Chapter 23

Conceptual: 2, 3, 6, 8, 9, 14, 17, 19

2. In a virtual image, light rays do not actually come from a point on an image but instead only appear to diverge from a single point. In a real image, the rays actually do pass through the image point. A real image may be detected using photographic film.

3. A rainbow is created when rays of light from the sun are reflected from drops of water backwards into the eyes of an observer. An observer should therefore look in a direction opposite the sun in order to see a rainbow. As the rays enter the raindrop, dispersive effects cause some wavelengths to be refracted more than others. Thus, the observed reflected light is separated into bands containing the colors present in solar light. A secondary rainbow is formed from rays that are reflected twice within the raindrop. Only a fraction of the light incident upon a boundary between air and water is reflected, the rest is transmitted. Secondary rainbows are therefore fainter because a large fraction of incident light is lost as a result of the second reflection.

6. A plane mirror can be thought of as a spherical mirror with an infinite radius of curvature. As such, the focal length of a plane mirror is also infinite. With this focal length, the spherical mirror equation indicates that the image distance must be the negative of the object distance. Furthermore, the transverse magnification for plane mirrors equals one.

8. The index of refraction of the refractive medium is greater than that of the incident medium. The speed of light in a medium is inversely proportional to the index of refraction. Thus, the speed of light is greater in the first medium than the second.

9. (a) The image is upright.
   (b) The image is inverted.
   (c) The real image is formed at a distance greater than $2f$, and therefore, cannot be seen.

14. The larger index of refraction for the diamond ($n \approx 2.4$) results in a smaller critical angle for total internal reflection. Thus, a greater portion of the light incident on the gemstone is reflected back out, giving it a greater sparkling brilliance. An artificial diamond made from glass ($n \approx 1.5$) would be even less brilliant than the cubic zirconium ($n \approx 1.9$), since the index of refraction for glass is smaller.

17. An image formed by a projector needs to be located on the viewing screen, where the light is diffusely reflected allowing the image to be seen from any angle. Since the light from the projector actually comes from the location of the image, it is a real image. For a camera, the image must be focused on the film so that the exposed film forms a copy of the actual image. Thus, the camera must form a real image as well. The lens in the eye works like a camera, forming a real image on the retina.

19. As is evident by sketching a diagram, rays from every part of the object still converge to the image, but only half as many as if the lens were not half blocked. The entire image will therefore still be visible, but it will be half as bright.