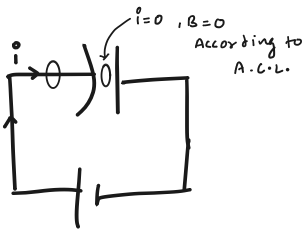
Maxwell's Contribution

(1) **Ampere's Circuital law**

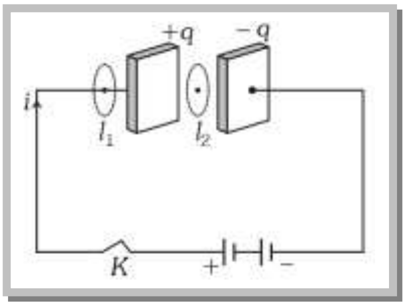
$$\oint \vec{B}.\vec{dl} = \mu_0 i$$



(2) **Inconsistency of Ampere's law**

Applying Ampere's law for loop l_1 and l_2 $\oint_{l_1} \vec{B}.\vec{dl} = \mu_0 i$

But $\oint_{l_2} \vec{B}.\vec{dl} = 0$ (Since no current flows through the region between the plates). But practically it is observed that there is a magnetic field between the plates. Hence Ampere's law fails



(3) **Modified Ampere's Circuital law or Ampere- Maxwell's Circuital law**

Maxwell assumed that some sort of current must be flowing between the

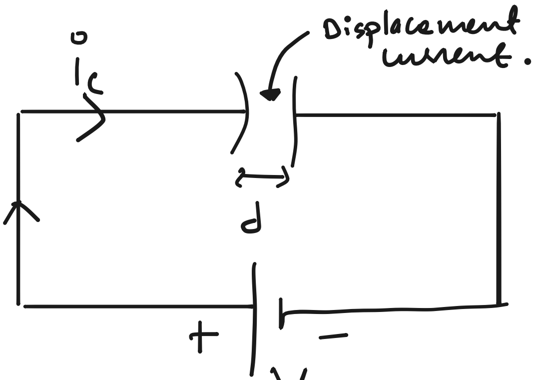
$$\oint \vec{B}.\vec{dl} = \mu_0 (i_c + i_d) \quad \text{or} \quad \oint \vec{B}.\vec{dl} = \mu_0 (i_c + \varepsilon_0 \frac{d\phi_E}{dt})$$

where i_c = conduction current = current due to flow of charges in a conductor and

i_d = Displacement current = $\varepsilon_0 \frac{d\phi_E}{dt}$ = current due to the changing electric field between the plates of the capacitor

$$\oint B.dl = \mu_0 (i_{conventional} + i_{Displacement})$$

$$E = \frac{V}{d}$$



$$q = CV$$

$$i_D = \frac{dq}{dt} = \frac{d}{dt} CV = C\frac{dV}{dt}$$

$$i_D = \frac{\varepsilon_0 A}{d} \frac{dV}{dt} = \varepsilon_0 A \frac{dE}{dt}$$

$i_D = \varepsilon_0 \frac{d\phi_E}{dt}$

Note: ❑ Displacement current (i_d) = conduction current (i_c).

❑ i_c and i_d in a circuit, may not be continuous but their sum is always continuous.

$$i_D = \frac{dcv}{dt} = c\frac{dv}{dt} = \frac{\varepsilon_0 A}{d}\frac{dv}{dt} = \varepsilon_0 A \frac{dE}{dt} = \varepsilon_0 \frac{d\phi_E}{dt}$$

(4) **Maxwell's equations**

(i) $\boxed{\oint_s \vec{E}.\vec{ds} = \frac{q}{\varepsilon_0}}$ (Gauss's law in electrostatics)

$\phi = \frac{q}{\varepsilon_0}$, $\phi = \oint \vec{E}\cdot\vec{ds}$

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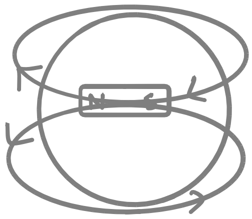
(ii) $\oint_s \vec{B}.\vec{ds} = 0$ (Gauss's law in magnetism)



It indirectly tells us monopole does not exist

(iii) $\oint \vec{E}.\vec{dl} = -\frac{d\phi_B}{dt}$ (Faraday's law of EMI)

$emf = -\frac{d\phi}{dt} = \int \vec{E}\cdot\vec{dl}$

(iv) $\oint \vec{B}\,\vec{dl} = \mu_o\left(i_c + \varepsilon_o \frac{d\phi_E}{dt}\right)$ (Maxwell- Ampere's Circuital law)

① $\oint \vec{E}\cdot\vec{ds} = \frac{q}{\varepsilon_0}$

② $\int \vec{B}\cdot\vec{ds} = 0$

③ $emf = -\frac{d\phi}{dt} = \int \vec{E}\cdot\vec{dl}$

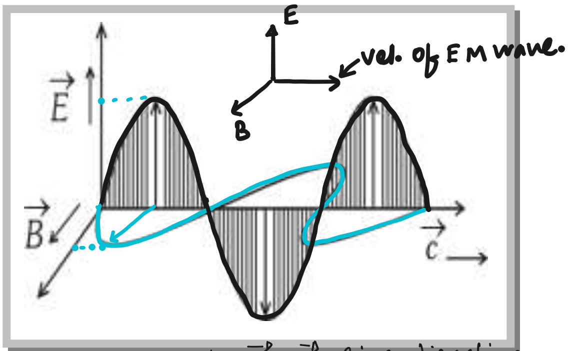
④ $\oint \vec{B}\cdot\vec{dl} = \mu_0 (i_c + i_D)$

EM Waves

(1) **Definition**

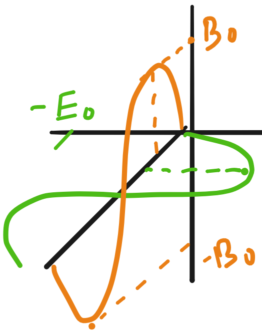
A changing electric field produces a changing magnetic field and vice versa which gives rise to a transverse wave known as electromagnetic wave.

