Lesson Title	Ballistic Pendulum Lab (Using Rotation Sensor)
Length of Lesson	1 day
Created By	Jed Leggett, William Funderburk, Dustin Spayde
Subject	Physics
Grade Level	11-12
State Standards	Physics: 3 a, b; 4 a;
DOK Level	DOK 3
DOK Application	Investigate, Draw Conclusions
National Standards	9-12: B (physical);
Graduate Research Element	Conservation of Energy and Momentum

Student Learning Goal: Develop student understanding of energy and momentum conservation laws and demonstrate their power in explaining everyday motion.

Physics: 3. Develop an understanding of concepts related to work and energy: (a) Explain and apply the conservation of energy and momentum; (b) Analyze real-world applications to draw conclusions about mechanical potential energy (the energy of configuration) - Concept of conservation of energy with simple examples.

National Science Education Standards of Content 9-12
B (Physical): Conservation of energy and the increase in disorder: All energy can be considered to be either kinetic energy, which is the energy of motion; potential energy, which depends on relative position; or energy contained by a field, such as electromagnetic waves.

Materials Needed (supplies, hand-outs, resources): Pasco: Projectile launcher, Rotation sensor, and Ballistic Pendulum Arm (Similar setups available from other vendors); Lab posts, Access to a personal computer with spreadsheet software and DataStudio.

Lesson Performance Task/Assessment:
In this lesson, students will use conservation laws and data from a rotation sensor that is attached to the arm of a ballistic pendulum to determine the muzzle velocity of a projectile launcher. The students will also determine the muzzle velocity by firing the projectile launcher horizontally from fixed height and using the kinematic equations to calculate the initial velocity. Students will compare their measurements, and if they don't agree within 10%, they must perform one of their measurements again.

Lesson Relevance to Performance Task and Students:
Collisions occur often in everyday life, and it is often desirable to know the initial velocities of objects before a collision. Forensic scientists can use conservation laws to determine the conditions before and after a collision, such as a car wreck or gunshot.

Anticipatory Set/Capture Interest:
The teacher will show a video of an ElectroThermal Gun being shot into a ballistic pendulum. An electro thermal gun uses electricity stored in a capacitor bank to convert aluminum powder into plasma to propel a projectile. The video can be found at: http://vimeo.com/769985

Guided Practice:
Since the setup for this lab is a bit complicated, the teacher should set up all equipment before class. The teacher will then use an example apparatus to demonstrate the method for taking data and entering it into excel. The teacher should then divide student groups into 2 larger groups and have half of the class perform the ballistic pendulum method first, and the other half perform the kinematic method first.

Independent Practice:
Students will perform measurements of the muzzle velocity of the projectile launcher using both of the following methods:

Method 1: First, students will measure the mass of the ball and the mass of the pendulum. Students will then fire the projectile launcher into the ballistic pendulum several times and record the resulting angle vs. time data. The students will fit the data and determine the maximum angle. From the maximum angle, they can use trig to determine the maximum height. From the maximum height they can determine the initial kinetic energy of the ball + pendulum system: $(M + m)*g*h=1/2*(M+m)*V^2$ (where m is the mass of the ball, M is the mass of the pendulum, h is the maximum height, and V is the initial velocity of the ball + pendulum system. From this equation they can determine the initial velocity of the ball + pendulum system. From conservation of momentum, the students can determine the muzzle velocity of the launcher, denoted v: $m*v=(M+m)*V$.

Method 2: Students will choose a launcher and measure its height. They will fire the launcher several times horizontally and measure the place of impact using carbon paper. From the height, the students can determine the time it took the projectile to fall, and from the time, the students can determine the muzzle velocity of the launcher.

Remediation and/or Enrichment:
R: individual IEP; partner help throughout lesson

E: Students can attach the pendulum arm in the middle and analyze the resulting motion using the equations of rotational motion.

Check(s) for Understanding:
During what parts of the ballistic pendulum experiment is energy conserved? Why do we need to use conservation of momentum?

Closure:
Students can calculate the percentage difference between their two measured values and discuss why they are different.

Possible Alternate Subject Integrations:
*Math- Trigonometry is used in both calculations of muzzle velocity.