1.2: Activities

Things You Will Need

[*For the labs we do this quarter that involve activities at home, you are expected to be resourceful. If you don't have precisely the items in these lists, you need to think outside the box to get materials that will do the same job. You may have to test several possibilities to see what works best. In short, you need to think like an engineer. Channel your inner MacGyver!*]

- several $8\frac{1}{2} \times 11$ sheets of paper
- a ruler
- a compass for drawing circles (not for telling which way is north) – a pencil and a string will do in a pinch
- a marble (steel or glass), or a small, round, smooth stone
- (useful, but not necessary) carbon paper
- pens of multiple colors

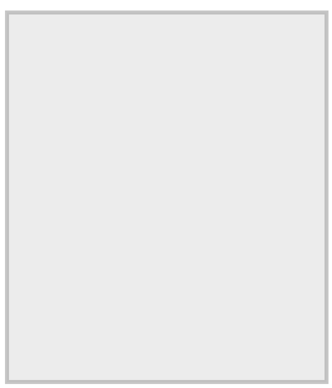
Data Collection

1. On the line that bisects the paper along its long axis, make a small dot with a pen, slightly (~1 inch, ~2.5 centimeters) off-center.
2. Place the paper onto a hard floor. If you have carbon paper, place it *beneath* the paper with the carbon side up.
3. Raise the marble to a height *over your head*, and do your best to drop it onto the dot you have made on the paper. *You should not be making adjustments between drops, to account for missing on previous drops – each drop should be a sincere attempt to hit the dot on **that** drop.* If you are not using carbon paper, you will need to find the indentation created by the marble, and mark it with a pen. Do your best to avoid any extraneous marks, or the paper will get overly cluttered.
4. Repeat the marble drop until you have 8 "data points" on the paper, and label each dot from 1 through 8.
5. With a fresh piece of paper, repeat this entire process, this time dropping the marble from waist height.

Data Analysis

For each of your two runs, do the following:

1. Use the "average of averages" method outlined in Background Material to determine the average landing position of the marble. This is where the multiple colors of ink will come in handy, as it can otherwise be difficult to keep straight all the dots on the paper.
2. Compute the standard deviation of the position from the average landing position, using the ruler to measure how far each data point is from the average. Creating a table like the one shown below will be helpful. Also, rounding the measurements of Δx to the nearest half-centimeter and using two significant figures for Δx^2 should be plenty of precision.



3. Use the compass and the ruler to draw a circle (probably best to use pencil) centered at the average landing position, with a radius equal to the uncertainty (standard deviation). If you don't have a compass, a string tied to a pencil and pinned at the other end should be adequate – precision is not really a major issue here.

Hypothesis

In any other experiment, developing an hypothesis comes before the data collection and analysis. In this exercise we have placed it later, because the experiment doesn't test any actual physical principles, but has rather just been contrived to illustrate the concept of uncertainty. Whenever performing an experiment, the hypothesis outlines the expected results. In this experiment, since we are aiming at a specific point on the paper, the hypothesis is as simple as, "The person is dropping the marble on the target point on the paper." While no individual drop actually hits this target point, the hypothesis states what would happen if all of the uncertainty could be removed (i.e. if the person had perfect aim).

So how do we use our data to *confirm* the hypothesis? The short answer is that we check to see if the expected result lands within the uncertainty range of the experimental result (i.e. the average). In terms of what we have done here, the hypothesis is confirmed if the target point lies within the circle we have drawn around the average landing point.

But not so fast. The person may have actually been aiming at any number of points besides the target point – anywhere inside the circle, in fact. So it turns out that this hypothesis is too broad to be useful. A better hypothesis would be one that involves a *comparison*. To see this, add the following to the two papers with all the dots:

1. Label the original target point with the letter "A."
2. Add a second target point, labeled with the letter "B," at the position on the same line lengthwise through the paper as target A, but on the opposite side of the widthwise line (again, about 1 inch / 2.5 centimeters off-center).

Now we can form a more specific hypothesis: "Given that the person is aiming at one of the two targets, the target they are aiming at is A." Not all hypotheses can be boiled-down to two possibilities, but this is a nicely illustrative example. There are several possibilities here:

- ***only target A lies within the circle, confirming the hypothesis*** – It is important to understand that even with this confirmation, it doesn't prove beyond all doubt that the hypothesis is correct. It only confirms it to within our agreed-upon level of certainty.
- ***only target B lies within the circle, refuting the hypothesis*** – This would indicate that, to within uncertainty, the person is actually aiming at the other target.
- ***neither target lies within the circle*** – This result should lead us to reevaluate our starting point, where it was given that one of the two points was the target. Either that assumption is incorrect, or some mistakes were made in the experimental procedure or data analysis, or there was some unseen source of systematic error (e.g. a steady wind that blowing the marble horizontally during its journey).
- ***both targets lie within the circle*** – There are two possibilities for this result. First, it can be "fixed" by adding more trials, which will have the effect of moving the average landing point closer to the actual target (assuming no systematic errors), and farther from the alternative target, such that the latter then lands outside the uncertainty range. The second possibility is that the two targets are simply too close to each other for the degree of uncertainty we have. In this case, we say that the experiment "doesn't provide sufficient resolution" to confirm or refute the hypothesis.

Lab Report

This lab is different from most of the labs we will have this quarter, in that it is more of an exercise in procedure and an illustration of principles of uncertainty than it is a test of physics. As such, the lab report is a little more "cookbook" than future labs will be. That is, your report will focus on some specific questions, rather than depend upon you – with little prompting – to extract and report on the relevant information.

Download, print, and complete this document, then upload your lab report to Canvas. [*If you don't have a printer, then two other options are to edit the pdf directly on a computer, or create a facsimile of the lab report format by hand.*]