



THE  
NATIONAL ADVANCED  
DRIVING SIMULATOR



COLLEGE OF  
**EDUCATION**

*Leaders. Scholars. Innovators.*

**Graph Interpretation and  
Motion Investigation  
for Junior High/Middle Students**

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# Curriculum Overview

This curriculum, for a physics unit on motion, teaches students about graphing and factors that influence motion, such as friction. It contains lesson plans, classroom activities, and assessments designed for the middle school level. This curriculum uses modern-day simulations provided by The National Advanced Driving Simulator (NADS) and relates classroom content to real-world experiences. Both of these attributes will engage students and make physics content relevant. The curriculum assists in meeting many standards for math, science, reading, and comprehension from the Iowa Core and Next Generation Science Standards (NGSS). This curriculum is designed to be used with a portable MiniSim simulator brought into your classroom by NADS, but it is also flexible enough, so teachers can use individual lessons to fit their needs.

This project was funded by a Safer-Sim Department of Transportation grant.

This project was created by The University of Iowa, College of Education, Social and Educational Applications of Physics class in cooperation with the National Advanced Driving Simulator and students from The University of Iowa College of Engineering.

# Standards and Benchmarks

This curriculum assists in meeting the following standards and benchmarks:

		NGSS STANDARDS								IOWA CORE STANDARDS											
Lesson Plan:		X:MS-PS 2-2	X:MS-PS 2-4	X:MS-PS 2-5	X:MS-PS 3-1	X:MS-PS 3-4	X:MS-PS 2-3	X:MS-PS 2-1	D:MS-PS 3-5	D:MS-PS 3-1	D:MS-PS 2-2.A	WHST.6-8.10	WHST.6-8.1	6.EE.B.6	6.EE.C.9	SL.8.4	SL.8.3	SL.8.2	SL.8.1	S.6-8.PS.3	
UNIT 1	On the Move	X			X	X															X
	Graphing Complex Motion	X			X	X															X
	Driving				X	X					X										X
UNIT 2	Factors that Affect Motion		X					X	X	X		X	X	X	X						X
	Simulation Driving Day	X	X	X			X	X								X	X	X	X	X	X
	Finalizing Friction	X	X	X			X	X								X	X	X	X	X	X

		NGSS STANDARDS								
Lesson Plan:		P:MS-PS 2-1	P:MS-PS 2-2	P:MS-PS 3-5	C:MS-PS 2-1	S:MS-PS 3-1	S:MS-PS 2-4	S:MS-PS 2-5	S:MS-PS 2-2	S:MS-PS 3-4
UNIT 1	On the Move				X			X	X	
	Graphing Complex Motion					X				X
	Driving							X	X	
UNIT 2	Factors that Affect Motion			X			X	X		
	Simulation Driving Day	X	X				X		X	
	Finalizing Friction	X	X				X		X	

## Key

NGSS:  
 D= Disciplinary Core Ideas  
 X= Cross Cutting Concepts  
 S= Science and Engineering Practices  
 C= Constructing Explanations and Designing Solutions  
 P= Performance Solutions

## Iowa Core Science:

- S.6–8.PS.3:
  - Essential Concept and/or Skill: *Understand and apply knowledge of motions and forces.*
    - The motion of an object can be described by its position, direction of motion, and speed. That motion can be measured and represented on a graph.
    - An object that is not being subjected to a force will continue to move at a constant speed and in a straight line.
  - If more than one force acts on an object along a straight line, then the forces will reinforce or cancel one another, depending on their direction and magnitude. Unbalanced forces will cause changes in speed or direction of an object’s motion.

## Comprehension and Collaboration:

- SL.8.1:

- Engage effectively in a range of collaborative discussions (one–on–one, in groups, and teacher–led) with diverse partners on *grade 8 topics, texts, and issues*, building on others’ ideas and expressing their own clearly.
- SL.8.2:
  - Analyze the purpose of information presented in diverse media and formats (e.g., visually, quantitatively, orally) and evaluate the motives (e.g., social, commercial, political) behind its presentation.
- SL.8.3:
  - Delineate a speaker’s argument and specific claims, evaluating the soundness of the reasoning and relevance and sufficiency of the evidence and identifying when irrelevant evidence is introduced.

### Presentation of Knowledge and Ideas:

- SL.8.4:
  - Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well–chosen details; use appropriate eye contact, adequate volume, and clear pronunciation.

### Mathematics:

- 6.EE.C.9:
  - Use variables to represent two quantities in a real–world problem that change in relationship to one another; write an equation to express one quantity, thought of as the dependent variable, in terms of the other quantity, thought of as the independent variable. Analyze the relationship between the dependent and independent variables using graphs and tables, and relate these to the equation.
- 6.EE.B.6:
  - Use variables to represent numbers and write expressions when solving a real–world or mathematical problem; understand that a variable can represent an unknown number, or, depending on the purpose at hand, any number in a specified set.

### Literacy

- WHST.6-8.1:
  - Write arguments focused on discipline–specific content.
- WHST.6-8.10:
  - Write routinely over extended time frames (time for reflection and revision) and shorter time frames (a single sitting or a day or two) for a range of discipline–specific tasks, purposes, and audiences.

## **NGSS**

### Disciplinary Core Ideas:

- MS-PS2-2.A:
  - All positions of objects and the directions of forces and motions must be described in an arbitrarily chosen reference frame and arbitrarily chosen units of size. In order to share information with other people, these choices must also be shared.
- MS-PS3-1:
  - Motion energy is properly called kinetic energy; it is proportional to the mass of the moving object and grows with the square of its speed.
- MS-PS3-5:

- When the motion energy of an object changes, there is inevitably some other change in energy at the same time.

### Cross-Cutting Concepts:

- MS-PS2-2:
  - Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object. All positions of objects and the directions of forces and motions must be described in an arbitrarily chosen reference frame and arbitrarily chosen units of size. In order to share information with other people, these choices must also be shared.
- MS-PS3-1:
  - Construct and interpret graphical displays of data to describe relationships of kinetic energy to the mass of an object and to the speed of an object.
- MS-PS 3-1, 3-4:
  - Proportional relationships (e.g. speed as the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes.
- MS-PS 3-4:
  - Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim.
- MS-PS 3-1 :
  - Construct and interpret graphical displays of data to identify linear and nonlinear relationships.
- MS-PS2-3, MS-PS2-5:
  - Cause and effect relationships may be used to predict phenomena in natural or designed systems.
- MS-PS2-1, MS-PS2-4:
  - Models can be used to represent systems and their interactions such as inputs processes and outputs and energy and matter flows within systems.
- MS-PS2-2:
  - Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales.

### Science and Engineering Practices:

- Planning and carrying out investigations to answer questions or test solutions to problems in 6–8 builds on K–5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or design solutions.
- MS-PS2-2:
  - Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim.
- MS-PS 2-5:
  - Conduct an investigation and evaluate the experimental design to produce data to serve as the basis for evidence that can meet the goals of the investigation.

- MS-PS2-4:
  - Construct and present oral and written arguments supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem.
- MS-PS2-2, MS-PS2-4:
  - Science knowledge is based upon logical and conceptual connections between evidence and explanations.

### Constructing Explanations and Designing Solutions:

- Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific ideas, principles, and theories.
- MS-PS 2-1:
  - Apply scientific ideas or principles to design an object, tool, process or system.

### Performance Expectations:

- MS-PS3-5:
  - Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object.
- MS-PS2-2:
  - 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. For any given object, a larger force causes a larger change in motion.
- MS-PS2-1:
  - For any pair of interacting objects, the force exerted by the first object on the second object is equal in strength to the force that the second object exerts on the first, but in the opposite direction (Newton’s third law).

# Unit 1

## Graphing Interpretation Competition

### Goals:

To give students the skills to analyze and construct graphs (position vs. time, velocity or speed vs. time, acceleration vs. time, and direction vs. time).

### Justification:

Students are often introduced to graphs, but according to teachers consulted, students rarely have the ability to fully analyze and describe them.

Graphical interpretation is needed in many professions, day-to-day life, and is seen on many standardized tests.

By introducing students to graphing early, they will be given the opportunity to improve graphing skills throughout middle and high school.



# Lesson One: On the Move

**Grade level:** 6-8

**Expected length of lesson:** 45 minutes

## Overview:

Introduction to graphing motion starting with probes to discuss misconceptions. An activity titled “On the Move: Velocity Activity” follows the probes to engage students in kinesthetic learning. The activity produces data that are graphed. Speed and acceleration are calculated based on the data acquired.

## Standards and/or benchmarks:

### NGSS:

#### Disciplinary Core Idea:

- MS-PS2-2:
  - All positions of objects and the directions of forces and motions must be described in an arbitrarily chosen reference frame and arbitrarily chosen units of size. In order to share information with other people, these choices must also be shared.

#### Science and Engineering Practices:

##### Planning and Carrying Out Investigations

- MS-PS2-2:
  - Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim.
- MS-PS2-5:
  - Conduct an investigation and evaluate the experimental design to produce data to serve as the basis for evidence that can meet the goals of the investigation.

##### Constructing Explanations and Designing Solutions

- MS-PS2-1:
  - Apply scientific ideas or principles to design an object, tool, process or system.

#### Cross-Cutting Concept:

##### Scale, Proportion, and Quantity

- MS-PS3-1, MS-PS3-4:
  - Proportional relationships (e.g. speed as the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes.

## Iowa Core:

- S.6–8.PS.3
  - Essential Concept and/or Skill: Understand and apply knowledge of motions and forces.
  - The motion of an object can be described by its position, direction of motion, and speed. That motion can be measured and represented on a graph

## Learning Goals:

Students will understand:

- Graphs do not directly represent the motion; addresses the “What You See Is What You Get (WYSIWYG)” issue.
- The relationship of position to velocity and acceleration.

## Learning Performances:

Students will be able to:

- Collect data to generate graphs.
- Generate graphs:
  - Position vs. time
  - Speed vs. time
  - Acceleration vs. time.
- Identify the motion of the object.

## Materials:

- Following Jack Part II
  - Probe teacher guide
- Go Cart Test Run
  - Probe teacher guide
- *On the Move: Velocity Activity* worksheet
  - *On the Move: Velocity Activity* Teacher notes
- Masking tape
- Timer
- Meter stick
- Motion story worksheet

## Safety:

Consider location during *On the Move: Velocity Activity*; walking and running is required.

## Critical Thinking Question:

What story are the graphs are telling us?

## Students’ Ideas:

The students should have some familiarity with distance, direction, speed and/or velocity, acceleration and what those mean scientifically. Students will likely have misconceptions about graphing.

## Main Lesson:

1. Teachers present the lesson’s critical thinking question: What story are the graphs telling us?
2. Hand out Go Cart Test Run probe and instruct students to complete it.
3. After students are done with the probe sheets, instruct students to form small groups (2~3 students).
  - a. Students discuss reasoning for their answers.

- b. This is to engage students who are most comfortable with talking in smaller groups.
4. Instruct students to have a class discussion sharing thoughts from the small group discussion.
  - a. Whole class discussion reveals class misconceptions.
5. Instruct students to start *On the Move: Velocity Activity*.
  - a. Use a jigsaw activity to allow students to explain different parts of the instructions to their peers.
  - b. Model the experiment set up. (Applying tape, walking, running etc.)
  - c. Model how to create and/or fill out the table.
6. Pair students to conduct the activity.
  - a. Monitor progress.
  - b. Ensure data table completion.
7. After data is collected, instruct students to return to seats and begin graphing.
  - a. Instruct students work individually or in pairs.
  - b. Monitor the graphing process, and if necessary, model how to fill out the graphs.
  - c. Collect worksheets.
8. Hand out Motion Story Worksheet Homework:
  - a. Read instructions out loud.
  - b. Go over the worksheet example.
  - c. Stories will include 3-5 events such as: stopping for a light, changes in speed, turning left or right, etc.
  - d. The length of the trip can be adjusted to meet student needs

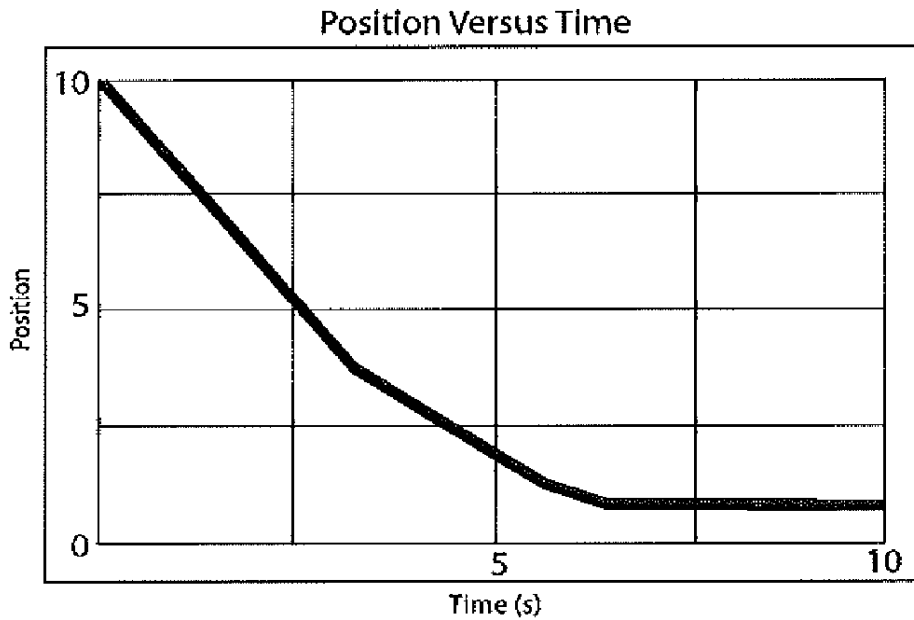
**Differentiation:**

- Students should be grouped appropriately.
- Activity worksheet differentiation is described in section five *On the Move: Teacher Notes*.
- Homework can be modified with maps and drawing instead of writing long descriptions.

**Assessment:**

The assessment is *On the Move: Velocity Activity*. Rubric is found in section four of *On the Move: Teacher Notes*.

