Lesson Title	Impulse/Momentum Lab
Length of Lesson	1 Day
Created By	Jed Leggett, William Funderburk, Dustin Spayde
Subject	Physics
Grade Level	11-12
State Standards	Physics: 3 c;
DOK Level	DOK 3
DOK Application	Explain Phenomena in Terms of Concepts
National Standards	9-12: B (physical);
Graduate Research Element	Integration of data over a time interval

Student Learning Goal: Develop student understanding of the relationship between impulse and momentum. Introduce students to the idea quantifying the area under a graphical curve.

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) – Principles of impulse in inelastic and elastic collisions.

National Science Education Standards of Content 9-12
B (Physical): Motions and Forces: Objects change their motion only when a net force is applied. Laws of motion are used to calculate precisely the effects of the forces on the motion of objects.

Materials Needed (supplies, hand-outs, resources): Cart and tracks (available from several vendors, i.e. PASCO), Force Sensor, Motion Detector, String, Masses, Computer with DataStudio installed.

Lesson Performance Task/Assessment: In this lesson, students will investigate the relationship between Force and momentum through the concept of Impulse. A string attached to a cart will cause an abrupt change in the velocity of the cart. The force that causes the change in velocity will be measured using a force sensor.

Lesson Relevance to Performance Task and Students: Students often have experiences that can be explained using the concept of impulse. From a bat hitting a ball to a car smashing into a wall, impulse changes our course in life.

Anticipatory Set/Capture Interest: The teacher will show a high-speed photography video of a ball smashing into a wall. Shown at slow frame-rate, one can see significant deformation of the ball.

Guided Practice: The teacher will demonstrate the lab setup, which consists of: 1. A track with feet only on one side, so that it rests at an incline; 2. A lab post with a force sensor attached at one end; 3. A motion detector at the other end of the track; and 4. A string attaching the force sensor to the cart, so that the cart will stop short of the motion detector. The teacher will take one run of data by rolling the cart up the incline about 20 cm (care should be taken not to exceed the maximum force of the force sensor. Plots should be made of velocity versus time and force versus time.

Independent Practice: Students will perform several runs using the procedure above. Students should apply different masses and use different starting heights in each run. Students will then analyze their data by finding the area under the force versus time curve and finding the velocity just before and just after the collision. Students should compare the area under the force versus time graph with the change in momentum $m*\Delta v$, both of these should give the impulse for the collision.

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

E: Students familiar with calculus can fit the force versus time graph and calculate the integral.

Check(s) for Understanding:
What is required for an object's momentum to change? Why is the force required greater when the mass on the cart is greater?

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

Possible Alternate Subject Integrations:
*Math – Curve fitting can be used for this lab, along with integration of a polynomial.

Teacher Notes: