What Makes For a Good Ride at the Fair or an Amusement Park?

A Physics Unit for Eighth Grade Physical Science

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CONTENTS

I. Overall Rational

The driving philosophy of this project is that the true power of science is manifested in the use of specific criteria or methods to validate and produce a uniform and pertinent theory that reflects observations. Science education provides an opportunity for the student to become aware of the phenomenon that surrounds them. It introduces them to investigations that will lead them to discover the importance and power of their own observations and reinforces known theories. The investigations in this project are embedded in students' daily lives, providing real-world context. In addition, these investigations are student-centered in an attempt to promote inquiry and engagement. Many are set up with the "PEOE" format: students *P*redict what they expect to occur and *E*xplain their rational, then they *O*bserve, and then *E*xplain why their prediction was correct or not. These investigations will serve as a means to assess comprehension rather than traditional pen and paper tests. The assessments will be validated by the students' ability to apply the concepts and information learned, through research and lab experiences, during the concluding project. The concluding project allows students to reflect on what they have been exposed to in class. During this reflection, the teacher should encourage the students' confidence in their own observations such that they may produce applicable solutions to varying conditions.

This project designed for middle school students, particularly 8th grade students. These students will gain important insight into several fundamental concepts of the physical world that deal with motion. Specifically, they will learn key concepts of motion, such as speed, velocity, acceleration, and momentum. This aspect of the unit has import in the fact that students' understanding of motion dictates their success with understanding much of the phenomenon that occurs in the world around them. Gaining a baseline understanding of the principals related to these terms will enable students to grasp more challenging physics concepts with greater ease, such as force and Newton's Laws. Another important facet to this project is the introduction and reinforcement of graphing skills, again critical baseline knowledge for interpreting physical phenomenon. Students will sharpen skills as they graph collected data and interpret motion graphs. Finally, the inclusion of motion sensors and graphing software will allow students to use technology as a learning tool in this unit.

In order to address the content of this project in a way that is interesting and relevant to the students, a thematic approach is used in which student investigations center around a central topic. Amusement park or fair rides present a good forum for demonstrating physics principals while incorporating enjoyable and real-world experiences for the students. This project revolves around a driving question that provides feasibility, context, meaning, sustainability, and worth:

What makes for a good ride at the fair or an amusement park?

Answering this question will probe students to think about types of motion, changes in motion, and forces in an appealing and motivating way. Sub-driving questions address the main driving question by breaking it down into manageable parts. Middle school students will investigate:

How does a ride move you?

How fast are you going in a ride?

How does your velocity change in a ride?

Why do I need to wear a seatbelt on the rides?

Each sub-question will lend itself to investigating a particular aspect of the overall project, while relating back to the main driving question.

II. Goals of the Project

The primary goals of this project are that students will be able to discuss motion in terms of speed, velocity, and acceleration; contrast speed and velocity; contrast velocity and acceleration; graph velocity and acceleration versus time; and interpret motion graphs. Students will also investigate momentum and Newton's 1^{st} Law. The lessons incorporate physics principals seen at the fair or an amusement park as a means for demonstration and explanation of motion. The unit culminates with a day at the fair where the students through a series of activities explore the concepts.

These objectives relate to the American Association for the Advancement of Science Benchmarks in that they provide a backdrop to the study of force and the relationship between force and motion. Middle school students should possess the understanding that "an unbalanced force acting on an object changes its speed or path of motion, or both." They also relate to AAAS Benchmarks in that they build on the knowledge that students gain in upper elementary grades, "changes in speed or motion are caused by forces." A further goal of the unit is to correct misconceptions possessed by students at this grade level. AAAS Benchmarks outlines several common misconceptions about motion: "students believe constant speed needs some cause to sustain it", and "students believe that an object resists acceleration from the state of rest because of friction". As for graphing, "students often interpret graphs of situations as literal pictures rather than as symbolic representations of the situations", and "students interpret time/distance graphs as the paths of actual journeys". In other words, students often associate the peaks and dips in a line as heights rather than a measure of rates. This adds to the import of reinforcing graphing skills as a function of this unit.

The nature of science will be communicated to the students through scientific inquiry. Students will see how outside variables may influence investigations, and that the desired outcome may not always be achieved. The National Standards state that to achieve science as inquiry, "the use of tools and techniques, including mathematics, will be guided by the question asked and the investigations students design. The use of computers for the collection, summary, and display of evidence is part of this standard. Students should be able to access, gather, store, retrieve, and organize data, using hardware and software designed for these purposes." This project therefore employs motion probes and graphing software to address this standard.

III. National/ South Carolina Standards

<u>8th Grade Physical Science: Motion and Forces:</u>

A. The motion of an object can be described by its position, direction of motion, and speed and can be measured and represented on a graph

a. Operationally define speed, velocity, acceleration, and momentum, and apply these in real-world situations.
b. Distinguish between speed and velocity in terms of direction.
c. Create and plot a time-distance line graph and make predictions based on the graph.

IV. Concept Design

The unit begins with an engaging demonstration that becomes the anchoring experience that students use throughout the unit. The demonstration is then related to the motion of fair rides. Students perform a series of "PEOE" (Predict, Explain, Observe, Explain) activities. The unit concludes with a series of activities at the fair that assesses students' knowledge gained in these 2 weeks of study. Students will be assessed on lab activities and a final "Fair Scavenger Hunt" in which they must match motion graphs to rides at the fair. Curriculum tie-ins would certainly include mathematics: graphing skills, unit conversions, and converting word problems into equations could be reinforced.

Calendar

Day 1: Introduce unit and driving question; define motion; demonstration with motion probes

Day 2: Defining and comparing speed and velocity; average velocity; graphing; toy car activity

Day 3: Velocity with probes and computer graphing; matching video clips of rides with graphs

Day 4: Acceleration with toy car activity, then with probes and computer; contrasting velocity and acceleration

Day 5: Momentum with ballistic cart and egg; Intro to Fair Scavenger Hunt

V. Materials:

- worktable in front of classroom
- masking tape
- measuring tapes
- graphing paper
- stacks of books (20 cm tall)
- toy cars (represents roller coaster carts)
- stopwatches
- wood ramps (50 cm long)
- bell shaped ramps (represents hill of roller coaster)
- motion probes
- motion probe graphing software
- laptop computers
- video clips of fair rides: http://solomon.physics.sc.edu/~tedeschi/midway
- worksheets for Scavenger Hunt (attached)
- ballistic cart
- eggs
- LCD projector with laptop hook-up
- viewing screen

VI. Lesson Plans

Target: 8th grade physical science

Timeframe: 2 weeks (5 90-minute blocks)

Day 1: What makes for a good ride at the fair: Motion

Duration: 1 90-minute block

Purpose: This lesson is designed to introduce students to the overall unit by 1) building on their existing ideas about motion, 2) define motion as a means to investigate the driving question (*What makes for a good ride at the fair?*), and 3) to demonstrate how motion probes can graphically represent movement. Demonstrations of motion in multiple representations will be performed with the "roller coaster" (toy car and ramp) and motion probe; these will provide anchoring experiences for students that they will use throughout the unit as they continue to perform activities with these materials.

Activity Type: Introducing the unit; Whole class activity; Small group activity

Objectives: Students will be able to:

- operationally define distance, reference points, and motion from inquiry-based activities
- relate the definition of motion to personally relevant and real-world experiences (i.e., fair rides)
- match motion with graphs using motion probes and graphing software

Teacher Information:

- Set-up of demonstration: place a wooden board with one end on a short stack of books, preferably on a worktable at the front of the classroom so students can see. Place the toy car at the top of the ramp, then release it. Repeat several times while students think about how they would define "motion".
- Content and Definitions:

  > Motion: the change in position of an object compared with a reference point. The statement "something is in motion" is meaningless without a frame of reference. There is no such thing as absolute motion. You know something is moving because you compare it to something that is not moving. Objects move from point A to point B.

  > Distance: the length the object traveled while in motion.

- Set-up of motion probe and laptop: place laptop on chair or worktable; connect it to LCD projector in front of viewing screen. Place motion probe (connected to laptop) on chair or worktable. Stand in front of probe with room to move forward and backwards, about 6 feet. Have a volunteer press the start and stop buttons on the laptop while you move.
- Scaffold for students how anomalies in the graphing indicate various mistakes in the set-up (i.e., be sure to minimize all background motion so probe does not sense it).
- Set-up of group work: Each group will need space to move in front of their motion probe, so they may need to spread out, go out in the hall, etc. Remind them to curtail all background motion so they can get accurate results. Students will need to take several trials in order to get the hang of the software, learn how to diagnose mistakes, and to match their movements with the graphs.

Materials:

- laptop computer with graphing software, 1 per group
- LCD projector and screen for whole-class viewing
- motion probe, 1 per group
- toy car
- ramp
- stack of books

Procedure:

1. Open unit with the Driving Question: *What makes for a good ride at the fair or an amusement park?* Have students share with the class their ideas for what makes a good ride and the experiences they have had on rides. Those who may not have had the opportunity to experience a ride can learn from their peers during this discussion.
2. Provide a brief overview of the next two weeks, explaining that the students will be doing a series of activities that will help them investigate this driving question, and that they will end the unit with a day-trip to the fair to assess their understanding of physics principles with real-world experiences. (Post the question on a banner in the front of the room so that students can refer to it over the next two weeks and reflect on how their daily activities relate back to it.)
3. Students will most likely suggest that a good ride is fast and has loops, curves, and hills that cause you to move in “weird” ways. In order for us to figure out what makes for a

good ride, we need to examine the motions of the ride. Introduce first sub-question: *How does a ride move you?* Example: the roller coaster- if you are watching your friend on the roller coaster, how do you know when they are moving? Perform demonstration with toy car and ramp. How do you know the car is in motion?

4. Think-Pair-Share: Have students individually write down their existing definition of motion, along with an example. Sample guiding questions for them to consider: Is the earth moving? If the car is still, is it moving? Then have students pair up with partners and combine their definitions to assist them with explaining their ideas. Then have pairs share with the class their definitions as a means to develop shared criteria the definition. Have them demonstrate their examples if possible (i.e., walking). Jot down key points in student definitions on the board as they share.
5. Introduce motion probe and software: The sensor sends out waves that we cannot hear (ultrasound). The sound waves come out of the sensor and bounce off the objects in front of it. The sensor can calculate the distance the object is from the sensor. In this case, the sensor will bounce off the teacher.
6. Demonstrate on viewing screen using LCD projector for whole class. Prompting questions: What does the graph represent? When I do this (speed up, slow down, move forward, move backward, etc.), what does the graph do? How could I move to make a (straight line, positive, negative) slope?
7. Break class into several small groups of four, each with a laptop and motion probe. Give each student an opportunity to walk in front of their sensor at different speeds. The other group members should watch and learn from the member performing the activity. Introduce activity: students will match their motion with the given graphs in the software. This will be a "PEOE" activity: First have students look at the given graph and compose a written description of the motion they predict is occurring. Be sure they explain why they predict this. Then have students perform their predicted motion. Students should then explain on their paper how their graph differed from the one provided (this should help them to consider alternative approaches). Then have students refine their predictions and repeat the experiment again.
8. Bring the class back together and have students share what they discovered about motion in this inquiry process. Add to the key points previously written on board things they

learned about motion based on what they saw in their groups with the motion probe. Combine points to make a class definition, which should include:

> Motion: the change in position of an object compared with a reference point. Scaffold for misconceptions: the statement "something is in motion" is meaningless without a frame of reference; there is no such thing as absolute motion. You know something is moving because you compare it to something that is not moving. Objects move from point A to point B.

> Distance: the length the object traveled while in motion.

- To conclude, have students think of rides at the fair where they can apply the definition of motion and discuss as a class.

Assessment:

- Write-up of PEOE activity including students' prediction and explanation, observations, and explanation of differences (see Rubric A: omit Graphing segment; use only 15 points)

Day 2: How does a ride move you: Speed and Velocity

Duration: 1 90-minute block

Purpose: This lesson is designed to encourage students to use personal experiences and scientific ideas and promote learning from each other to understand how motion is measured by velocity. They will explore this concept through comparing it with speed, observing it with an activity, and graphing it for multiple visual representation.

