Engineering Science (National 5): Question paper

Candidate evidence

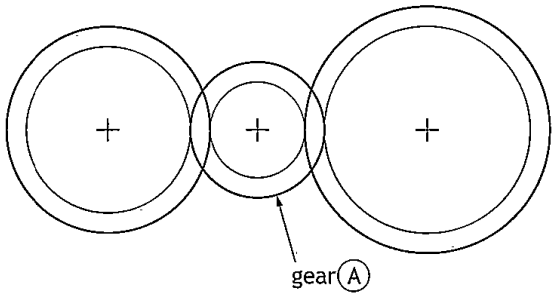
Candidate 1 evidence

MARKS | DO NOT WRITE IN THIS MARGIN

SECTION 1 — 20 marks

Attempt ALL questions

1. A gear train is shown below.



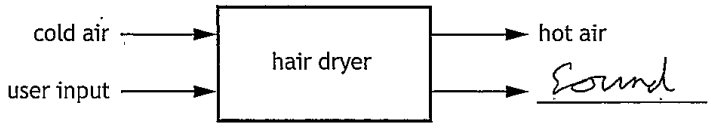
(a) State the type of **gear train** shown. 1

Compound

(b) State the name of gear (A). 1

~~Idler~~ Idler gear

2. An incomplete system diagram for a hair dryer is shown.



(a) Complete the system diagram above by adding the missing output. 1

(b) State the type of control that has **no** feedback. 1

open loop

MARKS | DO NOT WRITE IN THIS MARGIN

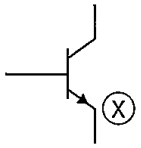
3. A force of 2200 N is required to push a workbench across a workshop floor.
Calculate the work done when the workbench is pushed a distance of 12 m. 2

$E_W = Fd$

$E_W = 2200 \times 12$

$E_W = 26,400\,J$

4. Transistors are used in many electronic products.



(a) Describe the **function** of a transistor. 1

To be used as a voltage switch or a voltage threshold setter

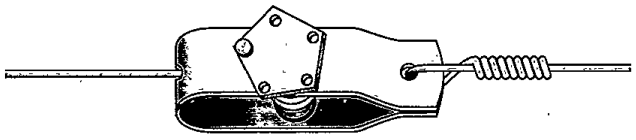
(b) State the name of connection (X) on the transistor symbol above. 1

emiter

[Turn over

MARKS | DO NOT WRITE IN THIS MARGIN

5. A tensioner is used to tighten the wire on a farm fence.



A 25 m length of wire was stretched by 0.012 m when fully tensioned.

(a) Calculate the strain in the wire. 2

$\epsilon = \frac{\Delta l}{l}$

$\epsilon = \frac{0.012}{25}$

$\epsilon = 4.8 \times 10^{-4}$ m

The table below shows details of materials that were considered for the wire.

Material	Corrosion resistant	Property
A	no	ductile
B	yes	brittle
C	yes	ductile
D	no	brittle

(b) Select the most suitable material (A–D) from the table for the wire and justify your choice. 2

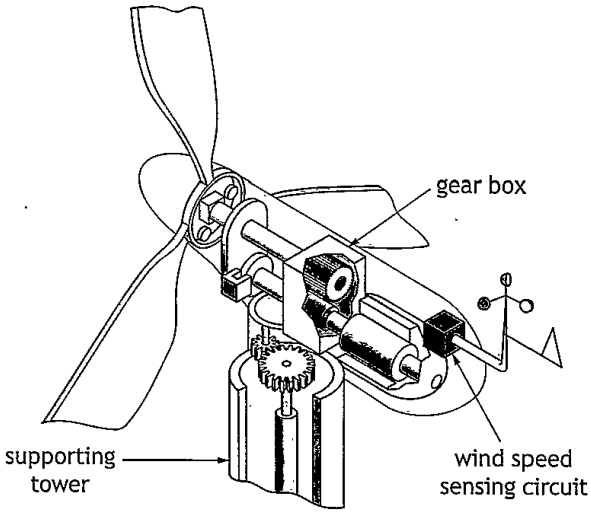
Choice of material C

Justification It is not brittle and it will not be distorted by the elements

MARKS | DO NOT WRITE IN THIS MARGIN

6. An offshore wind farm has wind turbines which are located out at sea.

A diagram of the inside of one of the wind turbines is shown.



(a) State which branch of engineering would be responsible for the design of the:

(i) wind speed sensing circuit 1

electrical

(ii) supporting tower 1

Structural

(iii) gear box. 1

Macanical

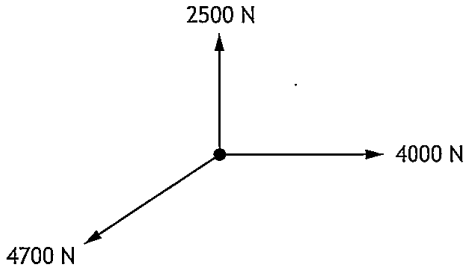
(b) Describe one role an **environmental** engineer would have during the **construction** of the offshore wind farm. 1

To ensure that all government enviormated Standerd where being met

[Turn over

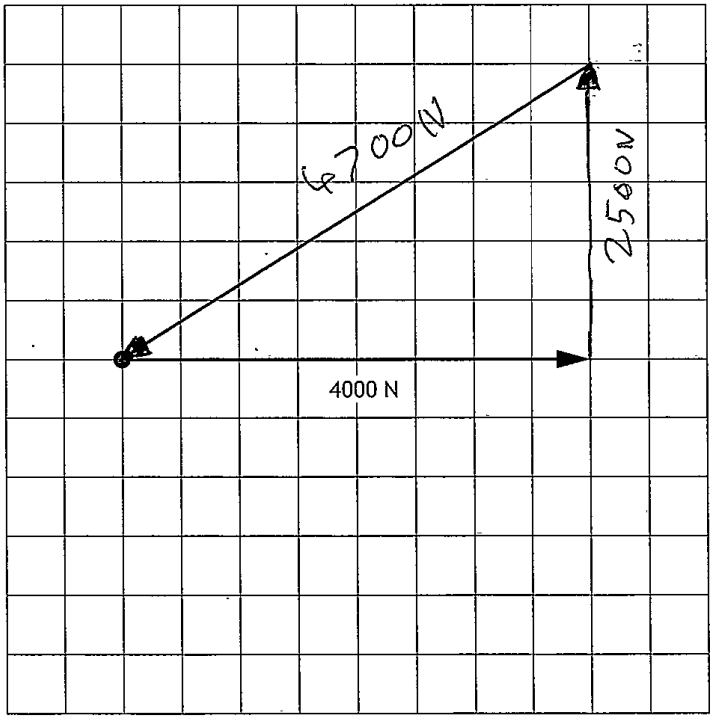
MARKS | DO NOT WRITE IN THIS MARGIN

7. Three forces, in equilibrium, acting on part of a structure are shown below.



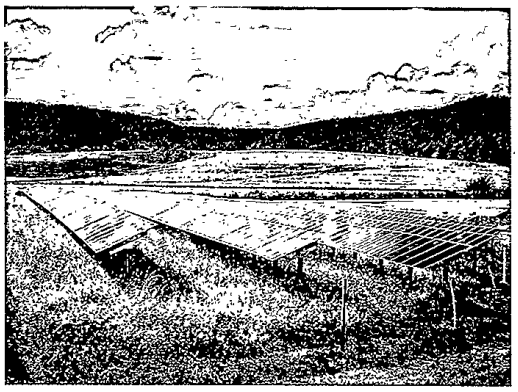
Complete the triangle of forces **scale drawing** below for the given forces.
Forces must include an arrow head to show the direction. 2

scale 10 mm = 500 N



MARKS | DO NOT WRITE IN THIS MARGIN

8. A solar farm is shown.



Describe two **environmental** impacts of solar as a source of energy. 2

1 It takes up a lot of area and this can destroy habitat

2 It does not relase green house gasses.

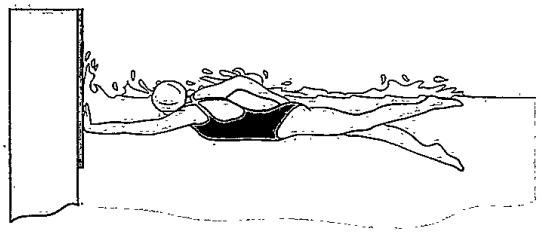
[Turn over

DO NOT WRITE IN THIS MARGIN

SECTION 2 — 90 marks

Attempt ALL questions

9. In a swimming competition, a system is used to automatically measure a competitor's time.



The system is operated by a microcontroller.

The input and output connections to the microcontroller are shown in the table below.

Input connections	Pin	Output connections
	7	buzzer
	6	timer
lane switch	1	
master switch	0	

The system operates using the following sequence.

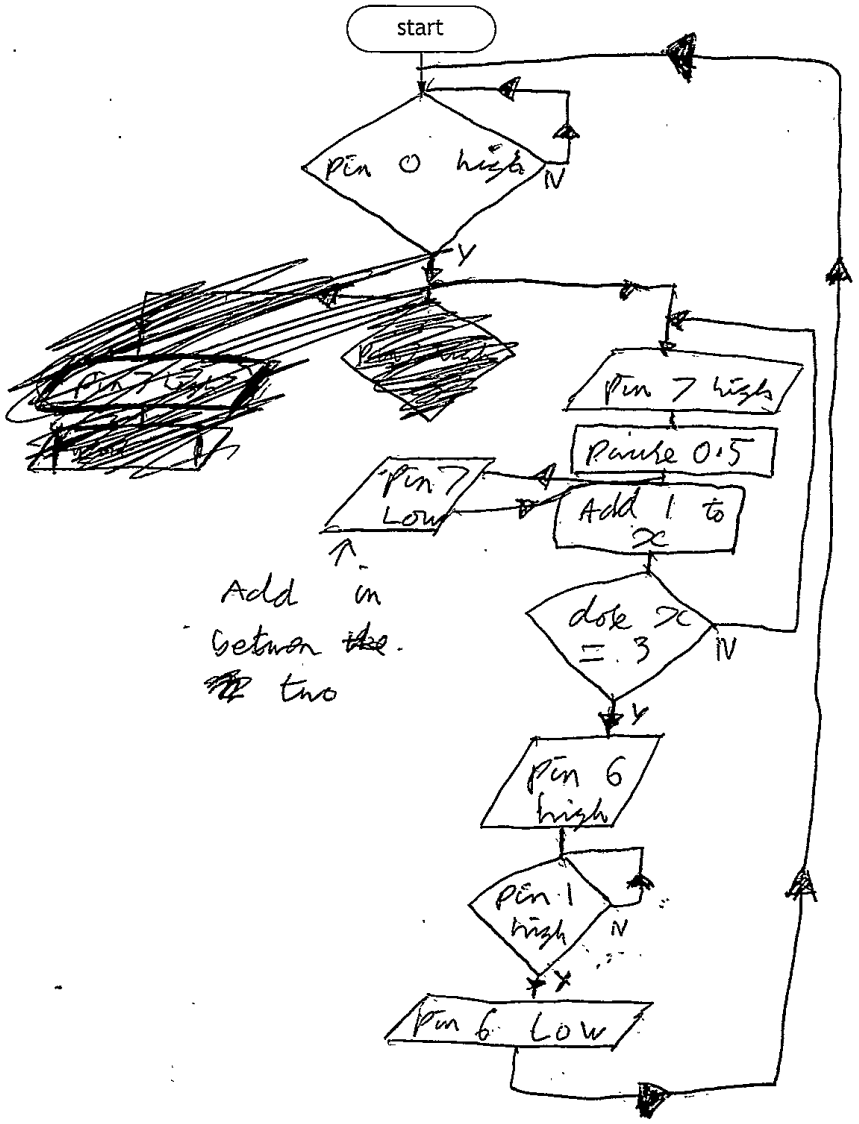
- A master switch is pressed
- A buzzer then sounds on and then off three times over 1.5 seconds
- The timer then starts
- When a lane switch is pressed the timer stops
- The system will then reset ready to be used again

MARKS | DO NOT WRITE IN THIS MARGIN

9. (continued)

(a) Complete the flowchart for the sequence, with reference to the data booklet and input/output connections.

Include **all** pin numbers and delay units in your flowchart. 10



MARKS | DO NOT WRITE IN THIS MARGIN

9. (continued)

A program used in a different control system is listed below.

```
line   program
1      main:     let count = 0
2      label_1:     switch on 4
3                   switch on 5
4                   pause 600
5                   switch off 4
6                   switch off 5
7                   pause 600
8                   let count = count + 1
9                if count = 20 then label_2
10               goto main
11     label_2:  if Input0 is on then label_3
12               goto label_2
13     label_3:  switch on 7
14               pause 3000
15               switch off 7
16               goto main
```

(b) Describe the function of **line 16** in the program. **1**

reset the program to the start

Lines 2 to **9** should repeat twenty times before moving on to **line 11**.
During testing an electronic engineer found that this did not happen.

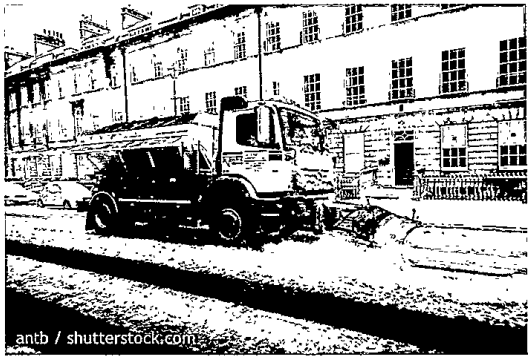
(c) Explain why **lines 2** to **9** did not repeat twenty times before moving on to **line 11**. **2**

At no point does it tell the program to reset it self

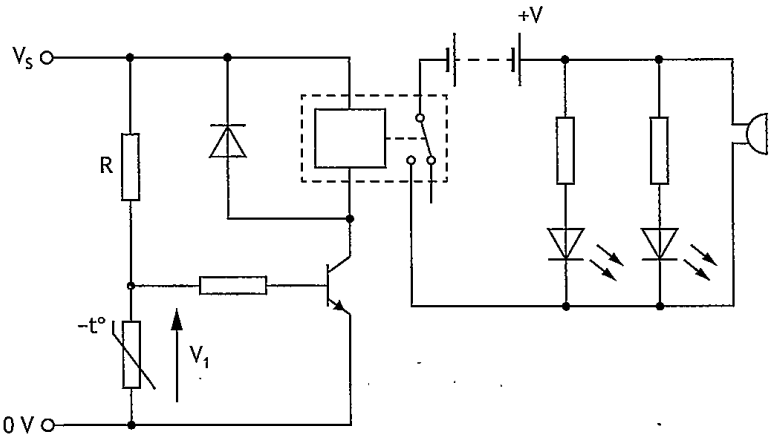
The code on line 10 stated that even 20 times it counted you need to go to main

DO NOT WRITE IN THIS MARGIN

10. The road gritter shown below is used to spread salt on icy roads.



The warning circuit shown below is used to alert the driver of a low temperature.



