Force and Motion - Newton's Laws and Inertia

This 5E model for instruction will help students gain an understanding of Newton's First Law of Motion and the concept of inertia.	
Student Science Performance	
Grade level: 9-12 Physical Science	**Title:** Car Stop - Seatbelts and Airbags
Topic: Inertia and Newton's First Law of Motion	

Performance Expectations for GSE:

SPS8. Obtain, evaluate, and communicate information to explain the relationships among force, mass, and motion.

a. Plan and carry out an investigation and analyze the motion of an object using mathematical and graphical models.
   (*Clarification statement:* Mathematical and graphical models could include distance, displacement, speed, velocity, time and acceleration.
b. Construct an explanation based on experimental evidence to support the claims presented in Newton's three laws of motion.
   (*Clarification statement:* Evidence could demonstrate relationships among force, mass, velocity, and acceleration.
c. Analyze and interpret data to identify the relationship between mass and gravitational force for falling objects.
d. Use mathematics and computational thinking to identify the relationships between work, mechanical advantage, and simple machines.

Performance Expectations for Instruction:

- Explore the concept of inertia and Newton's Laws.
- Explain inertia and how it applies to objects in motion and at rest.
- Explain inertia applies to real world scenarios such as seatbelts and airbags.
- Analyze motion of objects with mathematical and graphical models.
- Identify relationships between work, mechanical advantage, and simple machines.

Additional notes on student supports

Materials

- Constant velocity cars (available from science vendors- 1 per group)
- Balls with different masses- at least 2-3 per group (ex. bowling ball, soccer ball, kick ball, Styrofoam ball, baseball, golf ball, ping pong ball, etc.)
- If you choose to do the Swift Mission Education and Public Outreach (NASA) activity (Newton's First Law):
  - YoYo (1)
  - Large piece of smooth paper (1 per group)
  - Book with glossy cover (1 per group)
  - Book with textured cover (1 per group)
  - Other objects (eraser, pen, etc.)- (several per group, students can use available classroom objects.)
  - Tennis Ball (1 per group)
  - Chalk (if done outside), tape (if done inside)- 1 piece per group
  - jars with lids (2 identical per group)
  - Binders (2 per group- students can use their own as long as they are the same size)
  - Flour or sand in half of the jars
  - Lead pellets or rocks in the other

○ Measuring tape or meter sticks (1 6m length per group)	
Engaging Learners	***Phenomenon:*** When a car starts or stops, a person or object will initially move in the opposite direction of the motion of the car. Discuss with students what happens to their body as they drive in a car and the car stops suddenly. Also discuss when the car starts quickly, and you are pushed back in the seat. Have the students think of other instances when this motion occurs. ***Communicating***: Students will propose a model for the movement of an object after a car starts or stops based on the discussion. Have each student write a paragraph explaining this phenomenon. The teacher can determine where each student is in understanding the basics of the concept of inertia. Additional notes on topic, focus, and phenomena.
Exploring	***Obtaining*:** Students will investigate the phenomenon of using toy "constant velocity cars" that are available from many science catalogs. In this investigation the students place small objects on the cars. Students observe and record what happens to the objects after a collision with a wall or when the car starts initially. Have students investigate by rolling physics carts down a ramp and placing unbreakable objects on the carts and observe, sketch and label what happens to the objects as they are ejected forward after a collision or fall backwards as the car starts rolling down the ramp. Challenge students to mathematically model what is happening to the toy car and object in each instance. They should calculate for distance, speed, and time. Explain that if they know either the distance, the time it takes, or the speed, they can use the formula that best fits the situation: ● Distance = Speed x Time ● Time = Distance/Speed ● Speed= Distance/Time *Teacher Notes: The goal of the investigation is for students to experience the phenomenon of inertia. This is explained in Newton's First Law and is something anyone that rides in a car can experience. Allow students to test many different scenarios with their cars to explore this phenomenon.* Students will next explore this phenomenon using a number of different balls with different masses. Use balls such as a bowling ball, soccer ball, kick ball, Styrofoam ball, baseball, golf ball and ping pong ball. Have students roll these to stop at a certain distance from a starting point. Students can compete to see who is closest to a target distance. *Teacher Notes: The goal of this investigation is to allow students to understand that the more massive an object, the more force it takes to get it moving. One method to help students understand is to give them a ball of unknown mass and ask them to try and push it to the correct mark.*
	Evaluating:

	After exploring the movement of the objects in the investigations, have the students research Newton's Laws of Motion. Let them know that in this lesson they focus on the 1st Law of Motion. As each student finds the law have them write the version they find on the board. After some students have written the various versions of the law on the board, have a class discussion about what this law is trying to tell us and how it applies to the investigations. The discussion should focus on these understandings: 1. Objects in motion want to stay in motion. 2. Objects at rest want to stay at rest. 3. If I want an object to move, I will have to apply a force to make it move. 4. If I want an object to stop while it is moving, I will have to apply a force to make it stop. 5. Objects with more mass are more difficult to move and more difficult to stop. Use the term *inertia* so students make the connection between the language and the observations they are making in the investigations.
	Communicating: After this discussion have the students write a short paragraph explaining Newton's First Law of Motion and inertia. Expect students to use the words *motion, force, mass* and *inertia* in their writing. **Part 2:** *Obtaining* There are two activities that provide opportunities for students to explore motion as they make claims and predictions about various objects and scenarios: • In Walk It Out, students use claim-evidence-reasoning model to analyze different motion scenarios. • In Which Way Did It Go? students make predictions about acceleration of moving objects with similar scenarios as Walk It Out. Use this website information to help students gain a background or refresh their understanding of acceleration. *Calculating Acceleration from Force and Mass* *Communicating* In small groups, have students use common materials such as toy cars, weights, scales, stopwatch, and meter sticks to practice scenarios while collecting data and using the formula to calculate acceleration. *Evaluating* Have them explain their thinking using a claim, evidence, and reasoning format and share their analysis with other groups. In additional to claims, students could predict motion graphs of different objects; consider encouraging them to predict and then produce the graphs. A reference sheet

	for student support is Graphing Motion Sheet. Now have students devise ramps or inclined planes to gather data and calculate how the change in angles of the ramp affects the acceleration of the toy car with and without added weight. Connecting Newton's First and Second Laws: *Dangerous Pennies* Ask: How does the acceleration of falling objects differ from the investigation using the toy cars. Challenge small groups of students to find ways to investigate the relationship between mass and gravitational force for falling objects. Have them simulate a penny drop from a stairwell or top of the bleachers. Encourage them to observe, collect data and calculate their data to analyze what happens when a different weight coin or object is used. *Evaluating* This data to analyze could include a velocity-time graph. Ask: Does the slope of the line show "g" ($9.8m/s^2$)? Have them share their findings using a claim, evidence, and reasoning format and revise their investigation and analysis after discussion with classmates in other groups. *Teacher Notes: Use safety measures to insure there are procedures in place to cordon off the area and protect students from falls.*
Explaining	***Obtaining:*** After the initial investigations and class discussion the students begin to understand the basic concepts of inertia and Newton's First Law of Motion. The next step is to set up various demonstrations of inertia and other investigations that explore inertia. The main objective of these new investigations is for the students to predict the outcome before starting the investigation. There are several activities on the internet for demonstrating and investigating inertia. This is one good example by Swift Mission Education and Public Outreach (NASA): Newton's First Law
	Communicating: After these investigations, give the students the short paragraph they wrote earlier explaining Newton's First Law of Motion and inertia. The students must now "grade" their paragraph based on their increased understanding of inertia and Newton's Laws. Make sure they know that they must use the words *motion, force, mass* and *inertia* in their writing. Emphasize that they cannot simply define the words in their paragraph. They must use these words to explain the concepts. The goal is to move students closer to a correct interpretation of inertia and Newton's Laws. If the students are having a difficult time, then have them describe how they have inertia in action in their everyday experience. An alternative activity for students to

	construct explanations of these terms and other from this unit Concept Cards Review; this is a game format where students have to describe each concept without using certain terms. Additional terms from this unit or others can be added.
Elaborating	***Communicating:*** Using the understanding of the concept of inertia students will investigate how the manufacturers of cars attempt to overcome the inertia of a person riding in the car if there is a collision. Sample article- Crash Courses They will investigate the role of seatbelts and airbags to prevent injuries in a collision. This investigation can take the form of: 1. Internet search or teacher provided materials to obtain information about the design and role of seatbelts and airbags in preventing injury during a collision. 2. The knowledge students gain in their search can be in a class discussion or in individual presentations. 3. Students could also have a debate about the use of seat belts.
Evaluating	*Obtaining* Have students use what they have learned to apply this knowledge to the relationships among work, mechanical advantage and simple machines. *Teacher Notes: Students have worked with simple machines in elementary and middle school. A simple formative probe for what experiences they remember will help you in grouping the students for investigations.* *Communicating* **Phenomenon:** Can you use a pulley system to lift something that weighs more than you do? This interactive simulation explains work and the mechanical advantage of using different types of pulley designs. CK-12: Block and Tackle Background on Mechanical Advantage Challenge: Think about a car and all of the simple machines that operate in the efficiency of its design. Imagine that you are in charge of one of the simple machines highlighted in the design of a car. 1. Sketch the part and label why it is a simple machine. 2. Make a model of the part using common materials such as craft sticks, tape, glue, etc. 3. Research and calculate the work the machine does. 4. Calculate the mechanical advantage of different designs to figure out the most efficient design. Have students share their information, data, and designs with other classmates and revise according to feedback. After time for students to revise their designs, display the work in an expo of car design efficiency in a common

