Tutorial 3: Partial Reflection of Light

1. Introduction

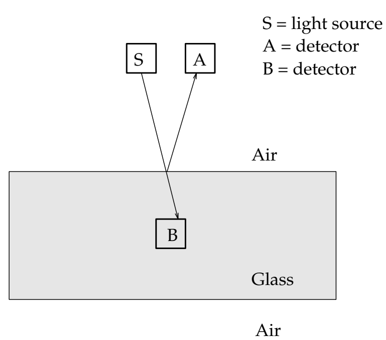
Recall the stopwatch rules for describing probabilities for reflection and transmission of light through air and glass:

- Traveling through air or glass: stop watch hand turns at a constant rate
- Reflection at top glass surface (coming from air): turn stop watch hand 180°; multiply length by 0.2
- Reflection at bottom glass surface (coming from glass): multiply length by 0.2
- Transmission from air to glass: multiply length by 0.98
- Transmission from glass to air: multiply length by 0.98

Today we will be using a computer program to help us apply these rules to study the partial reflection of light. The program animates the stopwatch model and performs the mathematical calculations for us.

2. Second Detector Inside Glass

In this section, we analyze the situation when detector B is inside the glass slab.



A. Preliminary Calculations

Before running the computer program, answer the following questions. A calculator is necessary for this.

1. Based on the rules given above, what is the probability that the photon will be detected at B? (Your answer should be **exact**.)

We would like to acknowledge Edwin Taylor for much of the material in this tutorial and for the computer programs.

2. Based on the rules given above, what is the probability that the photon will be detected at A? (Your answer should be **exact**.)

3. What is the **exact** value of the sum of these probabilities? This sum gives the probability that the photon will be detected either at A or at B.

4. Assuming that any photon leaving the source winds up at A or B (*i.e.*, no photon goes off in another direction), what value **should** these probabilities add up to? Explain why. Do they?

5. Find a more accurate value (good to 4 decimal places) for the amount by which the arrow shrinks at each transmission, such that the sum of the probabilities **does** add up to your answer above. *Hint:* the probability that the photon will be detected at A determined in problem 2 is **correct**. (This is the value used by the computer program.)

B. Computer Exercises

Now start up the RFLCT program by first clicking on the shortcut to H:PHYS-008/QM and then dragging rflct.ctb onto the blue CT Executor icon.

To explore the case with a detector in the glass, click on the '2ND DETECTOR' button. Click anywhere inside the glass in the left panel to set the location of Detector B. To begin the simulation, click on 'START.'

6. Approximately how many revolutions does the original air clock make for the downward first portion of the path between A and the top of the glass?

7. Place Detector B at several different locations inside the glass. Does the probability for detection at A depend on the location of B?

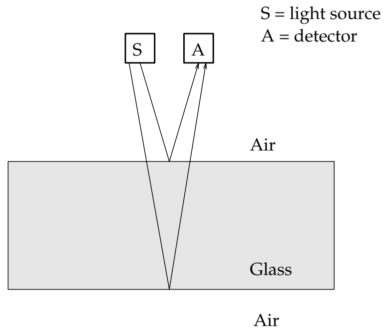
8. Does the probability for detection at B depend on the location of B inside the glass?

9. Describe everything that changes concerning detection at B for different locations of B inside the glass.

10. Describe everything that changes concerning detection at A for different locations of B inside the glass.

3. Single Detector at A

Here we consider the situation in which there is a detector at A only.



A. Preliminary Calculations
Answer these questions **without** using the computer program. Assume three significant digits in these calculations (arrow lengths change by factor of 0.980 for transmission, and 0.200 for reflection). Give your answers to three significant digits.

1. What is the length of the arrow after the photon enters the glass in its first downward path inside the glass?

2. What is the length of the arrow after the first reflection from the **lower** surface of the glass?

3. What is the length of the arrow after transmission back into the air at the **upper** surface of the glass?

4. Does changing the thickness of the glass change in any way the arrow associated with the path from S to A involving a reflection off the bottom surface of the glass? Explain your answer.

5. The diagram above shows two paths through which a photon can arrive at A: one involving a reflection off the top surface of the glass, and one involving a reflection off the bottom surface of the glass. What is the **maximum** length possible for the final arrow obtained by adding the arrows for the two paths?

   Sketch an example of how the arrows for the two paths look when the final arrow has this maximum length.

6. What is the **maximum** probability that the photon will be detected at A?

7. What is the **minimum** length possible for the final arrow obtained by adding the arrows for the two paths?

   Sketch an example of how the arrows for the two paths look when the final arrow has this minimum length.

8. What is the **minimum** probability that the photon will be detected at A, to three significant digits?

Two students are having a discussion about the partial reflection of light:

- *Beavis*: This partial reflection stuff is *cool*! I got that the minimum probability for the photon to arrive at A was not zero, it just was very small. Perhaps something else is going on to make the total probability zero.
- *Butthead*: No buttmunch, the professor said to measure the probability to three significant digits which is zero. There isn't anything else going on.

With which student do you agree or disagree. Explain why.

B. Computer Exercises

Click on the buttons 'FAST' and 'DETECTOR A ONLY.' Use the 'CHANGE GLASS WIDTH' option and the 'GRAPH' feature to answer the following questions.

You will need to run the program many times to produce the graphs you need. I suggest that you switch to the **fast mode** on the program, once you feel comfortable with how the program runs (you can select fast mode only after choosing NEW CASE).

9. What thickness of glass nearest to 100 pixels gives a minimum in the probability for reflection?

10. What thickness of glass (either larger or smaller) nearest to your answer above gives the next maximum in the probability for reflection?

11. What is the smallest thickness of glass (in pixels) for a maximum in the probability of detection at A?

12. What is the smallest thickness of glass (in pixels) for a minimum in the probability of detection at A?

13. Are the glass thicknesses corresponding to maxima in the probability for reflection equally spaced? Explain why or why not.

4. Using a Different Color of Light

The stopwatch hand rotates at different rates for different colors of light. We have been using red light so far. Let's see how things change with blue light.

A. Preliminary Calculations

1. Consider the path from the source to detector A that goes through a single reflection at the top surface of the glass. In what way(s) does the arrow associated with this path change if the stopwatch hand is rotating at a faster rate?

2. Now consider the other path–the one that reflects off the bottom surface of the glass. In what way(s) does the arrow associated with this path change if the stopwatch is rotating at a faster rate?

3. Taking into account these two alternate paths, what are the minimum and maximum probabilities that a photon will be detected at A if blue light is used instead of red?

4. Will the minimum in the probability of detection at A occur at the same glass thickness for blue light as for red? Why or why not?

Computer Exercises

Select the 'BLUE' option. We will continue to use the 'DETECTOR A ONLY' setup.

1. Approximately how many revolutions does the original air clock make for the downward portion of the path between A and the top of the glass?

2. What is the smallest thickness of glass (in pixels) for a maximum in the probability of detection at A?

3. What is the smallest thickness of glass (in pixels) for a minimum in the probability of detection at A?

4. Sketch a graph showing how the probability of detection at A depends on the thickness of the glass on the next page. Include curves for red light and blue light on the same graph.


Prob. of detection at A
20%
10%
0%
0
10
20
30
40
50
60
Thickness of glass in pixels