MARKS | DO NOT WRITE IN THIS MARGIN

10. (continued)

(a) Describe the operation of the warning circuit shown opposite. Make reference to the **resistance of the thermistor** and the **voltage V_1**. 4

When the temperature decreases to a low temperature . . .

The thermistors resistance goes up and so does the voltage (V_1) when the voltage reaches 0.7v it activates the transistor and switches the relay. The relay circuit then activates the buzzer and the LEDS.

The fixed resistor (R) is replaced with a variable resistor.

(b) Explain the effect on the **operation** of the warning circuit by replacing the fixed resistor (R) with the variable resistor. 2

[redacted]

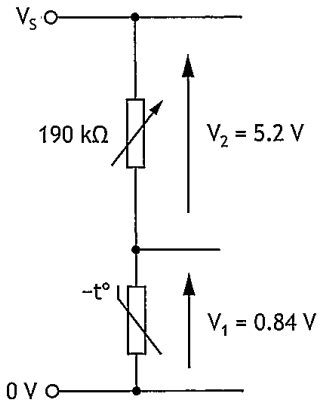
it would make the voltage across it vary possibly changing the temperature that the circuit activates at

[Turn over

MARKS | DO NOT WRITE IN THIS MARGIN

10. (continued)

The input sensing circuit (which is part of the warning circuit) is shown below.



(c) Calculate the resistance of the thermistor. 3

$\frac{V_1}{V_2} = \frac{R_1}{R_2}$

$\frac{5.2}{0.84} = \frac{190}{x}$

$x \times 5.2 = 0.84 \times 190$

$x = \frac{0.84 \times 190}{5.2}$

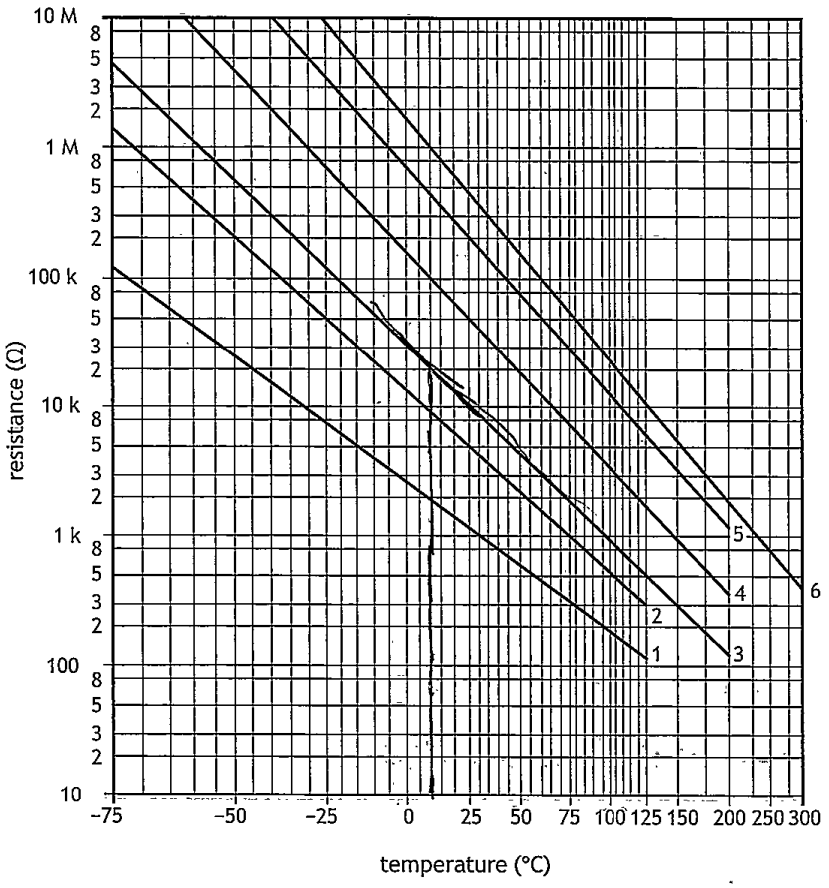
$x = 30.7$

$x = 31\ \Omega$.

MARKS | DO NOT WRITE IN THIS MARGIN

10. (continued)

The operating characteristics of a range of thermistors are shown on the graph below.



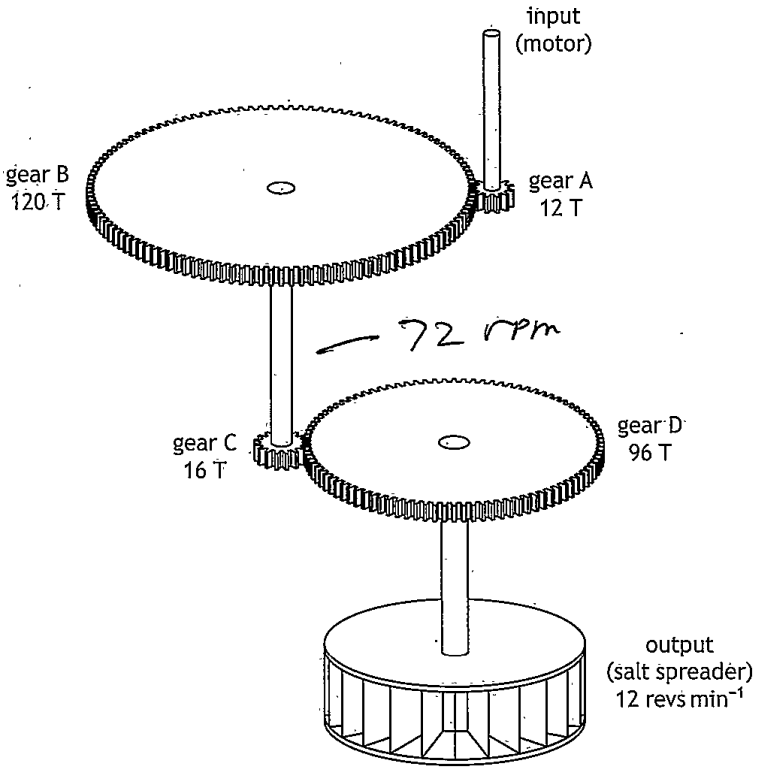
(d) Determine (with reference to the graph above) the resistance of a **type 3** thermistor when the temperature is 10 °C. 1

20 000 Ω

[Turn over

10. (continued) MARKS | DO NOT WRITE IN THIS MARGIN

The gear train shown below is used to drive the salt spreading system.



(e) Calculate the **input** speed of the motor. 4

$VR\left(\frac{96}{16}\right) \times 12 = 72$

$VR\left(\frac{120}{12}\right)$

$VR = 10$

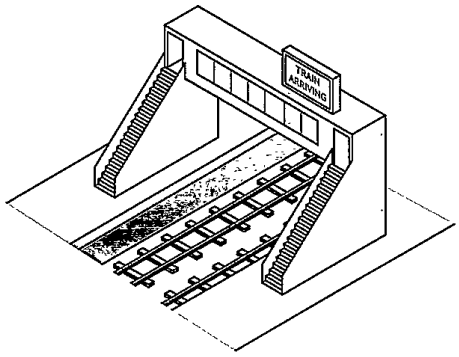
10×72

$= 720$ rpm

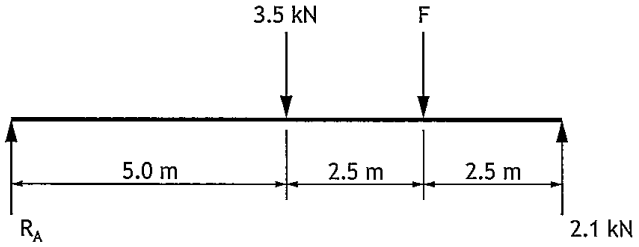
$= 720$ revs min^{-1}

MARKS | DO NOT WRITE IN THIS MARGIN

11. A walkway linking two railway platforms is shown.



A simplified freebody diagram of the walkway and sign (force F) is shown below.



(a) (i) Calculate the **force F** by taking moments about R_A. **3**

$R_A F \times 7.5 = 5 \times 3.5$

$F R_A \times 7.5 = 17.5$

$F = \frac{17.5}{7.5}$

$F = 2.3\,kN$

MARKS | DO NOT WRITE IN THIS MARGIN

11. (a) (continued)

(ii) Calculate the reaction force R_A. 2

$R_A + 2.1 = 3.5 + 2.3$

$R_A = 3.5 + 2.3 - 2.1$

$R_A = 3.7\ kN$

Lifts are installed at both ends of the walkway.

(b) (i) Describe one **positive social** impact of installing the lifts. 1

people can get to higher

(ii) Describe one **positive economic** impact of installing the lifts. 1

faster movement

(iii) Describe one **negative economic** impact of installing the lifts. 1

They cost alot of

money

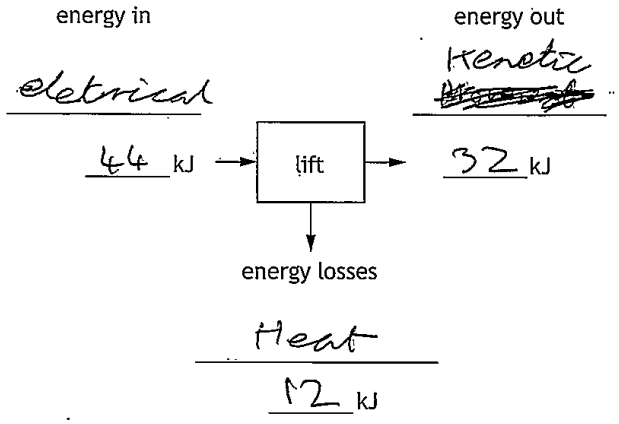
[Turn over

MARKS | DO NOT WRITE IN THIS MARGIN

11. **(continued)**

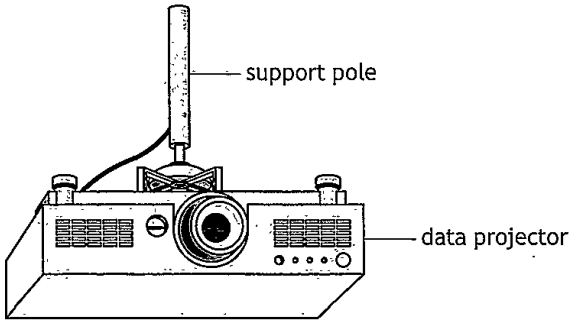
The electrical energy supplied to raise one lift up to the walkway is 44 kJ.
The lift has a potential energy of 32 kJ when it is at the top of the walkway.

(c) Complete the energy audit diagram below for the lift. 3
Include the main forms of energy **and** their values.

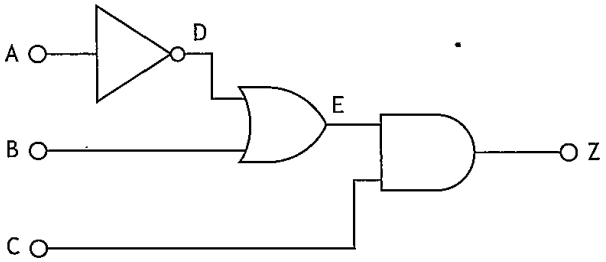


MARKS | DO NOT WRITE IN THIS MARGIN

12. A ceiling mounted data projector and support pole are shown.



Logic circuits are used to control the data projector. A logic diagram for one of the circuits is shown below.



(a) Complete the truth table for the logic diagram shown above. 3

A	B	C	D	E	Z
0	0	0	1	1	0
0	0	1	1	1	1
0	1	0	1	1	0
0	1	1	1	1	1
1	0	0	0	0	0
1	0	1	0	0	0
1	1	0	0	1	0
1	1	1	0	1	1

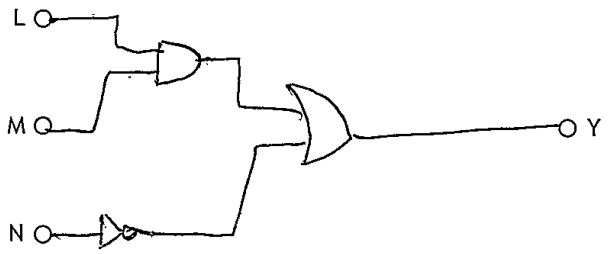
MARKS | DO NOT WRITE IN THIS MARGIN

12. **(continued)**

The Boolean equation for a second logic circuit is given below.

$$(L \bullet M) + \overline{N} = Y$$

(b) Complete the logic diagram below for this Boolean equation. 3



(c) Describe two **advantages** of using computer simulation to test a logic circuit before constructing a prototype. 2

1 cheaper to edit and fix

2 can be shared online with other people to check and discuss work

MARKS | DO NOT WRITE IN THIS MARGIN

12. (continued)

The support pole used to hold the data projector has a cross-sectional area of 190 mm^2 and a stress of 0.84 N mm^{-2}.

(d) (i) Calculate the force acting on the support pole. 3

$P = \frac{F}{A}$

$F = P \times A$

$F = 190 \times 0.84$

$F = 160\ N$

(ii) State the **nature** of the force in the support pole as the data projector pulls down on it. 1

Compression

The pole supporting the data projector is replaced with one which has a larger cross-sectional area.

(e) Describe the effect this will have on the stress in the support pole. 1

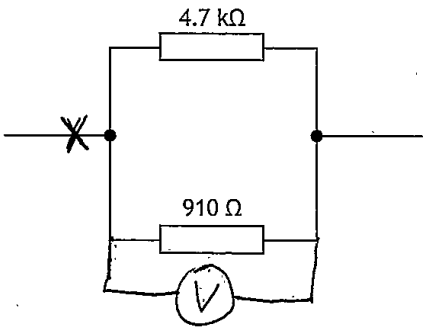
The stress will increase

[Turn over

MARKS | DO NOT WRITE IN THIS MARGIN

13. A hoverboard is shown.

Part of the circuit used in the control of the hoverboard is shown below.



