Q1.

A room contains dry air at a temperature of 20.0 °C and a pressure of 105 kPa.

(a) Show that the amount of air in each cubic metre is about 40 mol.

(1)

(b) The density of the dry air is 1.25 kg m^{-3}.

Calculate c_{rms} for the air molecules.
Give your answer to an appropriate number of significant figures.

c_{rms} = ____________________ m s^{-1}

(3)

(c) Calculate, in K, the change of temperature that will double c_{rms} for the air molecules.

change of temperature = ____________________ K

(2)

(d) A room contains moist air at a temperature of 20 °C.
A dehumidifier cools and then condenses water vapour from the moist air.
The final temperature of the liquid water that collects in the dehumidifier is 10 °C.
Drier air leaves the dehumidifier at a temperature of 20 °C.

The table below compares the air flowing into and out from the dehumidifier.

	$\frac{\text{mass of water}}{\text{mass of air}}$
moist air flowing in	0.0057
drier air flowing out	0.0037

In one hour, a volume of 960 m^3 of air flows through the dehumidifier.
Assume that the density of the air remains constant at 1.25 $kg\ m^{-3}$.

Determine how much heat energy is removed in one hour from the water vapour by the dehumidifier.

specific heat capacity of water vapour = 1860 $J\ kg^{-1}\ K^{-1}$
specific latent heat of vaporisation of water = 2.3×10^6 $J\ kg^{-1}$

heat energy removed = ____________________ J

(3)

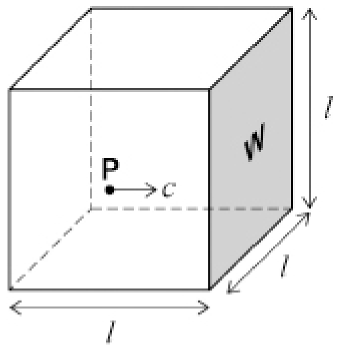
(Total 9 marks)

Q2.

(a) State what is meant by the internal energy of an ideal gas.

(1)

The figure below shows a single gas particle **P** of an ideal gas inside a hollow cube.



The cube has side length l and volume V.
P has mass m and is travelling at a velocity c perpendicular to side **W**.

(b) Explain why **P** has a change in momentum of $-2mc$ during one collision with **W**.

(1)

(c) **P** collides repeatedly with **W**.

Show that the frequency f of collisions is $\frac{c}{2l}$.

(1)

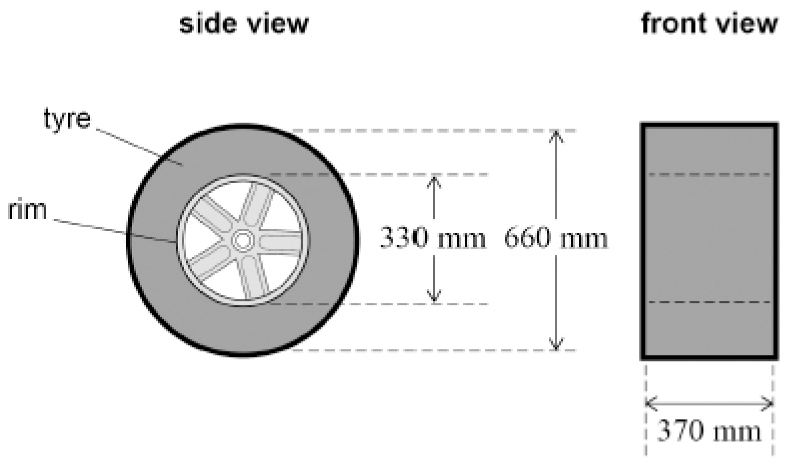
(d) Deduce an expression, in terms of m, c and V, for the contribution of **P** to the pressure exerted on **W**.
Refer to appropriate Newton's laws of motion.

(2)
(Total 5 marks)

Q3.

The figure below shows a wheel used in motorsport. A rubber tyre is fitted around a cylindrical metal rim. The tyre is filled with a gas.
The dimensions shown in the figure are for the volume of the gas in the tyre.

Assume that this volume remains constant throughout this question.



(a) The mass of the wheel is measured when the gas in the tyre is at a pressure of 1.01×10^5 Pa.
More of the same gas is added to the tyre and the mass of the wheel is measured again.

The table below shows the pressure in the tyre and the mass of the wheel before and after the addition of the extra gas.
The gas is kept at a constant temperature of 100 °C.

