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12th Physics Study Material

Unit – 7 Dual Nature Of Radiation And Matter

It includes

- **Book Back Answers**
- **One Marks With Hints**
- **Book Back Problem Solution**
- **Book Inside Question**
- **Concept Based One Marks**

Unit – 7 DUAL NATURE OF RADIATION AND MATTER

Multiple Choice Questions

1. The wavelength λ_e of an electron and λ_p of a photon of same energy *E* are related by

a. $\lambda_e \alpha \lambda_p$ b. $\lambda_p \alpha \sqrt{\lambda_e}$ c. $\lambda_p \alpha \frac{1}{\sqrt{\lambda_e}}$ d. $\lambda_p \alpha \lambda e^2$

Hint : $E_e = \frac{p^2}{2m} = \frac{h^2}{\lambda_e^2}$

$E_p = \frac{hc}{\lambda_p}$

Since same energy

$\frac{h^2}{\lambda_e^2} = \frac{hc}{\lambda_p}$ which implies $\lambda_p \alpha \lambda e^2$ **d. $\lambda_p \alpha \lambda e^2$**

2. In an electron microscope, the electrons are accelerated by a voltage of 14 *kV*. If the voltage is changed to 224 *kV*, then the de Broglie wavelength associated with the electrons would

a. increase by 2 times b. decrease by 2 times
c. decrease by 4 times d. increase by 4 times

Hint : $\lambda_o = \frac{1.227}{\sqrt{V}} \tilde{A}$

$\frac{\lambda_1}{\lambda_2} = \sqrt{\frac{V_2}{V_1}} = \sqrt{\frac{224000}{14000}} = \sqrt{16} = 4$

$\lambda_2 = \frac{\lambda_1}{4}$ **c. decrease by 4 times**

3. A particle of mass 3×10^{-6} *g* has the same wavelength as an electron moving with a velocity 6×10^{-6} ms^{-1} . The velocity of the particle is

a. 1.82×10^{-18} ms^{-1}. b. 9×10^{-18} ms^{-1} c. 3×10^{-31} ms^{-1} d. 1.82×10^{-15} ms^{-1}

Hint : $\lambda = h/mv$

since they has same wavelength

$\frac{h}{m_1 v_1} = \frac{h}{m_2 v_2}$

$m_1 = 3 \times 10^{-6}$ $m_2 = 9.1 \times 10^{-31}$ $v_1 = 6 \times 10^{-6}$

$v_1 = m_2 v_2 / m_1 = 1.82 \times 10^{-15}$ ms^{-1} **d. 1.82×10^{-15} ms^{-1}**

4. When a metallic surface is illuminated with radiation of wavelength λ , the stopping potential is *V*. If the same surface is illuminated with radiation of wavelength 2λ , the stopping potential is *V*/ 4 . The threshold wavelength for the metallic surface is

a. 4λ b. 5λ c. 5/ 2 λ d. 3λ

Hint : By photo electric equation $eV = hc/\lambda - hc/\lambda_o$

First case

$eV = hc/\lambda - hc/\lambda_o$ ……..(1)

By second case

$P = \frac{hc}{\lambda} \times N \rightarrow N = \frac{P\lambda}{hc}$.........(1)

Given : λ =550 *nm* *P* = 3.8 × 10^{26}*W* *t = 1sec*

Sub given value in (1)

N = $\frac{3.8 \times 10^{26} \times 550 \times 10^{-9}}{6.626 \times 10^{-34} \times 3 \times 10^{8}} = 10^{45}$ **a) 10^{45}**

11.The threshold wavelength for a metal surface whose photoelectric work function is 3.313 *eV* is

a)4125Å b)3750Å c)6000Å d)2062 .5 Å

Hint; hc/ λ = $\emptyset_o$

λ = 6.626 × 10^{-34} × 3 × 10^{8}/ 3.313 × 1.6 × 10^{-19} = 3750 × 10^{-10} **b)3750Å**

12. A light of wavelength 500 *nm* is incident on a sensitive plate of photoelectric work function 1.235 *eV*. The kinetic energy of the photo electrons emitted is be

(Take *h* = 6.6 × 10^{-34} *Js*)

a) 0.58 *eV* b) 2.48 *eV* c) 1.24 *eV* d) 1.16 *eV*

Hint: $E = \emptyset_o + K.E$ **Given** $\emptyset_o$ = 1.235 *eV* **λ** =500 *nm*

K.E = $\frac{hc}{\lambda} - \emptyset_o$ ....(1)

Sub Given values in (1)

K.E = $\frac{6.626 \times 10^{-34} \times 3 \times 10^{8}}{500 \times 10^{-9}} - 1.235$ = 1.24 *eV* **d) 1.24 eV**

