Unit Introduction

Force and motion are two of the most important concepts in science. Without forces, nothing in the universe would ever happen. Without motion, the universe would cease to exist. They are united in a subject called "dynamics," the science of the way objects move when acted upon by a force.

In this unit, students work in teams to build a balloon-powered race car. They calculate speed, acceleration, work, power, and momentum. They recognize the car is a system comprised of simple machines—wheels/axles, pulleys, levers, screws, wedges, and inclined planes. Students investigate and describe Newton’s Laws of Motion and apply these laws to the motion of their cars.

Students’ experiences include becoming competent in using formulas to calculate motion. These formulas are:

<table>
<thead>
<tr>
<th>Speed</th>
<th>distance divided by time</th>
<th>$s = \frac{d}{t}$</th>
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</thead>
<tbody>
<tr>
<td>Acceleration</td>
<td>final velocity - initial velocity divided by change in time</td>
<td>$a = \frac{v_f - v_i}{\Delta t}$</td>
</tr>
<tr>
<td>Momentum</td>
<td>mass multiplied by velocity</td>
<td>$p = mv$</td>
</tr>
<tr>
<td>Work</td>
<td>Force multiplied by distance</td>
<td>$W = Fd$</td>
</tr>
<tr>
<td>Power</td>
<td>Work divided by time</td>
<td>$P = \frac{W}{t}$</td>
</tr>
<tr>
<td>Force</td>
<td>mass multiplied by acceleration</td>
<td>$F = ma$</td>
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<tr>
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</table>
### Overview of Learning Experiences

<table>
<thead>
<tr>
<th>TEKS</th>
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<tbody>
<tr>
<td><strong>4) Science concepts.</strong> The student knows the laws governing motion. The student is expected to:</td>
</tr>
<tr>
<td><strong>(A)</strong> calculate speed, momentum, acceleration, work, and power in systems such as moving toys, and machines;</td>
</tr>
<tr>
<td><strong>(B)</strong> investigate and describe applications of Newton's laws such as in vehicle restraints, [sports activities, geological processes, and satellite orbits];</td>
</tr>
<tr>
<td><strong>(C)</strong> analyze the effects caused by changing force or distance in simple machines as demonstrated in [household devices, the human body,] and vehicles;</td>
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<thead>
<tr>
<th>ENGAGE</th>
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<tbody>
<tr>
<td><strong>See: Steve’s Motion Clip</strong></td>
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<tr>
<td><strong>Do: “Cars and Ramp” Inquiry</strong></td>
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<tr>
<td>Teams of three or four students are given a car, a ramp, and wooden blocks. Students explore the materials to determine an answer to the following question:</td>
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<tr>
<td><strong>What do I need to know in order to determine how fast our car goes?</strong></td>
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<tr>
<td><strong>What factors affect the speed of our cars?</strong></td>
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<tr>
<th>EXPLORER</th>
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<tr>
<td><strong>Do: “Playing with Toy Cars”</strong> – Students investigate and calculate motion using toy cars.</td>
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<tr>
<td><strong>Do: “Gathering Momentum”</strong> – Students calculate momentum.</td>
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<tr>
<td><strong>Do: “Crash Test Dummies”</strong> – Students investigate Newton’s Laws of Motion.</td>
</tr>
<tr>
<td><strong>Do: “Balloon Racers”</strong> – Students design and race balloon cars.</td>
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<table>
<thead>
<tr>
<th>EXPLAIN</th>
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<tbody>
<tr>
<td><strong>WHOLE GROUP DISCUSSION</strong></td>
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<tr>
<td>Teacher facilitates a class discussion of findings and new understandings that resulted from the exploration activities. Students explain what they have learned.</td>
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<table>
<thead>
<tr>
<th>ELABORATE</th>
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<tbody>
<tr>
<td><strong>TECHNOLOGY CONNECTIONS</strong></td>
</tr>
<tr>
<td>Students surf websites for safety information regarding the use of seat belts in cars. Which cars are the safest and why? Students review motion websites and extend their learning by creating their own physics animations.</td>
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</table>

<table>
<thead>
<tr>
<th>EVALUATE</th>
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<tbody>
<tr>
<td><strong>FINAL PROJECT: “The Fast and Furious Toy Car Race”</strong></td>
</tr>
<tr>
<td>Students design cars to meet a challenge issued by the Fast and Furious Toy Car Company and are asked to improve their designs to meet the challenge. They discover the need for background information on factors that affect motion before they improve their designs. The experiences in the MOTION unit are designed to ensure that students are successful in meeting the design challenge.</td>
</tr>
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</table>
Fast and Furious Car Race Unit Project

PROJECT DESCRIPTION:
Students design cars to meet a challenge issued by the Fast and Furious Toy Car Company and are asked to improve their designs to meet the challenge. They discover the need for background information on factors that affect motion before they can improve their designs. The experiences in the MOTION unit are designed to ensure that students are successful in meeting the design challenge.

ACTION:
The Fast and Furious Toy Car Company has issued a challenge to design a fast and furious toy car. Matchbox® and Hot Wheels® have dominated the car toy market for years. It is time for a new and exciting design. The company is looking for a fast and furious car that is cost efficient (using simple everyday materials), creative, and fast. A recent market study has indicated that children like balloons so the company has asked all designers to use a balloon as the force to accelerate the car. Several design constraints have been identified for all designers.

DESIGN CONSTRAINTS:
The toy car must be a land transportation vehicle. Balloons are to remain the ONLY energy source. No other energy source may be added or substituted. Use simple materials; teams are limited only by their imaginations. Students must perform calculations for speed/velocity, acceleration, momentum, and force and record these calculations in their lab journals.

DIRECTOR’S (Teacher) NOTES:
1. Have students work in teams of three or four to build their cars.
2. Provide simple materials such as balloons, milk cartons, Styrofoam cups, (Styrofoam cup bottoms can be used as wheels.).
3. After students inventory the parts provided, they begin designing their own balloon powered cars. They test run their cars and decide how they can further improve their designs.
4. Hold car distance trials on a smooth surface.
5. Invite student teams to discuss the many variables discussed previously in the unit’s activities and how each affects the performance of their cars.
6. Students manipulate one variable at a time to improve their cars recording all data and observations in their journals. Students test run their cars in three trials and calculate average distance and speed to determine the “Fastest and Most Furious Car!”
7. Students create data tables to record their observations and calculations. Students also graph data and identify independent and dependent variables.
“Cars and Ramps” Inquiry

To set up this Motion Unit the teacher shows Steve Wolf’s engaging Motion clip. Movie clips of cars racing, cars crashing, cars doing cool car things might also be used to capture students’ interest. For example: NASCAR racing; big crash; film clip from “The Fast and Furious;” different types of vehicles and how they accelerate; crash dummy clip; safety test clips; vehicle restraints; motorcycle stunts; Starsky and Hutch.

After the engaging film clip—

1. Each team is given a car, a ramp, and wooden blocks. Students explore the materials to determine answers to the following questions:
   - What do I need to know in order to determine how fast our car goes?
   - What factors affect the speed of our car?

2. Students record ideas in their science journals regarding the variables that would have to be tested.

3. Students communicate their ideas on large sheets of butcher paper and display their ideas for the whole class to view and discuss.

4. Together students create a class priority list identifying possible experiments that could be conducted so they can ultimately build a fast and furious race car of their own. See Unit Project Description.
Explore

**Exploration Activity One: “Playing with Toy Cars”**

Students investigate the effects of the following variables on a car’s speed —time on the ramp, height of the ramp, mass of the car, and the surface on which the car travels. Students graph results for the different variables.

**Exploration Activity Two: “Gathering Momentum”**

Students investigate the relationships between changing mass of a moving car and its momentum. Students measure the velocity and mass of the car and then calculate the momentum of the car. They observe the effect of momentum on the stationary barrier that the car hits as they measure the distance that the barrier moves upon impact. Students relate the results of their experiment to the Law of Conservation of Momentum. After calculating the average acceleration of the car, students calculate the force of impact using Newton's Second Law. They also apply this experiment to Newton’s First and Third Laws of Motion.

**Exploration Activity Three: “Crash Test Dummies”**

Students conduct experiments using passengers of different masses and belted and unbelted passengers. When cars hit a barrier, students measure the distance the passengers move with and without seat belts. They apply Newton’s Laws and the concepts of inertia and momentum to analyze their observations.

**Exploration Activity Four: Balloon Racers**

Students investigate Newton’s First, Second, and Third Laws of Motion. They build a car using Styrofoam meat trays, balloons, and straws to investigate the effect of balloon size on the distance the car travels.
**Explore 1: Playing with Toy Cars**

**Type of Lesson:** Content with Process: Focus is on constructing knowledge through active learning.

**Learning Goal & Instructional Objectives**

<table>
<thead>
<tr>
<th>Key Questions:</th>
<th>What factors affect the average speed of a small toy car?</th>
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<tbody>
<tr>
<td></td>
<td>How does each factor affect the motion of the car?</td>
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</tbody>
</table>

**Instructional Objectives:**

1. Calculate the speed of an object using the appropriate formula with data gathered in the laboratory and printed information.
2. Calculate the acceleration of an object using the appropriate formula with data given in the problem.

\[ s = \frac{d}{t} \]
\[ a = \frac{v_f - v_i}{\Delta t} \]

**Key Questions:**

- What factors affect the average speed of a small toy car?
- How does each factor affect the motion of the car?

**IPC Content TEKS:** 4A Calculate speed and acceleration in systems such as moving toys.

**Related Process TEKS:**

1. **Scientific processes.**
   - The student, for at least 40% of instructional time, conducts field and laboratory investigations using safe, environmentally appropriate, and ethical practices.
   - The student is expected to:
     - (A) demonstrate safe practices during field and laboratory investigations;

2. **Scientific processes.**
   - The student uses scientific methods during field and laboratory investigations.
   - The student is expected to:
     - (A) plan and implement experimental procedures including asking questions, formulating testable hypotheses, and selecting equipment and technology;
     - (B) collect data and make measurements with precision;
     - (C) organize, analyze, evaluate, make inferences, and predict trends from data; and
     - (D) communicate valid conclusions.

