PH202-1G
Spring 2014

Worksheet March 10

Refraction

Define the index of refraction. What quantities does it depend on?

$n = \frac{c}{v_n}$ where v_n is the speed of light in that medium. It depends on wavelength and temperature.

Describe refraction. Can refraction and reflection happen at the same time?

Refraction - change in orientation of light as it passes through the boundary between two media. Refraction and reflection can happen at the same time.

Give a mathematical expression for the relationship between an incident angle and the refracted angle.

$n_1 \sin\theta_1 = n_2 \sin\theta_2$ Snell's law

Describe apparent depth? What causes this phenomenon?

Objects in a fluid appear to be closer than they actually are. This is caused by refraction of light traveling from the fluid to the air.

Give a mathematical expression for the apparent depth of an object from the perspective of an observer directly above it.

$d' = \frac{n_2}{n_1} d$ The object is located in the medium whose refractive index is n_1.

Give a mathematical expression for the displacement of a ray of light passing through a thin medium.

$d = \frac{t \sin(\theta_1 - \theta_2)}{\cos\theta_2}$

Describe total internal reflection.

When the incident angle is greater than a critical angle, all of the incident light is reflected and none is refraction.

Give a mathematical expression for the critical angle of an incident light ray.

$\theta_c = \arcsin\left(\frac{n_2}{n_1}\right)$ if $n_1 > n_2$

What happens to an incident ray of light when the incident angle is equal to the Brewster angle?

The reflected ray is completely polarized, and the refracted ray is partially polarized.

Give a mathematical expression for the Brewster angle.

$\theta_B = \arctan\left(\frac{n_2}{n_1}\right)$

Describe dispersion. Does light with a longer wavelength refract to a greater or lesser degree than light with a shorter wavelength?

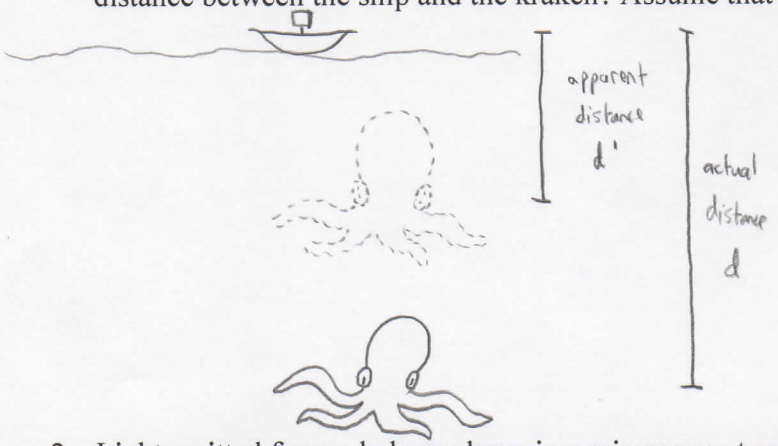
Dispersion is the splitting of white light into its constituent wavelengths.

Light with a longer wavelength is refracted to a greater degree.

PH202-1G
Spring 2014

Problems

1. A sailor looks over the side of his ship into the ocean. To his alarm, the sailor discerns a massive kraken approaching the ship 60 m below the surface of the ocean. What is the actual distance between the ship and the kraken? Assume that sea water has a refractive index of 1.4.

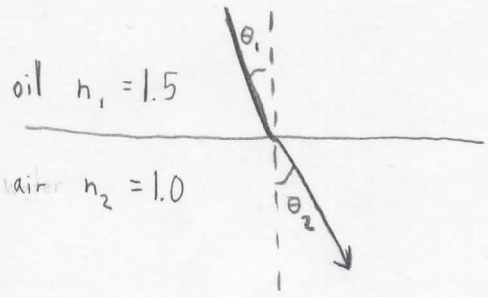


$$d = \frac{n_1}{n_2} d'$$

$$d = \frac{1.4}{1.0} 60\ m$$

$$d = 84\ m$$

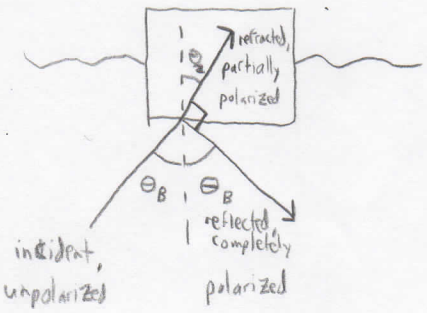
2. Light emitted from a halogen lamp in a microscope travels through immersion oil (refractive index 1.5) and approaches a boundary with the air at an incident angle of 25°. a) Find the angle with respect to the normal at which the light leaves the oil. b) Find the critical angle for the oil-air boundary.



a) $\theta_2 = \arcsin\left(\frac{n_1}{n_2} \sin\theta_1\right) = \arcsin\left(\frac{1.5}{1.0} \sin 25°\right) = 39°$

b) $\theta_c = \arcsin\left(\frac{n_2}{n_1}\right) = \arcsin\left(\frac{1.0}{1.5}\right) = 42°$

3. Light travels within a glass of water (refractive index 1.333) and strikes an ice cube from below. When the angle of refraction is 45.52°, the reflected light is completely polarized. a) Find the angle of incidence. b) Find the refractive index of the ice.



a) $\theta_2 = 45.52°$

Since $\theta_2 + 90° + \theta_B = 180°$, we know that

$\theta_B = 90° - \theta_2 = 90° - 45.52° = 44.48°$

b) $n_2 = n_1 \tan\theta_B = 1.333 \tan(44.48°) = 1.309$

At the Brewster angle, the angle between the refracted and reflected light rays is 90°