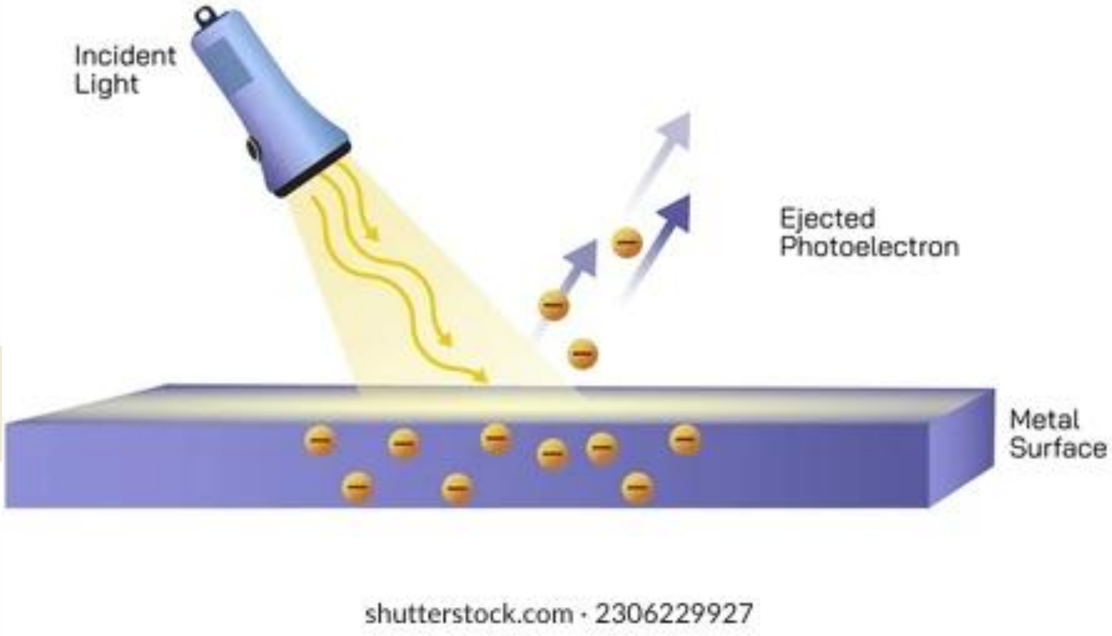


Chapter 16

Corpuscular Aspect of Light

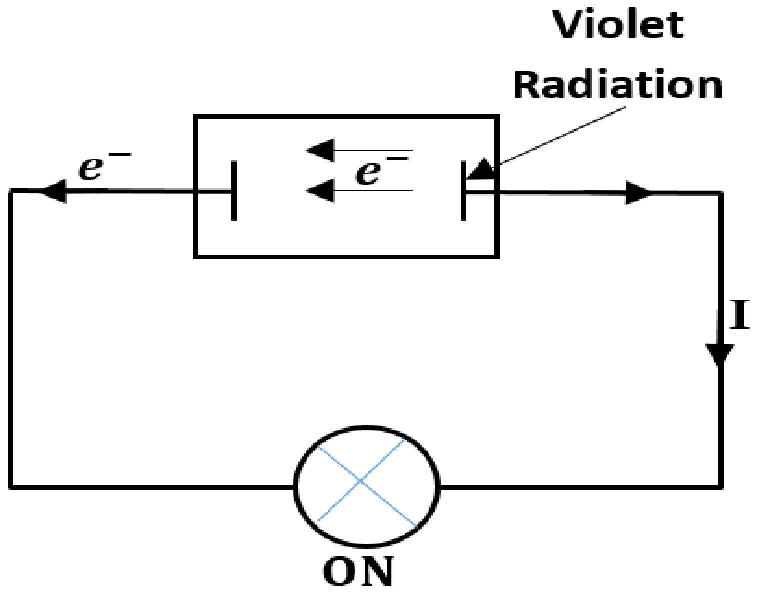
Prepared and Presented by: Mr. Mohamad Seif

OBJECTIVES

1. Emission of electrons by radiations
2. Definition of photoelectric effect
3. Corpuscular (particle) aspect

Emission of electrons by radiations

Experiment 1



When the cathode is illuminated by Violet radiation, the lamp turns ON.
This means an electric current is traversing the circuit.
Cathode emits electrons.

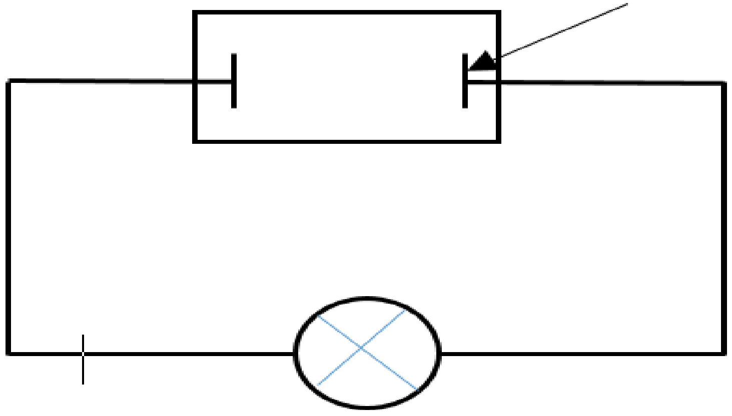
Conclusion:

The electrons are given energy from the violet radiation successively.

Emission of electrons by radiations

Experiment 2

When the Cathode is illuminated by red radiation, the lamp is off.
This means no electric current traversing the circuit. No emission of electrons.



Conclusion:

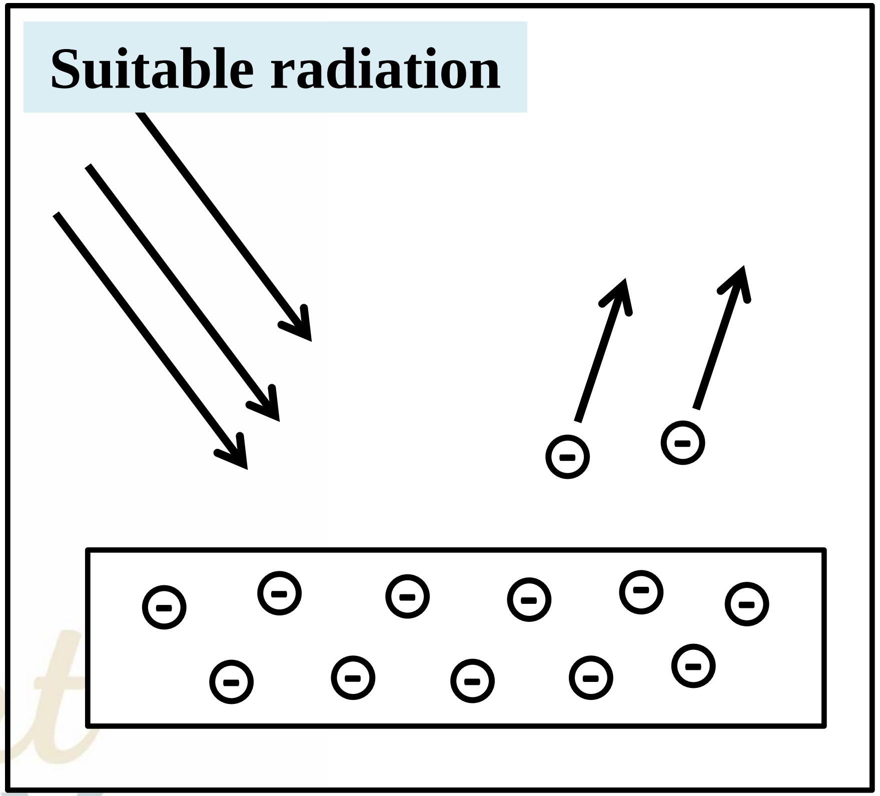
The electrons are not emitted, so the given energy is not sufficient even when illuminated for long time.
This shows contradiction of wave aspect of light.

Definition of photoelectric effect

A metal can emit electrons when exposed to a suitable radiation.

Definition:

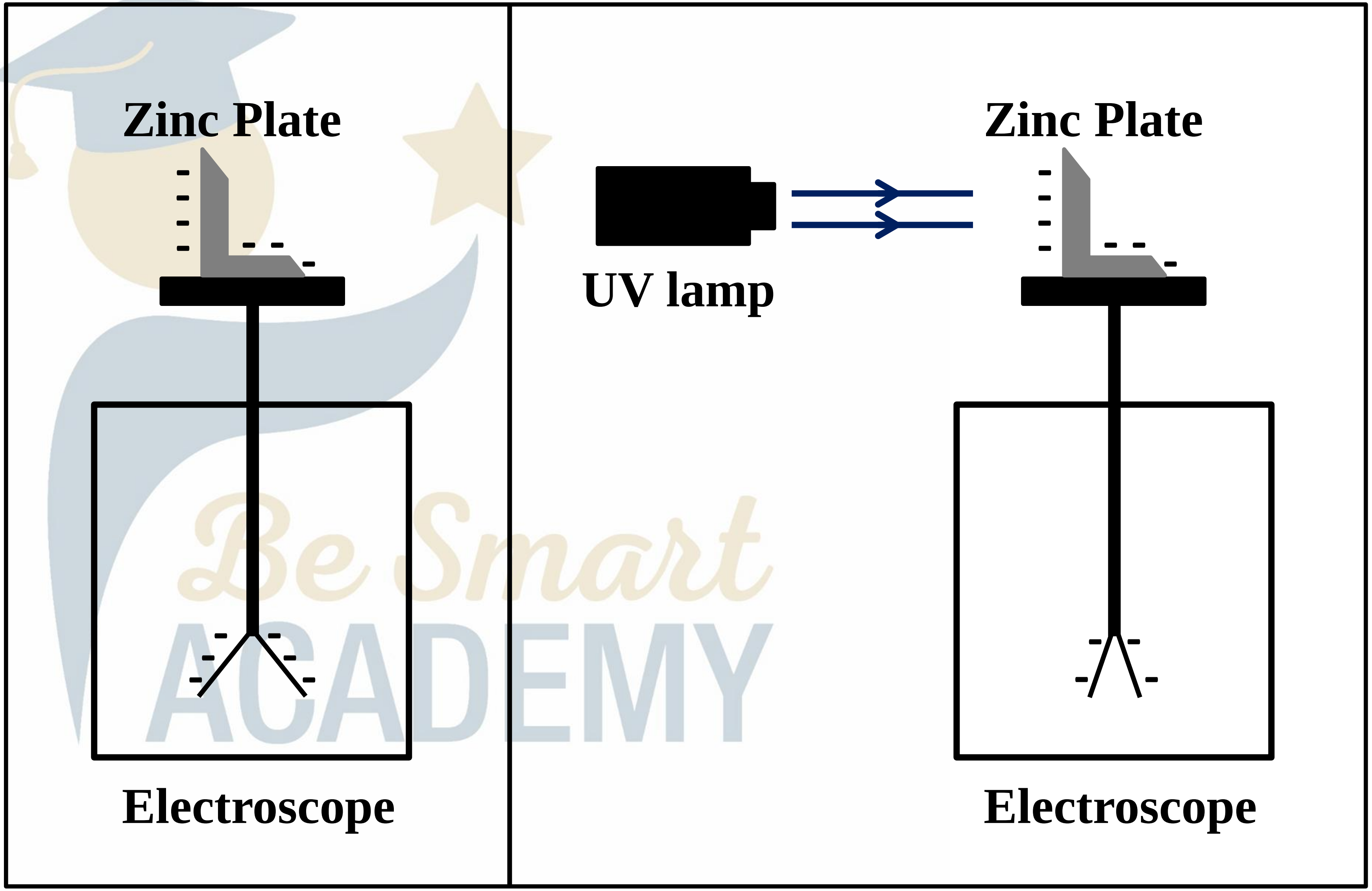
Photoelectric effect is the phenomenon of the emission of electrons from the surface of a body (generally a metal) when illuminated by suitable radiation



Corpuscular (particle) aspect

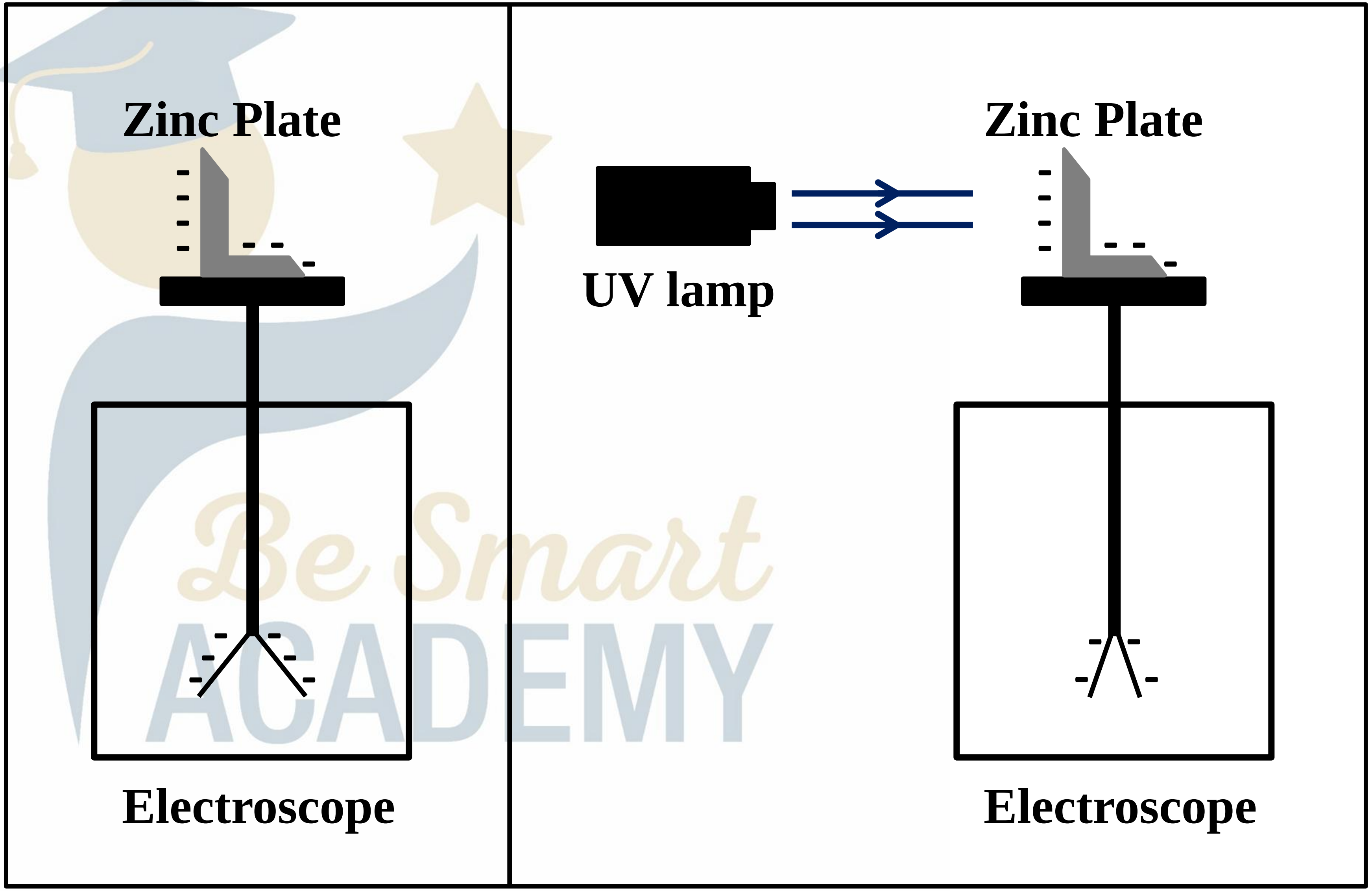
Hertz observation:

If an electroscope, initially negatively charged is exposed to light rich in ultraviolet radiations, we notice that the leaves collapse.



