PHYS302 Fall 2023

Homework 9

1. There is a light wave (assume a plane wave) that is propagating in the z direction. Write down an equation for the electric field of this light if:

    a. the light is linearly polarized;

    b. the light is circularly polarized;

    c. the light is elliptically polarized.

2. Natural (unpolarized) light with intensity I_0 goes through two linear polarizers.

    a. How much light makes it through the first polarizer?

    b. If no light makes it through both polarizers, describe their relative orientation.

    c. You are given 1 more polarizer (3 in total). You put it in between the polarizers in part b without changing their relative orientation from part b. What angle of the new polarizer (with respect to the first polarizer) gives you the maximum light through the system? How much light is this?

    d. You are given 9 more polarizers (11 in total, counting the first two). Keeping the first two polarizers in the same orientation as part b, you place all the others with their axes tilted at 9 degrees from their nearest neighbors each other (including the first polarizer). How much light makes it though the system?

3. At what angle will the reflection of the sky coming off the surface of a pond (n = 1.33) completely vanish when seen through a (properly oriented) Polaroid filter? (I am asking for the angle of reflection made by the light.)

4. Right-circular light passes through a half-wave plate whose fast axis is vertical. Describe the emerging polarization state.

5. Linear light oscillating at 60° above the horizontal *x*-axis in the first and third quadrants passes through a quarter-wave plate with its fast axis horizontal. Explain why the light emerges as left elliptical with its major axis vertical.

6. Suppose you were given a linear polarizer and a quarter-wave plate. How could you determine which was which, assuming you also had a source of natural light?

7. (8.34 from Hecht): The calcite crystal in **Fig. P.8.34** is shown in three different orientations. Its blunt corner is on the left in (*a*), the lower left in (*b*), and the bottom in (*c*). The Polaroid's transmission axis is horizontal. Explain each photograph, particularly (*b*).

Figure P.8.34a

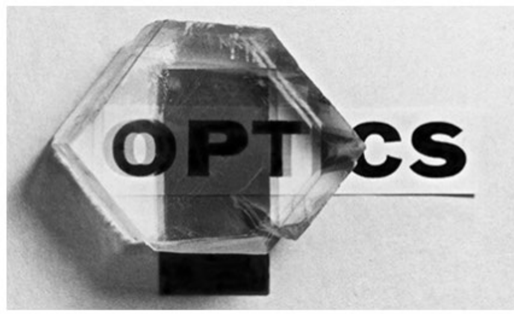


Figure P.8.34b

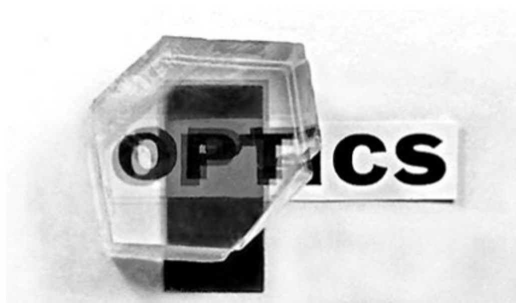
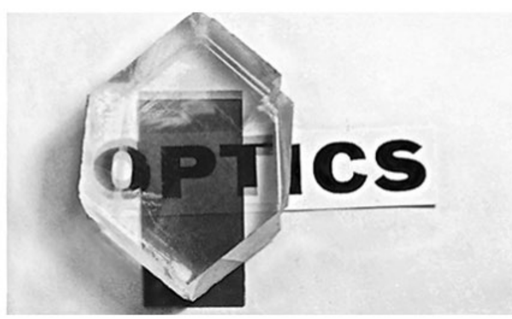


Figure P.8.34c



Extra credit:

The polarization of light is also called the “spin angular momentum of light” and has a basis set of 2 states. In quantum optics, we often use spin “up” and spin “down” for right- and left-circular polarizations.

There is also orbital angular momentum of light, which is different from polarization, and which can have many more states than just 2. This light may no longer have the simple plane wave with a flat wavefront that we usually use in class.

An example of light with non-zero angular momentum is the “donut mode” beam (also called a vortex bean or the Laguerre-Gaussian TEM01* mode).

Research this donut mode beam. Describe it. What gives it its unique profile? How would you make such a beam? (Hint: a special diffraction grating is one way. Can you understand how the diffracted beams have this special angular momentum profile?) Can you find any unique uses of this type of beam?