Physics Notes

BY

Er. Lalit Sharma
B.Tech (Electrical)
Ex. Lecturer Govt. Engg. College Bathinda
Physics Faculty Ranker's Point, Bathinda

Arun Garg
M.Sc. Physics
Gold Medalist
Physics Faculty Ranker's Point, Bathinda

Class:10+2

Unit: VII

Topic: Dual Nature of Matter and Radiation

SYLLABUS: UNIT-VII

Photoelectric effect, Hertz and Lenard's observation; Einstein's photoelectric equation-particle nature of light. Matter waves – wave nature of particles, de Broglie relation, Davisson-Germer experiment.

Q.1. What is Modern Physics?

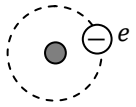
Ans. Physics developed during (1880-1970) can be termed as Modern Physics.

1. 1887 → Photoelectric effect discovered by Hertz/Hall watch.
2. 1887 → Electromagnetic wave experiment by Hertz.
3. 1897 → J.T. Thomson model of atom.
   Every element in periodic table have different spectra. For sodium bulbs, value of wavelength is 5896Å. From observed values, empirical formula is formed i.e.

   $\frac{1}{\lambda}$ = cons $\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$
   ↓
   Constant

4. 1905 → Einestein :-
   a) Photoelectric effect (1921-Nobel Prize)
   b) E = $M.C^2$ (In 1945, making nuclear bomb)
   c) Theory of Relativity
   d) Brownian Motion

5. (1910-11)→ Rutherford α – scattering experiment
   (He performed experiment along with his two students and tells right size of nucleus)



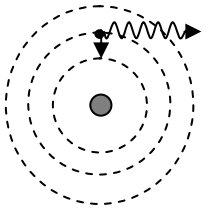
6. (1913-14)→ Bohr's atom

   $E_2 - E_1 = h\,v$

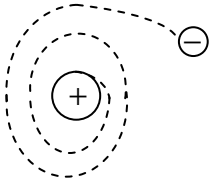
   $= \frac{hc}{\lambda}$

   $\frac{1}{\lambda} = \frac{E_2 - E_1}{\lambda}$

   $\frac{1}{\lambda} = (10^7)\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$



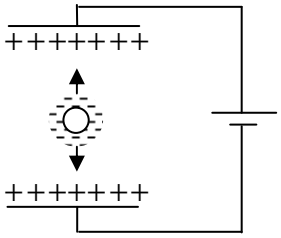
   He suggested that electron is revolving around nucleus.



<u>But Bohr could not explain that</u>

Every charged particle revolving around nucleus accelerates and continuously releases energy in the form of E.H. waves.

∴ Electron (charged particles) will ultimately collapse into the nucleus.



7. 1913 → Millikan's Oil drop experiment
   By experiment, he said that charge is an integral multiple of 1.602 x 10^{-19}C

8. 1924 → According to De Broglie relation

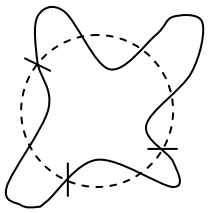
$$\lambda = \frac{h}{m.v}$$

$$2\pi r = 4\lambda$$

For 4^{th} orbit

Standing waves are formed. So, no loss of energy where standing waves are formed.

Bohr justified the stay of e^- in a given orbit on the basis of above theory. He tells that electron is not only particle but also have wave character. Electron can stay in 4^{th} or 5^{th} orbit but cannot in between the orbit. He jumps to higher shell from lower shell by getting energy and vice versa.



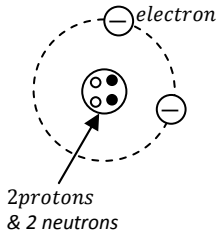
$4th\ orbit$

9. 1927 → Davison Germer experiment
   Measured value of λ for e^- = $1.6A^0$ (experimentally)

10. 1929 → Experimental value of above matched with the theoretical value. Noble Prize to De Broglie

$$\lambda = \frac{h}{m.u}$$

11. 1932 → Neutron by J. Chadwick
    When electron break energy release is -ev but when nucleolus break energy releases is the order of Mega Electron Volt.



