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COLLAB #11

Electromagnetic waves, polarization, energy and momentum

The x component of an electromagnetic wave at frequency ω is given by

$$E^x = E_1 \sin\left(\beta \left[x + \sqrt{3}z\right] + \omega t\right) ,$$

where β is positive. The electric field has no y component. Give answers to PARTS 1 through 3, below in terms of E_1 , ω , and c .

PART 1 (20 points)

What is the value of β ?

PART 2 (20 points)

What is the z component of the electric field?

PART 3 (20 points)

What is the magnetic field $\vec{\mathbf{B}}(x, z, t)$?

The questions below, in PARTS 4, 5 and 6, are related to each other, but are not related to the questions above.

An electromagnetic wave propagating in the z direction has an electric field given by

$$\vec{\mathbf{E}} = E_p \sin(\omega t - \omega z/c) \hat{\mathbf{i}}.$$

The electromagnetic field is incident on a sheet of material at $z = 0$. An electron in one of the atoms of the material is accelerated by the electric field, which forces the electron to oscillate in the x direction with a motion given by

$$x = X_p \sin(\omega t + \delta) .$$

(The amplitude and phase of this motion are determined by atomic interactions, including dissipation of the electron's energy due to interactions with other electrons, and due to the emission of radiation by the electron.)

Give answers in PARTS 4, 5 and 6 in terms of E_p , X_p , ω , δ , c and $q = -e$, the charge of an electron.

PART 4 (15 points)

What is the time average power absorbed by the electron?

PART 5 (15 points)

Find the magnetic force on the electron. (There will be a magnetic force since the electron is moving and the electromagnetic wave has a magnetic field.) Give the force as a function of time and be sure to give the vector direction of the force. From this, find the time average magnetic force on the electron.

PART 6 (10 points)

In complete coherent sentences discuss the rate at which the electron absorbs momentum from the wave (see PART 5) and the rate at which it absorbs energy (see in PART 4). Show that the relationship agrees with Eq. (34-23).