Today

I. Update on Thanksgiving
II. Lab Decision
III. Last Time
IV. Carnot Engine and Entropy
V. Entropy as a State Variable

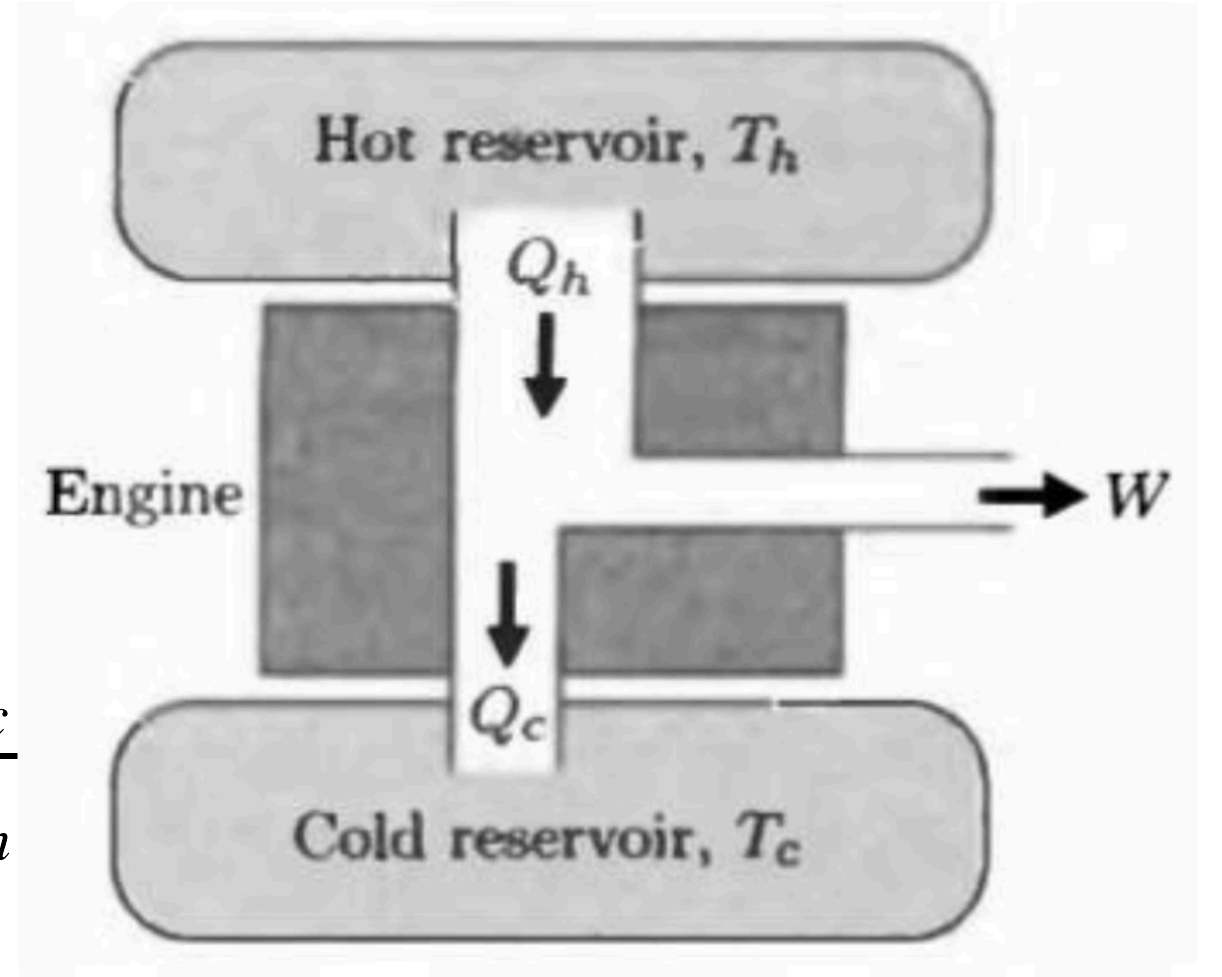
I. We made a distinction between reversible and irreversible processes: a reversible process is one where you can retrace your steps, concretely we can imagine a piston that slowly compresses a gas and then slowly expands it back out.

