SOFT MATTER

ChatGPT

Soft matter refers to a class of materials characterized by their ability to undergo significant deformation or structural rearrangement under external forces, such as mechanical stress, temperature changes, or electromagnetic fields. These materials typically have properties that lie between those of conventional liquids and solids, displaying a combination of fluidity and elasticity.

Wikipedia

Soft matter or soft condensed matter is a type of matter that can be deformed or structurally altered by thermal or mechanical stress which is of similar magnitude to thermal fluctuations.

The science of soft matter is a subfield of condensed matter physics. Soft materials include liquids, colloids, polymers, foams, gels, granular materials, liquid crystals, flesh, and a number of biomaterials. These materials share an important common feature in that predominant physical behaviors occur at an energy scale comparable with room temperature thermal energy, and that entropy is considered the dominant factor. At these temperatures, quantum aspects are generally unimportant.

SOFT MATTER at Nordita...

... Statistical Physics, Biophysics, Thermodynamics

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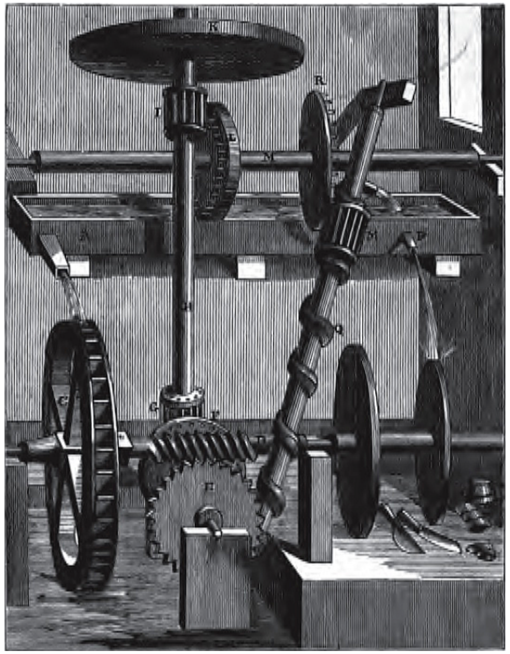
The 2nd law of thermodynamics

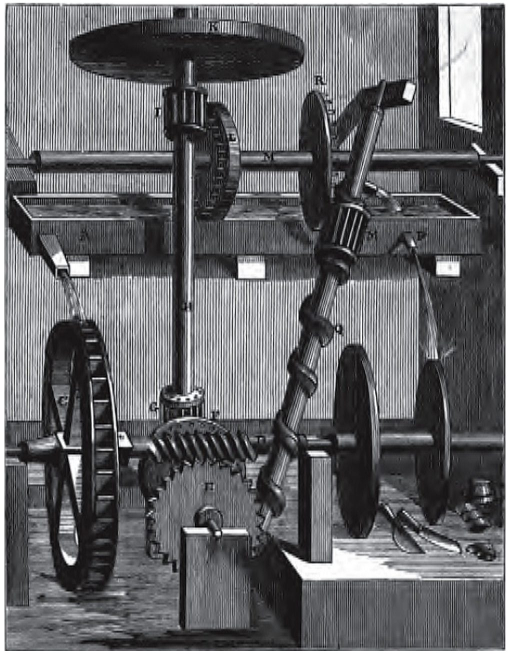
$$\boxed{\Delta S \geq 0}$$



- forbids perpetual motion machines
- limits the efficiency of heat engines
- thermodynamic arrow of time
- ...