12. (1932-45)→ Nuclear Energy Development (for war purpose)

13. (1945-70)→ Nuclear Energy Development for Civil Applications (Nuclear Power Plant)

14. 1970 → Development of Electronics (Diode, Transistor Applications) example: Mobile charge converts *AC* to *DC,* it is termed as rectifier.

15. (1980-2000)→ Development of Chip, Integrated Circuit

16. (2000-2010)→ Transfer of digital data, Computers, transfer of data through internet.
    That means extensive use of Electronic Circuit, Computers, Chips for communication and other purpose.

Q2. a) What is work function? Examples.
b) Discuss different methods of electron emission from metal surface.

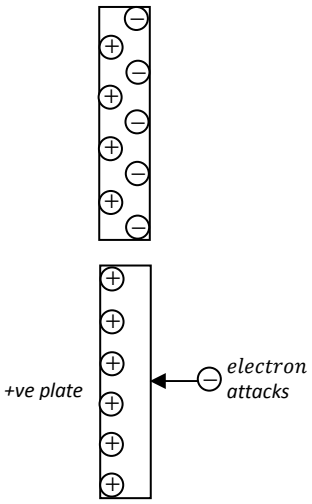
Ans. **Work Function**:-

Metal is neutral with equal +ve and –ve charge due to free electron.

If e^- tries to leave metal, metal becomes +ve and attracts the e^- back to surface.

So, certain minimum amount of energy is required to remove e^- from metal.

This minimum amount of energy required to remove e^- is called "*Work Function*".



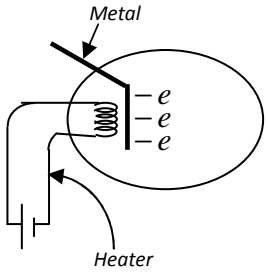
Example:-

	Metal	Work Function
1.	Cs	2.14 ev
2.	Cu	4.65 ev
3.	Pt	5.65 ev

Different methods of e^- emission:-

i) **Thermionic Emission**:-

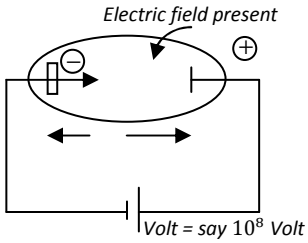
Heater supplies the required energy for e^- to come out of surface.



ii) **Field Emission**:-

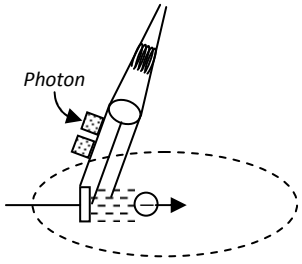
High electric field exerts force on e^-.
e^- moves out of metal due to this force.

The electric field = $10^8 \frac{Volt}{m}$



iii) **Photoelectric Emission**:-

Photons provide required energy to e^- to come out of surface.



Q3. a) Who discover Photoelectric Effect?
b) Who carried out controlled experiment on photoelectric effect for 1st time? What were the observations.

Ans.a) **Heinrich Hertz**:-

Heinrich Hertz discovered Photoelectric effect in 1887. Avc produced Ultra Violet rays, when Ultra Violet rays hit metal surface, it becomes more +ve.

b) **Hallwachs and Lenard**:-

Hallwachs and Lenard carried out controlled experiments on photoelectric effect for the 1st time (1886-1902).

Observations:-

1. Uncharged zinc plate became positively charged when it was irradiated by ultraviolet light.

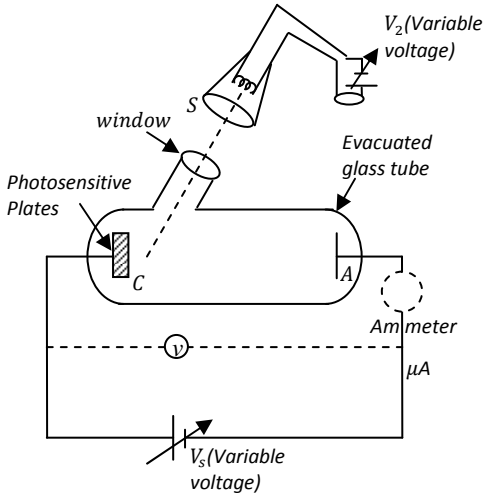
2. No e^- (After 1897) were emitted from metal surface if frequency was less than minimum value (threshold frequency).