$E_x = E_0 \sin(\omega t - kz)$



Direction of $\vec{E} \times \vec{B}$ give direction of velocity of E-M wave.

The electric vector is responsible for the optical effects of an EM wave and is called the *light vector*.



identify direction of propagation.

moving towards $+z$.

$E_y = E_0 \sin(\omega t - kx)$

$B_z = B_0 \sin(\omega t - kx)$

$B_y = B_0 \sin(\omega t - kz)$

(2) **History of EM waves :**

(i) **Maxwell :** Was the first to predict the EM wave.

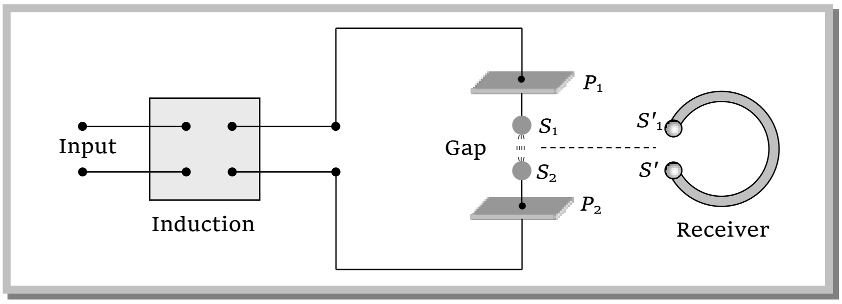
(ii) **Hertz :** Produced and detected electromagnetic waves experimentally at wavelengths of 6 *m*.

Experimental setup

Hertz experiment based on the fact that a oscillating charge is accelerating continuously, it will radiate electromagnetic waves continuously. In the following figure

• The metallic plates (P_1 and P_2) acts as a capacitor.

• The wires connecting spheres S_1 and S_2 to the plates provide a low inductance.



When a high voltage is applied across metallic plates these plates get discharged by sparking across the narrow gap. The spark will give rise to oscillations which in turn send out electromagnetic waves. Frequency of these wave is given by $\nu = \frac{1}{2\pi\sqrt{LC}}$

The succession of sparks send out a train of such waves which are received by the receiver.

(iii) **J.C. Bose :** Produced EM waves of wavelength ranging from 5*mm* to 25 *mm*.

(iv) **Marconi :** Successfully transmitted the EM waves up to a few *kilometer*.

Note :

- ❑ In an atom an electron circulating around the nucleus in a stable orbit, although accelerating does not emit electromagnetic waves; it does so only when it jumps from a higher energy orbit to a lower energy orbit.

- ❑ Electromagnetic waves (*X*-rays) are also produced when fast moving electrons are suddenly stopped by a metal target of high atomic number.

- ❑ Most efficient antennas are those which have a size comparable to the wavelength of the of electromagnetic wave they emit or receive.

(5) **Nature of EM waves**

The EM Waves are transverse in nature. They do not require any material medium for their propagation.

$c = \frac{E_0}{B_0} = \frac{1}{\sqrt{\mu_0 \varepsilon_0}} = 3 \times 10^8 \, m/s$

(6) **Properties of EM waves**

(i) Speed : In free space it's speed $c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}} = \frac{E_0}{B_0} = 3 \times 10^8 \, m/s$.

In medium $v = \frac{1}{\sqrt{\mu \varepsilon}}$; where $\mu_0 =$ Absolute permeability, $\varepsilon_0 =$ Absolute permittivity

E_0 and $B_0 =$ Amplitudes of electric field and magnetic field vectors.

(ii) Energy : The energy in an EM waves is divided equally between the electric and magnetic fields.

Energy density of electric field $u_e = \frac{1}{2}\varepsilon_0 E^2$, Energy density of magnetic field $u_B = \frac{1}{2}\frac{B^2}{\mu_0}$

$\frac{\text{Energy}}{\text{Vol}_\circ} = \frac{1}{2}\varepsilon_0 E^2 = \frac{1}{2}\frac{B^2}{\mu_0}$

It is found that $u_e = u_B$. Also $u_{av} = u_e + u_B = 2u_e = 2u_B = \varepsilon_0 E^2 = \frac{B^2}{\mu_0}$

(iii) Intensity (I) : The energy crossing per unit area per unit time, perpendicular to the direction of propagation of EM wave is called intensity. $I = u_{av} \times c = \frac{1}{2}\varepsilon_0 E^2 c = \frac{1}{2}\frac{B^2}{\mu_0}.c$

$\text{Intensity} = \frac{1}{2}\varepsilon_0 E^2 c$

$= \frac{1}{2}\frac{B^2 c}{\mu_0}$

$\text{Intensity} = \frac{\text{Energy}}{\text{Area} \times t}$

$\frac{E}{A \times l} = \frac{\text{Energy}}{\text{Vol}} = \frac{1}{2}\varepsilon_0 E^2$

Speed of EM wave.

$\frac{E}{A \times t} = \frac{1}{2}\frac{\varepsilon_0 E^2 \times l}{t} = \frac{1}{2}\varepsilon_0 E^2 c$

(iv) Momentum : EM waves also carries momentum, if a portion of EM wave of energy u propagating with speed c, then linear momentum $= \dfrac{\text{Energy } (u)}{\text{Speed } (c)}$

Note : ❑ When the incident EM wave is completely absorbed by a surface, it delivers energy u and momentum u / c to the surface.