(a) (i) Calculate the total resistance of the circuit. 2

$\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2}$

$\frac{1}{R_t} = \frac{1}{910} + \frac{1}{4.7 \times 10^3}$

$\frac{1}{R_t} = 1.3... \times 10^{-3}$

$R_t = 762.4\ \Omega$

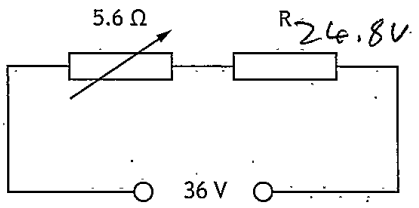
(ii) Draw the symbol for a voltmeter, connected **on the circuit above**, to measure the voltage across the 910 Ω resistor. 2

(iii) Indicate, with an X, **on the circuit above** where an ammeter would be connected to measure the **total** current. 1

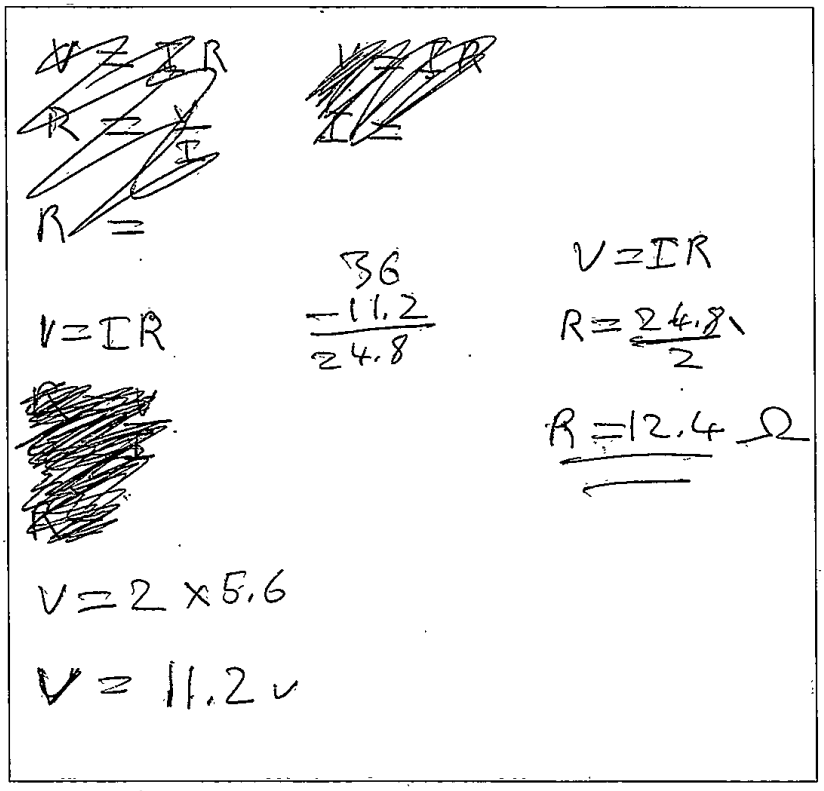
MARKS | DO NOT WRITE IN THIS MARGIN

13. (continued)

Part of a second circuit used in the hoverboard is tested using a 36 V supply.



(b) Calculate the value of resistor R to ensure that the circuit current is 2.0 A. 4



[Turn over

MARKS | DO NOT WRITE IN THIS MARGIN

13. (continued)

The hoverboard and rider have a combined mass of 64 kg.

(c) Calculate the kinetic energy of the hoverboard and rider when they are travelling at 3.4 $m\,s^{-1}$. 2

$E_K = 0.5 \times m \times v^2$

$E_K = 0.5 \times 64 \times 3.4^2$

$E_K = 370\,J$

The hoverboard is an established technology.

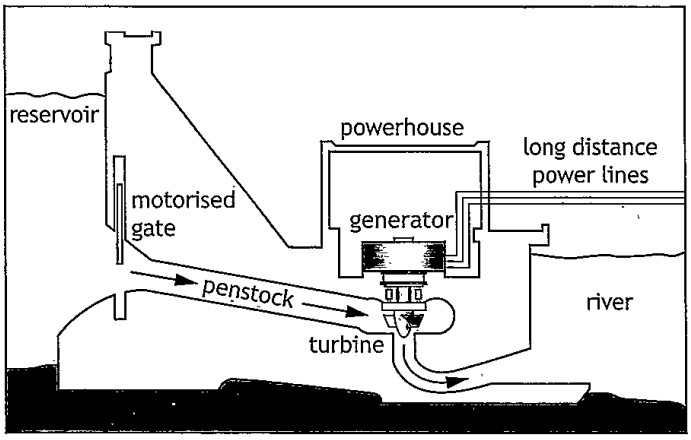
A driverless car is an **emerging technology** that is not yet established.

(d) Explain a possible impact of driverless cars on **road safety.** 2

Road Safety might increase due to all cars sticking to the speed limit and there being no need for speed cameras

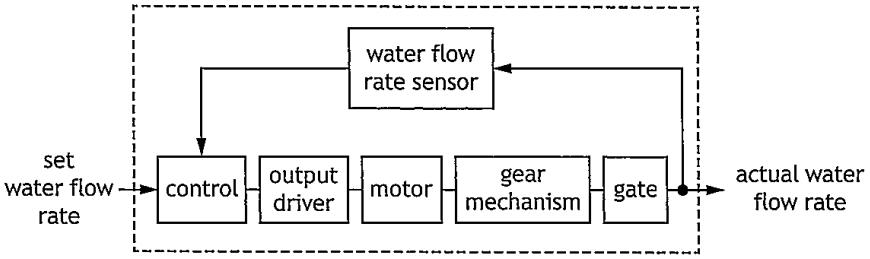
14. Hydropower is used to produce electricity from stored water in a reservoir. A diagram of a hydropower station is shown.

MARKS | DO NOT WRITE IN THIS MARGIN



A steady flow rate of water must move through the penstock to rotate the turbine. The water flow rate is adjusted by a motorised gate which can move up or down.

A sub-system diagram for the control of the motorised gate is shown.



(a) Describe (with reference to the sub-system diagram) the operation of the system. 5

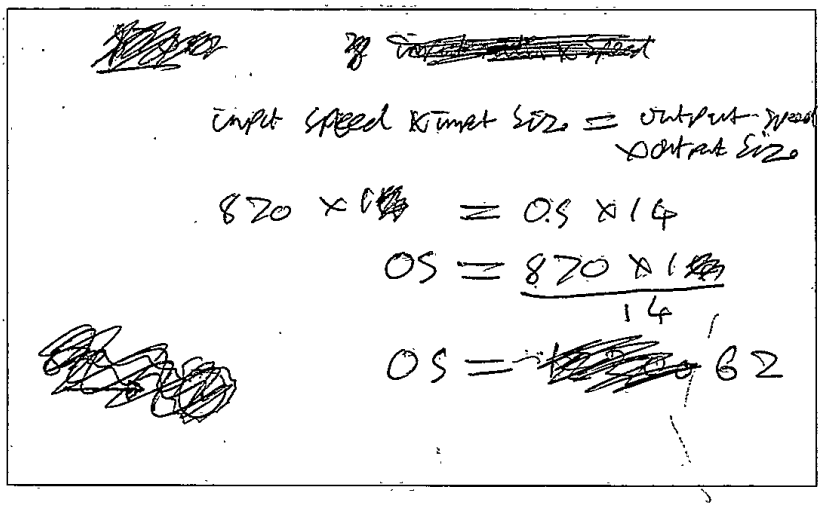
Someone inputs a flow rate it then sets put in to control that tells an output driver to activate a motor which turns a gear mechanisms that opens or closes a gate and when the water flow is reached a sensor senses this and tells control to stop opening the gate

MARKS | DO NOT WRITE IN THIS MARGIN

14. (continued)

Part of the gear mechanism used to control the gate movement has a velocity ratio of 14:1 and an input speed of 870 revs min^{-1}.

(b) Calculate the output speed of this part of the gear mechanism. 3



A microcontroller is used in the control of the hydropower station.

(c) Describe one **advantage** of using a microcontroller instead of a hard wired circuit. 1

can be reprogrammed

MARKS | DO NOT WRITE IN THIS MARGIN

14. **(continued)**

The hydropower station is 0.85 (85%) efficient and generates an output power of 15 MW.

(d) Calculate the input power. 3

$\eta = \frac{\text{energy out}}{\text{energy in}}$

$E_I = \frac{\text{energy out}}{\eta}$

$E = \frac{15 \times 10^6}{0.85}$

$E = 17.6\ MW$

(e) Explain the impact of **using** hydropower on **climate change.** 2

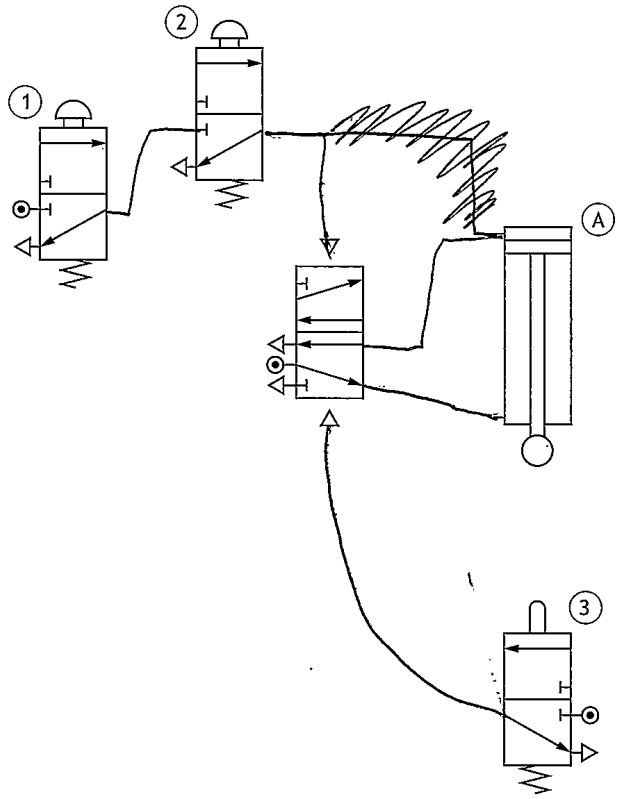
The use of hydro power is good for the planet because it uses gravity and water to generate electricity which is in plentyful supply

[Turn over

15. A pneumatic circuit is used in part of a manufacturing process.

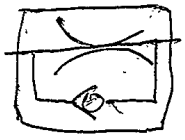
MARKS | DO NOT WRITE IN THIS MARGIN

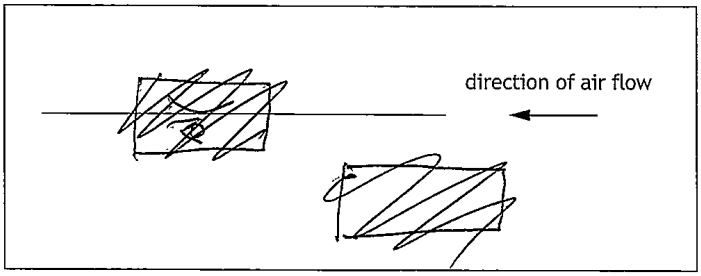
(a) Complete the piping of the pneumatic circuit below to outstroke the piston in cylinder (A) when valve (1) and valve (2) are actuated. The piston will instroke when valve (3) is actuated. 5



The speed of the piston movement needs to be slowed down.

(b) Draw the symbol for a uni-directional restrictor to slow the air flow in the direction shown. 2





MARKS | DO NOT WRITE IN THIS MARGIN

15. (continued)

Cylinder (A) is supplied with an air pressure of 1.4 N mm^{-2} and the piston has an outstroking force of 490 N.

(c) Calculate the area of the piston in cylinder (A). 3

$P = \frac{F}{A}$

$A = \frac{F}{R}$

$A = \frac{490}{1.4}$

$A = 350$ mm^2

An engineer compared the size of the outstroke force and the instroke force of a double-acting cylinder when supplied with the **same** air pressure.

The result of the test showed that there was a difference in the size of the two forces.

(d) Explain the difference in the size of these two forces. 2

because the instroke stroke
because the instroke stroke
had the piston arm in it way it can
on push on a donut sized area
instead of a full circle

[END OF QUESTION PAPER]

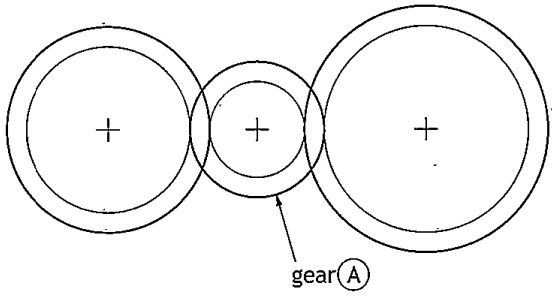
Candidate 2 evidence

MARKS | DO NOT WRITE IN THIS MARGIN

SECTION 1 — 20 marks

Attempt ALL questions

1. A gear train is shown below.



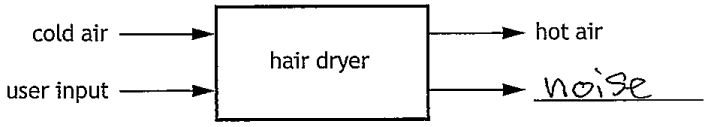
(a) State the type of **gear train** shown. 1

Idler gear Compound gear

(b) State the name of gear (A). 1

Idler gear

2. An incomplete system diagram for a hair dryer is shown.



(a) Complete the system diagram above by adding the missing output. 1

(b) State the type of control that has **no** feedback. 1

Open loop Control

MARKS | DO NOT WRITE IN THIS MARGIN

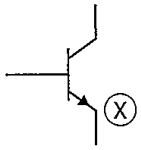
3. A force of 2200 N is required to push a workbench across a workshop floor.
Calculate the work done when the workbench is pushed a distance of 12 m. 2

$E_W = Fd$

$= 2200 \times 12$

$= 26400$ J

4. Transistors are used in many electronic products.



(a) Describe the **function** of a transistor. 1

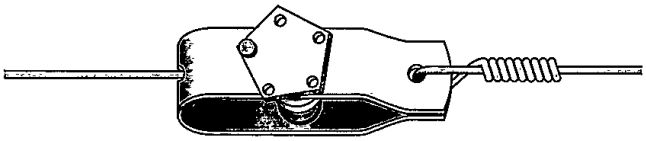
Its a electric switch

(b) State the name of connection (X) on the transistor symbol above. 1

[Turn over

MARKS | DO NOT WRITE IN THIS MARGIN

5. A tensioner is used to tighten the wire on a farm fence.



A 25 m length of wire was stretched by 0.012 m when fully tensioned.