Activity Type: Introducing a student investigation; Science process skills; Small group activity

Objectives: Students will be able to:

- operationally define speed and velocity
- compare and contrast speed and velocity
- practice converting units of measurement
- calculate average velocity
- create distance-time graphs
- interpret graphs as a representation of motion

Teacher Information:

- Set-up of demonstration: place a wooden board with one end on a short stack of books, preferably on a worktable at the front of the classroom so students can see. Mark off increments of 0.5 meters with masking tape along the path of the car. Place the toy car at the top of the ramp, then release it. Repeat several times while students think about how they would measure the motion. Use a stopwatch for each run if students need a hint.
- Content and Definitions:

  >Speed: distance an object moves over time, defined by the equation *v = change in d/ change in t*

  >Velocity: speed in a definite direction. If a car speeds up, both its speed and velocity change; however, if the car changes direction without speeding up, it still changes velocity. Speed is the *magnitude* of velocity.

  >Average speed = total d/total t
- Sample unit conversions: 1 km = 0.6 miles; 1 meter = 3.3 feet
- Students should run several practice trials with the toy car, ramp, and stopwatch before recording data. *It is very important that the car travel slow enough for the students to be able to make time measurements at 1.0 meter intervals- this can be accomplished by*

using a very short stack of books for the ramp or by adding a drag to the car (i.e., tape a slab of cardboard to the front of the car).

- The same students should keep the same "jobs" throughout the experiments in order to maintain accuracy- i.e., have 1 student release the car, 1 student use the stopwatch, 1 student record data, etc.

Materials:

- toy car and ramp, 1 set per group
- masking tape
- stopwatch, 1 per group
- measuring tape, 1 per group
- stack of books, 1 per group
- graphing paper
- worksheets for Middle School Activity I: "Speed, Velocity, and Acceleration" (see attached)

Procedure:

1. Open lesson with review of yesterday. Students will use prior knowledge and personally relevant examples of motion to help introduce some adverbs describing motion. For example, ask "What happened to your motion when the graph dipped down or peaked up?" Students will most likely suggest words such as faster and slower… use these terms to lead into speed. When something is moving, what two things do we want to know? Solicit ideas from students: how *fast* it is moving and what *direction* it is moving… i.e., fair rides.
2. Speed was most likely suggested when students were asked to think about what makes for a good ride at the fair. Sub-question: *How fast are you going in a ride?* Using multiple visual models, refer back to the roller coaster, run toy car on ramp as demonstration. In a group discussion, ask students for suggestions on how they would measure its motion. What does it do when it goes faster? (it covers more distance in less time).

   >Speed: distance an object moves over time, defined by the equation *v = change in d/change in t*

3. Now that we know how to measure how *fast* something moves, how do we figure in *direction*?
   >Velocity: speed in a definite direction. If a car speeds up, both its speed and velocity change; however, if the car changes direction without speeding up, it still changes velocity. Scaffold confusion through the scientific inquiry process: Explain to students that many times scientist mix terms because they assume they are all speaking the same language. Students need to be aware of the common mistakes that this causes in the field. For example,"80 mph" is speed, "80 mph North" is velocity.
4. The standard units for velocity are meters divided by seconds, or meters per second. Other common units are mi/hr or km/hr. Practice/Review: unit conversions. Have students come to the board and calculate converting several example problems, in order to help students that may still be having trouble with unit conversion.
5. Whole class activity/demonstration: Have students graph another representation of speed and velocity with a graph of time vs. distance of the toy car on a flat surface. Use masking tape to mark increments of 1.0 meters along the floor or down the hallway. Have 2 volunteers- 1 to work the stopwatch and 1 to measure the distances. Review labeling the x- and y-axes. Have students predict what the line will look like for the car to roll on a flat slope. Scaffold to explain their ideas: many will think that the line will be flat too. What would a flat, horizontal line indicate? It means the object has zero velocity: its just staying in one spot the whole time. Review positive and negative slopes as a function of rates: i.e., steep slopes, higher velocities.
6. Demonstrate again with toy car and ramp- as a class ask students if the toy car stays at the same speed the whole time it moves. Few objects travel at a constant speed like the merry-go-round. For example, roller coasters stop and go and travel at a variety of speeds. Are there any other objects in their daily lives that travel at a constant speed?
   >Average speed = total d/total t.
7. Introduce lab activity, "Speed, Velocity, and Acceleration" (Middle School Activity I- see attached). Have students work in small groups of four and only do the procedure for Part A of the activity. Each student will have a "job" during the activity to help promote participation during the lab. Distribute toy cars, ramps, stopwatches, masking tape. Time the car traveling 5.0 meters for 4 trials, then find the average velocity. Next time the car

every meter for 4 trials. Find the average time at each 1.0 meter increment. Graph the results on a time-distance graph.

Assessment:

- Data chart of velocities and questions for Middle School Activity I (use answer key as guide for assessing)
- Graphs of average velocity (use Graphing segment of Rubric A, 5 points only)

Day 3: Velocity with Motion Probes; Matching Rides and Graphs

Duration: 1 90-minute block

Purpose: This lesson is designed to implement technology in order to continue exploring velocity and to reinforce concepts through multiple representations. Students will also examine velocity and motion graphs as they relate back to fair rides.

Activity Type: Introducing a student investigation; Science process skills; Small group activity

Objectives: Students will be able to:

- perform simple experiments with motion probes that investigate velocity
- manipulate graphs using software
- interpret motion graphs of real-world objects (fair rides)

Teacher Information:

- Set-up of demonstration: Place laptop connected to LCD projector and viewing screen at front of classroom so students can see. Set up wooden board supported by a stack of books at one end. Place toy car at top of ramp. Place motion probe above toy car so that it captures motion on entire ramp. Plan on several trial runs to get correct placement of probe so that it properly takes measurements. Remember to minimize all background motion. Laptop should be set to display both a time-position graph as well as a chart of collected numerical data.
- Students should be well spread out to perform their motion probe experiments- make sure they minimize any background motion that could convolute their data. The same students should keep their same "jobs" throughout the experiments to control for errors- i.e., 1 student starts the car, 1 student starts and stops the timer on the laptop, 1 student records data, etc. Allow for several practice trials before beginning data collection.
- Video clips: Show one at a time. You may need to repeat each clip several times for students. This graphing activity is purely qualitative. As long as students' graphs "make sense" with the motions of the rides and are supported by rational, encourage their thinking process.

