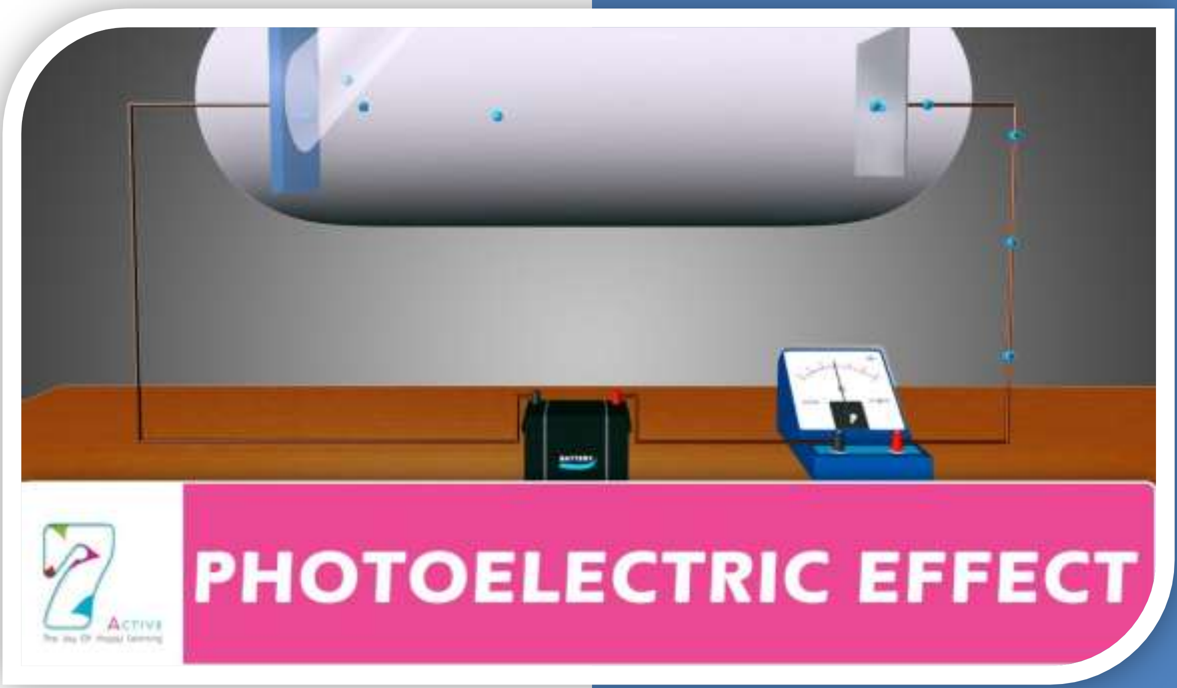
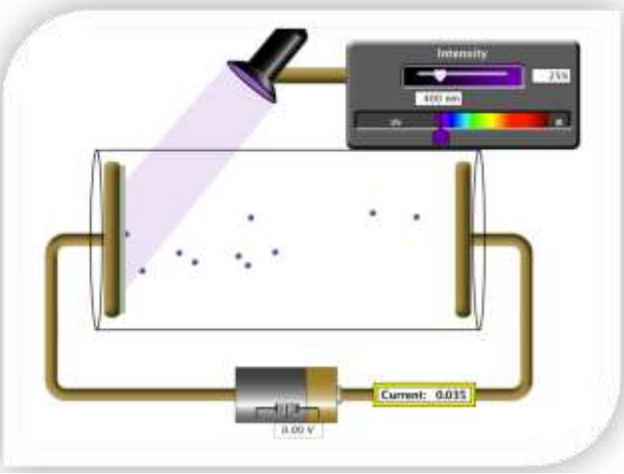
2020

PHOTOELECTRIC EFFECT





TEACHERS OF PHYSICS

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7/30/2020

1. Explain the term “work function” (1mk)

✓ ***Minimum amount of energy needed to dislodge an electron from the surface of a metal.***

2. Define the term monochromatic light. (1mk)

✓ ***Light or radiation of a single wavelength or frequency.***

3. What do you understand by the term photoelectric effect? (1mk)

✓ ***The process by which electrons are emitted from metal surface when illuminated with electromagnetic radiation of sufficient frequency.***

4. Distinguish between thermionic emission and photoelectric effect. (1mk)

✓ ***Thermionic emission is the process of emitting electrons from the metal surface due to heat energy while photoelectric effect is the process of emitting electrons from metal surface by electromagnetic radiation of sufficient frequency.***

5. Give one application of photoelectric effect(1mk)

Applied in: i) Photocells i.e. solar panels

ii) Emissive cells used in conveyor belts.

6. State two factors that affect photoelectric emission from a given metal surface.

i) Intensity of radiation

ii) Energy of radiation

iii) Type of metal

7. Name one factor that determines the velocity of photoelectrons produce on a metal surface when light shine on it. (1mk)

✓ ***Frequency of the incident radiation.***

✓ ***Material of the surface***

8. Photoelectrons emitted by illuminating a given metallic surface constitute a “photocurrent”. What is the effect of increasing the intensity of the illumination of the magnitude of the photocurrent?

✓ ***Increase in magnitude of photocurrent.***

9. A monochromatic beam of radiation is directed on a clean metal surface so as to produce photoelectrons. Give a reason why some of the ejected photoelectrons have more kinetic energy than others.

✓ ***An electron is bounded with nucleus of the metal atom with coulombic interaction. When a photon is incident on the metal surface, some of the energy of the photon is used up to overcome coulombic interaction and the remaining energy becomes the kinetic energy of the emitted photo electrons.***

10. Name a device used to convert light energy directly into electric energy.(1mk)

✓ ***Photocell***

11. State two uses of photocell (2mk)

✓ ***Used in solar panels***

✓ ***Used in burglar alarm***

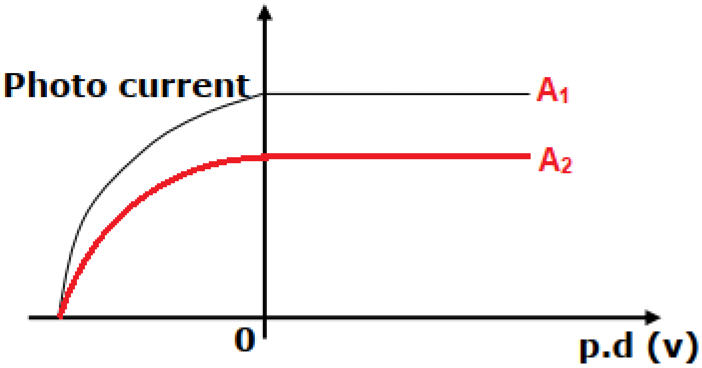
12. What energy conversion occurs in a photocell? (1mk)

13. What is meant by photo-voltaic effect? (1mk)

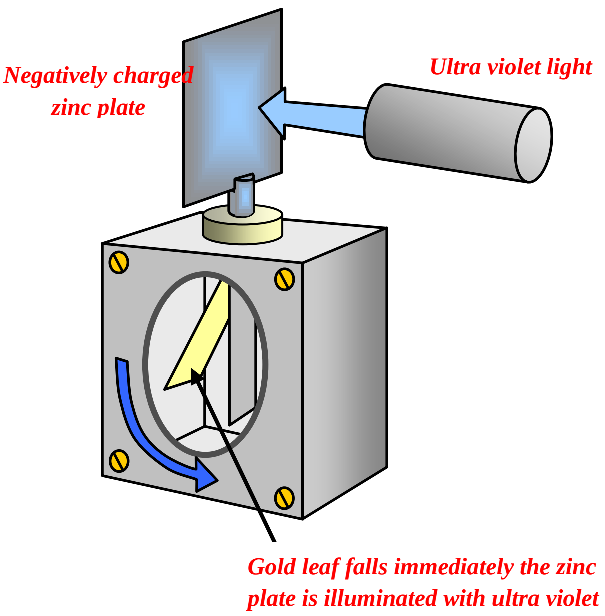
- ✓ ***Photo-voltaic effect is the process that generates voltage or electric current in a photo-voltaic cell when it exposed to sunlight.***

14. You are provided with a clean Zinc plate, a leaf electroscope, a charging rod and a source of ultra-violet (U.V.). Describe briefly with the aid of a diagram how photo-electric effect may be demonstrated. (5mks)

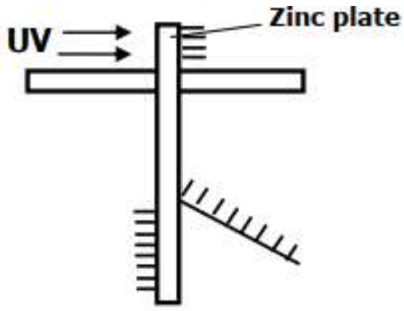
15. Sketch on the same axes the graphs of photo-electric current (y-axis) against the voltage for two different intensities A1 and A2 of ultra-violet where A1> A2 (3mk)



16. Describe with the aid of a labeled diagram an experimental set-up for observing the photoelectric effect.



17. The figure below shows ultra violet light striking a polished zinc plate placed on a negatively charged gold leaf electroscope.



Explain the following observation

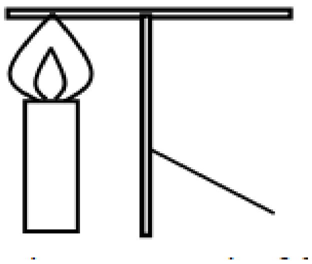
i) The leaf of the electroscope falls.

- ✓ ***Photoelectrons emitted from negatively charged zinc plate are repelled and electroscope becomes discharged causing the lf divergence to fall.***

ii) When the same experiment was repeated with a positively charged, the leaf did not fall.

- ✓ ***Photoelectrons emitrted from positively charged zinc plate are attracted back i.e they do not escape. Thus leaf divergence remains.***

18. A candle is used to heat the cap of a charged electroscope as shown in the figure below.



Explain the following observation

i) It is observed that the electroscope leaf falls after sometime. Explain why the leaf falls after some time.

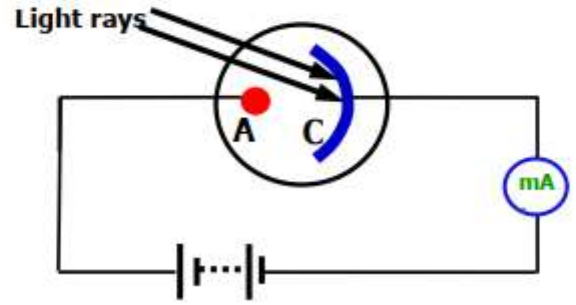
- ✓ ***Heat from the candle causes emission of electrons from the cap of charged electroscope. Emitted electrons repelled by negative charges discharges the electroscope causing the electroscope leaf to fall.***

ii) State with a reason the likely charge of the electroscope.

- ✓ ***Negatively charged. Negative charges repel emitted electrons discharging the electroscope.***

INVESTIGATING PHOTO-ELECTRICITY

1. The figure below show a circuit diagram for a photocell.



a) Name the parts A and C

A – Anode

C - Cathode

b) Why is the micro ammeter showing a deflection when ultraviolet light is shown on the photocell?

- ✓ ***When UV is illuminated on photocell, photoelectrons are emitted. Emitted photoelectrons are attracted toward plate A, completing the circuit, photocurrent flows hence deflection on the micrometer.***

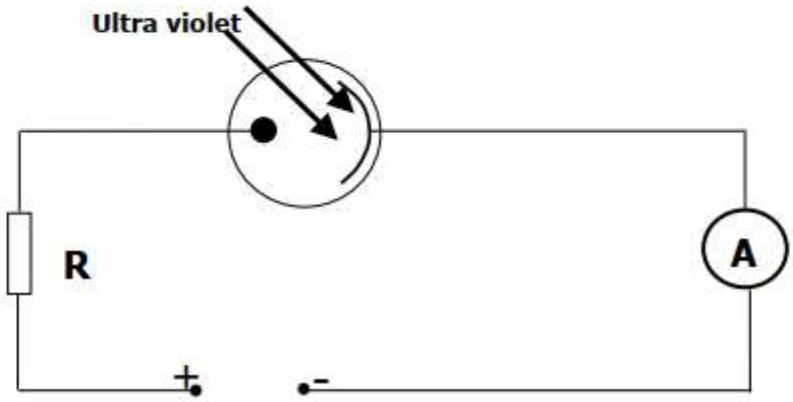
c) Explain how the millimeter reading is affected when the intensity of light is increased.

- ✓ ***Micrometer reading increases/Deflection on micrometer increases***

d) State the factors that determine the velocity of the emitted electrons (2mk)

- ✓ ***Energy of radiation***
- ✓ ***Work function of the metal.***

2. The diagram shows a photocell in action



i) The photocell is either evacuated or filled with an inert gas at low pressure. Give one reason for this.

- ✓ ***To ensure that all the electrons emitted by the cathode reach the anode to maximize the photocurrent.***

ii) What is the function of the resistor R in the circuit?

