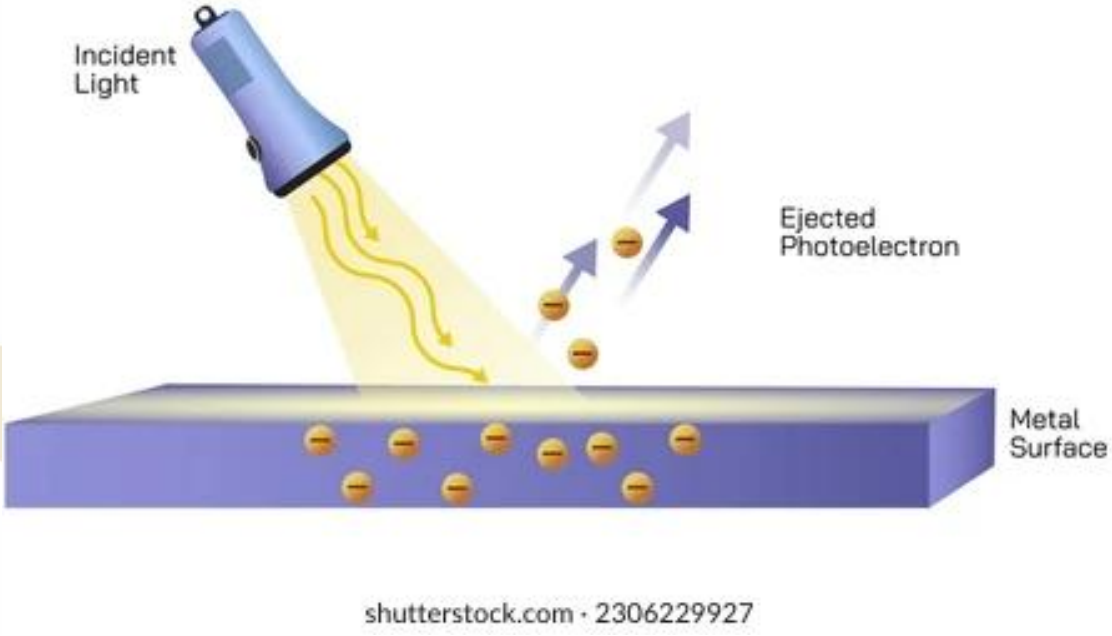
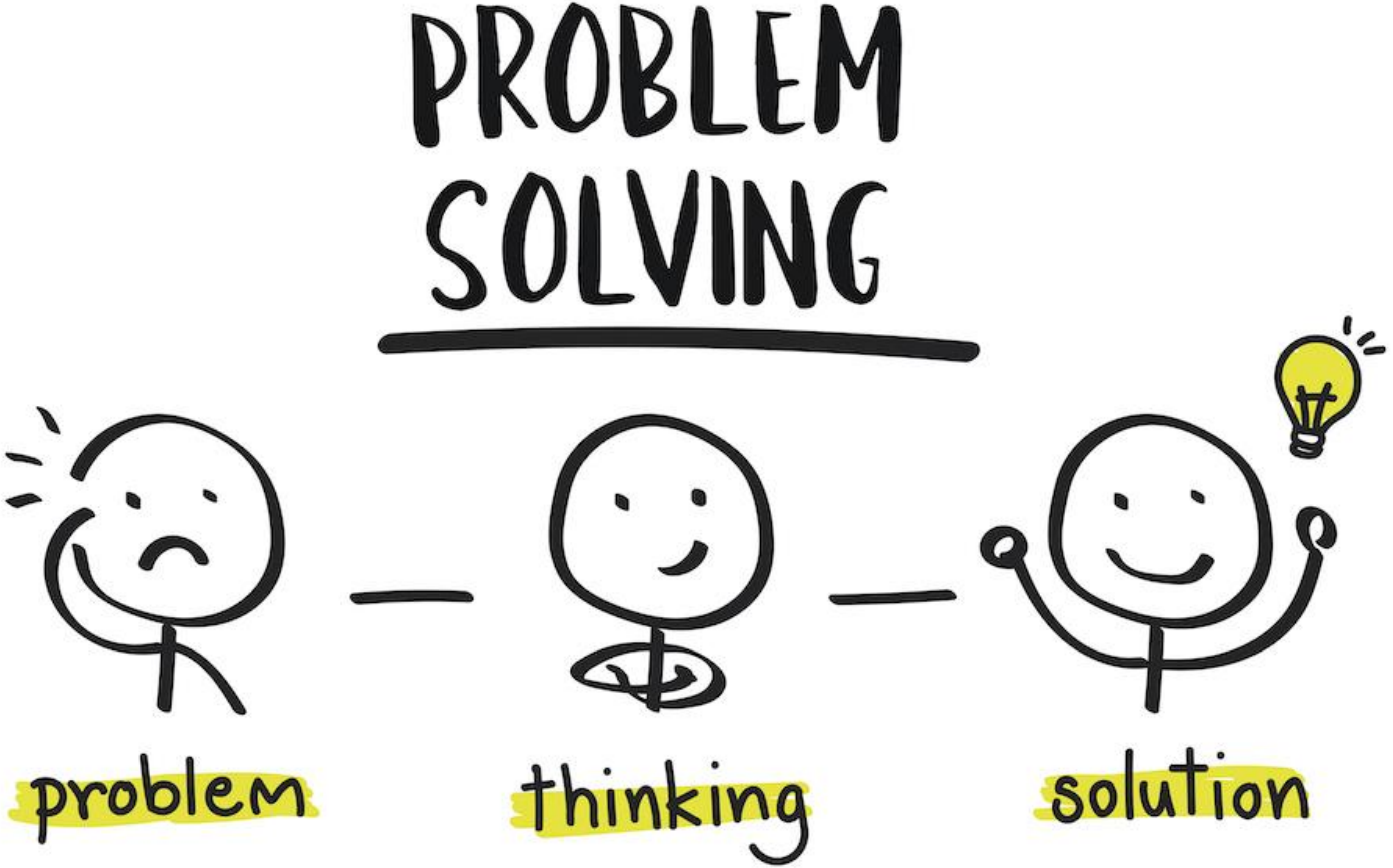


