Massachusetts Institute of Technology - Physics Department

Physics - 8.02 **Assignment #9** April 24, 2002.

We strongly recommend that you read about a topic before it is covered in lectures.

Lecture Date	Topics Covered	Reading from Giancoli
#29 Fri 4/26	Snell's law - Refraction - Total Reflection Dispersion - Prisms - Huygen's Principle The Illusion of Color - The weird Benham Top Edwin Land's famous demo	Sect. 33-5, 33-6 & 33-7 Chapter 35 through Sect. 35-2
#30 Mon 4/29	Polarizers - Malus's law Brewster angle Polarization by reflection and scattering Why is the sky blue, why are sunsets red? ***the sun will set in 26-100!***	**Handout Optics Kits** Sect. 36-11 & 36-12 *Take Notes!*
#31 Wed 5/1	***Rainbows*** (***take notes***) ***A modest rainbow will appear in 26-100!*** Supernumerary bows - Fog bows Polarization of the bows Halo's around the sun and the moon - mock suns	***Bring a friend, this lecture may also be appreciated by non 8.02 "experts".*** Sect. 33-6

Due before 4 PM, Wednesday, May 1 in 4–339B.

Problem 9.1
Wavelength of radio waves.
Giancoli 32-37.

Problem 9.2
Traveling Electromagnetic Waves.
Consider three examples of a plane, monochromatic, electromagnetic wave traveling in a homogeneous medium. The electric field vector is given in each case by

case (1) $E_x = 0$; $E_y = 0$
$E_z = -25\, sin(1.57x + 4.71 \times 10^8 t)$

case (2) $E_x = 0$; $E_z = 0$
$E_y = 50\, cos(3.14x - 9.42 \times 10^8 t)$

case (3) $E_x = 0$; $E_y = 0$
$E_z = 40\, cos(6.28x + 1.34 \times 10^9 t)$

where $|\vec{E}|$ is measured in V/m, t in sec, and x in m. For each case, answer the following questions:

(a) What is the propagation direction of the wave?

(b) What is the wavelength? What is the wave number?

(c) What is the frequency of the wave in Hz?

(d) What is its speed?

(e) What is the index of refraction of the three media?

(f) What are the corresponding equations for the magnetic field, $\vec{B}$

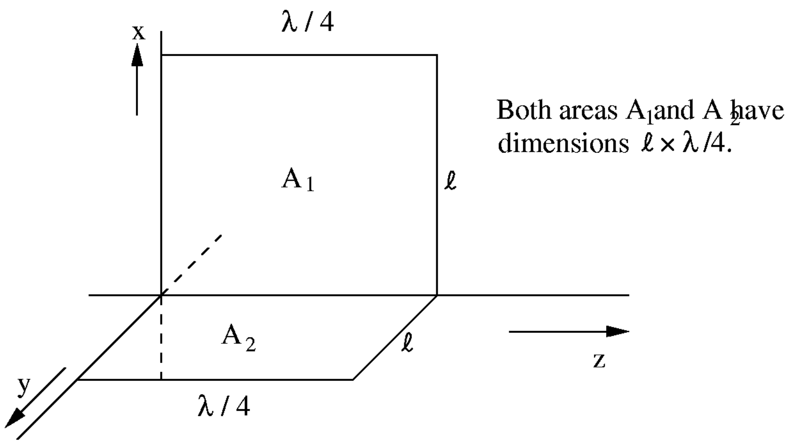
(g) For case (3), what is the time-averaged Poynting vector (magnitude and direction) for the position $x = y = z = -3$, and what for $x = 5$, $y = z = -3$?

Problem 9.3 *E-M Waves – Maxwell's Equations, and the "speed of light".*
We discussed in lectures that traveling Electromagnetic waves in vacuum of the form

$$\vec{E} = E_o\,\hat{x}\,\cos(kz - \omega t), \vec{B} = B_o\,\hat{y}\,\cos(kz - \omega t)$$

satisfy *all* 4 Maxwell's equations. In lectures, I showed that an application of the generalized Ampere's Law (closed loop surrounding area A_2, see below), leads to: $B_o = \varepsilon_o \mu_o c E_o$, and I mentioned that independently it follows from an application of Faraday's Law that $B_o = E_o/c$. Combining these two results then leads to the fantastic result that the "speed of light" in vacuum $c = 1/(\varepsilon_o \mu_o)^{0.5}$. I want you to show that Faraday's Law indeed leads to the result $B_o = E_o/c$. You can show this by choosing a similar special area as we did in lectures:

Apply Faraday's Law, $\oint \vec{E} \cdot d\vec{\ell} = -\frac{d\phi_B}{dt}$, by choosing an area A_1, shown below, and calculate separately $d\phi_B/dt$ and $\oint \vec{E} \cdot d\vec{\ell}$.



Problem 9.4
A Standing Electromagnetic Wave.
A wave solution to Maxwell's Equations is given by $\vec{E} = E_0\,\hat{x}\,cos(2\sqrt{3}z)\,cos(7.0 \times 10^{10}t)$ where z is measured in centimeters and t in seconds.

(a) What is the wavelength and the frequency (in Hz) of the wave?

(b) What is the index of refraction, n, of the medium?

(c) Give the expression for the associated magnetic field, $\vec{B}$, in terms of E_0, z and t.

(d) What is the time-averaged Poynting vector for $x = y = 3$, $z = \sqrt{3}$?

Note: Part (c) is not as easy as it may seem. Your solution must satisfy all Maxwell's equations.

Problem 9.5
Polarization of Electromagnetic Radiation.

(a) Describe the polarization state of the plane E-M waves represented by the following equations for the electric field $\vec{E}(x,t)$ ($E_x = 0$ *in all three cases*):

(1) $E_y = E_0\, sin(kx - \omega t)$, $E_z = 4E_0\, sin(kx - \omega t)$
(2) $E_y = -E_0\, cos(kx + \omega t)$, $E_z = E_0\, sin(kx + \omega t)$
(3) $E_y = 2E_0\, cos(kx - \omega t + \frac{\pi}{2})$, $E_z = -2E_0\, sin(kx - \omega t)$

(b) In each case, give the corresponding equations for the magnetic field, $\vec{B}$. Assume $\omega/k = c$.

Problem 9.6
Radiation pressure due to the Sun.
Giancoli 32-29.

Problem 9.7
Snell's law in action ⇒ Dispersion!
Giancoli 33-46.

Problem 9.8
Snell's law in action ⇒ Fiber optics!
Giancoli 33-53.