13. Photons of wavelength λ are incident on a metal. The most energetic electrons ejected from the metal are bent into a circular arc of radius *R* by a perpendicular magnetic field having magnitude *B*. The work function of the metal is

a) $\frac{hc}{\lambda} - m_e + \frac{e^2B^2R^2}{2m_e}$ b) $\frac{hc}{\lambda} + 2m_e\left[\frac{eBR}{2m_e}\right]^2$

c). $\frac{hc}{\lambda} - m_ec^2 - \frac{e^2B^2R^2}{2m_e}$ d) $\frac{hc}{\lambda} - 2m_e\left[\frac{eBR}{2m_e}\right]^2$

Hint: $h\upsilon = \emptyset_o + \frac{1}{2}mv^2$.......(1)

Bev = $\frac{m_ev^2}{R} \rightarrow v = \frac{BeR}{m_e}$

Sub v in (1)

$\emptyset_o = \frac{hc}{\lambda} - 2m_e\left[\frac{eBR}{2m_e}\right]^2$ **d)** $\frac{hc}{\lambda} - 2m_e\left[\frac{eBR}{2m_e}\right]^2$

14. The work functions for metals *A*, *B* and *C* are 1.92 *eV*, 2.0 *eV* and 5.0 *eV* respectively. The metals which will emit photoelectrons for a radiation of wavelength 4100Å is/are

a. *A* only b. both *A* and *B*

c. all these metals d. none

Hint: **E** = $\frac{hc}{\lambda}$

λ =4100Å E = $\frac{6.626 \times 10^{-34} \times 3 \times 10^{8}}{4100 \times 10^{-10}}$ = **3eV**

The work function of A and B are less than 3Ev.So A and B will emit photoelectrons

b. both *A* and *B*

15. Emission of electrons by the absorption of heat energy is called………emission.

a. photoelectric b. field c. thermionic d. secondary

Hint: heat energy **c. thermionic**

Book inside

1. When an electron is accelerated with a potential difference V, its de Broglie wavelength is proportional to

a) V b) V c)$V^{1/2}$ **d)$V^{-1/2}$**

Hint $\lambda = \frac{12.27}{\sqrt{V}}$

2. If the kinetic energy of the moving particle is E, then the de Broglie wavelength is

a) $\lambda = \frac{h}{\sqrt{2me}}$ b) $\lambda = \frac{h}{\sqrt{me}}$ **c) $\lambda = \frac{h}{\sqrt{2mE}}$** d) $\lambda = \frac{h}{\sqrt{mE}}$

3. The wavelength of matter wave is independent of

a) mass b) velocity c) momentum **d) charge**

Hint; $\lambda = \frac{h}{mv}$ **There is no charge term in de Broglie equation**

4. At the threshold frequency, the velocity of the electron is

a) unity b) minimum . **c) zero** d) infinite

5.An electron of mass m and charge e accelerated from rest through a potential of V volt, then its final velocity

a) $v = \sqrt{\frac{2e}{mV}}$ b) $v = \sqrt{\frac{4e}{mV}}$ **c) $v = \sqrt{\frac{2eV}{m}}$** d) $v = \sqrt{\frac{eV}{m}}$

6. A photon of frequency u is incident on a metal surface or threshold frequency υ_O . The kinetic energy of the emitted photoelectron is

a) $h(\upsilon - \upsilon_O)$ b)$h\upsilon_O$ c) $h\upsilon$ d)$h(\upsilon + \upsilon_O)$

7. The stopping potential of a metal surface is independent of

a) frequency of incident radiation **b) intensity of incident radiation**

c) the nature of the metal surface d) velocity of the electrons emitted

8. The photo electric effect can be explained on the basis of

a) corpuscular theory b) wave theory of light

c) electromagnetic theory of light **d) quantum theory of light**

9.The photo current during a photo electric effect increases if

a)exposure time is decreased

b)Exposure time is increased

c)intensity of the source is increased

d) intensity of the source is decreased

10.The particle which has zero mass but has energy

a)electron b)proton c)neutron **d)photon**

11.Electron microscope works on the principle of

a)Particle nature of electron b)photo electric effect

$\frac{hc}{\lambda_1} = \frac{nhc}{\lambda_2}$

$\lambda_1 = 8000$ Ǻ $\lambda_2 = 4000$Ǻ

n = 8000/4000 = 2

21. An electric bulb of 100W converts 3% of electrical energy into light energy. If the wavelength of light emitted is 6625 Ǻ ,the number of photons emitted is

a) 10^{17} b) 10^{20} **c) 10^{19}** d) 10^{30}

Hint: E = $\frac{nhc}{\lambda}$ n = $\frac{E\lambda}{hc}$ E = 3 λ = 6625Ǻ after sub we get n = 10^{19}

