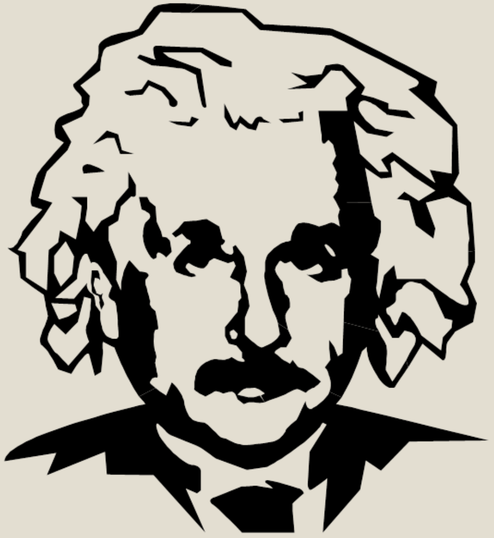
The Photoelectric Effect



Experiment

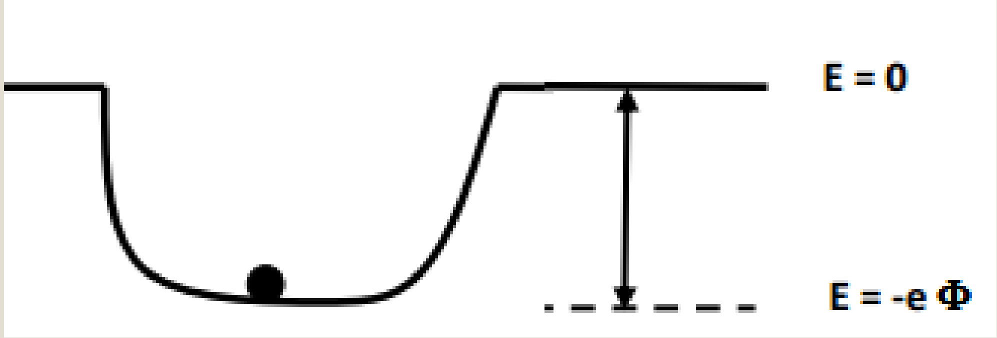
- Objective of the experiment
- Theory
- Working formula
- Experimental Data
- Graphical Analysis
- Calculation
- Results
- Precautions & Discussion

Objective of the experiment

I. To determine Planck's constant '*h*'
II. To determine the work function "φ" of metals.

Theory

An electron in a metal can be modelled as a particle in an average potential well due to the net attraction and repulsion of protons and electrons. The minimum depth that an electron is located in the potential well is called the work function of the metal, Φ. It is a measure of the amount of work that must be done on the electrons (located in the well) to make it free from the metal. Since different metal atoms have different number of protons and different values for electrical properties, the work function (Φ) depends on the metal.



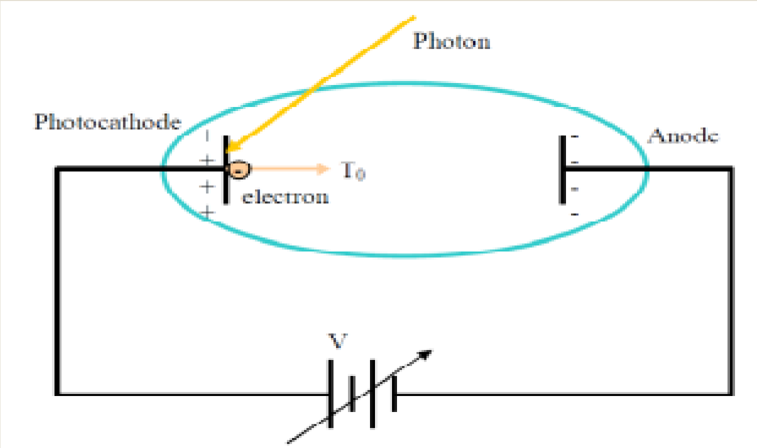
Theory

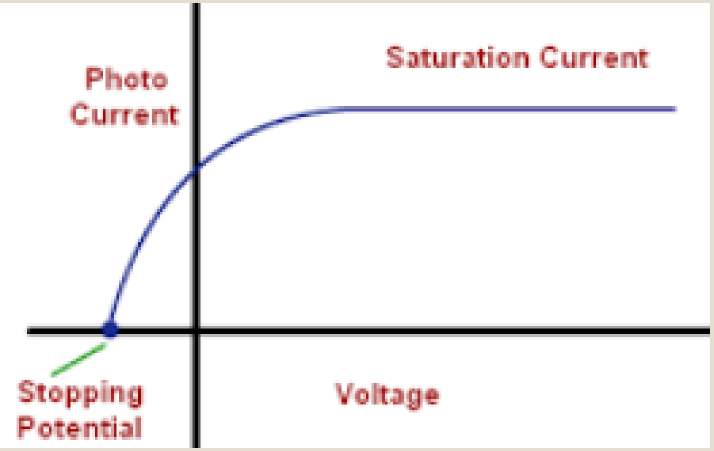
When a photon with frequency "ν" strikes the surface of a metal, it imparts all of its energy to a conduction electron near the surface of the metal. If the energy of the photon (hν) is greater than the work function (Φ), the electron may be ejected from the metal. By conservation of energy, the maximum kinetic energy with which the electron could be emitted from the metal surface T_{max}, is related to the energy of the absorbed photon hν, and the work function Φ, by the relation,

$$T_{max} = \frac{1}{2} m v^2_{max} = h\nu - e\Phi$$

Theory

Now, if we consider the case of electrons being emitted by a photocathode in a vacuum tube, all emitted electrons are slowed down as they approach the anode. If the voltage just stops the electrons (with maximum kinetic energy T_{max}) from reaching the anode. The voltage required to do this is called the “stopping potential" (V_o).