3. **Scientific processes.**
   - The student uses critical thinking and scientific problem solving to make informed decisions.
   - The student is expected to:
     - (A) analyze, review, and critique scientific explanations, including hypotheses and theories, as to their strengths and weaknesses using scientific evidence and information;
     - (B) draw inferences based on data related to promotional materials for products and services;
     - (C) evaluate the impact of research on scientific thought, society, and the environment;

**To the Teacher:**

If you have photo gates and computers available, adapt the lab so that students can more accurately measure the time and calculate the speed. Since this experiment cannot accurately measure the final velocity of the toy car as it reaches the bottom of the ramp, acceleration was calculated in the analysis section using a given final velocity.

Students must know that velocity is defined as speed and direction. Acceleration is defined as the change in velocity divided by the change in time.

**Multiple Intelligences:**

- **Logical-Mathematical Intelligence—** Consists of the ability to detect patterns, reason deductively, and think logically. This intelligence is most often associated with scientific and mathematical thinking.
- **Linguistic Intelligence—** Involves having a mastery of language. This intelligence includes the ability to effectively manipulate language to express oneself rhetorically or poetically. It also allows one to use language as a means to remember information.
- **Spatial Intelligence—** Gives one the ability to manipulate and create mental images in order to solve problems. This intelligence is not limited to visual domains. Gardner notes that spatial intelligence is also formed in blind children.
MOTION UNIT

Fast and Furious — Off to the Races!

Materials:
- One toy car per team
- One ramp per team. The ramp should be at least one meter long
- One stopwatch per team
- One meter stick per team
- Sandpaper and towels to cover the ramps
- Wax paper for the ramp (one full roll of waxed paper)
- Masking tape (one roll)

SAFETY NOTE: See Texas Science Safety Manual for lab and investigation guidelines:

Engage:

Introduce the ideas of speed and acceleration by discussing car races such as the Indianapolis 500. Find out what students know by asking the following facilitation questions.

Facilitation Questions:
1. How fast do you think those cars are going?
2. How can a driver figure out the car’s speed if the car’s speedometer is not working?
3. How does a race car driver change the speed of the car?
4. What is the difference between acceleration and speed?

Explore:

Part 1: Height of ramp

1. With the ramp flat on a table or floor, place the back of the car's wheels at one end of the ramp and measure the distance from the front of the car to the end of the ramp. Record this distance on the data sheet.
2. Raise the ramp up on the blocks. Measure the height in meters and record on the data sheet.
3. Place the back of the car's wheels at the top end of the ramp.
4. Release the car as you start the stopwatch.
5. Stop timing when the front of the car gets to the bottom of the ramp. Record this time on the data sheet.
6. Repeat steps 3-5 two more times then calculate the average time and record on the data sheet.
7. Calculate the average speed of your car by using the formula: speed = \frac{\text{distance}}{\text{time}} \text{ or } s = \frac{d}{t}.
8. Raise one end of the ramp on two blocks and repeat steps 2-7.
9. Raise one end of the ramp on three blocks and repeat steps 2-7.
MOTION UNIT

Fast and Furious — Off to the Races!

Part Two: Mass of Car (Height stays the same, mass changes)

1. Raise one end of the ramp on one block. Measure the height in meters and record on the data sheet.
2. Place the back wheels of the car at the top end of the ramp.
3. Time how long it takes to reach the bottom of the ramp. Record on the data sheet.
4. Repeat steps 2 and 3 two more times then calculate the average time and record on the data sheet.
5. Add a known mass to the car then repeat steps 2 - 4 recording all measurements on the data sheet.
6. Add a second known mass to the car then repeat steps 2 - 4 recording all measurements on the data sheet.
7. Record observations in your journal.

Part Three: Surface of the ramp (Height of ramp changes, mass stays the same)

1. Raise one end of the ramp on 2 blocks. Measure the height in meters and record on the data sheet.
2. Place the back wheels of the car at the top end of the ramp.
3. Time how long it takes to reach the bottom of the ramp. Record on the data sheet.
4. Repeat steps 2 and 3 two more times, then calculate the average time and record on the data sheet.
5. Cover the surface of the ramp with a higher friction material such as a towel or sandpaper.
6. Repeat steps 2 - 4 two more times then calculate the average time and record on the data sheet. NOTE: If the car stops before it reaches the bottom of the ramp, measure the distance from the top of the ramp to the back wheels and record this distance on the data sheet.
7. Cover the ramp with waxed paper.
8. Repeat steps 2 - 4 two more times then calculate the average time and record on the data sheet.
9. Record observations in your journal.

Explain:

Have students record their calculations in their lab journals and communicate their findings in a class discussion.

Part Four: Calculation, Graphs and Analysis

1. Calculate the average speed for each line in the chart using the formula:
   \[ \text{speed} = \frac{\text{distance}}{\text{time}} \text{ or } s = \frac{d}{t}. \]
2. Graph the data from Parts One, Two, and Three on separate graphs.
3. Identify the manipulated variable and responding variable for Parts One, Two, and Three.
4. Write about your findings in your journal and attach your graphs.
### Data Sheets*

#### Part 1: Does the height of the ramp affect the average speed of the car?

<table>
<thead>
<tr>
<th>Distance Traveled (m)</th>
<th>Height of Ramp (m)</th>
<th>Time (s)</th>
<th>Average Time (s)</th>
<th>Average Speed (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Average time (s)</td>
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<td></td>
<td>Average time (s)</td>
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</table>

#### Part 2: Does the mass of the car affect the average speed of the car?

<table>
<thead>
<tr>
<th>Distance Traveled (m)</th>
<th>Mass on Car (g)</th>
<th>Time (s)</th>
<th>Average Time (s)</th>
<th>Average Speed (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td>Average time (s)</td>
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<td>Average time (s)</td>
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</tbody>
</table>

#### Part 3: Does the surface of the ramp affect the average speed of the car?

<table>
<thead>
<tr>
<th>Distance Traveled (m)</th>
<th>Surface of Ramp (m)</th>
<th>Time (s)</th>
<th>Average Time (s)</th>
<th>Average Speed (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td>Average time (s)</td>
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*Have students use Excel to construct graphs of their data.
Elaborate: Have students respond to the following questions in their science journals and then discuss their responses as a team.

Analysis:

1. **Why did you do each timing three times, and then average them?**
   
   For more accuracy in experiments, measurements should be done more than once.

2. **How did the height of the ramp affect the average speed of the car?**
   
   The average speed increased because gravity was able to act on the car over a longer vertical distance.

3. **How did the mass of the car affect its average speed?**

   When the car goes down the ramp, gravity pulls at it with the same acceleration no matter what its mass is. (Teacher note: Students have problems with this concept because many of them believe that heavier objects will hit the ground first.) The final velocity of each car no matter what its mass should be the same velocity. There are some factors that may influence the results. These include air resistance, wheel traction, and the pressure exerted on the car's axles due to the increased mass. (Teacher note: A discussion of Galileo before the exploration might help the students understand this concept.)

4. **How did the surface of the ramp affect the average speed of the car?**

   The more the friction between the ramp and the car wheels, the slower the car will travel. The wax should make the car go faster. However, if the friction is too little, the wheels will not be able to have traction with the surface and might go slower. Students must look at their data to see if that situation happened.

5. **What other factors do you believe would affect the average speed of the car? How do you think that each factor would affect the speed?**

   This is open to student opinion. They might want to test wheel size (circumference) or change the front of the car so it has less air resistance. Let them visualize their cars and what they could do to change the speed.

6. **What sources of error were involved in this lab? How do you think each source of error affected your results?**

   Timing correctly was probably the area of most error. If the time was wrong, it would definitely affect the average speed accuracy. To try to overcome this error possibility, three time measurements were done for each trial.

7. **What was the initial velocity of the car at the point that you let the car go?**

   It was 0 meters per second because the car was not moving until it was released.

8. **If a device measured the final velocity of a car as 2 m/s south on the ramp, calculate the acceleration of the car if it took 4 seconds to reach the bottom of the ramp. Use the formula:**

   
   \[
   \text{acceleration} = \frac{\text{final velocity} - \text{initial velocity}}{\text{change in time}}
   \]

   
   \[a = \frac{2 \text{ m/s} - 0 \text{ m/s}}{4 \text{ s}} = 0.5 \text{ m/s/s} \text{ or } 0.5 \text{ m/s}^2 \text{ [South]}\]
Have students answer these questions using data, observations, and information learned from this experience and record responses in their journals.

Explain fully. All conclusions are recorded in their lab journals. Students must analyze factors that affect the speed of a car and support their answers using data from the lab. At this point, go back to the Indianapolis 500 Car Race and discuss how drivers increase the speed and acceleration of their cars during the race. Discuss why certain cars accelerate faster than others. Ask about cruise control and its application to speed and acceleration. Also, include in the discussion how velocity can change even if speed is constant (because the direction changes).

“I’d offer you a lift home, but the company cars are well . . . you know.”
**Evaluate:** Use this rubric to assess student understanding of speed and acceleration of the car.

