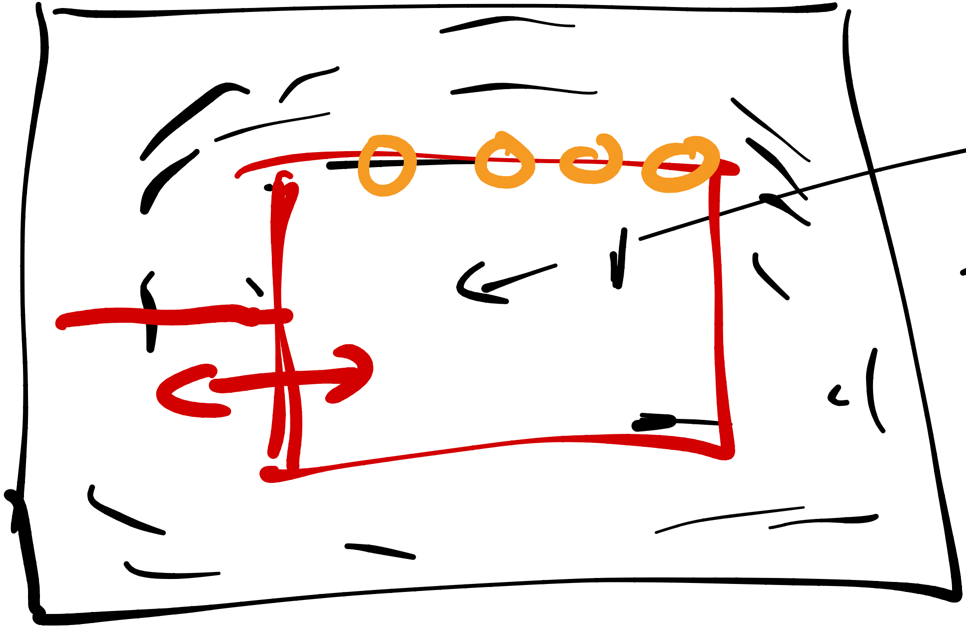


system

options

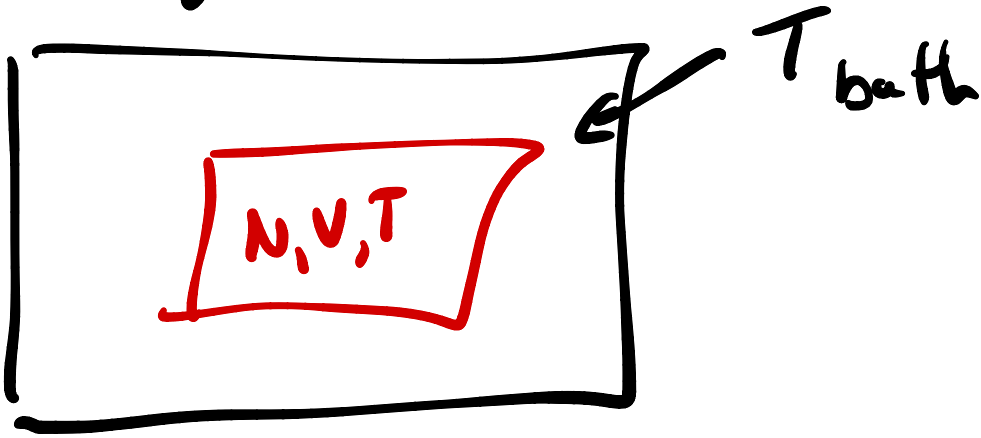
N, V, E

N, V, T

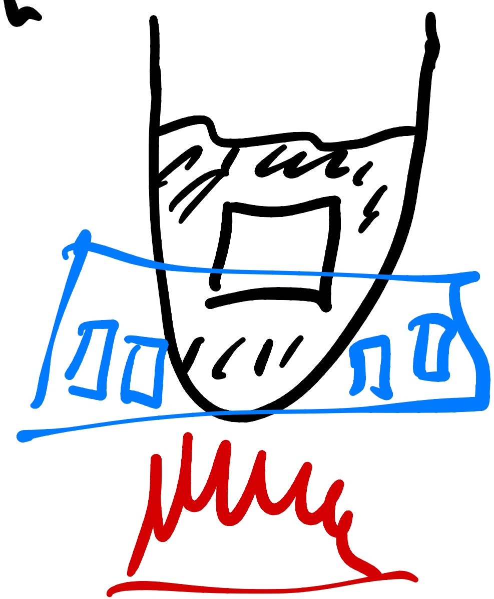
μ, V, T

N, P, T

Changes of state



Change from $T_1 \to T_2$



change from V_1 to V_2 by moving piston

