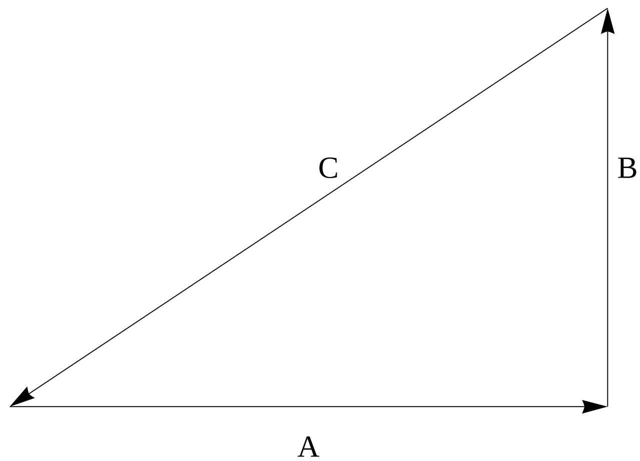
PHYS328
IN CLASS DISCUSSION FOR 6 SEPT. 2012

Our question is based on the PV diagram for a three step process shown below :



Pressure is along the horizontal axis, and volume is along the vertical axis. In class, we discussed the signs of the quantities ΔU, Q and W for each step of the process. Recapping briefly, we found that :

Step A : W is negative because the gas expands along the constant pressure line A. ΔU is positive since we can combine equipartition and the ideal gas law to show that :

$$\Delta U = \frac{f}{2}\Delta(PV)$$

Since the product of PV is greater at the final stage of A than at the start of A, $\Delta(PV)$ is positive and therefore so is ΔU. Now, using the first law of thermodynamics :

$$\Delta U = Q + W \Rightarrow Q = \Delta U - W$$

Thus, if ΔU is positive and W is negative, Q must be positive.

Step B : The volume is constant so W is zero (since $W = -\int P\,dV$). ΔU is positive since $\Delta(PV)$ is positive along B. If W = 0, the first law tells us that $Q = \Delta U$ and is also positive.

Step C: ΔU is negative since both P and V decrease along C. W is positive since the gas is compressed. (Remembering that $W = -\int P\,dV$, we have that P is always positive (albeit decreasing) along C while dV is negative. Thus, the sign of $-P\,dV$ is positive.) Applying the first law here, $Q = \Delta U - W < 0$.

Now, the question for class discussion was to determine the signs of ΔU, Q and W for the entire cycle.

Let' s begin with the easy one, ΔU. Since $\Delta U = (f/2)\, Nk\, \Delta T$, the sign of ΔU must be the same as the sign of ΔT. However, if we begin and end at the same P, V conditions, the ideal gas law tells us that we must begin and end with the same temperature, therefore $\Delta T = 0 = \Delta U$.

Our analysis above shows us that W is negative along A and positive along C. Even though we do not have numerical values, we can see graphically that the area under C is greater than the area under A, so that the positive work done along C is greater in magnitude than the negative work done along A. Thus, the total work done for the whole cycle is positive.

Knowing that $\Delta U = 0$ means that :

$\Delta U = 0 = Q + W \Rightarrow Q = - W$. If W is positive for the whole cycle, then Q is negative. This is a process that produces work while losing heat to the outside environment.