22. Which of the following phenomenon cannot be explained by quantum theory of light?

a) Emission of radiation from blackbody

b) Photo electric effect

c) Polarisation

d) Crompton effect

23. If de-Broglie wavelength of electron is increased by 1% its momentum

a) increases by 1% **b) decreases by 1%**

c) increased by 2% d) decreases by 2%

24. Photosensitive surface is incident by light having frequency 3 times its threshold frequency.In this condition , if frequency of light is made half and intensity of light is made double ,magnitude of photo electric current becomes

a) Fourth **b) double** c)half d)zero

25. Wavelength of an electron having energy 10keV is

a) 0.12 Ǻ b) 1.2 Ǻ c) 0.012 Ǻ d)120Ǻ

$$\lambda = \frac{h}{\sqrt{2mE}}$$

$$\lambda = \frac{6.626\times10^{-34}}{\sqrt{2\times9.1\times10^{-31}\times10\times10^{4}\times1.6\times10^{-19}}} = 0.12\text{Å}$$

26. In the Davission and Germer's experiment the filament of electron gun is coated with

(a) Cotton **b) BaO** c) Oil d) FeO

Book Back

Short Answer Questions

1.Why metals have a large numbers of free electrons?

- The electrons in the outermost shell of a metal loosely bound to the nucleus .
- Even at room temperature there are large number of electrons moving in random manner

2.Define work function of a metal. Give its unit

- The **minimum energy** needed for an **electron** to **escape** from the metal surface is called work function of that metal.
- It is denoted by φ_0

Unit : electron volt

3.What is photo electric effect ?

The ejection of electrons from a metal plate when illuminated by light or any other electromagnetic radiation of suitable wavelength (or frequency) is called **photoelectric effect** and the corresponding current as **photoelectric current or photo current**.

4.How does photocurrent vary with the intensity of incident light?

- Frequency of the incident light and accelerating potential V of the anode are kept constant.
- Potential of anode A is kept positive with respect to cathode C so that the electrons are attracted towards A.
- Intensity of the incident light is varied and the corresponding photoelectric current is measured.
- A graph is drawn between intensity along x-axis and the photocurrent along y-axis
- Photo current – number of electrons emitted per second is directly proportional to intensity of the incident light.

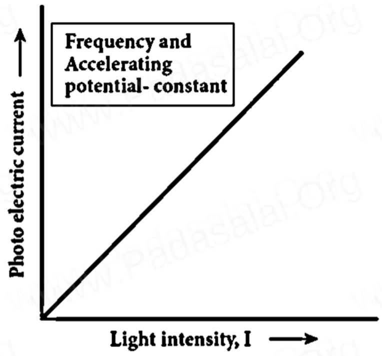


Figure 7.9 Variation of photocurrent with intensity

5.Give the definition of intensity of light and give its unit

It is defined as the **number of energy quanta or photons incident per unit area per unit time**, with each photon having same energy.

Unit : Wm^{-2}.

6.How will you define threshold frequency?

- It is defined as minimum frequency of light which causes electrons to be emitted from metal surface.
- Below this frequency no electrons can be ejected out.

12. Write the relationship of de Broglie wavelength λ associated with a particle of mass *m* in terms of its kinetic energy *K*.

$$K.E = \frac{p^2}{2m}$$

$$p = \sqrt{2m(K.E)}$$

$$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2m(K.E)}}$$

13. Name an experiment which shows wave nature of the electron. Which phenomenon was observed in this experiment using an electron beam?

Davisson – Germer experiment shows wave nature of the electron.

The phenomenon of **constructive interference** was observed in Davisson – Germer experiment

14. An electron and an alpha particle have same kinetic energy. How are the de Broglie wavelengths associated with them related?

$$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mqV}}$$

For given kinetic energy

$$\lambda \propto \frac{1}{\sqrt{m}}$$

$$\frac{\lambda_e}{\lambda_\alpha} = \sqrt{\frac{m_\alpha}{m_e}}$$

Long Answer Questions

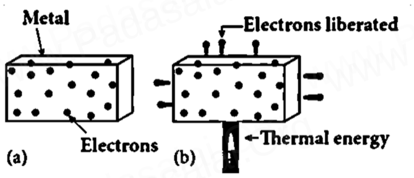
1.What do you mean by electron emission? Explain briefly various methods of electron emission.

Electron emission

Liberation of electrons from any surface of substance is called electron emission

There are mainly **four types** of electron emission depending upon the **form of energy being utilized**

i)Thermionic emission

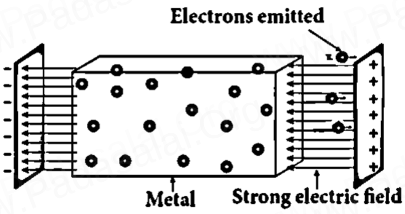


- When a metal is heated to a high temperature, the free electrons on the surface of the metal get sufficient energy in the form of thermal energy so that they are emitted from the metallic surface.
- This type of emission is known as **thermionic emission.**
- The intensity of the thermionic emission (the number of electrons emitted) depends on the metal used and its temperature.

