Making It to School on Time

Unit:	Utah SEEd Standard / NGSS Performance Expectation:	Time:
Newton's 2nd Law	Physics Standard 1.1 / PS2.A	~120 minutes

Access to all material for this lesson: Link to final lesson folder

Anchor Phenomenon	**What lane would you pick?** You are coming to a red light. The street lane in front of you has a semi-truck stopped at the light. The lane next to you has a line of cars that extends twice as far as the semi-truck. Which lane do you want to be in?
Driving Question(s)	How do the variables affecting motion explain the choice of lane?
Performance Task	Students will justify their claim with evidence of their choice of driving lane. Students will complete worksheets and work with students to collect and analyze data to inform their claims.

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Lesson Summary: Predict changes in the motion of objects using Newtons Second Law. Determine the variables that affect the changes in motion. What variables affect changes to motion? Which variable causes the motion to change?			
	Time	**Guiding Question / Learning Objective**	**How are students answering the guiding question or meeting the learning objective?** (Highlight the SEPs, DCIs, and CCCs in the corresponding color.)
 **Engage**	10 min.	Picture: How will the different vehicles move when the light turns green? Which lane would you pick?	Students will make observations and then discuss with a partner which scenario they would rather be in so they can efficiently make it to school on time.
 **Explore**	50 min.	Guiding Question: Which variables affect acceleration and how?	Students will collect acceleration data on a cart while testing cause and effect by changing the variable mass and then changing force.
 **Explain**	15 min.	Learning Objective: Can you visually and graphically observe the relation between mass, force and acceleration.	Students will graph the data from the experiment and determine the mathematical relationships of the variables. Students derive the formula for Newton's 2nd Law.
 **Elaborate**	10 min.	Learning Objective: Using computational thinking to gather evidence for which lane student would choose.	Students use Newton's 2nd Law formula to calculate acceleration values for a sedan and a semi-truck to help them make sense of the phenomenon.
 **Evaluate**	20 min.	Guiding Question: Which lane would you choose when stopped at a red light and why?	Claim: Which lane would you pick? Evidence: Provide evidence from the lab Reasoning: Cause and effect relationship of force and motion
 Extension	15 min.	Learning Objective: Review evidence gathered from the lab the lesson before and review how mass and force affect acceleration.	Use Newton's 2nd Law to calculate force, mass, or acceleration for several vehicles. Practice computational skills and recognizing cause and effect.

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Three Dimensions Focused on in This Lesson		
Disciplinary Core Idea: NGSS Appendix E **Standard PHYS.1.1** Analyze and interpret data to determine the cause-and-effect relationship between the net force on an object and its change in motion as summarized by Newton's Second Law of Motion.	**Science and Engineering Practices:** NGSS Appendix F **Analyzing and Interpreting Data**: Students analyze data to determine a mathematical model used to interpret the relationships between the net force, mass, acceleration.	**Crosscutting Concept:** NGSS Appendix G **Cause and Effect**: Empirical evidence can establish the mathematical relationship that the net force over the object's mass causes the acceleration of an object.
Learning Objectives 1. Predict changes in the motion of objects using Newtons Second Law.		
Related Knowledge and Skills from Prior Grades		
Disciplinary Core Idea: NGSS Appendix E 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. Analyzing and interpreting position-time graphs, velocity-time graphs, and acceleration-time graphs Mathematical relationships (direct, inverse)	**Science and Engineering Practices:** NGSS Appendix F Construct, analyze, and/or interpret graphical displays of data and/or large data sets to identify linear and nonlinear relationships. Use graphical displays (e.g., maps, charts, graphs, and/or tables) of large data sets to identify temporal and spatial relationships. Distinguish between causal and correlational relationships in data. Analyze and interpret data to provide evidence for phenomena.	**Crosscutting Concept:** NGSS Appendix G Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation. Cause and effect relationships may be used to predict phenomena in natural or designed systems. Phenomena may have more than one cause, and some cause-and-effect relationships in systems can only be described using probability.
Connections to Mathematics and ELA/Literacy Standards		
ELA/Literacy Standards: **RST.11-12.7:** Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem.		**Mathematics Standards:** **MP.4**: Model with mathematics.

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Handouts		Lab Supplies		Other Resources
- Student Worksheet - Vocabulary List - CER Sentence Stems		Cart Masses Motion sensor Thera Bands	Scales Rulers Tape	- Teacher Slides: How to Make It to School on Time - CER Rubric - Student worksheet answer key - Bellringer

ENGAGE

How do the variables affecting motion explain the choice of lane?
Determine the variables that affect the changes in motion. What variables affect changes to motion? Which variable causes the motion to change?

