Composition of the Nucleus

Nucleus

For an element X:

$$ {}^{A}_{Z}X $$

A → Mass number = No. of protons + Neutrons
Z → Atomic number

Size of the Nucleus

Radius of a nucleus: $R = R_0 A^{1/3}$

$R_0 = 1.2 \times 10^{-15}\ m = 1.2\ fm$

$10^{-15} m = fm$ (fermi)

Volume of the nucleus $\propto R^3 \propto A$

$V = \frac{4}{3}\pi R^3 \propto R^3 \propto (A^{1/3})^3 \propto A$

$\text{Density} \propto \frac{\text{Mass}}{\text{Volume}} \propto \frac{A}{A} = \text{Constant}$ → Derivation

Nuclei density is constant

Nuclear density $= 2.3 \times 10^{17}\ kg\,m^{-3}$

Example 13.1 Given the mass of iron nucleus as 55.85u and A = 56, find its nuclear density. (Given 1 u = 1.66×10^{-27} kg)

MASS-ENERGY EQUIVALENCE

$E = mc^2$ (E → J, m → kg, c → ms^{-1})

$c = 3 \times 10^8\ m/s$
↳ Speed of light in vacuum.

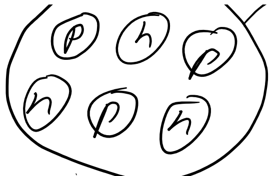
1u = 931.5 MeV

Eg 13.2 :- Calculate the energy equivalent of 1g of substance.

Nuclear Binding Energy

Mass defect: $\Delta M = [Zm_p + (A-Z)m_N] - M$

Mass defect: $\Delta M = [Zm_p + (A-Z)m_N] - M$ ✓✓



$M < 3(m_p + m_N)$

Binding Energy: → $E_b = \Delta M c^2$ (Energy Released)

Eg 13.3 Find the energy equivalent of one atomic mass unit, first in Joules, then in MeV.
Using this, express the mass defect of $^{16}_{8}O$ in MeV/c^2.
(Given: $m_p = 1.00727u$, $m_N = 1.00866u$, $m_O = 15.99053u$)
($1u = 1.660539 \times 10^{-27}\,kg$)

$\Delta m = (8m_p + 8m_N) - m_O = X\,u = 931.5 \times x\,MeV/c^2$

Sol:- $E = mc^2$

$E = (1u)(3\times10^8)^2$

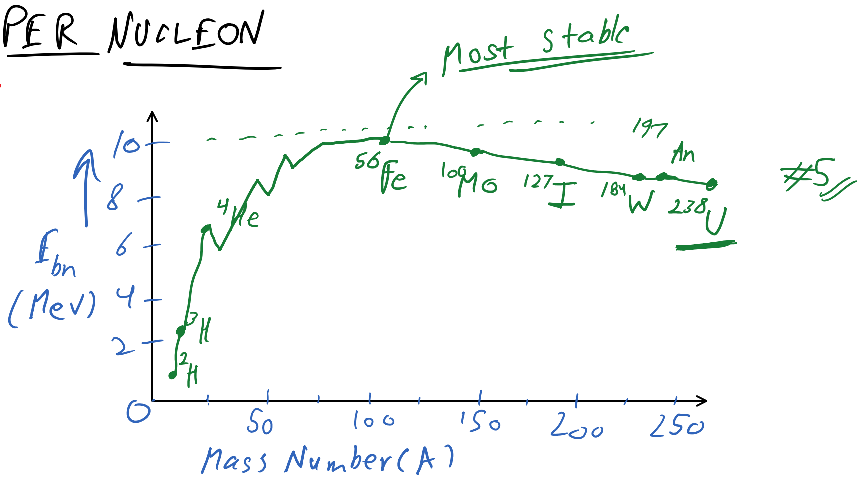
$= \dfrac{(1.660539\times10^{-27})(3\times10^8)^2}{1.6\times10^{-19}}\,eV = 931.5\,MeV$

$\Delta m = [Zm_p + (A-Z)m_n] - N = \{[8m_p + (16-8)m_N] - m_O\}u \Rightarrow \dfrac{\Delta mc^2\,MeV}{c^2}$
$= \phi\,MeV/c^2$

———————— x ———→ x ————————

BINDING ENERGY PER NUCLEON

$$E_{bn} = \frac{E_b}{A}$$



#5

NUCLEAR FORCE
(Strong)

(i) Nuclear Force is much stronger than the Coulomb force or gravitational force.

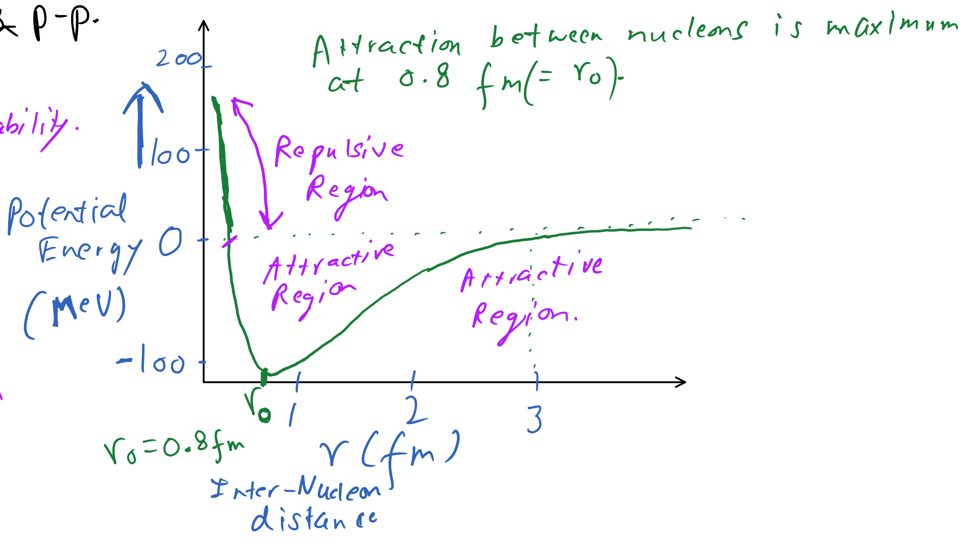
(ii) Nuclear force between two nucleons rapidly falls to zero as their distance becomes more than a few femtometers.

(iii) Nuclear force does not depend on charge. It is approximately same between n-n, p-n & p-p.

▷ Less energy means more stability.

▷ Nuclear force is attractive when P.E. < 0.

▷ The minima of P.E. in the graph is the region of most stability & strongest attraction.



NUCLEAR FISSION

* Larger Nucleus breaking into smaller Nuclei.

Eg:- $${}^{1}_{0}n + {}^{235}_{92}U \rightarrow {}^{236}_{92}U \rightarrow {}^{144}_{56}Ba + {}^{89}_{36}Kr + 3\,{}^{1}_{0}n + \text{Energy (Q-Value)}$$

* The energy released (Q-Value) in the fission reaction of nuclei like Uranium is of the order of 200 MeV per fissioning nucleus.
  → When 1 ${}^{236}_{92}U$ breaks, it gives out around 200 MeV of Energy (Heat)

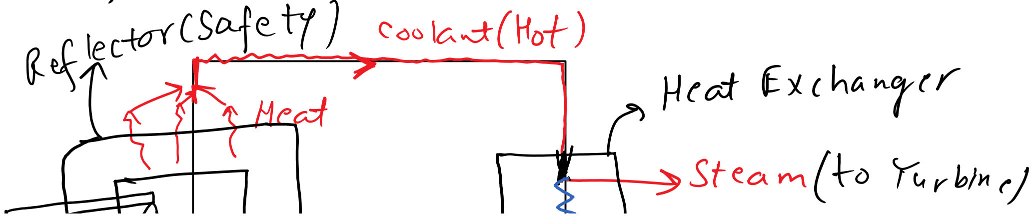
Nuclear Reactor

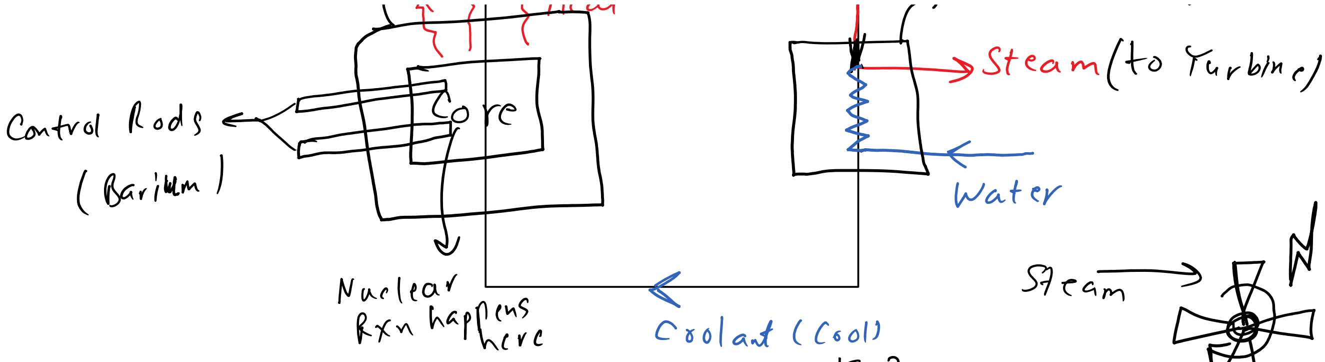
$${}^{238}_{92}U + n \text{ (slow moving)} \rightarrow {}^{239}_{93}Np + e^- + \bar{\nu}$$

$\bar{\nu}$ (Anti-neutrino) (Particle type)

$${}^{239}_{93}Np \rightarrow {}^{239}_{94}Pu + e^- + \bar{\nu}$$

* Then, Plutonium undergoes fission with slow neutrons to give nuclear Energy (Mostly Heat) (Q-Value)





H.W. Exercise 13.1 – 13.5, 13.15 – 13.17, 13.20, 13.21

Nuclear Fusion

↳ Small nuclei combining to give larger nuclei/nucleus.

$${}^{1}_{1}H + {}^{1}_{1}H \rightarrow {}^{2}_{1}H + e^{+} + \nu + 0.42\ MeV$$

(Positron) (Neutrino)

$$e^{+} + e^{-} \rightarrow \gamma + \gamma + 1.02\ MeV$$

(Gamma Photons)

$${}^{2}_{1}H + {}^{1}_{1}H \rightarrow {}^{3}_{2}He + \gamma + 5.49\ MeV$$

$${}^{3}_{2}He + {}^{3}_{2}He \rightarrow {}^{4}_{2}He + {}^{1}_{1}H + {}^{1}_{1}H + 12.86\ MeV$$

$$4\,{}^{1}_{1}H + 4e^{-} \rightarrow {}^{4}_{2}He + 2\nu + 6\gamma + 26.7\ MeV$$

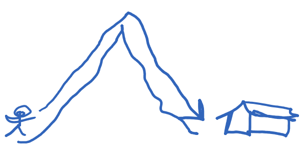
13.1 (a) $\frac{(7.5)}{100} \times M_{{}^{6}_{3}Li} + \frac{92.5}{100} M_{{}^{7}_{3}Li}$ (b) $\frac{x}{100} M_{{}^{10}_{5}B} + \frac{(100-x)}{100} M_{{}^{11}_{5}B}$

13.2

13.16 $Q = \Delta m c^2 = (M_p - M_R)c^2 = (2 \times M_{Al} - M_{Fe})c^2$

If $Q > 0$, then energetically feasible

If $Q < 0$, " " not ".

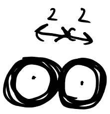


$${}^{56}Fe \longrightarrow 2\,{}^{28}Al + Q$$

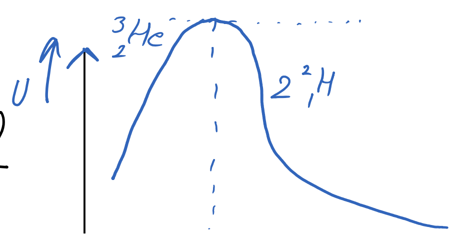
13.17 $M_{Pu^{239}} \simeq 239u$ $Q = 180\ MeV$

$$E = \frac{1\ Kg}{239 \times 1.66 \times 10^{-27}} \times 180\ MeV$$

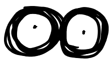
13.20

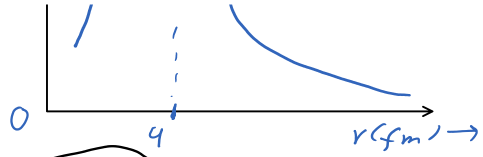


$$U = \frac{1}{4\pi\varepsilon_0} \frac{(+e)(+e)}{(4 \times 10^{-15})}$$



$$U = \frac{1}{4\pi\varepsilon_0}\frac{(\ldots)}{(4\times10^{-15})}$$





$$T = \frac{1}{f} \quad \therefore f = \frac{1}{T} \qquad T = \frac{2\pi r}{v} \qquad r = r_0 \frac{n^2}{Z}$$

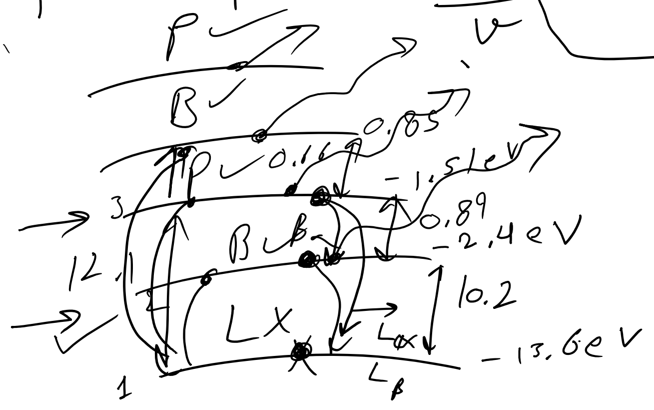
53 pm
0.53 Å

$$v = v_0 \frac{Z}{n}$$

$$v_0 = 2.2\times10^6$$

(9)

$$\begin{array}{r} 151 \\ -85 \\ \hline 066 \end{array}$$

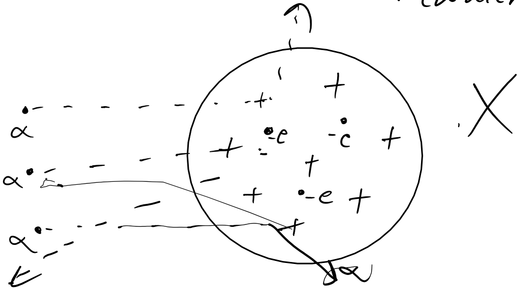


$$\frac{E_0}{n^2} = \frac{13.6}{1} \qquad \frac{13.6}{16}$$

$$\frac{13.6}{4}$$

$$\frac{13.6}{9}$$

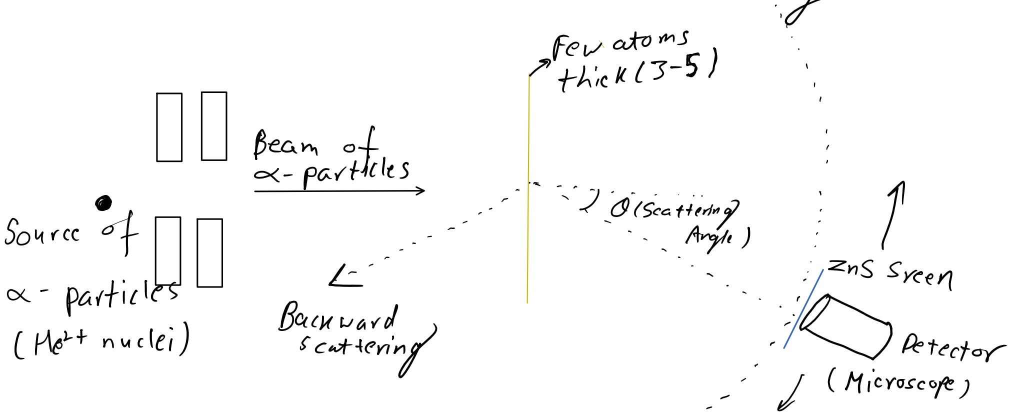
Thomson's Model of Atom (Plum Pudding Model)
or (Watermelon Model)

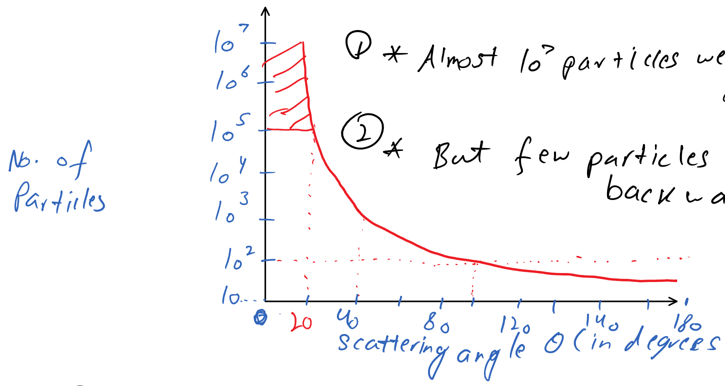


J.J. Thomson discovered the electron.
James Chadwick " " neutron.