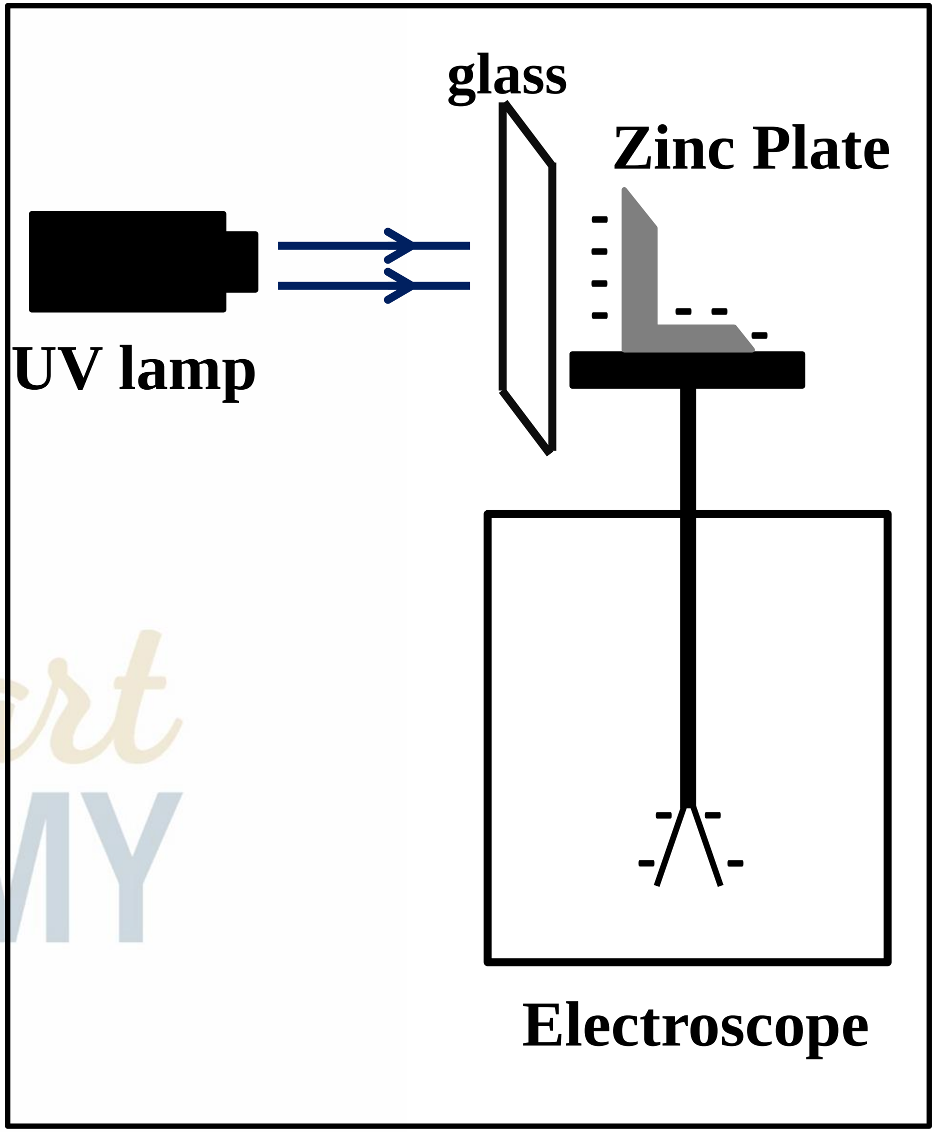
Corpuscular (particle) aspect

This means that it loses its negative charge, and this means that the zinc plate emits electrons. This electron is called an extracted electron.



Corpuscular (particle) aspect

If we insert a glass plate that does not allow Ultraviolet radiations to pass, the leaves of the electroscope are not affected, which means that the zinc plate does not emit electrons.



Conclusion: The zinc plate emits electrons when it exposed to convenient radiation (Ultraviolet, X-ray, …) and not to ordinary light.

Corpuscular (particle) aspect

The photo electric effect experiment shows that, the light is composed of small particles called photons .

The photon is characterized by:

- **Zero mass.**
- **Zero charge.**
- **Its speed is speed of light in vacuum:** $c = 3 \times 10^8 m/s.$

The light processes corpuscular (particle) aspect

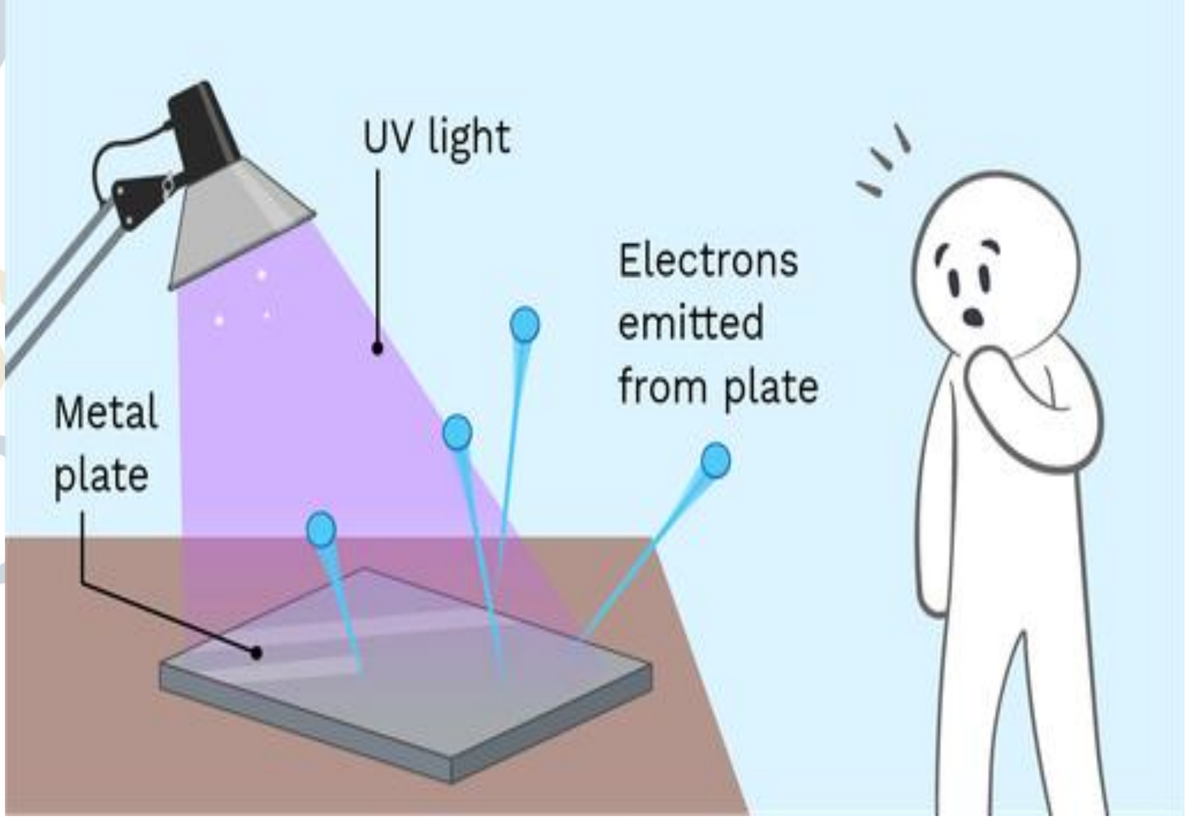
Corpuscular (particle) aspect

Application 1:

Consider a metal plate illuminated by UV light as shown in the figure. Electrons are emitted from the surface of the metal.

1) **Indicate the aspect of light revealed by this experiment.**
2) **The UV light is composed of particles.**

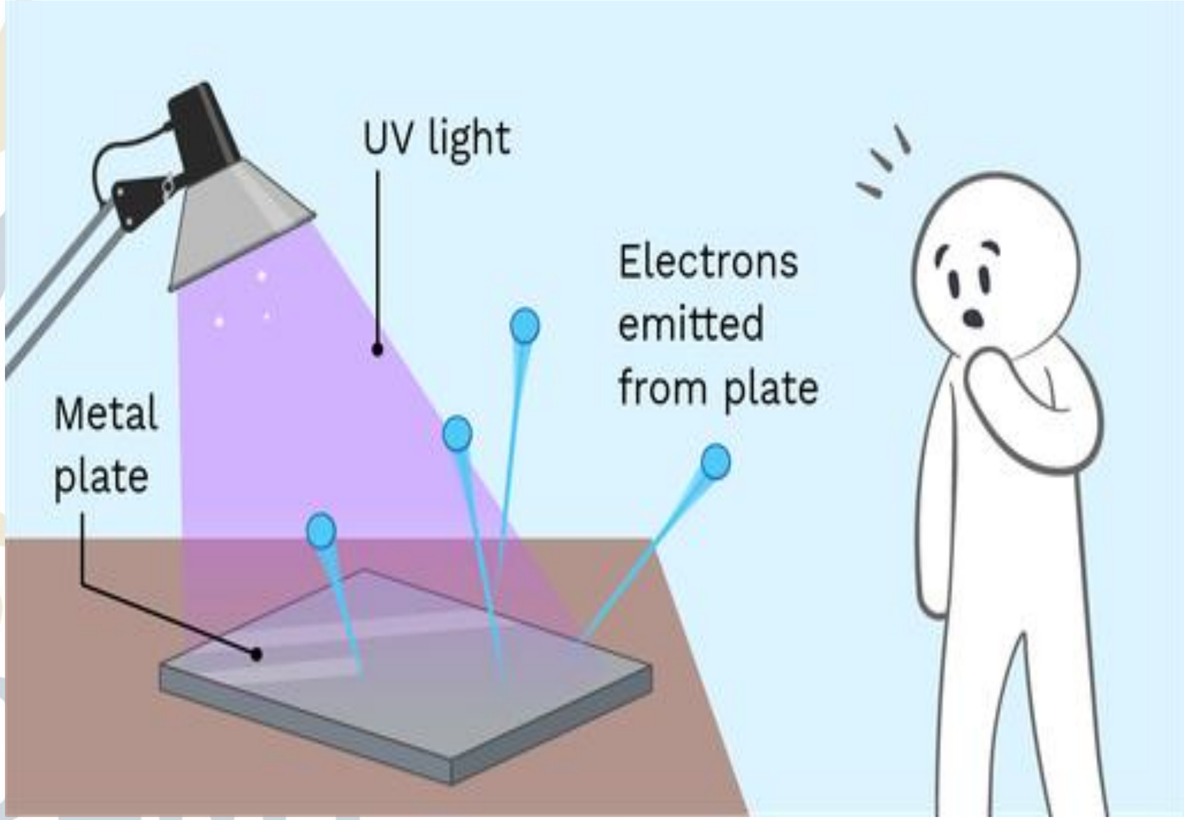
Give 3 characteristics of these particles.