Materials:

- laptop with graphing software, 1 per group
- motion probe, 1 per group
- LCD projector and screen for whole-class viewing

- toy car and ramp, 1 per group
- measuring tape, 1 per group
- masking tape
- stack of books, 1 per group
- video clips of fair rides: http://solomon.physics.sc.edu/~tedeschi/midway
- graphing paper
- worksheets for Middle School Activity II: "Graphing Velocity with a Motion Probe" (see attached)

Procedure:

1. Open lesson with a demonstration on the screen using LCD projector of how the graphing software can graph velocity with the motion probe: run toy car down ramp while software graphs and tabulates data. Demonstrate for students how to represent data in both chart and graphical formats.
2. Break class into groups of four. Have students repeat the procedure for Part A of Middle School Activity I (see attached) with motion probes and laptop instead of paper and stopwatches. Perform the experiment for several runs. Students should complete their worksheets for Middle School Activity II (see attached) in groups. Have students select one run and print the graph. They should then write an explanation of the motion occurring for that graph.
3. Have students complete worksheet questions from Middle School Activity II: Mark on the graph the point when the car began rolling. How far was it from the sensor when it started? How did the graph change while it rolled down the ramp? Mark the point when it stopped. What was its final position? Over what period of time did it roll? Answers will vary.
4. "PEOE" Activity: As an extension, have students predict what will happen if they add a hill to their ramp. They should draw a sample graph and include a written explanation of their prediction. After running several trials, they should print a graph, attach it to their predicted graph, and explain the differences.
5. Relate velocity back to fair rides by returning to sub-question: *how fast am I going in a ride?* Ask students for ideas on how they might measure velocity on different rides at the fair. Break students into pairs. Show video clips of 6 fair rides from Internet site, one at

a time. Demonstrate and model your thought process for how you would hypothetically graph the motion.

6. Have students work in pairs to graph the motion of rides seen in the video clips (no numbers are needed on the axes). They should include an explanation.
7. Finish with pairs taking turns coming up and drawing graphs on board to share with class. Let peers critiques and add suggestions.
8. Concluding discussion: Refer back to first day when students suggested what made for a good ride. What do the graphs look like for the "good" rides? Why?

Assessment:

- graph and answers to questions from Middle School Activity II (answers will vary)
- PEOE results: predicted graph and explanation, actual graph and explanation of differences for ramp with hills (use Rubric A)

Day 4: How does your velocity change in a ride: Acceleration

Duration: 1 90-minute block

Purpose: This lesson is designed to introduce students to the concept of acceleration through graphical representation, incorporating both traditional methods as well as technology. In addition, students will gain an understanding of the difference between velocity and acceleration.

Activity Type:

Objectives: Students will be able to:

- operationally define acceleration and distinguish between positive and negative acceleration
- use motion probes and graphing software to visually represent acceleration
- compare and contrast velocity and acceleration

Teacher Information:

- Set-up of demonstration: Place a wooden board with one end on stack of books in front of room. Place at least one "hill" at bottom of ramp in the car's pathway. Place toy car at top and release. Repeat several times while students think about when and where the velocity of the car changes.
- Content and Definitions:

  >Acceleration: change in velocity over change in time- expressed as meters per second per second (meters per second squared).

  > Acceleration can be positive or negative. "Negative" acceleration here implies deceleration, or acceleration opposite velocity (a slowing down).

  > Newton's 1st Law: a change in velocity (acceleration) is always caused by an (unbalanced) force acting on the object. Something pushes or pulls the object to change its velocity.

  > Graphing: What do curved lines or sudden jumps represent? A change in velocity (acceleration) caused by a force.

  > To get change in velocity, subtract $V_{initial}$ from V_{final}.
- Students should run several trial runs with the ramp and toy car. They should keep the same "jobs" they have held previously- i.e., the student that started and stopped the stopwatch in the velocity lab should continue that job here for accuracy and proficiency. Students should be familiar with the motion probe and laptop set-up by now.

Demonstrate with LCD projector and viewing screen how to add in the display of the acceleration graph, and the velocity and acceleration graphs simultaneously.

Materials:

- laptop with graphing software, 1 per group
- motion probe, 1 per group
- LCD projector and screen for whole-class viewing
- toy car and ramp with hill, 1 per group
- stopwatch, 1 per group
- masking tape
- measuring tape, 1 per group
- stack of books, 1 per group
- graphing paper
- worksheets for Middle School Activity II: “Speed, Velocity, and Acceleration”

Procedure:

1. Demonstrate and review how the toy car’s velocity changes while it moves along the ramp with hill(s). Have students consider when and where the toy car’s velocity changes (as it falls from the ramp, it travels faster and faster; it slows as it climbs hills). Think about roller coasters, or the slides. Sub-question: *How does your velocity change in the ride?* An object can speed up or slow down, thus its velocity changes. This change is called acceleration.
   >Acceleration: change in velocity/change in time- expressed as meters per second per second (meters per second squared).
2. What occurs or changes in the ride that causes the change in velocity? Solicit suggestions from students (these may include gravity, friction, momentum).
   > Newton’s 1st Law: a change in velocity is always caused by an (unbalanced) force acting on the object. Something pushes or pulls the object to change its velocity.
3. How do we find the change in velocity? To get change in v, subtract $v_{initial}$ from v_{final}. Acceleration can be positive or negative (often referred to as deceleration).
4. Break students into groups of four. Have students now do Part B of Middle School Activity I (see attached). Once students have completed their worksheets and graphs,

discuss the results: What do curved lines or sudden jumps in the graph represent? A change in velocity (acceleration) caused by a force.

