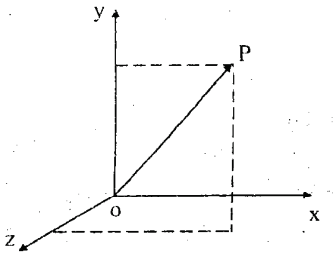
ADVENT OF MODERN PHYSICS 17

17.1 FRAME OF REFERENCE:

The reference axis which are needed to locate the accurate position of any object in a plane or space is called Frame of Reference.



For this purpose we use set of two or three perpendicular lines which are intersect to each other at a single point, called origin.

Types of Frame of Reference:

There following two types of frame of reference.

1) Inertial Frame of Reference:

The frame of references which are in rest or moving with uniform velocity are called Inertial Frame of Reference and because acceleration of Inertial Frame is zero therefore it is also called Non-accelerative Frame of References.

For example our class room, inner Frame of Aeroplane or compartment of train when they move with uniform velocity.

Properties:

a) In Inertial Frame of Reference all types of accelerations (Linear & angular) are zero.

b) In Inertial Frame of Reference Law f conservation of momentum and law of addition of velocities are remain same.

c) According to the measurement all Inertial frame of reference are equivalent.

2) Non Intertial Frame of Reference:

The frame of references which are moving with variable velocity are called Non-inertial frame of reference and because their acceleration is not equal to zero there fore, these are also called accelerative frame of reference.

For Example:

Inner frame of aeroplane when it is take off or landing.

17.2 GALILEAN TRANSFORMATION OR FRAME OF REFERENCE IN UNIFORM TRANSLATIONAL MOTION

The conversion of co-ordinates from one inertial frame to another inertial frame is called Transformation and the set of equations which obtained is called Transformation equation.

Galilean Hypothesis:

All laws of Physics remain same in inertial frame of reference which are moving with uniform velocity, w.r.t each other.

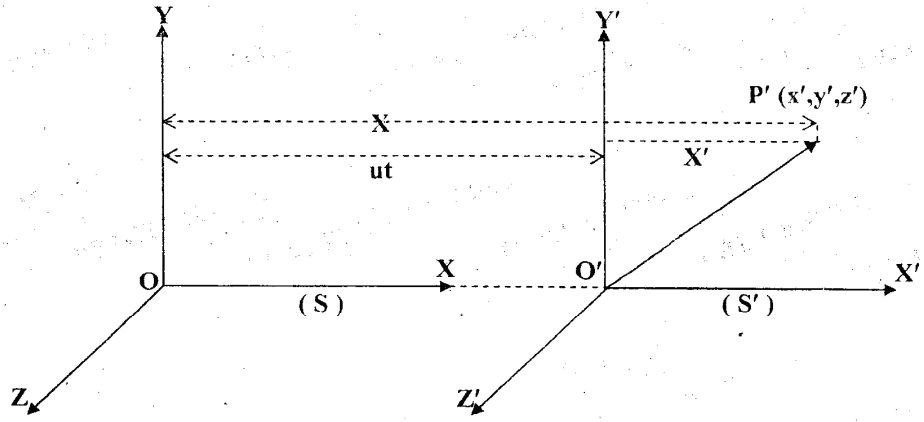
For Example:

If F = ma is valid inertial frame "S" then this equation is also valid or similar in other frame " S' " which moving with uniform velocity w.r.t 1st .

Time is absolute (t = t') in Galilean Transformation.

Transformation of Space:

Consider two frame of references "S" & "S'" coincide to each other at t = 0 now suppose that frame "S'" is moving with uniform velocity "u" along the x–axis, also suppose that a point "p" whose co-ordinates are (x, y, z) with respect to frame "S" and (x', y', z') w.r.t frame S' as shown.



The position of point "P' " measured w.r.t frame "S" is $x = x' + ut$ _____ (1) $y = y'$ $z = z'$ $t = t'$	Similarly Position of point P' measured w.r.t to frame S' $x' = x - ut$ _____ (2) $y' = y$ $z' = z$ $t' = t$

Above sets of equation are known as. Transformation Equations.