An irreversible is one that creates entropy and cannot be easily reversed. Lighting an object on fire is a good example.

What role does entropy play in the behavior of engines?

IV. Let's study an engine that doesn't create any entropy.

From the general schematic we see that conservation of energy dictates $Q_h = W + Q_c$.



Recall our definition of efficiency

$$e = \frac{\text{benefit}}{\text{cost}} = \frac{W}{Q_h} = \frac{Q_h - Q_c}{Q_h} = 1 - \frac{Q_c}{Q_h}$$

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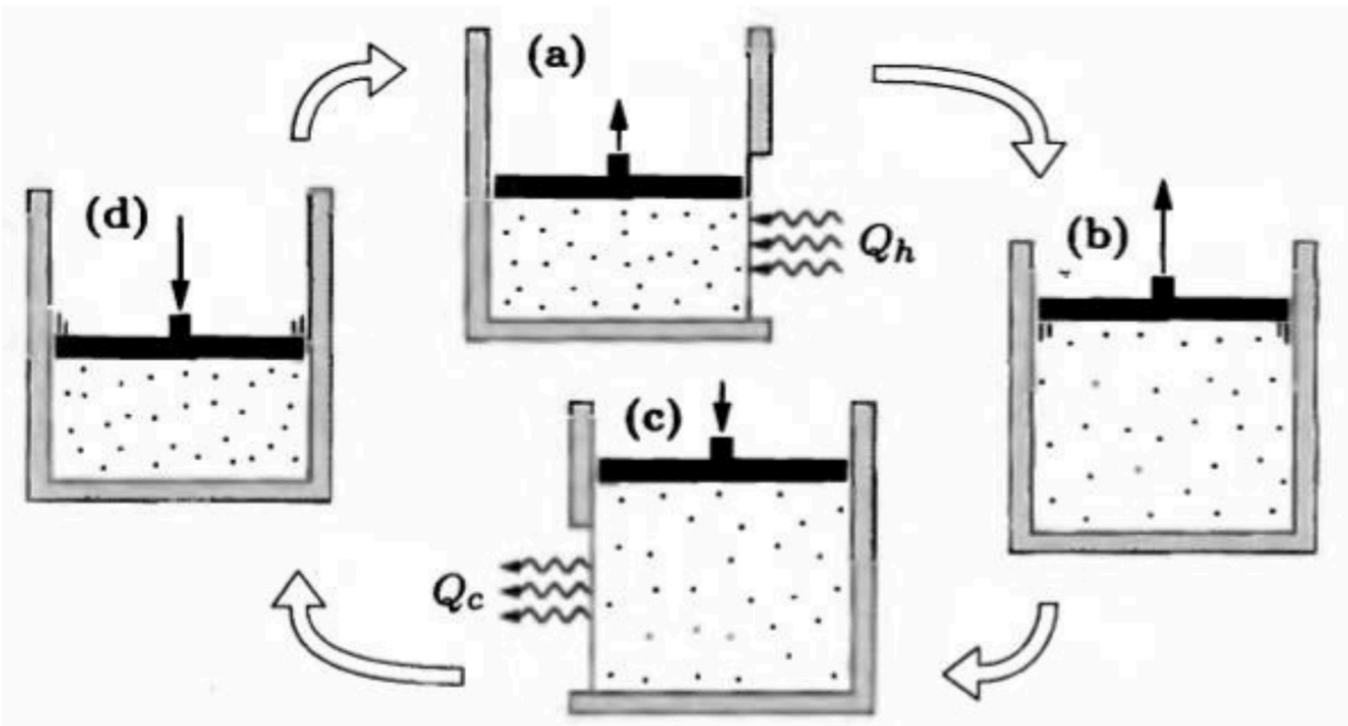

