

Projectile Lab – student

You will shoot a projectile across the room using a rubber band and calculate how far it flies.

Part 1 – Preliminary Measurements

Tasks 1, 2, and 3 can be done at the same time by different members of your group.

Task 1 – Mass of the Projectile

You will use a simple balance to measure the mass of your projectile.

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 (the wooden stick with metal nuts on the end) 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. **Find the right combination of pennies and beads so that they balance out the projectile when placed into the other baggie.** The wooden bar should be horizontal when you hold the balance by the central string.



1 projectile = _____ pennies + _____ beads

3. Now calculate the mass of your projectile using the following information:
 - One US penny has mass **2.5 g**
 - Each of the beads provided has a mass of approximately **0.19 g**

Putting it all together, the projectile has mass _____ g

Task 2 – Elasticity of the Rubber Band

You will measure the “elastic constant” of the rubber band which will be used to shoot your projectile. This elastic constant tells you how strong the rubber band is. The bigger the elastic constant, the more force is required to stretch the band and the more energy is stored in the band by stretching it.

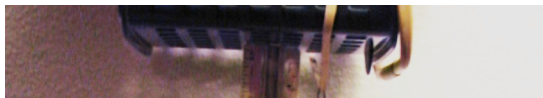
1. Place a rubber band around the basket provided. On one side of the basket, the rubber band should go across the 1st row of holes under the open top. On the other side of the basket, it should go across the 2nd row of holes from the top. **The side where it passes the 2nd row of holes is the side you will use to load your projectile.**
2. Adjust the rubber band so that it is evenly tight all around the basket. **Do not** adjust the rubber band after you measure the elasticity – this would throw off your predictions.
3. **Place the package of candy from your kit into a ziploc bag.** Use a paper-clip to suspend the bag from the rubber-band. The bag should hang from the center of the rubber band on the side where it goes across the 2nd row of holes.



The mass hanging from my rubber band is $m =$ _____ g.

(Look for the “net weight” on the package of candy to find the appropriate number)

4. Use a ruler to measure the distance from the rubber band (where the paper-clip is attached) to the side of the basket, as illustrated below:



5. **The rubber band stretched a total of _____ cm from the basket.**
6. If an object of mass m hanging from a rubber band stretches that rubber band by a distance x , then the elastic constant is given by

$$k = \frac{m \times 980 \left(\frac{cm}{s^2} \right)}{x}$$

Therefore, the elastic constant of the rubber band is $k =$ _____ g/s²

Task 3 – Time of flight

You will calculate the time it takes for your projectile to hit the ground after it is launched. The time of flight depends only on the starting height and on the acceleration of gravity, $g = 980 \text{ cm/s}^2$. It does not depend on the mass of the projectile or on its horizontal speed as it is launched!

1. Use the meter stick to measure the height of the table from which you will be launching the projectile.

The projectile will be launched from height _____ cm

2. An object that falls at a constant acceleration g for a time t will travel a vertical distance h given by:

$$h = \frac{1}{2}gt^2 \quad (\text{where } g = 980 \text{ cm/s}^2)$$

How long will it take the projectile to hit the floor after it is launched? Solve the equation for time, plugging in the numbers for height h and acceleration g .

The time to fall from the top of the table to the ground is _____ seconds.

3. If you are done and other members of your group are still working, help them with their task.

Part 2 – Ready, Aim, Fire!

To predict how far the projectile will fly, you need to know the speed v with which it leaves the launcher. To find this speed, we will use the conservation of energy.

A rubber band with elasticity constant k , stretched a distance x stores an energy of:

$$\text{Potential Energy} = \frac{1}{2}kx^2$$

A object of mass m , moving at speed v has an energy of:

$$\text{Kinetic Energy} = \frac{1}{2}mv^2$$

If all the energy stored in the rubber band is converted into the kinetic energy of the projectile, then we set these expressions equal to each other and solve for the speed (v) to get:

$$v = x\sqrt{\frac{k}{m}}$$

1. Plug in the values you measured in Part 1 to find the speed of the projectile:

(m)= for the **mass** of the projectile [see Task 1]

(k)= the **elastic constant** of the rubber band [see Task 2].

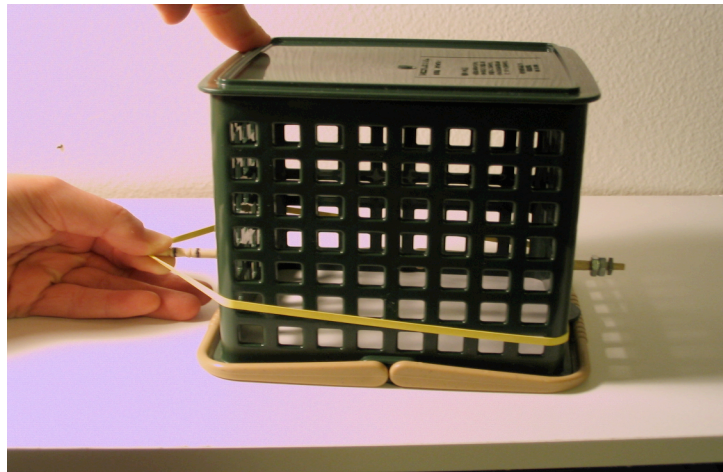
(x)=**distance** rubber band is stretched [see the table below]

$$v = x \sqrt{\frac{k}{m}}$$

Note: Fill in the speed of the projectile for different values of x.

Distance rubber band is stretched (x)	Speed of projectile (v) (in cm/sec)	Predicted Flight Distance	Actual Flight Distance
2 cm	cm / sec	cm	cm
3 cm	cm / sec	cm	cm
4 cm	cm / sec	cm	cm

- For each row in the table, find the distance that the projectile should travel. Use the time of flight you found in Task 3. Use the formula: **distance = rate * time**.
- Place the targets from your kit at the predicted distances from the edge of the table. If the floor is slippery, tape them to the floor.
- The tail edge of the projectile has been marked at 1 cm intervals. Put the projectile in the launcher as illustrated below.



- The projectile should be horizontal as it is launched. Try launching the projectile by pulling back to the 2, 3, and 4 cm mark. Everyone should get a turn to launch.

One member of your group should stand to the side and watch where the tip of the projectile lands.

Measure the distance the projectile actually flew, and fill in the last column of the table.

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 / decreases
If the projectile is heavier, distance traveled:	increases / decreases
If the rubber band has a smaller elastic constant, distance traveled:	increases / decreases
If you were to launch on the moon, distance traveled would:	increase / decrease

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

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 / decrease / depends on the angle
The distance traveled by the projectile would:	increase / decrease / depends on the angle

(Hint: consider what would happen if you launched straight upwards)