Transformation of Velocity:

Using equation (1)

$$x = x' + ut$$

Divided by 't' on both side.

$$\frac{x}{t} = \frac{x'}{t} + \frac{ut}{t}$$

$$\frac{x}{t} = \frac{x'}{t} + u$$

But $\frac{s}{t} = \frac{x}{t}$ = velocity

$$\boxed{v = v' + u} \text{ ---------- (A)}$$

The equation is said to be law of addition of velocities.

v = Velocity of point "P" measured w.r.t frame "S"

v' = Velocity of point "P" measure w.r.t frame "S'"

u = Relative velocity of frame "S'" w.r.t "S"

Transformation of Acceleration:

Using equation (A) law of addition of velocities.

$$v = v' + u \text{ _____ (a)}$$

Now consider object change its position from point P_1 to P_2 therefore at point P_1 and "P_2" equation (a) can be written as.

$$v_1 = v_1' + u \text{ _____ (b)}$$

and $v_2 = v_2' + u$ _____ (c) [u is uniform or constant]

Subtract (b) from (c)

$$v_2 - v_1 = (v_2' + u) - (v_1' + u)$$

$$v_2 - v_1 = v_2' + u - v_1' - u$$

$$v_2 - v_1 = v_2' - v_1' \quad \text{(d)}$$

Since time is absolute for Galilean Transformation

$t = t'$ $\quad t_1 = t_1'$ $\quad t_2 = t_2'$ $\quad \therefore \quad \Delta t = \Delta t'$

Hence divided by Δt both sides of (d)

$$\frac{v_2 - v_1}{\Delta t} = \frac{v_2' - v_1'}{\Delta t}$$

or $$\frac{\Delta v}{\Delta t} = \frac{\Delta v'}{\Delta t'}$$

or $\boxed{a = a'}$ ----------(B) $\left[\begin{array}{l} \frac{\Delta v}{\Delta t} = a \\ \frac{\Delta v'}{\Delta t'} = a' \end{array}\right]$

It shows that acceleration is not transform and it is remain same in both frames.

Transformation of Force:

Consider mass of the object which is under observation from both frames S & S' is "m" therefore, force on object measured in frame "S" can be written as.

$F = ma$ _____ (1)

Similarly force measured in frame "S'" is

$F' = ma'$ _____ (2)

but $a' = a$

$\therefore \quad F' = ma$

From (1)

$F' = F$

This shows that force is remains same in both frames S & S' it means that Force is also not transform.

Limitations:

Galilean Transformation is not applicable for electromagnetic phenomenon.

17.3 THEORY OF RELATIVITY:

Theory of relativity is given by Albert Einstein in 1905 which states that there is no absolute state exist in universe, all state are relative. There are two types of relativities theory.

i) (General Theory of Relativity:)

(It is belongs to the accelerative motion of object and frame of reference.)

ii) Special Theory of Relativity:

It is belongs to uniform motion relative of objects or frame of reference (Inertial frame) .

Postulates of Special Theory:

Special Theory of Relativity based or depends upon some assumptions which are called postulates of theory. These are given below.

i) There is no absolute inertial frame of reference. All frames are equivalent for the description of all Physical laws.

ii) The speed of light in vacume or space always remains same and does not depends upon relative motion of observer, source or both observer and source so it called universal constant and its value approximately 3×10^8 m/sec ($c = 3 \times 10^8$ m/sec)

RESULTS / CONSEQUENCES OF SPECIAL THEORY OF RELATIVITY:

i) Mass Variation (Increase in Mass)

If an object is moving with such a high speed that comparable to the speed of light then the mass of the object is change which can be determine as follows

$$m = \frac{m_o}{\sqrt{1-\frac{v^2}{c^2}}}$$

ii) Length Contraction:

If an object is moving such a high speed that comparable to the speed of light then its length become smaller along the direction of motion which can be determine as follows.

$$L = L_o \sqrt{1-\frac{v^2}{c^2}}$$

iii) Time Dilation:

If a clock is lying in an inertial frame of reference that is moving such a high speed which compareable to the speed of light then it observed that the clock is going slow, it means that needle of second take long time to transfer from one digit to other, this phenomenon is known is Time Dilation, which can be determine as follows.

$$t = \frac{t_o}{\sqrt{1-\frac{v^2}{c^2}}}$$

iv) Mass Energy Relation:

It is the famous and remarkable relation which called Mass-Energy Relation. According to this relation mass can be converted in energy and Energy can be converted in mass it is explained by Einstein.

$$E = mc^2$$

$$m = \frac{m_o}{\sqrt{1-\frac{v^2}{c^2}}}$$

Where

m = mass of the moving object or observed in moving frame.

m_o = mass of the object in Rest (Rest mass)

L_o = Length of the object in Rest (Rest Length)

L = Length of the moving object or observed in moving frame.

v = velocity of moving object or frame

c = velocity of light

Limit of Speed of Material Body:

Experimentally the speed of any massive body can never be equal to or granter than speed of light to prove it consider.

$$v = c$$

$$m = \frac{m_o}{\sqrt{1-\frac{v^2}{c^2}}} = \frac{m_o}{\sqrt{1-\frac{c^2}{c^2}}}$$

$$m = \frac{m_o}{\sqrt{1-1}} = \frac{m_o}{o}$$

$$m = \infty$$

If mass of a object becomes infinite it means that its energy is also becomes infinite but practically it is impossible. Hence we can say that the speed of any massive body always smaller than speed of light.

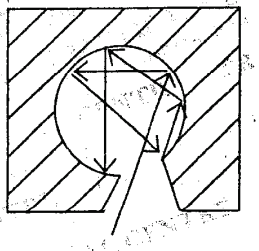
$$V \neq c \text{ OR } V \not> c \quad \text{OR} \quad V < c$$

17.4 BLACK BODY RADIATION:

A black body is the one which can absorb radiations falling on its surface. An absorber is simultaneously a radiator also.

Perfect Black Body:-

A perfect black body is the one which can absorb all radiations that falls on it. A perfect black body does not exist. For all forms of radiations a hollow sphere of metal with a fine hole in it called **cavity radiator** is approximately a perfect black body, which is shown in the figure.

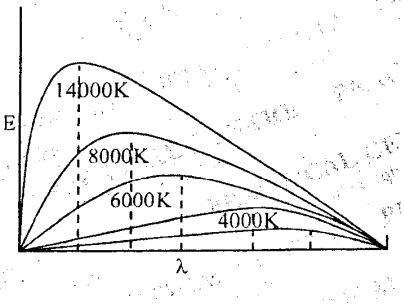


Any radiation entering the hole of the cavity is trapped by multiple reflections inside and very little of which are able to escape. If this black body is heated, a number of radiations start to emit, due to this property it is also a perfect radiator.

Characteristics of Black Body Radiation:-

(1) If different materials are heated to some uniform temperature, then they emit radiations.

(2) The graph of such radiations are the curves with no regularity or similarity. But if the cavity radiator is made up of different materials is put in a furnace, then the study of their curves obtained tells that the energy distribution is independent of the material of the cavity and it only depends upon the temperature of the cavity. That is the reason why radiations from a perfect black body are sometimes called **temperature radiations**.



(3) Black body radiations lie in the region of infra red and visible light only.

(4) There is a single radiation nor there are infinite radiations from any black body.

Wien's Displacement Law:-

Wien studied the relationship between wavelength of maximum energy radiation and temperature and states that ***"The wavelength corresponding to the maximum energy "λ_m" is inversely proportional to the absolute temperature "T" of the black body",*** mathematically:

$$\lambda_m \propto \frac{1}{T}$$

OR $\lambda_m T = \text{constant}$

This constant is a universal constant and its value is 0.0029 mK.

ENERGY DISTRIBUTION FORMULAE:

Stefan's Law:-

According to the Stefan's law, ***the amount of energy of all wavelengths radiated per second per unit area of a black body is directly proportional to the fourth power of absolute temperature,*** mathematically:

$$E \propto T^4$$

OR $E = \sigma T^4$

Where σ is the constant of proportionality called Stefan's constant and its value is $5.67 \times 10^{-8} w/m^2/k^4$. Stefan's law is however failed to predict energy distribution in the entire curve at all curves.

Raleigh-Jeans Law:

An attempt to modify the Wien's law, Raleigh and Jeans proposed a law based on the assumption that radiations are emitted by a large number of atomic oscillators such that each mole of vibration was supposed to be associated with thermal energy KT, where K is the Boltzman constant. According to Rayleigh-Jeans law the energy associated with a particular wave length is inversely proportional to the forth power of wave length

i.e. $$E = \frac{\text{constant}}{\lambda^4}$$

This law had been found fit well for long wavelengths but it leads to infinite energy for short wave lengths which is found in ultraviolet catastrophe.

Plank's Law:

In 1900, Max Plank proposed a formula which explained in detail the whole black body radiation spectrum for all wavelengths. In all the previous attempts the basic assumption of the theories was that the energy exchange between the radiation and the material of the cavity took place in a continuous way as this assumption was based upon classical Physics. According to Plank radiant energy comes out in discrete amount of bundles of energy or wave Packets called **quanta**. The energy content of each quantum was directly proportional to the frequency of radiation.

Mathematically.....

$$E = h\upsilon$$

The departure of plank's law from classical theory lies in the fact that classically energy is dependent of wave amplitude, but in quantum theory energy is dependent of frequency of radiations.

Ultraviolet Catastrophe:-

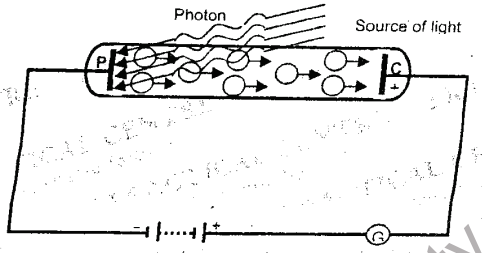
Ultraviolet catastrophe is the series of infinite energy radiations in the region of x-rays and ultraviolet rays.

17.5 PHOTOELECTRIC EFFECT:

When ultraviolet light of certain frequency falls on a metallic plate then some electron emits from the surface of metal which are called photo-electrons, current is called photocurrent while the phenomenon is called Photoelectric Effect.

Construction:

For the production of photoelectrons a glass tube shown in figure which consists two metallic plates one is connected to positive terminal of the battery, called collector and other is connected to negative terminal of the battery, called plate. A galvanometer is also connected in series to indicate the photocurrent or flow of Photoelectron.



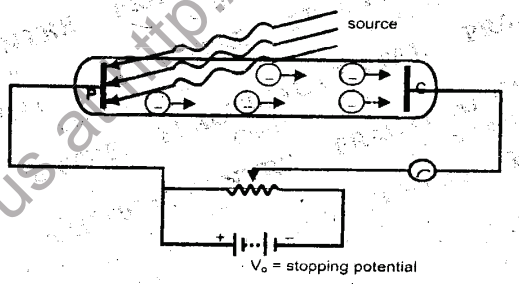
Working:

When ultraviolet light falls on metallic surface (plate) then photoelectrons emit from it and moves towards +ve plate (collector) and galvanometer shows deflection due to photocurrent.

APPARATUS SETUP:

For Maximum Energy of Photoelectrons:

To find the maximum energy of photoelectrons we change the terminals of battery now plate becomes +ve and collector becomes –ve as shown.



When ultraviolet light falls on metallic plate then electrons are emitting from the surface of metal but due to +ve charge on plate some electrons deposit on it which are called captured electrons and those electrons reaches to the –ve collector whose energy is maximum. If we make collector more negative continuously then after sometime no electrons reach to collector and galvanometer shows zero deflection.

The potential at which galvanometer shows no deflection or zero current is called stopping potential denoted by "Vo" Now.

$$(K.E)_{max} = V_o e$$

$$\frac{1}{2}mv_o^2 = V_o e \longrightarrow (a)$$

v_o = maximum velocity

V_o = stopping potential

Hertz Observations:

(1) For the emission of photoelectrons from the surface of metal a light of certain frequency is required this minimum frequency is called threshold frequency denoted by "υ_o" It means that No photoelectron emits from metallic surface if the frequency of incident light is less than threshold frequency.

After Threshold frequency (υ_o):

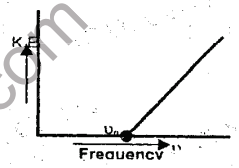
(2) The energy of emitting electron is directly proportional to the frequency of incident light.

(3) The number of photoelectrons emits from metallic surface are directly propositional to the intensity of the incident light.

GRAPHICAL RESULTS:

(1) Graph between Frequency and Kinetic Energy of Photoelectrons:

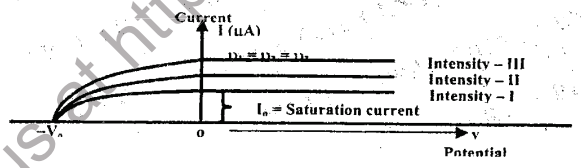
When the graph plotted between frequency of light and K.E of photoelectrons, then it shows that no photoelectrons are emitting when frequency of incident light is less than a certain minimum value which is called threshold frequency (υ_o), after υ_o the K.E of photoelectrons is directly proportional to the frequency of light.