5. Have students now set-up their laptops and motion probes to repeat the procedure for Part B of Middle School Activity I (they should be proficient with this by now). Demonstrate on the television how to display the acceleration graphs with the graphing software. Have students run several experiments; they should then print one acceleration graph. Compare this to the graph that you drew manually, and write an explanation for any differences you see.
6. Demonstrate with LCD projector on screen how to display both the velocity and acceleration charts and graphs simultaneously on the laptop screen. Have students compare and contrast velocity and acceleration in different situations: i.e., 1) toy car on flat surface, 2) toy car with ramp, and 3) toy car with ramp with hill(s). For each case, students should write a brief description of how the two graphs differ.

Assessment:

- data chart of velocities and questions for Middle School Activity I (use answer key as guide for assessing)
- graph of acceleration (use Graphing segment of Rubric A, 5 points only)
- comparison of manual and software acceleration graphs (use Rubric B)
- description of velocity vs. acceleration graphs for 3 scenarios (use Rubric B)

Day 5: Why do I wear a seatbelt on a ride: Momentum

Duration: 1 90-minute block

Purpose: This lesson is designed to introduce students to the concept of momentum, including the conservation of momentum. Through an activity students will see why they wear a seatbelt on rides at the fair as a function of momentum. The lesson will conclude with a summary of the concepts learned in the unit and how students will use them on their fieldtrip to the fair.

Activity Type: Individual; Introduce Outdoor activity (fieldtrip); Assessments; Closure activity

Objectives: Students will be able to:

- operationally define momentum
- interpret how momentum relates to velocity
- analyze how momentum is conserved (bumper cars)

Teacher Information:

- Set-up of demonstration: Place a wooden board with one end on a stack of books on a worktable in the front of the room where students can see. Place one egg on a ballistic cart and place cart at top of the ramp. Place a brick or other stopping device at end of ramp. After students make predictions, release cart. This may take several trials so have several eggs ready to use, or use hard-boiled eggs if you do not want a mess to clean up!
- Content and Definitions:

  > Momentum: the strength of the object's motion; an object's mass times its velocity. Momentum is neither lost nor destroyed; it is transferred from object to object.
- Set-up of momentum demonstration: place several of the toy cars on a table in the front of the room. Simulate bumper cars by moving the cars amongst each other.

Materials:

- ballistic cart
- eggs
- object to block moving cart (i.e., brick)
- stack of books
- ramp
- toy cars from previous activities to represent bumper cars

Procedure:

1. Open lesson with review of past several days: we have learned how we move in a ride and how our motion changes during the ride. With all this motion taking place, how do we stay in our seats? Students will most likely suggest seatbelts. What would happen if we didn't wear seatbelts? Students will most likely suggest that the rider will fall out of the ride. Why would this happen? What is it about our motion in the ride that might allow us to fall out? Ask students to think about that while they watch the demonstration.
2. Introduce demonstration to students: an egg will be placed on a ballistic cart and the cart will be rolled down the ramp. The cart will then be blocked by an object at the bottom.
3. PEOE activity: Have students write down a prediction of what they think will happen to the egg. Guiding question: will the egg fly forward, fly backward, or fly up and land back on the cart?
4. Perform the demonstration. Have students make observations with these guidelines (written on board):
   Describe what happened as the egg and cart traveled down the ramp.
   Describe what happened to the egg and the cart when they reached the barrier.
   Describe what happened during the collision of the egg with the tabletop.
5. Have students share whether or not they predicted correctly. Go over possible explanations for what happened. Relate to velocity: Was there a separate velocity for the egg and for the cart? How did their velocities change when the cart stopped? (the cart became zero, but the egg maintained its velocity). Introduce the term momentum.
   > Momentum: the strength of the object's motion; an object's mass times its velocity.
   Ask students to describe how the events of the collision would be changed by a seatbelt.
6. Ask students what happens on the bumper cars ride. Demonstrate with toy cars on a table at the front of the room. They will most likely describe how one car hits another, they "bounce" off of each other, or how you make the other cars move by hitting them. So if one car has momentum, and it hits another car and that car moves, what happened to the momentum? It was *transferred*. This is referred to as the conservation of momentum: it is never lost, only transferred from one object to another. Can you think of other examples at the fair where we can observe this?

7. Closing discussion: Review driving questions and key terms learned up to this point: *How does a ride move you?* Motion, distance, frame of reference. *How fast are you going in a ride?* Speed, velocity. *How does your velocity change in a ride?* Acceleration. Why do you wear a seatbelt on a ride? Momentum. So, now that we have answered our sub-questions, do we have a better understanding of *what makes for a good ride at the fair*?
8. Introduce closing activity: the Fair Scavenger Hunt (see section VII). Relate how students will use the knowledge they have learned over the past 2 weeks to actual rides at the fair during a fieldtrip.

Assessment:

- PEOE write-up of predictions, observations, and explanations of momentum demonstration (use Rubric A)

Possible Lesson Plans Extension:

Students may continue the project after the field trip using fair rides to address the following objectives:

- analyze forces in terms of type and direction
- distinguish between balanced and unbalanced forces and discuss how they affect motion in terms of speed and direction
- use Newton's Laws of Motion to understand the motion-force relationship in real-world situations
- apply the principles of motion and force to machines (i.e., fair rides)

VII. Overall Assessment

Fair Scavenger Hunt:

This aspect of the project is designed to provide students with the opportunity to explore what they have learned. Students will conclude the unit by taking a field trip to the state fair (or possibly an amusement park) and investigate physics phenomenon in real situations. They will perform a series of activities, depending on grade level, in which they must use various concepts to complete a "Fair Scavenger Hunt". For example, students in 8^{th} grade will complete a worksheet (Middle School Activity III- see attached) that gives them sample motion graphs of four unidentified rides, and they must find the ride that matches the graphs. The graphs show distance-time and velocity-time. Students must provide an explanation for why they think that ride goes with that graph. In addition, they must choose a ride not on the worksheet and draw these same two graphs for that ride.

