4 **(a)** **(i)** State what is meant by the internal energy of a system.

....

....

.... [2]

(ii) Explain why the internal energy of an ideal gas is directly proportional to the thermodynamic temperature of the gas.

....

....

....

.... [2]

(b) A sample of an ideal gas at thermodynamic temperature T has internal energy U.

The gas is compressed so that its temperature increases to $3T$.
During this compression, work W is done on the gas.

The gas is then cooled at constant volume so that its temperature decreases to $2T$.

Complete Table 4.1 to show, in terms of some or all of W, T and U, the work done on the gas, the thermal energy supplied to the gas and the increase in internal energy of the gas for each of the two processes.

Table 4.1

	work done on gas	thermal energy supplied to gas	increase in internal energy of gas
compression	$+W$		
cooling			

[4]

[Total: 8]

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....

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	work done on gas	thermal energy supplied to gas	increase in internal energy of gas
compression	$+W$		
cooling			

[4]

[Total: 8]

3 **(a)** The product pV for an ideal gas is given by

$$pV = \frac{1}{3}Nm\langle c^2\rangle$$

where p is the pressure of the gas and V is the volume of the gas.

(i) State the meaning of the symbols N, m and $\langle c^2\rangle$ in this equation.

N: ....

m: ....

$\langle c^2\rangle$: ....
[3]

(ii) Use the equation of state for an ideal gas to show that the average translational kinetic energy E_K of a molecule of the gas at thermodynamic temperature T is given by

$$E_K = \frac{3}{2}kT.$$

[2]

(b) The surface of a star consists mainly of a gas that may be assumed to be ideal. The molecules of the gas have a root-mean-square (r.m.s.) speed of 9300 m s^{-1}.

The mass of a molecule of the gas is 3.34×10^{-27} kg.

Determine, to three significant figures, the temperature of the surface of the star.

temperature = ... K [2]

(c) The radiant flux intensity of the radiation from the star in **(b)** is $2.52 \times 10^{-8}\,\mathrm{W\,m^{-2}}$ when observed at a distance of $4.16 \times 10^{16}\,\mathrm{m}$ from the star.

(i) Calculate the luminosity of the star. Give a unit with your answer.

luminosity = ... unit .... [2]

(ii) Determine the radius of the star.

radius = ... m [2]

(d) The gas at the surface of a star has a very high pressure.

Use the basic assumptions of the kinetic theory to suggest why, in practice, a gas at the surface of a star is unlikely to behave as an ideal gas.

....

....

....

.... [2]

[Total: 13]

4 **(a)** State **two** of the basic assumptions of the kinetic theory of gases.

1 ....

....

2 ....

....
[2]

(b) An ideal gas has amount of substance *n*.
The gas is initially in state X, with pressure 2*p* and volume *V*.
The gas is cooled at constant volume to state Y, with pressure *p*.
The gas is then heated at constant pressure to state Z, with volume 2*V*.
Finally, the gas returns at constant temperature to state X.

(i) Determine an expression for the temperature *T* of the gas in state X, in terms of *n*, *p* and *V*.
Identify any other symbols that you use.

[2]

(ii) On Fig. 4.1, sketch the variation with volume of pressure for the gas as the gas undergoes the three changes. The state X is labelled. Label states Y and Z.

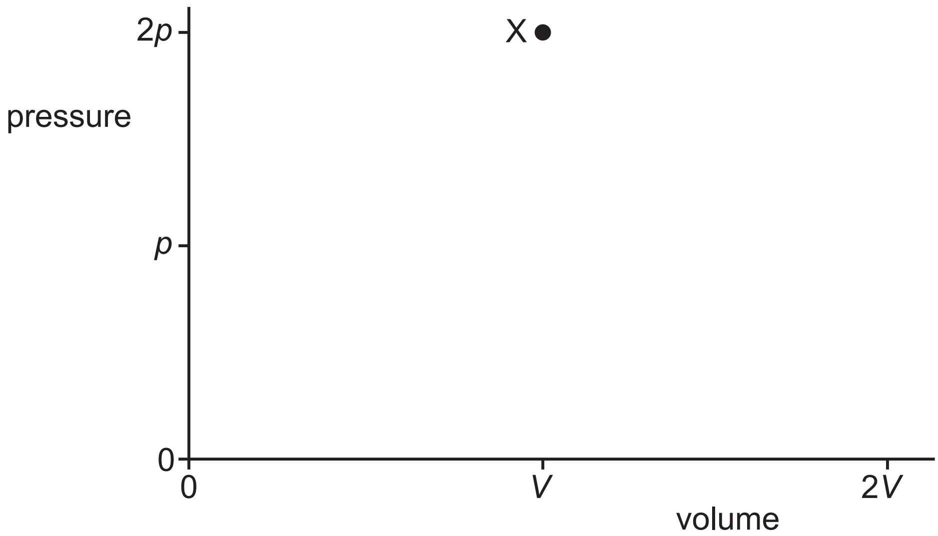

Fig. 4.1

[3]

(iii) During the change of state from Y to Z, the increase in internal energy of the gas is U. During the change of state from Z to X, the work done on the gas is W.

Complete Table 4.1 to indicate, for each of the three changes of state, the increase in internal energy of the gas, the thermal energy transferred to the gas and the work done on the gas, in terms of p, V, U and W.

Table 4.1

change	increase in internal energy of gas	thermal energy transferred to gas	work done on gas
X to Y			
Y to Z	$+U$		
Z to X			$+W$

[5]

[Total: 12]