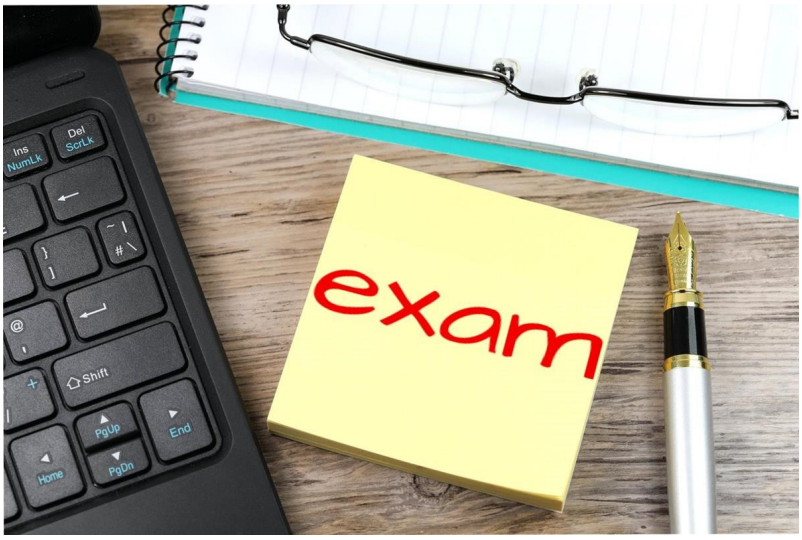
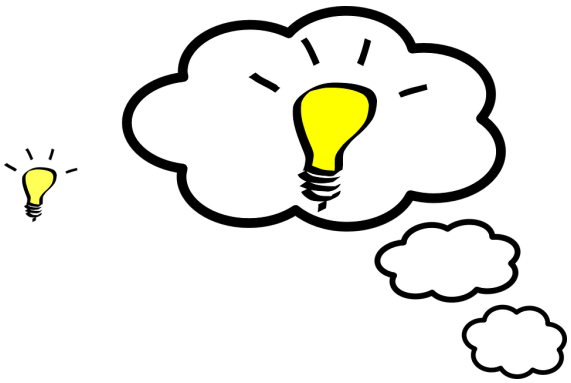
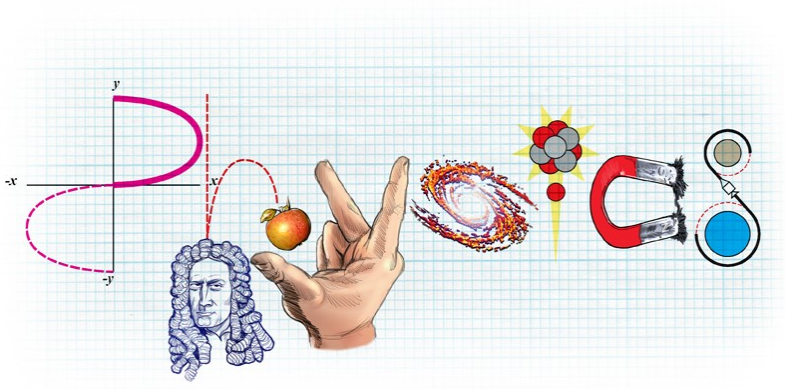
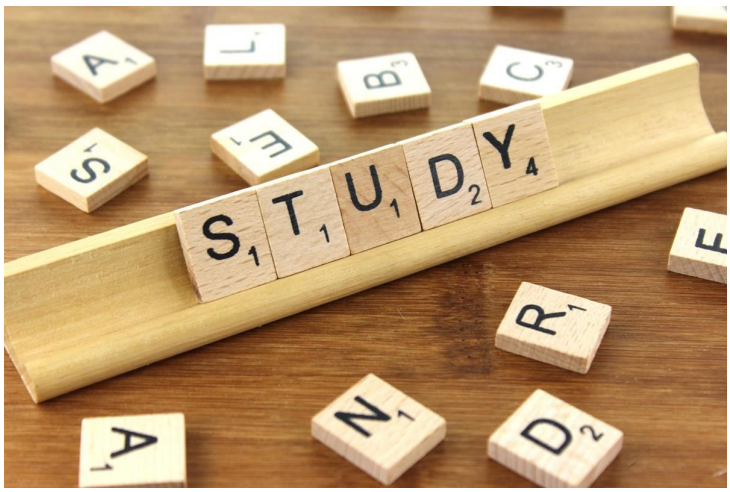




National 5 Physics
Immersion Day
Challenging past paper questions





DATA SHEET

Speed of light in materials

Material	Speed in $m\,s^{-1}$
Air	3.0×10^8
Carbon dioxide	3.0×10^8
Diamond	1.2×10^8
Glass	2.0×10^8
Glycerol	2.1×10^8
Water	2.3×10^8

Gravitational field strengths

	Gravitational field strength on the surface in $N\,kg^{-1}$
Earth	9.8
Jupiter	23
Mars	3.7
Mercury	3.7
Moon	1.6
Neptune	11
Saturn	9.0
Sun	270
Uranus	8.7
Venus	8.9

Specific latent heat of fusion of materials

Material	Specific latent heat of fusion in $J\,kg^{-1}$
Alcohol	0.99×10^5
Aluminium	3.95×10^5
Carbon Dioxide	1.80×10^5
Copper	2.05×10^5
Iron	2.67×10^5
Lead	0.25×10^5
Water	3.34×10^5

Specific latent heat of vaporisation of materials

Material	Specific latent heat of vaporisation in $J\,kg^{-1}$
Alcohol	11.2×10^5
Carbon Dioxide	3.77×10^5
Glycerol	8.30×10^5
Turpentine	2.90×10^5
Water	22.6×10^5

