Chapter 25  Electromagnetic Waves

Outline

25-1  The production of Electromagnetic Waves
25-3  The Electromagnetic Spectrum
25-4  Energy and momentum in Electromagnetic Waves
25-5  Polarization
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Natural white light is non-polarized, since the its E vector of the electromagnetic wave vibrates randomly in any direction.

If the E vector vibrates only in one direction, the wave is said to be polarized --- linearly polarized.

The electric field defines the polarization direction.

![Figure 25-11](image)

**Figure 25-11**
Polarization of Electromagnetic Waves
Figure 25-12
Polarized Versus Unpolarized Light

Representation of Polarization

(a) Polarized beam
Polarization direction
Propagation direction

(b) Unpolarized beam
Propagation direction
Light Passing through Polarizer

The polarizer is made of special material, and it allows light go through along one direction – called transmission axis.

Figure 25-13
Mechanical Analog of a Polarizer
The Law of Malus (Transmission of Polarized Light Through a Polarizer)

\[ I = I_0 \cos^2 \theta \]  
\hspace{1cm} (25-13)

Where \( \theta \) is the angle of the polarization direction of the linear polarized input light and the polarizer transmission axis.
Exercise 25-5

Vertically polarized light with an intensity of 515 W/m² passes through a polarizer oriented at an angle $\theta$ to the vertical (transmission axis of a polarizer). Find the transmitted intensity of the light for (a) $\theta=10.0^\circ$ and (b) $\theta=45.0^\circ$, and (c) $\theta=90.0^\circ$.

Solution

(a) \[ I = I_0 \cos^2 \theta = (515W/m^2) \cos^2 10.0^\circ = 499 \ W/m^2 \]

(b) \[ I = I_0 \cos^2 \theta = (515W/m^2) \cos^2 45.0^\circ = 258 \ W/m^2 \]

(c) \[ I = I_0 \cos^2 \theta = (515W/m^2) \cos^2 90.0^\circ = 0 \ W/m^2 \]
Transmission of an un-polarized light

\[ I = \frac{1}{2} I_0 \quad (25-14) \]

It is independent to the angle \( \theta \).
A common experiment

Figure 25-16
A Polarizer and an Analyzer

\[ I = \frac{1}{2} I_0 \cos^2 \theta \]
Example 25-5

In the polarization shown in the sketch, the final intensity of the beam is $0.200 I_0$. What is the angle $\theta$ between the transmission of the analyzer and polarizer?
Active Exercise

Calculate the transmitted intensity for the following cases: [(a) A vertically polarized beam of intensity $I_0$ passes through a polarizer with its transmission axis at 60° to the vertical (transmission axis)]. (b) A vertical polarized beam of intensity $I_0$ passes through two polarizers, the first with its transmission axis at 30° to the vertical, and the second with its transmission axis at 60° to the vertical.
CONCEPTUAL CHECKPOINT 25–3

Consider a set of three polarizers. Polarizer 1 has a vertical transmission axis, and polarizer 3 has a horizontal transmission axis. Taken together, polarizers 1 and 3 are a pair of crossed polarizers. Polarizer 2, with a transmission angle at 45° to the vertical, is placed between polarizers 1 and 3, as shown in the sketch. A beam of unpolarized light shines on polarizer 1 from the left. Is the transmission of light through the three polarizers (a) zero or (b) nonzero?