

Physics 5CL Prelab 0

Eric Du

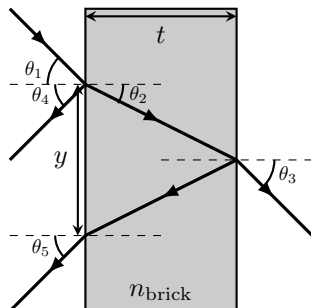
August 31, 2022

[NOTE:] Although we have separate prelab submissions, I worked extensively with **Andrew Binder** to complete this prelab, so that is the reason why our work shares relatively similar styles.

Problem 1: Brick Geometry

Consider the geometry of a ray of light incident on a rectangular brick of thickness t as shown. You may assume that the index of refraction of the surrounding air is 1.

Refer to the following diagram for solutions, thanks to Andrew Binder for the TikZ:



- a) Determine z in terms of the lengths t and y (you just need geometry for this part - no Snell's law is allowed)

Purely from geometry, we get

$$z = \sin \theta_2 = \frac{\frac{y}{2}}{\sqrt{\left(\frac{y}{2}\right)^2 + t^2}}$$

- b) Use propagation of errors to determine α_x as a function of θ_1 and α_{θ_1} . Then determine α_z as a function of t, y, α_t and α_y .

We have:

$$\alpha_z = \sqrt{\left(\frac{\partial z}{\partial y} \alpha_y\right)^2 + \left(\frac{\partial z}{\partial t} \alpha_t\right)^2}$$

Thus, computing the partial derivative separately:

$$\begin{aligned} \frac{\partial z}{\partial y} &= \frac{1}{2} \left(\frac{\sqrt{\frac{y^2}{4} + t^2} + \frac{y}{2(\frac{y^2}{4} + t^2)^{1/2}}}{\left(\frac{y}{2}\right)^2 + t^2} \right) \\ \frac{\partial z}{\partial t} &= \frac{y}{2} \cdot \frac{1}{\left[\left(\frac{y}{2}\right)^2 + t^2\right]^{3/2}} \cdot -\frac{1}{2}(2t) \\ \therefore \alpha_z &= \left[\left(\frac{\alpha_y}{2} \left(\frac{\sqrt{\frac{y^2}{4} + t^2} + \frac{y}{2(\frac{y^2}{4} + t^2)^{1/2}}}{\frac{y^2}{4} + t^2} \right) \right)^2 + \left(\frac{yt}{2 \left[\frac{y^2}{4} + t^2 \right]^{3/2}} \alpha_t \right)^2 \right]^{1/2} \end{aligned}$$

- c) Show that the geometry of reflection and refraction implies that $\theta_1 = \theta_3 = \theta_4 = \theta_5$

By the law of reflection, the angle of incidence equals the angle of reflection, and thus $\theta_1 = \theta_4$. From Snell's law, we have $\sin \theta_1 = n \sin \theta_2$ and $n \sin \theta_2 = \sin \theta_3$, so $\sin \theta_1 = \sin \theta_3 \implies \theta_1 = \theta_3$. This is also true because all $\theta < 90$ due to the way we interpret the angles, so there is only one unique solution to $\sin \theta_1 = \sin \theta_3$.

Further, by parallel lines we get $n \sin \theta_2 = \sin \theta_5 = \sin \theta_1$, so this leads to $\theta_1 = \theta_5$, and thus $\theta_1 = \theta_3 = \theta_4 = \theta_5$.

- d) Use Snell's law and your result from (a) to determine the index of refraction of the brick n_{brick} first in terms of x and z and then in terms of t, y and θ_1 .

From Snell's law earlier, we had $n \sin \theta_2 = \sin \theta_1$, so we have:

$$n = \frac{\sin \theta_1}{\sin \theta_2} = \frac{x}{z}$$

To express this in terms of t, y and θ_1 :

$$n = \frac{\sin \theta_1}{\frac{y/2}{\sqrt{\frac{y^2}{4} + t^2}}} = \frac{2 \sin \theta_1 \sqrt{\frac{y^2}{4} + t^2}}{y}$$

- e) Perform a propagation of errors to determine the uncertainty in n_{brick} based on the uncertainties of α_x and α_z .