Speed of sound in materials

Material	Speed in $m\,s^{-1}$
Aluminium	5200
Air	340
Bone	4100
Carbon dioxide	270
Glycerol	1900
Muscle	1600
Steel	5200
Tissue	1500
Water	1500

Specific heat capacity of materials

Material	Specific heat capacity in $J\,kg^{-1}\,°C^{-1}$
Alcohol	2350
Aluminium	902
Copper	386
Glass	500
Ice	2100
Iron	480
Lead	128
Oil	2130
Water	4180

Melting and boiling points of materials

Material	Melting point in °C	Boiling point in °C
Alcohol	–98	65
Aluminium	660	2470
Copper	1077	2567
Lead	328	1737
Iron	1537	2737
Water	–	100

Radiation weighting factors

Type of radiation	Radiation weighting factor
alpha	20
beta	1
fast neutrons	10
gamma	1
slow neutrons	3
X-rays	1

$$d = vt$$

$$d = \bar{v}t$$

$$s = vt$$

$$s = \bar{v}t$$

$$a = \frac{v-u}{t}$$

$$F = ma$$

$$W = mg$$

$$E_w = Fd$$

$$E_p = mgh$$

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

$$Q = It$$

$$V = IR$$

$$V_2 = \left(\frac{R_2}{R_1 + R_2}\right)V_S$$

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

$$R_T = R_1 + R_2 + \ldots$$

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

$$P = \frac{E}{t}$$

$$P = IV$$

$$P = I^2R$$

$$P = \frac{V^2}{R}$$

$$E_h = cm\Delta T$$

$$E_h = ml$$

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

$$p_1V_1 = p_2V_2$$

$$\frac{p_1}{T_1} = \frac{p_2}{T_2}$$

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

$$\frac{pV}{T} = \text{constant}$$

$$f = \frac{N}{t}$$

$$v = f\lambda$$

$$T = \frac{1}{f}$$

$$A = \frac{N}{t}$$

$$D = \frac{E}{m}$$

$$H = Dw_r$$

$$\dot{H} = \frac{H}{t}$$

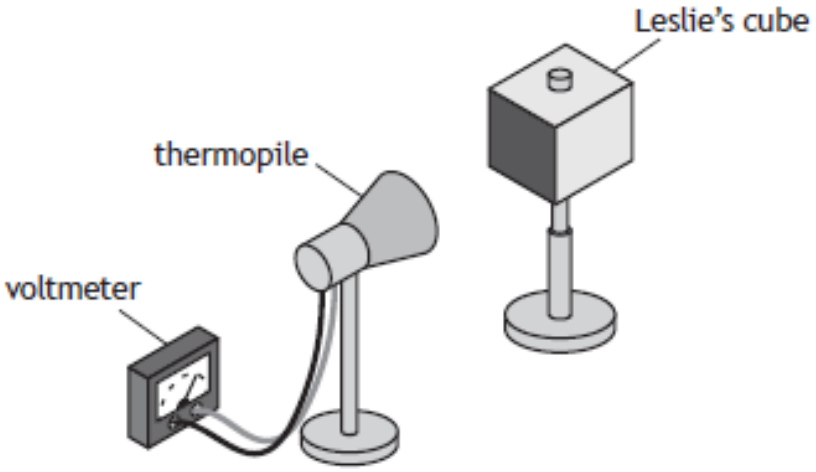
1.

A student uses a Leslie's cube and thermopile to investigate the amount of infrared radiation emitted by different surfaces of the cube.

A Leslie's cube is a hollow metal cube. Four sides of the cube have different finishes: matt white, matt black, shiny silver, and shiny black.

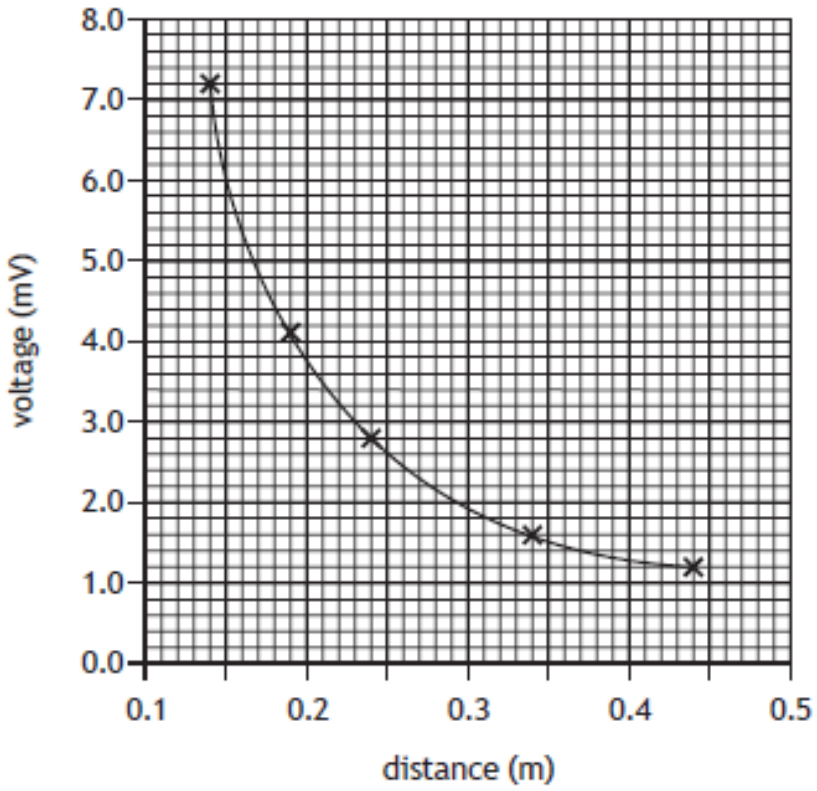
Darker surfaces emit more infrared radiation than lighter surfaces. Matt surfaces emit more infrared radiation than shiny surfaces.