Examples: cathode ray tubes, electron microscopes, X-ray tubes etc

ii) Field emission

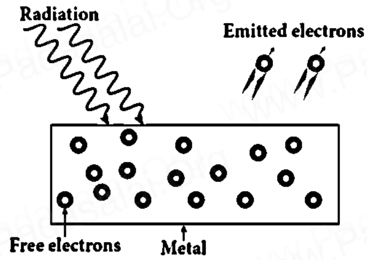
- Electric field emission occurs when a very strong electric field is applied across the metal.
- This strong field pulls the free electrons and helps them to overcome the surface barrier of the metal.



Examples: Field emission scanning electron microscopes, Field-emission display etc.

iii) Photo electric emission

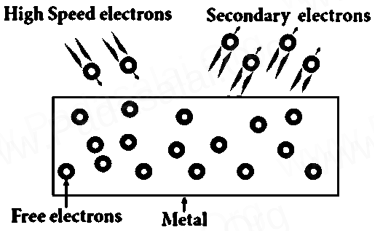
- When an electromagnetic radiation of suitable frequency is incident on the surface of the metal, the energy is transferred from the radiation to the free electrons.
- Hence, the free electrons get sufficient energy to cross the surface barrier and the photo electric emission takes place .
- The number of electrons emitted depends on the intensity of the incident radiation.



Examples: Photo diodes, photo electric cells etc.

iv) Secondary emission

- When a beam of fast moving electrons strikes the surface of the metal, the kinetic energy of the striking electrons is transferred to the free electrons on the metal surface.
- Thus the free electrons get sufficient kinetic energy so that the secondary emission of electron occurs .



Examples: Image intensifiers, photo multiplier tubes etc.

2. Briefly discuss the observations of Hertz, Hallwachs and Lenard.

Hertz observation

- The electromagnetic waves produced by his experiment were detected by a detector that has a copper wire bent in the shape of a circle.
- Although the detection of waves is successful, there is a problem in observing the tiny spark produced in the detector.
- In order to improve the visibility of the spark, Hertz made many attempts and finally noticed an important thing that small detector spark became more vigorous when it was exposed to ultraviolet light.

Conclusion

- The reason for vigorous behaviour of the spark was not known at that time.
- Later it was found that it is due to the photoelectric emission.
- Whenever ultraviolet light is incident on the metallic sphere, the electrons on the outer surface are emitted which caused the spark to be more vigorous.

- However a stage is reached where photocurrent reaches a saturation value **(saturation current)** at
- Which all the photoelectrons from C are collected by A.
- When a negative **(retarding)** potential is apllied to A with respect to C , the current does not immediately drops to zero because the photoelectrons are emitted with some definite and different kinetic energies.
- Due to their kinetic energy some of the electrons overcome the retarding electric field and the reach the electrode A.
- When the negative (retarding) potential of *A* is gradually increased, the photocurrent starts to decrease because more and more photoelectrons are being repelled away from reaching the
- electrode *A*. The photocurrent becomes zero at a particular negative potential V_0, called stopping or cut-off potential.

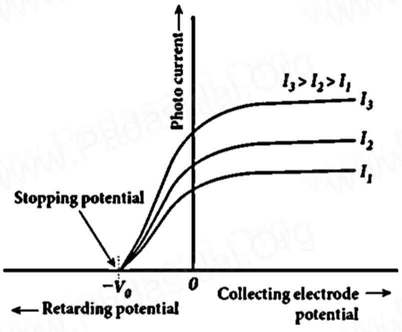


Figure 7.10 Variation of photocurrent with potential difference

- **Stopping potential** is that the value of the negative (retarding) potential given to the collecting electrode A which is just sufficient to stop the most energetic photoelectrons emitted and make the photocurrent zero.
- At the stopping potential, even the most energetic electron is brought to rest. Therefore, the initial kinetic energy of the fastest electron (K_{max}) is equal to the work done by the stopping potential to stop it (eV_0).
- When the intensity of the incident light alone is increased, the saturation current also increases but the value of V_o remains constant.
- Thus, for a given frequency of the incident light, the stopping potential is independent of intensity of the incident light.
- This also implies that the maximum kinetic energy of the photoelectrons is independent of intensity of the incident light.

4. Explain how frequency of incident light varies with stopping potential.

- The intensity of the incident light is kept constant.
- The variation of photocurrent with the collector electrode potential is studied for radiations of different frequencies and a graph drawn between them.
- From the graph, it is clear that stopping potential vary over different frequencies of incident light.
- Greater the frequency of the incident radiation, larger is the corresponding stopping potential.

