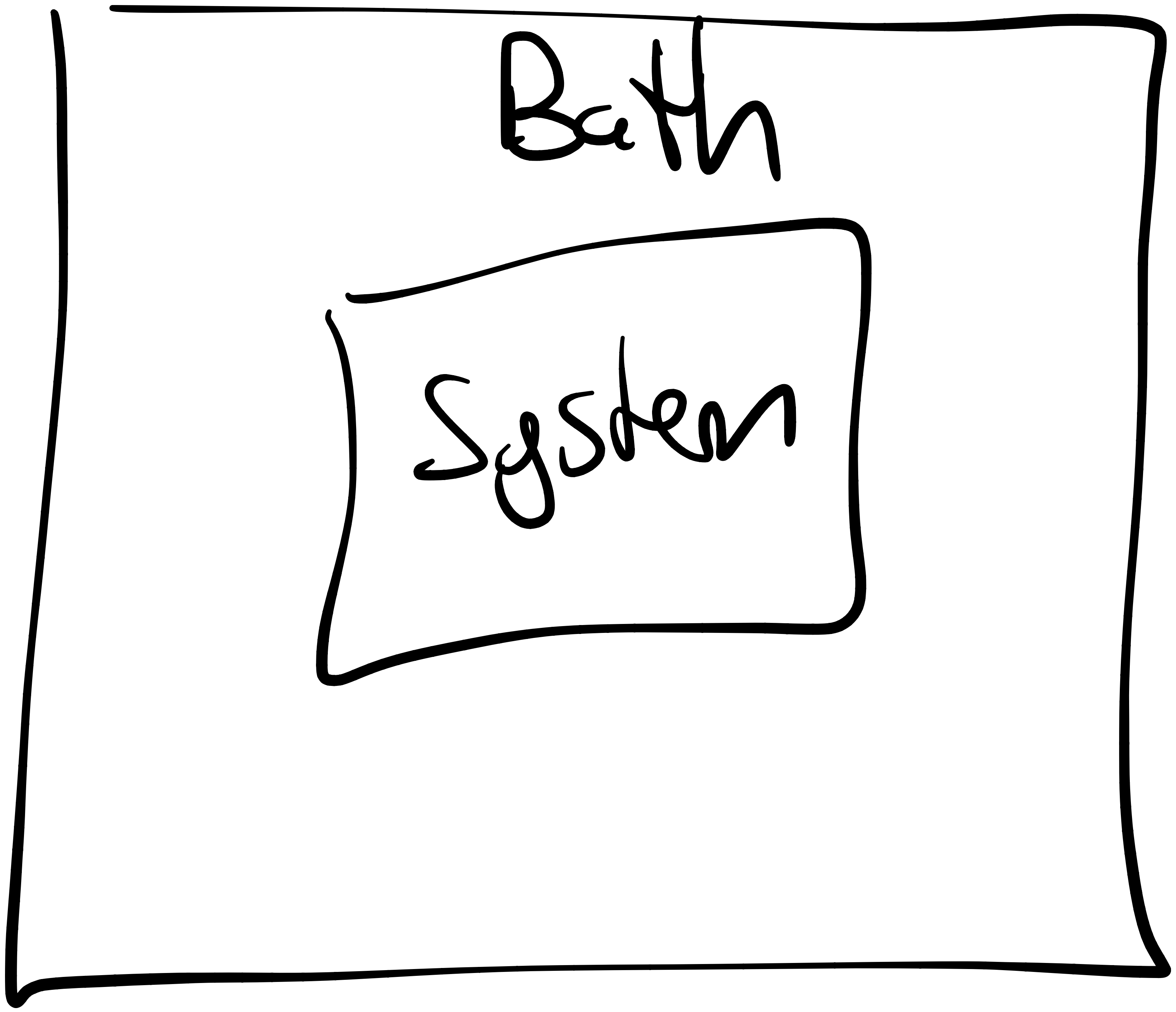
Lecture 5

How does system interact with Environment



Isolated: constant N, V, E

State system

What can change? How can we change

Make a change with:

