<u>Today</u>

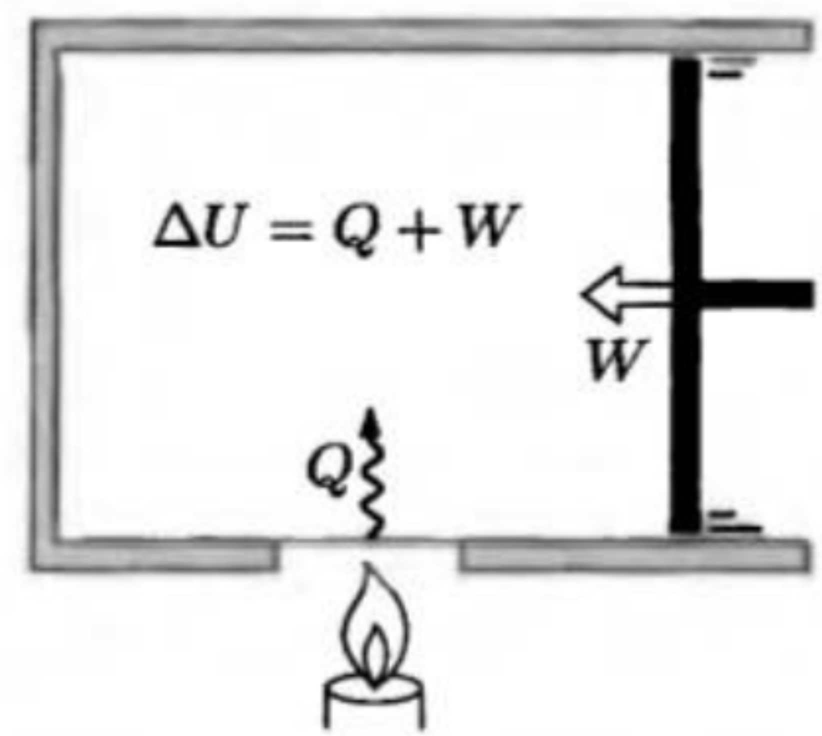
I. Last Time
II. Office Hour Change Tuesdays, Next week's Exam, Guest Lecture
III. The First Law of Thermodynamics
IV. Detailed Explorations of the Ideal Gas

I. We discussed heat and work. Heat is spontaneous energy transfer. Work is not spontaneous energy transfer. In other words it is energy transfer done by an external agent or system.

Conventions: Positive work is work done on the system. Positive heat is heat exchange that enters the system.

Discussed the equipartition theorem. Each quadratic degree of freedom contributes $\frac{1}{2}kT$ to the internal energy of the system. This assumes the system is held at fixed temperature.

III. Heat, Work, and Important Conventions



Both heat and work are energy in transition!

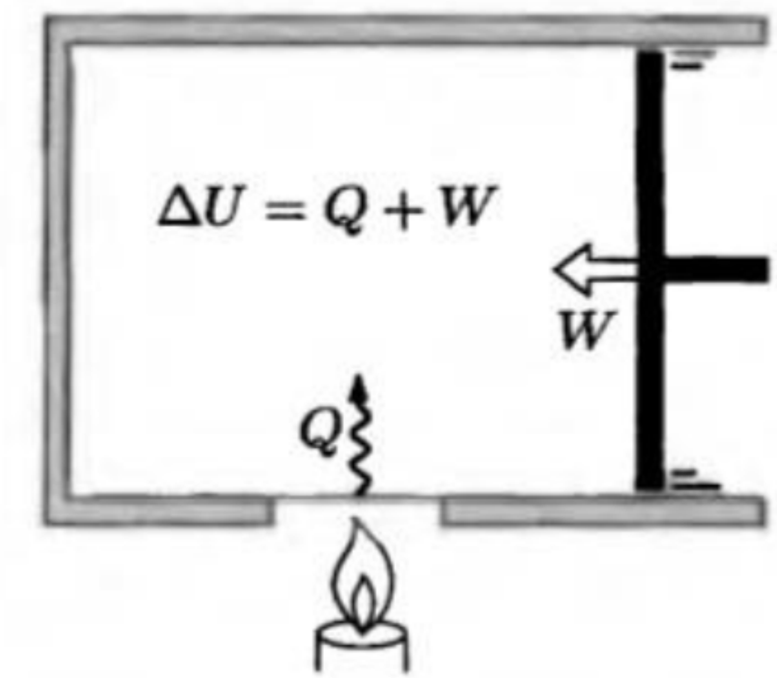
In our course, we will always consider heat *added to the system* as positive. Similarly, we say that work done *on the system* is positive work.

In this context, conservation of energy states that

$$\Delta U = U_f - U_i = Q + W$$

We call this the first law of Thermodynamics. Notice the strange notation with no Δ on the right…this notation is intended to remind you that expression like ~~$Q_f - Q_i$~~ are totally and utterly illegal.

III. Heat, Work, and Important Conventions



Both heat and work are energy in transition!