Chapter 16

Corpuscular Aspect of Light

Prepared and Presented by: Mr. Mohamad Seif

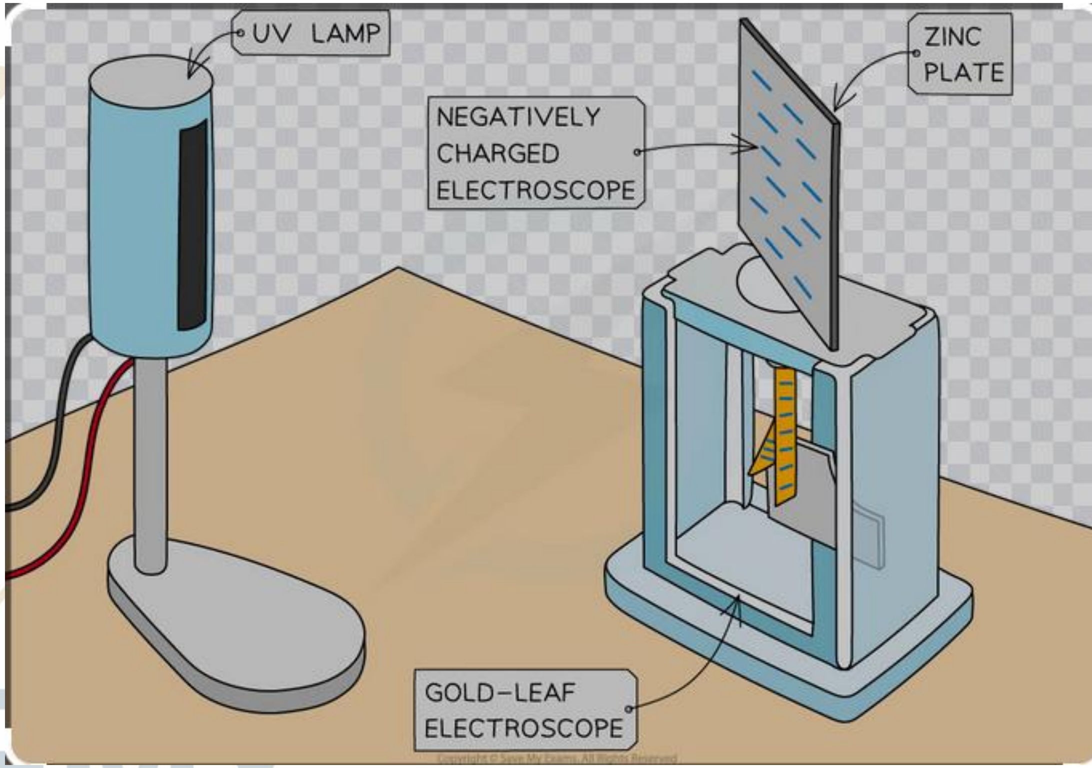

PROBLEM
SOLVING
problem
thinking
solution

Exercise 1

Given: speed of light in vacuum $c = 3 \times 10^8 m/s$; $1\, eV = 1.6 \times 10^{-19} J$.

The experiment represented in figure 1 may show evidence of this photoelectric effect.

A zinc plate is fixed on the conducting rod of an electroscope. The whole set-up is charged negatively.



Exercise 1

If we illuminate the plate by a lamp emitting white light rich with ultraviolet radiations (U.V), the leaves F and F' of the electroscope approach each other rapidly.

1)Due to what do the leaves approach?

The plate has excess of electrons.

When the plate is exposed to U.V radiations, electrons are extracted.

This explains the discharge of the electroscope

Exercise 1

2) The photoelectric effect shows evidence of an aspect of light. What is this aspect?

The photoelectric effect shows that the light possesses a corpuscular aspect of light or called particle aspect of light

Exercise 1

In an experiment using a plate of cesium, a convenient apparatus allows us to measure the maximum kinetic energy K.E of an emitted electron corresponding to the wavelength λ of the incident radiation.

The variation of K.E as a function of λ is represented in the graph of figure 2.

The aim of this part is to determine the value of Planck's constant h and that of the extraction energy W_0 of cesium.