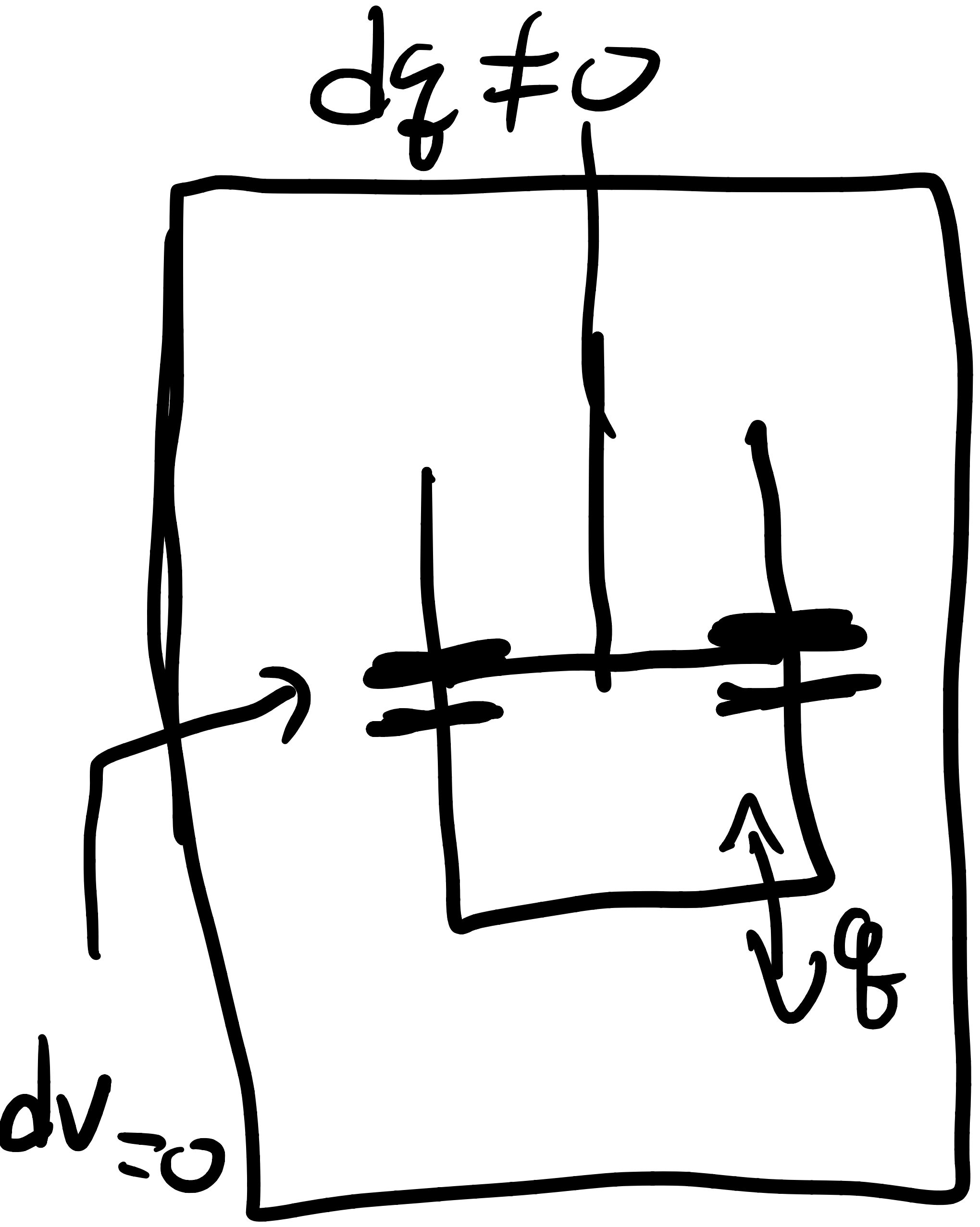
$\begin{cases} dq = 0 \\ dq \neq 0 \end{cases}$, no heat flow "adiabatic"
, heat flows "diathermal"

