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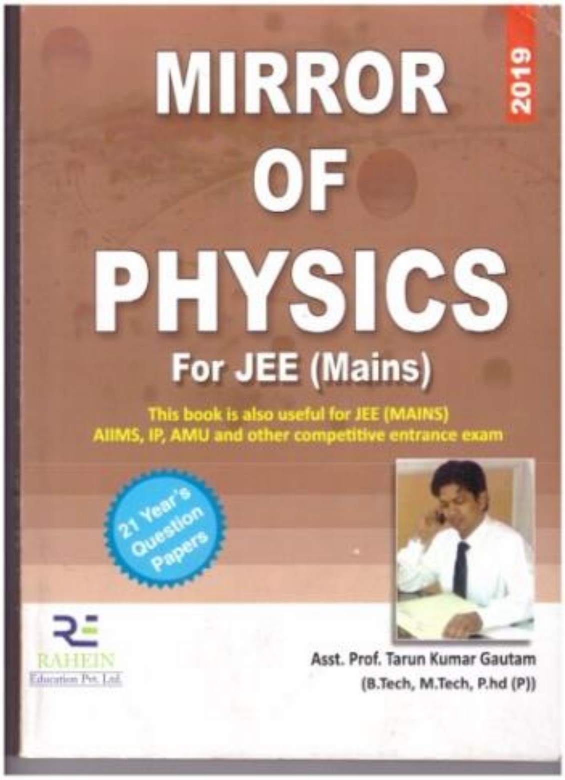
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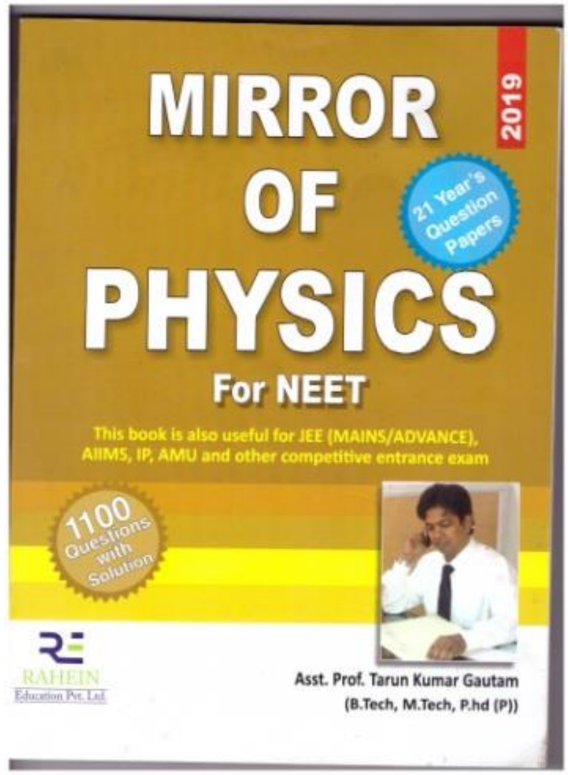
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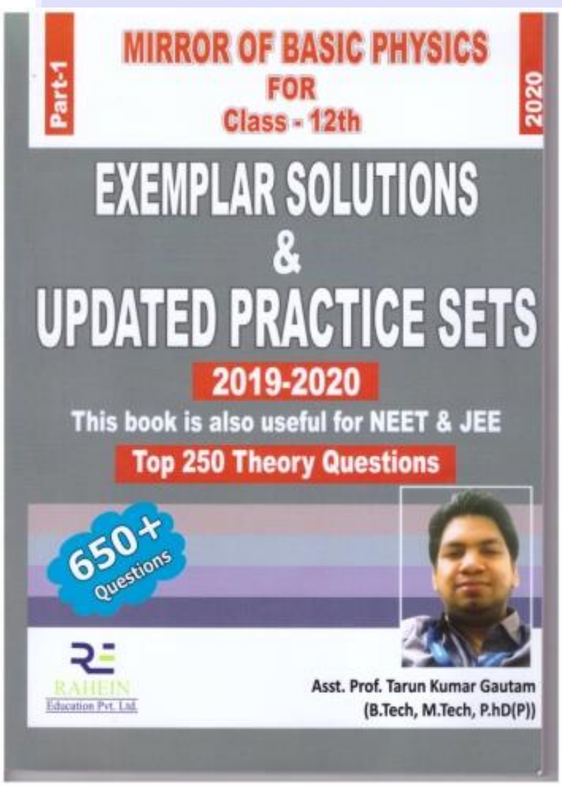
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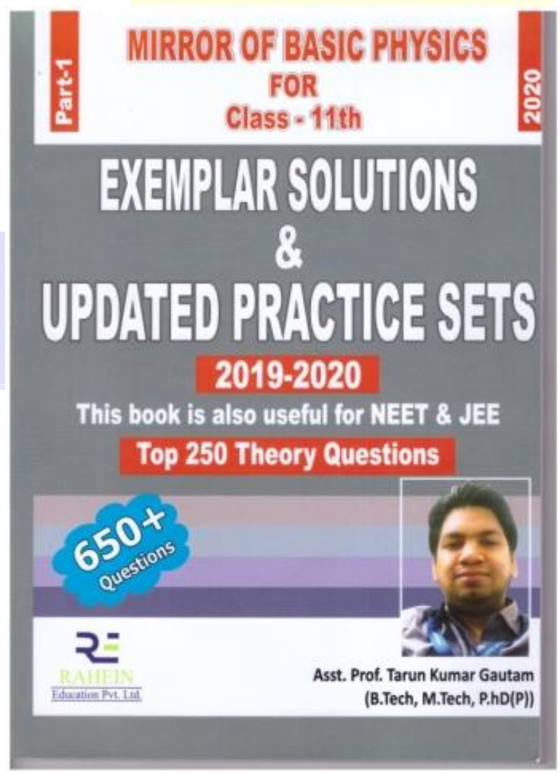
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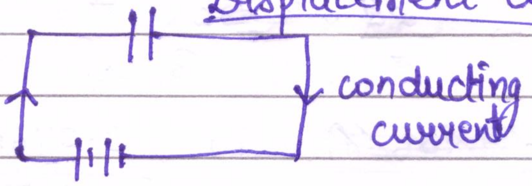
EMW

