VICTORIAN CURRICULUM AND ASSESSMENT AUTHORITY

Victorian Certificate of Education 2020

SUPERVISOR TO ATTACH PROCESSING LABEL HERE

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

SYSTEMS ENGINEERING

Written examination

Monday 30 November 2020

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	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 28 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.

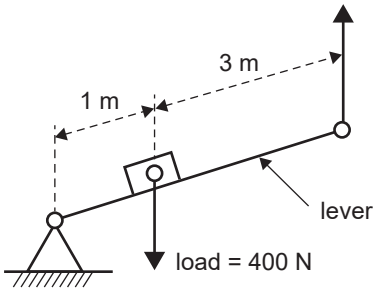
SECTION A – Multiple-choice questions

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

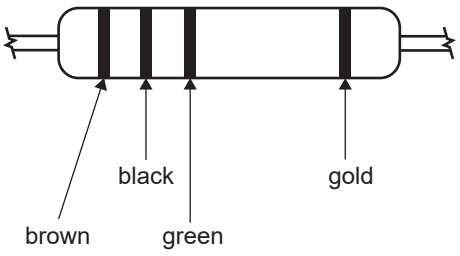
The lever in the diagram shown below is used to lift a load of 400 N.



The mechanical advantage of the lever is

A. 4
B. 3
C. 0.33
D. 0.25

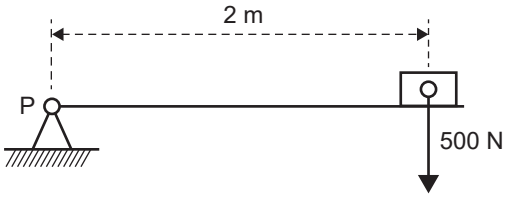
Question 2



What is the value of the resistor shown in the diagram above?

A. 1 kΩ
B. 10 kΩ
C. 1 MΩ
D. 100 kΩ

Question 3



The moment of the force F = 500 N about the point P in the diagram shown above is

A. 2 N m
B. 250 N m
C. 500 N m
D. 1000 N m

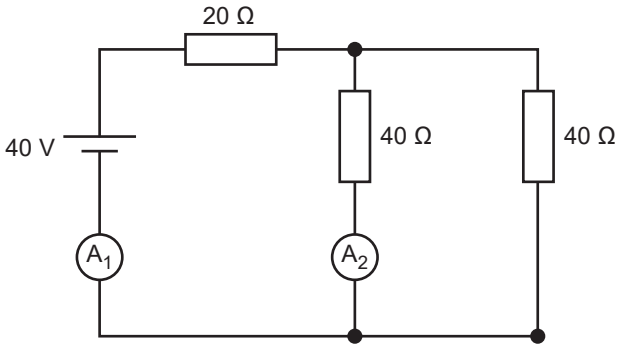
Question 4

Which one of the following is a DC motor that moves in discrete steps?

A. a dynamo
B. an alternator
C. a stepper motor
D. a brushless motor

Question 5

A schematic diagram for an electronic circuit is shown below.



The electric current through ammeters A_1 and A_2 is respectively

A. $I_{A_1} = 1$ A and $I_{A_2} = 1$ A
B. $I_{A_1} = 1$ A and $I_{A_2} = 0.5$ A
C. $I_{A_1} = 0.5$ A and $I_{A_2} = 0.5$ A
D. $I_{A_1} = 0.5$ A and $I_{A_2} = 0.25$ A

Question 6

A 4K7 resistor has a gold tolerance band.

The expected range for this resistor is

A. 3K76 to 5K64

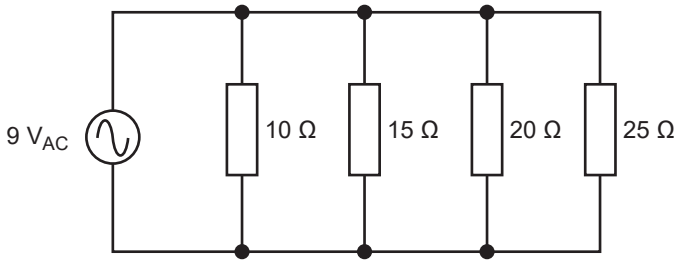
B. 4K23 to 5K17

C. 4K47 to 4K94

D. 4K61 to 4K79

Question 7

The circuit below shows four load resistors that are connected to a 9 V_{AC} power supply.



Which load resistor will dissipate the largest amount of energy in a 10-minute period?

