VICTORIAN CURRICULUM AND ASSESSMENT AUTHORITY

Victorian Certificate of Education 2016

SUPERVISOR TO ATTACH PROCESSING LABEL HERE

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

SYSTEMS ENGINEERING

Written examination

Monday 14 November 2016

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	26	26	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 26 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** for 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

When using a bench grinder to repair a flat-blade screwdriver, which combination of personal protective equipment (PPE) is most appropriate?

A. safety glasses, protective clothing and earmuffs
B. safety glasses, earmuffs and leather gloves
C. safety glasses, hairnet and leather gloves
D. safety glasses, hard hat and earmuffs

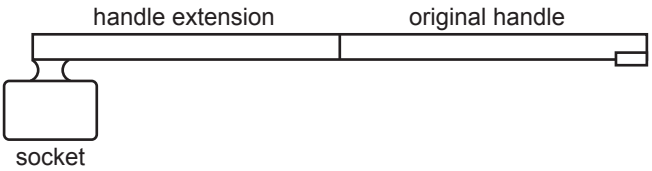
Question 2

During a manufacturing process, a small electrical fire starts.
The most appropriate action to take would be to immediately stop all work and then

A. call out 'Fire!' and leave the workshop.
B. leave the workshop in an orderly manner.
C. look for the nearest fire extinguisher.
D. raise the alarm and use a dry powder extinguisher on the fire.

Question 3

Below is a diagram of a tension wrench that can be extended.



The tension wrench has a handle extension that is equal in length to the original handle.
What should the torque setting be?

A. half
B. double
C. quarter
D. left the same

Question 4

The predominant force acting on the drive shaft of a vehicle is an example of

A. compression.
B. tension.
C. torsion.
D. shear.

Question 5

What is the most important intention of occupational health and safety (OH&S) standards in the workplace?

A. to have an independent officer in workplace safety
B. to make employers responsible for employee safety
C. to make employees responsible for safety in the workplace
D. to protect the safety, health and welfare of everyone in the workplace

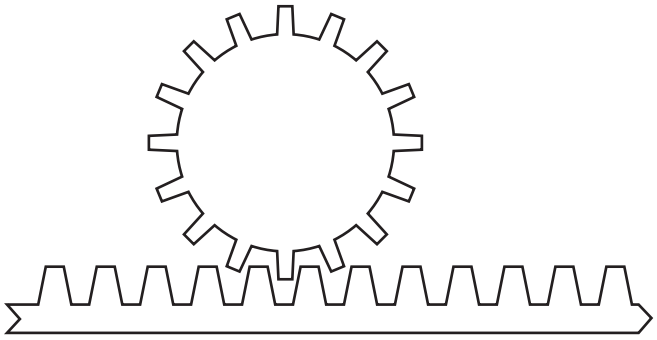
Question 6

Bolts have a recommended torque setting.

Which one of the following gives the best description of what a torque setting indicates?

A. how tight the bolt should be
B. how much the bolt can be stretched
C. the amount of resistance between the bolt and the component
D. how much pressure can be applied to the bolt before it breaks

Question 7



The gears shown above are referred to as

A. spur gears.
B. crown gears.
C. a rack and pinion.
D. an epicycle gear set.

Question 8

Solar cells operate by converting

A. heat to electrical energy.
B. light to electrical energy.
C. biomass to electrical energy.
D. thermal energy to electrical energy.

Question 9

Which one of the following statements about the law of conservation of energy is most accurate?

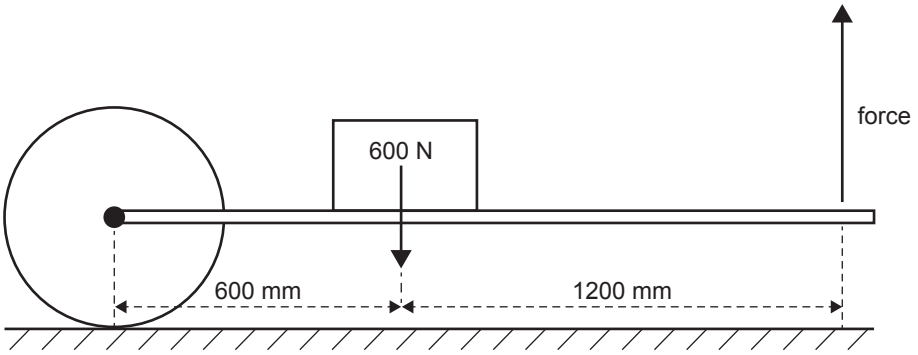
A. Energy can be created but not destroyed.

B. Energy is created and changed from one form into another.

C. Energy is destroyed when changed from one form into another.

D. Energy is not created or destroyed but changed from one form into another.

Question 10



What is the force required to balance the system shown above?

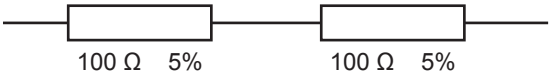
A. 200 N

B. 300 N

C. 600 N

D. 1200 N

Question 11



What would be the maximum reading on an ohmmeter if two 100 Ω 5% resistors are placed in series, as shown above?

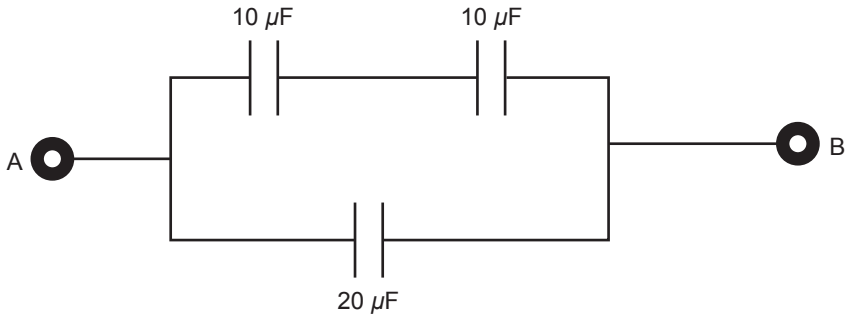
A. 200 Ω

B. 205 Ω

C. 210 Ω

D. 220 Ω

Question 12



What is the equivalent capacitance between points A and B in the network shown above?