Corpuscular (particle) aspect

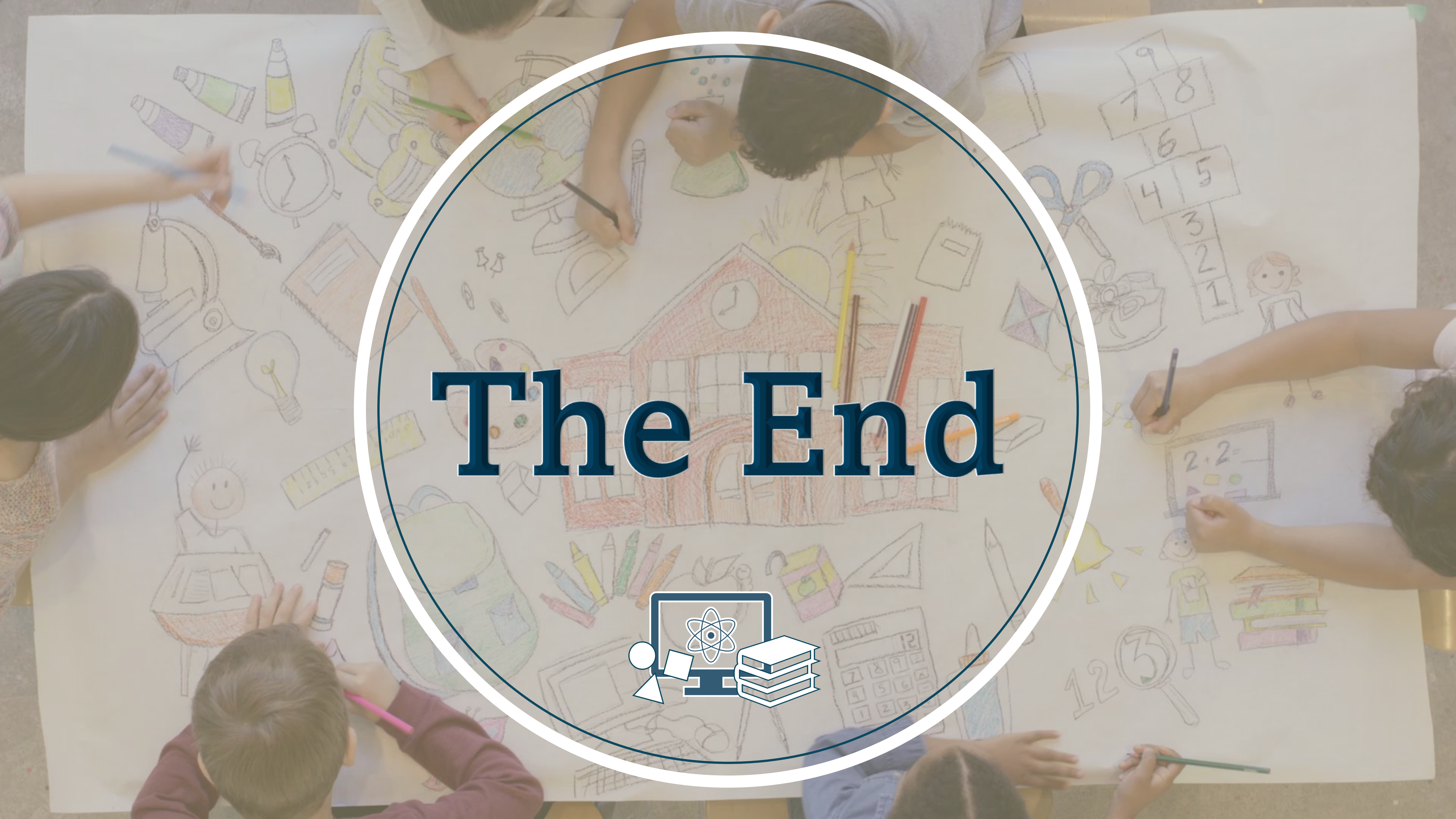
1) Indicate the aspect of light revealed by this experiment.

This experiment shows that the light processes corpuscular aspect.



2) The UV light is composed of particles. Give 3 characteristics of these particles.

The particles are photons of zero mass, zero charge and their speed in vacuum is $c = 3 \times 10^8 m/s$.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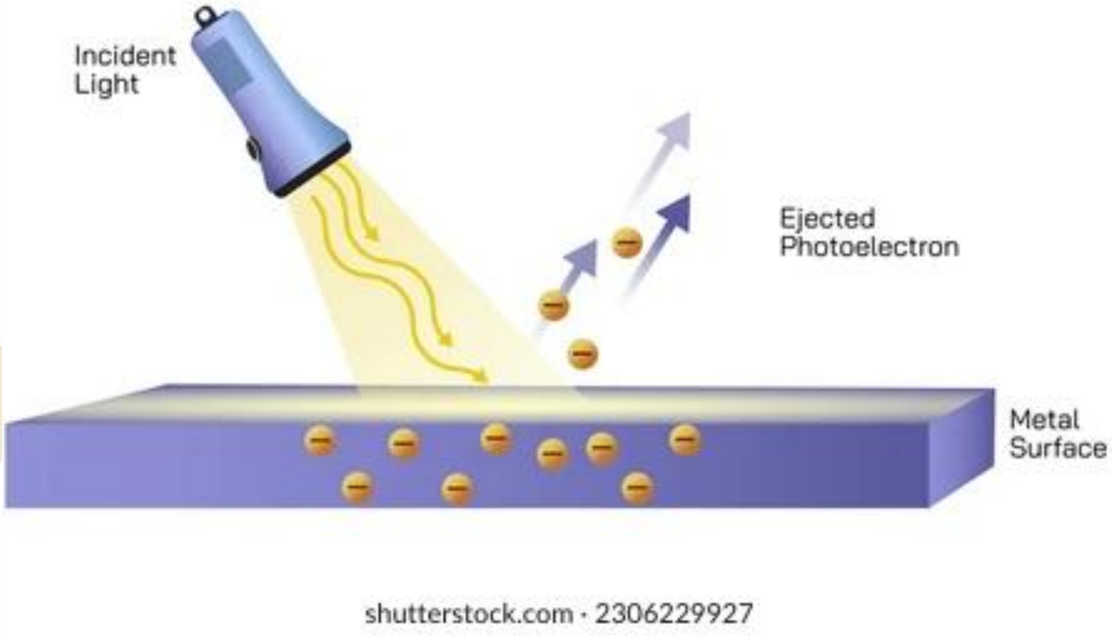

Chapter 16

Corpuscular Aspect of Light

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OBJECTIVES

4	**Interpretation of the Photoelectric Effect**
5	**Einstein's Relation**

Interpretation of the Photoelectric Effect

- For a pure metal, the photoelectric effect takes place only if the frequency ν of the incident radiation is larger than a certain limiting frequency ν_0, a characteristic of the metal, called threshold frequency (cut-off frequency) of photoelectric emission of the metal considered.
- To this threshold frequency ν_0 corresponds a wavelength in vacuum, called threshold wavelength λ_0 where $\lambda_0 = \frac{c}{\nu_0}$

Metal	Cs	K	Ca	Zn	Cu	Ag	Pt
λ_0[nm]	660	550	450	370	290	270	190

Interpretation of the Photoelectric Effect

Plank’s postulate:

The exchange of energy between matter and radiation is quantized.