(2) Graph between Current and Potential:

(a) When Frequency is constant but intensity is different:

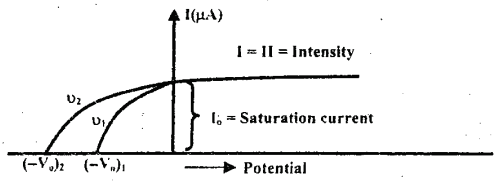
When the graph is plotted between current and potential at same frequency but different intensity of incident light then it shows that at a particular potential (v = o) current becomes constant which is called saturation current (Io). If we decreasing the potential towards –ve side then at a particular –ve potential current of all different intense lights becomes zero, this potential is called stopping potential (vo) as shown.



This shows that saturation current is depends upon intensity of incident light but stopping potential is intensity independent. It means that energy of photoelectrons does not depends upon intensity of light.

(b) When frequency different but Intensity constant:

When the graph is plotted between potential and current at same intensity but different frequency then following curve is obtain.



Above graph shows that stoping potential is frequency dependant but saturation current is frequency independent it is also shows that energy of photoelectron depends upon frequency of incident light.

SOME IMPORTANT DEFINITION:

Threshold Frequency:

The minimum frequency of incident light which is required to ejection of photo-electron from the metallic surface is called Threshold frequency denoted by "υ_o".

Work Function:

The minimum energy of incident light which is required for the ejection of photoelectron from the surface of metal is called work function denoted by (φ or φ_o) its value depends upon the nature of material of plate. Mathematically it can be written as:

$$\boxed{\varphi_o = h\upsilon_o} \quad \text{but} \quad \upsilon = \frac{c}{\lambda} \therefore \upsilon_o = \frac{c}{\lambda_o}$$

$$\therefore \quad \boxed{\varphi_o = \frac{hc}{\lambda_o}} \qquad \lambda_o = \text{Cut off wavelength}$$

Stopping Potential:

The potential across the metallic plates (collector and plate) at which photocurrent becomes zero is called stopping potential denoted by "V_o".

EINSTEIN'S PHOTOELECTRIC EQUATION:

According to the quantum theory, light consists large number of packet or bundle of energies which are called quanta or photon.

When a photon of energy ($E = h\upsilon$) falls on the surface of metallic plate then some part of its energy utilize to eject the electron from surface of metal and remaining part used in K.E of Photoelectron mathematically it can be written as.

$$\text{[Energy of Photon]} = \text{[Work function]} + \text{[K.E of Maximum of electron]} \longrightarrow (1)$$

OR

$$\boxed{E = \varphi_o + (K.E)_{max}} \longrightarrow (A)$$

But $E = h\upsilon$, $\varphi_o = h\upsilon_o$ $(K.E)_{max} = V_o e$

$\therefore$ $h\upsilon = h\upsilon_o + V_o e$

Or $V_o e = h\upsilon - h\upsilon_o$

Or $\boxed{V_o e = h(\upsilon - \upsilon_o)} \longrightarrow (B)$

But $c = \upsilon\lambda \therefore \upsilon = \frac{c}{\lambda}$ and $\upsilon_o = \frac{c}{\lambda_o}$

$\therefore$ $V_o e = h\left(\frac{c}{\lambda} - \frac{c}{\lambda_o}\right)$

$\therefore$ $\boxed{V_o e = hc\left(\frac{1}{\lambda} - \frac{1}{\lambda_o}\right)} \longrightarrow (C)$

Equation (A), (B) and (C) are the different forms of photoelectric equation.

V_o = Stopping potential

υ_o = Threshold frequency

λ_o = Cut off wavelength

Failure of Classical Physics:

(1) There is no concept of threshold frequency in classical physics.

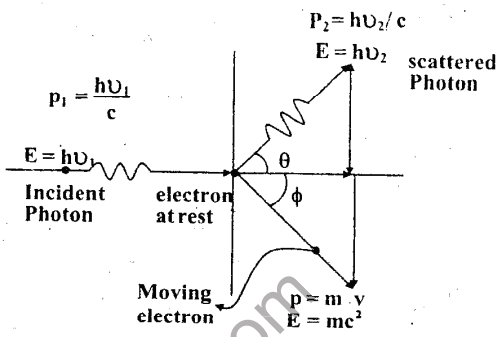
(2) Wave or light can not eject the particle (like electron) from surface of metal.

(3) According to classical physics energy of photoelectrons depends upon intensity (Amplitude) but experiment shows that the energy of photoelectrons depends upon the frequency of incident light.

