H2 Physics Revision Topic : First Law of Thermodynamicss

Structured Questions Name: ______________________

1 **(a)** An ideal gas initially at 300 K undergoes expansion at a constant pressure of 2.5 kPa. The volume of the gas increases from 1.0 m^3 to 3.0 m^3 and 12.5 kJ is transferred to the gas by heat.

Determine the change in the internal energy of the gas.

change in internal energy = ………………………… J [2]

(b) By reference to the first law of thermodynamics, state and explain the change, if any, in the internal energy of:

(i) a lump of solid lead as it melts at constant temperature

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.... [3]

(ii) some gas in a toy balloon when the balloon bursts.

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.... [3]

[Total: 8]

2 A fixed mass of monatomic ideal gas undergoes the cycle ABCA of changes shown in Fig. 1.1.

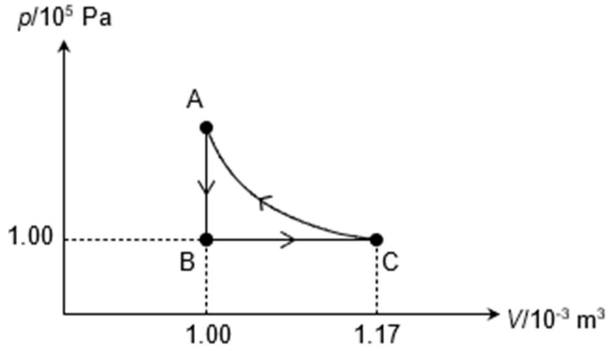

Fig. 1.1 (not to scale)

The temperature of the gas at points A, B and C is 350 K, 300 K and 350 K respectively.

(a) Calculate the amount of gas in moles.

amount of gas = …………………mol [2]

(b) Show that the change in internal energy ΔU of the gas during process AB is 25.0 J.

[1]

(c) The answer to part **(b)** is also the amount of heat released by the gas during process AB. Explain why this is so.

……………………………………………………………………………………………

……………………………………………………………………………………………[1]

2

(d) The gas is heated at constant pressure from point B to point C. Calculate the work done by the gas, and the heat supply to the gas from point B to point C.

work done by the gas = ………………… J

heat supply = ………………… J
[3]

(e) Deduce whether heat is absorbed or released by the gas during the cycle ABCA. Explain your deduction.

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………………………………………………………………………………………………………[2]

3 **(a)** **(i)** The pressure p of an ideal gas is related to the density ρ of the gas by

$$p = \frac{1}{3}\rho\langle c^2\rangle$$

State what is meant by the symbol $\langle c^2\rangle$. [1]

....

....

(ii) Use the expression in **(a)(i)** to show that the mean kinetic energy E_k of an ideal gas molecule is given by

$$E_k = \frac{3}{2}kT$$

where k is the Boltzmann constant and T is the thermodynamic temperature.

[3]

3 **(b)** State the first law of thermodynamics.

....

....

.... [2]

(c) Use the first law to explain whether the internal energy increases, decreases or remains constant when

(i) the gas in a balloon expands suddenly when the balloon bursts,

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.... [3]

(ii) ice melts at constant temperature and constant atmospheric pressure into water that is denser than the ice.

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.... [3]

3 **(d)** 1.0 mol of an ideal gas is heated at constant volume.

(i) Use the first law and the mean kinetic energy E_k of an ideal gas molecule in **(a)(ii)** to show that the thermal energy required to raise the temperature of the gas by 1.0 K is $\frac{3}{2}R$ (where R is the molar gas constant).

[3]

(ii) Nitrogen may be assumed to be an ideal gas.
The molar mass of nitrogen gas is 28 g mol^{-1}.

Calculate the specific heat capacity at constant volume for nitrogen.

specific heat capacity = ... J kg^{-1} K^{-1} [2]

3 **(e)** A fixed mass of an ideal gas undergoes the cycle of changes ABCA, as shown in Fig. 8.1.