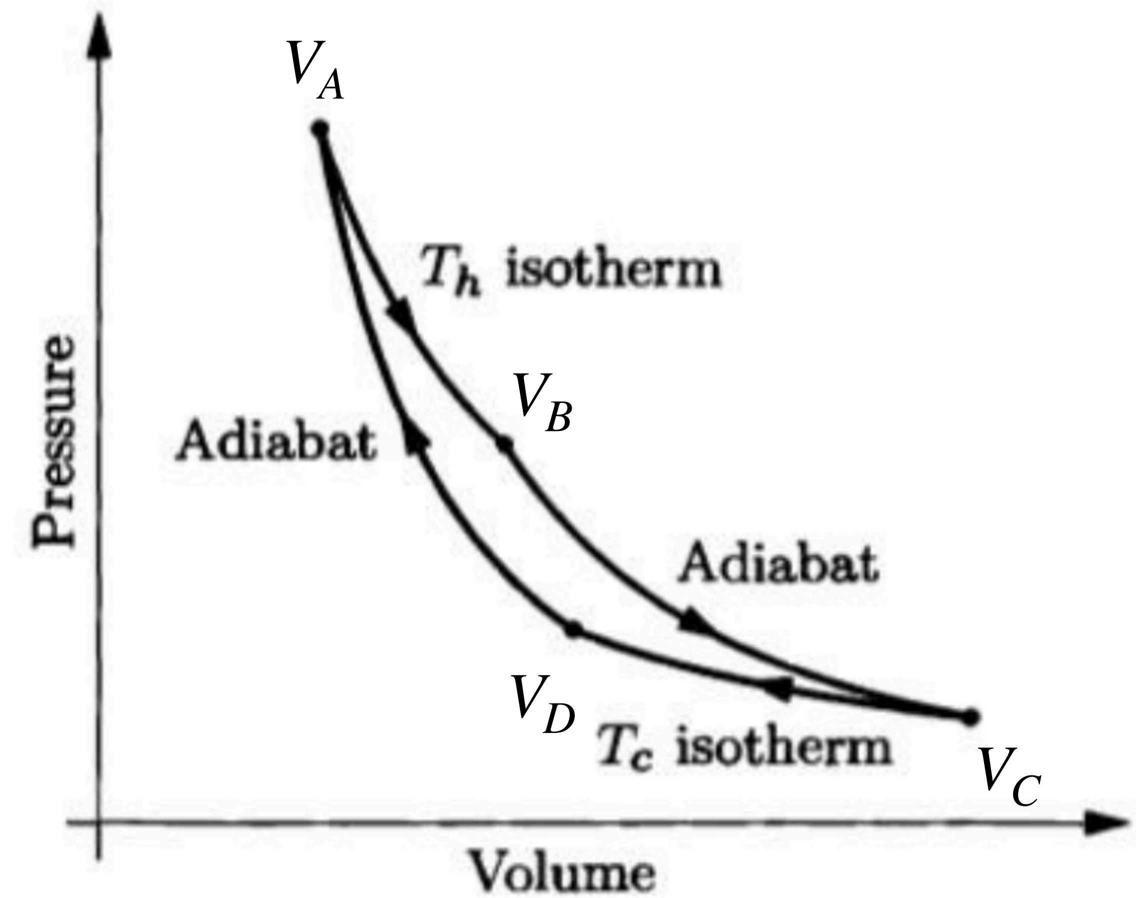

Let's study the two isotherms. Along the T_h isotherm the 1st law tells us that $\Delta U = Q_h + W_h$, but along an isotherm $\Delta T = 0 \implies \Delta U = 0$, but then

$$Q_h = -W_h = -\left(-\int PdV\right) = \int_{V_A}^{V_B} PdV = \int_{V_A}^{V_B} \frac{NkT_h}{V} dV = NkT_h \ln\left(V_B/V_A\right)$$

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Analogously along the lower isotherm we have

$Q_c = NkT_c \ln(V_C/V_D)$.