# Go-Cart Test Run Probe



Jim and Karen have built a go-cart. They take their go-cart for a test run and graph its motion. Their graph is shown above. They show the graph to their friends. This is what their friends say:

Bob: “That was a steep hill! You must have been going very fast at the bottom.”

Claire: “I think you were going fast at first, but then you were moving slowly at the end.”

Karl: “I think you were moving quickly, then slowed down to a stop at the end.”

Mary: “It looks like you were going downhill and then the road flattened out.”

Circle the name of the friend you think best describes the motion of the go-cart based on the graph. Explain why you agree with that friend.

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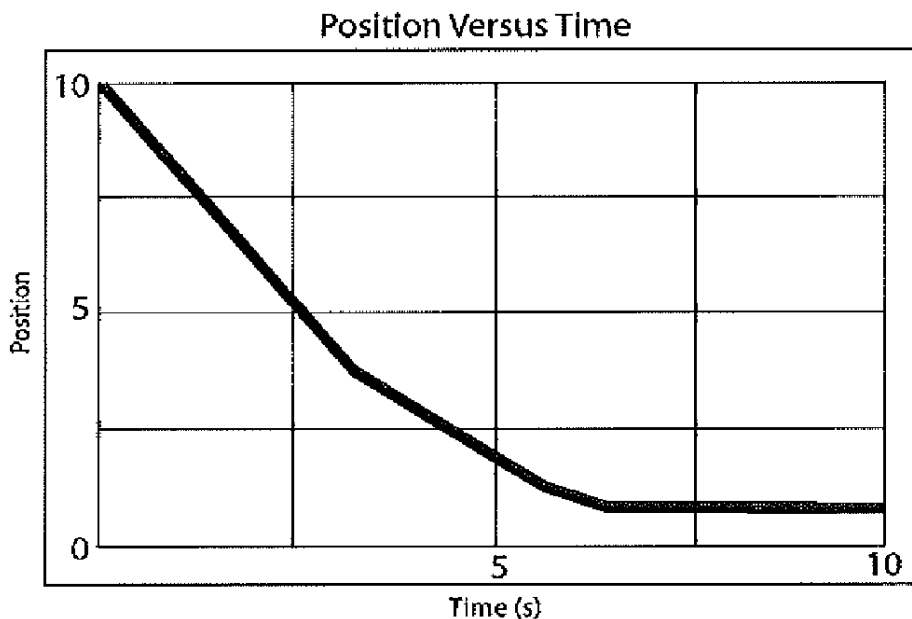
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Revised version of probe 5 Go-Cart Test Run in Vol. 1 of Uncovering Student Ideas in Physical Science (Keeley & Harrington, 2010)

# Go-Cart Test Run Probe Teacher Notes

## Purpose



The purpose of this probe is to examine how students interpret a graphical representation of motion. The probe is designed to reveal whether students interpret a motion graph pictorially or mathematically.

## Related Concepts

Clock readings, constant speed, graph, position, time, time intervals, speed, and uniform motion

## Explanation

Karl has the best answer: “I think you were moving quickly, then slowed down to a stop at the end.” The speed of the go-cart is related to the slope of the line on the graph. Between 0 and 3 seconds, the go-cart is moving at a constant speed. Between 3 and 6 seconds, the go-cart is still moving at a constant speed, but slower than the previous interval. Between 6 and 7 seconds, the go-cart is moving at a slower speed. From 7 seconds on, there is no change in position; the go-cart has stopped.

A graph can also be interpreted by the slope of the lines. A straight line with a steep slope indicates constant motion at a greater speed than a straight line with a more gradual slope. When the line on a graph is horizontal, that means that as time goes by, the position of an object is not changing. The horizontal line on this graph means that the go-cart stops at the end of the motion.

## **Administering the Probe**

This probe is appropriate for middle school students and high school students. You may adapt the probe by eliminating the answer choices and having students “tell the story” indicated by the graph. For students who may be unfamiliar with position versus time graphs, it may be helpful to describe the y axis as the milepost or distance marker.

## **Suggestions for Instruction and Assessment**

- Provide multiple opportunities for students to construct and interpret graphs, so you can see what students understand or misunderstand about graphs and graphing.
- Provide students with different types of motion graphs, and have them make up stories about what the graphs show. Encourage discussions about the accuracy of their stories. Do the stories accurately reflect the information on the graphs? This strategy, popular in mathematics classes, can help students overcome the tendency to view graphs as a literal picture.
- Use motion detectors and students’ real movements to help students construct a visual and kinesthetic understanding of position versus time. MBLs (microcomputer-based laboratories) are known to improve the development of students’ abilities to interpret graphs. MBLs are particularly effective in helping middle school students understand that a graph is not a literal picture.
- Most middle school science curricula use distance versus time graphs instead of position versus time graphs. Although both types of graphs can be interpreted in the same way, teachers should help students understand the distinction between distance and position. In some textbooks, distance may mean distance traveled whereas position refers to the location of an object. In some special cases (such as when the motion starts at zero position) these terms mean the same thing. However, to avoid confusion, physics teachers tend to use position, which has a well-defined meaning.

# On the Move: Velocity Activity

Name: \_\_\_\_\_ Date: \_\_\_\_\_

Group Mates: \_\_\_\_\_

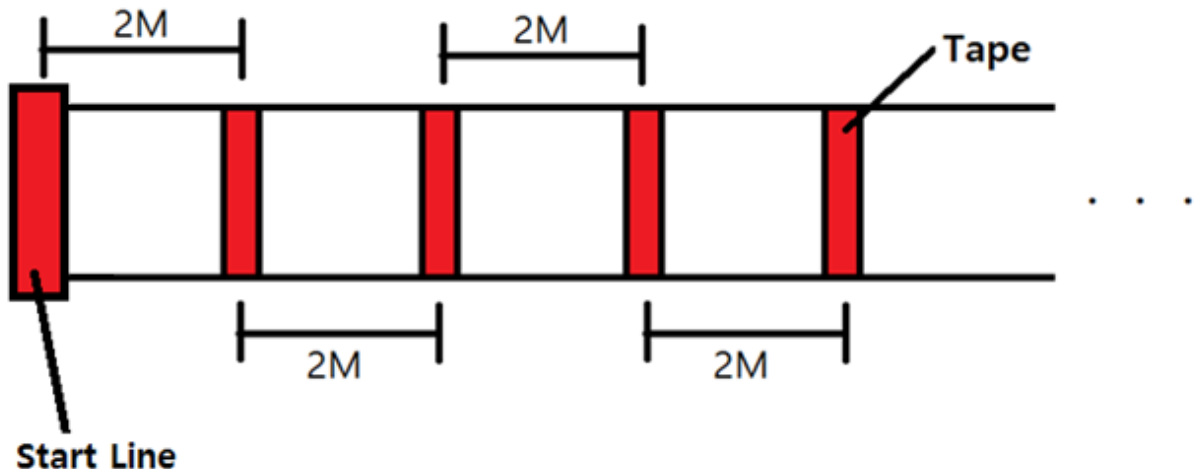
## Materials:

- Meter stick
- Masking tape
- Timer

## Directions:

In small groups you will conduct an experiment to create a position vs. time graph.

1. With masking tape, make a start line on the floor. Make sure it is visible to everyone.
2. Measure two meters from the start line. Place another strip of masking tape.
3. Have total of six masking tapes representing each two meter mark. The total distance marked off should be 12 meters.
4. After setting up your experiment, it should look something like this:

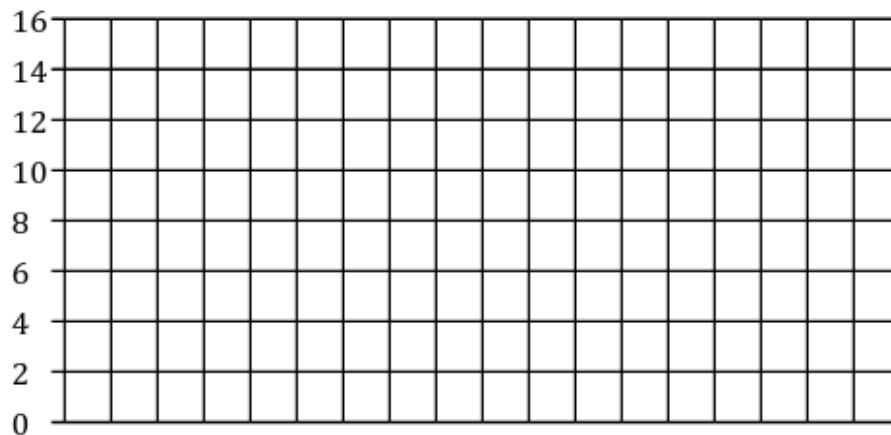


5. Start walking from 0-6 meters. Then, increase your speed (run) immediately after 6 meters and maintain a faster constant speed (same running speed).

**Data:**

Distance (m)	Time (seconds)
0	0
2	
4	
6	
8	
10	
12	

**Graph (fill in appropriate increments for the time axis):**



**Velocity Calculations and Questions:**

1. Calculate velocity.
  - a. Determining the velocity between 0-2 meters.
    1. What is the change in distance from the start to the 2-meter mark?
    2. What is the change in time from the start to the 2-meter mark?
    3. Calculate velocity as the change in distance (calculated in step 1) over the change in time (calculated in step 2).
  - b. Repeat this process for each increment (2-4, 4-6, 6-8, etc.) and fill in the table.



Distance Interval	Change in Distance (m)	Change in Time (seconds)	Velocity (m/s)
0m – 2m			
2m – 4m			
4m – 6m			
6m – 8m			
8m – 10m			
10m – 12m			

2. Did the velocity change over the 12 meter distance? Why do you think it changed or stayed the same?

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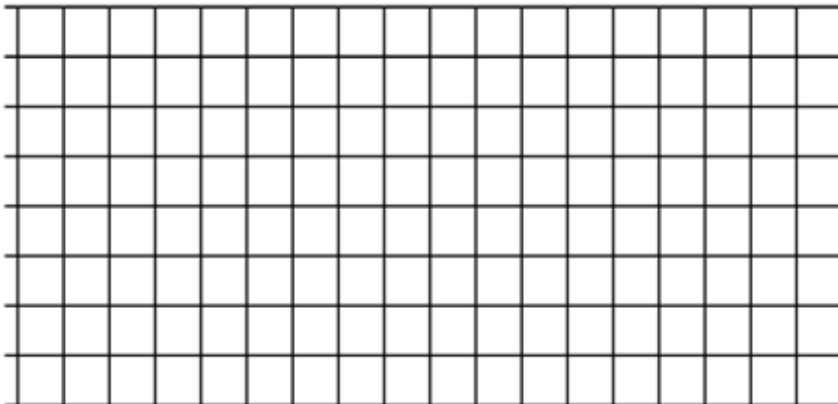
3. What do you think would happen to the velocity if you decreased your speed over the 12-meters?

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4. Draw a graph for velocity vs. time from the data you calculated in step 1.



## Acceleration Calculations and Questions:

1. There is a change in speed between 6 meters to 8 meters. Whenever there is a change in speed or direction vs. time, it is called **acceleration**.
2. Calculate acceleration.
  - a. Determining the acceleration between 6-8 meters.
    1. What is the change in velocity from the 6 to the 8-meter mark that you calculated in the table in the previous section (velocity calculations and questions)?
    2. What is the change in time from the 6 to the 8-meter mark?
    3. Calculate acceleration as the change in velocity (calculated in step 1 above) divided by the change in time (calculated in step 2 above).
  - b. Repeat this process for each increment (2-4, 4-6, 6-8, etc.) and fill in the table.

Velocity Interval	Change in Velocity (m/s)	Change in time (seconds)	Acceleration (m/s <sup>2</sup> )

3. What will happen to the acceleration if the speed increases more after 12m? Explain why.

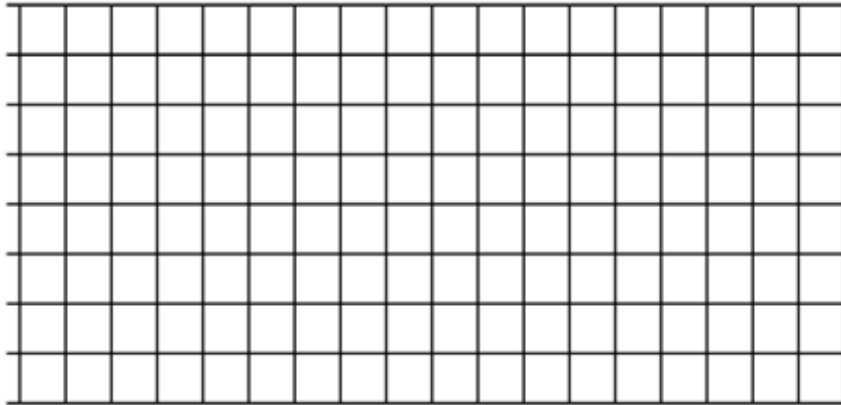
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4. Draw a graph for acceleration vs. time.



## On the Move: Teacher Notes

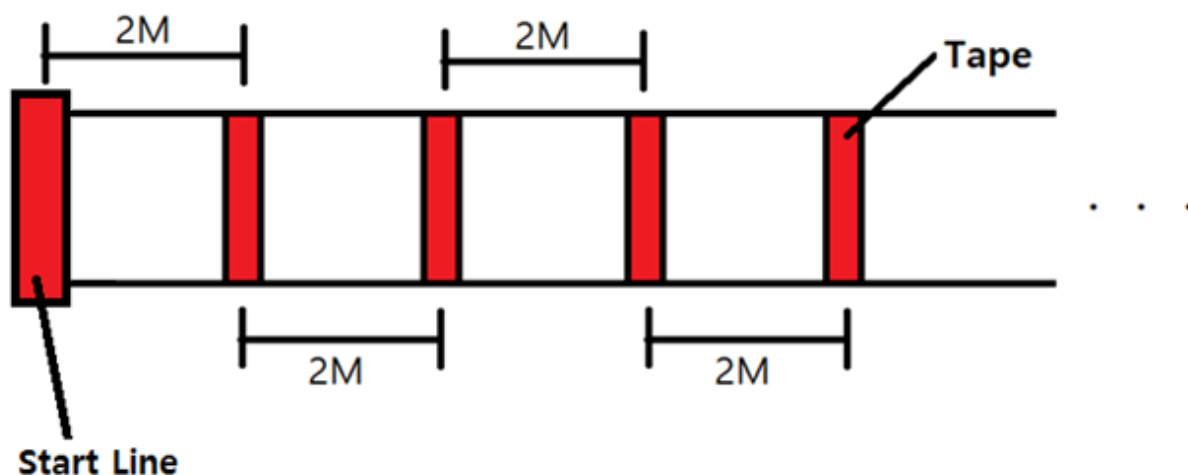
Groups of 2-4 are recommended.