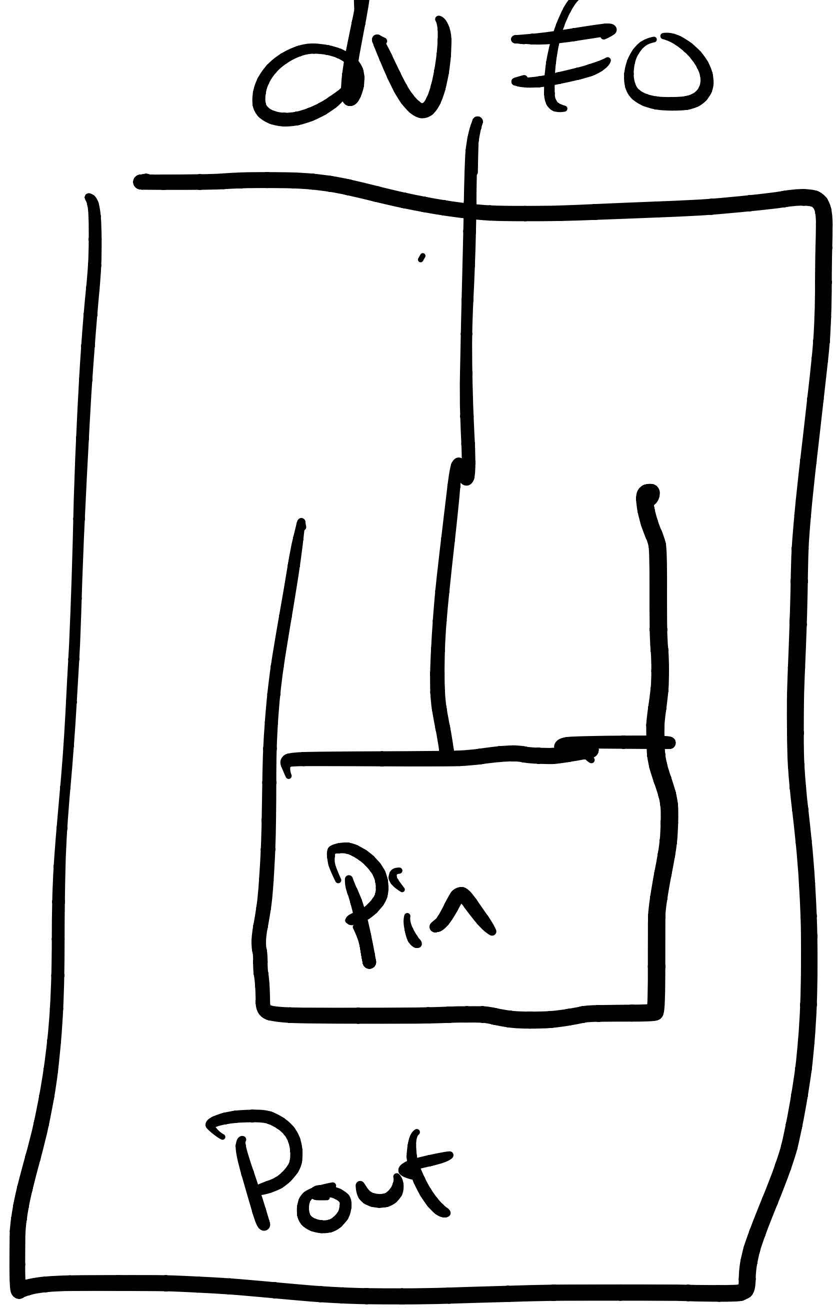
dia = through

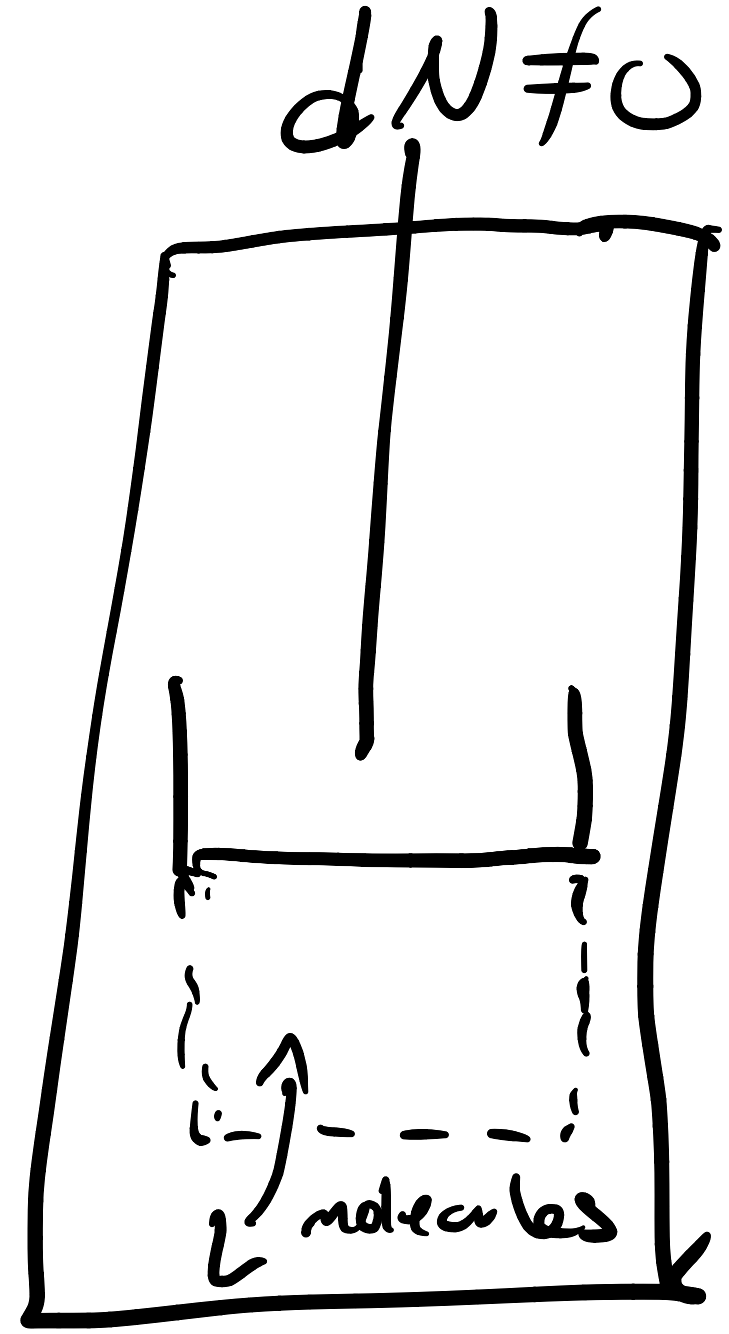
$\begin{cases} dV = 0 \\ dV \neq 0 \end{cases}$ isochoric
isobaric ~ pressure constant

$\begin{cases} dN = 0 \\ dN \neq 0 \end{cases}$ closed
open system (also diathermal)