A thermopile is a device that produces a voltage proportional to the amount of infrared radiation detected.



The student fills the cube with hot water and measures the amount of infrared radiation at different distances from the cube, using the thermopile.

(a) The student produces a graph of their results for the matt black side.



N5 2022 Question 12

1.

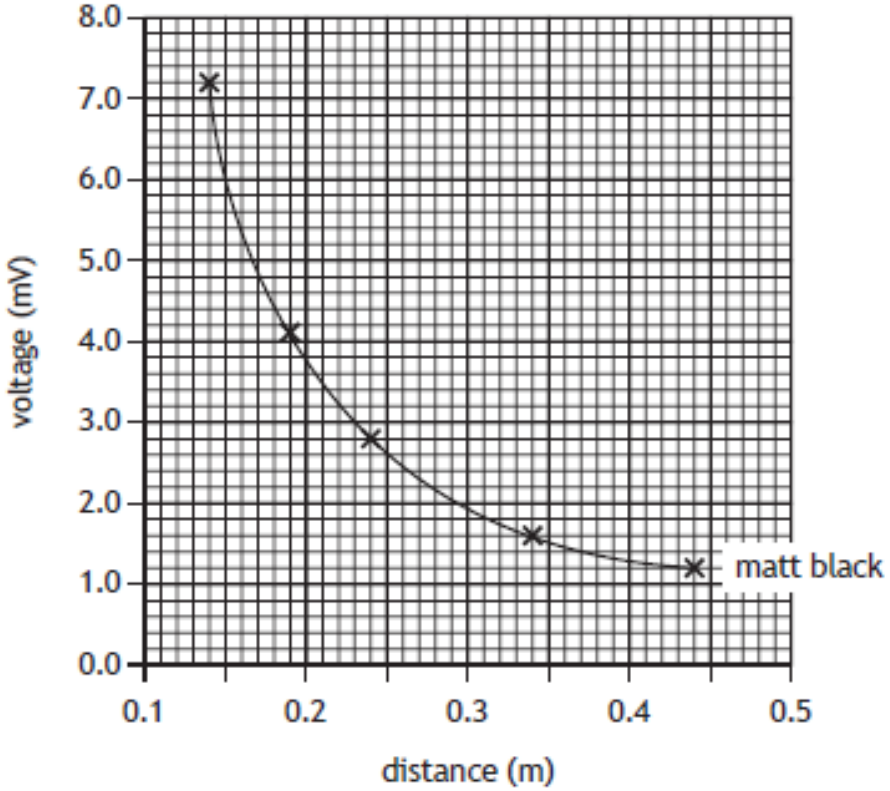
(a) (continued)

(i) State a conclusion that can be made about how the distance from a Leslie's cube affects the amount of infrared radiation detected by the thermopile. **1**

(ii) The experiment is repeated using the shiny silver side.

On the graph below, draw a line to show how the voltage produced by the thermopile varies with distance for the shiny silver side. **2**

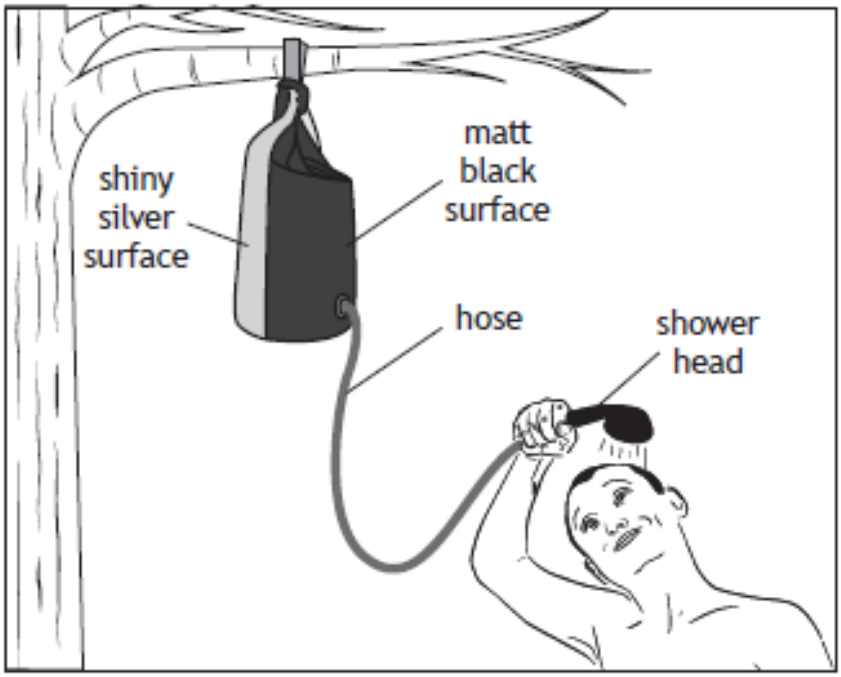
(An additional graph, if required, can be found on *page 49*.)



1.

(continued)

(b) A solar shower consists of a heavy-duty plastic bag, with a matt black surface and a shiny silver surface, connected to a hose and shower head. The bag uses infrared radiation from the Sun to heat water for a shower, when camping.



Using your knowledge of physics, comment on how the solar shower works. 3

2. A student is investigating how the length of a wire affects its resistance.

The student connects different lengths of wire to a power supply of fixed voltage and measures the current in each length of wire.

(a) The measurements taken by the student are shown in the table.