A. 10 μF

B. 20 μF

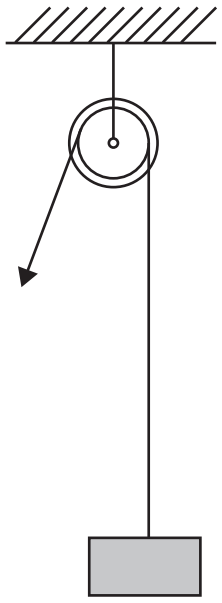
C. 25 μF

D. 40 μF

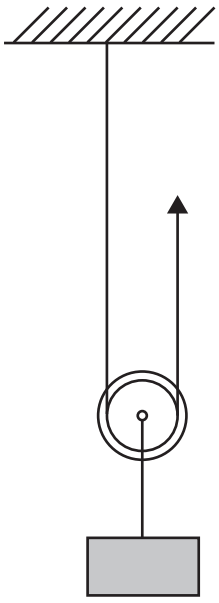
Question 13

Which one of the following pulley systems would have a mechanical advantage of 3:1?

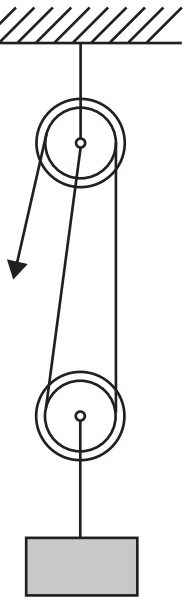
A.



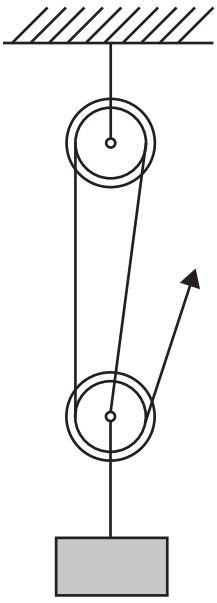
B.



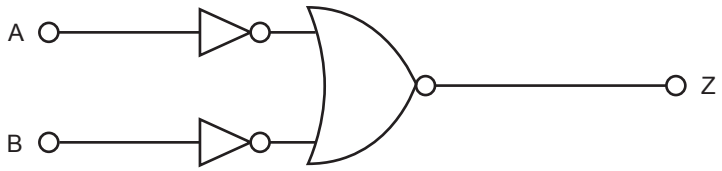
C.



D.



Question 14



Which one of the following is the truth table for the circuit shown above?

A.

A	B	Z
0	0	0
0	1	1
1	0	1
1	1	1

B.

A	B	Z
0	0	0
0	1	1
1	0	1
1	1	0

C.

A	B	Z
0	0	0
0	1	0
1	0	0
1	1	1

D.

A	B	Z
0	0	1
0	1	0
1	0	0
1	1	0

Question 15

What is the smallest equivalent resistance of a network that can be made from a set of four 100 Ω resistors?

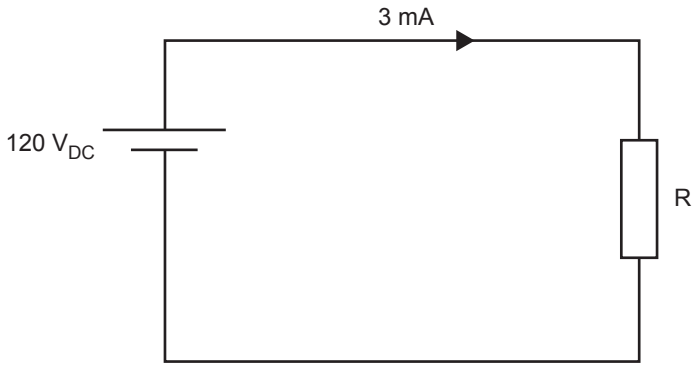
A. 10 Ω

B. 25 Ω

C. 200 Ω

D. 400 Ω

Question 16



What is the resistance of resistor R in the network shown above?

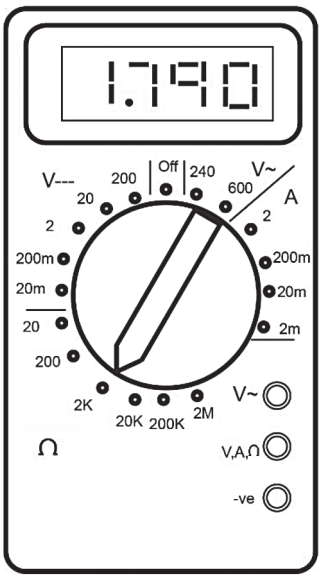
A. 40 Ω

B. 360 Ω

C. 40 kΩ

D. 360 kΩ

Question 17



What is the reading on the multimeter shown above?

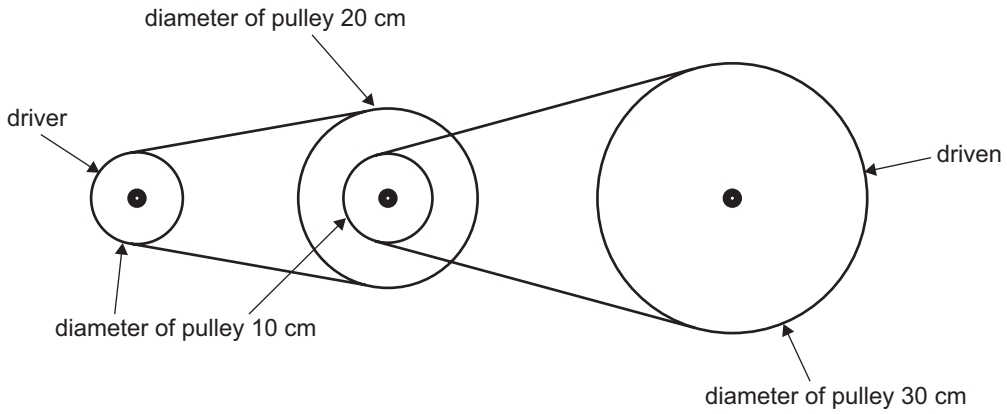
A. 179 kΩ

B. 1790 Ω

C. 179 Ω

D. 1.79 Ω

Question 18



What is the ratio of the pulley system shown above?