Einstein’s postulate:

Radiation itself is quantized: light is composed of particles called photons.

Interpretation of the Photoelectric Effect

All photons of a monochromatic radiation of frequency ν have same energy:

$$E = h\nu = \frac{hc}{\lambda}$$

Where h is a fundamental constant called Plank's constant.

Photon energy is expressed Joules (J) and in [eV].

$$h = 6.62 \times 10^{-34} J.S$$

$$1eV = 1.6 \times 10^{-19} J$$

Interpretation of the Photoelectric Effect

To extract an electron from a metal, we have to supply it with a minimum energy called work function W_0.

Work function (Ionization or extraction Energy) W_0: is the minimum energy needed to extract an electron from the surface of the metal.

Metal	Li	Cs	Rb	K	Na	An
W_0[eV]	2.39	1.89	2.13	2.15	2.27	4.31

Einstein's Relation

$$E = W_0 + K.E_{max}$$ → $$h\nu = h\nu_0 + \frac{1}{2}mV^2$$

- E: energy of the incident photon.
- W_0: work function. The minimum energy required to extract an electron from its surface.
- $K.E_{max}$: the kinetic energy of the extracted electron.
- ν: frequency of the incident photon.
- ν_0: frequency of the energy needed to extract the electron.
- h: blank's constant. $h = 6.6 \times 10^{-34} J.s$

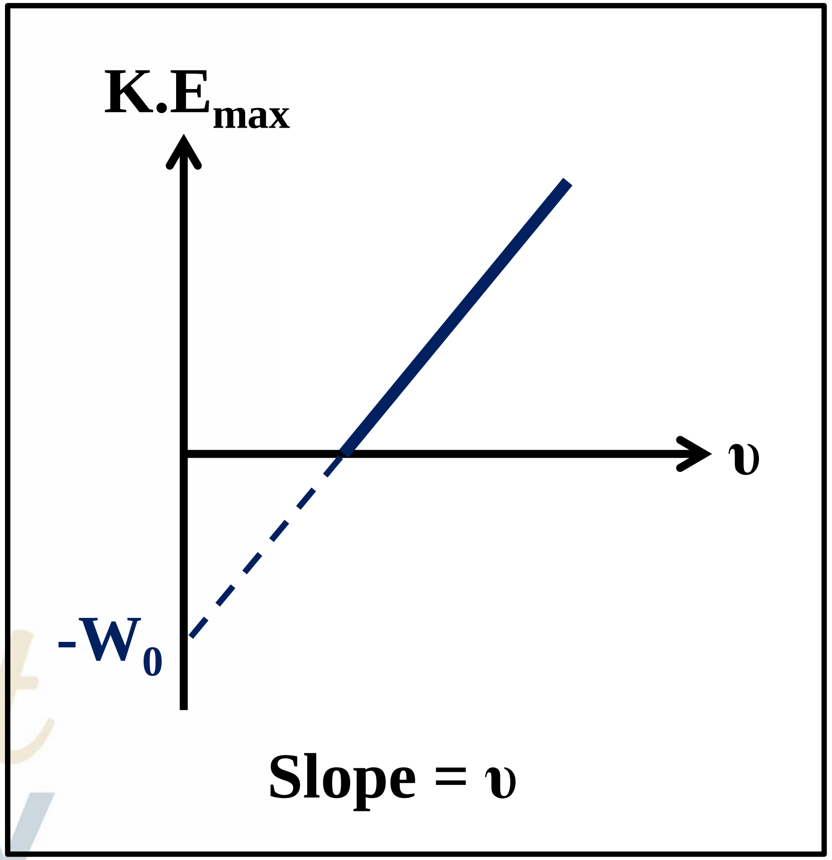
Einstein's Relation

$$E = W_0 + K.E_{max}$$

$$h\nu = W_0 + K.E_{max}$$

$$K.E_{max} = h\nu - W_0$$

- The graph of the K.E as a function of the frequency ν is a straight line of positive slope.
- The slope of this straight line is h and the y-intersect is $-W_0$



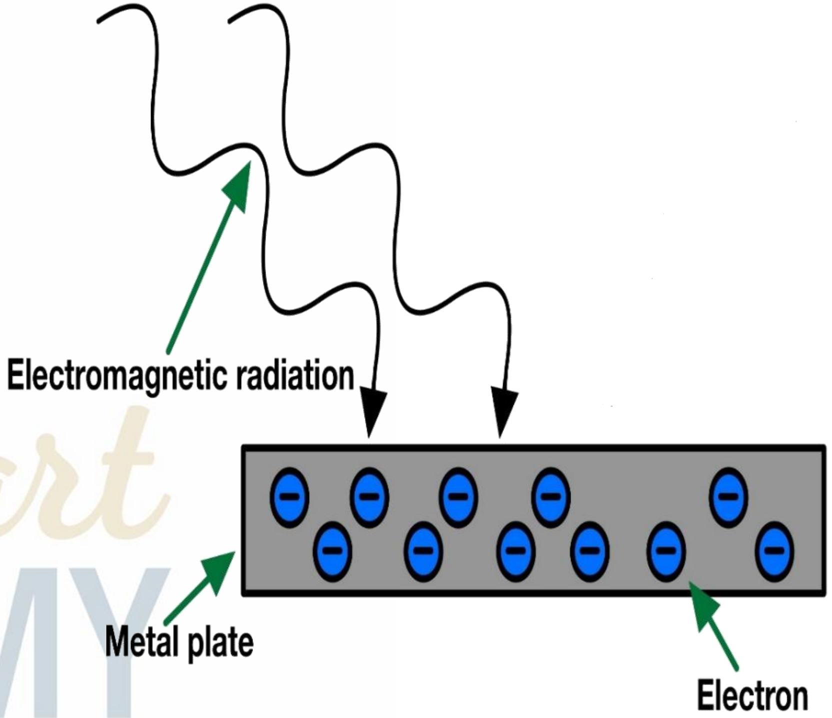
Einstein's Relation

- **If $E < W_0$ or $\nu < \nu_0$ or $\lambda > \lambda_0$: Electrons are not extracted.**
- **If $E = W_0$ or $\nu = \nu_0$ or $\lambda = \lambda_0$: Electrons are extracted with zero speed.**
- **If $E > W_0$ or $\nu > \nu_0$ or $\lambda < \lambda_0$: Electrons are extracted with a maximum possible kinetic energy $K.E_{max}$.**

Einstein's Relation

Application 2: A radiation of wavelength $\lambda = 300nm$, illuminates the surface of a metal having a threshold wavelength $\lambda_0 = 0.2\mu m$.

1) Indicate the type of this electromagnetic radiation.
2) Define the threshold wavelength of a material.
3) Are there any electrons emitted from the metal under this illumination? Justify.

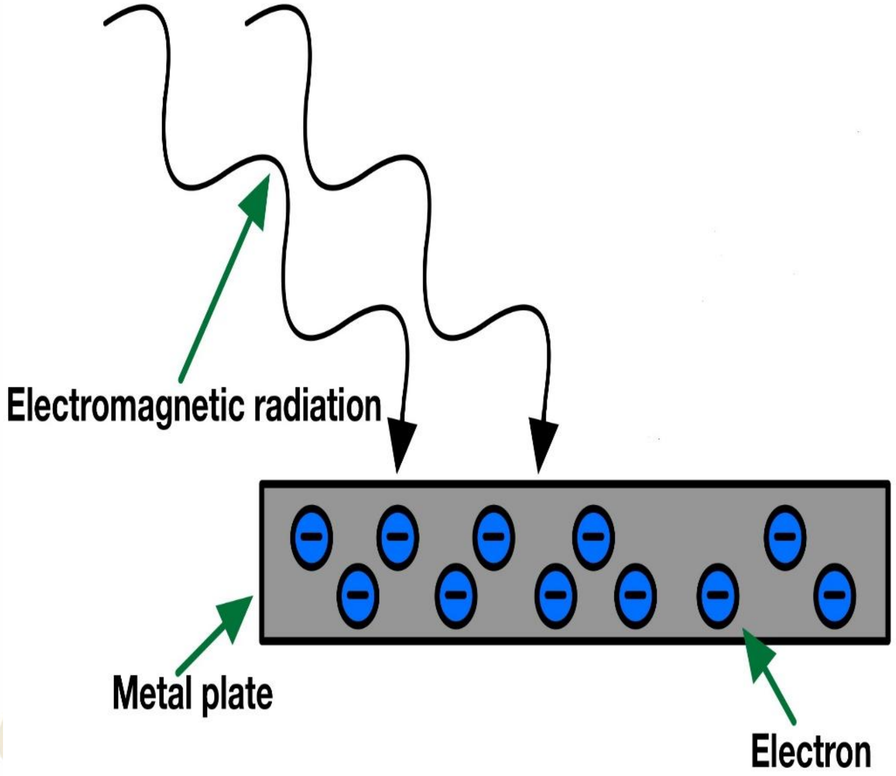


Einstein's Relation

$\lambda = 300nm; \lambda_0 = 0.2\mu m.$

1) **Indicate the type of this electromagnetic radiation.**

Invisible or UV because its wavelength is less than that of violet (400nm)



2) **Define the threshold wavelength of a material.**

The maximum wavelength of the radiation capable of extracting electrons from the surface of a metal.