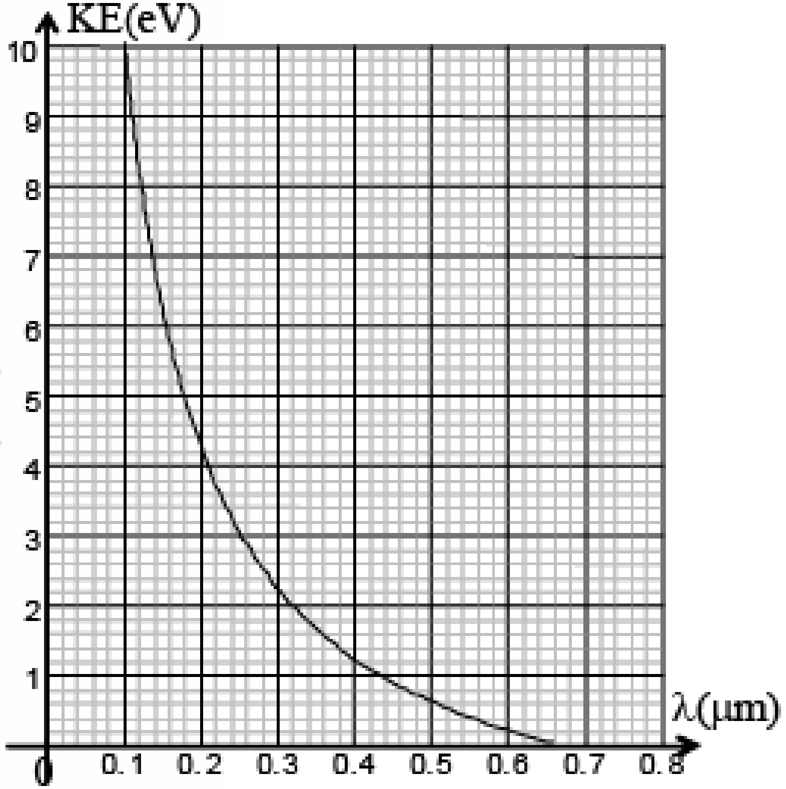


Fig.2

Exercise 1

1)Write down the expression of the energy E of an incident photon, of wavelength λ in vacuum, in terms of λ, h and c

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

2)Show that the maximum kinetic energy K.E of an extracted electron may be written in the form $K.E = \frac{a}{\lambda} + b$, where a and b are constants.

$$\mathrm{E} = \mathrm{W_0} + \mathrm{K.E} \Rightarrow \mathrm{K.E} = \mathrm{E} - \mathrm{W_0} \Rightarrow \mathrm{K.E} = \frac{hc}{\lambda} - \mathrm{W_0}$$

$$\mathrm{K.E} = \frac{a}{\lambda} + \mathrm{b}$$

Where $a = hc$ and $b = -\mathrm{W_0}$

Exercise 1

3) Deduce the expression of the threshold wavelength λ_0 of cesium in terms of W_0, h and c.

Using the previous equation:

$$K.E = \frac{hc}{\lambda_0} - W_0$$

$$\text{For } K.E = 0$$

$$0 = \frac{hc}{\lambda_0} - W_0$$

$$W_0 = \frac{hc}{\lambda_0}$$

Exercise 1

3) Referring to the graph:

a) Give the value of the threshold wavelength λ_0 of cesium.

From the graph, for $K.E = 0$

$$\lambda_0 = 0.66\mu m$$

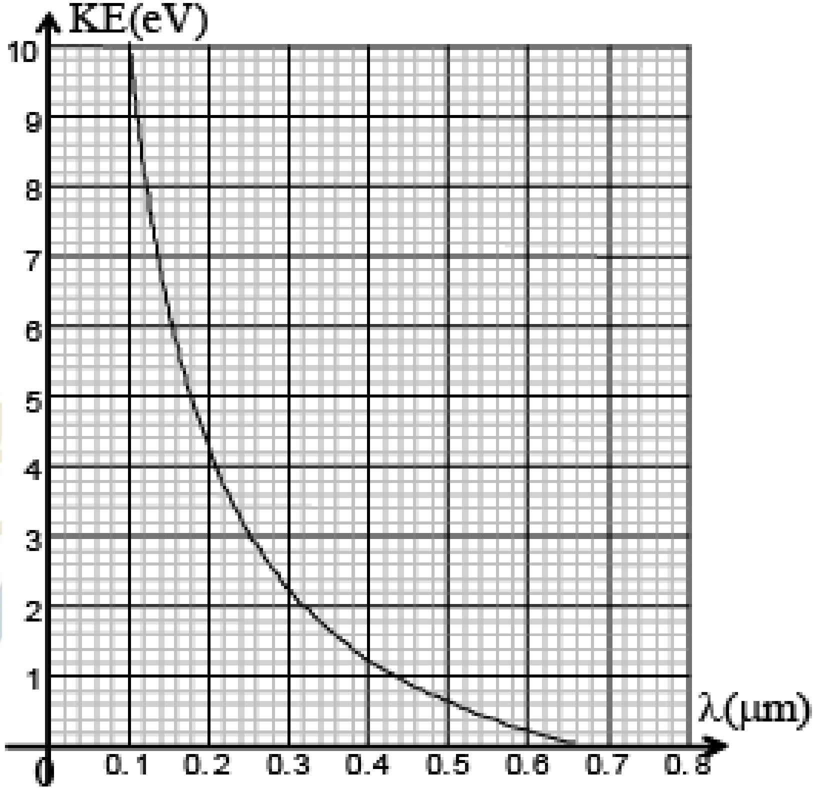


Fig.2

Exercise 1

b)Determine the value of W_0 and that of h.

