Phys 132 2022

Lecture 31

Mon: HW by 5pm

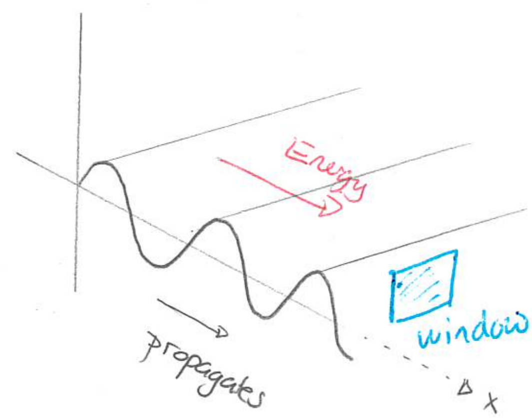
Ex 186, 187, 188, 192, 193, 194, 195, 196

Tues: Warm Up 12

Thurs: Ex III → Magnetism / waves
2017 Ex II Q 5-8
Ex III Q 1 → 3
2018 Midterm III All Q

Intensity of electromagnetic waves

In general one can ask what the wave pattern transports. In classical electromagnetic theory the answer is that the wave transports energy along the direction of propagation. This can be quantified in terms of the electric field.



For a plane sinusoidal wave

$$\vec{E} = \vec{E}_0 \sin(kx - \omega t)$$

We consider the energy propagating through a window that is perpendicular to the direction of propagation. Then the energy that passes depends on:

1) duration of observation
2) size of the window

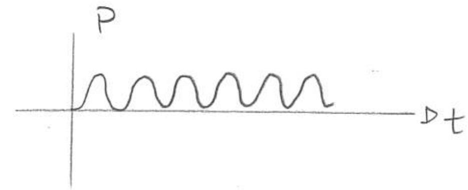
We account for the duration by determining the power delivered through the window. Recall

Power = rate of energy transfer.

Classical electromagnetic theory predicts that the power passing through a window with area A is:

$$P = c\epsilon_0 \vec{E}\cdot\vec{E} A$$

$$\Rightarrow \quad P = c\epsilon_0 E_0^2 A \sin^2(kx - \omega t)$$



We see that this fluctuates but is never negative. We account for the fluctuation by noting that in many situations, the frequency of oscillation is very high (e.g. visible light 10^{15} Hz). We can then determine the average power delivered over a large time. This gives

$$\text{time average power} = \frac{1}{2} c\epsilon_0 E_0^2 A$$

This still depends on the window area. So define

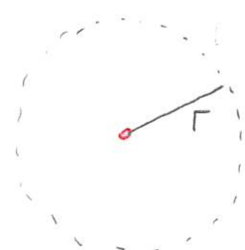
$$\text{Intensity} = I = \frac{\text{power passing through window}}{\text{window area}} = \frac{P}{A}$$

Thus we get

For a plane electromagnetic wave with electric field amplitude E_0,

$$I = \frac{1}{2} c\epsilon_0 E_0^2$$

We can consider a situation where a wave propagates spherically from a source. Then all power from the source passes a sphere with radius r. So at this sphere

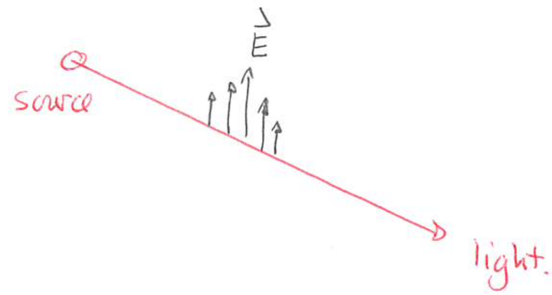


$$I = \frac{P_{source}}{4\pi r^2}$$

Warm Up 1

Polarization

An electric field has a vector nature and this should manifest itself with electromagnetic waves. Electromagnetic theory states that the electric field must be perpendicular to the direction of propagation. However, there are many possibilities.