### Materials:

- Timer
- Tape
- Meter stick

### Directions:

1. Setting up the experiment:
  - a. Students will follow the instructions that were provided on activity to set up the experiment.
  - b. On the ground tape 2-meter marks for 12 meters (see diagram) there will be 7 tape marks total.



2. Group students per your discretion.
3. One group member will physically walk and run per instructions.
  - a. A wheelchair bound or physically challenged student who is capable of multiple speeds may also choose to participate.
  - b. Remaining group members will use stopwatches and time when the tape marks are crossed.
4. Calculations
  - a. The calculation for velocity is the change in distance (m) over the change in time (seconds):

$$\frac{\Delta d}{\Delta t} = \frac{d_2 - d_1}{t_2 - t_1}$$

1. For this calculation, each distance interval will be 2 meters.

- b. The calculation for acceleration is the change in velocity (m/s) over the change in time (seconds):

$$\frac{\Delta v}{\Delta t} = \frac{v_2 - v_1}{t_2 - t_1}$$

1. The *velocity interval* (in the acceleration calculations and questions section) should be determined from the calculated velocities in the previous table.
2. The *change in time* column for the acceleration table should be calculated from the *change in time* column in the velocity table (in the velocity calculations and questions section), not from the distance table (in the data section).

5. Graphing

- a. When the students graph the distance vs. time data, ensure that each axis is given a label and units. Students may need some help determining appropriate intervals for the x-axis (time).
  - b. When graphing the velocity data, use the velocities calculated in the *velocity calculations and questions* section. For the time, use the times in the *data* section (distance vs. time collected by the student) starting with the time for 2m.
    1. Velocity is in m/s; therefore, the time used for plotting is the end time of the interval used to calculate the velocity (the time from 0-2m).
  - c. When graphing the acceleration data, use the acceleration calculated in the *acceleration calculations and questions* section. For the time, use the times in the *data* section (distance vs. time collected by the student) starting with the time for 4m.
    1. Acceleration is in m/s<sup>2</sup>; therefore, the time used for plotting is the end of the time interval used to calculate the acceleration (two time intervals: the times from 0-2m and 2-4m).
  - d. Have the students discuss what they observed during the experiment and how that relates to what they see on the graph.
6. Collect filled out worksheet from the students and grade based on the following rubric:

Item/Score	0	1	2	3
<b>Graph</b>	Students did not attempt to plot the data, label the axes or determine the best interval for time.	Students had numerous plotting, labeling, or interval errors in their graphs.	Students had some plotting, labeling, or interval errors in their graphs.	Students had few or no errors for each graphs.

<b>Calculation</b>	Students did not show their work and had incorrect answers.	Students had the correct answer but did not show their work.	Students did not have the correct answer but showed their work and the processes or formulas were correct.	Students had the correct answer and showed their work. Their processes or formulas were correct.
<b>Explanations</b>	Students did not write any response.	Student wrote a non-scientific response.	Students wrote a response with an incomplete scientific explanation.	Students wrote a response with a complete scientific explanation.

7. Differentiation

- For special education students, label the axes and determine appropriate time intervals for them to plot their data.
- For ELL students, model the activity, calculations, and graphing.
- For high achievers, use tables without headers and graphs without any labels on the axes.

# Motion Story Worksheet

Name: \_\_\_\_\_ Date: \_\_\_\_\_

Describe a trip you took or would like to take in or around your neighborhood. For example, you may write the events of a bike ride to a friend's house, your walk to school, or the drive to a grocery store. Use a term from each of the bullet points at least once when describing your trip:

- speeding up/sped up
- slowing down/slowed down
- constant speed
- stop/stopping/stopped
- turn/turning/turned (including direction - left or right)

Include approximate times and distances for each part of your trip. You may describe your trip as a written paragraph, a table, or a list with bullets or numbers. It may be helpful to draw or print a map (with a program like *Map My Route* or *GoogleMaps*) of your route.

Example:

On my way to my friend's house, I first walked at constant speed out my door and down the driveway for about 15 feet in about 10 seconds. I turned right at the sidewalk walking one step (about 3 feet) in about 1 second then walked at a constant speed for 3 blocks (about 300 feet) in about 2 minutes. I turned left walking one step (about 3 feet) in about 1 second and stopped to wait for about 1 minute for the light to change. I sped up in several steps (about 10 feet) in about 5 seconds and walked at constant speed for 3 blocks (about 300 feet) in about 2 minutes. I turned left in one step (about 3 feet) toward my friend's house in about 1 second and slowed down for about 15 feet in about 10 seconds until I stopped at her door.

## Lesson Two: Graphing Complex Motion

**Grade level:** 6-8

**Expected length of lesson:** Approximately 45 to 60 minutes

### Overview:

For the second day, students use their homework to evaluate position (distance), speed, acceleration and direction for complex motion. Students analyze the trip they wrote for their homework from the perspectives of distance, speed, acceleration, and direction to be used to graph the motion. Teacher asks students to draw a data set consisting of 4 graphs by the end of class: (1) distance vs. time, (2) speed vs. time, (3) acceleration vs. time, and (4) direction vs. time. Students are then expected to analyze a data set of a new situation and determine the trip events in order for complex motion. Students are in groups of 4 and roles for simulator are assigned.

### Standards and/or benchmarks:

#### NGSS:

##### Disciplinary Core Ideas:

##### Forces and Motion

- MS-PS2-2:
  - All positions of objects and the directions of forces and motions must be described in an arbitrarily chosen reference frame and arbitrarily chosen units of size. In order to share information with other people, these choices must also be shared.

##### Cross-Cutting Concepts:

##### Scale, Proportion, and Quantity

- MS-PS3-1, MS-PS3-4:
  - Proportional relationships (e.g. speed as the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes.

##### Science and Engineering Practices:

##### Planning and Carrying Out Investigations

- MS-PS3-4:
  - Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim.

##### Analyzing and Interpreting Data

- MS-PS3-1:
  - Construct and interpret graphical displays of data to identify linear and nonlinear relationships.

### Iowa Core:

- S.6–8.PS.3
  - The motion of an object can be described by its position, direction of motion, and speed. That motion can be measured and represented on a graph.



## Learning Goals:

Students will understand:

- Graphs depicting motion are related: (1) distance vs. time, (2) speed vs. time, (3) acceleration vs. time, and (4) direction vs. time.
- The relation of variables to time graphically.
- Graphs depicting complex motion are more complex.
- Multiple graphs are used to depict complex motion.

## Learning Performances:

Students will be able to:

- Write their trip from the perspective of (1) distance, (2) speed, (3) acceleration, and (4) direction.
- Use the write up their trip from each perspective to generate a graph for each (a data set).
- Find missing events of the trip in one graph that are represented in another graph.
- Analyze a new data set to determine the motion.

## Materials:

- Completed homework assignment
- Homework teacher notes
- Graph paper
- Project data set

## Safety:

NA

## Critical Thinking Question:

What story are the graphs telling us?

## Student Ideas:

Allow student to write the stories in whatever way makes the most sense to them (paragraph, bullets, numbered list, tabular, etc.).

## Main Lesson:

1. Instruct students to take out their homework assignments.
  - a. If students' assignments are incomplete or less detailed, provide additional help in the next steps.
  - b. If students did not complete the homework, pair them with an appropriate student who has finished the assignment.
2. Ask students where they went and how many drew maps to help them.
  - a. If students have similarities on the type of trip they wrote about, grouping may be used for the next steps to allow students to help each other.
3. Instruct students to identify their starting and ending points on a new piece of paper.
4. Instruct students to write their trip from 4 different perspectives:
  - a. distance from the starting point
  - b. speed

- c. acceleration
  - d. direction from the starting point
5. Provide instructions for writing each perspective from the starting point to the ending point.
    - a. Chunk the instructions for each perspective.
    - b. Consider how students organize the information (table format, bullets, or numbering the steps).
    - c. Either use an example or one of the students' trips to model how to write the trip from each perspective. An example is provided in the teacher notes accompanying the homework.
    - d. Monitor while students are writing their trips from each perspective to ensure that all the necessary details are included.
  6. Explain to students how to make each graph after the story is written from each perspective.
    - a. As a whole class, ask students to determine the variables in each perspective. They need to identify time as one variable in each.
    - b. As a whole class, ask students to identify where each variable goes on the graph. Ask them to explain their thinking. Students may not use the terms dependent and independent variable, but they should be able to reason that time goes on the bottom from instruction the day before.
    - c. Chunk the instructions and model how to generate a graph for each perspective. Use an example or one of the students' trips.
    - d. Emphasize the shape over exact values at this time.
    - e. Monitor while students graph their trip from each perspective.
  7. Pair students to review each other's work.
    - a. Have the students compare the *originally* written trip to the graphs. It is not necessary to read the trip from each perspective.
    - b. Allow students to change and improve their graphs.
  8. After students are satisfied with their graphs, have a short discussion.
    - a. Ask students if the graphs look how they expected them to.
    - b. Ask students if there are any parts missing from the trip in one of the graphs (a change in direction is not seen in the other graphs, etc.).
    - c. Ask students if all the graphs are necessary. It may help to ask if it is easy to determine the acceleration in the distance graph.
  9. Have students turn in their paperwork (the homework, the four perspectives, and graphs).
  10. While handing out the activity data set (a new set of graphs like the ones the students just generated), explain to the students they need to figure out the "trip" this time.
    - a. Instruct students to determine three parts:
      1. What is happening?
        - a. Speeding up or positive acceleration
        - b. Slowing down or negative acceleration
        - c. Constant speed or constant acceleration
        - d. Stopping (constant position or distance)
        - e. Turning left or right (changing direction where right is positive and left is negative).

2. How long it takes in seconds. This needs to include the increment (e.g. for 20 seconds) and the total time when it starts and stops (e.g. at 80 seconds until 100 seconds).
  3. The value of the motion
    - a. If the speed is constant, what that speed is.
    - b. Model how to generate a table for the information using an example.
11. Explain to students that the table should be their best work because they are going to drive this trip on a simulator the next day.
- a. Describe the contest to them.
    1. The trip they write from the graphs is going to be driven on the simulator.
    2. Graphs from the simulator are going to be generated and they are going to compare them to the ones they were just handed.
    3. The winning group will be chosen by the students.
      - a. The winner will be the group with the graphs that are closest to the originals.
      - b. Get the students thinking about how they will pick the winner; what criteria will they use.
12. Select groups of 3 or 4 depending upon the number of students.
- a. Assign roles to the members of the groups. Depending upon the class, groups may assign roles themselves.
  - b. Roles include
    1. Driver - Student driving the simulation.
    2. Manager - Student who determines the final driving trip and writes up the instructions to follow.
    3. Coach - Student who gives explicit instructions to the driver of what to do at each step of the driving simulation.
    4. Timer - Student who watches the on-screen timer to signal when the next step will occur.
  - c. Emphasize the need to be collaborative for the best result.

### **Differentiation:**

- Advanced learners can make a more complex trip and do not provide pre-labeled graphs or tables. Ensure they have used one of each: deceleration, complete stop, acceleration, constant speed, and direction.
- Special needs students can make a scenario with 3 events and should be given graphs with axes pre-labeled.
- For ELL students, adjust the requirements for more visual learning. Stress the terms distance, speed, acceleration, and direction.

### **Assessment:**

- While monitoring the perspective writing and graphing ask individuals or groups probing questions.
- Collect the homework, perspectives, and graphs.

# Motion Story Homework Teacher Notes

Individual work is recommended but small groups with similar trips may be used for students to help each other.

## Materials:

- Graph paper

## Directions:

1. The example on the next pages may be used as an example for instructing students on how to write their stories.
  - a. This example may be handed out at your discretion.
2. Instruct students to rewrite their stories from each of four perspectives: distance, speed, acceleration, and direction.
  - a. Provide instruction on how to do one of the perspectives.
  - b. If the story is written in multiple units (both minutes and seconds or feet and miles), the rewritten stories will need to be converted to only one unit (either minutes or seconds, etc.).
  - c. Allow students some time to struggle with figuring out the others before providing guidance.
  - d. Use the example on the following pages as needed.
  - e. Tables with more instructions may be provided for struggling students.
  - f. Repeat for each of the other perspectives.
3. Instruct students to graph the stories from each of the four perspectives.
  - a. Graphs with labeled axes may be provided for struggling students.
  - b. Emphasis should be on the shape of the graphs and how they relate to each other rather than exact values.

