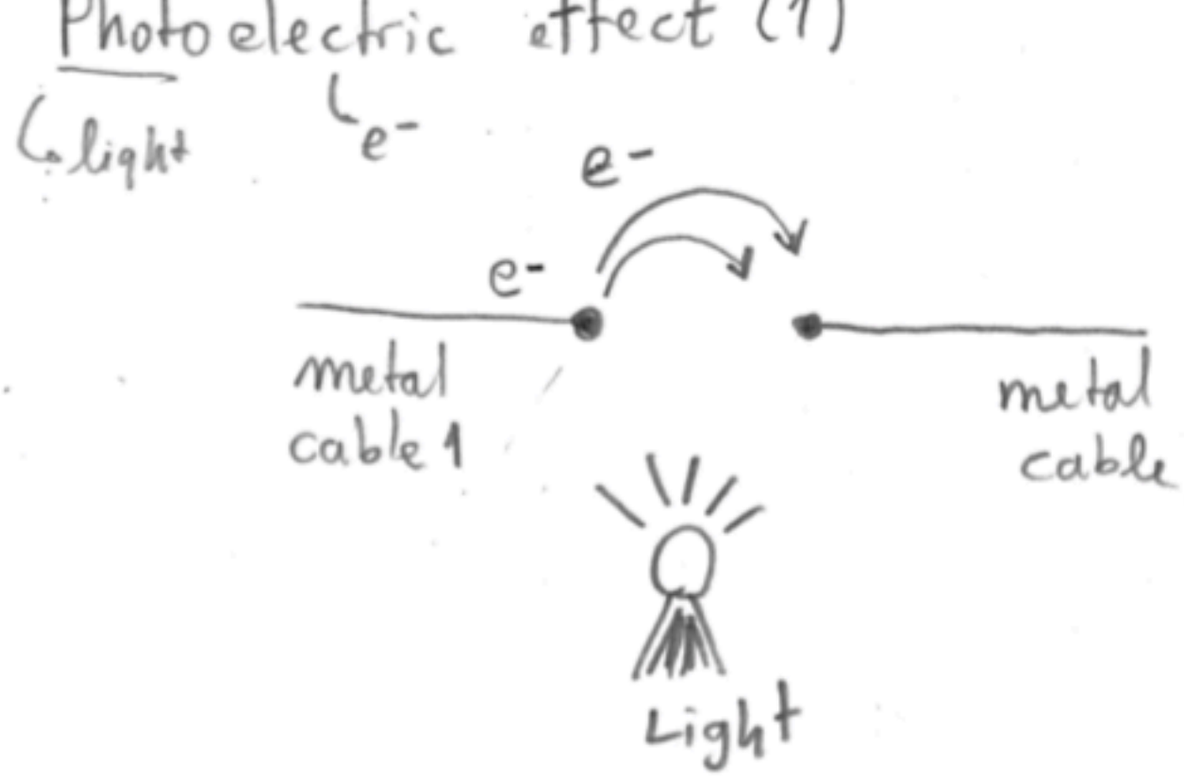
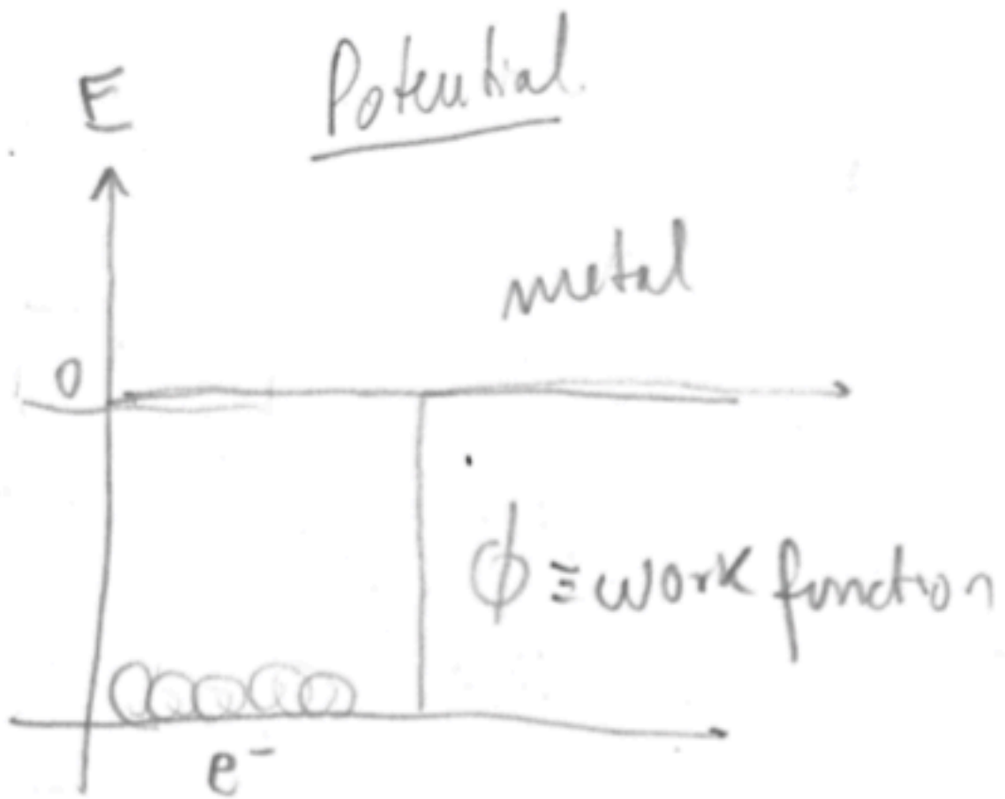
# The Photoelectric Effect

It is a process by which e- can be removed from a metal surface.

- **1887 -** H. Hertz discovers the Photoelectric Effect by irradiating metal plates with light.
- Irradiated polished plates emit photons called photo-electrons.



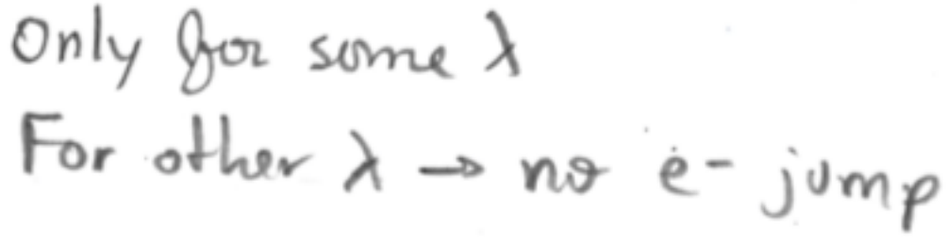
# The Photoelectric Effect

- **Why does the photoelectric effect occurs?**

Classical (wave) view:


- **Did experiments agree?** No.

Photoelectric effect occurs:



# The Photoelectric Effect

- **Einsteins' view:** photons come in packets of energy.

Einstein: Beam of light $\nu$

Photons $\gamma$ $\quad E_\gamma = h\nu$

$h \equiv$ Planck's constant $= 6.63 \times 10^{-34}\ J \cdot s$

$$E_\gamma = h\frac{c}{\lambda} = \frac{2\pi\hbar c}{\lambda}$$

$$\hbar = \frac{h}{2\pi}$$

$\hbar c = 200\ MeV \cdot fm$ → fermi

$fm = 10^{-15}\ m$

$\hbar c = (197.33)$

- **Einsteins' prediction:**

$$E_{e^-} = \frac{1}{2}mv^2 = E_\gamma - \phi = h\nu - \phi$$ ← Einstein's prediction

$\frac{1}{2}mv^2$: Leftover energy

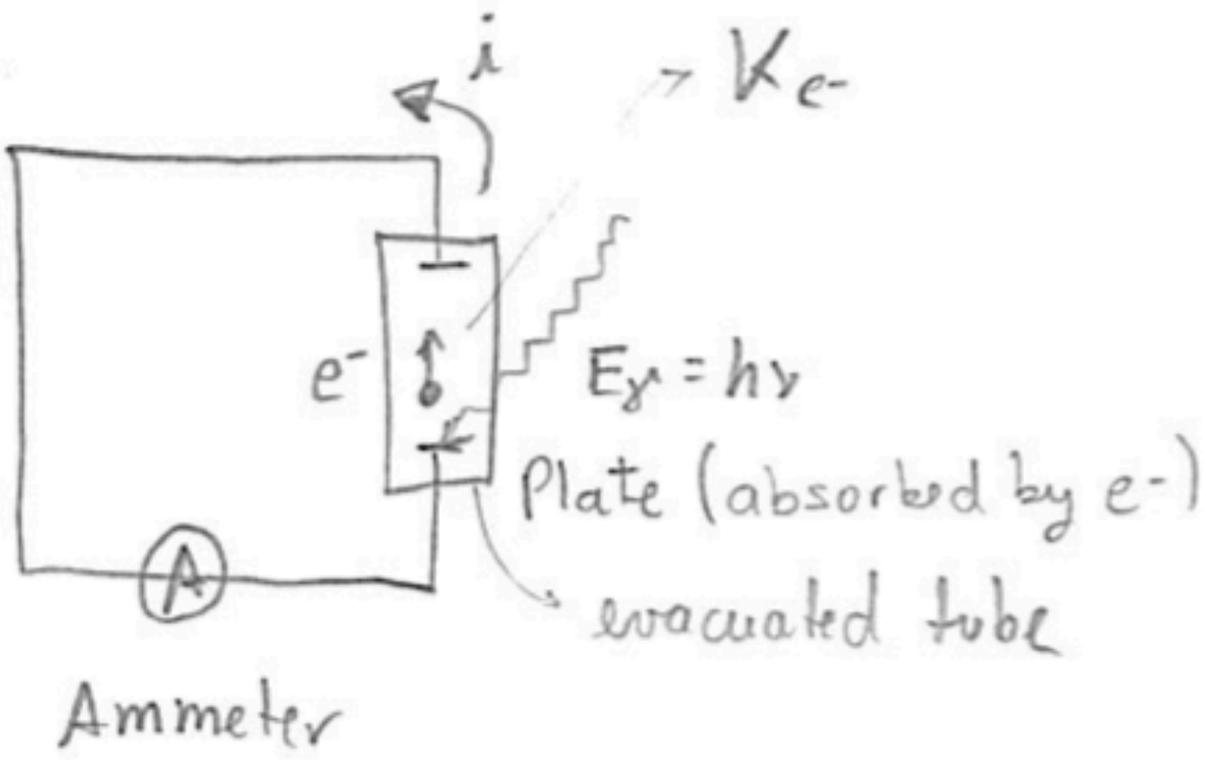
$E_\gamma$: E given to e⁻

$\phi$: E needed to liberate e⁻

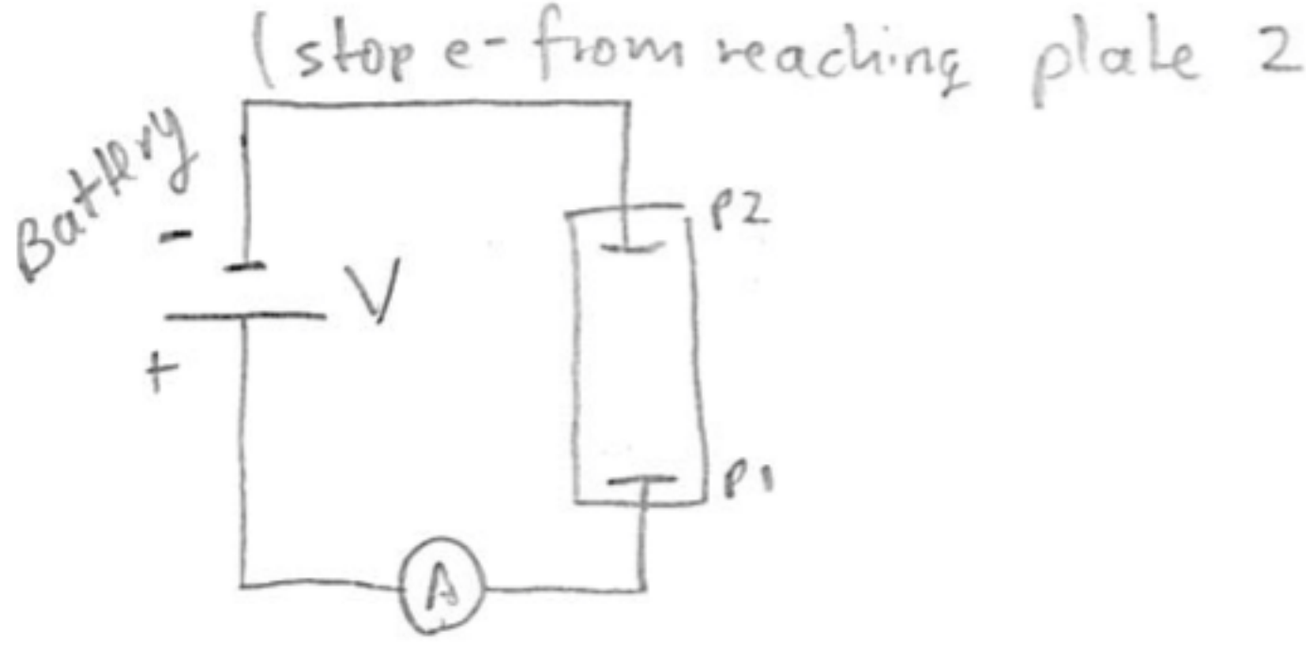
# The Photoelectric Effect

- **1915 -** Millikan's experiment:

**Instance 1** (no battery)



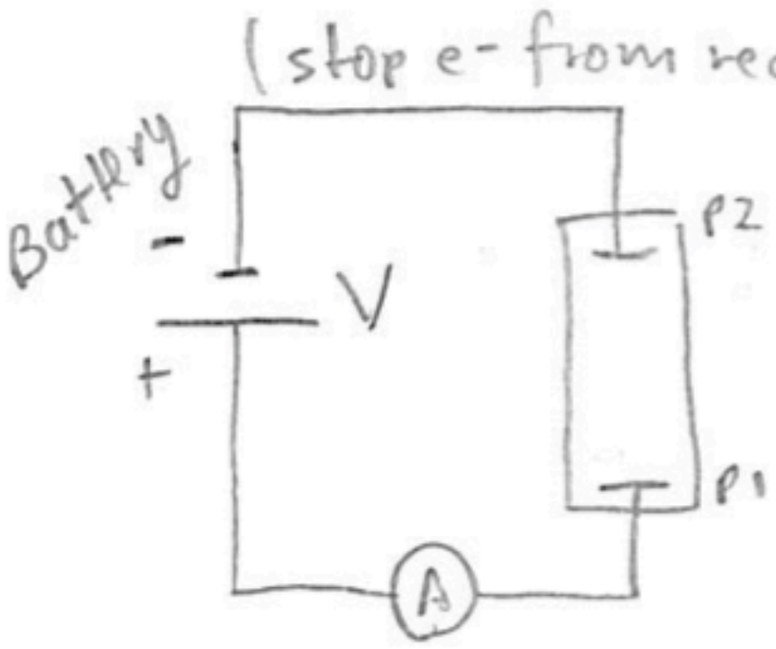

**Instance 2** (battery added)




- There is a threshold frequency above which there is electric current.
- Energy to remove e- from the metal plates depends on the metal, crystalline structure on the surface of the plates.

# The Photoelectric Effect

- **1915 -** Millikan's experiment:




- Increase V until no e⁻ reach plate 2
- Stopping potential ($V_s$)

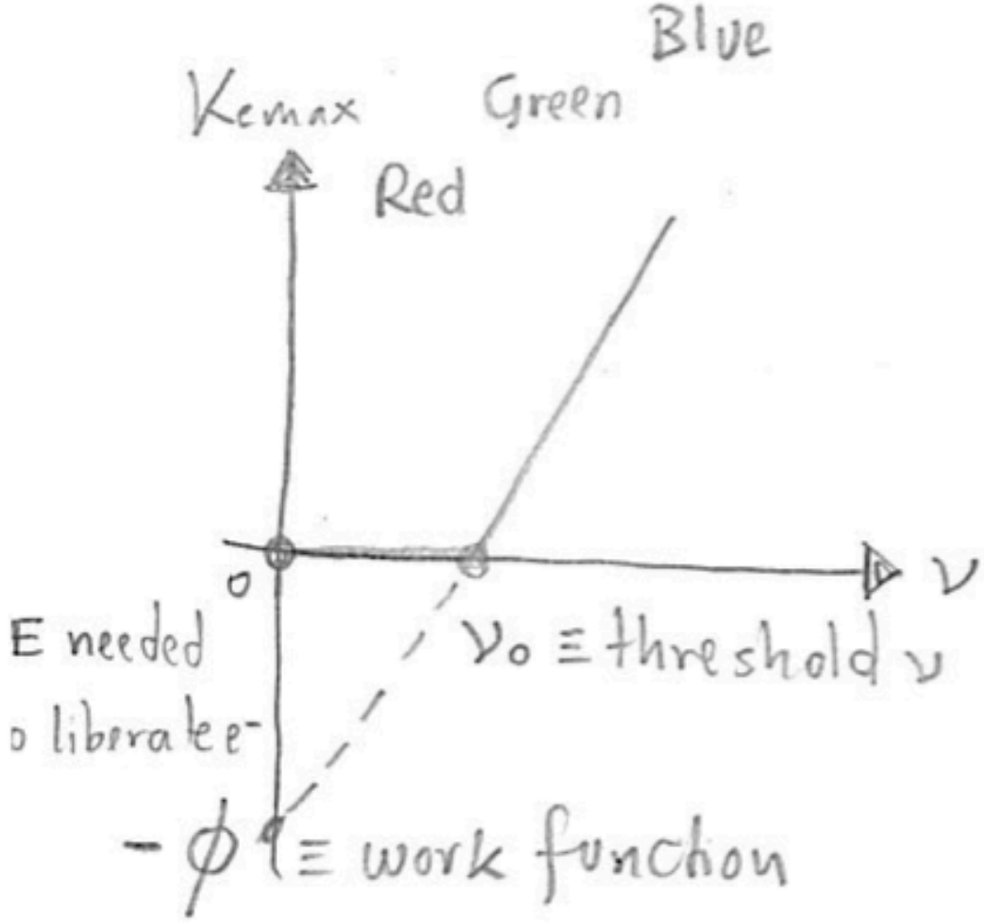
$$-V = \frac{E_c}{q} \Rightarrow V_s = \frac{\frac{1}{2}m v_2}{e} = \frac{K_e}{e}$$

$$\Rightarrow K_e = eV_s \Rightarrow \boxed{K_{emáx} = eV_s}$$

↳ only from the surface

# The Photoelectric Effect

- **1915 -** Millikan's experiment:




$$E_{e^-} = \frac{1}{2}mv^2 = E_\gamma - \phi = h\nu - \phi$$ } Einstein's prediction

$$\Rightarrow \boxed{K_{e\,max} = h\nu - \phi}$$

- $K_{e\,max}$: Leftover energy for e- after liberation
- $h\nu$: E given to e- by γ
- $\phi$: E needed to liberate e-

$$0 = h\nu_0 - \phi$$

$$\nu_0 = \frac{\phi}{h}$$

$$\Rightarrow \boxed{\phi = \nu_0 h}$$

$$\boxed{K_{e\,max} = h(\nu - \nu_0)}$$

Higher Intensity
- More γ do not ↑ $K_{e^-_{max}}$
- 1 γ absorbed by 1 e-
- Light exists as quanta

# The Photoelectric Effect

- **1915 -** Millikan's experiment conclusions:

- Magnitude of the current (# of photo-e-) is proportional to light intensity.

- Energy of photo-e- is independent of light intensity

- Energy of photo-e- increases linearly with the frequency of the light.

**It is NOT easy to understand the above with waves.**

# Light duality

- **1905** - Einstein proposes light's wave/particle duality.

  Light is made of wave-packets, bundles of energy.

  Did not say explicitly that light is a particle.

  It comes in discrete packets of energy -> **photons**

  (Lewis proposes the name photon in the 1920s)

# Discovery of photons

- **Properties of photons:**
  - Photons are packets of energy.
  - Photons are the smallest pieces of light.
  - Energy = constant times a colour.
  - Charge = 0, Rest mass = 0, Spin = 1 (Right and Left)
  - Light speed c, E=pc, inability of experience time-space