PHYS 212, Honors Section – Review Material

Chapter 34: Electromagnetic Waves

- Maxwell's equations: Four equations that contain all information on how electric and magnetic fields are produced,

$$\int_S \mathbf{E} \cdot d\mathbf{A} = q_{enc}/\varepsilon_0 \quad \text{(Gauss' law for } \mathbf{E}\text{, equivalent to Coulomb's law)}$$
$$\int_C \mathbf{E} \cdot d\mathbf{s} = -\, d\Phi_B/dt \quad \text{(Faraday's law)}$$
$$\int_S \mathbf{B} \cdot d\mathbf{A} = 0 \quad \text{(Gauss' law for } \mathbf{B}\text{)}$$
$$\int_C \mathbf{B} \cdot d\mathbf{s} = \mu_0 I_{enc} + \mu_0 \varepsilon_0\, d\Phi_E/dt \text{ (Ampère-Maxwell law).}$$

  Relationship between the right-hand sides of the equations and the absence of magnetic monopoles.

- Displacement current: Can be seen in the second term of the right-hand side in the Ampère-Maxwell equation,

$$I_d = \varepsilon_0\, d\Phi_E/dt\ .$$

- Electromagnetic waves: Plane harmonic waves propagating along the x direction, for example, have

$$E = E_{max} \cos(kx - \omega t) \ \text{ and } \ B = B_{max} \cos(kx - \omega t)\ ,$$

  where $k = 2/\lambda$, $\omega = 2\pi f$ and, as for all waves, $\lambda f = v$, the speed. The fields **E** and **B** are perpendicular to each other and to the direction of propagation, with $E/B = c$, and in vacuo the speed is

$$c = (\mu_0 \varepsilon_0)^{-1/2} = 3.00 \times 10^8 \text{ m/s}\ .$$

- Energy carried by electromagnetic waves: The Poynting vector $\mathbf{S} = (1/\mu_0)\ \mathbf{E} \times \mathbf{B}$, representing the energy crossing a surface perpendicular to the direction of propagation, per unit area and unit time.

- Momentum and radiation pressure: The pressure exerted by radiation on a surface on which it is normally incident is $P = S/c$ if the surface is absorbing and $P = 2S/c$ if it is reflecting (S is the magnitude of the Poynting vector).

- Electromagnetic spectrum: It includes, in order of decreasing wavelength (increasing frequency) radio waves, infrared radiation, visible light, ultraviolet radiation, X-rays, gamma rays. Visible light corresponds to wavelengths approximately between 400 and 700 nm.

Note: You are not required to know the topics and equations inside square brackets.

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