Einstein's Relation

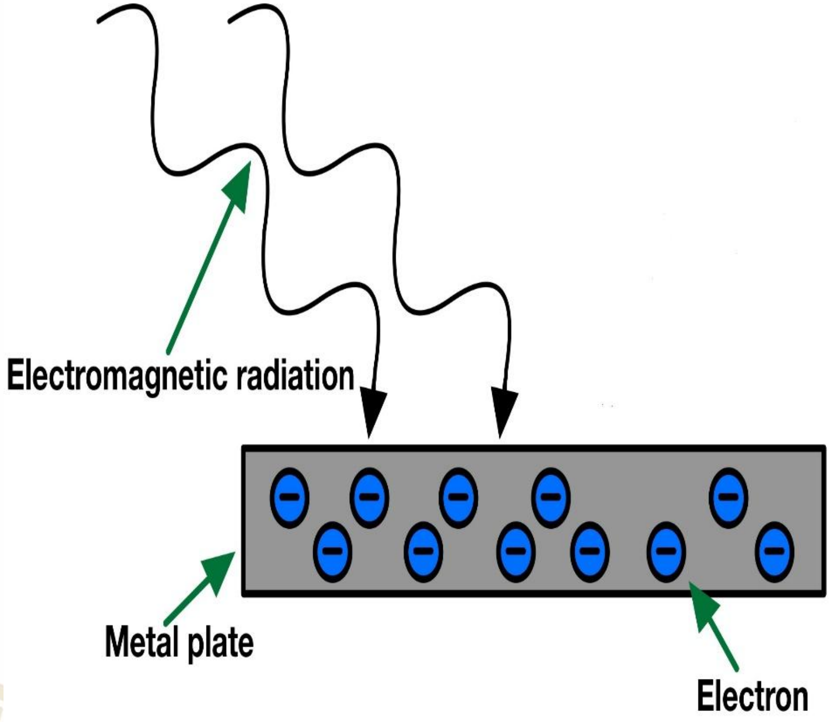
$\lambda = 300nm; \lambda_0 = 0.2\mu m.$

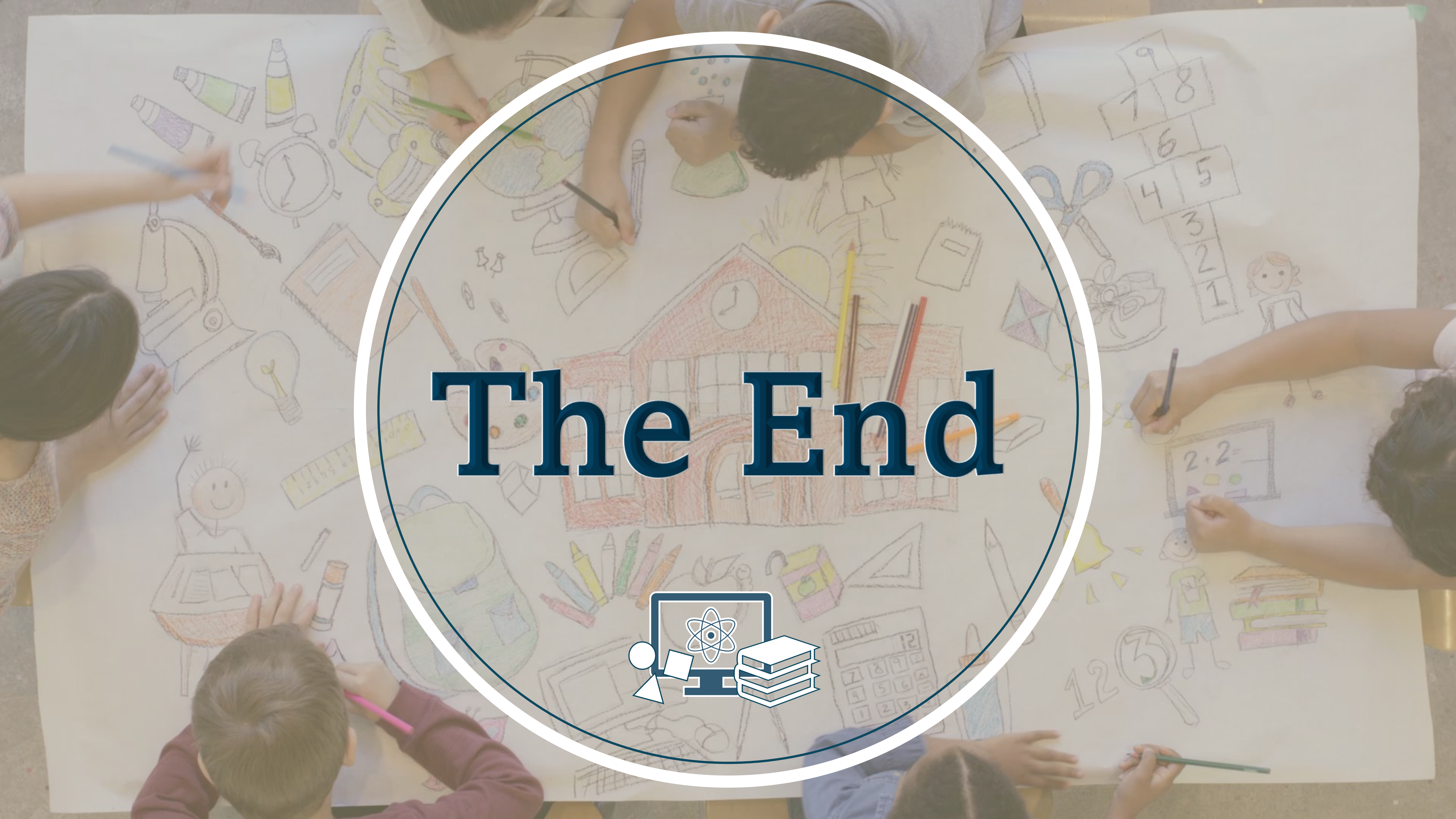
3) Are there any electrons emitted from the metal under this illumination? Justify.

$\lambda = 300nm \times 10^{-3} = 0.3\mu m > \lambda_0 = 0.2\mu m$

Then no emission of electrons from the metal.

No photoelectric effect.

