# CLASS 12 PHYSICS CHEAT SHEET

# RAY OPTICS
# CHEAT SHEET

Reflection of Light: $i = r$, Magnification $m = \frac{h_i}{h_o} = -\frac{v}{u}$

→ Convex mirror $+f, m < 1$ and negative
→ concave Mirror -f, $m > 1, < 1, = 1$ both + & −

− real inverted.
+ virtual errect

$m > 1$ (enlarged)
m < 1 (small)

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Refraction of Light: $\mu = \frac{\sin i}{\sin r}, \mu_{21} = \frac{\mu_2}{\mu_1} = \frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2} = \frac{1}{\mu_{12}}$

Total Internal Reflection (i) Denser → Rarer  ii) $i > i_c$  iii) $\sin \hat{i}_c = \left(\frac{1}{\mu_d}\right)$

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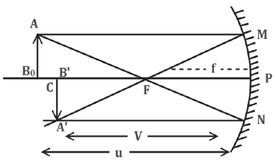
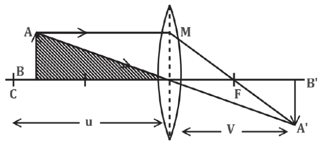
### Mirror Formula:-




Object $AB$ image $A'B'$
$\triangle AFB \approx \triangle PFN$
$\frac{AB}{PN} = \frac{AB}{A'B'} = \frac{FB}{PF} = \frac{u-f}{f}$ ... (i)
$\triangle A'B'F \approx \triangle MFP$
$\frac{MP}{A'B'} = \frac{AB}{A'B'} = \frac{PF}{FB'} = \frac{f}{V-f}$ ... (ii)
from eq. (i) and (ii)
$\frac{u-f}{f} = \frac{f}{v-f}$
By sign convention $u, v, f$ are -ve,
$f^2 = (u-f)(v-f)$
$f^2 = uv - uf - fv + f^2$
$uv = uf + vf$
Dividing by uvf
$\frac{uv}{uvf} = \frac{uf}{uvf} + \frac{vf}{uvf}$
$\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$
$m = h_i/h_o = -v/u$

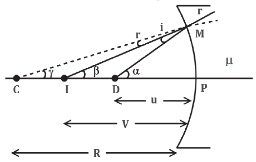
### Thin Lens Formula:-




$\triangle ABP \approx \triangle A'B'P$
$\frac{AB}{A'B'} = \frac{PB}{PB'} = \frac{u}{v}$ ... (i)
$\triangle MPF \approx \triangle A'B'f$
$\frac{PM}{A'B'} = \frac{PF}{FB'} = \frac{f}{v-f}$
$\frac{AB}{A'B'} = \frac{v}{v-f}$ ... (ii)
From eq (i) and (ii)
$\frac{f}{v-f} =$ [illegible]
Since $u = -ve$ sign convention
$vf = (-u)v - (-u)f$
$vf = -uv + uf$
$uv = uf - vf$
Dividing by uvf
$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$

### REFRACTION THROUGH SPHERICAL SURFACE

Surface Assumpsion:-
1) Small Aperture
2) Point Size object




By Snell's Law (since i & r are very small)
$\mu = \frac{\sin i}{\sin r} = \frac{i}{r}$
$i = \mu r$
$\Delta COM$
$\alpha = i + \gamma \therefore i = \alpha - \gamma$
$\Delta CIM$
$\beta = r + \gamma \therefore r = \beta - \gamma$
$\alpha - \gamma = \mu(\beta - \gamma)$
$\frac{PM}{-u} - \frac{PM}{-R} = \mu\left(\frac{PM}{-v} - \frac{PM}{-R}\right)$
$\frac{1}{u} - \frac{1}{R} = \frac{\mu}{v} - \frac{\mu}{R}$
$\frac{\mu}{v} - \frac{1}{u} = \frac{\mu}{R} - \frac{1}{R}$
$\frac{\mu}{v} - \frac{1}{u} = \frac{(\mu - 1)}{R.}$

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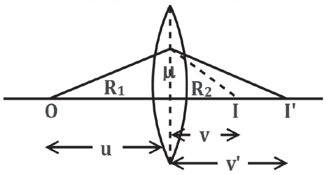
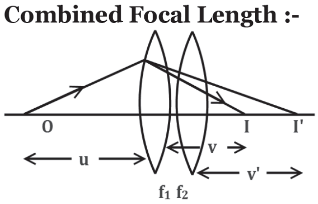
### Lens Maker Formula:-




By Refraction through first surface
$\frac{\mu}{v'} - \frac{1}{u} = \frac{\mu - 1}{R_1}$ ...(i)
I' acts as an object for second surface so that final image is formed at $I$, so for second surface.
$\frac{1/\mu}{v} - \frac{1}{v'} = \frac{1/u - 1}{R_2}$
$\frac{1}{\mu v} - \frac{1}{v'} = \frac{1-\mu}{\mu R_2}$
Multiplying by $\mu$
$\frac{1}{v} - \frac{\mu}{v'} = \frac{1-\mu}{R_2}$ ...(ii)
adding eq (i) & (ii)
$\frac{1}{v} - \frac{1}{u} = (\mu - 1)(1/R_1 - 1/R_2)$
$\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

### Combined Focal Length :-




First lens forms image I′ of O
$\frac{1}{f_1} = \frac{1}{v'} - \frac{1}{u}$ ... (i)
I′ acts as object for second lens and final image is formed at I, so for second lens.
$\frac{1}{f_2} = \frac{1}{v} - \frac{1}{v'}$ ... (ii)
Adding eq (i) & (ii)
$\frac{1}{v} - \frac{1}{u} = \frac{1}{f_1} + \frac{1}{f_2}$

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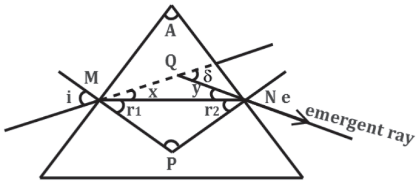
### Power of Lens :-