<table>
<thead>
<tr>
<th>POINTS</th>
<th>Scientific Accuracy</th>
<th>Reasoning</th>
<th>Communication</th>
<th>Collaboration</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>4</strong></td>
<td>Excellent</td>
<td>My measurements are precise and I included units in all calculations. Tables and graphs are accurate and variables are correctly identified.</td>
<td>My answers to the analysis questions show application level and are well reasoned. I am able to support my conclusions with lots of examples.</td>
<td>I answered all questions clearly and accurately. My answers are clear with examples and data to back up conclusions. I recorded all calculations and answers in my lab journal.</td>
</tr>
<tr>
<td><strong>3</strong></td>
<td>Good</td>
<td>My measurements are somewhat precise and I included units in my calculations. Tables and graphs are complete and variables are identified.</td>
<td>My answers to the analysis questions show application level. I am able to support my conclusions with some examples.</td>
<td>I answered all questions clearly and accurately. I used examples and data to back up some of my conclusions. I recorded most of my calculations and answers in my lab journal.</td>
</tr>
<tr>
<td><strong>2</strong></td>
<td>Fair</td>
<td>My measurements are complete but may or may not be accurate. Tables and graphs are somewhat complete and a few variables are identified.</td>
<td>My answers to the analysis questions show application level. I am able to support my conclusions with a few examples.</td>
<td>I answered the questions. I used some examples and data to back up some of my conclusions. I recorded some of my calculations and answers in my lab journal.</td>
</tr>
<tr>
<td><strong>1</strong></td>
<td>Poor</td>
<td>My measurements are not complete and are not very accurate. My tables and graphs are incomplete and no variables are identified.</td>
<td>My answers to the analysis questions show a superficial understanding. I don’t get what we are doing. I am not able to support my conclusions with examples.</td>
<td>I did not answer the questions and I didn’t record my calculations in my journal.</td>
</tr>
</tbody>
</table>

Subtotal: ____ Subtotal: ____ Subtotal: ____ Subtotal: ____ TOTAL: ____/16pts

**References/Resources/Websites:**

- Science’s 10 Most Beautiful Experiments including Galileo rolling balls down inclined planes and Foucault’s Pendulum: [http://physics.nad.ru\physics\english\top10.htm](http://physics.nad.ru\physics\english\top10.htm)
- Toy Challenge: [http://www.sciencenewsforkids.org/articles/20031224/refs.asp](http://www.sciencenewsforkids.org/articles/20031224/refs.asp)
- Coursework on Newton’s Laws: [http://www.courseworkbank.co.uk/GCSE/Physics_Coursework/Force_Mass_and_Acceleration/](http://www.courseworkbank.co.uk/GCSE/Physics_Coursework/Force_Mass_and_Acceleration/)
- Describing Motion with Words: [http://www.physicsclassroom.com/Class/1DKin/U1L1d.html](http://www.physicsclassroom.com/Class/1DKin/U1L1d.html)
MOTION UNIT

**Explore 2: Gathering Momentum**

**Type of Lesson:** Content with Process: Focus on constructing knowledge through active learning.

**Learning Goal & Instructional Objectives:** In this investigation, students calculate speed, momentum, acceleration, and force using data they collect in experiments. Students make connections between speed and acceleration and learn how they are used to calculate momentum and force.

**Instructional Objectives:**

1. Students calculate the speed of an object using the appropriate formula with data gathered in the laboratory and printed information.
2. Students calculate the acceleration of an object using the appropriate formula with data gathered in the laboratory and printed information.
3. Students calculate momentum of an object using the appropriate formula with data gathered in the laboratory and printed information.
4. Students calculate the force of an object using the appropriate formula with data gathered in the laboratory and printed information.

**Key Question:** How does an increase in mass affect the momentum of a car as it hits an object?

**IPC Content TEKS:**

4A Calculate speed, momentum, acceleration, and force in systems such as in moving toys, and machines.

**Related Process TEKS:**

**(1) Scientific processes.** The student is expected to:

(A) demonstrate safe practices during field and laboratory investigations; and

(B) make wise choices in the use and conservation of resources and the disposal or recycling of materials.

**(2) Scientific processes.** The student uses scientific methods during field and laboratory investigations. The student is expected to:

(A) plan and implement experimental procedures including asking questions, formulating testable hypotheses, and selecting equipment and technology; (B) collect data and make measurements with precision; (C) organize, analyze, evaluate, make inferences, and predict trends from data; and (D) communicate valid conclusions.

**(3) Scientific processes.** The student uses critical thinking and scientific problem solving to make informed decisions. The student is expected to:

(A) analyze, review, and critique scientific explanations, including hypotheses and theories, as to their strengths and weaknesses using scientific evidence and information; (B) draw inferences based on data related to promotional materials for products and services; (C) evaluate the impact of research on scientific thought, society, and the environment; (D) describe connections between physics and chemistry and future careers; and (E) Research and describe the history of physics, chemistry, and contributions of scientists.
MOTION UNIT

Fast and Furious — Off to the Races!

To the Teacher:

This investigation includes calculations of speed, momentum, acceleration, and force. The students collect data and use the information to make the calculations. They make connections between speed and acceleration and learn how they are used to calculate momentum and force.

Momentum can be also be referenced when discussing driving and safety. Once the students understand that mass is a factor that affects momentum, they can better understand why it is important not to cut in front of a large truck. If a small car is in front of a large truck and the car’s driver suddenly slams on the brakes, the large truck cannot stop as quickly as the car and a crash may result. A small car has less momentum than a large truck when both are traveling at the same velocity. On a similar note, a small car going very fast has a great deal of momentum because, as its velocity increases, its momentum increases.

Blocks or other heavy objects can replace the milk cartons used in this investigation. Fill the milk cartons only half full with sand. If the carton has too much mass, the car may not have enough momentum to move it. The students measure the mass of the car in grams, therefore they will need to convert to kilograms prior to doing the calculations.

As the students conduct the investigation, they observe that as the mass of the car increases, the distance the milk carton moves increases.

A NOTE ABOUT CALCULATIONS:
The investigation is designed without the use of photogates or other technology that could determine the instantaneous velocity of the car at impact. Therefore students must calculate the final velocity using data obtained during this investigation. This calculated final velocity will be used to calculate both momentum and acceleration. IF PHOTOGATES ARE AVAILABLE, CONSIDER MODIFYING THE LAB TO ELIMINATE THIS CALCULATION OF FINAL VELOCITY.

Use formula for average velocity.
1. Calculate average speed as they did in the first investigation.
2. Multiply the average speed by 2.
Example: A car starts from rest and rolls down a 1.0 meter incline taking 1.68 seconds.

Step 1: Calculate average speed $s = \frac{d}{t} = \frac{1 \text{ m}}{1.68 \text{ s}} = 0.6 \text{ m/s}$

Step 2: Calculate final velocity $2 \times 0.6 \text{ m/s} = 1.2 \text{ m/s}$

You can walk the student through this additional calculation to assure it is mathematically correct. The formula for average velocity is not on the state provided formula chart so the students may not understand the concept fully, however they should understand the concept of average (7th grade math TEKS). This procedure is conceptually identical to the situation where a student has taken two quizzes and has a 45 average. He knows he received a 0 on the first one, what did he receive on the second?

TEACHING SUGGESTION:
If possible, have a discussion with the students prior to giving out the lab sheet about how THEY would put together a lab to investigate the problem. The class may have great suggestions to test the momentum in addition to that given on the lab sheet. Try and guide them in the right direction as to plausible experiments. If the students have a difficult time arriving at a suitable solution to the problem, then provide the lab sheet for them to use. Continue guiding the students in the right direction so they can strengthen their process skills in conducting investigations using their own suggestions rather than a provided lab sheet.

Multiple Intelligences:

<table>
<thead>
<tr>
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<th>Consists of the ability to detect patterns, reason deductively and think logically. This intelligence is most often associated with scientific and mathematical thinking.</th>
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MOTION UNIT

Fast and Furious — Off to the Races!

Materials:
- Hall’s carriage car (can easily add mass to it)
- Stopwatch
- Meter stick
- Ramp
- Blocks/books
- Milk carton half filled with sand or other heavy object

SAFETY NOTE: See Texas Science Safety Manual for lab and investigation guidelines: 

Engagement:
Engage the students in a conversation about traveling on a freeway or busy road. Inquire if anyone is taking or has taken the driver’s education test for his/her driver’s license. Discuss the rules concerning following distance at different speeds. Focus on the interactions between large vehicles such as semis/tractor trailers and small cars. Guide students in making predictions as to the rules of pulling in front of vehicles and following too closely.

Facilitation Questions:
1. How many feet should you stay behind another vehicle on the freeway?
2. What happens if you don’t see the car in front of you as it brakes?
3. What could happen if you cut off a semi in busy traffic on the freeway?
4. Which vehicle can stop faster, a small car or a semi?

Explore:
1. With the ramp flat on a table or floor, place the back of the car's wheels at one end of the ramp and measure the distance from the front of the car to the end of the ramp. Record this as “distance car travels” on the data sheet.
2. Raise the ramp up on the blocks. Place the milk carton at the bottom of the ramp positioning a meter stick just behind and offset from the milk carton so that when the carton is hit, it will move without disturbing the meter stick.
3. Mass the empty car and record your results on the data sheet.
4. Place the back of the car's wheels at the top end of the ramp.
5. Release the car as you start the stopwatch. Stop timing when the car hits the milk carton. Record this time on the data sheet.
6. Observe the car and the milk carton as the car hits the milk carton. Record your observations.
   Measure the distance the milk carton moved after being hit and record this distance.
7. Complete three trials using the same mass. Record all data.
8. Add a 100 gram load to the car. Record the combined mass of the car and its load. Repeat steps 4 – 7.
9. Add another 100 gram load to the car (200 gram total load). Record the combined mass of the car and its load then repeat steps 4 - 7.
Distance car traveled ___________

Data Table

<table>
<thead>
<tr>
<th>Mass (g)</th>
<th>Trial</th>
<th>Time (s)</th>
<th>Distance milk carton moved (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Empty car</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Car + 100 g load</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Car + 200 g load</td>
<td>1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Average =

Average time for all trials =

Explain:

1. Convert mass from grams to kilograms (1000 g = 1 kg) and record in the Data Table.
2. Calculate the average time for all trials and record in the Data Table.
3. Calculate the average distance the milk carton moved for each mass and record in the Data Table.
4. Write the final velocity in the chart below. The final velocity is the same for each car.
5. Calculate the final velocity of the car (the velocity at impact).