Open the "How to Make It To School on Time" PowerPoint Slides

Show Slides 1, 2, and 3

Teacher:
- "I will show you two scenarios; pay attention to the position of your car in each one."
- "Picture this: you have a big test first hour. You stayed up all night studying for this test and didn't hear your alarm this morning. You are rushing to get to school on time. A couple blocks away from the school, there is a stop light. There are two lanes of traffic at the stop light. The right lane has five cars, and the left lane has a semi-truck. The light turns green as you are approaching. Do you get in the lane with five cars or one semi-truck?"
- "Why?"
    - Ask students to think about how each scenario will affect their ability to get to school on time.
    - Ask students if they need clarification about the prompt. For example, is the semi-truck carrying a massive load, or is it empty? Can you violate traffic law? (No)

Show Slide 4: Students see two scenarios and make observations.

Students:
- In section A of the student worksheet, ask students to predict how each scenario will affect their ability to get to school on time.

Teacher:
- Answer prompt on slide: "Based on the images, which lane would you want to be in?"
- Have students share their thoughts with other students.

Teacher Tips

- This story forms the anchoring phenomenon. Try to illustrate the situation for your students to help them visualize it.
- If possible, identify an intersection in your community where the phenomenon could take place.

- "Pens without Friends" is a good technique for section A of the worksheet.

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- Have students raise their hands for which lane they chose.
- Prompt students: “Who can volunteer their reason for choosing option “A” going behind the line of cars?”
- Prompt students: “Who can offer their reason for choosing option “B” going behind the semi-truck?”

After time to discuss, reiterate that the objective in the lab will be to find data-based evidence to support their choice of lane to make it to school on time.

Reiterate our Guiding Question: Determine the variables that affect the changes in motion. What variables affect changes in motion? Which variable causes the motion to change?

EXPLORE

Learning Objective:
Students will collect acceleration data on a cart while testing cause and effect by changing the cart’s mass and then changing the force acting on the cart.

Show slide 5
- Organize students into groups of 2-4.
- Provide each group with the necessary lab materials to collect their data on acceleration.
- Model how to set up and use carts and motion detectors.
- Ask students to read the Safety Measures found on their student worksheets.
- Guide students through the parameters found on the student worksheet. Explain that they are to derive the formula that relates mass, force, and acceleration. Explain that students are to use good science and engineering practices to plan their tests and how to alter their variables to identify those relationships.
- Have students set up a procedure for gathering data on the cause-and-effect relationship between MASS and acceleration.
- Have students set up a procedure for gathering data on the cause-and-effect relationship between FORCE and acceleration.
- Tell students they need to get their procedures checked by the teacher before continuing.
- Do not tell students what to test. Guide students towards testing the cause-and-effect of the mass and force variables on the cart using the equipment. Ensure that students have the chance to participate in the messiness of data collection in science.
- Go to different groups and see if students are recording data that makes sense. Prompt students to question their data if the patterns are not visible.

Show Slide 6 and 7
- If students struggle to figure out where to start testing with the lab, direct them to slide the slides; it will give them a little more scaffolding.

Students will:
- Develop a set of procedures to test the cause-and-effect relationship between **mass** and acceleration.
- Develop a set of procedures to test the cause-and-effect relationship between **force** and acceleration.
- Have procedures checked by the teacher before continuing and moving on to the lab.

Teacher Tips

- To save time, introduce students to the carts and motion sensors in a previous lesson. It is also advised to let the students know they are just gathering the data during the lab; interpreting it will come later. They shouldn’t spend excess time trying to get perfect data.
- You can do this lab with low-tech if you don’t have the software or materials mentioned. You will need a cart that students can roll and put mass on, meter sticks, and stopwatches. Instead of the software tracking the cart’s acceleration, students will do it by hand by measuring how long it takes to travel a certain distance. Use the formulas:
  - **Speed=distance/time**
  - **Acceleration** = **change in velocity/time**
  - If you use this method, ensure students use the same distance each time for more accurate data.
- If you have a large class, you can show students a video on collecting data on LabQuest or show them on a larger screen in the front of the classroom. This could be done in a prior lesson or at the beginning of this lab.
- If using Pasco SmartCarts, have the students use an acceleration-time graph or the preset Position, Velocity, and Acceleration experiment. They should get the peak acceleration from the

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- Use motion carts and motion sensors to identify variables that affect acceleration and whether the relationship is direct or indirect. - Add data to Tables 1 & 2 on the student worksheet.	spike when the car is launched. Start recording BEFORE starting the cart. • The method for applying force could change. Teachers could use an elastic band or a plunger to apply force on certain types of carts as long as the way the force is applied is constant throughout the experiment. • Students who struggle can use the data tables on their worksheets to help them know which variables to test.

