}_2$	
$\frac{\text{gear A rpm}}{\text{gear B rpm}} = \frac{\text{number of teeth gear B}}{\text{number of teeth gear A}}$		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 × area	
voltage = current × resistance		torque = force × distance	
power = voltage × current		frequency = $\frac{1}{\text{period}}$	
area of circle = πr^2 ($\pi = 3.14$)		speed = $\frac{\text{distance}}{\text{time}}$	
circumference of circle = $2\pi r$			
resistors in series	$R_t = R_1 + R_2 + R_3 + \ldots$	capacitors in series	$\frac{1}{C_t} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} \ldots$
resistors in parallel	$\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \ldots$	capacitors in parallel	$C_t = C_1 + C_2 + C_3 + \ldots$
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%

END OF FORMULA SHEET