[Electro Magnetic Waves]

① **Displacement current**



$$I = I_D + I_C$$

$I_D \rightarrow$ displacement current
$I_C \rightarrow$ conduction current

$$I_D = \varepsilon_0 \frac{d\phi}{dt} \quad \Rightarrow \quad [\because \phi = EA]$$

$$I_D = \varepsilon_0 \frac{d(EA)}{dt} = \varepsilon_0 \times A \times \frac{dE}{dt}$$

$$\boxed{I_D = \varepsilon_0 \times A \times \frac{dE}{dt}}$$

$\rightarrow$ $E \rightarrow$ Electric field.

② **Ampere Circuital Law** $\rightarrow$ $\boxed{\oint \vec{B} \cdot \vec{dl} = \mu_0 I}$

③ **Maxwell's equation**

(i) **Gauss Law of Electrostatic**

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

(ii) **Gauss Law of Magnetism**

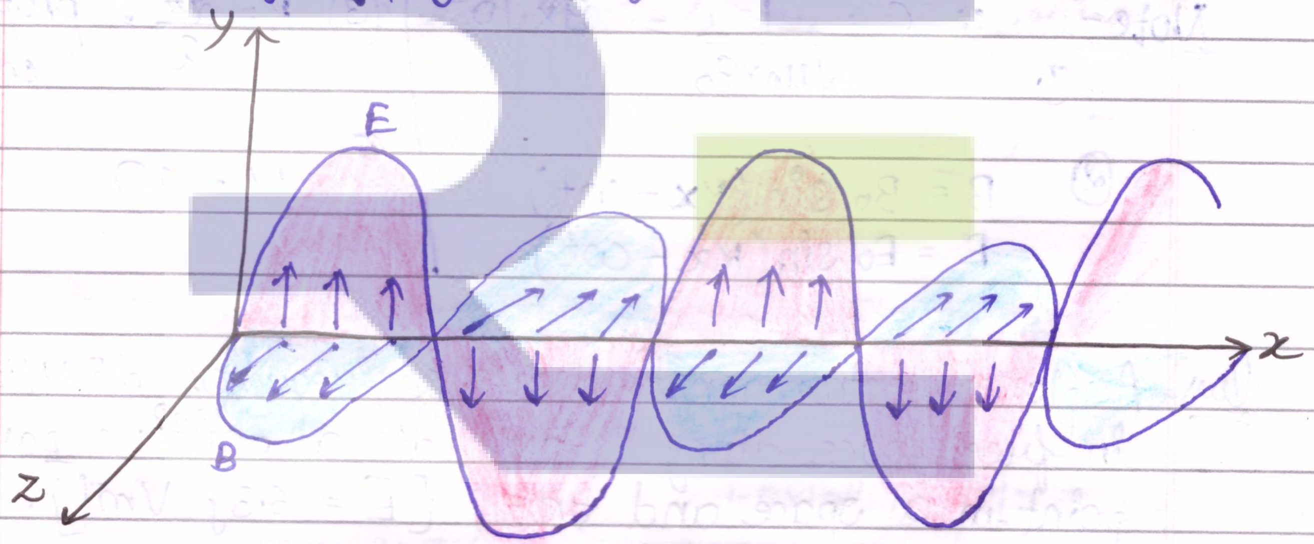
$$\boxed{\oint \vec{B} \cdot \vec{ds} = 0}$$

