Physics 15c Lab – Fall Semester 2020

Spreadsheets:

- Lab1: [https://docs.google.com/spreadsheets/d/1IPbaezNrFXNBH8aQo3AomqhJztA1l-gpgBsvTxY-hTM/edit?usp=sharing](https://docs.google.com/spreadsheets/d/1IPbaezNrFXNBH8aQo3AomqhJztA1l-gpgBsvTxY-hTM/edit?usp=sharing)
- Lab2: [https://docs.google.com/spreadsheets/d/1sWo08rqXaoHt65eH4aGiJ-Tj3G_I9X4z-QtbLNdswcw/edit?usp=sharing](https://docs.google.com/spreadsheets/d/1sWo08rqXaoHt65eH4aGiJ-Tj3G_I9X4z-QtbLNdswcw/edit?usp=sharing)
- Lab4: [https://docs.google.com/spreadsheets/d/1Nqi0e7X7jEvIR1PPoLum4Owgcw3zDqyVmWzu7COY7o/edit?usp=sharing](https://docs.google.com/spreadsheets/d/1Nqi0e7X7jEvIR1PPoLum4Owgcw3zDqyVmWzu7COY7o/edit?usp=sharing)
- Lab5: [https://docs.google.com/spreadsheets/d/1KIs_8rKpZG_o7L_r0M1laqr6zu24f1-xgO6iSlf6o8w/edit?usp=sharing](https://docs.google.com/spreadsheets/d/1KIs_8rKpZG_o7L_r0M1laqr6zu24f1-xgO6iSlf6o8w/edit?usp=sharing)

Notes Lab 1: Coupled Pendula

- Ask students to provide 2 small cans of soup/beans
- Door frame with hooks
- Make sure the two hooks are at least 12-14 inches apart

- Set up the two pendula
- Ask students to attach one end of the small slinky to a single pendulum and start driving the system with a periodic motion. Ask them how the response changes when the relative phase shift of the driving force changes. How can you amplify/reduce the amplitude of motion?
- Measure the period of a single pendulum. How many cycles do you average over? What is the meaning of the standard deviation?
- Connect the two soup cans with the small slinky - find oscillations that don't change in time. What are the two modes and their frequencies?
• Parametric oscillator – students should remove one of the two black strings from the soup can, and start pulling it up and down (vertically). For what frequency of this vertical (cyclical) pull do you get the best amplification of horizontal motion of the pendulum?

Notes Lab 2: Standing waves and Optics

Wave equation and standing waves:
• Start with the wave equation – show the intuition that: acceleration = v^2 * curvature
• Connect this to how the (large black) slinky works - linear vs curved & how it accelerates
• Then show a wave-packet
• Attach the slinky to a door handle, and make wave packets/standing waves

Snell’s law and Prisms
• Ask why light can be considered a ray in this case?
• Snell’s law sin(t1)n1=sin(t2)n2
• Explain what is the intuition in terms of the marching band holding hands walking on grass/mud
• Show the prism and how it connects to this
• For this part they will need:
  o Lenticular Foil lens: detach the sticky part, and with the laser off attach it to the laser output aperture to make a “vertical column” beam
  o One sheet of paper
  o One prism
  o Wooden clothing pins

• What is the minimal angle?
• Ask them to calculate the index of refraction of the prism based on the angle of the outgoing beam relative to the initial beam
Lens equation:

- Place magic tape on the flashlight to act as a diffuser

- Add the black arrow, and set up the optical workbench

- Deduce what is the focal length is based on fitting \((1/a + 1/b = 1/f)\) equation
- How does the magnification change?
Notes Lab 3: Pinhole Camera, Telescopes and Microscopes

- Ideally students should image something outside their window on a bright day.
- Start with an intuitive explanation of the role of the pinhole (magnification, distances a and b, etc)

![Diagram of pinhole camera](image1)

- Have them build the pinhole camera with the small pinhole attached to one side of the long (small diameter) tube and a diffuse piece of plastic (can also be magic tape) on the other end of the tube.
- What do you expect happens with a bigger pinhole? Blurrier, edge effects, many rays

![Diagram of pinhole camera with lens](image2)

- Add a lens – first the big magnifying glass (need to bend the rays at the edge of the aperture so that now they all hit a given spot). Have the students look as far away as possible.
• Connect this to the eye: retina is the screen, and the lens is in front. How does the eye change focal length? With the muscle
• Review the simple lens and lens diagrams. Have students draw one:

  ![Lens Diagram](image)

• Remove the pinhole (keeping the lens). Have them construct the double cardboard tube with magnifying glass and partial screen on the other side.
• See when it the image is in focus on the screen, ask the students: when is it in focus if you just look straight through (with no screen)?
• Develop the intuition that now the eyepiece lens can magnify that focused “image”.
• What do you have to do to get a good magnification for a telescope? Think of it in terms of the geometric considerations above.
• What about a microscope?
• Have them construct a microscope with the double tube setup (and third large diameter tube to keep the two together). Students can look at pixels on their computer screen.
• Connect this to cameras, real-world telescopes, microscopes, zoom, role of apertures etc.
Notes Lab 4: Thin film interference

- Tell students to get some paper towels ready to cover their keyboard.
- What is interference, what does it mean? Have you experienced it in day-to-day life? What is soap?
- What length scales are important for visible light waves compared to radio waves? Sound waves?
- Start from the simple case – normal incidence and thin film. Calculate the thickness – index of refraction – wavelength dependence of the constructive/destructive interference
- Have the students draw out the wedge/thin film system too.
- Connect the computer to zoom and have their phone available as a “light source” (with the white, red/blue pdf).
- Turn up screen brightness & charge the phone
- Discuss first white light - what they see, and then monochromatic light
- Then discuss also the phase transition, why is it that when the liquid is very thin it turns black?
- Applications of this. Why don’t you see it in window glasses? Concept of coherence
- Observe the different colors of the thin film square.
- Connect it to other systems:
  - 20-dollar bill has the same effect for the number (also the 10-dollar bill for 2017 series onwards)
  - Structural colors like butterflies
- Falstad simulation follow the spreadsheet mostly: https://www.falstad.com/ripple/
  - Two sources ½ wavelength apart - talk about how in one direction they constructively interfere but in the other they do not
  - Then have them one wavelength apart – discuss the vertical direction
- How can you place the sources so that you create a plane wave?
- Put sources on an arc and to get focusing
Notes Lab 5: Finding the wavelength of a laser with a ruler

- Follow the spreadsheet

  1) What is the optical path length difference between two incoming waves at an angle $\alpha$?

  ![Diagram 1]

  2) What is the optical path length difference between two outgoing waves at an angle $\beta$?

  ![Diagram 2]

  3) What is the total optical path length difference between beams 1 and 2?

  ![Diagram 3]

- See how the different periodicity marks affect the pattern on the paper
- How does the error of the calculated wavelength scale with distance?