# Questions

Q1.

According to the Football Association (FA) rules, the football used in a professional match should have a circumference of between 68.0 cm and 70.0 cm. The pressure of the air in the football must be between 60 kPa and 110 kPa above atmospheric pressure.

(a) A football was inflated with air at a temperature of 16.0 °C. When inflated, the circumference of the football was 68.5 cm and it contained $2.50 \times 10^{23}$ molecules of air.



Deduce whether this football met the FA rules.

atmospheric pressure = 105 kPa

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*(b) The pressure inside a football decreases as the temperature of the air inside falls. The volume of the ball remains constant.

Explain why, in terms of the motion of the molecules.

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**(Total for question = 12 marks)**

Q2.



**Answer the question with a cross in the box you think is correct ☒ . If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒ .**

A closed container holds a mixture of two gases at a constant temperature. Each molecule of gas X has a mass four times that of each molecule of gas Y.

What is the ratio $\frac{\text{r.m.s. velocity of molecules in gas X}}{\text{r.m.s. velocity of molecules in gas Y}}$ ?

☒ **A** $\frac{1}{4}$

☒ **B** $\frac{1}{2}$

☒ **C** 2

☒ **D** 4

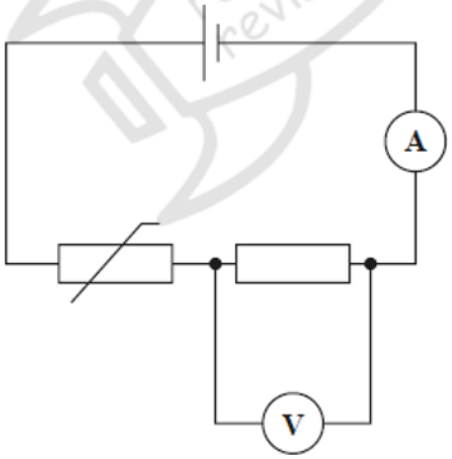
**(Total for question = 1 mark)**



Q3.

**Answer the question with a cross in the box you think is correct ☒ . If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒ .**

A negative temperature coefficient thermistor and a resistor are connected as shown.




The temperature of the thermistor decreases.

Select the row of the table that shows how the readings on the meters change.



| | Ammeter | Voltmeter |
|---|---|---|
| ☒ **A** | decreases | decreases |
| ☒ **B** | decreases | increases |
| ☒ **C** | increases | decreases |
| ☒ **D** | increases | increases |

**(Total for question = 1 mark)**

Q4.

**Answer the question with a cross in the box you think is correct ☒ . If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒ .**

A solid is heated and it melts at a constant temperature.



Which row of the table shows how the kinetic energy and the potential energy of the molecules change as the solid melts?

| | | Molecular kinetic energy | Molecular potential energy |
|---|---|---|---|
| ☒ | **A** | increases | stays the same |
| ☒ | **B** | increases | increases |
| ☒ | **C** | stays the same | increases |
| ☒ | **D** | stays the same | stays the same |

**(Total for question = 1 mark)**

Q5.

A kettle was used to heat 855 g of water to boiling point. The initial temperature of the water was 21.5 °C and it took 115 s to heat the water to 100 °C.



The kettle is left switched on for 175 s after the water has reached 100 °C.

Calculate the mass of water that was boiled away.

specific heat capacity of water = 4190 J $kg^{-1}$ $K^{-1}$
specific latent heat of vaporisation of water = 2.26 × $10^6$ J $kg^{-1}$

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Mass of water that was boiled away = .....

**(Total for question = 4 marks)**

Q6.

A portable electric heater with a power of 280 W is used to boil water for a hot drink.
The heater is placed into a cup of water.

There is 165 g of water in the cup. The initial temperature of the water is 12.5 °C.
Assume that all the energy from the heater is transferred to the water.

(a) The heater is used in London, where the boiling point of water is 100.0 °C.

Show that the time taken for the water to reach a temperature of 100.0 °C is about 220 s.

specific heat capacity of water = 4190 J $kg^{-1}$ $K^{-1}$



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(b) The same heater is used in La Paz, the world's highest capital city, where the boiling point of

water is 87.7 °C.

The mass and initial temperature of the water are the same as in (a), and the heater is used for the same time.

Calculate the mass of water converted to water vapour as the water boils.

latent heat of vaporisation of water = $2.29 \times 10^6$ J $kg^{-1}$

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Mass of water converted to water vapour = .....

