4/11:

Properties of air:

Volume V
\# of molecules n
Pressure P
Temperature T

→ If I increase the volume, pressure decreases at constant temperature.

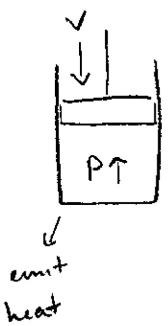
→ V, n constant, T ↑, P ↑

→ P, n constant, T ↑, V ↑

⇓

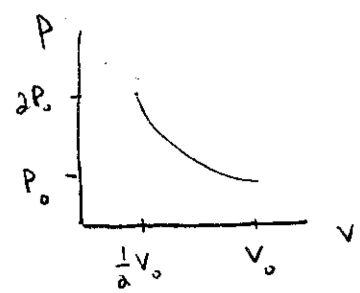
Ideal Gas Law: $\boxed{PV \propto T}$ $PV = nkT$

Consider constant temp:



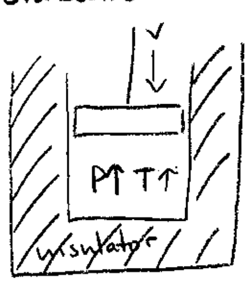
compress volume → pressure increases

$P \propto \frac{1}{V}$

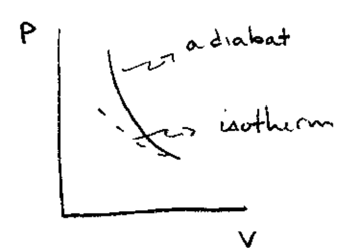


PV = const. "isotherm"

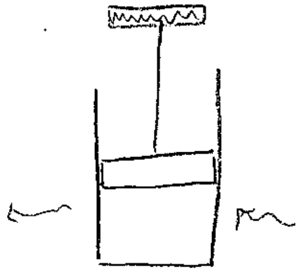
Consider adiabatic: no heat in or out

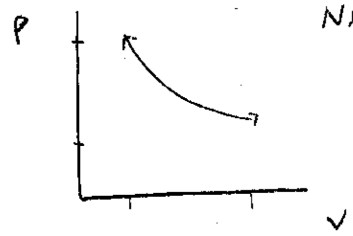


$PV^{\gamma} = \text{constant}$



Silly Engine #1: isothermal





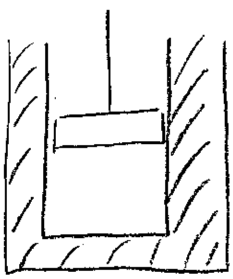
Net Work = $\int P\,dV = 0$

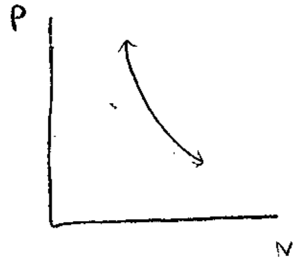
(No temp gradient - how would there be?)

isotherm

Silly Engine #2:

adiabatic





No heat flow

$\Rightarrow$ Net Work = $\int P\,dV = 0$

To get net work, I need:
- temp diff.
- heat flow

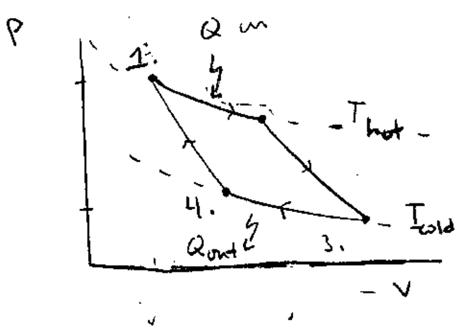
(• area on PV diagram)

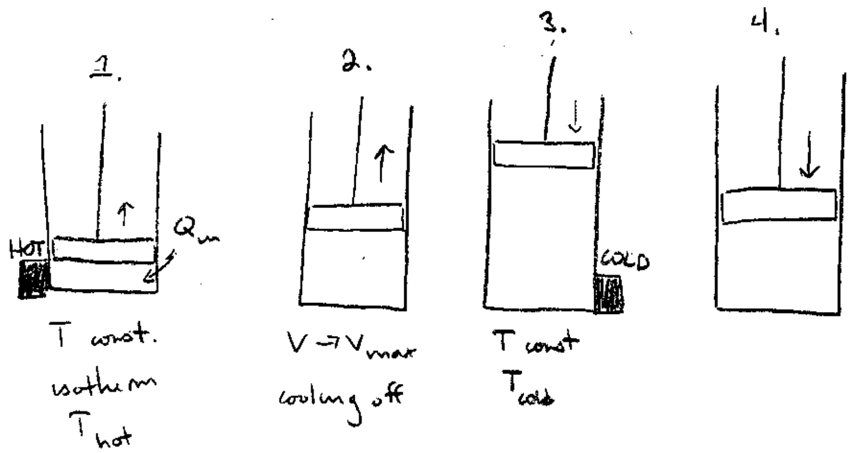
Carnot's Insight: add heat when system is hottest $\rightarrow$ most efficient engine

remove heat when system is coldest

at all other times, no heat flow

perfect Carnot engine





Something important -

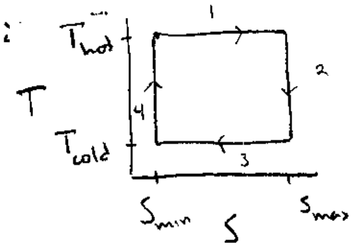
Entropy (S)
- measure of disorder
- every process increases disorder $\Rightarrow$ entropy always increases

$$dS = \frac{dQ}{T}$$

$$\oint T \cdot dS = \oint P \cdot dV = W$$

↳ easier way to find Work is to use entropy!

Carnot Cycle:



($dS = 0$ for adiabatic processes!)

$$W = \oint T \cdot dS = (T_{hot} - T_{cold})\underbrace{(S_{max} - S_{min})}$$

consider step 1: $\Delta S = \frac{\Delta Q}{T} = \frac{Q_{in}}{T_{hot}}$

$$W = \frac{(T_{hot} - T_{cold}) * Q_{in}}{T_{hot}}$$

$$\text{efficiency} = \boxed{\varepsilon =} \frac{W}{Q_{in}} = \frac{T_{hot} - T_{cold}}{T_{hot}} = \boxed{1 - \frac{T_{cold}}{T_{hot}}}$$

* T is measured in K

Something else important: Reversibility

engine "reversible" if no unnecessary losses

Q_{hot} ↓ $\rightarrow W$ ↓ Q_{cold}

reverse:

Q_{hot} ↑ $\leftarrow W$ ↑ Q_{cold}

* a refrigerator is a heat cycle in reverse

* heat pump: make my house warmer by making outside colder