



Victorian Certificate of Education 2010

SUPERVISOR TO ATTACH PROCESSING LABEL HERE

STUDENT NUMBER

Figures

Words

Letter

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SYSTEMS ENGINEERING

Written examination

Friday 12 November 2010

Reading time: 11.45 am to 12.00 noon (15 minutes)

Writing time: 12.00 noon to 1.30 pm (1 hour 30 minutes)

QUESTION AND ANSWER BOOK

Structure of book

<i>Section</i>	<i>Number of questions</i>	<i>Number of questions to be answered</i>	<i>Number of marks</i>
A	20	20	20
B	29	29	50
			Total 70

- 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 white out liquid/tape.

Materials supplied

- Question and answer book of 23 pages including formulas on page 23.
- 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.
- All calculations must show appropriate formulas and working.
- 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.

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.

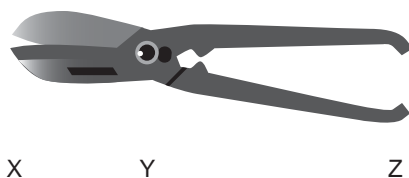
No marks will be given if more than one answer is completed for any question.

A formula sheet is provided on page 23.

Unless indicated diagrams are not to scale.

Question 1

The figure below shows a pair of tin snips.



Which of the following shows the correct positions of the effort, load and fulcrum?

	X	Y	Z
A.	fulcrum	load	effort
B.	effort	load	fulcrum
C.	fulcrum	effort	load
D.	load	fulcrum	effort

Question 2

What class of lever are the tin snips?

- A. class 1 only
- B. class 2 only
- C. class 3 only
- D. both class 1 and class 2

Question 3

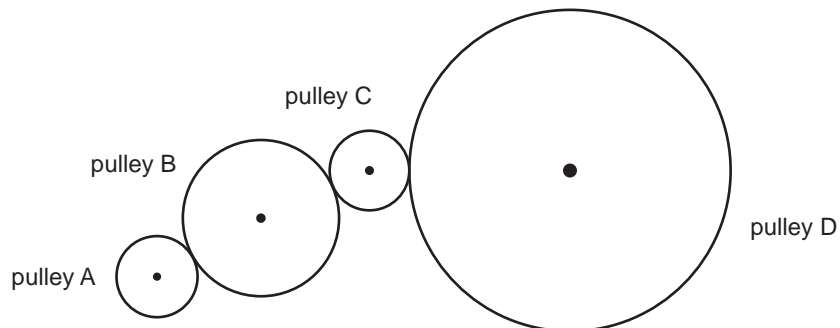
In the diagram below

pulley A has a radius of 4 cm

pulley B has a radius of 8 cm

pulley C has a radius of 4 cm

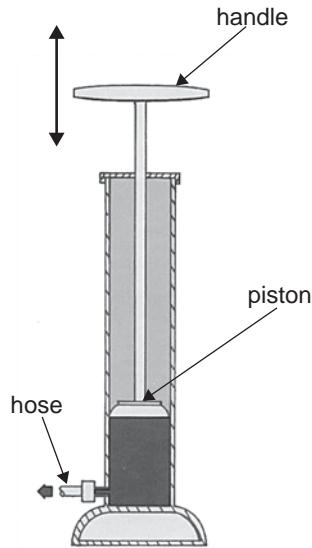
pulley D has a radius of 16 cm.



If pulley A rotates at 16 rpm, pulley D will rotate at

- A. 1 rpm
- B. 2 rpm
- C. 4 rpm
- D. 16 rpm

Questions 4 and 5 refer to the diagram below.



Question 4

The motion of the piston in the bicycle pump when pumping can best be described as

- A. linear.
- B. rotary.
- C. oscillating.
- D. reciprocating.

Question 5

A force of 100 N is applied to the pump handle. The area of the piston is 0.001 square metres.

What pressure is produced within the cylinder?

- A. 10 kpa
- B. 100 kpa
- C. 10 000 kpa
- D. 100 000 kpa

Question 6

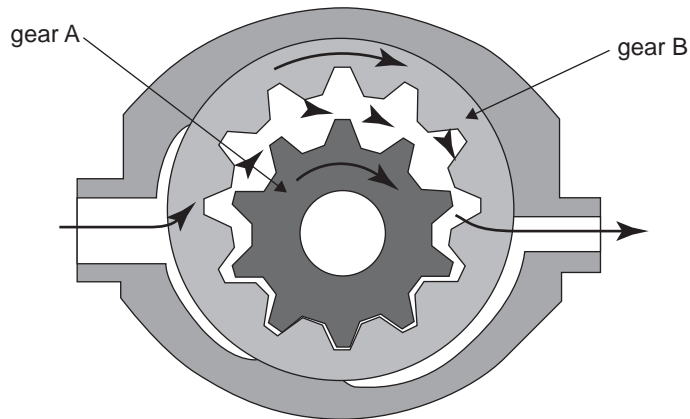
A 20 cm long spanner is used to produce a torque of 60 Nm.