A. 10 Ω

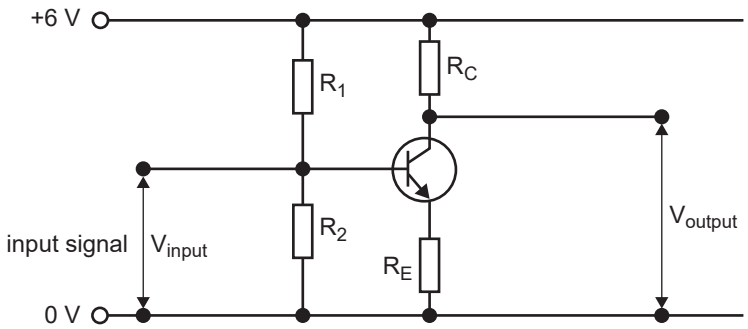
B. 15 Ω

C. 20 Ω

D. 25 Ω

Question 8

A schematic diagram of a simple transistor amplifier circuit is shown below.



To increase the efficiency of this transistor amplifier circuit, what must be reduced?

A. the size of the input signal V_{input}

B. the size of the output signal V_{output}

C. the losses in the transistor amplifier circuit

D. the length of time that the transistor amplifier operates

Question 9

The main purpose of using a three-dimensional (3D) modelling tool prior to fabricating and assembling the components of an engineering system is to

A. ensure that the system is visually appealing.

B. ensure compliance with occupational health and safety (OH&S) requirements.

C. select the cheapest materials for fabricating components.

D. identify potential issues or problems with the system design.

Question 10

Which one of the following is an example of a technological development used by coal-fired power stations to reduce their environmental impact?

A. burning off captured gases

B. using carbon capture and storage

C. using brown coal instead of black coal

D. applying thin-film solar photovoltaic technology

Question 11

The evaluation of a systems engineering solution involves an examination of its features and/or functions.

Why is it necessary to conduct an evaluation of a systems engineering solution?

A. to ensure that the solution looks good

B. to determine whether the solution will work

C. to determine the cost effectiveness of the solution

D. to determine how well the solution satisfies the design brief

Question 12

The forms of renewable energy that would be available in Victoria's inland regions are

A. wind, tidal, wave, hydro-electric.

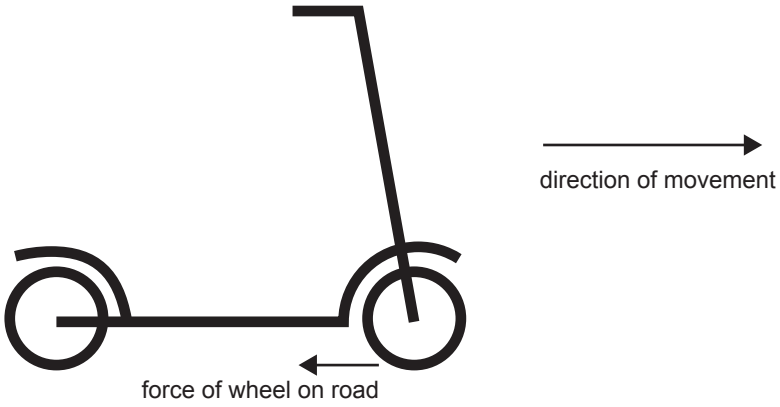
B. solar, hydro-electric, biomass, tidal.

C. wind, solar, hydro-electric, biomass.

D. solar, geothermal, wave, biomass.

Question 13

The electric scooter shown in the diagram below is travelling to the right. When accelerating, the wheel exerts a force on the road, as shown.



Which one of the following shows the direction of the corresponding action–reaction force according to Newton's third law?

A. ←

B. ↑

C. ↗

D. →

Question 14

A shopper needs to go to a store one level up in a shopping centre and is carrying 10 kg of purchased items in a shopping bag. The shopper has three options for going up one level:

- a lift
- a set of stairs
- a 20 m ramp

Which one of the following best describes the work that would be done on the shopping bag as the shopper goes up one level in the shopping centre?

A. greatest for the stairs

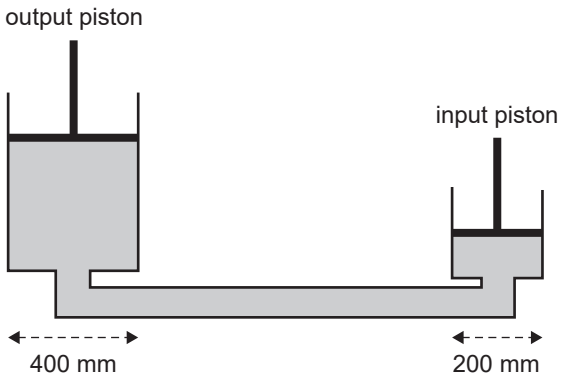
B. equal for all options

C. greatest for the ramp

D. greatest for the lift

Question 15

An output piston and an input piston are connected in a hydraulic system, as shown in the diagram below. The output piston has a diameter of 400 mm and the input piston has a diameter of 200 mm.

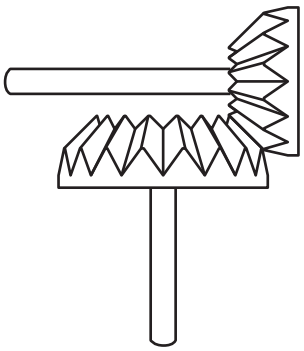


If a force of 100 N is applied by the input piston, what is the force on the output piston, correct to the nearest newton?