## Examples:

1. Writing the trip in different formats:
  - a. In paragraph form:
    - On my way to my friend's house, I first walked at *constant speed* out my door and down the driveway for about 15 feet in about 10 seconds. I *turned right* at the sidewalk walking one step (about 3 feet) in about 1 second then walked at a *constant speed* for 3 blocks (about 300 feet) in about 2 minutes. I *turned left* walking one step (about 3 feet) in about 1 second and *stopped* to wait for the light to change for about 1 minute. I *sped up* in several steps (about 10 feet) in about 5 seconds and walked at *constant speed* for 3 blocks (about 300 feet) in about 2 minutes. I *turned left* in one step (about 3 feet) toward my friend's house in about 1 second and *slowed down* for about 15 feet in about 10 seconds until I *stopped* at her door.
  - b. In bulleted or numbered form:
    - First walked at *constant speed* out my door and down the driveway for about 15 feet in about 10 seconds

- I *turned right* at the sidewalk walking one step (about 3 feet) in about 1 second
- Then I walked at a *constant speed* for 3 blocks (about 300 feet) in about 2 minutes
- I *turned left* walking one step (about 3 feet) in about 1 second
- Then I *stopped* to wait for the light to change for about 1 minute
- I *sped up* over several steps (about 10 feet) in about 5 seconds
- I walked at *constant speed* for 3 blocks (about 300 feet) in about 2 minutes
- I *turned left* in one step (about 3 feet) toward my friend’s house in about 1 second
- Finally, I *slowed down* for about 15 feet in about 10 seconds until I *stopped* at her door.

c. In tabular form:

<b>Action</b>	<b>Approximate Distance</b>	<b>Approximate Time</b>
First walked at constant speed out my door and down the driveway	15 feet	10 seconds
I turned right at the sidewalk	1 step (3 feet)	1 second
Then walked at a constant speed	3 blocks (300 feet)	2 minutes (120 seconds)
I turned left	1 step (3 feet)	1 second
Then I stopped to wait for the light to change	0 feet	1 minute (60 seconds)
I sped up	Several steps (10 feet)	5 seconds
I walked at constant speed	3 blocks (300 feet)	2 minutes (120 seconds)
I turned left toward my friend’s house	1 step (3 feet)	1 second
Finally, I slowed down until I stopped at her door	15 feet	10 seconds

2. Writing the trip from **distance perspective**:

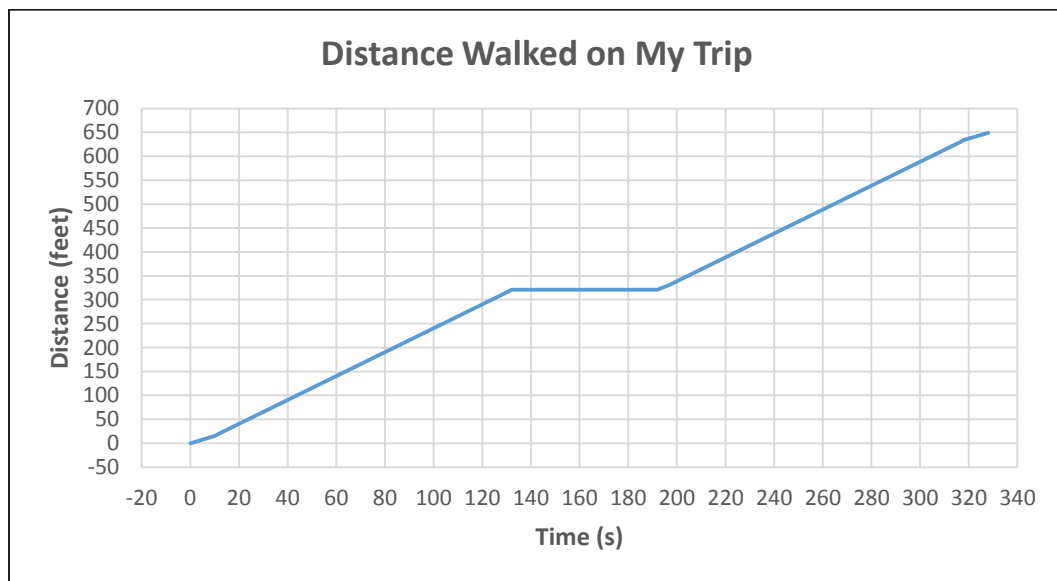
a. In bulleted form:

- First walked at *constant speed* out my door and down the driveway for about 15 feet in about 10 seconds
- I *turned right* at the sidewalk walking one step (about 3 feet) in about 1 second
- Then I walked at a *constant speed* for 3 blocks (about 300 feet) in about 2 minutes
- I *turned left* walking one step (about 3 feet) in about 1 second
- Then I *stopped* to wait for the light to change for about 1 minute
- I *sped up* over several steps (about 10 feet) in about 5 seconds
- I walked at *constant speed* for 3 blocks (about 300 feet) in about 2 minutes

- I *turned left* in one step (about 3 feet) toward my friend’s house in about 1 second
- Finally, I *slowed down* for about 15 feet in about 10 seconds until I *stopped* at her door.

b. An example table and graph:

Time (seconds)	Total Time (seconds)	Distance (feet)	Total Distance (feet)
0	0	0	0
10	10	15	15
2	11	3	18
120	131	300	318
2	132	3	321
60	192	0	321
5	197	10	331
120	317	300	631
1	318	3	634
10	328	15	649



3. Writing the trip from **speed perspective**:

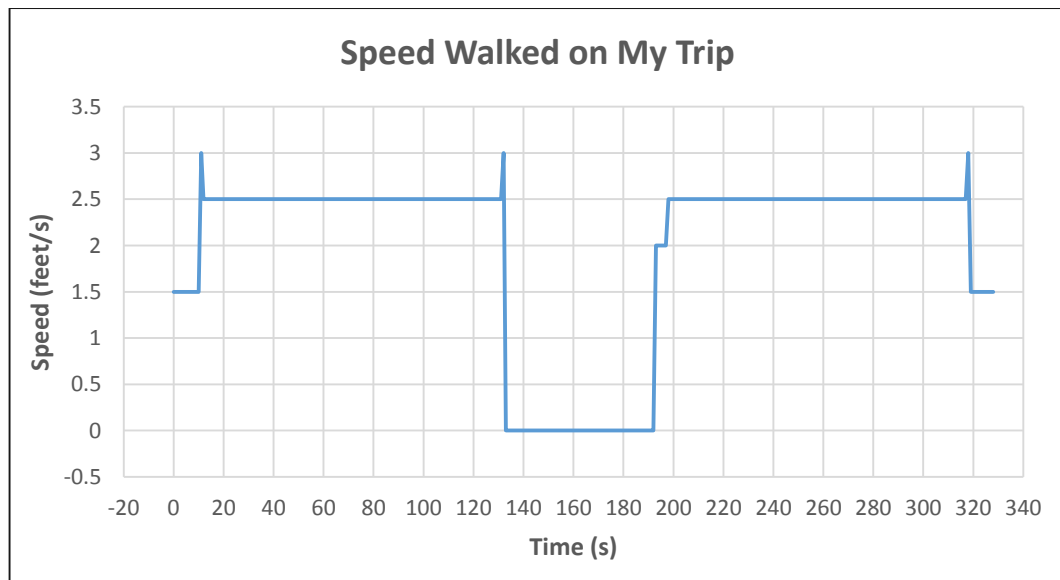
a. In bulleted form:

- First walked at *constant speed* out my door and down the driveway for about 15 feet in about 10 seconds
- I *maintained this speed* when I turned right at the sidewalk walking one step (about 3 feet) in about 1 second
- Then I continued to walk at a *constant speed* for 3 blocks (about 300 feet) in about 2 minutes
- I *maintained this speed* when I turned left walking one step (about 3 feet) in about 1 second

- Then I *decreased my speed suddenly before stopping* to wait for the light to change for about 1 minute
- I *sped up* over several steps (about 10 feet) in about 5 seconds
- I walked at *constant speed* for 3 blocks (about 300 feet) in about 2 minutes
- I *maintained my speed* while I turned left in one step (about 3 feet) toward my friend's house in about 1 second
- Finally, I *slowed down* for about 15 feet in about 10 seconds until I *stopped* at her door.

b. An example table and graph:

Time (seconds)	Speed (feet/s)
0	0
0-10	1.5
10-11	3
11-131	2.5
131-132	3
132-192	0
192-197	2
197-317	2.5
317-318	3
318-328	1.5



4. Writing the story from **acceleration perspective**:

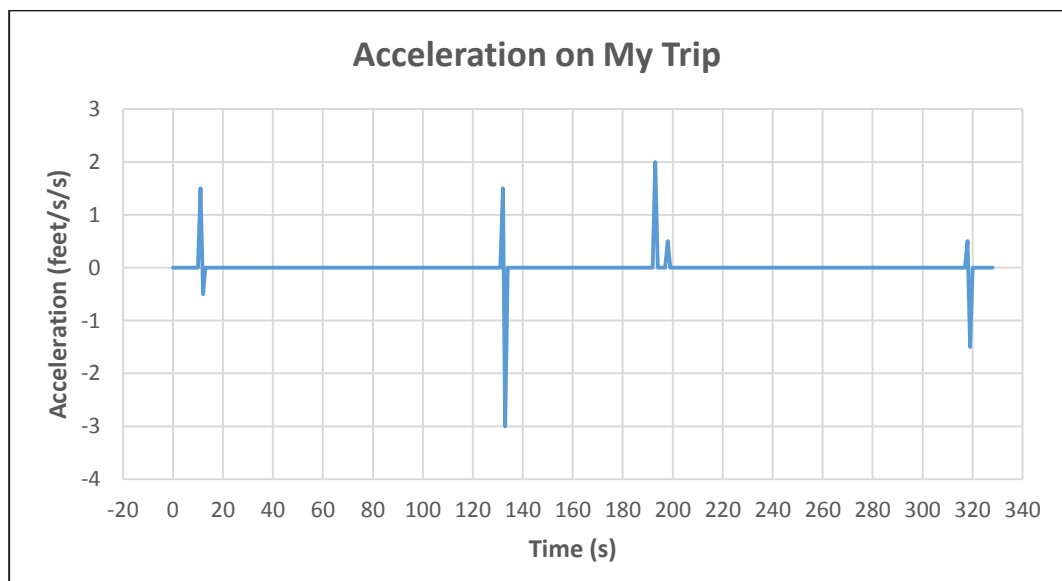
a. In bulleted form:

- First I walked *with no acceleration* out my door and down my driveway (about 10 seconds)
- I turned right *while accelerating slightly* at the sidewalk (about 1 second)

- Then walked *with no change in acceleration* for about 3 blocks (about 2 minutes)
- I turned left *while accelerating slightly* (about 1 second)
- Then I *quickly decelerated* (about 2 seconds) to a stop (about 1 minute)
- I *accelerated to reach constant walking speed* (about 5 seconds)
- I walked *with no acceleration* for about 3 blocks (about 2 minutes)
- I turned left *while accelerating slightly* (about 1 second)
- Finally, I *decelerated slowly* (about 10 seconds) until I stopped at her door.

b. An example table and graph:

Time (seconds)	Acceleration (feet/s/s)
0	0
0-10	0
10-11	1.5
11-12	-0.5
12-131	0
131-132	1.5
132-133	-3
133-192	0
192-193	2
193-197	0
197-198	0.5
198-317	0
317-318	0.5
318-319	-1.5
319-328	0





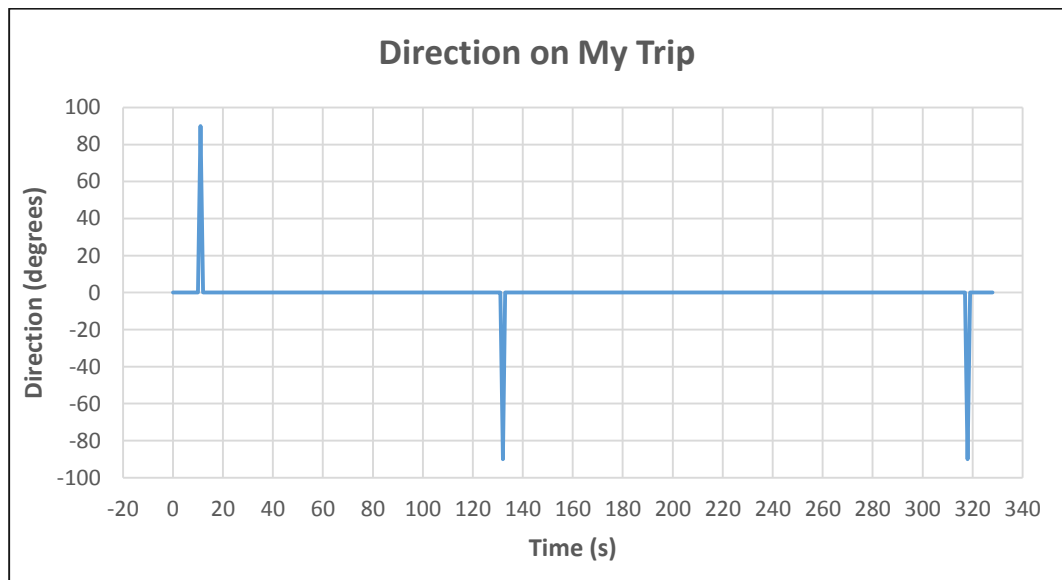
5. Writing the trip from **direction perspective**:

a. In bulleted form:

- First I walked **straight** out my door and down my driveway (about 10 seconds)
- I **turned right** at the sidewalk (about 1 second)
- Then walked **straight** for 3 blocks (about 2 minutes)
- I **turned left** (about 1 second)
- Then I stopped **without turning** to wait for the light to change (about 1 minute)
- I sped up walking **straight** (about 5 seconds)
- I walked **straight** for 3 blocks (about 2 minutes)
- I **turned left** toward my friend’s house (about 1 second)
- Finally, I slowed down while walking **straight** (about 10 seconds) until I stopped at her door.

b. An example table and graph:

Time (seconds)	Direction (degrees)
0	0
0-10	0
10-11	90
11-131	0
131-132	-90
132-317	0
317-318	-90
318-328	0