	Pressure in tyre / Pa	Mass of wheel / kg
Before	1.01×10^5	14.897
After	2.11×10^5	14.991

Determine, in $\mathrm{kg\ mol^{-1}}$, the molar mass of the gas.

molar mass = ____________________ $\mathrm{kg\ mol^{-1}}$

(5)

(b) Motorsport regulations specify a minimum amount of gas in the tyre.

The amount of gas in the tyre is checked by measuring the pressure before the wheel is put onto the car. The regulations also specify a maximum temperature for the tyre when making this measurement.

Explain why a maximum temperature is specified.

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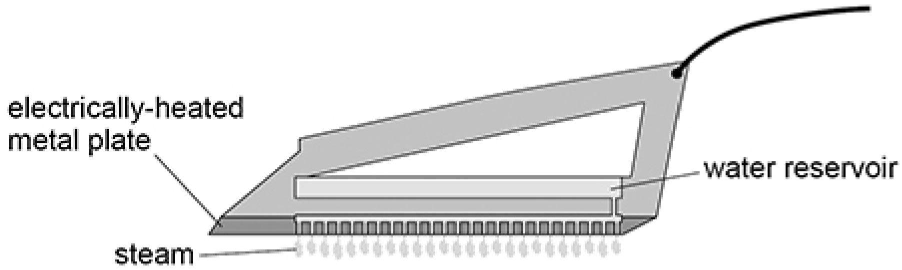
(2)

(Total 7 marks)

Q4.

The figure below shows an electric steam iron.



Water from a reservoir drips onto an electrically-heated metal plate. The water boils and steam escapes through holes in the metal plate.

The electrical power of the heater inside the iron is $2.1\ \mathrm{kW}$.

Assume that all the energy from the heater is transferred to the metal plate.

(a) The metal plate has a mass of $1.2\ \mathrm{kg}$ and is initially at a temperature of $20\ °\mathrm{C}$.
The heater is switched on. After a time t the metal plate reaches its working temperature of $125\ °\mathrm{C}$.

Calculate t.

specific heat capacity of the metal = $450\ \mathrm{J\ kg^{-1}\ K^{-1}}$

t = ________________ s

(2)

(b) The metal plate is maintained at its working temperature.
Water at $20\ °C$ drips continuously onto the metal plate.
Steam at $100\ °C$ emerges continuously from the iron.

The maker claims that the iron can generate steam at a rate of $60\ g\ min^{-1}$.

Determine whether this claim is true.

specific latent heat of vaporisation of water = $2.3 \times 10^6\ J\ kg^{-1}$
specific heat capacity of water = $4200\ J\ kg^{-1}\ K^{-1}$

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(3)
(Total 5 marks)

Q5.

(a) In the kinetic theory model, it is assumed that there are many identical particles moving at random.

State **two** other assumptions made in deriving the equation $pV = \frac{1}{3}Nm(c_{\mathrm{rms}})^2$.

1 ____

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2 ____

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(2)

(b) Explain why molecules of a gas exert a force on the walls of a container. Refer to Newton's laws of motion in your answer.

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(3)

(c) A sealed flask of volume $0.35\ m^3$ contains an ideal gas at a pressure of $220\ kPa$.
The mean kinetic energy of the gas molecules is $6.7 \times 10^{-21}\ J$.

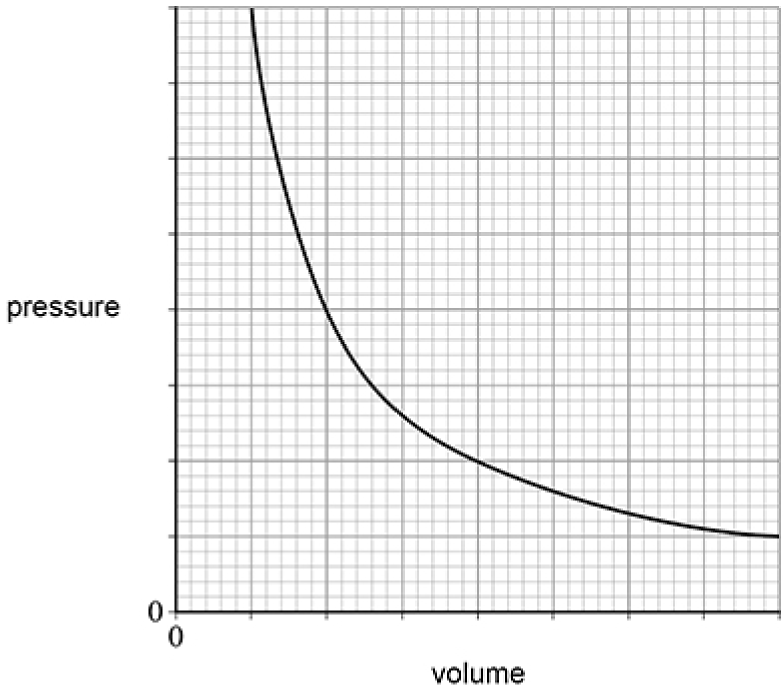
Calculate the amount of gas in the container.

amount of gas = _______________ mol

(3)

(d) The figure below shows the variation of pressure with volume for a fixed mass of an ideal gas at constant absolute temperature T.