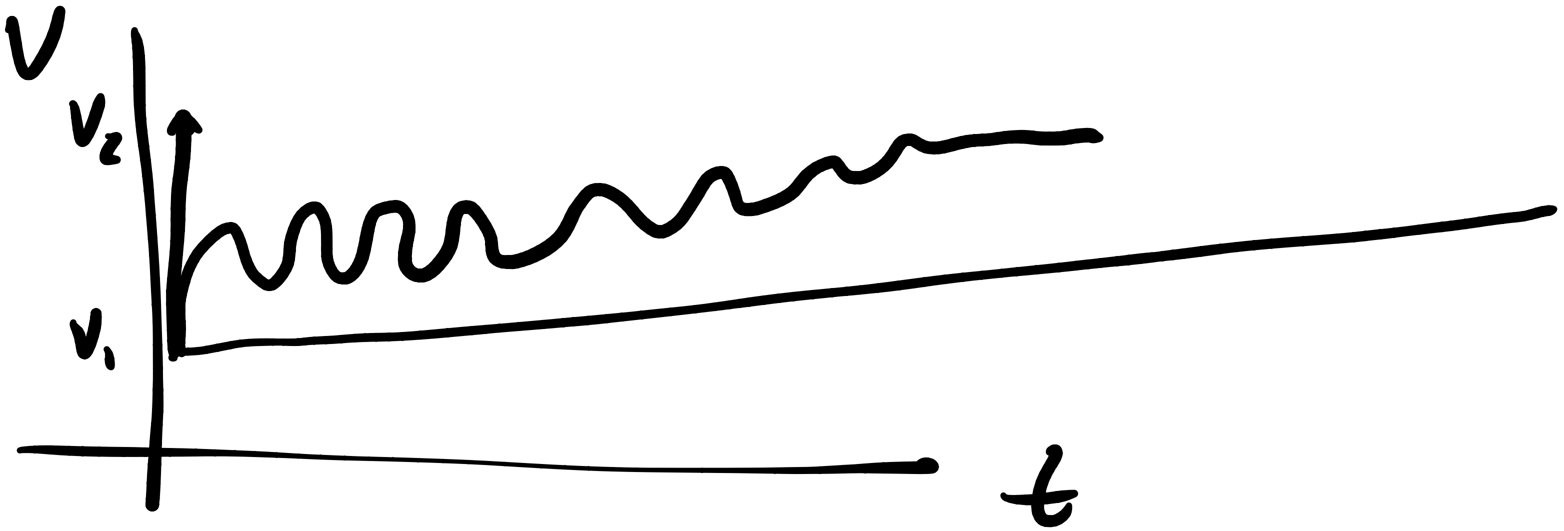
$[P = nRT/V]$

Reversible change of state

from V_1 to V_2

$V_1 \to V_1 + dV \to V_1 + 2dV \to \dots \to V_2$

wait for infinitely long time


V
V2
V1
t

Equation of State (EOS)

Relationship between thermo quantities

Theorem if in one phase (s, l, g)