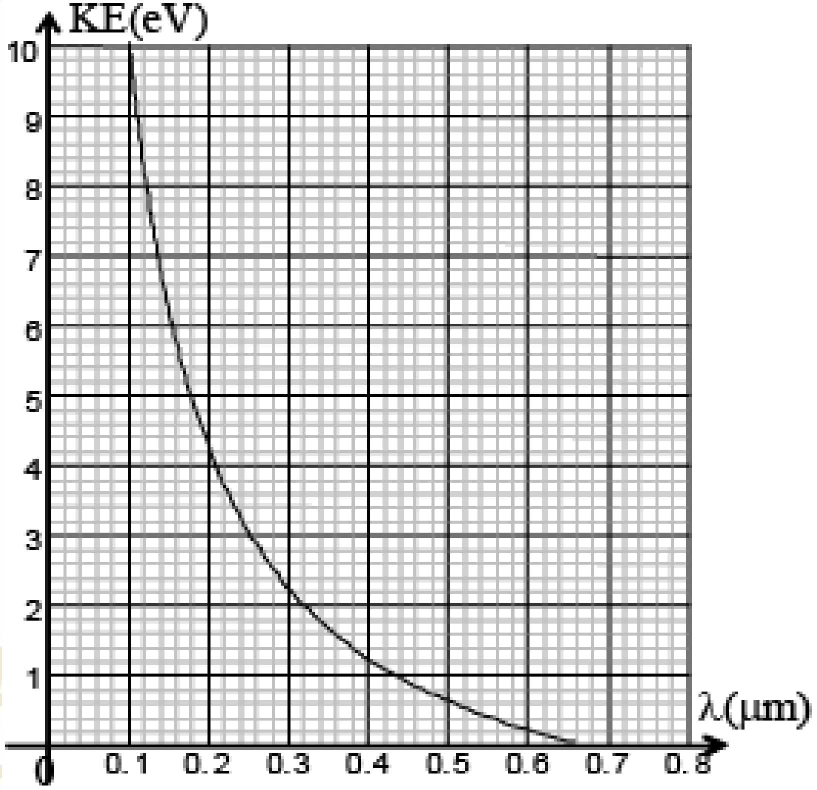


Fig.2

For $\lambda_0 = 0.66\mu m$ ➡ $K.E = 0$

$$0 = \frac{hc}{0.66 \times 10^{-6}} - W_0 \dots\dots (1)$$

For $\lambda = 0.18\mu m$ ➡ $K.E = 5eV$

$$5 \times 1.6 \times 10^{-19} = \frac{hc}{0.18 \times 10^{-6}} - W_0$$

$$8 \times 10^{-19} = \frac{hc}{0.18 \times 10^{-6}} - W_0 \dots\dots (2)$$

Exercise 1

$$\begin{cases} \dfrac{hc}{0.66 \times 10^{-6}} - W_0 = 0 \;\ldots\ldots\ldots \times (-1) \\ \dfrac{hc}{0.18 \times 10^{-6}} - W_0 = 8 \times 10^{-19} \end{cases}$$

$$\begin{cases} -\dfrac{hc}{0.66 \times 10^{-6}} + W_0 = 0 \\ \dfrac{hc}{0.18 \times 10^{-6}} - W_0 = 8 \times 10^{-19} \end{cases}$$

Add the two equation

Exercise 1

$$-\frac{h \times 3 \times 10^{8}}{0.66 \times 10^{-6}} + \frac{h \times 3 \times 10^{8}}{0.18 \times 10^{-6}} = 8 \times 10^{-19}$$

