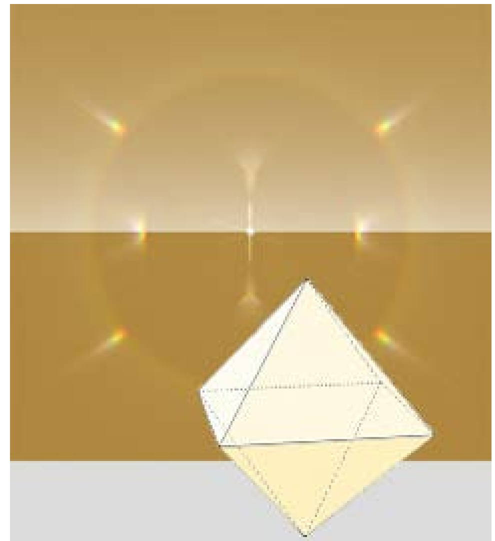
General Physics II Quiz #6 Name ________________________________

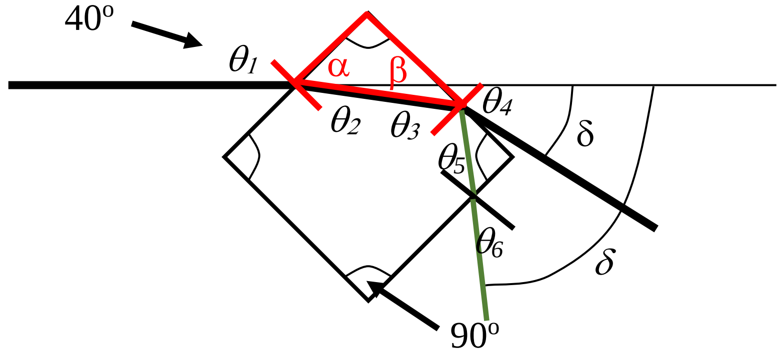
Halos on other worlds



(See http://www.atoptics.co.uk/halo/oworld.htm and Light Scattering from Ammonia and Water Crystals, Alan Holmes, PhD dissertation 1981, University of Arizona)

Jupiter and Saturn have a significant amount of ammonia in its atmosphere. Although the melting point of ammonia is -77.7 ^{o}C, crystals do not form until a temperature of -95 ^{o}C is reached. When they do form, ammonia crystals can be octahedral or form four sided pyramids.

The following diagram shows the path of light through an ammonia crystal. From this orientation, the cross-section of the crystal is a square with each angle being 90^{o}. Assuming the index of refraction for the air surrounding the crystal is 1.000 and the index of refraction for the ammonia crystal is 1.250, what is the angle of deflection, δ?



The incident angle, θ_1, is given. Using Snell's law solve for the angle of refraction, θ_2.

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

$$\theta_2 = \sin^{-1}\left(\frac{n_1}{n_2}\sin\theta_1\right) = \sin^{-1}\left(\frac{1.000}{1.250}\sin 40\right) = 30.9^\circ$$

α is the compliment of θ_2, therefore, $\theta_2 = 59.1^o$.
Sum of the angle of a triangle is 180^{o}. Therefore,

$$\beta = 180 - 90 - \alpha = 90 - 54.2 = 30.9^o.$$

θ_3 is the compliment of β, therefore, $\theta_3 = 59.1^o$.
Using Snell's law again the value of θ_4 is

$$\theta_4 = \sin^{-1}\left(\frac{n_3}{n_4}\sin\theta_3\right) = \sin^{-1}\left(\frac{1.250}{1.000}\sin 59.1\right) = \sin^{-1}(1.07)$$

Since we are trying to take the arcsin of a number greater than 1.00, the ray of light does not leave the crystal. Therefore, there is no angle θ_4. Instead, it internally reflects at the same angle in which it hit the surface. Following it to the next surface, it hits it at an angle of 30.9 relative to the normal. This angle is θ_5. Now use Snell's law to calculate the angle at which it leaves.

Calculating this angle gives

$$\theta_6 = \sin^{-1}\left(\frac{n_5}{n_6}\sin\theta_5\right) = \sin^{-1}\left(\frac{1.250}{1.000}\sin 30.9\right) = 40^\circ$$

Since the entrance surface and exit surface are parallel, their surface normals are in the same direction. Therefore, the surface normal is 40º below the original direction of the light. The light leaving the lower surface is 40º below the surface normal. Therefore, the angle of divergence is

$$\delta = 40^o + 40^o = 80^o$$

The index of refraction for violet light is larger than the index of refraction for red light. Which color of light will have the largest angle of deflection? (Violet/Red)

Violet. It has the largest index of refraction and will deflect more.