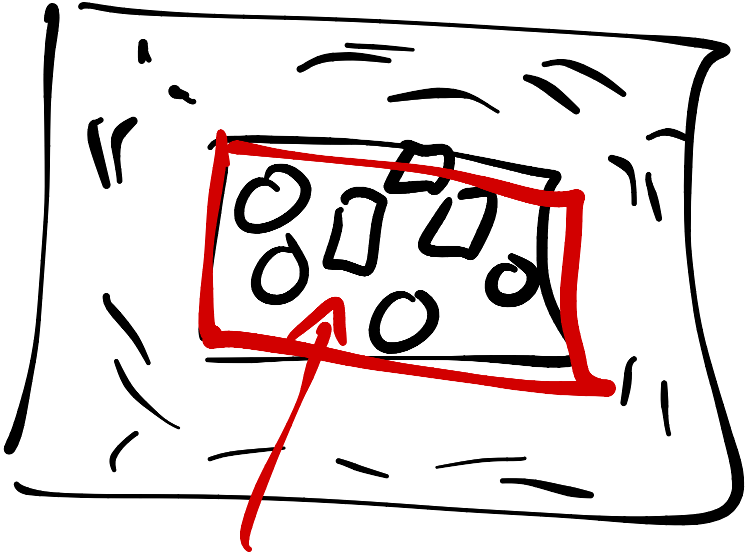
then $(2 + \#^{comp})$ thermodynamic props to specify state of system

1 component → N, P, T or N, V, T

$V(\underline{N}, \underline{P}, \underline{T})$ or $P(\underline{N}, \underline{V}, \underline{T})$

2 + #

2 components



$PV = nRT$

$P = nRT/V$

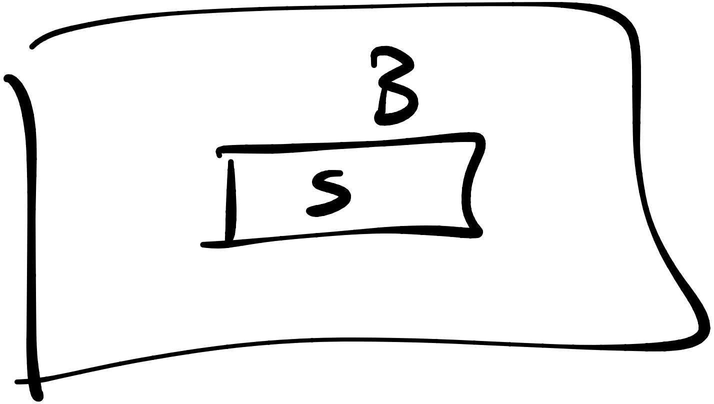
$V = nRT/P$

N_1, N_2, V, T

$T = \frac{PV}{nR}$

First law of thermo

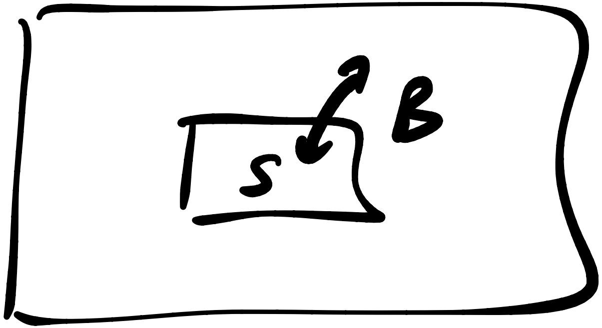
Energy is conserved
(for an isolated system)



S+B energy
is conserved

Equation

$$dE_{system} = \underbrace{\text{đ}q}_{\text{heat in}} + \underbrace{\text{đ}w}_{\text{work on system}}$$



heat & work are path dependent

doesn't depend on path "State variable"