The 2nd law of thermodynamics

$$\boxed{\langle \Delta S \rangle \geq 0}$$



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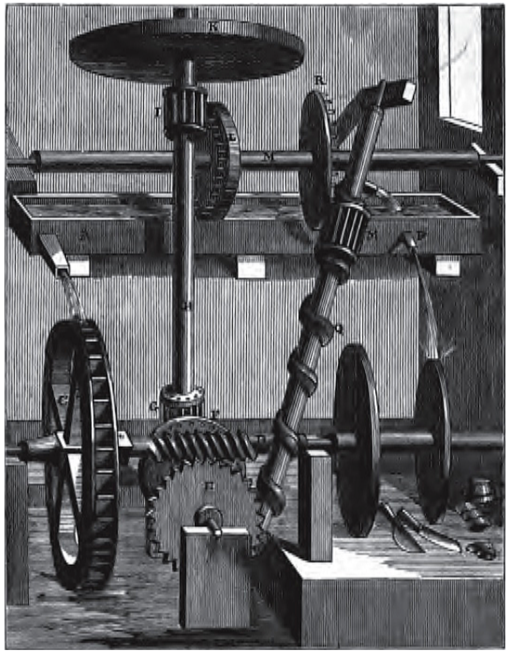
Thermodynamics

2nd law

$$\langle \Delta S \rangle \geq 0$$



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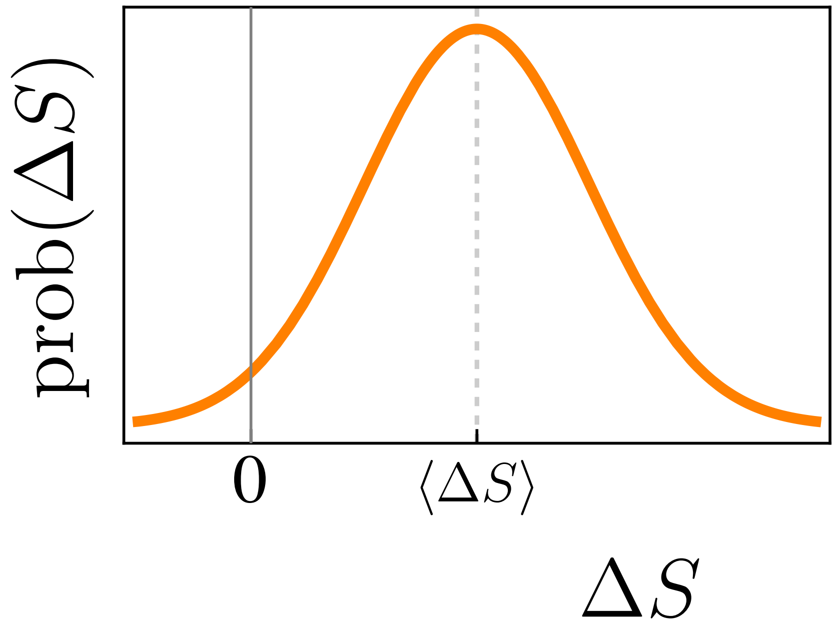
Stochastic Thermodynamics

refinement of the 2nd law

$$\left\langle e^{-\Delta S} \right\rangle = 1$$



e.g. for Brownian motion

$\hookrightarrow$ thermodynamic consequences?

Are there universal laws (far) away from equilibrium?

fluctuation theorems $\left\langle e^{-\Delta S/k_{\mathrm{B}}} \right\rangle = 1$

Jarzynski relation $\left\langle e^{-\Delta W/k_{\mathrm{B}}T} \right\rangle = e^{-\Delta F/k_{\mathrm{B}}T}$

“extensions of the second law”

thermodynamic uncertainty relation $\dfrac{\mathrm{Var}(J_\tau)}{\langle J_\tau \rangle^2} \geq \dfrac{2k_{\mathrm{B}}}{\Delta S}$

“trade-offs”, clocks,...

efficiency fluctuations $p(\eta) \sim e^{-\tau J(\eta)}$

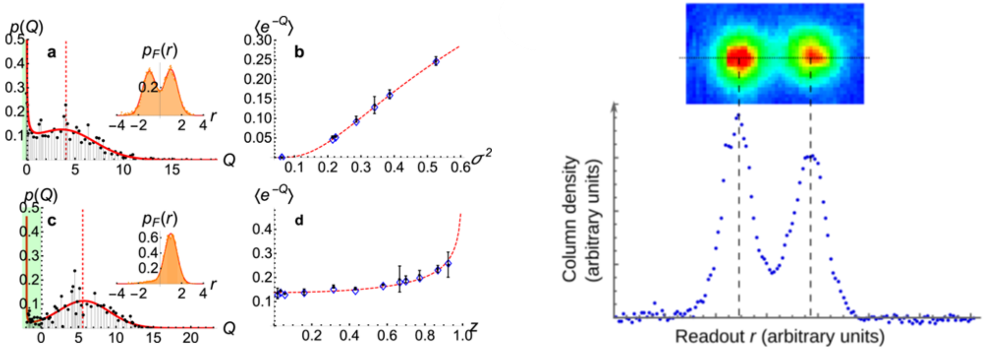
energy conversion (in fluctuating environments)