6. Step 1: Calculate the average speed of the car using the formula: \( s = \frac{d}{t} \) or

average speed = distance car traveled / average time for all trials

Step 2: Make sure that the final velocity has been entered in the correct column.

7. Calculate Momentum.

   Step 1: Copy the values for mass (kg) to the table below.

   Step 2: Enter the final velocity into the table. It is the same for all.

   Step 3: Calculate the momentum of each of the three cars at impact using the formula \( p = mv \)

   or momentum = (mass in kg) (final velocity in m/s).

<table>
<thead>
<tr>
<th>Mass (kg)</th>
<th>Final velocity (m/s)</th>
<th>Momentum (kg-m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Empty car</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Car + 100 g</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Car + 200 g</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
8. Calculate acceleration using the formula \( a = \frac{v_f - v_i}{\Delta t} \). The initial velocity is the velocity of the car at rest at the top of the ramp, in other words, 0 m/s. The final velocity you calculated above and the change in time is what you measured. Use the average time of all the trials.

9. Calculate the force applied to the milk carton.
   - Step 1: Copy the values for mass (kg) to the table below.
   - Step 2: Enter the acceleration into the table. It is the same for all.
   - Step 3: Calculate the force with which each of the car configuration hits the milk carton using the formula \( F = ma \).

<table>
<thead>
<tr>
<th>Car</th>
<th>Mass (kg)</th>
<th>Acceleration (m/s(^2))</th>
<th>Force (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Empty car</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(no mass added)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100 grams added</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>200 grams added</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**ANALYSIS/CONCLUSIONS:**

1. What observations did you make about the movement of the milk carton? *As the mass of the car and its load increased, the distance the carton moved increased.*

2. Why were three trials done for each part of this experiment? *In case some of the measurements were wrong, doing more than one measurement makes the data more accurate.*

3. What observations did you make about the movement of the car during collision? *The car jumped backward after collision with the milk carton.*

4. Which car had the greatest momentum? *The car with the greatest mass had the greatest momentum.*

5. What is the relationship between mass and momentum? *As the mass increases, the momentum increases.*

6. What do you predict would happen to the distance the milk carton would move if you added another 100 grams of mass to the car? *The carton would move farther as the mass increased.*

7. Which car had the greatest force on the milk carton? *The car with the greatest mass had the greatest force.*

8. Define the Law of Conservation of Momentum. How would this law apply to what you observed as the cars hit into the barriers? *The Law of Conservation of Momentum states that the total momentum before the collision equals the total momentum after the collision unless other forces (such as friction) are involved. In this exploration, the energy of the car’s momentum (mass times velocity) was transferred to the barrier and the barrier moved.*

**Elaborate:**

Ask students to use knowledge learned in this investigation to write a convincing paragraph explaining why it is important not to cut in front of large vehicles and then brake sharply.
Evaluate: Use the rubric below to evaluate student performance during the exploration activity.

<table>
<thead>
<tr>
<th>POINTS</th>
<th>Scientific Accuracy</th>
<th>Reasoning</th>
<th>Communication</th>
<th>Collaboration</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Excellent</td>
<td>I used the appropriate tools and measured accurately. I used the appropriate formulas and calculated correctly.</td>
<td>I made many connections between the calculations and related to daily life.</td>
<td>I answered questions using complete sentences and proper grammar. My classmates understood what I was explaining.</td>
</tr>
<tr>
<td>3</td>
<td>Good</td>
<td>I measured accurately. I used the correct formulas but made errors in my calculations.</td>
<td>I made a connection between the calculations and related to daily life.</td>
<td>I tried to use proper grammar and vocabulary words. My classmates had a difficult time understanding what I was saying.</td>
</tr>
<tr>
<td>2</td>
<td>Fair</td>
<td>I measured accurately. I didn’t use the correct formulas and calculations were incorrect.</td>
<td>I struggled to understand and found it difficult to make connections to daily life.</td>
<td>I used a few vocabulary words and tried to use proper grammar. My classmates did not understand what I was explaining.</td>
</tr>
<tr>
<td>1</td>
<td>Poor</td>
<td>I had a difficult time measuring and the measurements are not accurate. I didn’t use the correct formulas and calculations were incorrect.</td>
<td>I could not relate the concepts from the investigation to daily life.</td>
<td>I used incorrect grammar and didn’t include scientific vocabulary to explain myself.</td>
</tr>
</tbody>
</table>

Subtotal: ____  Subtotal: ____  Subtotal: ____  Subtotal: ____  TOTAL: ____/16pts

Sample TAKS Items:

1. Which of the following objects would have the greatest momentum if they were all moving with the same velocity?

   ![Image of objects A, B, C, D]

   A 195 m/s South  
   B 8745 m/s South  
   C 8835 m/s North  
   D 39556 m/s North

2. Calculate the velocity of a train that is headed south and has a mass of 4500 kilograms and whose momentum is 879,000 kg•m/sec.

   A 195 m/s South  
   B 8745 m/s South  
   C 8835 m/s North  
   D 39556 m/s North
3. Calculate the momentum of an 85 kilogram person skating on roller blades and traveling at a velocity of 5 m/s.

A 17 kg•m/s  
B 80 kg•m/s  
C 90 kg•m/s  
D 425 kg•m/s

Some students conducted a laboratory investigation to determine if the height of a ramp affects the momentum of a toy car. They set up the experiment similar to the picture. They used one book for trial 1, two books for trial 2, three books for trial 3, and 4 books for trial 4. They collected the data given in the table.

<table>
<thead>
<tr>
<th>Trial</th>
<th>Mass (kg)</th>
<th>Distance traveled (m)</th>
<th>Time to travel (s)</th>
<th>Average speed (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 book</td>
<td>152</td>
<td>1.2</td>
<td>5.8</td>
<td></td>
</tr>
<tr>
<td>2 books</td>
<td>152</td>
<td>1.2</td>
<td>4.6</td>
<td></td>
</tr>
<tr>
<td>3 books</td>
<td>152</td>
<td>1.2</td>
<td>3.5</td>
<td></td>
</tr>
<tr>
<td>4 books</td>
<td>152</td>
<td>1.2</td>
<td>2.7</td>
<td></td>
</tr>
</tbody>
</table>

4. For which trial did the car have the greatest average speed?

A 1 book  
B 2 books  
C 3 books  
D 4 books

5. For which trial did the car have the least momentum at the bottom of the ramp?

A 1 book  
B 2 books  
C 3 books  
D 4 books

6. Which statement best supports the relationship between mass and momentum when the velocity is constant?

A As the mass increases, the momentum decreases.  
B As the mass increases, the momentum increases.  
C As the mass decreases, the momentum decreases.  
D There is no relationship between mass and momentum.

References/Resources/Websites:
- http://regentsprep.org/Regents/physics/phys01/accident/default.htm
## Motion Unit

**Fast and Furious — Off to the Races!**

### Explore 3: Crash Test Dummies

<table>
<thead>
<tr>
<th>Type of Lesson:</th>
<th>Content with Process: Focus on constructing knowledge through active learning.</th>
</tr>
</thead>
</table>
| Learning Goal & Instructional Objectives | Students investigate Newton’s first law, the law of inertia, using cars, ramps, and clay objects to observe the distance clay objects fly out of a car after impact. After completing the investigation, students relate Newton’s first law of motion to daily life and moving cars. The purpose of this lab is to demonstrate inertia. Instructional Objectives:  
1. Students state Newton’s first law—an object at rest will remain at rest unless acted upon by an unbalanced force while an object in motion will remain in motion with constant speed and direction unless acted upon by an unbalanced force.  
2. Students demonstrate in classroom and laboratory situations that an object in motion tends to remain in motion and an object at rest tends to remain at rest.  
3. Given a written scenario in a laboratory investigation, students predict where an object will come to rest when acted upon by a force. |
| Key Question: | Does the mass of a person affect the inertia of the person? What variables measure an object’s inertia? |
| IPC Content TEKS: | 4B The student knows the laws governing motion |
| Related Process TEKS: | (1) **Scientific processes.** The student, for at least 40% of instructional time, conducts field and laboratory investigations using safe, environmentally appropriate, and ethical practices. The student is expected to:  
(A) demonstrate safe practices during field and laboratory investigations; |
| | (2) **Scientific processes.** The student uses scientific methods during field and laboratory investigations. The student is expected to:  
(A) plan and implement experimental procedures including asking questions, formulating testable hypotheses, and selecting equipment and technology;  
(B) collect data and make measurements with precision;  
(C) organize, analyze, evaluate, make inferences, and predict trends from data; and  
(D) communicate valid conclusions. |
| | (3) **Scientific processes.** The student uses critical thinking and scientific problem solving to make informed decisions. The student is expected to:  
(A) analyze, review, and critique scientific explanations, including hypotheses and theories, as to their strengths and weaknesses using scientific evidence and information;  
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(C) evaluate the impact of research on scientific thought, society, and the environment;  
(D) describe connections between physics and chemistry and future careers; and  
(E) Research and describe the history of physics, chemistry, and contributions of scientists. |
To the Teacher:

During this investigation, students reinforce the concept of inertia and its relationship to mass. Newton's first law of motion states that an object at rest will remain at rest unless acted upon by an unbalanced force while an object in motion will remain in motion with constant speed and direction unless acted upon by an unbalanced force. Sometimes we forget that we are in motion while in a car even though we are just sitting still. As the investigation will demonstrate, people will continue to stay in motion if the car stops.