3. These electrons coming out of photo sensitive substance called photo electrons.

Q4. Draw experimental set-up to show photoelectric effect experiment. Explain the uses of various components?

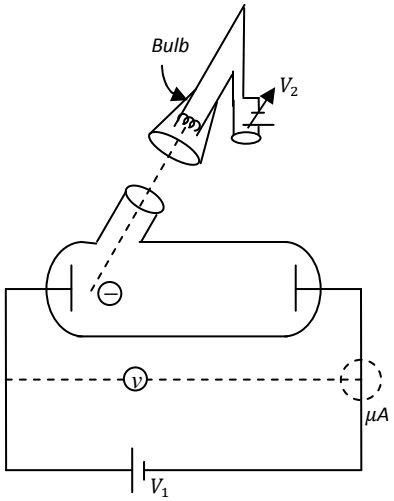
Ans. **Experimental Setup**:-

It consists of an Evacuated Tube having photosensitive plate and another metal plate *A*. Monochromatic Light from the sources of sufficiently short wave length passes through the window. The electrons are emitted by the plate C and are collected by plate *A* by the electric field created by the battery. The battery maintains the potential difference between the plates. The emission of electron causes the flow of current in the circuit. The potential difference between the emitter and collector plate is measured by a voltmeter where as the electric current flow through circuit measure by a micrometer. The intensity and the frequency of light can be varied. The polarity of the plates *C* and *A* can also be reversed by commutator/switch. Light of different frequencies can be used by putting appropriate coloured filter or coloured glass in the path of light falling on emitter *C*. Intensity can be varied by changing the distance of light source from the emitter.



Q5. Explain in detail, experiment carried out on photoelectric effect before 1905 observation?

Ans. **<u>Experiment no.1</u>**:-



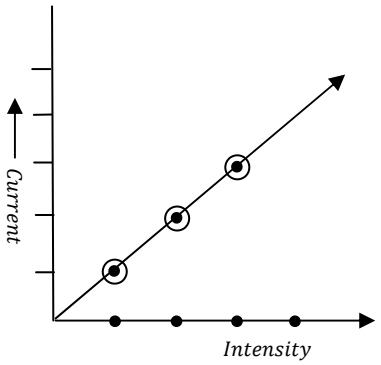
Setup:- V_1 = constant (1 volt say)

V_2 = changes (0 to 10 volt)

A → Reading changes

Observation:-

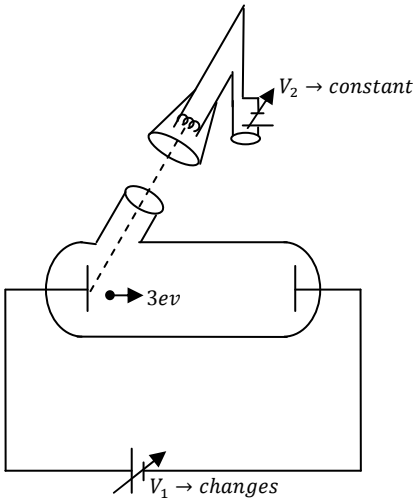
As intensity increases, photoelectric Current increases, (ammeter reading increases) Intensity – current graph was a straight line.



Explanation after 1905:-

When intensity increases, number of packets (photons) ejected also increase. Energy/photon remain constant as bulb remain same. Each packet gives one electron (suppose). So, as intensity increases, number of electrons increase, current also increases.
(By changing V_2 we can increase number of photons).

<u>Experiment no.2</u>:-



Setup:- V_1 = changes

V_2 = constant (say 5 volt)

For step 1 say ($5\ volt\ P = 25\ watt$)

Observation:-

Stopping potential remain same (say – 3 volt).

As intensity increase. Current increases.

Explanation:-

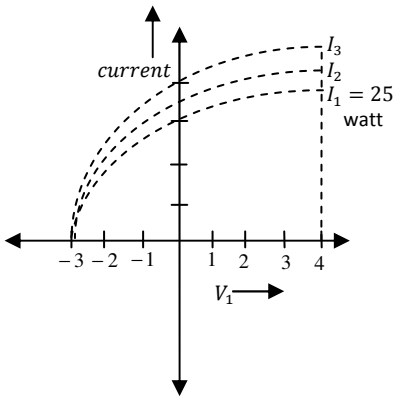
As intensity increase, number of photons coming out increase but size of each photon will remain same and energy of each electron also remain same (say 3ev). So, stopping potential will also remain same but current flowing increases.

when V_1= -1 volt, electron comes out of plate *C*.

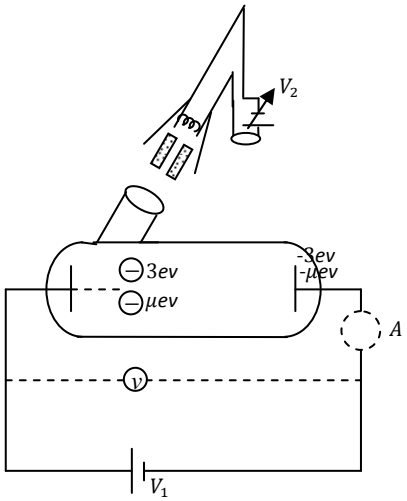
when V_1= -2 volt, electron comes out of plate *C*.

when V_1= -3 volt, electron just comes out of plate.

when V_1= -4 volt, electron does not come out of plate.



Experiment no.3:- Effect of frequency on current



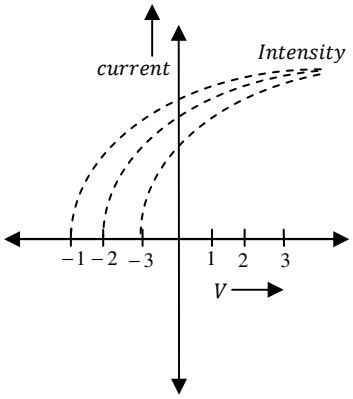
Setup:

In this setup we can change frequency by changing bulb. Because bulb changes, the packet coming out are of different sizes:

$V_1 \rightarrow$	Constant
$V_2 \rightarrow$	Constant
Intensity →	Constant
Frequency →	Changes due to different bulb
A →	reading change

Observation:-

Stopping potentional will change, as frequency changes

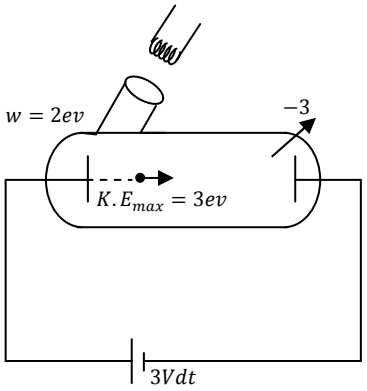


Explanation:-

In the given example frequency changes it means size of packet changes. So, electron comes out with more Kinetic Energy or they need more stopping potentional.

Q6. Who wrote photoelectric effect equation? Discuss the equation. Is it in confirmation with experiments conducted upto 1905.

Ans. Einestien wrote photoelectric effect equation in 1905.



Equation:- $h\nu$ = W + $K.E_{max}$
(5eV) (2eV) (3eV)

A photon of energy $h\nu$ falls on a metal with work function W. Remaining energy of the photons appears as Kinetic Energy of electron, $K.E_{max}$. Einestien Equation based on one-to-one interaction.

[One-to-one interaction means one photon interacts with one electron only]

Explanation:-

As given in previous question.

Q7. Why wave nature of radiation could not explain photoelectric effect?

Ans.

1. As per wave theory, or wave nature of light as intensity increase energy of electron should increase i.e. electron should come out with more Kinetic Energy.

   It was contrary to experimental fact that is Kinetic Energy does not depend on intensity.

2. As per wave theory, photoelectric effect should take place for all frequencies provided sufficient intensity. It was contrary to experimental fact as photoelectric effect takes place for frequency $\geqslant$ threshold frequency.

3. **Time**:- As per wave theory electron should take hours to come out of metal.
   It was contrary to experimental facts, ejection time is almost *ZERO*.

Q8. What is a photon? Characteristics of photon?

Ans. Energy travel in form of "*packets*" of energy called *Photons*.

Characteristics/Properties:-

1. Photon behave as packet of energy

2. Energy, $E = h\nu$
   Momentum $p = \frac{h\nu}{C}$ $\because$ $\lambda = \frac{h}{P} \Rightarrow P = \frac{h}{\lambda} \Rightarrow \frac{h\nu}{C}$

3. All "*Photons*" from same source are identical

4. Photons are electrically neutral

5. Photon particle collisions, Law of Conservation of Momentum and Law of Conservation Energy are valid.

6. –

7.

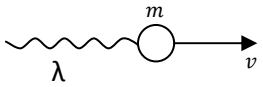
Q9. a) De Broglie Hypothesis
b) Find wavelength of a charged particle having charge q and acc through a potential of V_0 volt.

Ans.

a) **<u>De Broglie Hypothesis</u>**:-

A particle of mass m, speed v has wavelength λ associated.

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



b) When charge q is accelerated through voltage V_0, Its energy changes by "$q.V_0$", So K.E. = $q.V_0$

$$\frac{1}{2}mv^2 = q.V_0$$

$$v = \sqrt{\frac{2.q.V_0}{m}} \quad \text{——— (1)}$$

$$\lambda = \frac{h}{m.v} \quad \text{——— (2)}$$

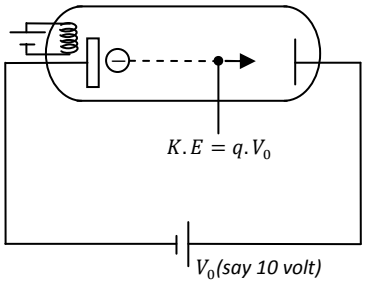
put value of *v* from (1) in (2)

$$\lambda = \frac{h}{m\sqrt{\frac{2q.V_0}{m}}} \Rightarrow \frac{h}{\sqrt{2q.V_0.m}}$$

$$= \frac{6.6 \text{ x } 10^{-34}}{5.3 \text{ x } 10^{-34}\sqrt{V_0}}$$

$$= \frac{12.2}{\sqrt{V_0}} A^\circ$$

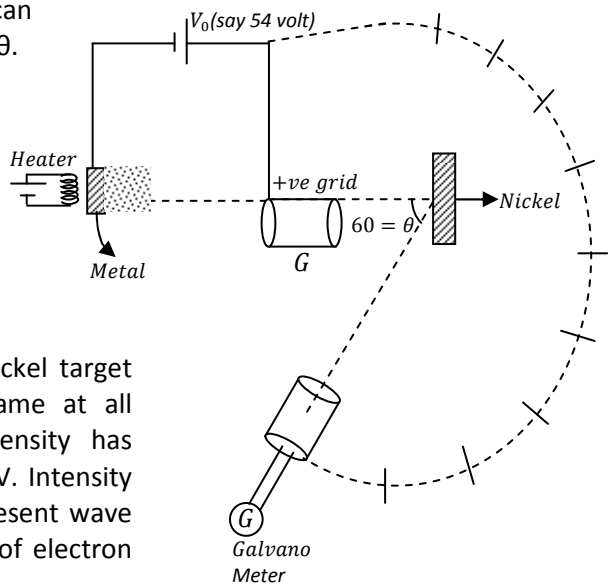
$$\boxed{\lambda = \frac{12.2}{\sqrt{V_0}} A^\circ}$$



Q10. Experimental setup, observation and conclusion of Davison-Germer experiment.

Ans. Heating coil *H* is used to heat metal *M* or thermionic emission of electron. Grid *G* is at +ve potential w.r.t. metal *M*.

Nickel is used as target. Galvanometer (*G*) can measure number of electrons at any angle θ.



Observation/Conclusion:-

When fast moving electron hit Nickel target intensity of electron was not same at all angles. It was noticed that intensity has maximum at θ = 50° and V_0 = 54V. Intensity maxima at a particular point represent wave nature of electrons. Wave length of electron was measured to be.

λ practical	= 1.65 A°

As per theory

$$\lambda \text{ theory} = \frac{12.27}{\sqrt{V_0}} A^{\circ}$$

$$= \frac{12.27}{\sqrt{54}} A^{\circ}$$

λ theory	= 1.67 A°

It was concluded that electrons have wave properties because experimental result was very very close to theoretically predicted wave length of electrons.