See Rubric C for assessment

Answer Key for Middle School Activity III:

Graph Set #1: Drop of Fear

Graph Set #2: Gondola

Graph Set #3: Log Flume

Graph Set #4: Super Slides

VIII. Rubrics

A. <u>Rubric for PEOE Lab Write-ups (Part 1): 20 pts. Total</u>

- **Predictions- 5 pts.**

  5: student has thought through a reasonable and rational possible outcome and provided a logical explanation

  3: student has stated a reasonable possible outcome but has no explanation for support

  1: possible outcome is unreasonable and there is no explanation

- **Observations- 5 pts.**

  5: student has noted several key concepts and provided detailed descriptions of the event

  3: student has noted only one key concept and provided a general description

  1: student noted only one concept and has no descriptions

- **Graphs- 5 pts.**

  5: students has correctly labeled axis, drawn a neat line, and correctly graphed the data they obtained from their experiment

  3: student has graphed the data obtained from the experiment

  1: axes labeled incorrectly, or graph drawn incorrectly from data

- **Explanation of Differences- 5 pts.**

  5: student has thought through a reasonable explanation for why their outcome differed from their prediction and provided key concepts they learned as support

  3: student has explained the differences

  1: student has described or noted what was different but does not explain

B. <u>Rubric for Comparison Lab Write-ups (Part 1): 10 pts. Total</u>

- **Description- 5 pts.**

  5: student has thoroughly described all graphs being compared, detailing the uniqueness of each one, and noting key differences between them

  3: student has described all graphs being compared and noted differences

  1: student described all graphs being compared

- **Explanation- 5 pts.**

  5: student has provided a thorough explanation of why the graphs are different supported by logical rational

3: student has briefly explained the differences between the graphs

1: student notes *how* graphs differ but there is no clear explanation of *why*

C. <u>Rubric for Fair Scavenger Hunt (Part 1): 10 pts. Total</u>

- **Results and Explanation- 5 pts.**

  5: student has correctly matched all rides with their corresponding graphs; student has provided clear rational for their choices, addressing each type of graph as support for why they chose that ride

  3: student has correctly matched all rides with their corresponding graphs but rational is weak; only one of the graphs is used as supporting evidence

  1: student has incorrectly matched rides with their corresponding graphs (2 or 0 out of 4 correct); explanation is descriptive rather than using logic

- **Graphs- 5 pts.**

  5: student has correctly completed distance-time and velocity-time graphs for their chosen ride with clear logic and rational; an explanation for their depiction is included

  3: student has completed both graphs but only one is correct; explanation is descriptive rather than displaying logic

  1: student has completed all graphs but has not correctly displayed the motion; logic and rational are not explained

IX. References

1. American Association for the Advancement of Science: Benchmarks for Science Literacy. www.aaas.org > Project 2061
2. National Standards for Science Education. www.myscschools.com/standards
3. University of Michigan: www.hi-ce.org
4. University of South Carolina: Amusement Park Physics: http://solomon.physics.sc.edu/~tedeschi/midway
5. Linn, M.C., and Hsi, S. (2000). Computers, Teachers, Peers: Science Learning Partners. Mahwah, NJ: Lawrence Erlbaum Associates.

X. Attachments

- Middle School Activity I: Worksheet: Speed, Velocity, and Acceleration
- Middle School Activity I- Answers: Speed, Velocity, and Acceleration Answer Key
- Middle School Activity II: Worksheet: Graphing Velocity with Motion Probes
- Middle School Activity III: Directions and Worksheets for Fair Scavenger Hunt

Name____ Date_____________________

SPEED, VELOCITY, and ACCELERATION

PART A

Speed is defined as the distance an object travels per unit time. *Velocity* is speed in a definite direction. The rate of speed and velocity can be expressed in kilometers per hour, meters per second, and so on. In most cases, moving objects do not travel at a constant speed. The speed of an object usually increases and/or decreases as it moves. Therefore, the average speed or average velocity is used to describe the motion. Average speed is a ratio between the total distance and the total time that the object traveled.

Average speed = total distance / total time

Procedure:

1. Clear an area for a runway, about 5 meters long.
2. At one end of the runway, set up a launching ramp: put one end of the wood ramp on a *short* stack of books and the other end on the floor. You will launch your car from the top of this ramp.
3. Put a masking tape marker where the ramp touches the floor and label this 0.0 meters. Using a measuring tape, place similar markers at every 1.0 meters up to 5.0 meters.
4. Practice running the car down the ramp several times to observe its motion and path; add or remove books to make sure it travels 5.0 meters.
5. Measure the time that the car takes to travel 5.0 meters using the stopwatch. Remember to start the time at the bottom of the ramp (0.0 meters). Record the time and distance in Data Table A-1.
6. Complete this process for 4 trials. Find the average time of your trials.
7. Determine the average speed of the car to the nearest 0.1 meter per second.

Data Table A-1:

TRIAL	DISTANCE (m)	TIME (s)
1		
2		
3		
4		
Average		

The car's average speed is:___________m/s.

8. Next, make a practice run with the car again, however, this time measure the time as the car crosses each meter marker. You may require several practice runs to be able to quickly observe and record the time. You may need to add friction to the car to slow it down so you can make measurements (i.e., tape a cardboard flap to the car to drag it).

9. Make a total of four trials. Record the time traveled as the car crosses each meter marker in Data Table A-2.
10. Calculate the average time at each meter marker for the four trials.

Data Table A-2:

TRIAL	1.0 meter	2.0 meters	3.0 meters	4.0 meters	5.0 meters
1					
2					
3					
4					
Average time					

11. On a sheet of graph paper, plot your distance versus average time. Remember to label the axes, title the graph, and draw a smooth line.

Questions:

1. What does this line represent?

2. How did the car's position change with time?

PART B

Acceleration is the rate at which an object's speed or velocity increases. You can express the rate of acceleration using meters per second per second (meters per second squared). This unit represents the change in velocity each second. Forces cause objects to accelerate positively (increase rate of speed) or negatively (decrease rate of speed). If a car averages 80 kilometers per hour on a hilly road, it probably changes velocity many times. The car accelerates positively and negatively. If the car is traveling at a constant speed of 80 kilometers per hour on a level road, it is not changing velocity. The acceleration is zero.

Procedure:

1. Repeat steps 8 and 9 from Part A: measure the time as the car crosses each meter marker. You may require several practice runs to be able to quickly observe and record the time.
2. Make a total of four trials. Record the time traveled as the car crosses each meter marker in Data Table B.
3. Calculate the average time for the five trials. Calculate the average speed of the car over each interval (1.0 m, 2.0 m, etc.) from the time it takes to pass each meter. Record this information in Data Table B.