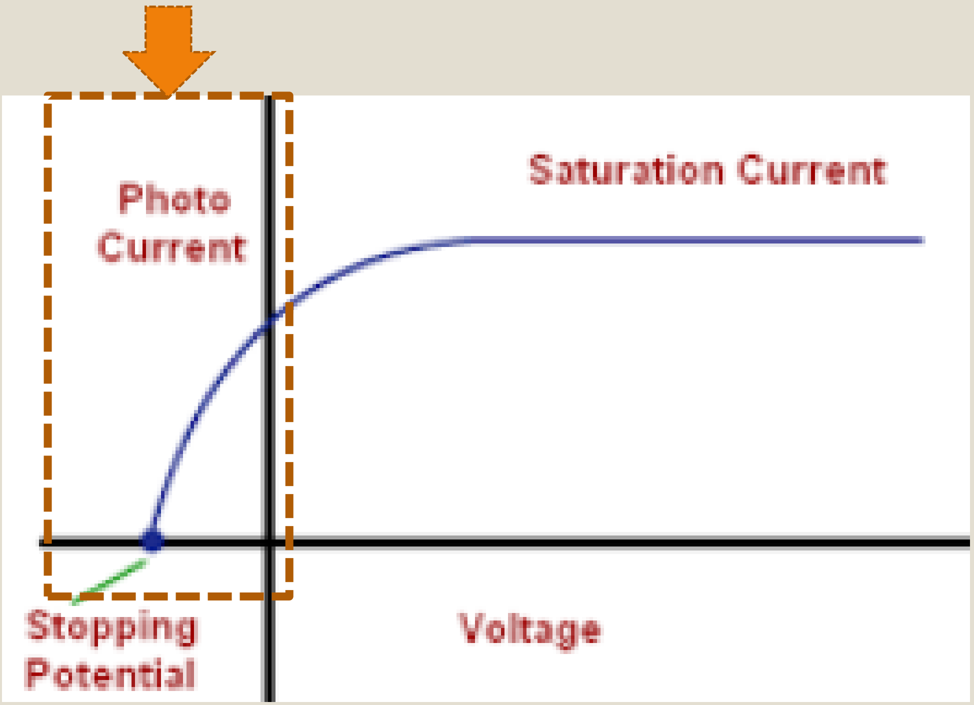
$$T_{max} = \frac{1}{2} m v^2_{max} = h\nu - e\Phi$$

$$eV_0 = h\nu - e\Phi$$

$$\boxed{V_0 = \frac{h}{e}\nu - \Phi}$$

Working formula

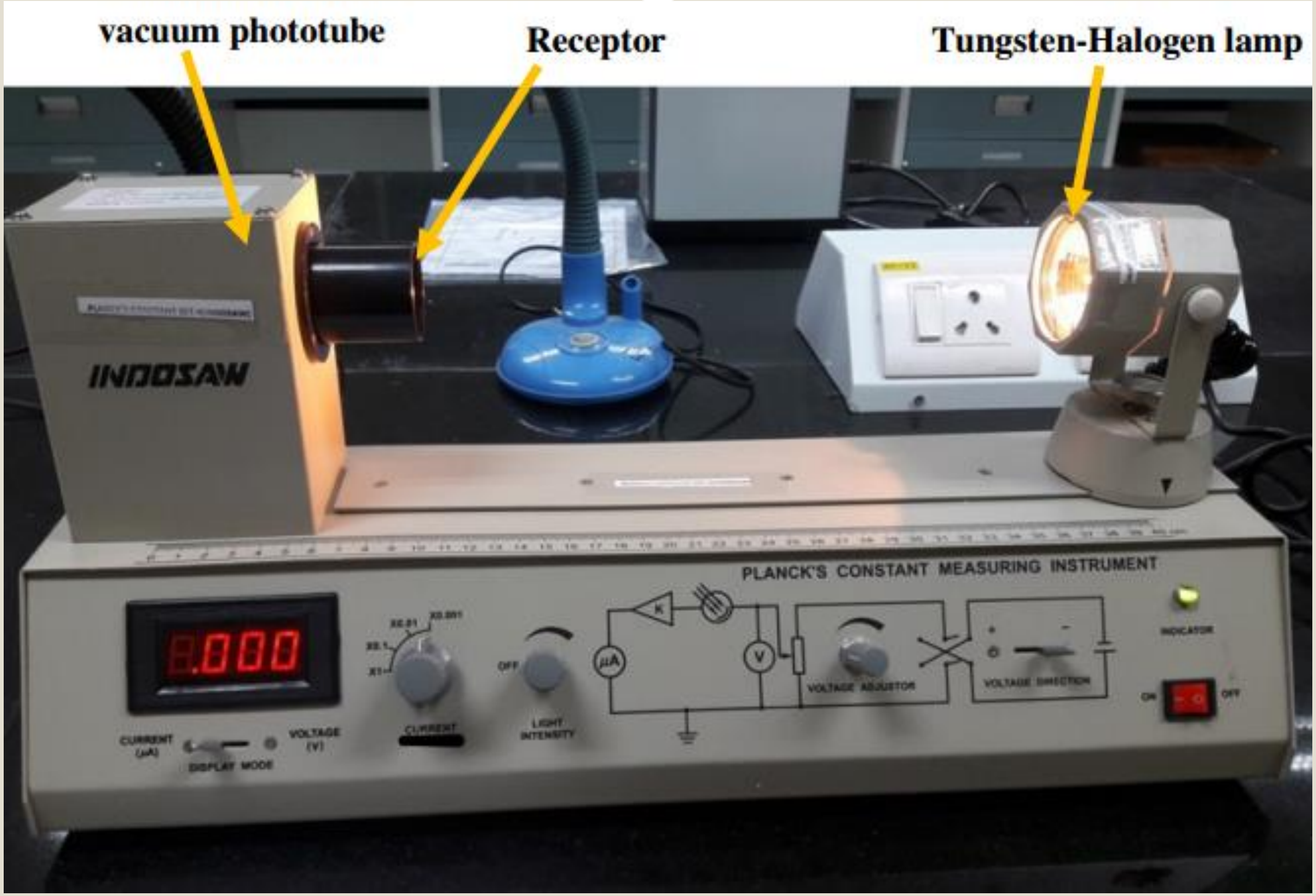
We will focus on this part of the Photo current vs. Voltage curve