The force applied to the spanner is

- A. 3 N
- B. 12 N
- C. 120 N
- D. 300 N

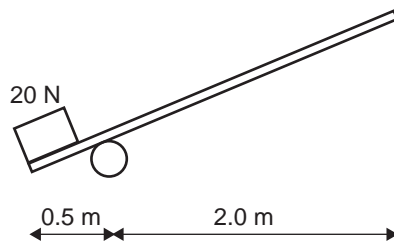
Question 7

Gear A rotates at 12 rpm in the hydraulic pump below.



Gear B will rotate at

- A. 10 rpm
- B. 12 rpm
- C. 14.2 rpm
- D. 120 rpm

Question 8

The mechanical advantage of this lever is

- A. 0.25
- B. 4
- C. 10
- D. 40

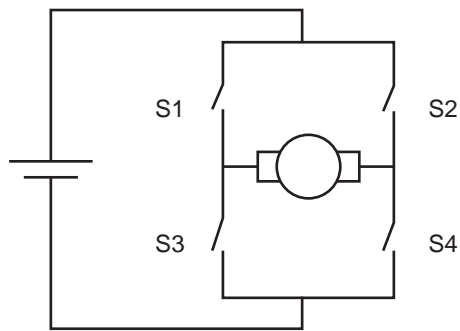
Question 9

Which capacitance value is the smallest?

- A. 10 farads
- B. 47 microfarads
- C. 220 millifarads
- D. 100 nanofarads

Question 10

The four switches, S1 to S4, in the circuit shown below are in the OFF position.



When turned ON, which pair of switches will allow the motor to operate?

- A. S1 and S2
- B. S1 and S3
- C. S1 and S4
- D. S3 and S4

Question 11

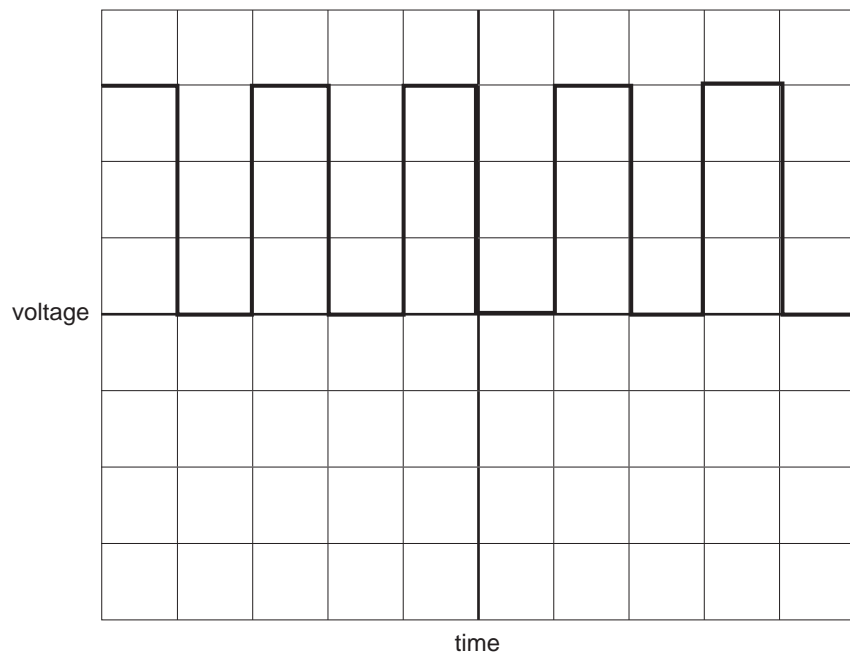
Batteries can be connected in series or in parallel.

The main advantage of connecting batteries in parallel is to increase the

- A. current drawn.
- B. voltage available.
- C. internal resistance.
- D. external resistance.

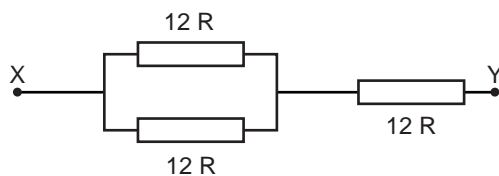
Question 12

Below is the display on a cathode ray oscilloscope.



