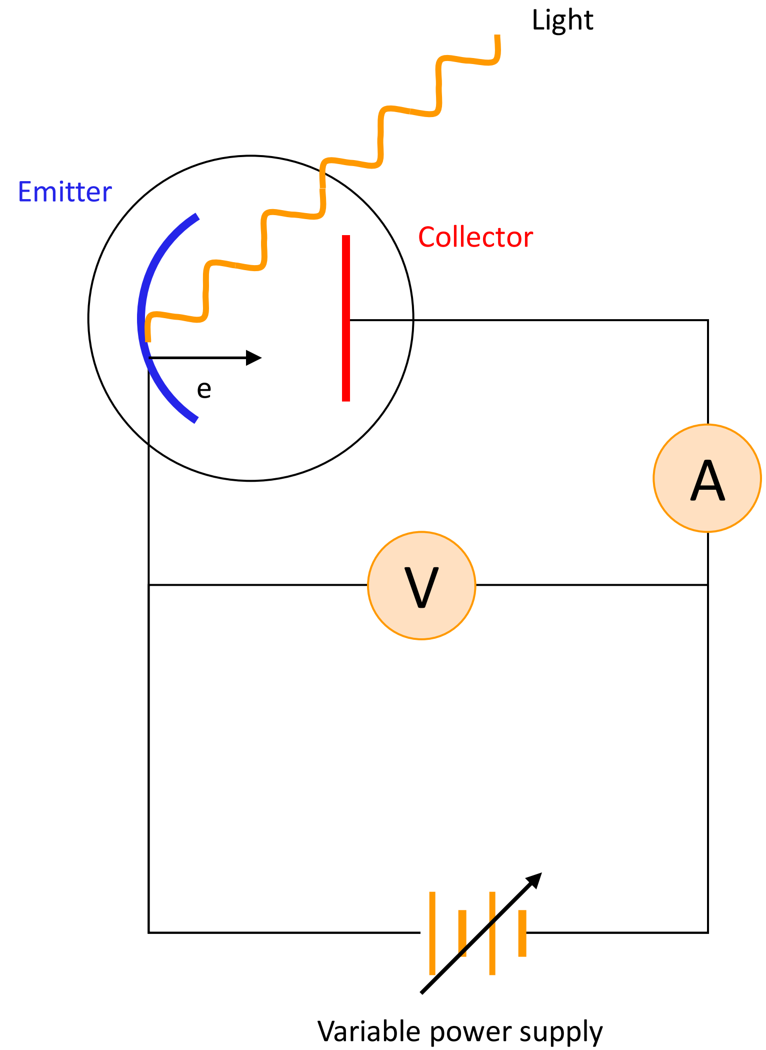
PARTICLE PROPERTIES OF WAVES

1. Electromagnetic Waves.
2. Blackbody Radiation.
3. Photoelectric Effect.
4. What is Light?
5. X-Rays.
6. X-ray Diffraction.
7. Compton Effect.
8. Pair Production.
9. Photons and Gravity.

PHOTOELECTRIC EFFECT

What is photoelectric effect?

A beam of light directed on an emitter ejects electrons (**<u>photoelectrons</u>**) from it. A potential difference is maintained between the emitter and the collector to sweep these electrons. The collection produces a **<u>photoelectric current</u>**.



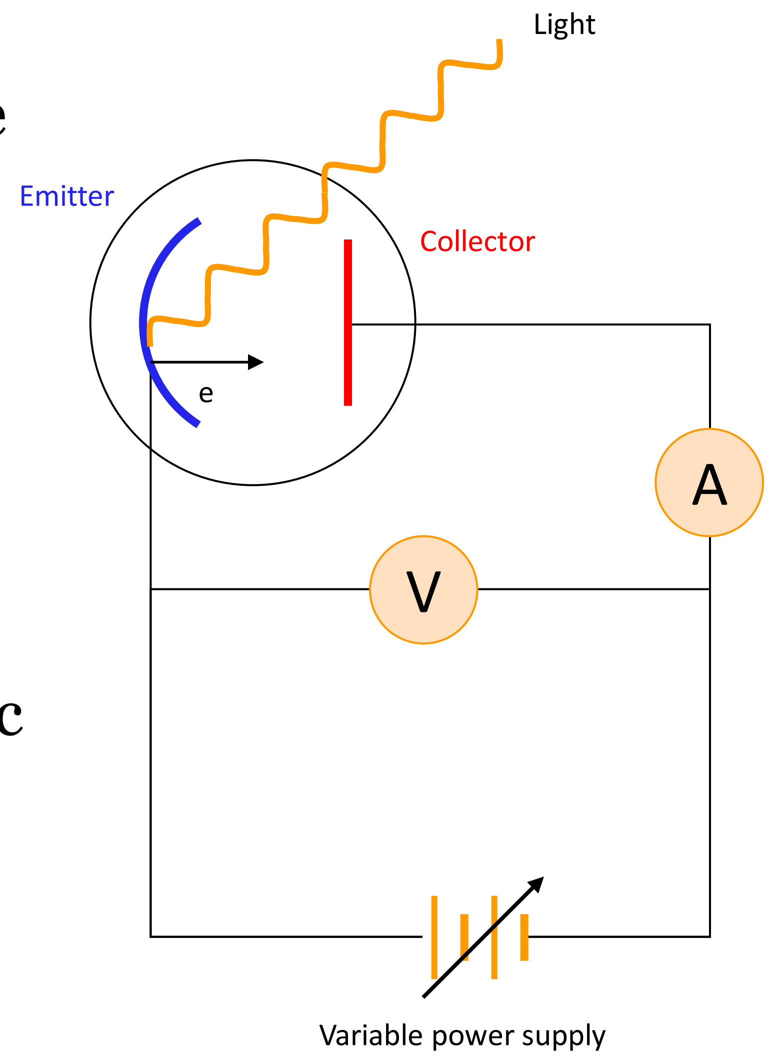
Does this effect comes as a surprise since light is considered as a wave?