$$\boxed{V_0 = \frac{h}{e}\nu - \Phi}$$

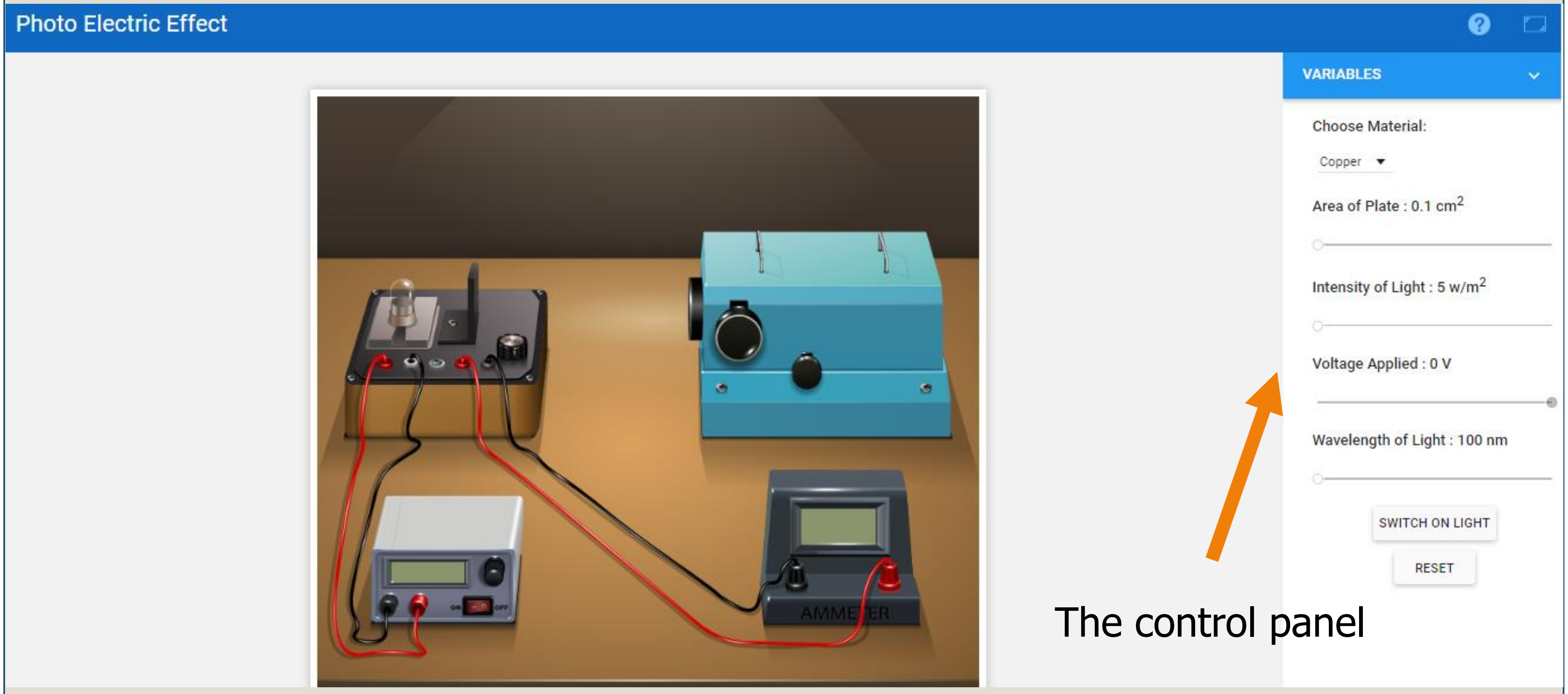
Working formula

Experimental Set-up*

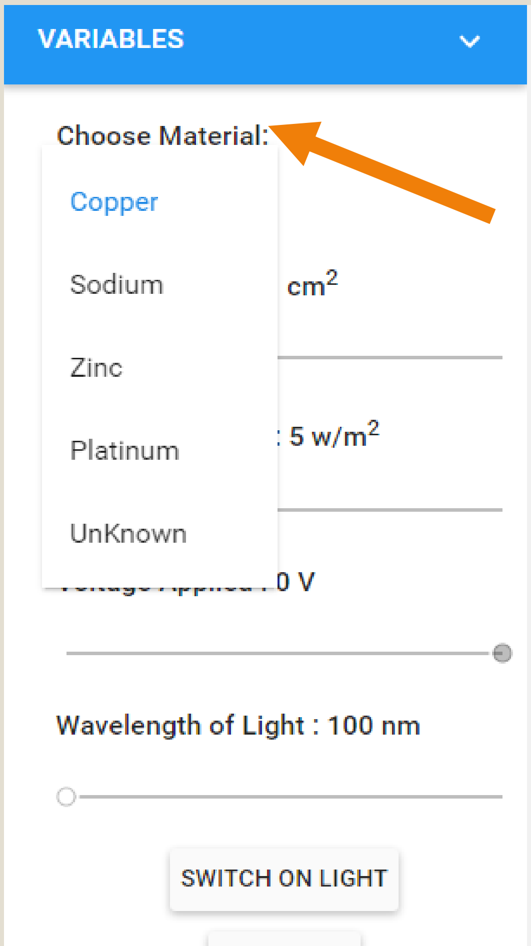


Experimental Set-up (Virtual)

Link: http://mpv-au.vlabs.ac.in/modern-physics/Photo_Electric_Effect/experiment.html



Experimental Set-up (Virtual)



Experimental Set-up (Virtual)

VARIABLES

Choose Material:

Copper

Area of Plate : 0.1 cm^2

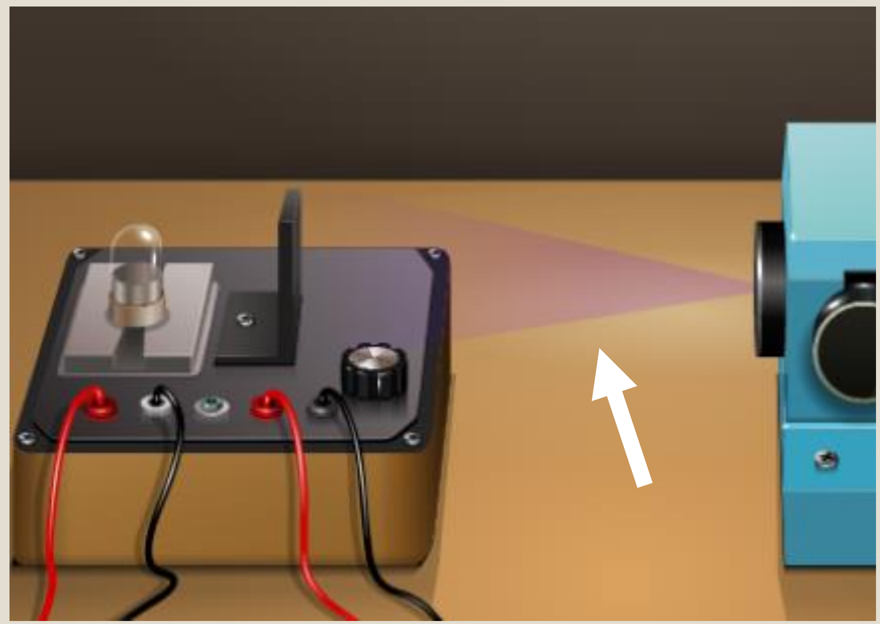
Intensity of Light : 5 w/m^2

Voltage Applied : 0 V

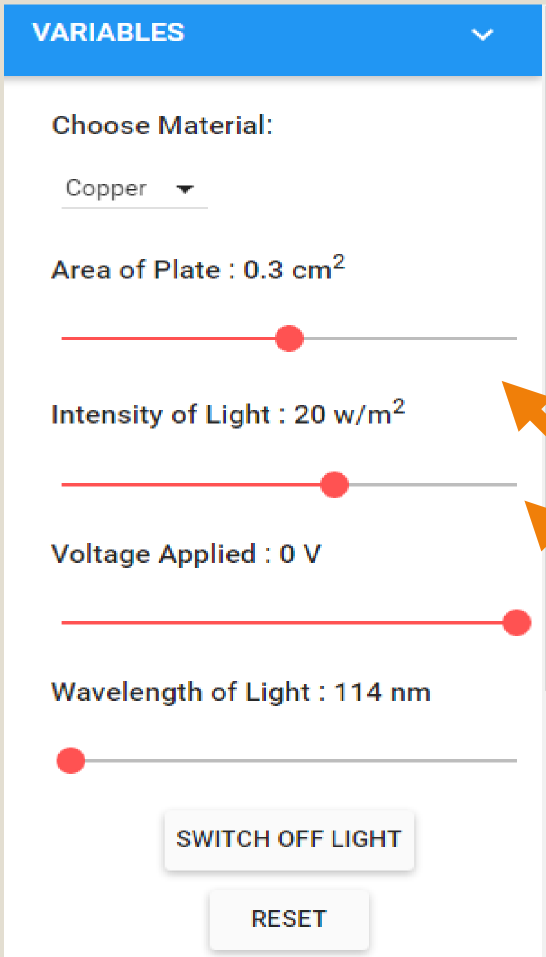
Wavelength of Light : 100 nm

SWITCH ON LIGHT

RESET

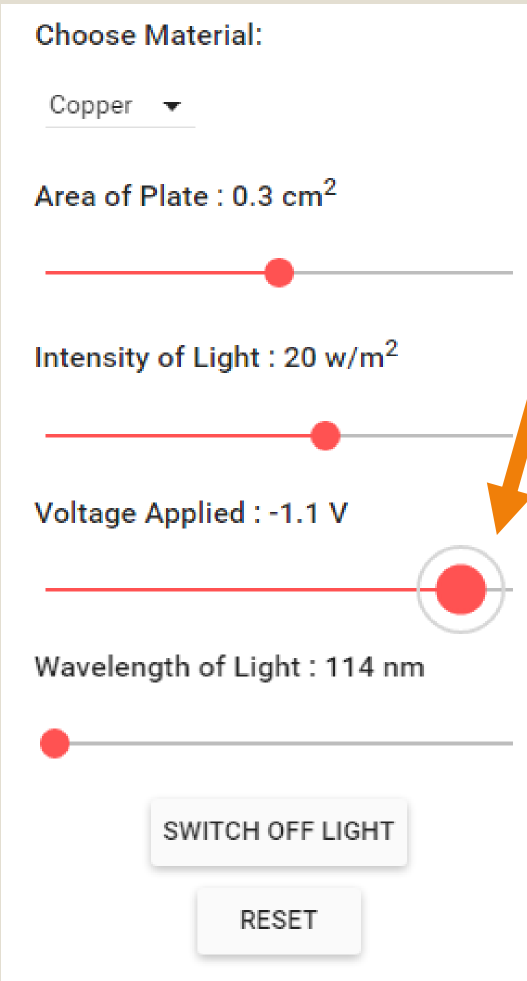


Experimental Set-up (Virtual)

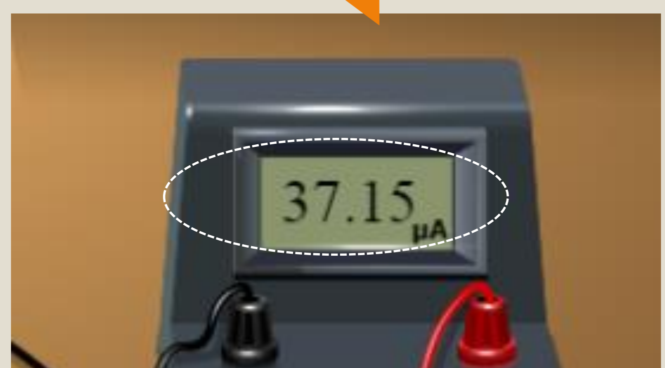


- Set all the three knobs.
- Fix area and intensity at a reasonable value. You should not change these while taking data.
- Voltage should be maximum (i.e., 0).
- Record data for current.

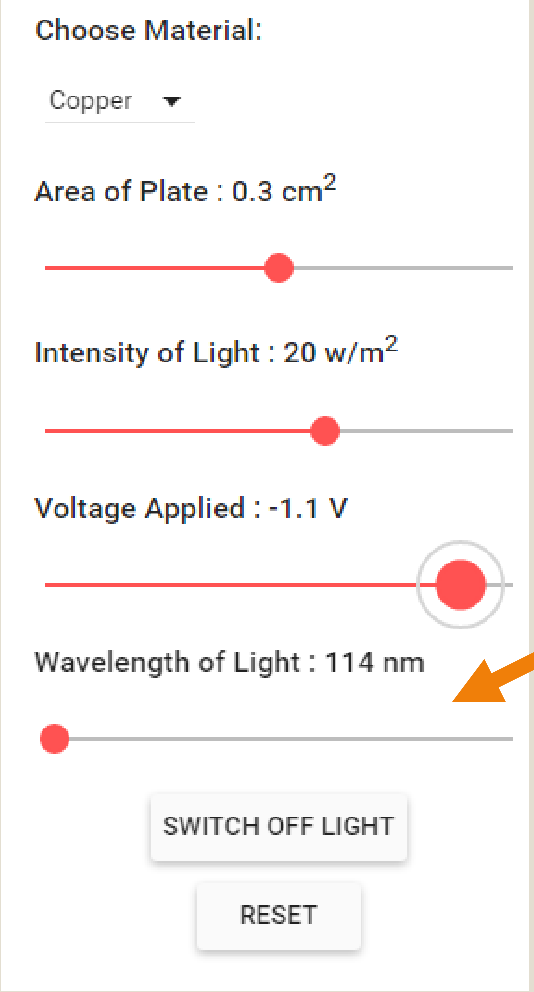
Experimental Set-up (Virtual)



- Vary the voltage and record the current till the value of current becomes zero.
- Record data for current for each voltage.