	area of the school.
SEP, CCC, DCI	**Science Essentials**
Science and Engineering Practices	● Planning and carrying out investigations ● Analyzing and interpreting data ● Constructing explanations ● Use Mathematics and computational thinking
Crosscutting Concepts	● Patterns ● Cause and Effect ● Systems and System Models ● Energy and Matter
Disciplinary Core Ideas	From A Framework for K-12 Science Education: **PS2.A: Forces and Motion** The motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, its motion will change. The greater the mass of the object, the greater the force needed to achieve the same change in motion. **SPS2.B: Types of Interactions** ● Gravitational forces are always attractive. There is a gravitational force between any two masses, but it is very small except when one or both of the objects have large mass—for example, Earth and the sun. **PS3.A: Definitions of Energy** ● “Mechanical energy” generally refers to some combination of motion and stored energy in an operating machine.

<u>Additional Supports for struggling learners:</u>

The following supports are suggestions for this lesson and are not the only options to support students in the classroom. These supports target students that struggle with science material, this lesson or a previous lesson. These are generalized supports and do not take the place of IEP accommodations as required by each student's Individualized Education Program.

General supports for the following categories:

<u>Reading:</u>

1. Provide reading support by reading aloud or doing partner reads
2. Have the teacher model what they are thinking when reading the text
3. Annotate the text with students so that they may refer to it as they work through the lab

<u>Writing:</u>

1. The teacher can provide a sentence starter for the students.
2. The teacher can give students an audience to write to (i.e. Write a letter to your sibling explaining this topic).
3. The teacher can provide constructive feedback during the writing process to help students understand the expectations.

<u>Math:</u>

1. Provide calculators as needed.
2. Provide graph paper as needed.

Supports for this specific lesson if needed:

Performance expectations for instruction:

1. The teacher should provide information to students in various formats to reach as many students as possible.
2. The students should be given adequate time to complete each part of the lesson.
3. The students should be allowed to express their knowledge in various formats.
4. The teacher should be sure to provide multiple ways for the students to communicate their knowledge of the material.

Engage:

1. The teacher should try to connect this to something the students have experienced. This could be the students' parents having to stop quickly in the care and the students body continuing to be propelled forward until the seat belt stops them. It could also be spilling a drink in the car when someone slams on the brakes.

2. The teacher can connect this to roller coasters as well.
3. The teacher should be sure to provide multiple ways for the students to communicate their knowledge of the material. These formats could include writing, drawing or designing a play.

Exploring:

1. The teacher should provide a data sheet for students to record data, observations and draw what is occurring in the experiment.
2. The teacher should remind students how to measure and record. The teacher should be sure to remind students of what units of measure they should use.
3. The teacher should provide calculators and consider pairing students up to work on the calculations.
4. The teacher should walk around and monitor student work to notice and correct misconceptions.
5. The teacher should be prepared to repeat directions as needed.
6. The teacher should consider giving students resources to use when researching newton's laws.
7. The teacher should provide a formative assessment to check for misconceptions. This can be used to determine which students need re-teaching, reviewing and enriching.
8. The teacher should be sure to provide multiple ways for the students to communicate their knowledge of the material. These could include writing, drawing or designing a play.
9. The teacher should provide a data sheet for the activities.
10. The teacher should use flexible and intentional grouping. Best practice is to use data to drive instruction.
11. The teacher should have students draw comparisons between the falling objects.
12. The teacher may need to assist with the calculations and graphing.
13. Students may need additional time to complete their data analysis and to revise their claim.

Explaining:

1. The teacher should provide a data sheet for students to record observations and data during the investigation.
2. Students may need additional time to revise their claim.
3. The teacher should use formative assessment to determine which students need re-teaching, reviewing or enriching.

Elaborating:

1. The teacher may want to provide videos and access to text to speech for students to see how manufactures attempt to overcome inertia.
2. The teacher should consider giving resources and an organizer to aid in the research.
3. The teacher should have clear and consistent guidelines for class discussion or debate to make students feel more at ease when participating.

Evaluating:

1. The teacher should be sure to check for understanding throughout the lesson and build in re-teaching, review and enrichment as needed by each student.
2. The teacher should provide tangible and constructive feedback for students throughout the lesson.
3. The teacher should provide multiple formats for students to express their knowledge. These formats could include writing, drawing or designing a play.
4. Students may need additional time to complete their design.

Walk It Out

*You will be using the **Claim-Evidence-Reasoning Model (C-E-R Model)** to both make predictions and reevaluate those predictions/models once new evidence is collected.*

Claim: *Statement of a student's understanding about an event or investigation; this may be your prediction statement…*

- It answers, what can you conclude?
- It should not start with yes or no.
- It should describe the relationship between dependent and independent variables.