Draw, on the figure below, the graph for the same gas at temperature $2T$.



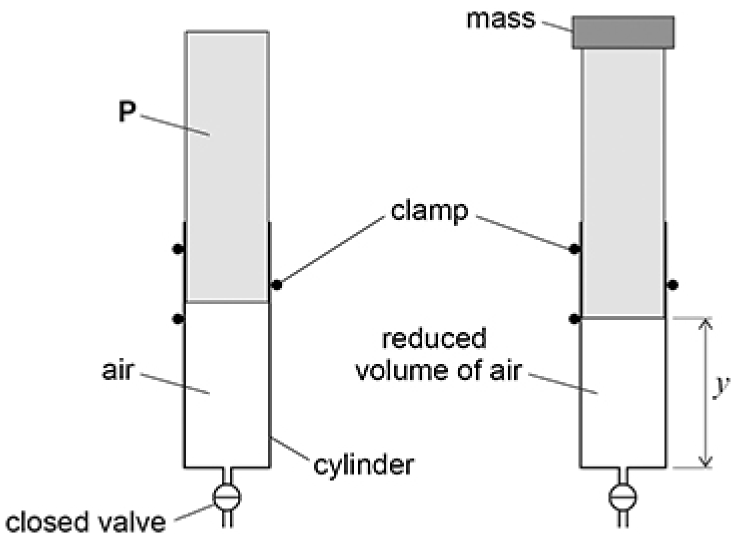
(2)
(Total 10 marks)

Q6.

Figure 1 shows air trapped in a vertical cylinder by a valve and a piston **P**.
The valve remains closed throughout the experiment.

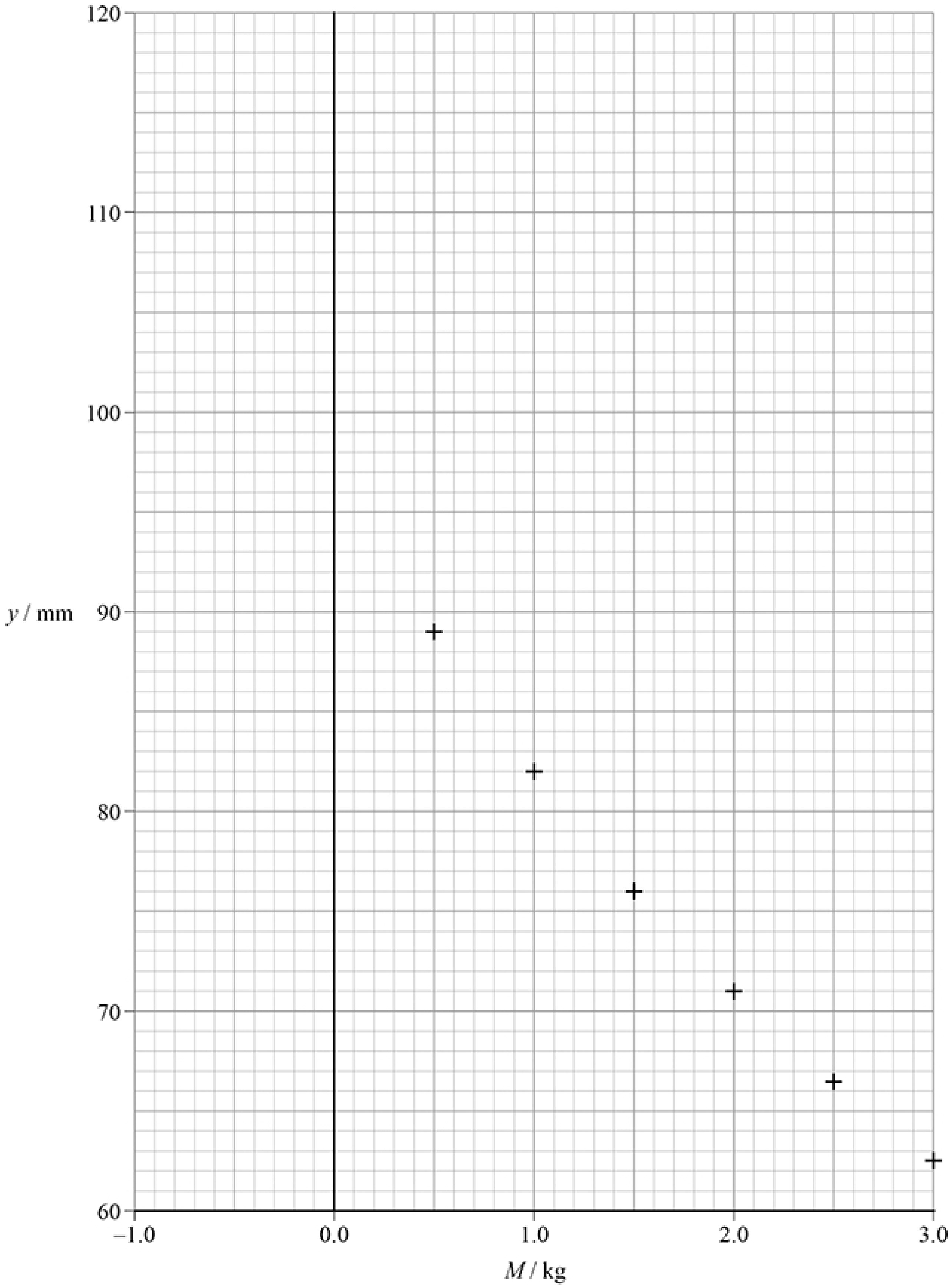
A mass is placed on top of **P**.
P moves downwards and the volume of the trapped air decreases.
There are no air leaks and there is no friction between the cylinder and **P**.

