Projectiles: Target Practice

Student Version

In this lab you will shoot a chopstick across the room with a rubber band and measure how different variables affect the distance it flies. You will use concepts of kinetic and potential energy to understand how the chopstick is propelled.

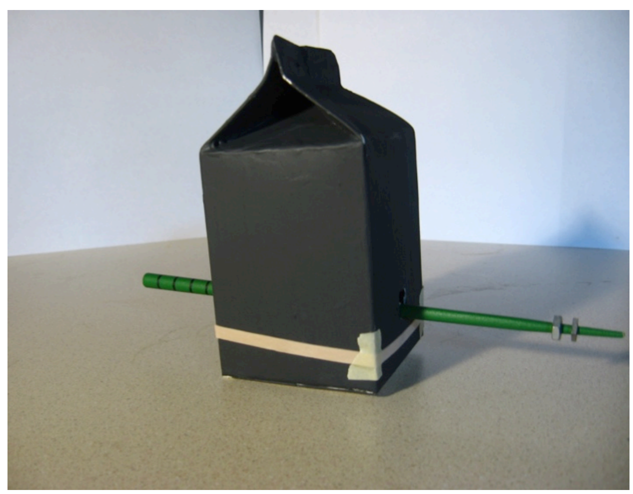
Key concepts:

- A ***projectile*** is a flying object given an initial push. Launching a projectile usually involves converting ***potential energy*** to ***kinetic energy***. The distance a projectile travels depends on how fast it flies and how much time it takes to hit the ground.
- Conservation of energy. When you stretch a rubber band, you store ***elastic potential energy***. The farther you stretch, the more elastic energy is stored. This can then be converted into ***kinetic energy*** (energy associated with motion) to make a projectile fly. The more kinetic energy it has, the faster it flies.
- Heavier objects with a given amount of kinetic energy move slower than lighter objects with the same amount of energy.

Part 1 – Elastic Energy

In this first part, you will look at how the distance traveled by the projectile is affected by how far back you pull the rubber band.

1. **Place a rubber band around the milk carton, as shown in the illustration to the right.** The rubber band should stretch below the hole from which the projectile will leave the carton, and on level with the hole in the carton through which the projectile will be pulled back to launch the chopstick. Do not readjust the rubber band after you start the experiment. **Put a little piece of tape at each of the two corners on the side of the carton through which the chopstick will leave to keep the rubber band in place.**



2. Orient the milk carton near the edge of the table such that it is pointed in a direction with at least 3 meters of open floor space. **Use a piece of masking tape to mark off the point of the floor in line with edge of the table from which the projectile will be launched.** Lay down the meter stick or tape measure on the line along which the chopstick will be launched. **If you're using a meter stick, mark off three 100-cm increments with masking tape to save yourself time later.**

3. **Put the projectile in the launcher as illustrated.** The projectile should be mostly horizontal when launched. The tail end of your projectile should be marked at 1 cm intervals**. Launch the projectile by pulling the rubber band and chopstick back to the 2 cm mark, then releasing the rubber band.** Make sure the nose of the projectile is lined up with the edge of the table when you launch. **One member of your group should stand to the side and watch where the tip of the projectile lands, while another should hold down the milk carton firmly on the table.** Repeat this process 2-3 times to ensure that you are launching the projectile consistently.

4. Once you are comfortable that you are launching the projectile consistently, pull the rubber band back to the 2 cm mark, release, and **measure the horizontal distance from the edge of the table to where your projectile landed.** Record it in the table below.

Data Table:

Distance pulled (*d*)	**Distance flown (*x*)**	**Factor change (compared to 2 cm measurement)**
2 cm		1
3 cm		
4 cm		

5. Repeat steps 3 and 4, this time pulling back to the 3 cm and 4 cm mark.

6. In the last column of the table above, **fill in the factor change in distance flown when compared to the 2 cm distance.** To find the factor change, divide the distance x for each row by the distance in the first row. See the example table below for guidance on how to calculate the factor changes.

Example Table:

Distance pulled (*d*)	**Distance flown (*x*)**	**Factor change (compared to 2 cm measurement)**
2 cm	75 cm	75 ÷ 75 = 1
3 cm	120 cm	120 ÷ 75 = 1.6
4 cm	145 cm	145 ÷ 75 = 1.93

Note: The numbers above are just example data points to demonstrate how the factor change calculations are done. The actual distance the chopstick flies will depend on many factors, including the type of rubber band used, the weight of the chopstick, and the height of the table. **Use the distances you recorded in the data table at the top of the page for your calculations, and fill in the answers in the last column of the data table.**

Q1. Which of the following best describes how the distance flown by the projectile (x) depends on how far you stretched the rubber band (d)?

(a) doubling the length pulled makes the projectile travel twice as far
(b) doubling the length pulled makes the projectile travel 4 times as far
(c) doubling length pulled makes the projectile travel 1.4 times as far

Q2. Using your answer from the previous question, how far would you expect the projectile to travel if you stretched the rubber band 5 cm? (Hint: 5 cm is 2.5 times your original distance of 2 cm.)

Predicted distance traveled for d = 5 cm: x = ______________

7. Pull back 5 cm and **measure how far the projectile flies.**

Actual distance traveled for d = 5 cm: x = _______________

Q3. How close were you? Calculate the percent error:

$$\%\,\text{error} = \frac{(\text{actual distance - predicted distance})}{\text{predicted distance}} \times 100 = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_$$

Concept Question:

Q4. Which of the following correctly describes what occurred when you pulled the rubber band back farther to launch the projectile? (More than one choice may be correct!)