Evidence: *Data used to support the claim; this may come from prior experiences, numerical data, or observations… Evidence must be:*

- Sufficient—Use enough evidence to support the claim.
- Appropriate—Use data that supports your claim. Leave out information that does not support the claim.
- Qualitative, Quantitative, or a combination of both.

Reasoning: *Ties together the claim and the evidence; explains why the evidence is relevant/important…*

- Shows how or why the data serves as evidence to support the claim.
- Provides the justification for why this evidence is important to this claim.
- Includes one or more scientific principles that are important to the claim and evidence

PRE-LAB:

Part I: **(Use the *C-E-R Model* to answer the following questions, with NO PRONOUNS.)**

1. If the student walking at a constant speed, how should the student adjust the lengths of their steps to keep the time intervals of their steps equal to each other?

Example:

Claim: Each step will need to be the same size.

Evidence: When walking at a constant rate, the time between steps does not change.

Reasoning: If the time interval between steps is constant, the steps must be evenly spaced in order for the speed to be constant.

2. While a student keeps the time intervals of their steps equal, how should the student adjust the lengths of their steps to increase their speed and the total distance traveled?
3. While a student keeps the time intervals of their steps equal, how should the student adjust the lengths of their steps in order to decrease their speed and the total distance traveled?

Part II:

For each of the **SIX** cases below construct a data table **(1 CASE PER PAGE – FRONTS ONLY)** in your notebook/binder. You need to put ***ONE DATA TABLE PER PAGE***. You will be placing graphs on the back of each page.

Sample Data Table

Data Point (Number of steps)	Distance from starting Point to each bean bag(m) ***Total Distance (d_T)***	Distance between bean bag (m) ***Interval Distance (d_i)***
0	0 m	
1		
2		
3		
4		
5		
Pre-Lab Prediction Diagram *(see Part III for instructions)*		
Your observations Diagram		

HINTS FOR PROCEDURE:

- **You will need to mark a starting point on the ground using a piece of painter's tape; this starting point will be used for all cases.**
- **Do NOT measure the distance between the bean bags only measure from the starting point to the individual bean bags.**
- **You will calculate the distances between bean bags once all of your data is collected.**
- **One person from your group needs to be the Data Collector, however ALL group members must eventually have complete Data Tables to get credit.**
- **Always start with your *left* foot.**
- **Before you make any measurements have your teacher check the bean bags that are sitting on the floor.**

Case 1: Forward at a Constant Rate

1. Your group needs to devise a way to obtain a correct data set for this Case.
2. You will need to write a brief set of procedures; several bullet points will be acceptable. You need to take into account direction, size of step, frequency of steps (how often). This should include a prediction of Use the CER model to make and support your claim for your procedures.
3. Right below Date Table I, make a prediction of what you think the bean bags will look like on the floor after you walk. Use an 'X' to represent each bean bag.
4. For example, if you think that the spacing will vary on the bean bag, you might draw this diagram:

   | X X X X X

   (Start)

5. **Your teacher MUST check your procedures before you begin your data collection**.

6. Start from rest at the starting line walking forward at a ***constant rate.*** Remember start with your ***left*** foot and drop a bean bag every time your right foot hits the ground.
7. **Your teacher will need to check the positioning of your bean bags before you can proceed with the lab.**
8. Measure the distance from the starting line to each bean bag. Fill in your Data Table for case 1.
9. Make a diagram of your **observations** of the bean bag lying on the ground, similar to the way you did your prediction diagrams. (Note all your diagrams will NOT look the same)

Case 2: Backward at a Constant Rate

1. Your group needs to devise a way to obtain a correct data set for this Case.
2. You will need to write a brief set of procedures; several bullet points will be acceptable. You need to take into account direction, size of step, frequency of steps (how often). This should include a prediction of Use the CER model to make and support your claim for your procedures.
3. Right below Date Table IV, make a prediction of what you think the bean bags will look like on the floor after you walk. Use an 'X' to represent each bean bag.
4. **Your teacher MUST check your procedures before you begin your data collection.**

5. Starting from rest, begin walking backwards at a ***constant rate.*** Remember start with your ***left*** foot and drop a bean bag every time your right foot hits the ground.
6. **Your teacher will need to check the positioning of your bean bags before you can proceed with the lab.**
7. Measure the distance from the starting line to each bean bag. Fill in your Data Table for case 2.
8. Make a diagram of your **observations** of the bean bag lying on the ground, similar to the way you did your prediction diagrams. (Note all your diagrams will NOT look the same)

----------------------------------*PAUSE HERE FOR A CLASS DISCUSSION*--

Case 3: Forward Speeding Up

1. Your group needs to devise a way to obtain a correct data set for this Case.
2. You will need to write a brief set of procedures; several bullet points will be acceptable. You need to take into account direction, size of step, frequency of steps (how often). This should include a prediction of Use the CER model to make and support your claim for your procedures.
3. Right below Date Table II, make a prediction of what you think the bean bags will look like on the floor after you walk. Use an 'X' to represent each bean bag.
4. **Your teacher MUST check your procedures before you begin your data collection**.