**(Total for question = 6 marks)**

Q7.

A mixture of oxygen gas and nitrogen gas is kept at room temperature. Oxygen molecules are more massive than nitrogen molecules.

Which of the following is correct?

☒ **A** The mean velocity of the oxygen molecules is greater than the mean velocity of the nitrogen molecules.

☒ **B** The mean speed of the oxygen molecules is the same as the mean speed of the nitrogen molecules.

☒ **C** The mean kinetic energy of the oxygen molecules is greater than the mean kinetic energy of the nitrogen molecules.

☒ **D** The mean kinetic energy of the oxygen molecules is the same as the mean kinetic energy of the nitrogen molecules.

**(Total for question = 1 mark)**

Q8.

**Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.**

Helium gas in a closed cylinder is heated until the pressure exerted by the helium is four times the original pressure. The volume occupied by the helium stays constant.

The mean square speed of the helium molecules before heating is $\langle v_I^2 \rangle$. The mean square speed of the helium molecules after heating is $\langle v_F^2 \rangle$.

What is the ratio $\frac{\langle v_F^2 \rangle}{\langle v_I^2 \rangle}$?

☒ **A** 1

☒ **B** 2

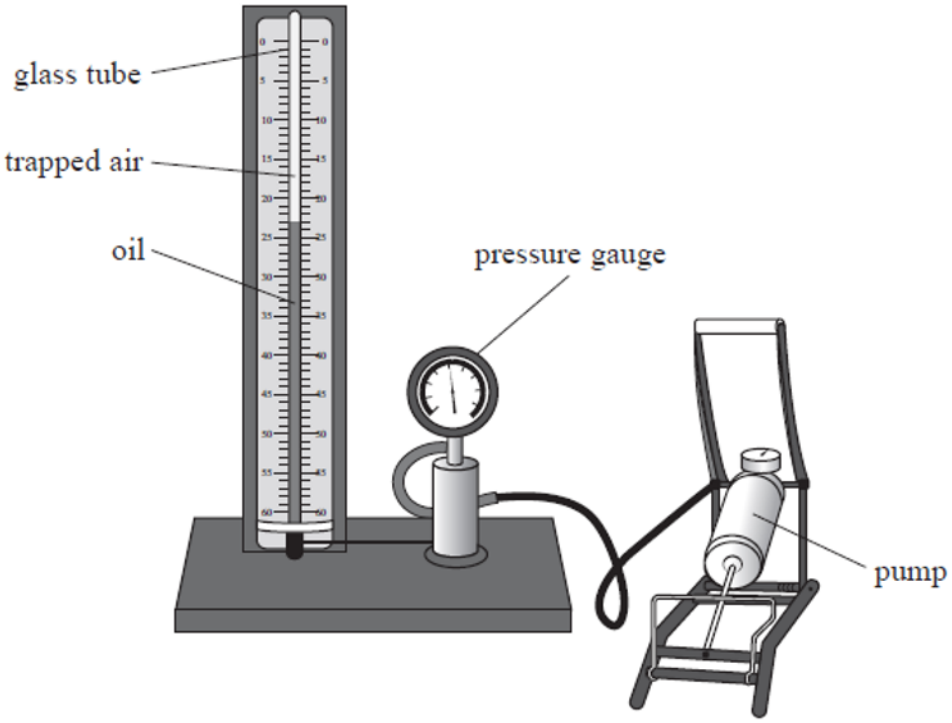
☒ **C** 4

☒ **D** 8

**(Total for question = 1 mark)**

Q9.

The school apparatus shown is used to demonstrate a gas law.






Air is trapped in a glass tube of uniform cross-sectional area. A pump forces oil into the base of the glass tube. This forces the air into a smaller volume. The pressure of the trapped air is displayed on the pressure gauge.

(a) The pressure of the trapped air increases when the air is forced into a smaller volume.

Explain why, using ideas of molecular motion.

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(b) The apparatus is used in a laboratory where the temperature is 293 K.

When the air occupies a volume of $2.43 \times 10^{-3}$ $m^3$ the reading on the pressure gauge is $1.05 \times 10^5$ Pa.

Calculate the number of molecules of air trapped in the glass tube.

