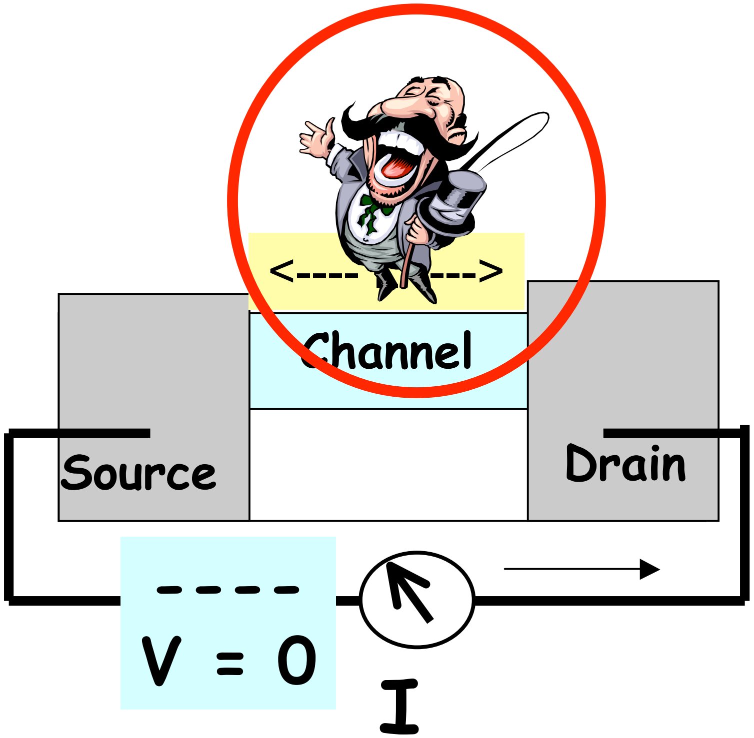
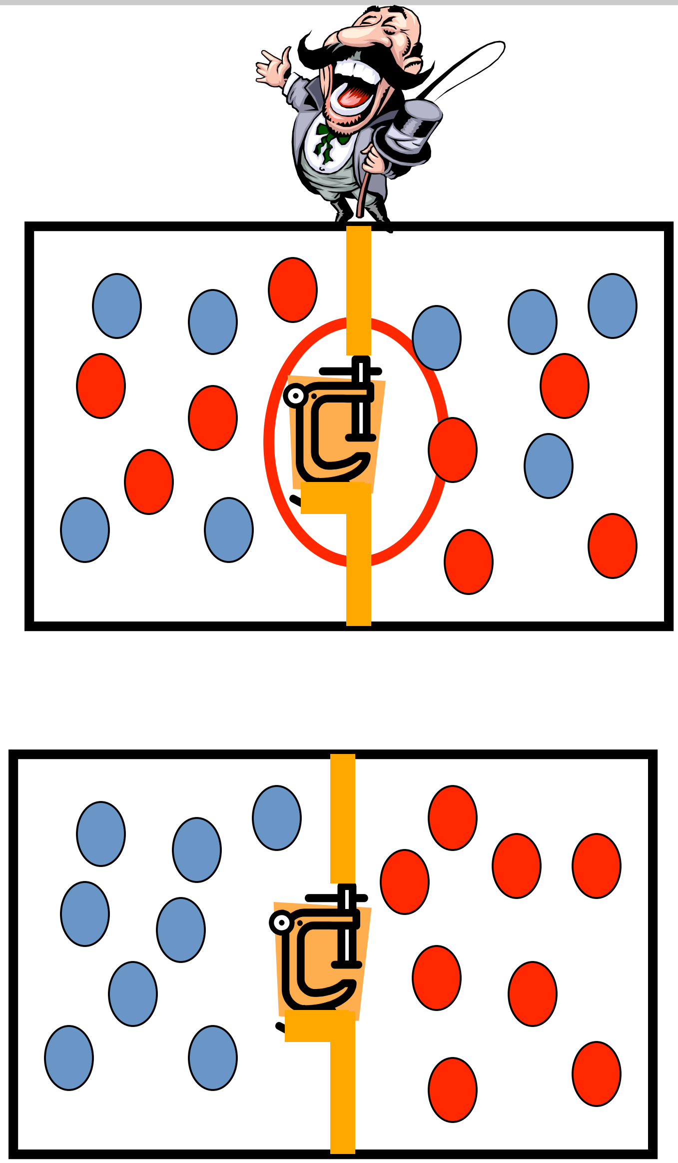
Nanodevices and Maxwell's Demon

Electronic demon

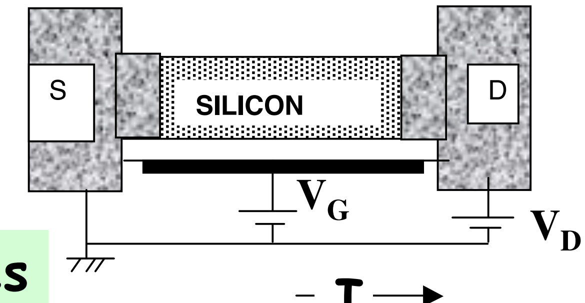




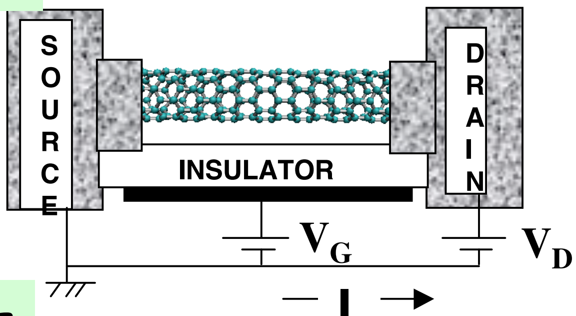
For a detailed write-up
See arXiv:condmat/0704.1623