PHOTOELECTRIC EFFECT

What are the parameters involved?

- The potential V to slow down the emitted electrons.
- We vary the potential until it reaches a certain value called the **<u>stopping potential</u>** V_{stop}, at which no current is produced.
- When $V=V_{stop}$, the most energetic ejected electrons (with $K = K_{max}$) are turned back before reaching the collector.

$$K_{\max} = eV_{stop}$$



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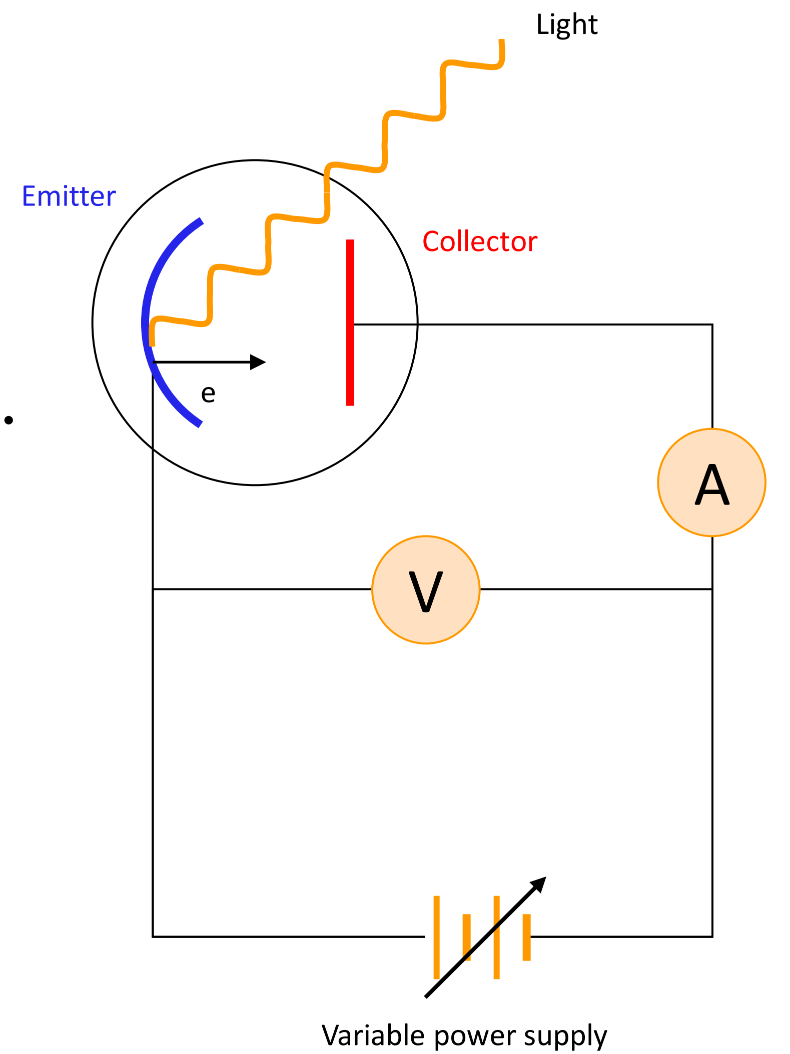
What are the parameters involved?