❑ When a wave of energy u is totally reflected from the surface, the momentum delivered to surface is $2u/c$.

$$E = \frac{hc}{\lambda}, \quad P = \frac{E}{c} = \frac{h}{\lambda}$$ (Momentum of E.M wave)

(v) Poynting vector $(\vec{S})$. : In EM waves, the rate of flow of energy crossing a unit area is described by the poynting vector. It's unit is $watt/m^2$ and $\vec{S} = \frac{1}{\mu_o}(\vec{E}\times\vec{B}) = c^2\varepsilon_0(\vec{E}\times\vec{B})$. Because in EM waves $\vec{E}$ and $\vec{B}$ are perpendicular to each other, the magnitude of $\vec{S}$ is $|\vec{S}| = \frac{1}{\mu_0}EB\sin 90^o = \frac{EB}{\mu_0} = \frac{E^2}{\mu C}$.

Note : ❑ The direction of the poynting vector $\vec{S}$ at any point gives the wave's direction of travel and direction of energy transport the point.

(vi) Radiation pressure : Is the momentum imparted per second pre unit area. On which the light falls.

For a perfectly reflecting surface $P_r = \frac{2S}{c}$; S = Poynting vector; c = Speed of light

For a perfectly absorbing surface $P_a = \frac{S}{c}$.

Note : ❑ The radiation pressure is real that's why tails of comet point away from the sun.

$P = \frac{I}{c}$ ← intensity.

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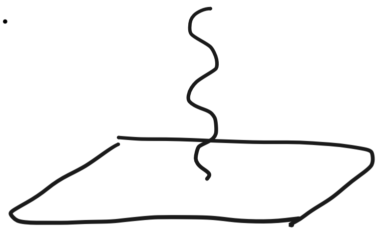

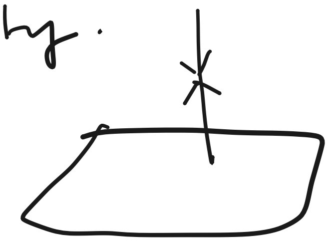

100% absorb $P = \frac{2I}{c}$

EM Spectrum

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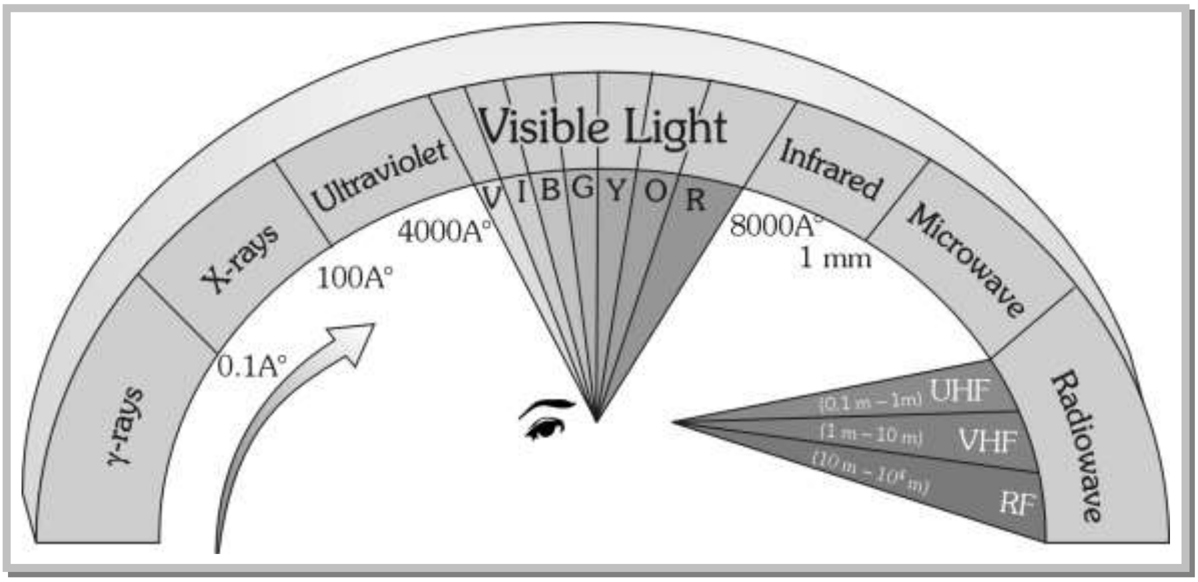
The whole orderly range of frequencies/wavelengths of the EM waves is known as the EM spectrum.



Uses of EM spectrum

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Radiation	Uses
γ-rays	Gives informations on nuclear structure, medical treatment *etc.*
X-rays	Medical diagnosis and treatment study of crystal structure, industrial radiograph.
UV- rays	Preserve food, sterilizing the surgical instruments, detecting the invisible writings, finger prints etc.
Visible light	To see objects
Infrared rays	To treat, muscular strain for taking photography during the fog, haze etc.
Micro wave and radio wave	In radar and telecommunication.

Matter waves (de-Broglie Waves)

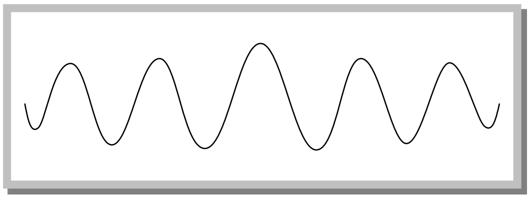
According to de-Broglie a moving material particle sometimes acts as a wave and sometimes as a particle.

or

A wave is associated with moving material particle which control the particle in every respect.

The wave associated with moving particle is called matter wave or de-Broglie wave and it propagates in the form of wave packets with group velocity.

$\lambda = \frac{h}{p}$ ← Momentum of particle



$KE = \frac{P^2}{2m}$

$P = \sqrt{2mKE}$

$P = mv$, $KE = \frac{1}{2}mv^2 \times \frac{m}{m} = \frac{(mv)^2}{2m}$

(1) **de-Broglie wavelength**

According to de-Broglie theory, the wavelength of de-Broglie wave is given by

$$\boxed{\lambda = \frac{h}{p} = \frac{h}{mv} = \frac{h}{\sqrt{2mE}}} \qquad \Rightarrow \lambda \propto \frac{1}{p} \propto \frac{1}{v} \propto \frac{1}{\sqrt{E}}$$

Where h = Plank's constant, m = Mass of the particle, v = Speed of the particle, E = Energy of the particle.

