PHY385H1F – "Introductory Optics"
Problem Set 5
Due: **November 24**, 2011

Instructions: Please complete the following problems on separate paper. 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.

Total Possible: 30 points.

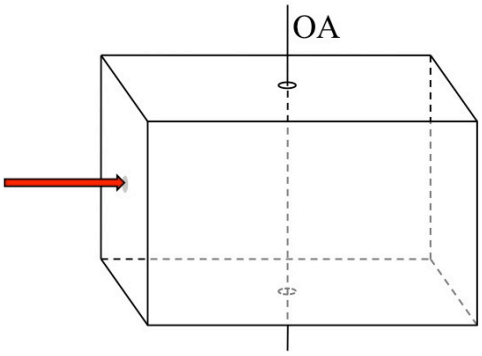
Based on Chapter 8 of Optics (4th Edition) by Eugene Hecht, ©2002 by Addison-Wesley:

1. **[2 points for part a, 3 points for part b]** Describe the polarization state of the following waves:
   a. $\vec{E} = \hat{i}E_0\cos(kz-\omega t) - \hat{j}E_0\cos(kz-\omega t)$
   b. $\vec{E} = E_0\left(3\hat{i} - 4i\,\hat{j}\right)e^{i(kz-\omega t)}$

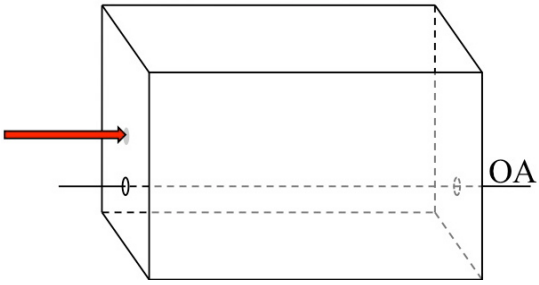
   Please be careful to distinguish between i, which is the base unit of imaginary numbers ($i = \sqrt{-1}$), and $\left(\hat{i},\hat{j},\hat{k}\right)$, which are unit vectors in the (x, y, z) directions, and k, which is the propagation number of the wave with units of rad/m ($k = 2\pi/\lambda$). In your description of the polarization state, please specify if the light is in a $\mathcal{P}$, $\mathcal{L}$, $\mathcal{R}$ or $\mathcal{E}$ state, and make a rough sketch of how the electric field vector oscillates in the x-y plane.
2. **[4 points]** Initially unpolarized light traveling in the +z-direction passes in turn through three linear polarizers, with transmission axes at 0°, 30°, and 60°, respectively, relative to the x-axis. What is the irradiance of the produced light, expressed as a percentage of the original Unpolarized light irradiance?

3. **[8 points]** Unpolarized light is incident on a block of birefringent material, with the optic axis (OA) oriented as shown in the diagrams below. For each situation (a, b, c and d), answer the following questions:
   i. Is there a single refracted ray or double refracted rays?
   ii. Is there any phase retardation between the different emerging polarization states?
   iii. Is there polarization of any of the refracted rays?

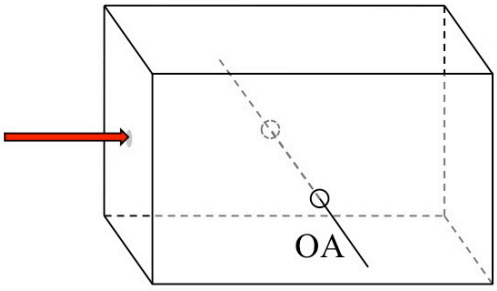
a)



b)

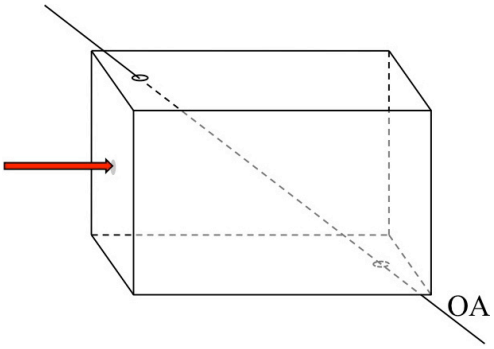


c)

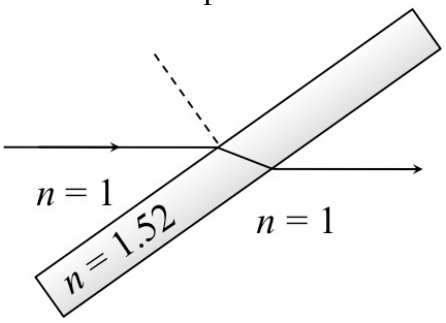


(Optic Axis emerging normal to front surface of the block)

d)



4. **[1 point for part a, 4 points for part b]** A Brewster's Window is a slab of material, such as glass, oriented at an angle relative to a beam of light, so that the emerging beam is polarized. Shown in the diagram below is a Brewster's Window made of glass with $n = 1.52$.
   a. Find the Brewster's angle, θ_p, such that the light transmitted into the glass from the first air-glass interface is polarized.
   b. Find the angle of incidence of the polarized beam on the second interface (glass-air). Compare this with the Brewster's angle in this case.



5. **[3 points]** The electric field vector of an incident $\mathcal{P}$-state state wave traveling in the $+z$-direction makes an angle of +30° with the fast x-axis of a quarter-wave plate. Describe the state of polarization of the emergent wave. In your description of the polarization state, please specify if the light is in a $\mathcal{P}$, $\mathcal{L}$, $\mathcal{R}$ or $\mathcal{E}$ state, and make a rough sketch of how the electric field vector oscillates in the x-y plane.

6. **[3 points]** What is the rotation of linear polarization vector, in degrees, due to optical activity by the thinnest quarter wave plate of quartz? Assume the refractive indices for quartz are: $n_e = 1.56771$, $n_o = 1.55815$, $n_{\mathcal{R}} = 1.55810$, and $n_{\mathcal{L}} = 1.55821$.

7. **[2 points]** Compute the half-wave voltage for a longitudinal Pockels cell made of ADA (ammonium dihydrogen arsenate) at a vacuum wavelength of $\lambda_0 = 550$ nm, where the electro-optic constant is $r_{63} = 5.5 \times 10^{-12}$ m/V and the ordinary index of refraction is $n_o = 1.58$.