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Chapter 30 - Maxwell's Equations and Electromagnetic Waves

1. Electromagnetic Waves

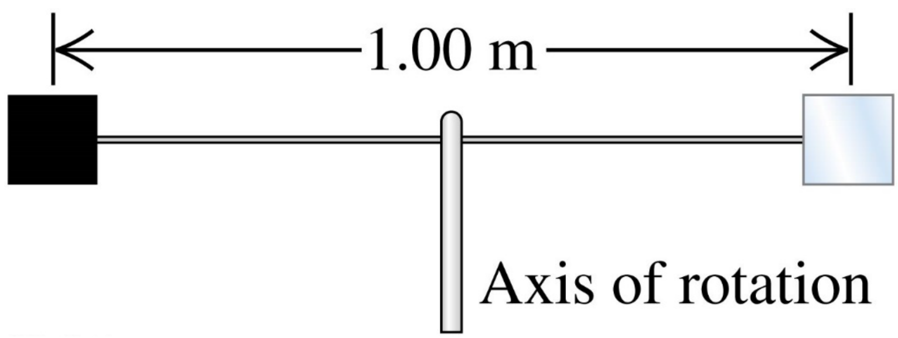
Consider a sinusoidal electromagnetic wave with fields $\vec{\boldsymbol{E}} = E_{max}\hat{\jmath}\cos(kx - \omega t)$ and $\vec{\boldsymbol{B}} = B_{max}\hat{k}\cos(kx - \omega t + \phi)$, with $-\pi \leq \phi \leq \pi$. Show that if $\vec{\boldsymbol{E}}$ and $\vec{\boldsymbol{B}}$ are to satisfy $\frac{\partial E_y(x,t)}{\partial x} = \frac{\partial B_z(x,t)}{\partial t}$ and $-\frac{\partial \boldsymbol{B}_z(x,t)}{\partial x} = \mu_0\epsilon_0\frac{\partial B_z(x,t)}{\partial t}$, then $E_{max} = cB_{max}$ and $\phi = 0$.

2.

A source of sinusoidal electromagnetic waves radiates uniformly in all directions. At a distance of 10.0 m from this source, the amplitude of the electric field is measured to be 3.50 N/C. What is the electric field amplitude 20 cm from the source?

3.

Two square reflectors, each side of length a and of mass m, are located at opposite ends of a thin, extremely light, rod length l that can rotate without friction and in vacuum about an axle perpendicular to it through its center. These reflectors are small enough to be treated as point masses in moment-of-inertia calculations. Both reflectors are illuminated on one face by a sinusoidal light wave having an electric field of amplitude A that falls uniformly on both surfaces and always strikes them perpendicular to the plane of their surfaces. One reflector is covered with a perfectly absorbing coating, and the other is covered with a perfectly reflecting coating. What is the angular acceleration of this device?



4. HeNe Laser

He-Ne lasers are often used in physics demonstrations. They produce light of wavelength 633 nm and a power 0.500 mW spread over a cylindrical beam 1.00 mm in diameter (although these quantities can vary). What is the intensity of this laser beam? What are the maximum values of the electric and magnetic fields? What is the average energy density in the laser beam?

5. Space Dust

Interplanetary space contains many small particles referred to as *interplanetary dust*. Radiation pressure from the sun sets a lower limit on the size of such dust particles. To see the origin of this limit, consider a spherical dust particle of radius R and mass density ρ.

a) Write an expression for the gravitational force exerted on this particle by the sun (mass M) when the particle is a distance r from the sun.

b) Let L represent the luminosity of the sun, equal to the rate at which it emits energy in electromagnetic radiation. Find the force exerted on the (totally absorbing) particle due to solar radiation pressure, remembering that the intensity of the sun's radiation also depends on the distance r. The relevant area is the cross-sectional area of the particle, not the total surface area of the particle. As part of your answer, explain why this is so.

c) The mass density of a typical interplanetary dust particle is about 3000 kg/m^3. Find the particle radius R such that the gravitational and radiation forces acting on the particle are equal in magnitude. The luminosity of the sun is 3.9 x 10^{26} W. Does your answer depend on the distance of the particle from the sun? Why or why not?

d) Explain why dust particles with a radius less than that found in part (c) are unlikely to be found in the solar system. [*Hint:* Construct the ratio of the two force expressions found in parts (a) and (b).]