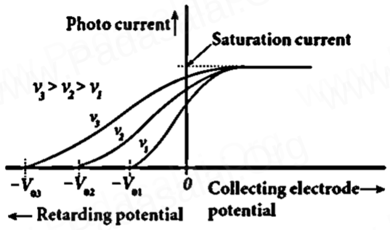


Figure 7.11 Variation of photocurrent with collector electrode potential for different frequencies of the incident radiation

9. Explain experimentally observed facts of photoelectric effect with the help of Einstein's explanation.

i) As each incident photon liberates one electron, then the **increase of intensity of the light (the number of photons** per unit area per unit time) increases the number of electrons emitted thereby increasing the photocurrent. The same has been experimentally observed.

ii)By $K_{max} = h\upsilon - \emptyset_o$ it is evident that K_{max} **is proportional** to the **frequency** of the light and is independent of intensity of the light.

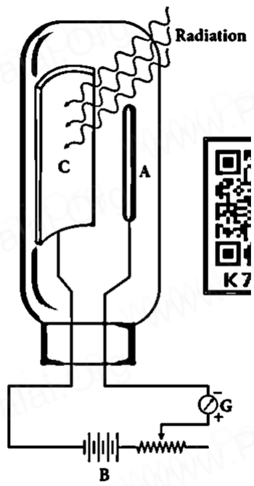
iii) By $h\upsilon = h\upsilon_o + \frac{1}{2}mv^2$ there must be minimum energy (equal to the work function of the metal) for incident photons to liberate electrons from the metal surface. Below which, emission of electrons is not possible. Correspondingly, there exists minimum frequency called threshold frequency below which there is no photoelectric emission.

iv)According to quantum concept, the transfer of photon energy to the electrons is instantaneous so that there is no time lag between incidence of photons and ejection of electrons.

10. Give the construction and working of photo emissive cell.

Construction:

- It consists of an evacuated glass or quartz bulb in which two metallic electrodes – a cathode and an anode are fixed .
- The cathode *C* is semi-cylindrical in shape and is coated with a photo sensitive material.
- The anode *A* is a thin rod or wire kept along the axis of the semi-cylindrical cathode.
- A potential difference is applied between the anode and the cathode through a galvanometer *G*.



Working:

- When cathode is illuminated, electrons are emitted from it.
- These electrons are attracted by anode and hence a current is produced which is measured by the galvanometer.
- For a given cathode, the magnitude of the current depends on
- the intensity to incident radiation and
- the potential difference between anode and cathode.

11. Derive an expression for de Broglie wavelength of electrons.

The momentum of photon of frequency *v* is given by $p = \frac{h\upsilon}{c} = \frac{h}{\lambda}$

since c = υλ

The wavelength of a photon in terms of its momentum is

- Electrons are emitted from the hot filament by **thermionic emission.**
- They are then accelerated due to the potential difference between the filament and the anode aluminium cylinder by a high tension (H.T.) battery.
- Electron beam is collimated by using two thin aluminium diaphragms and is allowed to strike a single crystal of Nickel.
- The electrons scattered by Ni atoms in different directions are received by the electron detector which measures the intensity of scattered electron beam.
- The detector is rotatable in the plane of the paper so that the angle ϕ between the incident beam and the scattered beam can be changed at our will.
- The intensity of the scattered electron beam is measured as a function of the angle θ.
- Scattered wave shows a peak at an angle of **50°** to the incident electron beam.

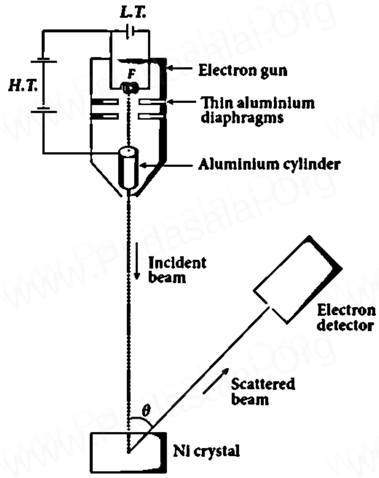


Figure 7.17 Experimental set up of Davisson – Germer experiment

- From the known interplanar spacing of Nickel , the wavelength of the electron wave has been experimentally calculated as **1.65 Å**
- By $\lambda = \frac{12.27}{\sqrt{V}}$ Å where V = 54 V , wavelength found to be **1.67Å**
- This value agree well with experimentally observed wavelength of 1.65Å.
- Thus this experiment directly verifies de Broglie's hypothesis of the wave nature of moving particles

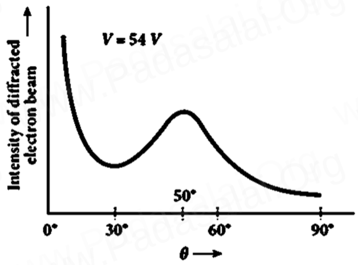


Figure 7.18 Variation of intensity of diffracted electron beam with the angle θ

Book inside

Short answers

1.Why electrons in the metals do not leave the surface of metal even though they move freely inside the metal ?

Free electrons reach the surface of the metal, they are attracted by he positive nuclei of the metal. It is this attractive pull which will not allow free electrons to leave the metallic surf ace at room temperature.