Equilibrium - something on inside and outside balance with eachother







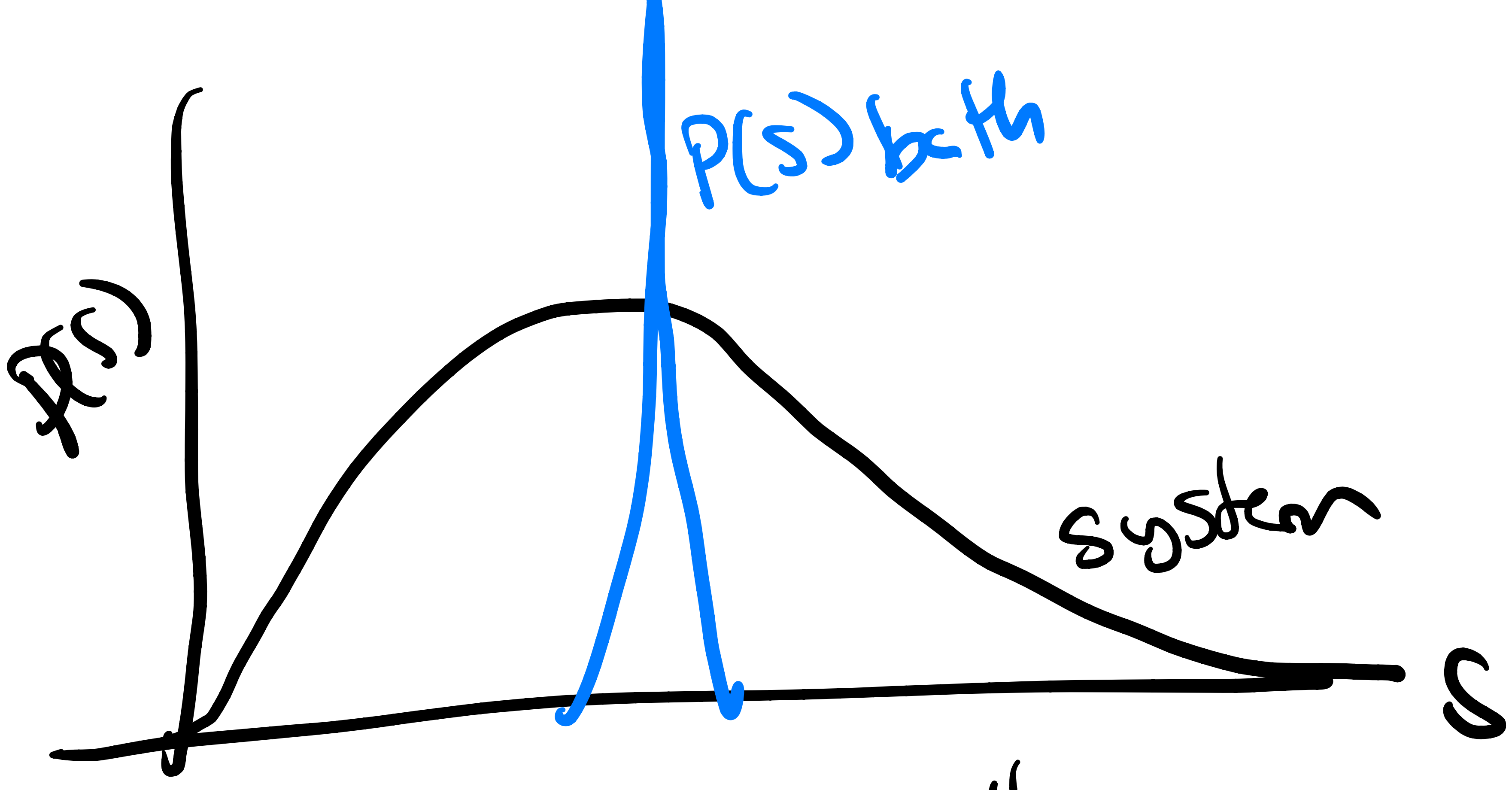
allow piston to move
but $dq = 0$
$P_{in} = P_{out}$

$\mu_{sys} = \mu_{bat}$

$T_{system} = T_{bath}$
at equilibrium

const N, V, T system

const N, P, E system



Maxwell Boltzmann dist

same mean squared velocity

Key concept:

Intensive: doesn't depend on the size of system: T, P, μ $\rho = \frac{N}{V}$

ratios: E/N

Extensive: E, V, S, N

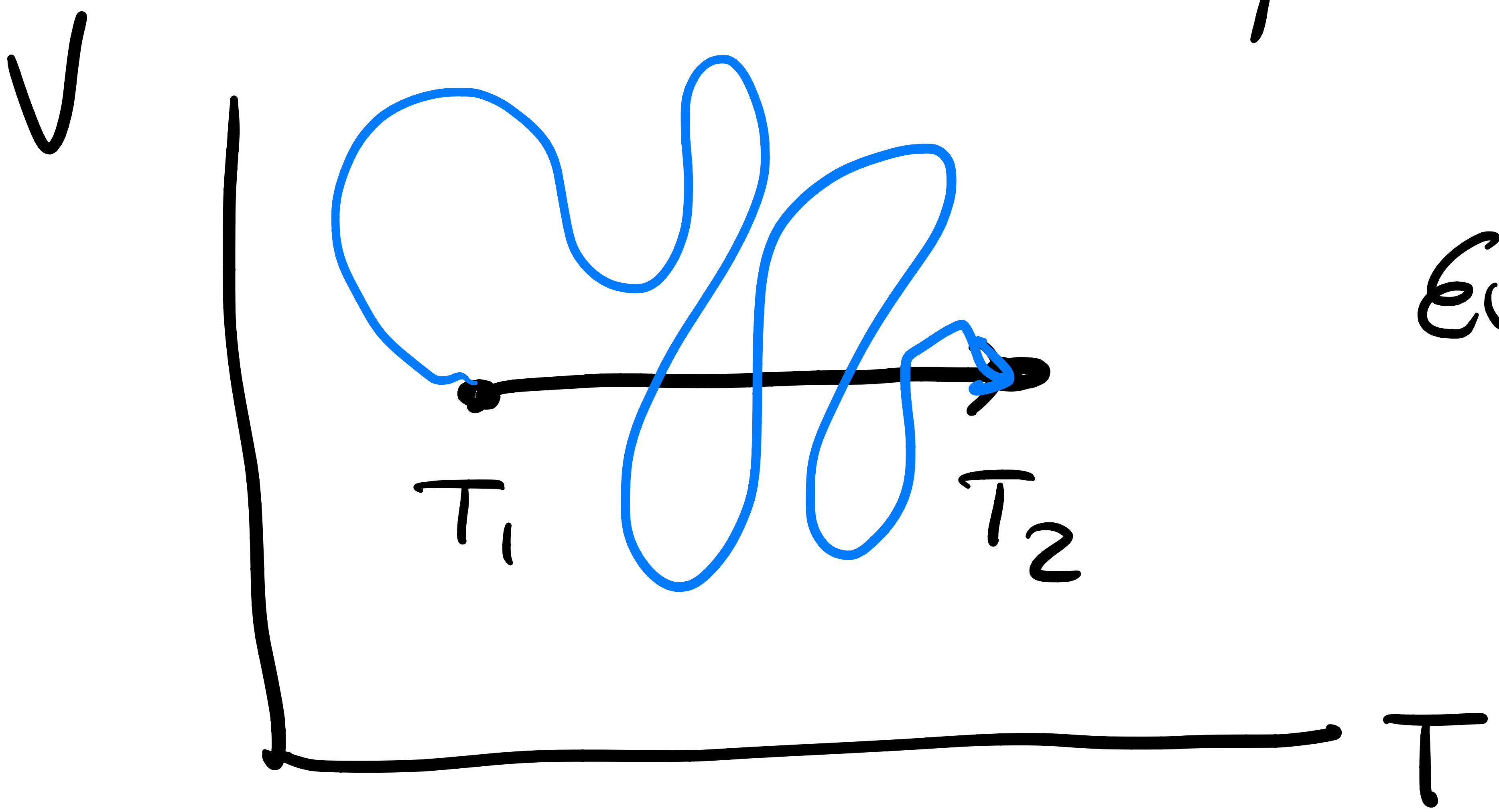
What happens if you duplicate your system

Changes of state

How do we go from A -> B

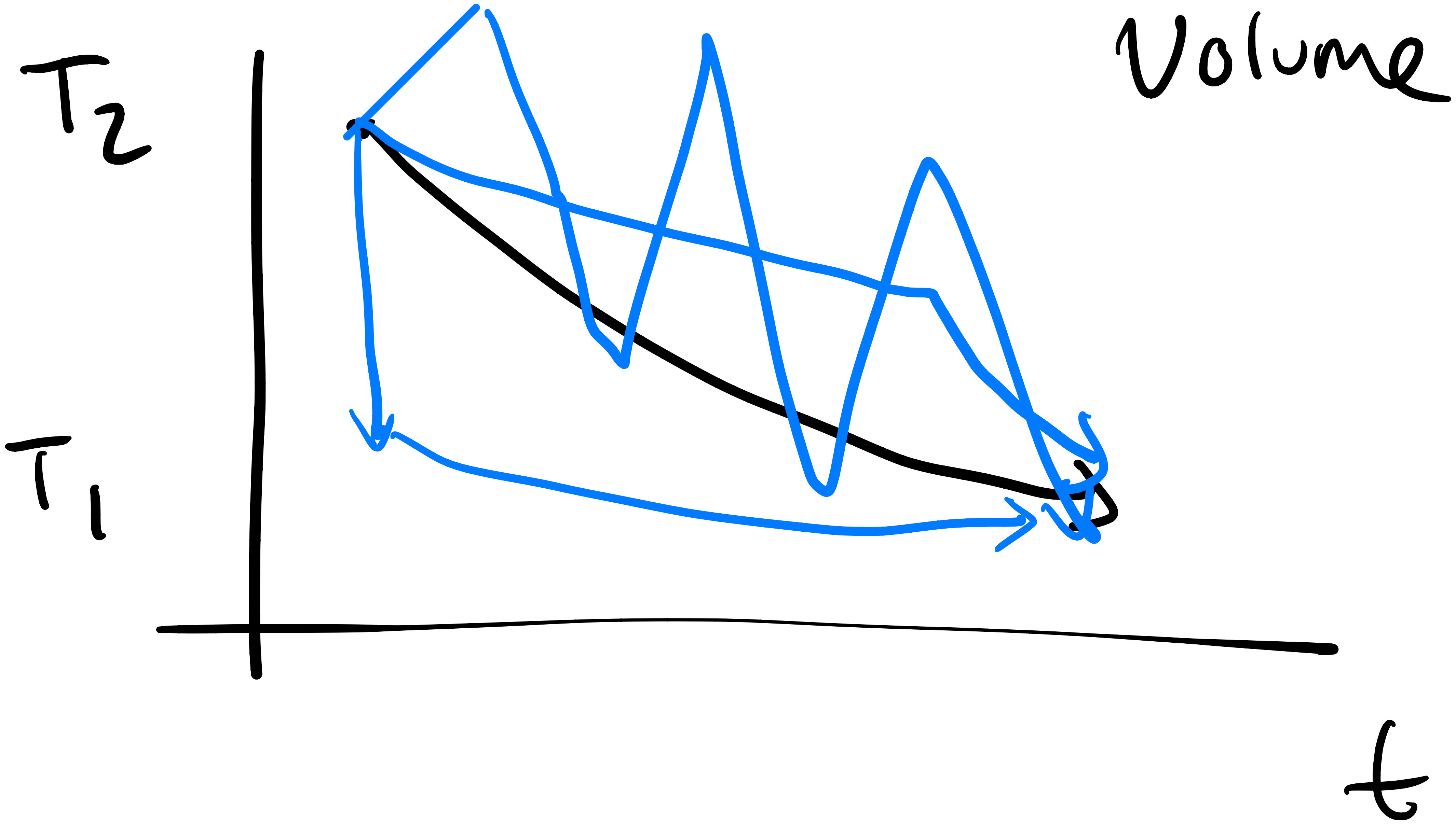
Eg $N_1, V_1, T_1 \rightarrow N_1, V_1, T_2$

