The Ballistic Pendulum

**Introduction**:

It might seem like you would need a “high tech” method to measure the speed of a bullet, but you can do it easily with a simple distance measurement and two simple mass measurements. The ballistic pendulum is nothing more than a block of wood suspended by strings so that it is free to swing back and forth and is large enough to capture and fully contain a high-speed bullet. It was used before the advent of high-speed timers to measure the speed of a bullet. It is quite accurate, safe, and is a very elegant example of the power of both the law of conservation of energy and the law of conservation of momentum. This is my High School Physics teacher, Mr. Lapp, actually demonstrating the ballistic pendulum in class….It was a different time.

To use the ballistic pendulum, a bullet is fired into the block of wood and the block moves forward and up. Because no momentum is lost in collisions, the momentum of the block and bullet after the collision is equal to the momentum of the bullet before the collision. And, because of energy conservation, the gravitational potential energy of the block at its highest point is equal to its kinetic energy at the lowest point, (after the bullet has entered the block).

 You can use the height that the block rises (easily measured with a meter stick) to calculate the gravitational potential energy of the block and bullet at the highest point. Then you can use this to find the speed of the block and its momentum at the lowest point. Finally, you can use the momentum of the block after it is hit to find the original speed of the bullet. Now that is impressive!

Figure 15.3 shows a method to easily measure the height (h) the block rises. “L” is the length of the pendulum (1.50 m) and “d” is the distance the block moves forward after the shot.



Therefore:

$$h=L-\left(L-h\right)\rightarrow h=L-\sqrt{L^{2}-d^{2}}$$

Figure 15.4 shows the block after being split open. You can use the ruler at the bottom to measure the length of the block and the penetration distance of the bullet. The length of the block can be used to estimate the distance the block moved forward (d) after being shot.



**Data**: Bullet Mass: 7.13 grams Block Mass: 3.713 kg Gun Mass: 2.86 kg

Length of string: 1.50 m Distance Block moved: 82.0 cm Bullet Penetration distance: 20.2 cm

**Calculations**:

1. Calculate the height that the block traveled.
2. Calculate the final Ugrav of the Block and bullet system.
3. Calculate the velocity of the block and bullet system at the bottom of the swing, after the collision using Conservation of Energy.
4. Calculate the speed of the bullet before the collision using Conservation of Momentum.
5. Calculate the KE of the bullet before it strikes the block. Then us the KE of the block after collision to calculate the % of KE lost in the collision.
6. If total energy is ALWAYS conserved, explain clearly and in detail where the missing KE went. Be specific and don’t use “heat” as your answer. (it may help to look at Figure 15.4)
7. Calculate the acceleration of the bullet during impact.
8. How many “g”s is this?
9. Calculate the force acting on the bullet during impact. How many pounds is this (1 lb = 4.45N)
10. Calculate the recoil speed of the gun.
11. Calculate the KE of the gun after firing.
12. Compare the KE of the gun and the KE of the bullet. Explain why even though the gun and bullet have the SAME momentum after the shot, it is much safer to be on the gun end instead of the bullet end.