2.What is called surface barrier?

potential barrier which **prevents free electrons** from leaving the metallic surface is called surface barrier.

3. What is called electron emission?

Th eliberation of electrons from any surface of substance is called electron emission

$\lambda_o - Cut\ off\ wavelngth$

Substituting the known values

$$\lambda_o = \frac{12400}{V}\tilde{\text{Å}}$$

Long answers

1.Explain about experimental setup to produce photoelectric current

Experimental setup

- *S* is a source of electromagnetic waves of known and variable frequency *ν* and intensity *I*.
- *C* is the **cathode** (negative electrode) **made up of photosensitive material** and is used to emit electrons.
- The **anode** (positive electrode) *A* **collects the** electrons emitted from *C*.
- These electrodes are taken in an evacuated glass envelope with a quartz window that permits the passage of ultraviolet and visible light.
- The necessary potential difference between *C* and *A* is provided by high tension battery *B* which is connected across a potential divider arrangement *PQ* through a key *K*.

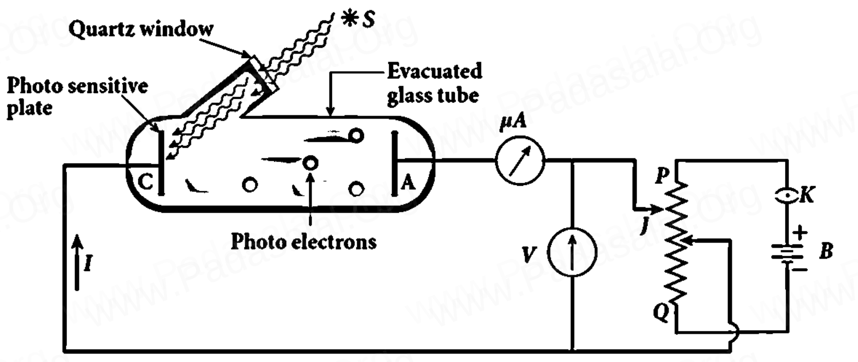
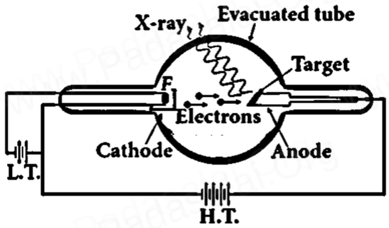


Figure 7.8 Experimental setup for the study of photoelectric effect

- *C* is connected to the centre terminal while *A* to the sliding contact *J* of the potential divider.
- The plate *A* can be maintained at a desired positive or negative potential with respect to *C*.
- To measure both positive and negative potential of *A* with respect to *C*, the voltmeter is designed to have its zero marking at the centre and is connected between *A* and *C*.
- The current is measured by a micro ammeter *mA* in series.

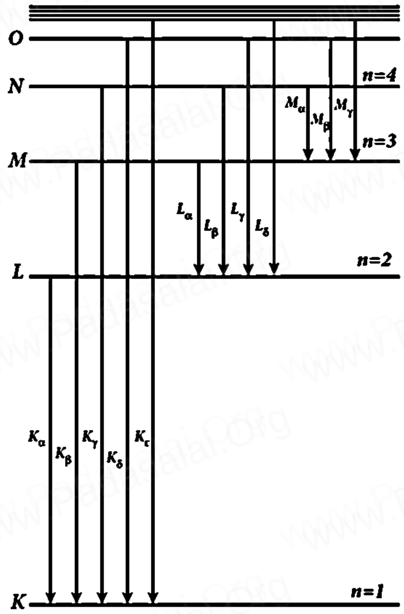
Working

- If there is no light falling on the cathode *C*, no photoelectrons are emitted and the microammeter reads zero.
- When ultraviolet or visible light is allowed to fall on *C*, the photoelectrons are liberated and are attracted towards anode. As a result, the photoelectric current is set up in the circuit which is measured using micro ammeter



- When high-speed electrons strike the target, they are decelerated suddenly and lose their kinetic energy.
- As a result, x-ray photons are produced.
- Since most of the kinetic energy of the bombarding electrons gets converted into heat, targets made of high-melting-point metals and a cooling system are usually employed.

5.Explain about origin of Characteristic x – ray spectra



- The intensity of the x-rays when plotted against its wavelength gives a curve called **x-ray spectrum**
- X – ray spectra show some narrow peaks at some well – defined wavelengths when the target is hit by fast electrons.
- The line spectrum showing these peaks is called **characteristic x – ray spectrum**. This x – ray spectrum is due to the electronic transitions within the atoms.
- When an energetic electron penetrates into the target atom and removes some of the *K*-shell electrons.
- Then the electrons from outer orbits jump to fill up the vacancy so created in the *K*-shell.
- During the downward transition, the energy difference between the levels is given out in the form of x– ray photon of definite wavelength. Such wavelengths, characteristic of the target, constitute the line spectrum.
- From the Figure it is evident that *K*-series of lines in the x-ray spectrum of an element arises due to the electronic transitions from *L*, *M*, *N*, . . levels to the *K*-level.
- Similarly, the longer wavelength *L*-series originates when an *L*-electron is knocked out of the atom and the corresponding vacancy is filled by the electronic transitions from *M*, *N*, *O*,... and so on.

