Today

I. Upcoming exam, this Friday, Nov 6th.
II. Last Time
III. High Quality Heat
IV. Heat Engines
V. Entropy

I. Tomorrow let's meet as a whole group for the lab session. This week: Antu Antu will be providing homework support. Hours are: Tu 8-9pm, Th 8-9pm.

II. We found how different processes look on a pressure vs. volume plot, otherwise known as PV diagram. For example, we we discussed isothermal curves: $P = \text{const}/V$.

Here are several of the examples that we studied last time:

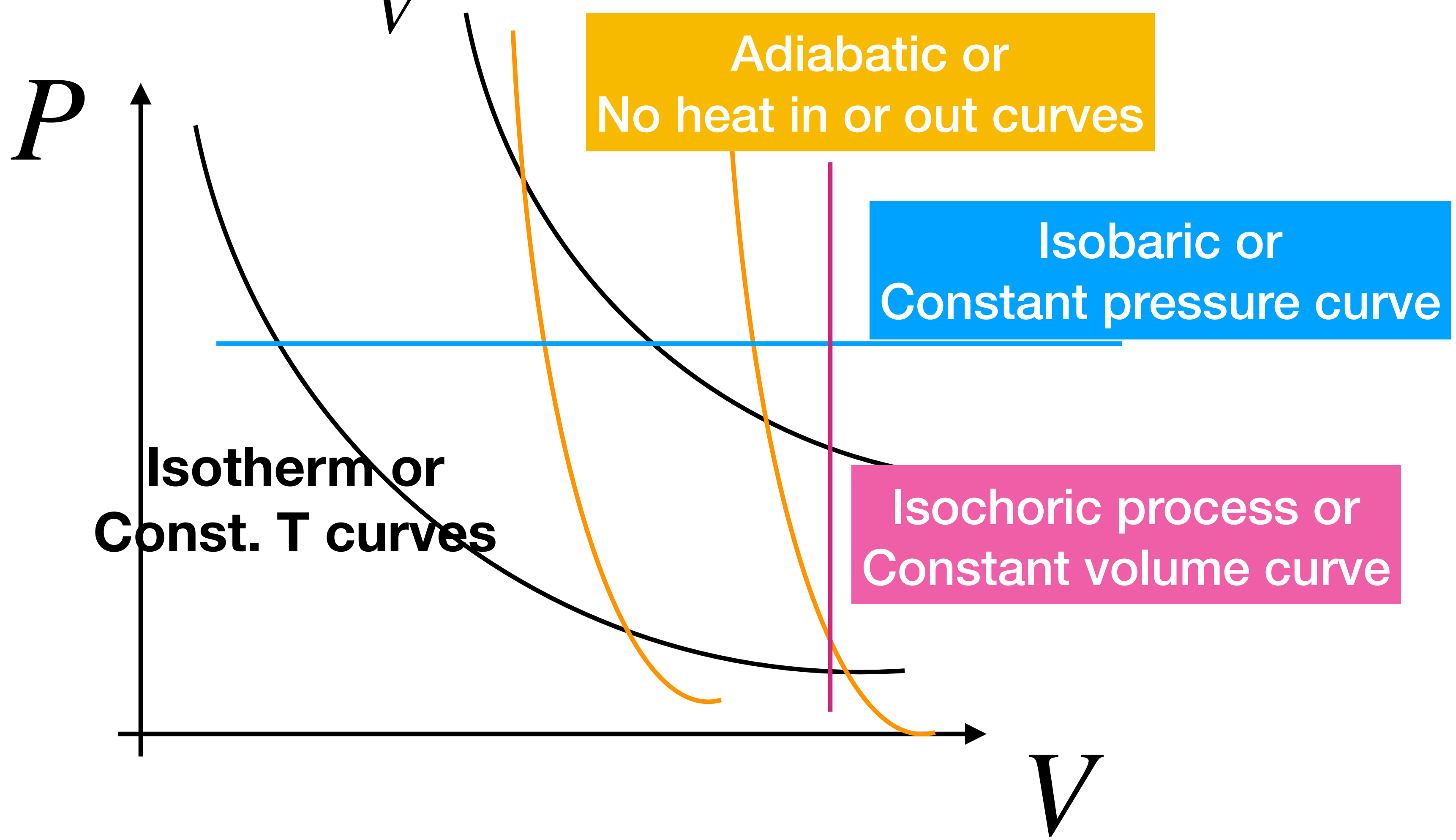
$$P = \frac{\text{const}}{V^\gamma}, \text{ with } \gamma > 1, \text{ (adiabatic, no heat in or out)}$$

where $\gamma = (f+2)/f$. All ideal gases have $PV = NkT$.

