Phys 112 2019

Lecture 23

Tues: Exam Review

Weds: Exam II

Covers Ch 22, 23.1 → 23.3, 24, 25.1 → 25.4

Review previous: 2012 Ex II except Q7

2013 v1, v2 ~~all~~ Ex II all Q

Electromagnetic Waves

Maxwell's equations provide a prescription for determining electric and magnetic fields if the source charges and currents are known. In a vacuum, where no such sources exist the equations predict the existence of waves of electric and magnetic fields.

Demo: PhET Radio waves → make these oscillate
→ show "curve with vectors"
→ show "full field."

The theory also predicts:

1) electromagnetic waves with all possible wavelengths and frequencies exist
2) regardless of the wavelength and frequency the speed of an electromagnetic wave in a vacuum is

$$c = 3.0 \times 10^8 \mathrm{m/s}$$

and this is the speed of light.

In all cases a general rule for waves applies

$$v = \lambda f \Rightarrow \boxed{c = \lambda f}$$

Demo: Show NASA EM radiation

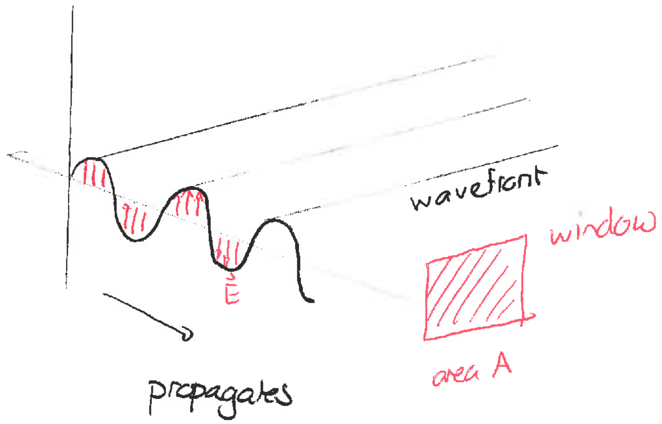
Energy, power and intensity of electromagnetic waves

The theory of electromagnetism also predicts that waves transport energy along the direction in which the pattern propagates.

The amount of energy transported depends on:

1) the time for which the wave propagates

2) the spatial extent of the wavefront



For this reason we consider

1) the power transported

$$P = \text{Energy} / \text{Time}$$

2) the area of the window through which the wave is viewed, A.

Then the intensity of the wave is:

$$\boxed{I = P/A}$$

units W/m²

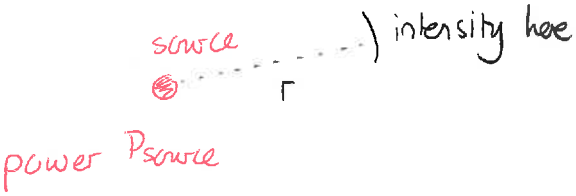
This is what we usually perceive as brightness. Electromagnetic theory predicts that

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

where E_0 is the amplitude of the electric field and $\epsilon_0 = 8.85 \times 10^{-12}\ Nm^2/C^2$

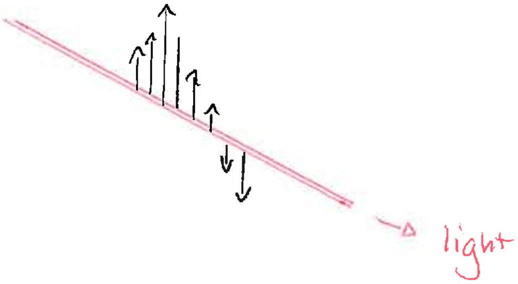
For light that radiates uniformly in all directions from a small point light source, the intensity at distance r from the source is

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



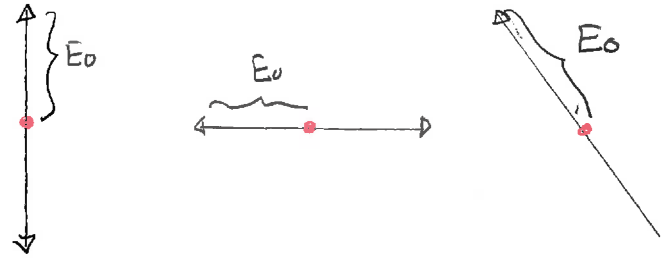
Warm Up 1

Polarization



Consider a narrow beam of light. This is accompanied by an electric field, which is a vector. The only constraint that electromagnetic theory requires is that the vector is perpendicular to the direction of polarization. This implies that there are many possible directions for the field. Some possibilities are.

Light approaches you



electric field always vertical (vertically polarized)

horizontally polarized

These all give the same intensity. Most dectectors (e.g. eyes) cannot tell the difference between these.