$$-4.54 \times 10^{14} h + 16.66 \times 10^{14} h = 8 \times 10^{-19}$$

$$12.12 \times 10^{14} h = 8 \times 10^{-19}$$

$$h = \frac{8 \times 10^{-19}}{12.12 \times 10^{14}}$$

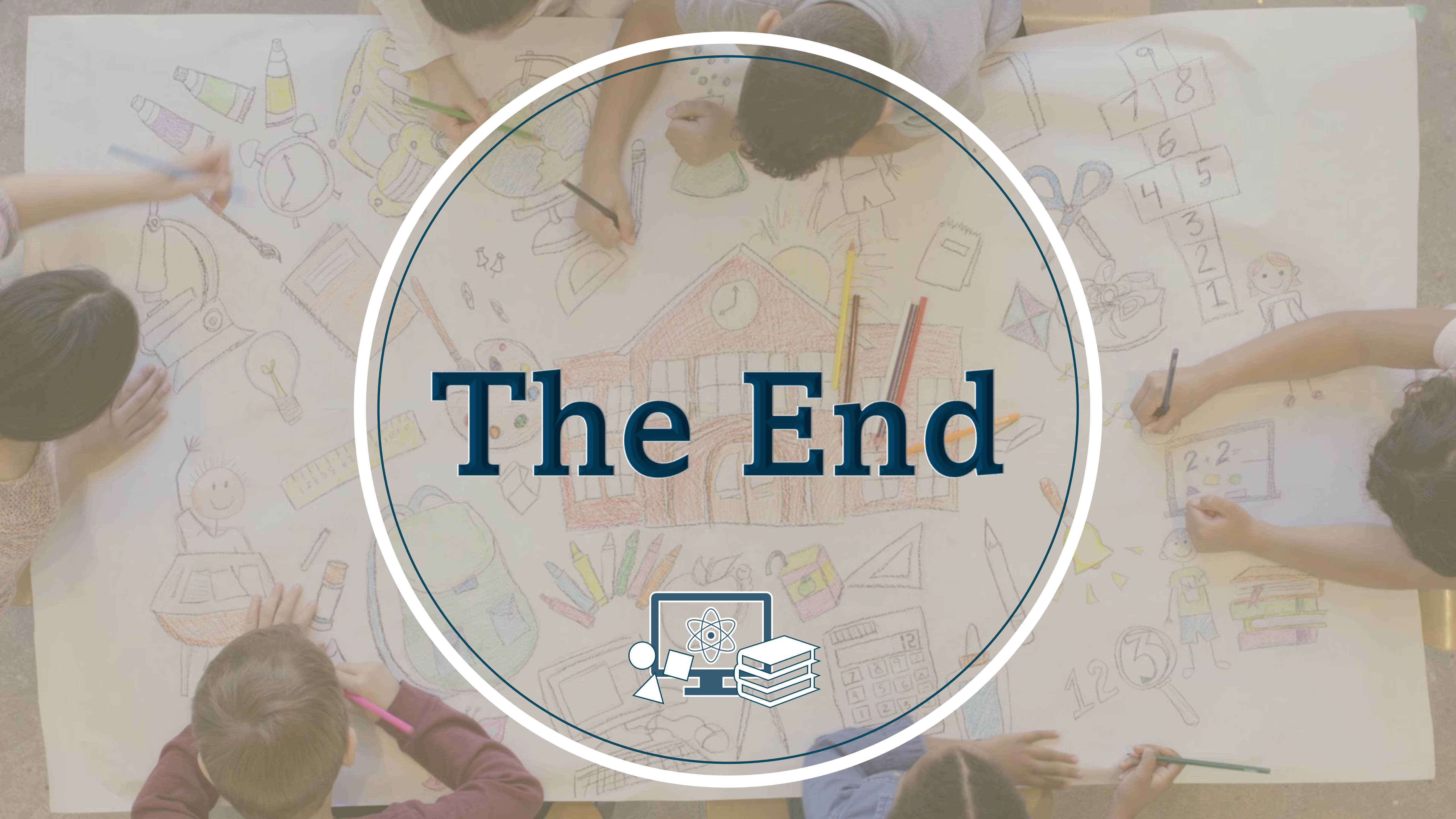
$$\mathrm{h} = 6.6 \times 10^{-34} \mathrm{J.s}$$