Rutherford's Alpha-Scattering Experiment

Geiger - Marsden Experiment





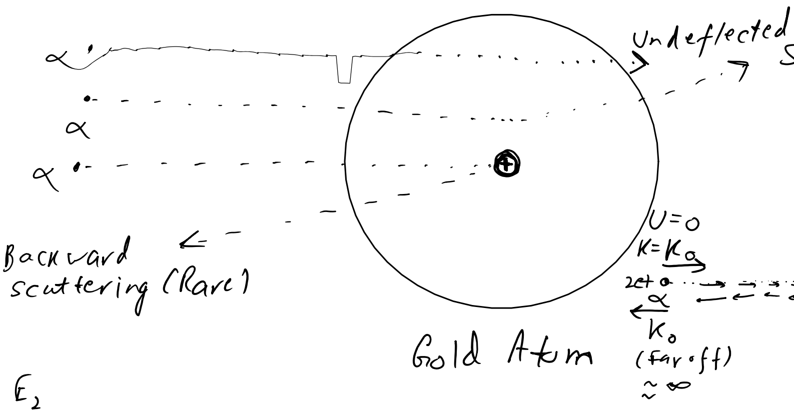
① * Almost 10^7 particles were slightly deflected or undeflected

② * But few particles were scattered backwards (>90°)

① Most of the atom is empty space.

② Most of the mass & all positive charge resides in a small region at the centre of the atom called the Nucleus

Hence, E. Rutherford DISCOVERED THE NUCLEUS



$$U = \frac{1}{4\pi\varepsilon_0}\frac{(2e)(Ze)}{r_0}$$

r_0 = Distance of Closest Approach.

$E_1 = E_2$

$U_1 + K_1 = U_2 + K_2$

$U_1 + K_1 = U_2 + K_2$

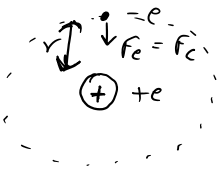
$0 + K_0 = \frac{1}{4\pi\varepsilon_0}\frac{(2e)(Ze)}{r_0} + 0$

ELECTRON ORBITS (H-atom)

$r \rightarrow$ Radius of H-atom

Bohr radius

$\simeq 53\,pm$ or $5.3 \times 10^{-11}\,m$



Electrostatic Force = Centripetal Force

$$\frac{1}{4\pi\varepsilon_0}\frac{(e)(e)}{r^2} = \frac{mv^2}{r}$$

$K = \frac{1}{2}mv^2$; $U = \frac{1}{4\pi\varepsilon_0}\frac{(+e)(e)}{r}$

$$\Rightarrow \boxed{r = \frac{e^2}{4\pi\varepsilon_0 m v^2}}$$

Total Energy, $E = K + U = \frac{e^2}{8\pi\varepsilon_0 r} - \frac{e^2}{4\pi\varepsilon_0 r}$

$$\boxed{E = -\frac{e^2}{8\pi\varepsilon_0 r}}$$

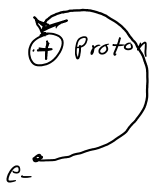
$$\boxed{E = -K = \frac{U}{2}}$$ Imp

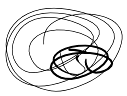
Eg 12.3 :- $E = -13.6\,eV$

H.W. Ex-1, 2

DRAWBACKS OF RUTHERFORD'S MODEL OF ATOM

* According to Electromagnetic theory, an accelerated charged particle should emit Electromagnetic Radiation & Hence lose Energy.
* By this logic, an electron in an atomic orbit should lose energy & hence collapse into the nucleus.
* Therefore, matter cannot be stable according to Rutherford's model.
* This dilemma was solved by Neils Bohr in his atomic model.





BOHR'S MODEL OF ATOM

(i) Bohr's first postulate was that an electron in an atom could revolve in certain stable orbits without the emission of radiant energy, contrary to the electromagnetic theory. These stable orbits are called stationary states of the atom.

(ii) Bohr's second postulate defines these stable orbits.

$$L = \frac{nh}{2\pi}$$

$L \rightarrow$ Angular momentum $= mvr$

$n \rightarrow$ whole number

$h \rightarrow$ Planck's constant

$h = 6.6 \times 10^{-34}\,Js$

(iii) An electron might make a transition from one stationary state to another by emitting or absorbing a photon. The energy of photon is equal to the energy difference between the two states.

$$h\nu = |E_f - E_i|$$

$\ast$ $L_n = m v_n r_n = \frac{nh}{2\pi}$

But, $v_n = \frac{e}{\sqrt{4\pi\varepsilon_0 m r_n}}$

$\therefore v_n = \frac{1}{n} \frac{e^2}{4\pi\varepsilon_0} \frac{1}{h/2\pi}$ $\Rightarrow$ $v_n \propto \frac{Z}{n}$

$\therefore r_n = \left(\frac{n^2}{m}\right)\left(\frac{h}{2\pi}\right)^2 \frac{4\pi\varepsilon_0}{e^2}$ $\Rightarrow$ $r_n \propto \frac{n^2}{Z}$

$\therefore E_n = \frac{-me^4}{8n^2\varepsilon_0^2 h^2}$ $\Rightarrow$ $E_n \propto \frac{Z^2}{n^2}$

V. Imp

$\Rightarrow v_n = \frac{Z}{n} v_0$

$v_0 = 2.2 \times 10^6$ m/s

$\Rightarrow r_n = \frac{n^2}{Z} r_0$

$r_0 = 5.3 \times 10^{-11}$ m

$\Rightarrow E_n = \frac{Z^2}{n^2} E_0$

$E_0 = -13.6$ eV

Z = Atomic Number

n = Orbital Number

- ENERGY LEVELS
- ENERGY SPECTRA

H.W Revise Notes

ENERGY LEVELS

(H-atom) $\Rightarrow$ Z = 1

$E_n = -13.6\text{eV}\left(\frac{Z^2}{n^2}\right) = \frac{-13.6\text{eV}}{n^2}$

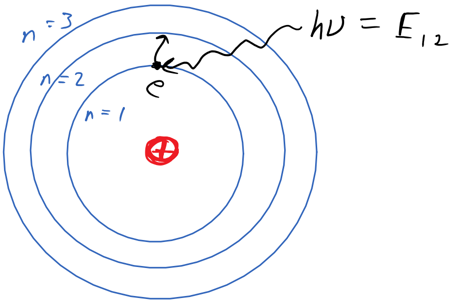
$E_1 = -13.6$ eV

$E_2 = \frac{-13.6\text{eV}}{2^2}$

$E_3 = \frac{-13.6\text{eV}}{3^2}$

⋮

$E_n = \frac{-13.6\text{eV}}{n^2}$



$E_{12} = E_2 - E_1 = -13.6\text{eV}\left(\frac{1}{4} - 1\right) = 10.2$ eV

$\therefore h\nu$ or $\frac{hc}{\lambda} = 10.2$ eV

$$E_{ij} = E_j - E_i = \frac{hc}{\lambda}$$

$$\Rightarrow \frac{1}{\lambda} = \frac{E_j - E_i}{hc} = \left(\frac{13.6\text{ eV}}{hc}\right)\left[\frac{1}{i^2} - \frac{1}{j^2}\right]$$

where $i < j$

$$\frac{1}{\lambda} = R\left[\frac{1}{i^2} - \frac{1}{j^2}\right]$$

$\lambda \rightarrow$ metres

$R \rightarrow$ Rydberg Constant

$R = 1.097 \times 10^7\ \text{m}^{-1}$

Eg:- Using the Rydberg formula, find the wavelength for $i = 1$ & $j = 2, 3, 4, 5$.