Length of wire (m)	Current (A)
0·20	0·94
0·40	0·66
0·60	0·47
0·80	0·37
1·00	0·32

(i) Using the graph paper, draw a graph of these measurements. 3

(ii) State whether the resistance of the wire increases, decreases or stays the same, as the length of wire increases.

Justify your answer. 2

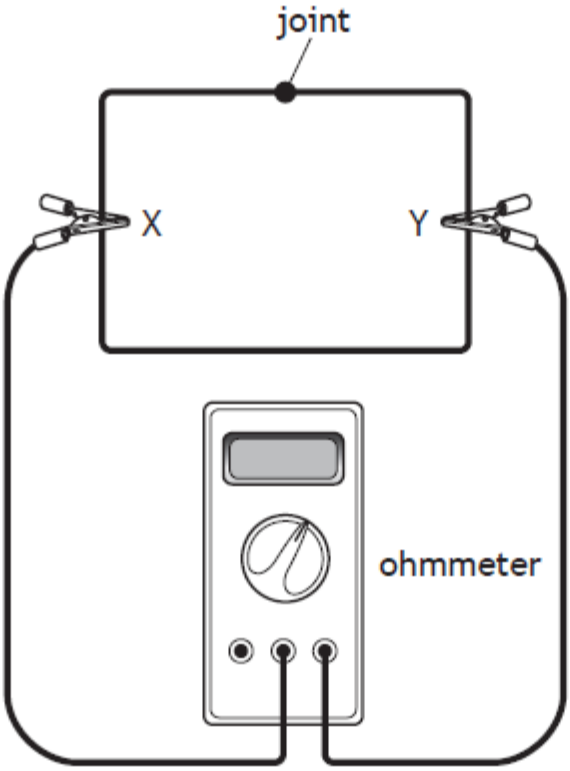
(iii) Use your graph to predict the current in a 0·50 m length of wire, when connected to the power supply. 1

(iv) Suggest one way in which the experimental procedure could be improved to give more reliable results. 1

2.

(b) A length of the wire with a resistance of 5·2 Ω is then folded into a rectangular shape and the ends are joined together.

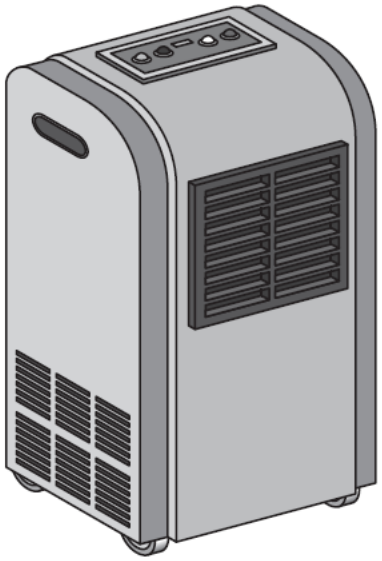
An ohmmeter is connected across the wire between point X and point Y as shown.



State whether the reading on the ohmmeter would be less than, equal to or greater than 5·2 Ω.

You must justify your answer. 2

3. A dehumidifier is an appliance that extracts water from the air around it.



One particular dehumidifier operates at 230 V a.c. and has a power rating of 0.35 kW.

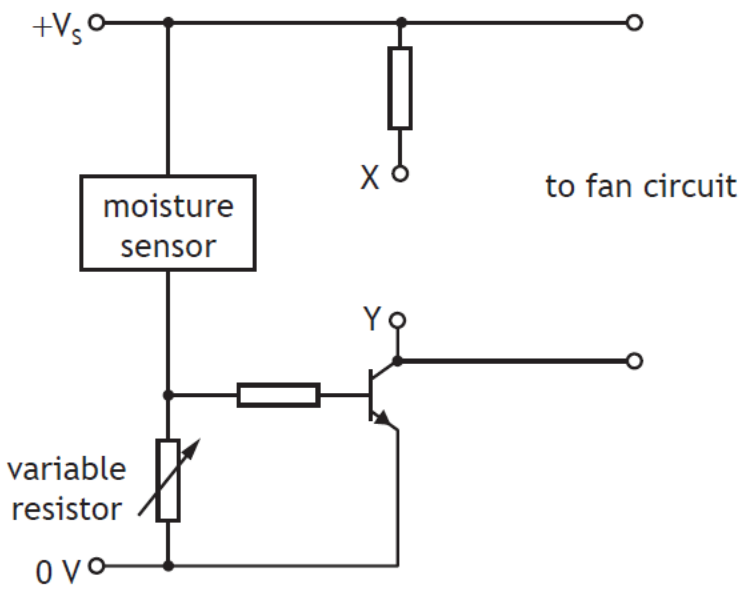
(a) State the fuse rating that should be used for this dehumidifier. **1**

(b) Calculate the resistance of the dehumidifier. **3**

3.

(c) The dehumidifier switches on automatically when the moisture in the air increases above a certain level. This causes an LED to light and a fan to turn on.

Part of the circuit diagram for the circuit is shown.



(i) Complete the circuit diagram to show the LED connected correctly between X and Y. **1**

(An additional diagram, if required, can be found on *page 48*.)

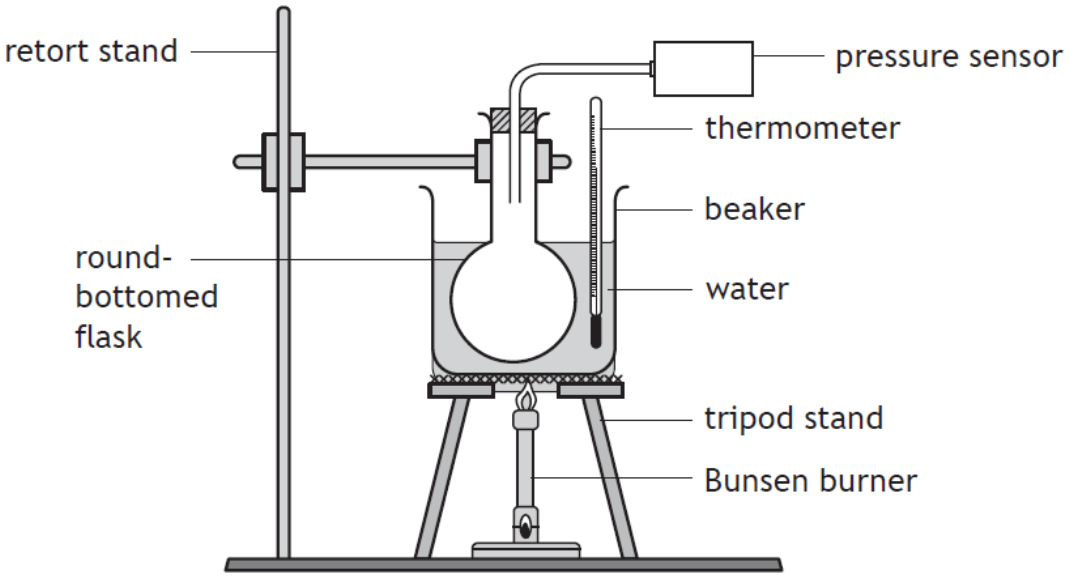
(ii) The voltage across the moisture sensor decreases as the moisture in the air increases.

Explain how the circuit operates to turn on the LED when the moisture in the air increases above a certain level. **2**

(iii) Explain the purpose of the variable resistor in this circuit. **1**

4. A group of students are investigating how the pressure of a fixed mass of gas varies with its temperature. This is known as Gay-Lussac's Law.

The students set up an experiment as shown.



The round-bottomed flask contains a fixed mass of gas.

The Bunsen burner is used to heat the apparatus as shown. Readings of temperature and pressure are taken every 10 °C.

During the experiment the volume of the gas in the round-bottomed flask remains constant.

The students' results are shown.

Temperature (°C)	Temperature (K)	Pressure (kPa)
50	323	121
60	333	124
70	343	128
80	353	132

(a) Use **all** the appropriate data to establish the relationship between the pressure and the temperature of the gas. **3**

(b) Predict the pressure of the gas at a temperature of 100 °C. **1**

(c) Suggest one way the students could improve the experiment. **1**

(d) The tyre pressure in racing cars is carefully monitored throughout a race.

As the cars drive around the racing circuit, the temperature of the gas inside the tyres increases.

Explain, using the kinetic model, how this affects the pressure of the gas inside the tyres. **3**

5. Nuclear fission is used in nuclear reactors to generate electricity. **MARKS**

Nuclear fusion happens naturally in stars such as the Sun.

(a) State what is meant by the term *nuclear fission*. **1**

(b) Electricity generated from nuclear fission reactions is used to power the engines of an icebreaker ship.

(i) The power output of the nuclear reactor in the icebreaker ship is 150 MW.

Each nuclear fission reaction releases 2.9×10^{-11} J of energy.

Determine the minimum number of fission reactions that occur in the reactor each hour. **4**

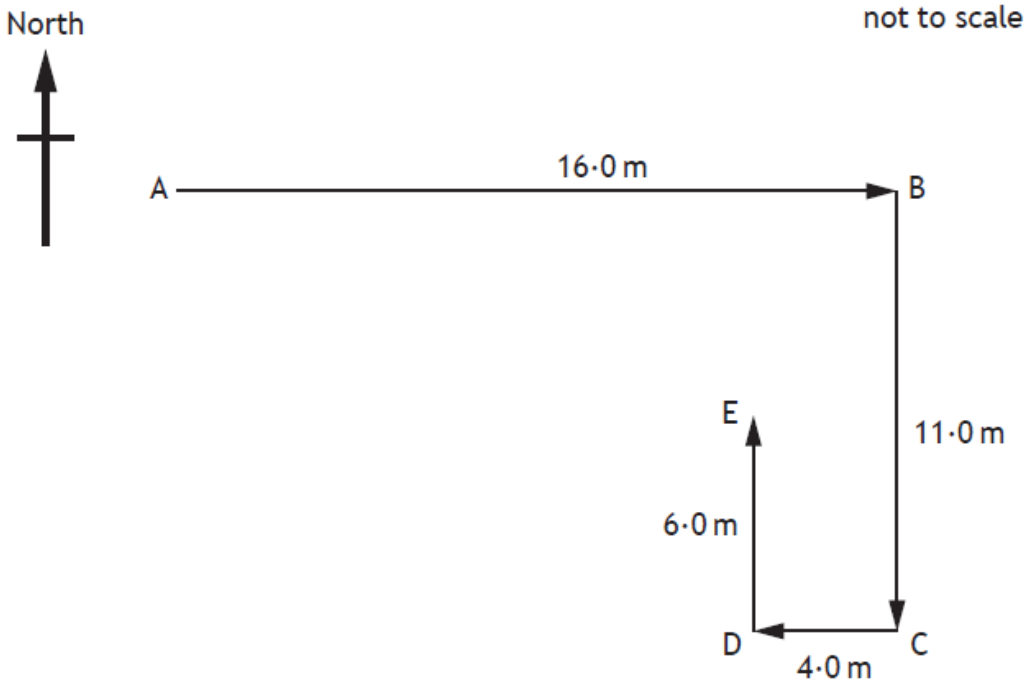
(ii) For many years, scientists have been attempting to develop nuclear fusion reactors. Current fusion reactors can only sustain reactions for a limited period of time.

Describe one difficulty in sustaining nuclear fusion reactions in a reactor. **1**

6.