(iii) **Faraday Law of EMI** $\boxed{\oint \vec{E} \cdot \vec{dl} = -\frac{d\phi_B}{dt}}$

(iv) Modified Ampere Circuital Law

$$\oint \vec{B} \cdot \vec{ds} = \mu_0 [I_c + I_D] \Rightarrow \mu_0 \left[I_c + \epsilon_0 \frac{d\phi}{dt}\right]$$

Electromagnetic wave is a wave radiated by an accelarated charge and which propogate through space as couplied electric & magnetic field, oscillating perpendicular to each other & to direction of propagation of wave.



Direction of propagation ⟶

Let 'E' is electric Field.

(y) E ⟶ $\vec{E} = E_y \hat{j} = E_0 \sin(kx - \omega t)\hat{j}$

(z) Let 'B' is magnetic field.

$$\vec{B} = B_z \hat{k} = B_0 \sin(kx - \omega t)\hat{k}$$

k = propagation constant $= \frac{2\pi}{\lambda}$

Let 'λ' is wavelength

$\because E_x = E_z = 0$
$B_x = B_y = 0$

E_0 & B_0 are amplitude of Electric field & Magnetic field

$$\boxed{\frac{E_0}{B_0} = C} \Rightarrow \boxed{\frac{E}{B} = C}$$

Note-

1. $\because C = \frac{1}{\sqrt{\mu_0 \times \varepsilon_0}} = 9 \times 10^9$

2. $B = B_0 \sin(kx - \omega t)$
   $E = E_0 \sin(kx - \omega t)$

3. $k = \frac{2\pi}{\lambda}$ = propagation constant

4. $V = \lambda \nu$

Ques A plane electromagnetic wave of frequency 25 MHz travels in free space along x-axis at a position particular point in a space and time, $[\vec{E} = 6.3\hat{j}\ Vm^{-1}]$. what is 'B' at the point.

Ans $\nu = 25\ mH = 25 \times 10^6\ Hz$

$\vec{E} = 6.3\hat{j}$

$$\boxed{\frac{E}{B} = C} \qquad \frac{E}{C} = B \Rightarrow \boxed{B = \frac{6.3}{3 \times 10^6}\ T}$$

Electric field → 'y' → $(\hat{j})$
EMW → 'x' → $(\hat{i})$
Magnetic field → 'z' → $(\hat{k})$

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Note

① $B_x = B_0 \sin(kx - \omega t)$

$B_x = B_0 \sin\left(\frac{2\pi}{\lambda} \cdot x - \frac{2\pi}{T} \cdot t\right)$

② $E_z = E_0 \sin(kx - \omega t)$

$E_z = E_0 \sin\left(\frac{2\pi}{\lambda} \cdot x - \frac{2\pi}{T} \cdot t\right)$

Ques Magnetic field in plane electromagnetic wave

$B_z = 2\times10^{-7} \sin(0.5\times10^{3} x + 1.5\times10^{11} t)\ T$

(a) What is wavelength & frequency of wave?

(b) Write the expression for electric field?