$P = \frac{1}{f(m)} = \frac{100}{f(cm)}$ Diopter

ARNI

**Refraction Through a Prism :-**

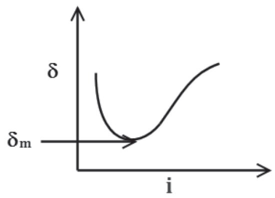



$i = r_1 + x\}$ vertically
$e = r_2 + y\}$ opposite Angles.
$i + e = (r_1 + r_2) + (x + y)$ ... (i)
$\delta = x + y$
exterior ∠ is equal to sum of interior angles.
$\angle P = 180 - (r_1 + r_2)$
In quadilateral AMPN.
$\angle A + 90° + \angle P + 90° = 360°$
$A + 90° + 180 - (r_1 + r_2) + 90 = 360$
$A = r_1 + r_2$ ... (ii)
$i + e = A + \delta$
At minimum deviation $\delta_m$
i.e, $r_1 = r_2 = r$
$2i = A + \delta_m$
$\therefore i = \dfrac{(A + \delta_m)}{2}$ ... (iii)
$A = 2r \therefore r = (A/2)$ ... (iv)
By Snells Law

$$\mu = \frac{\sin\ i}{\sin\ r}$$

$$\mu = \frac{\sin\left(\frac{A + \delta_m}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$

For thin prism




$$\mu = \frac{\frac{A + \delta_m}{2}}{\frac{A}{2}}$$

$\boldsymbol{\delta m = (u - 1)A}$
A-Prism Angle
$\mu$ = Refractive Index.

**Angular Dispersion:** $\theta = \delta_v - \delta_R = (\mu_v - \mu_R)A$
**Dispersive Power:** $\omega = \frac{\theta}{\delta y} = \frac{\delta_v - \delta_R}{\delta y} = \frac{(\mu_v - \mu_R)A}{(\mu_y - 1)A} = \omega = \frac{(\mu_V - \mu_R)}{(\mu_y - 1)}$

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**Scattering of Light:** $\delta \propto 1/\lambda^4$ (RAYLEIGH LAW)

- Danger signals Red.
- Sky appears blue.
- Reddish appearance of sunrise, sunset.

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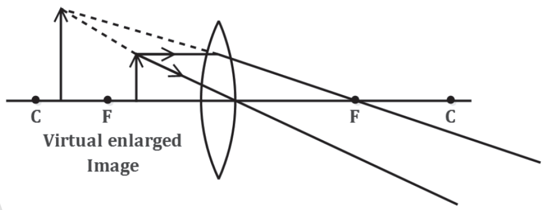
## OPTICAL INSTRUMENTS

**Simple Microscope:**
Convex lens of low focal length and high power.

**i) Image at D. object placed b/w focus and lens.**

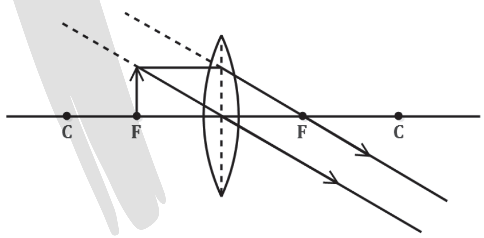



Magnifying power.

$\boldsymbol{m = 1 + \frac{D}{f_e}}$

$m = \frac{\beta}{\alpha} = \frac{\textit{Angle made by image}}{\textit{angle made by object}}$

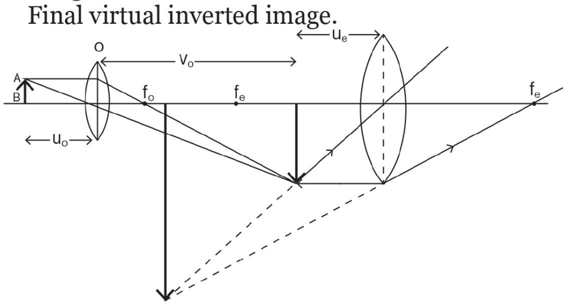
**ii) Image at ∞**




Object placed on focus.
Magnifying power $m = \frac{D}{f}$

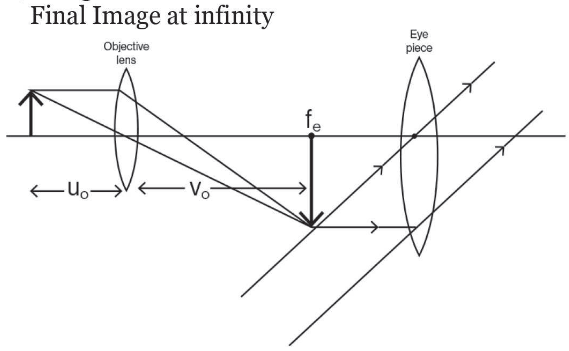
**Compound Microscope:** Objective – (convex lens of low focal length and small aperture).
Eye lens – (convex lens of high focal length and large aperture).

i) Image at D.
Final virtual inverted image.




$m = m_0 \times me = \frac{v_0}{-u_0}\left(1 + \frac{D}{f_e}\right) \approx \frac{1}{f_e}\left(1 + \frac{D}{f_e}\right)$

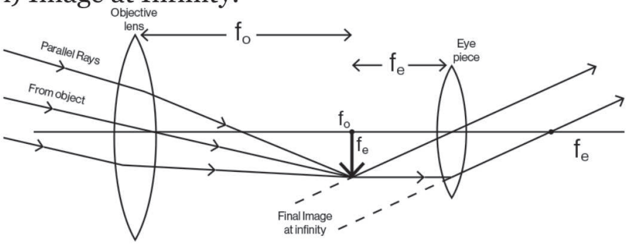
ii) Image at ∞
Final Image at infinity




$m = -\frac{v_0}{u_0}\left(\frac{D}{f_e}\right) \approx \frac{L}{f_0} \cdot \frac{D}{f_e}$
Length of tube $L = v_0 + f_e$

**Astronomical Telescope:** Objective – (convex lens of high focal length and large aperture).
Eye lens – (convex lens of low focal length and small aperture).

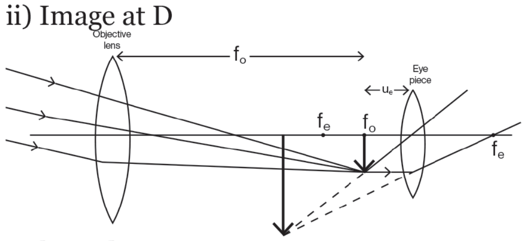
i) Image at Infinity.




