**Physics 112 Refraction**

1. A ray of light enters glass (n=1.60) at an angle of incidence of 20°. What is the angle of refraction? Suppose the ray leaves the glass with an angle of incidence of 20°; what is the angle of refraction? *(12°, 33° )*
2. Light strikes a glass plate at an angle of incidence of 65°, part of the beam being reflected and part being refracted. It is observed that the reflected and the refracted portions make an angle of 80° with each other. What is the index of refraction of the glass? *(1.6)*
3. A rectangular tank 8.0 cm deep is filled with water, n=1.33. A light ray enters the top surface of the water at a point just touching the side of the tank. After refraction it falls on a point on the bottom of the tank 3.0 cm from the same side. What is the angle of incidence of the entering ray? *(28° )*
4. Suppose that the same tank were filled with another liquid, such that in order for the ray of light to hit the same point on the bottom, the angle of incidence of the entering ray had to be 31°. What is the index of refraction of this liquid? *(1.5)*
5. An incident ray of light makes an angle of 30° with the surface of a glass plate with index of refraction 1.55. What is the angle between the refracted ray and the surface of the glass? *(56° )*
6. A ray of light is incident at an angle of 40° on one surface of a glass plate (n=1.50) which is 2.0 cm thick. On either side of the glass plate is air. Draw a ray diagram of the path of the ray through the glass. What is the horizontal displacement between the incident ray and the emerging ray? *(0.95 cm)*
7. A ray of light traveling in water (n=1.33) strikes a surface of glass at an angle of incidence of 36°. What is the angle of refraction in the glass (n=1.80)? *(26° )*
8. A glass prism, whose index of refraction for red light is 1.60, is made up with angles 30°, 60° and 90°.
   1. Assume that a ray of monochromatic red light is incident perpendicularly on the 2nd longest side (opposite the 60° angle). Draw a diagram showing the ray of light until it emerges from the prism. Calculate all angles of incidence and refraction.
   2. Repeat, assuming the ray of light is incident perpendicularly on the shortest side.

**More Refraction Questions**

1. A ray of light is incident on diamond passing from glass (n=1.50) at 40°, and the relative index of refraction is 1.61.
   1. What is the index of refraction of diamond? *(2.42)*
   2. What is the angle of refraction? *(25° )*
   3. If the light passed from diamond to glass what would be the critical angle?*(41.8° )*
2. What is the critical angle for light traveling from glass into water (n=1.50 for glass, 1.33 for water)? What is the relative index of refraction?  *(62.5° , 0.887)*
3. A ray of light is incident upon an equilateral glass prism (n=1.50) at 20.0°. The sides of the prism are each 10.0 cm long. The ray enters the glass 2.00 cm from one corner. Trace the path of the light until it emerges from the prism. Find all angles, and how far from a corner of the prism the light emerges. *(DISTANCE IS TOUGHER - depends on how which way the light enters).*
4. Calculate the speed of light in
   1. water (n=1.33) *(2.26 x 108 m/s)*
   2. glass (n=1.50) *(2.00 x 108 m/s)*
   3. diamond (n=2.42) *(1.24 x 108 m/s)*
5. What is the relative index of refraction when travelling from oil (n=1.40) to each of the substances given in question 12? *(0.950, 1.07, 0.579)*
6. A camera lens has several thin coatings to prevent a large amount of reflection. These coatings however, do affect how the light bends. One particular lens (n=1.50) has three thing coatings with indices of refraction (going from the air to the lens) of 1.35, 1.40, and 1.45.
   1. If light is incident on the outermost coating at an angle of 50.0°, what is the angle of refraction when it leaves the lens (back into air)? What would the angle of refraction be if there were no coatings? Can you explain this? *(50.0° )*
   2. Notice that the index of refraction increases as you get closer to the lens and that none of the coatings has an index of refraction higher than that of the lens. Can you think of any reason for this? *(To prevent TIR)*
7. A ray of light is incident on a layer of water (n=1.33) from oil (n=1.30) at an angle of 50.0°. Underneath the water is a layer of glass (n=1.50), under which there is a layer of air. Trace the ray of light until it passes into the air or reflects back into the oil again. *(84.8° in air)*