Given that the horizontal scale is 0.01 seconds per division and the vertical scale is 2 volts per division, the voltage and frequency of the above signal are

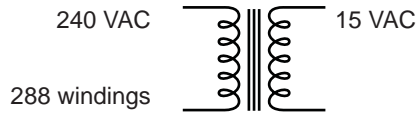
- A. 3 volts and 1 Hz
- B. 3 volts and 2 Hz
- C. 6 volts and 50 Hz
- D. 6 volts and 100 Hz

Question 13

The total resistance between points X and Y is

- A. 4 R
- B. 12 R
- C. 18 R
- D. 36 R

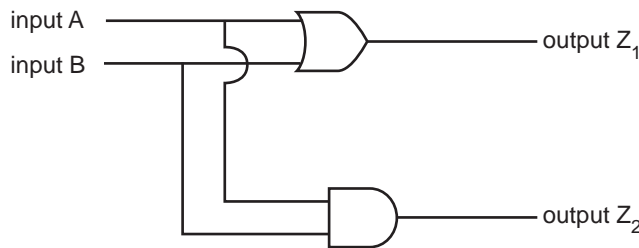
Question 14



The number of output windings in the diagram above is

- A. 16
- B. 18
- C. 4320
- D. 4608

Question 15



Which of the truth tables below represents the circuit above?

A.

A	B	Z ₁	Z ₂
0	0	0	0
0	1	1	1
1	0	1	1
1	1	0	1

B.

A	B	Z ₁	Z ₂
0	0	0	0
0	1	1	1
1	0	1	1
1	1	1	0

C.

A	B	Z ₁	Z ₂
0	0	0	0
0	1	1	0
1	0	1	0
1	1	0	0

D.

A	B	Z ₁	Z ₂
0	0	0	0
0	1	1	0
1	0	1	0
1	1	1	1

Question 16

In an electronic circuit, the main purpose of an electromagnetic relay switch is to allow

- A. a small output current using a large input current.
- B. a small output current using a small input current.
- C. a large output current using a large input current.
- D. a large output current using a small input current.

Question 17

A globe has a power rating of 24 watts. The globe has 200 mA passing through it.

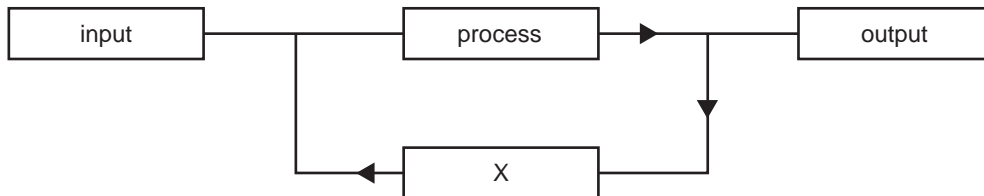
What is the voltage?

- A. 120 mV
- B. 4.8 V
- C. 48 V
- D. 120 V

Question 18

A design brief is best described as which of the following?

- A. the process of designing a product
- B. the process of constructing a product
- C. the instruction to a designer from a client
- D. the plan for constructing a product

Question 19

The **system** in box X is best described as

- A. a closed-loop system.
- B. an open-loop system.
- C. a control system.
- D. a feedback loop.

Question 20

The flow chart below is for the operation of a flashing LED on a programmable integrated circuit.

High 0 turns the LED on. Low 0 turns the LED off. Wait 1 gives a 1-second time delay.



Which of the following is true?

- A. It is a closed-loop circuit where the flashing LED has a period of 1 second.
- B. It is an open-loop circuit where the flashing LED has a period of 1 second.
- C. It is a closed-loop circuit where the flashing LED has a period of 2 seconds.
- D. It is an open-loop circuit where the flashing LED has a period of 2 seconds.

SECTION B – Short answer questions

Instructions for Section B

Answer **all** questions in the spaces provided.
A formula sheet is provided on page 23.
Unless indicated the diagrams are not to scale.

Forklifts are used in many industries including supermarkets and manufacturing. They may be used to move materials. The forklift below is powered by an electric motor and hydraulics are used to raise and lower the load.

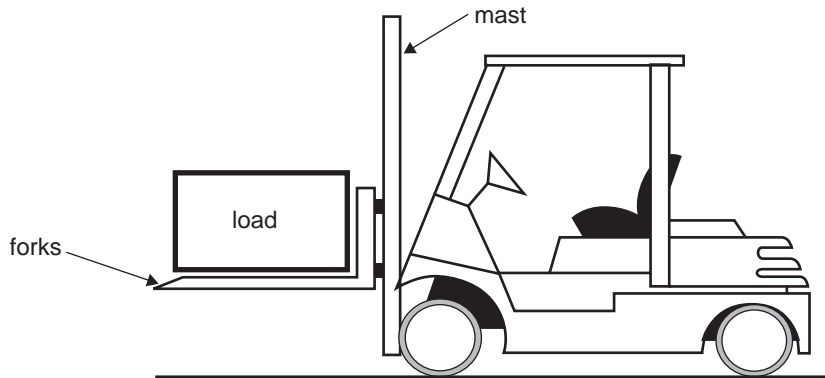


Figure 1

Question 1

Explain why this forklift is an integrated system.