Data Table B: Travel times (s)

TRIAL	1.0 meter	2.0 meters	3.0 meters	4.0 meters	5.0 meters
1					
2					
3					
4					
Average time					
V at each marker (m/s)					

4. Make a graph that compares the velocity of the car with the distance to each marker. Remember to label the axes, title the graph, and draw a smooth line. Also make a graph of the velocity of the car with time.

Questions:

1. Describe the motion of the car as it moved across the floor.
2. What caused the car to slow down and stop?
3. Did the car travel at a constant rate? How do you know?
4. When did the car accelerate?
5. How could you change the activity to make the car not accelerate as much?
6. How could you change the activity to make the car accelerate more?

SPEED, VELOCITY, and ACCELERATION- ANSWER KEY

PART A

Data Table A-1:

TRIAL	DISTANCE (m)	TIME (s)
1	5.0	4.27
2	5.0	4.25
3	5.0	4.14
4	5.0	4.33
Average	5.0	4.25

The car's average speed is:____1.2_____m/s. (average speed = distance/time)

Data Table A-2:

TRIAL	1.0 meter	2.0 meters	3.0 meters	4.0 meters	5.0 meters
1	0.58 s	1.41 s	2.05 s	3.15 s	4.53 s
2	0.61 s	1.26 s	2.33 s	3.45 s	4.40 s
3	0.70 s	1.31 s	2.25 s	3.37 s	4.17 s
4	0.43 s	1.40 s	2.16 s	2.90 s	4.20 s
Average	0.58 s	1.35 s	2.20 s	3.22 s	4.33 s

Questions:

1. What does this line represent?
   The position at any given time.

2. How did the car's position change as it traveled?
   The position increases with increasing time.

PART B

Data Table B: Time (s)

TRIAL	1.0 meter	2.0 meters	3.0 meters	4.0 meters	5.0 meters
1	0.58	1.41	2.05	3.15	4.53
2	0.61	1.26	2.33	3.45	4.40
3	0.70	1.31	2.25	3.37	4.17
4	0.43	1.40	2.16	2.90	4.20
Average	0.58	1.35	2.20	3.22	4.33
V at each marker (m/s)	1.72	1.48	1.36	1.24	1.15

Questions:

1 Describe the motion of the car as it moved across the floor.
The car slowed or decelerated or experienced negative acceleration.

2. What caused the car to slow down and stop?
Friction with the floor.

3. Did the car travel at a constant rate? No How do you know?
The line on the graph indicated slower speeds as distance from the ramp increased.

4. When did the car accelerate?
First when traveling down the ramp (positive acceleration), then when slowing down on the floor (negative acceleration).

5. How could you change the activity to make the car not accelerate as much?
The ramp could be lowered so the car has less initial acceleration. Friction can be reduced to the car slows less on the level floor.

6 How could you change the activity to make the car accelerate more?
The angle of the ramp could be increased (raise the stack of books).
More friction on the level part of the path by using carpet or by adding something to the car that causes drag.

Name____ Date____________________

GRAPHING VELOCITY WITH A MOTION PROBE

1. Select one run of your car with the motion probe and print the velocity graph.
2. Write an explanation of the motion occurring on your graph.

3. Mark on the graph the point when the car began rolling.
4. How far was it from the sensor when it started?

5. How did the graph change while it rolled down the ramp?

6. Mark the point when it stopped.
7. What was its final position?

8. Over what period of time did it roll?

Middle School Activity III

FAIR SCAVENGER HUNT!!

Welcome to the “Physics at the Fair” Day!

Directions:

I. You have been given four sets of motion graphs that depict four different rides found at the State Fair. The motion graphs include distance-time and velocity-time. Your job is to examine each of the graphs and try to determine what type of motion is being depicted. Once you figure that out, you will need to match the graphs to the ride that displays those types of motion. Choose from the word bank below. Locate each ride at the fair. Watch carefully from the ground, then ride the ride- this will help you determine the motions of that particular ride.

II. Once you think you have matched the ride to a set of graphs, you need to explain how you came up with your answer. Do this by addressing BOTH of the graphs, explaining how the motion depicted is representative of that ride. Use logic and rational in your explanation rather than a description of the graph.

III. Finally, using graph paper or the back of the worksheets, choose a ride that is not in the word bank and create the same two types of graphs for it: time-distance and velocity-time. You do not need to incorporate numbers in your graph, but you do need to label the axes. Again, you will need to provide an explanation of how and why you drew your graphs the way you did.

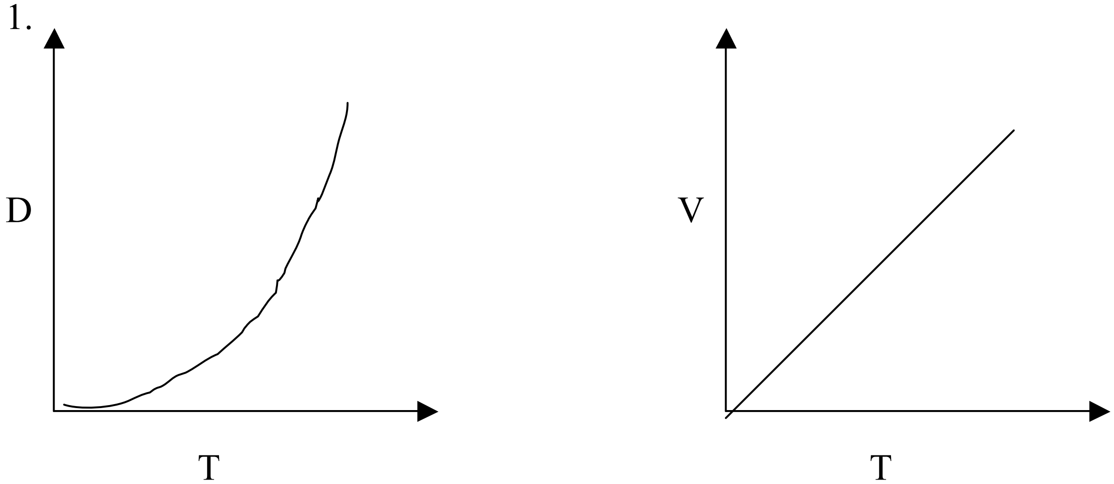
There will be a prize provided for each student that correctly matches the graphs and rides! There will be an additional prize for each student that also correctly draws three motion graphs for the ride they chose!

