4.5: Polarization

Tutorial 4.5: Polarization

In the last simulation a **polarized wave** was defined to be an electromagnetic wave that has its electric field confined to change in only one direction. In this simulation we will further investigate polarized waves. In the simulation the small graph on the upper right (which can be expanded with the Phasor checkbox) shows the electric field component[s] for a plane wave traveling straight towards you in the $+y$ direction and the resultant field, $E(y,t) = E_{\max}\sin(ky - \omega t)$, in blue. The two other graphs plot the E_x and E_z components of the electric field. The magnitude of E_x is fixed at $6.0\ \mathrm{N/C}$. The magnetic component, always perpendicular to the electric component, is not shown. In all cases the components are sinusoidal (the time component of the field is shown for $\omega = 1$ and a fixed location of $y = 0$).

Polarization

Questions:

Exercise 4.5.1

Play the simulation. Describe what you see. The graph on the right, which can be enlarged with the phasor check box, is what was happening in red box in the initial case of the previous simulation; an electric field oscillating in the x-direction. What is the maxium field in the present case? Is this a polarized wave?

The Poynting vector is the vector cross product of the electric and magnetic field vectors: $\mathbf{S} = \mathbf{E}\times\mathbf{B}/\mu_0$ where μ_0 is a constant called the permeability (recall from simulation three that the speed of an electromagnetic wave is given by $c = (1/\mu_0\varepsilon_0)^{1/2}$ where μ_0 is the permeability and ε_0 is the the permittivity. The magnitude of the vector gives the intensity of an electromagnetic wave in $\mathrm{W/m^2}$ and the vector points in the direction that the wave is traveling. Since the magnetic field amplitude is proportional to the electric field amplitude, the Poynting vector (the intensity) is proportional to electric field amplitude squared.

Exercise 4.5.2

If the Poynting vector points out of the screen towards you, what direction does the magnetic field point that corresponds to the electric field vector shown in the simulation initially?

Exercise 4.5.3

The x-component of the electric field is fixed at $6\ \mathrm{N/C}$. Use the slider to choose a value of $6\ \mathrm{N/C}$ for the value for the z-component of electric field and play the simulation. Describe what you see. How is this case similar to that of question 4.2.7? Is this a polarized wave?

Exercise 4.5.4

Try some other values for E_z. Describe the case for $E_x = 6\ \mathrm{N/C}$ and $E_z = 4\ \mathrm{N/C}$. Which way does the electric field vector point? These are all polarized waves with different orientations.

The phase, φ, determines the phase between E_x and E_z. For zero phase the two vector components start out at zero at the same time and increase together, in phase.

Exercise 4.5.5

For $E_z = 6\ \mathrm{N/C}$ choose a phase difference of $1\ \pi$ radians (use the slider to set the phase to 1.0). What do you observe?

Exercise 4.5.6

Reset the simulation, use $E_z = 6 \text{ N/C}$ and try $0.5\,\pi$ radians. This case is called **circularly polarized** light. Note that the x- and y-components are still sine waves but the total electric vector (blue arrow) has a fixed magnitude. Describe what you see.

If the phase angle φ is not a whole number or half a whole number times π the light is **elliptically** polarized.

Exercise 4.5.7

Try other values for the phase with the maximum amplitudes the same. Describe what you see. What can you conclude about whole numbers of π radians for a phase difference? What about half whole numbers? What about values in between?

Exercise 4.5.8

In your own words, describe how an elliptically polarized electromagnetic wave looks as it probagates through space. (Recall that the wave is travelling in the y-direction which is out of the screen towards you in this case.)

Cirularly and elliptically polarized waves can be **right-circularly polarized** or **left-circularly polarized** depending on the sign of the phase angle.

Exercise 4.5.9

Try some negative values for the phase. What is the difference between negative and positive values of phase? In which case does the polarization rotate clockwise as as the wave probagates forward?

Exercise 4.5.10

Explain the difference between left and right circular polarization.