Ans $B_z = 2\times10^{-7} \sin(0.5\times10^{3} x + 1.5\times10^{11} t)$

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

$B_0 = 2\times10^{-7}$

$k = \frac{2\pi}{\lambda} = 0.5\times10^{3}$

$\boxed{\lambda = \frac{2\times22}{0.5\times10^{3}\times7}}$

$\omega = 1.5\times10^{11} = \frac{2\pi}{T}$

$\boxed{T = \frac{2\pi}{1.5\times10^{11}}}$

$\omega = 2.5\times10^{11} = 2\pi\nu$

$\boxed{\nu = \frac{1.5\times10^{4}\ Hz}{2\pi}}$

(ii) $E = E_0 \sin(kx + \omega t)$

$E = E_0 \sin(0.5\times10^{3} x + 1.5\times1.5\times10^{11} t)\ NC^{-1}$

$\boxed{\frac{E_0}{B_0} = C} \Rightarrow E_0 = B_0 \times C$

$\boxed{E_0 = 2\times10^{-7} \times 3\times10^{9}}$

GOOD WRITE

Ques A light Beam travelling in x-direction is described by electric field $E_y = 270 \sin(\omega(t - \frac{x}{c}))$

an electron is constrained to move along the y-direcⁿ with speed of 2×10^7 m/sec. Find the maximum electric force and maximum force on electron?

Ans

$$E_y = 270 \sin \omega\left(t - \frac{x}{c}\right)$$

$$E_0 = 270 \ Vm^{-1}$$

(i) $\frac{E_0}{B_0} = C$

$$B_0 = \frac{E_0}{C} = \frac{270}{9\times10^9} = 9\times10^{-7} \ T$$

(ii) max electric force on electron

$$f_e = qE_0$$

$$f_e = 1.6\times10^{-19} \times 270 \ N$$

(iii) max. magnetic force on electron

$$f_m = qVB_0$$

$$f_m = 1.6\times10^{-19} \times 2\times10^7 \times 9\times10^{-7} \ N$$

Ques Electromagnetic wave travel in a medium at speed 2×10^8 $msec^{-1}$. The relative permiability of medium is 1. Find the relative permiability of electric?

Medium → $V = [2\times10^8 \ m\,sec^{-1}]$

$$\mu_r = 1$$

$$C = \frac{1}{\sqrt{\mu_0 \times \varepsilon_0}}$$

[μ_0 → Magnetic Permiability
ε_0 → electrical Permiability]

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$$V = \frac{1}{\sqrt{\mu \times \varepsilon}}$$ [μ = Medium Magnetic Permiability, ε = Medium Electrical permiability]

$$2\times10^8 = \frac{1}{\sqrt{\mu\times\varepsilon}}$$ [$\mu = \mu_r \times \mu_0$, $\varepsilon = \varepsilon_r \times \varepsilon_0$]

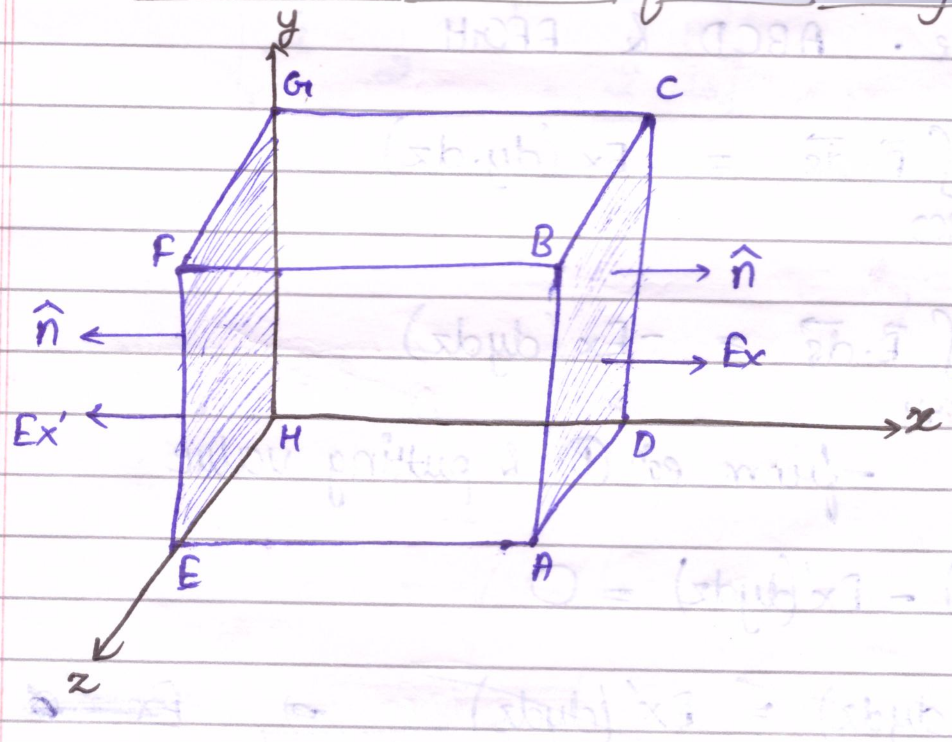
$$2\times10^8 = \frac{1}{\sqrt{\mu_r\times\mu_0\times\varepsilon_r\times\varepsilon_0}}$$