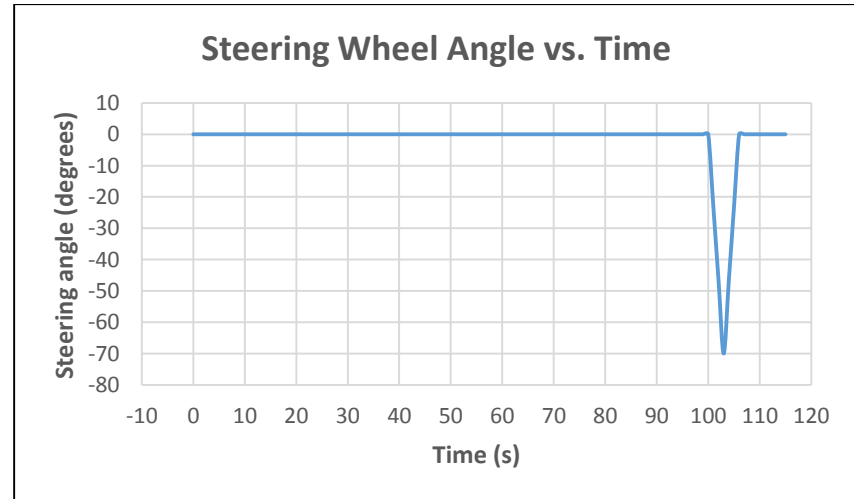
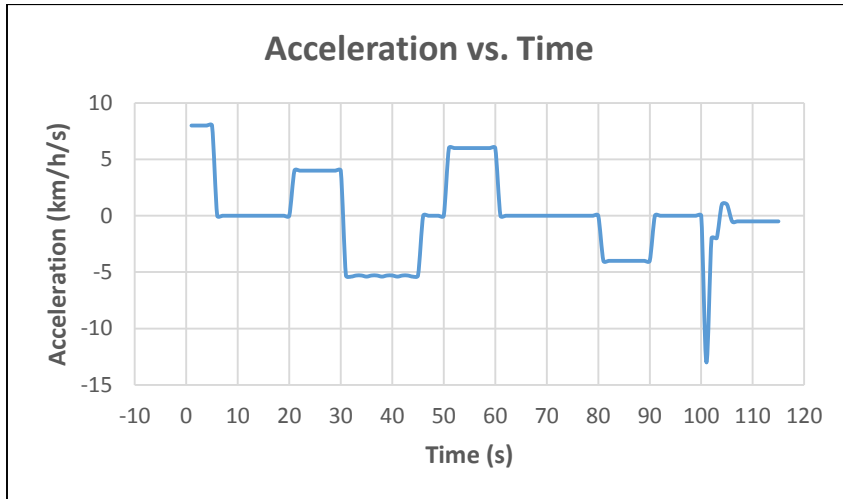
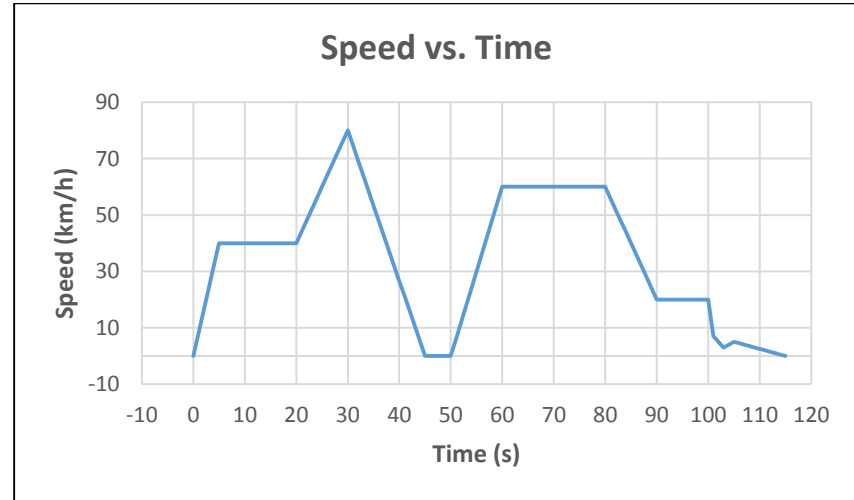
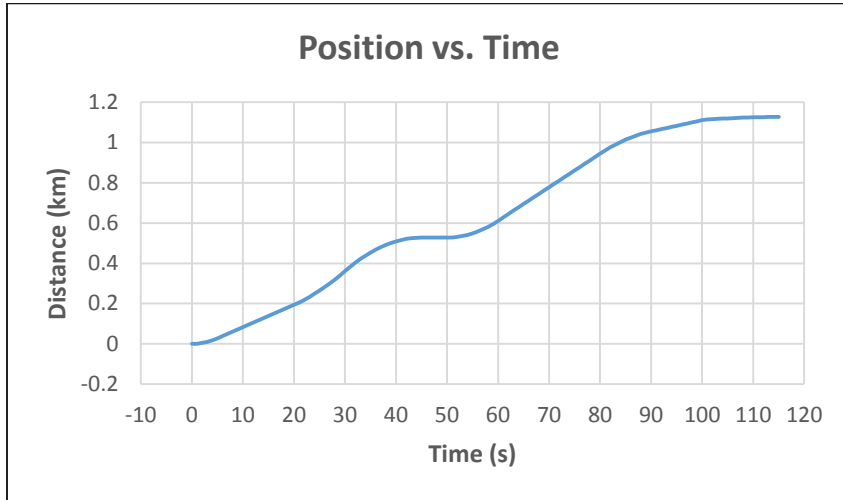


6. These stories can be used by struggling students as additional practice for graphing. Other adjustments may be made to challenge higher performing students and assist ELL students.

7. The basic skills of this task should not be altered in order to interpret the graphs for the simulation activity on day 3.
8. Students will need help with graphing. Provide examples of:
  - a. Graph titles
  - b. Labeling axes - both title and units
  - c. Axes increments
9. For the speed and acceleration graphs, use the same time intervals as in the distance graph. Students can draw the basic shape of the graph. The velocity and acceleration calculations from the *On the Move* activity and teacher notes may be used to calculate actual values, if desired.
10. Grade the homework with the following rubric:

Item/Score	0	1	2	3
<b>Trip Rewrites (from each perspective)</b>	Students did not attempt to write trip from each perspective.	Students attempted to write one or two perspectives, but not all. Student did not include all the necessary details.	Students attempted to write the trip in all three perspectives. Most of the necessary details were included.	Students wrote the trip from all three perspectives with few errors. Most or all of the necessary details were included.
<b>Graphs</b>	Students did not attempt to plot the data, label the axes or determine the best interval for time.	Students had numerous plotting, labeling, or interval errors in their graphs.	Students had some plotting, labeling, or interval errors in their graphs.	Students had few or no errors for each graphs.

# Driving Simulation Graphs Homework



Write out a driving plan that describes the motion of the car that is represented in the above graphs. Compare your plan with your group members and decide on a final plan to use with the simulator.

# Lesson Three: Simulation Driving Day

**Grade level:** 6-8

**Expected length of lesson:** Two days, approximately 90 minutes

## Overview:

On the third day, groups should finalize their driving plan before driving the simulator to replicate the graphs given to them the prior day. Afterwards, NADS generated graphs are compared to the homework graphs. An assessment will follow the NADS simulation and graph comparison.

## Standards and/or benchmarks:

### NGSS:

#### Disciplinary Core Idea:

##### Forces and Motion

- MS-PS2-2:
  - All positions of objects and the directions of forces and motions must be described in an arbitrarily chosen reference frame and arbitrarily chosen units of size. In order to share information with other people, these choices must also be shared.

#### Cross-Cutting Concepts:

- MS-PS3-1, MS-PS3-4:
  - Proportional relationships (e.g. speed as the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes.

#### Science and Engineering Practices:

##### Planning and Carrying Out Investigations

- MS-PS2-2:
  - Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim.
- MS-PS2-5:
  - Conduct an investigation and evaluate the experimental design to produce data to serve as the basis for evidence that can meet the goals of the investigation.

## Iowa Core:

- S.6–8.PS.3
  - Essential Concept and/or Skill: *Understand and apply knowledge of motions and forces.*
    - The motion of an object can be described by its position, direction of motion, and speed. That motion can be measured and represented on a graph.

## Learning Goals:

Students will understand:

- How position vs time, speed vs time, acceleration vs time and steering (or direction) vs time are related
- Multiple graphs are necessary to know the whole story of complex motions.

## Learning Performances:

Students will be able to:

- Generate a driving plan from the 4 graphs provided.
- Compare simulation graphs to activity graphs.
- Compare simulation graphs between groups.
- Decide the criteria to pick a winner of the driving contest.

## Materials:

- Activity graphs
- NADS simulator
- Describing Motion and Position Using Graphs (Assessment Activity)
- Assessment Key and Rubrics

## Safety:

Make sure students with a history of motion sickness do not drive the simulator.

## Critical Thinking Question:

What story are the graphs are telling us?

## Student Ideas:

Students will devise a method to translate a graphical representation of motion into a real-world complex motion using the simulator.

## Main Lesson:

At the end of the second lesson plan, students were given the four activity graphs to analyze to create a list of motion segments from information on the graphs. Roles for each group member were also assigned (timer, driver, manager, coach).

1. Students will gather in assigned groups of 3-4, with member roles already assigned.
  - a. Students should compare the trips they wrote from the graphs.
  - b. An example of the trip that may be used to check the work of the students:

Action	Details	Total Time (seconds)
Accelerate	Go from 0 km/h to 40 km/h in 5 seconds	5
Constant speed	Continue at 40 km/h for 15 seconds	20
Accelerate	Go from 40 km/h to 80 km/h in 10 seconds	30
Decelerate	Go from 80 km/h to 0 km/h in 10 seconds	40
Full stop	Stop for 10 seconds	50
Accelerate	Go from 0 km/h to 60 km/h in 10 seconds	60 (1:00)

Constant speed	Continue at 60 km/h for 20 seconds	80 (1:20)
Decelerate	Go from 60 km/h to 20 km/h in 10 seconds	90 (1:30)
Constant speed	Continue at 20 km/h for 10 seconds	100 (1:40)
Turn	Turn left	105 (1:45)

- c. The manager should determine the final trip for the group.
  1. This will be the instructions the group uses to drive on the simulator.
2. When the trips are finalized, have the class decide the criteria that will determine the winner.
  - a. Examples of criteria include: accelerating at the right times, accelerating at the correct rate, maintaining correct speeds, turning the correct direction, etc.
3. Explain that each group will have one attempt to drive the simulation to generate graphs as close to the given activity graphs as possible.
  - a. If time permits, groups may have the ability to drive more than once.
4. Choose how to decide the order of groups.
  - a. Groups should not be allowed to watch others drive the simulator.
5. Graphs will be generated by the simulation program after all groups have finished their simulation.
  - a. The ideal graphs (from the homework) will be the black line on the graph.
  - b. Each graph will contain all of the trials from the groups in different colors.
  - c. Groups will not know what color they are until after the winner is decided.
  - d. Winners will be given prizes brought by NADS (pencils, highlighters, etc.).
6. Based on the criteria chosen above (in step 2), the class chooses which color is the winner.
  - a. Each group's color will then be revealed.
7. A whole class discussion will facilitate a comparison of the graphs between groups and given activity graphs.
  - a. Discuss what they could have done differently to create graphs closer to the graphs given to them.
  - b. Discuss why their graphs are not identical to the graphs given to them.

### **Differentiation:**

- ELL: Put them in groups with stronger students who will assist them in understanding.
- TAG: Have them create their own scenario and their own graph for the Describing Motion and Position Using Graphs Worksheet.
- Special Education: Provide the labels on graphs axes for the Describing Motion and Position Using Graphs Worksheet.

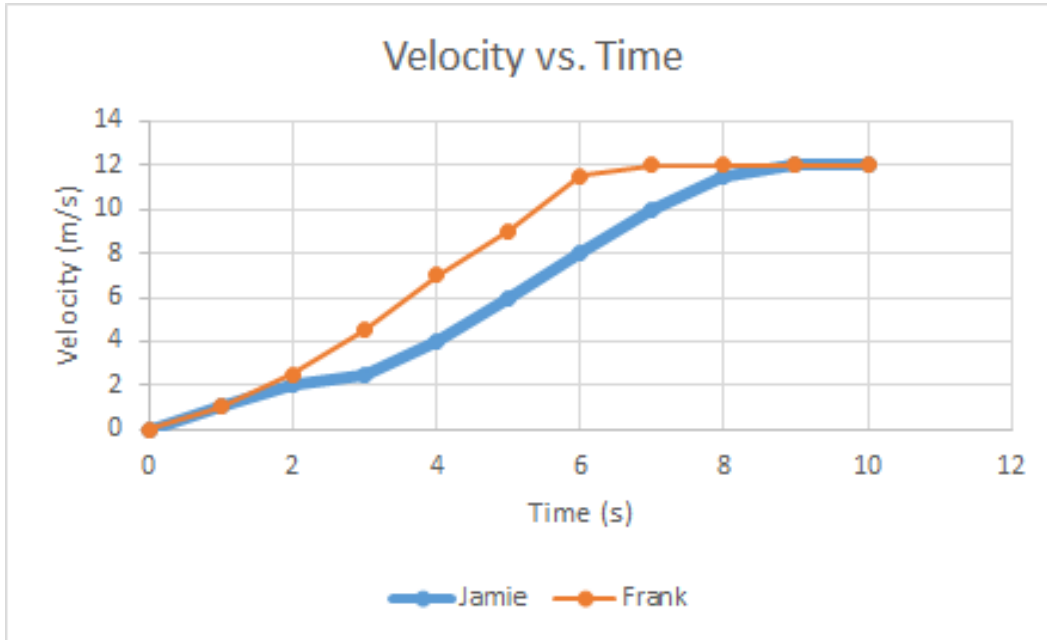
### **Assessment:**

Use the *Describing Motion and Position Using Graphs* assessment worksheet to check for understanding at the end of the progression:

- Graph axes may be filled in for students with special needs.
- ELL students may be allowed to use verbal descriptions to answer the questions.

# Describing Motion and Position Worksheet

Name: \_\_\_\_\_ Date: \_\_\_\_\_



1. How does velocity relate to acceleration? From 2-4 seconds, did Jamie or Frank accelerate faster? Explain why.

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2. What does a horizontal line on each graph indicate about the motion?