Since $n = \frac{x}{z}$, the error propagation is as follows:

$$\alpha_n = \sqrt{\left(\frac{-x}{z^2} \alpha_z\right)^2 + \left(\frac{1}{z} \alpha_x\right)^2}$$

$$= \frac{1}{z} \sqrt{\frac{x^2}{z^2} \alpha_z^2 + \alpha_x^2}$$

Problem 2: Least-Squares with Hypothesis $y = -x + b$

Consider the hypothesis $y = -x + b$. The function χ^2 for a **weighted** least squares analysis is

$$\chi^2 = \sum w_i (y_i + x_i - b)^2 = \sum \left(\frac{y_i + x_i - b}{\alpha_{y,equiv,i}} \right)^2$$

where $\alpha_{y,equiv,i}$ is given by $\sqrt{\alpha_{y_i}^2 + \alpha_{x_i}^2}$

1. Find the best fit value b which minimizes χ^2 . You may use the weights w_i in your answer as we did in Eqs. 5.3.1 and 5.3.3-5.3.5 in the Statistics Review Sheet

From equation 5.4.5b on the statistics review sheet, we have

$$b = \frac{\sum w_i y_i - m \sum w_i x_i}{\sum w_i}$$

And since our model is $y = -x + b$, we have $m = -1$ so:

$$b = \frac{\sum w_i y_i + \sum w_i x_i}{\sum w_i}$$

2. Use propagation of errors on your answer from (a) to determine the error in your best fit value α_b . Hint: Use the trick of shifting all the errors from x over to y , so $\delta x_i = 0$ and $\delta y_i = \delta y_{equiv,i}$ (You may use the weights w_i in your answer.)

Following the hint, we assume that $\delta x_i = 0$, and so all errors are in δy_i . For this specific formula, the error propagation is:

$$\alpha_b = \sqrt{\sum \left(\frac{\partial b}{\partial y_i} \alpha_{y_i} \right)^2} = \sqrt{\sum \left(\frac{w_i}{\sum w_i} \alpha_{y_i} \right)^2} = \sqrt{\frac{(\sum w_i \alpha_{y_i})^2}{(\sum w_i)^2}}$$

Part 3: Laser Safety

Here's the screenshot for laser safety:

The screenshot shows a web browser window titled "Laser safety_lms_8-3-2017_html5 only". On the left is a "Menu" sidebar with a tree structure: Introduction, Identification, Hazards, Controls, Test (expanded), TEST, Laser Class, Components, Biological Hazards, Biological Hazards, Non-beam Hazards, Non-beam Hazards, Engineering Controls, Engineering Controls, Engineering Controls, Administrative Controls, Administrative Controls, Work Practices, Work Practices, PPE, PPE, PPE. The main content area is titled "Laser Safety Quiz" and displays a green checkmark icon followed by the text: "Congratulations, you passed the quiz. Please take a screenshot now and e-mail it to the Laser Safety Officer at Iso@berkeley.edu. Click here for screen shot instructions." Below this are five blue input fields containing the following text: "Name: Yutong Du", "UCB ID #: 3036730753", "PI/Supervisor: Daniel Barsky", "Department: Physics", and "Today's Date: Aug. 30, 2022". At the bottom of the main area is a red button with white text: "After taking the screen shot, click here to EXIT & EVALUATE THE COURSE". The browser's address bar and navigation controls are visible at the bottom.

Menu

- Introduction
- Identification
- Hazards
- Controls
- Test
 - TEST
 - Laser Class
 - Components
 - Biological Hazards
 - Biological Hazards
 - Non-beam Hazards
 - Non-beam Hazards
 - Engineering Controls
 - Engineering Controls
 - Engineering Controls
 - Administrative Controls
 - Administrative Controls
 - Work Practices
 - Work Practices
 - PPE
 - PPE
 - PPE

Laser safety_lms_8-3-2017_html5 only

Resources

Laser Safety Quiz

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Name: Yutong Du

UCB ID #: 3036730753

PI/Supervisor: Daniel Barsky

Department: Physics

Today's Date: Aug. 30, 2022

After taking the screen shot, click here to EXIT & EVALUATE THE COURSE

PREV NEXT