Quantum Theory and Black Body Radiation
: Photoelectric effect:

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CONCEPT OF CLASSICAL MECHANICS:

THE STUDY OF PHENOMENA RELATING **TO THE OBSERVABLE OBJECTS ARE REFERRED AS CLASSICAL PHYSICS. CLASSICAL MECHANICS EXPLAINED SUCCESSFULY THE MOTION OF OBSERVABLE OBJECTS**

CONCEPT OF QUANTUM PHYSICS :

THE STUDY OF PHENOMENA RELATING TO THE ATOMS, NUCLEI AND ELEMENTARY PARTICLES ARE REFERRED AS QUANTUM PHYSICS. THE BASIC MATHEMATICAL THEORY OF QUANTUM PHYSICS IS KNOWN AS QUANTUM MECHANICS.

:INADEQUACY OF CLASSICAL MECHANICS :

- **FAILED TO EXPLAIN THE STABILITY OF THE ATOMS.**
- **FAILED TO EXPLAIN THE SPECTRUM OF HYDROGEN ATOM.**
- **FAILED TO EXPLAIN THE ENERGY DISTRIBUTION FOR THE ENTIRE CURVE IN BLACK BODY RADIATION.**

INTRODUCTION OF PLANK QUANTUM HYPOTHESIS :

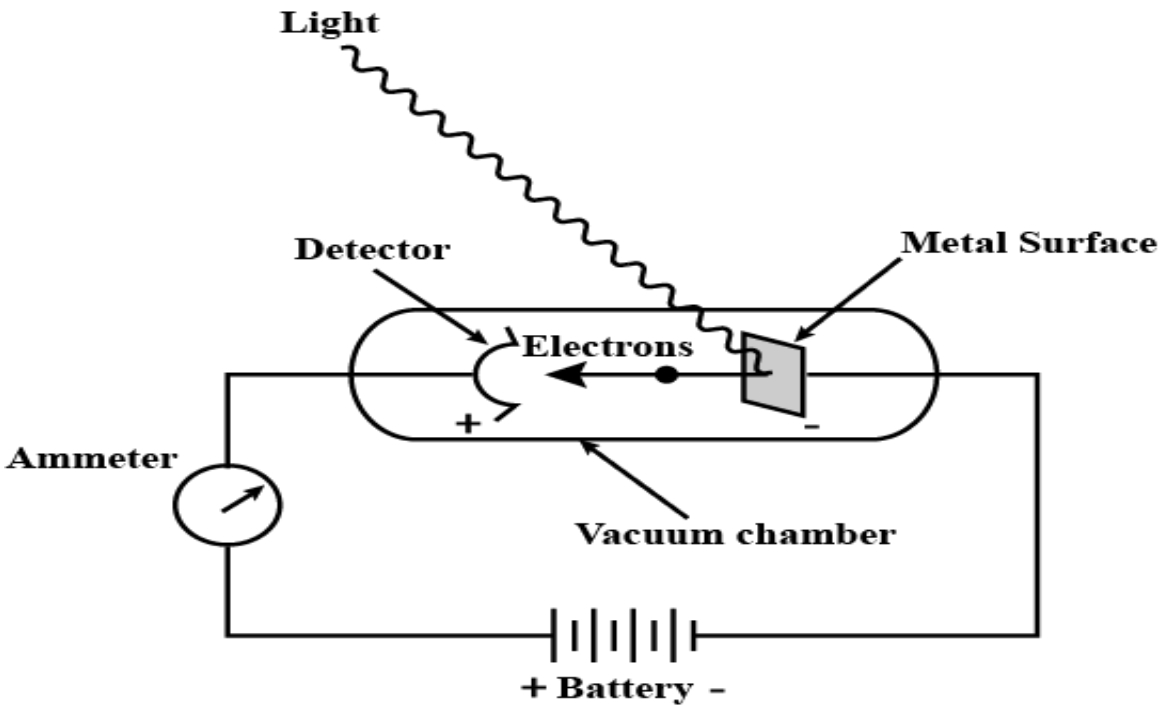
- Max Planck gave a revolutionary idea for energy distribution of black body radiation which is known as Planck's law.
- According to him energy change in black body radiation takes place in a discrete manner, as an integral multiple of a bundle of small energy $h\sqrt{}$ which is called as quantum or photon.
- This law was successful in explaining the spectral energy distribution in black body radiation.

APPLICATION OF QUANTUM THEORY:

a) PHOTOELECTRICT EFFECT

b) COMPTON EFFECT

Photo electric effect:



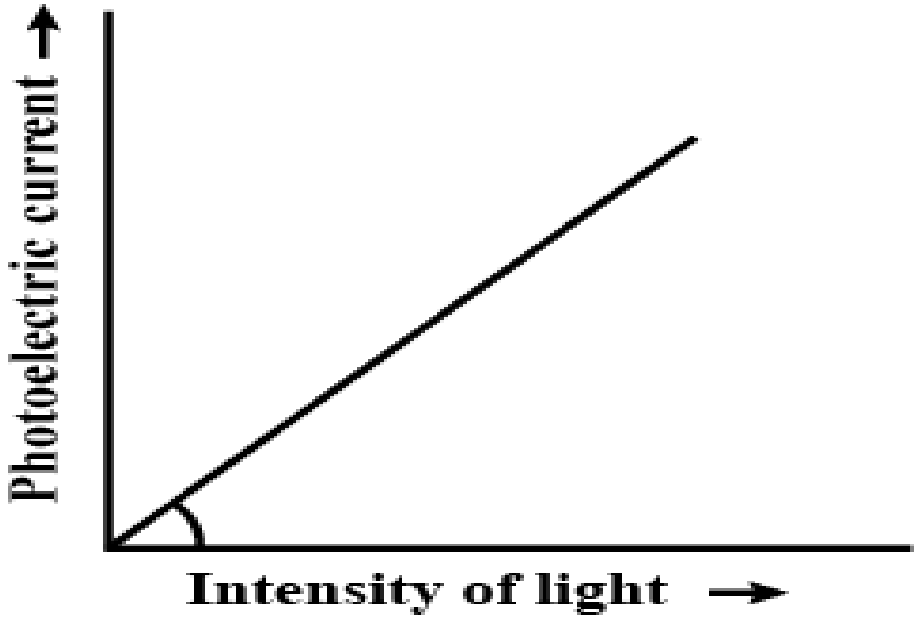
Experimental arrangement of photo electric effect

KEY WORDS:

I) WORK FUNCTION
II) THRESHOLD FREQUENCY
III) STOPPING POTENTIAL

Fundamental laws of photoelectric effect:

i) Photoelectric current increases with the increase of intensity of light:



ii) VELOCITY AND HENCE KINETIC ENERGY OF EMITTED PHOTO ELECTRONS INCRESE WITH INTENSITY OF LIGHT.

THE VELOCITY AND KINETIC ENERGY OF THE EMITTED ELECTRONS DO NOT CHANGE WITH INTENSITY OF INCIDENT LIGHT PROVIDED THE FREQUENCY OF THE INCIDENT LIGHT REMAINS THE SAME.

iii) Maximum velocity and kinetic energy of the electrons increase with frequency of the incident light:

- THE MAXIMUM VELOCITY AND KINETIC ENERGY OF THE EJECTED PHOTOELECTRONS IS DIRECTLY PROPORTIONAL TO THE FREQUENCY OF THE INCIDENT LIGHT.

- THERE EXISTS A MINIMUM FREQUENCY WHICH VARIES WITH THE NATURE OF THE EMITTER WHICH IS CALLED AS THRESHOLD FREQUENCY.

- BELOW THE THRESHOLD FREQUENCY, NO ELECTRONS ARE EMITTED FROM THE METAL SURFACE.

iii) Variation of current with negative potential on collector:

- When the collector is made negative with respect to metal surface ,the current decreases rapidly and vanishes at V= -Vo. Vo is called as stopping potential .

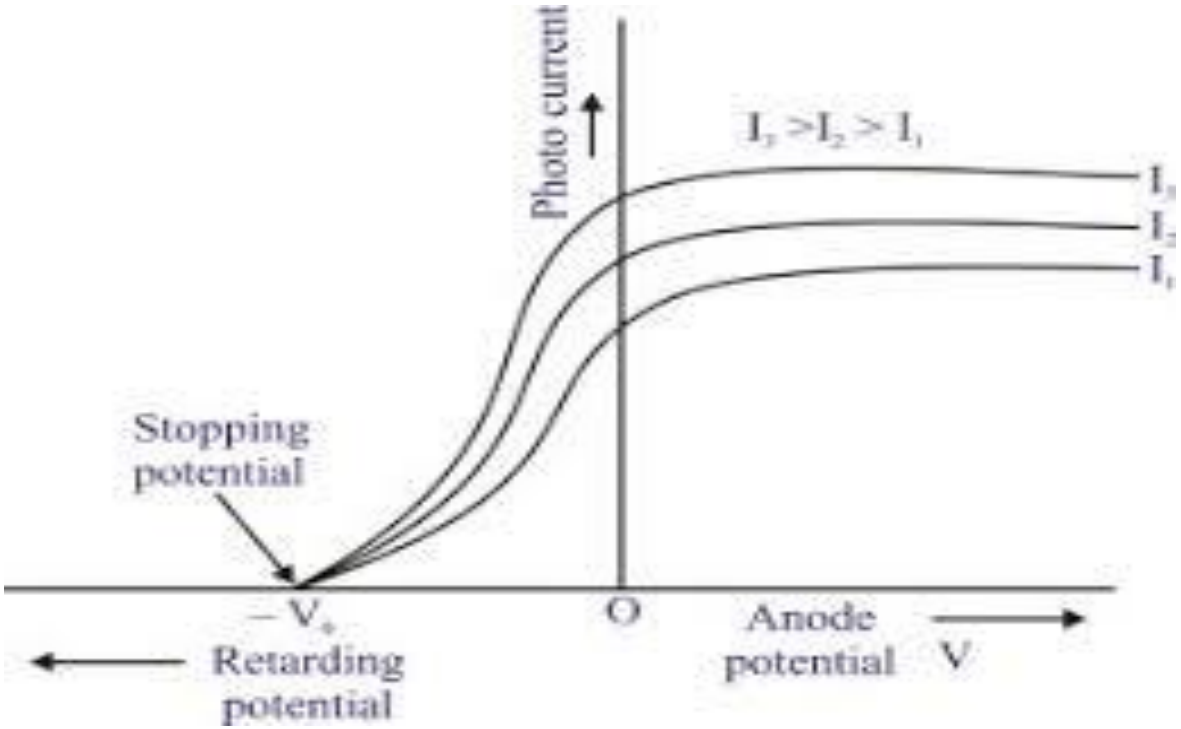
- The magnitude of stopping potential Vo does not depend on intensity of the incident light. As the incident light is increased the current increases in positive potential region but again becomes zero at V= -Vo.

VARIATION OF STOPPING POTENTIAL WITH FREQUENCY.

- THE MAGNITUDE OF STOPPING POTENTIAL VO INCREASES LINEARLY WITH FREQUENCY OF THE LIGHT USED.

- AT POTENTIAL -VO, THE ELECTRON FROM E JUST FAIL TO REACH C, SO PHOTOELECTRIC CURRENT IS ZERO. AS THE POTENTIAL AT C IS MADE MORE AND MORE NEGATIVE, THE FASTEST ELECTRON WILL BE PREVENTED FROM REACHING C.

iii) VARIATION OF CURRENT WITH NEGATIVE POTENTIAL:



CONCLUSIONS:

THIS EFFECT CANNOT BE EXPLAINED ON THE BASIS OF ELECTROMAGNETIC THEORY OF LIGHT.

ACCORDING TO ELECTROMAGNETIC THEORY OF RADIATION THE MORE INTENSE LIGHT RADIATION HAVING STRONGER ELECTRIC FIELD, WOULD PRODUCE MORE ENERGETIC ELECTRON.

ALSO THE EXISTENCE OF THRESHOLD FREQUENCY IS DIFFICULT TO EXPLAIN.

EINSTEIN'S THEORY OF PHOTO ELECTRIC EFFECT:

EINSTEN IN 1905, PROPOSED AN ENTIRELY DIFFERENT EXPLANATION ON THE BASIS OF PLANK'S QUANTUM HYPOTHESIS.

ACCORDING TO HIM, RADIATION ALWAYS CARRIES LIGHT QUANTA OR PHOTON. ENERGY CONSISTED WITH A PHOTON OF FREQUENCY **ν IS**

$$E=h\nu \quad \text{.....(1)}$$

AND IT MOVES WITH VELOCITY OF LIGHT

.

LET **Wo** THE MINIMUM WORK TO BE REQUIRED BY THE PHOTON TO RELEASE THE ELECTRON JUST FROM THE METAL SURFACE.

WHEN A PHOTON OF ENERGY **E=hν** STRIKES THE ATOM THEN IF Wo = hνo AMOUNT OF ENERGY IS USED TO JUST RELEASE THE ATOM FROM THE SURFACE AND THE REMAINING ENERGY IS AVAILABLE IN IMPARTING MAXIMUM KINETIC ENERGY TO THE PHOTOELECTRON

$$h\nu - Wo = \frac{1}{2}mVmax^2$$

THIS IS KNOWN AS EINSTEIN'S PHOTOELECTRIC EQUATION .

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IF Wo = hν₀ BE THE ENERGY OF THE PHOTON OF FREQUENCY ν₀ JUST TO RELEASE THE ELECTRON FROM THE SURFACE, THEN

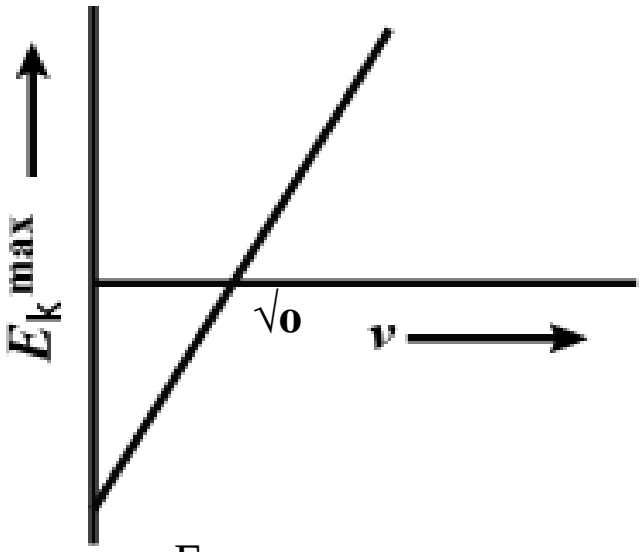
$$h(\nu - \nu_0) = \frac{1}{2}mV_{max}^2$$

WE KNOW THAT STOPPING POTENTIAL IS A MEASURE OF MAXIMUM KINETIC ENERGY OF THE ELECTRON SO WE CAN WRITE,

$$eV_0 = \frac{1}{2}mV_{max}^2$$

$$eV_0 = h\nu - W_0$$

SINCE Wo IS THE MINIMUM WORKDONE TO RELESE AN ELECTRON FROM THE MATEL SURFACE, SO STOPPING POTENTIAL IS ALINEAR FUNCTION OF FREQUENCY OF THE INCIDENT RADIATION.



So for an electron, in the Fermi level energy equation is

$\frac{1}{2}mVmax^2$=h√- Wo

For an inner electron energy equation is

$\frac{1}{2}mVmax^2 \leq$ h√– Wo

THUS PHOTO ELECTRIC EFFECT ESTABLISHES THE PHOTON OR QUANTUM NATURE OF LIGHT.

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THANK YOU