Book uses U energy

← common

U means pot. Energy

$E = U + K$

← kinetic energy

$dE = \text{đ}q + \text{đ}w$

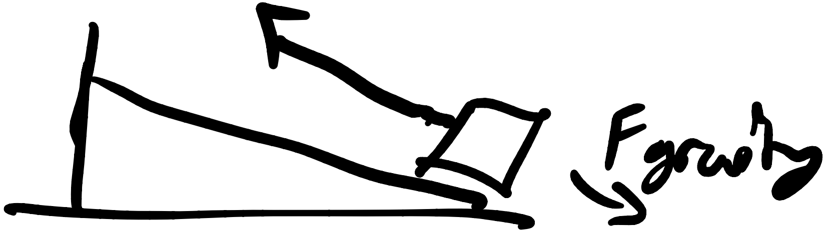
Sign of q, w

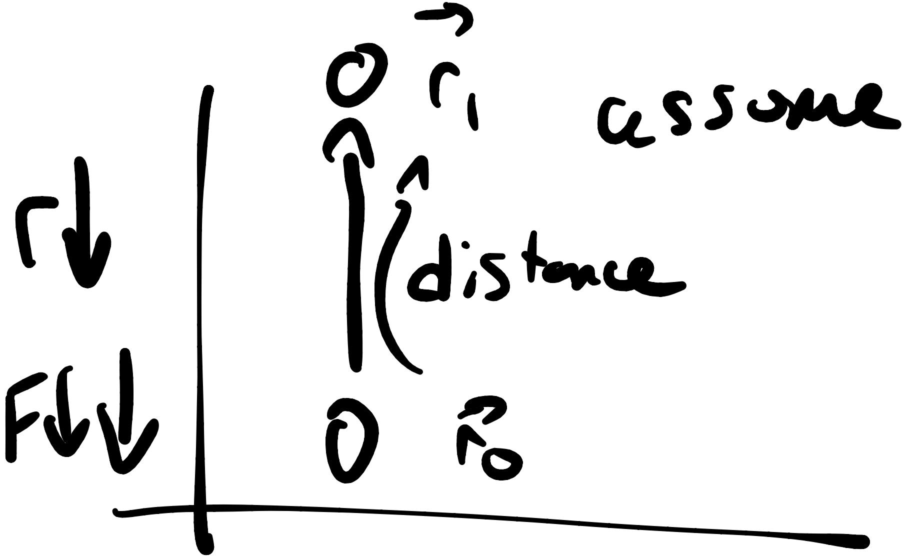
if $\text{đ}q > 0$ or $\text{đ}w > 0$

then system energy goes up

What is work

$$w = -\int_{r_0}^{r_1} \vec{F} \cdot d\vec{r}$$





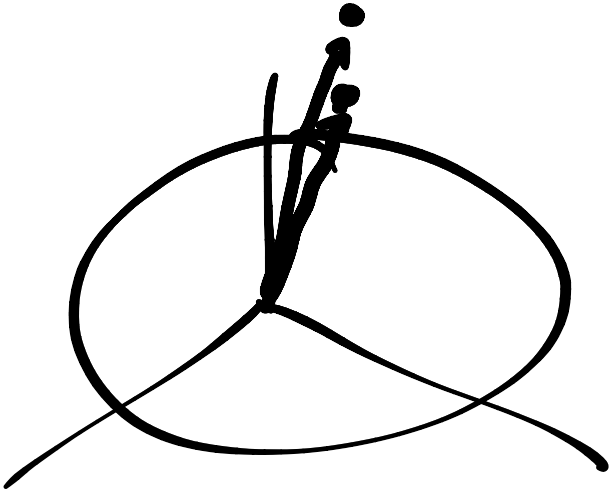
assume $F = mg$

$$W = -\int_0^{-h} F\,dr$$

$$= mgh$$

force & displacement are in same direction

$$\vec{F} \cdot d\vec{r} = F\,dr$$

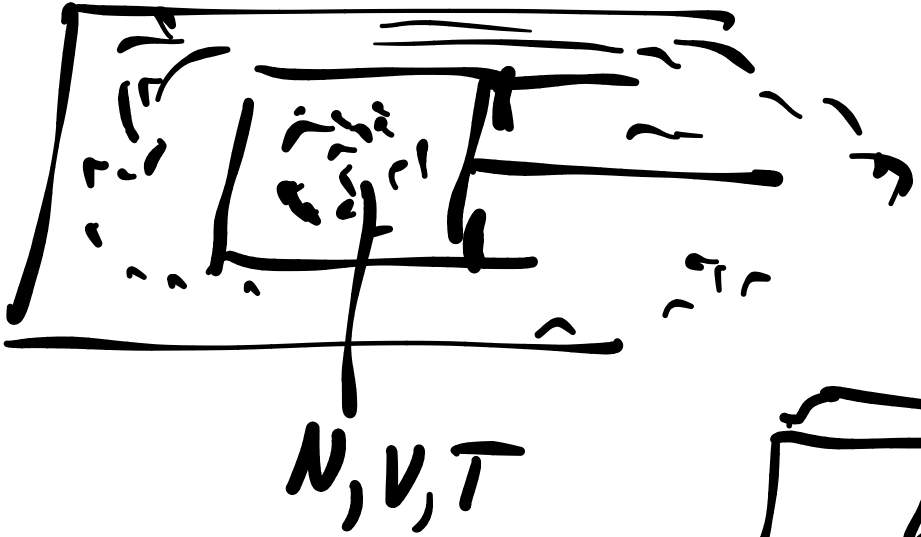


