7 **(a)** State the first law of thermodynamics.

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

………………………………………………………………………………………………………

(b) A fire piston is an ancient device that is used to ignite kindling for fires through the use of an adiabatic compression. A small amount of material to be set on fire is placed at the base of a hollow cylinder which is sealed on one end. A plunger is placed into the open end, and quickly pressed down to rapidly heat the air within, which can be hot enough to cause the material to be set alight without an external heat source, known as auto-ignition, as shown in Fig. 7.1.

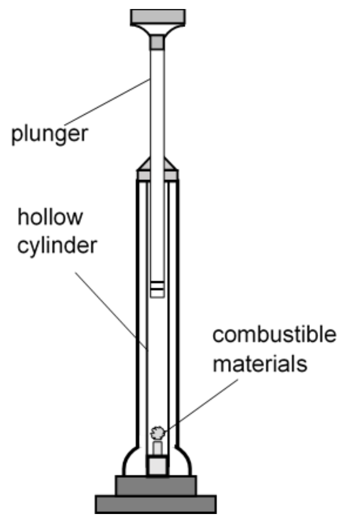

Fig. 7.1

(i) Suggest why the rapid compression leads to no net heat exchange in the fire piston and the surrounding.

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

……..…………………………………………..…………………………………

(ii) One such piston has an initial volume of 20.0 cm^3, pressure of 125 kPa and temperature of 302 K. During compression, the air within is reduced to 5.0% of the initial volume and the temperature of the air rises to 1000 K. You may assume that air is a monoatomic ideal gas.

For the fire piston, determine

1. the final pressure of the air after compression,

[2]

final pressure = ……………..……………. kPa

2. the change in total internal energy of the air,

[2]

change in total internal energy = ………………..……………. J

3. work done on the air by the piston.

[2]

work done on the air = ………………..……………. J

(c) The fire piston demonstrates one of the processes in the thermodynamic cycles commonly used in many modern devices.

A particular device utilises a thermodynamic cycle shown in the *p*-*V* diagram shown in Fig. 7.2.

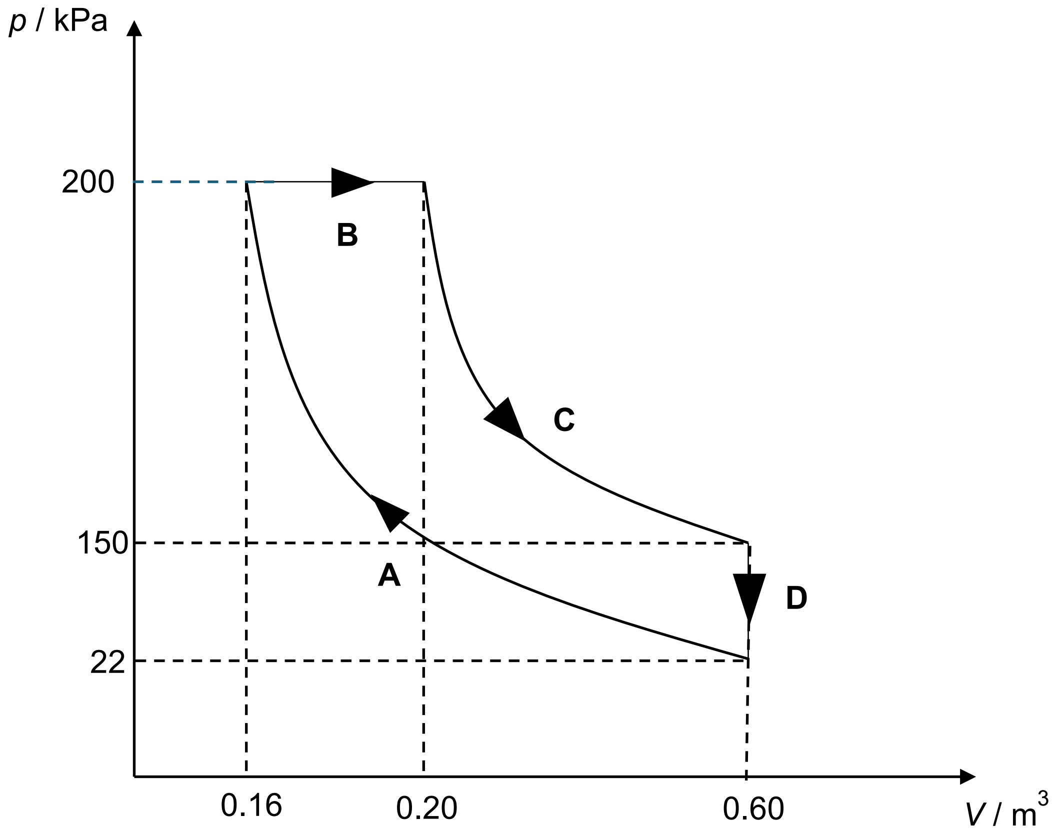

Fig. 7.2

The cycle is made out of four processes: A, B, C and D. Processes A and C are processes with no net heat transfer.

(i) State the process in Fig. 7.2 that is most similar to the process observed in the fire piston in **(b)**.

……..……………………………………………..…………………………………

[1]

……..……………………………………………..…………………………………

(ii) Complete the table below with the values of *ΔU*, *Q* and *W* for the 4 processes.

Process	*ΔU*	*Q*	*W*
A		0	31100
B	12000		
C		0	-28100
D			

[6]

(iii) There are 2.0 moles of gas in the device.

Determine, with calculations, the increase in the temperature in Process B.

[2]

increase in temperature = ……………..……………….. K

(iv) A vehicle engine converts the heat of burnt fuel into mechanical work.

By considering the sign of the net heat supplied and net work done on the gas in this cycle, suggest whether this cycle could be used as a vehicle engine.

…………………………………………..………………………………………..

…………………………………………..………………………………………..

…………………………………………..………………………………………..

…………………………………………..……………………………………….. [3]

……………………………………………………………………………………....

……………………………………………………………………………………....