De-Broglie's Explanation of Bohr's 2nd Postulate of Quantisation

$L_n = n\frac{h}{2\pi}$

$2\pi r_n = n\lambda$ (Here, λ is the de-Broglie wavelength of electron)

$\therefore 2\pi r_n = \frac{nh}{mv_n}$ $\left[\because \lambda = \frac{h}{p} \text{ or } \frac{h}{mv}\right]$

$\Rightarrow mv_n r_n = \frac{nh}{2\pi}$ OR $\boxed{L_n = \frac{nh}{2\pi}}$

Atomic Spectra

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

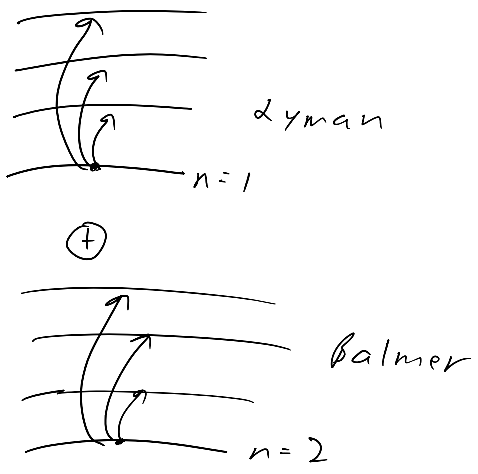
If $n_1 = 1 \Rightarrow$ Lyman Series (U.V.)

$n_1 = 2 \Rightarrow$ Balmer Series (Visible)

$n_1 = 3 \Rightarrow$ Paschen Series (Visible)

$n_1 = 4 \Rightarrow$ Brackett Series (I.R.)

$n_1 = 5 \Rightarrow$ Pfund Series (I.R.)



Eg:- Find the wavelengths of 1st 4 spectral lines of the Paschen Series.

H.W. :→ Exercise (Ch-12)

Energy Bands

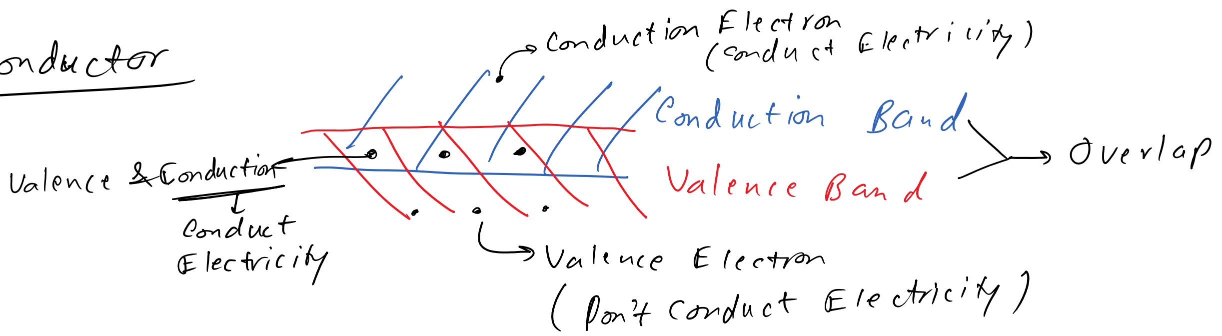
$\rho \to$ Resistivity
$\sigma \to$ Conductivity

(i) Metals :→ $\rho \sim 10^{-2} - 10^{-8}\ \Omega m^{-1}$
$\sigma \sim 10^{2} - 10^{8}\ Sm^{-1}$

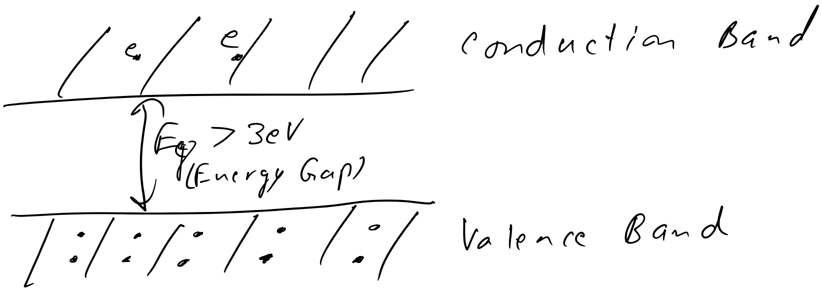
(ii) Semiconductors :→ $\rho \sim 10^{-5} - 10^{-6}\ \Omega m^{-1}$
$\sigma \sim 10^{5} - 10^{6}\ Sm^{-1}$

(iii) Insulators :→ $\rho \sim 10^{11} - 10^{19}\ \Omega m^{-1}$
$\sigma \sim 10^{-11} - 10^{-19}\ Sm^{-1}$

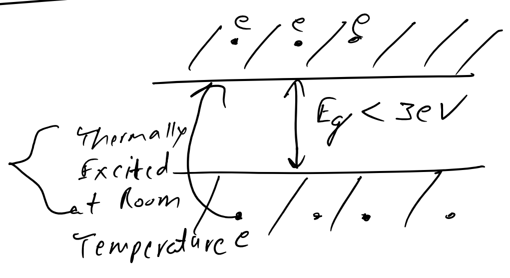
* Conductor



* Insulator



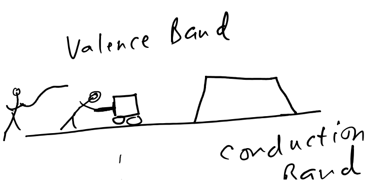
* Semiconductor

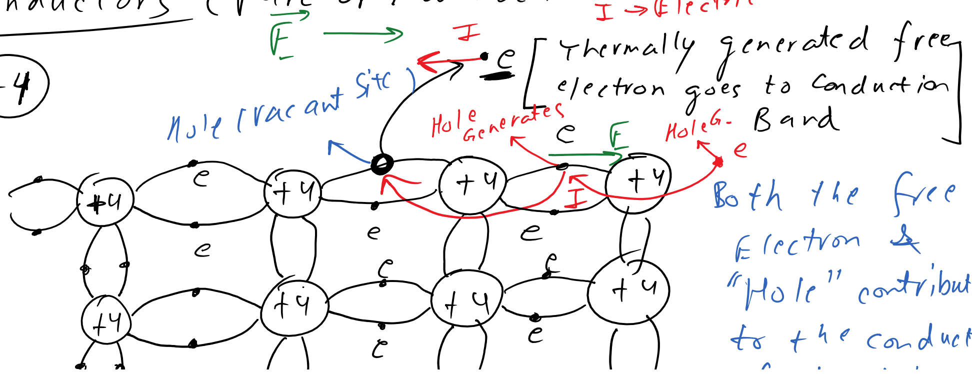


Intrinsic Semiconductors (Pure or Natural)

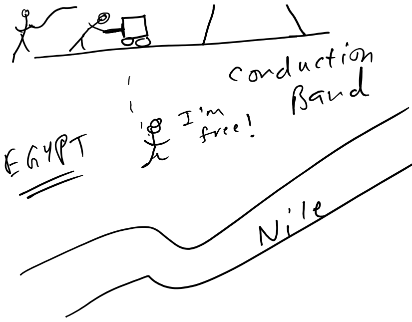
E → Electric Field
I → Electric Current

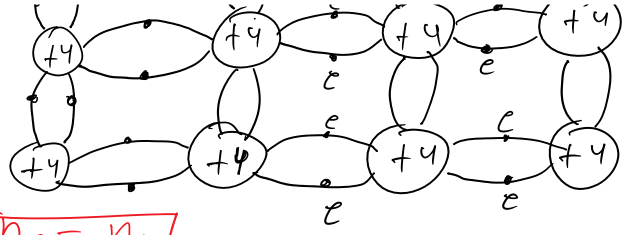
Si or Ge → +4





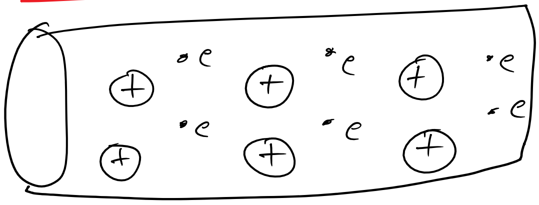
Both the free Electron & "Hole" contribute to the conduction





"Hole" contribute to the conduction of electricity.