A. 6:1

B. 1:6

C. 3:1

D. 1:3

Question 19

The number 278 000 written in engineering notation and accurate to exactly two significant figures is

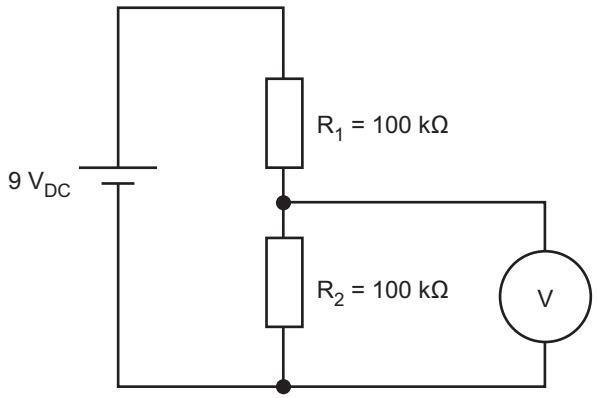
A. 278×10^3

B. 280×10^3

C. 2.78×10^5

D. 2.8×10^5

Question 20



In the circuit shown above, the reading of the voltmeter is 3 V.

The best possible explanation for this is

A. R_2 has a short.

B. R_1 is open circuit.

C. the voltmeter has an internal resistance of 100 kΩ.

D. an ammeter was mistakenly used instead of a voltmeter.

END OF SECTION A

CONTINUES OVER PAGE

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.

Carmen decided to buy a yacht and travel around Phillip Island. Figure 1 shows the main features of Carmen's yacht.

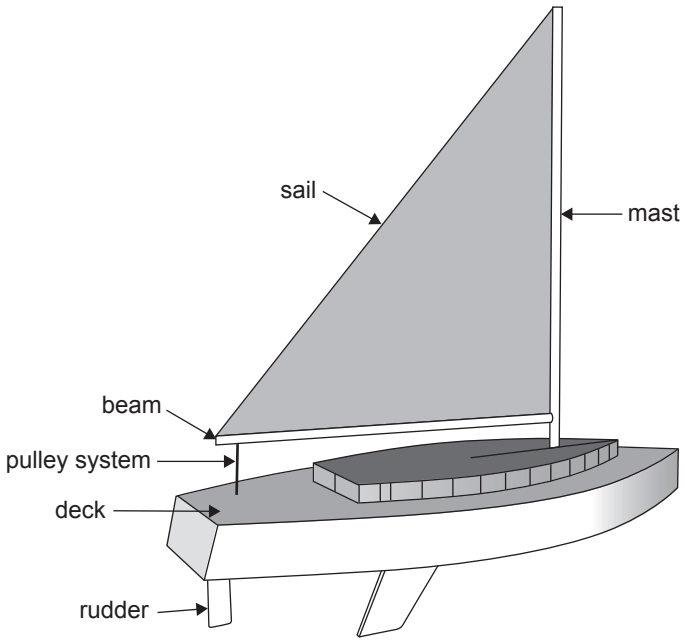


Figure 1

Question 1 (1 mark)

What type of energy powers a yacht under sail to move?

Question 2 (4 marks)

a. Label the effort, load and fulcrum in the spaces provided on Figure 2 below. 3 marks

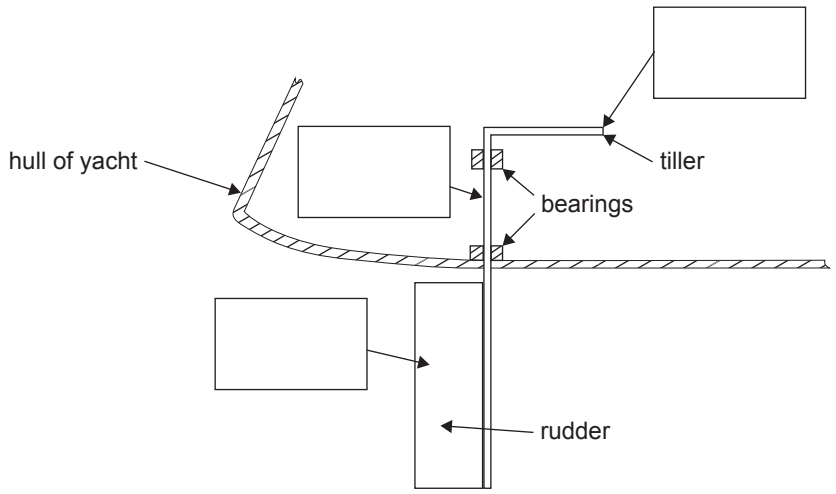


Figure 2

b. What class of lever is the rudder in Figure 2? 1 mark

_____

A rope and simple winch can be used to control the angle of the sail. When winding the handle, Carmen can produce a maximum force of 400 N on the handle.

Figure 3 shows a simple winch system.