$$2\times10^8 = \frac{c}{\sqrt{\mu_r\times\varepsilon_r}}$$

$$4\times10^{16} = \frac{(3\times10^8)^2}{\mu_r\times\varepsilon_r}$$

$$4\times10^{16} = \frac{9\times10^{18}}{1\times\varepsilon_r} \Rightarrow \boxed{\varepsilon_r = 2.25}$$

Transverse nature of Electromagnetic waves



By Gauss Theorem

$$\oint_{ABCDEFGH} \vec{E}\cdot\vec{ds} = 0$$

$$\rightarrow \left[\int_{ABCD} \vec{E}\cdot\vec{ds} + \int_{EFGH} \vec{E}\cdot\vec{ds}\right] + \left[\int_{ABFE} \vec{E}\cdot\vec{ds} + \int_{DHGC} \vec{E}\cdot\vec{ds}\right]$$

$$+ \left[\int_{AFHD} \vec{E}\cdot\vec{ds} + \int_{BFGC} \vec{E}\cdot\vec{ds}\right] = 0$$

'E' don't depend on (y) & (z), the contribution from forces.

$$\rightarrow \int_{ABCD} \vec{E}\cdot\vec{ds} + \int_{EFGH} \vec{E}\cdot\vec{ds} = 0$$

Normal to (y) & (z), so $\theta = 90°$
Let E_x & E_x' be the components of Electric Field at force. ABCD & EFGH

$$\rightarrow \int_{ABCD} \vec{E}\cdot\vec{ds} = E_x (dy \cdot dz)$$

$$\rightarrow \int_{EFGH} \vec{E}\cdot\vec{ds} = -E_x (dy dz)$$

from eqⁿ ① & putting value

$$E_x(dy\,dz) - E_x'(dy dz) = 0$$

$$E_x (dy dz) = E_x' (dy dz) \Rightarrow \boxed{E_x = E_x'}$$

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i.e, Component of Electric field along the direc^n of propagation is constant. But a constant or static field cannot produce a wave, so this constant must be equal to zero i.e $E_x = 0$

Similarly, $B_x = 0$, Thus the electric or magnetic field have no can present along the direction of propagation or electromagnetic wave bothe electric field & magnetic field are perpendicular to direc^n of propagation i.e so they are transverse nature.

Energy density of EMW (u)

u_E = energy density of electric field $= \frac{1}{2}\varepsilon_0 E^2$ ---- (1)

u_B = energy density of Magnetic field $= \frac{1}{2}\frac{B^2}{\mu_0}$ ---- (2)

$$u = u_E + u_B$$

$$\boxed{u = \frac{1}{2}\varepsilon_0 E^2 + \frac{1}{2}\frac{B^2}{\mu_0}}$$

$$E = \frac{E_0}{\sqrt{2}}, \quad B = \frac{B_0}{\sqrt{2}}$$

$$u = \frac{1}{2}\frac{\varepsilon_0 \times E_0^2}{2 \times 2} + \frac{1 \times B_0^2}{2 \times 2 \times \mu_0}$$

$$\boxed{u = \frac{1}{4}\varepsilon_0 E_0^2 + \frac{1}{4}\frac{B_0^2}{\mu_0}}$$

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Intensity of EMW

$$I = \frac{\text{energy}}{\text{Area} \times \text{Time}} = \frac{\text{energy} \times \text{length}}{\text{Area} \times \text{Time} \times \text{length}}$$

$$= \frac{\text{energy} \times \text{length}}{\text{volume} \times \text{Time}} = \text{energy density} \times \text{velocity}$$

$$\boxed{I = u \times C}$$

$$I = \left(\frac{1}{2}\varepsilon_0 E^2 + \frac{1}{2}\frac{B^2}{\mu_0}\right) \times C$$

$$\boxed{I = I_E + I_B}$$

So here by comparing, we get

$$\boxed{I_E = \frac{1}{2}\varepsilon_0 E^2 \times C}, \quad \boxed{I_B = \frac{1}{2}\frac{B^2}{\mu_0} \times C}$$