Ride Choices:

Gondola	Log Flume
Slides	Drop of Fear

NAME: ______________________________ DATE: _____________

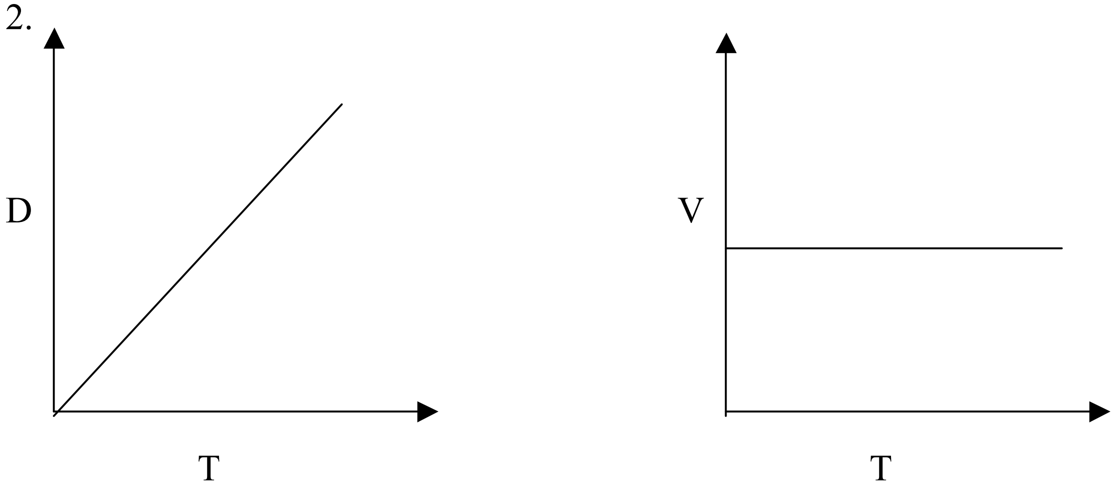
1.



Name of Ride: _________________________________

Why do you think these graphs represent your ride?

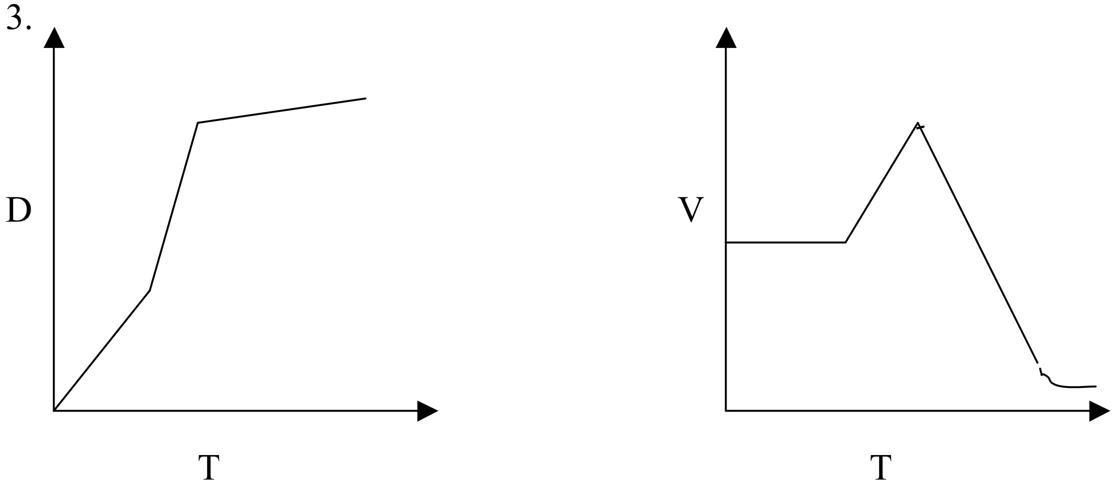
2.



Name of Ride: _________________________________

Why do you think these graphs represent your ride?

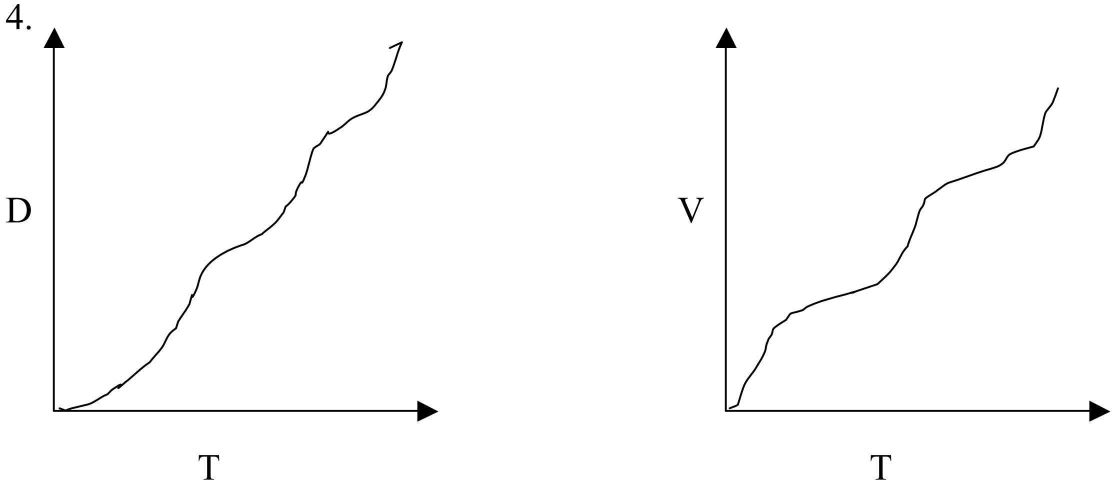
3.



Name of Ride: ____

Why do you think these graphs represent your ride?

4.



Name of Ride: ____

Why do you think these graphs represent your ride?