Projectile Lab – Notes for Teachers

Materials:
For each group (of 2-4 students) you will need the following:

- 1 wooden chopstick, with a couple of metal nuts on one end to increase the weight; the tail end of the chopstick should be marked at 1 cm intervals (up to 5 cm)
- 1 meter stick
- 1 small metric ruler (in addition to the meter stick!)
- 1 rudimentary balance, consisting of a wooden or cardboard bar with a hole at the center of mass and 2 holes equidistant from the center, with a ziploc bag attached to each edge hole
- 5 pennies
- 25 beads
  (Note: in the advanced lab, students measure the mass of the beads themselves; for the basic lab, however, the mass of the particular beads should be measured in advance and given to the students)
- 1 quart-size ziploc bag with a hole at the top
- 1 package of candy with net weight on the order of 200g, or anything else of that approximate weight where the weight is marked on the package, and where the packaging itself is light (no metal cans)
- 3 paper targets
- 1 rubber band (standard 5mm size, or similar)
- a flat table or desk of reasonable height, with at least ~3 m free space in front of it for launching the projectile
- ideally, 1 calculator per student; at a minimum, 1 per group

Notes:
- The 3 tasks in Part 1 should be done simultaneously by different students in the group
- Each group needs to have at least one student (or helper) capable of moving around to fetch the projectile and measure the distance to the targets. The first 2 tasks in Part 1, as well as the actual launching of the projectile can be done without a student needing to leave their chair.
- The projectile will always fly below chest height, but if there are multiple groups using the same shooting range, the students should still be warned to be careful and not hit someone with the projectile.
- If there is extra time in the end, the students could have another contest where everyone gets a different size rubber band, and they have to recalculate and aim for a target to see who can come closest.

Answers to Basic Post-Lab Questions:

1. How does changing the following variables affect the distance traveled by the projectile? (Circle the right answer)

   If the projectile is launched from a greater height, distance traveled: *increases*
   If the projectile is heavier, distance traveled: *decreases*
   If the rubber band has a smaller elastic constant, distance traveled: *decreases*
   If you were to launch on the moon, distance traveled would: *increase*

2. Did your calculations tend to overestimate or underestimate the distance which the projectile flew? Can you think of any reason for this?

Most likely the calculations will overestimate the distance (the projectile lands closer than the target). This happens because the projectile scrapes along the sides of the basket as it is launched, which slows it down by the time it leave the table.

If the calculations are underestimating (the projectile lands further than the target), then this is most likely due to an error in how far the rubber band is being pulled back, or because the projectile is being launched at an angle.

3. What do you think would happen if you launched the projectile at an angle upwards rather than horizontally off the table.

   The time spent in flight would: *increase*
   The distance traveled by the projectile would: *depends on the angle*

(*Launching slightly upward will increase the distance because the projectile travels for a longer time. But launching too close to straight up would decrease the distance, since the projectile has no horizontal velocity.*)

Answers to Advanced Post-Lab Questions:

1. By what factor will the distance that the projectile flies change, if the following variables are altered:

   (a) The projectile is twice as heavy. *factor of 1/sqrt(2)*
   (b) The table is twice as high. *factor of sqrt(2)*
   (c.) The elastic constant of the rubber band is twice as large. *factor of sqrt(2)*
   (d) You pull the rubber band back twice as far *factor of 2*
   (e) You launch on the moon, where gravity is 1/6 that of earth. *factor of sqrt(6)*

2. Did your calculations tend to overestimate or underestimate the distance which the projectile flew? If you overestimated, where did some of the stored potential energy go? If you underestimated, where did the extra energy come from?

Most likely the calculations will overestimate the distance (the projectile lands closer than the *target). This happens because the projectile scrapes along the sides of the basket as it is launched, which slows it down by the time it leave the table. The extra energy goes into the heat generated by friction.*

3. Which of the following errors in measurement would have the greatest effect on your predicted flight distance?
   (a) A 10% error in measuring the mass.
   (b) A 10% error in measuring the elastic constant
   (c) A 10% error in measuring the height of the table
   (d) A 10% error in measuring the distance to which you pull back the rubber band

   (d) – the other variables go under a square root and thus have less of an effect

4. How would the time of flight and the distance traveled by the projectile change if you were to launch at an angle upwards rather than horizontally off the table?

Launching slightly upward will increase the distance because the projectile travels for a longer time. But launching too close to straight up would decrease the distance, since the projectile has no horizontal velocity.

5. Suppose you had as many pennies as you wanted in your kit, but you **did not know the mass of a penny**. Could you still do this lab with the materials provided? What extra measurement would be required or what measurement would you change and how?

   You could use units of pennies for your mass everywhere instead of grams. You would need to either balance the package of candy against the pennies (to find its mass in units of pennies – or equivalently to find the mass of a penny for yourself), or you could just use a lot of pennies instead of the package of candy for measuring the elastic constant