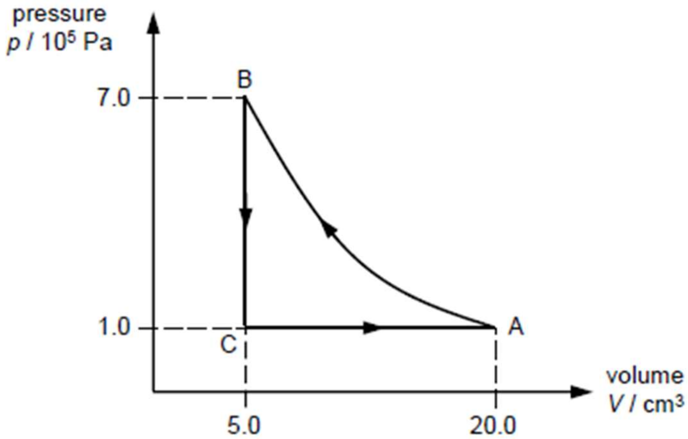

Fig. 8.1

Some energy changes during one cycle of ABCA are shown in Fig. 8.2.

change	heating supplied to gas / J	work done on gas / J	increase in internal energy / J
A → B	0	4.2	
B → C	– 8.5		
C → A			

Fig. 8.2

Complete Fig. 8.2. [3]

[Total: 20]

4 A cycle of changes in pressure, volume and temperature of gas inside a cylinder of a petrol engine is illustrated in Fig. 9.1. The gas is assumed to be ideal.

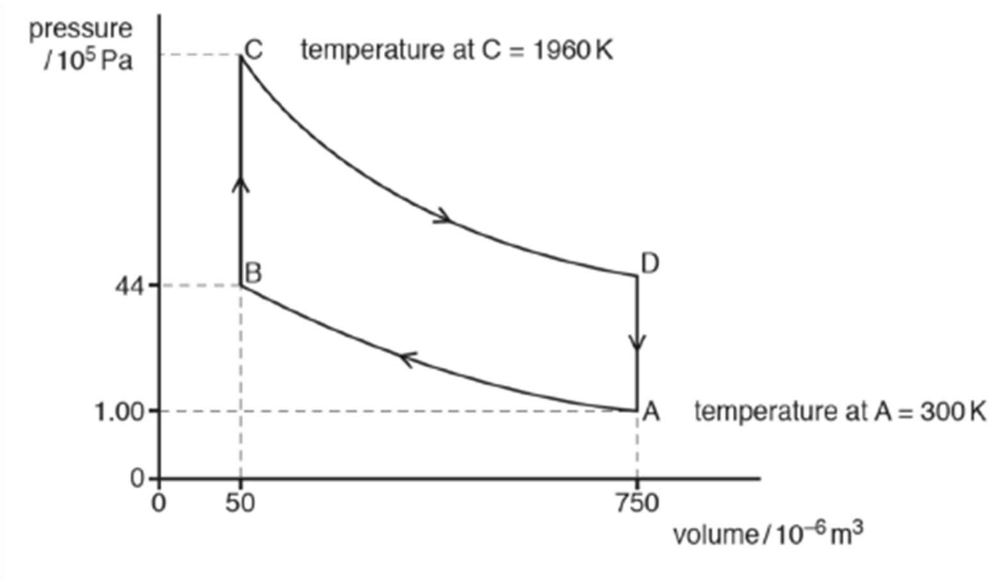

Fig. 9.1 (not to scale)

There are four stages in the cycle.

stage	description
A to B	Rapid compression of the gaseous petrol/air mixture with the temperature rising from 300 K at A. The pressure at B is 44 × 10^5 Pa.
B to C	The petrol/air mixture is exploded, resulting in an almost instant rise in pressure. At C the temperature is 1960 K.
C to D	Rapid expansion and cooling of the hot gases.
D to A	Return to the initial state of the cycle.

(a) **(i)** Using appropriate values from Fig. 9.1, determine the number of moles present in the gases in the cycle.

number of moles = ... mol [2]

4 **(ii)** Calculate the temperature of the gas at B.

temperature = ...K [2]

(iii) Calculate the pressure of the gas at C.

pressure = ...Pa [2]

(iv) State

1. the numerical value of work done by the gas from B to C,

.... [1]

2. what is represented by the area ABCD enclosed by the graph.

....

.... [2]

(b) Complete Table 9.1, which shows the work done on the gas, the heat supplied to the gas and the increase in internal energy of the gas, during the four stages in the cycle.

Table 9.1

stage	work done on gas /J	heat supplied to gas /J	increase in internal energy of gas /J
A to B	+ 360	0	
B to C		+ 670	
C to D		0	– 810
D to A			

[4]

4 **(c)** The efficiency of this engine is the ratio of the net work done by the gas to the heat supplied to the gas. Calculate the efficiency of this cycle.

efficiency = ... % [1]

(d) Using the First Law of Thermodynamics, explain whether the r.m.s. speed of the molecules of the gas will increase, decrease or remains the same when the gas expands rapidly from C to D.