17.6 COMPTON'S EFFECT:

In 1924 A.H Compton confirmed the existence of photon by studying the scattering of high energy photon (x-ray photon) with an electron. In the photo electric effect it was assumed that photon imparts all its energy to electron, where as in Compton's effect photon imparts its energy partially to the electron.

It is sufficient to analyze the scattering process in a single frame of reference. The electron is treated at rest for high energy photons. The photon approaches to wards the electron with a frequency υ_1 and is scattered at an angle θ with a lower frequency υ_2. The photon energies before and after collision are $h\upsilon_1$ and $h\upsilon_2$. Where as the corresponding momentum are $h\upsilon_1/c$ and $h\upsilon_2/c$. The energy and momentum of recoiled electron are $(m-m_0)c^2$ and mv respectively. If the laws of conservation of energy and momentum along and across the directions of approach are applied, we will get the following equations:



Conservation of Momentum along the Line of Impact:

$$\frac{h\upsilon_1}{c}\text{Cos}0 + 0 = \frac{h\upsilon_2}{c}\text{Cos}\theta + mv\,\text{Cos}\varphi$$

$$\frac{h\upsilon_1}{c} = \frac{h\upsilon_2}{c}\text{Cos}\theta + mv\,\text{Cos}\varphi \qquad \text{---------- (1)}$$

Conservation of Momentum across the Line of Impact:

$$\frac{h\upsilon_2}{c}\text{Sin}0^0 + 0 = \frac{h\upsilon_2}{c}\text{Sin}\theta - mv\,\text{Sin}\phi$$

$$0 = \frac{h\upsilon_2}{c}\text{Sin}\theta - mv\,\text{Sin}\phi \qquad \text{---------- (2)}$$

Conservation of Energy:

$$h\upsilon_1 + m_0c^2 = h\upsilon_2 + (m - m_0)c^2 \qquad \text{---------- (3)}$$

By solving these three equations, the following results were obtained:

$$\frac{1}{\upsilon_2} - \frac{1}{\upsilon_1} = \frac{h}{m_0c^2}(1 - \cos\theta)$$

but $\quad c = \upsilon\lambda \quad$ or $\quad \frac{1}{\upsilon} = \frac{\lambda}{c}$

$$\therefore \quad \frac{1}{c}(\lambda_2 - \lambda_1) = \frac{h}{m_0c^2}(1 - \cos\theta)$$

$$\lambda_2 - \lambda_1 = \frac{h}{m_oc}(1 - \cos\theta)$$

This equation is the famous Compton formula for increase in wave length of the scattered photon and the factor h/m_0c is called Compton's wave length, denoted by:

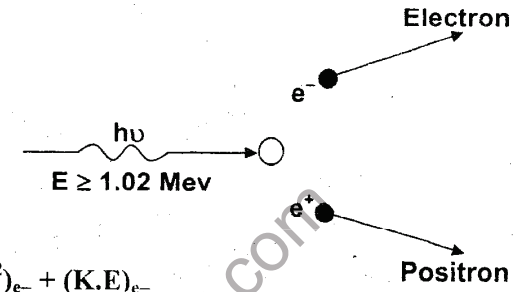
$$\lambda_c = \frac{h}{m_oc} = 2.426 \times 10^{-12}\,\text{m}.$$

17.7 PAIR PRODUCTION:

When a photon of high Energy (γ-Photon) collide with the heavy nucleus then it losses its identity and disintegrate into a pair of antiparticles one particle have – ve charge, called electron (e^-), other have + ve charge called positron (e^+) and this phenomenon is known as ***pair production*** **or** ***materialization of energy.***

In this phenomena Energy, mass and momentum are conserved.

Since rest mass Energy of an electron is 0.511MeV therefore Energy of incident photon for this production of pair of antiparticles must be equal or greater then 1.02MeV.



