PHI-101: Physics-I **Lecture Schedule** **Autumn 2023-24**

1-2 Vector algebra: Different orthogonal coordinate systems:
i) Cartesian, ii) Cylindrical, and iii) Spherical Polar coordinate system and transformation among themselves; the unit vectors for each coordinate system; Vectors in different coordinate systems.

3-4 Vector calculus: differential length, differential area, differential volume; Line, Surface and Volume integrals in the 3 coordinate systems. The scaling factors for the 3 coordinate systems.

5-8 Del operator in the three coordinate systems; Gradient of a scalar; Divergence (Gauss's theorem) and Curl of a vector (Stoke's theorem) with their physical interpretations.

9-10 Divergence and Curl of electrostatic fields: Maxwell's first equation and electric potential, divergence and curl of magnetic field: Ampere's law and magnetic vector potential.

11-13 Conservation of charge and energy (continuity equation); Maxwell's equations (in Differential form & in Integral form); Poynting vector.

14-16 Boundary conditions for Electric and Magnetic fields at interfaces

MTE

17-21 Electromagnetic waves in matter: Plane waves in free space and in lossless dielectric; Reflection and transmission of plane waves at normal incidence.

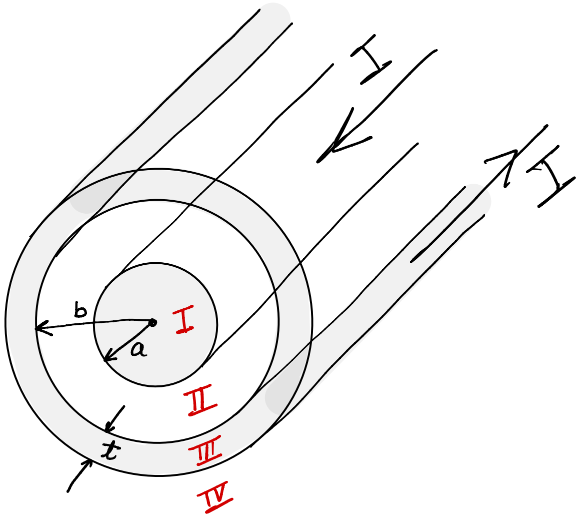
22-25 Black body radiations: Rayleigh-Jeans Law, Wein's law, number density of standing waves in 1-, 2-, and 3-D, Planck's law of blackbody radiation, Stefan's law, Wein's displacement law.

26-30 Need of particle nature of light to explain the Photoelectric effect; Compton effect; Frank-Hertz experiment; de Broglie waves, electron diffraction (Davisson-Germer experiment); Wave packet, Phase and Group velocities, Uncertainty principle (single slit thought experiment) and its simple applications.

31-33 Basic postulates of quantum mechanics and meaning of measurement, Schrödinger wave equation, physical significance of the wave function.

Lecture-14 8/09/23

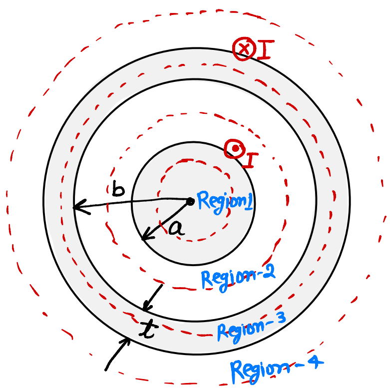
* Infinitely Long Coaxial Transmission line ⇒



* Two concentric cylinders.
* Inner conductor radius a & it carries current I.
* Outer conductor has inner radius 'b', thickness 't' & carries return current −I.

* Determine B everywhere, Assuming that current is uniformly distributed in both conductors.

Crossection



I^{st} region ⇒

$$\oint B\cdot dl = \mu_0 I$$

$$B\cdot 2\pi r = \mu_0 \frac{I}{\cancel{\pi} a^2} \times r^2 \cancel{\pi}$$

$$B = \frac{\mu_0}{2\pi}\frac{I r}{a^2} \qquad [r \le a]$$

II^{nd} region ⇒

$$\oint B\cdot dl = \mu_0 I$$

$$B \times 2\pi r = \mu_0 I$$

$$B = \frac{\mu_0}{2\pi}\frac{I}{r} \qquad [a \le r \le b]$$

III^{rd} region

$$\oint B\cdot dl = \mu_0 I_{enclosed}$$

$$B\cdot 2\pi r = \mu_0 I\left[1 - \frac{r^2 - b^2}{(b+t)^2 - b^2}\right]$$

$$B = \frac{\mu_0 I}{2\pi r}\left[1 - \frac{r^2 - b^2}{t^2 + 2bt}\right]$$

$$I_{enclosed} = I - I'$$

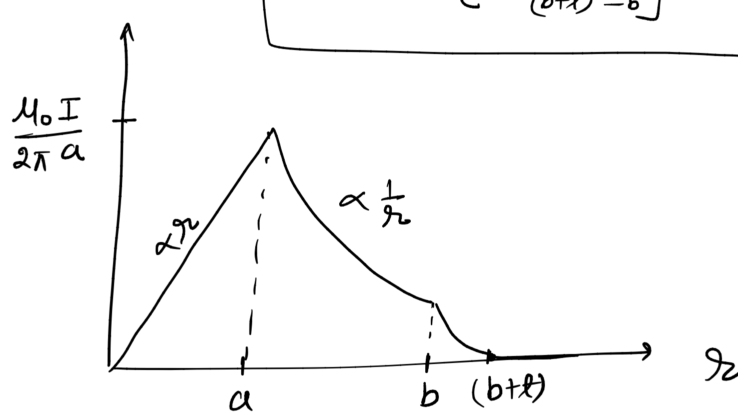
$$= I - \left[\frac{I}{\cancel{\pi}(b+t)^2 - \cancel{\pi} b^2} \times (\cancel{\pi} r^2 - \cancel{\pi} b^2)\right]$$

$$I_{enl} = I\left[1 - \frac{r^2 - b^2}{(b+t)^2 - b^2}\right]$$

(IV) region ⇒

$$\oint B\cdot dl = \mu_0 I_{encl}$$

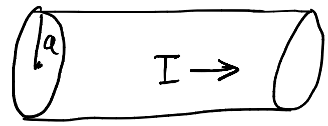
$$B = 0 \qquad [r \ge b+t]$$



Homework:

Q ⇒ A steady current I flows down a long cylindrical wire of radius a. Find the magnetic field, both inside & outside the wire if,

(a) ⇒ The current is uniformly distributed over the outside surface of the wire.



(b) ⇒ The current is distributed in such a way that J is proportional to s, the distance from the axis.

Ans ⇒ (a) ⇒

$$B = \begin{cases} 0 & \text{for } s<a \\ \dfrac{\mu_0 I}{2\pi s}\hat{\varphi} & \text{for } s>a \end{cases}$$

(b) ⇒

$$B = \begin{cases} \dfrac{\mu_0 I s^2}{2\pi a^3}\hat{\varphi} & \text{for } s<a \\ \dfrac{\mu_0 I}{2\pi s}\hat{\varphi} & \text{for } s>a \end{cases}$$

Magnetic flux density (B) ⇒

Magnetic field intensity (H)
strength

$$\boxed{B = \mu H}$$

$$\boxed{B = \mu_0 [H + M]}$$

↓

Magnetization (Magnetic moment per unit volume)

$D = \varepsilon E$

$D = \varepsilon_0 E + \overline{P}$

↓

Polarization (dipole moment per unit volume)

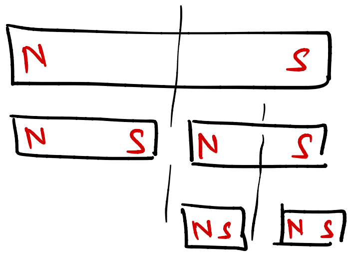
* Magnetic field is generated by external current. When the generated field pass through magnetic materials, they themself contribute in internal magnetic field.

* $\overline{H}$ is the magnetic influence from external currents in the material & it is independent of the materials magnetic response.

$$\therefore \oint H \cdot dl = I_{enclose}$$

No magnetic monopole ⇒

* Sucessive division of a bar magnet.

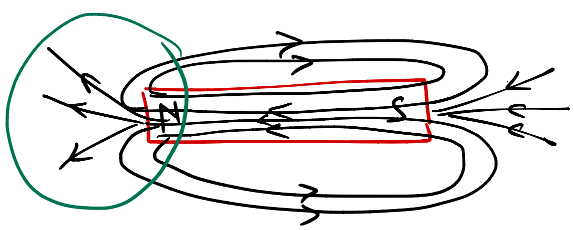


⇒ Magnetic poles cannot be isolated

⇒ Magnetic monopole does not exist

⇒ An isolated magnetic charge does not exist.

*



$$\oint_S B \cdot ds = 0$$

$$\int_V \nabla \cdot B \, dV = 0$$

$$\boxed{\nabla \cdot B = 0}$$

$\nabla \cdot B = 0$

$\therefore \boxed{B = \nabla \times \bar{A}}$

$\downarrow$

Magnetic Vect. Pot.

* $\nabla \times E = 0$

$\therefore E = -\text{grad} V$

$\downarrow$

Scalar. Pot.

* For line current ⇒

$$\boxed{\bar{A} = \frac{\mu_0}{4\pi} \int \frac{I \, d\bar{l}}{r}}$$

$$B = \frac{\mu_0}{4\pi} \int \frac{I \, dl \sin\theta}{r^2}$$

$$B = \nabla \times A$$

For surface current

$$A = \frac{\mu_0}{4\pi} \int \frac{K \, ds}{r}$$

For volume current

$$A = \frac{\mu_0}{4\pi} \int \frac{J \, d\tau}{r}$$

Magnetic flux through a given area ⇒

$$\varphi = \int_S B \cdot ds$$

$$\varphi = \int (\nabla \times A) \cdot ds$$

$$= \oint A \cdot dl$$

Q ⇒ Given the following two magnetic vector pot.

$$A_1 = (\sin x + x \sin y)\, a_y$$

$$A_2 = (\cos y\, a_x + \sin x\, a_y$$

Show that they give the same magnetic flux density B. Show that B is solenoidal.

A ⇒ $B = \nabla \times A_1$

$$= \begin{vmatrix} a_x & a_y & a_z \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ 0 & \sin x + x \sin y & 0 \end{vmatrix}$$

$$= a_x(0) - a_y(0) + a_z(\cos x + \sin y)$$

$$= (\cos x + \sin y)\, a_z \checkmark$$

$$B = \nabla \times A_2$$

$$= \begin{vmatrix} a_x & a_y & a_z \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ \cos y & \sin x & 0 \end{vmatrix} \Rightarrow (\cos x + \sin y)\, a_z \checkmark$$

$$\nabla \cdot B = \frac{\partial}{\partial x}(0) + \frac{\partial}{\partial y}(0) + \frac{\partial}{\partial z}(\cos x + \sin y) = 0$$ [Hence Solenoidal]