Problem Set 3 – Phys 4510 Optics – Fall 2014

Due date: Th, September 25, in class

Reading: Hecht 4.2 -4.6, 8.6 and Fowles 2.2 - 2.4, 2.6 - 2.7

1. We want to study the effect of a refractive medium (without loss) on the propagation of a light wave. Consider a glass plate of thickness d with index of refraction n, and a incident plane wave $E(x,t) = E_0 \exp\{i\omega(t - x/c)\}$ (x-direction normal to the glass plate). Give the expression for the electric field after passing the glass plate and explain the terms that arise from the modification of the field through n.

2. Brewster's Angle: for this problem you shall actually do a real experiment, with the help of your polarizers. What you shall learn is that in fact with even quite primitive equipment one can actually do nice physics. The goal is to conceive and carry out a simple experiment to determine the Brewster angle with reasonable accuracy. First, you need a light source: take the sun, a halogen desk lamp, a flash light, or a laser pointer, or what have you. If your source is divergent consider using paper or cardboard to aperture it down to a narrow beam of light. As medium, what dielectric surfaces come to mind, window, water, coffee, beer, ... A ruler, tape measure, ... Take it from there.

    a) Sketch your setup and label and annotate with key experimental parameter.
    b) Provide the value of your Brewester angle with an estimate of its uncertainty based on your experimental configuration. Use your value to derive a value for the index of refraction of the medium you choose.
    c) Compare your Brewester angle and index of refraction with its theoretical value based and the literature value for the index of refraction for your medium.

3. We continue with that interesting phenomenon of the Brewster angle. In class, before introducing the Fresnel equations we have derived it based on an empirical argument on the emission direction of induced optical dipoles. Now use the Fresnel equations and work the following problems:

    a) Show that light incident at $\theta_i = 90^\circ - \theta_t$ results in a reflected beam that is polarized.
    b) Derive the relationship for the Brewster's angle $\tan\theta_{\mathrm{i}} = \mathrm{n1/n2}$

4. In class we have used Fermat's principle to derive Snell's law. Apply the principle to derive the law of reflection, i.e., $\theta_i = \theta_r$.

5. A scuba diver, at a depth of $d = 10$ m below the water surface, when looking up sees a circular region through which he can look outside the water. The index of refraction of water is $n = 1.33$. Provide corresponding sketches with your solutions to the following problems:

    a) Suppose the sun is at $\phi_S = 45^\circ$ above the horizon as seen by an observer outside the water. Under what angle with respect to the water surface would the diver see the sun from his vantage point 10 m below the surface?
    b) What would be the angle ϕ_{max} under which the diver would observe sun set?
    c) How large is the radius r of that circular field of view of the diver? What does the driver see when looking in other directions?

6. We want to study reflection and refraction of unpolarized light impinging onto a glass surface in air. Consider two different colors: red light at $\lambda_r = 656$ nm subject to a index of refraction of $n_r = 1.5076$, and violet light at $\lambda_v = 405$ nm with $n_v = 1.5236$.

    a) How large is the reflectivity of the surface for normal incidence for both wavelengths?
    b) Under what angle of incidence is the reflected light completely polarized?
    c) How large is the critical angle α_c for total internal reflection?