Unified viewpoint: Materials

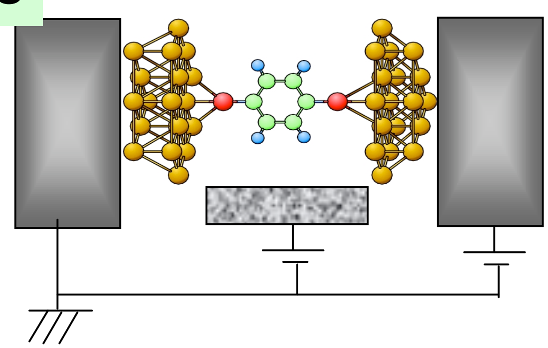
Nanowires



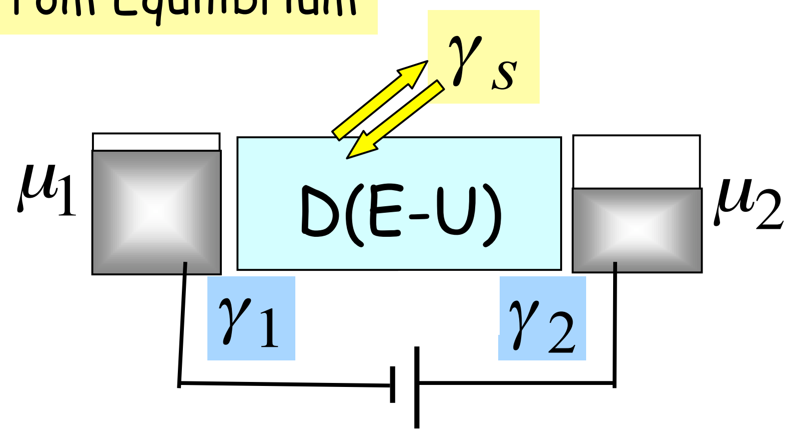
Nanotubes /Graphene

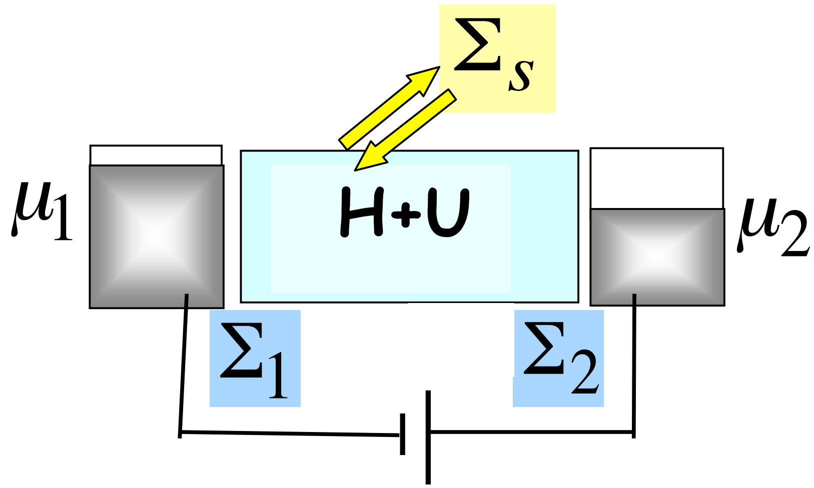


Molecules



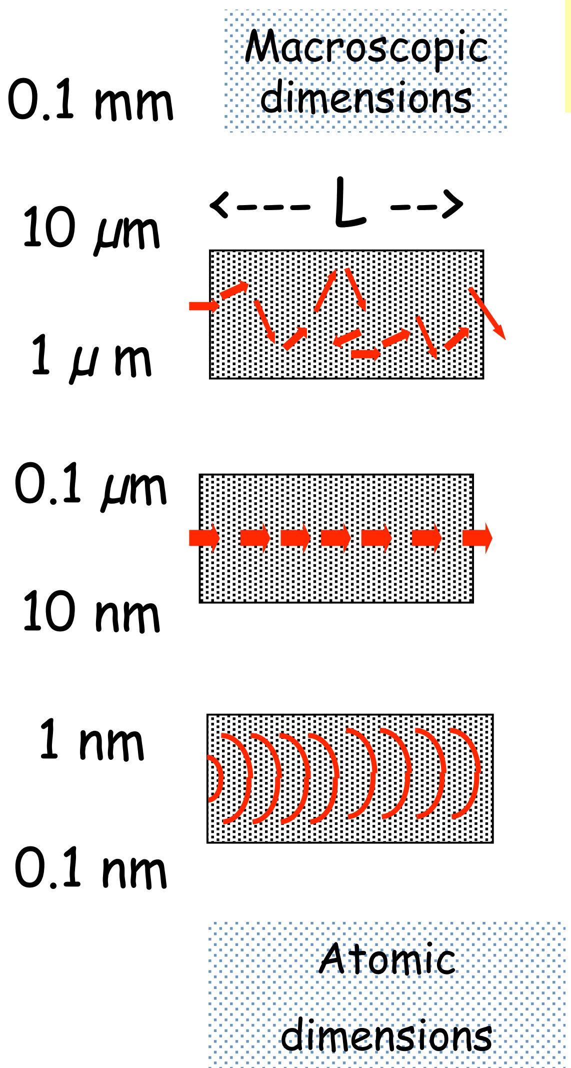
Quantum Transport Far from Equilibrium



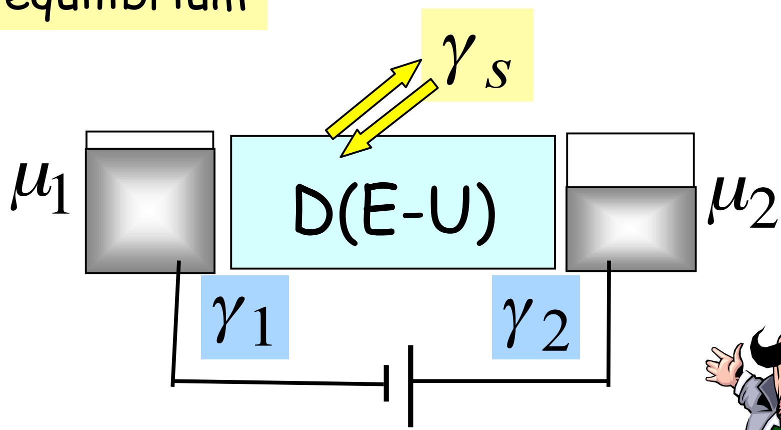


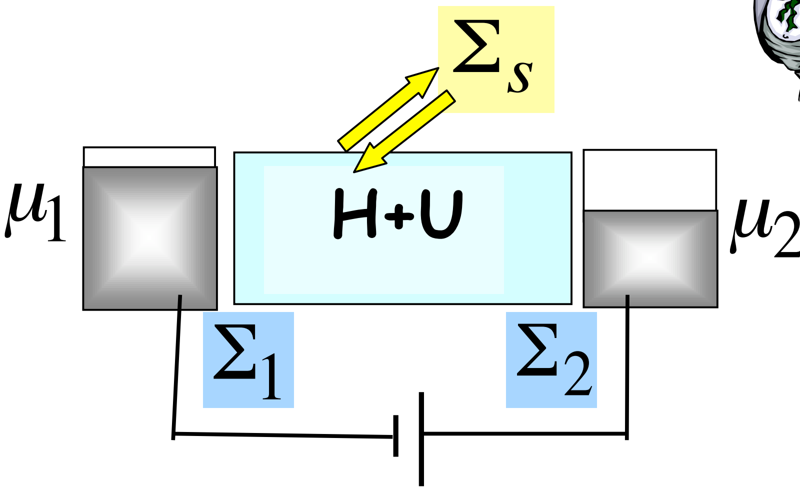
$$\Gamma = i\left[\Sigma - \Sigma^{+}\right]$$

Unified viewpoint: Ballistic to Diffusive



Quantum transport far from equilibrium





$$\Gamma = i\left[\Sigma - \Sigma^{+}\right]$$

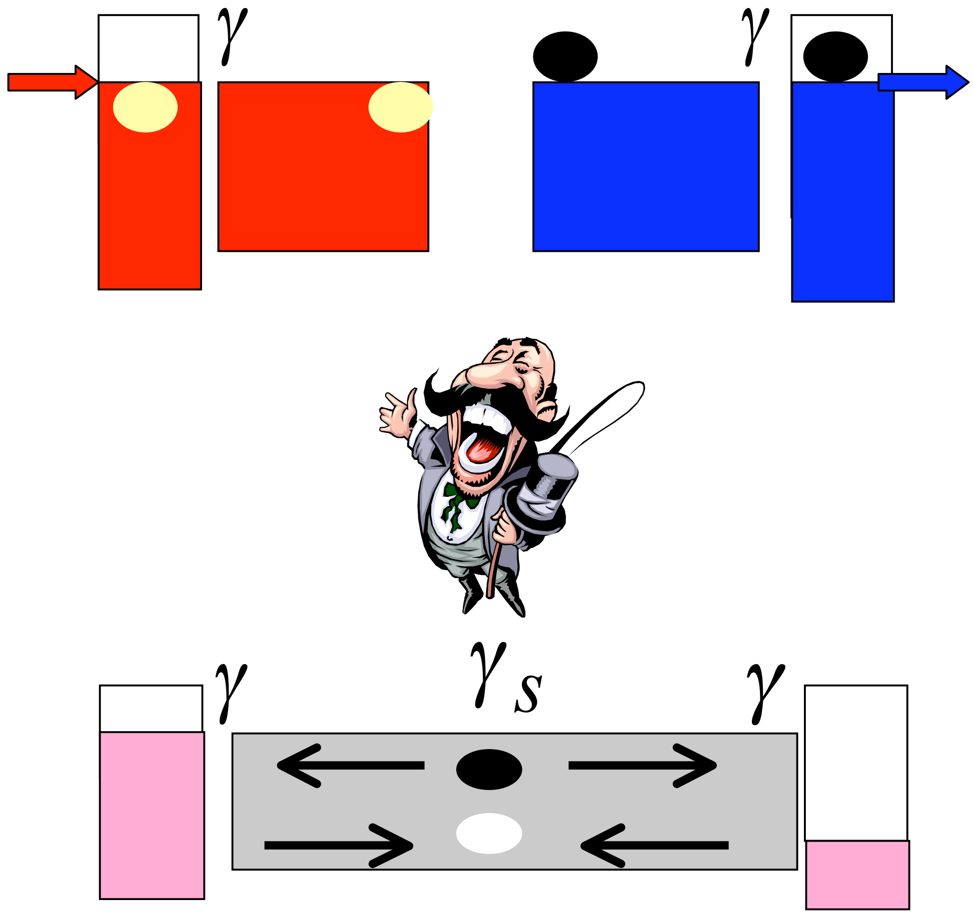
Designing an energy conversion device

Need two groups of states:

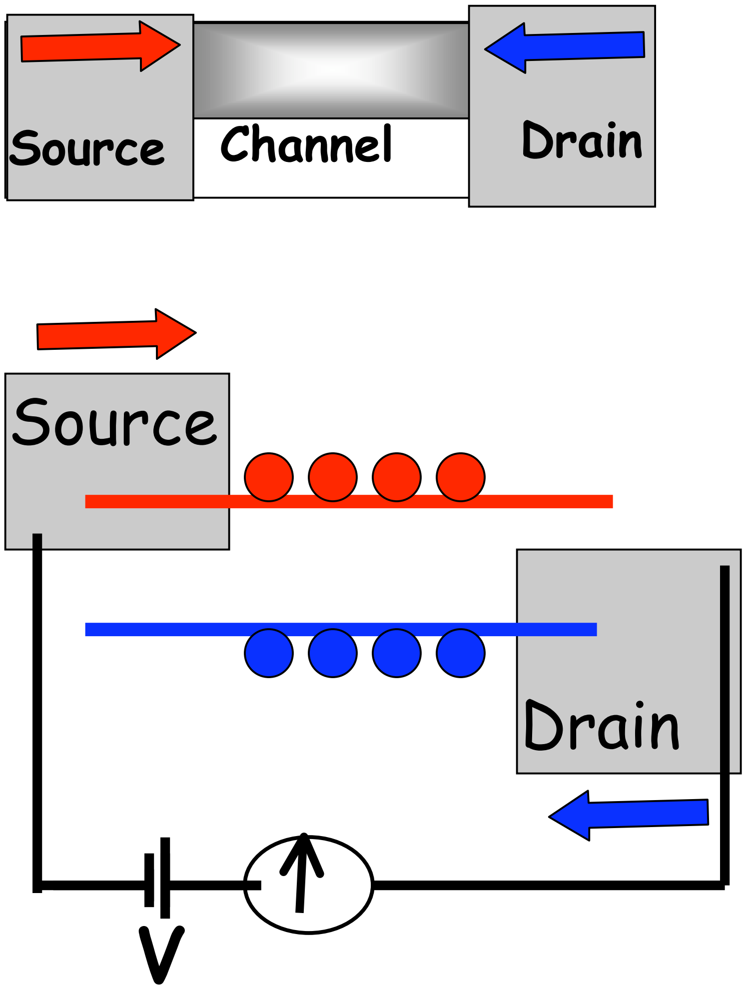
"Red"

