PHY385H1F – "Introductory Optics"
Term Test 1
October 12, 2010
Duration: 50 minutes

Please complete the following problems in the examination booklet provided. Show all your work. You will be graded more on correct method than correct answer. If you take an equation from the Hecht text, please give the equation number and page number.

Aids allowed: A pocket calculator with no communication ability. "Optics" 4th Edition (Copyright 2002) by Eugene Hecht.

Possibly helpful information:

The permittivity of free space is $\varepsilon_0 = 8.85 \times 10^{-12}\ \mathrm{m^{-3}\ kg^{-1}\ s^4\ A^2}$
The mass of the electron is $m_e = 9.11 \times 10^{-31}$ kg
The charge of the electron is $q_e = 1.60 \times 10^{-19}$ C

You may not communicate with anyone other than the invigilator during the test.

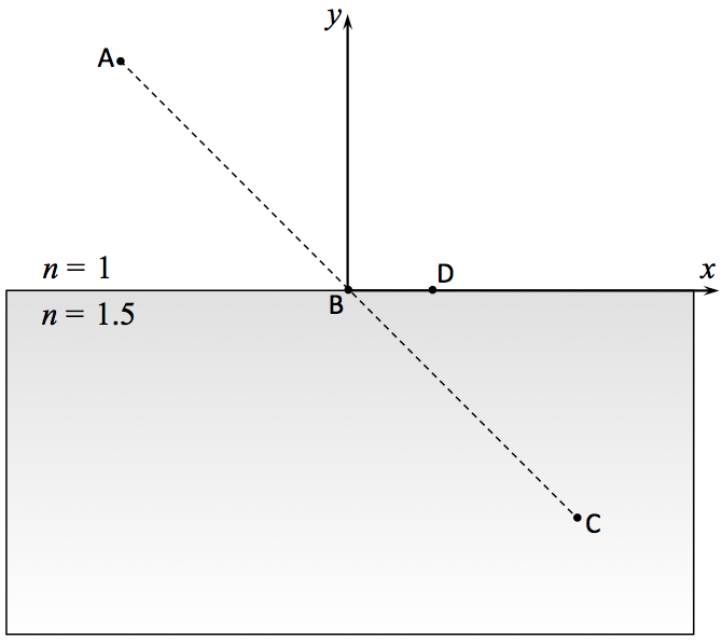
[50 points total for the test]

1. A harmonic travelling plane-wave in the electric field is moving in the negative x-direction with an amplitude of $2\,\hat{j}$ V/m, a wavelength of 3 m, and a period of 10^{-8} s. (Note that $\hat{j}$ is the unit vector in the $+y$-direction.) The electric field at the origin is zero at time zero. Immediately after $t = 0$, the electric field at the origin is in the $+y$-direction. Write an equation for this wave
   a. using trigonometric functions. **[5 points]**
   b. using complex exponentials. **[5 points]**

2. A crown-glass prism has a strong absorption resonance at a frequency of 2.9×10^{15} Hz. The electrons which contribute to the polarization density in the glass at this frequency have a density of $N = 1.4 \times 10^{29}\ \mathrm{m^{-3}}$. From this information, predict the index of refraction of glass for light with a frequency of 4.1×10^{14} Hz. [Please write your final answer to 3 significant figures.] **[10 points]**

3. Consider a long, narrow source of light that emits cylindrically symmetric electromagnetic radiation. Using energy arguments, show that the electric-field amplitude the waves must be proportional to $[\rho]^{-1/2}$, where ρ is the distance from the source. **[10 points]**

4. A quick pulse of laser light is sent from point A, in air, to point B, on the surface of a large glass block. At point B, it immediately triggers another laser pulse to be sent to point C, which is within the glass. Points A, B and C lie along a straight line, as shown. Point A has coordinates: $(x_A,y_A) = (-1.0\text{ m}, +1.0\text{ m})$. Point B lies at the origin, and point C has coordinates: $(x_C,y_C) = (+1.0\text{ m}, -1.0\text{ m})$. The index of refraction of the glass for this laser light is $n = 1.50$. The time for the pulse to travel the path A-B-C is $t_{AB} + t_{BC} = x_{AB}/c + n\,x_{BC}/c = \dfrac{\sqrt{2}}{3\times10^8}(1+n) = 11.8$ ns.



Consider the path A-D-C, where the coordinates of point D are $(x_D,y_D) = (+0.36265\text{ m}, 0\text{ m})$.

a. Compute the time for the laser light pulse to travel along the path A-D-C. **[5 points]**
b. Show that this is the minimum possible travel time for this pulse. **[5 points]**

5. Unpolarized light in air is reflected from a plane surface of fused silica glass of index 1.458.
   a. Determine the polarizing angle for external reflection. **[2 points]**
   b. If light is reflected at an incidence angle of 45°, what is the ratio P_{TE}/P_{TM}, where P_{TE} is the power reflected in the TE-mode, and P_{TM} is the power reflected in the TM-mode? **[8 points]**