A. 25 N
B. 50 N
C. 200 N
D. 400 N

Question 16

The gear system shown in the diagram below is used to change the plane of drive shafts.

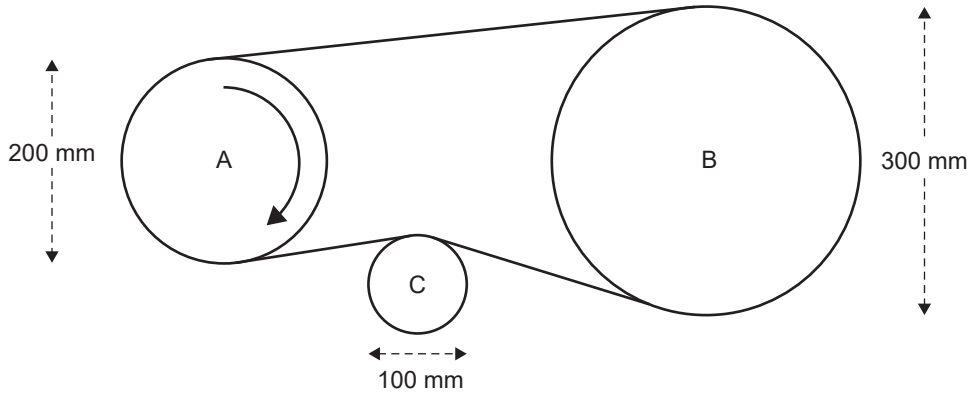


This type of gear system is known as a

A. bevel gear.
B. spur gear.
C. worm gear.
D. compound gear.

Question 17

Two pulleys, A and B, are connected by a belt, as shown in the diagram below. Pulley A has a diameter of 200 mm and Pulley B has a diameter of 300 mm. An additional pulley, Pulley C, is used as a tensioner. Pulley C has a diameter of 100 mm.



If Pulley A rotates clockwise at 200 revolutions per minute (rpm), in what direction will Pulley C rotate and at how many revolutions per minute?

A. clockwise at 200 rpm

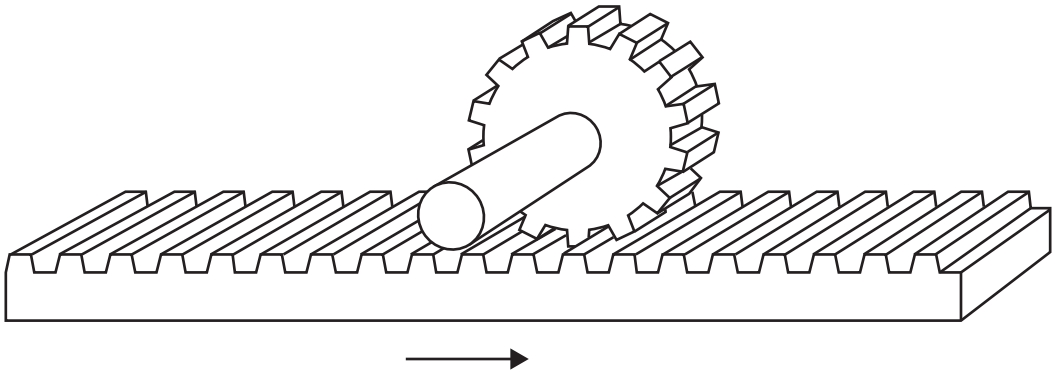
B. clockwise at 400 rpm

C. anticlockwise at 200 rpm

D. anticlockwise at 400 rpm

Question 18

The diagram below shows a rack and pinion gear.



What is the purpose of using a rack and pinion gear?

A. changing clockwise motion to anticlockwise motion

B. changing linear motion to rotational motion

C. increasing torque

D. decreasing torque

Question 19

Safety in the workshop should be a high priority in any engineering workshop.

Which of the following lists common workshop safety actions in the correct order to minimise risk?

	1st action	2nd action	3rd action	4th action	5th action
A.	Identify tools.	Identify risks.	Use tools.	Identify areas for improvement.	Document changes.
B.	Use tools.	Identify tools.	Identify risks.	Document changes.	Identify areas for improvement.
C.	Document changes.	Identify risks.	Use tools.	Identify tools.	Identify areas for improvement.
D.	Identify tools.	Identify areas for improvement.	Use tools.	Document changes.	Identify risks.

Question 20

The energy of water stored in a dam is to be used to generate electricity using a small turbine generator.

Which of the following indicates the main energy transformations in the system as electricity is generated?

A. electrical → mechanical → potential

B. kinetic → mechanical → electrical

C. potential → kinetic → electrical

D. kinetic → electrical → potential

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 (2 marks)
Figure 1 is a block diagram of an automated and controlled system.