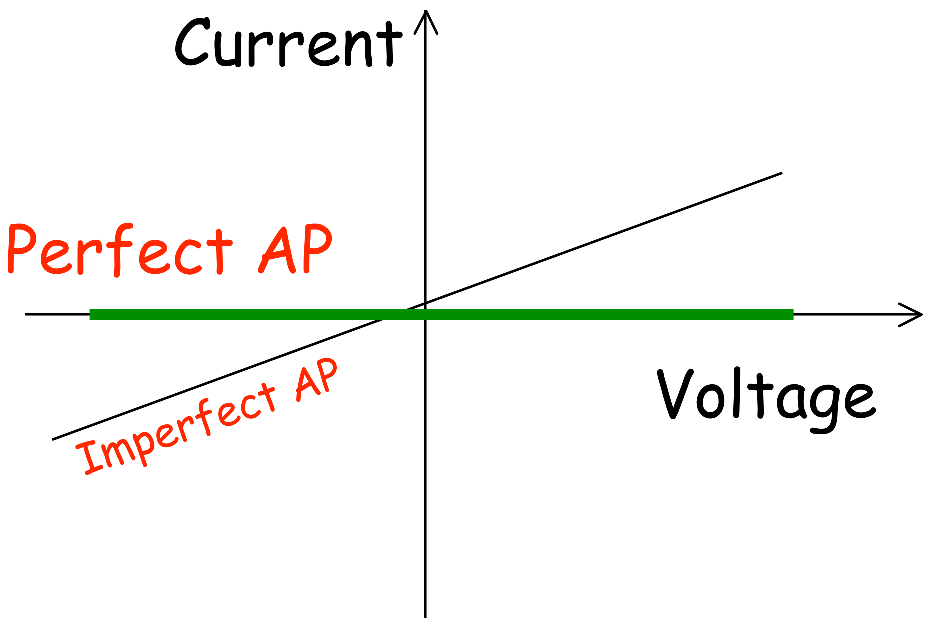
&

"Blue"