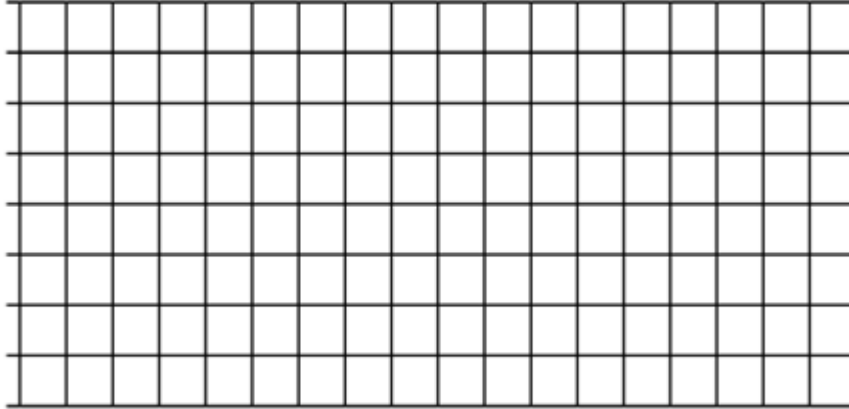
Position vs. time \_\_\_\_\_

Velocity vs. time \_\_\_\_\_

Acceleration vs. time \_\_\_\_\_

Direction vs. time \_\_\_\_\_

3. John starts timing and documenting the speed of the car while his mother is driving. She is going 25 km/h for the first 10 seconds and then speeds up to 35 km/h in 5 seconds. She stays at 35 km/h for 5 seconds until she comes to a red light and stops in 10 seconds. Draw and label the velocity vs. time graph.





## Describing Motion and Position Assessment Key and Rubrics

Question 1 Rubric:

Item/Score	0	1	2	3
<b>Mathematical Concepts</b>	Velocity and acceleration are not related.	An incorrect relationship between velocity and acceleration is presented.	A relationship between velocity and acceleration is correct but does not demonstrate understanding (e.g. m/s/s).	Acceleration is defined as the change in velocity over change in time.
<b>Explanation</b>	Fails to state that Frank accelerated at a faster rate.	Claims that Frank accelerated at a faster rate without an explanation.	Claims that Frank accelerated at a faster rate with a partial explanation (e.g. steeper graph).	Claims that Frank accelerated at a faster rate with an explicit explanation (e.g. steeper graph means that velocity changes at a faster rate which means a higher value of acceleration).

Question 2 Answer Key:

Position vs. time                    Object is not moving

Velocity vs. time                    Object is moving at constant velocity

Acceleration vs. time              Object is accelerating at a constant rate

Direction vs. time                  Object is moving in a straight line

Question 3 Rubric:

<b>Item/Score</b>	<b>0</b>	<b>1</b>	<b>2</b>	<b>3</b>
<b>Accuracy of Plot</b>	Points are not plotted correctly or extra points were included.	Most points are plotted correctly or some points are missing.	All points are plotted correctly and are easy to see but may not have carefully drawn lines.	All points are plotted correctly and are easy to see. A ruler is used to neatly connect the points or make the bars, if not using a computerized graphing program.
<b>Title</b>	A title is not present.	A title is present at the top of the graph but does not relate to the graph.	Title relates to the graph but may not be completely correct.	Title is explicit and printed at the top of the graph.
<b>Labeling of X-Axis</b>	The X axis is not labeled.	The X axis has a label without units.	The X axis is labeled with the units only (e.g. seconds, minutes)	The X axis has a clear, neat label that includes the units used for the independent variable (e.g, time).
<b>Labeling of Y-Axis</b>	The Y axis is not labeled.	The Y axis has a label without units.	The Y axis is labeled with units only (e.g, m/s, meters).	The Y axis has a clear, neat label that includes the units for the dependent variable (e.g, velocity, acceleration, distance, direction).

# Unit 2

## A World with Friction

### Goals:

To educate middle school students about friction and how it affects driving. Students will understand that there are forces and factors that influence motion, including mass, velocity, and friction.

### Justification:

Middle school students have many misconceptions about physics, particularly friction. These misconceptions are as follows:

- Friction is caused by surface roughness (there are many times when this is indeed true, but others where a surface may not be as rough but still have more friction, ex: the sticky side of tape is less rough than sandpaper but has more friction)
- An object doesn't stop because of a presence of a force; it stops because of an absence of a force
- Objects at rest have no forces acting on them
- Moving objects come to a stop even when there is no friction
- Friction only occurs between solids
- There are tiny bumps that cause friction (the use of sandpaper)
- Friction always hinders motion; reducing friction is always desired

The science teacher should identify where these misconceptions come from, and provide experiences for students to address these ideas to construct scientifically accepted understandings.

# Lesson One: Factors that Affect Motion

**Grade level:** 6-8

**Expected length of lesson:** 45-90 Minutes

## Overview:

This lesson will serve as an introduction to the driving simulator activity. Students will collect data and draw conclusions about how different variables such as mass, velocity, and friction affect motion. Students will then be introduced to the stopping distance calculation that they will use in the driving simulation activity.

## Standards and Benchmarks:

### NGSS:

#### Performance Expectations:

- MS-PS3-5:
  - Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object.

#### Disciplinary Core Ideas:

- MS-PS3-1:
  - Motion energy is properly called kinetic energy; it is proportional to the mass of the moving object and grows with the square of its speed.
- MS-PS3-5:
  - When the motion energy of an object changes, there is inevitably some other change in energy at the same time.

#### Cross-Cutting Concepts:

- MS-PS2-1, MS-PS2-1:
  - Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy and matter flows within systems.

#### Science and Engineering Practices:

- MS-PS2-4:
  - Construct and present oral and written arguments supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem.
- MS-PS2-5:
  - Conduct an investigation and evaluate the experimental design to produce data to serve as the basis for evidence that can meet the goals of the investigation.

## Iowa Core

### Science:

- S.6-8.PS.3:
  - Understand and apply knowledge of motions and forces.

### Mathematics:

- 6.EE.C.9:
  - Use variables to represent two quantities in a real–world problem that change in relationship to one another; write an equation to express one quantity, thought of as the dependent variable, in terms of the other quantity, thought of as the independent variable. Analyze the relationship between the dependent and independent variables using graphs and tables, and relate these to the equation.
- 6.EE.B.6:
  - Use variables to represent numbers and write expressions when solving a real–world or mathematical problem; understand that a variable can represent an unknown number, or, depending on the purpose at hand, any number in a specified set.

### Literacy:

- WHST.6-8.1:
  - Write arguments focused on discipline–specific content.
- WHST.6-8.10:
  - Write routinely over extended time frames (time for reflection and revision) and shorter time frames (a single sitting or a day or two) for a range of discipline–specific tasks, purposes, and audiences.

### **Learning Goals:**

Students will understand that:

- There are many forces and factors that influence motion, including mass, velocity, and friction.
- Friction is a force that opposes motion.
- Velocity is a measure of distance traveled during a certain time.
- Mass is what is pulled on by gravity to determine weight.
- Stopping distance varies with road surface conditions (friction), mass of the vehicle, and velocity of the vehicle.

### **Learning Performances:**

Students will be able to:

- Solve the stopping distance equation:
- Describe the effects that velocity, friction, and mass have on the motion of an object.

$$d = \frac{v_0^2}{2\mu g}$$

### **Materials:**

- Friction Probe #17 *Uncovering Student Ideas in Physical Science* 2010 (by Page Keeley)
- 3 small model cars
- 3 ramps
- Weight to attach to car (to increase mass of car)
- Towel or other material (to increase friction)
- Textbooks to elevate ramps (for control experiment and to increase velocity)

### **Students' Ideas:**

- Students may think there is no friction between stationary objects.
- Students may not know terms such as mass, velocity, and friction.
- Students may not realize what factors affect stopping distance.

## Critical Thinking Questions:

- What factors affect motion?
- What factors affect stopping distance of a vehicle?

## Main Lesson:

The teacher gives a brief outline of the simulation project and shows a video of the simulator being driven so students know what to expect. This engages students and prepares them for driving the simulator, as they do not have driving experience.

1. The teacher administers the Friction Probe to elicit students' current understanding/misconceptions about friction and forces. The teacher passes out the friction probe, or projects it and students will have 5 minutes to complete it or write their answers in their science notebooks. The teacher collects the probe to see what misconceptions students have about friction and tallies the responses on the board.
2. Students are broken into groups of 3 (Simulation Groups). Within each group, students decide which area of expertise to join, either mass, friction, or velocity (Expert Groups). If there need to be 4 students in a Simulation Group, two students should join Expert Group 2: Friction.

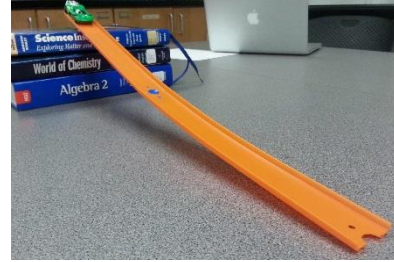
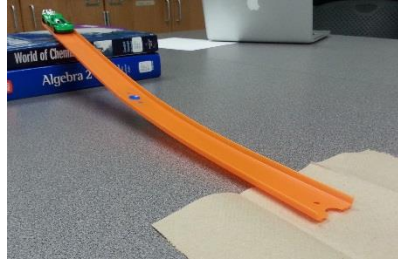
Expert Groups:

- a. Group 1: Mass
- b. Group 2: Friction
- c. Group 3: Velocity

The goal is for each student to become an expert in one area, which they will later bring back to their group to assist in the simulation. The three groups do three variations of the activity to see how different factors affect stopping distance. Each student receives a worksheet on which to record their predictions, data, and conclusions.

3. Each Expert Group sets up a ramp and rolls a toy car down it to measure how far from the bottom of the ramp it stops. They record this on their worksheet. Then they perform the activity according to their specific variation.
  - a. Expert Group 1 weighs their car, then adds a weight to it and weighs it again. They measure the stopping distance of the car with the added mass.
  - b. Expert Group 2 adds a paper towel to the bottom of the ramp (at least as long as the meter stick) to increase friction and records the stopping distance of the car on the new surface.
  - c. Expert Group 3 makes their ramp steeper (2 times steeper if possible) so the velocity of the car is increased. They measure their new stopping distance.





4. Students draw conclusions in their Expert Groups, then have a whole class discussion where one or two students from each Expert Group share their findings with the rest of the class by drawing a picture on the board and orally describing their observations. All students should record the conclusions of each group.
5. The teacher passes back the Friction Probe papers and then reviews the correct answers with the students. Students make changes to their original ideas on their papers or in their science notebooks.
6. Students get into their Simulation Groups and the teacher introduces the stopping distance equation used for the simulation activity. Students should understand what each variable means, and they should be exposed to some examples of how to use the equation.

$$d = \frac{v_0^2}{2\mu g}$$

d = stopping distance  
 v = velocity  
 $\mu$  = coefficient of friction  
 g = gravity

7. Wrap up:
  - a. The teacher gives brief instructions for how the simulation day will proceed so that students are organized and prepared.

### **Differentiation:**

#### Special Needs Students:

- Assistive technologies such as Dragon, Read & Write GOLD, etc.
- Modeling of tasks
- Modified worksheets or notes provided by the teacher

#### ELL Students:

- Strategic grouping
- Modeling of tasks
- Pictures
- Vocabulary list of difficult terms: mass, velocity, friction, stopping distance, force, motion, ramp, vehicle, variable, control group, experimental group
- Word-bank for worksheet
- Allow use of translation devices

#### Advanced Learners:

- Can be introduced to more advanced formulas and concepts, such as how friction is determined ( $F = \mu N$ , Frictional Force = coefficient of friction times Normal Force) and how speed could be adjusted to produce different stopping distances.

**Assessment:**

- Formative assessment:
  - Friction Probe (pre-lesson and post-lesson)
  - Student presentations of findings from Expert Groups
  - Simulation calculations and performance
- Summative assessment:
  - Activity Worksheet
  - Activity Homework
  - Assessment quiz
  - Class discussion



# Friction

Ansel slides down the playground slide. He notices that the new pants he is wearing slow him down on the slide. When he mentions this to his friend Sergio, Sergio says the rubbing of Ansel's pants against the slide was caused by something called friction—and it is the friction that made Ansel slow down. Ansel wonders about the other ways friction could occur. Check off all the kinds of contact that could cause friction.



- A** Car tires rolling on the road
- B** A magnet on the front of a refrigerator
- C** A box sliding down a hill
- D** A box sitting on the slope of a hill (not moving)
- E** A box sitting on a flat table
- F** Rollerblading on a flat road
- G** Ice skater gliding on an ice rink
- H** Car parked on a steep driveway (not moving)
- I** Laundry hanging on a clothesline with clothespins

Explain your thinking. What rule or reasoning did you use to decide what causes friction?

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# Friction

## Teacher Notes



### Purpose

The purpose of this assessment probe is to elicit students' ideas about friction between solid objects. The probe is designed to determine (a) whether students recognize friction as an interaction between two objects or materials that rub against/slide over each other and (b) whether they limit this interaction to a particular type of matter or contact.

### Related Concepts

contact force, friction, interaction, kinetic friction, rolling friction, sliding friction, static friction

### Explanation

All of the choices are examples of friction with the exception of E (box sitting on a flat table). A wheel rolling on a surface is an example of "rolling friction." A magnet is attracted to the refrigerator with a magnetic force, but it is the frictional force that prevents the magnet from sliding down the front of the refrigera-

tor. A box would slide down a hill if there were no friction between the box and the hill. Although an ice rink provides a low friction surface, there is still some friction between an ice skate and the ice rink (the skater will eventually slow down and stop if she does not push off). Even a clothespin can only work because of the friction force between the clothes and the surface of the clothespin. In all of the examples except for A and F, which are examples of rolling friction, the friction force acts parallel to the two surfaces that are in contact with each other. Because the surfaces are sliding past each other, C and G are examples of what is called "kinetic friction." The other examples (except for A and F) are called "static friction" because the surfaces are not moving relative to one another.

### Administering the Probe

This probe is best used with middle school and high school students. It can also be used with upper elementary students by removing the

## Forces and Newton's Laws

static friction distracters that don't involve a visible rubbing or sliding (i.e., B, D, H, and I).

### Related Ideas In *National Science Education Standards* (NRC 1996)

#### 5–8 Motions and Forces

- ★ Unbalanced forces will cause changes in the speed or direction of an object's motion.

#### 9–12 Motions and Forces

- Objects change their motion only when a net force is applied.

### Related Ideas In *Benchmarks for Science Literacy* (AAAS 1993, 2009)

#### 3–5 Motion

- Changes in speed or direction of motion are caused by forces.

#### 6–8 Motion

- ★ An unbalanced force acting on an object changes its speed or direction of motion, or both.