$n_e = n_h$

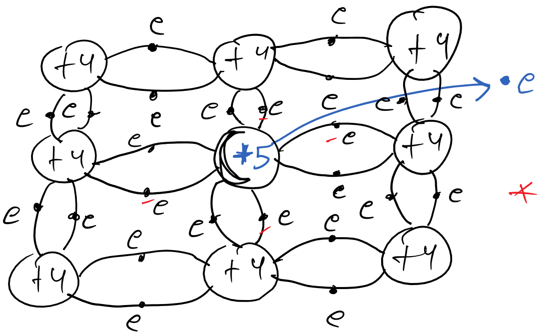


In conductor, most electrons are free.
In semiconductors, few electrons are free.

In semiconductor, both the movement of free electron and hole leads to electric current.

EXTRINSIC SEMICONDUCTOR (Doped)

↳ Performance enhanced semiconductor



•e [One extra electron per atom of the dopant is always free]

n-type

$n_e >> n_h$ → intrinsic

* A large number of free electrons is generated by doping.

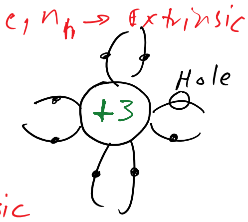
$n_i^2 = n_e n_h$

n_i → Intrinsic Carriers (Holes & Electrons)
n_e, n_h → Extrinsic Carriers.

* Pentavalent Dopands like Arsenic (As), Antimony (Sb), Phosphorus (P).

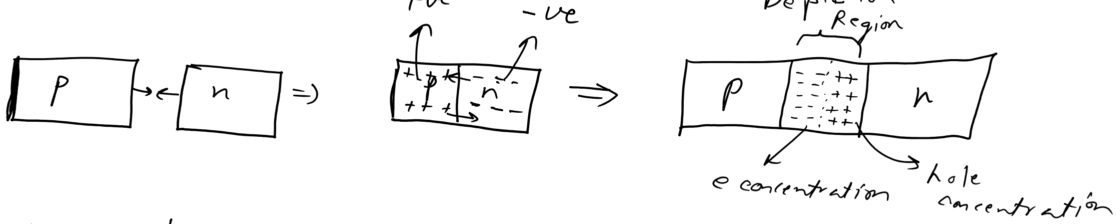
p-type

$n_h >> n_e$
↳ intrinsic

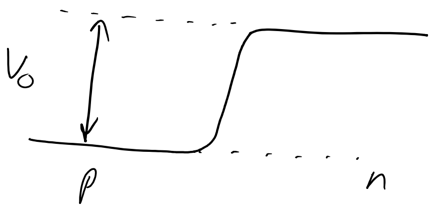


* Trivalent Dopants like Al, Indium (In), Boron (B).

* P-n Junction



For an electron or hole to cross the depletion region, it requires energy to overcone a potential Barrier.

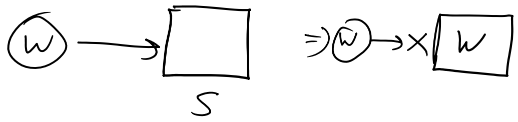


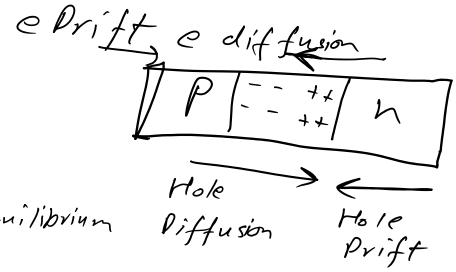
* There are two types of movements of the electrons & holes:
(i) Drift (ii) Diffusion.

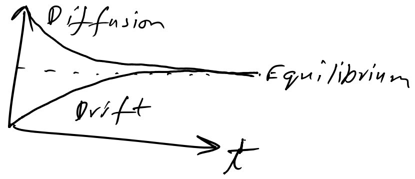
* At the equilibrium stage of a

p n

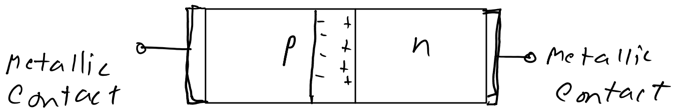
* At the equilibrium stage of a p-n junction, drift equals diffusion.

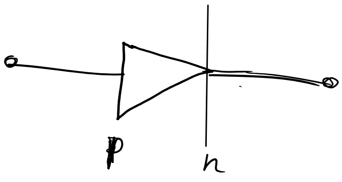






Semiconductor Diode (p-n junction diode)

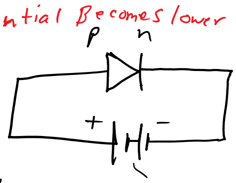




* There are two ways of connecting a diode to a battery

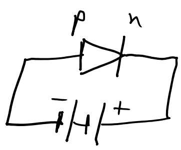
(a) Forward Bias :→ Barrier Potential Becomes lower

▷ Depletion region becomes thinner



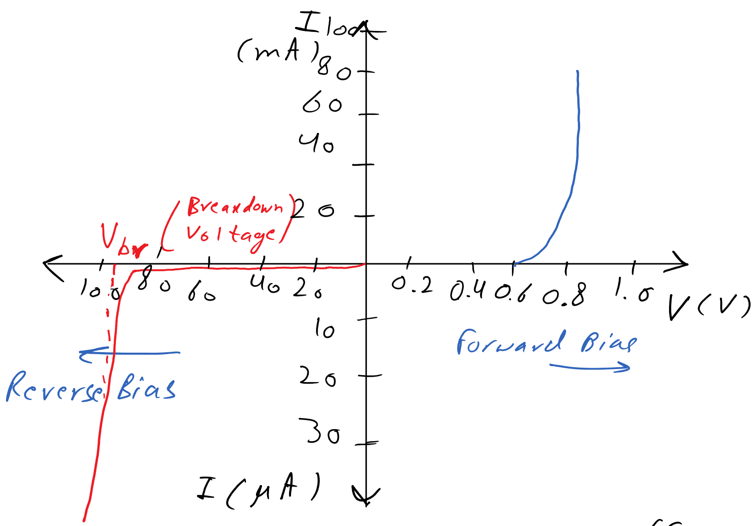
(b) Reverse Bias :→ Barrier Potential Becomes Higher.

▷ Depletion region becomes thicker.



For an ideal diode, there is zero resistance in forward bias & infinite resistance is offered in reverse bias.

V-I characteristics of a diode



Eq 14.4

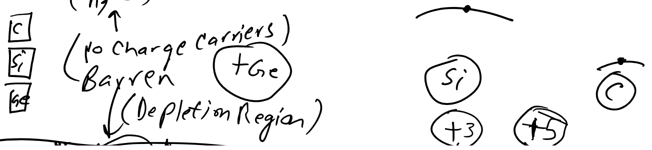
Ex - 14.1 to 14.5

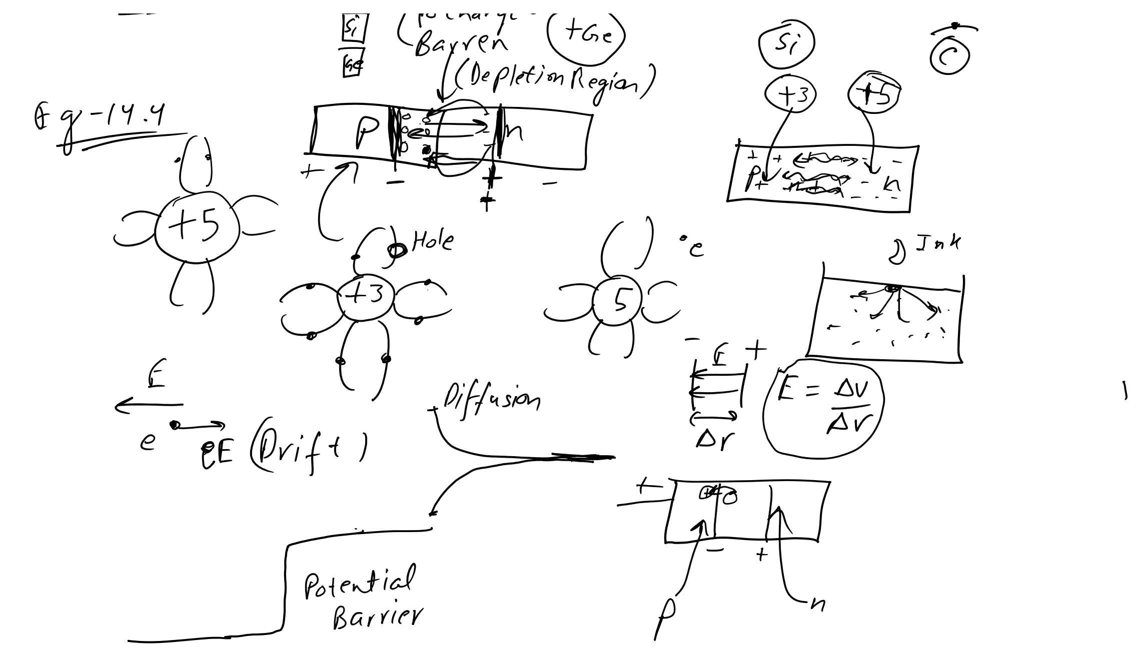
Ex - 14.3

$(E_g)_C > (E_g)_{Si} > (E_g)_{Ge}$

(h, e)