Exercise 1

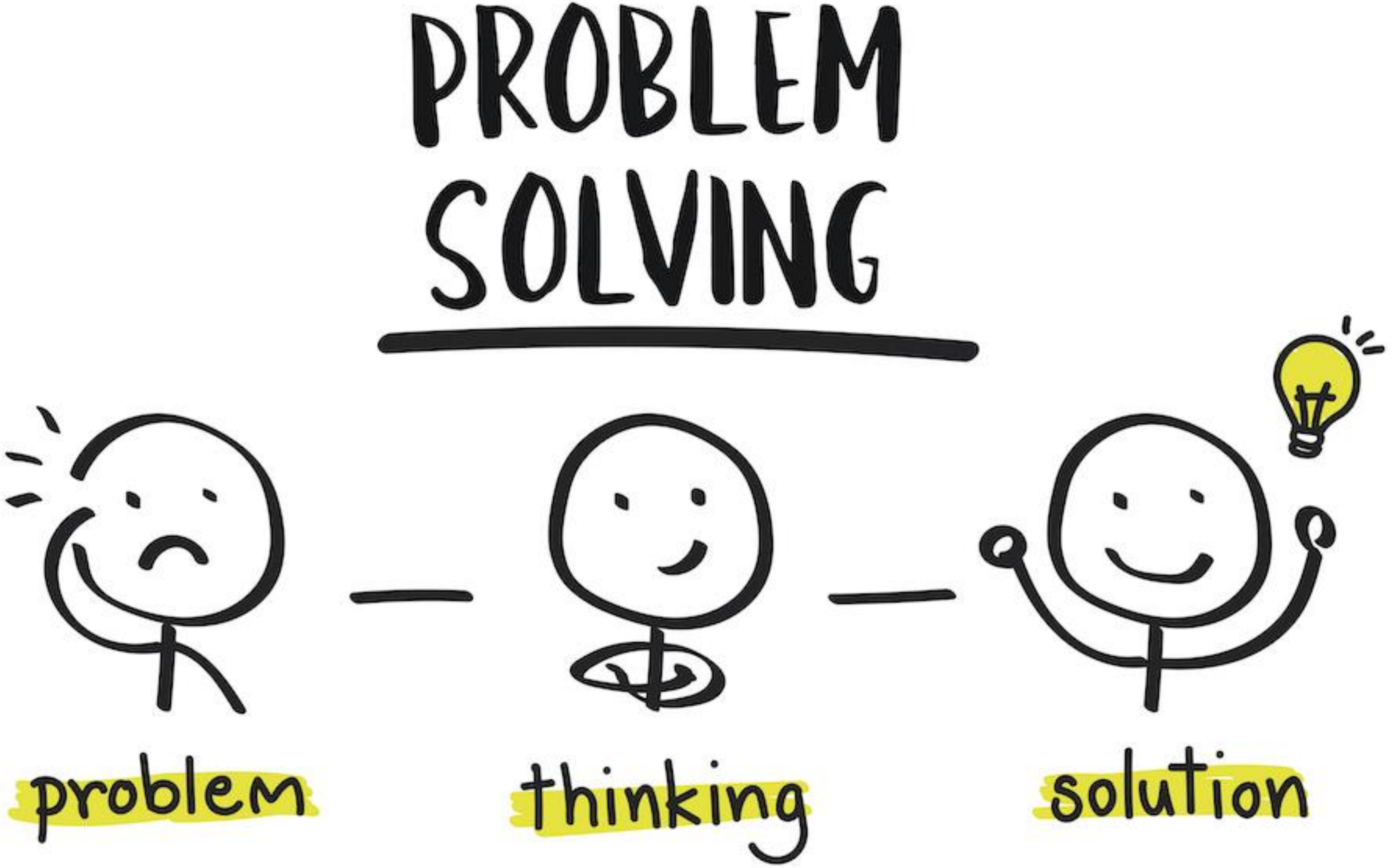
$$W_0 = \frac{hc}{\lambda_0}$$

$$W_0 = \frac{6.6 \times 10^{-34} \times 3 \times 10^{8}}{0.66 \times 10^{-6}}$$

$$W_0 = 3 \times 10^{-19} J$$



The End


PROBLEM
SOLVING
problem
thinking
solution

Exercise 2

The object of this exercise is to determine, Planck's constant (h), as well as the threshold frequency ν_0 of potassium and the extraction energy W_0 of potassium and that of cesium when illuminated by monochromatic radiation of adjustable frequency ν.

Exercise 2

Part A:

1) **What aspect of light does the phenomenon of photoelectric effect show evidence of ?**

The phenomenon of photoelectric effect show evidence of corpuscular (particle) aspect of light

2) **A monochromatic radiation is formed of photons. Give two characteristics of a photon.**

The photon have zero mass; speed in vacuum is c ; zero charge and energy $E = h\nu = \frac{hc}{\lambda}$

Exercise 2

3)For a pure metal, the incident photons of a monochromatic radiation provoke photoelectric emission. Give the condition for this emission to take place.

The emission of electron from the metal occurs when:

$$E_{ph} > W_0$$

Or

$$\lambda < \lambda_0$$

Or

$$\nu > \nu_0$$

Exercise 2

Part B: In the first experiment we use potassium, a convenient apparatus is used to measure the kinetic energy K.E of the electrons corresponding to frequency ν of the incident radiation. The obtained results are tabulated in the following table:

$\nu(\text{Hz})$	K.E(e.V)
6×10^{14}	0.25
7×10^{14}	0.65
8×10^{14}	1.05
9×10^{14}	1.45
10×10^{14}	1.85

Given

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

Exercise 2

1) Show that the kinetic energy of an extracted electron may be written in the form: $K.E = a\nu + b$.