- ✓ ***To lower/control the current in the circuit.***

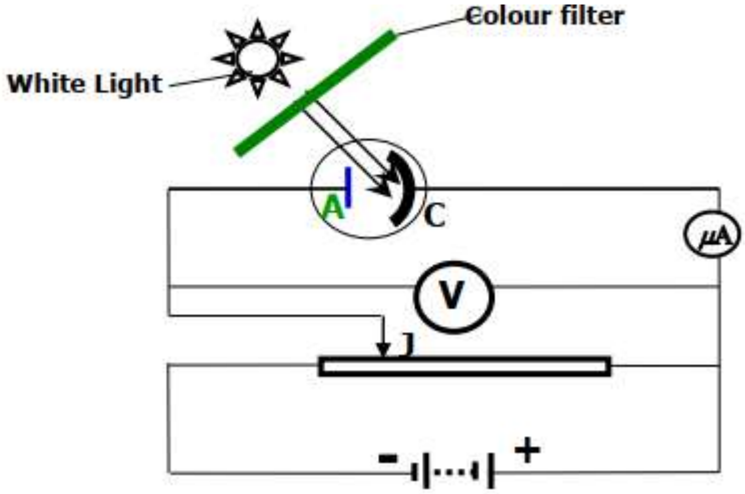
iii) State the reason for using a particular radiation such as ultraviolet for a given photocell.

- ✓ ***The energy of the incident light must be greater than work function of cathode surface if photoelectron emission has to occur.***

iv) Explain how the set-up shown in the diagram may be used as an automatic switching device for a burglar alarm. (2mk)

- ✓ ***Add a relay circuit in the above circuit.***
- ✓ ***Consisting of soft-electromagnet and burglar alarm.***
- ✓ ***The current flowing in the circuit ensures that the relay switch is attracted to the electromagnet. When UV light is cut off, the photocurrent ceases and the relay switch completes the burglar alarm circuit and alarm sounds.***

3. The figure below shows an arrangement used to investigate photoelectric effect.



i) What is the purpose of the color filter? 1mk

- ✓ ***Selectively to transmit/allow light with desired wavelength while restricting others.***

ii) State two measurable quantities in this set up 2mk

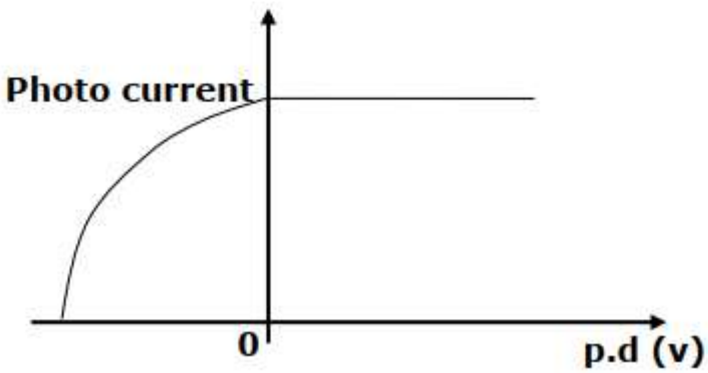
i) Voltage

ii) Photocurrent

iii) State how the intensity of light affects photo current 1mk

- ✓ ***Increase in intensity of light increases photocurrent.***

4. The graph below is a sketch of photo current against the potential difference across the terminals of a photocell when radiated with light of frequency f and intensity t



On the same axes sketch the graph of the photo current against the potential difference (p.d) when the photocell is radiated with light of:

a) Higher frequency and of same intensity t. (1mk)

b) Lower intensity and of same frequency f. (1mk)

CALCULATIONS

1. Write Einstein's photoelectric equation and explain the meaning of each part.(3mk)

✓ $hf = w_o + \frac{1}{2}m_e v^2$

$hf = hf_o + \frac{1}{2}m_e v^2$

Where hf = Energy of photon; w_o = Energy needed to dislodge an electron from metal surface; and ½ $m_e v^2$ = maximum energy gained by this electron.

2. Light of frequency 5.5×10^{14} Hz is made to strike a surface whose work function is 2.5eV. Show that photoelectric effect will not take place $h = 6.6 \times 10^{-34}$Js.

✓ *Freq = 5.5×10^{14}Hz*

W_o = 2.5 eV

h = 6.6×10^{-34}Js

For photoelectric effect to take place, the energy of photon should be greater/ more than/exceed the work function of the metal.

Energy of photon $= hf$

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

$= 3.36 \times 10^{-49}$ J

$W_o = 2.5 \times 1.6 \times 10^{-19} = 4 \times 10^{-9}$ J

3. Electrons emitted from a metal when light of a certain frequency is shone on the metal are found to have to have a maximum energy of 8.0×10^{-19}J. If the work function of the metal is 3.2×10^{-19}J, determine the wavelength of the light used.

✓ $KE_{max} = 8.0 \times 10^{-19}$ J

$W_o = 3.2 \times 10^{-19}$ J

λ of the light used

$hf = W_o + ½ m_e v^2$

$$\frac{hc}{\lambda} = W_o + KE$$

$$\lambda = \frac{hc}{w_o + KE}$$

$$\lambda = \frac{6.6 \times 10^{-34} \times 3.0 \times 10^{8}}{3.2 \times 10^{-19} + 8.0 \times 10^{-19}}$$

$\lambda = 1.768 \times 10^{-7}$ m

4. The work function of a certain material is 3.2eV. Determine the threshold frequency of the material. (1eV=1.6×10^{-19} and h=6.62×10^{34}Js)

✓ W_o = 3.2eV

1eV = 1.6×10^{-19} J

$W_o = 3.2 \times 1.6 \times 10^{-19}$ J

h = 6.62×10^{-34}Js

$W_o = hf_o$

$f_o = \frac{W_o}{h}$

$$\lambda = \frac{3.2 \times 1.6 \times 10^{-34}}{6.62 \times 10^{-34}}$$

$f_o = 7.734 \times 10^{14} Hz.$

5. The wavelength of light from a sodium lamp is 5.9 x 10^{-7}m. A 200W sodium vapour has an efficiency of 40%.

✓ $\lambda = 5.9 \times 10^{-7} m$

$p = 200W$

$n = 40\%$

Calculate:

a) The energy of one quantum of sodium light.

✓ $E = hf = \frac{hc}{\lambda} = \frac{6.62 \times 10^{-34} \times 3.0 \times 10^{8}}{5.9 \times 10^{-7}}$

$E = 3.366 \times 10^{-19} J$

b) The number of quanta emitted in one second.

✓ *Energy of one quata*

$1 = 3.366 \times 10^{-19} J$

$? = 80Js$

$= \frac{80}{3.366 \times 10^{-19}} = 2.377 \times 10^{19}$ *quantas*

6. The threshold frequency for potassium is 5.37 x 10^{14}Hz. When the surface of potassium is illuminated by another radiation, photoelectrons are emitted with the speed of 7.9 x 10^{5}m/s.