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.... [2]

(e) Explain, in terms of the collision of the molecules of the gas with the walls of the container, why an expansion results in a change in the kinetic energy of the molecules from C to D.

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.... [2]

(f) Calculate the total kinetic energy of the molecules of the gas at C.

total kinetic energy = ... J [2]

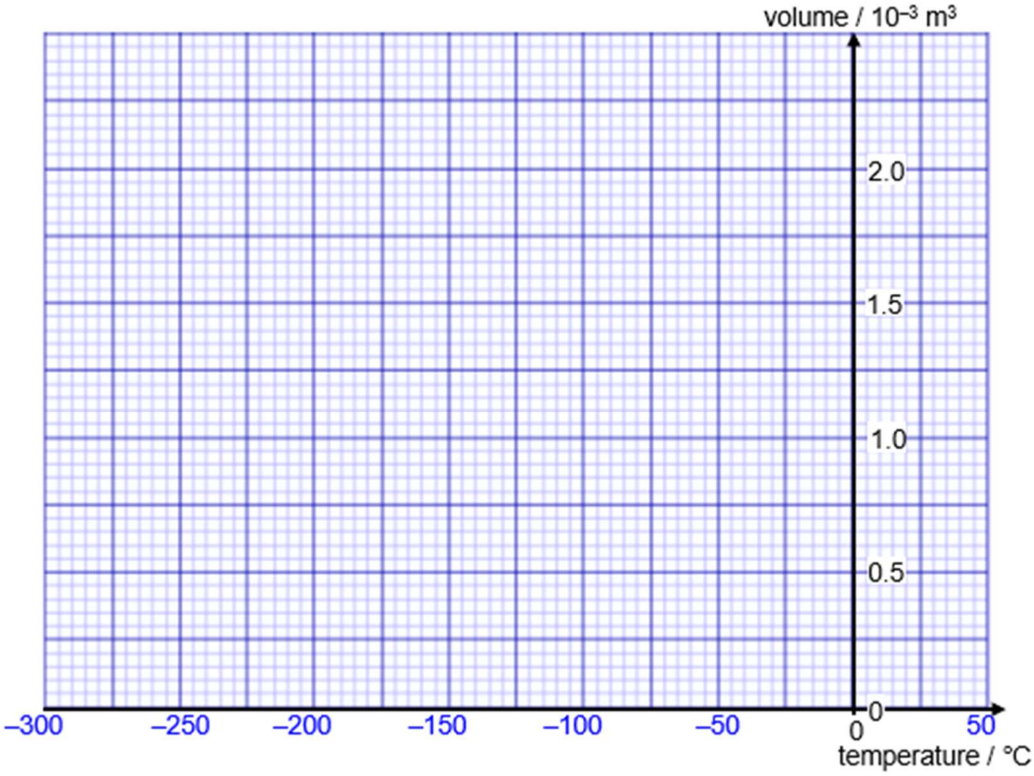
[Total: 20]

5

A fixed mass of ideal gas at a low temperature is trapped in a container at constant pressure. The gas is then heated and the volume of the container changes so that the pressure stays constant at 1.00×10^5 Pa.

When the gas reaches a temperature of 0.00 °C, the volume is 2.20×10^{-3} m^3.

(a) Draw a graph on the axes below to show how the volume of the gas varies with temperature in °C. [2]



(b) Calculate the number of moles of gas in the container.

number of moles = ... mol [2]

5 **(c)** Calculate the average kinetic energy of a molecule when this gas is at a temperature of 50.0 °C.

kinetic energy = ... J [2]

(d) Hence or otherwise, calculate the total internal energy of the gas at a temperature of 50.0 °C.

internal energy = ... J [2]

(e) By considering the collisions of gas molecules with the walls of the container, explain why the volume of the container must change if the pressure is to remain constant as the temperature increases.

....

....

....

.... [2]

6 **(a)** Explain why a real gas approaches ideal behaviour at very low pressure.

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.... [2]

(b) The variation with pressure p of the volume V of a fixed mass of an ideal gas is shown in Fig. 2.1. The gas undergoes a cycle of changes A to B to C to A.

