Scattering Lab, Measuring What You Can't See.

PHYS 104L

1 Goal

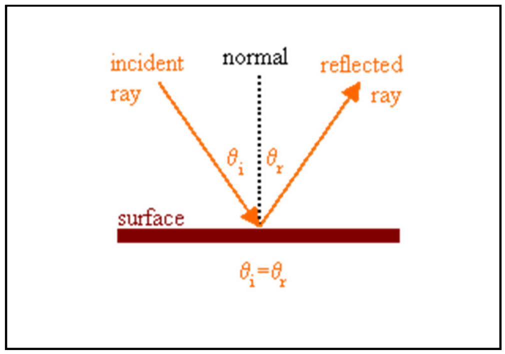
The goal of this week's lab is to follow up on last week's activity with another exposure to determining the characteristics of something you can't see. You will utilize the scattering of steel bearings to determine the shape of an object you are not able to directly see.

2 Introduction

The study of the nucleus, and the testing of various nuclear models, was made difficult due to the inability of scientists to directly see the nucleus. Making direct physical observations at a scale of that small size was simply not possible. The challenge, then, was how to learn information about nuclear characteristics without being able to directly see the nucleus of interest. One technique to collect such information was from what are called "scattering" experiments. In a scattering experiment, projectiles (typically a beam of charged particles) are fired at a target source of nuclei of interest. Some of the projectiles interact with the target nuclei and, as a result, are scattered such that they head off in a different direction than they were originally traveling. By detecting these scattered projectiles, observing their new path after scattering, measuring their characteristics, and understanding the process via which the interaction occurred, scientists were able to learn information about the target nuclei the projectiles were scattered from.

In this lab, you will be using a scattering technique to study an object you cannot see. However, in order to do so, we must understand the process via which our "projectile" and "target" will interact. The "target" in today's lab will be a solid wooden block, cut into some shape, laying on a flat surface. The "projectile" will be a steel ball bearing rolled down a ramp such that it is rolling towards the hidden object. The process via which they will interact will be a simple bounce off of the object. When the ball bearing bounces off the object, it will be scattered such that it comes out in some different direction. We are able to understand something about how the incoming direction and outgoing direction of the "projectile" are related to each other and determined by the shape of the object at the location the ball bearing contacted it. By probing the object's surface at different locations by rolling the ball in at different locations, you will try to map out the surface of the object and, thus, determine its shape.

Let's discuss what we can assume about our "scattering" event when the ball bounces off a wooden object's surface. The process is very similar to the way light reflects off of a flat mirrored surface, as pictured below. The "normal" line in the picture is a line drawn perpendicular to the mirrored surface at the point where the light will strike it. When light is incident upon a mirrored surface such that the incident ray's direction makes and angle, θ_i, with respect to the normal line, the light will reflect from the surface such that the reflected ray's path will make an angle with the normal line, θ_r, that is equal to the incident angle. The rule is sometimes described as saying the angle of incidence will be equal to the angle of reflection.



We can imagine drawing a "tangent line" to the surface of the wooden object at the location where the ball bearing strikes the surface. This "tangent line" is a straight line that just comes up to the surface parallel to it at the point of contact. This tangent line acts like the flat surface of a mirror. The path along which the ball bearing is initially rolling is analogous to the incident light ray's path and the outgoing ball bearing direction is analogous to the reflected light ray. We will assume that the angle of reflection is equal to the angle of incidence for the scattering of the ball bearing. We can identify the incident path and the scattered (reflected) path and see where those two paths intersect. We know that is where the ball struck the object so we can identify that as a point on the surface of the object. In addition, we also know that the normal line to the object's surface must be halfway between those two paths, so that the angle of incidence equals the angle of reflection. This normal line must be perpendicular to the wooden surface at that point. As a result, by observing the incident path and scattered path of the ball bearing, we can identify a point on the object's surface and the shape of the object at that point. By investigating the object's surface at many points, by sending in a ball bearing at several different locations, one can try to map out the surface of the entire object and determine its shape without ever having seen the wooden object.

Procedure

There are four different scattering stations, each with a different shaped wooden object. Each station consists of a flat board with a grid marked out on it. The wooden object is secured somewhere in the middle of the board. A cover, with fringe attached around it, is attached to the object so that you are not able to see the wooden object. You are not supposed to try to peak under or around the fringe to visually see the wooden object. Each station also will have a steel ball bearing and a wooden ramp. You are able to place the wooden ramp anywhere on the board so that it points under the cover. You can release the ball at the top of the ramp so that it will roll down the ramp and head under the cover along the direction the ramp points. This will be your "incident" path. You can use the grid to identify and record this incident path. The ball will disappear under the cover and then reemerge. You will watch the ball and use the grid to describe and record this "scattered" path for the ball. The shapes are constructed such that the ball can only reflect a single time; there won't be any multiple reflections. There are data sheets with a printed grid pattern matching that on the board. You can record your incident and scattered paths on the data sheet and map out the wooden object's shape on this data sheet. You and your partners will have 20 minutes to study and collect data about the surface of the hidden wooden object at each station in this manner.

1.) Use a fresh data sheet for each station. Note which station you are at on the top of the data sheet.
2.) Place the wooden ramp and record the incident path on your data sheet. Release the ball at the top of the ramp and observe the scattered ball's path. Record this path on the data sheet. You should use the same color of pencil for all incident paths and a different color for the scattered paths. Identify these colors at the top of the data sheet.
3.) Trace the two paths back to their point of intersection and make a small dot. Sketch in the "normal" line that splits these two paths and then sketch in the "tangent" line to the surface at the point of contact. You should use different consistent colors of pencil for the normal lines and tangent lines. Identify these colors at the top of the data sheet.
4.) Repeat for many different incident paths until you feel you have sufficiently determined the shape and location of the wooden object on your data sheet.
5.) Repeat this process at each of the other stations.

Calculations

1.) At the bottom of each sheet, calculate the area of the wooden object you collected data for. The grids on the board are spaced in 2 inch (5 cm) increments. This means your data sheet should give a scale model drawing of the wooden object you can use to determine the dimensions of the wooden object and calculate the area. You may use the area formulas for regular shaped objects from the handout reference sheet available in lab.

Lab Questions

1.) If you placed the wooden ramp further away from the object, but still pointing along the same incident path, would you expect the ball to scatter along a different path or the same path you observed? Explain.

2.) If you knew how the ramp was positioned and were only able to identify the point that the ball came back out under the cover, and not how the ball continued after it came out from under the cover, would you still be able to determine the contact point and the shape of the surface at that point? Explain.

3.) What would change about this lab if the size of the wooden object was much smaller than the steel ball you are rolling at it? What if the size of the wooden object is much larger than the steel ball you are rolling at it? In which case do you think you would be able to better determine the shape of the wooden object?

4.) What would change about this lab if you didn't know the ball could only bounce off of the wooden object once? Would you still be able to measure the incident and scattered paths? Would you still be able to determine the contact point and the shape of the surface?

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Data Sheet / Report

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Station # __________ Incident Path Color ______________ Scattered Path Color ______________

Normal Line Color _________________ Tangent Line Color ________________

Determine the area of your shape. Show your work.