Experimental Set-up (Virtual)



- Vary the voltage and record the current till the value of current becomes zero.
- Record data for current for each voltage.
- This provides you with data to plot the I-V characteristics for the wavelength (or frequency).
- Repeat for at least 3-4 frequencies.

Experimental Data

Chosen colors and corresponding wavelengths:

Colour					
Wavelength (nm)					

Table 1: For I-V characteristics

(To be prepared for all frequencies)

Voltage (V)					
Current (μA)					

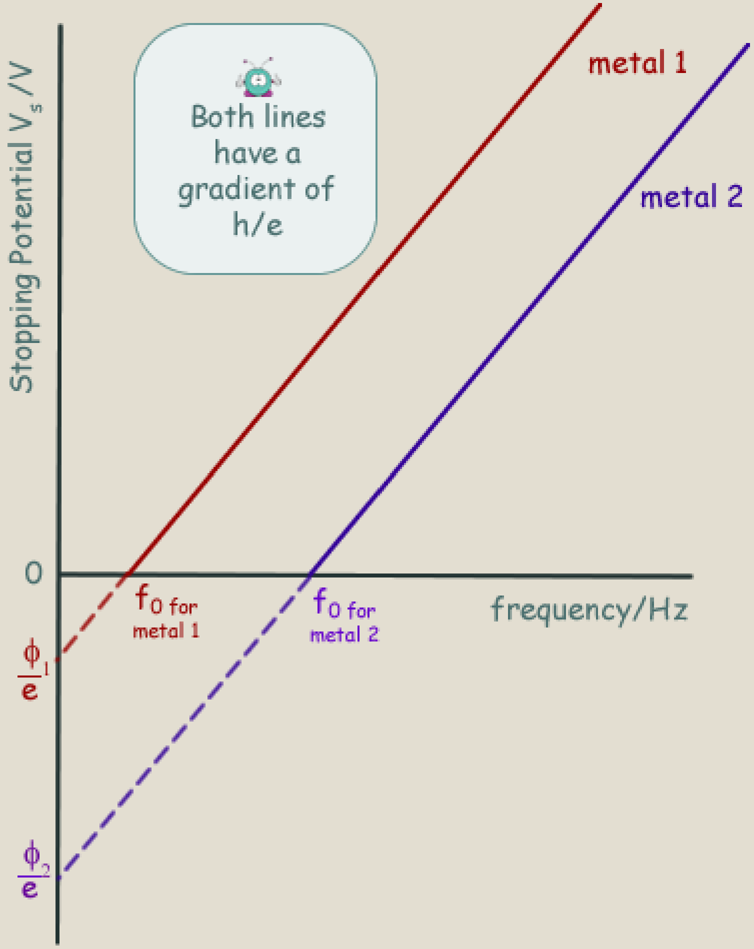
Table 2: Data for stopping potential ~ wavelength

Stopping potential (V)					
Wavelength (nm)					

Graphical Analysis

Graph:

1. Experiment has to be repeated for at least TWO different metals.
2. Plot I~ V characteristics for different wavelengths.
3. Plot Stopping potential ~ frequency (i.e., c/wavelength). A sample graph is shown.



Calculation, Result, Precautions

Graph:

Intercept	?
Slope	?

- Calculate the slope and intercept using the working formula.
- Determine h. Take an average.
- Determine φ for different metals.

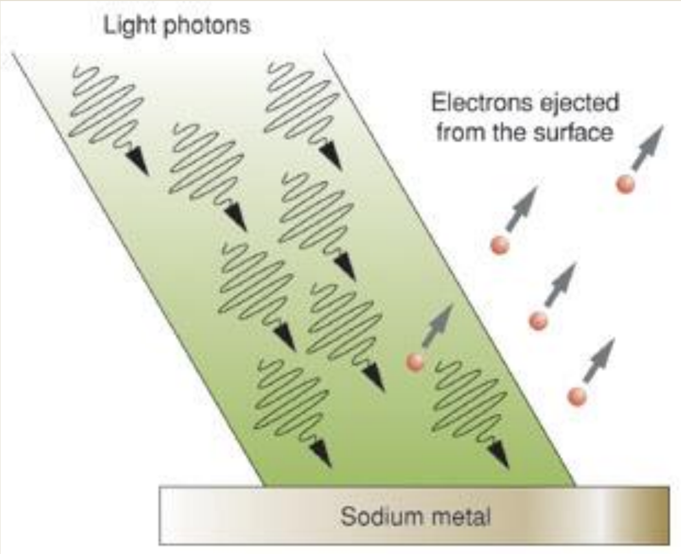
Extra Slides for discussion on Photoelectric Effect Phenomena

(Could be added at the beginning as per need of the instructor)

Photo (light) + electric

- A photoelectric effect is any effect in which light energy is converted to electricity.