(a) Calculate the strain in the wire. 2

$\varepsilon = \frac{\Delta L}{L}$

$= \frac{0.012}{25}$

$= 4.8 \times 10^{-4}$

$= 48000$

The table below shows details of materials that were considered for the wire.

Material	Corrosion resistant	Property
A	no	ductile
B	yes	brittle
C	yes	ductile
D	no	brittle

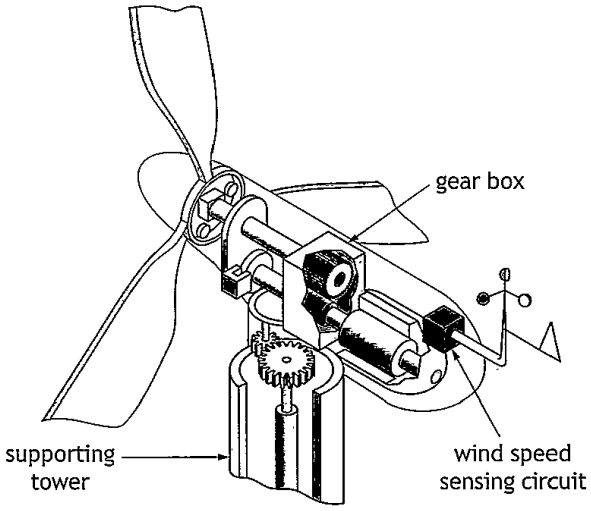
(b) Select the most suitable material (A–D) from the table for the wire and justify your choice. 2

Choice of material C

Justification It not brittle and its & corrosion resistant

MARKS | DO NOT WRITE IN THIS MARGIN

6. An offshore wind farm has wind turbines which are located out at sea.
A diagram of the inside of one of the wind turbines is shown.



(a) State which branch of engineering would be responsible for the design of the:

(i) wind speed sensing circuit 1

electronical engineer

(ii) supporting tower 1

structural engineer

(iii) gear box. 1

mechanical engineer

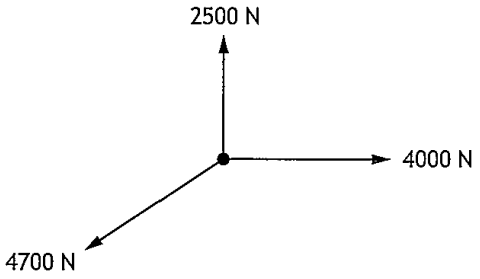
(b) Describe one role an **environmental** engineer would have during the **construction** of the offshore wind farm. 1

to moniter the afect on the wild life near by

[Turn over

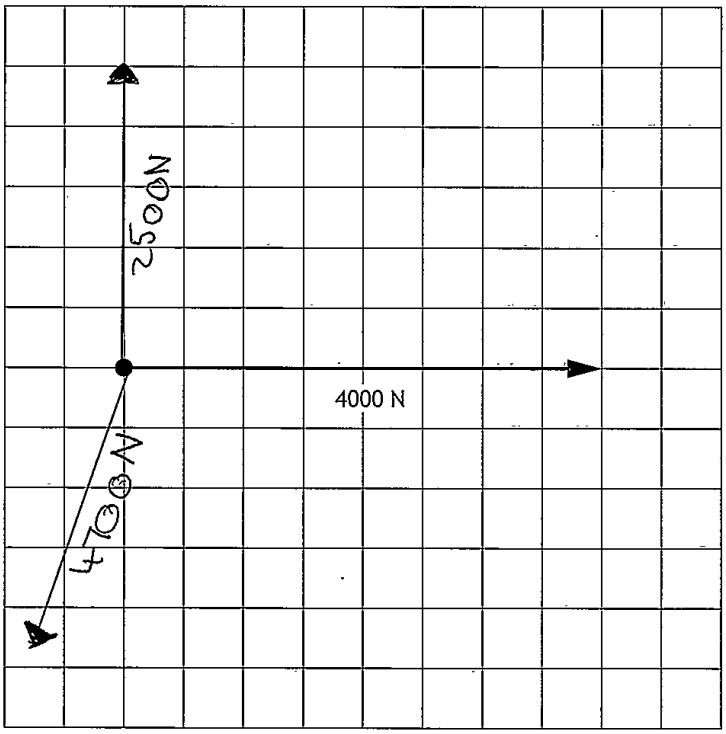
MARKS | DO NOT WRITE IN THIS MARGIN

7. Three forces, in equilibrium, acting on part of a structure are shown below.



Complete the triangle of forces **scale drawing** below for the given forces.
Forces must include an arrow head to show the direction. 2

scale 10 mm = 500 N



MARKS | DO NOT WRITE IN THIS MARGIN

8. A solar farm is shown.

Describe two **environmental** impacts of solar as a source of energy. 2

1 They dont produce Co^2

2 they take up animals habbitats

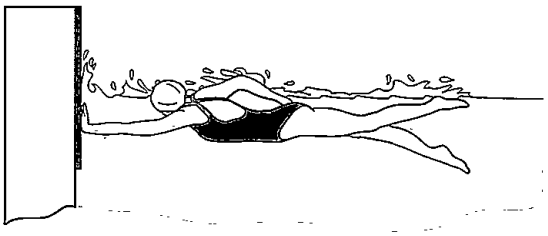
[Turn over

DO NOT WRITE IN THIS MARGIN

SECTION 2 — 90 marks

Attempt ALL questions

9. In a swimming competition, a system is used to automatically measure a competitor's time.



The system is operated by a microcontroller.

The input and output connections to the microcontroller are shown in the table below.

Input connections	Pin	Output connections
	7	buzzer
	6	timer
lane switch	1	
master switch	0	

The system operates using the following sequence.

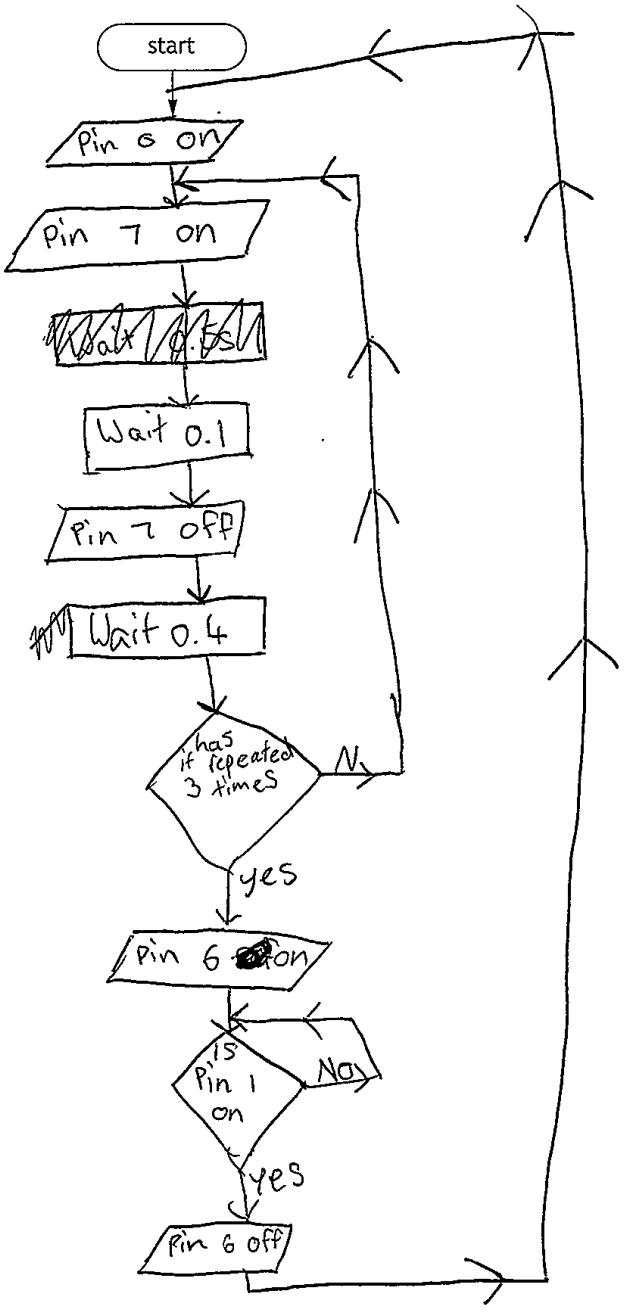
- A master switch is pressed
- A buzzer then sounds on and then off three times over 1.5 seconds
- The timer then starts
- When a lane switch is pressed the timer stops
- The system will then reset ready to be used again

MARKS | DO NOT WRITE IN THIS MARGIN

9. (continued)

(a) Complete the flowchart for the sequence, with reference to the data booklet and input/output connections.

Include **all** pin numbers and delay units in your flowchart. **10**



MARKS | DO NOT WRITE IN THIS MARGIN

9. (continued)

A program used in a different control system is listed below.

```
line   program
1      main:     let count = 0
2      label_1:     switch on 4
3                   switch on 5
4                   pause 600
5                   switch off 4
6                   switch off 5
7                   pause 600
8                   let count = count + 1
9                if count = 20 then label_2
10               goto main
11     label_2:  if Input0 is on then label_3
12               goto label_2
13     label_3:  switch on 7
14               pause 3000
15               switch off 7
16               goto main
```

(b) Describe the function of **line 16** in the program. 1

It resets the ~~[illegible]~~ counter

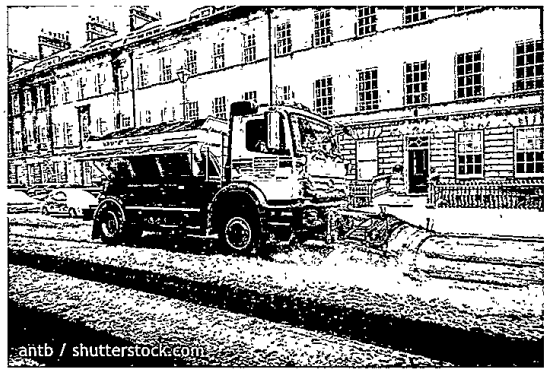
Lines 2 to **9** should repeat twenty times before moving on to **line 11**.
During testing an electronic engineer found that this did not happen.

(c) Explain why **lines 2** to **9** did not repeat twenty times before moving on to **line 11**. 2

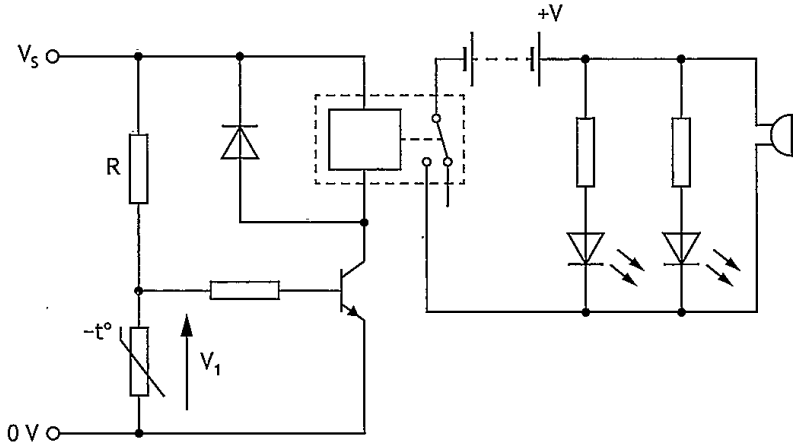
It says "goto main" when it should say goto label_1. It says "goto label_2" when it ~~[illegible]~~ should say goto label_1

DO NOT WRITE IN THIS MARGIN

10. The road gritter shown below is used to spread salt on icy roads.



The warning circuit shown below is used to alert the driver of a low temperature.



MARKS | DO NOT WRITE IN THIS MARGIN

10. (continued)

(a) Describe the operation of the warning circuit shown opposite. Make reference to the **resistance of the thermistor** and the **voltage V_1**. 4

When the temperature decreases to a low temperature . . .

the risistence decreases. When V_1 is above 0.7V the transistor turns on ~~to~~ which turns on the relay. the diode is there to protect the relay from [redacted] back emf. the relay turns on the bigger circuit. the base risistor protects the transistor from to much voltage.

The fixed resistor (R) is replaced with a variable resistor.

(b) Explain the effect on the **operation** of the warning circuit by replacing the fixed resistor (R) with the variable resistor. 2

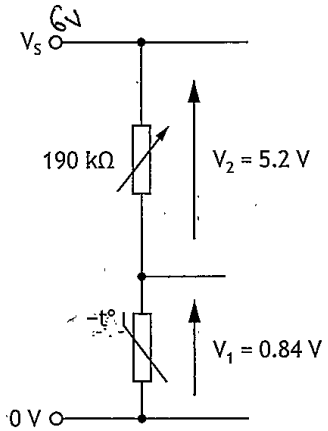
It would make the circiot more sercitive and you could change the temperature that it would turn on at.

[Turn over

MARKS | DO NOT WRITE IN THIS MARGIN

10. (continued)

The input sensing circuit (which is part of the warning circuit) is shown below.