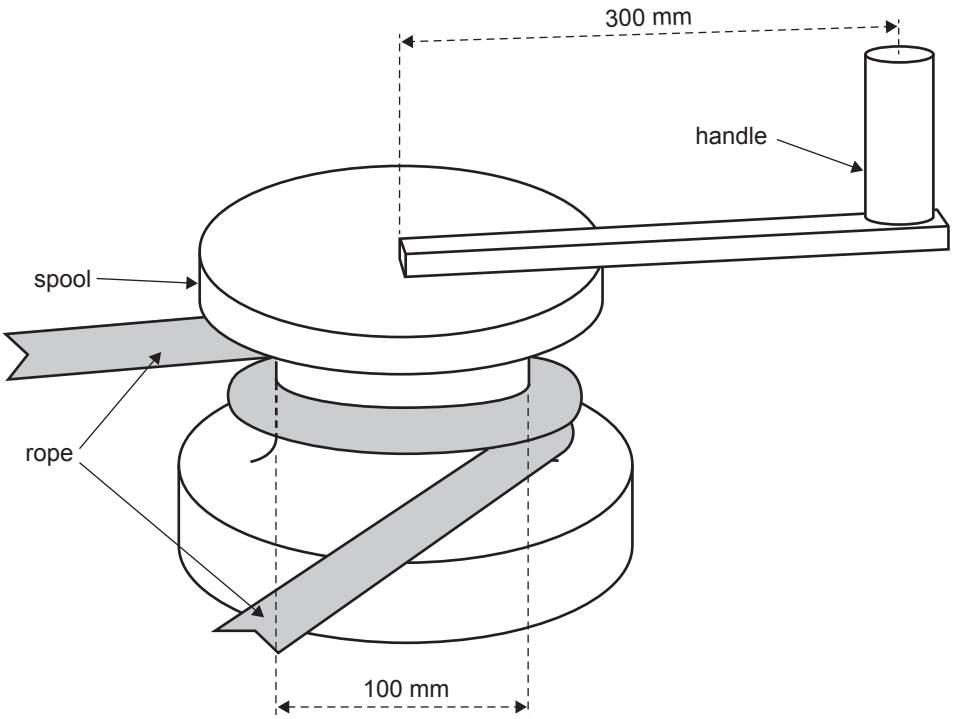


Figure 3

Question 3 (4 marks)

a. Calculate the torque produced by Carmen in the simple winch system shown in Figure 3. Show your working. 2 marks

Nm

b. Calculate the maximum force applied to the rope in Figure 3. Show your working. 2 marks

N

Question 4 (3 marks)

a. Name a device that Carmen could use to stop the winch from unwinding. 1 mark

b. Explain, using technical terms, how the device named in **part a.** works. 2 marks

Carmen found that she needed to apply a greater force on the sail than she could on her own, so she decided to use a pulley system. Figure 4 shows a simple pulley system.

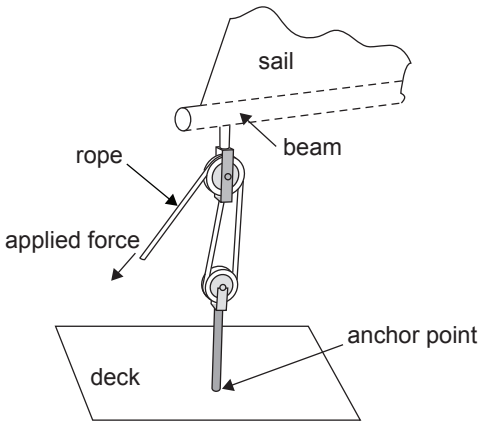


Figure 4

Question 5 (1 mark)

If a force of 400 N was applied to the rope, what would be the force on the sail?

N

Question 6 (2 marks)

An alternative to the set-up shown in Figure 4 is to place the anchor point halfway between its present position and the mast, as shown in Figure 5 below.

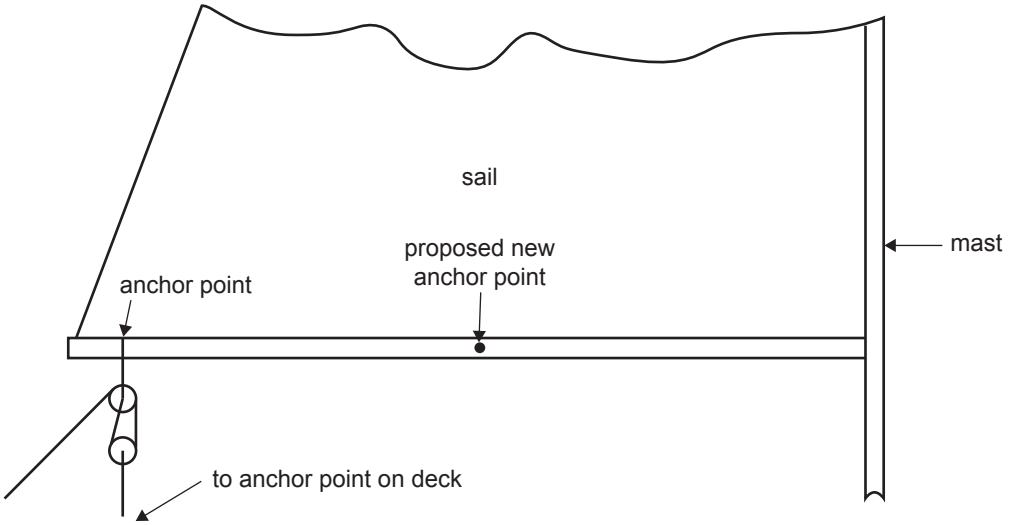


Figure 5

Is the proposed set-up shown above more efficient than the original set-up? Explain your answer.

Question 7 (1 mark)

As wind can be unpredictable, Carmen attached a motor to the stern of her yacht. The motor is to be raised and lowered using a hydraulic system. Figure 6 shows the flow of hydraulic fluid from the hydraulic pump to the hydraulic cylinder. The shaded region shows the hydraulic fluid that is under pressure.

Indicate the direction in which the piston rod will move by drawing an arrow in the box below.

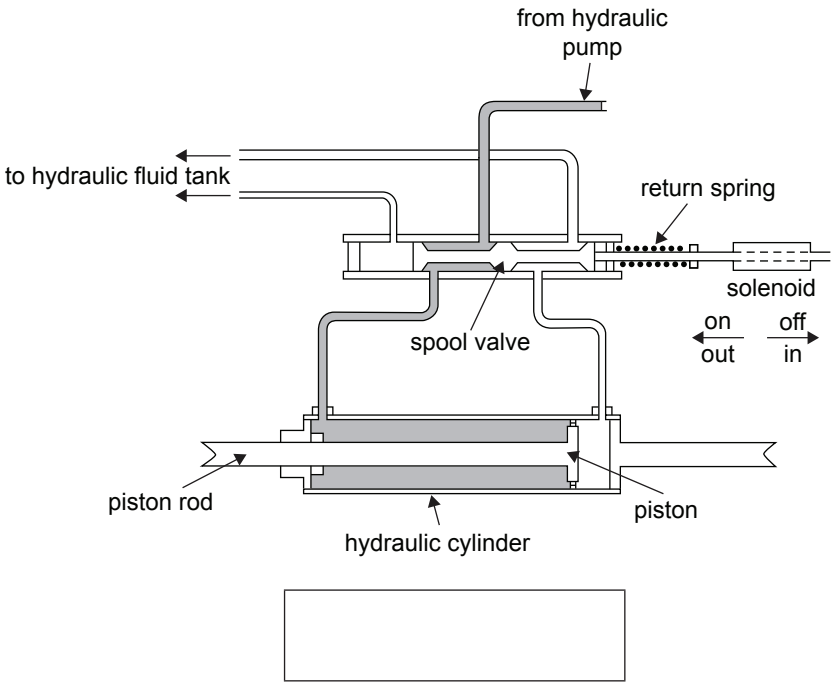


Figure 6

Question 8 (2 marks)

On Figure 7, draw the path, using a line with arrows, that indicates the hydraulic fluid flow from the hydraulic pump **and** from the hydraulic cylinder as the piston goes to the left.

