First Law: Conservation of Energy

Noether's theorem

Continuous symmetry → Conserved "charge"

Time translation invariance → Conserved Energy.

If we do not allow heat exchange, nor particle exchange

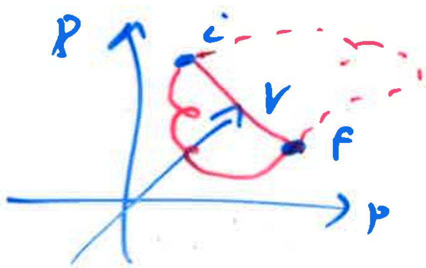
$$dU = đW \longrightarrow U = W + \text{const}$$

↑ mechanical work

$$U = U(J_i, \xi_i)$$

$$= U(P, V, F_{tension}, x, \ldots)$$

independent of path → depends only on endpoints



$$\Delta U = U(P_f, V_f, F_{t_f}, x_f \ldots) - U(P_i, V_i, F_{t_i}, x_i \ldots)$$

With heat exchange

$$dU = đW + đQ + \sum_i \mu_i dN_i$$

- dU ↑ depends on state
- $đW$: depends on path
- $đQ$: depends on path
- $đW + đQ$: depends on state

dW can take many forms:

In general $dW = \sum_i J_i \, d\xi_i$ (generalized forces J_i; generalized displacements $d\xi_i$)

	J	$d\xi$
spring	$F_{tension}$	dx, ds, dl
surface	σ (surface tension)	dA (area)
gas	$-P$	dV ← work done on the gas
magnet	B ← magnetic field	dM ← magnetization

not our book: some books $dW = PdV$, $dU = -dW + dQ$

chemical	μ	dN	— "chemical work"
thermo	T	? = dS	"thermal work" heat – dQ

↑ intensive: constant if the system gets 2x big.

↑ extensive: double if the system gets twice as large.

$\frac{ext_1}{ext_2} = int$ e.g. $\frac{M}{V} = \rho$	$ext_1 \cdot int = ext_2$	$ext_1 \cdot ext_2 =$ wrong!