diathermal, isochoric



Even for straight line, infinite paths

Volume is fixed



Unique path where we change quantity infinitely slowly

"reversible" ⟺ every step system is at equilibrium

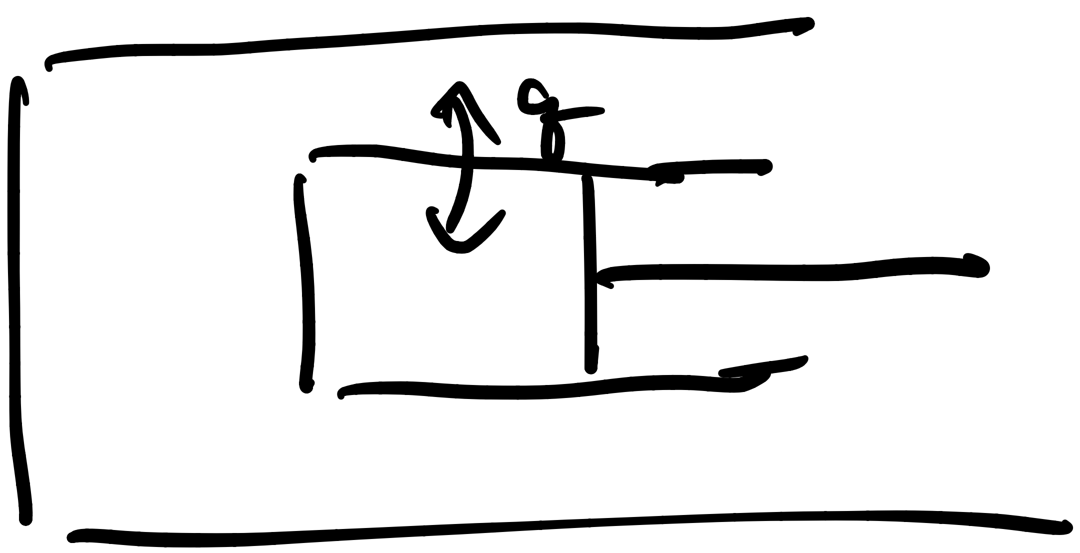
1) $T_{sys} = T_{bath} = T_1$

2) $T_{bath} \to T_{bath} + dT$

3) wait until $T_{sys} = T_{bath}$

4) repeat 2&3 until

$T_{sys} = T_{bath} = T_2$



Change in volume at const T

$V \to V + dV$

During reversible change of state
Every intermediate is at equilibrium

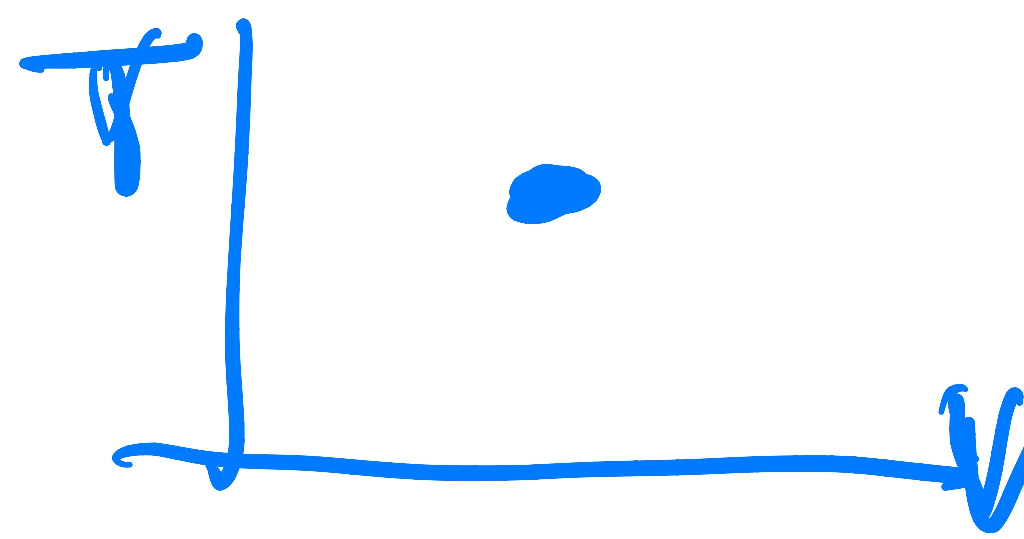
3 variables specify state