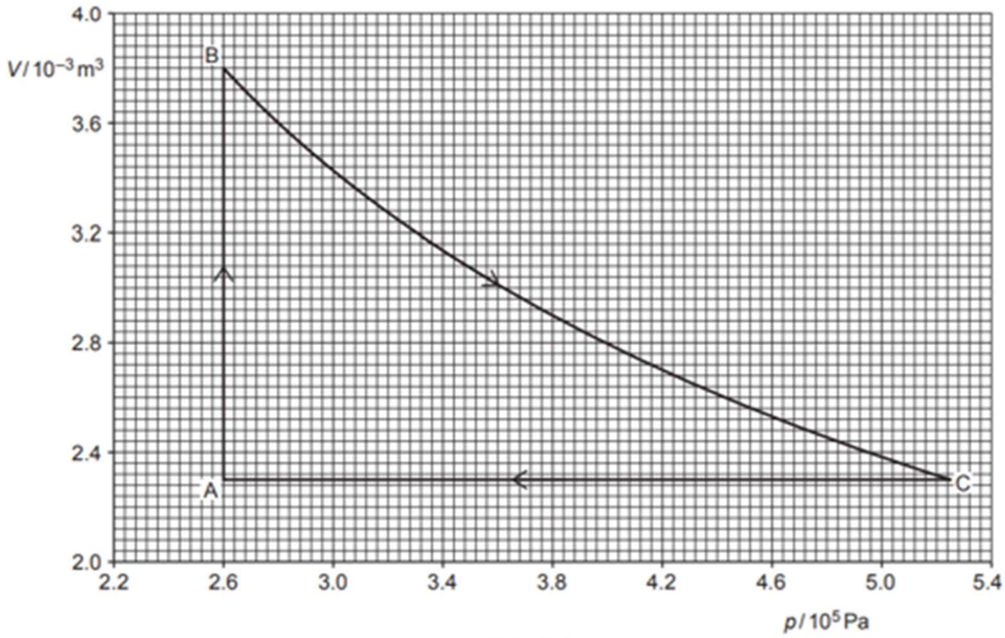

Fig. 2.1

(i) Show that the change from B to C is not an isothermal process.

[1]

6 **(ii)** Calculate the work done on the gas during the change A to B and C to A.

work done from A to B = ……………………………. J

work done from C to A = ……………………………. J [2]

(iii) During the change A to B, 1370 J of thermal energy is transferred to the gas. During the change B to C, no thermal energy enters or leaves the gas. The work done on the gas during this change is 550 J.

Complete the table below.

Process	Heat supplied, Q /J	Work done on gas, W / J	Change in internal energy, ΔU / J
A to B	1370		
B to C	0	550	
C to A			

[2]

(iv) The cycle of change is now reversed from A to C to B to A. It is now operating as a heat engine, converting some heat energy to useful work. The efficiency of this heat engine is defined as the

$$\text{Efficiency} = \frac{\text{net work done in a cycle}}{\text{heat absorbed in a cycle}}$$

Calculate the efficiency of this engine.

efficiency = ……………………………… [2]

7 **(a)** 0.050 moles of ideal gas is contained in a cylinder fitted with a piston. The piston moves slowly outwards, resulting in the variation of pressure shown in Fig. 1.1.