(c) Calculate the resistance of the thermistor. **3**

$\frac{V_1}{V_2} = \frac{R_1}{R_2}$ 8.5000

$\frac{0.84}{5.2} = \frac{190}{R_2}$

$\frac{0.84}{5.2} \times 190 = R_2$

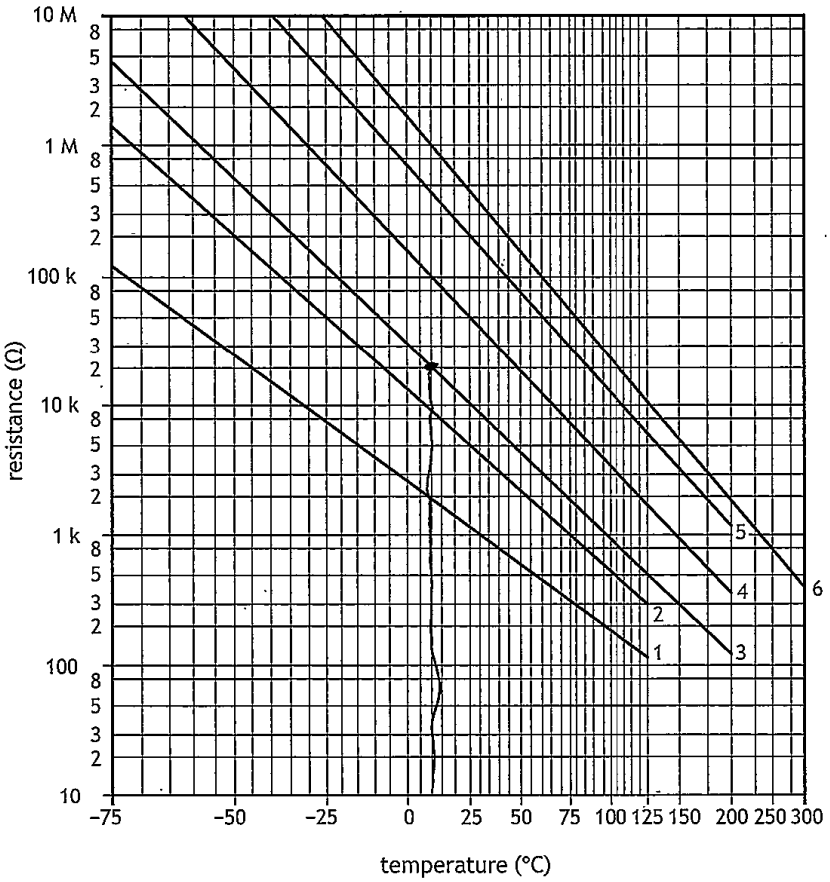
$8.5 \times 10^{-4} = R_2$

$R_2 = 85000\,k\Omega$

MARKS | DO NOT WRITE IN THIS MARGIN

10. (continued)

The operating characteristics of a range of thermistors are shown on the graph below.



(d) Determine (with reference to the graph above) the resistance of a **type 3** thermistor when the temperature is 10 °C. 1

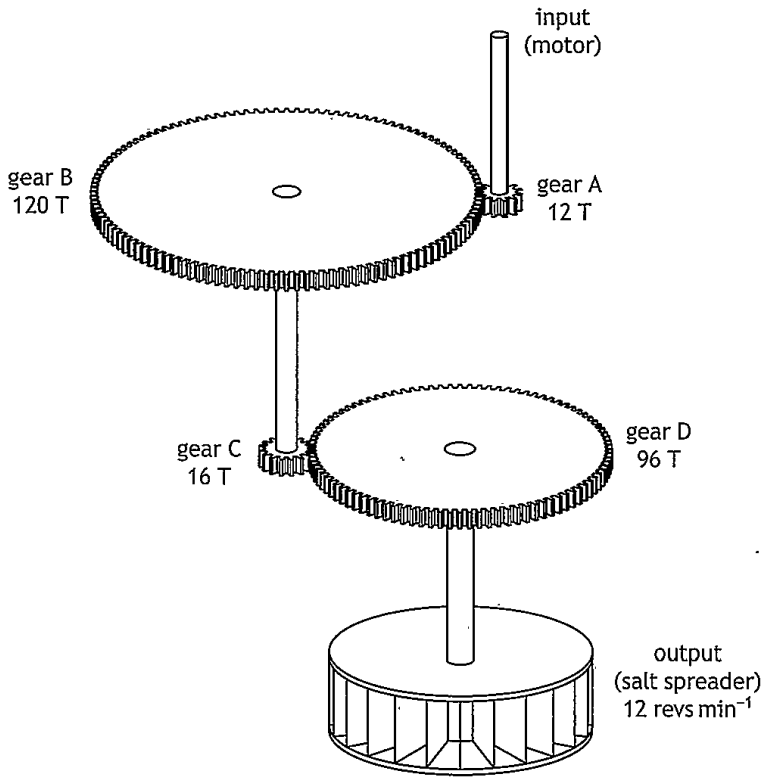
20 kΩ

[Turn over

10. (continued)

MARKS | DO NOT WRITE IN THIS MARGIN

The gear train shown below is used to drive the salt spreading system.



(e) Calculate the **input** speed of the motor. 4

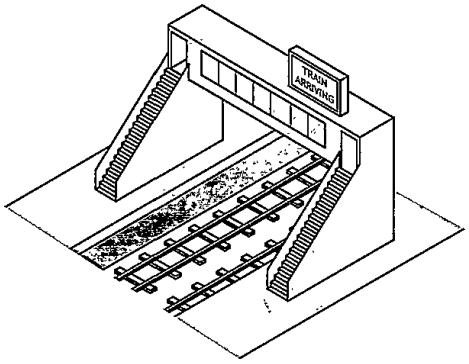
mmr = 16/96 = 0.16 Vout = 12/0.16 = 75

mmr = 12/120 = 0.1 Vout = 75/0.1 = 750 revs per min

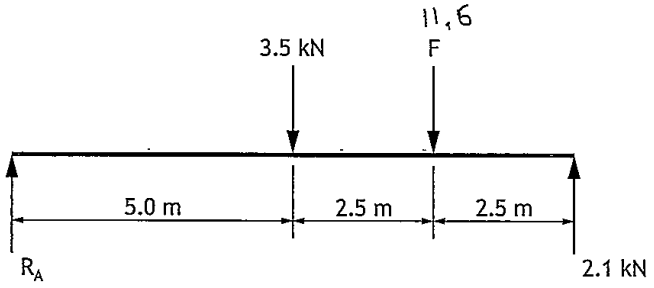
input speed = 750 revs per min

MARKS | DO NOT WRITE IN THIS MARGIN

11. A walkway linking two railway platforms is shown.



A simplified freebody diagram of the walkway and sign (force F) is shown below.



(a) (i) Calculate the **force F** by taking moments about R_A. **3**

$\Sigma M_{RA} = 0$

$(5 \times 3.5) - F = 0$

$17.5 = 0$

$17.5 = R_A$ kN

y, +, x

$17.5 - 2.1 - 3.5$

$= 11.9$ kN

MARKS | DO NOT WRITE IN THIS MARGIN

11. (a) (continued)

(ii) Calculate the reaction force R_A. 2

$\Sigma F_v = 0$

$= 0$

y +

x

Lifts are installed at both ends of the walkway.

(b) (i) Describe one **positive social** impact of installing the lifts. 1

People can get places faster

(ii) Describe one **positive economic** impact of installing the lifts. 1

more people will go because they dont have to walk up stairs

(iii) Describe one **negative economic** impact of installing the lifts. 1

they cost a lot of money to make and install.

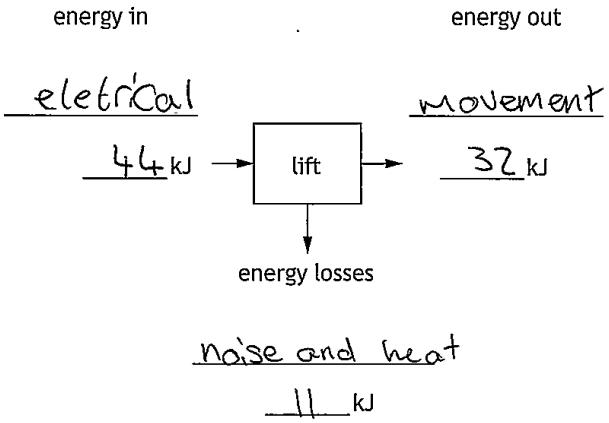
[Turn over

MARKS | DO NOT WRITE IN THIS MARGIN

11. **(continued)**

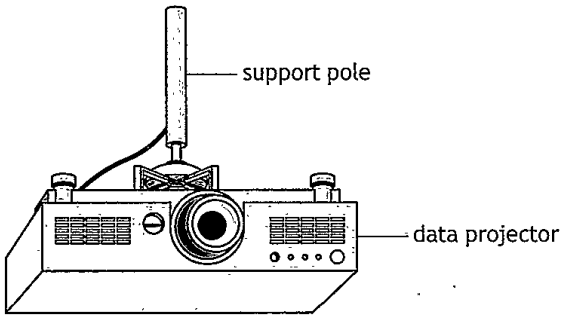
The electrical energy supplied to raise one lift up to the walkway is 44 kJ.
The lift has a potential energy of 32 kJ when it is at the top of the walkway.

(c) Complete the energy audit diagram below for the lift. 3
Include the main forms of energy **and** their values.

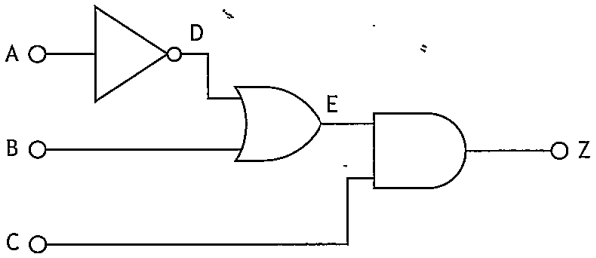


MARKS | DO NOT WRITE IN THIS MARGIN

12. A ceiling mounted data projector and support pole are shown.



Logic circuits are used to control the data projector. A logic diagram for one of the circuits is shown below.



(a) Complete the truth table for the logic diagram shown above. 3

A	B	C	D	E	Z
0	0	0	1	1	0
0	0	1	1	1	1
0	1	0	1	1	0
0	1	1	1	1	1
1	0	0	0	0	0
1	0	1	0	0	0
1	1	0	0	1	0
1	1	1	0	1	1

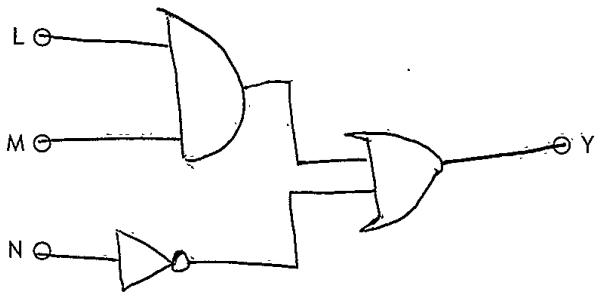
MARKS | DO NOT WRITE IN THIS MARGIN

12. (continued)

The Boolean equation for a second logic circuit is given below.

$$(L \bullet M) + \overline{N} = Y$$

(b) Complete the logic diagram below for this Boolean equation. 3



(c) Describe two **advantages** of using computer simulation to test a logic circuit before constructing a prototype. 2

1 Its cheaper to do a Simulation

2 Its faster to do a Simulation

MARKS | DO NOT WRITE IN THIS MARGIN

12. (continued)

The support pole used to hold the data projector has a cross-sectional area of 190 mm^2 and a stress of 0.84 N mm^{-2}.

(d) (i) Calculate the force acting on the support pole. 3

$\sigma = \frac{F}{A}$

$F = \sigma \times A$

$= 0.84 \times 190$

$= 159.6N$

(ii) State the **nature** of the force in the support pole as the data projector pulls down on it. 1

tension

The pole supporting the data projector is replaced with one which has a larger cross-sectional area.

(e) Describe the effect this will have on the stress in the support pole. 1

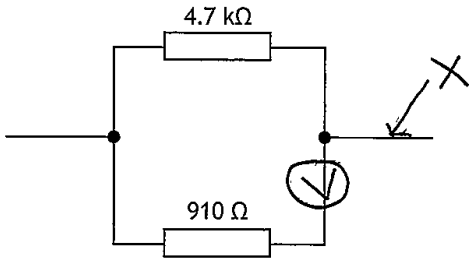
the stress on the pole would reduce.

[Turn over

MARKS | DO NOT WRITE IN THIS MARGIN

13. A hoverboard is shown.

Part of the circuit used in the control of the hoverboard is shown below.



(a) (i) Calculate the total resistance of the circuit. 2

$R_t = \frac{R_1 R_2}{(R_1 + R_2)}$

$R_t = \frac{4700 \times 910}{(4700 + 910)}$

$R_t = 762.4\ \Omega$

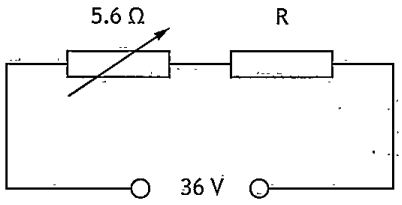
(ii) Draw the symbol for a voltmeter, connected **on the circuit above**, to measure the voltage across the 910 Ω resistor. 2

(iii) Indicate, with an X, **on the circuit above** where an ammeter would be connected to measure the **total** current. 1

MARKS | DO NOT WRITE IN THIS MARGIN

13. (continued)

Part of a second circuit used in the hoverboard is tested using a 36 V supply.



(b) Calculate the value of resistor R to ensure that the circuit current is 2.0 A. 4

$I=2$ $R=?$

$V=36$ $V=IR$

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

$=\frac{36}{2}$

$=18$

$18-5.6=12.4$

$R=12.4\,\Omega$

[Turn over

MARKS | DO NOT WRITE IN THIS MARGIN

13. (continued)

The hoverboard and rider have a combined mass of 64 kg.

(c) Calculate the kinetic energy of the hoverboard and rider when they are travelling at 3.4 $m\,s^{-1}$. 2

$E_K = \frac{1}{2} m v^2$

$= \frac{1}{2} 64 \times 3.4^2$

$= 369.92\ N$

The hoverboard is an established technology.

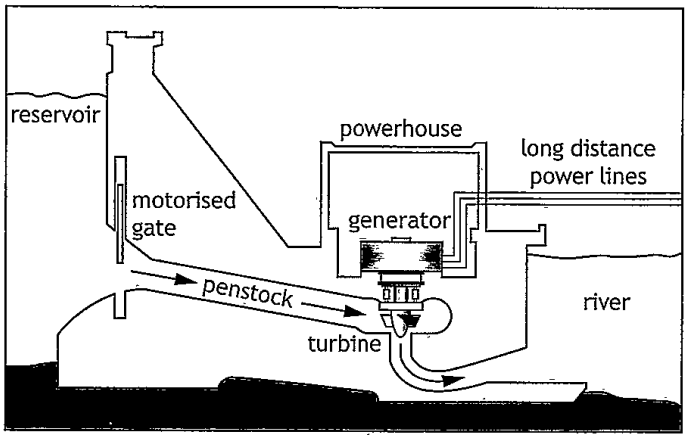
A driverless car is an **emerging technology** that is not yet established.

