1. C Gamma rays have wavelengths shorter than m. Don’t confuse wavelength and frequency: gamma waves have a very high frequency, thus they have a short wavelength.

2. C Wavelength and frequency are related by the formula . In the case of light, m/s, so we can solve for f with the following calculations:

3. A When the wave enters the glass, its frequency does not change; otherwise, its color would change. However, the wave moves at a different speed, since the speed of light, v, in different substances is given by the formula v = c/n, where c is the speed of light in a vacuum, and n is the index of refraction for the given substance. Since , we can also reason that . Further, we know that , so substituting these equations in, we get:

4. C Statement I is true, but it doesn’t explain why a refracted ray should have a different wavelength. The fact that some of the incident ray is reflected means that the refracted ray will have a different amplitude, but it will not affect the frequency.Statement II is false, and even if it were true, a change in energy would affect the frequency of the wave, not its wavelength.Statement III correctly explains why refracted rays have different wavelengths from their incident rays. A light ray will maintain the same frequency, and hence color, when it is refracted. However, since the speed of light differs in different substances, and since the wavelength is related to the speed of light, v, by the formula , a change in the speed of light will mean a change in the wavelength as well.

5. A Snell’s Law gives us the relationship between the indices of refraction and the angles of refraction of two different substances: sin = sin . We know that , the index of refraction for air, is 1, and we know that , the index of refraction for plastic, is 2. That means we can solve for sin :

6. B Total internal reflection occurs when the refracted ray is at an angle of 90º or greater, so that, effectively, the refracted ray doesn’t escape into the air. If = 90º, then sin = 1, so by Snell’s Law:

7. E Only concave mirrors and convex lenses can produce images that appear upside down. However, concave mirrors produce these images on the same side of the mirror as the object, while convex lenses produce these images on the opposite side of the mirror from the object.

8. E Whenever we see a pattern of maxima and minima, we know we are dealing with the phenomenon of diffraction, which rules out the possibility that A is a polarization filter or a prism. Both single- and multipleslit diffraction gratings tend to produce bands of light, but not concentric circles. The correct answer is E, the pinhole: light passing through the pinhole will spread out in concentric circles and will alternate between bright and dark patches to produce concentric rings.

9. D Visible light can be polarized because it travels as a transverse wave, meaning that it oscillates perpendicular to the direction of its motion. Polarization affects the oscillation of transverse waves by forcing them to oscillate in one particular direction perpendicular to their motion. Sound waves, on the other hand, are longitudinal, meaning that they oscillate parallel to the direction of their motion. Since there is no component of a sound wave’s oscillation that is perpendicular to its motion, sound waves cannot be polarized.

10. A The idea behind polarized sunglasses is to eliminate the glare. If the solar glare is all at a 90º angle to the normal line, sunglasses polarized at a 0º angle to this normal will not allow any of the glare to pass. Most other light is not polarized, so it will still be possible to see the road and other cars, but the distracting glare will cease to be a problem.