4 A cylinder contains a fixed mass of an ideal gas at pressure $2Y$ and volume $6X$.

The gas undergoes a sequence of changes from its initial state A, through states B, C and D, then finally back to its initial state A, as shown in Fig. 4.1.

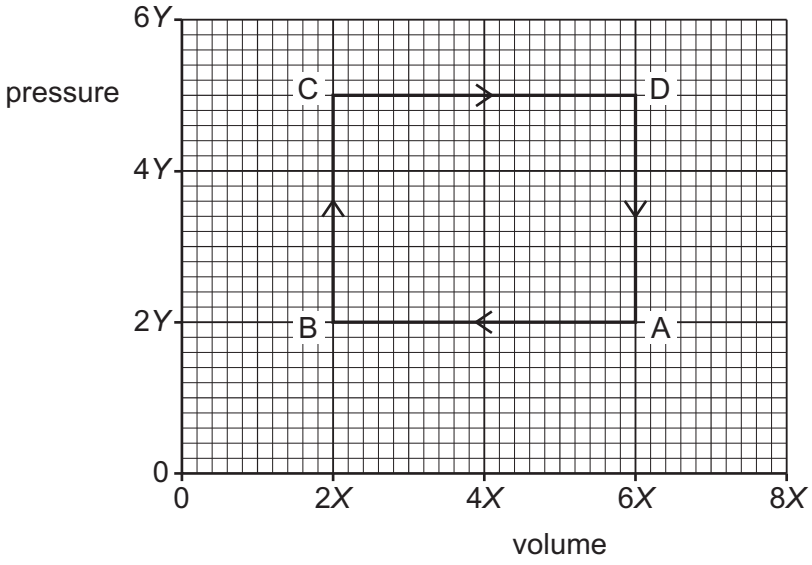

Fig. 4.1

Fig. 4.2 shows the variation with time of the internal energy of the gas.

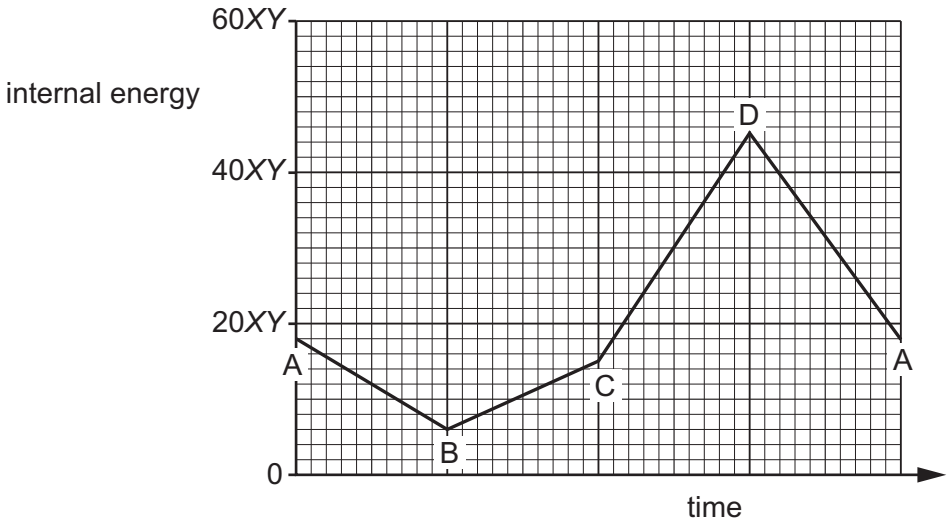

Fig. 4.2

(a) State the first law of thermodynamics.

.....

.....

..... [2]

(b) **(i)** Use Fig. 4.1 and Fig. 4.2 to determine the general expression for the internal energy U of the gas when it has pressure p and volume V.

U = ... [1]

(ii) An ideal gas at thermodynamic temperature T contains N molecules.

Use your answer in **(b)(i)** and the equation of state for an ideal gas to deduce an expression for U in terms of N and T. Identify any other symbols you use.

U = ... [2]

(c) Determine expressions, in terms of X and Y, for the work W done on the gas during:

(i) change AB

W = ... [1]

(ii) change CD.

W = ... [1]

(d) Use your answers in **(c)** and the first law of thermodynamics to determine an expression, in terms of X and Y, for the net thermal energy Q supplied to the gas during one full cycle ABCDA. Explain your reasoning.

Q = ... [3]

[Total: 10]