Momentum of EMW (P)

$$\boxed{P = \frac{u}{c}} \rightarrow \frac{\text{Total energy}}{c}$$

Note ① $\frac{E_0}{B_0} = C = \frac{1}{\sqrt{\mu_0 \times \varepsilon_0}}$

② $C = \frac{1}{\sqrt{\mu_0 \times \varepsilon_0}} = 3 \times 10^8$

③ $\mu_0 = 4\pi \times 10^{-7}$

$C = \nu\lambda = 3 \times 10^8 \, ms^{-1}$

$\varepsilon_0 = 8.85 \times 10^{-12}$

$\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9$

$\therefore \boxed{C = \frac{1}{4\pi\varepsilon_0}}$

Electromagnetic Spectrum

→ (G) Gamma rays
→ (X) X-rays
→ (U) Ultraviolet rays
→ (V) Visible rays
→ (I) Infrared rays
→ (M) Microwave
→ (R) Radiowave

Going down
$\nu(\downarrow)$, $\lambda(\uparrow)$
decrease, increase

RMI – VUXG

Ques Arrange Infrared, X-rays, Radiowaves, gamarays? according to frequency. (I), (X), (R), (G)

Ans going down ν decreases
So, (G) > (X) > (I) > (R)

Ques VISIBLE it consist VIBGYOR

V – Violet
I – Indigo
B – Blue
G – Green
Y – Yellow
O – Orange
R – Red

Going down
$\nu(\downarrow)$ decreases, $\lambda(\uparrow)$ increases

Ques Arrange Violet, orange, red, Blue, Indigo.
Arange wavelength(λ) & frequency(ν).

Ans As we know VIBGYOR, (λ)→ R > O > B[redacted] > I > V
(ν)→ V > I > B > O > R

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Radio waves
- radio and television communication system

Microwave
- Radar system for aircraft Navigation
- long distance communication system (geostationary
- Microwave oven.
- Accurate measurement of temp. variation in universe

Infrared waves
- remote control of TV, VCR
- green house
- Haze photograph
- Treatment of Muscular complaints
- reading secret writing of Ancient times.
- Knowing the molecular structure.
- Maintain Earth's warmth

Visible Light
- Reflection
- Refraction
- Interference
- Diffraction
- Polarisation
- Photoelectric effect.
- Photographic action
- Sensation of sight.
- motion of object

UV Rays
- Study of Invisible writing, forged documents, finger prints
- Study of molecular structure