The smallest wavelength whose measurement is possible is that of γ-rays.

The wavelength of matter waves associated with the microscopic particles like electron, proton, neutron, α-particle *etc*. is of the order of 10^{-10} *m*.

(i) **de-Broglie wavelength associated with the charged particles.**

The energy of a charged particle accelerated through potential difference V is $E = \frac{1}{2}mv^2 = qV$

$W = q\Delta V = \Delta KE$

q

V_A $\quad$ V_B

Hence de-Broglie wavelength $\boxed{\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mE}}} = \frac{h}{\sqrt{2mqV}}$

$\lambda = \frac{h}{p} = \frac{h}{mv} = \frac{h}{\sqrt{2mKE}} = \frac{h}{\sqrt{2mq\Delta V}}$

Potential

$\lambda_{electron} = \frac{12.27}{\sqrt{V}}\mathring{A}$, $\quad \lambda_{proton} = \frac{0.286}{\sqrt{V}}\mathring{A}$, $\quad \lambda_{deutron} = \frac{0.202 \times 10^{-10}}{\sqrt{V}}\mathring{A}$,

$\lambda_{\alpha-particle} = \frac{0.101}{\sqrt{V}}\mathring{A}$

(ii) **de-Broglie wavelength associated with uncharged particles.**

For *Neutron* de-Broglie wavelength is given as

$$\lambda_{Neutron} = \frac{0.286 \times 10^{-10}}{\sqrt{E(\text{in}\, eV)}}m = \frac{0.286}{\sqrt{E(\text{in}\, eV)}}\mathring{A}$$

give ΔV same

$\lambda = \frac{h}{\sqrt{2mq\Delta V}}$

$\frac{\lambda_\alpha}{\lambda_e} = \frac{\frac{\cancel{h}}{\sqrt{2m_\alpha q_\alpha \cancel{\Delta V}}}}{\cancel{h}}$

$\sqrt{2m_e q_e \Delta V}$

Energy of thermal neutrons at ordinary temperature

$\because \quad E = kT \Rightarrow \lambda = \dfrac{h}{\sqrt{2mkT}}$; where k = Boltzman's constant = 1.38×10^{-23} *Joules/kelvin* , T = Absolute temp.

$KE = \frac{3}{2}kT$

$KE \propto T$

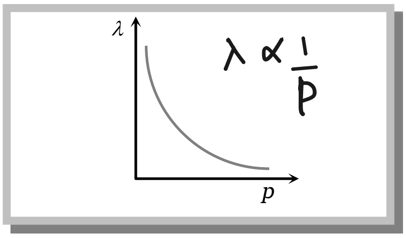
So $\lambda_{\text{Thermal Neutron}} = \dfrac{6.62 \times 10^{-34}}{\sqrt{2 \times 1.07 \times 10^{-17} \times 1.38 \times 10^{-23}\, T}} = \dfrac{30.83}{\sqrt{T}} \mathring{A}$

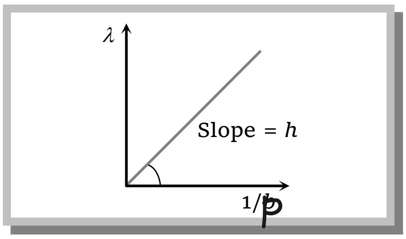
$\lambda = \dfrac{h}{p} = \dfrac{h}{\sqrt{2mKE}}$

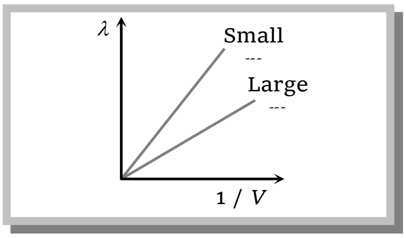
$\lambda \propto \dfrac{1}{\sqrt{\text{Temp.}}}$ For Neutral particle

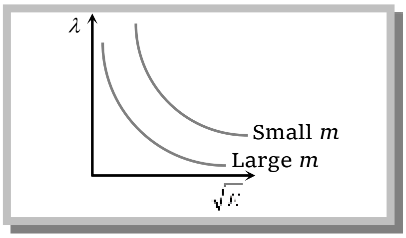
$\dfrac{\lambda_1}{\lambda_2} = \sqrt{\dfrac{T_1}{T_2}}$

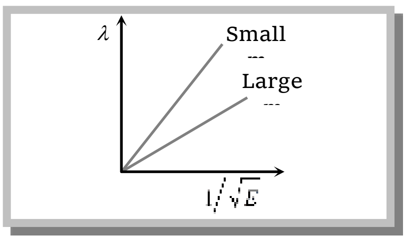
(2) **Some graphs**

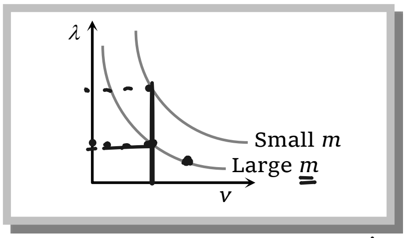






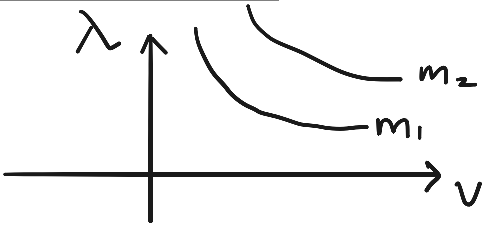






$$\lambda = \frac{h}{p} = \frac{h}{mv}$$

$$\downarrow \lambda = \frac{h}{qmV}$$



$m_2 > m_1$

mains

Note : ❑ A photon is not a material particle. It is a quanta of energy.

