

The Ballistic Pendulum

Apparatus: Beck Ballistic Pendulum.

Objective: The purpose of this experiment is to study the principals of conservation of energy and conservation of momentum.

Physics Theory: Consider a system such as that shown in Figure 1., where a projectile is fired horizontally from the projectile launcher towards a receiver in the pendulum arm.

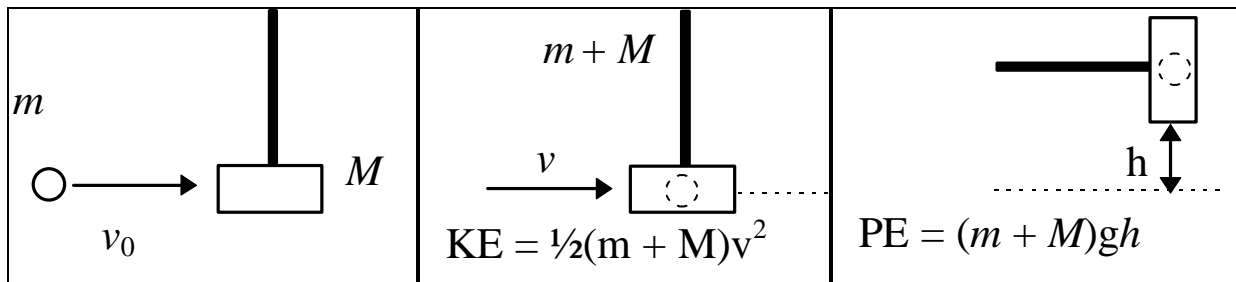


Figure 1.

The projectile is launched with an initial velocity of v_0 , giving it an initial momentum of mv_0 , as shown in the first panel in figure 1. Since the receiver is not in motion before the collision, the entire pre-collision momentum of the system is accounted for by the moving projectile. Panel two depicts the system at the moment the projectile collides *inelastically* with the receiver. Because the collision is inelastic, momentum can be conserved before and after the collision but energy cannot. In order to conserve momentum before and after the collision the total momentum of the system must remain unchanged:

$$mv_0 = (m + M)v \quad (1)$$

After the collision, the system behaves in basically a conservative manner, i.e., $\Delta KE + \Delta PE = 0$, so kinetic energy is converted to potential energy as the pendulum arm rises without much energy being lost. Immediately after the collision, the system has kinetic energy given by:

$$\frac{1}{2}(m + M)v^2 \quad (2)$$

which is converted to potential energy given by:

$$(m + M)gh \quad (3)$$

and since the system is conservative:

$$\frac{1}{2}(m + M)v^2 = (m + M)gh \quad (4)$$

Combining these equations and solving for v yields the velocity of the system at the moment of the collision:

$$v = \sqrt{2gh} \quad (5)$$

One may then substitute equation (5) into equation (1) and solve for the initial velocity of the projectile:

$$v_0 = \frac{(m + M)}{m} \sqrt{2gh} \quad (6)$$

Experimental: Part I - Calibration

The first step in the experimental portion of this procedure is to calibrate the projectile launcher. Shoot the projectile into the receiver enough times to generate good statistics (the number of trials is left up to you but you should be prepared to explain why you chose the number that you did), recording the notch into which the ratchet settles with each trial. When you have completed your trials, compute the mean position of the ratchet and reposition the pendulum arm in this position.

Measure the height of the center of mass of the projectile/receiver combination (where is the center of mass of the projectile/receiver combination and why is it important?). Return the pendulum arm to the down position and measure the height of the center of mass of the projectile/receiver combination. The difference between these two measurements is the height, h , through which the pendulum rises. Record this measurement along with the standard deviation of h .

Measure and record the mass of the projectile (m) and the receiver (M).

Part II - Kinetic Energy Before and After the Collision

Use equation (6) to determine the initial velocity of the projectile. Use the standard deviation of h to compute the standard deviation of v_0 . Next calculate the kinetic energy before and after the collision. What percentage of the initial kinetic energy was lost during the collision?

Questions:

1. Compare/contrast elastic and inelastic collisions.
2. Where did the energy lost during the collision between the projectile and the receiver go?
3. During what portions of this process is momentum conserved?
4. During what portions of this process is energy conserved?
5. Overall, is the operation of the ballistic pendulum a conservative or non-conservative process?