(No charge carriers)
Barren
(Depletion Region)

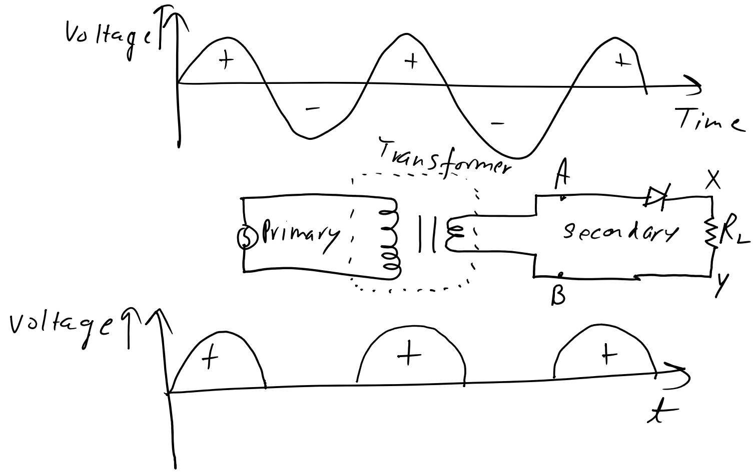




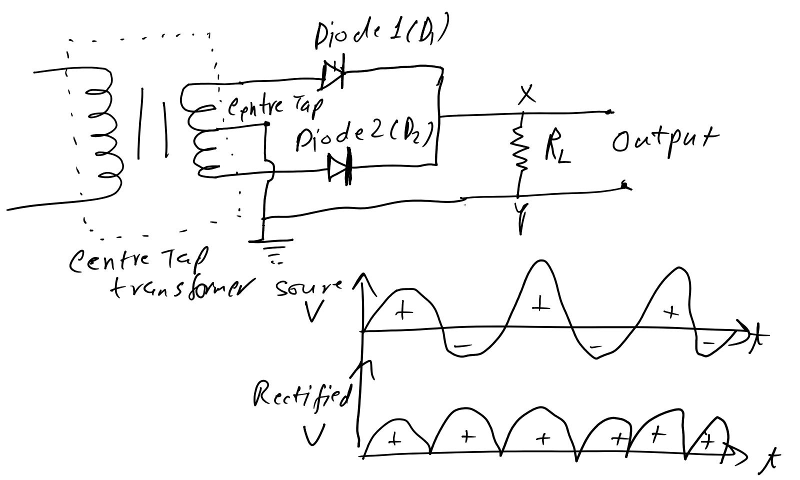
Application of Junction Diode as a Rectifier

→ Converts AC to DC
current

Half-Wave Rectifier



Full Wave Rectifier

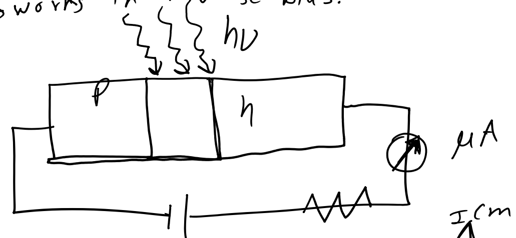


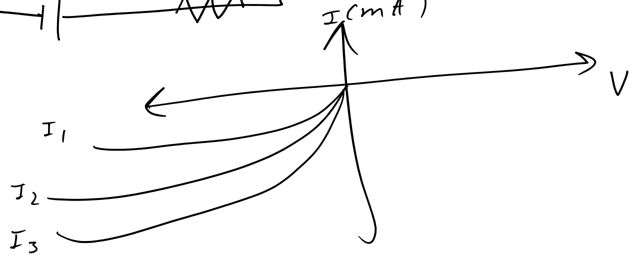
Photodiode

→ To measure the intensity of light. (Light Intensity Sensor)

Photo diode

↳ To measure the intensity of light. (Light Intensity Sensor)
↳ works in reverse bias.





$I_3 > I_2 > I_1$ (Intensities)

Light Emitting LED

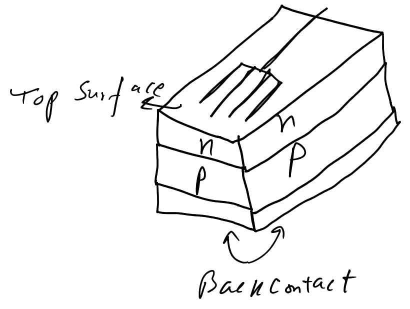
↳ p-n junction diode that emits light in forward bias.

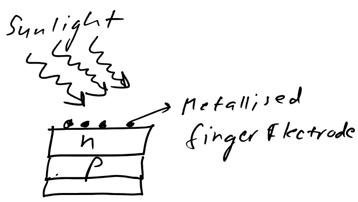
Benefits of LED

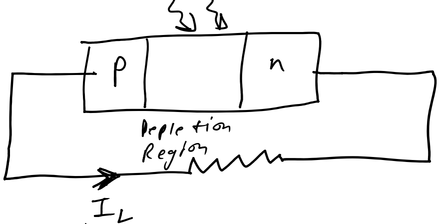
(i) Low operational Voltage & less power
(ii) Fast action and no warm up time required (unlike Sodium Lamps)
(iii) The bandwidth of emitted light is 100 Å to 500 Å or in other words it is nearly monochromatic.
(iv) Long life & ruggedness.
(v) Fast on-off switching capability.

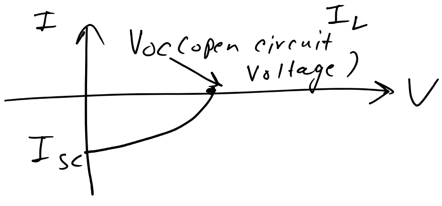
Solar Cell

↳ Generates Voltage (Emf) when light falls on them.









Exercise (1 hour)

- Lens Formula → Practice
- Lens Maker's Formula
- Refraction at a curved Surface

LENS FORMULA

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$$

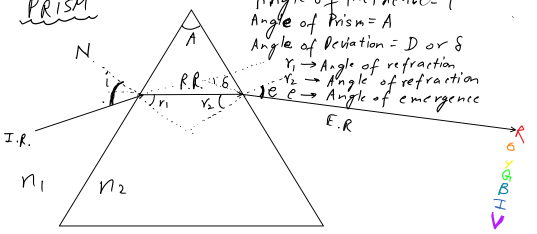
Magnification
$$m = \frac{v}{u} = \frac{h_I}{h_o}$$

Q1:- If an object of height 10 cm is placed to the left of a concave lens at a distance of 30 cm from the lens. What would be the focal length of the lens if height of image is : (a) 20 cm → 28.57 cm
(b) 10 cm → 27.27 cm

Q2:- Where should the object be placed in front of a convex lens of 30 cm (focal length) if the image is twice the size of the object.

$v = 90 cm$
$u = -45 cm$

PRISM



Angle of incidence = i
Angle of Prism = A
Angle of Deviation = D or δ
r_1 → Angle of refraction
r_2 → Angle of refraction
e → Angle of emergence

n_1 → Refractive index of external media
n_2 → Refractive index of the material of the prism.

$$\delta = i + e - A$$

$$n_{21} = \frac{n_2}{n_1} = \frac{\sin[(A+D_m)/2]}{\sin[A/2]}$$

D_m → Angle of minimum deviation.