The mass will not affect the distance that the clay person travels after the crash. During free fall, as the car goes down the ramp, the acceleration due to gravity is constant no matter what the mass is. Air resistance can affect the results, but in this exploration the shapes of the clay figures are similar. Since the velocity at impact is the same, each unrestrained passenger flies out of the car at the same velocity and should hit at approximately the same distance away. If another force increases the car's velocity before impact, the distance that the passengers will land will increase. Inertia and momentum of each passenger's mass can be observed by using a force pad that indents upon impact or a flat piece of clay where the depth of the impact crater can be observed. An object with greater mass, momentum and inertia will make a larger indentation than an object with less mass, momentum and inertia even if their velocity is the same.

Newton's second law is represented by the formula Force = mass x acceleration (\( F = ma \)). If a force large enough to move an object is applied, the object will accelerate in the direction of the force. Additionally, the greater the force applied to an object, the greater the acceleration of that object.

Newton's third law of motion is often referred to as the action-reaction law. For every action there is an equal and opposite reaction. When a person rides a skateboard, he uses one foot to push himself forward by pushing backward.

The following is an email correspondence from a physics teacher who field tested Crash Test Dummies:

Okay, we actually did the crash test dummies experiment 2nd hour. We used a Hot Wheels car, angle of ramp = 21 degrees, length of ramp = 0.6 m.

We used clay balls that were integral multiples of the mass to the car (unlike an actual collision, where the mass of the occupants is a small fraction of the mass of the system). The "baby" trial had the mass of the car and mass of the clay ball being equal. We did this because we believed that if the balls were small that the system would accelerate at very nearly equal rates for each trial, giving each ball the same initial velocity on its way to the pavement.

We video taped three trials with each clay ball/Hot Wheels combination.

The time it took for the car to travel down the ramp was seemingly not significantly affected by the mass of the "rider." It took 20 frames (.67 seconds) to travel down the ramp for each trial. The data concerning the distance traveled by the clay ball seemed quite random and independent of the mass of the ball. The ranges were from 2 cm to 6 cm for the three trials for 1 mass (baby), 2 cm to 5 cm for the three trials for 2 masses (child), and 2 cm to 5 cm for 3 masses (fat adult). This seemed to indicate no particular relationship at all related to the mass of the rider. We further believe that changing the Hot Wheels car to a laboratory acceleration cart would have little affect on the outcome. We will work out the consequences of a much lighter cart relative to the clay balls.

Back to the experiment, fourth hour suggested that the end of the ramp be at the edge of the table, as the distances traveled by the balls aren't easily observed as the lab is written. They also suggested using carbon paper over the top of white paper in the landing area to more easily determine the landing point. That still wouldn't help the "fit" of the experiment to inertia. While it would be true that bigger balls have more inertia, they wouldn't have bigger velocities. And the acceleration of gravity on each ball is the same regardless of its mass. So the measurement of distance traveled by the balls doesn't really confirm inertia, it merely confirms that the velocity that the balls leave with, the time they're airborne, and the distance that they travel are all constants.

Multiple Intelligence

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MOTION UNIT

Fast and Furious — Off to the Races!

Materials:

- Car that will hold a clay “person”
- Ramp
- Books/blocks
- Milk carton with sand or other “wall”
- Modeling clay
- Rubber bands of various sizes
- Meter stick

SAFETY NOTE:

Remind students that the clay is for creating the crash test dummies and not to be used inappropriately. Rubber bands should not be “shot” at another person. See also Texas Science Safety Manual for lab and investigation guidelines:

Engage:

Show crash test dummy animation. Science Photo Library: Crash Test Dummies http://www.sciencephoto.com/html_features_archive/archiveStory.html?id=969&featureid=760. Discuss seat belt safety with your students. Focus your questions on the motion of the people and objects within a moving car and with what happens when a car comes to a sudden stop.

Facilitation Questions:
1. Why do we wear seat belts when riding in a car?
2. What happens when the driver slams on the brakes to stop the car quickly? What does your body do?
3. Have you ever experienced a car crash? What happened?
4. Have you watched crash test dummy commercials?

Explore:

1. Set up the ramp on the books. Place the milk carton with the sand on its side at the bottom of the ramp to create a short wall for the car to crash into.

2. Form three clay people of varying masses. The clay people could represent an adult, a teenager, and a baby.
3. Place one of the people in the car and let it roll down the ramp and crash into the wall. Measure the distance the person flies out of the car over the wall. If the wall is too tall, a different object might be needed to act as a wall. Record the distance in a data table.
4. Complete three trials with each clay person and record your results.
5. After all measurements are taken, secure one of the people in the car using a rubber band as a seat belt. Roll the car down the ramp and observe what happens.
6. Repeat the process with each person. Record your observations.
MOTION UNIT

Fast and Furious — Off to the Races!

**Explain:**

**DATA TABLE:** Copy into your journal.

<table>
<thead>
<tr>
<th>Trial</th>
<th>Distance clay person flew (cm)</th>
<th>Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baby</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Teen</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Adult</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>

1. Describe Newton’s first law of motion? *An object at rest will remain at rest unless acted upon by an unbalanced force while an object in motion will remain in motion with constant speed and direction unless acted upon by an unbalanced force.*

2. What factors, besides mass, could have affected how far each passenger flew out of the car? *If the velocity was different because I did not let the car go the same distance, the passenger would not be going at the same velocity as the other passengers so would not travel the same distance. Friction could affect my results. If the clay passenger stuck to the car, it would have trouble moving when the car stopped. Air resistance could have affected my results if I shaped my figures differently and air slowed down one passenger more than the others.*

3. What is inertia and which person had the greatest inertia? How do you know? *Inertia is the tendency of an object to remain at rest or stay in motion. The adult had the greatest inertia because that person had the greatest mass (for the same velocity) Note: If the impact crater can be measured for the depth of impact, the student can use this in the answer.*)

4. Why did the people fly out of the car? *They were not restrained.*

5. What is the independent variable for this investigation? *The mass of the clay person.*

6. What is the dependent variable for the investigation? *The distance the clay person flew after the collision.*

7. What variables were held constant in this investigation? *Height of the ramp, car, and distance the car traveled.*

8. What could be done to the car to make the people fly out farther? *If the car is going faster, the people are going faster and have more momentum. Car will go faster if height is increased or if given a push.*

9. What is the relationship between mass and inertia? *As the mass of the object increases, its inertia increases. Mass is the measure of inertia of a body and it is measured in kilograms.*

10. When the seat belts were put on the passengers what happened to the people when the car hit the milk container barrier and stopped? *If the seat belt functioned properly, the person stayed in the seat and was not thrown out.*

11. Why should the velocity of each car be the same at impact even if the mass is different? *Since the car is going down the ramp, it is under the influence of gravity and gravity pulls with the same acceleration even if the car has a different mass.*

12. Why did the mass differences of the baby, teen and adult do little to affect the distance each flew out after the collision? *The baby, teen and adult had the same velocity as they flew out of the car at impact so they should travel the same distance unless friction, air resistance or another force interferes. They had different momentum values because their masses were different.*
**Elaborate:**

1. How can you relate this investigation of Newton’s first law of motion to daily life when you wear seat belts in a car? *When we wear seat belts, they keep us in our seats in the event our car stops suddenly.*

2. A friend does not wear his seat belt when in the car. From this investigation, how could you convince him of the importance of wearing seat belts? *Wearing a seat belt is important because it prevents you from being thrown out of a car.*

3. Change the experiment so that the velocity of the impact changes (Use different heights of ramp) and use the same passengers. Compare the distances that the unrestrained passengers fly out and the depth of the impact crater.

4. Measure the depth of the impact crater for each unrestrained passenger and apply the concepts of inertia, momentum and the Law of Conservation of Momentum to the data. Are there other ways to observe the differences in momentum and inertia?
**Evaluate:**
Students evaluate and analyze their data and observations from the investigation. Based on their data and observations, students complete the questions and relate to the daily life of moving vehicles. Students also answer multiple choice questions relating to Newton’s first law of motion.

<table>
<thead>
<tr>
<th>POINTS</th>
<th>Scientific Accuracy</th>
<th>Reasoning</th>
<th>Communication</th>
<th>Collaboration</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>4</strong> Excellent</td>
<td>I can always identify and apply Newton’s 1st law of motion to daily life relating to vehicles. I can correctly identify the variables of the investigation.</td>
<td>I analyzed the data and made many reasonable predictions about other objects….</td>
<td>I communicated answers to the investigation questions completely and thoroughly using correct grammar. I shared my ideas about the investigation in the whole group discussion and with my teammates.</td>
<td>I worked well with my group. Each person had input and participated in the investigation.</td>
</tr>
<tr>
<td><strong>3</strong> Good</td>
<td>I can identify and apply Newton’s 1st law of motion to daily life relating to vehicles. I can identify some variables of the investigation.</td>
<td>I analyzed the data and made reasonable predictions about other objects.</td>
<td>I communicated answers to the investigation. I shared some ideas about the investigation in a whole group discussion.</td>
<td>I worked well with my group. Some group members had input and participated in the investigation.</td>
</tr>
<tr>
<td><strong>2</strong> Fair</td>
<td>I can sometimes identify and apply Newton’s 1st law of motion to daily life relating to vehicles. I can identify a few variables of the investigation.</td>
<td>I analyzed the data and made a few reasonable predictions about other objects.</td>
<td>I communicated a few answers to the investigation. I did not share my ideas in the whole group discussion.</td>
<td>I worked with my group. Only a few group members had input and participated in the investigation.</td>
</tr>
<tr>
<td><strong>1</strong> Poor</td>
<td>I can not identify and apply Newton’s 1st law of motion to daily life relating to vehicles. I cannot identify the variables in this investigation.</td>
<td>I did not analyze the data and did not make reasonable predictions about other objects.</td>
<td>I did not answer the questions in this investigation and I did not share my ideas.</td>
<td>I did not work well with my group. We did not work together.</td>
</tr>
</tbody>
</table>

| Subtotal: ____ | Subtotal: ____ | Subtotal: ____ | Subtotal: ____ | **TOTAL:** ____/16pts |
Sample TAKS Items:

A group of students conducts an investigation to determine if the velocity of a car at impact affects the distance that an unrestrained object flies out of a car when the car suddenly stops when it collides with a stationary object. Analyze the data below and answer the following questions.