5. Start from rest at the starting line with your ***left*** foot, and start walking forward ***speeding up.*** Each time your right foot hits the ground drop a bean bag.
6. **Your teacher will need to check the positioning of your bean bags before you can proceed with the lab.**
7. Measure the distance from the starting line to each bean bag. Fill in your Data Table for case 3 you did your prediction diagrams. (Note all your diagrams will NOT look the same)

Case 4: Forward Slowing Down

1. Your group needs to devise a way to obtain a correct data set for this Case.
2. You will need to write a brief set of procedures; several bullet points will be acceptable. You need to take into account direction, size of step, frequency of steps (how often). This should include a prediction of Use the CER model to make and support your claim for your procedures.
3. Right below Date Table III, make a prediction of what you think the bean bags will look like on the floor after you walk. Use an 'X' to represent each bean bag.
4. **Your teacher MUST check your procedures before you begin your data collection.**

5. Start from rest at the starting line with your ***left*** foot, and start walking forward ***slowing down.*** Each time your right foot hits the ground drop a bean bag.
6. **Your teacher will need to check the positioning of your bean bags before you can proceed with the lab.**
7. Measure the distance from the starting line to each bean bag. Fill in your Data Table for case 4.
8. Make a diagram of your **observations** of the bean bag lying on the ground, similar to the way you did your prediction diagrams. (Note all your diagrams will NOT look the same)

Case 5: Backward Speeding Up

1. Your group needs to devise a way to obtain a correct data set for this Case.
2. You will need to write a brief set of procedures; several bullet points will be acceptable. You need to take into account direction, size of step, frequency of steps (how often). This should include a prediction of Use the CER model to make and support your claim for your procedures.
3. Right below Date Table V, make a prediction of what you think the bean bags will look like on the floor after you walk. Use an 'X' to represent each bean bag.
4. **Your teacher MUST check your procedures before you begin your data collection.**

5. Starting from rest, begin walking backwards ***speeding up.*** Each time your right foot hits the ground, drop a bean bag.
6. **Your teacher will need to check the positioning of your bean bags before you can proceed with the lab.**
7. Measure the distance from the starting line to each bean bag. Fill in your Data Table for case 5.
8. Make a diagram of your **observations** of the bean bag lying on the ground, similar to the way you did your prediction diagrams. (Note all your diagrams will NOT look the same)

Case 6: Backward Slowing Down

1. Your group needs to devise a way to obtain a correct data set for this Case.
2. You will need to write a brief set of procedures; several bullet points will be acceptable. You need to take into account direction, size of step, frequency of steps (how often). This should include a prediction of Use the CER model to make and support your claim for your procedures.
3. Right below Date Table VI, make a prediction of what you think the bean bags will look like on the floor after you walk. Use an 'X' to represent each bean bag.
4. **Your teacher MUST check your procedures before you begin your data collection.**

5. Starting from rest, begin walking backwards ***slowing down.*** Each time your right foot hits the ground drop a bean bag.
6. **Your teacher will need to check the positioning of your bean bags before you can proceed with the lab.**
7. Measure the distance from the starting line to each bean bag. Fill in your Data Table for case 6.
8. Make a diagram of your **observations** of the bean bag lying on the ground, similar to the way you did your prediction diagrams. (Note all your diagrams will NOT look the same)

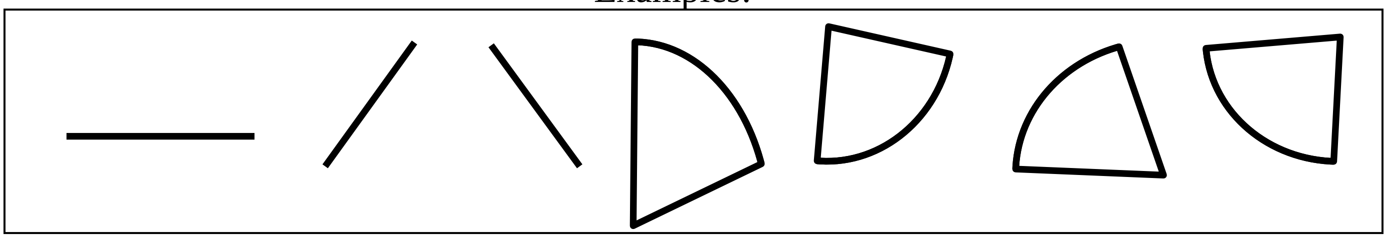
REMEMBER, ***ALL*** GROUP MEMBERS NEED TO HAVE RECORDED DATA, AND COMPLETE THE DATA TABLES FOR EACH CASE.