1 mark

Question 2

Is the forklift an open-loop system or a closed-loop system? Explain your answer.

1 mark

Question 3

It is unsafe to drive a forklift while the load is raised high.
Give two valid safety reasons why this is so.

i. _____

ii. _____

2 marks

Figure 2 is a diagram of the mast and hydraulic system of a forklift.

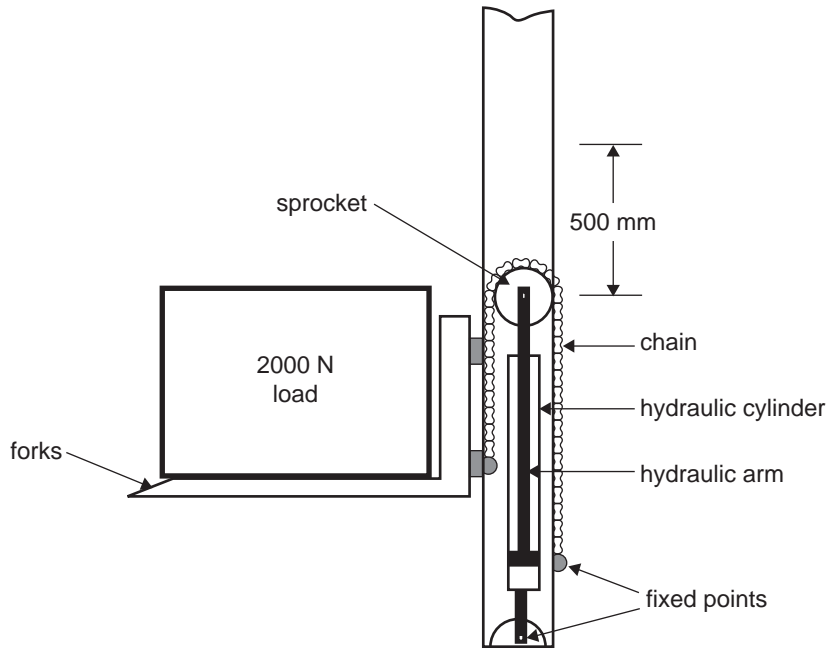


Figure 2

Question 4

If the hydraulic arm is extended 500 mm from its current position, what distance is the 2000 N load raised?

1 mark

Question 5

Given that the effort applied to the hydraulic arm and cylinder is 4000 N, calculate the mechanical advantage of the system.

1 mark

A 2000 N load is raised a distance of 600 mm.

Question 6

Calculate, in joules, the work done. Show working and include units.

2 marks

SECTION B – continued
TURN OVER

The hydraulic cylinder has a diameter of 150 mm. The hydraulic arm has a diameter of 30 mm.

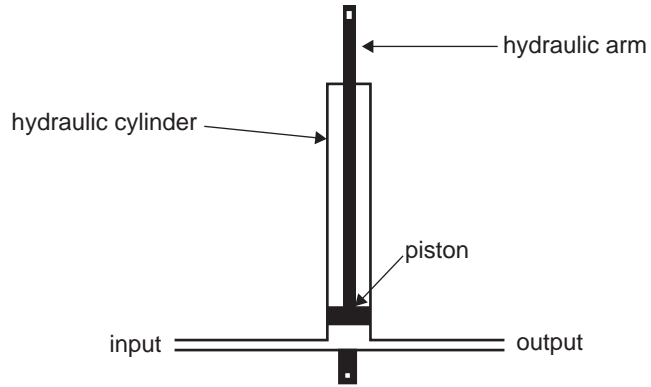


Figure 3

Question 7

Given that this hydraulic pump produces a pressure of 100 000 Pa, calculate the maximum force that acts on the hydraulic piston as the arm is forced up. Show working and include units.

3 marks

Figure 4a shows the original hydraulic cylinder. This cylinder developed a fault and a service person replaced it with another type of cylinder as shown in Figure 4b.