$m = \frac{f_0}{f_e}$

$L = f_0 + f_e$ (Length of tube)

ii) Image at D




Enlarged Image

$m = \frac{f_0}{f_e}\left(1 + \frac{f_e}{D}\right)$

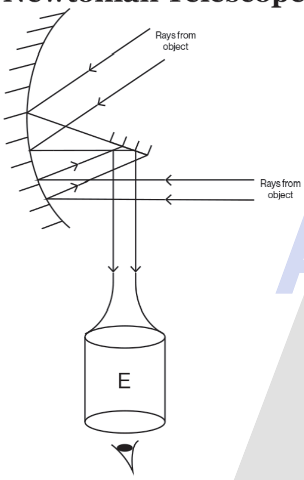
$R.P = \frac{D}{1.22\lambda}$

D-Diameter of objective

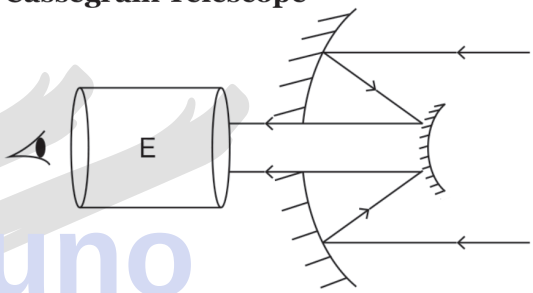
Length of tube $L = f_0 + u_e$

**Reflecting Telescope:** Concave mirror acts as an onjective.

**Newtonian Telescope**




**Cassegrain Telescope**




ADVANTAGES:
1) Bright Image is formed.
2) Image free from Chromatic abberation.



**Resolving Power:** The ability of optical instrument to form distinct image of two object situated close to each other.

**Resolving power of microscope**

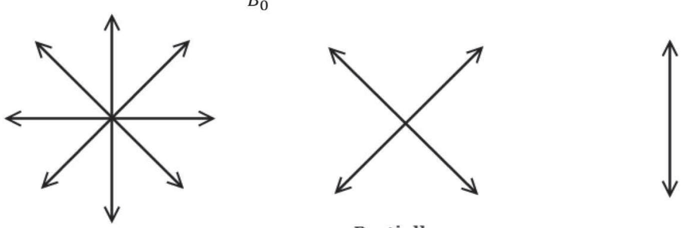
$\left[(R.P)_m = \frac{2\mu \sin\theta}{\lambda}\right]$

$R.P \propto \frac{1}{limit\ of\ resolution}$

**Resolving power of Telescope**

$\left[(R.P)_T = \frac{D}{1.22\lambda}\right]$

**Polarisation:** $C = \frac{E_0}{B_0}$



unpolarised

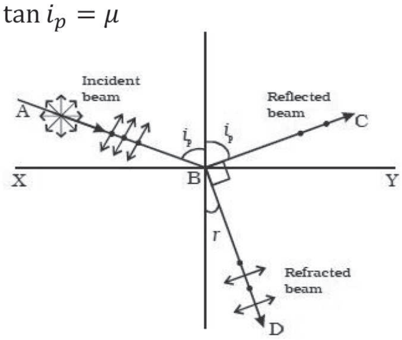
Partially Polarised

Linear polarised

**Malus Law:** $I_\theta = I_0 \cos^2\theta$

**Brewster's Law:**

$\tan i_p = \mu$

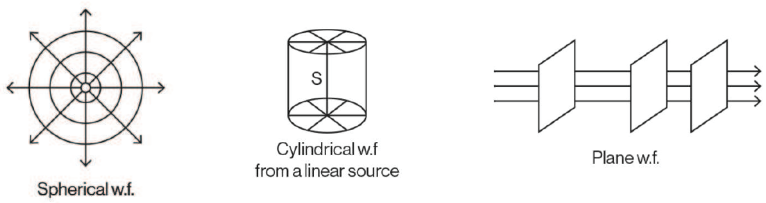


# WAVE OPTICS
# CHEAT SHEET

A wavelet is the point of disturbance due to propagation of light.

A wavefront is the locus of points having the same phase of oscillation.

A line perpendicular to a wavefront is called a 'ray'.

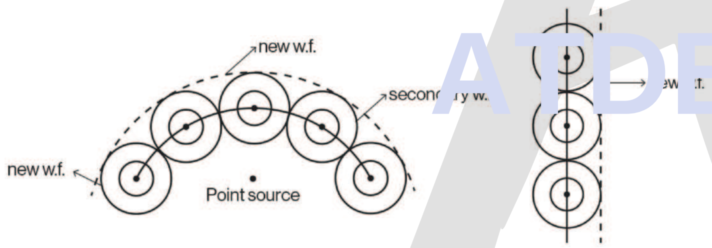



## HUYGEN'S PRINCIPLE

For the shape of wavefront at any particular instance. The two postulate are-

I. Each point on primary wave's acts as a source of secondary wavefront which travel in all direction with speed of light.

II. The forward envelope are common tangent of secondary wavefront give shape of new wavefronts.




## INTERFERENCE OF LIGHT

Variation of intensity of light due to overlapping of two light waves.

### CONSTRUCTIVE

Resultant increase and bright light is formed.

Path diff.:- $\Delta x = 0\ , \lambda, 2\lambda, \ldots\ldots, 3\lambda$

Phase diff.:- $\Delta\phi = 0\ , 2\pi, 4\pi, 6\pi, \ldots\ldots, 2n\pi$

Destructive:-

Path diff.:- $\Delta x = \frac{\lambda}{2}, \frac{3\lambda}{2}, \ldots\ldots, (2n-1)\frac{\lambda}{2}$

Phase diff.:- $\Delta\phi = \pi\ , 3\pi, 5\pi, \ldots\ldots, (2n-1)\pi$

### DESTRUCTIVE

Resultant is minimum.

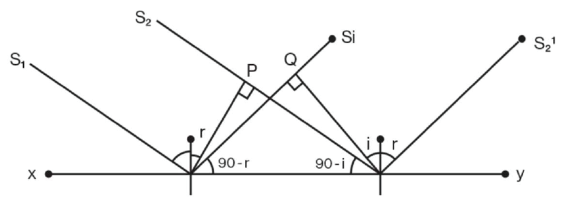
$$\Delta\phi = \frac{2\pi}{\lambda} \times \Delta x$$

### Young's double slit Experiment (YDSE)

A monochromatic light beam is incident in double slit the pattern obtain on screen consist of alternate bright and dark bands called fringes.



## Reflection by Huygen's Principle




$\Delta MPN$ and $\Delta MQN$ , MN = MN common side

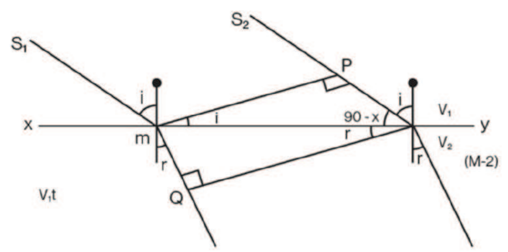
$\angle P = \angle Q = 90^{o}, PN = MQ$ (dist. covered by light in same time)

$\Delta MPN \approx \Delta MQN$ (by SAS)

$90 - i = 90 - \gamma$

$\boxed{i = \gamma}$

## Refraction by Huygen's Principle

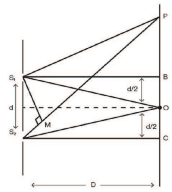



$PN = V_1 t$

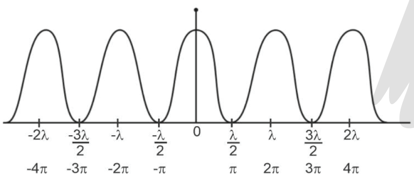
$MQ = V_2 t$

$$\mu_0 = \frac{\sin i}{\sin\gamma} = \frac{PN / MN}{MQ / MN} = \frac{PN}{PQ}$$

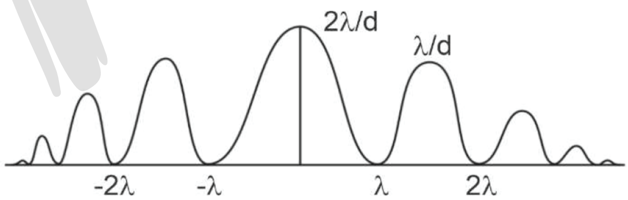
$$\boxed{\mu_0 = \frac{v_1 t}{v_2 t} = \frac{v_1}{v_2}}$$

| Expression for Interference Pattern | Expression for fringe width |
|---|---|
| Let, two interference wave<br>$y_1 = a_1 \sin\omega t$<br>$y_2 = a_2(\sin(\omega t + \phi))$ [$\because \phi =$ phase diff.]<br>by P. of Superposition-<br>$y = y_1 + y_2$<br>$y = a_1 \sin\omega t + a_2 \sin(\omega t + \phi)$<br>$y = a_1 \sin\omega t + a_2 \sin\omega t \cos\phi + a_2 \cos\omega t \sin\phi$<br>$y = \sin\omega t (a_1 + a_2 \cos\phi) + a_2 \cos\omega t \sin\phi$<br>$y = R \sin\omega t \cos\theta + \cos\omega t \; R \sin\theta$<br>$\left\{ \begin{matrix} a_1 + a_2\cos\phi = R\cos\theta \\ a_2 \sin\phi = R\sin\theta \end{matrix} \right\}$<br>$y = R\sin(\omega t + \theta) \cdot a_1 + a_2\cos\phi + a_2 \sin\phi = R\cos\theta + R\sin\theta$<br>Square both side<br>$a_1^2 + a_2^2(\cos^2\phi + a_2^2 \sin^2\phi = R^2\cos^2\theta + R^2\sin^2\theta$<br>$a_1^2 + a_2^2(\cos^2\phi + \sin^2\phi) = R^2(\sin^2\theta + \cos^2\theta) + 2a_1a_2\cos\phi$<br>$a_1^2 + a_2^2 + 2a_1a_2\cos\phi = R^2$<br>$\boxed{R = \sqrt{a_1^2 + a_2^2 + 2a_1a_2\cos\phi}}$<br>$R_{max} = (a_1 + a_2) \quad \theta = 0°$<br>$R_{min} = (a_1 - a_2) \quad \theta = 180°$<br>$\boxed{I \alpha a^2 \alpha \omega}$ | <br>$S_2M = S_2P - S_1P$ from $\Delta S_2PC$<br>$S_2P^2 = D^2 + (x + d/2)^2$ from $\Delta S_1BP_1$<br>$S_1P^2 = D^2 + (x - d/2)^2$<br>$\boxed{S_2P^2 = S_1P^2 = 2xd}$<br>$(S_2P - S_1P)(S_2P + S_1P) = 2xd$<br>$(S_2P - S_1P)(D + D) = 2xd$<br>$(S_2P - S_1P)(D + D) = 2xd$<br>$S_2P - S_1P = \frac{2xd}{2D}$<br>From bright fringe for bath difference,<br>$S_2P - S_1P = n\lambda$<br>$\frac{xd}{D} = n\lambda$<br>$x_n = \frac{nD\lambda}{d}$<br>$\boxed{x = \frac{D\lambda}{d}}$<br>$\beta = x_{n+1} - x_n$<br>$\beta = (2(n+1) - 1)\frac{\lambda D}{d} - \frac{(2n-1)\lambda D}{2d}$<br>$\boxed{\beta = \frac{\lambda D}{d}}$<br>For destructive interference:<br>$\frac{xd}{D} = (2n - 1)\frac{\lambda}{2}$<br>$\boxed{x_n = (2n-1)\frac{\lambda D}{2d}}$<br>$\beta = x_{n+1} - x_n$<br>$\beta = (2(n+1) - 1)\frac{\lambda D}{2[illegible]} - \frac{(2n-1)\lambda D}{[illegible]}$<br>$\boxed{\beta = [illegible]}$ |

Interference pattern the intensity of all bright band is equal.




## Intensity distribution curve




## Coherent Source

The two light source behave like coherent source if they belong to same parent source.

## Linear width of central maxima

$$\left[ \text{angle} = \frac{\text{arc}}{\text{raclivs}} \right], \quad \beta_0 = \theta \times D$$

$$\boxed{\beta_0 = \frac{\lambda D}{d}}$$

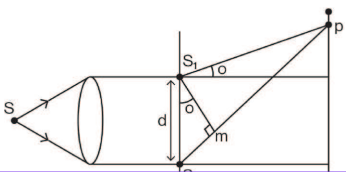
## Diffraction

It is bending of light at sharp corners or edges.

## Single slit diffraction

dark band or minima $d \sin\theta = n\lambda$

maxima $d\sin\theta = \frac{(2n+1)}{2}\lambda$



# DUAL NATURE OF MATTER AND RADIATION CHEAT SHEET

## Photoelectric emission

The emission of electron due to action of light of suitable energy is called photoelectric emission. The $e^-$ emitted are called photoelectrons.