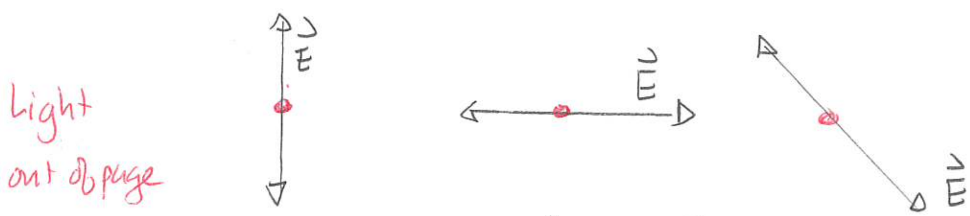


Slide 1

Slide 2

Slide 3

We can view this along the direction of propagation



electric field oscillates along vertical
~ vertically polarized

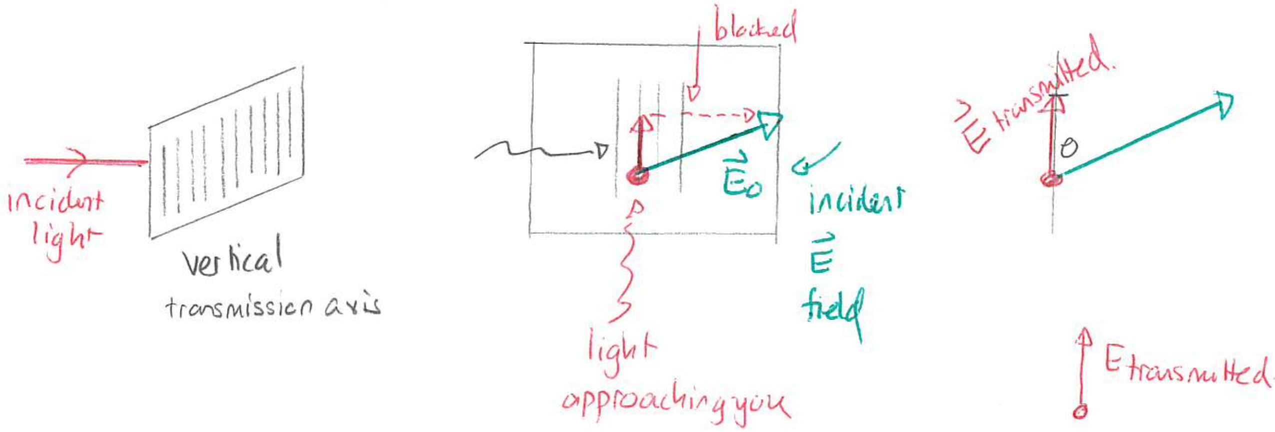
horizontally polarized

linearly polarized.

Linearly polarized light is such that the $\vec{E}$ field oscillates along one line only. Unpolarized light is such that the line of oscillation changes frequently and randomly.

Polarized light can be manipulated via a polarizer or a polarizing filter

> A polarizing filter has a preferred axis called the transmission/polarizer axis. The polarizer blocks the component of the electric field vector perpendicular to the axis and transmits the parallel component.



In general the electric field for the transmitted light will be smaller than that for the incident light. This can be used to show:

> Suppose linearly polarized light with intensity I_o is incident on a polarizer. Then:
>
> 1) the transmitted light will be linearly polarized along the polarizer axis
>
> 2) the intensity of the transmitted light is $I = I_o \cos^2\theta$
>
> where θ is the angle between polarization axis of incident light and the transmission axis

Separately:

> If unpolarized light with intensity I_o is incident on a polarizer then:
>
> 1) the transmitted light is linearly polarized along the polarizer axis
>
> 2) the intensity of the transmitted light is $I = \frac{1}{2} I_o$

~~Demo~~

Quiz1

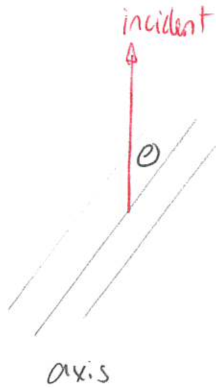
Quiz 2

Warm Up2

} Demo: pol. filters

Example: Vertically polarized light is incident on a polarizer. The intensity of the transmitted light is $\frac{1}{4}$ of the intensity of the incident light. Determine the orientation of the polarization axis.

Answer:



$$I = \frac{1}{4} I_0$$

$$\cancel{I_0} \cos^2\theta = \frac{1}{4} \cancel{I_0}$$

$$\cos\theta = \frac{1}{2}$$

$$\Rightarrow \theta = \cos^{-1}(1/2) \Rightarrow \theta = 60°$$

So the angle is 60° from the vertical.