✓ $f_o = 5.37 \times 10^{`4} Hz$

$V_e = 7.9 \times 10^{5} m/s$

Calculate:

a) The work function for potassium

✓ $W_o = hf_o$

$= 6.62 \times 10^{-34} \times 5.37 \times 10^{14}$

$= 3.55 \times 10^{-59} J$

b) The K.E of the photoelectrons

✓ $K.E = ½ m_e v^2$

$= ½ \times 9 \times 10^{-31} \times (7.9 X 10^{5})^2$

$= 2.808 \times 10^{-19} J$

c) The frequency of the second source.

✓ $hf = W_o + K.E$

$f = \frac{w_o + KE}{h}$

$$f = \frac{3.55 \times 10^{-19} + 2.808 \times 10^{-19}}{6.62 \times 10^{-34}} = 9.604 \times 10^{14} Hz$$

7. A metal has a work function of 2eV. Calculate the threshold wavelength of the metal given that e=1.6 x 10^{-19}C, h=6.63 x $^{-19}$C and m_e = 9 x 10^{-31}kg.

✓ $W_o = 2eV$

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

$= 2 \times 1.6 \times 10^{-19} J$

$$w_o = \frac{hc}{\lambda_o}$$

$$\lambda_o = \frac{hc}{w_o}$$

$$\lambda_0 = \frac{6.62\times10^{-34}\times3.0\times10^{8}}{2\times1.6\times10^{-19}} = 6.21 \times 10^{-7} m$$

8. A surface whose work function ɵ is 2.46eV is illuminated by light of frequency 3 x 10^{15}Hz. Calculate the maximum kinetic energy of the ejected photoelectrons. (h=6.63 x 10^{-34}Js).

✓ $W_o = 2.46eV$

$f = 3 \times 10^{15} Hz$

$hf = W_o + KE_{max}$

$KE_{max} = hf - W_o$

$KE_{max} = (6.62 \times 10^{-34} \times 3 \times 10^{15}) - (2.46 \times 1.6 \times 10^{-19})$

$KE_{max} = 1.5924 \times 10^{-18} J$

9. A radiation of frequency 8.5 x 10^{14}Hz is incident on a metal emitting photoelectrons. Determine the threshold wavelength.

(Plank's constant = 6.63 x 10^{-31}Js)

✓ $f = 8.85 \times 10^{14} Hz$

$h = 6.63 \times 10^{-34} J$

$$hf = \frac{hc}{\lambda_o}$$

$$\lambda_o = \frac{hc}{hf}$$

$$\lambda_o = \frac{c}{f}$$

$$= \frac{3.0\times10^{8}}{8.85\times10^{14}}$$

$\lambda_o = 3.389 \times 10^{-7} m$

10. The threshold wavelength of a photo emissive surface is 5.55 x 10^{-7}m.

Take C = 3.0 x 10^{8}m/s, h = 6.6 x 10^{-31}Js and M_e = 9.1 x 10^{-31}kg. Calculate:

i) Its threshold frequency.

✓ $\lambda_o = 5.55 \times 10^{-7} m$

$$f_o = \frac{c}{\lambda_o}$$

$$f_o = \frac{3.0\times10^{8}}{5.55\times10^{-7}}$$

$f_o = 5.405 \times 10^{13} Hz$

ii) The work function in electron volt.

✓ $W_o = hf_o$

$= 6.62 \times 10^{-34} \times 5.405 \times 10^{15}$
$= 3.578 \times 10^{-19} J$
$= 2.236 eV$

iii) The maximum speed with which a photoelectron is emitted if the frequency of radiation is 6.2×10^{14}z.

✓ ***Maximum speed***

$hf = W_o + KE_{max}$

$hf = W_o + \frac{1}{2} m_e v^2$

$\frac{1}{2} m_e v^2 = hf - W_o$

$KE_{max} = (6.63 \times 10^{-34} \times 6.2 \times 10^{14}) - (3.598 \times 10^{-19})$

$= 5.326 \times 10^{-20} J$

$KE_{max} = \frac{1}{2} m_e v^2$

$$v = \sqrt{\frac{KE_{mx} \times 2}{m_e}}$$

$$v = \sqrt{\frac{5.326 \times 10^{-20} \times 2}{9.1 \times 10^{-31}}}$$

$v = 3.42 \times 10^5 m/s$

11. Sodium has a work function of 3.68×10^{-19}J. Calculate the minimum frequency of light that can free a photoelectron from the surface of sodium.

✓ $W_o = 3.68 \times 10^{-19} J$

$W_o = hf_o$

$$f_o = \frac{w_o}{h} = \frac{3.68 \times 10^{-19}}{6.62 \times 10^{-34}}$$

$f_o = 5.55 \times 10^{14} Hz$

12. A surface whose work function $\varphi = 6.4 \times 10^{-19}$ Joules is illuminated with light of frequency 3.0×10^{15}Hz. Find the maximum kinetic energy of the emitted photoelectrons. ($n = 6.63 \times 10^{-34}$Js)

✓ $W_o = 6.4 \times 10^{-19} J$

$f = 3.0 \times 10^{15} Hz$

Max K.E

$hf = W_o + K.E_{max}$

$K.E_{max} = hf - W_o$

$K.E_{max} = (6.62 \times 10^{-34} \times 3.0 \times 10^{15}) - (6.4 \times 10^{19})J$

$K.E_{max} = 1.346 \times 10^{-18} J$

13. The longest wavelength of radiation that can produce photoelectric effect in iron is 2.67×10^{-7}. Calculate the work function of iron. Take speed of light $= 3.0 \times 10^8$m/s, Plank's constant $= 6.63 \times 10^{-34}$Js).

✓ $\lambda_o = 2.67 \times 10^{-7} m$

$W_o = hf_o$

$$W_o = \frac{hc}{\lambda o}$$

$$W_o = \frac{6.63 \times 10^{-34} \times 3.0 \times 10^{8}}{2.67 \times 10^{-7}}$$

$$W_o = 7.44 \times 10^{-19} J$$

GRAPHS

1. In a photoelectric effect experiment, a certain metal surface was illuminated with radiation of different frequencies the table below shows the variation between frequency and stopping potential.

Frequency, f(Hz) (x10^{14})	8.2	9.1	10.0	11.5	13.0
Stopping potential, V_s(V)	**0.2**	**0.6**	**1.0**	**1.6**	**2.2**

i) Plot a graph of stopping potential (y – axis) against frequency.

ii) Use the graph to determine Plank's constant and threshold frequency of the metal.

2. The table below shows the relationship between the wavelength λ, of a radiation falling on a surface and the energy of E of the emitted electrons.