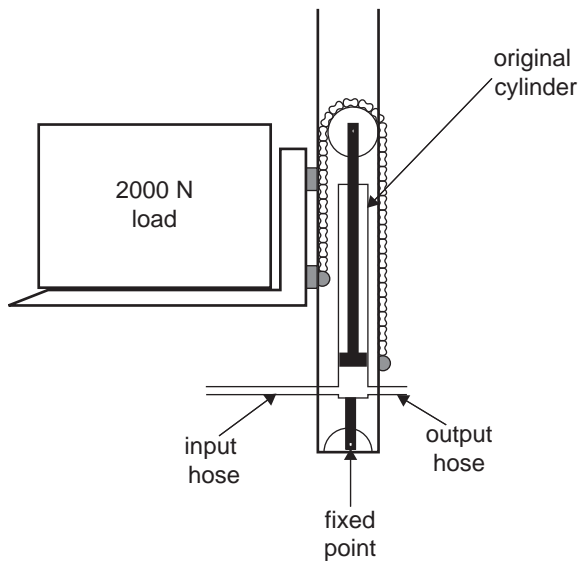


Figure 4a

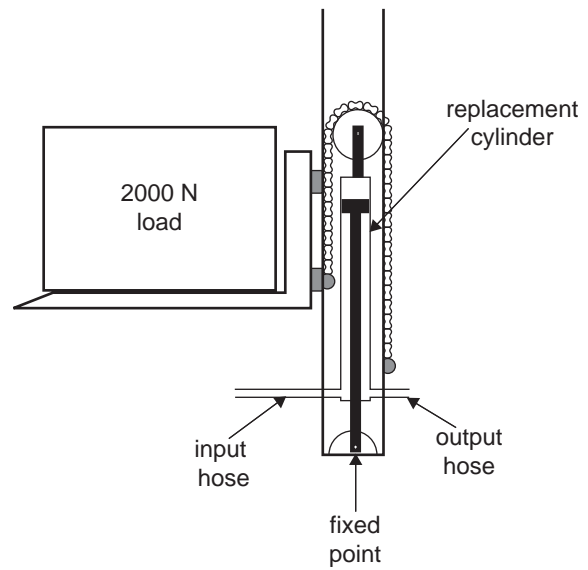


Figure 4b

Question 8

Give two negative effects of using the replacement cylinder rather than the original cylinder. (Note the design configuration of the replacement cylinder.)

2 marks

The drive of the forklift is powered by an electric motor that is connected to a battery power pack. The motor requires 48 volts and draws a current of 200 amps.

Question 9

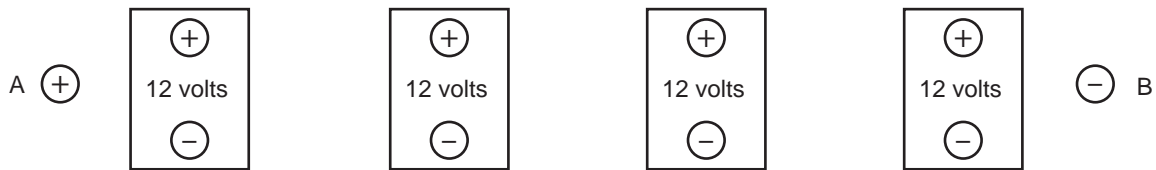
Calculate the power of the electric motor. Show working and include units.

2 marks

The battery power pack consists of a number of 12-volt batteries connected in series and/or parallel.

Question 10

On the diagram below, draw the connections between the battery terminals to produce a 48-volt supply across the terminals A(+) and B(-).

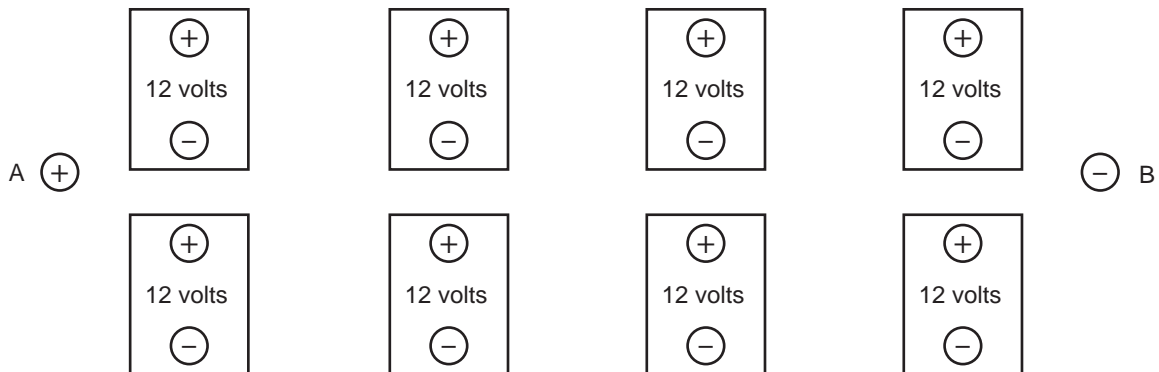


1 mark

Using 4 batteries, the forklift can run for 2.5 hours before a recharge is necessary. To increase the operating time, 8 batteries could be used.