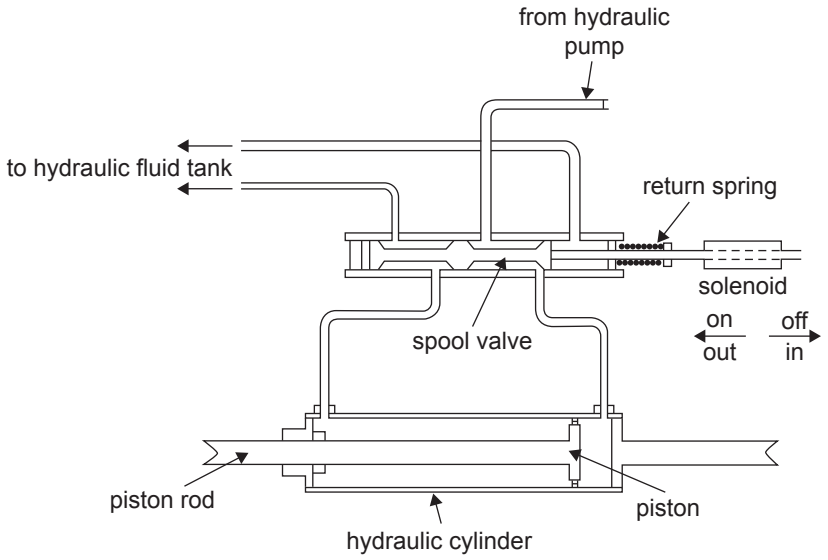


Figure 7

Question 9 (5 marks)

In Figures 6 and 7, the inner diameter of the hydraulic cylinder is 60 mm and the diameter of the piston rod is 20 mm. The pressure from the hydraulic pump is 200 kPa.

a. Calculate the force on the piston rod when the piston is moving to the left. Show your working. 2 marks

N

b. Calculate the force on the piston rod when the piston is moving to the right. Show your working. 3 marks

N

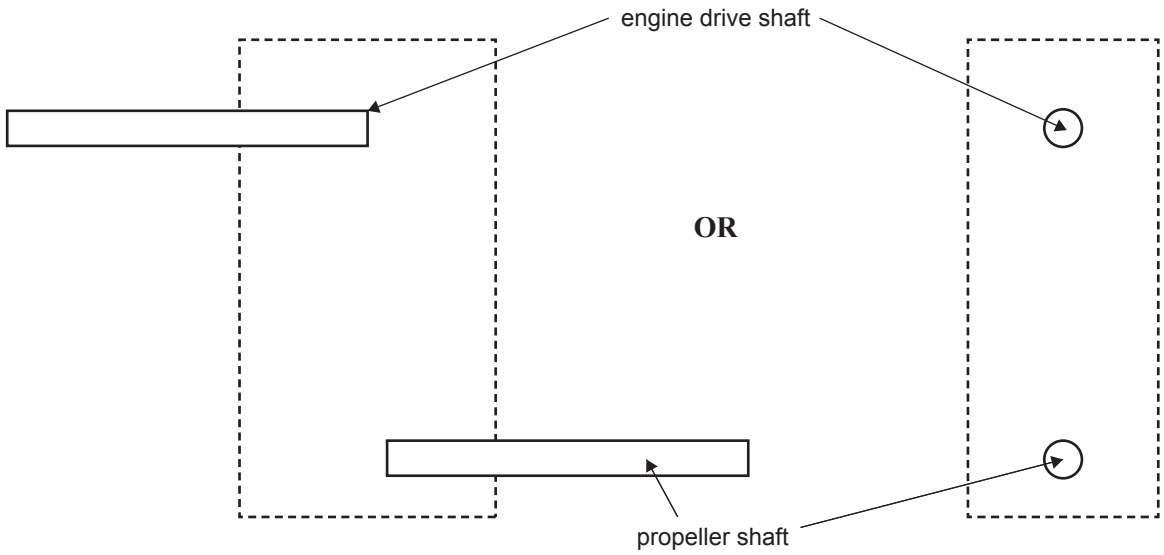
Question 10 (4 marks)

The energy produced by the motor needs to be transferred to the propeller.

Design a system to drive the propeller in the same direction as the engine and six times as fast as the engine. You may use bevel gears, sprockets and/or spur gears with 10 teeth, 20 teeth, 30 teeth or 40 teeth. A chain or another shaft may also be used.

Use **either** the side view **or** the front view diagram provided below for your answer. Label your design on the diagram.

Side view **Front view**



Question 11 (3 marks)

a. Name two stages that should be undertaken in managing and developing a Systems Engineering project. 2 marks

1. _____

2. _____

b. Choose one of the stages named in **part a.** and outline what is involved at this stage. 1 mark

Stage _____

Outline _____

Question 12 (1 mark)

Carmen finds it useful to know the wind speed relative to the yacht. An anemometer is a simple device used to measure wind speed. Figure 8 shows a simple anemometer.

Draw an arrow to show the direction of rotation of the anemometer in Figure 8.