If E = hυ = 1.02 Mev then

$$\boxed{E = (m_oc^2)_{e+} + (m_oc^2)_{e-}}$$

And If E = hυ > 1.02 Mev then

$$E = (m_oc^2)_{e+} + (K.E)_{e+} + (m_oc^2)_{e-} + (K.E)_{e-}$$

$$(m_oc^2)_{e+} + (m_oc^2)_{e-} = m_oc^2$$

$$\boxed{E = 2m_oc^2 + (K.E)_{e+} + (K.E)_{e-}}$$

OR

$$\boxed{h\upsilon = 2m_oc^2 + (K.E)_{e+} + (K.E)_{e-}}$$

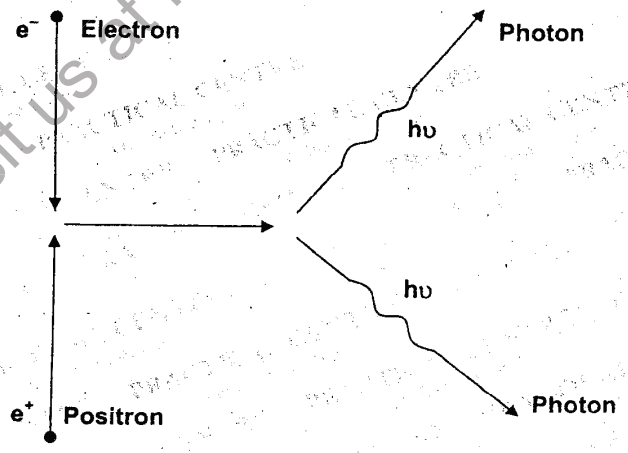
From

Above equations it is clear that if Energy of photon is less that 1.02 Mev then phenomenon of pair production is not possible.

If energy of incident photo is greater than 1.02 MeV then 1.02 MeV use to produce the pair of antiparticle and remaining part used as a K.E of both electron and positron.

Annihilation of Matter:

The phenomenon in which electron and positron are combine to each other and disappear and produce two photon (γ-rays) is called Annihilation of matter.



This process is also called inverse of pair production and the energy of each photon (hυ) is equal to 0.511. In this process mass Energy and momentum are conserved.

$2h\upsilon = 2moc2 + (K.E)e- + (K.E)e+$

$2h\upsilon > 1.02$ Mev

17.8 WAVE PARTICLE DUALITY OR DE'BROGLIE'S HYPOTHESIS:

It has been observed that the phenomena like photoelectric effect and the Compton effect could be explained if electromagnetic radiation was supposed to consist of packets of energy called quanta or photon which behaves like a particle and move through space with the velocity of light. On the other hand phenomena interference, diffraction and polarization could be explained if light is treated as wave phenomena. This fact led Louis De'broglie to make in 1924 a daring suggestion that if light which is known to consist of waves can under certain circumstances assume the aspect of particle then the particle should also behave like a wave. He based his reasoning on the assumption that nature possess symmetry and that the two physical entities, i.e. matter and wave must be symmetrical also. ~~De-broglie took quantum idea of emission of energy of photon of radiation of frequency given by:~~

$$E = h\upsilon \quad \text{---------- (1)}$$

If photon is considered to be a particle of relativistic mass "m", its energy is given by:

$$E = mc^2 \quad \text{---------- (2)}$$

Under wave-particle symmetry:

$$h\upsilon = mc^2$$

$$h\upsilon = (mc)c$$

where p = mc, the momentum of photon

$$\therefore \quad h\upsilon = pc$$

also $c = \upsilon\lambda$

OR $\upsilon = \dfrac{c}{\lambda}$

$$\therefore \quad \frac{h\cancel{c}}{\lambda} = p\cancel{c}$$

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

OR $\lambda = \dfrac{h}{p}$

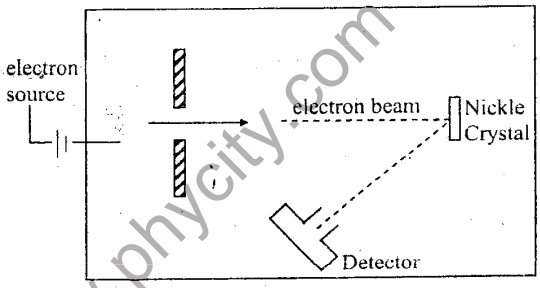
This equation is called De'brogleis equation and this wavelength is called De-broglie's wavelength. The novel idea of this equation is wave-particle nature of matter i.e. with relative motion of particle a certain wave links with it. This idea leads to dual nature of light also.

17.9 THE DAVISSON AND GERMER EXPERIMENTS:

The theoretical prediction of De'broglie's hypothesis of wave nature of particle was experimentally confirmed by the famous experiment conducted by Davisson and Germer in the year 1927. They were investigating the scattering of electron beam by the metallic crystal of Nickle. The experimental set up which was enclosed in a vacuum chamber is schematically in figure:

A beam of electron accelerated through the potential V were allowed to strike the Nickle crystal. Measurements were made to count the number of electrons scattered by the crystal.