❑ When a particle exhibits wave nature, it is associated with a wave packet, rather then a wave.

read by own

(3) **Characteristics of matter waves**

(i) Matter wave represents the probability of finding a particle in space.

(ii) Matter waves are not electromagnetic in nature.

(iii) de-Brogile or matter wave is independent of the charge on the material particle. It means, matter wave of de-Broglie wave is associated with every moving particle (whether charged or uncharged).

(iv) Practical observation of matter waves is possible only when the de-Broglie wavelength is of the order of the size of the particles is nature.

(v) Electron microscope works on the basis of de-Broglie waves.

(vi) The electric charge has no effect on the matter waves or their wavelength.

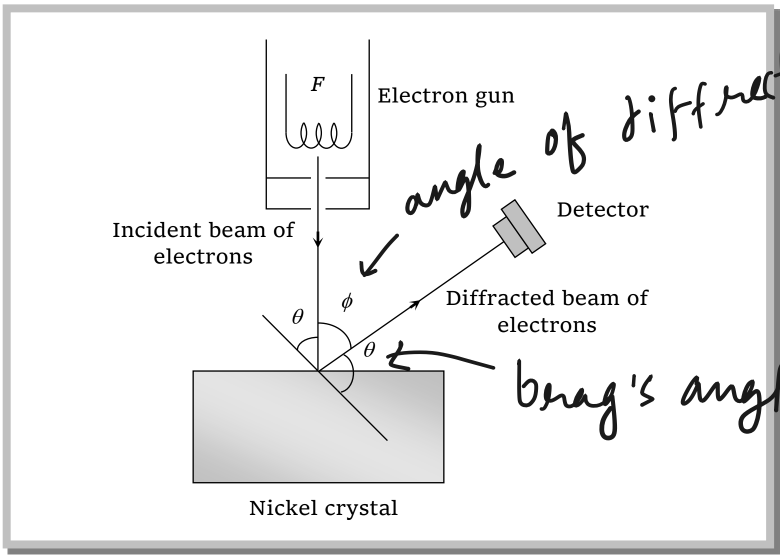
(vii) The phase velocity of the matter waves can be greater than the speed of the light.

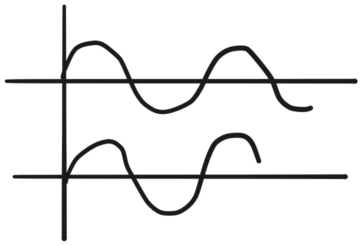
(viii) Matter waves can propagate in vacuum, hence they are not mechanical waves.

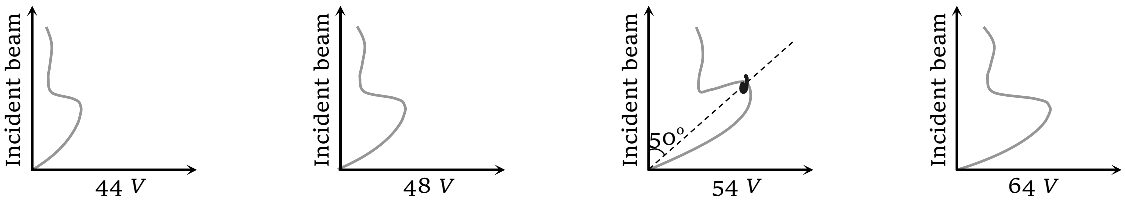
(ix) The number of de-Broglie waves associated with n^{th} orbital electron is n.

(x) Only those circular orbits around the nucleus are stable whose circumference is integral multiple of de-Broglie wavelength associated with the orbital electron.

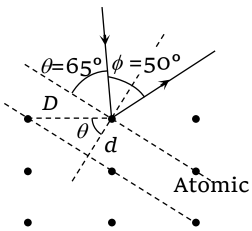
(4) **Davision and Germer experiment**







$$\lambda = \frac{h}{\sqrt{2mq\Delta V}} = 1.66\,\mathring{A}$$



Intensity is maximum at 54 V potential difference and 50° diffraction angle.

If the de-Broglie waves exist for electrons then these should be diffracted as X-rays. Using the Bragg's formula $2d\sin\theta = n\lambda$, we can determine the wavelength of these waves.

$\Delta x = n\lambda$

$2d\sin\theta = n\lambda$, $\theta = 65°$

Where d = distance between diffracting planes, $\theta = \frac{(180-\phi)}{2}$ = glancing angle for incident beam = Bragg's angle.

The distance between diffraction planes in Ni-crystal for this experiment is d = $0.91\mathring{A}$ and the Bragg's angle = 65^o. This gives for n = 1, $\lambda = 2 \times 0.91 \times 10^{-10} \sin 65^o = 1.65\ \mathring{A}$

Now the de-Broglie wavelength can also be determined by using the formula $\lambda = \frac{12.27}{\sqrt{V}} = \frac{12.27}{\sqrt{54}} = 1.67\mathring{A}$.

Thus the de-Broglie hypothesis is verified.

Photo-electric Effect

It is the phenomenon of emission of electrons from the surface of metals, when light radiations (Electromagnetic radiations) of suitable frequency fall on them. The emitted electrons are called photoelectrons and the current so produced is called photoelectric current.

This effect is based on the principle of conservation of energy.

(1) **Terms related to photoelectric effect**

(i) **Work function (or threshold energy) (W_o) :** The minimum energy of incident radiation, required to eject the electrons from metallic surface is defined as work function of that surface.

$W_0 = h\nu_0 = \dfrac{hc}{\lambda_0}\, Joules$; ν_o = Threshold frequency; λ_o = Threshold wavelength

Work function in electron volt $W_o(eV) = \dfrac{hc}{e\lambda_0} = \dfrac{12375}{\lambda_0(\text{Å})}$

Note : By coating the metal surface with a layer of barium oxide or strontium oxide it's work function is lowered.