***Post-Lab* – every Group Member is responsible for completing these.**

1. Calculate the distance between bean bag (Interval Distance), and record this on your data tables for each trial. **You MUST show <u>one</u> sample set (total) of these calculations FOR EACH DATA TABLE (6 total) in your 3-Ring Binder.** Your sample **MUST** include:
   a. The equation or formula you intend to use **WITHOUT** any numbers
   b. An equation with the numbers **AND** units substituted into the equation
   c. The answer with numbers and units.
2. Construct the following graphs **(12 in total)** from your data table for case. (2 cases per page – these go on the back of the pages for your data tables)

All your graphs will look like one of the following lines. You might need to use some lines more than once.

Examples:



   a. **Total Distance (m)** from the starting point to each bean bag (y-axis) **vs. Number of steps** (x-axis)
   b. **Interval Distance (m)** between consecutive bean bags (y-axis) (0-1,1-2, 2-3, 3-4, 4-5) **vs. Number of steps** (x-axis). For all graphs you will **<u>NOT</u>** start at “0”. You will start with data for step #1

***Analysis* – These must be answered in COMPLETE SENTENCES, with NO PRONOUNS.**

1. For the Cases, describe the slope for each of your graphs **(12 total)**.
   a) What type of line do we have? (Linear or Non-linear)
   b) How is the ***<u>slope</u>*** of the line changing? (Increasing, Decreasing, or Constant)
   c) What direction is the line pointing? (Positive or Negative)
2. Pair the following Cases: 1 & 2, 3 & 5, 4 & 6. **(3 Total)**
   a) How did the Instructions for Case 1 differ from the instructions for Case 2? What about Cases 3 & 5? Cases 4 & 6?
   b) Compare the graphs for each of the Case pairs. Are the Interval Distance graphs the same for the pair? Are the Total Distance graphs the same for the pair? Are the shapes the same?
   c) Explain why your graphs in each pair are the same OR not the same.

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Which Way Did It Go?

Materials: Accelerometer

- Make a copy of the table below
- For each of the following cases we will use the accelerometer to predict which direction the acceleration is going.
- When you are making the changes in each case, you need to make these changes **very** fast.
- You need to observe what the stopper/water does **AS** the change in motion takes place!
- For the stopper/water, we are only interested in motion that is parallel to the direction you will be moving.

  Answer the following 5 questions for each Case:

Question #1: What direction is the student moving?
Question #2: What direction did the stopper move?
Question #3: Is there an acceleration taking place (to the person that is walking)? If so, what direction did the acceleration take place in?
Question #4: What relationship do you see between the direction the **stopper** is moving and the direction your acceleration is taking place? (Think about what is happening to the stopper)
Question #5: If your speed is changing, what relationship do you observe between the direction of **your** motion and the direction of **your** acceleration? (Think about what is happening to the person walking)

- Construct the data table below.
- Use the following potential answer to answer question 1 – 5 in your data table
  - ***For questions 1 – 3 use one of the following answers:***
    - Forwards
    - Backwards
    - Not at all
  - ***For questions 4 – 5 use one of the following answers:***
    - Same direction
    - Opposite direction
    - No acceleration
    - No relationship

	Case #1	**Case #2**	**Case #3**	**Case #4**	**Case #5**	**Case #6**
Question #1						
Question #2						
Question #3						
Question #4						
Question #5						

- Case 1: Walking forward at a constant rate
- Case 2: Walking backwards at a constant rate
- Case 3: Walking forward then changing quickly to running forward only looking at what the stopper is doing when you **start** running.
- Case 4: Running forward then **stopping** quickly only looking at what the stopper is doing as you are stopping.
- Case 5: Walking backwards then changing quickly to running backward only looking at what the stopper is doing when you **start** running.
- Case 6: Jogging/running backwards then stopping quickly only looking at what the stopper is doing as you are **stopping**.