Davisson and Germer reported the unexpected result that electrons reflect very strongly at certain angles and not at other direction. These results remained unexplained for sometime until it was suggested that, perhaps this was an outcome of wave nature of electron.



Vacum chamber

Davisson and Germer then further investigated to observe that if it could be possible to interpret that electrons behave as waves of wavelength λ as given by the De-broglie's relation:

$$\lambda = \frac{h}{p} \qquad \text{---------- (1)}$$

They calculated the wavelength of electron from the accelerating potential V by applying the relation for kinetic energy of the electron i.e.

$$\frac{1}{2}m_0v^2 = eV$$

OR

$$v = \sqrt{\frac{2eV}{m_0}}$$

From eq (1)

$$\lambda = \frac{h}{m_0 v}$$

OR

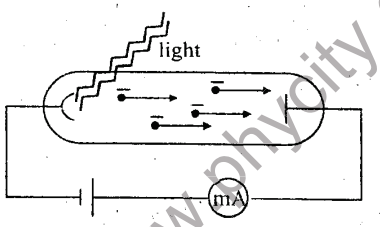
$$\lambda = \frac{h}{m_0\sqrt{\frac{2eV}{m_0}}}$$

$$\lambda = \frac{h}{\sqrt{2m_0eV}}$$

The wavelength found from this formula agreed with the De-broglie's prediction and it was concluded electrons are reflected from various planes of the crystal in the same manner as their De-broglies waves should be reflected thus the Davisson and Germer experiment had provided a direct evidence for De-broglies hypothesis that particles have wave like properties. As the years passed it has been confirmed that other particles neutron, protons atoms molecules etc. are associated with the same wave effects as that of electrons.

17.10 PHOTOCELLS OR PHOTOTUBE OR PHOTOEMISSIVE CELLS:

A photo cell is based on photoelectric effect. It consists of an evacuated glass envelope fitted with an anode wire and a cathode of appropriate emitting surface.



The material of cathode is selected for a frequency range over which it has to operate. The cathode is made of a concave shape.

When light of frequency greater than the threshold frequency of cathode is incident on it, it emits photo electrons. These electrons are attracted by the positive anode and the current flows in the external circuit. The current increases with light intensity. The current increases with light intensity. The current will ceases to flow if the light is interrupted.

Photocells can be used in many devices where the beam of light falling on it is broken e.g.:

1) To count the number of vehicles or items on a conveyor belt.
2) To open doors automatically.
3) To operate burglar alarms.
4) To operate automatic lifts.
5) To open and close street lights in the evening and in the morning.

17.11 PHOTO VOLTAIC CELLS:

A photo voltaic cell consists of a copper disc, oxidized on one face, over which a film of gold is deposited by evaporation in vacuum. The film is so thin that light can pass through it, thereby generating an e.m.f. and therefore provides a current without a *battery.*

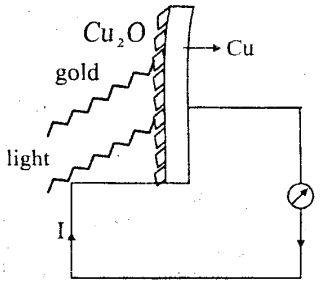


Photo voltaic cells are sensitive to visible light and are frequently used as exposure meters in photography. One of their important use in the production of pictures in T.V. camera and the sound tracks of motion pictures. The sound information is stored on the film run between the light source and photocells.

Variation in light intensity reaching the cell cause pulsation in the current that after being amplified activates the loudspeaker and reproduce sound.

17.12 THE UNCERTAINTY PRINCIPLE:

In classical physics it is assumed that position and momentum of a macroscopic moving object can be measured simultaneously with a high degree of accuracy but for microscopic particles there is a fundamental limitation to the accuracy of finding their position and momentum simultaneously. This limitation was first expressed by Heisenberg in 1927 and is known as Heisenberg's uncertainty principle. The uncertainty principle states that:

"It is impossible to measure with accuracy both position and momentum of a particle simultaneously."

Mathematically..... $$\Delta x \Delta p \approx \frac{h}{2\pi}$$

Similar to the uncertainty of momentum and position, yet there is another uncertainty exist between time and energy, as:

$$\Delta E \, \Delta t \approx \frac{h}{2\pi}$$