(d) Explain a possible impact of driverless cars on **road safety.** 2

Driver error would be reduced because No body would be driving. Machine error would increase puting people at risk.

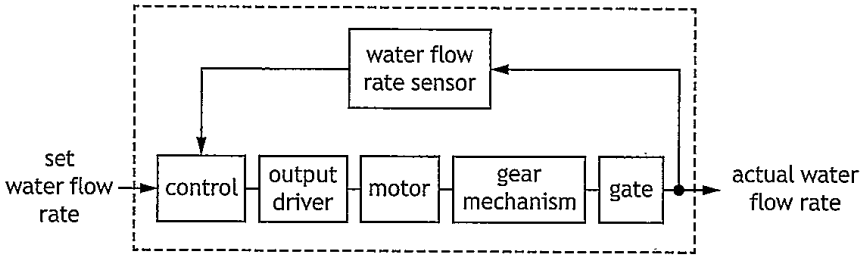
14. Hydropower is used to produce electricity from stored water in a reservoir.
A diagram of a hydropower station is shown.

MARKS | DO NOT WRITE IN THIS MARGIN



A steady flow rate of water must move through the penstock to rotate the turbine.
The water flow rate is adjusted by a motorised gate which can move up or down.

A sub-system diagram for the control of the motorised gate is shown.



(a) Describe (with reference to the sub-system diagram) the operation of the system. 5

the contron unit compares the actual state to the disired state and if they dont match the out put driver will turn on. Which turns on the motor which turns the motor mechanism Which will ~~turn on~~ open the gate and the water flow sensor will tell the control the water flow.

MARKS | DO NOT WRITE IN THIS MARGIN

14. (continued)

Part of the gear mechanism used to control the gate movement has a velocity ratio of 14:1 and an input speed of 870 revs min^{-1}.

(b) Calculate the output speed of this part of the gear mechanism. 3

$V_{out} = \frac{870}{14} = 62.1$ revs per min

A microcontroller is used in the control of the hydropower station.

(c) Describe one **advantage** of using a microcontroller instead of a hard wired circuit. 1

its easyer to change because its digital

MARKS | DO NOT WRITE IN THIS MARGIN

14. (continued)

The hydropower station is 0.85 (85%) efficient and generates an output power of 15 MW.

(d) Calculate the input power. 3

85% = 15MW

15 x 1.15 = 17.25MW

100% = 17.25MW

(e) Explain the impact of using hydropower on climate change. 2

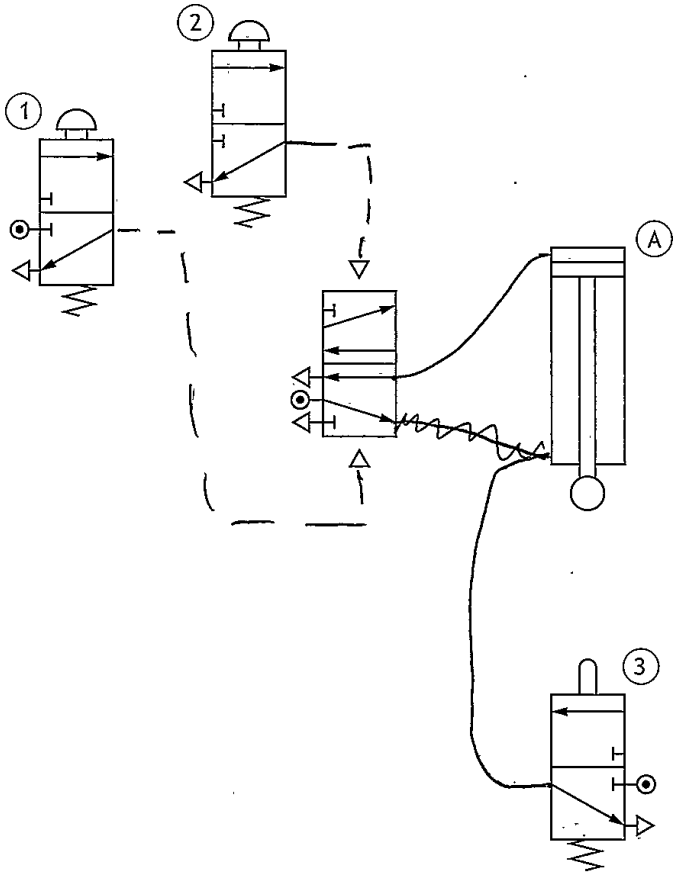
It doesn't produce an Co^2 which is good for the enviroment. ~~It does destroy habbitas which is bad~~ It take a lot of machines to build and they produce co^2.

[Turn over

15. A pneumatic circuit is used in part of a manufacturing process.

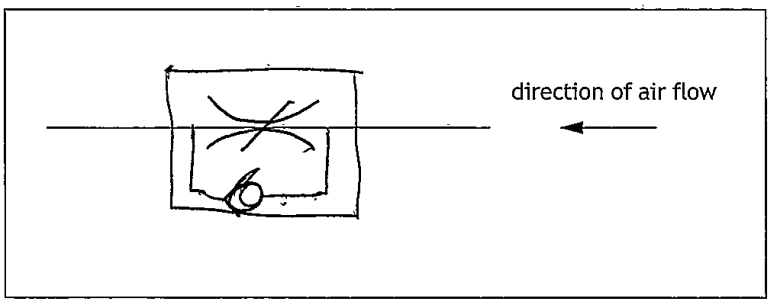
MARKS | DO NOT WRITE IN THIS MARGIN

(a) Complete the piping of the pneumatic circuit below to outstroke the piston in cylinder (A) when valve (1) **and** valve (2) are actuated. The piston will instroke when valve (3) is actuated. 5



The speed of the piston movement needs to be slowed down.

(b) Draw the symbol for a uni-directional restrictor to slow the air flow in the direction shown. 2



MARKS | DO NOT WRITE IN THIS MARGIN

15. (continued)

Cylinder (A) is supplied with an air pressure of 1.4 N mm^{-2} and the piston has an outstroking force of 490 N.

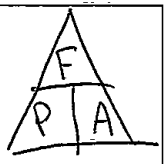
(c) Calculate the area of the piston in cylinder (A). 3

$P = \frac{F}{A}$

$A = \frac{F}{P}$

$= \frac{490}{1.4}$

$= 350 mm^2$



An engineer compared the size of the outstroke force and the instroke force of a double-acting cylinder when supplied with the **same** air pressure.

The result of the test showed that there was a difference in the size of the two forces.

(d) Explain the difference in the size of these two forces. 2

There is more force when in stroking because there is less room in the cylinder.

[END OF QUESTION PAPER]

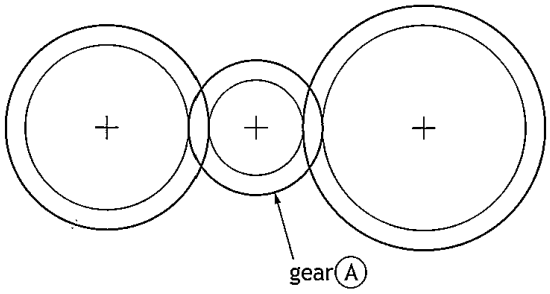
Candidate 3 evidence

MARKS | DO NOT WRITE IN THIS MARGIN

SECTION 1 — 20 marks

Attempt ALL questions

1. A gear train is shown below.



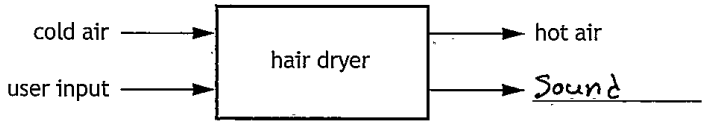
(a) State the type of **gear train** shown. 1

Driven gear box

(b) State the name of gear (A). 1

Drive gear

2. An incomplete system diagram for a hair dryer is shown.



(a) Complete the system diagram above by adding the missing output. 1

(b) State the type of control that has **no** feedback. 1

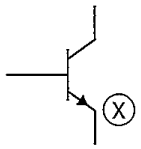
Closed Loop

MARKS | DO NOT WRITE IN THIS MARGIN

3. A force of 2200 N is required to push a workbench across a workshop floor.
Calculate the work done when the workbench is pushed a distance of 12 m. 2

WD = FD
WD = 2200 x 12
WD = 26400 J

4. Transistors are used in many electronic products.



(a) Describe the **function** of a transistor. 1

a transistor splits the voltage

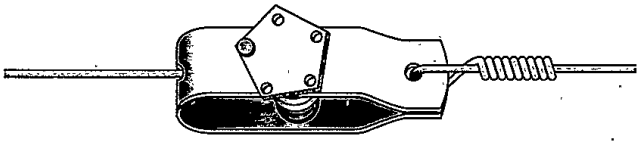
(b) State the name of connection (X) on the transistor symbol above. 1

NP N transistor

[Turn over

MARKS | DO NOT WRITE IN THIS MARGIN

5. A tensioner is used to tighten the wire on a farm fence.



A 25 m length of wire was stretched by 0.012 m when fully tensioned.

(a) Calculate the strain in the wire. 2

$\varepsilon = \frac{\Delta L}{L}$

$\varepsilon = \frac{0.012}{25}$

$\varepsilon = 4 \times 10^{-4}$

The table below shows details of materials that were considered for the wire.

Material	Corrosion resistant	Property
A	no	ductile
B	yes	brittle
C	yes	ductile
D	no	brittle

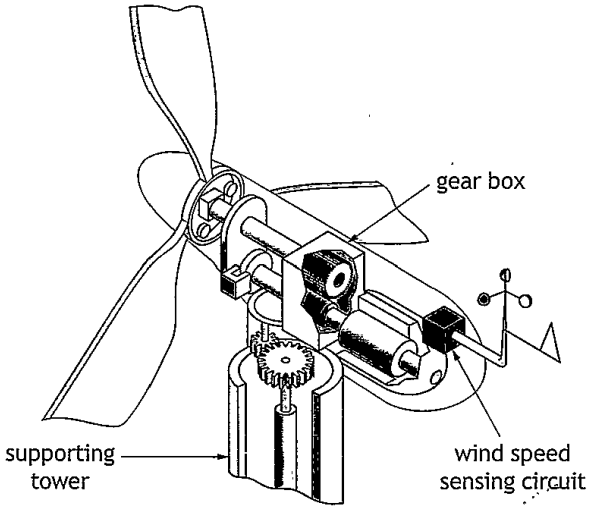
(b) Select the most suitable material (A–D) from the table for the wire and justify your choice. 2

Choice of material C

Justification the material must be corrosion resistant and it cant be brittle as it would shatter

MARKS | DO NOT WRITE IN THIS MARGIN

6. An offshore wind farm has wind turbines which are located out at sea.
A diagram of the inside of one of the wind turbines is shown.



(a) State which branch of engineering would be responsible for the design of the:

(i) wind speed sensing circuit 1

Eletrical engineer

(ii) supporting tower 1

~~Civil~~ civel engneer ~~civil civil civil~~

(iii) gear box. 1

mechanical engneer

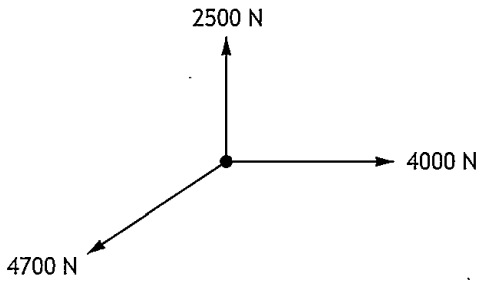
(b) Describe one role an **environmental** engineer would have during the **construction** of the offshore wind farm. 1

Looking at environmental ~~impacts~~ Impacts the wind farm might have such as wild life

[Turn over

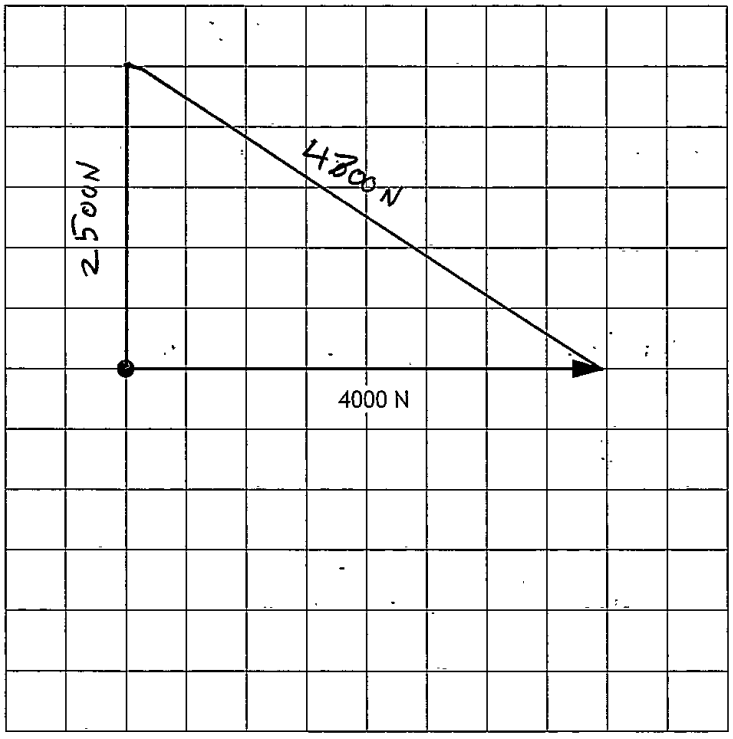
MARKS | DO NOT WRITE IN THIS MARGIN

7. Three forces, in equilibrium, acting on part of a structure are shown below.



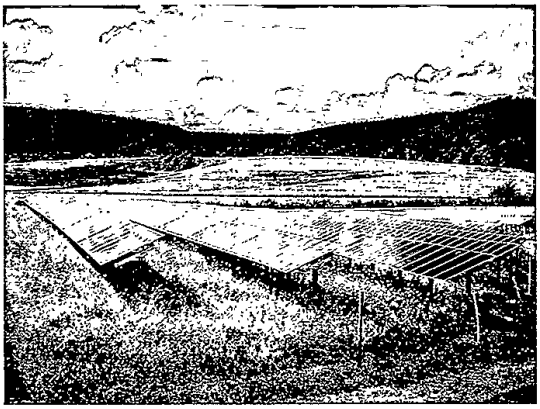
Complete the triangle of forces **scale drawing** below for the given forces.
Forces must include an arrow head to show the direction. 2

scale 10 mm = 500 N



MARKS | DO NOT WRITE IN THIS MARGIN

8. A solar farm is shown.



Describe two **environmental** impacts of solar as a source of energy. 2

1 Takes up space in area that ~~~~ wildlife live

2 required machine and wires to create

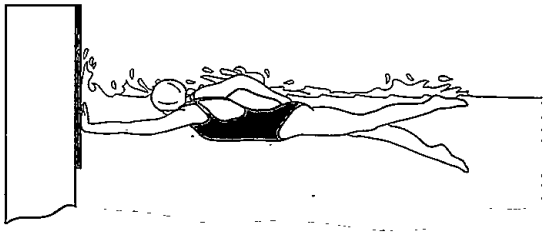
[Turn over

DO NOT WRITE IN THIS MARGIN

SECTION 2 — 90 marks

Attempt ALL questions

9. In a swimming competition, a system is used to automatically measure a competitor's time.



The system is operated by a microcontroller.

