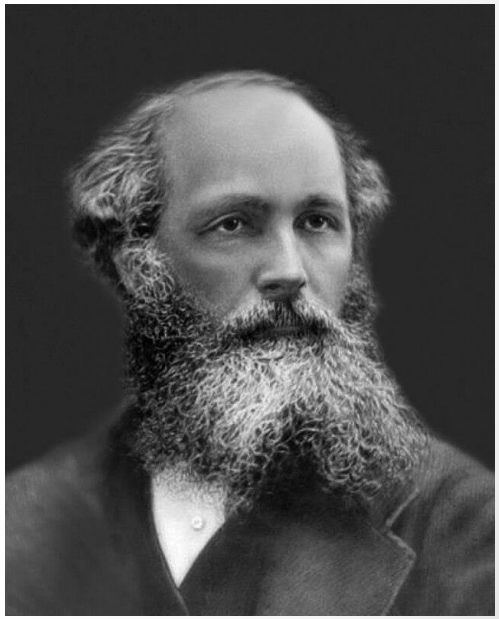
Maxwell's Demon

Tomás Ricardo Basile Álvarez

Physics of Biological Non Equilibrium

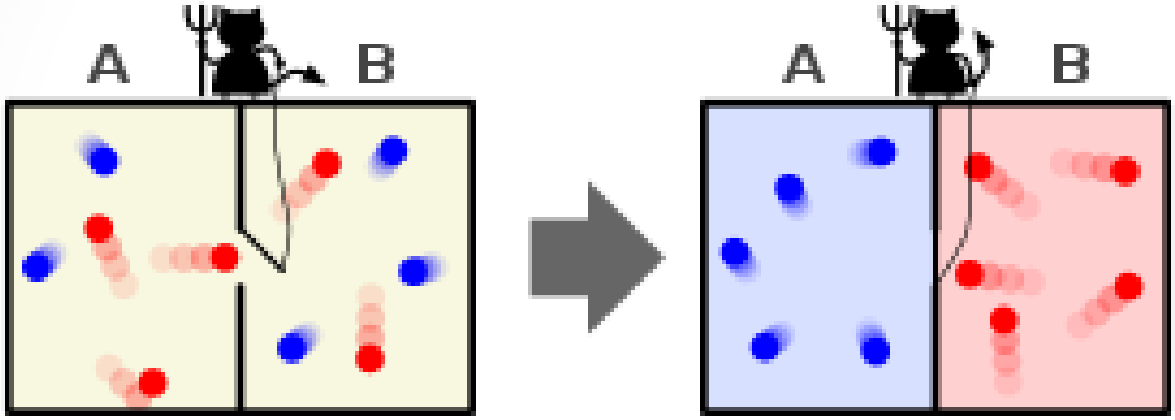
Maxwell (1831 – 1879)

- Born in Edinburgh in 1831.
- Found the equations of electromagnetism.
- Realized that light is an EM wave.
- Studied color vision.
- Contributions to thermodynamics:
  - Maxwell-Boltzmann distribution.
  - Maxwell relations.
  - Maxwell's demon.
- Died at 48 of cancer.



Maxwell's Demon (1867)

- Thought experiment.