Slide 1

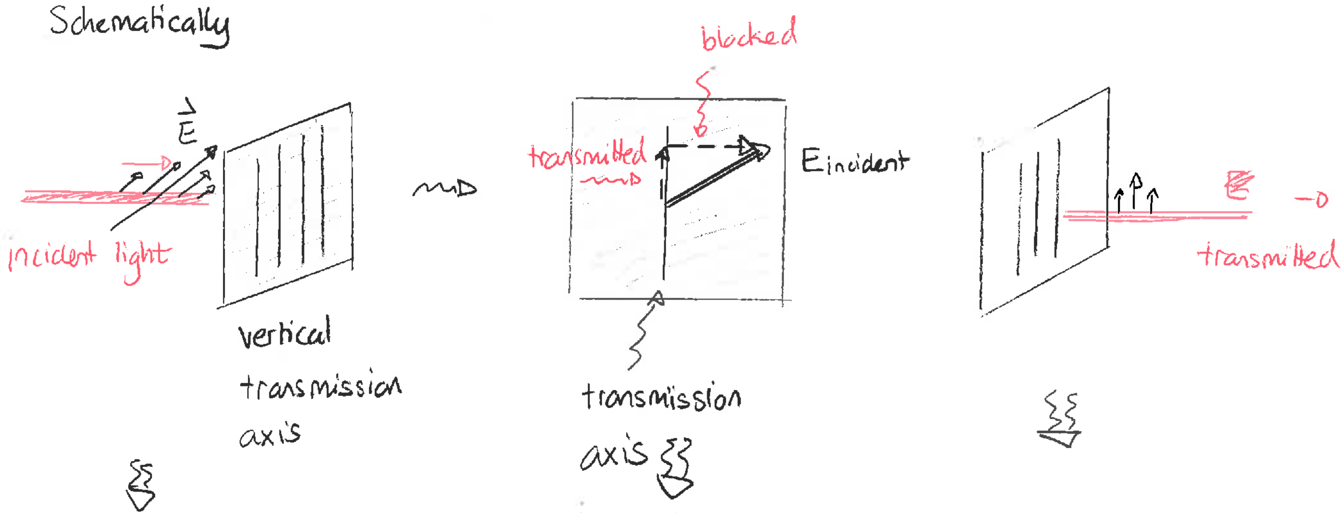
Slide 2

Slide 3

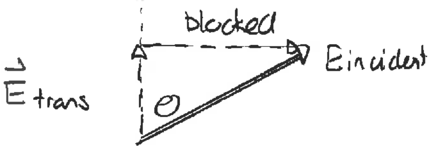
We can manipulate the electric field vectors associated with light via a polarizer or polarizing filter. The crucial facts are:

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

Schematically



Incident field angled relative to transmission axis



Transmitted field along transmission axis

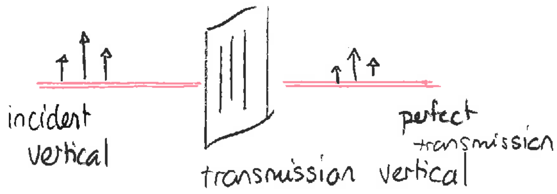
⇒ light is polarized along direction of transmission axis.

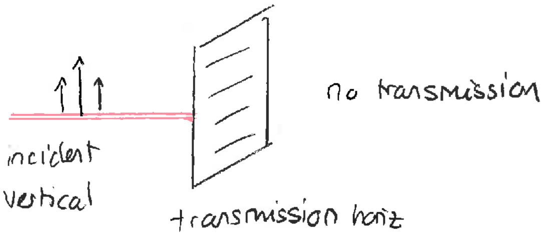
Warm Up 2

Demo: Show polarizing filters

Quiz 1 90%

Note extremes.

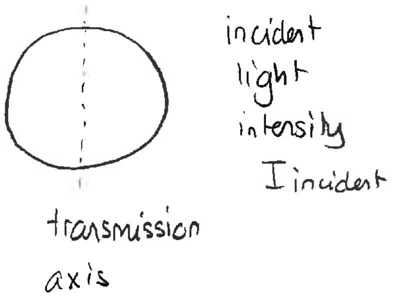




We can predict the relative intensity of the transmitted light as follows:

Incident light

unpolarized



transmitted light:

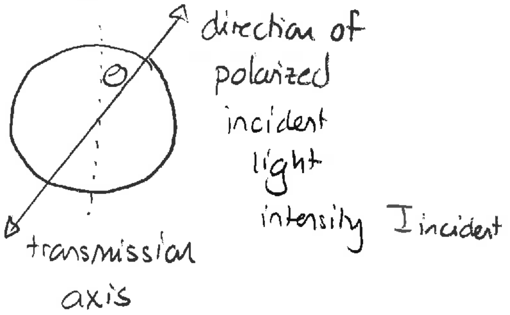
* intensity

$$I_{transmitted} = \frac{1}{2} I_{incident}$$

* polarized in direction along polarization axis

Incident light

polarized



transmitted light:

* intensity

$$I_{transmitted} = \cos^2\theta \ I_{incident}$$

* polarized in direction along polarization axis

Quiz 2