Figure 1



The vertical distance y between the end of **P** and the closed end of the cylinder is measured.
Additional masses are used to find out how y depends on the total mass M placed on top of **P**.
Figure 2 shows a graph of these data.

Figure 2

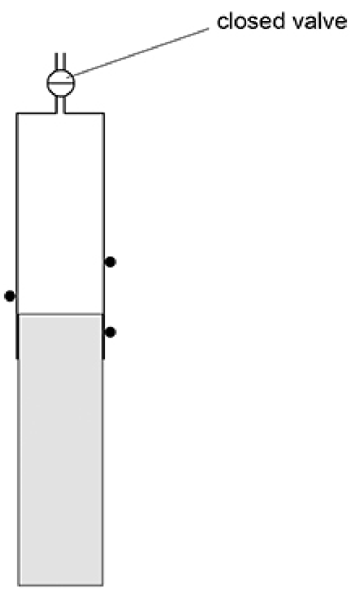


(a) Show that y is **not** inversely proportional to M.
Use data points from **Figure 2**.

(2)

(b) The masses are removed and the cylinder is inverted.
P moves downwards without friction before coming to rest, as shown in **Figure 3**.

Figure 3



Explain why **P** does not fall out of the cylinder unless the valve is opened.

(3)

(c) The mass of **P** is 0.350 kg.

Deduce y when the cylinder is in the inverted position shown in **Figure 3**.

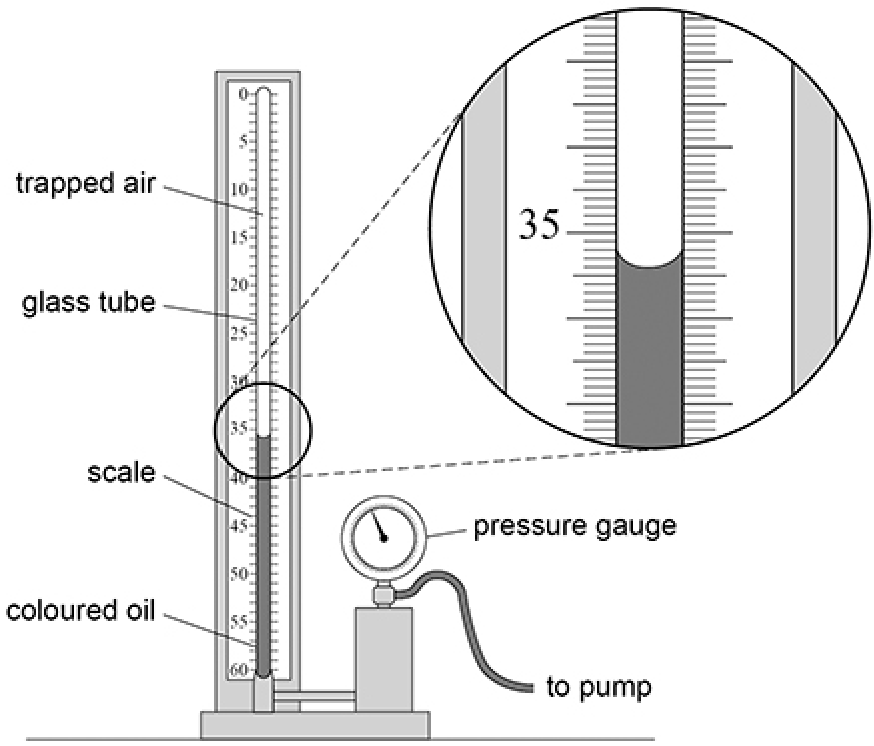
Draw a line of best fit on **Figure 2** to arrive at your answer.

y = ______________ mm

(4)

Figure 4 shows apparatus used in schools to investigate Boyle's law.