λ (m) x 10^{-7}	**2.0**	**1.5**	**1.0**	**0.5**
E(J) x 10^{-19}	**10**	**13**	**20**	**40**
Frequency(f)				

i) Plot a graph of energy E against the frequency f of the incident light.

ii) Determine the work function, W_o of the surface used. (Take C = 3.00 x 10^8 m/s and h = 6.663 x 10^{-34}Js)

3. In an experiment to observe photoelectric emission from a clean cesium surface, the following readings were obtained.

Stopping potential (V)	**0.6**	**1.0**	**1.4**	**1.8**	**2.2**
Light frequency (x 10^{14}Hz)	**6.0**	**7.0**	**8.0**	**9.0**	**10.0**

i) Plot the graph of stopping potential VS (y axis) against frequency.

ii) From the graph, determine the threshold frequency of the surface.

iii) Use the graph to determine Plank's constant (e = 1.6 x 10^{-19}C)

4. In an experiment of photoelectric emission from a clean metal surface, the following readings were obtained as shown below.

Frequency f (10^{15}Hz)	**0.6**	**0.7**	**0.8**	**1.0**
Maximum Kinetic energy, K.E (10^{-19})	**0.58**	**1.25**	**2.56**	**3.26**

i) The metal surface used normally should be cleaned. Explain.

ii) Plot a graph of kinetic energy, E_R against frequency f and use the graph to determine.

(i) The Plank's constant

(ii) The work function of the metal in electron volts(eV)

5. A student carried out an experiment to determine the Plank's constant and the work function of a metal surface, she obtained the following results.

Kinetic energy ke (x 10^{-20}J)	**4.0**	**10.4**	**16.5**	**22.7**	**29.3**	**35.8**
Frequency (x 10^{14}Hz)	**4**	**5**	**6**	**7**	**8**	**9**

i) On the grid provided, plot a graph of KE against frequency.

ii) Given that hf = w_o + ke, determine the Plank's constant.

iii) The threshold wavelength **λ_o.**

6. A metal surface is illuminated with radiations of different wavelength and the kinetic energy of the photoelectrons ejected by each wavelength is recorded in the table below.

Wavelength (x 10^{-19}m)	**415**	**387**	**368**	**345**	**325**	**315**
Energy (x 10^{-19}J)	**0.5**	**0.8**	**1.1**	**1.5**	**1.75**	**2.00**
Frequency(Hz)						

a) Complete the table by filling the frequency.

b) Plot a graph of energy (y-axis) against frequency on the grid paper provided.

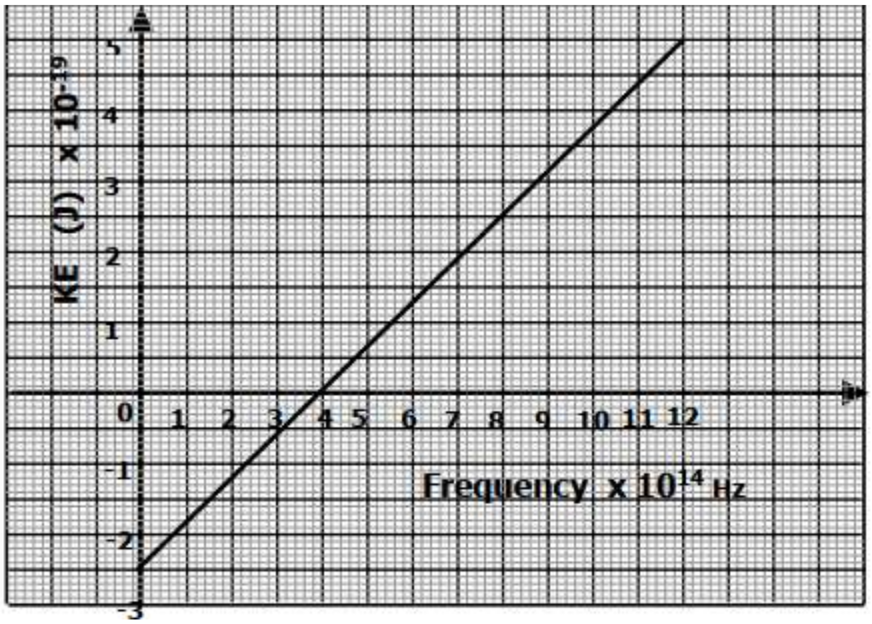
c) Use the graph to find:

i) Work function

ii) Plank's constant

iii) Stopping potential when wavelength is 315x10^{-9}m.

7. The graph below shows the variation of kinetic energy (K.E) of a photoelectric emitted against frequency of the incident radiation.



From the graph determine the:

i) Threshold frequency of the metal used

✓ *f_o = 4.0 x 10^{14}Hz*

ii) Plank's constant(h)

✓ ***Plank's constant = Gradient of the graph***

$hf = hf_o + KE \Rightarrow \frac{(5-2.5)\times 10^{-19}}{(12-8)\times 10^{14}} = \frac{2.5\times 10^{-19}}{4\times 10^{14}}$

$h = 6.25 \times 10^{-34} Js$

iii) Work function of the metal in joules

✓ $W_o = hf_o = 6.25 \times 10^{-34} \times 4.0 \times 10^{14} = 2.5 \times 10^{-19} J$

Alternatively

✓ ***Work function = y – intercept***

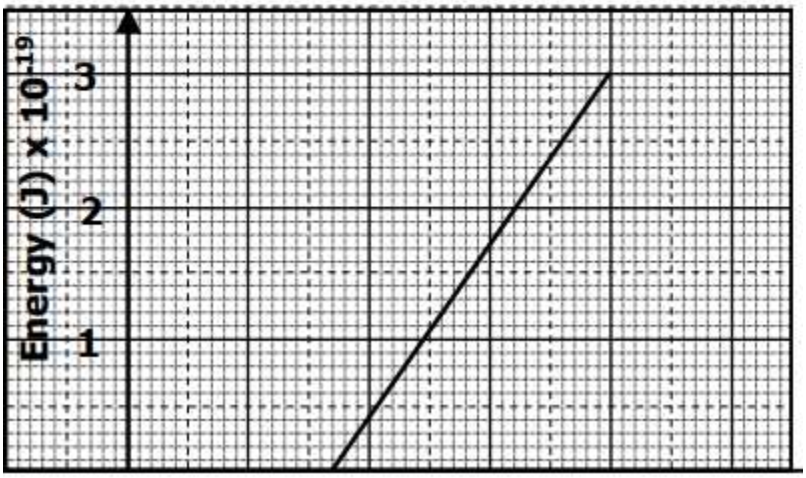
$= 2.5 \times 10^{-19} J$

iv) The threshold wavelength.

