## Section 10.5: Polarization of Light

### Mini Investigation: Observing Polarization from Reflection, page 534

**A.** Sample answer: When the second filter is rotated, the bright light is blocked out completely.
**B.** Answers may vary. Sample answer: Glare on a surface is reduced when I use a Polaroid filter because the polarizer blocks some of the light travelling through the filter. I see less of the light reflecting from the surface, therefore reducing the glare.
**C.** Answers may vary. Sample answer: Variations in light seen from changing the location of a Polaroid filter against various regions of the sky occur because polarized light in different parts of the sky reaches me at different angles. Depending on the angle, light rays either pass through the filter or are blocked by the filter.

### Research This: Holography, page 536

**A.** Answers may vary. Sample answer: Holography is the process of making three-dimensional images, called holograms, on a single film. To produce a hologram, a laser beam is split into two halves by a beam splitter. One half of the laser beam reflects off a mirror to the object that will be made into a hologram, and reflects onto a photographic plate. The hologram is created on the photographic plate. The other half of the laser beam, called the reference beam, does not come into contact with the object. The reference beam travels to the photographic plate. On the photographic plate, both beams intersect and interfere with each other, producing the hologram.
**B.** Sample answer: To make a hologram, the materials required are a laser, a beam splitter, a mirror, a photographic plate, and the object that will be the hologram.
**C.** Answers may vary. Sample answer: For holography to work, the laser beam must be polarized. The beams are reflected at Brewster's angle, so they are perfectly polarized. Polarization results in a clearer hologram.
**D.** Answers may vary. Sample answer: Holography is used for security. For example, holograms are used on money and credit cards because holograms are difficult to counterfeit (although it is getting easier to duplicate holograms). Holography is also used in art and interactive graphics. Novel applications of holography are data storage, museum tour guides who are holograms, and holograms as jewellery.
**E.** Answers may vary. Sample answer: Presentations will include the key points from the student's research, from questions A to D, and could include an actual hologram, if a kit is available. The presentation could also include images from the Internet of a hologram and an illustration of the setup and equipment required.

### Section 10.5 Questions, page 537

**1.** The light waves in polarized light vibrate in a single plane, whereas the light waves in unpolarized light vibrate in several different planes.
**2.** To test whether a pair of sunglasses has polarizing lenses or simply darkened plastic lenses, I would hold two of the same kind of lenses together and rotate them relative to each other to look for changes in transmission intensity. I could also test the lenses by rotating one of the lenses in front of my eyes to see how reflections from different objects change. With either method, if light intensity changes depending on the angles of incidence and refraction, the lenses are polarized.
**3.** Selective absorption polarizes light with a polarizing material. This polarizing material transmits only a certain polarization of light and absorbs the other polarizations. Light that leaves

the polarizing material is always linearly polarized along the direction of the axis of the polarizing material.

Polarization by reflection polarizes reflected light by the motion of electric charges within the reflecting material. The charges can vibrate more easily in a direction that leads to them emitting light polarized parallel to the surface.

Scattering polarizes light because the light scatters from air molecules with a polarization that depends on the direction of the scatter. Observers in a particular direction only see light with a certain polarization.

**4. (a)** If I place a sheet of Polaroid, whose transmission axis is parallel to the transmission axis of the polarizer, between a polarizer and an analyzer, the light will not change. This is because the sheet of Polaroid and the polarizer have parallel axes, so the light leaving the polarizer is unchanged after passing through the Polaroid filter.

**(b)** If I place a sheet of Polaroid, whose transmission axis is parallel to the transmission axis of the analyzer, between a polarizer and an analyzer, the light will not change. This is because the sheet of Polaroid and the analyzer have parallel axes, so the light leaving the analyzer is unchanged after passing through the Polaroid filter.

**(c)** If I place a sheet of Polaroid, whose transmission axis is at 45°, between a polarizer and an analyzer, more light will get through because light leaving the intermediate Polaroid is now at 45° polarization with respect to the final polarization axis.

**5.** The sky often looks very different when viewed wearing polarizing sunglasses than otherwise because of the different polarizations of light from different directions in the sky.

**6.** The light reflected from the surface of a still pond is horizontally polarized. When light is reflected from a surface, the reflected light is completely polarized parallel to the surface, which, in the case of the still pond, is horizontally. If the axis of the polarizer is set vertically, the reflected light will be completely absorbed, thus showing that the reflected light was horizontally polarized.

**7.** The sky appears blue because light from the Sun encounters small particles in the atmosphere, which scatter the waves. Shorter waves are scattered more than longer waves. Since the blue portion of the visible light spectrum has shorter wavelengths, the sky appears blue.

**8. Given:** $I_{in}$ = 250 candelas; $I_{out}$ = 17 % of $I_{in}$ = (0.17)(250 candelas)

**Required:** $\theta$

**Analysis:** $I_{out} = I_{in}\cos^2\theta$ ; $\cos^2\theta = \frac{I_{out}}{I_{in}}$

**Solution:**
$$\begin{aligned}\cos^2\theta &= \frac{I_{out}}{I_{in}} \\ &= \frac{(0.17)(250\ \cancel{\text{candelas}})}{250\ \cancel{\text{candelas}}} \\ &= 0.17 \\ \cos\theta &= 0.412\ \text{(one extra digit carried)} \\ \theta &= 66^\circ\end{aligned}$$

**Statement:** The polarization angle of the incident light with respect to the polarization angle of the filter is 66°.

**9. Given:** $n_1 = 1.00$; $n_2 = 1.54$
**Required:** $\theta_B$

**Analysis:** $\tan\theta_B = \dfrac{n_2}{n_1}$

**Solution:** $\tan\theta_B = \dfrac{n_2}{n_1}$

$$\tan\theta_B = \frac{1.54}{1.00}$$

$$\theta_B = 57°$$

**Statement:** The angle of incidence that results in perfectly polarized light is 57°. This angle is called Brewster's angle.

**10.** Answers may vary. Sample answer: Materials are able to reflect polarized light when the light source is unpolarized because electrons in the material's surface emit light with a polarization perpendicular to the electron's direction of vibration. Electrons on the material surface can vibrate much more easily parallel to the surface than perpendicular to the surface. The light reflected by the surface is light emitted by the surface electrons, so the electrons' parallel vibrations produce mostly perpendicularly polarized light.

**11.** Polarized sunglasses can make it easier to see through the window on a sunny day because the window partially polarizes sunlight through reflection. This light can then be filtered out using glasses with a different polarization.

**12.** Yes, it is possible for light intensity to be unaffected by a polarization filter if all the incoming light has the same polarization angle as the filter.

**13.** Answers may vary. Sample answer: 3D movies show two images overlaid on each other, one for each eye of the viewer. One method of projecting the images is to project the two images with different polarizations. The viewer wears glasses with filters in each eyepiece, which are also polarized differently to match the two images. This way, the light from only one of the images reaches each eye, and each eye sees a different image. The differences in the images' perspective create the impression of viewing a three-dimensional object.

**14.** Answers may vary. Sample answers: Each lens of the glasses has a different polarizing filter so only the light from the movie that is similarly polarized is seen through that lens and the other light is blocked. Therefore, each eye sees a different image, which produces the three-dimensional effect.