A quadcopter is a drone with four rotating blades.

(a) In a race, the quadcopter is flown along a route from point A to point E.



(i) By scale drawing or otherwise, determine the magnitude of the resultant displacement of the quadcopter from point A to point E. **2**

(ii) By scale drawing or otherwise, determine the direction of the resultant displacement of the quadcopter from point A to point E. **2**

(b) The quadcopter takes 32·5 s to complete the race.

Determine the average velocity of the quadcopter over the whole race. **3**

(c) A second quadcopter completes the race at an average speed of $1{\cdot}25\ \text{m s}^{-1}$.

The distance travelled by this quadcopter during the race is 37·0 m.

Determine the **difference** in the times taken by the quadcopters to complete the race. **3**

(d) After passing point E, the quadcopter hovers at a constant height.

Describe how the overall lift force provided by the four rotating blades compares to the weight of the quadcopter. **1**

7. A hot water dispenser is used to heat enough water for one cup at a time.

The rating plate for the hot water dispenser is shown.

Model: 1-KUPPA
3·5 kW
230 V
50 Hz

The hot water dispenser takes 26 s to heat enough water for one cup.

(a) Show that the energy supplied to the hot water dispenser during this time is 91 000 J. **2**

(b) The hot water dispenser heats 0·250 kg of water for each cup.

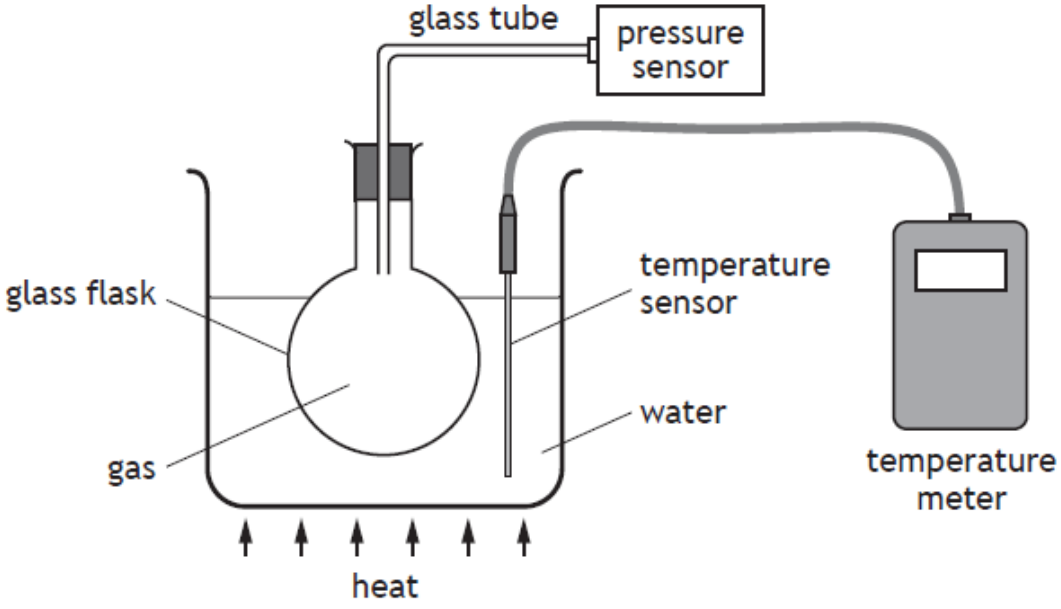
(i) Calculate the minimum energy required to heat 0·250 kg of water from an initial temperature of 20·0 °C to its boiling point. **3**

(ii) As the water is dispensed into the cup, steam is released.

Determine the maximum mass of steam that can be produced while the water for one cup is being heated. **4**

(iii) Explain why, in practice, the mass of steam produced is less than calculated in (b)(ii). **1**

8. A student sets up an experiment to investigate the relationship between the pressure and temperature of a fixed mass of gas as shown.



(a) The student heats the water and records the following readings of pressure and temperature.

Pressure (kPa)	101	107	116	122
Temperature (K)	293	313	333	353

(i) Using **all** the data, establish the relationship between the pressure and the temperature of the gas. 3

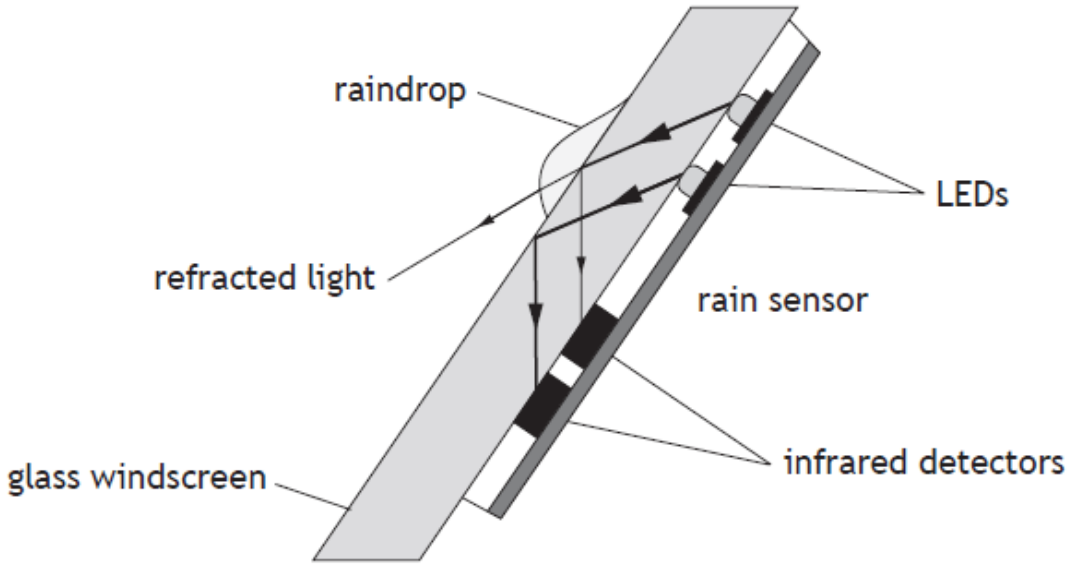
(ii) Using the kinetic model, explain why the pressure of the gas increases as its temperature increases. 3

(iii) Predict the pressure reading which would be obtained if the student was to cool the gas to 253 K. 1

(b) State one way in which the set-up of the experiment could be improved to give more reliable results.

Justify your answer. 2

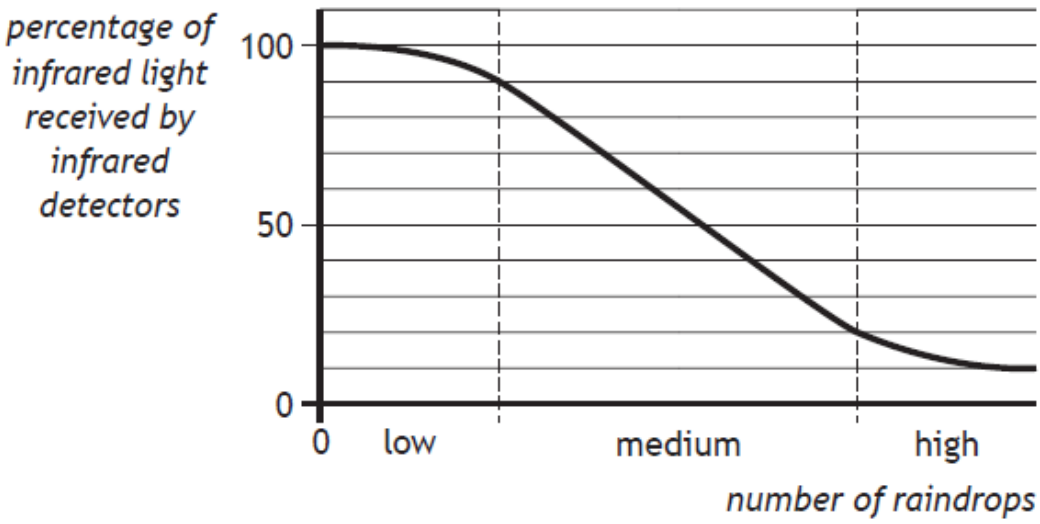
9. A rain sensor is attached to the glass windscreen of a vehicle to automatically control the windscreen wipers.



Infrared light is emitted from LEDs and is received by infrared detectors.

(a) State a suitable detector of infrared radiation for this rain sensor. **1**

9. (b) The graph shows how the number of raindrops affects the percentage of infrared light received by the infrared detectors.



The percentage of infrared light received by the infrared detectors from the LEDs controls the frequency with which the windscreen wipers move back and forth.

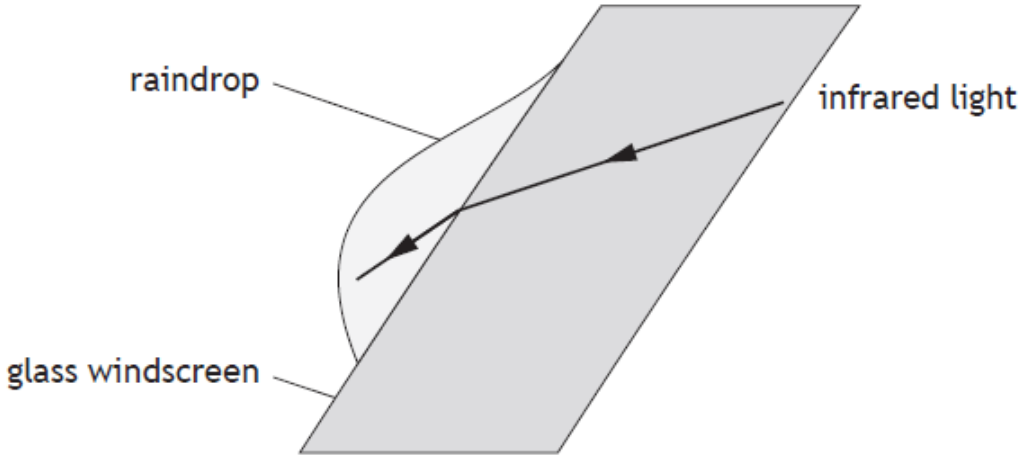
The table shows how the number of times the windscreen wipers move back and forth per minute relates to the number of raindrops.

Number of raindrops	*Number of times the windscreen wipers move back and forth per minute*
low	18
medium	54
high	78

At one point in time the infrared detectors receive 70% of the infrared light emitted from the LEDs.

Show that the frequency of the windscreen wipers at this time is 0·90 Hz. 3

9. (c) Some of the infrared light is refracted when travelling from the glass windscreen into a raindrop.