(Take charge of an electron = 1.6 x 10^{-19}C and C = 3.0 x 10^{8}m/s)

✓ $\lambda_o = \frac{c}{f} \Rightarrow \lambda_o = \frac{3.0\times 10^{8}}{4.0\times 10^{14}} = 7.5 \times 10^{-7} m$

8. The graph below shows how the energy of light incident on a metal varies with the frequency. Find the threshold frequency of the metal.



From the graph determine the:

i) Threshold frequency of the metal used.

✓ $3.4 \times 10^{14} Hz$

ii) Plank's constant(h)

✓ ***Plank's constant = Gradient of the graph***

✓ $h = \frac{(3-0)\times 10^{-19}}{(8-3.4)\times 10^{-14}} = 6.522 \times 10^{-34} J$

iii) Work function of the metal in joules

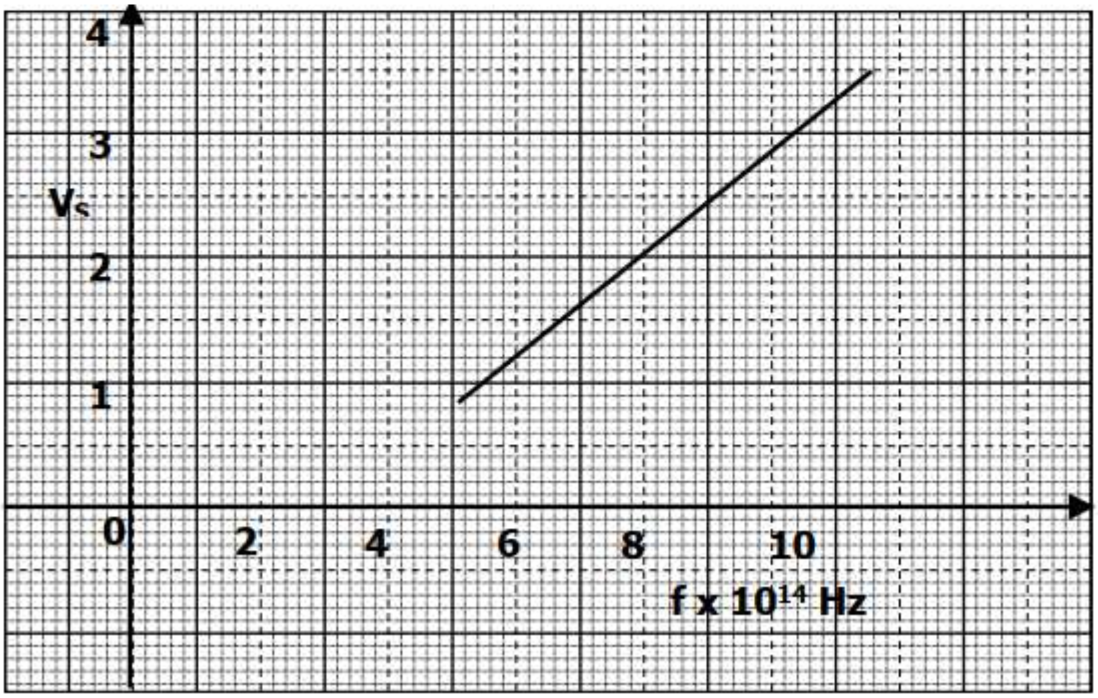
(Take charge of an electron = 1.6 x 10^{-19}C and C = 3.0 x 10^{8}m/s)

✓ $W_o = hf_o$

$= 6.522 \times 10^{-34} \times 3.4 \times 10^{14}$

$= 2.217 \times 10^{-19} J$

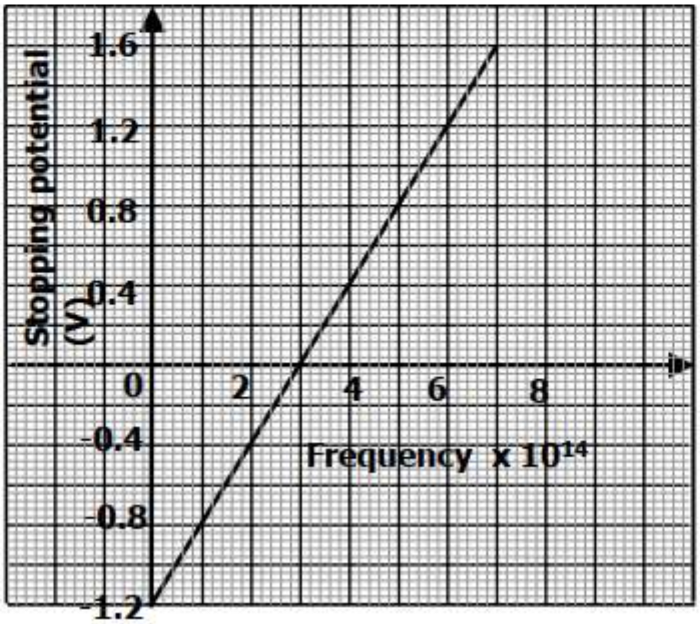
9. The graph below shows the variation of stopping potential, V_o, with incident frequency, f, for a certain metal producing photoelectrons.



i) What is meant by stopping potential?

ii) Use the graph to determine the working function of the metal.

10. In an experiment to find the relationship between frequency of ration and kinetic energy of photoelectrons in a photoelectric device, the following graph was obtained.