Question 11

On the diagram below, draw the connections between all the batteries to produce a 48-volt supply across terminals A(+) and B(-).



1 mark

The electric motor of the forklift is found to be running slowly. A service person suspects there is an open-circuit battery. Each battery is isolated before being tested.

Question 12

- a. Name a diagnostic test instrument that can be used to test the voltage output of the batteries.

1 mark

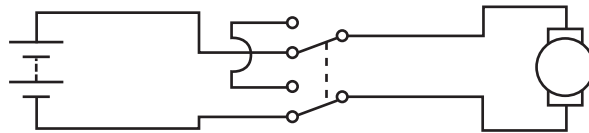
- b. One of the batteries is found to be open circuit. What is the expected reading on the diagnostic test instrument?

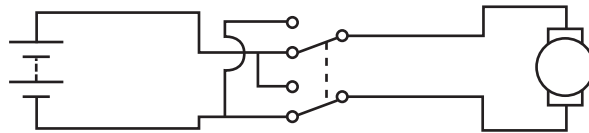
1 mark

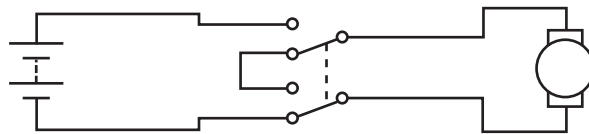
The electric motor of the forklift must power the forklift so it can move forwards or backwards.

Question 13

Explain what would happen if the motor was connected as shown in each of the following cases.







3 marks

The electric motor drives the axle and wheels of the forklift via a gearbox and differential assembly as shown in Figure 5.

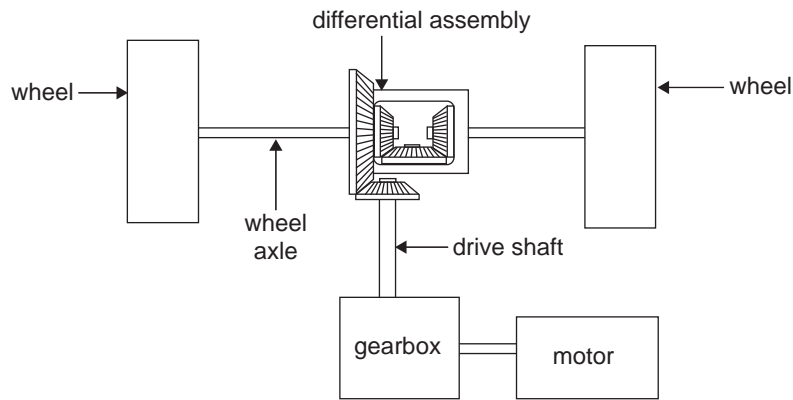


Figure 5

Question 14

Name the type of gears that are used in the differential assembly.

1 mark

Question 15

Give the main function of the differential assembly as shown in Figure 5.

1 mark

Gear A has 12 teeth and gear B has 36 teeth as shown in Figure 6.

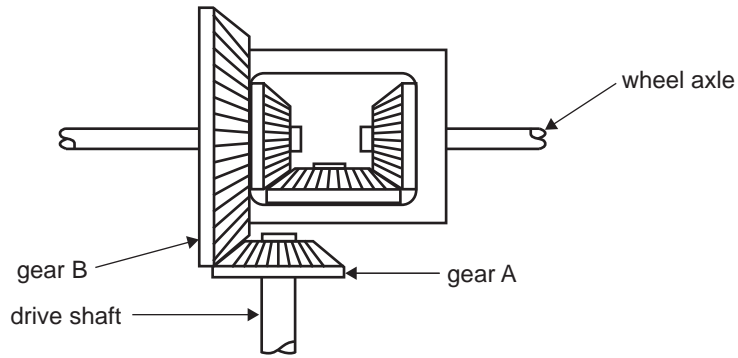


Figure 6

The forklift is moving in a straight line.

Question 16

If the wheel axle rotates at 100 rpm, calculate the rpm of the drive shaft. Show working.

2 marks

The circumference of the wheel (Figure 5) is 1 m.

Question 17

What is the speed of the forklift? Show working and include units.

2 marks

The motor to drive shaft needs to have a reduction ratio of 12 : 1.