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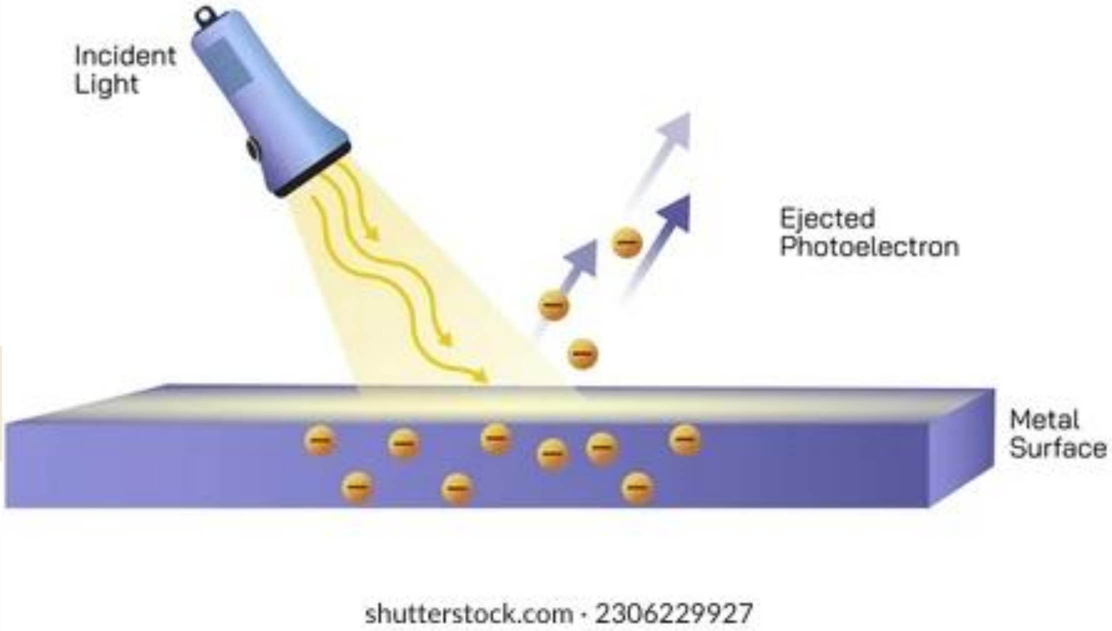

Chapter 16

Corpuscular Aspect of Light

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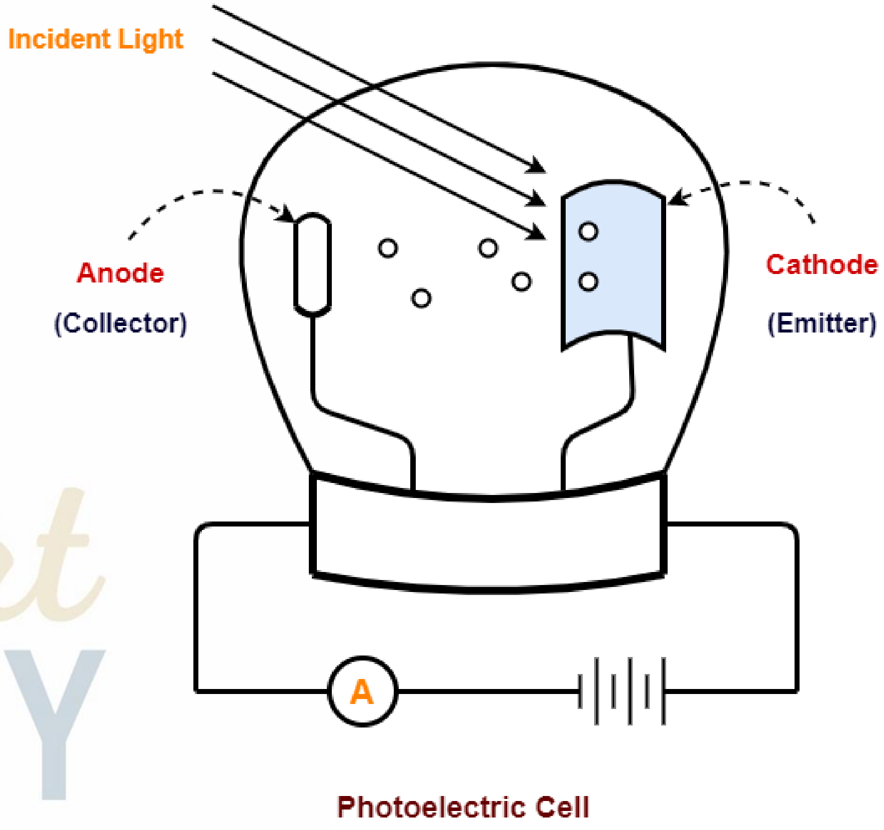
OBJECTIVES

6 **Study the Photoelectric cell**

Photoelectric cell

When a radiation falls on the cathode, the cathode may eject electrons.



The ejected electrons reach the anode, then the electrons flow in the circuit.

The flow of electrons leads to a flow of current in the circuit in the opposite direction to the electrons.

Photoelectric cell

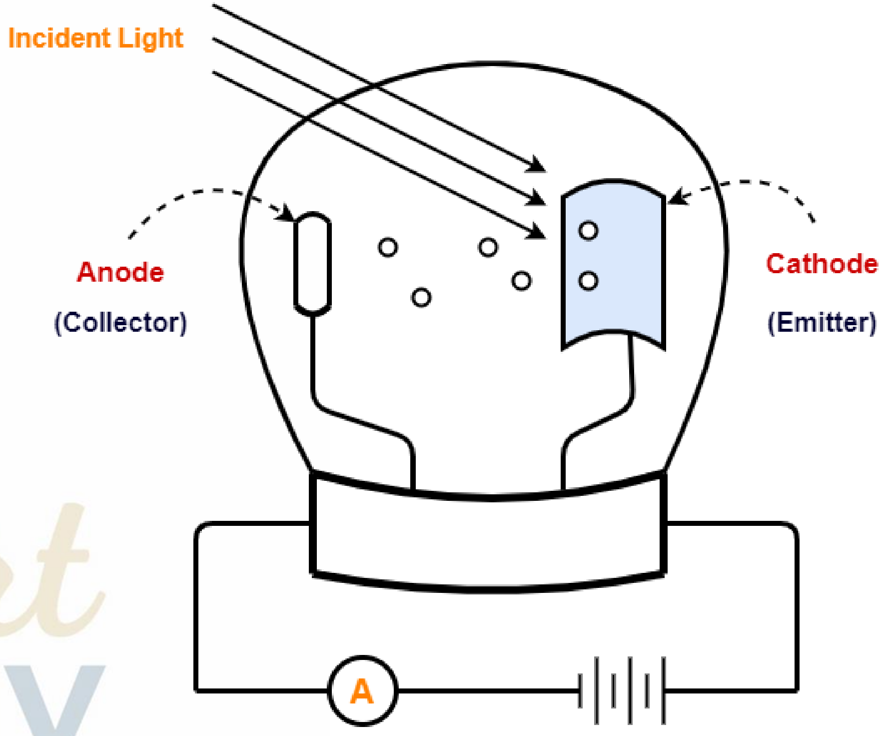
The energy E the incident radiation is given by:

$$E_{rad} = \mathrm{N} \times E_{ph}$$

The power is given by:

$$\mathrm{P_{rad}} = \frac{\mathrm{E}}{\mathrm{t}}$$

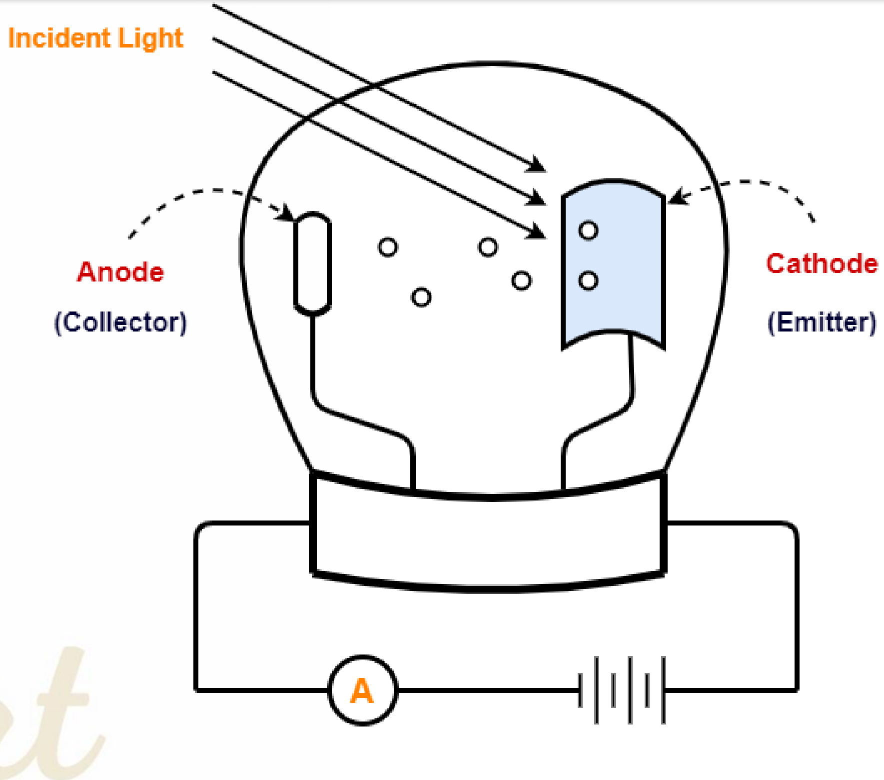
$$P_{rad} = \frac{\mathrm{N} \times E_{ph}}{t}$$