$$E = W_0 + K.E$$

$$h\nu = W_0 + K.E$$

$$K.E = h\nu - W_0$$

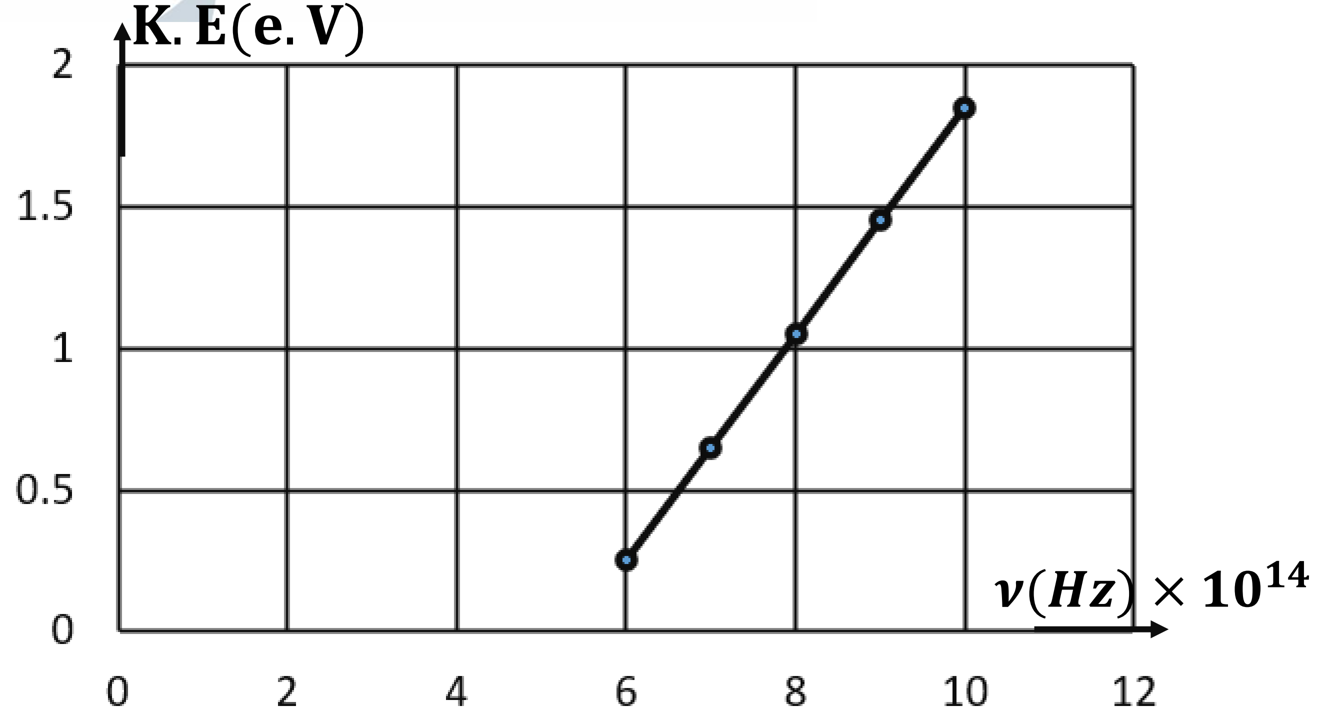
$$K.E = a\nu + b$$

Where $a = h$ and $b = -W_0$

Exercise 2

2)Plot, on the graph paper, the curve representing the variation of the kinetic energy K.E versus n, using the following scale: x –axis: $1cm \rightarrow 1014Hz$. Y-axis: $1\text{cm} \rightarrow 0.5\text{eV}$

$\nu(\text{Hz})$	K.E(e.V)
6×10^{14}	0.25
7×10^{14}	0.65
8×10^{14}	1.05
9×10^{14}	1.45
10×10^{14}	1.85



Exercise 2

3)Using the graph, determine: the value of Planck's constant h, and the threshold frequency ν_0 of potassium.

The obtained curve is straight line not passing through the origin having a slope h

$$h = \frac{K.E_2 - K.E_1}{\nu_2 - \nu_1} \Rightarrow h = \frac{(1.85 - 0.25) \times 1.6 \times 10^{-19}}{(10 - 6) \times 10^{14}}$$

$$h = 6.6 \times 10^{-34} J.s$$

Exercise 2

The electron is extracted without velocity (K.E = 0);
The metal is illuminated with a radiation of frequency ν_0 equal to threshold frequency.

The threshold frequency corresponds to the intersection of the obtained line with the axis of abscissa.

$$\nu_0 = 5.5 \times 10^{14} Hz$$

Exercise 2

3)Deduce the value of the extraction energy W_0 of potassium.

$$W_0 = h \times \nu_0$$

$$W_0 = 6.6 \times 10^{-34} \times 5.5 \times 10^{14}$$

$$W_0 = 3.52 \times 10^{-19}\text{J}$$

$$W_0 = \frac{3.52 \times 10^{-19}\text{J}}{1.6 \times 10^{-19}\text{J}}$$

$$W_0 = 2.2\text{eV}$$

Exercise 2

Part C:

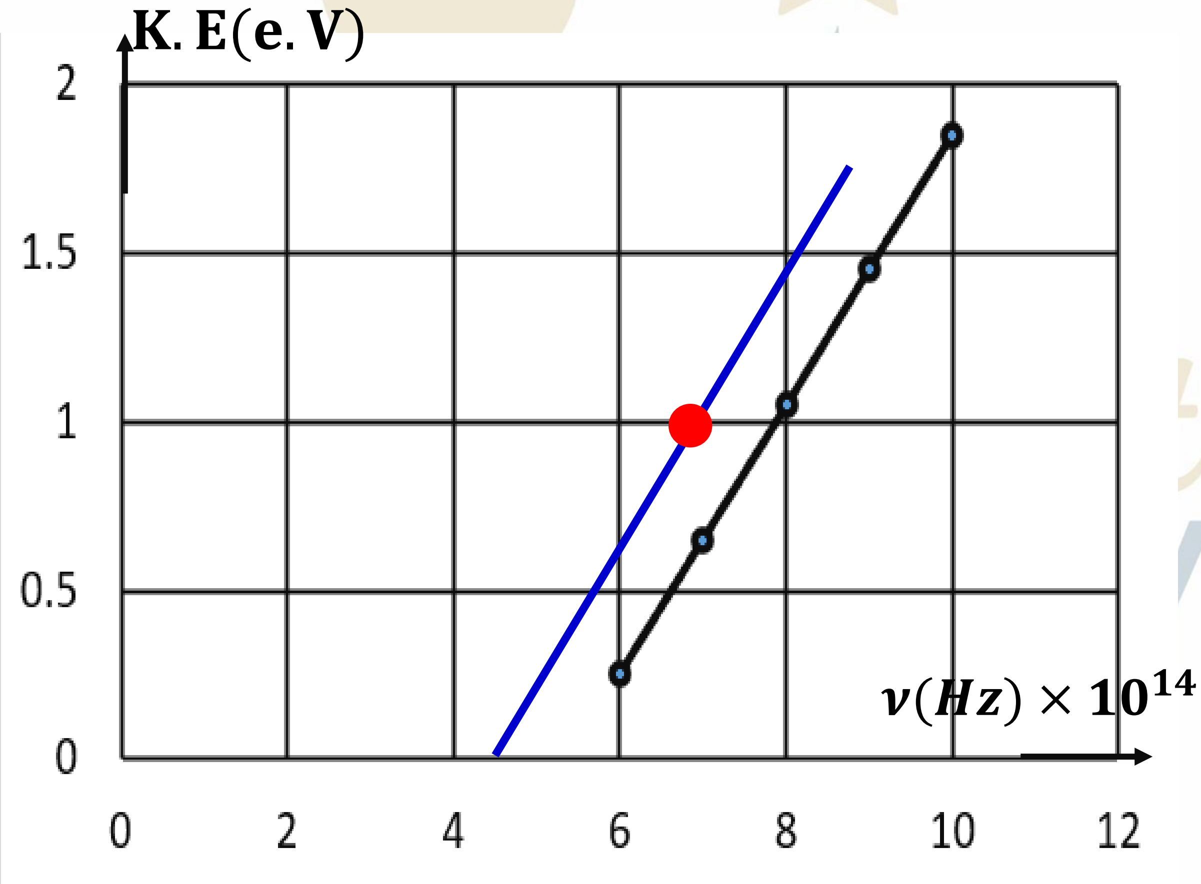
In the second experiment cesium have been used instead of potassium, we obtain the following values:

$K.E = 1\,eV$ **for** $\nu = 7 \times 10^{14}\,Hz$ ν = 7

1) **Plot, with justification on the preceding system of axes, the graph of the variation of K.E as a function of** ν**.**

Exercise 2

The new curve is parallel to the previous line and passing through the point (7×10^{14}Hz ; 1eV).