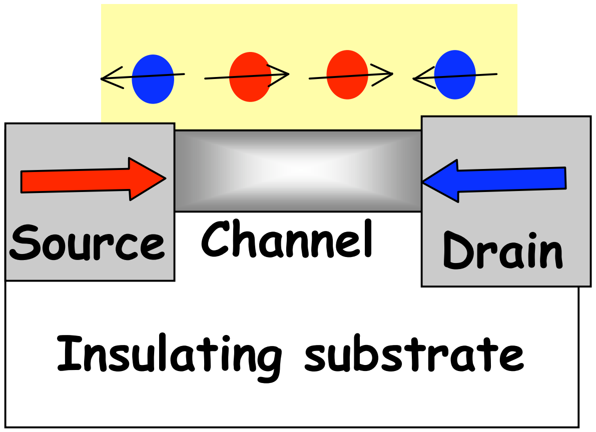


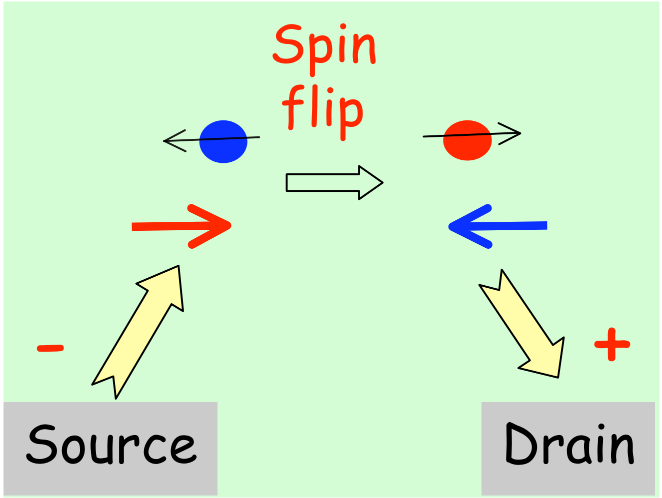
Anti-parallel (AP) Spin Valve

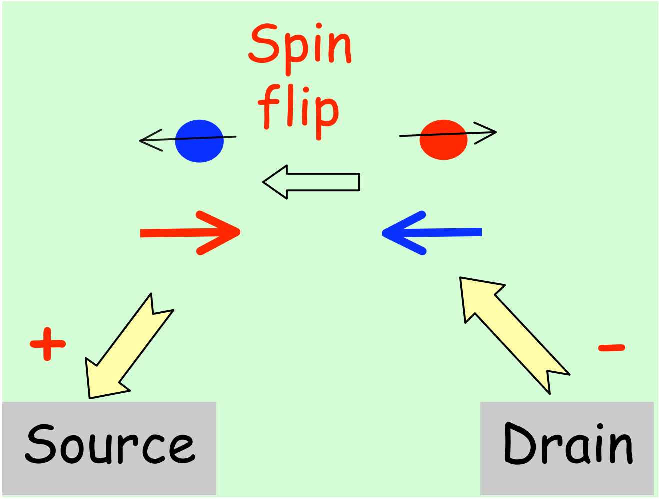


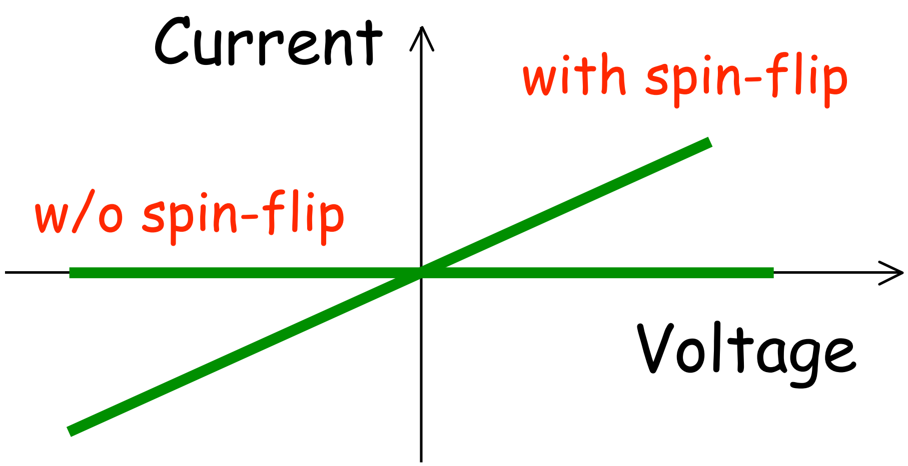


Perfect AP with Spin-flip Impurities

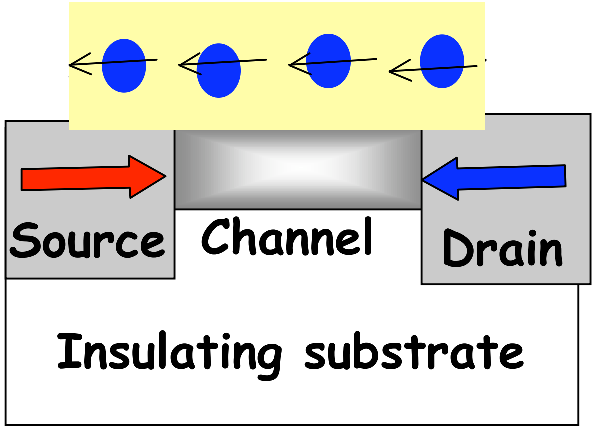


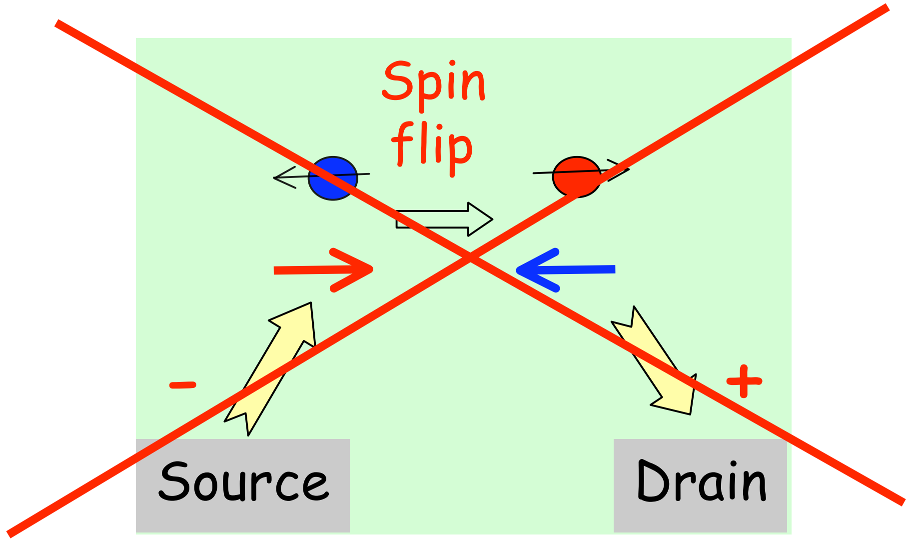


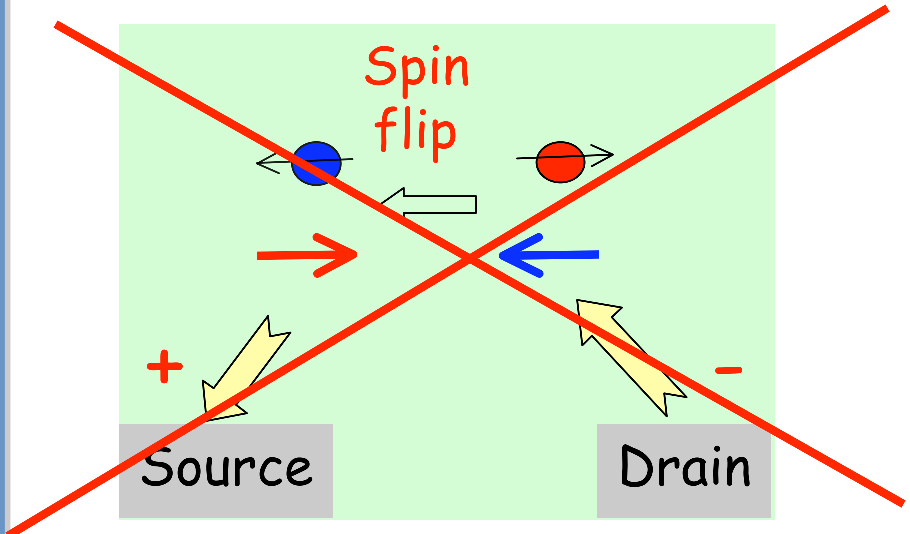


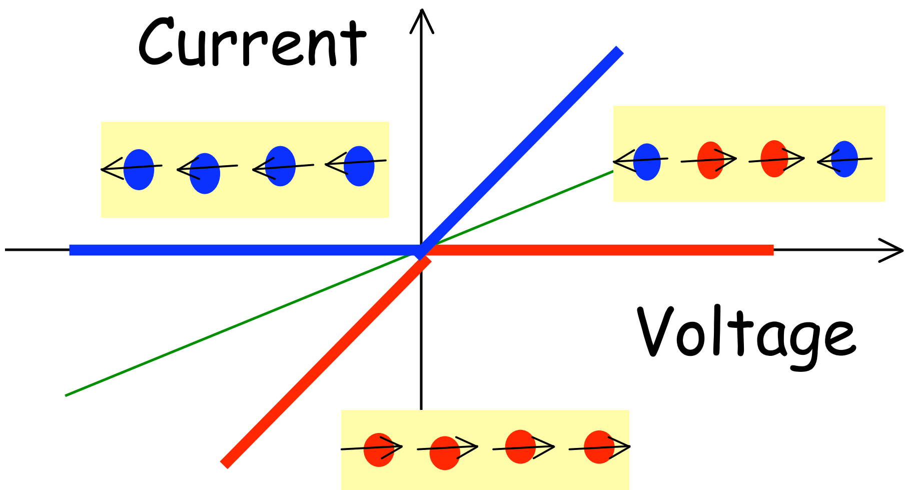


Perfect AP with Spin-polarized gate

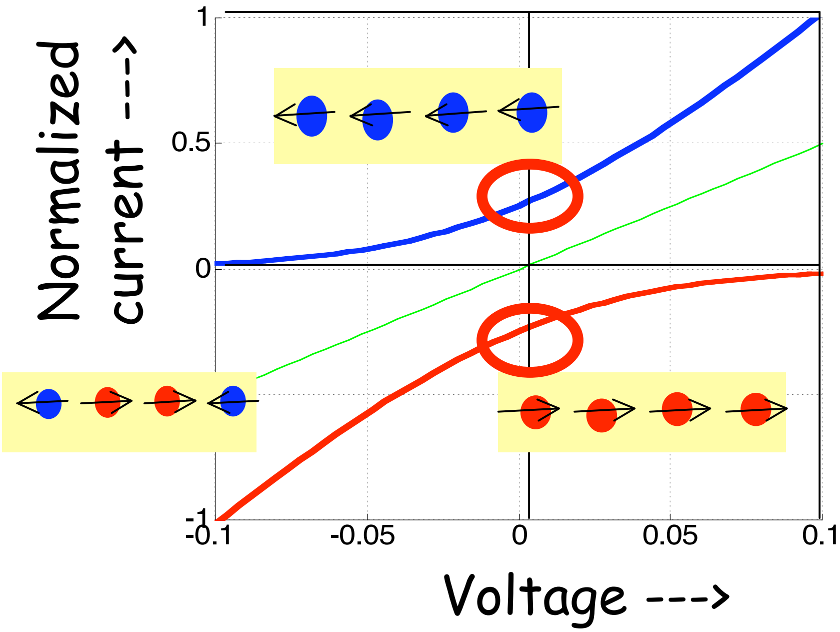


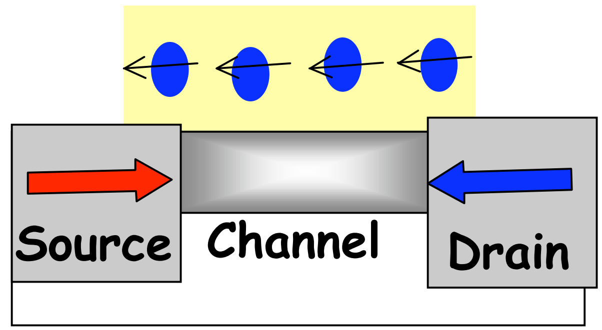


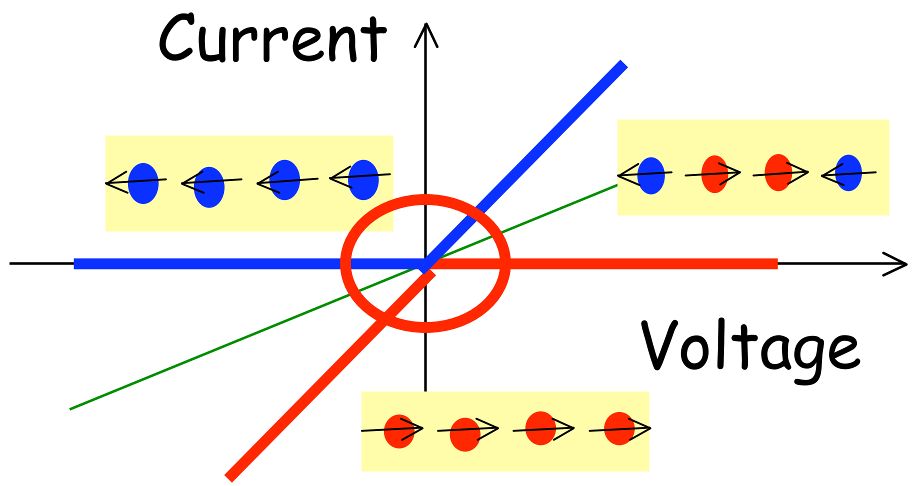




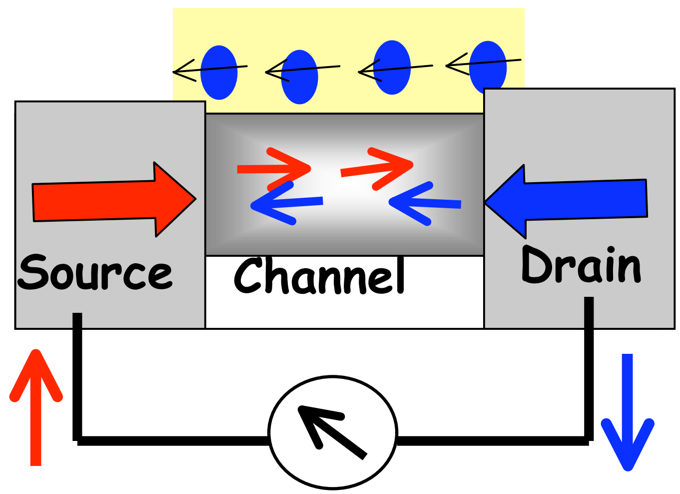
Current at zero voltage ! !

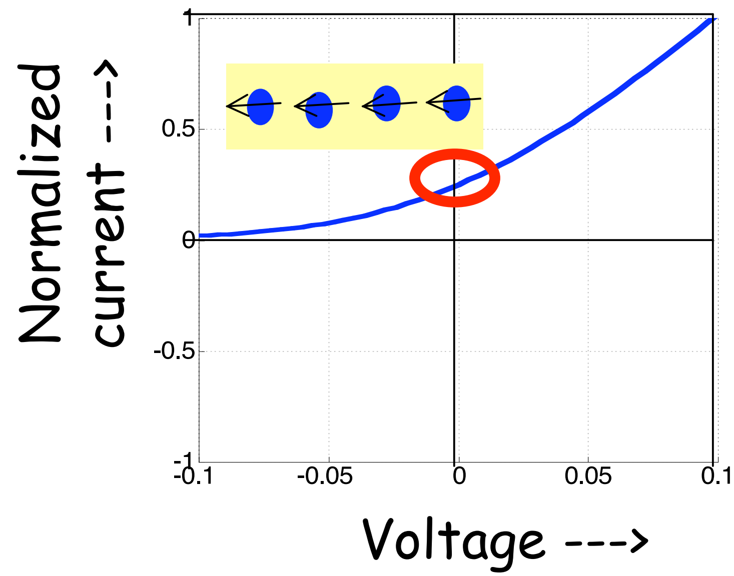


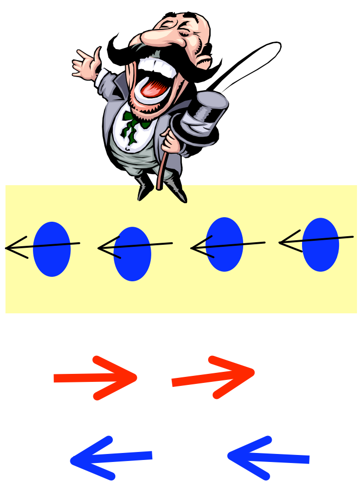


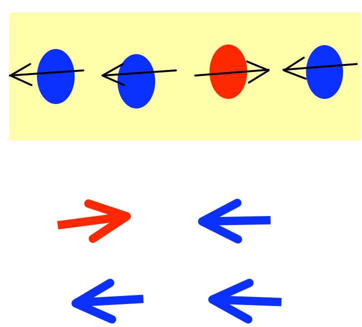


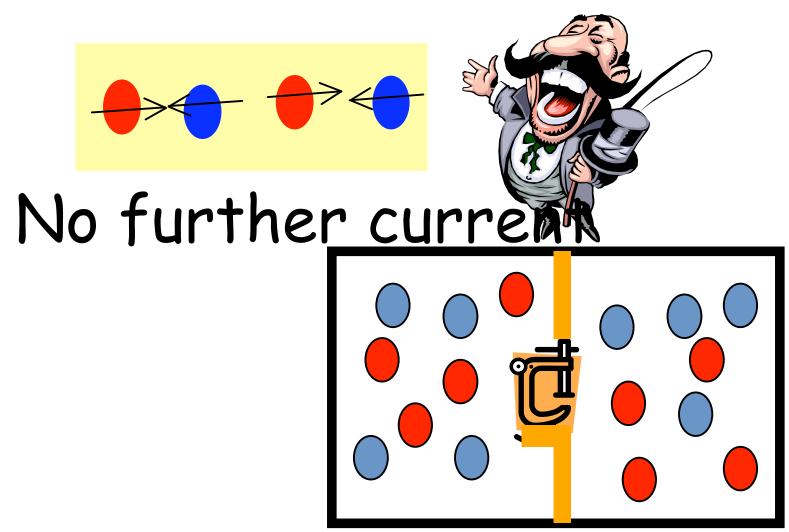
Device as a "demon"