## Properties of photon

(a) Photon is a bundle of energy
(b) Photon travel with speed of light (c) Rest mass of photon is zero.
(d) Momentum of photon is $p = E/c$
(e) Energy of a photon : E = $h\nu$ or $E = \frac{hc}{\lambda}$

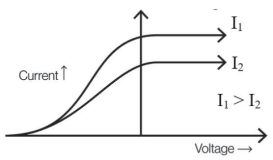
## Laws of photoelectric emission

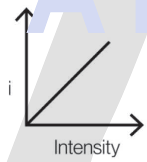
(a) Minimum energy required called threshold energy or work function. The frequency corresponding to threshold energy called threshold frequency.
E = $\phi$ = work function = $h\nu_0$ Where $\nu_0$ is threshold frequency.

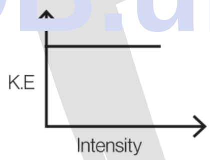
(b) Every photon interact with a single electron.

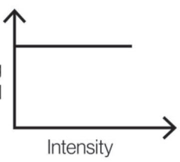
(c) Increase in energy of incident photon, the kinetic energy of $e^-$ emitted increase.

## Effect of Intensity: (Assuming frequency constant)

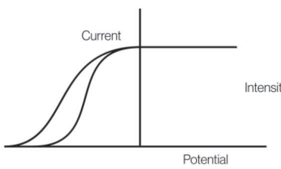


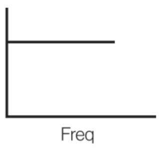


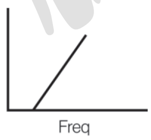


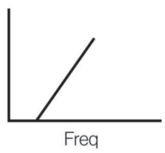



## Effect of Frequency: (Assuming Number of photons falling per second is constant)










## Determination of Plank's Constant:

frequency from Einstein Photoelectric equation

$$h\nu = h\nu_0 + K.E$$
$$eV_o = K.E$$
$$h\nu = h\nu_o + eV_o$$

## Einstein Photoelectric Equation:

Photoelectric effect was explained using quantum theory by Einstein.

$$E = \phi + K.E$$
$$h\nu = h\nu_o + \frac{1}{2}mv^2$$
$$h\nu - h\nu_o = \frac{1}{2}mv^2$$
$$h(\nu - \nu_o) = \frac{1}{2}mv^2$$

In terms of wavelength

$$h\left(\frac{c}{\lambda} - \frac{c}{\lambda_o}\right) = \frac{1}{2}mv^2$$
$$hc\left(\frac{1}{\lambda} - \frac{1}{\lambda_o}\right) = \frac{1}{2}mv^2$$

# DUAL NATURE OF MATTER

## De-Broglie Hypothesis

According to de broglie a wave is associated with every moving particle. This wave is called matter wave and its wavelength is known as debroglie wavelength.

### Expression for $\lambda$

By particle nature,

$E = mc^2$

By wave nature,

$E = h\nu$

Equation both the energy

$mc^2 = h\nu$

$$m = \frac{hc}{\lambda c^2}$$

$$m = \frac{h}{\lambda c}$$

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

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

### In term of energy

$p = mv$

$$E = \frac{1}{2}mv^2$$

$2E = mv^2$

$2mE = m^2v^2$

$2mE = p^2$

$p = \sqrt{2mE}$

Therefore,

$$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mE}}$$

(p = momentum)

### In term of charge & potential

$Energy = qV$

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

### For electron

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

$$\lambda = \frac{12.3A}{\sqrt{V}}$$

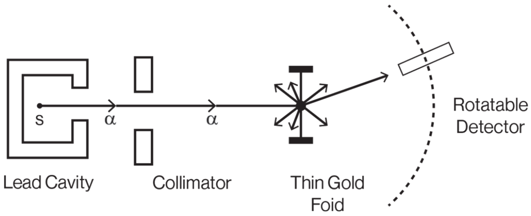
temp:-

$$\lambda = \frac{h}{\sqrt{3mk_BT}} \qquad E = \frac{3}{2}k_BT$$

$k_B$ = Boltzmann constant

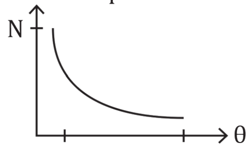
# ATOMS
# CHEAT SHEET

### Rutherford $\alpha$- particle scattering Exp:-




### Observations

i) Most of the $\alpha$ particle passed undeviated.
ii) Few $\alpha$ particle scattered at angle θ.




$$N \propto \frac{1}{\sin^4\left(\frac{\theta}{2}\right)}$$

iii) Very few retraces their path.

### RUTHERFORD'S MODEL OF ATOM

i) Most of the part of atom is empty .
ii) The central core is (+) very charged called nucleus ($10^{-15}$m).
iii) $e^-$ revolves around the nucleus

### DISTANCE OF CLOSEST APPROACH

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

$$\therefore r_0 = \frac{2Ze^2}{4\pi\varepsilon_0\left(\frac{1}{2}mv^2\right)}$$

### IMPACT PARAMETER

It is perpendicular distance of the initial velocity vector of the $\alpha$-particles from centre of nucleus when α-particle is far away from atom.

- smaller is b, larger is angle of scattering $\theta$.
- $\cot\frac{\theta}{2} = \frac{2b}{r_0}$
- for $\theta = 180°$ (rebounds) , b = 0

### BOHR'S MODEL (1913)

i) The $e^-$ can exist in certain orbit without radiating energy.

$$\frac{mv^2}{r} = \frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{r^2}$$ n = 1, 2, 3, .......... Quantum No.

ii) Only those orbit are allowed for which the angular momentum (mvr) is integral multiple of h/2π.