Photoelectric Cell

Photoelectric cell

Efficiency of the metallic surface on cathode:



Photoelectric Cell

$$r = \frac{P_{out}}{P_{in}}$$

$$P_{in} = P_{incident\,ph} = \frac{N \times E_{ph}}{t}$$

$$P_{emitted\,ele} = P_{eff.ph} = P_{out} = \frac{n_{eff} \times E_{photon}}{t}$$

Photoelectric cell

$$Efficiency(r) = \frac{P_{out}}{P_{in}} = \frac{\frac{n_{eff} \times E_{photon}}{t}}{\frac{N \times E_{photon}}{t}}$$

$$r = \frac{n_{eff}}{N} \times 100$$

Photoelectric cell

The electric current is:

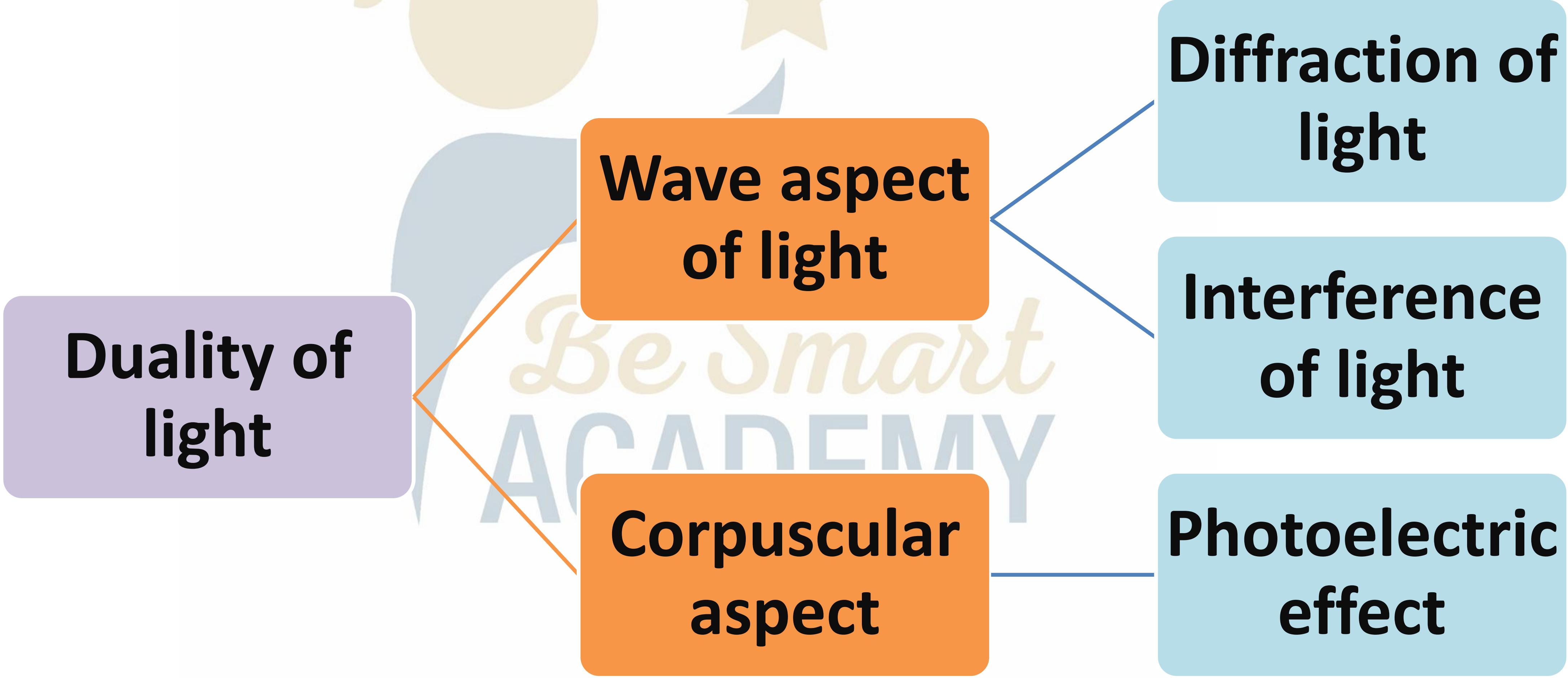
$$I = \frac{q}{t}$$

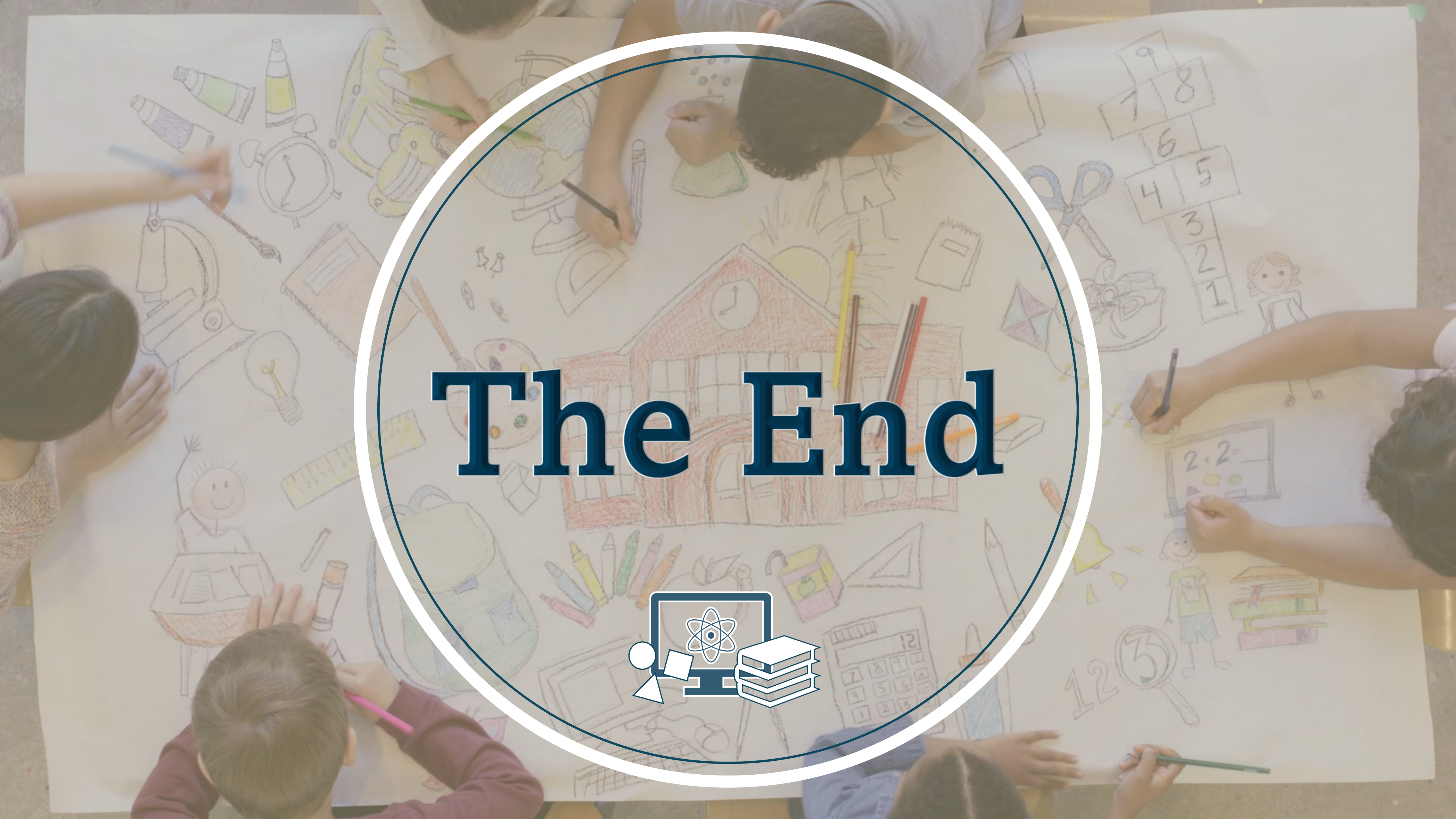
$$I = \frac{n_{ele} \times e}{t}$$

$$I = \frac{n_{eff} \times e}{t}$$

Duality of Light

Light has a dual nature, known as the duality of light. In each phenomenon, one aspect is dominant, as shown in the diagram below.

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