Q1:- Find the angle of minimum deviation if angle of emergence is 37° and Angle of Prism is 4°.
Hint:- For minimum deviation $i = e$.
Sol:- $\delta = 37° + 37° - 4 = 70°$

Q2:- When a glass prism (n = 1.51) is placed in water (n = 1.33), the angle of minimum deviation is 6°. Find angle of Prism.
[Hint: When θ is small, $\sin\theta \approx \theta$]

$$\left(\frac{1.51}{1.33}\right) = \frac{(A+6)/2}{A/2}$$

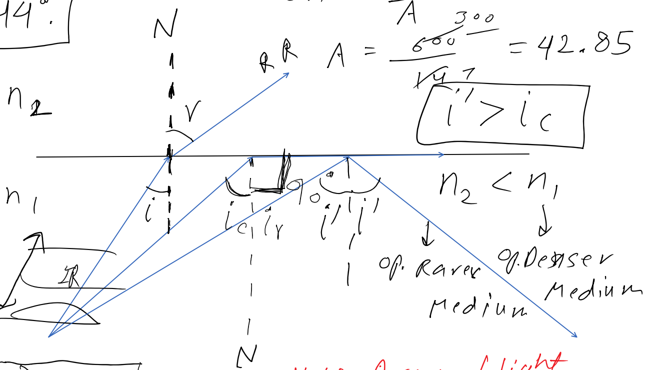
$$(1.14) = 1 + \frac{6}{A}$$

$$0.14 = \frac{6}{A}$$

$$A = \frac{600}{14} = \frac{300}{7} = 42.85$$

$$A = 44°.$$

Total internal Reflection



$i' > i_c$

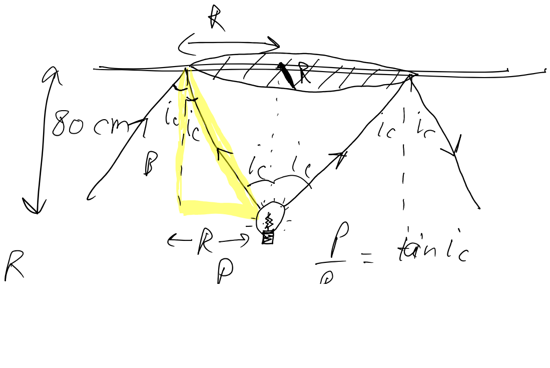
$n_2 < n_1$
op. Rarer Medium
op. Denser Medium

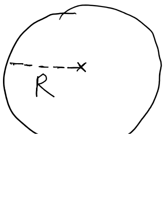
Note:- A ray of light moves away from the normal when it travels from optically denser to an optically rarer medium.

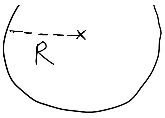
i_c = Critical Angle
when $i = i_c \Rightarrow r = 90°$.
when $i > i_c$, then $i = r$ (i')

$$\sin i_c = \frac{n_2}{n_1} = n_{21}$$

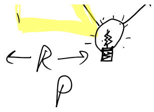
Ex - 9.5 :→
Pg 344
NCERT P-II







$\frac{R}{16}$



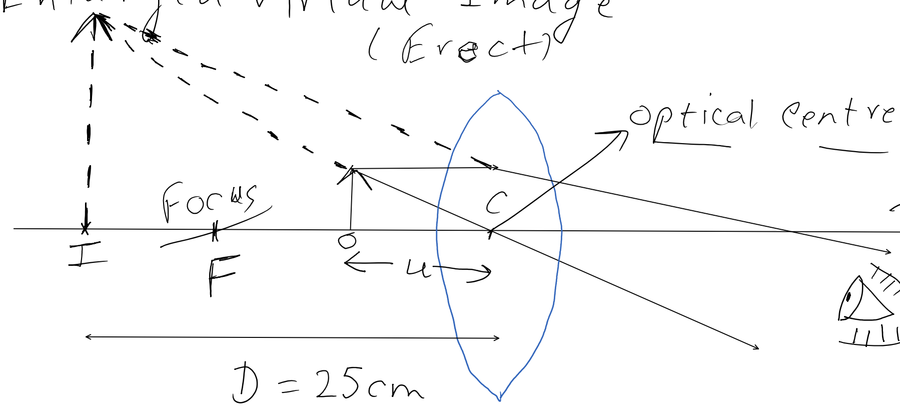
$\frac{P}{R} = \tan i_c$

Optical Instruments

(i) Simple Microscope (Magnifying Glass)

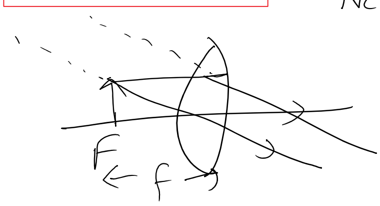
$m = \frac{v}{u} = \frac{h_I}{h_o}$ for

Enlarged Virtual Image (Erect)

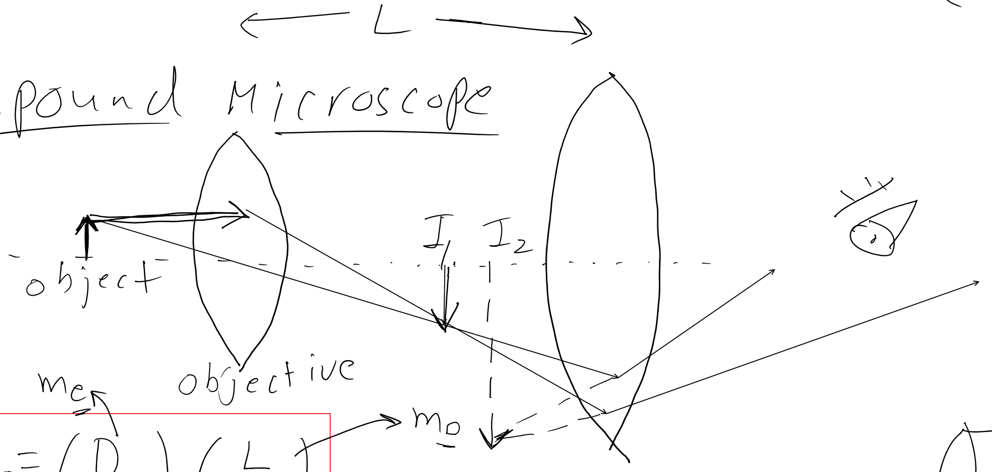


$m_\infty = \frac{D}{f}$ → Image at ∞

$m_D = 1 + \frac{D}{f}$ → Image at Near Point (+



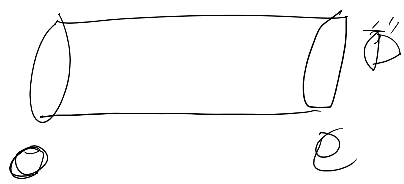
(ii) Compound Microscope



$m = m_1$…

$m_\infty = \left(\frac{D}{f_e}\right)\left(\frac{L}{f_o}\right)$ (m_e, m_o)

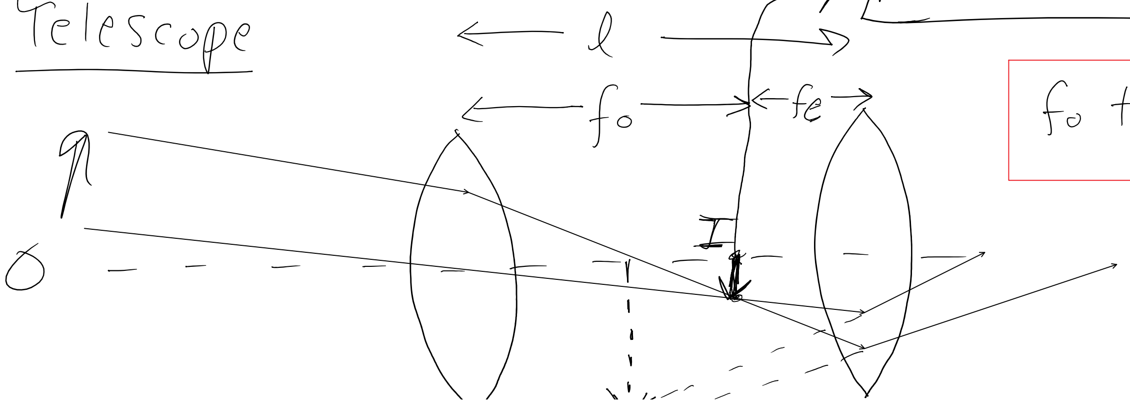
$m_D = \left(1 + \frac{D}{f_e}\right)\left(\frac{L}{f_o}\right)$ (m_e, m_o)



Telescope

Mutual Focus

$f_o + f_e = l$



$m = \frac{f_o}{f_e}$

① Find the focal length of a magnifying glass of m = 3 with object placed at the focus.