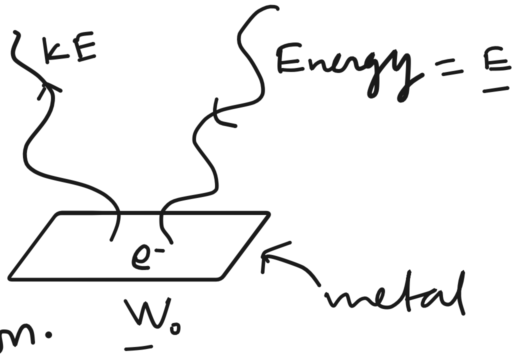
(ii) **Threshold frequency (ν_o) :** The minimum frequency of incident radiations required to eject the electron from metal surface is defined as threshold frequency.

If incident frequency $\nu < \nu_o \Rightarrow$ No photoelectron emission

(iii) **Threshold wavelength (λ_o) :** The maximum wavelength of incident radiations required to eject the electrons from a metallic surface is defined as threshold wavelength.

If incident wavelength $\lambda > \lambda_o \Rightarrow$ No photoelectron emission

(2) **Einstein's photoelectric equation**



$\boldsymbol{E = W_0 + K_{max}}$;

K.E. of emitted electron.

$KE = E - \phi_0$ ← work function

incident energy

Important formulae

$\Rightarrow h\nu = h\nu_0 + K_{\max}$

$\Rightarrow K_{\max} = eV_0 = h(\nu - \nu_0) \quad \Rightarrow \frac{1}{2}mv_{\max}^2 = h(\nu - \nu_0) \quad \Rightarrow v_{\max} = \sqrt{\frac{2h(\nu - \nu_0)}{m}}$

$\Rightarrow K_{\max} = \frac{1}{2}mv_{\max}^2 = eV_0 = hc\left(\frac{1}{\lambda} - \frac{1}{\lambda_0}\right) = hc\left(\frac{\lambda_0 - \lambda}{\lambda\lambda_0}\right) \Rightarrow v_{\max} = \sqrt{\frac{2hc}{m}\frac{(\lambda - \lambda_0)}{\lambda\lambda_0}}$

$\Rightarrow V_0 = \frac{h}{e}(\nu - \nu_0) = \frac{hc}{e}\left(\frac{1}{\lambda} - \frac{1}{\lambda_0}\right) = 12375\left(\frac{1}{\lambda} - \frac{1}{\lambda_0}\right)$

$KE = \underbrace{h\nu}_{E} - h\nu_0 \leftarrow \phi_0$

$KE = E - \phi_0$

$KE = \frac{hc}{\lambda} - \frac{hc}{\lambda_0}$

Fast calculation

$KE_{max} = \frac{12400}{\lambda \text{Å}} - \frac{12400}{\lambda_0 \text{Å}}$

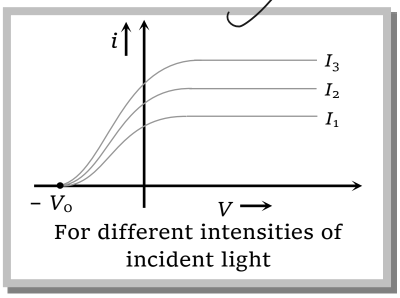
in eV

incident radiation

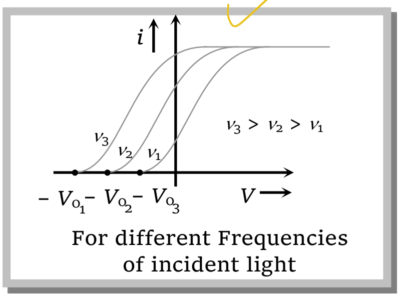
threshold wave length

(4) **Different graphs**

(i) Graph between potential difference between the plates P and Q and photoelectric current

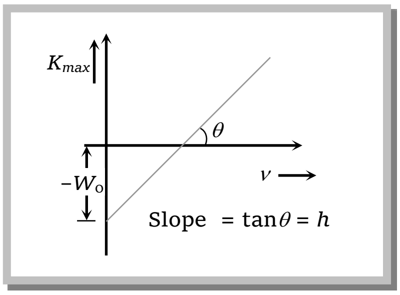


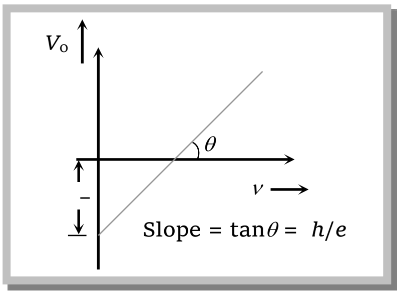
For different intensities of incident light



For different Frequencies of incident light

(ii) Graph between maximum kinetic energy / stopping potential of photoelectrons and frequency of incident light





X-rays

X-rays was discovered by scientist Rontgen that's why they are also called Rontgen rays.

Properties of X-rays

(i) X-rays are electromagnetic waves with wavelength range 0.1Å – 100Å.

(ii) The wavelength of X-rays is very small in comparison to the wavelength of light. Hence they carry much more energy (This is the only difference between X-rays and light)

(iii) X-rays are invisible.

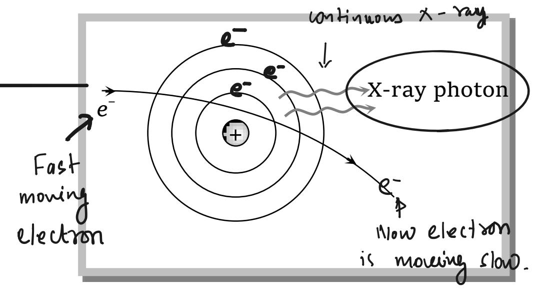
i.e. $I' = \frac{I_0}{2}$ is called half value thickness ($x_{1/2}$) and it is given as $x_{1/2} = \frac{0.693}{\mu}$.

