# Waves and Fields (PHYS 195): Week 13

Spring 2021 v1.0

**Intro:**

*In this last week of the semester we study physical optics, particularly the effects of diffraction and interference. This is cool stuff on its own but it is just the tip of an iceberg. From slits to thin films to interferometers these effects are the basis of many visually striking effects as well as high precision measurement. Interference has played many key roles in the development of physics including the first demonstration that the speed of light is constant (Michelson-Morley experiment 1887), the first detection of gravitational waves by LIGO 2017, and the first view of a black hole announced in 2019 by the Event Horizon Telescope collaboration.*

*Another is a focus of this week's problems - Young's double slit experiment that demonstrated that light has wave-like properties. (Ordinarily geometric optics works so well one might guess that it was a particle - Newton did!)*

**Reading:**

- Wednesday (Apr 28): HRW 35.1 - 2
- Friday: HRW 36.1 - 2 and 36.4
- Monday: HRW 36.5 and 35-4
- In these last two weeks we will discuss topics in Chapters 35 and 36. Although we may not discuss all these topics I recommend reading both chapters completely; there are lots of interesting applications of the wave-like property of light.

**Physics Topics:**

- Diffraction
- Interference
- Single and multiple slit diffraction patterns
- Rainbows and/or sundogs?
- Thin films (if we have time, likely we won't)
- Michelson interferometer (if we have time, likely we won't)

**Math Topics:**

- Phasors

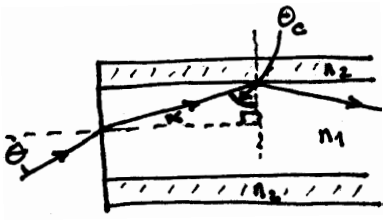
**Problems:** *Due Tuesday night, April 27, at 11:59 PM on gradescope code ZR34XK*

(1) HRW 29.11

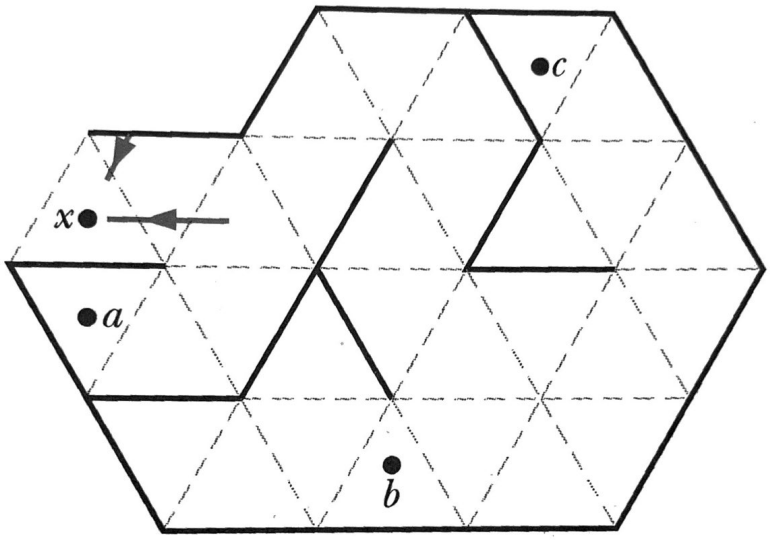
(2) HRW 29.56

(3) Initially unpolarized light is sent into a system of three polarizing sheets. The first is oriented at $\theta_1 = 15^o$ from the vertical axis. The second is at $\theta_2 = 35^o$ from the vertical axis. The third is at $\theta_3 = 135^o$ as measured from the vertical axis. What percentage of the light is transmitted through all three sheets?

(4) The figure shows a simple optical fiber made of a cylinder with index of refraction $n_1 = 1.58$ and a coating with index of refraction $n_2 = 1.53$. What is the maximum value of $\theta$ that allows total internal reflection?




(5) Monsters?!? The figure below shows a mirror maze that is based on equilateral triangle sections. Every wall, shown as a bold solid line, is a mirror. The maze contains three monsters at positions $a, b$ and $c$. Let's assume the maze is well lit. If you stand at the entrance $x$,
   (a) Can you see the monsters $a$ and $c$ in the virtual hallways extending from the entrance? Hint: Carefully draw light rays reflecting off the 'monsters' at $a$ and $c$.
   (b) If you can see them both, what is the angular separation between their images? If not, what part of the construction prevents you from seeing the hiding monster?
   (c) What is at the far end of the hallway?




(6) Monochromatic green light of wavelength $\lambda = 550.0$ nm illuminates two narrow parallel slits 7.70 $\mu$m apart. When viewed at a distance much larger than the slit spacing, what is the angular location of the third order bright fringe, when $m = 3$?

(7) HRW 35.12

(8) HRW 35.31

(9) HRW 36.10

(10) In class on we saw a demo where it appeared that a candle was lit underwater. The effect was created by a sheet of glass and another candle. Where do we have to place the candle to create

this effect? To start your answer make a sketch of the top view of the demonstration showing the unlit candle in the beaker, the lit candle, and the sheet of glass.[1]

(11) **Bonus:** In a physics text you read the statement: *Archimedes is said to have burned the whole Roman fleet in the harbor of Syracuse by focusing sunlight using an army of polished shields.* Is such a feat possible? Analyze this using the fact that sunlight falls on Earth with an intensity of about 1000 $W/m^2$ and what you know about mirrors. You will have to look up some thermal properties of wood. Although there is a lot of material online - to get started follow the links on the 195 web site - I'm interested in *your* analysis. Work this out carefully using the intensity of sunlight, the temperature at which wood burns, and anything else that is relevant. Write up your calculations and discussion. Submit the work separate from your usual solutions. Cite all your sources.

**Lab:**

Interference and diffraction

**A look ahead:** Thanks for a great semester! The next guide will have example questions to help you prepare for the final.

[1]This "Pepper's Ghost" illusion was popularized in the 1860's by John Henry Pepper. In recent years Pepper's Ghost was used for "guest appearances" of Tupac Shakur and Michael Jackson.