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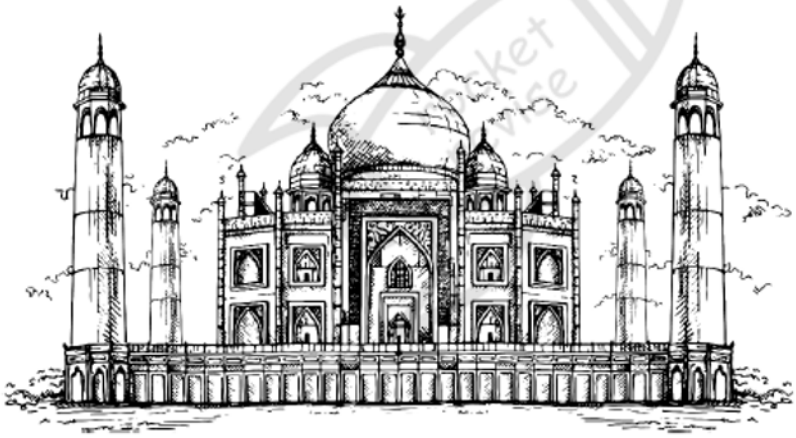
Number of molecules of air = .....

**(Total for question = 6 marks)**



Q10.

In the book Charlie and the Chocolate Factory, a palace is made entirely from chocolate. Soon after it was made the palace melted, due to energy transfer from the Sun.



(Source: Morkhatenok/Shutterstock)

The total volume of chocolate used for the palace was 1250 $m^3$. The initial temperature of the chocolate palace was
28.5 °C. Chocolate melts at a temperature of 36.0 °C.

The book states that the palace melted completely in less than a day.



Deduce whether this statement could be correct.

rate of energy transfer to the palace = $7.5 \times 10^5$ W
density of chocolate = 1325 kg $m^{-3}$
specific latent heat of chocolate = $4.5 \times 10^4$ J $kg^{-1}$
specific heat capacity of chocolate is $1.30 \times 10^3$ J $kg^{-1}$ $K^{-1}$

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**(Total for question = 6 marks)**

Q11.

Natural gas produced from landfill consists of a mixture of methane and carbon dioxide gases.

(a) At a temperature of 20.0 °C and a pressure of $1.01 \times 10^5$ Pa the volume occupied by 1 mole of carbon dioxide is 0.0241 $m^3$.

Show that the number of molecules in 1 mole of carbon dioxide is about $6.0 \times 10^{23}$

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(b) In a sample of natural gas, the r.m.s. velocity of the carbon dioxide molecules is 60.5 % of the r.m.s. velocity of the methane molecules.

$$\text{r.m.s. velocity} = \sqrt{\langle c^2 \rangle}$$

Deduce the ratio $\dfrac{\text{mass of carbon dioxide molecule}}{\text{mass of methane molecule}}$.

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$$\frac{\text{mass of carbon dioxide molecule}}{\text{mass of methane molecule}} = \text{.....}$$

**(Total for question = 6 marks)**

Q12.

Xenon gas is used as an anaesthetic. The gas is stored in cylinders, under pressure.
A cylinder with a volume of $6.0 \times 10^{-2}$ $m^3$ contains $7.5 \times 10^{24}$ atoms of xenon.

(a) The gas in the cylinder is at a temperature of 20 °C.

Calculate the pressure exerted by the gas.

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Pressure exerted by gas = .....

(b) Gas is removed from the cylinder. The temperature of the gas decreases by 5.0 °C and the new pressure of the gas
is $4.50 \times 10^5$ Pa.

Calculate the percentage of the original number of gas molecules remaining in the cylinder.

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Percentage = .....

**(Total for question = 5 marks)**

Q13.

A weather balloon takes scientific equipment high into the atmosphere to monitor atmospheric conditions.

A weather balloon is filled with hydrogen at a temperature of 22.5 °C and a pressure of $1.02 \times 10^5$ Pa. The volume of the balloon is 7.50 $m^3$.

The balloon rises through the atmosphere to a maximum height. At the maximum height, the temperature of the hydrogen in the balloon is –48.0 °C and the pressure of the hydrogen in the balloon is $8.40 \times 10^4$ Pa.

(a) Calculate the volume of the balloon at the maximum height.

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Volume of balloon = .....

(b) Calculate the decrease in the mean kinetic energy of a hydrogen molecule in the balloon as

the balloon rises to the maximum height.

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Decrease in mean kinetic energy = .....



**(Total for question = 5 marks)**

Q14.

Lead shot consists of small lead spheres.

Originally lead shot was made by dripping molten lead through a copper sieve from the top of a 'shot tower'. The lead cooled as it fell, before landing in water and producing solid lead spheres. Figure 1 shows a shot tower, and figure 2 shows the process of making lead shot in a shot tower.

(Source: © Espresso Addict)

**Figure 1**

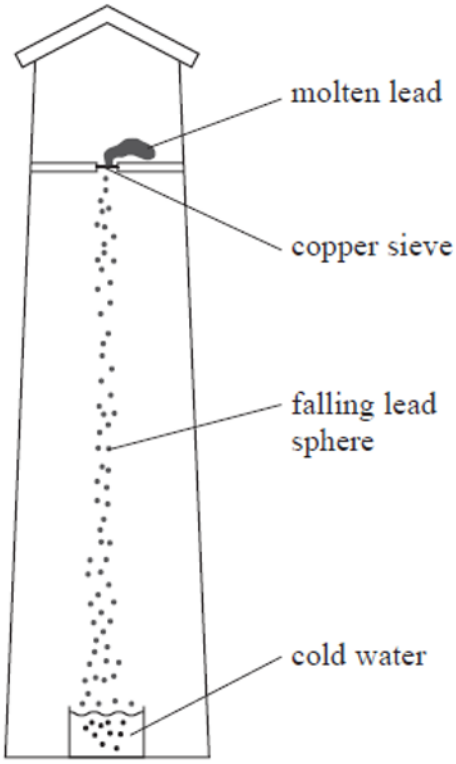


**Figure 2**



To avoid producing steam, the temperature of a lead sphere was below 100 °C as it reached the cold water.

(a) (i) A lead sphere falls through a distance of 41.5 m.

Show that it takes about 3 s for the lead sphere to fall through this distance.
Assume that resistive forces are negligible.

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(ii) The lead sphere has a radius of 1.2 mm. As it falls it cools from 615 K to 370 K.

The molten lead solidifies at 601 K.

Calculate the mean rate at which energy is transferred from the lead sphere to the surroundings.
You should assume that the specific heat capacities of liquid lead and solid lead are the same.

density of lead = $1.13 \times 10^4$ kg m$^{-3}$
specific latent heat of lead = $2.47 \times 10^4$ J kg$^{-1}$
specific heat capacity of lead = 130 J kg$^{-1}$ K$^{-1}$

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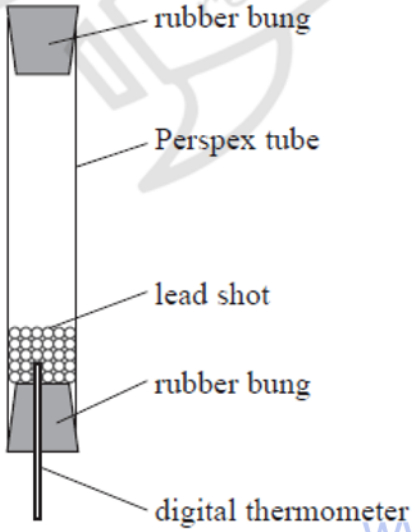
Mean rate of energy transfer from lead = .....

(b) A teacher demonstrates a mechanical method to determine the specific heat capacity of lead. Some lead shot at room temperature is placed in a Perspex tube.






The teacher turns the tube upside down, and the lead shot falls through a distance $d$.

The teacher repeats this $N$ times and measures the final temperature of the lead shot.
The change in temperature $\Delta\theta$ of the lead shot is calculated.

The teacher uses the values of $d$, $N$ and $\Delta\theta$ to determine a value for the specific heat capacity $c$ of the lead.

(i) Explain why the mass of lead shot in the tube should not affect the value of $\Delta\theta$.

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(ii) Assess whether this method would produce an accurate value for *c*.

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**(Total for question = 12 marks)**

Q15.

A cylinder contains oxygen gas at a temperature of 25 °C and a pressure of $1.4 \times 10^{7}$ Pa.

Calculate the density of the oxygen gas in the cylinder.

mass of an oxygen molecule = $5.3 \times 10^{-26}$ kg

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Density of oxygen gas = .....

**(Total for question = 5 marks)**

Q16.



**Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.**

The pressure law states that, if certain conditions are met, the pressure exerted by an ideal gas is proportional to the temperature of the gas.

Which of the following conditions is **not** correct?

☒ **A** The absolute temperature must be used.

☒ **B** The molecules in the gas must be identical.

☒ **C** The number of molecules in the gas must stay constant.

☒ **D** The volume of the gas must stay constant.

**(Total for question = 1 mark)**

Q17.