Notice then that

$$\frac{Q_c}{Q_h} = \frac{NkT_c \ln(V_C/V_D)}{NkT_h \ln(V_B/V_A)} = \frac{T_c \ln(V_C/V_D)}{T_h \ln(V_B/V_A)} = \frac{T_c}{T_h} \rightsquigarrow e = 1 - \frac{T_c}{T_h}$$

We previously showed that along an adiabat: $TV^{\gamma-1} = \text{const}$. Then $T_h V_A^{\gamma-1} = T_c V_D^{\gamma-1}$ and $T_h V_B^{\gamma-1} = T_c V_C^{\gamma-1}$, then the ratio gives…

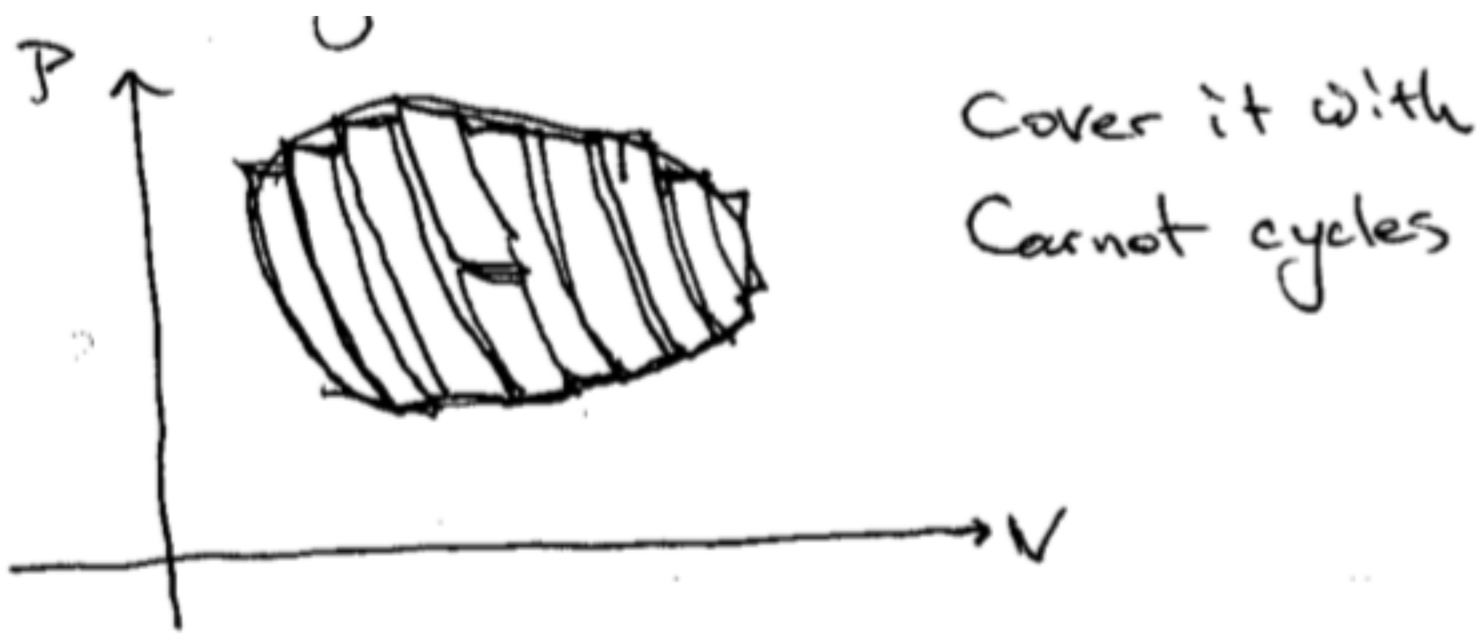
$$\frac{V_B^{\gamma-1}}{V_A^{\gamma-1}} = \frac{V_C^{\gamma-1}}{V_D^{\gamma-1}}, \implies \frac{V_C}{V_D} = \frac{V_B}{V_A}$$