The input and output connections to the microcontroller are shown in the table below.

Input connections	Pin	Output connections
	7	buzzer
	6	timer
lane switch	1	
master switch	0	

The system operates using the following sequence.

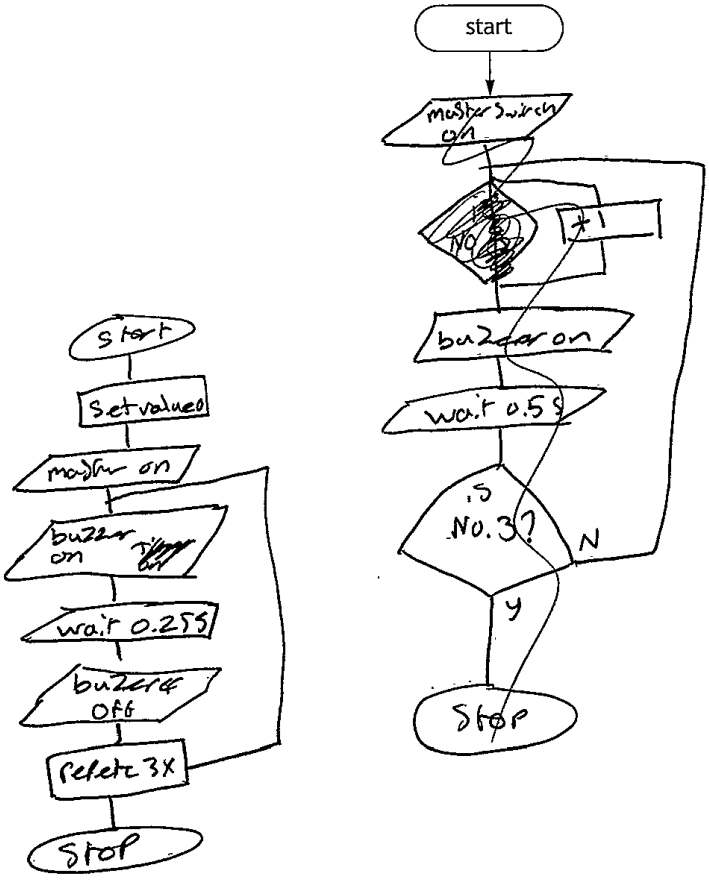
- A master switch is pressed
- A buzzer then sounds on and then off three times over 1.5 seconds
- The timer then starts
- When a lane switch is pressed the timer stops
- The system will then reset ready to be used again

MARKS | DO NOT WRITE IN THIS MARGIN

9. **(continued)**

(a) Complete the flowchart for the sequence, with reference to the data booklet and input/output connections.

Include all pin numbers and delay units in your flowchart. **10**



MARKS | DO NOT WRITE IN THIS MARGIN

9. (continued)

A program used in a different control system is listed below.

```
line   program
1      main:     let count = 0
2      label_1:     switch on 4
3                   switch on 5
4                   pause 600
5                   switch off 4
6                   switch off 5
7                   pause 600
8                   let count = count + 1
9                if count = 20 then label_2
10               goto main
11     label_2:  if Input0 is on then label_3
12               goto label_2
13     label_3:  switch on 7
14               pause 3000
15               switch off 7
16               goto main
```

(b) Describe the function of **line 16** in the program. 1

it resets the number to 0 making it ready for Next use

Lines 2 to **9** should repeat twenty times before moving on to **line 11**.

During testing an electronic engineer found that this did not happen.

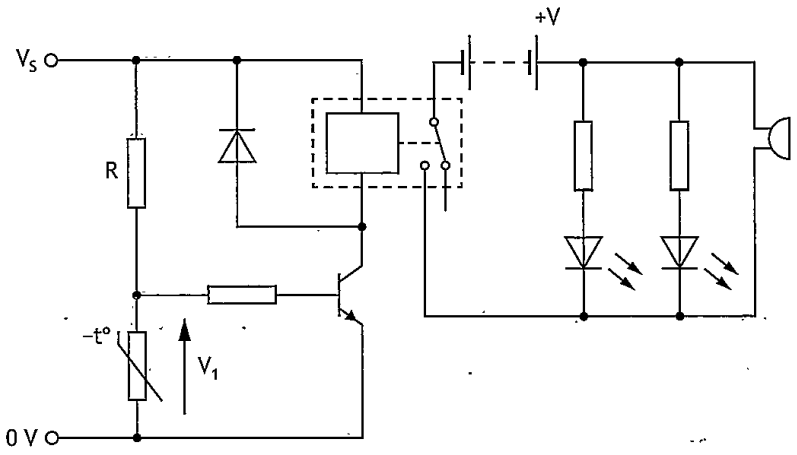
(c) Explain why **lines 2** to **9** did not repeat twenty times before moving on to **line 11**. 2

it recents at 8 and not at 2 and 9 3rt changing

DO NOT WRITE IN THIS MARGIN

10. The road gritter shown below is used to spread salt on icy roads.

The warning circuit shown below is used to alert the driver of a low temperature.



MARKS | DO NOT WRITE IN THIS MARGIN

10. (continued)

(a) Describe the operation of the warning circuit shown opposite. Make reference to the **resistance of the thermistor** and the **voltage V_1**. 4

When the temperature decreases to a low temperature . . .

the resistance in the thermistor decreases therefor the current Decreases allowing for the Led's to be Powered on

The fixed resistor (R) is replaced with a variable resistor.

(b) Explain the effect on the **operation** of the warning circuit by replacing the fixed resistor (R) with the variable resistor. 2

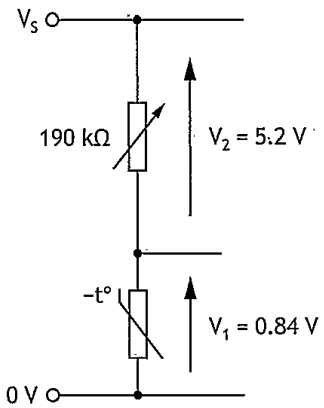
the circut would be the same as long as the variable resistor is set to the same amount of R as the Normal one

[Turn over

MARKS | DO NOT WRITE IN THIS MARGIN

10. (continued)

The input sensing circuit (which is part of the warning circuit) is shown below.



(c) Calculate the resistance of the thermistor. 3

$\frac{V_1}{V_2} = \frac{R_1}{R_2}$

$\frac{0.84 \times 190000}{5.2} = \frac{R1 \times 190000}{190000}$

$R_1 = \frac{190000 \times 0.84}{5.2}$

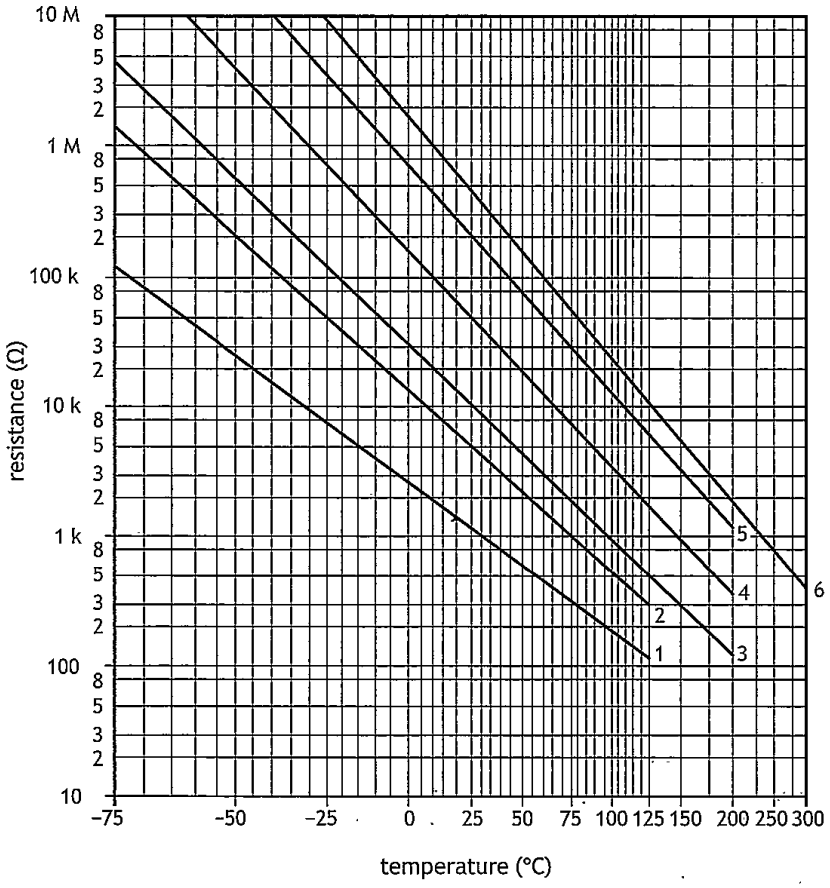
$R_1 = 30692$

$R_1 = 31 k\Omega$

MARKS | DO NOT WRITE IN THIS MARGIN

10. (continued)

The operating characteristics of a range of thermistors are shown on the graph below.



(d) Determine (with reference to the graph above) the resistance of a **type 3** thermistor when the temperature is 10 °C. 1

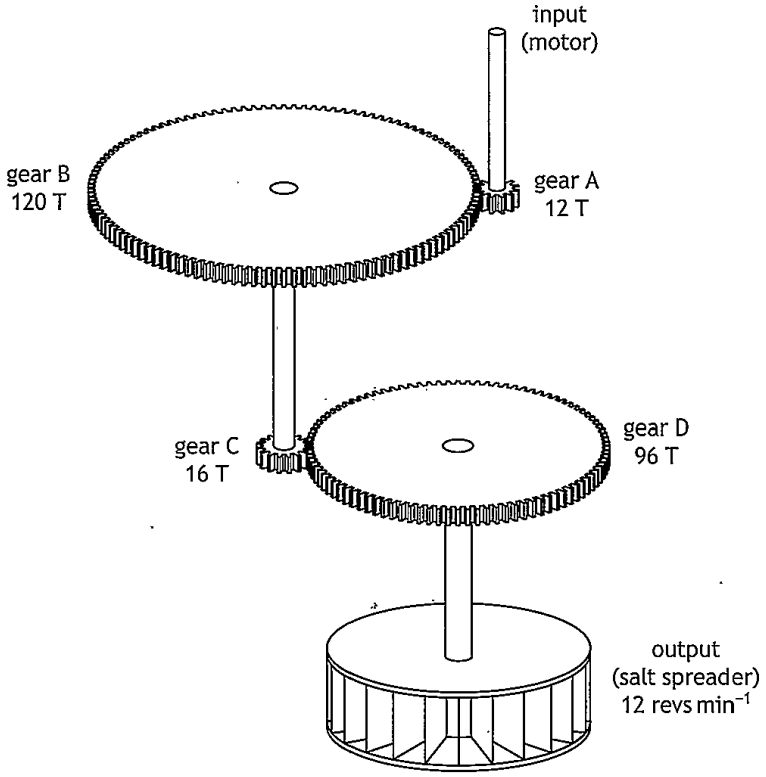
10KΩ

[Turn over

10. (continued)

MARKS | DO NOT WRITE IN THIS MARGIN

The gear train shown below is used to drive the salt spreading system.



(e) Calculate the **input** speed of the motor. 4

$VR = \frac{In}{out}$

$VR = \frac{No\ of\ teeth}{No\ of\ teeth}$

$VR = \frac{In}{12}$

$VR = \frac{12 \times 96}{120 \times 16}$

$In = VR \times 12$

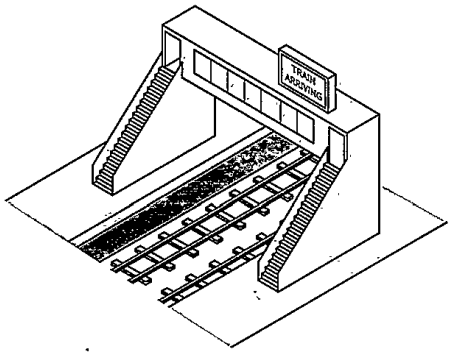
$VR = 0.794$

$In = 0.794 \times 12$

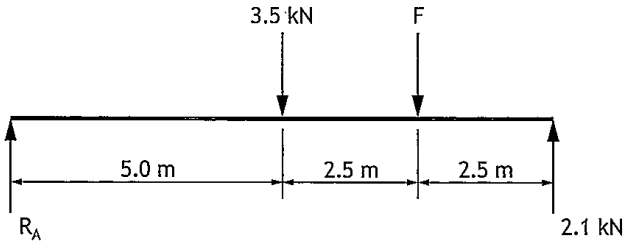
$In = 9.53\ rpm$

MARKS | DO NOT WRITE IN THIS MARGIN

11. A walkway linking two railway platforms is shown.



A simplified freebody diagram of the walkway and sign (force F) is shown below.



(a) (i) Calculate the force F by taking moments about R_A. **3**

$F = \frac{\text{left}}{\text{Right}}$

$F = \frac{3500 \times 5 \times 2.5}{2.5 \times 21000}$

$F = 8.[illegible]$ kN 5 2 N

MARKS | DO NOT WRITE IN THIS MARGIN

11. (a) (continued)

(ii) Calculate the reaction force R_A. 2

R_A = Total Down − Total Up

R_A = ~~1176 − 2~~ 3552 − 2100

R_A = ~~0.2 kN~~ 1452 N

Lifts are installed at both ends of the walkway.