- First explained by Albert Einstein in 1905

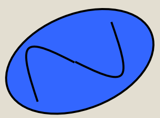


Photoelectric Effect

Metal Foil

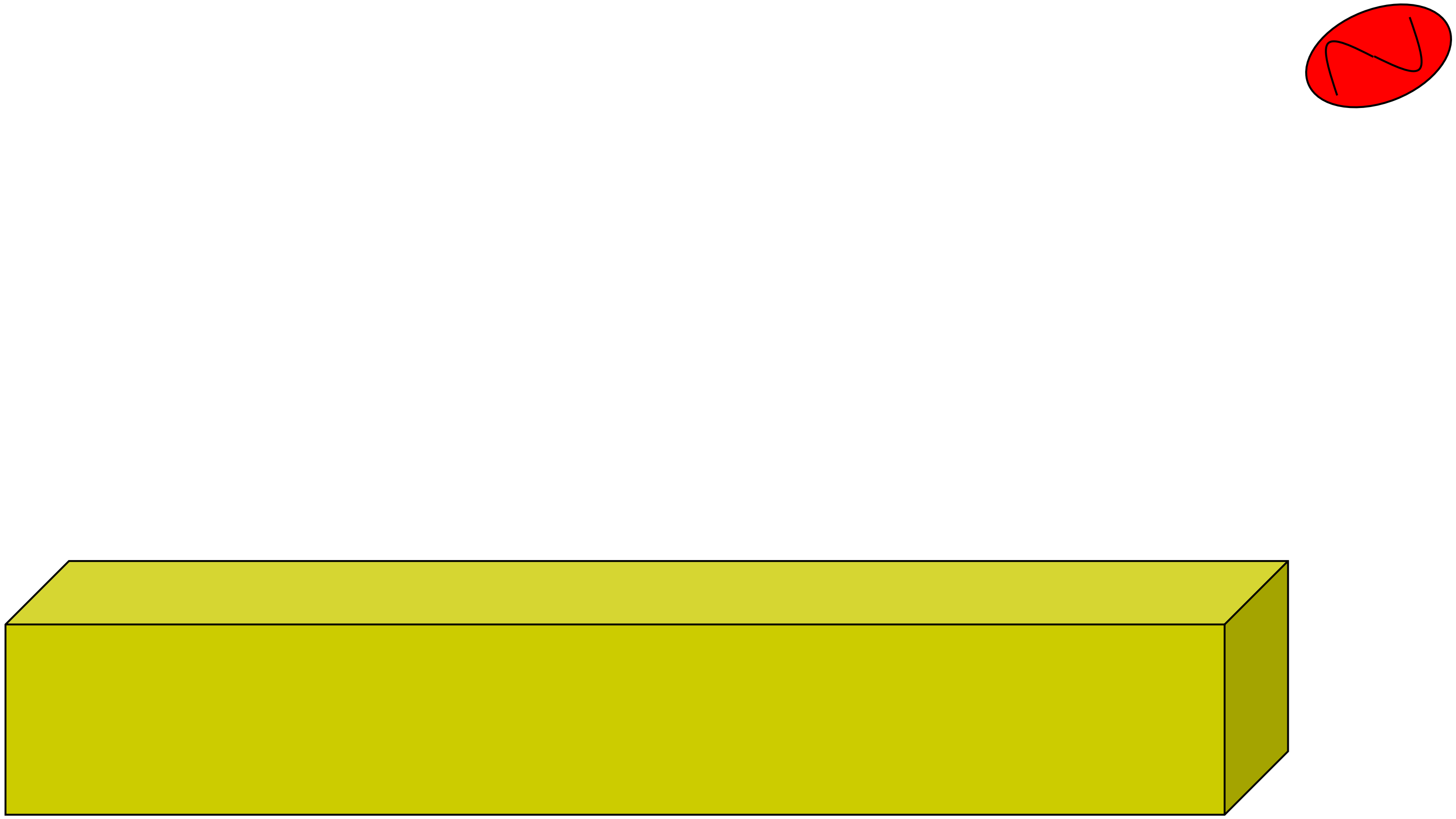
Photoelectric Effect

- As blue light strikes the metal foil, the foil emits electrons.