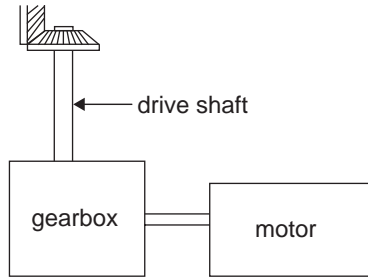
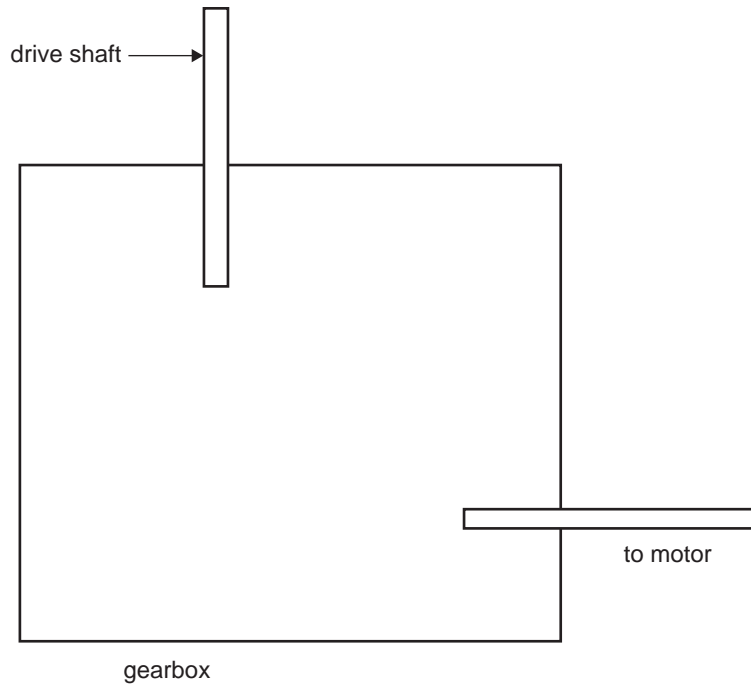


Figure 7

Question 18

Design a functional gearbox to give the needed ratio. Clearly show the number of teeth of each gear.

Note: The gearbox is big enough to have a maximum gear size of 50 teeth. A spur gear will not work with less than 8 teeth.



3 marks

The operators of the forklift discuss whether to use solar energy to recharge the batteries.

Question 19

Complete the following table. Give the input form of energy and output form of useful energy for each subsystem.

Subsystem	Input form of energy	Output form of useful energy
Solar cells		
Battery		
Motor		

3 marks

A typical solar cell is 18% efficient.

Question 20

If 450 joules of energy fall on the solar cell, how much useful output energy is produced? Show working.

2 marks

Question 21

Give two negative impacts on the environment that are due to the life cycle of a solar cell.

2 marks

The forklift operators decide to use solar energy to recharge the batteries.

Each lead-acid battery that powers the forklift is recharged using solar energy. An electronic circuit between the solar panel and the battery allows for voltage regulation and isolation. This circuit is shown in Figure 8.

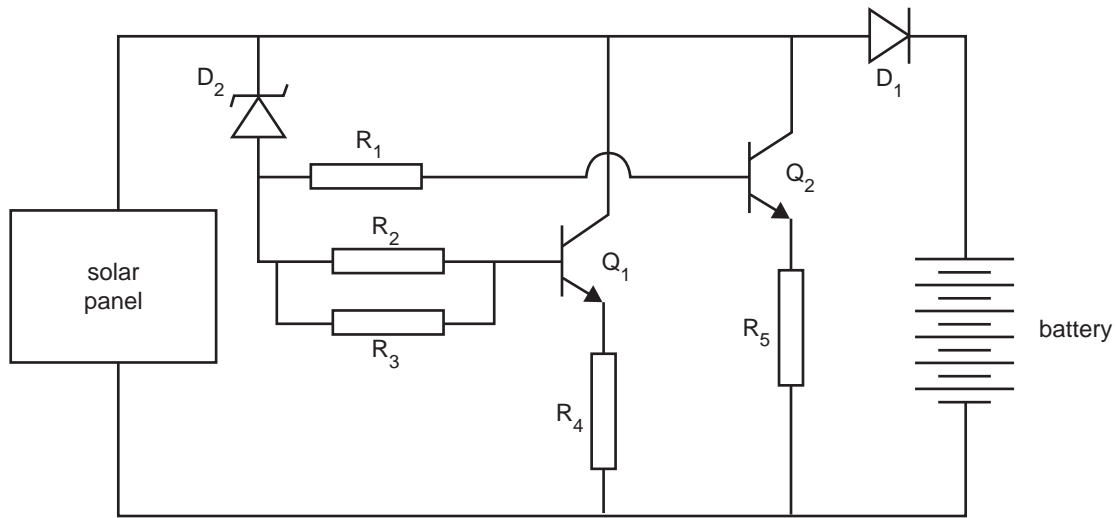


Figure 8

An analogue ammeter is connected to the battery to monitor the charging current.