EXPLAIN

Graphing variables: Students will graph the data from the experiment and determine the mathematical relationships of the variables. Students will derive the formula for Newton's 2nd Law.

Teacher

- If students are in groups larger than two, have them break into partners to complete the following steps.
- Direct students to complete their graphs and answer questions 1-6. Graphs should help students determine how mass and force affect acceleration.
- **Students**: Share answers with two people from different groups (student worksheet question 7). Identify any problems in data and compare overall patterns in the relationships between the two variables, emphasizing comparing the graphs' shapes.
- Be intentional in explaining that students will have different data, but the shapes of the graphs should be similar.
- If the data varies wildly from theirs, they should reason why or identify questions about their data to discuss with the class.

Show Slide 8

- Class discussion about data patterns.
- Have students complete question 8 individually (Which variables cause the change in acceleration? Which variables affect the change in acceleration?)
- Class discussion on what caused the change in acceleration, what affected the change in acceleration, and the different mathematical relationships (inverse and direct).
- Class discussion questions:
  - "When you increased the mass, how did it affect the acceleration?"
  - "What mathematical pattern did you observe in the mass vs acceleration graph?" (Inverse relationship)
  - "When you increase the force, how does that affect the acceleration?"
  - "What is the mathematical relationship called?" (Direct, proportional relationship)

Show Slide 9

- Explain that the *k* in the equation shows something else is involved. When we put our equations together, we can leave the *k* out.

Teacher Tips

- Provide scaffolding of graphing relationships if students have difficulty developing the mathematical association of the three variables.
- If student data and graphing patterns are incorrect, the teacher should spend time having students diagram the correct graph on top of their original.

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- Have students complete parts A and B for question 9 in partners, and have them talk about the 2 equations and how they would relate to Force and Mass.
- Have a class discussion on Force and Mass equations and relationships.
- Students will individually derive the equation A=F/m (Question 9, part C).
- If students are struggling to find the answer, use scaffolding questions such as:
- "If A = ____. Where does mass go? Where does force go?

Show Slide 10
-Have students take a moment to reflect on their graphs.
- Draw the pattern for each graph so all students can ensure they understand what it should have been.

Students will:
- Complete Graph 1 and Graph 2 to determine how the mass and the force affect acceleration.
- Answer questions 1-7.
- Share answers with two other people outside of their group. Identify any problems in data and observe overall patterns in the relationships between the two variables, emphasizing comparing the graphs' shapes.
- Answer question 8 individually.
- Participate in class discussion on what **caused** the change in acceleration and what **affected** the change in acceleration.
- Compare their data to the graphs on the board.

ELABORATE

Learning Objective: CER Statement Essay

Students will write a CER essay following the guides below.
- Claim: Which lane would you pick?
- Evidence: Provide evidence from the lab
- Reasoning: Cause and effect relationship of force and motion

Teacher:
Show Slide 11: Have a class discussion on the formula on the slide and talk with students about how they derived Newton's Second Law through their experiments and graphs they did in the lesson.

Show Slide 12: Have students complete practice problems using the small car and the semi-truck.
Show Slide 13: Ask students to compare their answers with the answer key.
Show Slide 14: Students reflect back to the origin question, ¨How to get to school on time?¨ Students will answer the question "Based on the images which lane would you rather be in?" Students will fill out the Claim, Evidence, Reasoning portion on page 4 of the worksheet.

Show Slide 15-20: Students practice Newton's Second Law with a variety of different transportation vehicles. Have

Teacher Tips

- Based on time, you could adjust how many example problems you do.
- Students could complete practice problems individually or with partners.
- Students can complete practice problems in a notebook or the worksheet's margins, depending on the materials available.

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a class discussion about some of the examples as you see fit. Students will complete page 5 of the worksheet. Model for students how to work through the calculations for the 2022 Tesla Model X to calculate the acceleration when given the change in velocity. They will also find the force using acceleration and mass. **Acceleration = change in velocity over time.** The change in velocity is 26.8 m/s. Have students divide 26.8 m/s by the time given on the chart to get the acceleration. Students will then find the force of the vehicle using F=m*a with the acceleration they just calculated and the mass in kg on the chart.	• The Sentence Stems for CER & Rubric document can be given to students as a scaffolding for writing effective CER statements.

EVALUATE

- The teacher will walk around and evaluate students' statements. - Students will complete the worksheet's claim, evidence, and reasoning portion individually.	**Teacher Tips:** • You may want to give students the CER sentence stems handout for help writing CER sentences.

POSSIBLE EXTENSION / ALTERNATIVE ADAPTATIONS

- This lesson will lead to lessons on balanced and unbalanced forces and force diagrams.
- Possible bell ringer: This is for the day after the "Will you get to school on time?" lesson has been taught.
- Bellringer

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