Cocoa powder, milk and hot water are mixed together to produce a 'hot chocolate' drink. The mass of the drink is 275 g, and its initial temperature is 71.5 °C.

Ice at 0.0 °C is added to the drink to reduce its temperature. Research indicates that the maximum serving temperature of any hot drink should be 58.0 °C.

Deduce whether 4.0 g of ice would be enough to bring the temperature below 58.0 °C.

specific latent heat of ice = $3.34 \times 10^5$ J $kg^{-1}$
specific heat capacity of 'hot chocolate' = 3750 J $kg^{-1}$ $°C^{-1}$
specific heat capacity of water = 4190 J kg–1 $°C^{-1}$

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**(Total for question = 5 marks)**

Q18.

A student learns that the energy required to heat water for a bath can be 10 times the energy required to heat water for a shower.

The student uses a shower for 9 minutes. The water comes out of the shower at 38 °C at a flow rate of $1.8 \times 10^{-5}$ $m^3$ $s^{-1}$.

The student usually fills the bath with 160 kg of water at 32 °C.

Deduce whether the bath uses 10 times more energy than using the shower.

initial temperature of water = 15 °C
density of water = $1.00 \times 10^3$ kg $m^{-3}$
specific heat capacity of water = $4.18 \times 10^3$ J $kg^{-1}$ $K^{-1}$

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**(Total for question = 5 marks)**

Q19.



**Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.**

Boyle's law states that, under certain conditions, the pressure exerted by a gas is inversely proportional to the volume occupied by the gas.

Which of the following conditions is **not** necessary?

☒ **A** The gas must be ideal.

☒ **B** The mean kinetic energy of the molecules must stay constant.

☒ **C** The molecules in the gas must be identical.

☒ **D** The number of molecules in the gas must stay constant.

**(Total for question = 1 mark)**

Q20.



**Select one answer from A to D and put a cross in the box ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.**

In an experiment to determine the specific latent heat of vaporisation of water $L_V$, a student used an electrical heater to boil water in a beaker.

The experimental data gave $L_V = 2.20$ MJ kg$^{-1}$. The textbook value of $L_V$ is 2.26 MJ kg$^{-1}$.

Which of the following could be an explanation for this difference in the values of $L_V$?

☒

**A** Some energy is transferred to the surroundings.

☒ **B** The heater power was underestimated.

☒ **C** The student did not stir the water.

☒ **D** The heater is inefficient.

**(Total for question = 1 mark)**



Q21.

**Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.**

A fixed mass of a gas occupies a constant volume. The temperature of the gas is increased.

Which of the following is **not** true?

☒ **A** The internal energy of the gas increases.

☒ **B** The mean kinetic energy of the molecules increases.

☒ **C** The mean momentum of the molecules increases.

☒ **D** The pressure exerted by the gas increases.

**(Total for question = 1 mark)**



Q22.

**Select one answer from A to D and put a cross in the box ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.**

A fixed mass of an ideal gas has a volume $V$ and exerts a pressure $p$. The absolute temperature of the gas is $T$. When the gas is heated, the new pressure is $4p$.

Which row of the table gives correct values of the new volume and the new temperature?

| | Volume | Temperature |
|---|---|---|
| ☒ A | $\frac{V}{2}$ | $2T$ |
| ☒ B | $\frac{V}{2}$ | $4T$ |
| ☒ C | $2V$ | $2T$ |
| ☒ D | $2V$ | $4T$ |

**(Total for question = 1 mark)**

Q23.

* A student is planning an experiment to investigate how the resistance of a thermistor changes with temperature. The student wants to use the temperature range 0°C to 100°C.

Describe a method the student could use to determine values of resistance and temperature over this range.

You should include one precaution the student should take to ensure accurate measurements.

You do not need to draw a circuit diagram.

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**(Total for question = 6 marks)**

Q24.

An electric kettle contains $4.25 \times 10^{-4}$ $m^3$ of water. The temperature of the water is 22°C.



The kettle is switched on. The water takes 85 s to reach a temperature of 100°C.

(a) Show that the power of the kettle is about 1600 W.

specific heat capacity of water = 4190 J $kg^{-1}$ $K^{-1}$
density of water = 998 kg $m^{-3}$

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(b) The water boils at 100°C.

Calculate the time now taken for 75% of the water to boil away.



specific latent heat of vaporisation of water = $2.26 \times 10^6$ J $kg^{-1}$

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Time taken = .....

**(Total for question = 7 marks)**

Q25.