Question 22

On Figure 8 draw an ammeter to measure the charging current of the battery.

1 mark

Component R_1 in Figure 8 is a $\frac{1}{4}$ watt resistor with a value of 180 ohms and a tolerance of 5%.

Question 23

Write down the four colours (in order) that are found on the resistor R_1 .

1 mark

Components R_2 and R_3 are both 330 ohm resistors.

Question 24

What is the combined resistance of R_2 and R_3 as connected in this circuit?

1 mark

Question 25

Name the component D_1 and explain its function in the circuit.

2 marks

Large electric currents can pass through power transistors Q_1 and Q_2 when the battery is being charged. Such large currents may destroy the transistors.

Question 26

What modification can be made to keep these transistors functioning under the condition described above.

1 mark

The transistor Q_1 is a BD649.

Transistor	Type	Polarity	Power	Collector current
1	BD649 (not available)	NPN	60 W	8 A
2	BD650	PNP	60 W	8 A
3	MJE2995	PNP	75 W	10 A
4	MJE3055	NPN	75 W	10 A
5	TIP31	NPN	40 W	3 A
6	TIP41C	NPN	65 W	6 A

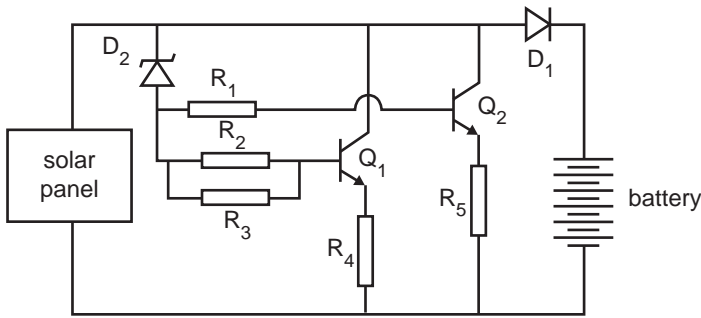
Question 27

Q_1 stops working and needs to be replaced. A replacement BD649 is not available. Select a transistor from the table above that would be the most suitable replacement.

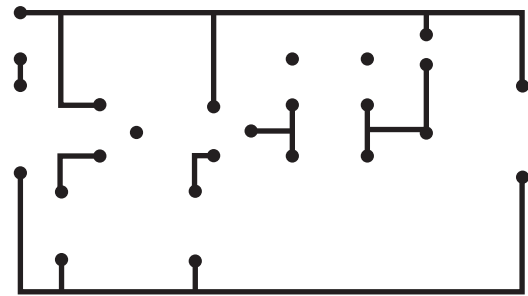
Transistor number

1 mark

The recharging circuit for the batteries and an incomplete circuit board are shown below.



circuit diagram



bottom of incomplete printed circuit board

Question 28

On the diagram of the printed circuit board above, draw the two missing tracks.

1 mark

Question 29

a. Identify two processes in the construction of a circuit board where people may be exposed to the risk of injury.

- i. _____
- ii. _____

2 marks

b. Explain a practical solution for reducing the likelihood of injury for the processes identified above.

- i. _____

- ii. _____

2 marks

Formula sheet

Work done = force \times distance moved

Gear ratio final = gear ratio 1 \times gear ratio 2

Efficiency = $\frac{\text{output energy}}{\text{input energy}} \times 100\%$

Voltage = current \times resistance

Resistance in parallel = $\frac{R_1 \times R_2}{R_1 + R_2}$

Colour codes

Colour	Value
black	0
brown	1
red	2
orange	3
yellow	4
green	5
blue	6
violet	7
grey	8
white	9
gold	5%
silver	10%

Resistance in series = $R_1 + R_2$

$$V = \frac{P}{I}$$

Area of circle = πr^2 ($\pi = 3.14$)

Force = pressure \times area

$\frac{\text{gear A rpm}}{\text{gear B rpm}} = \frac{\text{number of teeth gear B}}{\text{number of teeth gear A}}$

$\frac{\text{pulley A rpm}}{\text{pulley B rpm}} = \frac{\text{radius of pulley B}}{\text{radius of pulley A}}$

$$\frac{V_{\text{in}}}{V_{\text{out}}} = \frac{N_{\text{in}}}{N_{\text{out}}}$$

Speed = $\frac{\text{distance}}{\text{time}}$

Gear ratio = $\frac{\text{number of teeth on driven gear}}{\text{number of teeth on driver gear}}$

Mechanical advantage = $\frac{\text{load}}{\text{effort}}$

Torque = force \times distance