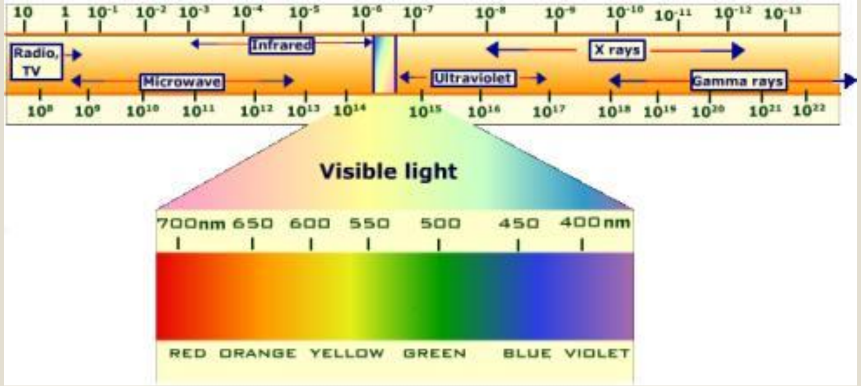
Metal Foil

Photoelectric Effect



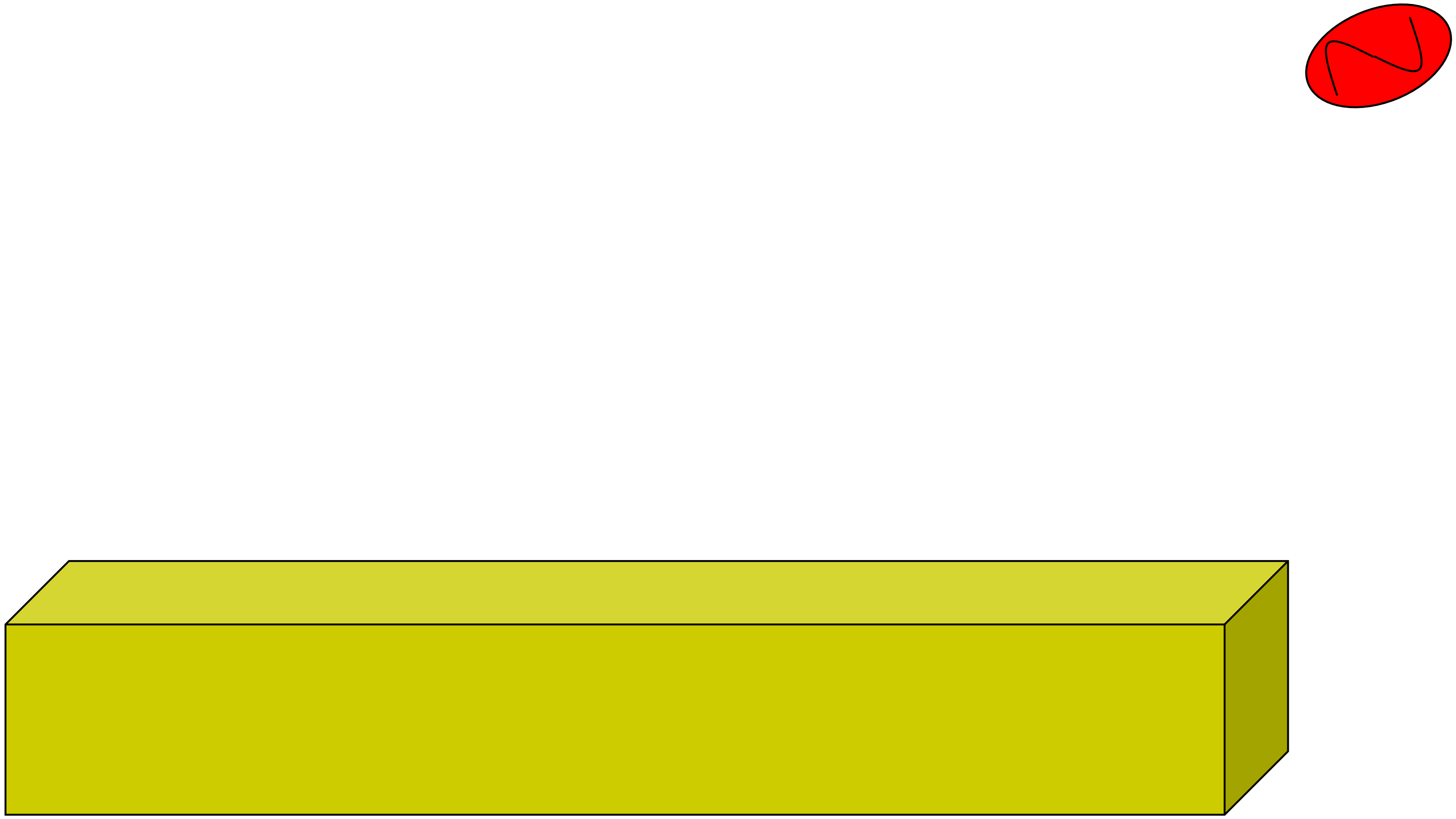
Photoelectric Effect

- <u>When red light hits the metal foil, the foil does not emit (give off) electrons.</u>
- <u>Blue light has more energy than red light.</u>



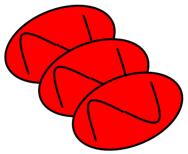
- How could we get more energy into the red light?
- Try increasing the brightness (intensity).

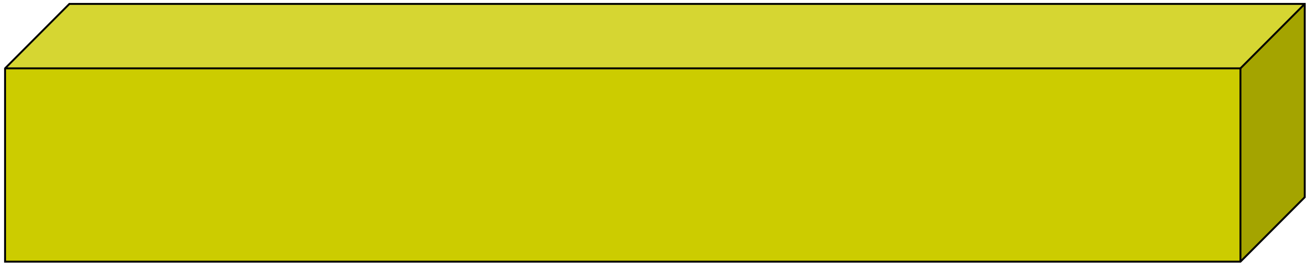
Photoelectric Effect



Photoelectric Effect

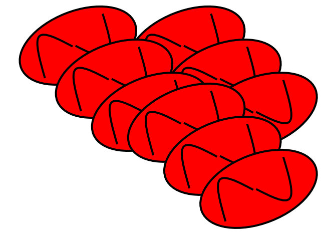
- That didn't work
- Maybe its still not bright (intense) enough.

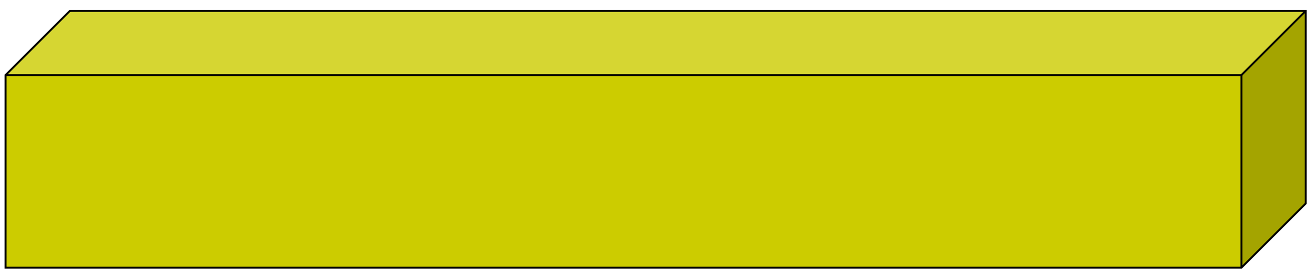




Photoelectric Effect

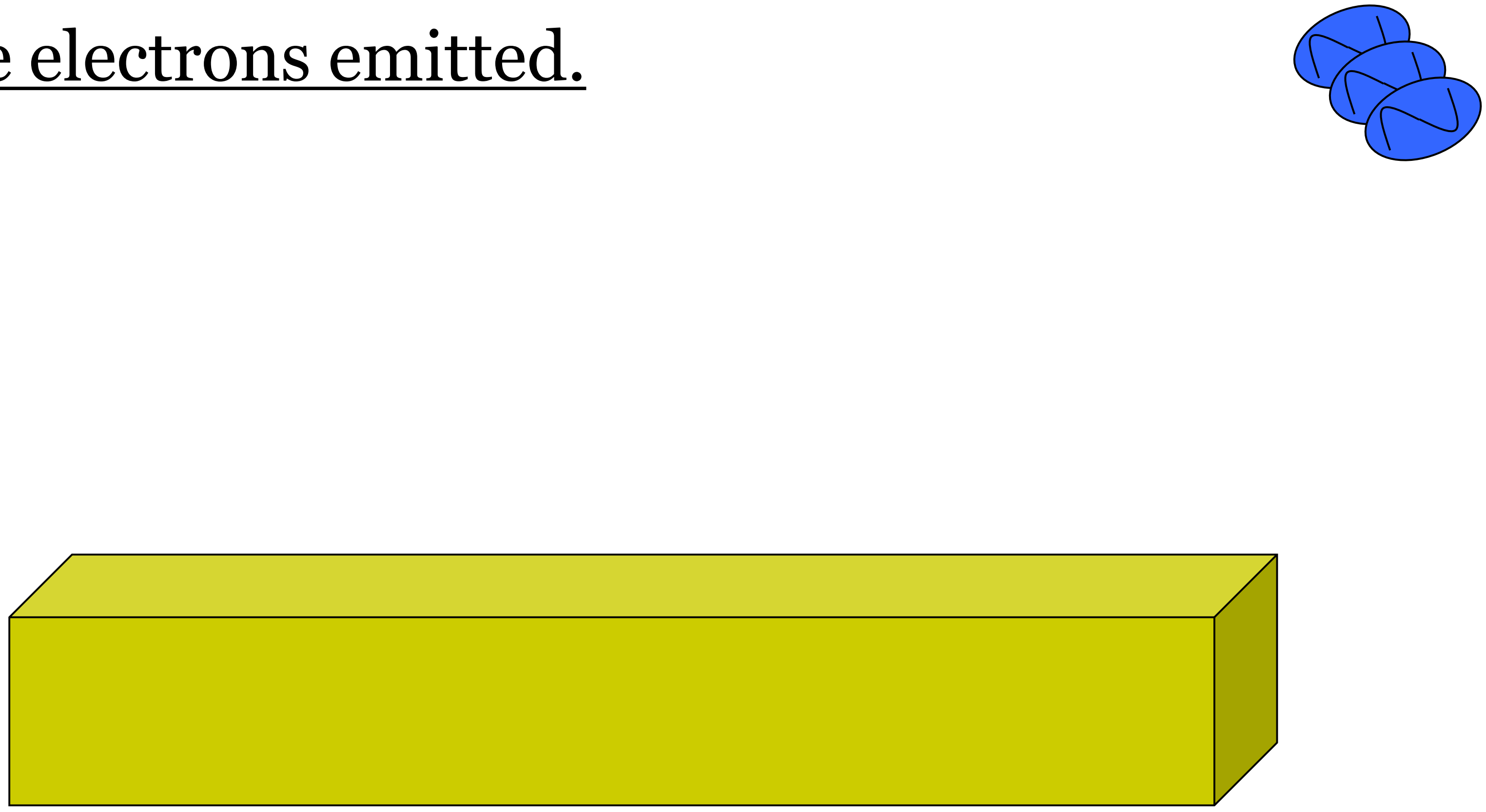
- Still not working.
- What happens with brighter (more intense) blue light?