Air is used to inflate a balloon.

The inflated balloon has a volume of $1.77 \times 10^{-3}$ $m^3$ and contains $5.15 \times 10^{22}$ air molecules. The air inside the balloon exerts a pressure of $1.15 \times 10^5$ Pa.

Calculate the average kinetic energy of the air molecules.

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Average kinetic energy of air molecules = .....



**(Total for question = 3 marks)**

Q26.

The water in a swimming pool at the Olympic Games should be at a temperature of 28.0 °C.

(a) A pool contains 2750 $m^3$ of water at 16.5 °C.

Calculate the increase in internal energy $\Delta E$ of the water when it is heated to 28.0 °C.

density of water = 998 kg $m^{-3}$
specific heat capacity of water = 4190 J $kg^{-1}$ $K^{-1}$

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$\Delta E$ = .....

(b) A heater is used to increase the temperature of the water.

State why the amount of energy supplied by the heater will be different from the value of $\Delta E$ calculated in (a).

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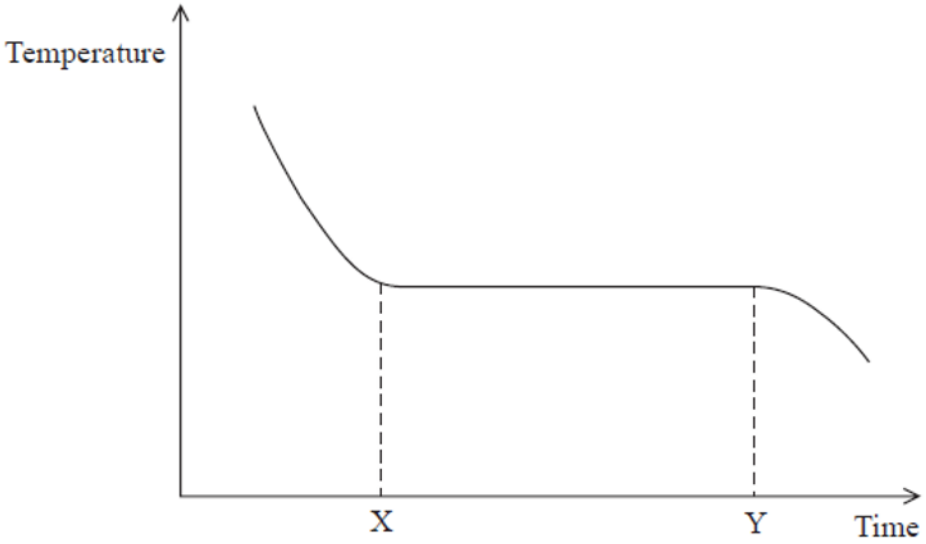
**(Total for question = 4 marks)**



Q27.

* Wax is heated until the temperature is above the melting point of the wax. The hot wax is poured into a bowl and allowed to cool.

The graph shows how the temperature of the wax varies with time as it cools.




Describe how the internal energy of the wax changes as the wax cools.



You should refer to the energy of the wax molecules as the liquid wax cools and becomes solid, and the solid wax cools.

Times X and Y have been included to help you refer to the graph.

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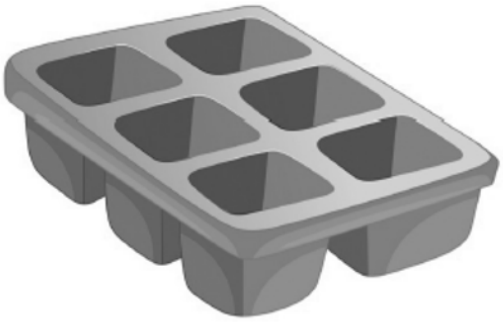
**(Total for question = 6 marks)**

Q28.

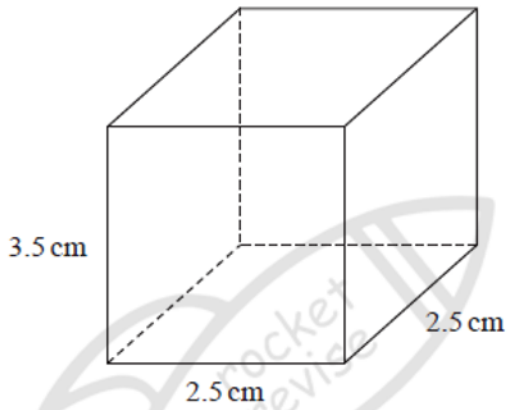
Ice cubes can be made in an ice cube tray. One type of ice cube tray is shown.