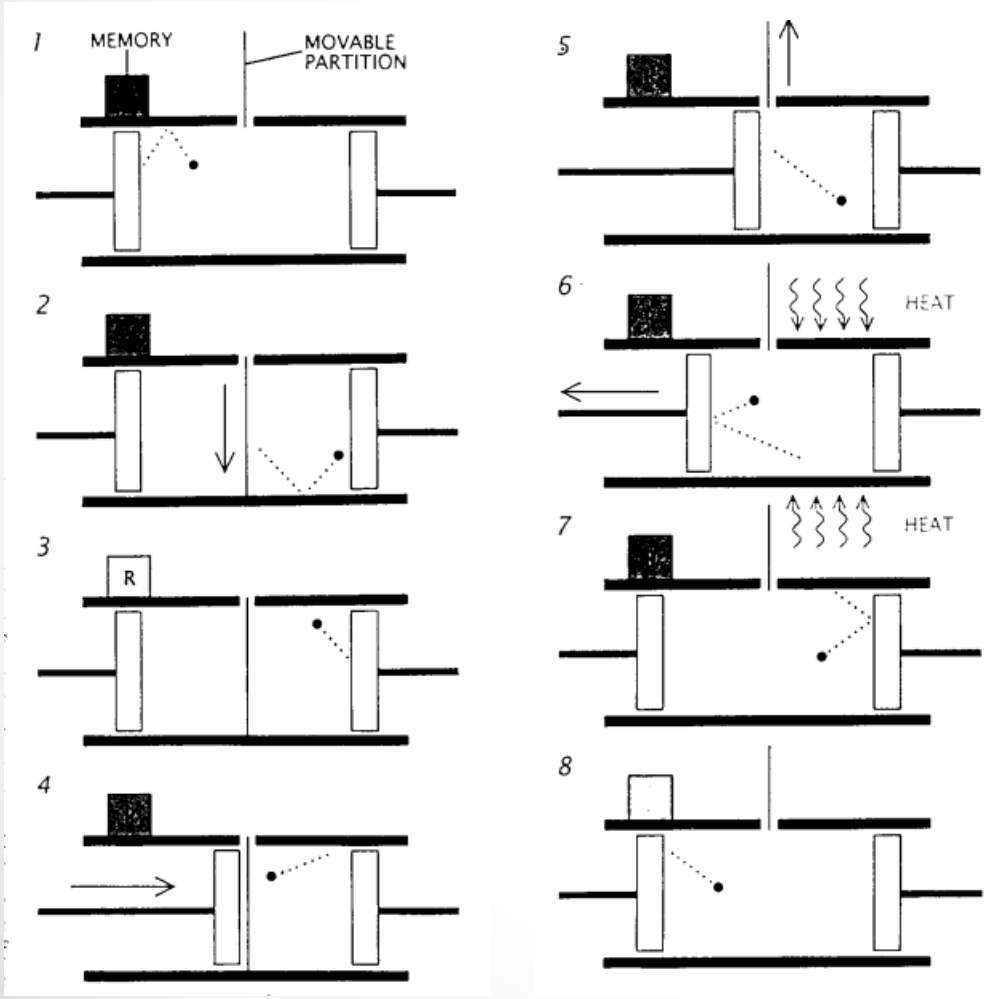


- Seems to break 2nd law: The entropy of the gas decreases.

Proposals for Solutions

Szilard (1929)

- Considers a "Maxwell demon" engine.



Seems to break the 2nd law:

It is impossible for any device that operates on a cycle to receive heat from a single reservoir and produce only a net amount of work.

$$W = kT \ln 2$$

What compensates this excess work?
The measurement?

Brillouin (1951)