Systems

- various classes of model systems (e.g. Brownian motion)
- active matter

- biological compounds on the cellular and sub-cellular level
- molecular motors
- artificial micro- and nano-devices
- climate physics
- quantum systems

Stochastic thermodynamics in the quantum regime: A continuous measurements' perspective

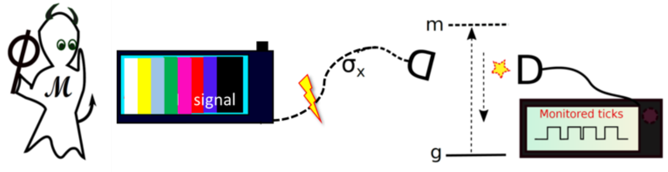


$\langle e^{-Q} \rangle = 1 - \mu$

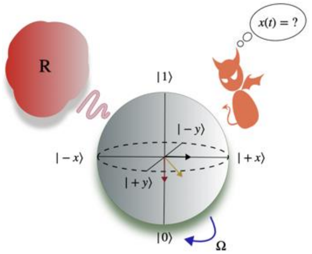
The arrow of time

$Q = \log(P_F/P_B)$

Fluctuation theorems for measuring spin of ultracold atoms:
Nature Communications 12, 1847 (2021)

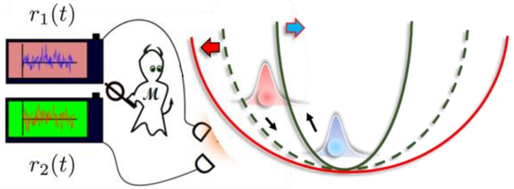


Autonomous quantum clocks:
Physical Review Research, 5(4), 043013. (2023)
arXiv:2411.08689 (2024)



Maxwell's Demon's perceived arrow of time:
Physical Review A, 106(4), 042221. (2022)

Optimal quantum engines and refrigerators using simultaneous quantum measurements of $\hat{x}$ and $\hat{p}$:



Physical Review E 105, no. 4 (2022): 044137.
Physical Review A, 107(2), 023516. (2023)

The framework of stochastic thermodynamics, fluctuation theorems, and the principle of large deviation can be extended to constrain quantum fluctuations in continuously monitored open quantum systems. Here they help to optimize the performance of quantum engines, refrigerators, and quantum clocks, realizable in experiments using superconducting artificial atoms and quantum harmonic oscillators.

- **Sreenath K. Manikandan,** Cyril Elouard, and Andrew N. Jordan. Physical Review A 99, no. 2 (2019): 022117.
- Maitreyi Jayaseelan*, **Sreenath K. Manikandan***, Andrew N. Jordan, and Nicholas P. Bigelow. Nature communications 12, no. 1 (2021): 1847. (equal first author)
- **Sreenath K. Manikandan** and Andrew N. Jordan (2019). Quantum studies: mathematics and foundations, 6, 241-268.
- Kagan Yanik, Bibek Bhandari, **Sreenath K. Manikandan**, and Andrew N. Jordan, Physical Review A 106, no. 4 (2022): 042221. (editors' suggestion)
- **Sreenath K. Manikandan,** Cyril Elouard, Kater W. Murch, Alexia Auffèves, and Andrew N. Jordan. Physical Review E 105, no. 4 (2022): 044137.
- **Sreenath K. Manikandan** (2023). Physical Review Research, 5(4), 043013.
- **Sreenath K. Manikandan** and Sofia Qvarfort (2023). Physical Review A, 107(2), 023516.
- Eldhose Benny, and **Sreenath K. Manikandan**. arXiv:2411.08689 (2024).

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