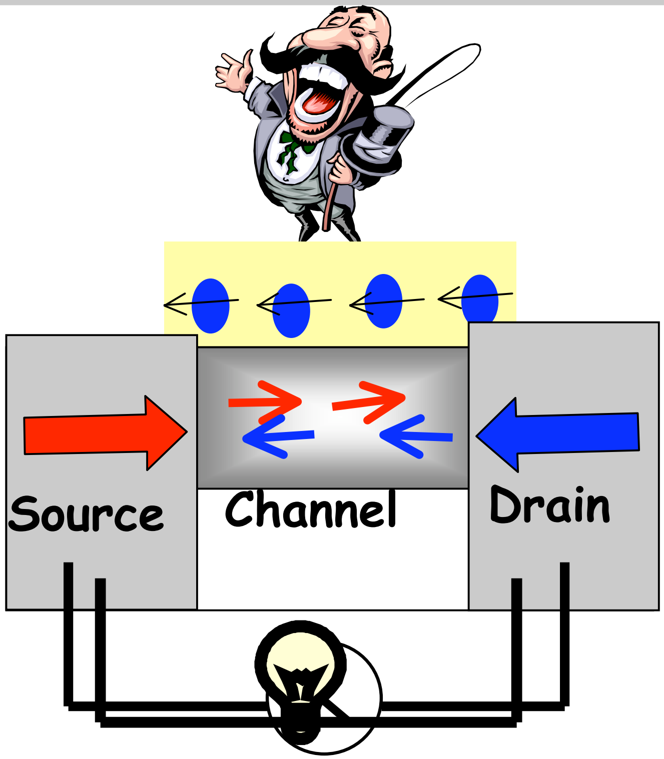


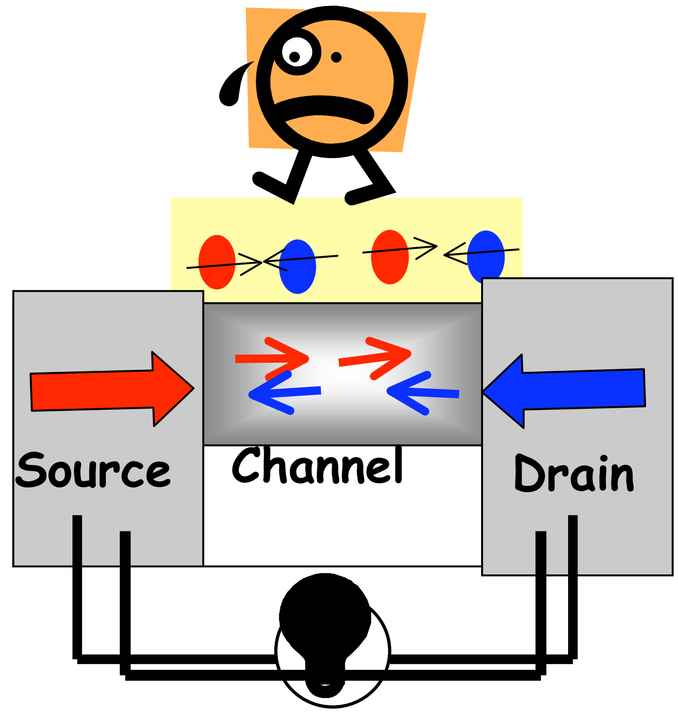




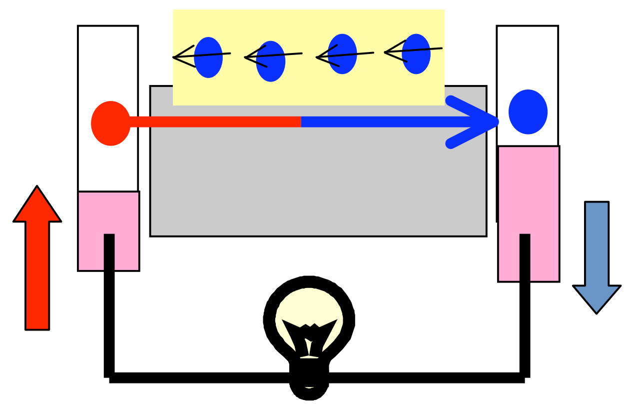


Where did the energy come from?

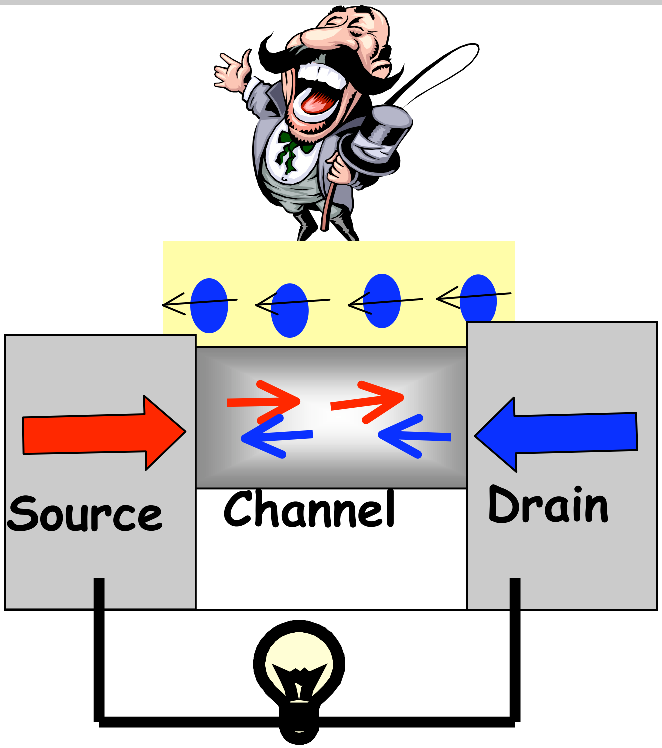


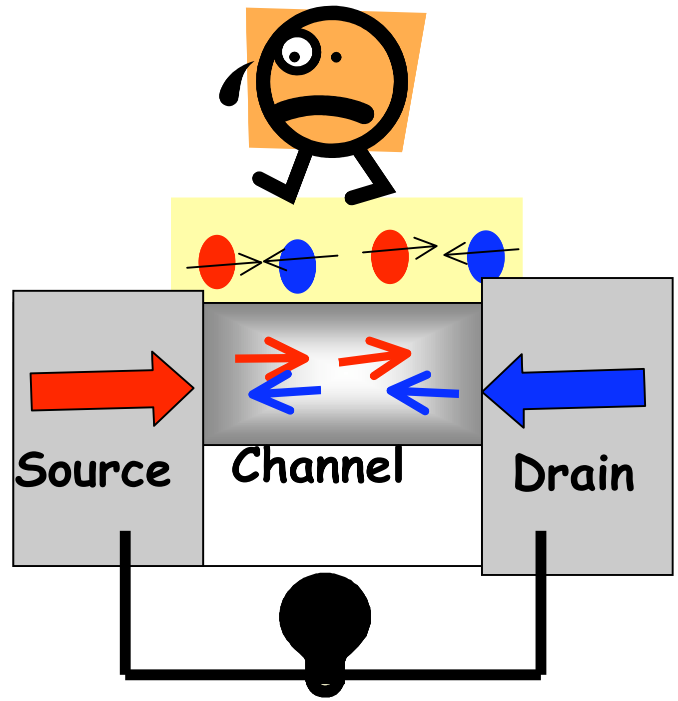


Answer: From the contacts



Second law ?