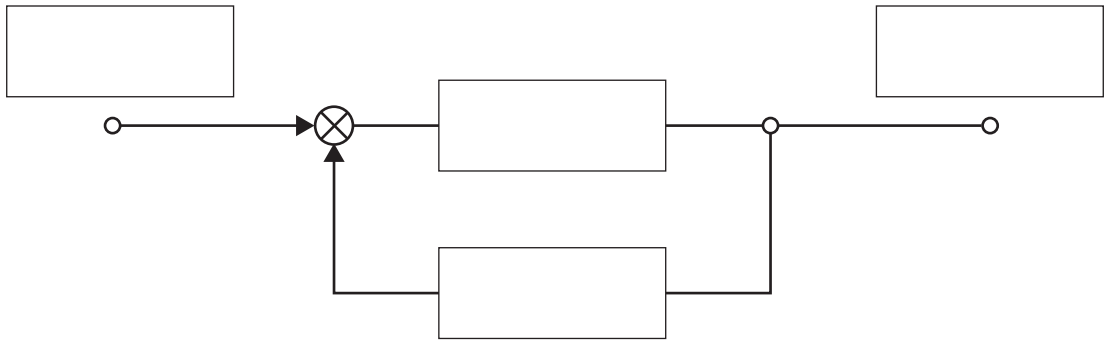


Figure 1

Using the list of terms below, complete the block diagram by writing the appropriate term in each of the boxes provided.

input feedback system output

Question 2 (6 marks)

An electric motor, M, is used to pull a load on an inclined plane, as shown in Figure 2.

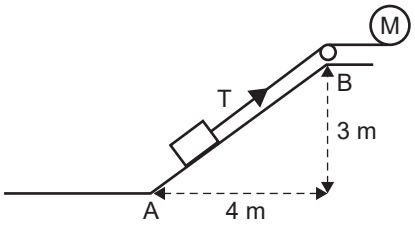


Figure 2

a. The required mechanical work to move the load from point A to point B is 3000 J.

Calculate the force, T, required by the electric motor to pull the load from point A to point B. Show your working. 2 marks

N

b. The electrical energy used by the electric motor to lift the load is 3192 J.

Calculate the efficiency of moving the load from point A to point B. Give your answer correct to the nearest whole number. Show your working. 2 marks

%

c. Calculate the mass of the load using $g = 10 \text{ m s}^{-2}$. Show your working. Use the following formula. 2 marks

force = mass × acceleration due to gravity

kg

Question 3 (10 marks)

Figure 3 shows a schematic diagram for an electric circuit. The voltage of the power supply is 30 V_{DC}, and the resistors R_1, R_2 and R_3 are all 60 Ω.

Initially the switch, S, is open.

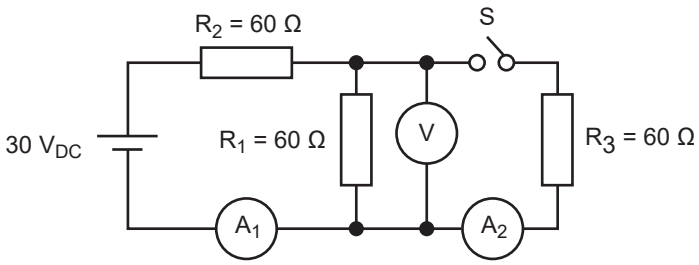


Figure 3

a. Calculate the expected readings on the voltmeter, V, and the ammeters, A_1 and A_2. Show your working. 4 marks

Voltmeter V ____ V

Ammeter A_1 ____ A Ammeter A_2 ____ A

b. After a period of correct functioning, a component in the circuit develops a fault. Due to this fault, the reading on voltmeter V becomes 30 V and the reading on ammeter A_1 becomes 0 A.

Identify the faulty component. Give your reasoning. 3 marks

c. After replacing the faulty component, the switch is closed.

What is the power dissipated by resistor R_1 with the switch closed? Show your working. 3 marks

W

Question 4 (3 marks)

In the table below, draw the electric/electronic symbol for each of the components listed.

Component	Electric/electronic symbol
battery	
PNP transistor	
variable DC power supply	
capacitor	
light-emitting diode (LED)	
light-dependent resistor (LDR)	

Question 5 (4 marks)

A solar energy storage system provides power for a night light, as shown in Figure 4.

The storage system relies on a capacitor, X, to store charge.