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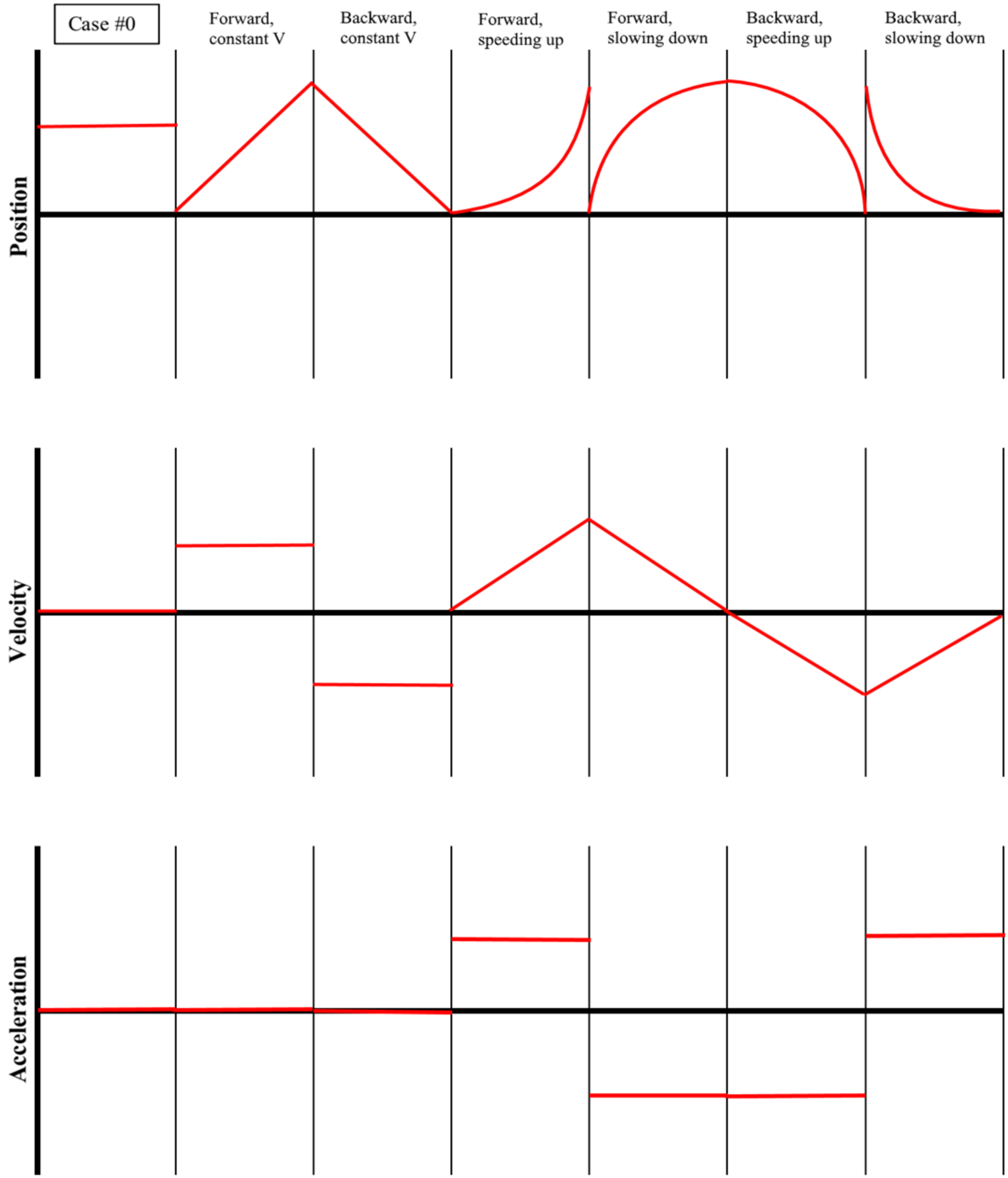
Graphing Motion Sheet



[Return to Instructional Segment]

Concept Review Cards: Force, Mass, and Motion

Directions: Get into groups of 4. You and a partner are playing against the other pair in the group. Sit across from your partner and next to someone from the other team.

You and your partner are playing a game where you are not allowed to mention certain terms. On the card, there is a term that you are trying to get your partner to say. You are **not** allowed to use the words listed below it. The other team monitors. For each 30 seconds, your goal is to get your partner to guess as many terms as possible. If you mention one of the forbidden words, that card is disqualified.

Force Push Pull Mass Newton Law apply	**Inertia** 1st law Newton Rest Motion Mass	**Mass** Kilogram Accelerate Newton Weight Property	**Newton** Law Force Acceleration Inertia Famous Scientist Unit
Acceleration Force Mass Law Velocity Change	**Newton's 3rd Law** Action Reaction Pairs Force Equal opposite	**Newton's 2nd Law** Acceleration Mass Force Equation	**Newton's 1st Law** Inertia Object Rest Motion force
Velocity Speed Fast Miles per hour Pace	**Distance** Far Traveled Space	**Simple Machine** Lever Pulley Wedge Work Easier	**Work** Force Distance Displacement Advantage

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Background on Mechanical Advantage

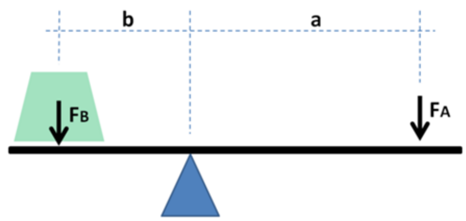

Diagram of lever used for mechanical advantage

<u>Mechanical advantage</u> (MA) is the factor by which a machine multiplies the force put into it.

Mechanical advantage is always calculated by the formula

- Load / effort.