Pressure - volume work

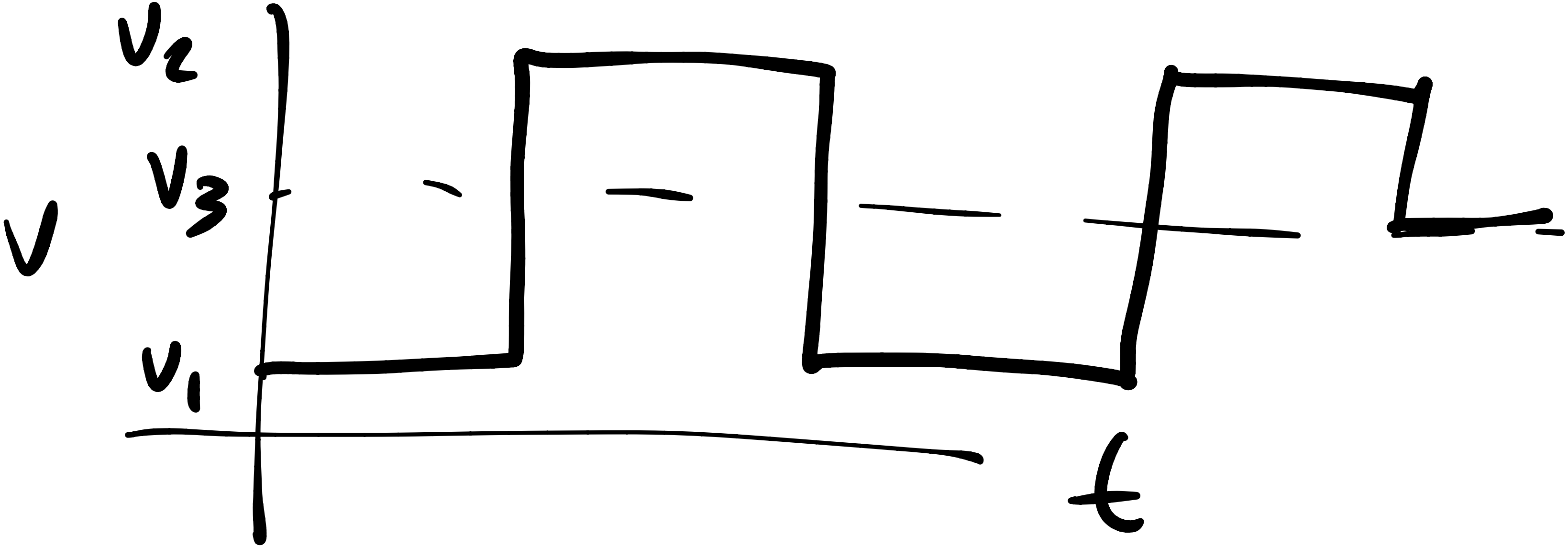
change volume against a pressure

$$dw = -P_{bath}\, dV$$

$$dW_{(\text{on system})} = -P_{\text{bath}} \cdot dV_{\text{system}}$$



$dV = dr\,A$



$$w = -\oint P\,dV$$

$$\text{đ}w = -P\,\text{đ}V$$

Squish means $\text{đ}U < 0$

V

$V_f - V_i < 0$

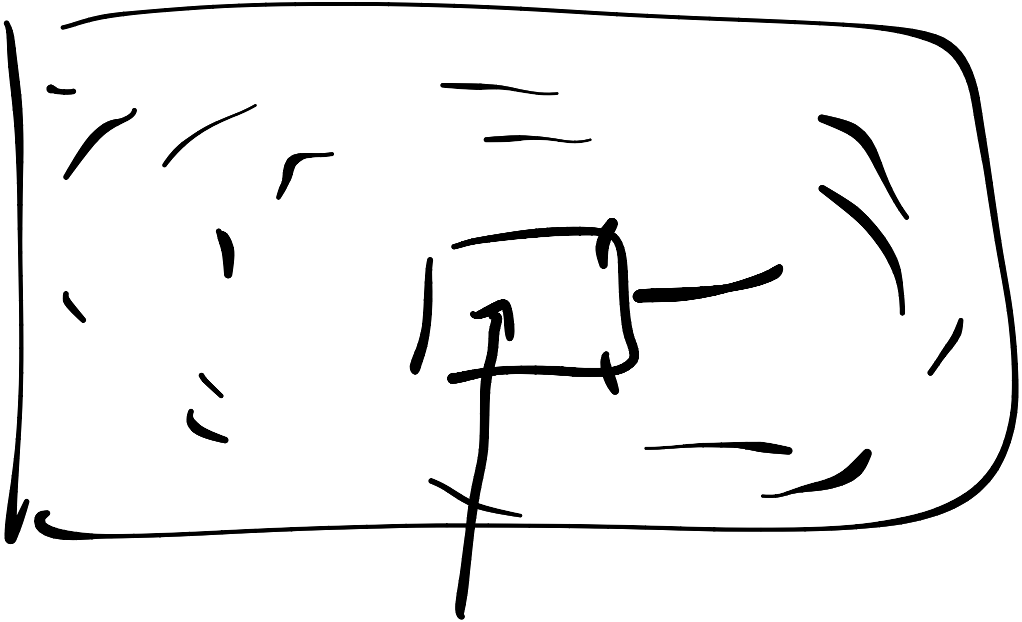
then work is positive

$$W = -\int_a^b \vec{F}\cdot d\vec{r}$$

$\vec{PA}\cdot d\vec{r}$

Pressure

$F/A = P$



Can do work on system
in 4 categories of ways

① Constant pressure
② Constant volume
③ Constant temperature
④ Adiabatic (no heat flow)

$$P = \frac{nRT}{V}$$

↗

Heat & Heat capacity

Heat is "amount of energy that flows as a result of a difference in temperature"

Heat flows until $T_{syst} = T_{bath}$

In equation form $dq = C\, dT$

C heat capacity

little $c = C/Nm \leftarrow$

water $4.18\ J/g°C$ $\quad (\rho = 1\ g/ml$

$1\ cal/g°C$

$\uparrow$

cm^3

$$dq = C\,dT \qquad C(T) \approx C$$

$$q = \int_{T_1}^{T_2} dq = \int_{T_1}^{T_2} C\,dT = C\,(T_2 - T_1)$$

$$q = C(T_2 - T_1) = C\Delta T$$

" $q = nc\Delta T$ "