Classification of X-rays

In X-ray tube, when high speed electrons strikes the target, they penetrate the target. They loses their kinetic energy and comes to rest inside the metal. The electron before finally being stopped makes several collisions with the atoms in the target. At each collision one of the following two types of X-rays may get form.

(1) **Continuous X-rays**

acc. potential



Note : ❑ Continuos X-rays are produced due to the phenomenon called "Bremsstrahlung". It means slowing down or braking radiation.

$q\Delta V$

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

$$\lambda_{min} = \frac{hc}{eV}$$

X-ray

NEET mains.

$\lambda_{min} = \frac{hc}{eV} = \frac{12400}{V}$, $\log \lambda_{min} = -\log V$

acc. potential

Minimum wavelength

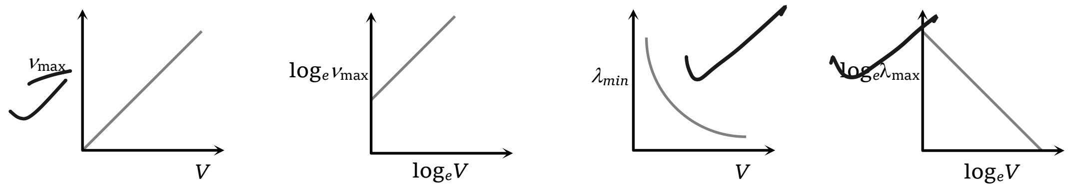
When the electron looses whole of it's energy in a single collision with the atom, an X-ray photon of maximum energy $h\nu_{max}$ is emitted *i.e.* $\frac{1}{2}mv^2 = eV = h\nu_{max} = \frac{hc}{\lambda_{min}}$

where v = velocity of electron before collision with target atom, V = potential difference through which electron is accelerated, c = speed of light = 3 × 10^8 m/s

Maximum frequency of radiations (X-rays) $\nu_{max} = \frac{eV}{h}$

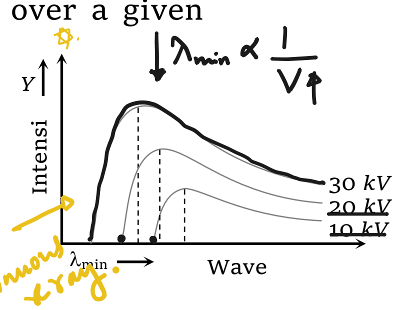
Minimum wave length = cut off wavelength of X-ray $\lambda_{min} = \frac{hc}{eV} = \frac{12375}{V}$ Å

Note : ❑ Wavelength of continuous X-ray photon ranges from certain minimum (λ_{min}) to infinity.



Intensity wavelength graph

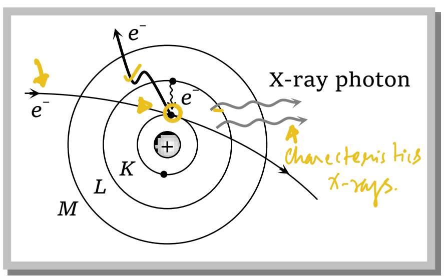
The continuous X-ray spectra consist of all the wavelengths over a given range. These wavelength are of different intensities. Following figure shows the intensity variation of different wavelengths for various accelerating voltages applied to X-ray tube.



For each voltage, the intensity curve starts at a particular minimum wavelength (λ_{min}). Rises rapidly to a maximum and then drops gradually.

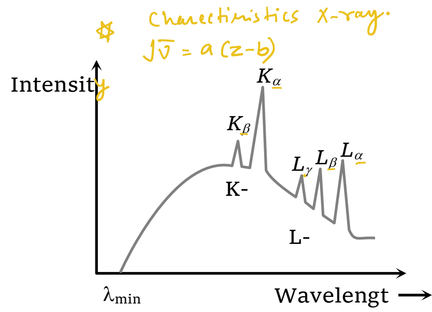
The wavelength at which the intensity is maximum depends on the accelerating voltage, being shorter for higher voltage and vice-versa.

(2) **Characteristic X-rays**



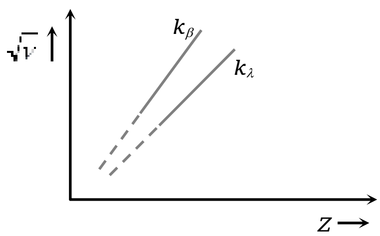
Intensity-wavelength graph

At certain sharply defined wavelengths, the intensity of X-rays is very large as marked K_α, K_β .... As shown in figure. These X-rays are known as characteristic X-rays. At other wavelengths the intensity varies gradually and these X-rays are called continuous X-rays.



Mosley's law

Mosley studied the characteristic X-ray spectrum of a number of a heavy elements and concluded that the spectra of different elements are very similar and with increasing atomic number, the spectral lines merely shift towards higher frequencies.



Freq. of X-ray
atomic no.
b = 1

He also gave the following relation $\sqrt{\nu} = a(Z - b)$

where ν = Frequency of emitted line, Z = Atomic number of target, a = Proportionality constant,

is a constant.

b = Screening constant.