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

iii) Electrons revolving in their stationary orbit do not radiate energy (non radiation orbits or Bohr's orbits)

iv) If the $e^-$ goes from higher orbit of enregy $E_2$ to other lower orbit of energy $E_1$ then a photon of energy $h\nu = E_2 - E_1$

**Radius of n^th Bohr Orbit For Hydrogen like atom having atomic number Z**

$$: r_n = \frac{\varepsilon_0 n^2 h^2}{\pi m e^2 Z} = 0.531\frac{n^2}{Z}\ A°$$

**like atom having atomic number Z**

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

Putting value of $r_n$ from previous

$$v = \frac{Ze^2}{2\varepsilon_0 nh}$$

$$= 2.18 \times 10^6\frac{Z}{n}\ m/s$$

### ENERGY OF BOHR ORBITS

$$E = KE + PE = \frac{1}{2}mv^2 + \frac{Ze(-e)}{4\pi\varepsilon_0 r}$$

$$= \frac{1}{2}\times\frac{Ze^2}{4\pi\varepsilon_0 r} - \frac{Ze^2}{4\pi\varepsilon_0 r} \qquad \therefore \left(\frac{mv^2}{r} = \frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{r}\right)$$

$$E_n = \frac{-Ze^2}{8\pi\varepsilon_0 r_n}$$

For H atom $E_n = \frac{-e^2}{8\pi E_0 r_n} = \frac{-13.6}{n^2}eV$

For H- like atom $E_n = \frac{-e^2}{8\pi E_0 r_n} = -13.6\frac{Z^2}{n^2}eV$

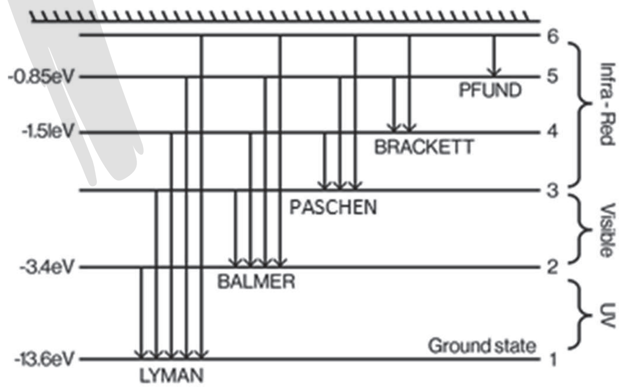
### HYDROGEN SPECTRUM

Hydrogen spectrum consist of group of radiation emitted by a H-atom whose wavelength is given as

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

Rydberg Constant $= 1.09 \times 10^7\ m^{-1}$

$$R = \frac{me^4}{8\varepsilon_0^2 h^3 c}$$




### LYMAN SERIES

When Electron jump from higher orbit to first orbit.

$n_1 = 1,\ n_2 = 2, 3, 4 \ldots\ldots$

$$v_1 = R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right) = \frac{3}{4}R$$

$$v_2 = R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right) = \frac{8}{9}R$$

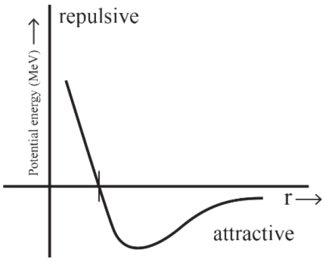
Ultra Voilet Region

**Balmer:** When Electron jump from higher orbit to second orbit. (Wavelength corresponding to balmers series lies in Visible Region)

# NUCLEI
# CHEAT SHEET

Nucleons = Protons + neutrons
A = Z + N
Mass = Atomic No. + No. of Neutrons.

$^A_ZX$ or $_ZX^A$




**Nuclear Force:**
- Strong
- Short range
- Spin dependent
- Charge independent

Nuclear volume ∝ Mass No.
$\frac{4}{3}\pi R^3 \propto A$
or $R = R_0 A^{1/3}$
$R_0 = 1.2 \times 10^{-15}$ m
1 Fermi = $10^{-15}$ m.

1 amu = $\frac{1}{12}$ mass of ($^{12}_6C$) atom $= 1.66 \times 10^{-27}$ kg
Electron Volt (eV) – unit of energy
1eV = $1.6 \times 10^{-19}$ J.
1 amu = 931 MeV

## NUCLEAR DENSITY :

Independent of mass no. and same for all elements
$$\rho = \frac{m.A}{\frac{4}{3}\pi R_0^3 A} = \frac{3m}{4\pi R_0^3} = 2.3\times10^{17}\ kg/m^3$$

## ISOTOPES

Same protons (z) but different (A) No. of Neutron.
Ex: $_1H^1, _1H^2, _1H^3; _2He^3, _2He^4, _2He^6$

## ISOBARS

Same protons (z) but different (A) No. of Neutron.
Ex: $_1H^1, _1H^2, _1H^3; _2He^3, _2He^4, _2He^6$

## ISOTONES

Same no. neutrons.
Ex: $_1H^3, _2He^4; _8O^{16}, _6C^{14}$

**Mass Energy Relation:** $E = \Delta mc^2$
Energy & mass are interconvertible.

## Mass Defect

Difference in masses of nucleons & nucleus.
$\Delta m = [ZM_P + (A - Z)Mn] - [\text{mass of } _ZX^A \text{ nucleus}]$

## Binding Energy

Energy equivalent to mass defect B.E. = $\Delta m.c^2$
**Packing Fraction:** B.E per nucleon.
P.F = B.E/A

## NUCLEAR FISSION

Splitting of heavy nucleus.
$U^{235} + n^1 \rightarrow Ba^{141} + Kr^{92} + 3n^1 + Q$

## NUCLEAR FUSION

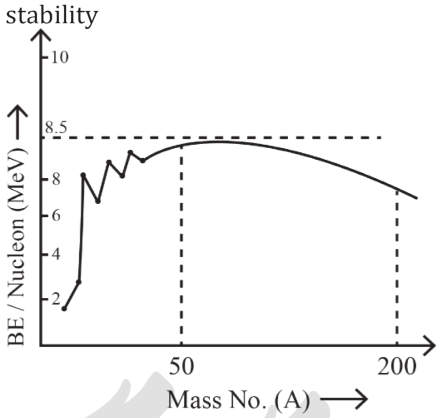
Fusing two or more lighter nuclei.
$_1H^1 + _1H^1 \rightarrow _1H^2 + e^+ + \nu$

## RADIOACTIVITY

Spontaneous emission of radiation (α, β, γ) from radioactive nuclei.