<table>
<thead>
<tr>
<th>Velocity of Car at Impact (m/s)</th>
<th>Average Distance that an unrestrained object flies out (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>.15</td>
</tr>
<tr>
<td>3</td>
<td>.2</td>
</tr>
<tr>
<td>4</td>
<td>.25</td>
</tr>
</tbody>
</table>

1. What was the independent variable in the investigation?
   A mass of object in car
   B average distance the car traveled
   C average distance the object flew out of the car
   D velocity of the car at impact

2. What was the dependent variable in the investigation?
   A mass of object in car
   B average distance the car traveled
   C average distance the object flew out of the car
   D velocity of the car at impact

3. Which of Newton’s laws of motion describes why the object flew out of the car when the car hit the stationary object?
   A Newton’s 1st law of motion
   B Newton’s 2nd law of motion
   C Newton’s 3rd law of motion
   D Newton’s 4th law of motion

References/Resources/Websites:
- Crash Test Dummies cartoons http://www.lasvegassun.com/sports/racing/images/032803.gif
- The Physics Classroom http://www.glenbrook.k12.il.us/gbssci/phys/mmedia/
- Crash Test Dummies Information: http://www.hwysafety.org/vehicle_ratings/dummies.htm
- Sample Assessment Items for Force and Motion: http://shs.westport.k12.ct.us/mjvl/science/capt/questions/stateReleased/forces_and_motion.htm
- Forces, Acceleration, and Car Crashes http://regentsprep.org/Regents/physics/phys01/accident/default.htm
### Explore 4: Balloon Racer

**Type of Lesson:** Content with Process: Focus on constructing knowledge through active learning.

**Learning Goal:** Students build a car that is propelled by a balloon. Students investigate the car’s motion and explain why the car moves forward while air rushes out of the balloon in the opposite direction. The rocket car is propelled along the floor according to the principle stated in Newton’s Third Law of Motion. The escaping air is the action and the movement of the car in the opposite direction is the reaction. The car’s wheels reduce friction and provide some stability to the car’s motion. Newton’s Third Law of Motion states: For every action, there is an equal and opposite reaction.

**Instructional Objective:**
Given examples (pictures) of everyday events students identify and describe the associated laws of motion. Given examples (pictures) of everyday situations students identify action and reaction forces.

**Key Question:** How does a balloon cause a car to move? In which direction will the car move?

**IPC Content TEKS:**
(4) The student knows concepts of force and motion evident in everyday life.

<table>
<thead>
<tr>
<th>IPC Content TEKS</th>
<th>Instructional Objective</th>
</tr>
</thead>
<tbody>
<tr>
<td>(4) The student knows concepts of force and motion evident in everyday life</td>
<td>The student is expected to:</td>
</tr>
<tr>
<td>(B) investigate and describe applications of Newton’s Laws such as in vehicle restraints, sports activities, geological processes, and satellite orbits.</td>
<td></td>
</tr>
</tbody>
</table>

**Related Process TEKS:**
(1) Scientific processes.
The student, for at least 40% of instructional time, conducts field and laboratory investigations using safe, environmentally appropriate, and ethical practices.

<table>
<thead>
<tr>
<th>Related Process TEKS</th>
<th>Instructional Objective</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Scientific processes.</td>
<td>The student is expected to:</td>
</tr>
<tr>
<td>The student, for at least 40% of instructional time, conducts field and laboratory investigations using safe, environmentally appropriate, and ethical practices</td>
<td>(A) demonstrate safe practices during field and laboratory investigations; and</td>
</tr>
<tr>
<td>(B) make wise choices in the use and conservation of resources and the disposal or recycling of materials.</td>
<td></td>
</tr>
</tbody>
</table>

**To the Teacher:**

**Multiple Intelligences:** Logical-Mathematical Intelligence

Consists of the ability to detect patterns, reason deductively and think logically. This intelligence is most often associated with scientific and mathematical thinking.
MOTION UNIT

Fast and Furious — Off to the Races!

Materials:
- 4 pins
- Styrofoam meat trays—body of a car
- Materials for wheels
- Cellophane tape
- Flexi-straw
- Scissors
- Drawing compass
- Marker pen
- Small party balloon
- Ruler

SAFETY NOTE: Be careful with construction tools and balloons. Balloons can be a choking hazard if swallowed. (Hey, your audience is the typical adolescent!). See also Texas Science Safety Manual for lab and investigation guidelines: http://www.tenet.edu/teks/science/safety/safety_manual.html

Engagement:
Show a video clip (if available) or a picture of a rocket being launched and ask students what they think made the rocket launch.

Facilitation Questions:
1. What causes the rocket to launch forward?
2. What can you say about the direction that the rocket moves and the force (air) that causes the rocket to launch forward?

Explore:
1. Using the ruler, markers, and drawing compass, draw a rectangle about 7.5 cm by 18 cm and four circles 7.5 cm in diameter on the flat surface of the meat tray. Cut out each piece.
2. Inflate the balloon a few times to stretch it. Slip the nozzle over the end of the flexi-straw nearest the bend. Secure the nozzle to the straw with tape and seal it tight so that the balloon can be inflated by blowing through the straw.
3. Tape the straw to the car as shown in the picture.
4. Push one pin into the center of each circle and then into the edge of the rectangle as shown in the picture. The pins become axles for the wheels. Do not push the pins in snugly because the wheels have to rotate freely. It is okay if the wheels wobble.
5. Inflate the balloon and pinch the straw to hold in the air. Set the car on a smooth flat surface and release the straw.
**MOTION UNIT  Fast and Furious — Off to the Races!**

**Explain:**
Describe how students are to communicate the results of their explorations. Will you use a class chart, data table, journal entries, and/or whole class discussions? How will STUDENTS explain their results?

1. What makes the car move forward? *The air rushing out of the balloon makes the car move forward. This air is the force that sets the car in motion.*

2. In which direction is the car moving? *The car moves forward.*

3. In which direction is the air that rushes out the balloon moving? *The air is rushing out of the balloon opposite to the car’s direction of motion.*

4. What are some variables that we discussed in class that can be manipulated to improve the car’s speed? *We can manipulate the mass of the car and the force by adding more than one balloon.*

5. At this point the teacher writes Newton’s Third Law of Motion on the board and explains that the balloon car demonstrates this law. The teacher also labels the two forces as either the action or the reaction force.

**Elaborate:**
In lab groups, students brainstorm five every day situations where Newton’s Third Law of Motion applies. Each group will present these situations to the class and explain how Newton’s Third Law applies. For each situation, students need to explain the action and reaction forces. Students may choose to present through demonstrations, pictures, PowerPoint presentations, pictures, etc...
**Evaluate:**

Students are evaluated on the accuracy of their explanations. Their explanations must be accurate and demonstrate an understanding of Newton’s Third Law of Motion. Students will also be expected to answer the following TAKS assessment items with 100% accuracy.

As shown in the diagram below, an inflated balloon, released from rest, moves horizontally with some velocity.

1. The velocity of the balloon is most likely caused by—
   
   A  action-reaction.
   B  air resistance.
   C  gravitational attraction.
   D  rolling friction.

2. Which of Newton’s laws is being demonstrated when the firefighters are pushed backwards as the water shoots out of the hose?
   
   A  first
   B  second
   C  third
   D  both A and B
## MOTION UNIT

### Fast and Furious — Off to the Races!

<table>
<thead>
<tr>
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<th>Reasoning</th>
<th>Communication</th>
<th>Collaboration</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Excellent</td>
<td>I can identify and apply Newton’s 3rd law of motion to daily life relating vehicles. I can correctly identify the variables of the investigation.</td>
<td>I analyzed the data and made many reasonable predictions about other objects.</td>
<td>I communicated answers to the investigation questions completely and thoroughly using correct grammar. I shared my ideas about the investigation in the whole group discussion and with my teammates.</td>
</tr>
<tr>
<td>3</td>
<td>Good</td>
<td>I can identify and apply Newton’s 3rd law of motion to daily life relating vehicles. I can identify a few variables of the investigation.</td>
<td>I analyzed the data and made reasonable predictions about other objects.</td>
<td>I communicated answers to the questions in the investigation and I shared some of my ideas in the whole group discussion.</td>
</tr>
<tr>
<td>2</td>
<td>Fair</td>
<td>I can identify and but not apply Newton’s 3rd law of motion to daily life relating vehicles. I can not correctly identify the variables of the investigation.</td>
<td>I analyzed the data and made a few reasonable predictions about other objects.</td>
<td>I communicated answers to the investigation. I did not share my ideas in the whole group discussion.</td>
</tr>
<tr>
<td>1</td>
<td>Poor</td>
<td>I can not identify and apply Newton’s 3rd law of motion to daily life relating vehicles. I can not identify the variables of the investigation.</td>
<td>I did not analyze the data and did not make reasonable predictions about other objects.</td>
<td>I did not communicate answers to investigation and I did not share my ideas.</td>
</tr>
</tbody>
</table>

| Subtotal: _____ | Subtotal: _____ | Subtotal: _____ | Subtotal: _____ | TOTAL: _____/16pts |

### References/Resources/Websites:
- **Science Education Partnerships:**
- **The Physics Classroom:**
- **Car crash animation:**
  - [http://departments.weber.edu/physics/amiri/director/dcrfiles/momentum/carCrashS.dcr](http://departments.weber.edu/physics/amiri/director/dcrfiles/momentum/carCrashS.dcr)
**MOTION UNIT**

*Fast and Furious — Off to the Races!*

**Explain**

**Discuss the following questions with the students:**

1. What factors did you use as you designed and built your car to increase speed and acceleration? Look at your data and graph to evaluate the results.