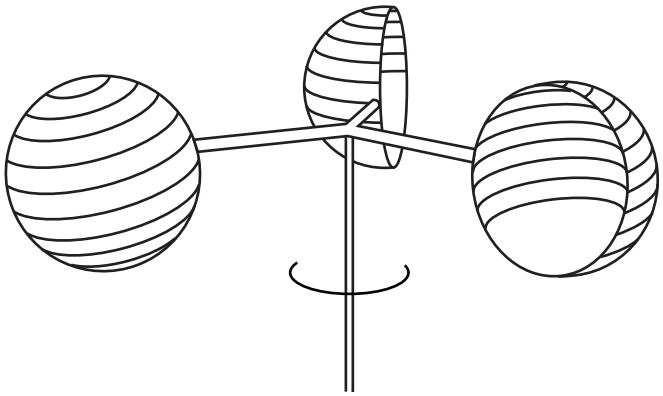
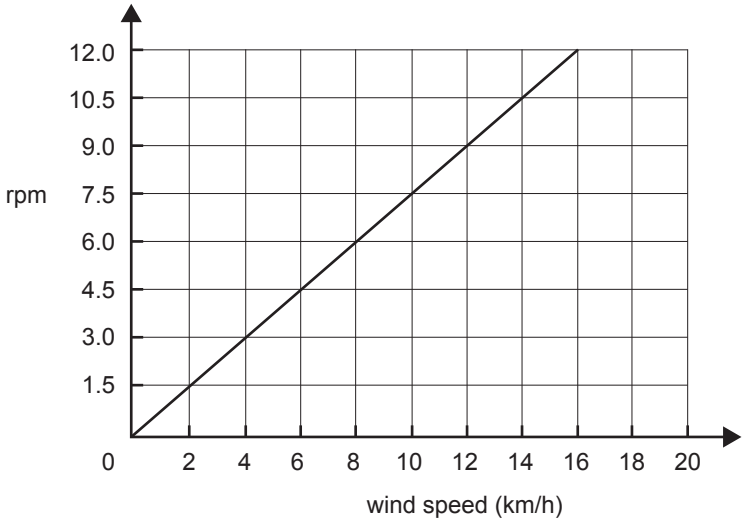


Figure 8

Question 13 (1 mark)

A graph of the revolutions per minute (rpm) of the anemometer versus the relative wind speed is given below.



From the graph above, what is the rpm of the anemometer if the relative wind speed is 14 km/h?

rpm

Question 14 (3 marks)

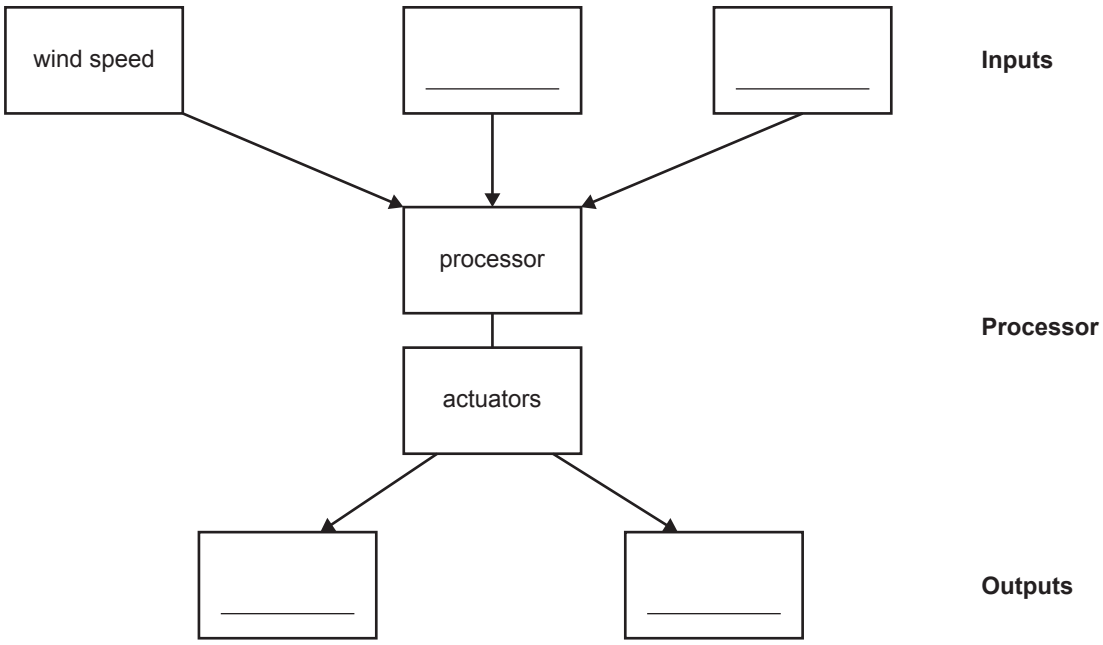
a. Give **one** possible type of sensor that would **not** affect the anemometer while it is measuring the rotation of the anemometer. 1 mark

b. Explain how the sensor given in **part a.** could be used so there is one pulse for each revolution of the anemometer. You may draw a diagram to help explain how the sensor works. 2 marks

Question 15 (5 marks)

Carmen considers installing an autopilot for her yacht.

a. Give two other appropriate inputs and two appropriate outputs for the diagram of an autopilot system provided below. 4 marks



b. Why is the system provided in **part a.** described as a closed-loop system? 1 mark

Question 16 (8 marks)

An ocean-going yacht is required to have a red navigation light on its port (left side) and a green navigation light on its starboard (right side). As the lights are needed only at night, a light-detector circuit is used to activate them automatically. One possible design is given in Figure 9 below.