Figure 4



A fixed mass of air is trapped above some coloured oil inside a glass tube, closed at the top.
A pump applies pressure to the oil and the air.
The trapped air is compressed and its pressure p is read from the pressure gauge.

(d) A scale, marked in $0.2\ cm^3$ intervals, is used to measure the volume V of the air.
A student says that the reading for V shown in **Figure 4** is $35.4\ cm^3$.

State:

- the error the student has made
- the correct reading, in cm^3, of the volume.

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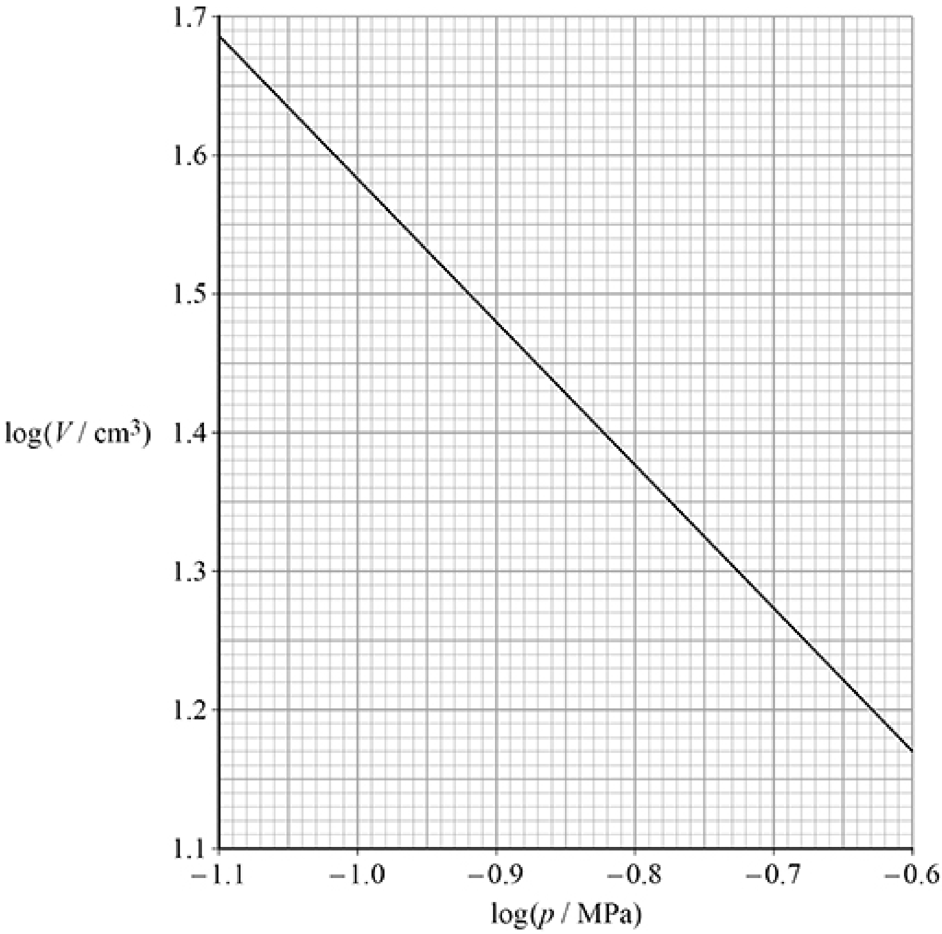
volume = _______________ cm^3

(2)

(e) **Figure 5** shows data obtained using the apparatus in **Figure 4**.

Figure 5



Explain why the gradient of the graph in **Figure 5** confirms that the air obeys Boyle's law.

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(3)

(f) The largest pressure that can be read from the pressure gauge is 3.4×10^5 Pa.

Determine, using **Figure 5**, the volume *V* corresponding to this pressure.

V = ____________ cm^3

(3)

(g) State **one** property of the air that must not change during the experiment. Go on to suggest how this can be achieved.

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(2)

(Total 19 marks)