2. Which was the independent variable? Which was the dependent variable? How do you know?

3. What happens to the momentum of your car as you change the mass and/or velocity of your car?

4. How does your car's inertia and momentum affect how quickly it starts up from rest or comes to a stop?

5. Why are seat belts required by law?

6. Why are motorcyclists more at risk during an accident than the passengers in a car? Why do helmets help reduce fatalities?

7. Why do small cars usually show more damage after a collision with a heavier truck?

Relate Newton's Third Law of Motion to the motion of the project cars. Include a discussion of the role of the size of the force in the distance that the car travels. Also include a diagram showing that the air in the balloon goes one way and the car moves the other direction. Newton's third Law is best explained by the sentences: "Forces always come in pairs. For every action (force applied), there is an opposite and equal reaction (equal force in the opposite direction).

In their own words, students write their operational definitions of the following terms: speed, velocity, acceleration, force, momentum, Law of Conservation of Momentum, Newton's Three Laws of Motion, mechanical advantage.

After defining the terms, students share their explanations and compare the definitions to other sources such as textbooks and the internet.

Discuss the relationship between force and motion and describe how mathematical calculations help describe this relationship.
**Have students extend their learning by participating in the following activities:**

1. Students design an experiment to study the effect of wheel size on the motion of a car. How do different balloon sizes affect the motion of the car?

2. Using the Internet, students conduct a research study to study the causes of car accidents and apply physics to explain them.

3. Students can use technology to locate and perhaps create their own physics animations.

- **The Physics Classroom** [http://www.glenbrook.k12.il.us/gbssci/phys/Class/newtlaws/u2l1a.html](http://www.glenbrook.k12.il.us/gbssci/phys/Class/newtlaws/u2l1a.html)
- **Crash Test Dummies cartoons** [http://www.lasvegassun.com/sports/racing/images/032803.gif](http://www.lasvegassun.com/sports/racing/images/032803.gif)
- **The Physics Classroom** [http://www.glenbrook.k12.il.us/gbssci/phys/media/](http://www.glenbrook.k12.il.us/gbssci/phys/media/)
- **Crash Test Dummies Information:** [http://www.hwysafety.org/vehicle_ratings/dummies.htm](http://www.hwysafety.org/vehicle_ratings/dummies.htm)
- **History of the Crash Test Dummies and Safety:** [http://inventors.about.com/library/inventors/blcrashtestdummies.htm](http://inventors.about.com/library/inventors/blcrashtestdummies.htm)
- **Sample Assessment Items for Force and Motion:** [http://shs.westport.k12.ct.us/mjvl/science/capt/questions/state_released/forces_and_motion.htm](http://shs.westport.k12.ct.us/mjvl/science/capt/questions/state_released/forces_and_motion.htm)
**Evaluate**

“The Fast and Furious Toy Car Race”

Use the following rubric to evaluate the car race. See page 38 for full version.

### ASSESSMENT RUBRIC:

<table>
<thead>
<tr>
<th>THUMBS UP</th>
<th>CAR DESIGN</th>
<th>CALCULATIONS</th>
<th>DATA COLLECTION</th>
<th>COLLABORATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>We successfully designed a car that is powered by a balloon. Our vehicle design exceeds expectations in creativity, performance, and workmanship.</td>
<td>Our calculations are complete and accurate — speed/velocity, acceleration, momentum, and force. We have a firm understanding of the factors that influence our car's performance.</td>
<td>Our data collection and calculations are complete. We recorded our data faithfully in our science journals. We constructed a table and chart to communicate our data clearly.</td>
<td>We worked as a team to design, build and test the car. Our calculations were rechecked by team members. We worked well together. There is a sense of community and ownership in our work. We are very proud of our vehicle design and performance.</td>
</tr>
<tr>
<td>3</td>
<td>We designed a car that is powered by a balloon. Our vehicle met the expectation for creativity, performance, and workmanship.</td>
<td>Our calculations are somewhat complete and accurate — speed/velocity, acceleration, momentum, and force. We have a good understanding of the factors that influence our car’s performance.</td>
<td>Our data collection and calculations are somewhat complete. We recorded our data in our science journals. We constructed a table and chart to communicate our data.</td>
<td>We worked as a team to design, build and test the car. Our calculations were rechecked by team members. There is some sense of community and ownership in our work. We are somewhat proud of our vehicle design and performance.</td>
</tr>
<tr>
<td>2</td>
<td>Our car design is incomplete and it meets only some of the expectations for performance.</td>
<td>Our calculations are complete but may not be accurate — speed/velocity, acceleration, momentum, and force. We have minimal understanding of the factors that influence our car’s performance.</td>
<td>Our data collection and calculations are incomplete. We recorded some data in our science journals.</td>
<td>We worked as a team to design, build and test the car. Our calculations were not rechecked by team members. We are not very proud of our vehicle design and performance.</td>
</tr>
<tr>
<td>1</td>
<td>Our vehicle does not meet design specifications.</td>
<td>Our calculations are incomplete and inaccurate — We do not understand the factors that influence our car’s performance.</td>
<td>Our data collection and calculations are incomplete. We did not record our data in our science journals.</td>
<td>We did not work as a team to design, build and test the car. There is no ownership in our work. We are not very proud of our vehicle design and performance.</td>
</tr>
</tbody>
</table>

Have students complete the MOTION TAKS items located in the pre/post test of this manual.

Have students discuss what they learned by sharing their journal notes and reflections during a debriefing session after all activities have been completed and the final project has been assessed.
**MOTION UNIT**

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### Fast and Furious — Off to the Races!

#### Unit Materials

**Materials Details Sheet**

- Lab Journal
- Butcher paper & markers
- Balloons
- Toy cars
- Ramps
- Stopwatches
- Blocks or books
- Mass weights or washers
- Meter tape or metric rulers
- Tape
- Milk carton filled with sand (or some other stationary object)
- Large box holding materials for “Ultimate Race” which includes wheels (CDs, poker chips, Legos, spools, buttons), axles (straws, skewers, dowels), car body (milk cartons, juice cartons, cardboard, Styrofoam meat trays), accessories (colors, feathers, stickers etc.)

#### Background Information for Teachers

**What should the IPC learner know about Motion and Force?**

At this level, students learn about relative motion, the action/reaction principle, wave behavior, the interaction of waves with matter, the Doppler Effect now used in weather analysis, and the red shift of distant galaxies. Relative motion is fun—students find it interesting to figure out their speeds in different reference frames, and many activities and films illustrate this principle. Learning this concept is important for its own sake and for the part it plays in the changing reference frames of the Copernican Revolution, and in simple relativity.

This level is also a time to show the power of mathematics. Once students realize that change in motion is proportional to the force applied, then mathematical logic requires that when F = 0, there be no change in motion. (So Newton's first law is just a special case of his second.) Students can move from a qualitative understanding of the force and motion relationship (more force changes motion more; more mass is harder to change) to one that is more mathematical (the change in motion is directly proportional to the amount of force and inversely proportional to the mass). Experimentally, they verify that the change in motion of an object is proportional to the applied force and inversely proportional to the mass—a step beyond knowing that change in motion increases with a larger force and decreases with a smaller mass.

Students should come to understand qualitatively that (1) doubling the force on an object of a given mass doubles the effect the force has, tripling triples the effect, and so on; and (2) that whatever effect a given force has on an object, it will have half the effect on an object having twice the mass, a third on one having triple the mass, and so on. This need not entail having students solve lots of numerical problems, but it does require them to verbalize these relationships often.

**Applying the concept of force and mass to predict the motion of objects.** Describe the motion of a thrown ball. Students should be familiar with the relationship between the change in motion of an object, the force applied to the object, and the mass of the object. This includes how Newton's three laws of motion relate to the motion of familiar objects. Those students best prepared for this outcome are those who have observed many moving objects, controlled and explained why they moved, why changes occur in the way they move, and why they have stopped.
Apply the use of simple machines to practical situations.
Describe how a lever or pulley can make a task easier. Students should have a basic understanding of how simple machines, such as levers, pulley systems, and inclined planes, change the effort and distance through which work is done. The simple principle that "You don't get something for nothing" is important here. Students should be able to apply the use of these machines to simple, practical situations as shown in pictures, diagrams, and charts. Students should discuss the advantages and disadvantages of many simple technological devices as they explore the functions of those devices in relevant contexts.

Watch out for the following common misconceptions:

- **The concept of force**
  Students hold various meanings for the word "force." Typically, students think force is something that makes things happen or creates change. Their descriptions of force often include related words such as energy, momentum, pressure, power, and strength. Younger students associate the word "force" with living things (Watts, 1983b).
  Students tend to think of force as a property of an object ("an object has force," or "force is within an object") rather than as a relation between objects (Dykstra, Boyle, & Monarch, 1992; Jung et al., 1981; Osborne, 1985). In addition, students tend to distinguish between active objects and objects that support or block or otherwise act passively. Students tend to call the active actions "force" but do not consider passive actions as "forces" (Gunstone & Watts, 1985). Teaching students to integrate the concept of passive support into the broader concept of force is a challenging task even at the high-school level (Minstrell, 1989).