6.Explain about Applications of x-rays

1) Medical diagnosis

X-rays can pass through flesh more easily than through bones. Thus an x-ray radiograph containing a deep shadow of the bones and a light shadow of the flesh may be obtained. X-ray radiographs are used to detect fractures, foreign bodies, diseased organs etc.

2) **Medical therapy**

Since x-rays can kill diseased tissues, they are employed to cure skin diseases, malignant tumours etc.

3) **Industry**

X-rays are used to check for flaws in welded joints, motor tyres, tennis balls and wood. At the custom post, they are used for detection of contraband goods.

4) **Scientific research**

X-ray diffraction is important tool to study the structure of the crystalline materials – that is, the arrangement of atoms and molecules in crystals.

Numerical problems

1. How many photons per second emanate from a 50 *mW* laser of 640 *nm*?

Given : $P = 50\ mW = 50 \times 10^{-3}$ $\lambda = 640\ nm = 640 \times 10^{-9} = 64 \times 10^{-8}$ $t = 1s$

Formula : $P = \frac{E \times N}{t}$

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

$N = \frac{P\lambda}{hc}$

$= \frac{50 \times 10^{-3} \times 64 \times 10^{-8}}{6.626 \times 10^{-34} \times 3 \times 10^{8}} = \mathbf{1.61 \times 10^{17} s^{-1}}$

2. Calculate the maximum kinetic energy and maximum velocity of the photoelectrons emitted when the stopping potential is 81*V* for the photoelectric emission experiment

Given : $V_0 = 81\ V$

Formula : $eV_o = \frac{1}{2} m v_{max}^2$, $eV_o = K.E$

$K.E = eV_o$

$= 1.6 \times 10^{-19} \times 81$

$= \mathbf{1.3 \times 10^{-17} J}$

$eV_o = \frac{1}{2} m v_{max}^2$

$v_{max}^2 = \frac{2eV_o}{m}$

$= \frac{2 \times 1.3 \times 10^{-17}}{9.1 \times 10^{-31}}$

$v_{max}^2 = 0.28 \times 10^{14}$

$v_{max} = \sqrt{0.28 \times 10^{14}} = \mathbf{5.3 \times 10^{6} ms^{-1}}$

3. Calculate the energies of the photons associated with the following radiation: (i) violet light of 413 *nm* (ii) X-rays of 0.1 *nm* (iii) radio waves of 10 *m*.

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

i)Given : $\lambda = 413\ nm = 413 \times 10^{-9} m$

$E = \frac{6.626 \times 10^{-34} \times 3 \times 10^{8}}{413 \times 10^{-9}} = \mathbf{0.04 \times 10^{-17} J}$

For converting J to Ev

$E = \frac{0.04 \times 10^{-17}}{1.6 \times 10^{-19}} = \mathbf{3 eV}$

ii)Given : $\lambda = 0.1\ nm = 1 \times 10^{-10}\ m$

$E = \frac{6.626 \times 10^{-34} \times 3 \times 10^{8}}{1 \times 10^{-10}} = \mathbf{19.8 \times 10^{-16} J}$

For converting J to Ev

$E = \frac{19.8 \times 10^{-16}}{1.6 \times 10^{-19}} = \mathbf{12424}eV$

iii)Given : $\lambda = 10m$

$E = \frac{6.626\times10^{-34}\times3\times10^{8}}{10} = 19.8 \times 10^{-26}J$

For converting J to Ev

$E = \frac{19.8 \times 10^{-16}}{1.6 \times 10^{-19}} = 1.24 \times 10^{-7}eV$

4. A 150 *W* lamp emits light of mean wavelength of 5500 Å. If the efficiency is 12%, find out the number of photons emitted by the lamp in one second

Given : Input power = 150 W ἠ = 12% λ = 5500 Å = $55 \times 10^{-8}m$ **t = 1s**

Formula : $\dot{\eta} = \frac{output\ power}{input\ power}$ $P = \frac{E\times N}{t}$

$12\ \% = \frac{output\ power}{150}$

Output power = 0.12 × 150 = 18W

$N = \frac{18\times1\times55\times10^{-8}}{6.626\times10^{-34}\times3\times10^{8}} = 5 \times 10^{19}$

5.How many photons of frequency 10^{14} *Hz* will make up 19.86 *J* of energy?

Given : $\upsilon = 10^{14}$ **E = 19.86J**

Formula : E = Nhυ

$N = \frac{E}{h\upsilon}$

$= \frac{19.86}{6.626 \times 10^{-34} \times 10^{14}}$

$= 2.99 \times 10^{20}$

6.What should be the velocity of the electron so that its momentum equals that of 4000 Å wavelength photon.

