CHAPTER 33
THE NATURE AND PROPAGATION OF LIGHT

Discussion Questions

Q33.1 Light travels only very slightly slower in air than in vacuum. And the distance it travels in the earth's atmosphere is a very small fraction of the total distance. The delay due to the earth's atmosphere is very, very small.

Q33.2 Light travels slower in the atmosphere than in vacuum; the refractive index of air is slightly greater than unity. When light goes from one material to another of larger refractive index it is bent toward the normal. The normal to the earth's atmosphere is vertical. This bending of starlight as it enters the atmosphere does mean that stars are not precisely where they appear to be.

Q33.3 The frequency f of the wave doesn't change when passing from one material to another. Since the interface cannot create or destroy waves, the number of wave cycles arriving per unit time must equal the number leaving per unit time. The period T is $T = 1/f$ so T also doesn't change. The wavelength decreases when the speed of light decreases. The distance traveled during one period is less when the wave speed is less, so the wavelength, the distance occupied by one cycle, decreases.

Q33.4 The sun can be seen even though it is below the horizon; see Problem 33.51. Similarly, the sun can be seen before it rises. This does slightly increase the time between the apparent sunrise and the apparent sunset.

Q33.5 The refractive index of air depends on the temperature of the air. Light passing through the moving warm air produces this effect.

Q33.6 $v = \frac{c}{n}$ so measuring n is equivalent to measuring v. (a) Let a ray of light in air refract into the glass and measure θ_a and θ_b, where a is air and b is glass. For air $n = 1.00$ and Snell's law, $n_a \sin\theta_a = n_b \sin\theta_b$, allows n_b to be calculated. (b) For light traveling in the glass measure the critical angle for a glass-air interface. $\sin\theta_{\text{crit}} = \frac{1.00}{n_{\text{glass}}}$ and n_{glass} can be calculated. (c) Reflect light traveling in air from the surface of the glass. Use a polarizing filter to measure the polarizing angle θ_{p}, the incident angle at which the reflected light is completely polarized perpendicular to the plane of incidence. Then the equation $\tan\theta_{\text{p}} = \frac{n_b}{n_a}$, where a is air and b is glass, can be used to calculate the refractive index of the glass.

Q33.7 One image is caused by reflection at the front surface of the window glass and the other from reflection at the back surface.

Q33.8 Light travels from the fish to the surface of the water, reflects there and travels to your eyes. The surface of the water, at the interface between the water and the air, forms an image of the fish, just like a conventional flat mirror. Each point in the image is the same distance above the surface of the water as the corresponding point on the fish is below the surface (see chapter 34), so the image is upside down. The top of the fish is on the bottom of the image.

Q33.9 No. Total internal reflection occurs only when light is incident in the material of larger refractive index. The refractive index of air is less than that of glass.

Q33.10 The angle of reflection equals the angle of incidence in all materials and for all wavelengths.

The angle of refraction depends on the indices of refraction of the two materials and the index of refraction depends on wavelength.

Q33.11 Take two pair and rotate one pair in relation to the other, as in Fig.33.25. If the transmitted intensity depends on the angle the one pair is rotated, then the lenses are Polaroid filters.

Q33.12 No. Only transverse waves exhibit polarization.

Q33.13 Produce polarized light, polarized along the horizontal direction, by letting the light reflect from the horizontal surface of water with the incident angle equal to the polarizing angle. Hold the filter vertical and rotate it until the intensity of this light transmitted through the filter is a maximum. In this position the polarizing axis of the polarizer is horizontal.

Q33.14 Yes, it would work. The light reflected from the roadway is partially polarized parallel to roadway. The polarizing axis of the windshield would need to be vertical to block this polarized component of the reflected light. An advantage is that it would be built into the car. A disadvantage would be that it would reduce the transmitted light that comes directly from the objects. All objects would appear dimmer.

Q33.15 The plastic wrap becomes birefringent when stretched and alters the polarization of the light passing through it.

Q33.16 The reflected light, the glare, is partially polarized in a horizontal direction. The polarizing axis of the Polaroid sunglasses is vertical, so this axis is perpendicular to the polarization axis of the glare and the sunglasses don't pass this light when your head is upright. But when you lie on your side the polarizing axis is horizontal and the glasses pass the reflected light.

Q33.17 Yes, it is true. The axis of the third polarizer has a nonzero component in both perpendicular directions. The third polarizer rotates the polarization axis of the light that has passed through the first polarizer.

Q33.18 The electromagnetic waves carrying the TV signal are polarized in a horizontal direction perpendicular to the direction of propagation of the wave. Therefore, the plane of the "ears" should be perpendicular to the direction from your location to the location of the transmitter for the TV station, so that the antenna will align with the electric field of the TV signal.

Q33.19 Light is scattered in all directions in the yz-plane so removes all polarization components equally from the incident light and the transmitted light is still unpolarized. Only scattering in the $-y$-direction is shown in Fig.33.31 since that is where our sunbather is.

Q33.20 Fig.33.31 shows that when the sun is low in the western sky the light scattered downward to the surface of the earth is polarized in a north-south direction. The polarizing axis of the Polaroid sunglasses is along the line that runs from your mouth to nose to between your eyes. You want this axis to be perpendicular to the north-south polarization direction of the light, so lie along an east-west line. It doesn't matter if your feet point west or east.

Q33.21 Light scattered from blue sky is scattered from linear molecules in the atmosphere that have a linear axis. Light scattered from cloud is not scattered by individual molecules but instead from water droplets or ice crystals that have no axis.

Q33.22 The scattered light contains much more blue light than red. The red-tinted sunglasses filter out the blue scattered light and pass the red light, which is predominantly light that hasn't been scattered by the particles or droplets.

Q33.23 Sunrises are red when the air is dusty or smoky. Human activities and wind during the day add dust and pollutants to the air during the day. Much of this material settles out during the night as so the air is cleaner at sunrise than at sunset.

Q33.24 In Fig.33.36, light travels slower in the air near the hot surface of the earth. For sound at night, sound travels slower in the cool air nearer the surface and follows a curved path just like that shown in Fig.33.36.

Q33.25 Yes, water waves can be reflected and refracted. Water waves produced by dropping a rock in a pool of water reflect from a surface that is perpendicular to the water. Water waves depend on the depth of the water so the waves refract at a line where the depth changes. Huygen's principle applies to all wave phenomena.