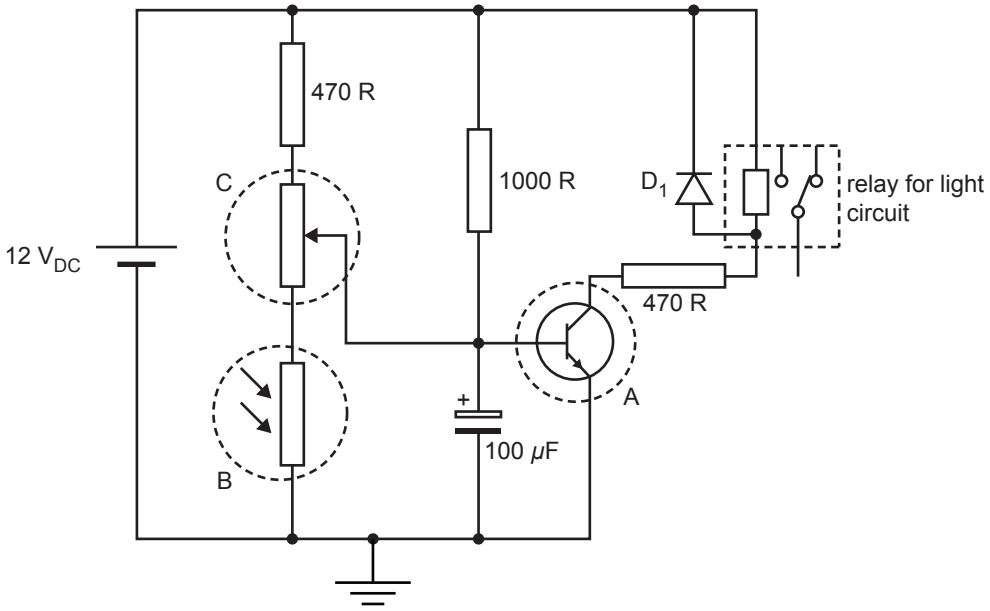


Figure 9

a. On Figure 9, show how an ammeter could be inserted into the circuit diagram in order to measure the current generated by the 12 V_{DC} battery. 1 mark

b. Give the colour code of the 470 R 5% resistor. 1 mark

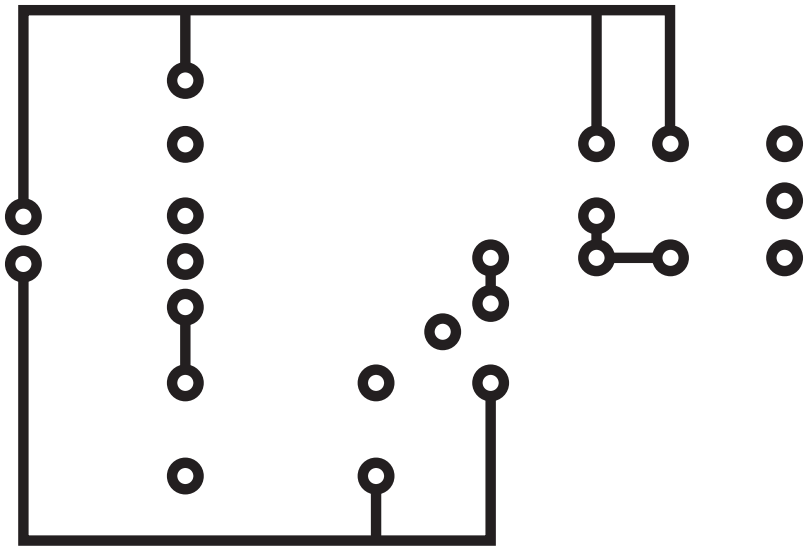
c. In the table below, identify components A, B and C from Figure 9, and state the purpose of each component in the circuit. 6 marks

	Name of component	Purpose in circuit
A		
B		
C		

Question 17 (3 marks)

An incomplete circuit board is shown below.

Complete the circuit board for the light-detector circuit. Do not include any wiring from the relay.



Question 18 (1 mark)

Carmen wants the yacht to run on a 24 V_{DC} supply. She wants to use a transformer to convert the 24 V_{DC} to the 12 V_{DC} required for the light-detector circuit.

Comment on Carmen's idea.

Question 19 (5 marks)

The lights connected to the light-detector circuit are 12 V.

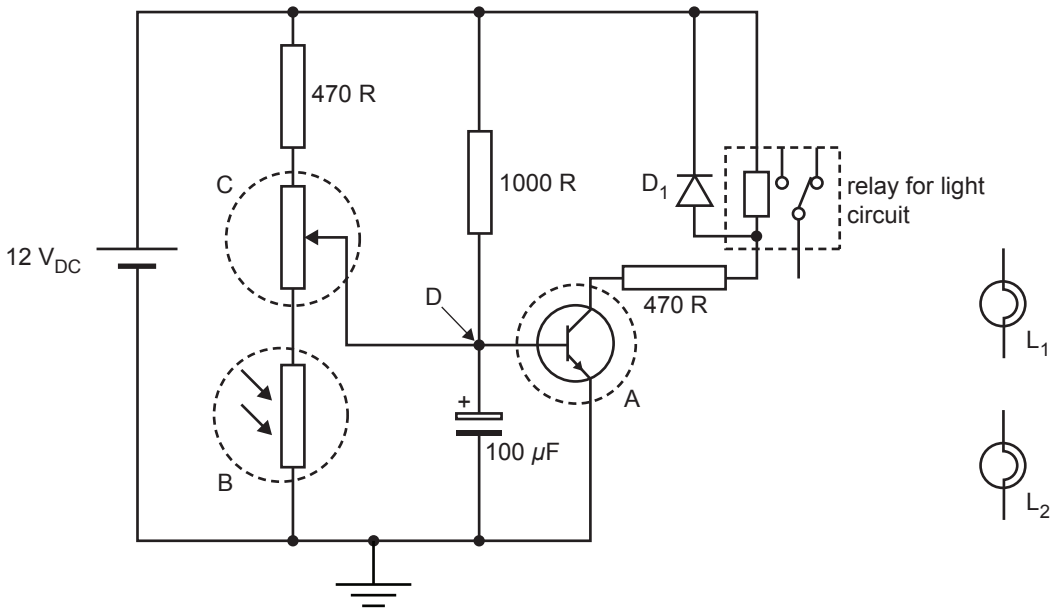


Figure 10

a. Complete the circuit in Figure 10 so that the relay circuit will operate lights L_1 and L_2 during the night. 3 marks

b. What would the voltage at point D be if the 1000 R resistor were to short circuit? 1 mark

c. Describe the effect the short circuit of the 1000 R resistor would have on component A. 1 mark

Question 20 (4 marks)

Carmen wants to explore alternative methods for supplying electrical energy to her yacht.

a. Apart from a wind generator, give two other feasible methods of generating electricity that Carmen could use while sailing. 2 marks

Method 1 _____

Method 2 _____

b. Give one disadvantage for each of the methods given in **part a.** 2 marks

Method 1 disadvantage _____

Method 2 disadvantage _____

Question 21 (3 marks)

Carmen decided to use a wind generator to supply electrical energy to her yacht. A typical output signal from a wind generator is shown in Figure 11.

