Exam 4

Instructions

1.) Unless otherwise specified, you have <u>one class period</u> to complete the questions below.

2.) Read all directions carefully.

3.) Show your work in enough detail to allow the graders to completely follow your thought process.

4.) Make sure your calculator is set to perform trigonometric functions in radians & not degrees & use at least 2 significant digits.

5.) Make sure to write your answers legibly. You can write on the back of the exam pages or ask for scratch paper.

1. Wave Polarization

For this problem, consider the time-varying wave equation for an EM wave propagating through free space in the +z direction. (This means E with respect to z and t.) In each subproblem, you may choose all the relevant constants as long as your answer meets the stated criteria.

a.) Write the equation for a wave with linear polarization and state its inclination angle.

b.) Write the equation for a wave with circular polarization.

c.) Write the equation for a wave with elliptical polarization and state its rotation angle and ellipticity angle.

d.) Choose one of the three waves you specified in parts a-c and calculate the average power density it contains.

2. Public WiFi

Suppose that the city of Troy builds a public 5 GHz WiFi network downtown. The WiFi signal is broadcast from many sources and scatters off of buildings and other objects. A component of the scattered broadcast wave travels directly downward into the Hudson river, hitting its surface at normal incidence with an electric field magnitude of 0.05 V/m. The water of the Hudson has $\varepsilon_r = 80$ and $\sigma = 0.1$ S/m.

a.) Does the water act like a good conductor, a low-loss dielectric, or neither for the 5 GHz WiFi signal?

b.) Calculate α, β, η, and λ in the Hudson River. Does the wavelength of the signal increase, decrease, or stay the same when it enters the water?

c.) Calculate the power density (i.e. Poynting vector magnitude) of the signal before it hits the Hudson. Then calculate the reflection coefficient of the wave as it hits the Hudson, and calculate the power densities of the reflected and transmitted waves.

d.) What is the magnitude of the signal's H-field before it hits the water?

e.) Calculate expressions for the conduction and displacement current for the signal transmitted into the water.

f.) What is the skin depth of the signal in the waters of the Hudson? If the Hudson River is 9m deep near Troy, how many skin depths deep is it?

3. Dark Side of the Moon
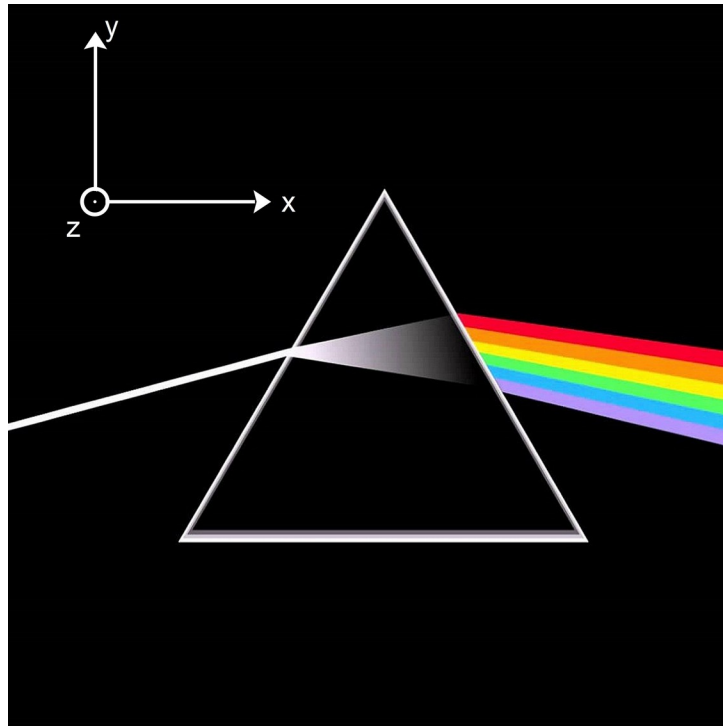
The year is 1973. The band Pink Floyd is trying to get a photograph of light through a prism so they can create some awesome cover art for their album. Unfortunately they're not very knowledgeable about optics so they ask you for help.

a.) In the image above, all the light going into and out of the prism is moving in the xy plane – there is no component moving into or out of the page. If the H-field of the light points in the +z direction, is the light parallel or perpendicularly polarized?

b.) If some of the light is traveling in the +x direction with the E-field in the +z direction, what direction does the E-field point?

c.) Suppose that the light hits the outside of the prism at an incident angle of 40° relative to the normal of the prism's surface. The prism is made of glass with permittivity $4\varepsilon_0$, and the wave is propagating through free space before hitting the prism. What is the angle of transmission into the prism? What is the E-field magnitude of the transmitted wave?

d.) Is there any reflection off of the prism surface? If so, what is its E-field magnitude and reflection angle?

e.) Is there a critical angle for the light entering the prism? If so, what is it?

f.) Is there a Brewster angle for the light entering the prism? If so, what is it?