tromagnetic waves like the oscillating electrons in a radio antenna, how must the magnetic field be oriented with respect to the galactic plane?

PROBLEMS

Section 48-1 Polarization

1. The magnetic field equations for an electromagnetic wave in free space are \( B_x = B \sin (ky + c ot) \), \( B_y = B_z = 0 \).
   \( a \) What is the direction of propagation? \( b \) Write the electric field equations. \( c \) Is the wave polarized? If so, in what direction?

2. Prove that two linearly polarized light waves of equal amplitude, their planes of vibration being at right angles to each other, cannot produce interference effects. \( \text{Hint: Prove that} \) the intensity of the resultant light wave, averaged over one or more cycles of oscillation, is the same no matter what phase difference exists between the two waves.

Section 48-2 Polarizing Sheets

3. A beam of unpolarized light of intensity 12.2 mW/m² falls at normal incidence upon a polarizing sheet. \( a \) Find the maximum value of the electric field of the transmitted beam. \( b \) Calculate the radiation pressure exerted on the polarizing sheet.

4. Unpolarized light falls on two polarizing sheets placed one on top of the other. What must be the angle between the characteristic directions of the sheets if the intensity of the transmitted light is one-third the intensity of the incident beam? Assume that each polarizing sheet is ideal, that is, that it reduces the intensity of unpolarized light by exactly 50%.

5. Three polarizing plates are stacked. The first and third are crossed; the one between has its axis at 45° to the axes of the other two. What fraction of the intensity of an incident unpolarized beam is transmitted by the stack?

6. A beam of linearly polarized light strikes two polarizing sheets. The characteristic direction of the second is 90° with respect to the incident light. The characteristic direction of the first is at angle \( \theta \) with respect to the incident light. Find angle \( \theta \) for a transmitted beam intensity that is 0.100 times the incident beam intensity.

7. A beam of unpolarized light is incident on a stack of four polarizing sheets that are lined up so that the characteristic direction of each is rotated by 30° clockwise with respect to the preceding sheet. What fraction of the incident intensity is transmitted?

8. A beam of light is linearly polarized in the vertical direction. The beam falls at normal incidence on a polarizing sheet with its polarizing direction at 58.8° to the vertical. The transmitted beam falls, also at normal incidence, on a second polarizing sheet with its polarizing direction horizontal. The intensity of the original beam is 43.3 W/m². Find the intensity of the beam transmitted by the second sheet.

9. Suppose that in Problem 8 the incident beam was unpolarized. What now is the intensity of the beam transmitted by the second sheet?

10. A beam of light is a mixture of polarized light and unpolarized light. When it is sent through a Polaroid sheet, we find that the transmitted intensity can be varied by a factor of five depending on the orientation of the Polaroid. Find the relative intensities of these two components of the incident beam.

11. At a particular beach on a particular day near sundown the horizontal component of the electric field vector is 2.3 times the vertical component. A standing sunbather puts on polaroid sunglasses; the glasses suppress the horizontal field component. \( a \) What fraction of the light energy received before the glasses were put on now reaches the eyes? \( b \) The sunbather, still wearing the glasses, lies on his side. What fraction of the light energy received before the glasses were put on now reaches the eyes?

12. It is desired to rotate the plane of vibration of a beam of polarized light by 90°. \( a \) How might this be done using only polarizing sheets? \( b \) How many sheets are required in order for the total intensity loss to be less than 5.0%?

Section 48-3 Polarization by Reflection

13. \( a \) At what angle of incidence will the light reflected from water be completely polarized? \( b \) Does this angle depend on the wavelength of the light?

14. Light traveling in water of index of refraction 1.33 is incident on a plate of glass of index of refraction 1.53. At what angle of incidence is the reflected light completely linearly polarized?

15. Calculate the range of polarizing angles for white light incident on fused quartz. Assume that the wavelength limits are 400 and 700 nm and use the dispersion curve of Fig. 4, Chapter 43.

16. When red light in vacuum is incident at the polarizing angle on a certain glass slab, the angle of refraction is 31.8°. What are \( a \) the index of refraction of the glass and \( b \) the polarizing angle?

Section 48-4 Double Refraction

17. Linearly polarized light of wavelength 525 nm strikes, at normal incidence, a wurzite crystal, cut with its faces parallel to the optic axis. What is the smallest possible thickness of the crystal if the emergent \( o \)- and \( e \)-rays combine to form linearly polarized light? See Table 1.

18. A narrow beam of unpolarized light falls on a calcite crystal cut with its optic axis as shown in Fig. 23. \( a \) For \( i = 1.12 \) cm and for \( \theta_i = 38.8^\circ \), calculate the perpendicular distance between the two emerging rays \( x \) and \( y \). \( b \) Which is the \( o \)-ray and which the \( e \)-ray? \( c \) What are the states of polarization of the emerging rays? \( d \) Describe what happens if a polarizer is placed in the incident beam and rotated. \( \text{Hint: Inside the crystal the E-vector vibrations for one ray} \)
are always perpendicular to the optic axis and for the other ray they are always parallel. The two rays are described by the indices $n_e$ and $n_o$; in this plane each ray obeys Snell’s law.)

19. A prism is cut from calcite so that the optic axis is parallel to the prism edge as shown in Fig. 24. Describe how such a prism might be used to measure the two principal indices of refraction for calcite. (Hint: See hint in Problem 18; see also Sample Problem 3, Chapter 43.)

Section 48-5 Circular Polarization

20. Find the greatest number of quarter-wave plates, to be used with light of wavelength 488 nm, that could be cut from a dolomite crystal 0.250 mm thick.

21. What would be the action of a half-wave plate (that is, a plate twice as thick as a quarter-wave plate) on (a) linearly polarized light (assume the plane of vibration to be at 45° to the optic axis of the plate), (b) circularly polarized light, and (c) unpolarized light?

22. A polarizing sheet and a quarter-wave plate are glued together in such a way that, if the combination is placed with face A against a shiny coin, the face of the coin can be seen when illuminated with light of appropriate wavelength. When the combination is placed with face A away from the coin, the coin cannot be seen. (a) Which component is on face A and (b) what is the relative orientation of the components?

Section 48-7 To the Quantum Limit

23. Assume that a parallel beam of circularly polarized light whose power is 106 W is absorbed by an object. (a) At what rate is angular momentum transferred to the object? (b) If the object is a flat disk of diameter 5.20 mm and mass 9.45 mg, after how long a time (assuming it is free to rotate about its axis) would it attain an angular speed of 1.50 rev/s? Assume a wavelength of 516 nm.