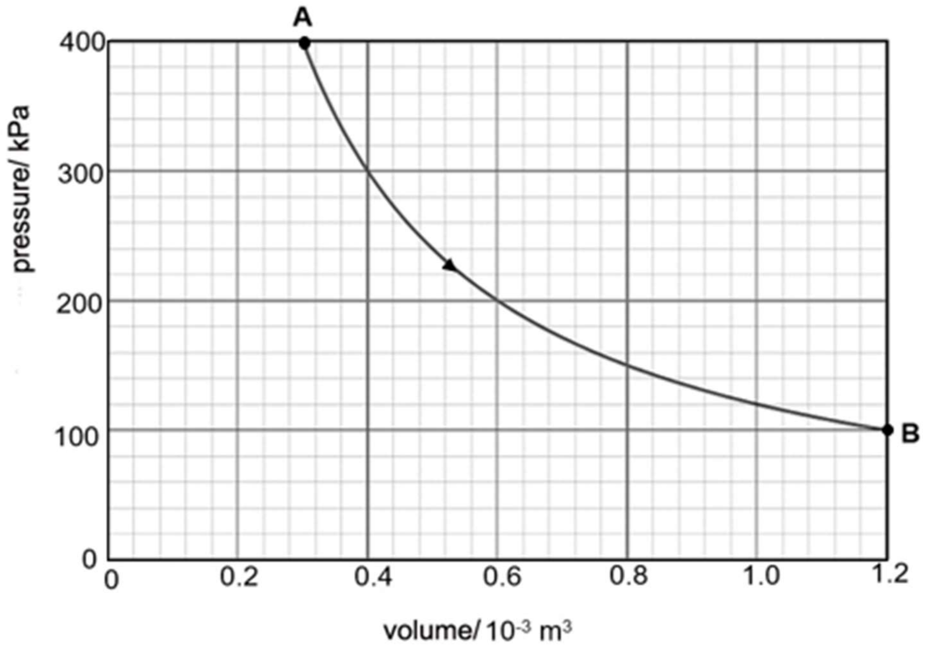

Fig. 1.1

(i) The temperature of the gas does not change from A to B.

Calculate this temperature.

temperature = ... K [2]

(ii) Calculate the total kinetic energy of the gas molecules in the cylinder.

kinetic energy = ... J [1]

7 **(iii)** Estimate the amount of work done by the gas as it expands from A to B.

work done = ... J [2]

(iv) State and explain, using the first law of thermodynamics, whether heat flows into the gas during the process from A to B.

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.... [2]

(b) An experiment is conducted to investigate how gas pressure varies with temperature.

Two identical sealed glass flasks P and Q are filled with the same amount of ideal gas at the same atmospheric pressure initially. Both flasks are heated from 27°C to 157°C. The pressure in flask P increases as expected, but the pressure in flask Q remains unchanged because some gas leak out of flask Q.

Calculate the ratio

$$\frac{\text{amount of gas in flask Q}}{\text{amount of gas in flask P}} \text{ at } 157°\text{C}.$$

ratio = ... [3]

8 **(a)** State the First Law of Thermodynamics.

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....

....

.... [2]

(b) Starting from kinetic theory expression $p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$, show that the internal energy of a fixed mass of an ideal gas is equal to $\frac{3}{2}NkT$, where the symbols have their usual meaning.

[2]

(c) A fixed mass of an ideal gas undergoes a cycle of changes ABCDA, as shown in **Fig. 3.1**.

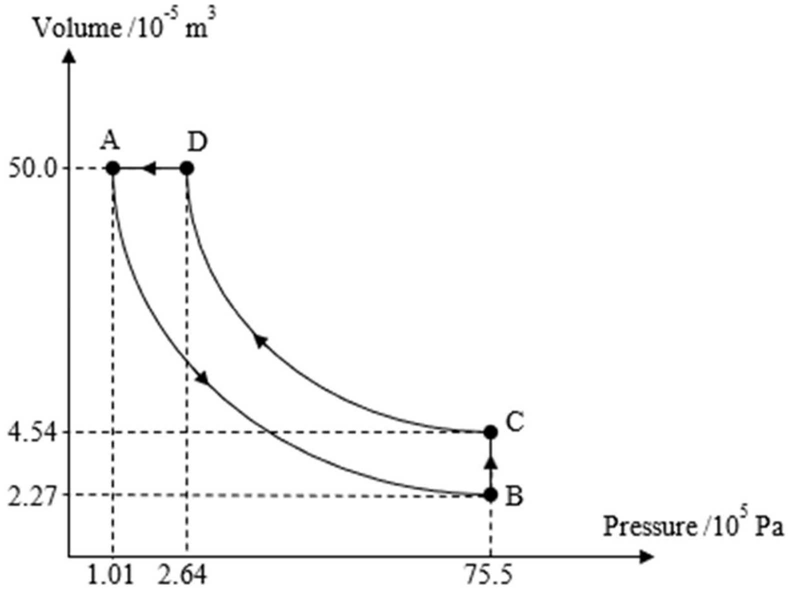

Fig. 3.1 (not to scale)

8 **(i)** For this mass of gas,

1. show that the increase in internal energy during the change from B to C is 257 J,

[1]

2. determine the work done on the gas during the change from B to C.

Work done = ……………………..[2]

(ii) Using your answers in **(c)(i)**, complete **Table 3.1** for the four stages of the cycle.

Stage of cycle	heat supplied to gas / J	work done on gas / J	increase in internal energy of the system / J
A → B	0	182	
B → C			257
C → D	0	- 316	
D → A			

Table 3.1

[4]