



light behaves like a particle, matter behaves like a wave: the same duality, seen from both sides

Photon energy

$$E = h\nu$$

a packet, not a spread-out wave

one photon, one electron

Work function

$$\phi_0$$

the least energy to free an electron

one photon, one electron

Max kinetic energy

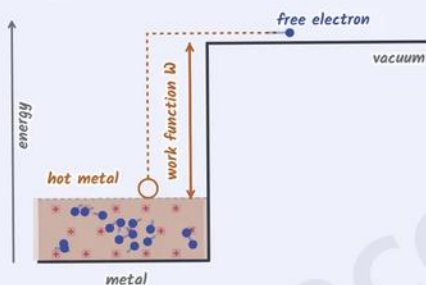
$$KE_{\max} = h\nu - \phi_0$$

whatever the photon leaves over

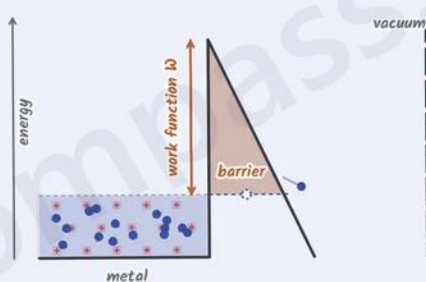
run it back: no photon energy means no emission at all, however bright the beam. that one fact broke the wave picture

Electron emission: three ways out

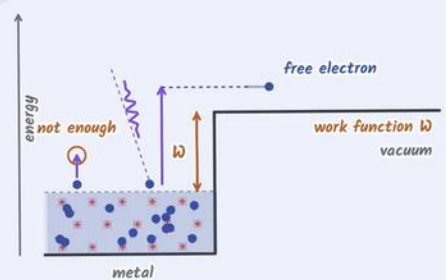
- free electrons move inside a metal but cannot leave on their own
- leaving costs the work function ϕ_0 (the wall, W in the figures)
- thermionic: heat the metal, a few electrons gain enough to climb out
- field emission: a strong field thins the barrier, electrons slip through
- photoelectric: one photon gives all its energy to one electron
- a photon with less than ϕ_0 frees none: the electron falls back



heat: the sea of electrons jiggles harder and a few climb the wall and leave



a strong field tilts the outside into a hill: the barrier thins and an electron slips through



one photon, one electron: enough energy climbs the wall, too little falls back

going further

How strongly heat and field matter *

- thermionic current $\propto T^2 e^{-W/kT}$: almost nothing until the metal is hot
- a lower work function gives far more current at the same temperature
- field emission needs no heating but a field of about 10^8 V/m
- in a hot or field-fed metal the electrons leave with little energy; a photon can give much more

