**Photoelectric Effect**

**Hertz 1887**

Ultra-violet light shining on a metal surface ejects particles with negative electric charge.

**Thompson 1897:** charged particles are electrons

**Leonard 1902**

Connect collector to metal by a wire. Study current $I$ as function of voltage $V$. 

![Diagram of photoelectric effect with collector, metal, and voltage source with ammeter and battery.]
- There is a minimum voltage $V_{\text{stop}}$ above which electrons are completely stopped.

- $V_{\text{stop}}$ does not depend on intensity of light.

- For $V < V_{\text{stop}}$, the current $I$ is proportional to the intensity of light.

- $V_{\text{stop}}$ is larger for light of higher frequency.

$\Rightarrow$

- Electrons in metal have energy distribution with a sharp maximum (Fermi energy $E_F$).

- Intensity of light determines number of electrons that absorb energy.

- Frequency of light determines the maximum energy they can absorb.

$$E_{\text{max}} = eV_{\text{stop}}$$
Light of frequency $\nu$ is absorbed by an electron in lumps of energy $h\nu$ (quantum).

If an electron of energy $E$ absorbs light, its energy becomes

$$E' = E + h\nu$$

- Electron inside metal has energy distribution with sharp maximum.
- Additional energy required to escape metal: $W$ (= $E_b$ ?)
  "work function" ("binding energy" ?)
- Electron absorbs quantum of energy $h\nu$ from light.
- Electrons that escape from metal have kinetic energy distribution with sharp maximum $E_{max}$.
metal-air interface

\[ V_0 = -(E_F + W) \]

Electron energy \( E \)

Before absorbing quantum: \( E < -V_0 + E_F \)

After absorbing quantum: \( E < -V_0 + E_F + h\nu = -W + h\nu \)

After escaping metal: \( E < -W + h\nu \)

Maximum kinetic energy: \( E_{max} = h\nu - W \)
Photelectric experiment

- electron inside metal absorbs quantum of light escapes from metal

- initial kinetic energy: $E < E_{\text{max}} = h\nu - W$

- electron can reach collector only if $E > eV$

- photovoltaic current stops flowing when $V$ is increased to $V_{\text{stop}}$

- $eV_{\text{stop}} = h\nu - W$

Prediction (Einstein)
- $V_{\text{stop}}$ increases linearly with $\nu$
- with same slope $\frac{e}{h}$ for all metals

Confirmation: Millikan 1916

Nobel prizes: Einstein 1921, Millikan 1923