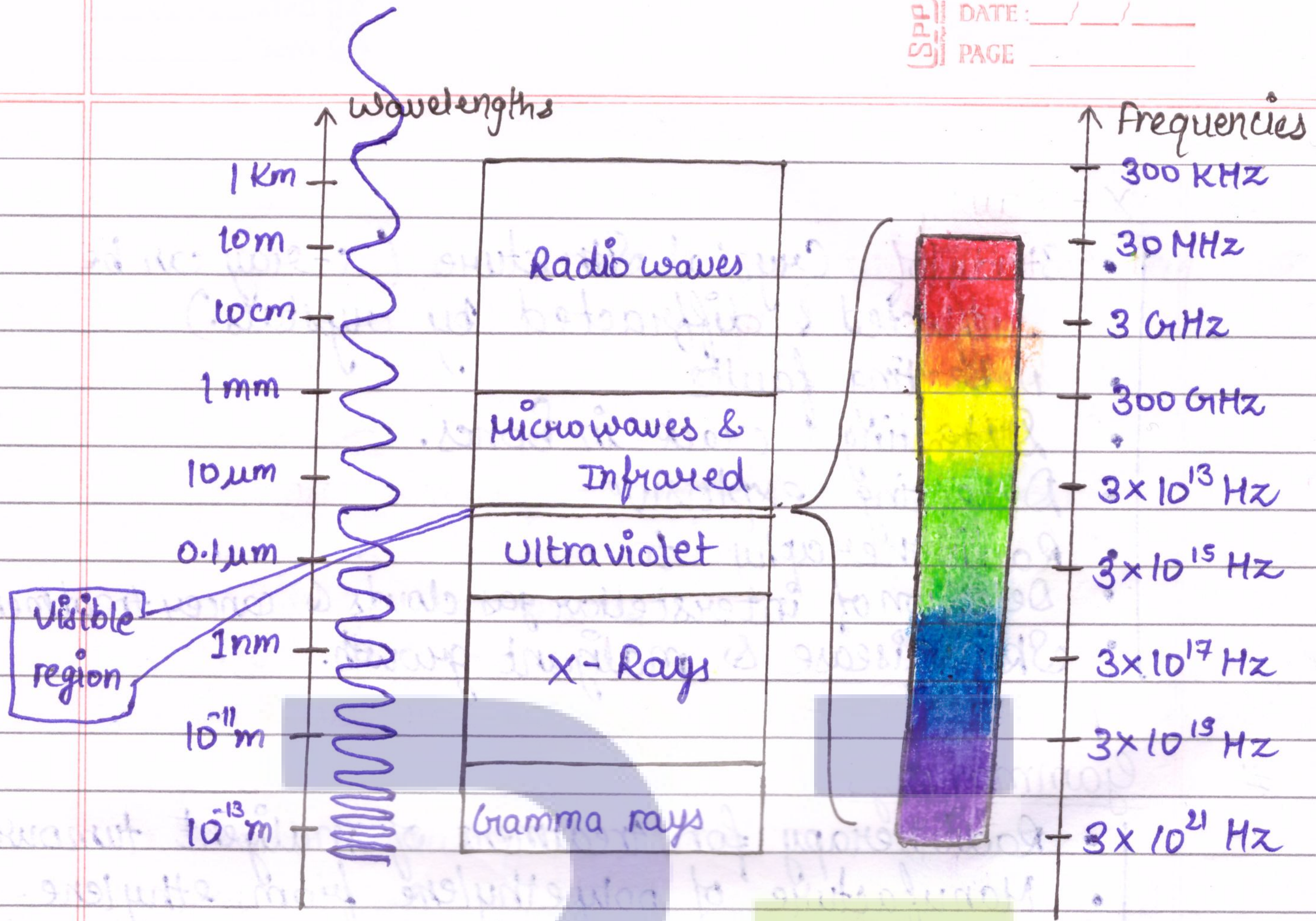
X-Rays

- Study of Crystal Structure (X-ray can be reflected & diffracted by crystals.)
- Detecting faults
- Detecting crack in bones.
- Detecting explosive
- Radiotheraphy to
- Detection of interstellar gas clouds & cancer treatment.
- Skin disease & maligant growth.

Gamma rays

- Radiotherapy for treatment of maligent tumour.
- Manufacture of polyethylene from ethylene.
- To initiate some nuclear reacn.
- Preserve food stuffs
- Study structure of Atomic Nuclei.

	Wave Type	(λ) wavenlength in m	frequency (ν) in Hz
1)	Radio wave	0.3 to 6×10^{2}	10^{9} to 5×10^{5}
2)	Micro wave	10^{-3} to 0.3	3×10^{11} to 1×10^{9}
3)	Infrared wave	8×10^{-7} to 10^{-3}	4×10^{14} to 3×10^{11}
4)	Visible light	4×10^{-7} to 8×10^{-7}	8×10^{14} to 4×10^{14}
5)	Ultra Violet	6×10^{-9} to 4×10^{-7}	5×10^{16} to 8×10^{14}
6)	X-Rays	10^{-13} to 3×10^{-8}	3×10^{21} to 1×10^{16}
7)	Gamma Rays	0.6×10^{-14} to 10^{-10}	5×10^{22} to 3×10^{18}


Wavelengths
1 Km
10m
10cm
1 mm
10 µm
0.1µm
1nm
10^{-11}m
10^{-13}m
Visible region
Radio waves
Microwaves & Infrared
Ultraviolet
X-Rays
Gamma rays
Frequencies
300 KHz
30 MHz
3 GHz
300 GHz
3×10^{13} Hz
3×10^{15} Hz
3×10^{17} Hz
3×10^{19} Hz
3×10^{21} Hz

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