### Variation in B.E/ Nucleon with mass no.

1) BE/A is very less for A = 8 and then increases upto A = 60
2) Decreases after A = 120
3) Maximum 10.5 meV for Range A = 30 to A = 120
4) Peak for $_2He^4, _6C^{12}, _8O^{16}$ etc indicate more stability




### Laws of Radioactive Decay

1) Sontaneous
2) Rate of disintegration is directly proportional to no. of atom at that time.
3) Independent of temperature, pressure etc.
4) α-β not emitted simultaneously

$N = N_0 e^{-\lambda t}$

Half Life : $T_{1/2} = \frac{0.693}{\lambda} = \frac{\log_e 2}{\lambda}$

Average Life
$= \frac{1}{\lambda} = 1.44\, T_{1/2}$

| | $\alpha(_2He^4)$ | β(electron) | γ (photon) |
|---|---|---|---|
| Charge= | $2 \times 1.6 \times 10^{-19}$C | $-1.6 \times 10^{-19}$C | 0 |
| Mass= | $4 \times 1.67 \times 10^{-27}$ kg | $9.1 \times 10^{-31}$ kg | Rest mass 0 |
| Infield= | Deflected by electric Or Mag field | Deflected by electric Or Mag field | No effect |
| Speed= | Less than β | Lessthan γ | Speed of light |

### Unit of Radioactivity

- Curie (Ci) $-3.7 \times 10^{10}$ decay/sec. (activity of 1g radium)
- Becquerel (Bq) −1 decay/sec (S.I unit of radioactivity)
- Rutherford (Rd) $-10^6$ Decay/sec

α-decay $_ZX^A \xrightarrow{-\alpha} {}_{Z-2}Y^{A-4} + {}_2He^4$

β-decay $_ZX^A \xrightarrow{-\beta} {}_{Z+1}Y^A + {}_{-1}e^0$

γ- decay $_ZX^A \xrightarrow{-\gamma} {}_ZX^A \begin{cases} H \rightarrow P + e^- + \nu^- & \beta^- \text{ decay} \\ P \rightarrow H + e^+ + \nu & \beta^+ \text{ decay} \end{cases}$

# SEMICONDUCTORS
# CHEAT SHEET

**Intrinsic Semiconductor:**

The pure semiconductors in which the electrical conductivity is totally governed by the electrons excited from the valence band to the conduction band and in which no impurity atoms are added to increase their conductivity are called intrinsic semiconductors and their conductivity is called intrinsic conductivity. Electrical conduction in pure semiconductors occurs by means of electron-hole pairs. In an intrinsic semiconductor,
$n_e = n_h = n_i$
where $n_e$ = the free electron density in conduction band, $n_h$ = the hole density in valence band, and $n_i$ = the intrinsic carrier concentration.

**Extrinsic Semiconductors:**

A Semiconductor doped with suitable impurity atoms so as to increase its conductivity is called an extrinsic semiconductor.

**Types of Extrinsic Semiconductors:**

Extrinsic semiconductors are of two types

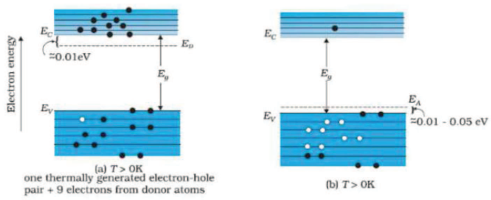
(i) n-type semiconductors
(ii) p-type semiconductors

**n-type semiconductors:**

The pentavalent impurity atoms are called donors because they donate electrons to the host crystal and the semiconductor doped with donors is called n-type semiconductor. In n-type semiconductors, electrons are the majority charge carriers and holes are the minority charge carriers. Thus, $n_e >> n_h$

**p-type semiconductors:**

The trivalent impurity atoms are called acceptors because they create holes which can accept electrons from the nearby bonds. A semiconductor doped with acceptor type impurities is called a p-type semiconductor. In p-type semiconductor, holes are the majority carriers and electrons are the minority charge carriers Thus, $n_h >> n_e$




Energy Band Diagram of n-type semiconductor    Energy band Diagram of p-type semiconductor

**Holes**

The vacancy or absence of electron in the bond of a covalently bonded crystal is called a hole. A hole serves as a positive charge carrier.

**Mobility**

a) The drift velocity acquired by a charge carrier in a unit electric field is called its
electrical mobility and is denoted by μ.

$$\mu = \frac{v_d}{E}$$

b) The mobility of an electron in the conduction band is greater than that of the hole (or electron) in the valence band.

**Electrical conductivity of a Semiconductor:**

a) If a potential difference V is applied across a conductor of length L and area of cross section A, then the total current I through it is given by,

$$I = eA(n_e v_e + n_h v_h)$$

where $n_e$ and $n_h$ are the electron and hole densities, and $v_e$ and $v_h$ are their drift
velocities, respectively.

b) If $\mu_h$ are the electron and hole mobilities, then the conductivity of the semiconductor
will be,

$$\rho = e(n_e\mu_e + n_h\mu_h)$$

and the resistivity will be,

$$\rho = \frac{1}{e(n_e\mu_e + n_h\mu_h)}$$

c) The conductivity of an intrinsic semiconductor increases exponentially with temperature as,

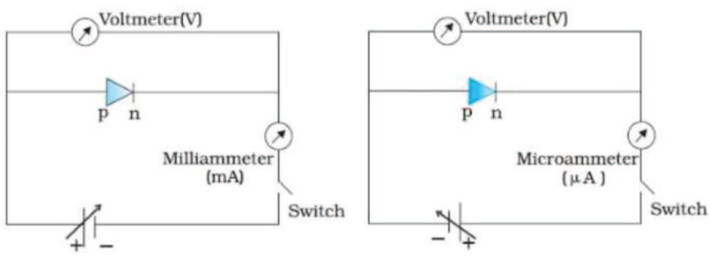
$$\sigma = \sigma_0 \exp\left(-\frac{E_g}{2kT}\right)$$

**Forward Biasing of a pn-junction:**

If the positive terminal of a battery is connected to the p-side and the negative terminal to the n-side, then the pn-junction is said to be forward biased. Both electrons and holes move towards the junction. A current, called forward current, flows across the junction. Thus a pn-junction offers a low resistance when it is forward biased.

**Reverse Biasing of a pn-junction:**

If the positive terminal of a battery is connected to the n-side and negative terminal to the p-side, then pn-junction is said to be reverse biased. The majority charge carriers move away from the junction. The potential barrier offers high resistance during the reverse bias. However, due to the minority charge carriers a small current, called reverse or leakage current flows in the opposite direction. Thus junction diode has almost a
unidirectional flow of current.




(a) Forward Bias: pn Junction    (b) Reverse Bias: pn Junction

# ELECTROMAGNETIC WAVES
# CHEAT SHEET

## Electromagnetic Waves:

(a) Electromagnetic waves are produced only by charges that are accelerating, since acceleration is absolute, and not a relative phenomenon.