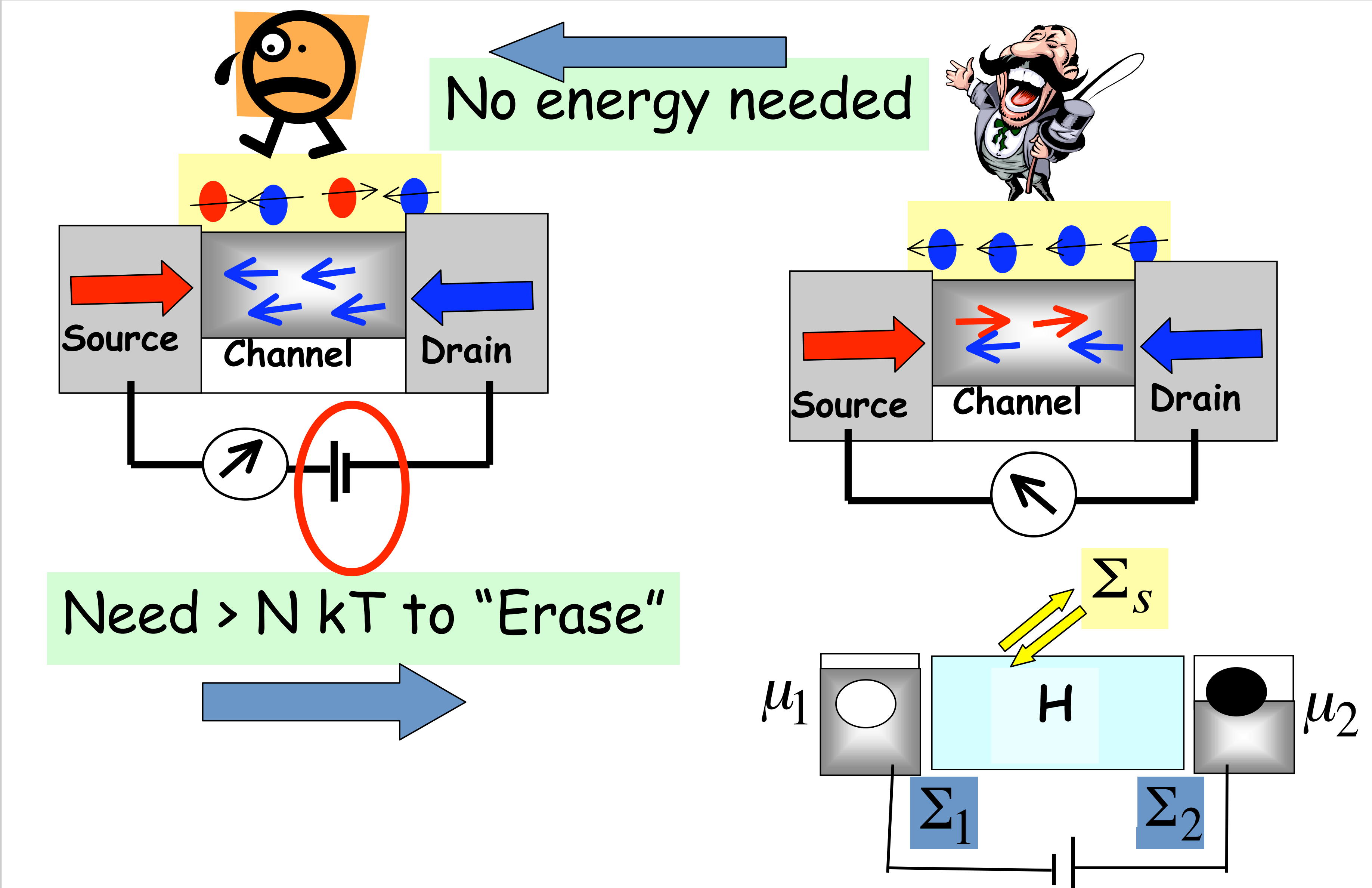
$S = 0$

$S = k \ln W$

$S = Nk \ln 2$

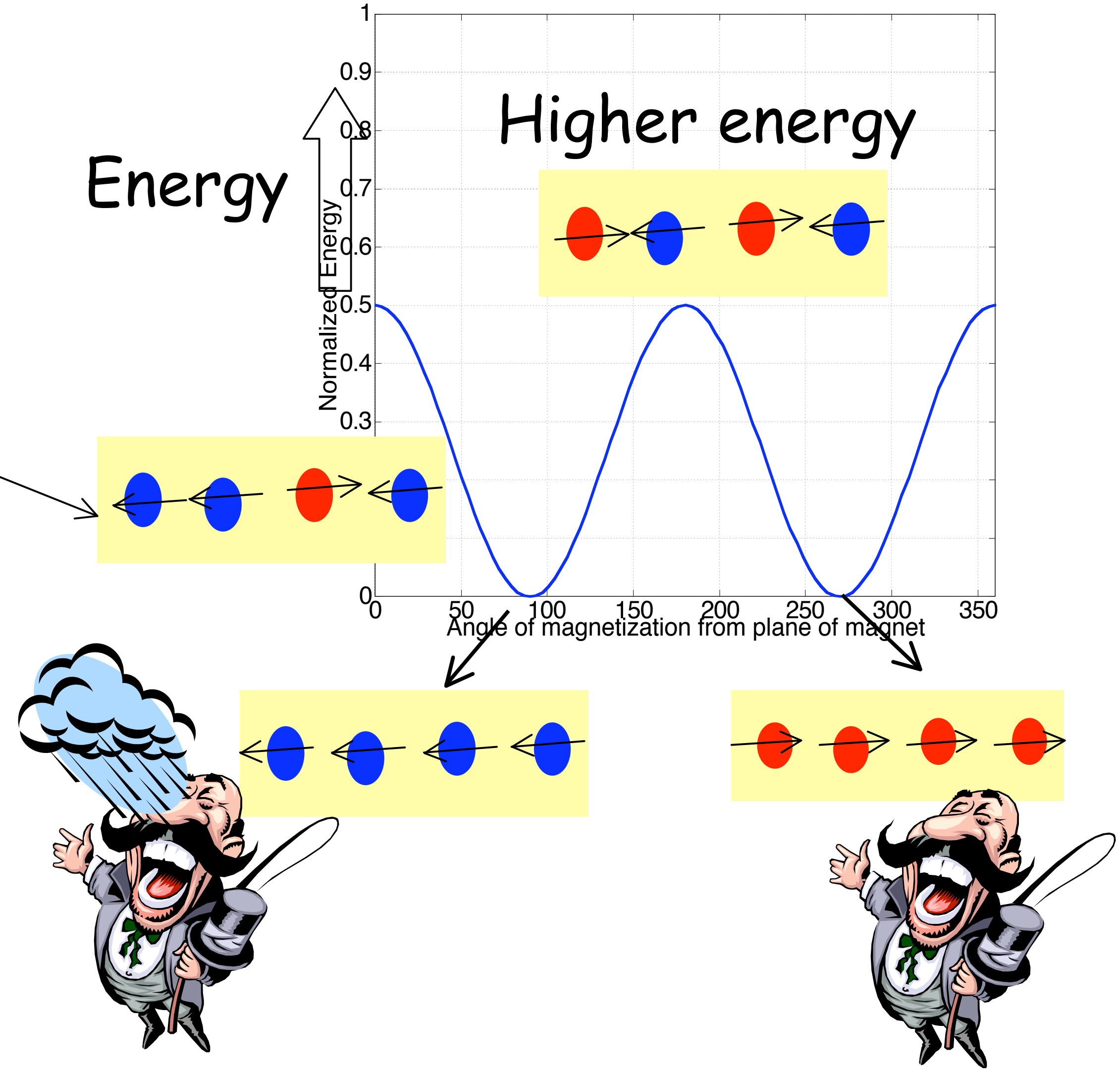
Energy upto $T\Delta S$ may be extracted