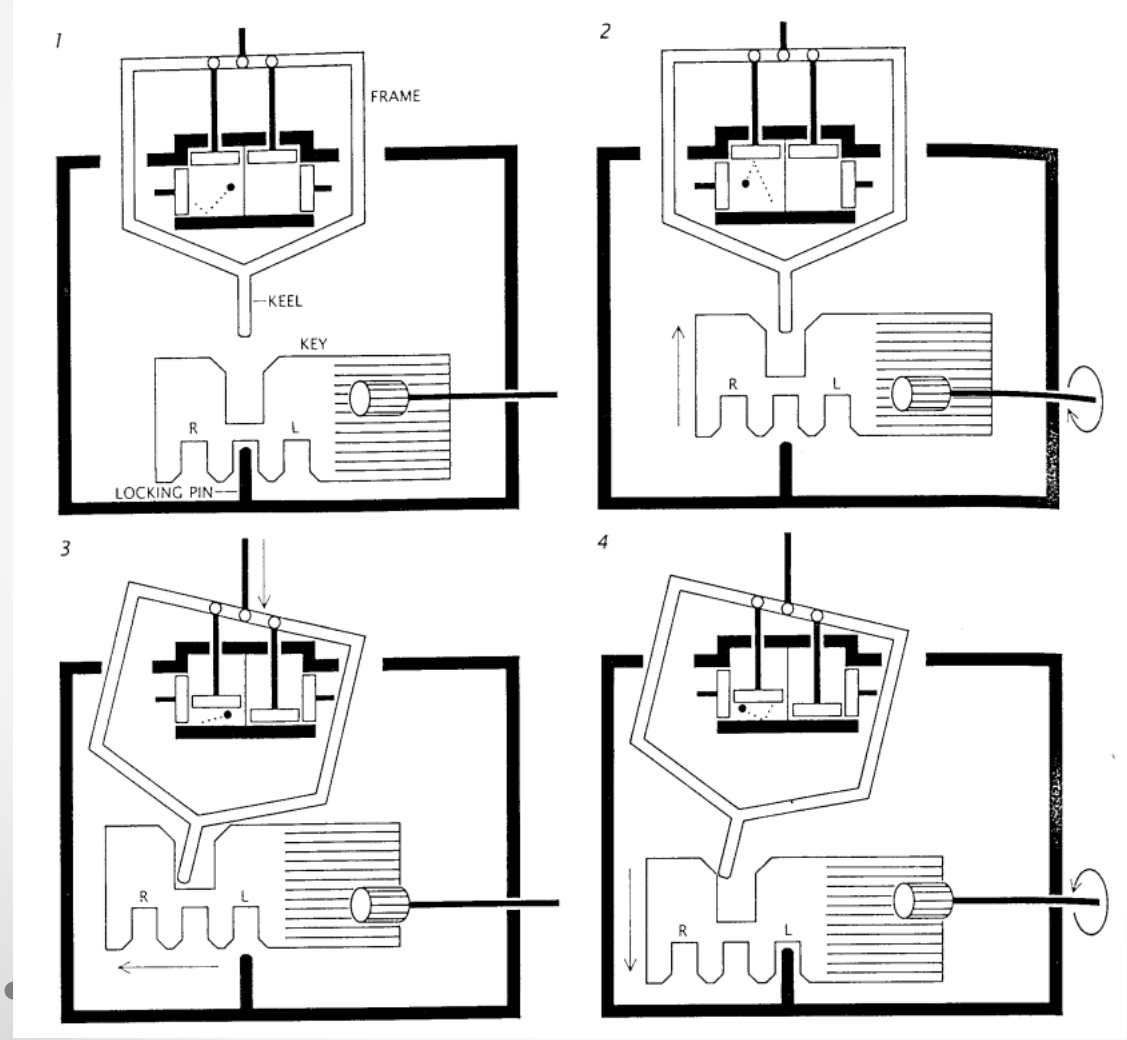
- Expanded on Szilard's idea that measurement requires work that compensates the $kT \ln 2$ obtained.

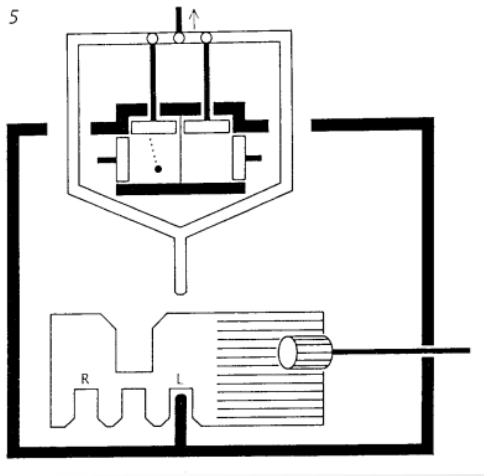
- Demon needs to emit a photon to see the molecule. To overcome blackbody radiation:

$$\hbar\omega_p \gg kT > k\,T \ln 2$$

Bennet (1982)

- Actually, measurement can be done without work!





Landauer (1961) / Bennet

- The problem isn't measuring, it is erasing the measured information.

Landauer's principle:

- Information is physical.
- Erasure of a bit of information requires at least $kT \ln 2$ of energy.

Measuring is reversible.

Erasing is irreversible.

Erasing one bit reduces entropy by $k \ln 2$, by the second law, entropy of the environment must increase in at least that amount, so $kT \ln 2$ of heat is dissipated.