(b) An electric charge oscillating harmonically with frequency v, produces
electromagnetic waves of the same frequency v.

(c) An electric dipole is a basic source of electromagnetic waves.

(d) Electromagnetic waves with wavelength of the order of a few metres were first produced and detected in the laboratory by Hertz in 1887. He thus verified a basic prediction of Maxwell's equations.

## Oscillation of Electric and Magnetic Fields:

These oscillate sinusoidally in space and time in an electromagnetic wave. The oscillating electric and magnetic fields, E and B are perpendicular to each other and to the direction of propagation of the electromagnetic wave.

• For a wave of frequency v, wavelength $\lambda$, propagating along z-direction,

$$E = E_X(t) = E_0 \sin(kz - \omega t)$$
$$= E_0 \sin\left[2\pi\left(\frac{z}{\lambda} - vt\right)\right] = E_0 \sin\left[2\pi\left(\frac{z}{\lambda} - \frac{t}{T}\right)\right]$$
$$B = B_Y(t) = B_0 \sin(kz - \omega t)$$
$$= B_0 \sin\left[2\pi\left(\frac{z}{\lambda} - vt\right)\right] = B_0 \sin\left[2\pi\left(\frac{z}{\lambda} - \frac{t}{T}\right)\right]$$

They are related by $\frac{E_0}{B_0} = c$

## • Relation between $\mu_0$ and $\varepsilon_0$:

• The speed c of electromagnetic wave in vacuum is related to $\mu_0$ and $\varepsilon_0$ (the free space permeability and permittivity constants) as $C = 1/\sqrt{\mu_0\varepsilon_0}$
• The value of c equals the speed of light obtained from optical measurements. Light is an electromagnetic wave; c is, therefore, also the speed of light.
Electromagnetic waves other than light also have the same velocity c in free space.

## Speed of Light:

The speed of light, or of electromagnetic waves in a material medium is $v = 1/\sqrt{\mu\varepsilon}$
Where $\mu$ is the permeability of the medium and $\varepsilon$ its permittivity

• Electromagnetic waves carry energy as they travel through space and this energy is
shared equally by the electric and magnetic fields.

## Energy Per Unit Volume:

If in a region of space in which there exist electric and magnetic fields $\vec{E}$ and $\vec{A}$, there exists Energy Density (Energy per unit volume) associated with these fields is,

$$U = \frac{\varepsilon_0}{2}\vec{E}^2 + \frac{1}{2\mu_0}\vec{B}^2$$

where we are assuming that the concerned space consists of vacuum only.

• Electromagnetic waves transport momentum as well. When these waves strike a
surface, a pressure is exerted on the surface.

• If total energy transferred to a surface in time t is U, total momentum delivered to this surface is p = U/c.

## Electromagnetic Spectrum:

The spectrum of electromagnetic waves stretches, in principle, over an infinite range of wavelengths.
The classification of electromagnetic waves according to frequency is the electromagnetic spectrum.
There is no sharp division between one kind of wave and the next.

• The classification has more to do with the way these waves are produced and detected.

## Different Regions of Spectrum:

Different regions are known by different names; $\gamma$ -rays, X-rays, ultraviolet rays, visible rays, infrared rays, microwaves and radio waves in order of increasing wavelength from $10^{-2}$ Å or $10^{-12}$ m to 106 m.

### (a) Radio Waves:

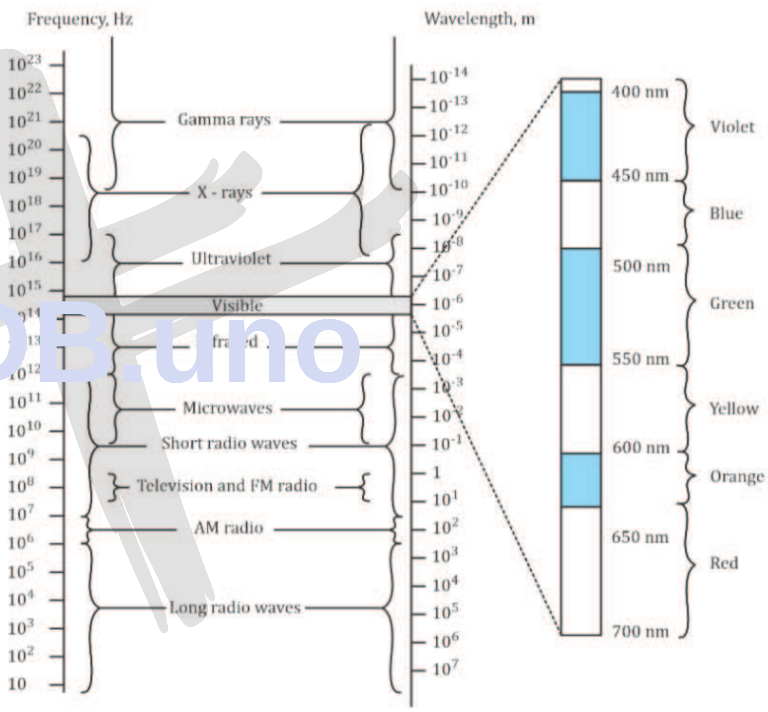
- These are produced by accelerated motion of charges in wires.
- These are used in radio and television communication systems.
- These are generally in the frequency range from 500 kHz to about 1000 MHz.

### (b) Microwaves:

- These are short wavelength radio waves with frequencies in the gigahertz range.
- Due to their short wavelengths, they are suitable for radar systems used in aircraft navigation.
- Microwave ovens use them for cooking.

### (c) Infrared Waves:

- These are produced by hot bodies and molecules.
- They lie in the low frequency or long wavelength end of the visible spectrum.




### (d) Visible Light:

- The spectrum runs from about 4 x $10^{14}$ Hz to about 7 x $10^{14}$ Hz.
- Our eyes are sensitive to this range of wavelengths. (e) Ultraviolet light:
- It covers wavelengths ranging from 400 nm to 0.6 nm.
- The sun is an important source of UV rays.

### (f) X-rays:

- These cover the range 10 nm to about $10^{-4}$ nm.

### (g) Gamma Rays:

- These lie in the upper frequency range of the spectrum, and have wavelengths in the range $10^{-10}$ m to $10^{-14}$ m.