Note : ❑ a and b doesn't depend on the nature of target. Different values of b are as follows

$b = 1$	for	K-series
$b = 7.4$	for	L-series
$b = 19.2$	for	M-series

❑ $(Z - b)$ is called effective atomic number.

$$\frac{\sqrt{\nu_1}}{\sqrt{\nu_2}} = \frac{\cancel{a}(Z_1 - b)}{\cancel{a}(Z_2 - b)}$$

$$\frac{\sqrt{\nu_1}}{\sqrt{\nu_2}} = \frac{(Z_1 - 1)}{(Z_2 - 1)}$$

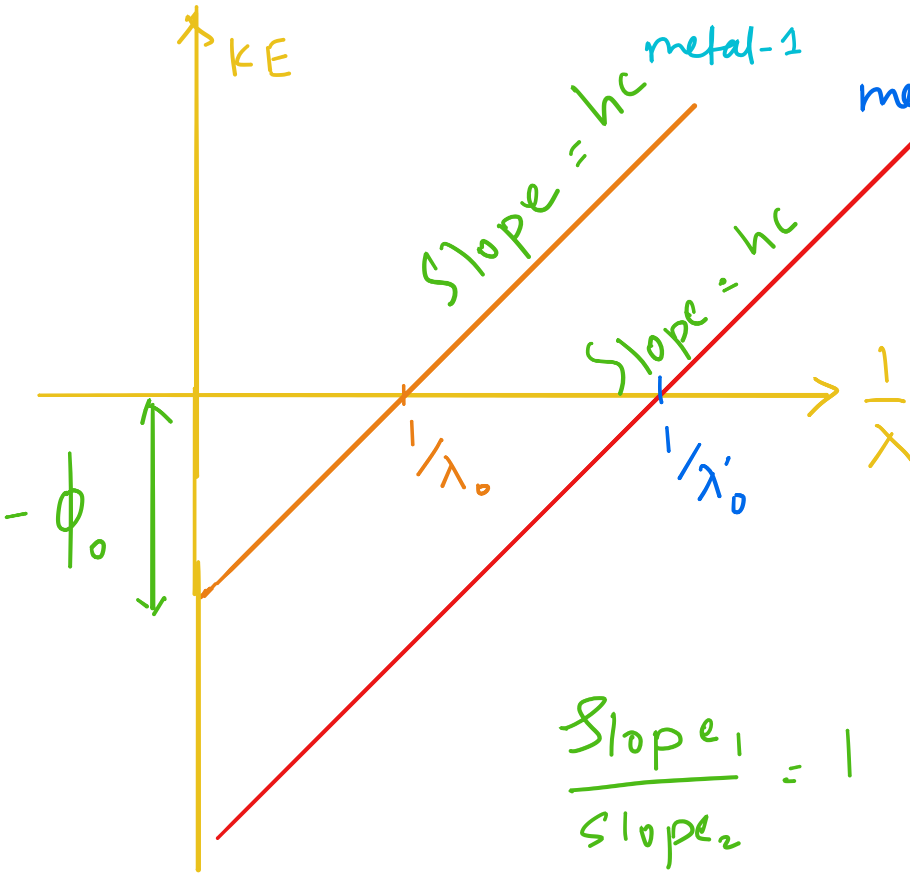
$$KE_{max} = E - \phi_0$$

$$KE_{max} = \frac{hc}{\lambda} - \phi_0$$

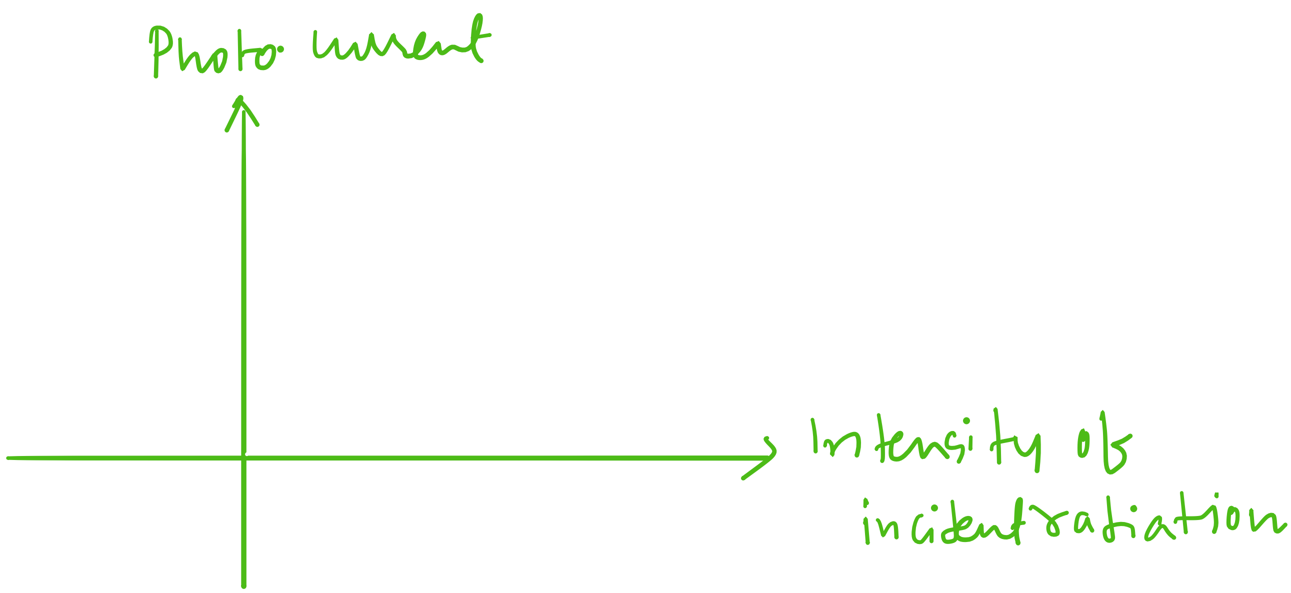
$$KE_{max} = \frac{hc}{\lambda} - \phi_0$$
$$\downarrow$$
$$y = mx + c$$

$$m = hc$$

$$c = -\phi_0$$



$$\frac{\text{Slope}_1}{\text{slope}_2} = 1 \quad (\text{IIT Adv})$$



Intensity of incident radiation $\propto$ no. of incident

Intensity of incident radiation ... of

photon.