1. Time.
2. Intensity.
3. Frequency :Wavelength (color).
4. Current i.
5. Voltage V.



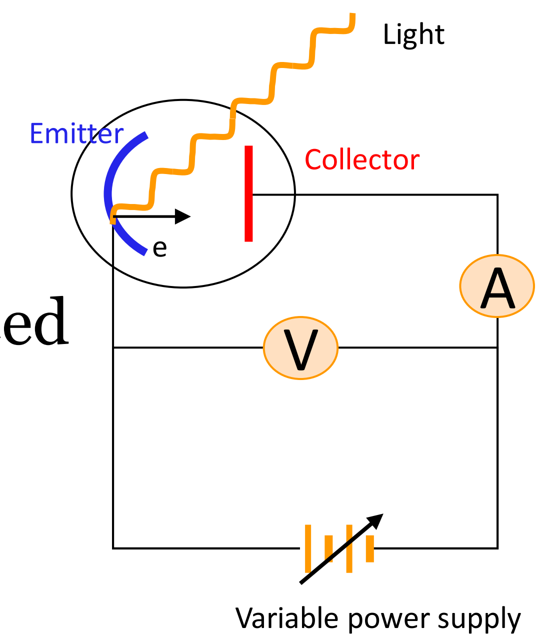
http://phet.colorado.edu/simulations/sims.php?sim=Photoelectric_Effect

PHOTOELECTRIC EFFECT

What was observed in the experiment?

TIME:

There is no time interval between the arrival of light at a metal surface and the emission of photoelectrons.



→For emission, 10^{-6} W/m² of EM energy need to be absorbed by the surface.

→There is 10^{19} atoms in 1 m².

→Each atom will receive 10^{-25} W.

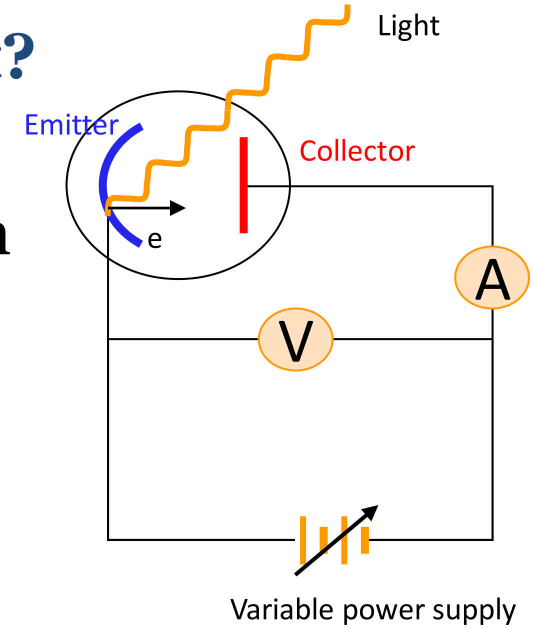
→At this rate, over a month is needed to accumulate the ejection energy!!!!

PHOTOELECTRIC EFFECT

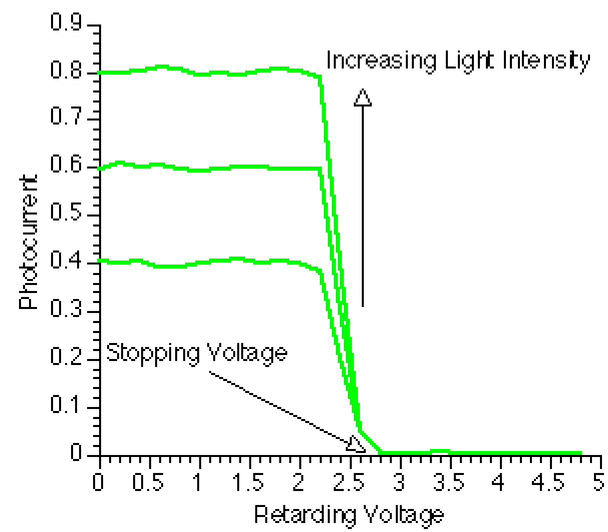
What was observed in the experiment?

INTENSITY:

Bright light yields more photoelectrons than dim light of the same frequency but the electron energy remains the same.



→ EM theory of light predicts that the more intense the light, the greater the energies of the electrons.



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What was observed in the experiment?

FREQUENCY:

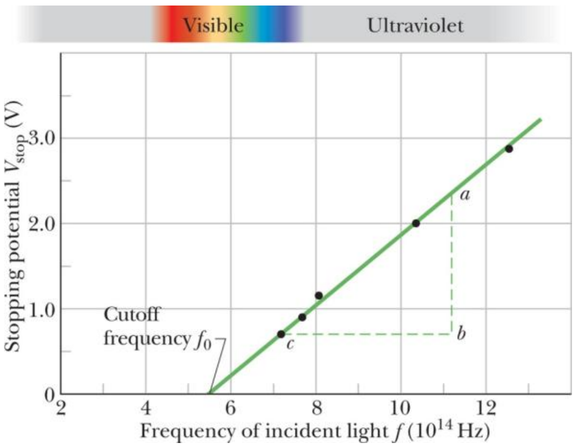
The higher the frequency of light, the more energy the photoelectrons have.