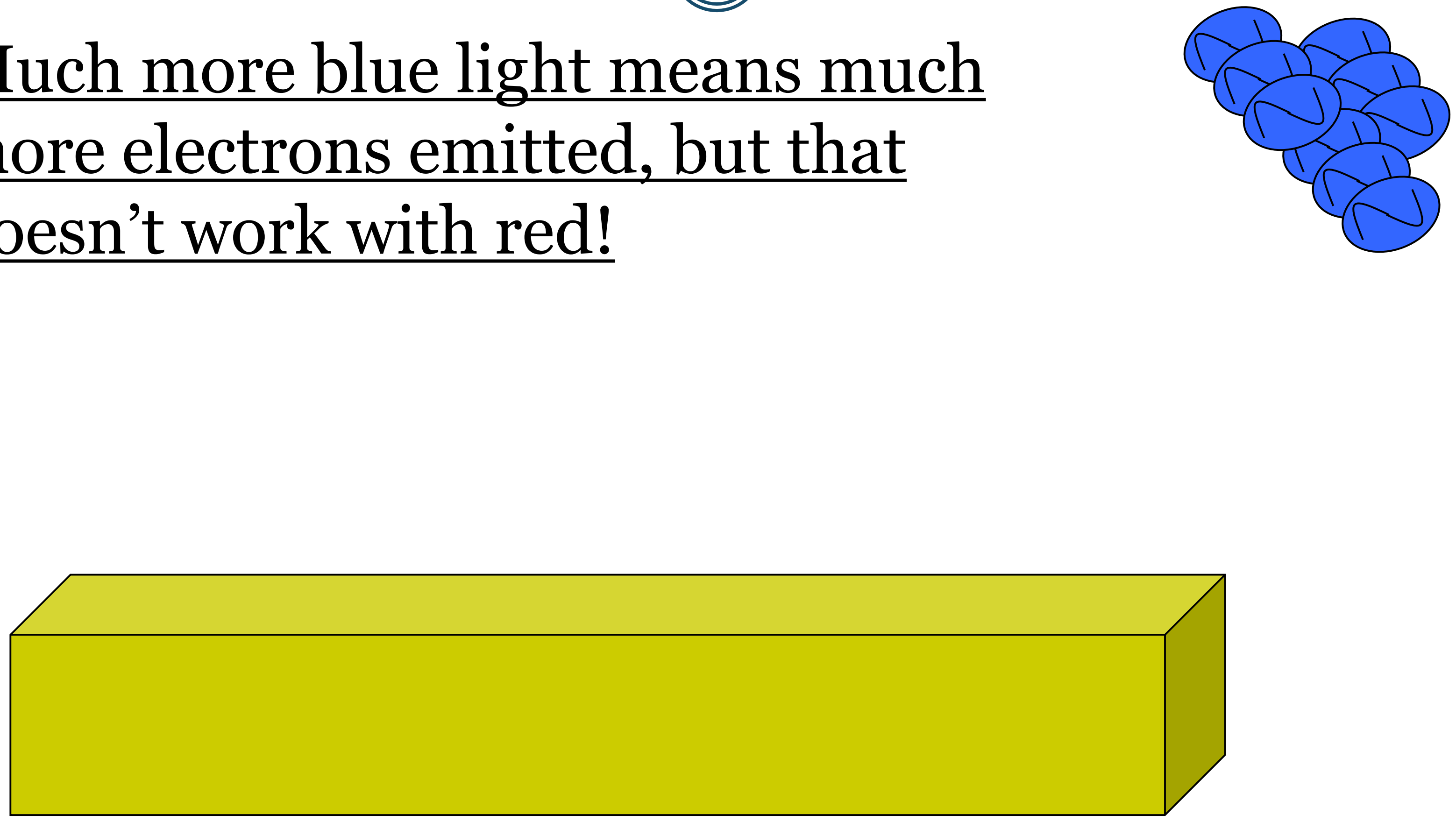
Photoelectric Effect

- <u>More electrons emitted.</u>



Photoelectric Effect

- Much more blue light means much more electrons emitted, but that doesn't work with red!



Photoelectric Effect

- **High** FREQUENCY light even from a dim source <u>can eject electrons</u> from a photosensitive metal

- Low FREQUENCY light, even very bright (very intense) <u>cannot dislodge electrons</u>

Photoelectric Effect

- Light, like all other radiation, is made up of small particles called photons.

- The higher the frequency, the more energy the photons have.

- Einstein stated that **light interacts with matter as a stream of particle-like photons.**

- Einstein received the Nobel Prize for this discovery.

Photoelectric Effect

- If a photon hits an atom of a certain material, it may be absorbed by an electron of that material.
- However, if the photon has enough energy, the electron is ejected, or emitted, from the atom.
- In this way, light energy changes into electrical energy.

Photoelectric Effect

- If wires are attached to a photoemittive material, the electrons can flow along the wires, forming an electric current.