The Ballistic Pendulum
Objectives of experiment

The ballistic pendulum works based on the conservation of momentum and the conservation of energy. When a projectile collides with a pendulum, momentum is transferred, causing both the pendulum and the ball to move. By measuring the vertical distance of the pendulum, one can determine the initial velocity of the projectile using the principles of conservation of energy and momentum.

The Ballistic Pendulum
Advance Study Assignment

1. **In determining the magnitude of the initial velocity of the ballistic pendulum projectile, what conservation laws are involved and in which parts of the procedure?** Momentum and energy are used to determine the initial velocity of the projectile for momentum; the equation mv = (m +M)V is used. Mv is before and (m + M) is after it is finished. For energy (m+M)gh is the potential energy and ½ (m+M)v^2 is the kinetic energy. Before getting fired momentum is conserved and all of the energy is potential energy stored in the spring. During it the momentum is conserved and the potential energy is turned into kinetic energy of velocity. After the collision the momentum is turned into potential energy of the height.

2. **Why is it justified to say that the momentum in the horizontal direction is conserved over the collision interval? Is momentum conserved before and after the collision? Explain.** The momentum before and after being hit is the same. Momentum is mass time velocity. When the collision occurs both objects trade velocities depending how much each of the objects weigh. The momentum before the collision is the same on the objects in the collision.

3. **Is the center of mass of the pendulum-ball system at the center of the ball? If not, were and how is the center of mass located?** It is not at the center of the ball. The center of mass is near the ball but not in it. This is because the center takes in account the other masses and factors in for them. To find it, it needs to be balanced on an edge, and on that edge is where the center of mass is.

4. **After the horizontal projectile leaves the gun what are the accelerations in the x and y directions?** The acceleration is constant with zero acceleration and some initial velocity however the y direction is affected by gravity.

5. **How is the location where the ball strikes the floor determined?**

It is determined by how much time the ball takes to hit the ground in the y direction and multiply it by the time with the velocity in the x direction.

6. **Besides the range, what else is needed to determine the magnitude of the initial velocity of the ball?** The equation to get initial velocity is v = (2gh)^½ which came from the ½ (m+ M)v^2 = (m+M)gh and what is needed is how much height the ball came from.

7. **For a given initial velocity how does the range of a projectile vary with the angle of projection θ?** The range of the equation is R = (v^2sin2θ)/g since the angle is determined by sin(2θ) a degree of 45 would be the most optical and would give out a 1.

8. **Theoretically the angle of projection for maximum range is 45°. Does this set a limit on the range? Explain.** Yes the maximum is 45 as sin 2 * 45 degrees is 1 and thus

moving it any higher or lower would degree the range. 135 would be the minimum range as the projectile would go in the maximum negative direction.

The Ballistic Pendulum
Summary of the Experiment

The Ballistic Pendulum is an experiment where the goal is to determine the initial velocity of the ball when it is shot out of the spring cannon. There are two ways of calculating the initial velocity; one way is to calculate initial velocity with momentum in which a ball shot by a spring cannon, that hits a block that slows the velocity of the two objects together and a clip catches the objets when they have reached their max height. The other way is by shooting that same ball like a projectile and seeing where it lands and the initial velocity can be calculated based on the range and height of the projectile. In the end the two ways of calculating the initial velocity will be compared to see if the concept of momentum is true.

The Ballistic Pendulum
Conclusions

1. **What principle or physical law of nature did you investigate?**

The physical law that was investigated was that momentum is conserved throughout the experiment. As the ball hit the blob, it lost some of its velocity but gained more mass and stopped once it reached its max height. The law of conservation of energy was used, the potential energy of the spring is equal to the potential energy of the gravity. In addition the kinetic energy of the projectile when it hits the ground is equal to the potential energy of the spring.

2. **What did you learn?**

I learned about momentum and how momentum is conserved even if an object collides with something and how its velocity can change differently based on how heavy an object is. I also learned about energy and how the relations with potential energy of height relates to kinetic

energy of velocity. I have also learned about how the angle of the trajectory can affect the range of the projectile, as a degree of 45 gives out the maximum range if the degree is higher or lower then the range is.

The Ballistic Pendulum
Error Analysis

The biggest source of error in the experiment is the friction force in the pivot point and will reduce the pendulum's maximum height and will reduce the accuracy of the initial velocity.

Another error is air resistance, the projectile will slow down during its flight and will reduce its initial velocity and range.

There are also some human errors, such as in measuring how long the pendulum is and how much the mass of the ball is.

Instrumental errors in how the range of the ball differentiates the projectile and how high the pendulum goes. The instruments are not very precise in having a constant force but instead they vary quite a lot. One way of reducing this error is by taking lots of shots and averaging them out to get a better overall value.

Lastly the collision is inelastic, the momentum transferred between them is lost and the height of the ball is less as some kinetic energy is lost.

The results of the initial velocity from part A and part B of the report are very accurate. In part A of the experiment the initial velocity was 6.625 meters per second while part B was 6.525 meters per second. So the percent difference between the two was .26%. The errors from part A, the friction and the inelasticity and from part B, the air resistance may have canceled themselves out to show a very similar score.

The Ballistic Pendulum
Questions

1. The collision between the ball and the pendulum is inelastic. Where some of the kinetic

energy is not 100% conserved. The equation for the potential energy and kinetic energy is $\sqrt{\frac{gx^2}{2y}} = \sqrt{2gh}$ where x is .098m and h is .098m

The kinetic energy of the left side of the equation was 1.33 N while the potential energy was .67m/s . So some energy was lost during the collision.

2. The collisions were inelastic and the fractional energy loss is 83%. The energy is lost through heat, sound, friction, and air resistance. $\frac{|1.33 - .67|}{1.33} \cdot 100\%$
3. The systematic error is repeatable while random error is inconsistent and unpredictable. Friction is always constant and won't change much so it is systematic. The source of error will be less than the actual velocity as the friction is subtracting from the velocity.

4. The force of gravity has no effect on the horizontal force. The horizontal force will stay constant throughout its trajectory. Gravity only has an effect on the y axis while it has no control on the x axis.

5. Air resistance affects the trajectory and slows down the velocity of the projectile as the ball. As a projectile moves through the air, it encounters resistance from the air molecules. This causes the trajectory and range to be smaller.

6. The equation to get the initial velocity is $v = \frac{m+M}{m}\sqrt{2gh}$ where m is .0574 kg, M is .217 kg and h is .098. The initial velocity is 6.625 m/s. The equation is almost the same as parts A and B except this equation includes mass time force while parts A and B only include force.

7. The maximum range is at 45 degrees and it is where the ball will have its highest range. While degrees below 45 will have an increased horizontal velocity but will have less range and degrees higher than 45 will have an increased vertical velocity and will reach a higher altitude than the rest.