(Source: © GraphicsRF.com/Shutterstock)



Each compartment in the ice cube tray has dimensions 2.5 cm by 2.5 cm by 3.5 cm, as shown.




(a) Show that the mass of water needed to fill one compartment is about 0.02kg.

density of water = $1.00 \times 10^3$ kg $m^{-3}$

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(b) All 6 compartments in the ice cube tray are filled with water to a depth of 3.5 cm.

The ice cube tray is placed in a freezer.

The initial temperature of the water is 22.5°C.

It takes 12 minutes for all the water to become ice at 0°C.

The manufacturer of the freezer states that the freezer can transfer energy at a rate of 110 W.

Evaluate whether energy is transferred from the water in the tray at a rate of 110 W.

specific heat capacity of water = 4180 J $kg^{-1}$ $K^{-1}$
specific latent heat of fusion of water = $3.34 \times 10^5$ J $kg^{-1}$

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**(Total for question = 7 marks)**

Q29.

**Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.**

Two gas cylinders have the same volume. One cylinder contains nitrogen gas. The other cylinder contains oxygen gas.

Both gases are at the same temperature and pressure.

Which of the following statements is **not** correct?



☒ **A** Each cylinder contains the same number of molecules.

☒ **B** The average molecular kinetic energy is the same for each gas.

☒ **C** The density of gas is the same in each cylinder.

☒ **D** The internal energy is the same for each gas.

**(Total for question = 1 mark)**

Q30.

An airbag is a safety feature used in cars.

Nitrogen gas is released into an airbag. The airbag inflates to a volume of $7.08 \times 10^{-2}$ $m^3$. The pressure of gas in the inflated airbag is $1.24 \times 10^5$ Pa.

(a) Show that the number of molecules of nitrogen gas released into the airbag is about $2 \times 10^{24}$.



temperature of gas in airbag = 25°C

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(b) Nitrogen gas escapes from small holes in the inflated airbag. The pressure decreases to $3.45 \times 10^4$ Pa.

Calculate the number of nitrogen molecules that escape from the airbag.

The volume and temperature remain constant.

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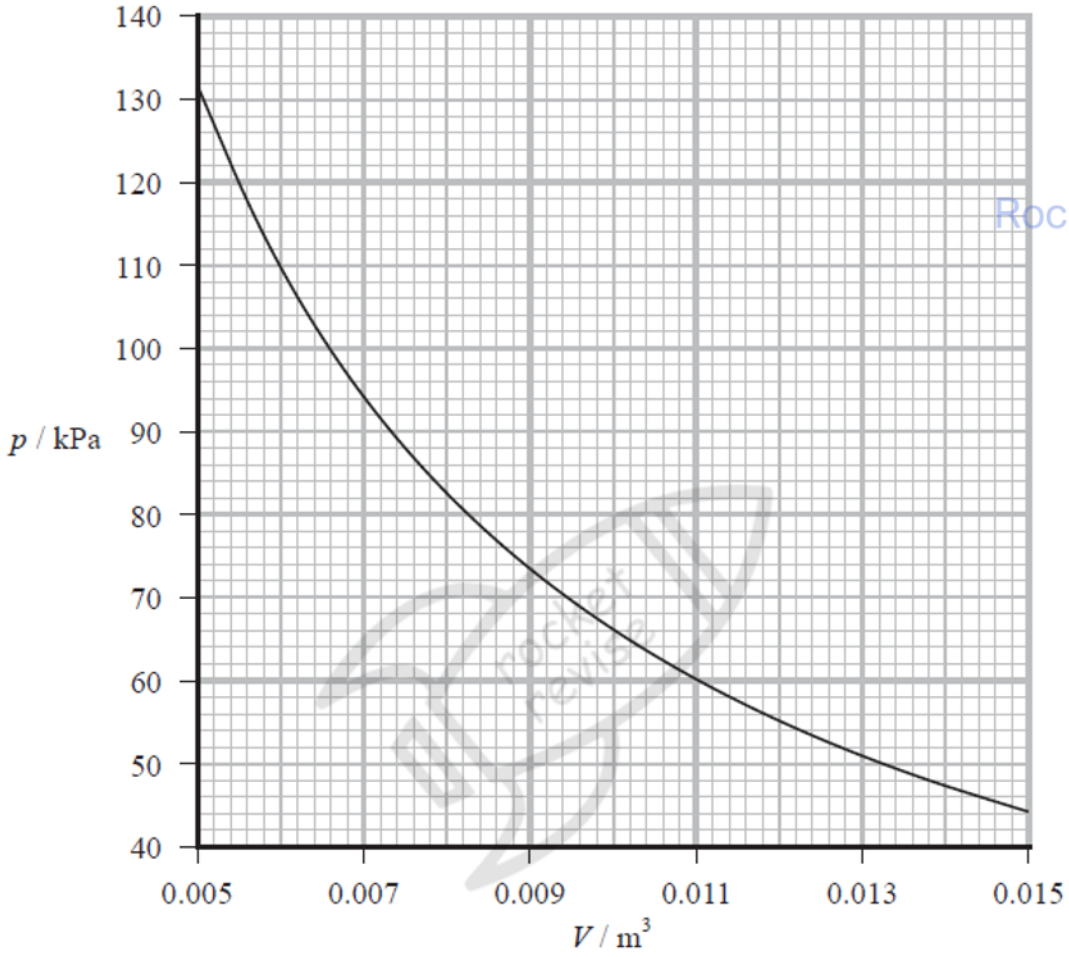
Number of nitrogen molecules that escape = .....

**(Total for question = 5 marks)**

Q31.

A student investigated the relationship between the pressure and volume of a fixed mass of gas at constant temperature.

He used his data to plot the following graph.




The student stated that his graph demonstrated that the pressure exerted by the gas was inversely proportional to the volume occupied by the gas.

Assess the validity of the student's statement.

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**(Total for question = 4 marks)**

Q32.

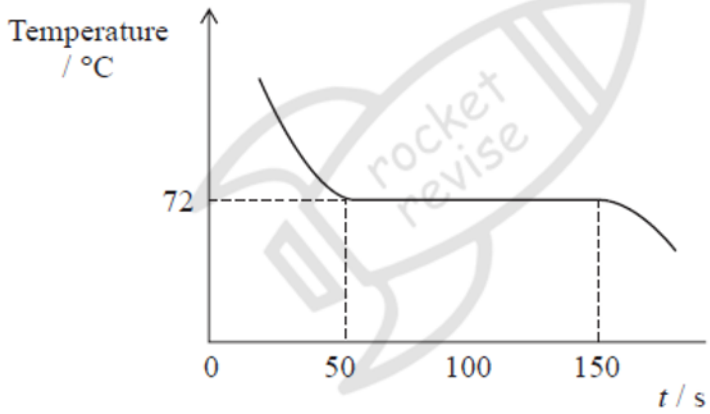
**Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.**



A student measured the temperature of 0.015 kg of wax as it cooled and changed state from a liquid to a solid.

Energy was transferred from the wax to the surroundings at a rate of 25 W.

The temperature of the wax varied with time *t*, as shown.




Which of the following expressions gives a value for the specific latent heat capacity of the wax?

☐ **A** $\frac{25 \times 100}{0.015}$

☐ **B** $\frac{25}{100 \times 0.015}$



☐ **C** $\frac{25 \times 100}{0.015 \times 72}$

☐ **D** $\frac{20 \times 72}{100 \times 0.015}$

**(Total for question = 1 mark)**

Q33.

**Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.**

A cylinder contains a mixture of gas X and gas Y. The mean kinetic energy of the molecules of gas X is $E_X$ and the mean kinetic energy of the molecules of gas Y is $E_Y$.

The molecules of gas X have twice the mass of the molecules of gas Y.



Which of the following equations is correct?

☒ **A** $E_X = \frac{1}{2} E_Y$

☒ **B** $E_X = E_Y$

☒ **C** $E_X = 2E_Y$

☒ **D** $E_X = 4E_Y$

**(Total for question = 1 mark)**

Q34.

A 'scuba tank' is used to store air at high pressure. A diver breathes underwater using air from the scuba tank.

(a) A scuba tank contains air at a pressure of $1.28 \times 10^7$ Pa and a temperature of 17.5 °C.



The scuba tank is left outside on a sunny day and the temperature of the air inside the scuba tank increases to 42.5 °C. The volume of the scuba tank remains constant.

Calculate the increase in the pressure exerted by the air inside the scuba tank.

**(4)**

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Increase in pressure = .....

*(b) Explain why the pressure of the air inside the scuba tank increases as the temperature increases. Your answer should refer to the motion of the air molecules.

**(6)**



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**(Total for question = 10 marks)**