Given : $\lambda = 4000$ Å $= 4000 \times 10^{-10}m = 4 \times 10^{-7}m$

Formula: $\lambda = \frac{h}{mv}$

$mv = \frac{h}{\lambda} = \frac{6.626\times10^{-34}}{4\times10^{-7}} = 1.66 \times 10^{-27}$**…….(i)**

$mv = 9.1 \times 10^{-31} \times v$ **……..(ii)**

Since (i) and (ii) are same

$9.1 \times 10^{-31} \times v = 1.66 \times 10^{-27}$

$$v = \frac{1.66 \times 10^{-27}}{9.1 \times 10^{-31}} = 0.182 \times 10^{4}ms^{-1}$$

material. Determine the value of Planck's constant and the threshold wavelength of the material.

Given : $\lambda_1 = 3310\,Å = 3310 \times 10^{-10}m = 331 \times 10^{-9}m$ $K.E_1 = 3 \times 10^{-19}$

$\lambda_2 = 5000\,Å = 5000 \times 10^{-10}m = 5 \times 10^{-7}m$ $K.E_2 = 0.972 \times 10^{-19}$

Formula : $E = \emptyset_O + K.E$

$$\frac{hc}{\lambda_1} = \emptyset_O + K.E_1$$

$$\frac{h \times 3 \times 10^8}{331 \times 10^{-9}m} = \emptyset_O + 3 \times 10^{-19}$$

$0.009 \times 10^{17}h = \emptyset_O + 3 \times 10^{-19}$............(1)

$$\frac{hc}{\lambda_2} = \emptyset_O + K.E_2$$

$$\frac{h \times 3 \times 10^8}{5 \times 10^{-7}m} = \emptyset_O + 0.972 \times 10^{-19}$$

$0.006 \times 10^{17}h = \emptyset_O + 0.972 \times 10^{-19}$..........(2)

Solving (1) – (2)

$0.003 \times 10^{17}h = 2.028 \times 10^{-19}$

$$h = \frac{2.028 \times 10^{-19}}{0.003 \times 10^{17}} = 6.76 \times 10^{-34}$$

Sub h in (1)

$0.009 \times 10^{17} \times 6.76 \times 10^{-34} = \emptyset_O + 3 \times 10^{-19}$

$\emptyset_O = 3 \times 10^{-19}V$

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

$$\lambda_o = \frac{hc}{\emptyset_O} = \frac{6.626 \times 10^{-34} \times 3 \times 10^8}{3 \times 10^{-19}} = 6.626 \times 10^{-7}m = 6260\,Å$$

10. At the given point of time, the earth receives energy from sun at 4 *cal cm⁻² min⁻¹*. Determine the number of photons received on the surface of the Earth per *cm²* per minute. (Given : Mean wavelength of sun light = 5500 Å)

Given : $\lambda = 5500\,Å = 5500 \times 10^{-10}m = 55 \times 10^{-8}m$ **E = 4 *cal cm⁻² min⁻¹***

Formula : $E = \frac{nhc}{\lambda}$

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

$$= \frac{E \times 5 \times 10^{-8}}{6.626 \times 10^{-34} \times 3 \times 10^8}J$$

To convert cal into joule : 1J = 0.239cal

$$= \frac{4 \times 5\ 5 \times 10^{-8}}{6.626 \times 10^{-34} \times 3 \times 10^8 \times 0.239} = 46.30 \times 10^{18}$$

Formula: $\lambda = \frac{h}{p} = \frac{h}{\sqrt{2meV}}$

$$= \frac{6.626\times10^{-34}}{\sqrt{2\times9.1\times10^{-31}\times1.6\times10^{-19}\times81}} = \frac{6.626\times10^{-34}}{48.56\times10^{-25}} = 0.136\times10^{-9}m = 1.36\text{Å}$$

It belongs to X-rays (0.1 to 100 Å)

15. The ratio between the de Broglie wavelengths associated with protons, accelerated through a potential of 512 *V* and that of alpha particles accelerated through a potential of *X* volts is found to be one. Find the value of *X*.

Given $V_P = 512$

Formula : $\lambda = \frac{h}{p} = \frac{h}{\sqrt{2meV}}$

$$\lambda \propto \frac{1}{\sqrt{mqV}}$$

Mass of an alpha particle = 4 times the mass of proton = $4m_p$

Charge of an alpha particle = 2e

$$\frac{\lambda_P}{\lambda_\alpha} = \frac{1}{\sqrt{m_p \times e \times 512}} \times \frac{\sqrt{4m_p \times 2e \times X}}{1} = 1$$

$$1 = \frac{1}{\sqrt{512}} \times \sqrt{8X}$$

$$\sqrt{8X} = \sqrt{512}$$

X = 64V

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