- **Newton's laws of motion**
  Students believe constant speed needs some cause to sustain it. In addition, students believe that the amount of motion is proportional to the amount of force; that if a body is not moving, there is no force acting on it; and that if a body is moving there is a force acting on it in the direction of the motion (Gunstone & Watts, 1985). Students also believe that objects resist acceleration from the state of rest because of friction—that is, they confound inertia with friction (Brown & Clement, 1992; Jung et al., 1981). Students tend to hold onto these ideas even after instruction in high-school or college physics (McDermott, 1983). Specially designed instruction does help high-school students change their ideas (Brown & Clement, 1992; Dykstra et al., 1992; Minstrell, 1989).
  Research has shown less success in changing middle-school students' ideas about force and motion (Champagne, Gunstone & Klopfer, 1985). Nevertheless, some research indicates that middle-school students can start understanding the effect of constant forces to speed up, slow down, or change the direction of motion of an object. This research also suggests it is possible to change middle-school students' belief that a force always acts in the direction of motion (White, 1990; White & Horwitz, 1987).
  Students have difficulty appreciating that all interactions involve equal forces acting in opposite directions on the separate, interacting bodies. Instead they believe that "active" objects (like hands) can exert forces whereas "passive" objects (like tables) cannot (Gunstone & Watts, 1985). Alternatively, students may believe that the object with more of some obvious property will exert a greater force (Minstrell, 1992). Teaching high-school students to seek consistent explanations for the "at rest" condition of an object can lead them to appreciate that both "active" and "passive" objects exert forces (Minstrell, 1982). Showing them that apparently rigid or supporting objects actually deform might also help (Clement, 1987).
Reference/Resources/ Helpful websites

- The Physics Classroom
  http://www.glenbrook.k12.il.us/gbssci/phys/Class/newtlaws/u2l1a.html
- Benchmarks for Science Literacy Online:
  http://www.project2061.org/tools/benchol/bolintro.htm
- The Physics Classroom
  http://www.glenbrook.k12.il.us/gbssci/phys/Class/newtlaws/u2l1a.html
- Crash Test Dummies cartoons
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- The Physics Classroom http://www.glenbrook.k12.il.us/gbssci/phys/mmedia/
- Crash Test Dummies Information:
  http://www.hwysafety.org/vehicle_ratings/dummies.htm
- History of the Crash Test Dummies and Safety:
  http://inventors.about.com/library/inventors/blcrashtestdummies.htm
- Science Net Links, “It’s a Crash Test, Dummy,” Lesson:
- Science 911: Car Crash Testing:
  http://www.pbs.org/safarchive/4_class/45_pguides/pguide_404/4544_crash.htm
- Sample Assessment Items for Force and Motion:
  http://shs.westport.k12.ct.us/mjvl/science/capt/questions/state_released/forces_and_motion.htm
- Science Photo Library: Crash Test Dummies
- Crash Test Dummies cartoons
  http://www.lasvegassun.com/sports/racing/images/032803.gif
- The Physics Classroom http://www.glenbrook.k12.il.us/gbssci/phys/mmedia/
- Crash Test Dummies Information:
  http://www.hwysafety.org/vehicle_ratings/dummies.htm
- History of the Crash Test Dummies and Safety:
  http://inventors.about.com/library/inventors/blcrashtestdummies.htm
- Science Net Links, “It’s a Crash Test, Dummy,” Lesson:
- Science 911: Car Crash Testing:
  http://www.pbs.org/safarchive/4_class/45_pguides/pguide_404/4544_crash.htm
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- Science Photo Library: Crash Test Dummies
# Fast and Furious — Off to the Races!

## Fast and Furious Car Race Assessment Rubric

<table>
<thead>
<tr>
<th>THUMBS UP!</th>
<th>CAR DESIGN</th>
<th>CALCULATIONS</th>
<th>DATA COLLECTION</th>
<th>COLLABORATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>We successfully designed a car that is powered by a balloon. Our vehicle design exceeds expectations in creativity, performance, and workmanship.</td>
<td>Our calculations are complete and accurate: speed/velocity, acceleration, momentum, and force. We have a firm understanding of the factors that influence our car's performance.</td>
<td>Our data collection and calculations are complete. We recorded our data faithfully in our science journals. We constructed a table and chart to communicate our data clearly.</td>
<td>We worked as a team to design, build and test the car. Our calculations were rechecked by team members. We worked well together. There is a sense of community and ownership in our work. We are very proud of our vehicle design and performance.</td>
</tr>
<tr>
<td>3</td>
<td>We designed a car that is powered by a balloon. Our vehicle met the expectation for creativity, performance, and workmanship.</td>
<td>Our calculations are mostly complete and accurate: speed/velocity, acceleration, momentum, and force. We have a good understanding of the factors that influence our car's performance.</td>
<td>Our data collection and calculations are mostly complete. We recorded our data in our science journals. We constructed a table and chart to communicate our data.</td>
<td>We worked as a team to design, build and test the car. Our calculations were rechecked by team members. There is some sense of community and ownership in our work. We are proud of our vehicle design and performance.</td>
</tr>
<tr>
<td>2</td>
<td>Our car design is incomplete and it met only some of the expectations for performance.</td>
<td>Our calculations are complete but may not be accurate: speed/velocity, acceleration, momentum, and force. We have minimal understanding of the factors that influence our car's performance.</td>
<td>Our data collection and calculations are incomplete. We recorded some data in our science journals.</td>
<td>We worked as a team to design, build and test the car. Our calculations were not rechecked by team members. We are somewhat proud of our vehicle design and performance.</td>
</tr>
<tr>
<td>1</td>
<td>Our vehicle does not meet design specifications.</td>
<td>Our calculations are incomplete and inaccurate. We do not understand the factors that influence our car's performance.</td>
<td>Our data collection and calculations incomplete. We did not record our data in our science journals.</td>
<td>We did not work as a team to design, build and test the car. There is no ownership in our work. We are not very proud of our vehicle design and performance.</td>
</tr>
</tbody>
</table>
Objectives:
The student investigates and describes applications of Newton’s Laws such as in vehicle restraints, sports activities, geological processes, and satellite orbits.

Background Information:
The rocket car is propelled along the floor according to the principle stated in Newton’s Third Law of Motion. The escaping air is the action and the movement of the car in the opposite direction is the reaction. The car’s wheels reduce friction and provide some stability to the car’s motion. A well-designed and constructed car will travel several meters in a straight line across a smooth floor.

Newton’s Third Law of Motion states: For every action, there is an equal and opposite reaction.

Procedure:
1. Using the ruler, marker, and drawing compass, draw a rectangle about 7.5 cm by 18 cm and four circles 7.5 cm in diameter on the flat surface of the meat tray. Cut out each piece.
2. Inflate the balloon a few times to stretch it. Slip the nozzle over the end of the flexi-straw nearest the bend. Secure the nozzle to the straw with tape and seal it tight so that the balloon can be inflated by blowing through the straw.
3. Tape the straw to the car as shown in the picture.
4. Push one pin into the center of each circle and then into the edge of the rectangle as shown in the picture. The pins become axles for the wheels. Do not push the pins in snugly because the wheels have to rotate freely. It is okay if the wheels wobble.
5. Inflate the balloon and pinch the straw to hold in the air. Set the car on a smooth surface and release the straw.

Materials
- 4 pins
- Styrofoam meat trays
- Cellophane tape
- Flexi-straw
- Scissors
- Drawing compass
- Marker pen
- Small party balloon
- Ruler
Conclusion Questions

1. What makes the car move forward? The air rushing out of the balloon makes the car move forward. This air is the force that sets the car in motion.

2. In which direction is the car moving? The car moves forward.

3. In which direction is the air that rushes out the balloon moving? The air is rushing out of the balloon opposite of the car’s motion.

4. What are some variables that we discussed in class that can be manipulated to improve this car’s speed? We can manipulate the mass of the car and the force by adding a larger balloon or possibly more than one balloon.
OBJECTIVE: Students investigate and describe Newton’s first law of motion. (TEKS 4B)

PROBLEM: Does the mass of a person affect the inertia of the person?

INVITATION TO INQUIRY: Record your predictions in your journal.

MATERIALS:
- Car that will hold a clay “person”
- Ramp
- Books/blocks
- Milk carton with sand or other “wall”
- Modeling clay
- Rubber bands of various sizes
- Meter stick

PROCEDURES:
1. Set up the ramp on the books. Place the milk carton with the sand at the bottom of the ramp on its side to create a short wall the car will crash into.

2. Make three clay people of varying masses. The clay people could represent a parent, a teenager, and a baby.

3. Place one of the people in the car and let it roll down the ramp and crash into the wall. Measure the distance the person flies out of the car toward the wall. If the wall is too tall, a different object might be needed to act as a stopping point. Record the distance in a data table.

4. Complete three trials with each person and record your results.

5. After all measurements are taken, secure one of the people in the car using a rubber band as a seat belt. Roll the car down the ramp and observe what happens.

6. Repeat Step 5 with each person. Record your observations.
### DATA:
Copy into your journal.

<table>
<thead>
<tr>
<th>Trial</th>
<th>Distance clay flew (cm)</th>
<th>Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baby 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
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<tr>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Teen 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
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<td>3</td>
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</tr>
<tr>
<td>Adult 1</td>
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<tr>
<td>2</td>
<td></td>
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<tr>
<td>3</td>
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</tr>
</tbody>
</table>

### ANALYSIS/CONCLUSIONS:

1. Describe Newton’s first law of motion?
2. Which person flew out of the car the farthest?
3. What is inertia?
4. Why did the people fly out of the car?
5. What could be done to the car to make the people fly out farther?
6. What is the relationship between mass and inertia?
7. When the seat belts were put on, what happened to the people?
8. How can you relate this investigation of Newton’s first law of motion to daily life when you wear seat belts in a car?
9. A friend does not wear a seat belt when in the car. From your experience during this laboratory exercise, how could you convince your friend the importance of wearing a seatbelt?