Consider a process at constant temperature (an isothermal process):

$$P = \frac{\text{const}}{V}.$$

$$W = -\int P dV$$



III. High Quality Heat

Intuitively, what is the difference between these two samples:

$m, T = 4T_0$

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Both are made of gallium, but one is 4 times bigger and 4 times cooler. What's different about these two samples?

Their volumes are different. Can't use this for much.
Their internal energies U are the same! This is a bit surprising because we generally of higher temperatures as leading to higher energies. We can explain this by their difference in amount of stuff.

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Even though these two systems are so similar, there is something I can do with the smaller one that I can’t do with the larger: I can use it to transfer heat to the larger one! In fact, I can use it to transfer heat to any system that has a temperature less than $4T_0$!!!!

Clausius wanted to quantify this effect. In particular, to invent a number that told us about this property of the smaller sample.

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The measure of quality that Clausius came up with, was the "Entropy":

$$S = \frac{Q}{T}.$$

Important notes:

1. Notice that high quality heat (in the sense of being able to heat many things) is low entropy.
2. Notice that in general T changes and we have to integrate to get the total entropy change. Often we can write $Q = CdT$

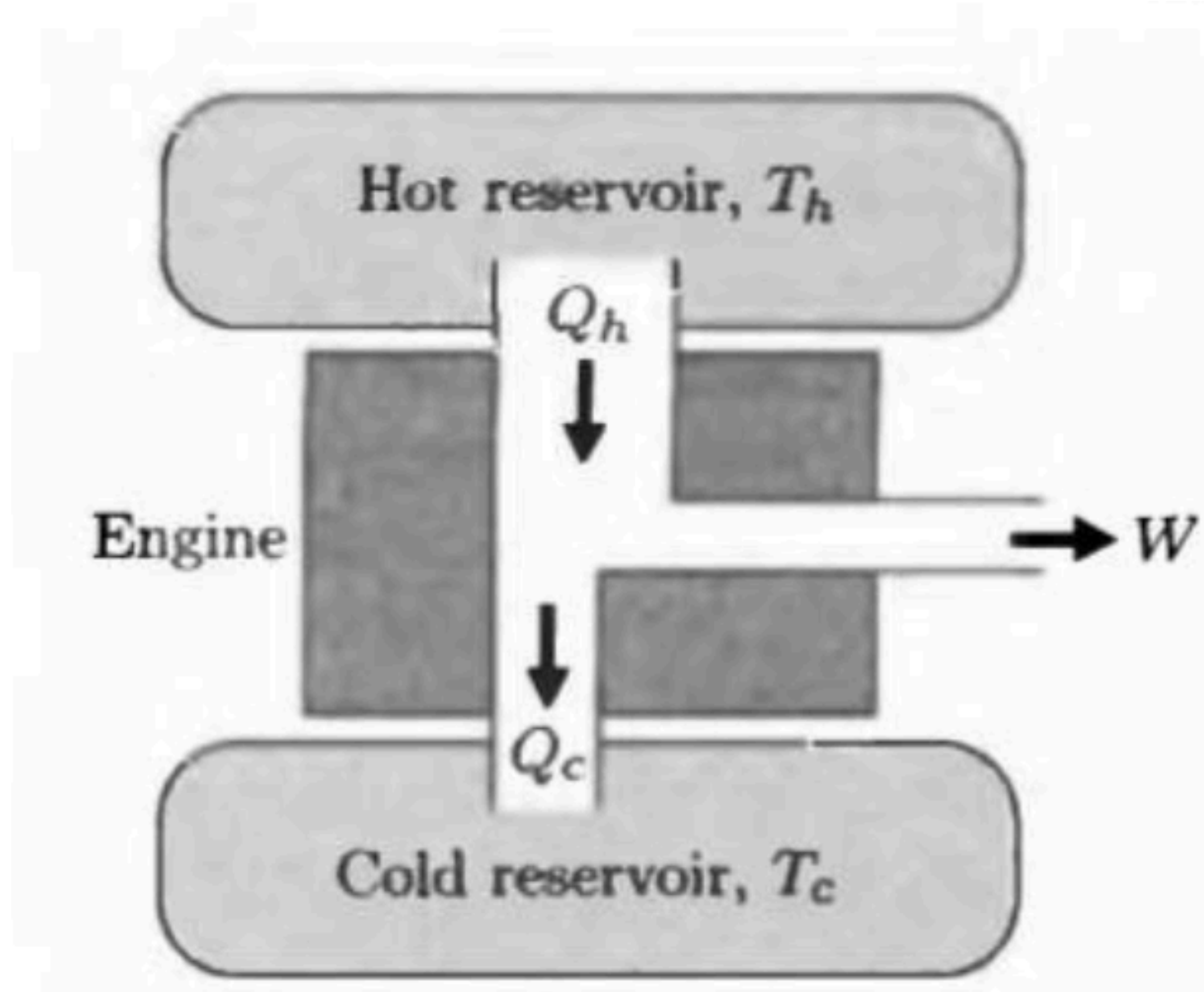
IV. Heat Engines

We can diagrammatically represent a heat engine in a simple way:

Important warning on notation: Up to now our convention was that heat that enters our system is positive. In heat engines, this convention is changed: we always talk about positive heats.

This means that conservation of energy is

$$Q_h = Q_c + W.$$



We also need a 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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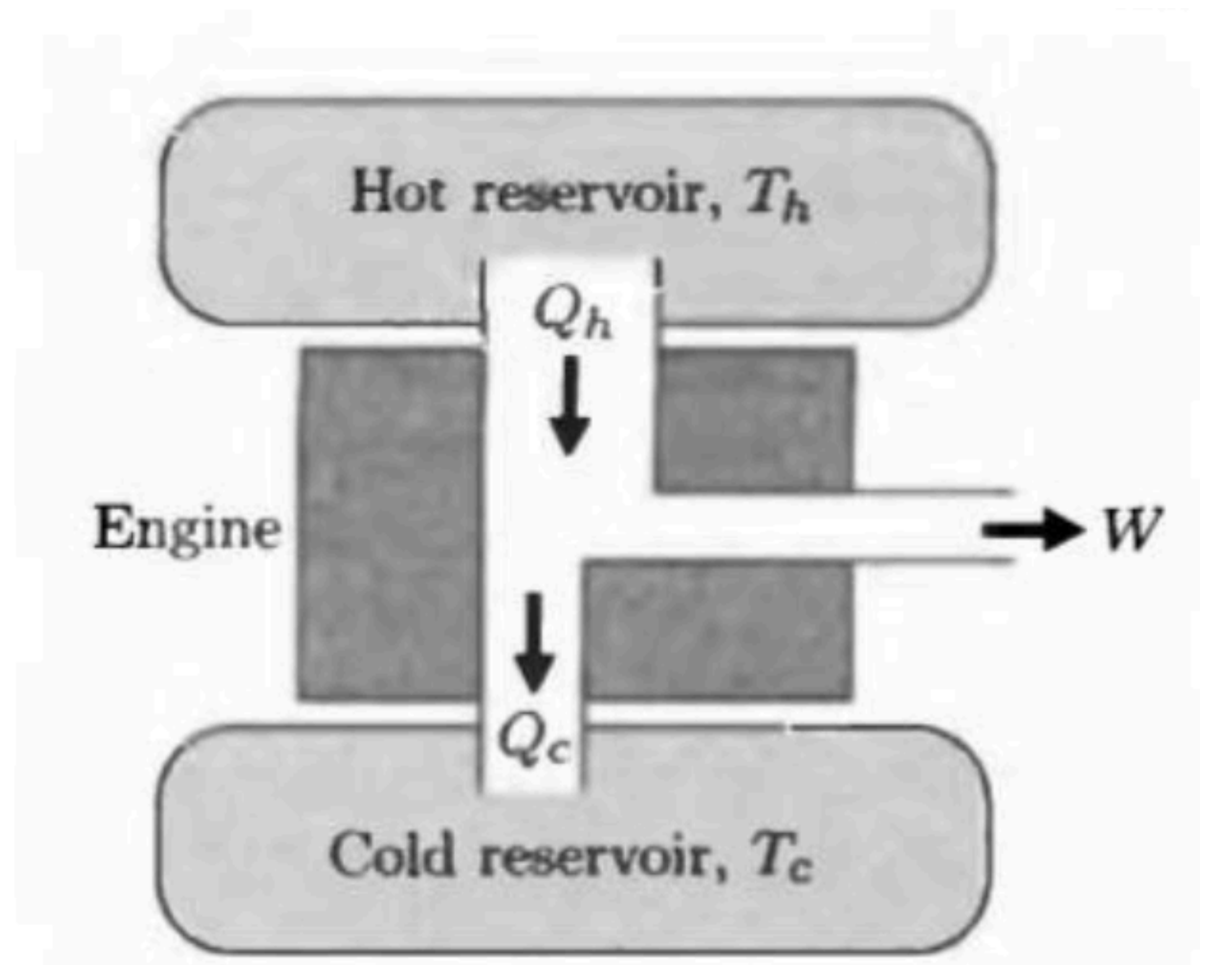
Notice here "reservoir" is a technical term and what it means is that the source (or sink) of heat is so large that when we draw (or deposit) heat, that doesn't change its temperature.

