Phys 172 Homework Chapter 09, 25-28

No need to submit this problem set.

Constants: $c = 3 \times 10^8 m/s$, $h = 6.63 \times 10^{-34} Js$, $e = 1.6 \times 10^{-19} C$, $\epsilon_0 = 8.85 \times 10^{-12} C^2 N^{-1} m^{-2}$, $\mu_0 = 4\pi \times 10^{-7} Tm/A$, mass of proton $m_p = 1.67 \times 10^{-27} kg$, mass of electron $m_e = 9.11 \times 10^{-31} kg$.

$n_{water} = 1.33, n_{glass} = 1.5, n_{diamond} = 2.42$, ground state energy of hydrogen: $-13.6eV$.

Law of Reflection and Refraction

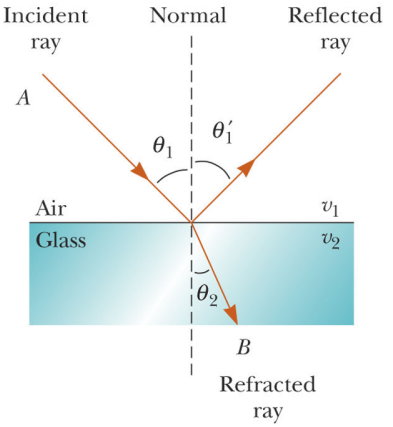
1. State the Snell's Law of Refraction.

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

2. Draw a diagram to define "angle of incidence", "angle of reflection", and "angle of refraction".

   See Figure 1. Angle of incidence = θ_1, angle of reflection = θ_1', angle of refraction = θ_2.

Figure 1: Answer to Question 2



3. A ray of light in the air enters the water surface ($n_{water} = 1.33$) with an angle of incidence $\theta_1 = 50°$. (i) Find the angle of reflection, θ_1'. (ii) Find the angle of refraction θ_{water}.

   (i) $\theta_1' = 50°$.

(ii) To calculate the angle of refraction:

$$\begin{aligned} 1 \sin\theta_1 &= 1.33 \sin\theta_{water} \\ \Rightarrow \theta_{water} &= \sin^{-1}\left(\frac{1}{1.33}\sin 50^\circ\right) = 35.17^\circ \end{aligned}$$

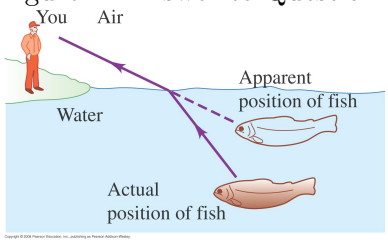
4. Calculate the speed of light in diamond.

$$\begin{aligned} n_{diamond} &= \frac{c_{vacuum}}{c_{diamond}} \\ \Rightarrow c_{diamond} &= \frac{c_{vacuum}}{n_{diamond}} = \frac{3 \times 10^8 m/s}{2.42} = 1.24 \times 10^8 m/s \end{aligned}$$

5. Why would an object appears to be more shallow inside the water when viewed from the air?

   Light bends away from the normal when passing from water to air, therefore creating the illusion in the way seen in Figure 2.

Figure 2: Answer to Question 5



Physical Optics

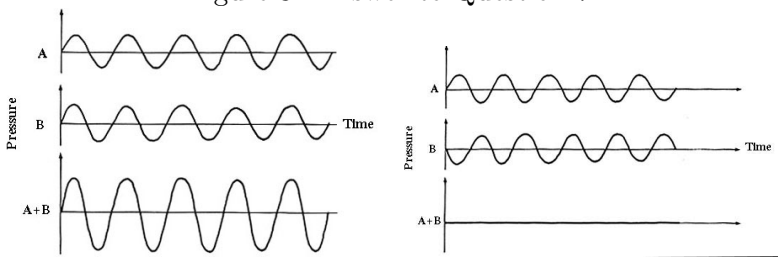
6. Explain the main difference between geometric optics and physical optics.

   Geometric optics: Assumes light travels in straight lines (rays), essentially behave like streams of particles.
   Physical optics: Takes into account the wave nature of light, accounting for the spreading and interference of waves.

7. Illustrate with the help of two diagrams the difference between constructive and destructive interference when two waves combines.

   See Figure 3.

Figure 3: Answer to Question 7



Constructive Interference Destructive Interference

8. What pattern does one observe from the Young's double slit experiment on light?

   A number of evenly-separated bright and dark fringes, corresponding to the constructive and destructive interference of light.

9. Give two examples of the interference of light.

   [Give two of the examples listed below or from elsewhere.]
   Young's double slit experiment
   Light spreads out after passing a narrow slit (with width of order of mm or less)
   The colored fringes on soap bubbles
   The ring like colored fringes on a thin layer of grease float on water

Relativity and Quantum Mechanics

10. State the postulates of the Special Theory of Relativity.

    All laws of physics are the same in all inertial frames.
    The speed of light in vacuum has the same values in all inertial frames.

11. State three of the consequences of relativity.

    [Give three of the examples listed below or from elsewhere.]
    Events that are simultaneous for one observer may not be simultaneous for another.
    When two observers measure a time interval or a length, they may not get the same results.
    Newton's Laws and equations for kinetic energy needed to be revised.
    The equivalence of energy and mass ($E = mc^2$)
    Space and time were no longer considered separate entities, but combined into four-dimensional space-time.
    Expansion or contraction of the universe.

The existence of exotic objects like black holes, worm holes.

12. Calculate the amount of energy released if a $5kg$ object is converted completely into energy.

$$E = mc^2 = (5)(3 \times 10^8)^2 = 4.5 \times 10^{17} J$$

13. Calculate the de Brogile wavelength of a $2kg$ object moving a speed of $3m/s$.

$$\lambda = \frac{h}{p} = \frac{h}{mv} = \frac{6.63 \times 10^{-34}}{(2)(3)} = 1.105 \times 10^{-34} m$$

14. State a possible method to verify the wave nature of electrons.

    By the Young's double-slit experiment, sending electrons through two (very closely separated) slits, a fringe patterns should form on a screen.

15. State the Uncertainty Principle as applied to position and momentum.

    It is impossible to simultaneously determine the position and momentum of a particle with infinite accuracy.