The mechanical advantage can be calculated for the following simple machines by using the following formulas:

- Lever: MA = length of effort arm / length of resistance arm.
- Wheel and axle: A wheel is essentially a lever with one arm the distance between the axle and the outer point of the wheel, and the other the radius of the axle. Typically, this is a fairly large difference, leading to a proportionately large mechanical advantage. This allows even simple wheels with wooden axles running in wooden blocks to still turn freely, because their friction is overwhelmed by the rotational force of the wheel multiplied by the mechanical advantage.
- Pulley: Pulleys change the direction of a tension force on a flexible material, e.g. a rope or cable. In addition, pulleys can be "added together" to create mechanical advantage, by having the flexible material looped over several pulleys in turn. More loops and pulleys increase the mechanical advantage.

Mechanical advantage - a measure of the force amplification achieved by using a tool, mechanical device or machine system.

Examples of mechanical advantage:

- SUV opener - leverage and angles, where to put it to make a small movement to open the door.

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Cause and Effect in Force and Motion GSE: **SPS8a, b, c, d; SPS7a**			
Anchoring Phenomenon: Seatbelts and Airbags- the human body during a car crash.			
Topic	**Focus**	**Lesson Phenomenon**	**GSE/Notes/Language**
Force and Motion	• Students will explain the term force and apply it to describe phenomena. • Students will predict the motion of an object based on knowledge of its current movement • Students will compare, contrast, and calculate speed, acceleration, and velocity.	*The motion of an object has multiple simultaneous and related properties including speed, velocity and acceleration.* Students must understand that terms often used interchangeably in common language are unique and are different in scientific terms.	SPS8a. Plan and carry out an investigation to analyze the motion of an object using mathematical and graphical models. (Clarification statement: Mathematical and graphical models could include distance, displacement, speed, velocity, time and acceleration.) Equations should include- Velocity Acceleration
Newton's Laws	• Students will understand (not just quote) the three laws. • Students should grasp that objects at rest stay at rest and objects in motion stay in motion unless acted upon by an outside force. • Students should relate Newton's laws to balanced and unbalanced forces. • Students should understand, conceptually and in practice, what "equal and opposite" force describes. • Students will demonstrate that acceleration is	*Seatbelts and airbags are needed because the objects inside a car would otherwise continue in motion in a crash.* Or *Water in a cup turned upside down will not spill if a card is placed on top.* This simple activity is a good representation of balanced and unbalanced forces.	SPS8b. Construct an explanation based on experimental evidence to support the claims presented in Newton's three laws of motion. (Clarification statement: Evidence could demonstrate relationships among force, mass, velocity, and acceleration.) Equations should include- Force

	directly proportional to force and indirectly proportional to motion.		
Gravitational Force	• Students should understand that as objects fall their mass is affected by gravitational force. This is also true for all objects in space. • Students must understand that objects at rest are also affected by gravitational force (They don't "float" away.). • Students should demonstrate an understanding of How gravity interacts with two objects such as the sun and earth, earth and moon, etc.	*Tides are caused by the gravity of the moon.* While many students know this fact, few can actually explain it. An explanation of this phenomena would show a deep understanding of gravitational force. cK-12 Tides	SPS8c. Analyze and interpret data to identify the relationship between mass and gravitational force for falling objects. Equations should include- Weight
Simple Machines	• Students are introduced to simple machines in previous years. The focus of this course is how a simple machine gives a person a mechanical advantage, but the total work stays the same. • Students will need to relate the effort force and resistance force to the mechanical advantage of a simple machine both mathematically and conceptually.	*Simple machines you can help you lift something twice your weight.* A common misconception about simple machines is that they reduce the mass of the item being moved or that they reduce the total force needed. cK-12 Block and Tackle	SP8d. Use mathematics and computational thinking to identify the relationships between work, mechanical advantage, and simple machines. Equations should include- Work Mechanical Advantage
Energy of Movement	• Returning to the overarching theme of the year, energy transformations, the	*Energy is required to cause motion in a rocket launch or a car.*	SPS7a. Construct explanations for energy transformations within a system.

	potential and kinetic energy changes in a car or rocket can be used as a model to explain the topics in this instructional segment.	A chemical reaction resulting in particles being pushed out of the bottom of a rocket creates the thrust needed to lift a rocket. Energy from the combustion reactions in a car turn pistons resulting in movement.	(Clarification statement: Types of energy to be addressed include chemical, mechanical, electromagnetic, light, sound, thermal, electrical, and nuclear.) -The focus of energy in this unit is mechanical. Remember to include potential and kinetic energy where they fit.

Anchoring Phenomenon:

Energy is required to launch a rocket or move a car.

Students will explain the phenomenon using the following concepts:

- Students will describe, in terms of force and motion, how energy is required to move a car or rocket.
- Students will relate the observed motion to the underlying chemical reactions taking place in the vehicles.
- Students will explain (in the case of the rocket) how gravitational force affects the motion of the rocket.

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