April 20, 2003

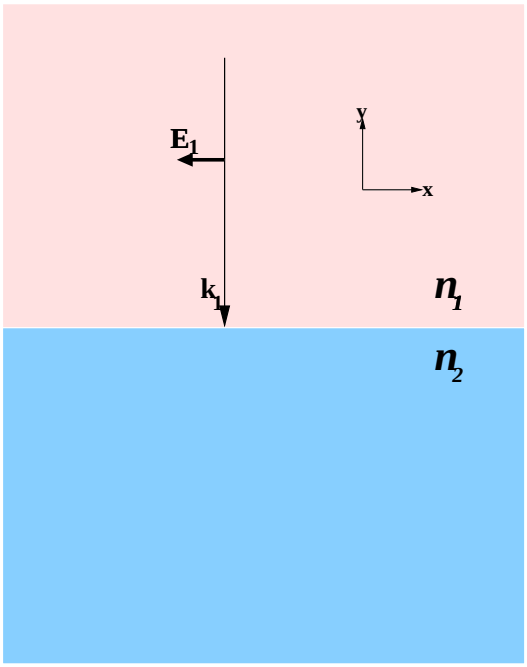
Name:_____

PHY 114 – Third exam

Note: Please record all of your work (diagrams, mathematical manipulations, and numerical work) in the the space provided on this exam paper (front and back). You should show your intermediate steps so that partial credit can be awarded if appropriate. There are 5 equal weight parts to the exam. The 5^{th} part is an essay-like question for which there are several choices. When your work is completed, please staple your equation sheet to the back of this exam and make sure that your name is on the front page of the exam.
It is assumed that all of your work is done under the guidelines of the honor code. Specifically, you may *only* consult your equation sheet and text book during the exam.

1. Write down Maxwell's equations, defining each of the terms.

2.



The figure above shows a snapshot of a plane polarized periodic electromagnetic wave traveling in a medium having a refractive index of n_1. The corresponding electric field takes the form

$$\mathbf{E}_1(y,t) = E_{max_1}(-\hat{\mathbf{x}}) \sin\left(-\frac{2\pi y}{\lambda_1} - 2\pi f_1 t\right). \tag{1}$$

There is an interface perpendicular to the direction of the incident wave below which there is a second medium of refractive index n_2. In the following, use the symbols $\{E_{max_1}, B_{max_1}, k_1, \lambda_1, f_1, \text{etc}\}$ to refer to the incident beam, $\{E'_{max_1}, B'_{max_1}, k'_1, \lambda'_1, f'_1, \text{etc}\}$ to refer to the reflected beam, and $\{E_{max_2}, B_{max_2}, k_2, \lambda_2, f_2, \text{etc}\}$ to refer to the refracted beam. The given numerical values are E_{max_1}=10 N/C, n_1=1, $f_1 = 6 \times 10^{14}$ cycles/s and n_2=1.5.

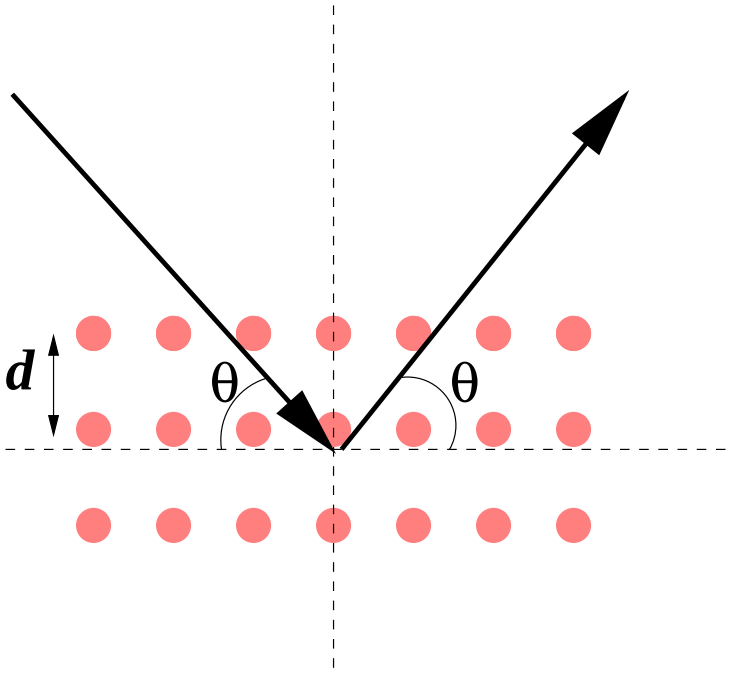
(a) Complete the sketch of the snap shot by including the refracted electric field $\mathbf{E}_2(y,t)$ with its propagation wavevector $\mathbf{k_2}$ and the reflected electric field $\mathbf{E}'_1(y,t)$ with its propagation wavevector $\mathbf{k'_1}$ on the figure.

(b) What is the direction and magnitude of the incident magnetic field amplitude B_{max_1}?

(c) Find the numerical values of the following quantities:

i. f_1
ii. f'_1
iii. f_2
iv. λ_1
v. λ'_1
vi. λ_2
vii. E'_{max_1}

3. The figure above shows Sherlock Holmes looking through a converging lens at a piece of evidence. Assume that the focal length of his lens is $f = 10$ cm. If he adjusts the distance p of the lens relative to the object appropriately, he is able to see the image magnified by 3 times its original size. In the space below, draw the ray diagram for this case, and determine the object and image distances p and q. Indicate whether the image is real or virtual.



4. The figure above shows an electron beam being diffracted from crystal planes separated by a distance of $d = 0.463$ nm. If the angle for the first order diffraction peak is found to be $\theta = 22^o$, what must be the kinetic energy of the electrons in the beam?

5. Choose one of the following "essay" questions. Be as quantitative as possible and include at least one appropriate equation in your answer.

   (a) Explain the basic physics of the operation and use of the scanning tunneling microscope.

   (b) Describe the basic physics of the Compton effect and explain how it contributed to the development of quantum theory.

   (c) Describe the Doppler effect for electromagnetic waves in comparison with the Doppler effect for sound waves. As an illustrative example, estimate the velocity of a star which has a spectral feature which has the frequency it its rest frame of $f = 7.5 \times 10^{14}$ cycles/s which is detected on Earth at a frequency of $f' = 5.0 \times 10^{14}$ cycles/s.

   (d) Describe how lenses can be used to help correct the vision of nearsighted or farsighted people.

   (e) Describe the basic physics of forming a rainbow.

**********End of Exam**********