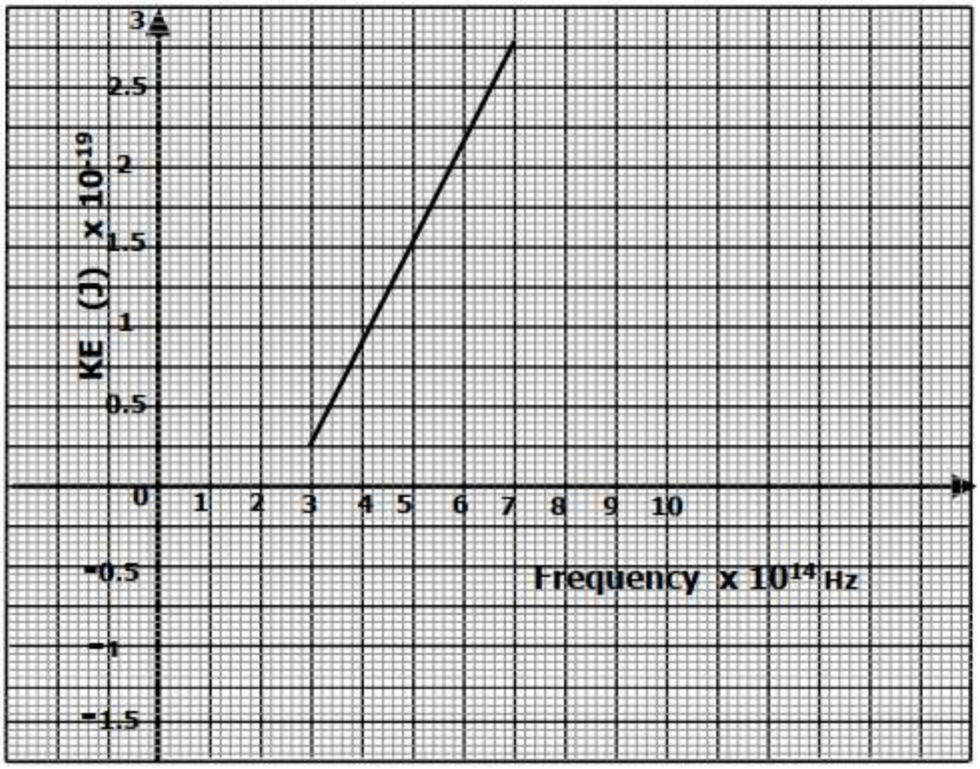
Determine from the graph to answer the following questions,

i) The threshold frequency

ii) Find the Plank's constant, h. (Charge of an electron is 1.6×10^{-19})

iii) Calculate the work function of the metal in joules.

11. A student investigated how the maximum kinetic energy of the photoelectrons, emitted from a zinc cathode, varies with the frequency of the incident radiation. The results obtained were plotted as shown on the graph below.



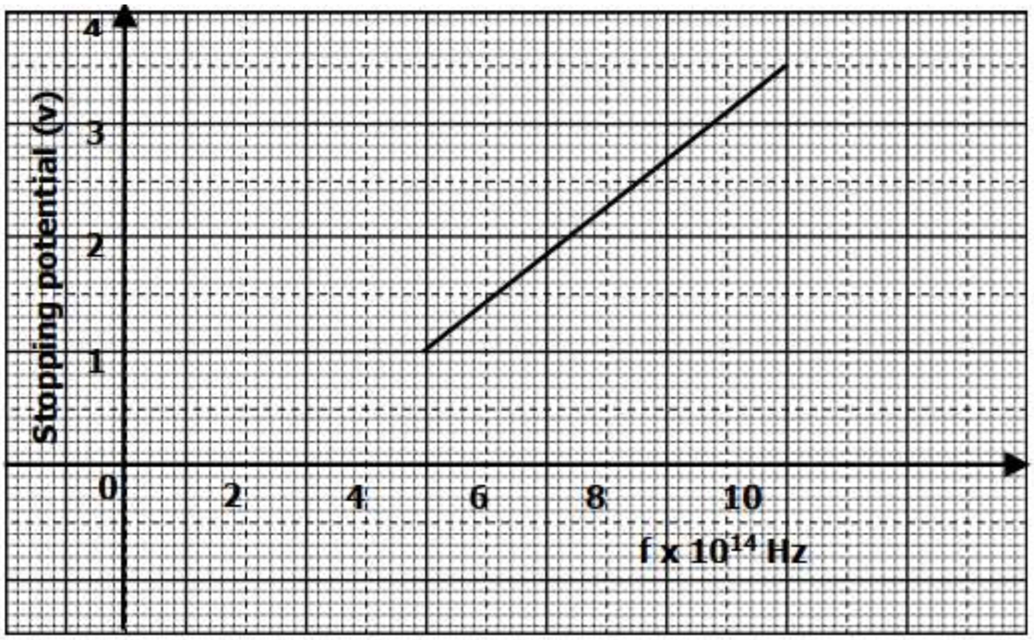
From the graph determine:-

i) The Plank's constant

ii) The work function

iii) Lithium metal has a higher work function than zinc. On the same axes, sketch a graph for lithium.

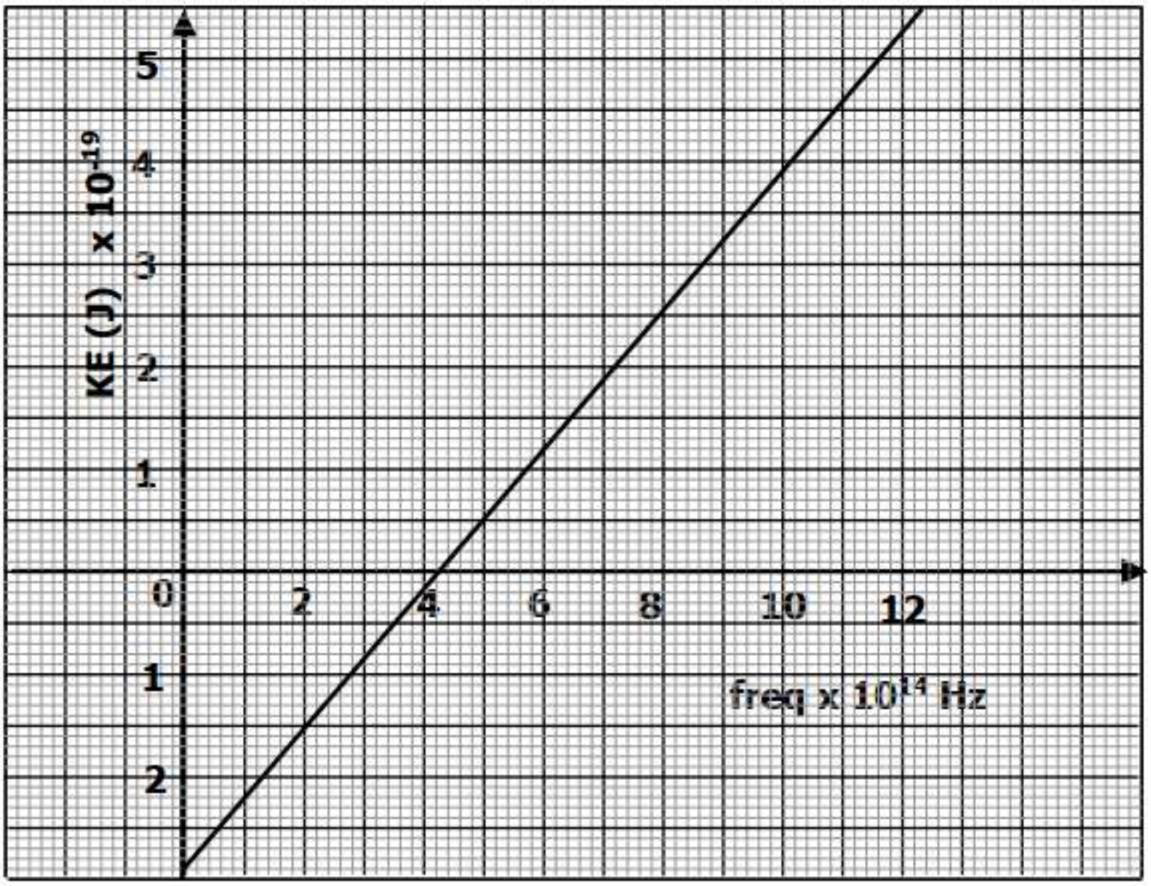
12. The graph below shows the variation of stopping potential, V_o, with incident frequency, f, for a certain metal producing photoelectrons.



i) What is meant by stopping potential?

ii) Use the graph to determine the working function of the metal.