Resetting the demon takes energy

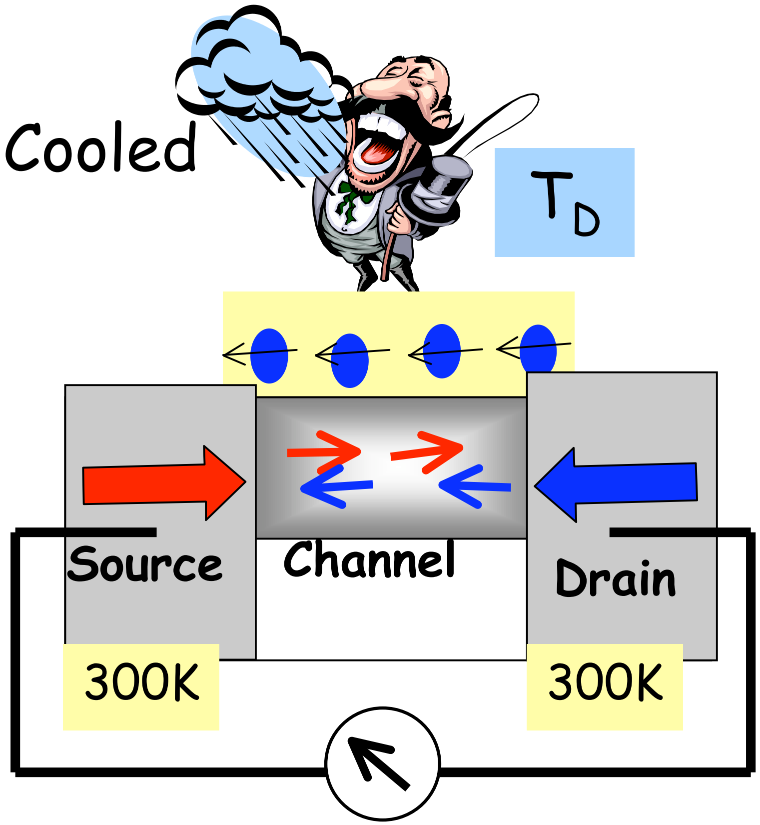


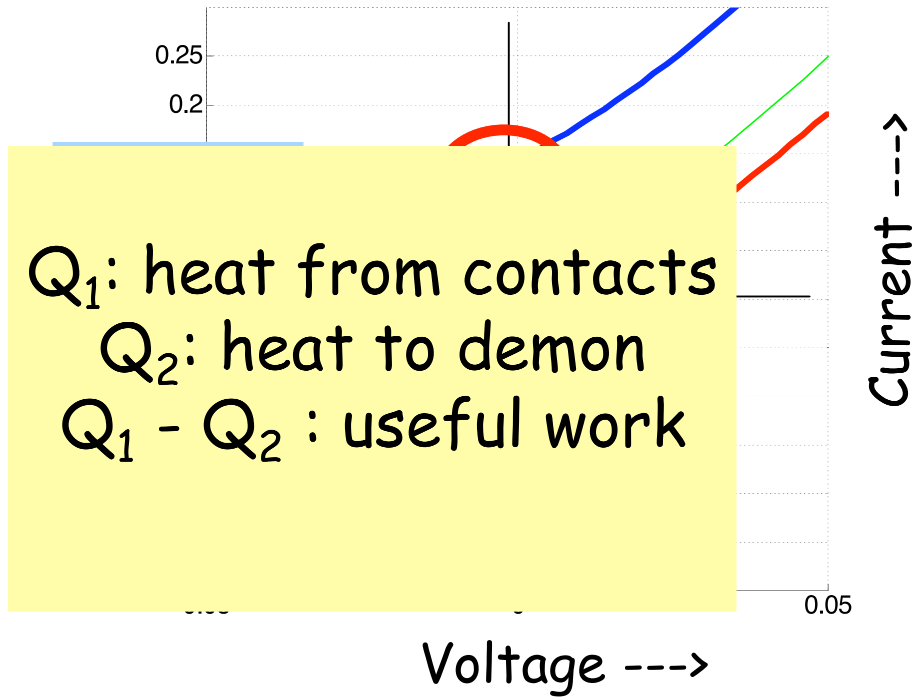
Nanomagnets

Flipping a spin costs energy

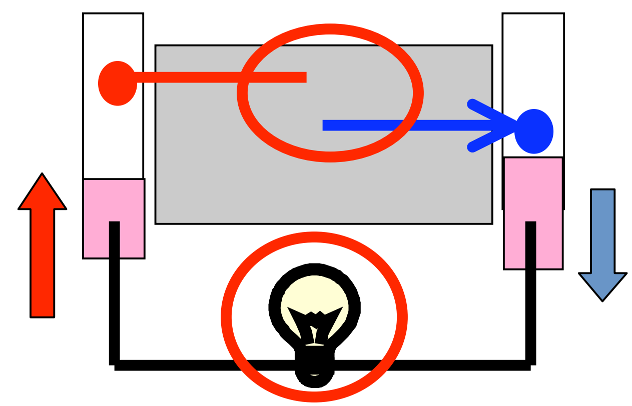


The cool demon as a heat engine





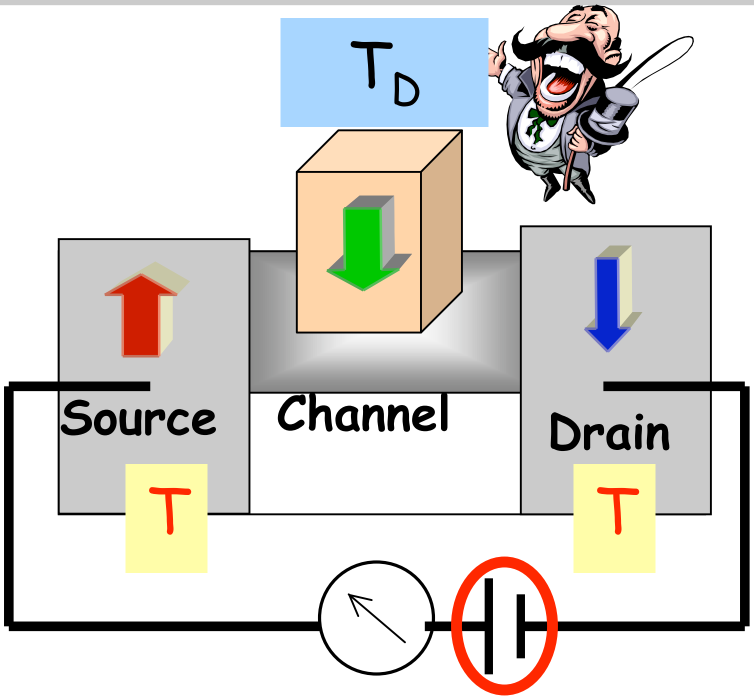
Q_1: heat from contacts
Q_2: heat to demon
Q_1 - Q_2 : useful work

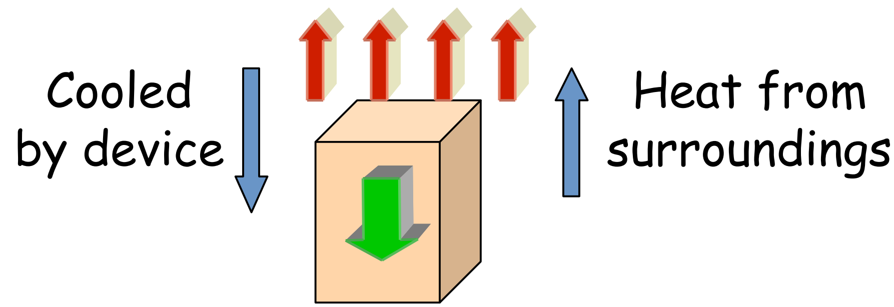


Carnot's principle

$$\frac{Q_1}{kT} < \frac{Q_2}{kT_D}$$

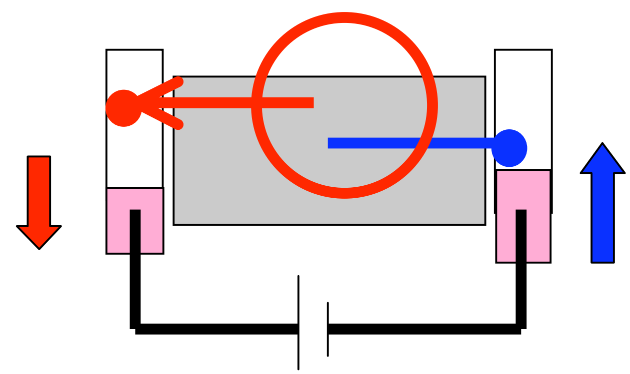
Nanoscale Refrigerator



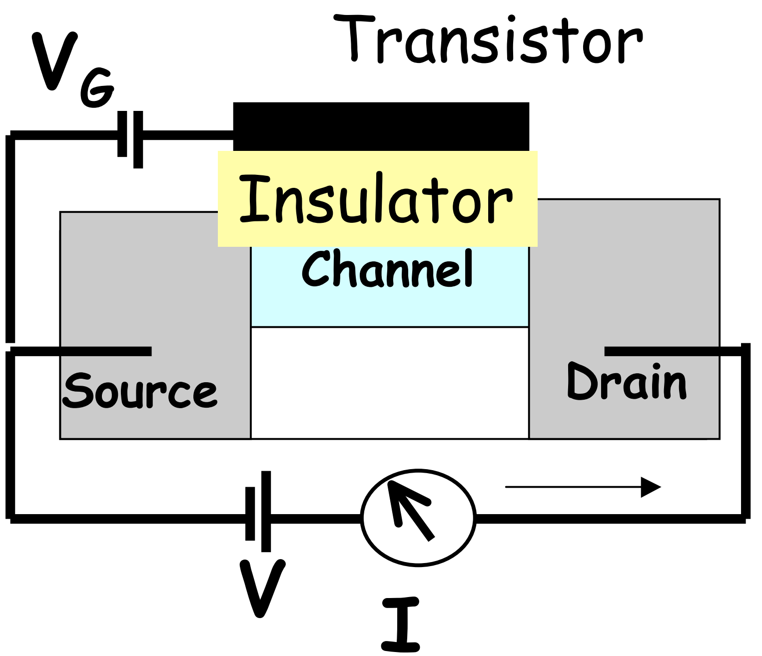


Carnot's principle

$$\frac{Q_1}{kT} > \frac{Q_2}{kT_D}$$



Switching a bistable demon



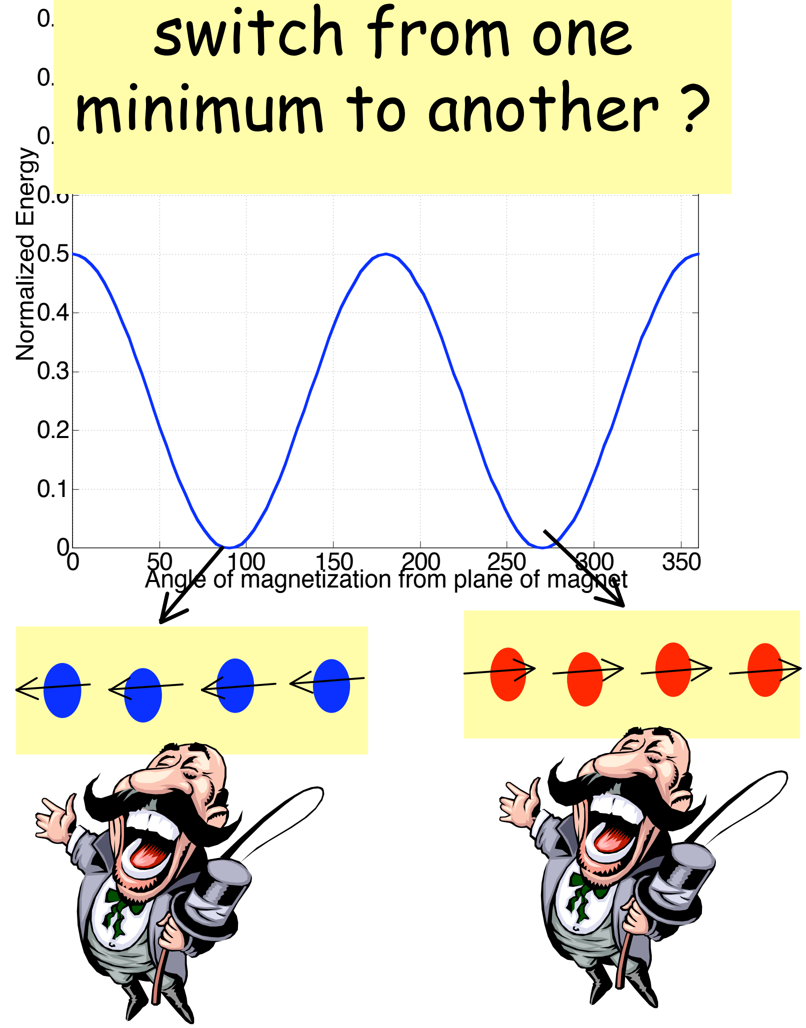
P = 10^4 electrons

x (40 kT)

x 10^9 Hz

= 1 μW / switch

Energy needed to switch from one minimum to another ?