IV. Notice that we can summarize our results with

$\frac{Q_c}{Q_h} = \frac{T_c}{T_h}$, but then the engine didn't creat any entropy!

$$S_h = \frac{Q_h}{T_h} = \frac{Q_c}{T_c} = S_c.$$

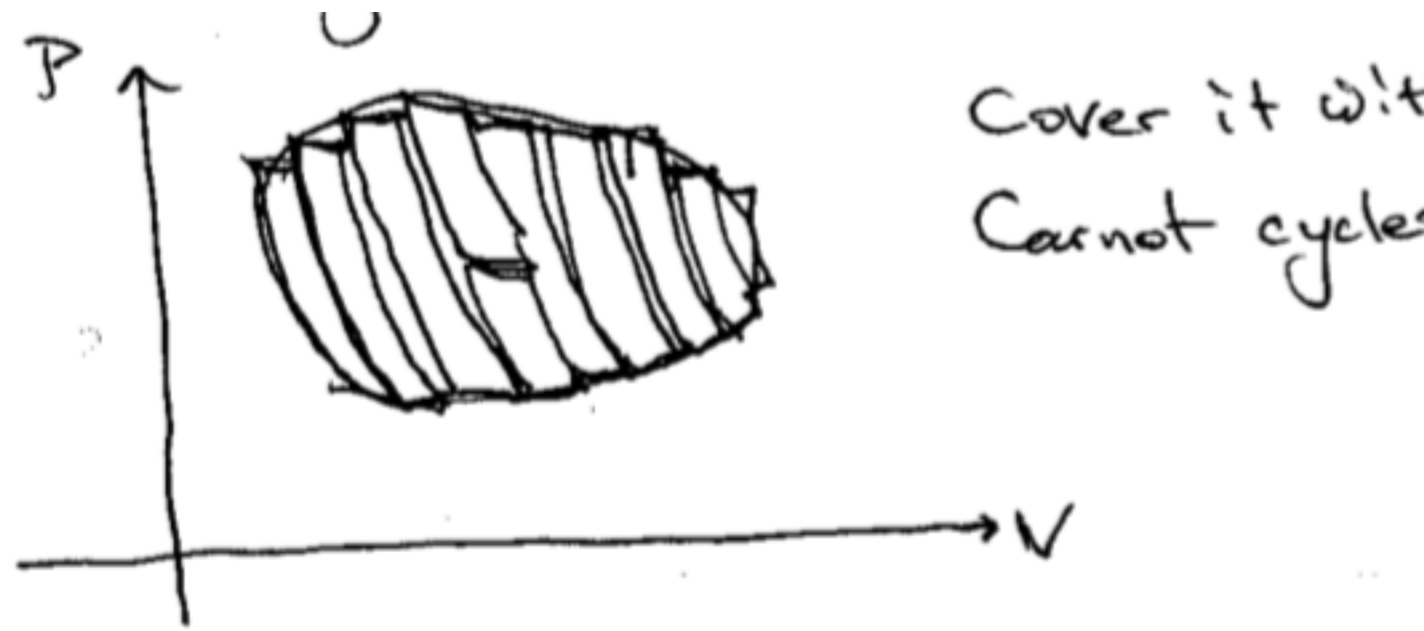
Consider a completely general revisable process:



$\sum_{edges\ i} \frac{đQ_i}{T_i} = 0$, but notice that all the internal lines cancel in pairs

IV. Let the number of long skinny Carnot cycles become larger and larger, and you get a perfect fit of the sawtooth to the original cycle for any reversible cycle:

$$\oint \frac{đQ}{T} = 0$$



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