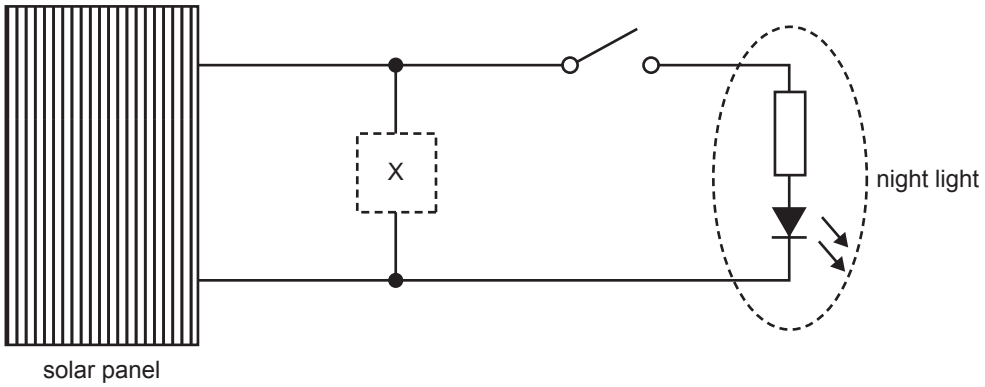


Figure 4

a. Describe the type of capacitor that would be best suited to this application. Give your reasoning. 2 marks

b. What is the purpose of the resistor connected in series to the light source? Give your reasoning. 2 marks

Question 6 (7 marks)

The cooling unit of a small refrigerator is controlled by a thermistor using the circuit shown in Figure 5.

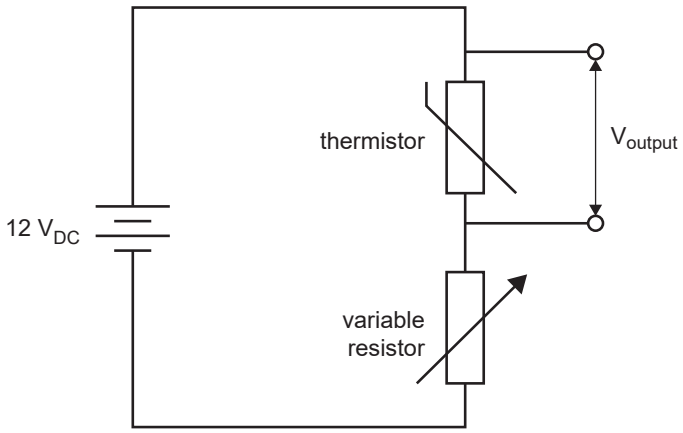


Figure 5

a. Explain the function of the variable resistor. 2 marks

b. On Figure 5, indicate where an ammeter should be located to measure the current flowing through the thermistor. 1 mark

c. If the variable resistor is set at 1 kΩ and V_{output} = 4 V, calculate the power consumed by the variable resistor. Show your working. You must include the unit. 4 marks

Question 7 (6 marks)

Ben has designed and built a scaled version of a rescue robot for retrieving injured children. His project uses a winch subsystem that is connected to a 12 V_{DC}-powered motor via a chain and sprocket mechanism. This rescue robot is shown in Figure 6.

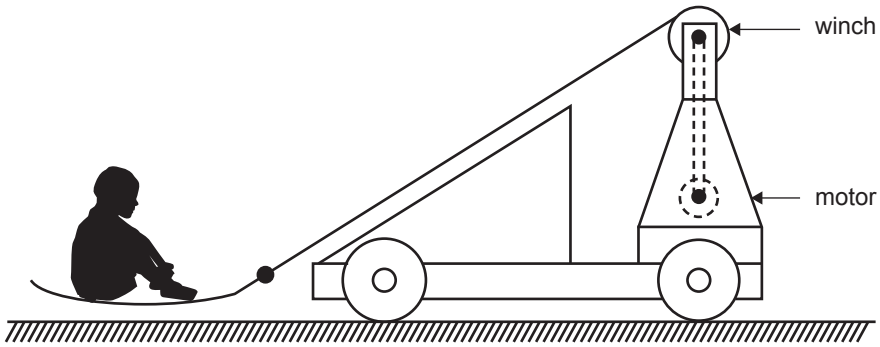


Figure 6

a. Explain why Ben should design and model the rescue robot's subsystem. 2 marks

b. Propose **one** appropriate diagnostic test that Ben should consider for the motorised chain and sprocket mechanism. Give your reasoning. 2 marks

c. Evaluation is an important part of the systems engineering process.

i. Why is it important for Ben to evaluate his rescue robot subsystem? 1 mark

ii. When should Ben evaluate his rescue robot subsystem? 1 mark

Question 8 (5 marks)

Figure 7 shows a typical wind farm used to generate renewable energy.

Source: Premier of Victoria (website), 'Ararat wind farm powering ahead', media release, 27 June 2017; © State of Victoria

Figure 7

a. What type of current would the wind turbines shown in Figure 7 typically produce? 1 mark

b. Identify **two** features of the wind turbine that could be modified to improve its efficiency. 2 marks

c. Explain **one** way in which computer simulation software can assist engineers in the design of wind turbine blades. 2 marks

Question 9 (3 marks)

A robotic pool cleaner has a power rating of 2000 W and the motor is supplied from the main power supply using a transformer. Four processes, including one unknown process, run by the robotic pool cleaner are listed in the table below with their respective power consumptions.

