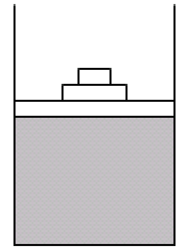
PROBLEM 1 – 15 points

You have some monatomic ideal gas in a cylinder. The cylinder is sealed at the top by a piston that can move up or down, or can even be fixed in place to keep the volume constant. Blocks can be added to, or removed from, the top of the cylinder to adjust the pressure, as necessary. Starting with the same initial conditions each time, you do six experiments. Each experiment involves the same amount of heat, Q.



A – Add heat Q to the system at constant pressure.
B – Add heat Q to the system at constant temperature.
C – Add heat Q to the system at constant volume.
D – Remove heat Q from the system at constant pressure.
E – Remove heat Q from the system at constant temperature.
F – Remove heat Q from the system at constant volume.

[2 points] (a) Which experiments result in a final temperature higher than the initial temperature? **Select all that apply.**

[**X**] A [ ] B [**X**] C [ ] D [ ] E [ ] F

[2 points] (b) Which experiment results in the highest final temperature?

[ ] A [ ] B [**X**] C [ ] D [ ] E [ ] F

All the heat goes into work in process C. Only some of it goes to work in process A.

[2 points] (c) Which experiments result in a final volume larger than the initial volume? **Select all that apply.**

[**X**] A [**X**] B [ ] C [ ] D [ ] E [ ] F

[2 points] (d) Which experiment results in the largest final volume?

[ ] A [**X**] B [ ] C [ ] D [ ] E [ ] F

The work is the area under the P-V graph. All the heat goes to doing work in process B, and the pressure goes lower in process B, while only some of the heat goes into doing work in process A.

[2 points] (e) Which experiments result in a final pressure higher than the initial pressure? **Select all that apply.**

[ ] A [ ] B [**X**] C [ ] D [**X**] E [ ] F

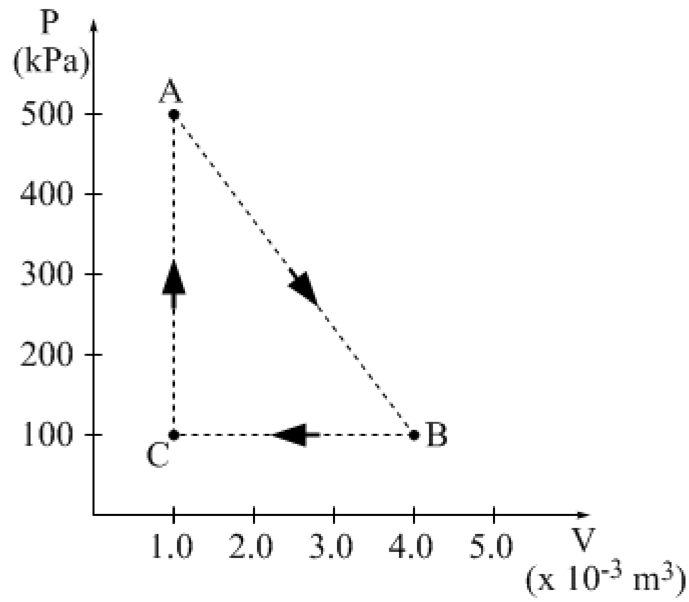
[5 points] (f) Rank the experiments based on the work done by the gas, from most positive to most negative. Use only > and/or = signs in your rankings (e.g., B=D>C>A=F>E).

B > A > C = F > D > E

For C and F, no work is done. For B, all the heat goes to work, while in A only some of the heat goes to work. For E, the work is equal to –Q, while for D the work is negative, but not as negative as –Q.

PROBLEM 2 – 10 points

A monatomic ideal gas is subject to the series of processes A→B→C→A, as shown on the P-V diagram. The number of moles is such that nR is exactly 4 J/K.



For a monatomic ideal gas

$$\Delta E_{\text{int}} = \frac{3}{2} nR\Delta T$$

1 Pa = 1 N/m^2

[6 points] (a) What is the amount of heat involved in the process A→B?

The work done in the A→ B process is the area under the curve for A→ B, which is the triangular area (+600 J) plus the rectangular area below C-B (+300 J). The work done for the A→ B process is thus +900 J.

We actually have enough information here to find the temperature, by using the ideal gas law. In state A, the temperature is $T_A = \frac{P_A V_A}{nR} = 125\text{K}$ **. By the same process, we find that the temperature in state B is 100 K. Thus, the change in internal energy for the A→ B process is:**

$$\Delta E_{\text{int}} = \frac{3}{2} nR\Delta T = \frac{3}{2}(4 \text{ J/K})(-25\text{K}) = -150 \text{ J}$$

Applying the first law of thermodynamics, we find that

$$Q = W + \Delta E_{\text{int}} = +900 \text{ J} - 150 \text{ J} = +750 \text{ J}$$

[2 points] (b) Is the heat in the process A→B absorbed by the gas or given off by the gas?

[**X**] absorbed by the gas [ ] given off by the gas

A positive value for the heat means that the heat is added to the gas.

[2 points] (c) What is the total amount of heat involved in the whole cycle A→B→C→A?

For a complete cycle, the total heat is equal to the net work done in the cycle, which is the area enclosed by the cycle on the P-V diagram. This is +600 J.