

## Conservation of Energy

### Equipment

Qty	Item	Part Number
1	Mini Launcher	ME-6800
1	Metal Sphere Projectile	
	1 and 2 Meter Sticks	
1	Large Metal Rod	ME-8741
1	Small Metal Rod	ME-8736
1	Support Base	ME-9355
1	Double Rod Clamp	ME-9873

### Purpose

The purpose of this activity is to see that the mechanical energy of a simple projectile acting solely under the force of gravity is conserved.

### Theory

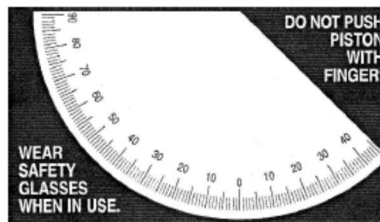
The total mechanical energy of a ball during projectile motion is its potential energy ( $PE$ ), and its kinetic energy ( $KE$ ). (Here we are ignoring any rotation of the ball) In the absence of air resistance, or any other non-conservative force, the total energy will be conserved. When a ball is shot straight up, its initial  $PE$  is usually to be zero since the initial height is normally defined to be equal to zero,  $PE_i = mgy_i = 0$ . This makes all of the ball's energy associated with its motion, i.e.  $KE_i = \frac{1}{2}mv_i^2$ . As the ball flies upward, the force gravity acts on the ball accelerating it downwards. Since gravity is a conservative force it will not change the amount of energy the ball possesses, but will cause the energy to transform from Kinetic to Potential and then back again. As the ball flies upwards its velocity will be constantly decreasing, again due to the force of gravity accelerating the ball downwards, till eventually the velocity will be zero,  $v_f = 0$ . At this point the ball will stop moving upwards, therefore, the ball will have reached its maximum (final) height,  $y_f$ , and the ball's Kinetic to Potential will be given by,  $PE_f = mgy_f$ , and  $KE_f = \frac{1}{2}mv_f^2 = 0$ . Since the only force acting on the mass (the ball) during this whole process is the force of gravity, then by Conservation of Energy we can set the sum of the initial energies equal to the sum of the final energies, giving us:

$$\begin{aligned}
 KE_i + PE_i &= KE_f + PE_f \\
 \frac{1}{2}mv_i^2 + mgy_i &= \frac{1}{2}mv_f^2 + mgy_f \\
 \frac{1}{2}mv_i^2 &= mgy_f
 \end{aligned}$$

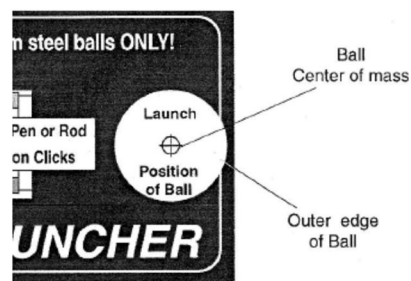
So we see that the initial Kinetic energy equals the final potential energy for our simple projectile.

## Procedure part 1: Determining Initial Velocity

1. Attach the Large Metal Rod to the Support Base, and then put the support base on the ground.
2. Then use the Double Rod Clamp, and the Small Metal Rod to attach the Mini-Launcher to the Large Metal Rod.
3. Use a meter stick to make sure that the bottom of the barrel opening of the Mini-Launcher is 1.00 meter above the floor. Record this as  $y_i$  for **TABLE 1**.
4. Using the protractor on the side of the Mini-Launcher set the initial launch angle to  $0^\circ$ . This will result in the initial velocity being purely in the in x-direction, and therefore the initial y-component of the velocity will be zero.
5. Now dangle the Plumb Bob right next to the Mini-Launcher such that its string crosses the little sign at the center of the white circle on its side, and the mass just barely touches the floor. With a pencil put a little mark on the floor where the Plumb Bob is touching it. This is the initial x-coordinate of the center of mass of the projectile at the moment it will leave the Mini-Launcher.
6. Place a large object about 2 to 3 meters in front of the Mini-Launcher. (One of your book bags, or something similar will do fine) This will serve as a barrier to stop the projectile.
7. Insert the Metal Sphere Projectile into the barrel of the Mini-Launcher, then using a pencil or pen push it back into the barrel until you hear a click. The Mini-Launcher is now at setting 1. (There are 3 settings)
8. Pull on the little rope attached to the Mini-Launcher's trigger to fire the projectile.
9. Note about where the projectile hit the floor, and tape a white piece of paper at that location.
10. Now on top of the white piece of paper place a piece of carbon paper with the carbon side (the dark/black side) facing downward. **DO NOT TAPE DOWN THE CARBON PAPER.**
11. Now shoot the projectile 5 times onto the carbon paper, then remove the carbon paper. There should now be 5



*Illustration 2: The mini launcher is equipped with a built-in protractor and plumb bob so as to launch from specific angles.*



*Illustration 1: When performing measurements such as range and launch height, always measure from the crosshatch, ie, the 'Ball Center of Mass' as shown in this picture.*



black marks on the white piece of paper signifying the locations that the projectile hit the floor. (These 5 marks should be closely packed together. If they are not, you need to make sure everything is still aligned correctly, and then try again.)

12. Using a meter stick(s) measure the displacements from the projectile's initial x-coordinate, and the 5 marks on the white paper. Record these x-displacements in **Table 1**, for setting 1.
13. Repeat steps 6 – 12 for settings 2, and then settings 3. (setting 2 = 2 clicks, setting 3 = 3 clicks)

## Procedure part 2: Conservation of Mechanical Energy of a Projectile

1. Reposition the Mini-Launcher so that it is just about as far down the Large Metal Post it can go without the mass hanging from the protractor touching the ground.
2. Using the protractor on its side set the launch angle to  $90^\circ$ . The Mini-Launcher should be aimed Straight upwards.
3. Place a meter stick, vertically, right next to the Mini-Launcher. Measure the height of the Center of Mass Mark on the side of the Mini-Launcher, and record this height as  $y_i$  for **Table 2**.
4. Insert the Metal Sphere Projectile into the barrel of the Mini-Launcher, then using a pencil or pen push it back into the barrel until you hear a click. The Mini-Launcher is now at setting 1.
5. Pull on the little rope attached to the Mini-Launcher's trigger to fire the projectile. The projectile will fly straight upwards. Repeat this a few times till you have a good idea how high the projectile is going to rise. Then with one of your group members positioned with their eye at about that level, fire the projectile again. This member should now be able to read off the height the projectile rises to. (Since we are measuring the initial height from the center of the ball, we need to measure the final height from the center of the ball too.) Record this height in **Table 2**.
6. Repeat till you have 5 measurements for setting 1.
7. Repeat procedure for settings 2, and 3. For setting 3, you will most likely need a 2-meter stick.
8. Weigh the ball, and record its mass in **Table 2**.







**Table 2: Conservation of Mechanical Energy**  $y_i = \underline{\hspace{2cm}}$   $m = \underline{\hspace{2cm}}$

	Setting 1	Setting 2	Setting 3
$y_{f1}$			
$y_{f2}$			
$y_{f3}$			
$y_{f4}$			
$y_{f5}$			
$y_{f-avg}$			
$PE_f$			
$v_i$			
$KE_i$			

1. Calculate the average final height for each setting, and the Potential Energy the projectile has at its maximum height. Then record those answers in **Table 2**. (20 points)

2. Transfer the values for the velocities for each setting from **Table 1** to **Table 2**, then calculate the initial Kinetic Energies for each setting. Record those answers in **Table 2**. (20 points)