In this context, conservation of energy states that

$$\Delta U = U_f - U_i = Q + W$$

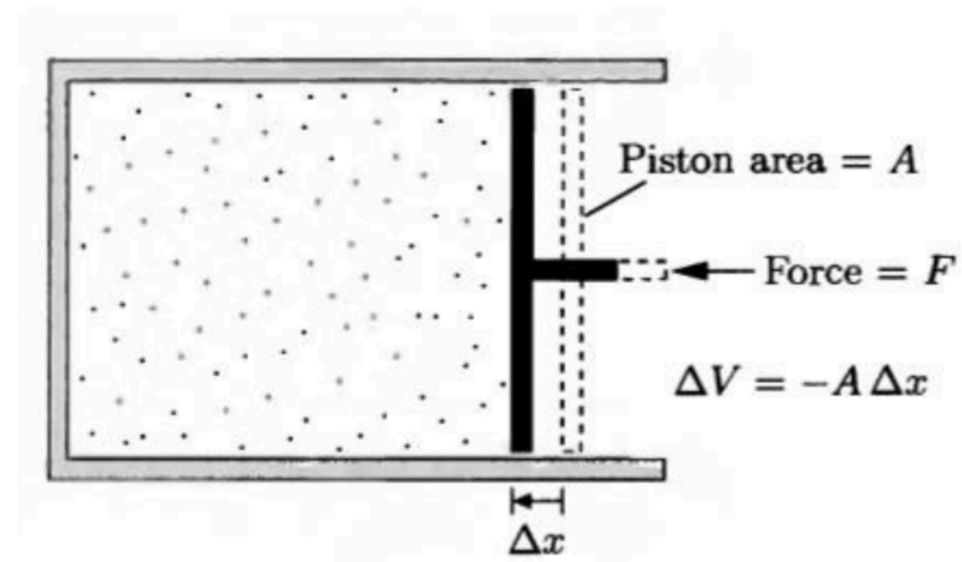
We call this the first law of Thermodynamics. Notice that the quantities on the right are both path dependent, that is, the amount of heat and work transfer depend on the history of how they happened. Meanwhile, the left hand side is a "state variable" and only depends on the current state of the physical system. For the equation to make sense, the path dependence of Q and W must cancel each other.

IV. Details of the Ideal Gas

First let's find an expression for the work on the system.

From the figure we have the following

$$W = F\Delta x = F\left(-\frac{\Delta V}{A}\right) = -P\Delta V.$$



If the displacement of the piston is infinitessimal, then

$$W = -PdV.$$

Let's consider the compression of a gas at fixed pressure, with that process and constraint we have the total work is

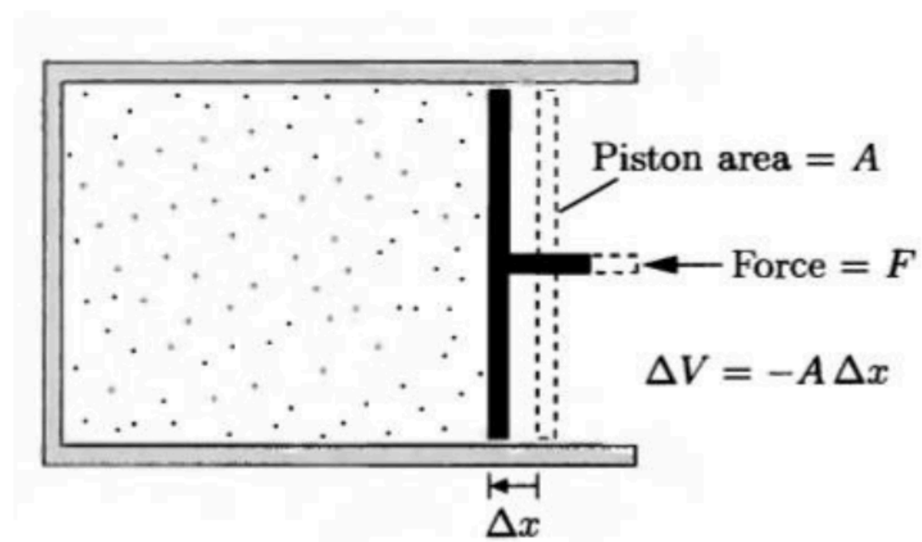
$$W = -\int_{V_i}^{V_f} PdV = -P\int_{V_i}^{V_f} dV = -P(V_f - V_i) = -P\Delta V$$

IV. Details of the Ideal Gas

Let's consider another process. Let's imagine that our piston is "adiabatically" compressed, i.e. so slowly that at every step the system is in equilibrium. Then during compression the temperature is fixed—we call this an "isothermal" process.

$$W = -\int_{V_i}^{V_f} PdV = -\int_{V_i}^{V_f} \frac{NkT}{V} dV = -NkT \int_{V_i}^{V_f} \frac{1}{V} dV = -NkT[\ln(V_f) - \ln(V_i)]$$

$$= -NkT\left[\ln\left(\frac{V_f}{V_i}\right)\right] = NkT\left[\ln\left(\frac{V_i}{V_f}\right)\right]$$



Calculate heat exchange next:

$$Q = \Delta U - W = \Delta(\frac{1}{2}NfkT) - W = 0 - W = -W$$