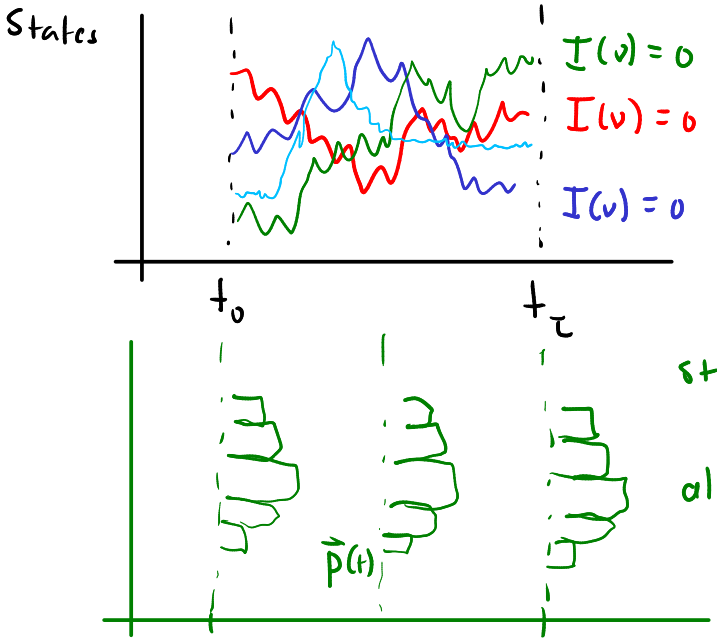
IFT: $\langle e^{-I(\nu)/k_B} \rangle = 1$

$$= \sum_\nu \mathcal{P}(\nu)\, e^{-I(\nu)/k_B}$$

$\langle I(\nu) \rangle \geq 0$ always $= 0$ true iff $I(\nu) = 0$ for every ν

$$= \sum_\nu \mathcal{P}(\nu)\, I(\nu)$$



Stat. state w/ $I = \langle I(\nu) \rangle = 0$

$\Rightarrow$ equil. stat. state (ESS)

stationary state: all histograms same

$\vec{p}(t) = \vec{p}^{\,s}$ indep. of t

$$I(\nu) = k_B \ln \frac{\mathcal{P}(\nu)}{\tilde{\mathcal{P}}(\tilde{\nu})}$$

$$= k_B \ln \frac{\mathcal{P}(\nu)}{\mathcal{P}(\tilde{\nu})}$$

Stat. state

for a stationary state, the final distr. of forw. ensemble = init. distribution $\tilde{\mathcal{P}}(\tilde{\nu}) = \mathcal{P}(\tilde{\nu})$

ESS $I(\nu) = 0$ for all ν $\Rightarrow$ $\mathcal{P}(\nu) = \mathcal{P}(\tilde{\nu})$ no "arrow of time"

no way of distinguishing a movie played forwards or backwards of ensemble traj.

LDB condition holds

$$\frac{W_{nm}}{W_{mn}} = e^{-\beta(E_n - E_m)} \iff p_n^s = \frac{e^{-\beta E_n}}{Z}$$

Upshot: we need to modify LDB to make NESS possible

$\Rightarrow$ include the possibility system coupling to external source of "work"

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up to now:

$$\frac{W_{nm}}{W_{mn}} = e^{-\beta(E_n - E_m)} = e^{-\beta Q_{nm}}$$

$\beta = \frac{1}{k_B T}$ = "generosity of environ."

Q_{nm} = energy taken from environment during $m \to n$ trans.

"heat"

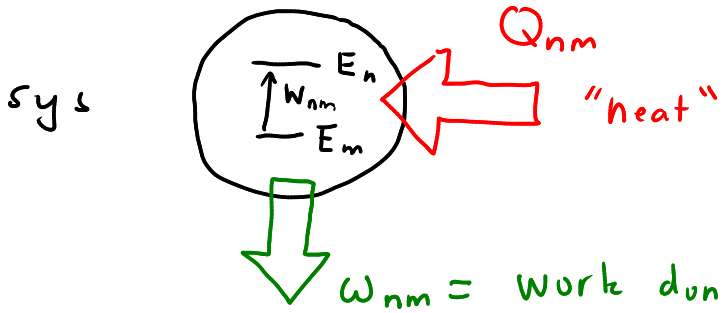
(note env. is "random" $\Rightarrow$ env. + sys. is ergodic + mixing)

$$Q_{nm} = E_n - E_m$$

$Q_{nm} > 0$ sys. gains from env.

< 0 loses to env.

generalize:



$$Q_{nm} = E_n - E_m + \omega_{nm}$$

need more energy from env. if $\omega_{nm} > 0$

$\omega_{nm} > 0$: sys. does work on something ext. → hinders trans.

$\omega_{nm} < 0$: something ext. does work on sys. → helps trans.

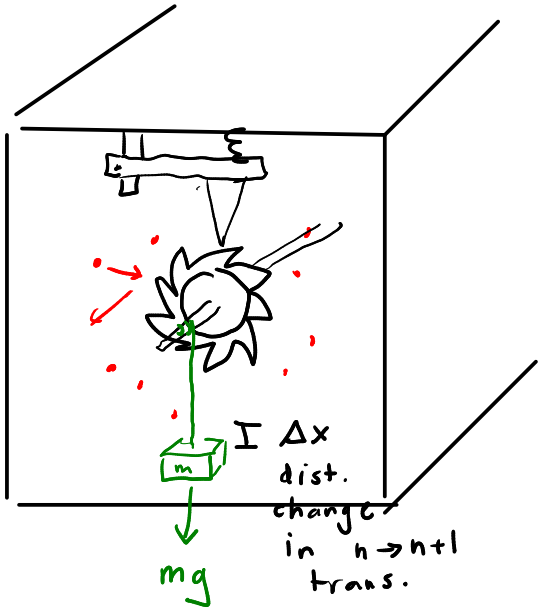
LDB stays the same in form:

$$\frac{W_{nm}}{W_{mn}} = e^{-\beta Q_{nm}}$$

universal form for ergodic + mixing env.

just need to tailor Q_{nm} to physical model

$$= e^{-\beta(E_n - E_m + \omega_{nm})}$$



$n \to n+1$ lifting mass

$n+1 \to n$ lowering mass

$$\omega_{n+1,n} = mg\,\Delta x$$

$$\omega_{n,n+1} = -mg\,\Delta x$$

Question: can we set up a stationary state where mass on avg. is lifted (i.e. perpetual motion machine)

$\Rightarrow$ ANSWER: no! (we will see why later)