(a) More <u>elastic energy</u> was stored in the rubber band
(b) The projectile had more <u>kinetic energy</u> when it left the launcher
(c) The projectile took a longer time to hit the floor
(d) The projectile took a shorter time to hit the floor
(e) The projectile was moving faster when it left the launcher

Part 2 – Projectile Mass

In this part, you will investigate the effect of the ***mass*** of your projectile on how far it travels. You will use a simple balance to estimate the projectile mass.

1. In your lab kit there should be a wooden bar with two Ziploc baggies attached. Use this balance as shown in the picture. When the masses in the two baggies are the same, the wooden bar should be horizontal.

2. **Put your projectile into one baggie on your balance.** If you hold the balance by the central string, it will tilt towards the heavier end, where you have placed the projectile.

3. **Add clay to the other baggie until the wooden bar is horizontal when you hold the balance by the central string.** The strings should line up with the black lines on the wooden beam. **Add this clay to the nose of the chopstick.**

Q5. By what factor has the mass of the projectile changed?

4. Copy over your results from Part 1 into Column 2 of the table below. **Launch the projectile as before, pulling back to the 2 cm and 4 cm mark. Measure the distance traveled** and record it in Column 3 in the table below.

5. In Column 4, **fill in by what factor the distance changed when you altered the projectile mass.**

Column 1	Column 2	Column 3	Column 4
Distance pulled	**Distance traveled (original projectile – from first table)**	**Distance traveled (heavier projectile)**	**Factor change** (column 3 ÷ column 2)
2 cm			
4 cm			

Q6. Which of the following best describes how the distance traveled by the projectile (x) depends on the mass of the projectile (m)? (Hint: look at your factor change in the above)

(a) doubling the mass makes the projectile travel 2 times as far
(b) doubling the mass makes the projectile travel ½ times as far
(c) doubling the mass makes projectile travel 1.4 times as far
(d) doubling the mass makes projectile travel .7 times as far

Q7. How far do you think the new, heavy projectile will travel if you pull the rubber band to the 5cm mark? (Hint: recall from the previous part what happens if you multiply the distance pulled back by 2.5.)

Predicted distance when pulling 5 cm: ___________

6. **Place a target** at the predicted distance from the table. Now **launch the projectile** after pulling back 5cm. **Did you hit the target?**

   Actual distance: _________________

Concept Questions

***** For those who have done the gravity lab:

**Q8. Does making the projectile heavier change the time it takes to fall to the ground?*

Q9. A heavy object must have more kinetic energy to move at the same speed as a lighter object. Explain why the heavier projectile did not fly as far. (Hint: Did its speed coming off the launcher change? Why?)

Part 3 – Starting Height

In this part, you will see how the distance that the projectile travels changes if you raise the launch height.

1. **Use a stack of textbooks to make the height from which you are shooting 1.5 times as big as it was before.**

   Original height of table: _______________
   *New height of table: _________________ (= original * 1.5)*

2. Copy over your results from Part 2 into Column 2 of the table below. **Shoot the projectile (with the modeling clay still on it)** as before, pulling back to the 2 cm and the 4 cm mark. Measure how far the projectile flies and fill in the following table. Column 4 is the factor change in the distance traveled when comparing the new and old height.

Column 1	Column 2	Column 3	Column 4
Distance pulled	**Distance traveled (original height, heavy projectile – from second table)**	**Distance traveled (new height, heavy projectile)**	**Factor change ($column\ 3 \div column\ 2$)**
2 cm			
4 cm			

Q10. Which of the following best describes how the distance traveled by the projectile (x) depends on launch height (h)?

(a) multiplying the height by 1.5 changes distance traveled by a factor 1.5
(b) multiplying height by 1.5 changes distance traveled by factor 2.25
(c) multiplying height by 1.5 changes distance traveled by factor 1.2
(d) multiplying height by 1.5 changes distance traveled by 0.66

*Q11. Using what you learned in part 2, how far do you think the projectile will fly if you launch from the new height**, take off the modeling clay**, and pull back 4 cm? (Hint: you will need to remember how far the light projectile flew from the original height when pulled back 4 cm – look at your first table!)*

*Predicted distance for **light projectile**, tall height, 4 cm: __________*

3. **Place a target where you predict the projectile will land**. Make sure you have enough space so the projectile won't hit anything! **Did you hit the target?**

Concept Question:

Q12. Which of the following correctly describes what happens when you raise the height of the launcher?

(a) The projectile leaves the launcher with more kinetic energy.
(b) The projectile has a faster horizontal speed when leaving the launcher.
(c) The projectile takes longer to reach the ground
(d) More elastic energy is stored in the rubber band.

Wrap-Up Questions

Q13. If you change the following variables, what will happen to the horizontal distance flown by the projectile?

(a) *pull the rubber band back farther* ***increase / decrease / depends***

(b) *use a stronger rubber-band (one that takes more effort to pull)* ***increase / decrease / depends***

(c) *use a lighter projectile* ***increase / decrease / depends***

(d) *launch from a lower height* ***increase / decrease / depends***

(e) *launch on the moon (weaker gravity than earth)* ***increase / decrease / depends***

(f) *launch at an angle downwards* ***increase / decrease / depends***

(g) *launch at an angle upwards* ***increase / decrease / depends***

(Hint: Think about launching at a slight angle up, not launching straight upwards.)

Q14. Give two examples of projectile motion that you have seen in real life or on TV, and explain where the energy comes from to make the projectile move.

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