(i) On the diagram, draw and label:

(A) a normal; **1**

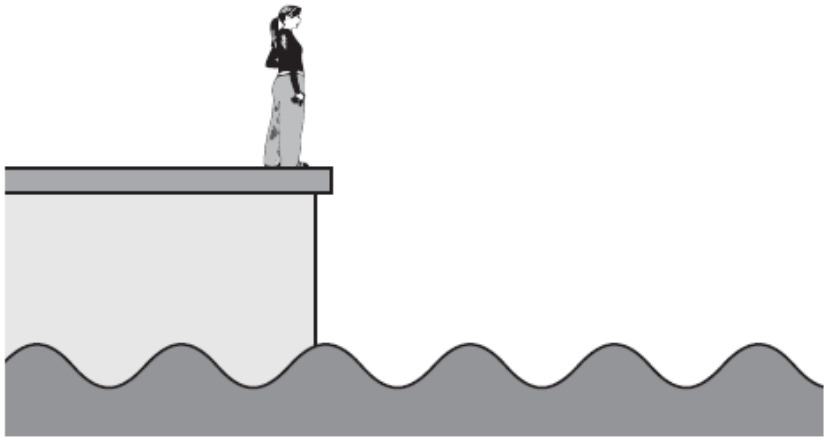
(B) an angle of incidence i and an angle of refraction r. **1**

(An additional diagram, if required, can be found on *page 44*.)

(ii) State whether the wavelength of the infrared light in the raindrop is less than, equal to or greater than the wavelength of the infrared light in the glass.

You **must** justify your answer. **2**

10. A student observes water waves entering a harbour.



(a) To determine the frequency of the waves, the student measures the time taken for a wave to pass a point at the harbour entrance.

The student measures this time to be 2·5 s

(i) Calculate the frequency of the waves. 3

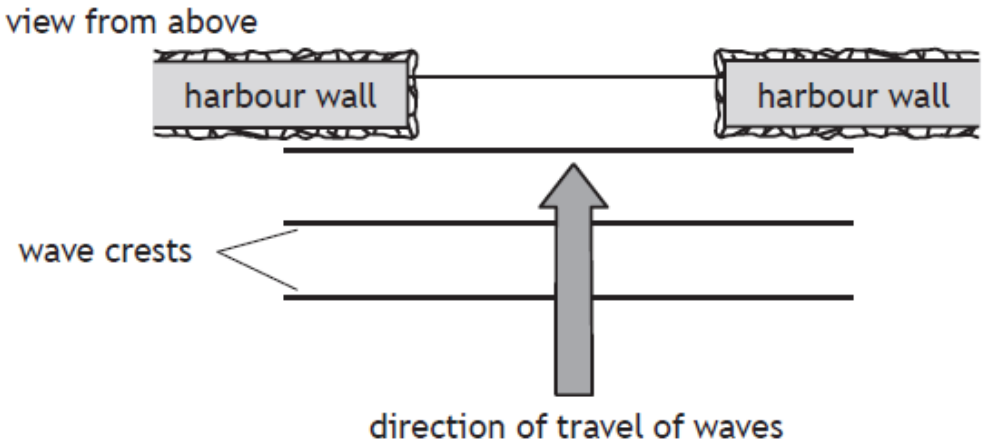
(ii) Suggest how the accuracy of the frequency determined by the student could be improved. 1

(b) The distance between one wave crest and the next crest is 8·0 m.

Calculate the velocity of the waves. 3

10.

(c) Waves travel towards the entrance of the harbour as shown.



Complete the diagram to show the pattern of wave crests inside the harbour. 2

(d) As the waves pass into the harbour the student observes that the amplitude of the waves decreases.

Explain this observation. 1

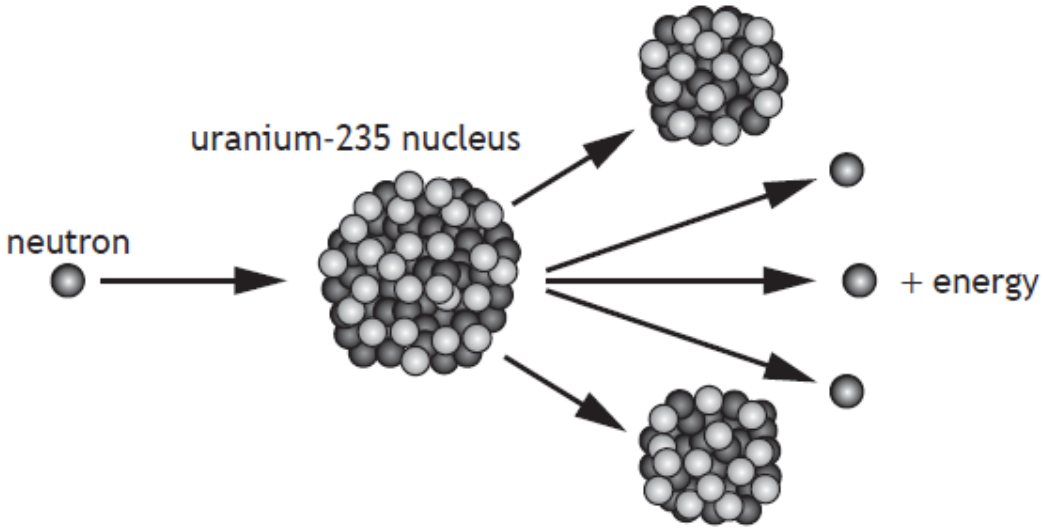
11. Nuclear reactions are used to generate electrical energy in a nuclear power station.

(a) The fuel for the power station is in the form of pellets, containing uranium-235.

A fuel pellet has an activity of 80 kBq.

State what is meant by an *activity of 80 kBq*. 1

(b) In a nuclear reaction a uranium-235 nucleus is split by a neutron to produce two smaller nuclei, three neutrons, and energy.



(i) Explain how a single reaction can lead to the continuous generation of energy. 2

(ii) One nuclear reaction releases $3{\cdot}2 \times 10^{-11}$ J.

In the reactor, $3{\cdot}0 \times 10^{21}$ reactions occur each minute.

Determine the maximum power output of the reactor. 4

(c) The nuclear reactor produces waste that emits nuclear radiation.

State a use of nuclear radiation. 1

N5 2017 Question 7