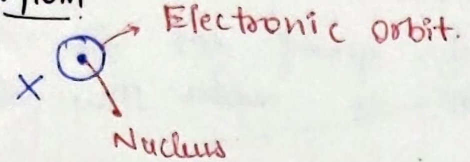
17/01/23

NUCLEAR PHYSICS.

* Atom



* Isotopes → Same Atomic no. + Diff mass no.

Ex: $^{1}_{1}H$, $^{2}_{1}H$, $^{3}_{1}H$ | $^{238}_{92}U$, $^{235}_{92}U$, $^{234}_{92}U$

* Nuclear forces

Salient features of Nuclear force.

1. Short range force.
2. Strongly attractive & large in magnitude.
3. Charge independent.
4. Spin dependent. [up spin & down spin]
5. Not a central force.
6. High energy is req to separate any nucleon from the nucleus.
7. Saturated force. {No. of nucleons ke independent protons ya neutrons badane se koi farak nahi hoga}

▫ Mass defects.

$^{A}_{Z}X$

M_x, M_z, M_n.

$$\Delta m = (ZM_z + nM_n) \sim M_x$$

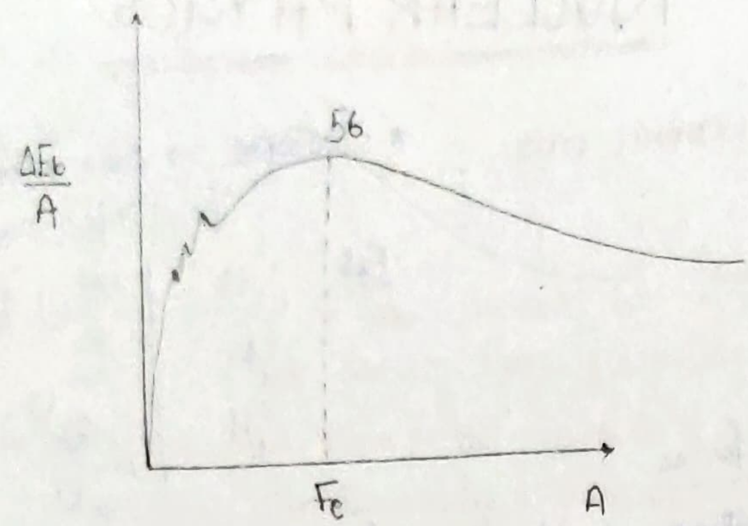
$$\boxed{\Delta m = \{ZM_z + (A-Z)M_n\} \sim M_x}$$ *

▫ Binding Energy: The energy equivalent to the missing mass is known as binding energy.

$$\Delta E_b = \Delta m c^2.$$
$$= [\{ZM_z + (A-Z)M_n\} \sim M_x] c^2.$$
$$= 931.5 [\{ZM_z + (A-Z)M_n\} \sim M_x] \text{ MeV}$$

Binding energy per nucleon: $\frac{\Delta E_b}{A} = \frac{931.5}{A} [\{ZM_z + (A-Z)M_n\} \sim M_x] \text{ MeV}$

* Graph



LIQUID DROP MODEL

Pre knowledge:

↳ Properties of Nucleus.

① Radius $R = R_0 A^{1/3}$ $\{R_0 = 1.5 \times 10^{-15} m\}$

② Charge on nucleus. $= Z$.

③ Density of Nucleus : $\frac{M_N}{V_N} = \frac{A M_p}{\frac{4}{3}\pi R^3} = \frac{m_p}{\frac{4}{3}\pi (1.4 \times 10^{-15})^3}$

$= 1.45 \times 10^{17} \ Kg/m^3$.

Back to topic :

① The density of the nucleus is independent of its volume analogous to the density of a liquid is independent of its volume.

② Surface Tension effect in liquid drop is analogus to the potential barrier effect on the surface of nucleus.

③ The molecule of liquid drop start evaporate when energy is given to it. This is due to thermal agitation. Analogously if the high energy nuclear projectile bombarded to the nucleus. compound nucleus is formed which quickly share the incident energy & emits the nucleon.

Bohr's Atomic Model.

① The e's moves in a stable orbit. ($2\pi r = n\lambda$).
② The e's can jump from one energy level to another. They will release or absorb the energy accordingly.
③ If the number of e^- in outer ~~obit~~ orbit is 2, 8, 18, 32.

Nuclear Shell Model.

① The nucleons are also moving in a stable orbit under the influence of force field produced by average interaction b/w the remaining nucleus.
② The nucleus which have specific numbers of protons or neutrons are more stable than others.
These numbers are as follows :-

$p = 2, 8, 20, 28, 50, 82$
$n = 2, 8, 20, 28, 50, 82, 126.$

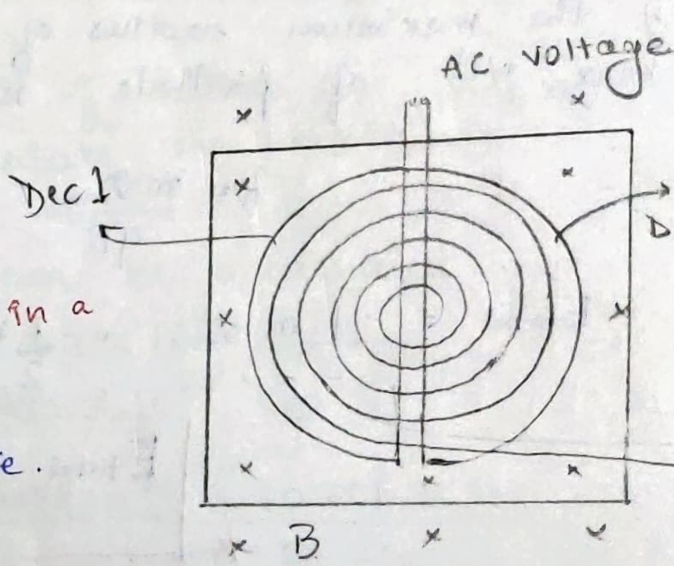
These numbers are also known as magic numbers.
* Nucleus ~~Elements~~ having these combinations are known as magic ~~elements~~. [protons & neutrons ~~nucleons~~ ~~and e's~~]
doubly mag

③ In nucleus the nucleons are arranged in shell, each shell containing restricted number nucleons in accordance to Pauli's principle.

~~Accelarao~~ Accelerator

- Cyclic
- Linear.

* Cyclotron.



Principle: The charged particle describes a curved path in a perpendicular mag. field.

Lorentz force.
$F_L = q(\vec{v} \times \vec{B})$
$F_L = qvB.$

Centripetal force.
$F_c = \frac{mv^2}{r}.$

$F_L = F_c.$

$\frac{mv^2}{r} = qvB.$

$\boxed{v = \frac{qBr}{m}}$ $\boxed{r = \frac{mv}{qB}}$

The time period of revolution.

$$\boxed{T = \frac{2\pi m}{qB}} \qquad \left\{ T = \frac{2\pi r}{v} \right\}$$

Frequency : $\nu = \frac{1}{T} = \frac{qB}{2\pi m}$

* Imp
NOTE : Condition of resonance : $T = T_0$

Time period of one revolution of particle.

{Time period of applied voltage source}.

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* $T = T_0$ [Condⁿ of Resonance].

Final energy of the particle. :

The energy gain by particle in one revolution $= 2qV$

- If N is the total no. of revolution of particle

Total energy of the particle $= \boxed{2NqV}$ → Voltage applied

In terms of velocity.

$$E_{total} = \frac{1}{2} m v^2$$

If the maximum radius of the path is R & the max. vel. of particle is v_{max} then,

$$R = \frac{m v_{max}}{qB}, \qquad v_{max} = \frac{qBR}{m}$$

$$E_{total} = \frac{1}{2} m v_{max}^2 = \frac{1}{2} m \times \frac{q^2 B^2 R^2}{m^2}$$

$$\boxed{E_{total} = \frac{q^2 B^2 R^2}{2m}} \; \star$$

Limitations of Cyclotron

① Large magnets are needed to create large B. MF.
High MF is req. for getting large energy particle.

② Increasing velocity of particle ($v \approx c$) leads to relativistic effects, its mass starts changing

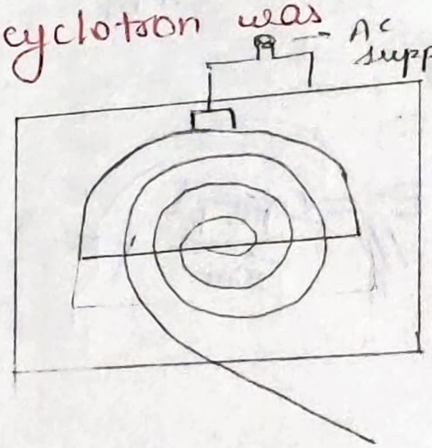
$$m = \frac{m_0}{\sqrt{1-\frac{v^2}{c^2}}}$$

, as the mass inc. the time period of revolution also ↑↑. $T = \frac{2m\pi}{qB}$.

Therefore, the cond^n of resonance is no longer applicable. Hence the particle starts deaccelarating.

* To overcome this limitation syncrocyclotron was introduced.

In this the freq. of applied voltage ↑↑ as the vel of particle is increased.



Numericals:

Q1 A cyclotron with its Dees of radius 2m has a MF of 0.75 Wb/m², Calculate the maximum energy to which :

(1) Protons. (2) Deutrons can be accelerated.

Given mass of proton : 1.67×10^{-27} Kg

" " Deutrons : 3.34×10^{-27} Kg

Sol (1) $E_{max} = \frac{q^2 B^2 R^2}{2m} = \frac{(1.6 \times 10^{-19})^2 \times (0.75)^2 \times 4}{2 \times 1.67 \times 10^{-27}}$

$= 1.72 \times 10^{-11}$ J. Ans

(2) $E_{max} = 0.86 \times 10^{-11}$ J Ans

Ques Deutrons are acc in a fixed freq^n cyclotron of max Dee orbit radius of 0.88 m. The MF is 1.4T. Calculate the energy of emerging deutron beam & the freq^n of Dee voltage. What change in mag. flux density is needed if doubly charged He ions are acc.

Sol $E = \frac{q^2 B^2 R^2}{2m} = \frac{(1.6\times10^{-19})^2 \times (1.4)^2 \times (0.88)^2}{2\times 3.34\times10^{-27}}$

$= 0.36 \times 10^{-11} = \frac{3.6\times10^{-12}}{10^{-13}}$ eV

$= \underline{36 MeV}$

$f = \frac{qB}{2\pi m} = 0.106 \times \frac{10^{-19}}{10^{-27}} = 0.106\times10^{8}$

$= 1.06\times10^{7}$

$= 10.6$ MHz.

$\cancel{E = \frac{q^2B^2R^2}{2m}}$ $\quad T = \frac{2m\pi}{qB}$.

$\nu = \frac{qB}{2\pi m}$ $\quad B = \frac{2\pi m \nu}{q}$

$B = \frac{2\pi \times 4\times1.67\times10^{-27} \times 10.67\times10^{6}}{2\times1.6\times10^{-19}}$

$\boxed{B = 1.39T}$

Hence diff $= 0.01$ T Ans

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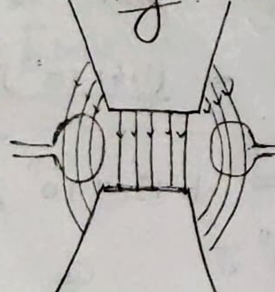
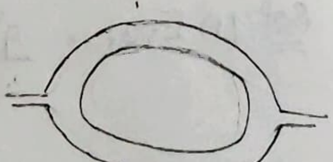
BETATRON.

Magnet





Doughnut shape

** Changing M.F.

→ Acc e^-

→ Circular motion of e^-.

* Magnetic flux (ϕ) · (V) $\mathcal{E} = -\frac{d\phi}{dt}$

* The work done on e^- $= -e\mathcal{E}$

$$= (-e)\left(-\frac{d\phi}{dt}\right)$$

$$W = \frac{e\,d\phi}{dt}$$

We know work done = F.S.

$$W = 2\pi r . F$$

$$\therefore 2\pi r F = e\frac{d\phi}{dt}$$

$$\boxed{F_1 = \frac{e}{2\pi r}\frac{d\phi}{dt}} \quad \text{—— (ii)}$$

Lorentz force due to magnetic field B

$$eBv = \frac{mv^2}{r}$$

$$\boxed{mv = eBr} \quad (1)$$

Taking differentiation wrt t in eq (1)

$$\frac{d(mv)}{dt} = \frac{d(eBr)}{dt}$$

$$\frac{dp}{dt} = er\frac{dB}{dt}$$

$$\boxed{F = er\frac{dB}{dt} = F_2} \quad \text{—— (iii)}$$

Now $F_1 = F_2$.

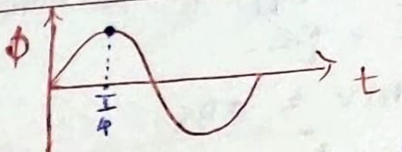
$$\frac{e}{2\pi r}\frac{d\phi}{dt} = er\frac{dB}{dt}$$

$$d\phi = 2\pi r^2 . dB$$

$$\boxed{\phi = 2\pi r^2 B}$$

Note. Imp

* we say that principle of transformer work in Betatron.



The particle is ejected at this point b/c we only want to acc the particle and after that peak the particle will deaccelerate. Hence it has max. acc. at top point.

The no. of revolution in fixed orbit:

Total length carried by e^- during time $\frac{T}{4}$

$$L = c \times \frac{T}{4}$$

speed is comparable to light.

$$L = c \times \frac{1}{4\nu} = c \times \frac{2\pi}{4 \times \omega}.$$

$$\boxed{L = \frac{\pi c}{2\omega}}$$

So Number of revolutions

$$N = \frac{L}{2\pi r} = \frac{\pi c}{2\omega} \times \frac{1}{2\pi r}$$

$$\boxed{N = \frac{c}{4\omega r}}$$

Total

- Energy of particle

$E = pc.$

$mv = eBr$

$$\boxed{E = eBrc}$$

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Bain Bridge Mass-spectrograph

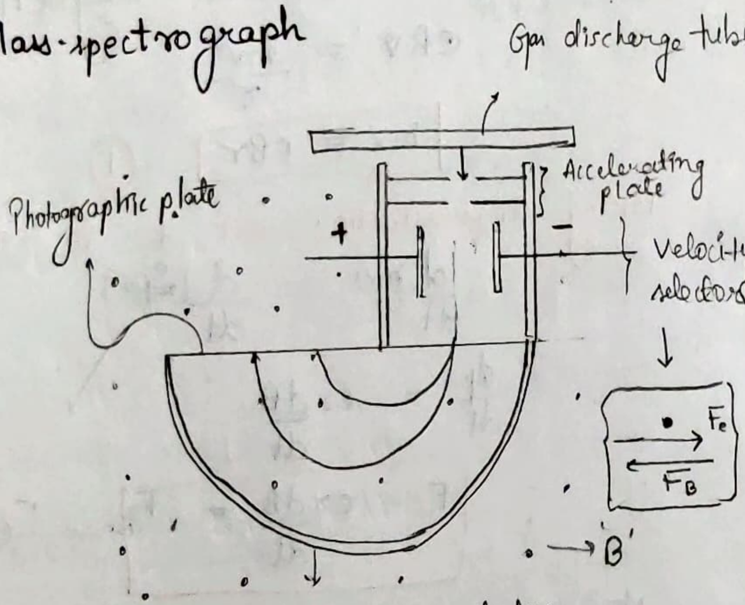
lorentz force : qvB

Force due to EF = qE.

Through velocity selector only that particle can pass which has

$qE = qvB$

$$\boxed{v = \frac{E}{B}}$$



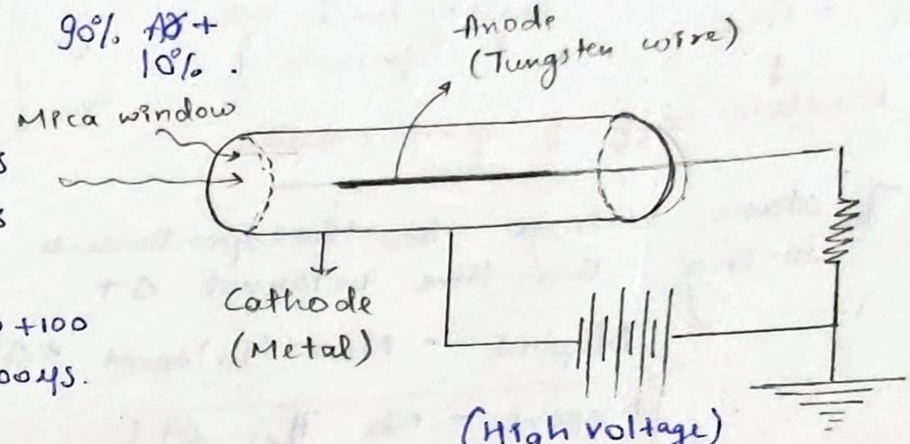
In momentum selector : $\frac{mv^2}{r} = qvB$

$$\boxed{r = \frac{mv}{qB}}$$

$r \propto m$

- Photographic plate is used as a pattern is observed on it.

Geiger Muller Counter (GM Counter).



Dead time: 100μs
Recovery time: 100μs

Paralysed time : 100 + 100
= 200μs.

* Disadvantages

① It has large paralysed time.

② It cannot detect no. of particles when a large amount of ~~particles~~ radiations falls on it.

09/02/2023

LASER

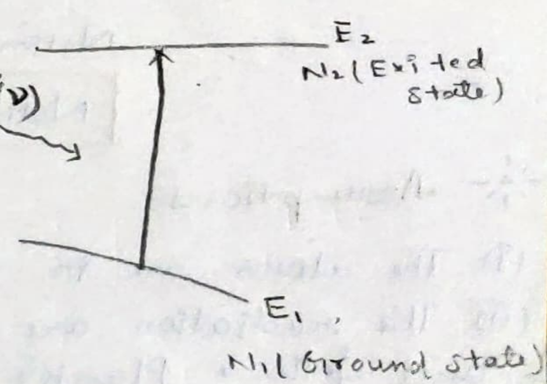
(i) Absorption, (ii) Spontaneous emission. (iii) Stimulated emission

(1) Absorption

$h\nu = E_2 - E_1$

$A + h\nu = A^*$ → Exited atom

photon density $\rho(\nu)$



$P_{12} \propto \rho(\nu)$

$P_{12} = B_{12} \cdot \rho(\nu)$

B_{12} → Einstein coefficient of absorption

→ The no. of atoms undergo absorption during time interval Δt.

$N_{ab} = N_1 \times P_{12} \times \Delta t$

$$\boxed{N_{ab} = N_1 B_{12} \rho(\nu) \Delta t}$$

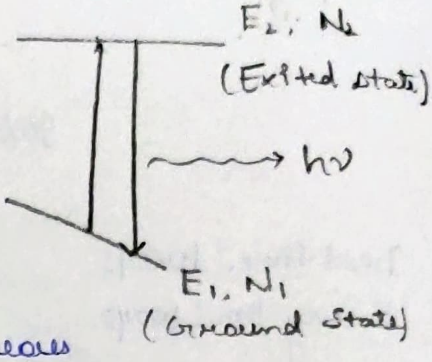
(2) Spontaneous emission

$A^* \longrightarrow h\nu + A$

$(P_{21})_{spont} = A_{21}$

{ No dependency on density hence not in formula }.

Einstein coeff of. spont emission



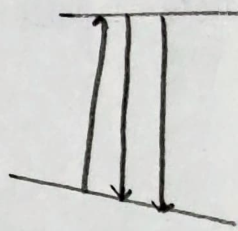
* The no. of atoms undergo to the spontaneous emission during ~~the~~ time interval Δt.

$$N_{spont} = N_2 \times (P_{21})_{spont} \times \Delta t.$$

$$\boxed{N_{spont} = N_2 A_{21} \Delta t}$$

(3) Stimulated emission

It requires a stimulas to initiate.



$$A^* + h\nu \longrightarrow A + h\nu + h\nu$$
$$\longrightarrow A + 2h\nu.$$

$(P_{21})_{stim} \propto \rho(\nu)$

$(P_{21})_{stim} = B_{21} \, \rho(\nu)$

↳ E.C. of stimulated emission

* The no. of atoms undergo to the ~~spontaneous~~ stimulated emission during time interval. Δt.

$$N_{stim} = N_2 \times (P_{21})_{stim} \times \Delta t$$

$$\boxed{N_{stim} = N_2 \times B_{21} \, \rho(\nu) \, \Delta t}$$

Assumptions.

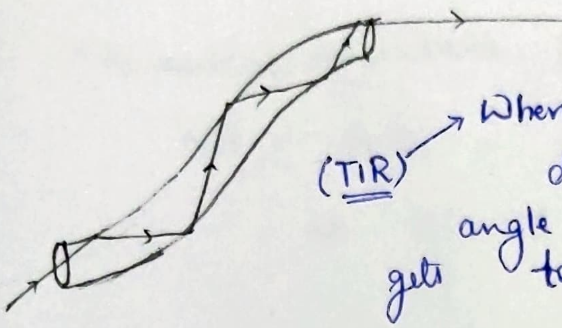
(i) The atoms are in thermal eqb.

(ii) The radiation are identical to Black Body radiation and follows Plank's radiation law.

(iii) The population densities in lower and excited states are N_1 & N_2 respectively and distributed according to. Boltzman law.

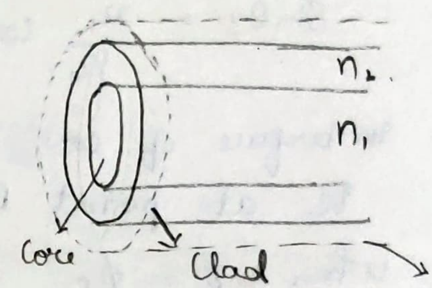
FIBER OPTICS.

Optical Fiber.



(TIR) → When a light travels from rarer to denser medium, after a certain angle all light falling on interface gets totally reflected.

→ Importance of cladding.



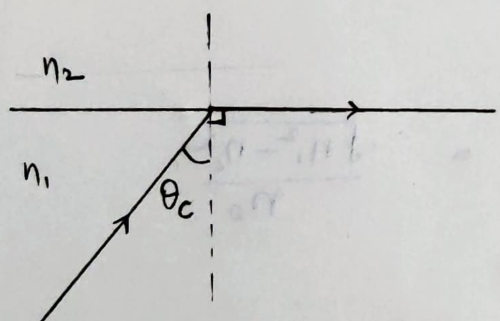
① To maintain the refractive index [clad is made up of uniform refractive index].

② To maintain uniform size as well as protect it from any external damage.

This layer can be of any hard material for protecting the core & cladding.

□ Total internal reflection.

Snell's Law



$$n_1 \sin\theta_c = n_2 \sin 90^\circ$$

$$\sin\theta_c = \frac{n_2}{n_1}$$

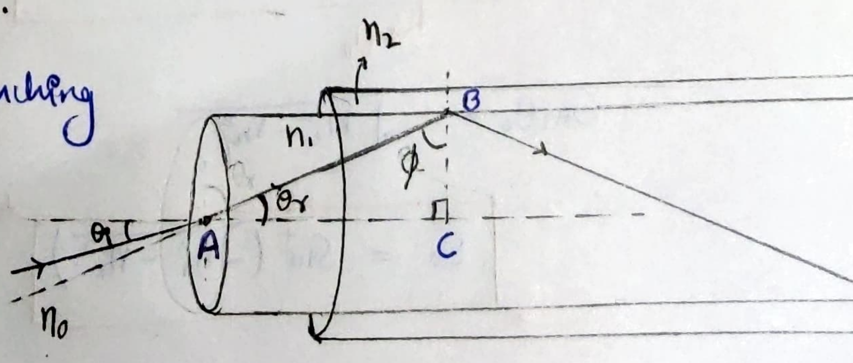
$$\boxed{\theta_c = \sin^{-1}\left(\frac{n_2}{n_1}\right)}$$

Acceptance Angle.

Using Snell's law at launching end.

$$n_0 \sin\theta_i = n_1 \sin\theta_r$$

$$\sin\theta_i = \frac{n_1}{n_0} \sin\theta_r \quad \text{—①}$$



* The maximum value of $\phi = \phi_c$.

In Δ-ABC.

$$\sin\theta_r = \sin(90-\phi)$$

$$\sin\theta_r = \cos\phi$$

So eq ①

$$\sin\theta_i = \frac{n_1}{n_0}\cos\phi.$$

Maximum value of $\phi = \phi_c$

$$\sin\theta_i = \frac{n_1}{n_0}\cos\phi_c \quad \text{—— (ii)}$$

At interface of core & cladding ie at point B.

when $\phi = \phi_c$

$$\frac{\sin\phi_c}{\sin 90^\circ} = \frac{n_2}{n_1}$$

$$\sin\phi_c = \frac{n_2}{n_1}.$$

$$\cos\phi_c = \sqrt{1-\sin^2\phi_c}$$

$$\cos\phi_c = \sqrt{1-\frac{n_2^2}{n_1^2}}$$

$$\sin(\theta_i)_{max} = \frac{n_1}{n_0}\,\frac{\sqrt{n_1^2-n_2^2}}{n_1} = \frac{\sqrt{n_1^2-n_2^2}}{n_0}$$

Generally $n_0 = 1$ [For air]

$$\boxed{\underbrace{\sin(\theta_i)_{max}}_{\theta_0} = \sqrt{n_1^2-n_2^2}}$$

$$\sin\theta_0 = \sqrt{n_1^2-n_2^2}$$

$$\boxed{\theta_0 = \sin^{-1}\left(\sqrt{n_1^2-n_2^2}\right)}$$ *

Fractional Refractive Index change.

$$\Delta = \frac{n_1 - n_2}{n_1} \cdots = +ve \qquad [n_1 > n_2]$$

always (tabhi to TIR hoga)

Numerical Aperture (NA)

$$NA = \sin\theta_0 = \sqrt{n_1^2 - n_2^2}$$

$$n_1^2 - n_2^2 = \underbrace{\left(\frac{n_1+n_2}{2}\right)}_{\approx n_1} \underbrace{\boxed{\left(\frac{n_1-n_2}{n_1}\right)}}_{\Delta} . 2n_1$$

$$n_1^2 - n_2^2 = n_1 \Delta 2n_1$$

$$\boxed{\sqrt{n_1^2 - n_2^2} = n_1\sqrt{2\Delta}}$$

★ It determines the gathering ability of fiber.

H.W.
1. Different types of fiber
2. Classification of fiber.
3. V- number.