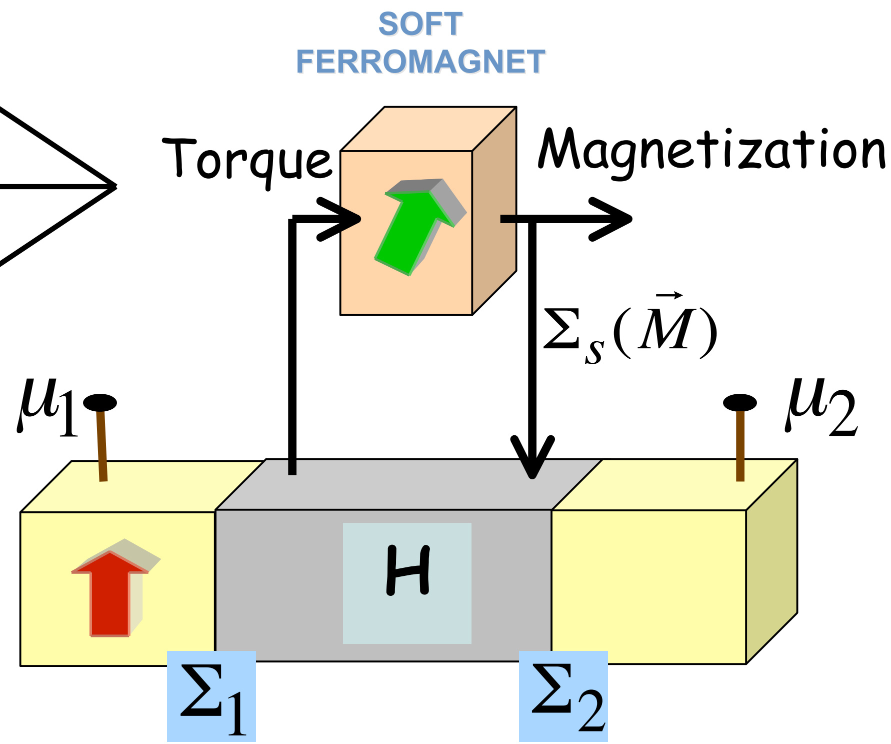


Transport +Dynamics of Magnetization

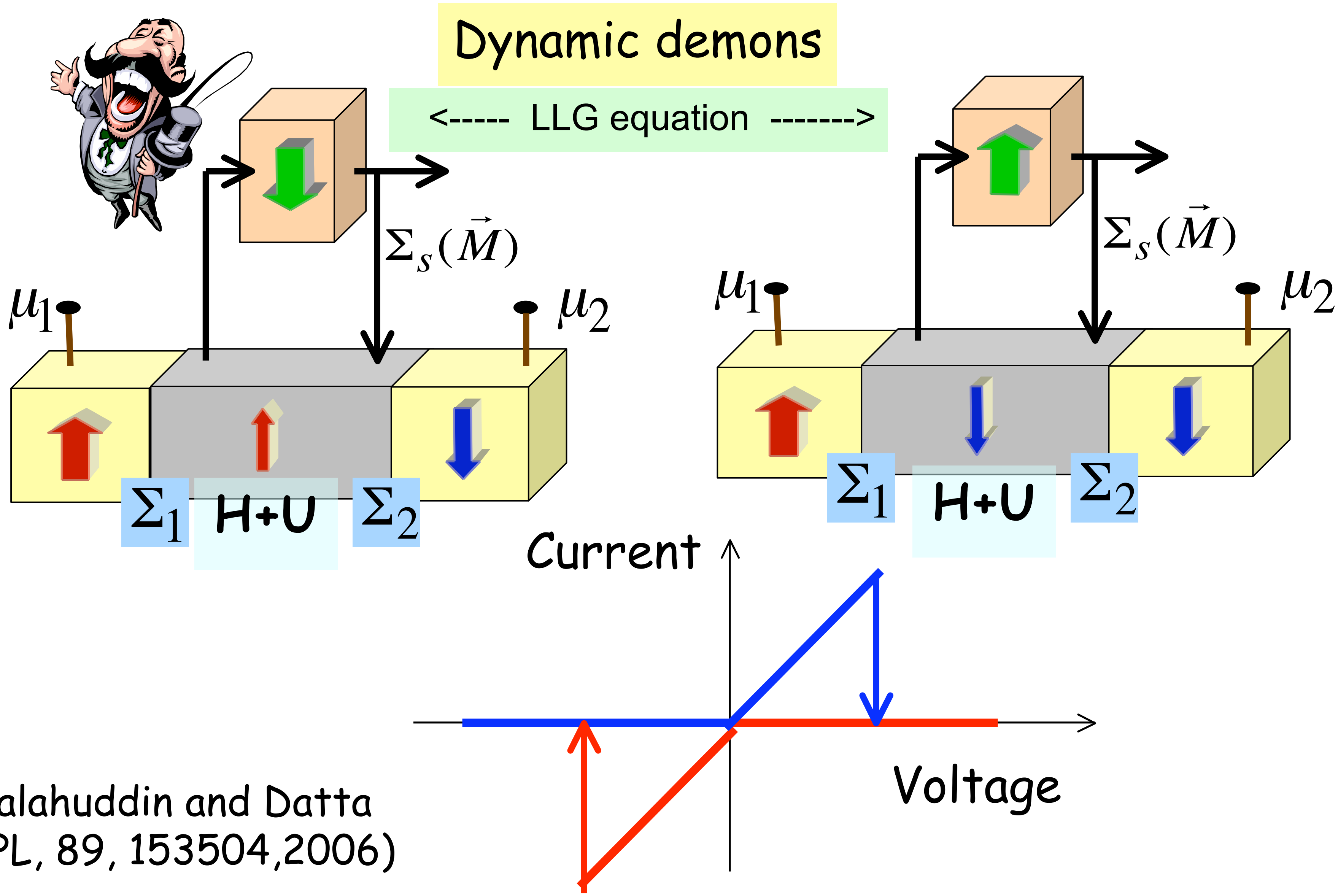
Isolated spins: Bloch equation

Weakly interacting spins:
Many-spin problem

Nanomagnets: LLG equation



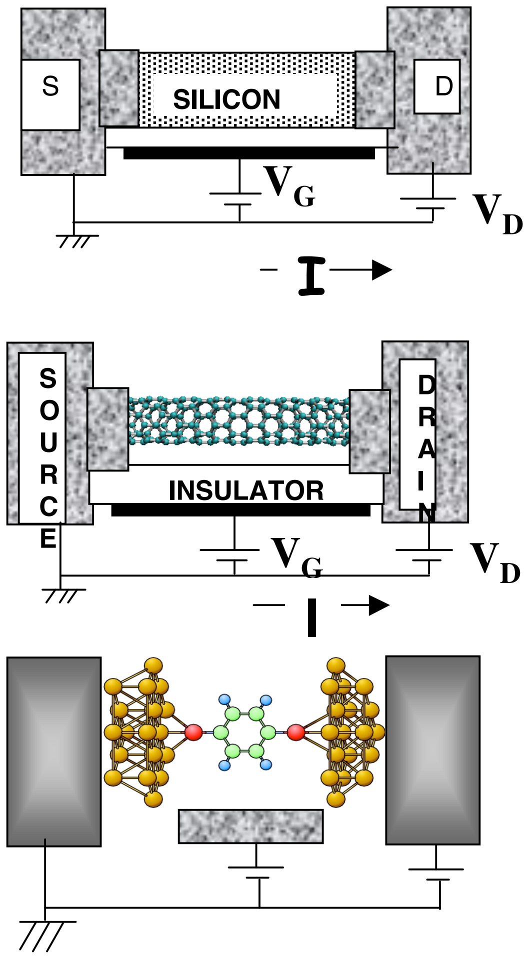
Pentalayer spin-torque device



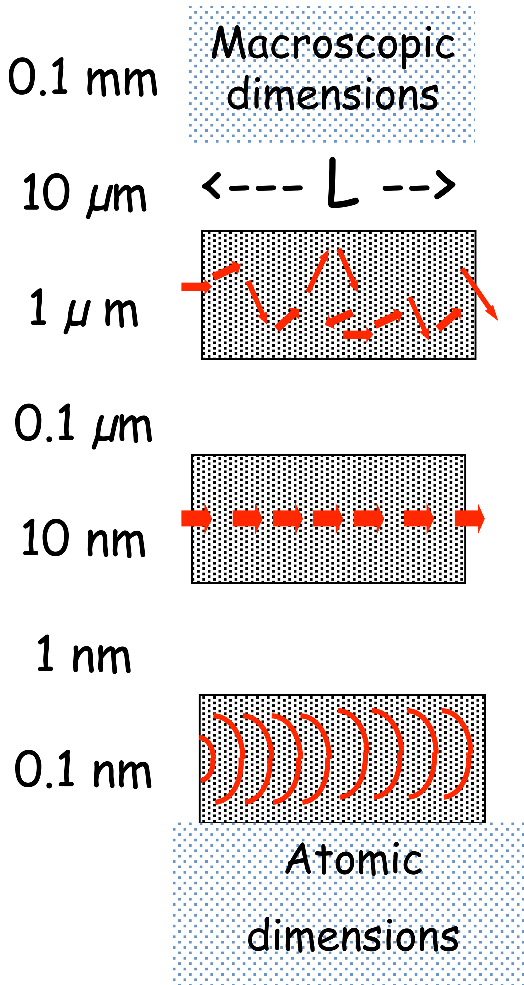
Salahuddin and Datta
(APL, 89, 153504,2006)

Quantum Transport far from Equilibrium

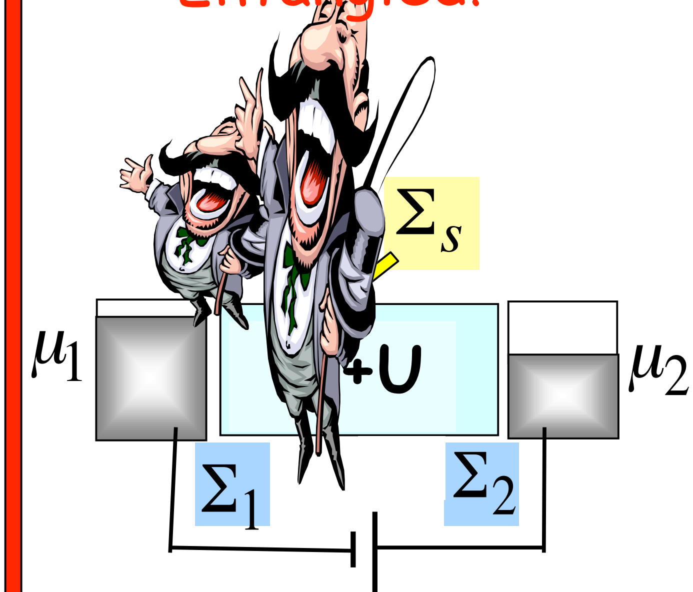
Materials



Transport Regimes



Correlated/ Entangled!



Reference:
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www.nanohub.org/courses/cqt