13. The graph below shows the variation of kinetic energy (K.E) of a photo electric emitted against frequency of the incident radiation.



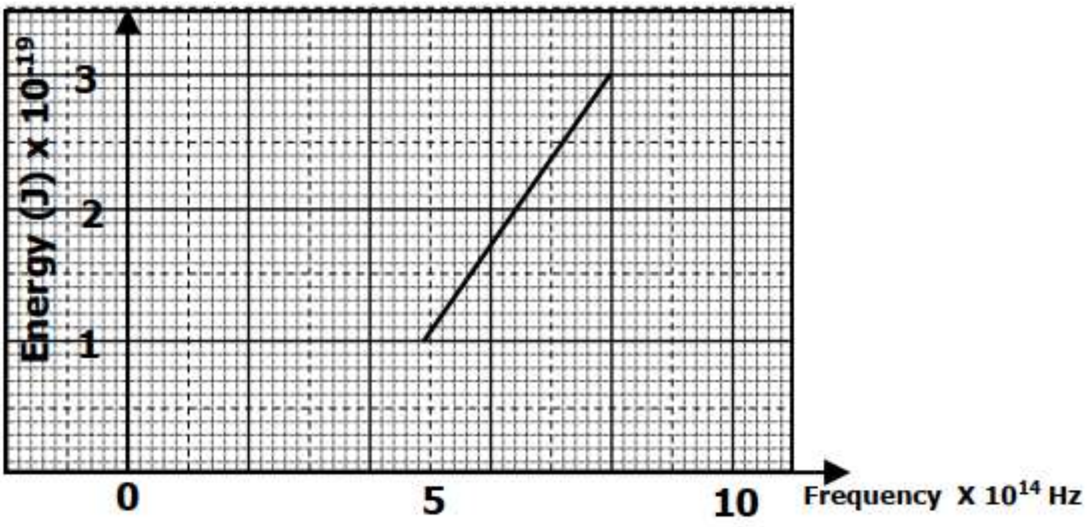
From the graph the equation $hf=hf_o + KE$ holds, determine:

i) The threshold wavelength λ_o (2mks)

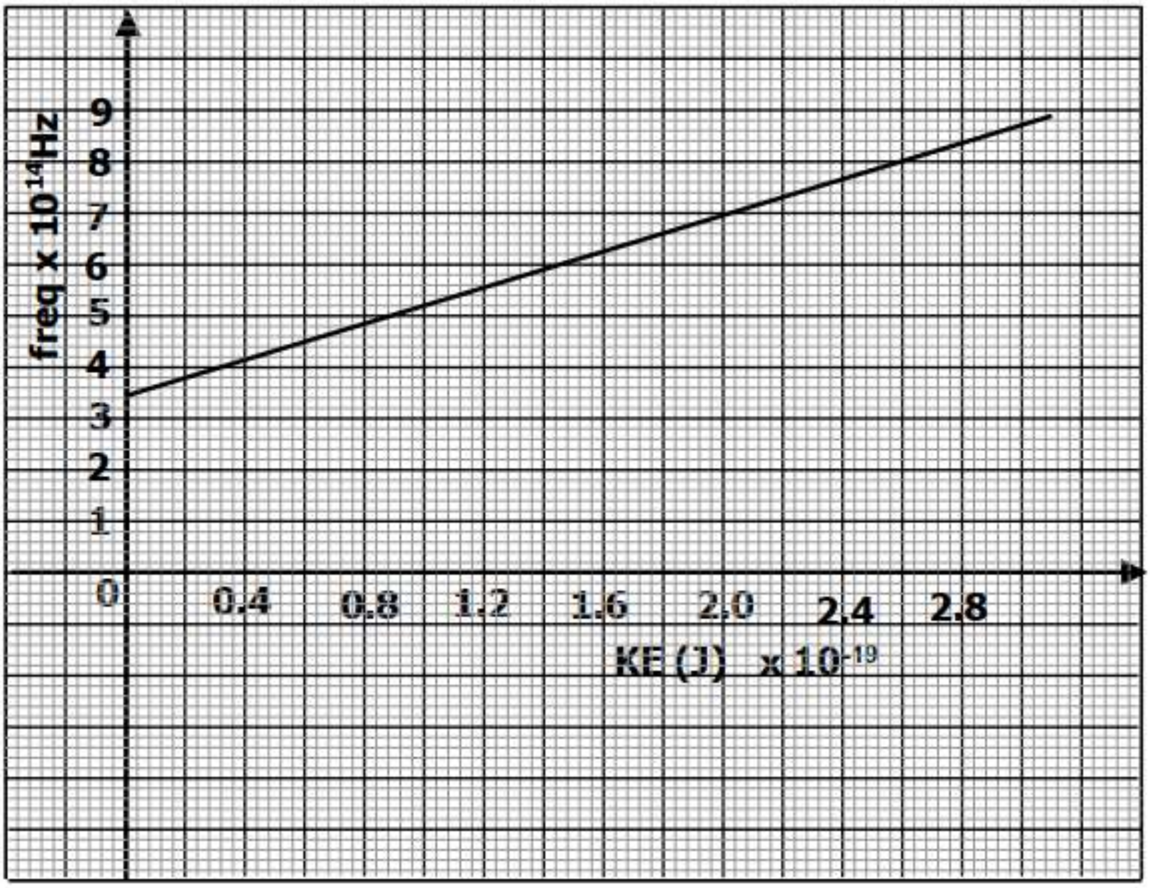
ii) The Plank's constant, h (3mks)

iii) Hence calculate the work function, w_o. (2mks)

14. The graph below shows how the energy of light incident on a metal varies with the frequency. Find the threshold frequency of the metal.(1mk)



15. The graph in figure shows the variation of frequency of radiation f with the greatest kinetic energy of the emitted electrons.



From the graph determine:-

i) Plank's constant (4mks)

ii) Hence or otherwise calculate the work function of the metal.(3mks)