Exercise 2

For cesium: K.E = 1 eV for $\nu = 7 \times 10^{14} Hz$.

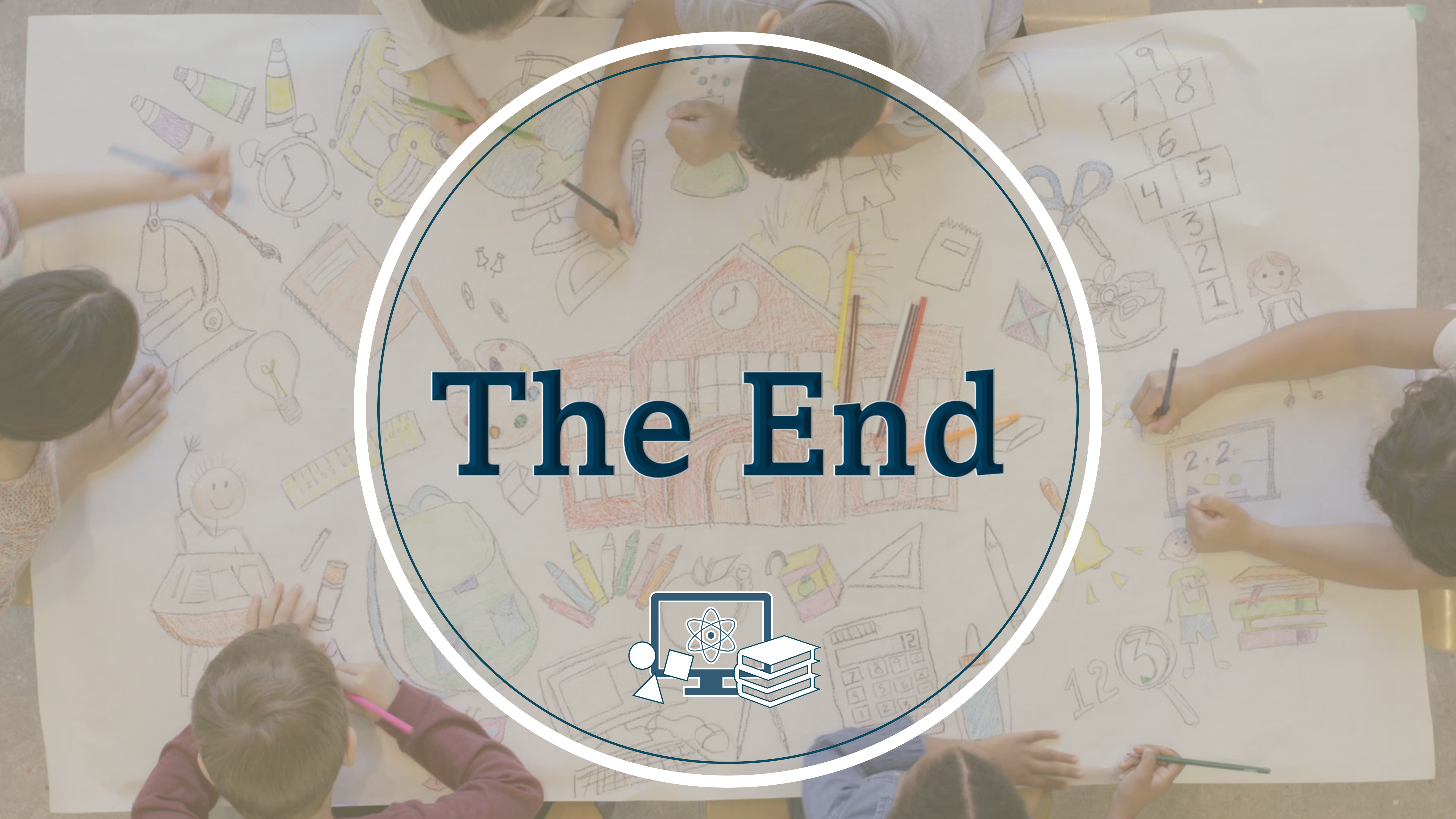
2) **Deduce from this graph the extraction energy W'_0 of cesium.**

Using the relation: $E = w'_0 + K.E$ ⇒ $w'_0 = h\nu - K.E$

$$W'_0 = 6.6 \times 10^{-34} \times 7 \times 10^{14} - 1 \times 1.6 \times 10^{-19}$$

$$w'_0 = 3.02 \times 10^{-19} \text{J}$$

$$w'_0 = \frac{3.02 \times 10^{-19} \text{J}}{1.6 \times 10^{-19}}$$ ⇒ $w'_0 = 1.9 \text{eV}$



The End