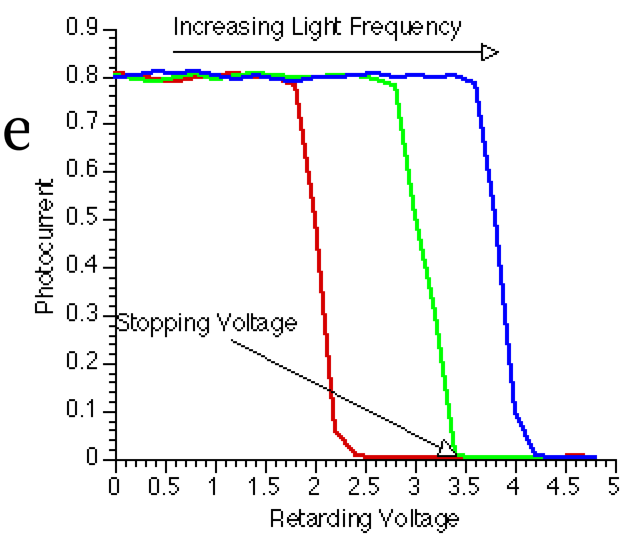
At frequencies below a critical frequency ν_o no electrons are emitted.

ν_o is a characteristic of the material.

Above ν_o the photoelectron energies range from 0 eV to a maximum value that increase linearly with increasing frequency.

→ This observation cannot be explained by EM theory of light.





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How can these results be interpreted?

• Einstein realized that the photoelectric effect could be understood if the energy in light is not spread out over wavefronts but is concentrated in small packets or **photon**.

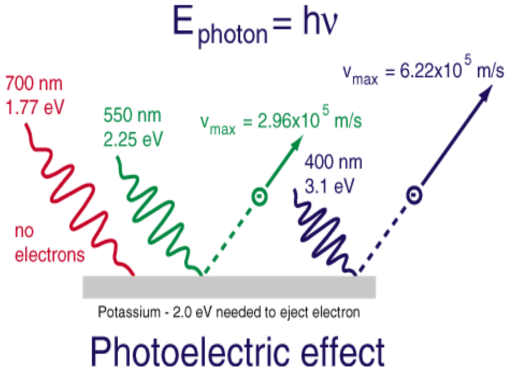
• Each photon of light of frequency ν has an energy of $h\nu$.

• Energy was given in separate quanta but also carried by the waves in separate quanta.

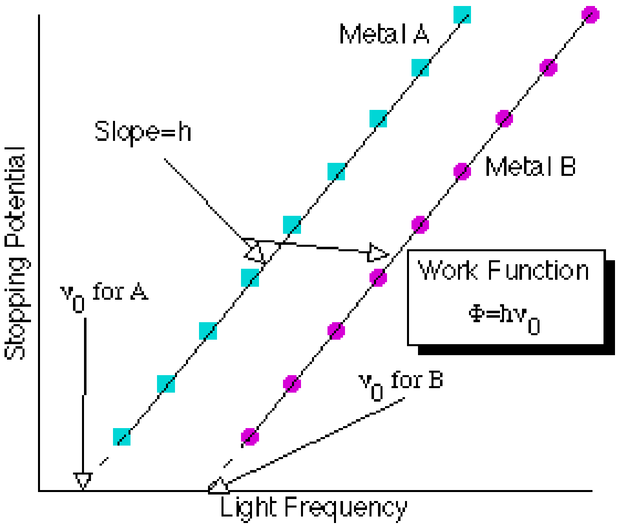
PHOTOELECTRIC EFFECT

What is the meaning of the critical frequency ν_o below which no photoelectrons are emitted ?

- There must be a minimum energy ϕ for an electron to escape from a particular metal surface or else electrons would pour out all the time.
- This energy is called the **work function** of the metal, and is related to ν_o by the formula: $\phi = h\nu_o$
- The photoelectric effect in a given metal should obey the equation: $h\nu = K_{max} + \phi$



$$K_{max} = h\nu - \phi$$



PHOTOELECTRIC EFFECT

Example 2.2:

Ultraviolet light of wavelength 350 nm and intensity 1 W/m^2 is directed at a potassium surface.

(a) Find the maximum KE of the photoelectrons.

(b) If 0.5 percent of the incident photons produce photoelectrons, how many are emitted per second if the potassium surface has an area of 1 cm^2?

PHOTOELECTRIC EFFECT

Remember….

The energies of electrons liberated by light depend on the frequency of light (not its intensity)…