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| **Lesson Title** | Velocity and Acceleration |
| **Length of Lesson** | 1 Day |
| **Created By** | Henry Stauffenberg IV |
| **Subject** | Physics |
| **Grade Level** | 9-12 (Physics) |
| **State Standards** | Physics: 1 a, b, c, d, e, f; 2 a, b, c |
| **DOK Level** | Physics: 3 |
| **DOK Application** | Organize, collect, interpret, investigate, connect, explain, prove, draw conclusions, graph, predict |
| **National Standards** | 9 – 12 A: Inquiry; B: Physical Science; E: Science and Technology |
| **Graduate Research Element** | Working with excel for statistical analysis and presentation of collected data drawn from experimentation |

**Student Learning Goal:**
The purpose of this lesson is to define and compare acceleration, instantaneous acceleration, deceleration, and velocity; using pasco equipment and excel creation of velocity and acceleration graphs, based on collected data. Using the graphs the students will interpret the results and be able to apply their conceptual knowledge on velocity and acceleration to explain what the parts/points of the graphs are illustrating. Students should be able to explain that deceleration does not always mean the object is slowing down with respect to negative velocity and directional vector analysis using their collected data. More importantly the purpose of this lesson is to also introduce that force is proportional to acceleration.

Mississippi State Standards
Physics: 1: (a) Use current technologies such as CD-ROM, DVD, Internet, and on-line data search to explore current research related to a specific topic; (b) Clarify research questions and design laboratory investigations; (c) Demonstrate the use of scientific inquiry and methods to formulate, conduct, and evaluate laboratory investigations; (d) Organize data to construct graphs to draw conclusions and make inferences; (e) Evaluate procedures, data, and conclusions to critique the scientific validity of research; (f) Formulate and revise scientific explanations and models using logic and evidence; 2: (a) Use inquiry to investigate and develop an understanding of the kinematics and dynamics of physical bodies; (b) Analyze, describe, and solve problems by creating and utilizing graphs of one-dimensional motion; (c) Analyze real-world applications to draw conclusions about Newton's three laws of motion.

National Science Education Standards of Content 9 – 12
A: Inquiry: identify questions and concepts that guide scientific investigations

- Students should formulate a testable hypothesis and demonstrate the logical connections between the scientific concepts guiding the hypothesis and the

design of an experiment. They should demonstrate appropriate procedures, a knowledge base, and a conceptual understanding of scientific investigations.

B: Physical Science: motion and forces

- Objects change their motion only when net force is applied. Laws of motion are used to calculate precisely the effects of forces on the motion of objects. The magnitude of the change in motion can calculated using the relationship F=ma, which is independent of the nature of the force. Whenever one object exerts force on another, a force equal in magnitude and opposite in direction is exerted on the first object.
- Gravitation is a universal force that each mass exerts on any other mass. The strength of the gravitational attractive force between two masses is proportional to the square of the distance between them.

E: Science and Technology: understanding about science and technology

- Scientists in different disciplines ask different questions, use different methods of investigation, and accept different types of evidence to support their explanations. Many scientific investigations require the contributions of individuals from different disciplines, including engineering. New disciplines of science, such as geophysics and biochemistry often emerge at the interface of two older disciplines.

**Materials Needed (supplies, hand-outs, resources):**

Computer, excel, kart, track that slopes upward, pasco spring gun, pasco accelerometer, and pasco force pad (measure force of impact).

**Lesson Performance Task/Assessment:**

- Ability to use pasco equipment and experimental design to gather excel data
- Application of excel to create graphs for velocity and acceleration interpretation and analysis
- Applying knowledge of concepts to explain what the graphs represent point by point
- Comparing and explaining velocity to acceleration to force using graphical data
- Answering the question: What does negative acceleration mean and does it only apply to objects slowing down?
- Inquire what is the relationship between force and acceleration after analysis of data

**Lesson Relevance to Performance Task and Students:**

- To develop student skills with new and useful technology, especially when it comes to data presentation using excel
- To introduce experimentation design and data analysis that graduate research utilizes
- To understand by doing and following scientific design; observe, describe, process, and interpret

- To promote inquiry about acceleration, velocity, and force by having students do most of work and applying what they have learned
- To use graphical and statistical results to prove, explain, and answer concepts or questions

**Anticipatory Set/Capture Interest:**
Show students that they will be launching karts with spring guns on a track. Ask them provocative questions such as show me what negative acceleration looks like? What does force have to do with acceleration? Gather acceleration data and using the graphs tell me what is going on with respect to what you have learned? The whole activity is the students doing the inquiry and let them know that they will be the ones to define acceleration and velocity using karts and springs.

**Guided Practice:**
Briefly show what each pasco instrument is for and how to use them and how to record any data they collect into excel. Have the students break into groups with one standard kart, sloped ramp track per group, and one set of pasco tools per group. The ramp should only be enough to provide a hill for the kart to move up and roll back down. Each group will have a set of springs for the pasco spring gun. Each spring will be tested using a force pad, launching the kart into pad on level ground, to record force output of each spring. Then students will take each spring to launch their kart up a sloped track and record its upward and downward acceleration/velocity using a pasco accelerometer. Make sure students are recording data into excel while they use the equipment. After data collection is finished the students will take their velocity/acceleration data and use excel to create graphs. The teacher may show students this if they do not know how to graph their data using excel. Give the students time to discuss their graphs in a group and apply what they have learned. After that ask each group to explain what each graph illustrates i.e what parts are acceleration? deceleration? positive and negative velocity? Have each group explain what does negative acceleration mean and does it only apply to objects slowing down? Also ask about the relationship between force and acceleration and see if they can prove a direct relationship between the two using their graphs. The teacher should walk around provoking questions and inquiry from the students. Also, for some teachers a questionnaire may be handy. Either way in the end the students should write a report on what they did, the results, and what it means. The report should have them explain in their own words defining and comparing/differentiating velocity, acceleration, deceleration, and directional force in vertical two directional motion.

**Independent Practice:**
Analysis of graphical data and writing of a report.

**Remediation and/or Enrichment:**
Remediation: individual IEP, partner with helpful student, make lesson more walk through intensive.

Enrichment: Have students work with karts of different masses. Have students also explore friction with different track types. Ask students to calculate instantaneous velocity and other more complex velocity/acceleration calculations. Using the direct relationship between force and acceleration dive into applying the laws of motion.

**Check(s) for Understanding:**

- Ability to use pasco equipment and gather complete data
- Completion of velocity/acceleration graphs
- Being able to answer question about deceleration and other questions that pertain to velocity, acceleration, motion, and force
- Ability to apply and explain the concepts they have learned using graphs
- Ability to inquire and prove the direct relationship between force and acceleration
- Ability to calculate average velocity and acceleration and possibly instantaneous acceleration
- Completion of a lab report and being able to define, compare, and contrast subject material

**Closure:**
Introduce the laws of motion and connect the graduate research element of data acquisition and presentation, especially with respect to excel and statistical analysis.

**Possible Alternate Subject Integrations:**

Calculus: Regression models, line equations, vector math, and formula/algebraic calculations

**Teacher notes:**
Google pasco scientific for karts and track materials. Pasco equipment is preferred as stated in materials.