#### 9–12 Forces of Nature

- ★ Electric forces hold solid and liquid materials together and act between objects when they are in contact—as in sticking or sliding friction.

### Related Research

- In a study by Stead and Osborne (1981), 50% of 13-year-olds in their sample group of 38 12- to 16-year-olds associated friction with rubbing (Driver et al. 1994).
- Some students thought that if a box is motionless on a slope, there is no friction (because there is no rubbing, heat, or wearing down of surfaces) (Stead and Osborne 1980).

- In a group of 47 secondary students, the following ideas about friction were held: Friction occurs only between solids (12 students) and friction occurs with liquids but not with gases (10 students). Only 16 students called friction a force (the responses of 9 students were in an “other” category) (Stead and Osborne 1980).

### Suggestions for Instruction and Assessment

- Ask students to recall times when they easily slid down a slide on a playground and other times when they were slowed down on the slide. Ask them to compare the interaction between themselves and the slide that occurred in each case.
- It is important to develop the concept of interactions when teaching about friction.
- Encourage students to come up with examples of friction involving moving and stationary objects.
- Consider extending the probe to examples that include fluid friction, such as the drag on an object in air or water.
- Research shows that some students may benefit from the introduction of an intermediate model of friction, similar to the bridging analogies used by Clement (1993) (Besson and Viennot 2004). For example, have students try to slide two hairbrushes across each other. Students will see the bristles pushing against each other.

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★ Indicates a strong match between the Ideas elicited by the probe and a national standard's learning goal.

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# Friction Matters Activity

Name: \_\_\_\_\_ Date: \_\_\_\_\_

**Materials:** Use the following materials to complete the experiment below.

- Toy car
- Ramp
- 2 Textbooks
- Yard Stick
- Weights, Paper Towel or Extra Textbook

**Activity Step by Step:** Use the following steps to complete the experiment

1. In your group of three pick your Expert Group Variable
  - YOUR EXPERT GROUP IS: \_\_\_\_\_
2. Retrieve your materials:
  - Velocity Expert = extra textbooks
  - Mass Expert = weights
  - Friction Expert = Towel
3. Control Group Trials:
  - Place 2 textbooks under one side of the ramp.
  - Place the yardstick at the end of the ramp.
  - Release the car from the top of the ramp, and use the yardstick to measure the distance between the end of the ramp and the stopped car (in centimeters). Repeat this THREE times.
4. Record your Control Group data in the chart on page 2.
5. Write a prediction on page 2, question 1.
6. Repeat the experiment three times using your experimental variable
  - Velocity Experts: raise the ramp by adding another textbook to increase velocity.
  - Mass Experts: attach a weight to the car to increase mass.
  - Friction Experts: lay the paper towels at the end of the ramp to change the friction of the surface.
7. Record your data in the chart on page 2
8. Compare your data from the Control and Experimental groups and write a brief conclusion (Note: Activity continues at end of packet.)

**Predictions:** Use the space below to answer the questions in complete sentences.

1. Based on what you know about the Expert Group Variable you have chosen, what do you predict will happen when your variable is added to the experiment?

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**Experiment Data:** Add your data found in the experiment to the chart below

	Control Group	Experimental Group
Trial 1 Stopping Distance		
Trial 2 Stopping Distance		
Trial 3 Stopping Distance		
Average Stopping Distance		

**Conclusion:** Use the space below to answer the questions in complete sentences.

1. Based on the data that you have collected through this experiment, what can you conclude about your Expert Group Variable?

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2. How can you use math to compute the stopping distance if given all the variables?

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### Activity Continued

1. Return to your Simulation Group.
2. In your Simulation Group, explain to the other members what data you found in your Expert Group.

## Friction Matters Homework

Name: \_\_\_\_\_ Date: \_\_\_\_\_

**Definitions:** Write your own definitions to each vocabulary word listed below.

Friction: \_\_\_\_\_  
\_\_\_\_\_

Mass: \_\_\_\_\_  
\_\_\_\_\_

Velocity: \_\_\_\_\_  
\_\_\_\_\_

Force: \_\_\_\_\_  
\_\_\_\_\_

Stopping Distance: \_\_\_\_\_  
\_\_\_\_\_

**Equations:** Based off of the given equation, match the variables with their abbreviations.

$$d = \frac{v_0^2}{2\mu g}$$

**d** = \_\_\_\_\_

**v** = \_\_\_\_\_

**μ** = \_\_\_\_\_

**g** = \_\_\_\_\_

**Discussion Questions:** Use the space provided to answer the questions in complete sentences.

1. Explain how surface type influences the amount of friction.

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

2. Analyze how friction can be both a positive and negative part of our everyday lives. Use examples to support your statements.

POSITIVE: \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

NEGATIVE: \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

3. Describe what a daily activity would be like if there were no friction. How would the activity be easier, and how would it be more difficult?

\_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

**Further Your Thinking:** Consider the picture below when answering the question below.

**Typical Stopping Distances**





1. How might reaction time influence your stopping distance?

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# Fiction Matters Homework Teacher Key

**Definitions:** Write your own definitions to each vocabulary word listed below

Friction: \_\_\_\_\_ The resistance of motion when one object rubs against another

\_\_\_\_\_

Mass: \_\_\_\_\_ A measure of a numbers of atoms in an object

\_\_\_\_\_

Velocity: \_\_\_\_\_ The speed and direction of an object

\_\_\_\_\_

Force: \_\_\_\_\_ Strength or energy that causes a physical action or motion

\_\_\_\_\_

Stopping Distance: \_\_\_\_\_ Measured amount of space it requires to become stationary

\_\_\_\_\_

**Equations:** Based off of the given equation, match the variables with their abbreviations.

$$d = \frac{v_0^2}{2\mu g}$$

**d** = \_\_\_\_\_ stopping distance

**v** = \_\_\_\_\_ velocity

**μ** = \_\_\_\_\_ coefficient of friction

**g** = \_\_\_\_\_ gravity

**Discussion Questions:** Use the space provided to answer the questions in complete sentences.

1. Explain how surface type influences the amount of friction.

\_\_\_\_\_ Answers may vary. Generally, a rougher surface causes there to be more friction  
and a smoother surfaces causes less friction.

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

- Analyze how friction can be both a positive and negative part of our everyday lives. Use examples to support your statements.

POSITIVE: Answers may vary. Friction allows you to travel, play sports, write with your pencil and many more things. Without friction we would always be moving unless stopped by an outside force.

NEGATIVE: Answers may vary. Friction causes you to lose energy while traveling, playing sports and writing with your pencil. Without a stronger opposing force friction would always slow you down.

- Hypothesize what a daily activity would be like if there were no friction. How would the activity be easier, and how would it be more difficult?

Answers may vary. When going to school without friction you would have to accurately aim and push off from your front door. You'd have to hope to not hit any objects that may change your route. This would make getting to school faster as long as you didn't run into any objects but would make it much more difficult overall and probably painful.

**Further Your Thinking:** Consider the picture below when answering the question below.

### Typical Stopping Distances



Photo from The Department of Transportation Highway Code

1. How does reaction time and distance change when your vehicle goes faster?

Answers may vary. As your car goes faster, you travel further during your reaction time, causing your stopping distance to be longer.

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# Lesson Two: Simulation Driving Day

**Grade level:** 6-8

**Expected length of lesson:** 45 minutes

## Overview:

The purpose of the lesson is to have students collect data on stopping distance using a combination of variables. Students are assigned their variable combination and are to complete their calculations predicting the stopping distance needed with that variable combination. The variables are: car type (either the BMW or Expedition) and coefficient of friction (COF) (0.85, 0.4, or 0.2). There are six possible car and coefficient of friction combinations: BMW+0.85 Coefficient Of Friction, BMW+0.4 COF, BMW+0.2 COF, Expedition+0.85 COF, Expedition+0.4 COF, and Expedition+0.2 COF. Students drive the simulator for their given variables. The simulation will be set up to match each group's variable combination when they arrive at the simulator. After students run the simulation for their assigned variables they record their results, discuss their results with class members, and partake in journaling as an assessment.

## Standards and Benchmarks:

### NGSS:

#### Performance Expectations:

- MS-PS2-2:
  - 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. For any given object, a larger force causes a larger change in motion.
- MS-PS2-1:
  - For any pair of interacting objects, the force exerted by the first object on the second object is equal in strength to the force that the second object exerts on the first, but in the opposite direction (Newton's third law).

#### Cross-Cutting Concepts:

- MS-PS2-3, MS-PS2-5:
  - Cause and effect relationships may be used to predict phenomena in natural or designed systems.
- MS-PS2-1, MS-PS2-4:
  - Models can be used to represent systems and their interactions such as inputs processes and outputs and energy and matter flows within systems.
- MS-PS2-2:
  - Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales.

#### Science and Engineering Practices:

- MS-PS2-4:

- Construct and present oral and written arguments supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem.
- MS-PS2-2, MS-PS2-4:
  - Science knowledge is based upon logical and conceptual connections between evidence and explanations.

## **Iowa Core**

### Science:

- S.6–8.PS.3:
  - Essential Concept and/or Skill: Understand and apply knowledge of motions and forces. The motion of an object can be described by its position, direction of motion, and speed. That motion can be measured and represented on a graph.

### Comprehension and Collaboration:

- SL.8.1:
  - Engage effectively in a range of collaborative discussions (one–on–one, in groups, and teacher–led) with diverse partners on *grade 8 topics, texts, and issues*, building on others’ ideas and expressing their own clearly.
- SL.8.2:
  - Analyze the purpose of information presented in diverse media and formats (e.g., visually, quantitatively, orally) and evaluate the motives (e.g., social, commercial, political) behind its presentation.
- SL.8.3:
  - Delineate a speaker’s argument and specific claims, evaluating the soundness of the reasoning and relevance and sufficiency of the evidence and identifying when irrelevant evidence is introduced.

### Presentation of Knowledge and Ideas:

- SL.8.4:
  - Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well–chosen details; use appropriate eye contact, adequate volume, and clear pronunciation.

## **Learning Goals:**

Students will understand:

- Motion is dependent on the forces acting on it. In our simulation, the motion of the car is dependent on the amount of friction of the pavement.
- The relationship between friction and stopping distance.
- How a simulation can be used to demonstrate a topic in a novel and real-world way.

## **Learning Performances:**

Students will be able to:

- Properly calculate stopping distance given the variables: car type and coefficient of friction.

- Understand how friction and stopping distance are related by understanding that an increase in friction means a decrease in stopping distance (higher friction (closer to 1.0) means less time required to stop).

### **Materials:**

- Calculations from the previous day
- Their science journals or notebooks to write down observations and discoveries
- The MiniSim Simulator provided by the National Advanced Driving Simulator

### **Safety:**

- Safety guidelines for simulation use from NADS:
- Do not use if you have motion sickness
- Do not use if you have any medical condition that would make your participation unsafe for you (heart condition, etc.)

### **Students' Ideas:**

There are two different aspects that students should know before the day of the simulation. The first idea is the definition of friction and how friction impacts everyday life. If students do not know what friction is they will not understand why there is a difference between pavement conditions. The second idea that students should know is how to do the mathematical calculation needed to figure out stopping distance. If students do not know how to use this calculation they will be unable to predict stopping distance for their given variables. Students will come into this topic with some misconceptions that need to be addressed and will hopefully be corrected during this lesson. The misconceptions that students may have are:

- Friction is caused by surface roughness (there are many times when this is indeed true, but others where a surface may not be as rough but still have more friction, ex: the sticky side of tape is less rough than sandpaper but has more friction)
- An object doesn't stop because of a presence of a force; it stops because of an absence of a force
- Objects at rest have no forces acting on them
- Moving objects come to a stop even when there is no friction
- Friction only occurs between solids
- There are tiny bumps that cause friction (the use of sandpaper)
- Friction always hinders motion; reducing friction is always desired

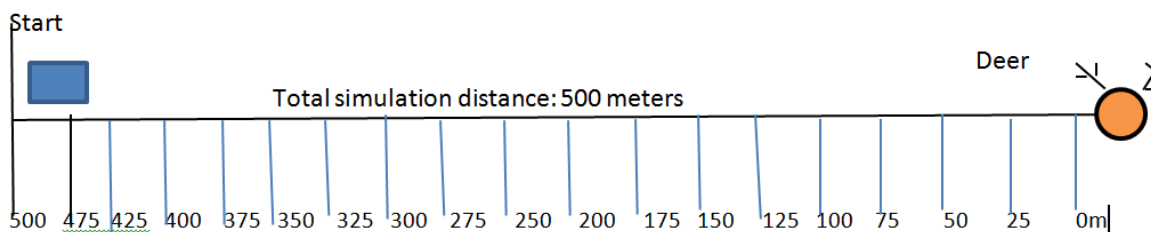
### **Critical Thinking Questions:**

- How much stopping distance does each vehicle require to stop safely at different driving conditions?
- Which vehicle will stop in a shorter distance? Why do you think that?
- What other factors might affect stopping distance?
- Why might your calculations have been off?
- How is the simulator different than the real world?

### **Main Lesson:**

#### **Introduction:**

Because these students are at a particular age when driving begins to be relevant to their lives, the simulation assists in their understanding of the concept of friction in a way that relates to their futures in driving. By using this real world scenario as a teaching tool, the students are more likely to engage in the classroom and be prone to learning. Before completing the simulation, students are to make predictions of how much stopping distance is required. After the simulation, those predictions are to be proven true or false, therefore, correcting any misconceptions or reinforcing the concept. Below is a rough drawing of what the simulation will look like:



**Lesson:**

1. The teacher splits the class into their Simulation Groups (about 3 students) and each team is assigned a combination of variables (BMW+0.85 COF, BMW+0.4 COF, BMW+0.2 COF, Expedition+0.85, Expedition+0.4, or Expedition+0.2).
2. Students will then plug in their variables to the stopping distance equation found below.

$$d = \frac{v_0^2}{2\mu g}$$

v=velocity=50mph=22.352meters/second  
 g=gravity=9.8meters/second<sup>2</sup>  
 μ=coefficient of friction  
 d=stopping distance

3. After the groups have computed their stopping distance they have to take turns driving the simulator. When one group is driving the rest should be journaling about what they predict will happen and how much stopping distance they will require to stop safely. The students can also practice the simulation by walking through what might happen and applying the mathematical equation above. Students within the groups driving the simulator assist the driver by recording the road marker at which they applied the brakes, the marker at which the vehicle came to a complete stop, and whether or not the vehicle hit the deer or stopped safely before it.
4. After driving the simulator the groups write another journal entry about the experience, whether their calculation was accurate, and whether they successfully completed the simulation.
5. When all groups have finished the simulation and journaling any remaining class time is to be used to discuss the results. The following class time will focus on these results and use official graphs from the simulation to interpret which team did a better job at stopping under each condition.
6. After completing the simulation students journal about their findings and defend or reevaluate their predictions from day one. If remaining class time allows, the entire class can discuss what each group's results were and whether or not they correlate with the mathematical calculations.