Because of this we can say that

$$S_{\text{in}} = \frac{Q_h}{T_h}, \text{ and } S_{\text{out}} = \frac{Q_c}{T_c}.$$



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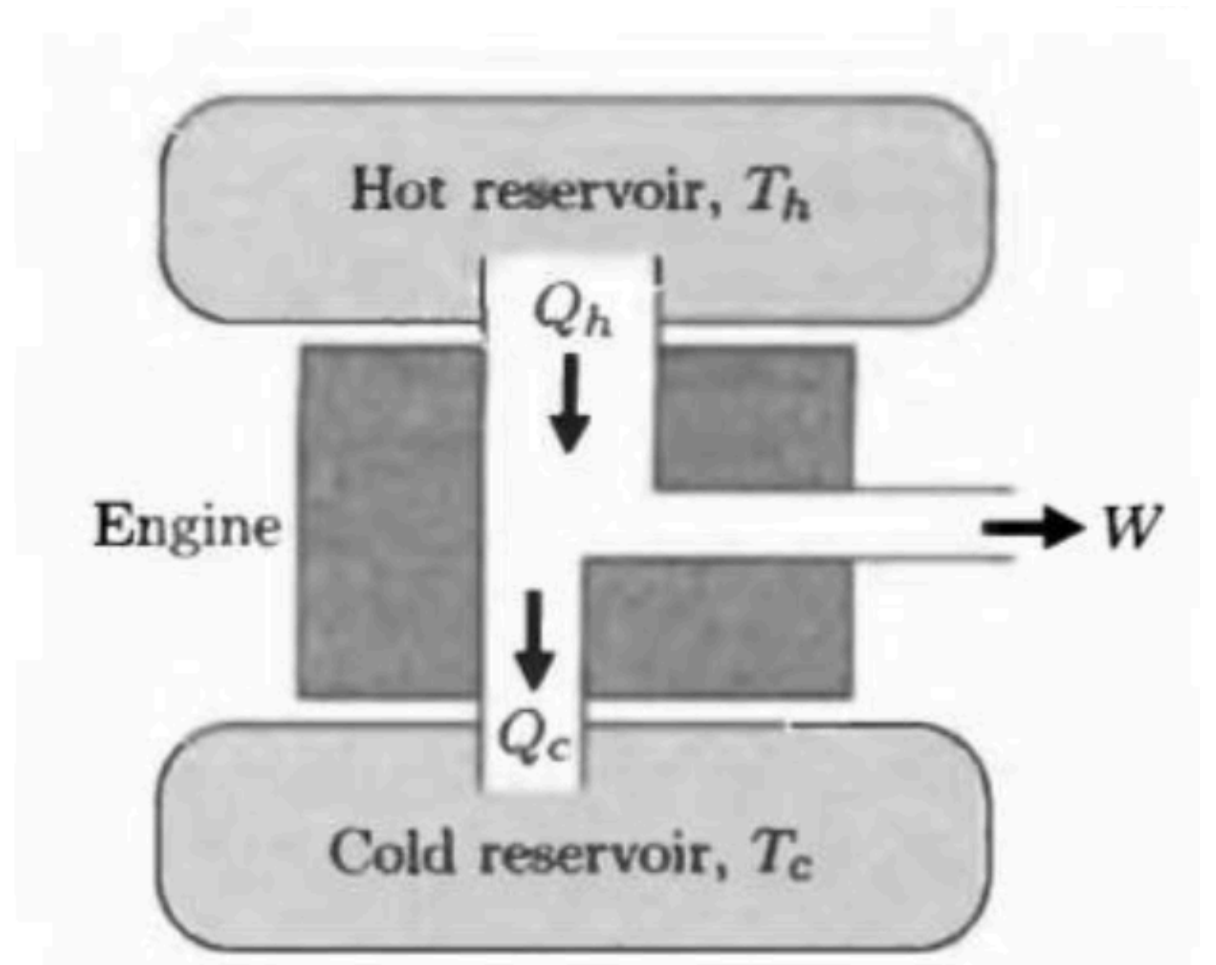
$S_{\text{in}} = \frac{Q_h}{T_h}$, and $S_{\text{out}} = \frac{Q_c}{T_c}$. (or if we create entropy $\frac{Q_c}{T_c} \geq \frac{Q_h}{T_h}$)



The <u>2nd law of thermo</u> states that Entropy can only increase or stay the same, it can't go down. Ideally we might have $S_{\text{in}} = S_{\text{out}}$. Then,

$\frac{Q_h}{T_h} = \frac{Q_c}{T_c} \implies \frac{Q_c}{Q_h} = \frac{T_c}{T_h}$ and

$e = 1 - \frac{T_c}{T_h}$. If we create entropy,

we instead have $e \leq 1 - \frac{T_c}{T_h}$. $e = 1 - \frac{293}{373} = 1 - .78 = 0.22$