...med

... Infinity

...ormed

...at

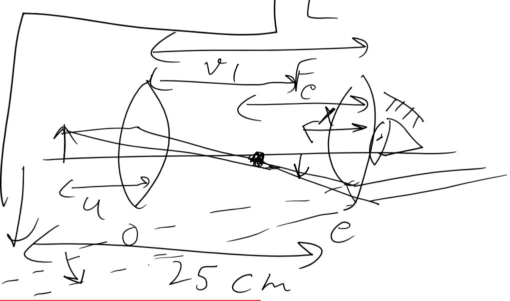
...oint (D)

...25 cm)

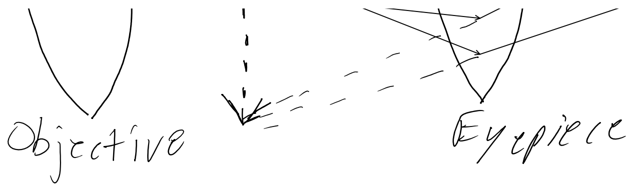
comfortably → clear image.

$\frac{25}{f} = 3$

$f = \frac{25}{3}$



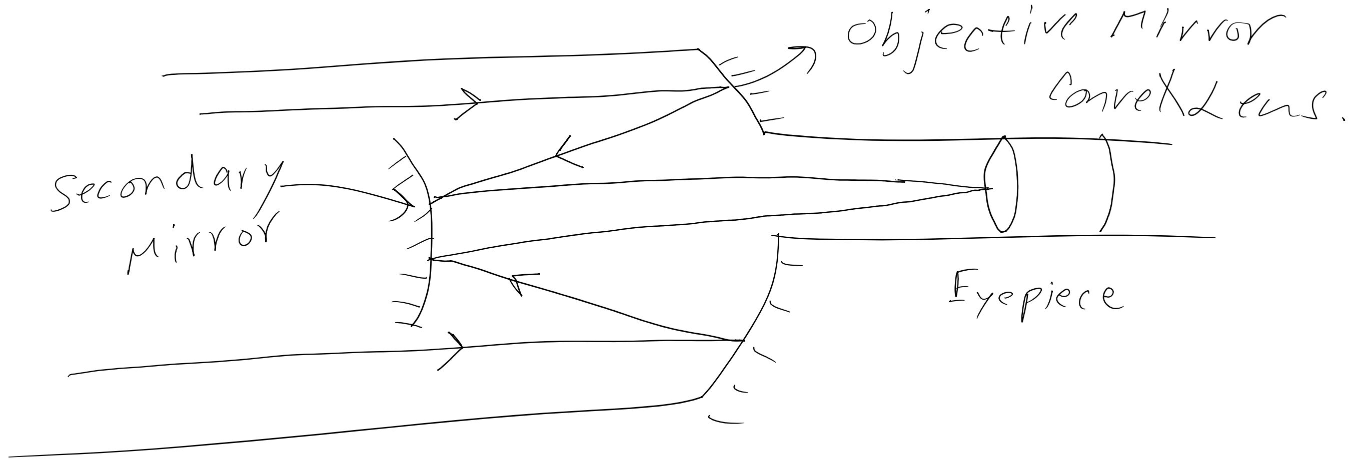
$M_1 M_2 M_3 \ldots$



fe

Galilean Telescope OR Reflecting Telescope OR (CAS

TELESCOPE



* Cassegrain Telescope removes Chromatic Aberration
(Multicolored Blurred Imag

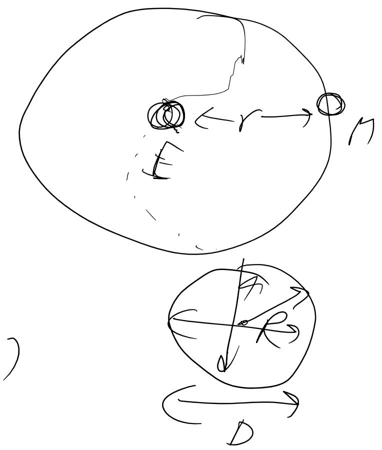
Exercise

9.5 A small bulb is placed at the bott
containing water to a depth of
what is the area of the surf
through which light from the bu
out? Refractive index of water
(Consider the bulb to be a point

Sol:- ??

SSEGRAIN

> Inventor



es)

om of a tank

80cm.

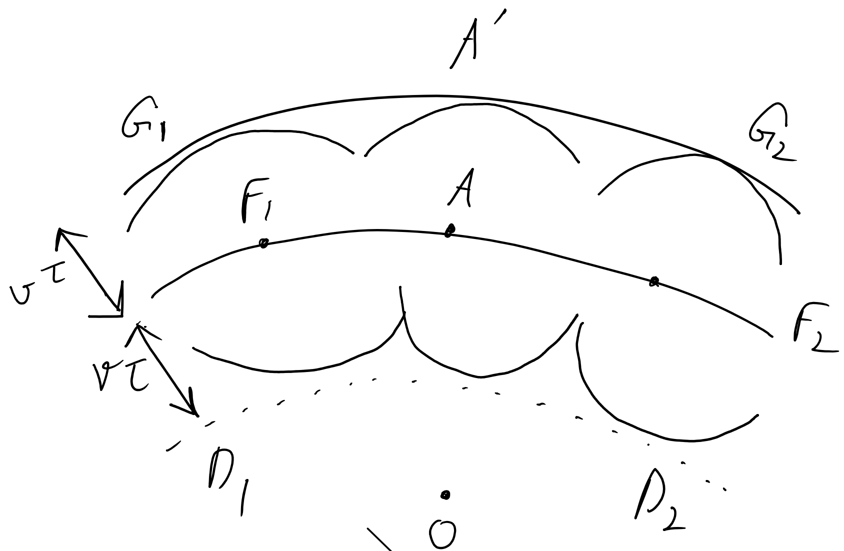
ace of water

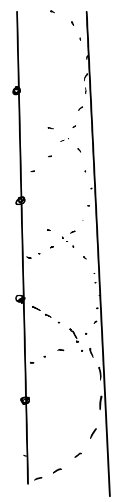
lb can emerge

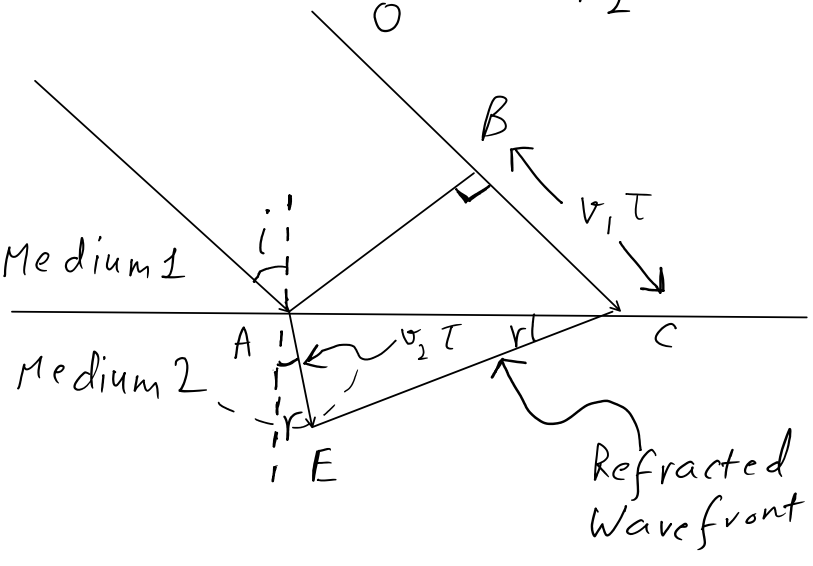
is 1.33.

source)

Huygen's Principle







$$\sin i = \frac{BC}{AC} = \frac{v_1 \tau}{AC}$$

$$\sin r = \frac{AE}{AC} = \frac{v_2 \tau}{AC}$$

$$\frac{\sin i}{\sin r} = \frac{v_1}{v_2}$$

$$n_1 = \frac{c}{v_1}$$

$$n_2 = \frac{c}{v_2}$$

$$\frac{\lambda_1}{\lambda_2} = \frac{BC}{AE} = \frac{v_1}{v_2}$$

$$\boxed{\frac{v_1}{\lambda_1} = \frac{v_2}{\lambda_2}}$$