Robotic pool cleaner process	Power consumption
motor drive	1000 W
water pump	650 W
sound from the motor or transformer	45 W
unknown	305 W

a. Suggest **one** possible robotic pool cleaner process for the unknown process listed in the table above. 1 mark

b. Calculate the overall efficiency of the robotic pool cleaner system if the motor drive and the water pump are considered useful processes. Show your working. 2 marks

%

Question 10 (6 marks)

Figure 8 shows part of a simple steering system using a worm drive and levers to change the direction of the front wheels on a car.

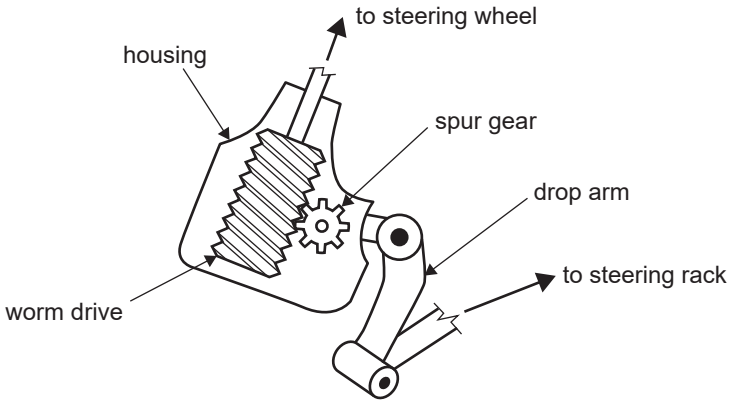


Figure 8

a. State **one** advantage of using the worm drive as the initial input to the steering system. 1 mark

b. If the spur gear had seven working teeth, with only one tooth meshing with the worm drive at any time, what is the gearbox ratio? 1 mark

c. The steering mechanism shown in Figure 9a is simplified into the lever shown in Figure 9b.

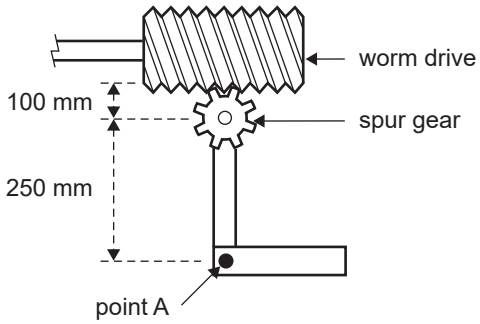


Figure 9a

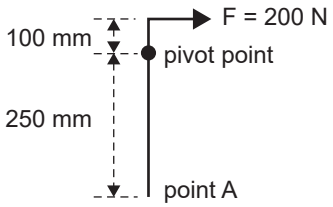


Figure 9b

When the driver of the car turns the steering wheel, the force exerted on the spur gear is 200 N, as shown in Figure 9b.

Calculate the force at point A on the steering arm. Show your working. You must include the unit. 4 marks

Question 11 (5 marks)

Jemma has designed a small electric motor-driven car as part of a school project to investigate drive mechanisms. She has used a rubber band belt drive system to connect the motor to the wheels, as shown in Figure 10.

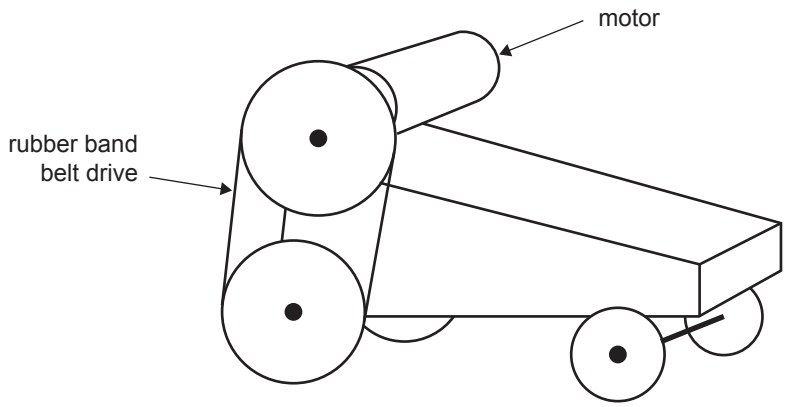


Figure 10

a. What is **one** advantage of using a rubber band belt drive system for a small electric motor-driven car? 1 mark

A close-up of the rubber band belt drive system is shown in a modified set-up in Figure 11. The speed of the wheel is 40 revolutions per minute (rpm).