Can write an "equation of state"
3 variables → 4th one

Eg ideal gas law : $PV = nRT$
$= N k_B T$

$$P(N, T, V) = k_B \cdot \frac{N \cdot T}{V}$$

$$T = \frac{PV}{N} \cdot \frac{1}{k_B}$$



First law of thermodynamics

Conservation of energy

Isolated system: energy is constant

for our system

1st law:

$$dE^{system}_{total} = \underset{\sim}{dq} + \underset{\sim}{dw}$$

(heat <u>in</u>: dq; work done <u>on</u>: dw)

define a "sign convention"

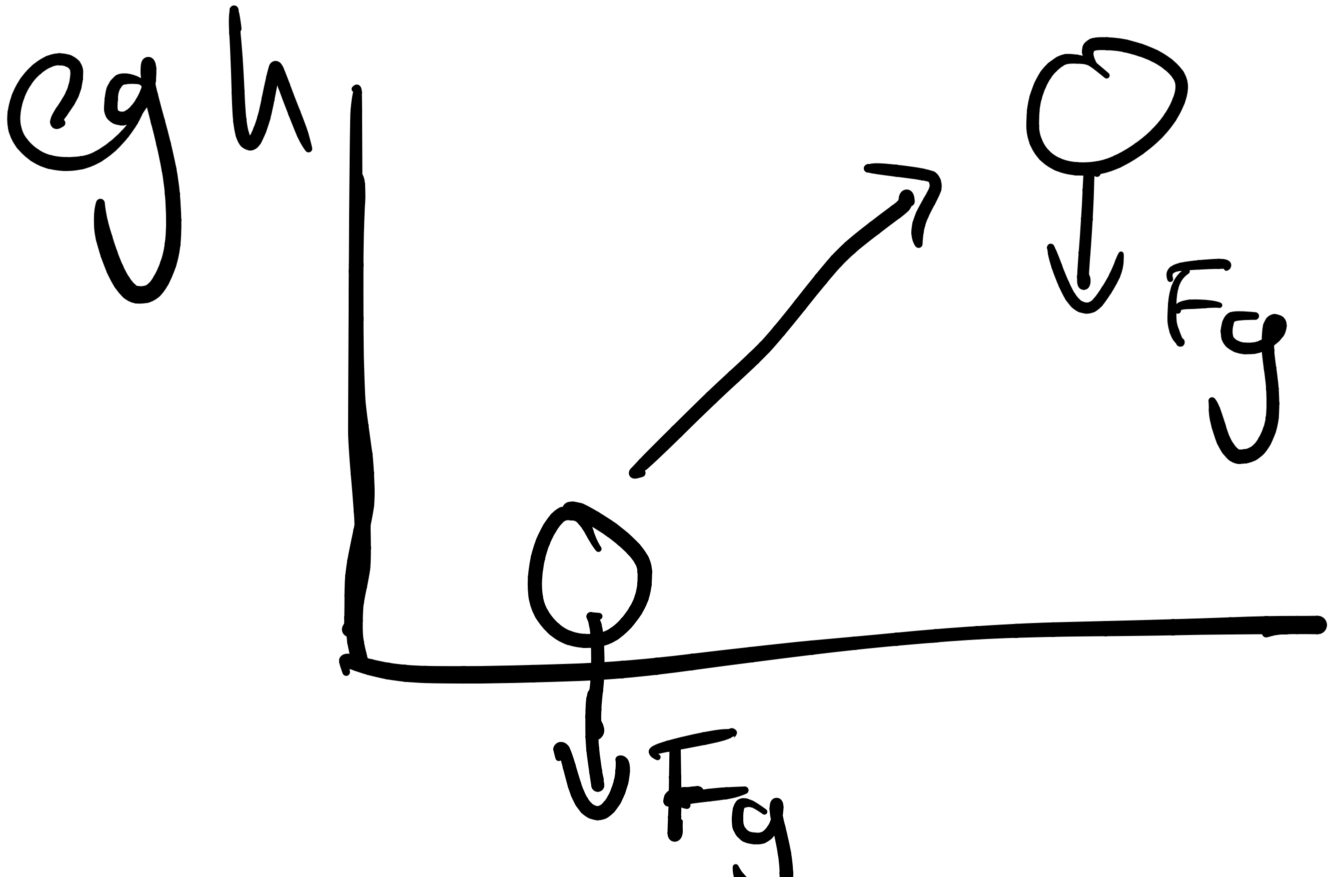
if q, w is >0, $dE^{sys} \uparrow$

What is work?

moving against a force → change in E

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

"mechanical work"



lift object

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

$$= -\int_0^{h} (mg)\,dr$$

$$= mgh$$

Thermodynamics

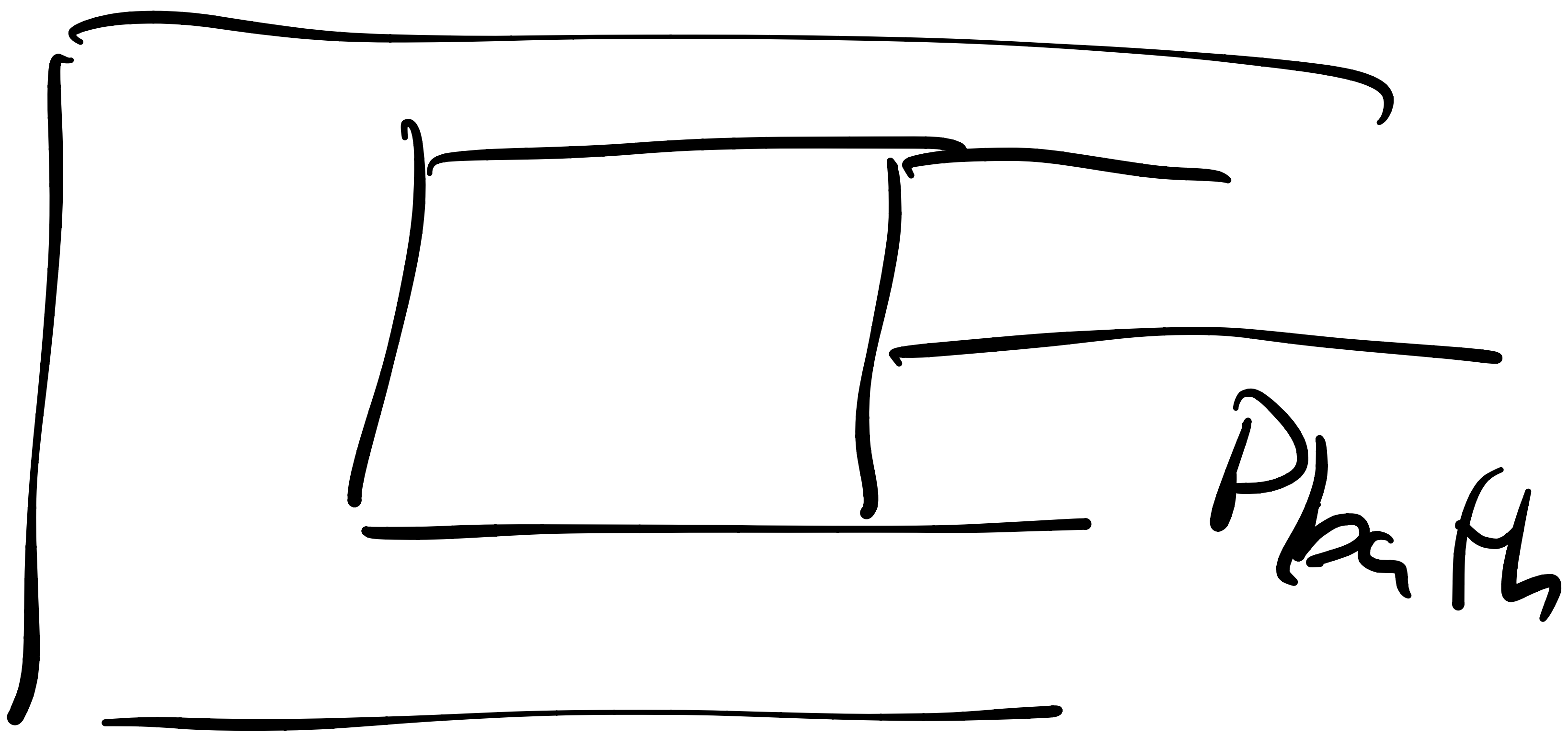
units same as $F \cdot dr$

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

path integral

$$w = \int_{V_1}^{V_2} -P\, dV$$

$P(V)$



sometimes $w = -P\Delta V$

So $dV < 0$, compressed, work done on the system

$dV > 0$, system did work

$$dE = dq + dw$$

Heat (q) is amount of energy that flows due to a difference in temperature

Not state variable ← depends on path

Anything besides the work

Define C , $dq = C\,dT$

↑ heat capacity

C response function

2 heat capacities

C_p and C_v

C_p: const P

C_v: const volume