## **Differentiation:**

### Students with Special Needs:

- For those students who are unable to be in the simulator because they get motion sickness, are unable to drive due to physical or mental disabilities, or have a health condition that prevents them from driving arrangements can be made to watch other students drive or to watch a video of someone driving in order to still see the results.
- Students who are unable to physically drive the simulator could serve the role as a stopping distance recorder or team coach to satisfy their participation during the simulation.

### ESL Students:

- For those who are ESL students, additional pictures, a vocab list, definitions, or modeling may be beneficial. Such vocab list could include the following terms: mass, velocity, stopping distance, and meters.
- A modified thinking guide may also be used for students whose first language is not English. More definitions or instructions may be used to aid the student, or a guide could be created incorporating their native language.

### Advanced Learners:

- For advanced learners, a modified thinking guide with less structure or information may be possible.
- Another opportunity for advanced learners would be the equation below. This equation is too advanced for most middle school students. This equation is used to calculate how much time it takes to accelerate to 0mph from 50mph as opposed to the stopping distance calculation used with non-advanced learners.

$$a = \frac{v_f - v_o}{t}$$

a = average acceleration

v<sub>f</sub> = final velocity

v<sub>o</sub> = initial velocity

t = time

## **Assessment:**

- By use of journaling and verbal explanation to the opposing teams the teacher can see how well each student understands why their results were the way they were and how the experiment is validated by this information.
- Students will construct an explanation as to how friction played a role in the results they got from the simulation. They will also explain why their calculations were similar or different from the results they obtained in the simulation. Finally, students will explain how differing masses and coefficients of friction would change how much stopping distance is required.
- After each group records their results from the simulation students will give a verbal explanation defending or refuting the results that they received.

## Driving With Friction Worksheet

Name: \_\_\_\_\_ Date: \_\_\_\_\_

**Materials:** Use the following materials to complete the activity stated below.

- MiniSim Simulator
- Science Journals or Notebooks
- Calculations from the previous day

**Activity Step by Step:** Use the following steps to complete the activity and in complete sentences answer the questions below.

1. In your groups of three you will be assigned a combination of variables.
  - YOUR ASSIGNED VARIABLES ARE: \_\_\_\_\_
2. Plug in your variables into the stopping distance equation.

$$d = \frac{v_0^2}{2\mu g}$$

d = stopping distance  
v = velocity = 50 mph = 22.352 meters/second  
 $\mu$  = coefficient of friction  
g = gravity = 9.8 meters/second<sup>2</sup>

YOUR REQUIRED STOPPING DISTANCE:  
\_\_\_\_\_

3. When driving the simulator one student within your groups will be the driver, one will be the recorder, and the other will be the driving assistant.
  - YOUR ASSIGNED JOB IS: \_\_\_\_\_
    - Driver: drive the simulation according to your calculations
    - Driving Assistant: help the driver by accurately counting the meter markers and preparing them to stop safely
    - Recorder: record your data found during the simulation.
4. If another group is using the simulator use this time to journal about your predictions. You can also practice the simulation by walking through what might happen and applying the equation.
5. After computing your stopping distance required to safely stop while driving the MiniSim, complete the simulation within your group.

6. After completing the number of trials of the simulation assigned to your group, record your data and your conclusion in your lab journals and answer the questions found below in complete sentences.
7. When all groups have finished the simulation and journal entries, discuss with the class your individual findings and interpretations of the data.

**Predictions:** Use the space below to answer the questions in complete sentences.

1. Based off of what you know about friction from previous activities completed in class, predict what you think will happen when your assigned variables are applied to the simulation.

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**Experiment Data:** Add your data found in the experiment to the chart below.

	Road Marker When Brakes Were Applied	Road Marker When Car Came to Complete Stop
Driving Run 1		
Driving Run 2		
Driving Run 3		
Average		

**Conclusion:** Use the space below to answer the questions in complete sentences after discussing with the rest of the class about their data.

1. Based on the data that you have collected about your assigned variables, what can you conclude about how different masses affect your ability to stop versus the different surface frictions?

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2. Did you complete the simulation successfully? If not, what could you have done differently to complete it?

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## Lesson Three: Finalizing Friction

**Grade level:** 6-8

**Expected length of Lesson:** 45 minutes

### Overview:

Students will be given the Finalizing Friction Quiz to assess their understanding of the concepts that are used in the previous lessons. After the quiz students engage in either an open or guided discussion of the simulation activity and/or discuss the concepts themselves, clearing up any misconceptions that still persist. There may also be opportunity for further journaling.

### Standards and Benchmarks:

#### NGSS:

##### Performance Expectations:

- 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. For any given object, a larger force causes a larger change in motion. (MS-PS2-2)
- For any pair of interacting objects, the force exerted by the first object on the second object is equal in strength to the force that the second object exerts on the first, but in the opposite direction (Newton's third law). (MS-PS2-1)

##### Cross-Cutting Concepts:

- Cause and effect relationships may be used to predict phenomena in natural or designed systems. (MS-PS2-3),(MS-PS2-5)
- Models can be used to represent systems and their interactions such as inputs processes and outputs and energy and matter flows within systems. (MS-PS2-1),(MS-PS2-4)
- Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales. (MS-PS2-2)

##### Science and Engineering Practices:

- Construct and present oral and written arguments supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem. (MS-PS2-4)
- Science knowledge is based upon logical and conceptual connections between evidence and explanations. (MS-PS2-2),(MS-PS2-4)

### Iowa Core:

#### Science:

- S.6–8.PS.3: Essential Concept and/or Skill: *Understand and apply knowledge of motions and forces.* The motion of an object can be described by its position, direction of motion, and speed. That motion can be measured and represented on a graph.

#### Comprehension and Collaboration:

- SL.8.1: Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on *grade 8 topics, texts, and issues*, building on others' ideas and expressing their own clearly.
- SL.8.2: Analyze the purpose of information presented in diverse media and formats (e.g., visually, quantitatively, orally) and evaluate the motives (e.g., social, commercial, political) behind its presentation.
- SL.8.3: Delineate a speaker's argument and specific claims, evaluating the soundness of the reasoning and relevance and sufficiency of the evidence and identifying when irrelevant evidence is introduced.

**Presentation of Knowledge and Ideas:**

- SL.8.4: Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well-chosen details; use appropriate eye contact, adequate volume, and clear pronunciation.

**Learning Goals:**

- Students will have an understanding of motion in how it relates to friction and mass.
- Students will engage in discussion using their newfound understandings of motion and friction expanding and challenging those ideas when prompted.

**Learning Performances:**

- Students will be given a quiz, discussion prompts, and journaling prompts to show their understanding of the material.

**Materials:**

- Finalizing Friction Quiz
- Discussion prompts (Main Lesson)
- Journaling prompts (Main Lesson)

**Students' Ideas:**

By engaging in the Friction and Simulation lessons students have a more complete understanding of how friction and mass affect the motions, and ultimately stopping distance, of a vehicle. Students use what they know about friction and apply it to other real world examples. There may be some misconceptions of what friction is because it can be more abstract than tires on pavement. The purpose of this lesson is to draw out what misconceptions may be lingering and to correct them.

**Critical Thinking Questions:**

- What could you do next time to improve your results?
- How has your understanding of friction changed after the simulation?
- What are some other real world examples that apply the ideas of friction and motion?

**Main Lesson:**

1. The quiz can be given at the beginning or the end of the lesson, be sure to allow a minimum of 10 minutes for the students to finish the quiz. The quiz is provided with this document.
2. The journaling portion of this lesson is optional, but encouraged. There should be at least three distinct prompts written on the board for the students to choose from. Encourage them to write as much as possible about one before writing about another. The students should be given 15 minutes to write. If they do not have a separate journal for the entire class this could be turned in for a completion grade, or used just as a prompt for the discussion. Here are some suggested journal prompts, but feel free to come up with unique ones to suit the classroom.
  - a. Journal Prompts:
    1. What would the world be like if there was no friction?
    2. What are some reasons people try to increase (or decrease) friction as much as possible?
    3. What are some unique ways that car makers could make stopping distance even shorter?
    4. How would you teach a class about friction?
3. There are two ways to do the discussion portion of this lesson, teacher led or student led. It is encouraged to have this discussion at the end so any extra time from the other activities can be utilized here.
  - a. Discussion Prompts/Suggestions
    1. The teacher led discussion has the teacher asking specific question and asking students to engage with their own unique experiences or insight. The overall goal is to get the students to challenge their understanding of friction and motion. They realize that even though it is the end of the lesson that these concepts are much larger than they think. This hopefully sparks intrigue into the subject matter and promotes further independent learning. Here are some suggested discussion prompts.
      - a. If there is any disagreement over the quiz questions now is a good time to go over any of those.
      - b. The journal prompts can serve as good discussion topics since the students have already formed thoughts about those topics.
      - c. Ask for any comments or opinions about the unit.
      - d. Find a short video that uses friction in interesting or counterintuitive ways. Then have the students talk out what they think is happening.
    2. The student led discussion is only encouraged for classrooms that are very task oriented and maybe towards the higher end of the suggested age range. The goal of this discussion method for the teacher is to create civil disagreement among the students. In this debate style atmosphere students are forced to refine and articulate their beliefs to their peers. Many times this leads to realizations about the topic and further help solidify their understanding of the topic. Here are some ideas that will help to promote this type of discussion, remember to allow the last 5 minutes to clear up any misconceptions that presented during the discussion.

- a. If there are any major disagreements over the quiz questions a good way to start off is to have the students take a side and discuss/defend their way of thinking.
- b. Other more thought provoking questions can also be instituted here. Such as, “Is a magnet holding a piece of paper on a refrigerator utilizing friction?” The best way to go about this method of discussion is to prompt the class, see where there is any disagreement, and then let the two sides discuss. Playing the devil’s advocate may be necessary for this.

## **Differentiation:**

### Special Needs Students:

- Students may need extended time for the quiz or take the quiz orally with the teacher or an aid. If they are uncomfortable speaking in a group setting, they could extend the journaling or have a more private discussion session.

### ELS Students:

- English language learners could benefit from a word bank or more illustrations to help them understand the tasks. If there is another student in the class that is fluent in both languages, have them work together.

### Advanced Learners:

- Advanced learners could benefit from incorporating more calculations (options will be provided on the quiz) or more advanced concepts, such as energy conservation. The student led discussion is also a good option for more advanced students to engage and challenge one another.

## **Assessment:**

This entire day will serve as an assessment for the previous lessons. The quiz will provide quantitative assessment while the journaling and discussion will help to show comprehensive understand of friction and motion concepts.



## Finalizing Friction Quiz

Name: \_\_\_\_\_ Date: \_\_\_\_\_

**Short Answer Instructions:** Answer the following questions in complete sentences.

1. What conditions had the shortest stopping distance? Why?

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2. What are some factors that could have caused errors in your data during the simulation?

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**Multiple Choice Instructions:** Circle the correct answer and use the space provided to explain your answer.

3. Which of the following is an example of increasing friction? Briefly explain your answer.
  - a. Squirting oil into door hinges

- b. Spreading sand on icy roads
- c. Waxing a snowboard

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4. Which of the following is NOT an example of friction? Briefly explain your answer.
- a. A baseball traveling through the air
  - b. A box sitting on a flat table
  - c. A boat floating across a lake

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**Further Your Thinking:** Use the equation below to answer the questions.

$$F = m \times a$$

5. A car starts out traveling at 22.4 m/s (about 50 mph) and has a mass of 2722 kilograms. The driver sees a deer in the distance and slams on the brakes causing a force of 1500 newtons. Using the equation provided, what is the acceleration of the vehicle?

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6. What does this acceleration mean?

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## Finalizing Friction Quiz Teacher Key

**Short Answer Instructions:** Answer the following questions in complete sentences.

1. What conditions had the shortest stopping distance? Why?

The BMW with completely dry pavement theoretically has the shortest stopping distance.

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2. What are some factors that could have caused errors in your data during the simulation?

Reaction time, how hard the brake is being pressed, not traveling in a straight line should be the most common answers.

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**Multiple Choice Instructions:** Circle the correct answer and use the space provided to explain your answer.

3. Which of the following is an example of increasing friction? Briefly explain your answer.
  - a. Squirting oil into door hinges
  - b. Spreading sand on icy roads

- c. Waxing a snowboard

Answers B should be circled. Explanations may vary. B: Spreading sand on icy roads.

The sand will increase surface friction by creating a courser surface.

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4. Which of the following is NOT an example of friction? Briefly explain your answer.

- a. A baseball traveling through the air
- b. A box sitting on a flat table
- c. A boat floating across a lake

Answer B should be circled. Explanations may vary. B: The only force acting on the box is gravity and friction requires two objects to be sliding past one another or trying to.

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**Further Your Thinking:** Use the equation below to answer the questions.

$$F = m \times a$$

5. A car starts out traveling at 22.4 m/s (about 50 mph) and has a mass of 2722 kilograms. The driver sees a deer in the distance and slams on the brakes causing a force of 1500 newtons. Using the equation provided, what is the acceleration of the vehicle?

Answer: 0.55 m/s<sup>2</sup>

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6. What does this acceleration mean?

This means that every second the vehicle will be slowing down by 0.55 meters per second,  
until the vehicle comes to a complete stop.

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# Appendix

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