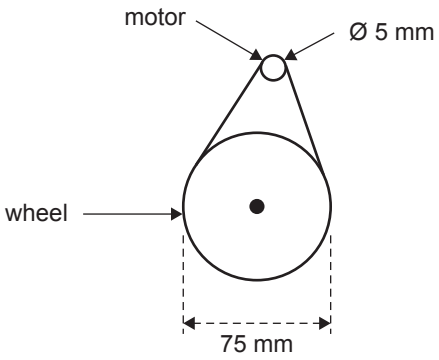


Figure 11

b. Use the information given in Figure 11 to answer the following questions.

i. Calculate the expected speed of the small electric motor-driven car in metres per minute. Show your working. 2 marks

m min^{-1}

ii. Convert your answer from **part b.i.** to metres per second. Show your working. 1 mark

m s^{-1}

c. Jemma would like the small electric motor-driven car to be able to reach a higher maximum speed.

Suggest **one** change Jemma could make to her car to achieve this. 1 mark

Question 12 (7 marks)

Figure 12 shows a cross-sectional front view of a sewing machine. The sewing machine uses a belt to connect the motor to the drive wheel, as shown.

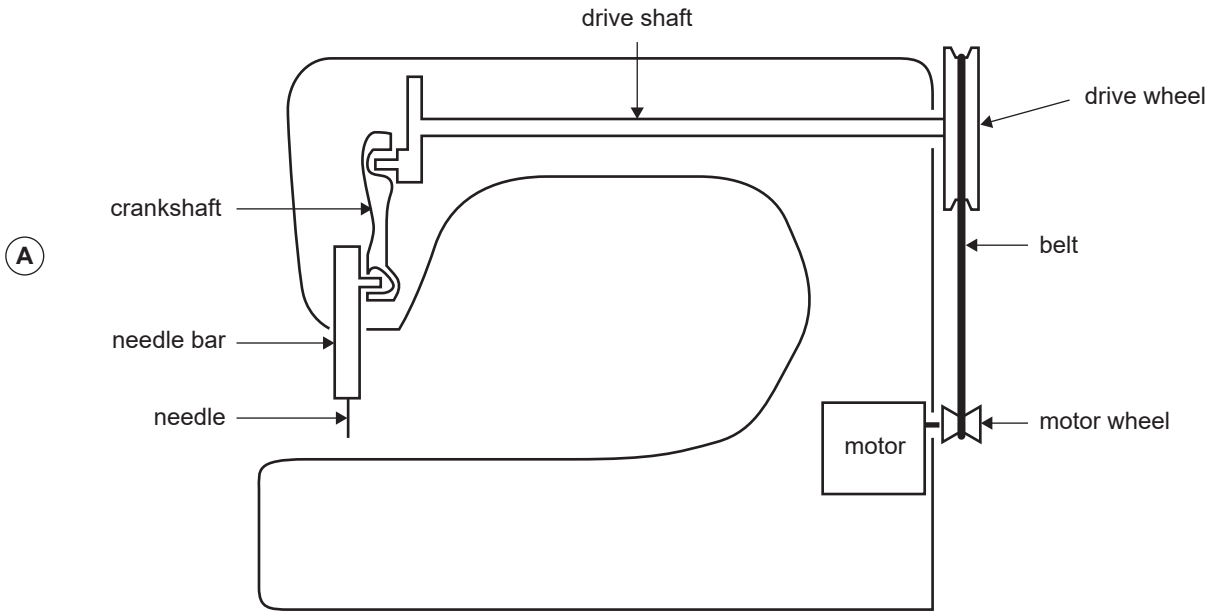


Figure 12

a. Describe the role of friction between the belt and the drive wheel. 2 marks

b. The motor wheel has a diameter of 20 mm. The drive wheel has a diameter of 180 mm.

Calculate the rotation speed of the motor wheel for the drive wheel to spin at 150 rpm. Show your working. 2 marks

rpm

c. Figure 13 shows a cross-sectional view looking from point A in Figure 12 directly at the crankshaft.

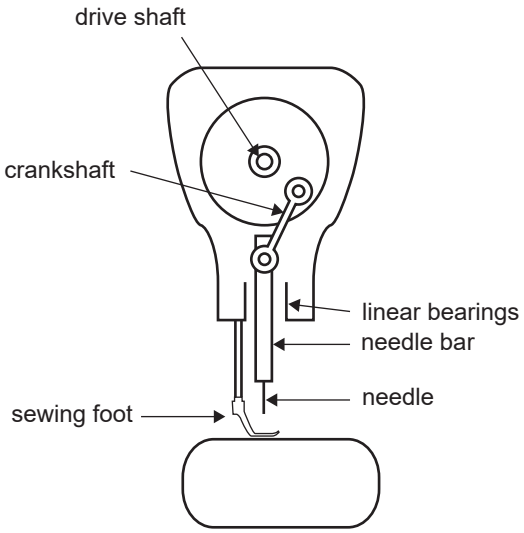


Figure 13

Using the additional information provided in Figure 13, explain how the rotational movement of the motor is transformed into the reciprocating motion of the sewing needle. 3 marks

Question 13 (8 marks)

Charlie is delivering a large heavy box using a tip truck with a tray that can be tilted at an angle, as shown in Figure 14. When unloading the box, he observes that the box does not start moving until the tray is tilted at a certain angle, *A*. As the tray is raised above the angle *A*, the box slides downwards.

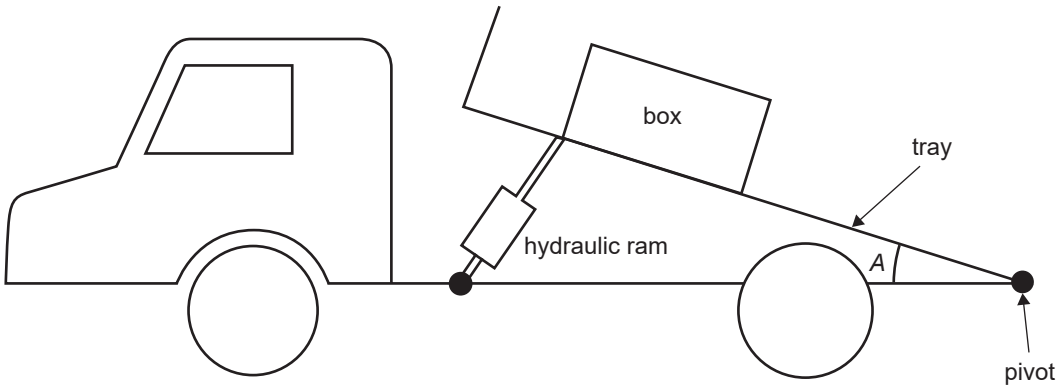


Figure 14

a. What class of lever is the tip truck's tray? 1 mark

b. At the angle *A*, the box starts to move.

Using Newton's laws, explain why this happens. 3 marks

c. The tip truck uses a hydraulic system to raise the tray, as shown in Figure 15.

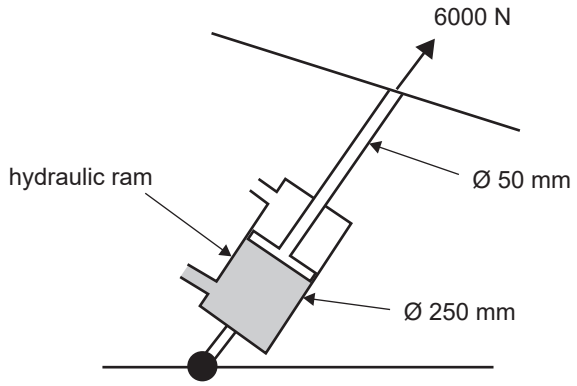


Figure 15

To lift the tray and the box, the piston must exert a force of 6000 N on the underside of the tray.

Calculate the pressure needed in the shaded area of Figure 15 to create the 6000 N force required. Show your working. 2 marks

kPa

d. Figure 16 shows the hydraulic ram in the fully extended position. Two regions of the rod are labelled point B and point C.

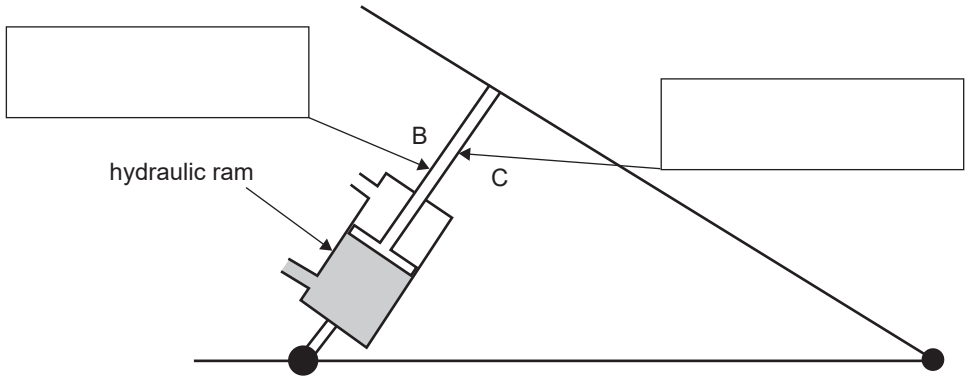


Figure 16

Four types of stress are given below.

tension compression torsion shear

From the options given, select the type of stress on point B and on point C, and write your answers in the boxes provided in Figure 16. 2 marks

Question 14 (3 marks)

Input-process-output (IPO) diagrams can be used to break down any system into smaller parts for analysis. IPO diagrams allow the identification of the inputs and outputs of a system and any processes that take place.

Complete the IPO diagram in Figure 17 for a cordless drill motor system by writing appropriate labels in the boxes provided.

Figure 17

Question 15 (5 marks)

The number of electric vehicles on Australian roads is currently lower than in other developed countries, but the number is expected to grow as cheaper models arrive and more charging infrastructure is built.

Evaluate the potential benefits and challenges of using electric vehicles in Australia in terms of economic and environmental sustainability.

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.

THIS PAGE IS BLANK

Systems Engineering formulas

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