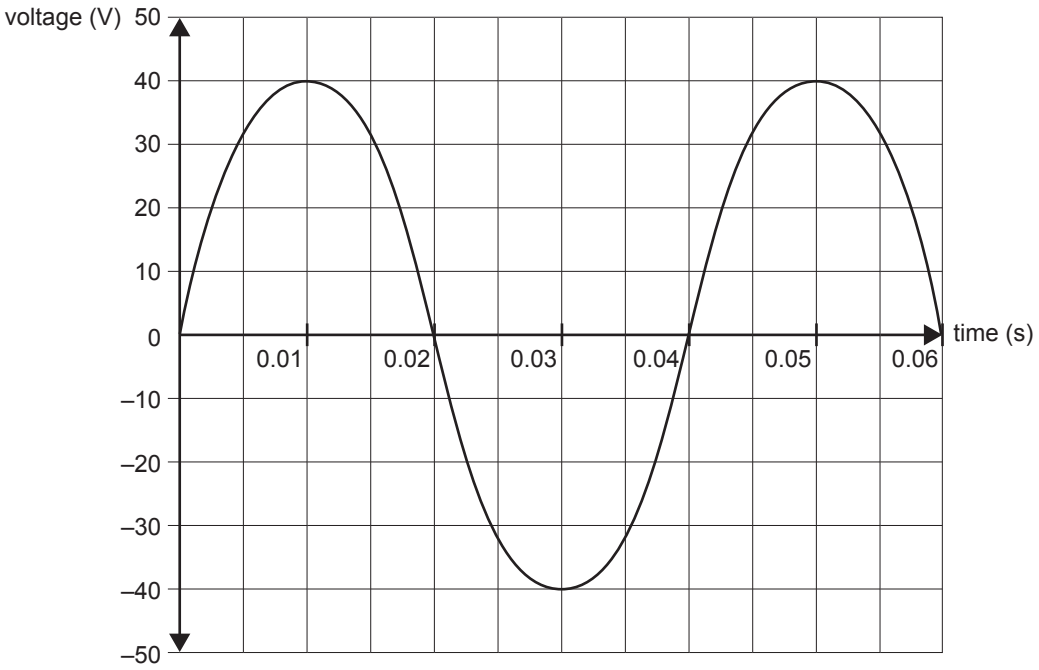


Figure 11

a. Using the graph in Figure 11, determine the peak-to-peak voltage. 1 mark

b. Give the period and the frequency of the signal shown in the graph in Figure 11. 2 marks

Period s Frequency Hz

Question 22 (4 marks)

Carmen needs to change the alternating current produced by the wind generator to direct current.

a. On the graph in Figure 12a below, sketch the output signal if only a single diode is used as a rectifier, as shown in Figure 12b. 2 marks

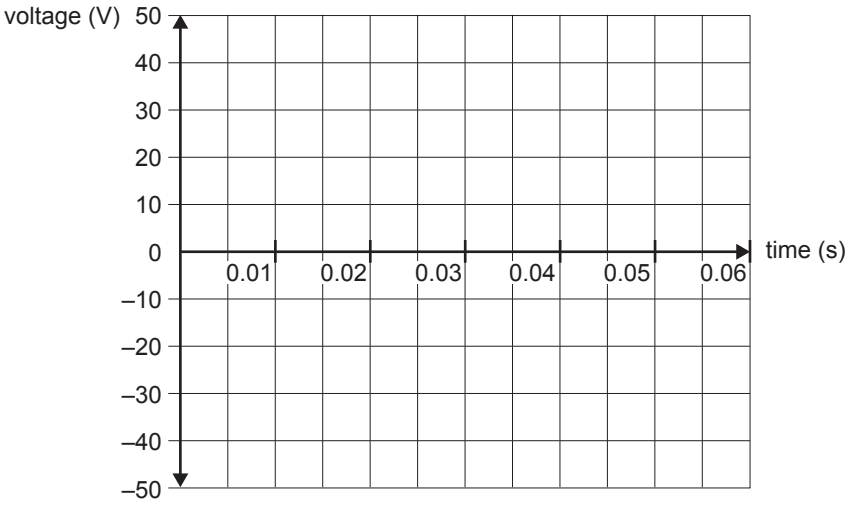


Figure 12a

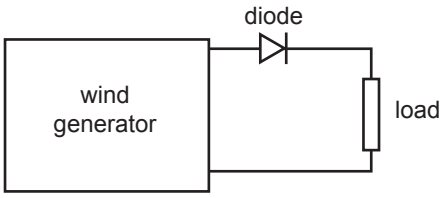


Figure 12b

b. Name two components that could be used to smooth the signal. 2 marks

1. _____

2. _____

Question 23 (2 marks)

Carmen needs to store the electricity generated in batteries. 45% of the energy passing through the wind generator blades is converted to electrical energy and the batteries used are 95% efficient.

What is the combined efficiency of the wind generator and battery system? Show your working.

_____

_____

Question 24 (2 marks)

Carmen uses two lithium-ion marine batteries, each rated at 12 V and 240 Ah, to store the electricity generated. The batteries are set up to provide a 24 V supply to the yacht.

Given that there is no wind and that Carmen uses a constant 20 A per hour at 24 V, how long should it take for these batteries to fully discharge? Show your working.

Question 25 (3 marks)

For extra safety, Carmen wants to design a variable rate flashing light. She decides to use a microcontroller for this purpose.

In the space below, draw a flow chart **or** write a microcontroller program that would generate a flashing light that would turn on for two seconds, then turn off for one second.

Question 26 (5 marks)

A superconductor is a material that can conduct electricity with no resistance or energy loss. Presently, superconductors only operate at temperatures below those found on Earth's surface.

If superconductors were to work at room temperature, suggest a possible application and discuss the implications for our society.

In your response, include:

- a description of the application
- the advantages of using superconductors for the application
- a list of possible implications for our 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