1. Consider the interface of water with class (say at the bottome of a beaker filled with water). Given: The index of refraction for water is $n_w = 1.33$ and the index of refraction for this particular glass is $n_g = 1.52$. A ray of light with incident angle $\theta_w = 60.0°$ comes from water towards the glass (drawings are encouraged!). Find the angle of reflection and refraction.

Solution: The angle of reflection is the same as the incident angle: $\theta_w = \theta_r = 60.0°$.

Refraction can be set up with Snell's Law:

$$n_w \sin\theta_w = n_g \sin\theta_g$$

$$\sin\theta_g = \frac{n_w}{n_g}\sin(60) = \frac{1.33}{1.52}\sin(60) = 0.758 \ \rightarrow \theta = \sin^{-1}(0.758) = 49.3°$$

2. The wavelength of the red light from a helium-neon laser is 633 nm in air but only 474 nm in the aqueous humor inside of your eye. Calculate the index of refraction of this substance and the speed and frequency of this light in it. *Hint: The frequency of light doesn't change!*

Solution:

Recall that the speed of light in a vacuum (empty space) is c and in a medium with index $n > 1$ is $v = c/n$. Also recall that $c = \lambda f$, and inside the medium, $v = \lambda_n f_n$. We then have:

$$\lambda_n f_n = c/n = (\lambda/n) f$$

And so:

$$n = \frac{\lambda}{\lambda_n} = \frac{633}{474} = 1.34$$

This then gives a speed of:

$$v = \frac{c}{n} = \frac{\left(2.99\times10^8\right)\frac{\mathrm{m}}{\mathrm{s}}}{1.34} = 2.25\times10^8\frac{m}{s}$$

3. Sunlight reflects off the smooth surface of a swimming pool. For what angle of reflection is the reflect light completed polarized? Given: $n_{air} = 1.00, n_{H_2O} = 1.33$; $\sin(90-\theta) = \cos\theta$. Drawings are encouraged.

Solution: Recall that we have total internal polarization when the angle between the reflected ray is 90 degrees to the angle of the refracted ray. That is:

$$\theta_p + 90 + \theta_w = 180 \ \rightarrow\ \theta_w = 90 - \theta_p$$

We now apply Snell's law to get:

$$n_{air}\sin(\theta_p) = n_{H_2O}\sin(\theta_w) = n_{H_2O}\sin(90-\theta_p) = n_{H_2O}\cos(\theta_p)$$

Rearranging to get:

$$\frac{1.33}{1} = \tan(\theta_p) \ \rightarrow \ \theta_p = \tan^{-1}(\frac{1.33}{1}) = 53.1$$

4. While conducting a photo-electric effect experiment with light of a certain frequency, you find that a reverse potential difference of 1.25 V is required to reduce the current to zero. Find KE_{max}, the maximum Kinetic energy. Given, the charge of the electron: $e = 1.60 \times 10^{-19} C$. When the voltage is turned back down to zero, how fast will the fastest electrons travel? Given, the mass of an electron: $m_e = 9.11 \times 10^{-31} kg$.

Solution: Recall that when the current has come to a full stop, all electrons including the ones with maximum kinetic energy are held onto the plate:

$$KE_{max} = eV_0 = \left(1.60 \times 10^{-19} C\right)(1.25V) = 2.00 \times 10^{-19} J$$

Setting that equal to $(1/2)mv^2$ and solving for v:

$$v = \sqrt{\frac{2\left(2.00 \times 10^{-19} J\right)}{9.11 \times 10^{-31} kg}} = 6.63 \times 10^5 \frac{m}{s}$$

5. An interesting proposition. Imagine reversing the photoelectric effect. Imagine that the voltage between the plates is off when light strikes one plate and liberates an electron, but before the electron reaches the second plate, the voltage is increased to stopping potential so that the electron slows down, comes to a stop, and then accelerates back towards the plate, impacting the plate with the same kinetic energy it had at liberation.

   Surprise! A photon is released.

   Electrons in an x-ray tube accelerate through a potential difference of 10.0 kV before striking a metal target. If an electron produces one photon on impact with the target, what is the minimum wavelength of the resulting photon (which is an x-ray here)? Given, the charge of the electron: $e = 1.60 \times 10^{-19} C$ and $hc = 1240 eV \cdot nm$ is Planck's constant times the speed of light given in eV units and nm units.

Solution:

Relating the maximum kinetic energy to the voltage difference to the photon energy:

$$KE_{max} = eV = hf = \frac{hc}{\lambda}$$

Plugging in,

$$10.0 \times 10^3 eV = \frac{1240 eV \cdot nm}{\lambda}$$

$$\lambda = 0.124 nm$$