(b) (i) Describe one **positive social** impact of installing the lifts. 1

more people can access the station

(ii) Describe one **positive economic** impact of installing the lifts. 1

can be used to transport goods quicker and safer

(iii) Describe one **negative economic** impact of installing the lifts. 1

costs money and uses energy

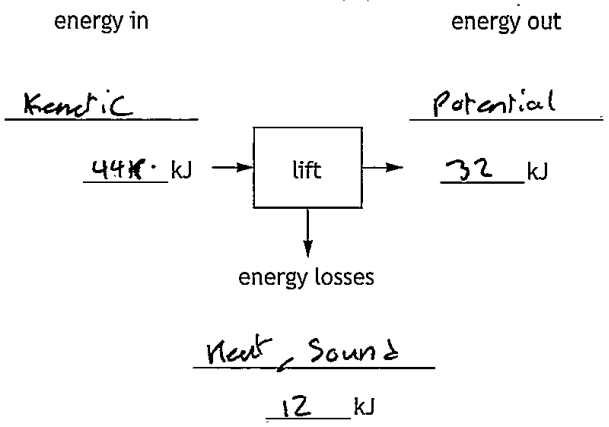
[Turn over

MARKS | DO NOT WRITE IN THIS MARGIN

11. (continued)

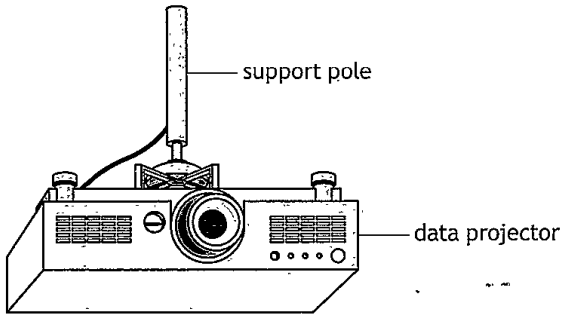
The electrical energy supplied to raise one lift up to the walkway is 44 kJ.
The lift has a potential energy of 32 kJ when it is at the top of the walkway.

(c) Complete the energy audit diagram below for the lift. 3
Include the main forms of energy and their values.

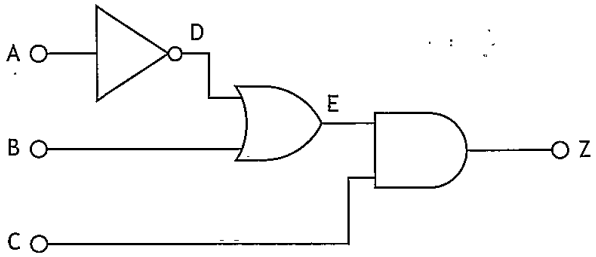


MARKS | DO NOT WRITE IN THIS MARGIN

12. A ceiling mounted data projector and support pole are shown.



Logic circuits are used to control the data projector. A logic diagram for one of the circuits is shown below.



(a) Complete the truth table for the logic diagram shown above. 3

A	B	C	D	E	Z
0	0	0	1	1	0
0	0	1	1	1	1
0	1	0	1	1	0
0	1	1	1	1	1
1	0	0	0	0	0
1	0	1	0	0	0
1	1	0	0	1	0
1	1	1	0	1	1

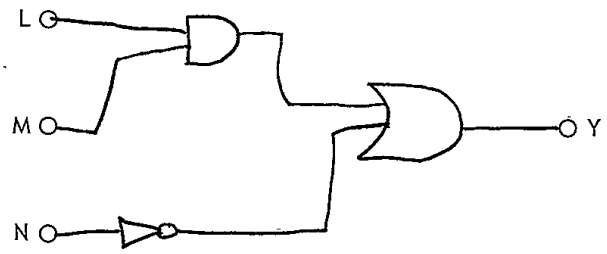
MARKS | DO NOT WRITE IN THIS MARGIN

12. (continued)

The Boolean equation for a second logic circuit is given below.

$$(L \bullet M) + \overline{N} = Y$$

(b) Complete the logic diagram below for this Boolean equation. 3



(c) Describe two **advantages** of using computer simulation to test a logic circuit before constructing a prototype. / 2

1 Quicker and doesn't require parts so if some thing breaks it Doesn't matter

2 tells you the issue of a failing circut

MARKS | DO NOT WRITE IN THIS MARGIN

12. (continued)

The support pole used to hold the data projector has a cross-sectional area of 190 mm^2 and a stress of 0.84 N mm^{-2}.

(d) (i) Calculate the force acting on the support pole. 3

$F = \sigma \times A$

$F = 0.84 \times 190$

$F = 159.6 N$

(ii) State the **nature** of the force in the support pole as the data projector pulls down on it. 1

Strut

The pole supporting the data projector is replaced with one which has a larger cross-sectional area.

(e) Describe the effect this will have on the stress in the support pole. 1

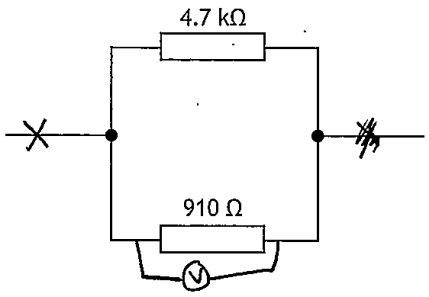
the stress would be more

[Turn over

MARKS | DO NOT WRITE IN THIS MARGIN

13. A hoverboard is shown.

Part of the circuit used in the control of the hoverboard is shown below.



(a) (i) Calculate the total resistance of the circuit. 2

$R_T = \frac{1}{R_1} + \frac{1}{R_2}$

$R_T = \frac{1}{4700} + \frac{1}{910}$

$R_T = 762.4\ \Omega$

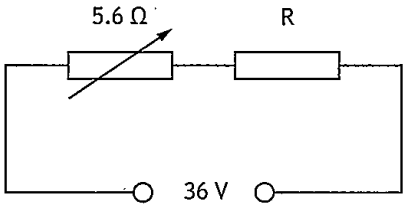
(ii) Draw the symbol for a voltmeter, connected **on the circuit above**, to measure the voltage across the 910 Ω resistor. 2

(iii) Indicate, with an X, **on the circuit above** where an ammeter would be connected to measure the **total** current. 1

MARKS | DO NOT WRITE IN THIS MARGIN

13. (continued)

Part of a second circuit used in the hoverboard is tested using a 36 V supply.



(b) Calculate the value of resistor R to ensure that the circuit current is 2.0 A. 4

$V_1 = IR$

$V_1 = 2 \times 5.6$

$V_1 = 11.2V$

$V_2 = IR$

$R_2 = \frac{V_2}{I}$

$R_2 = \frac{24.8}{2}$

$R_2 = 12.4\Omega$

$V = IR$

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

$I = \frac{36}{12.4 + 5.6}$

$I = 2A$

$\frac{V_1}{V_2} = \frac{R_1}{R_2}$

$\frac{11.2}{24.8} = \frac{5.6}{R_2} \times 5.6$

$R_2 = \frac{11.2 \times 5.6}{24.8}$

$R_2 = 2.5$

[Turn over

MARKS | DO NOT WRITE IN THIS MARGIN

13. (continued)

The hoverboard and rider have a combined mass of 64 kg.

(c) Calculate the kinetic energy of the hoverboard and rider when they are travelling at 3.4 $m\,s^{-1}$. 2

$KE = \frac{1}{2}mv^2$

$KE = 32 \times 7.4^2$

$KE = 369.92\ J$

The hoverboard is an established technology.

A driverless car is an **emerging technology** that is not yet established.

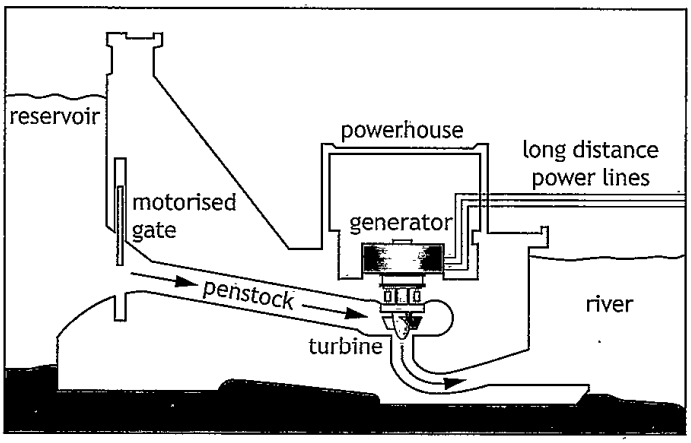
(d) Explain a possible impact of driverless cars on **road safety.** 2

the soft wear could fail or get hacked resulting in a un operatable car that is driven by technology resulting in crashes

the car could reduce human error on roads

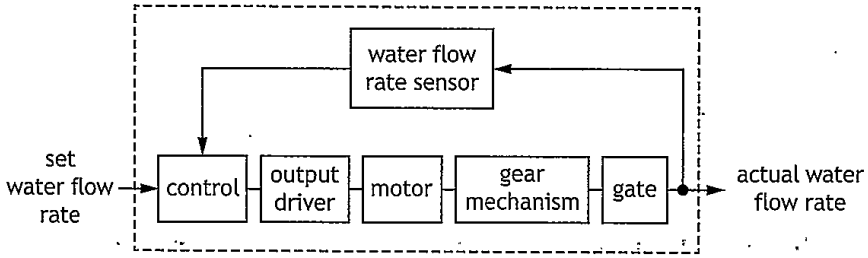
14. Hydropower is used to produce electricity from stored water in a reservoir. A diagram of a hydropower station is shown.

MARKS | DO NOT WRITE IN THIS MARGIN



A steady flow rate of water must move through the penstock to rotate the turbine. The water flow rate is adjusted by a motorised gate which can move up or down.

A sub-system diagram for the control of the motorised gate is shown.



(a) Describe (with reference to the sub-system diagram) the operation of the system. 5

User sets water flow rate that input goes to the control which then sends a signal to the out put driver that starts the motor spinning the gears opening the gate the flow rate sensor checks how much it is flowing then changes if needed to users set value

MARKS | DO NOT WRITE IN THIS MARGIN

14. (continued)

Part of the gear mechanism used to control the gate movement has a velocity ratio of 14:1 and an input speed of 870 revs min^{-1}.

(b) Calculate the output speed of this part of the gear mechanism. 3

• $Vr = \frac{In}{Out}$

$Out = \frac{In}{Vr}$

$Out = \frac{870}{14}$

$Out = 12870$

$Out = 62.14 RPM$

A microcontroller is used in the control of the hydropower station.

(c) Describe one **advantage** of using a microcontroller instead of a hard wired circuit. 1

a Micro controller is smaller and uses less wires

MARKS | DO NOT WRITE IN THIS MARGIN

14. (continued)

The hydropower station is 0.85 (85%) efficient and generates an output power of 15 MW.

(d) Calculate the input power. 3

85% = 15MW
÷85 ÷85
1% = 0.176MW
×100 ×100
100% = 17.65 MW
in = 17.65 MW

(e) Explain the impact of using hydropower on climate change. 2

using Hydropower is better for climate change as it is renewable

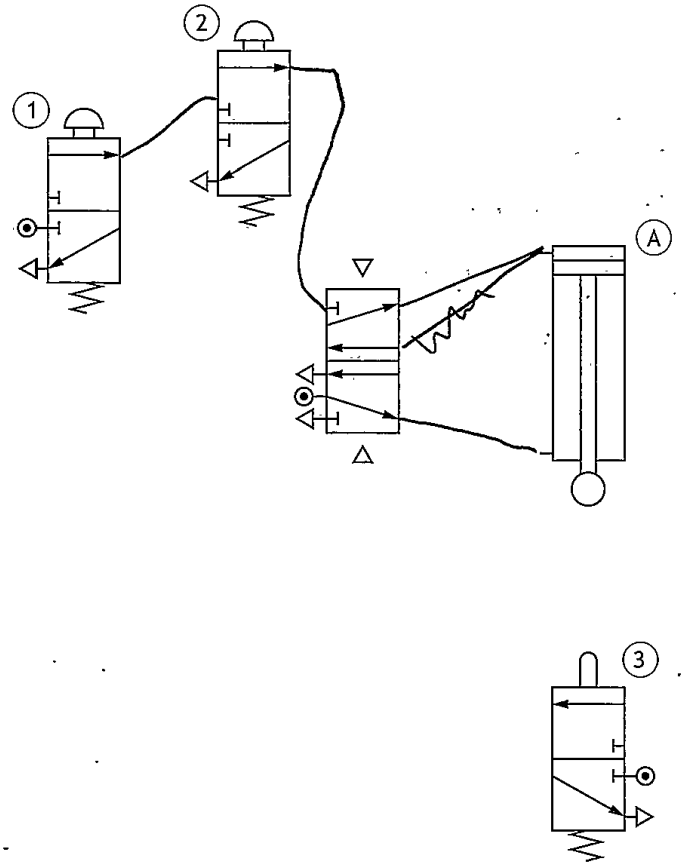
[Turn over

15. A pneumatic circuit is used in part of a manufacturing process.

MARKS

DO NOT WRITE IN THIS MARGIN

(a) Complete the piping of the pneumatic circuit below to outstroke the piston in cylinder (A) when valve (1) and valve (2) are actuated. The piston will instroke when valve (3) is actuated. 5



The speed of the piston movement needs to be slowed down.

(b) Draw the symbol for a uni-directional restrictor to slow the air flow in the direction shown. 2

direction of air flow

MARKS | DO NOT WRITE IN THIS MARGIN

15. (continued)

Cylinder (A) is supplied with an air pressure of 1.4 N mm^{-2} and the piston has an outstroking force of 490 N.

(c) Calculate the area of the piston in cylinder (A). 3

$A = \frac{F}{P}$

$A = \frac{490}{1.4}$

$A = 35 mm^2$

An engineer compared the size of the outstroke force and the instroke force of a double-acting cylinder when supplied with the **same** air pressure.

The result of the test showed that there was a difference in the size of the two forces.

(d) Explain the difference in the size of these two forces. 2

The out stroking force would be greater than the in stroking force

[END OF QUESTION PAPER]