



Stackable Instructionally- embedded Portable Science (SIPS) Assessments Project

Grade 8 Science Unit 1 Sample Lesson “Getting to the Bottom of Newton’s Second Law” Forces and Energy January 2023

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Science Grade 8
Unit 1: Forces and Energy
Sample Lesson: Getting to the Bottom of Newton's Second Law
Suggested Time to Complete: 180 minutes

Purpose & Use Statement: *This sample lesson was developed for state and local administrators and teacher leaders (e.g. curriculum directors, instructional facilitators, professional learning specialists) to (1) illustrate an example of an instructional lesson developed using a principled design approach, and (2) support accompanying process documentation about how to use the SIPS unit as an instructional framework to intentionally design high-quality lessons in an aligned curriculum, instruction, and assessment system. This sample lesson should be evaluated and refined, as necessary, to align appropriately with a standards-based curriculum, instruction, and assessment system prior to its use. Additionally, teachers should refine this lesson to meet the local, cultural, and individual needs of students.*

Desired Results

Overview of the Learning Goals

In this lesson, students experiment with a ramp and a single rolling object to develop an experiment to find the relationship between force and the change in motion, or acceleration. Students then work in small groups to analyze their data to find patterns and then revise their design to explore how changing mass impacts the experiment. Finally, the class comes together to share their findings and refine their explanation of the anchoring event.

Connections to Prior Learning

DCIs – (from NGSS Appendix E: DCI Progression within NGSS; see pg. 7)

- **Prior learning from 3-5:**
 - The effect of unbalanced forces on an object results in a change of motion.
 - Patterns of motion can be used to predict future motion.
 - Some forces act through contact; some forces act even when these objects are not in contact.
 - The gravitational force of Earth acting on an object near Earth's surface pulls that object toward the planet's center.
 - Moving objects contain energy. The faster an object moves, the more energy it has.
 - Kinetic energy can be distinguished from the various forms of potential energy. Energy changes to and from each type can be tracked through physical or chemical interactions.
 - When objects collide, contact forces transfer energy to change the objects' motions.

CCC – Scale, Proportion, and Quantity

- **Prior learning from 3-5:** Students are expected to understand that events depend on phenomena that operate at very different scales, but also that fundamental interactions are present through these differences. They are also expected to understand the importance of units and their association with observable quantities.
 - In grades 3-5, students learn to recognize that natural objects and observable phenomena exist from the very small to the immensely large.
 - They use standard units to measure and describe physical quantities such as weight, time, temperature, and volume. [Appendix G]
- **Prior learning from this grade band (e.g., Grades 6 & 7):** During all MS grades, students are expected to become adept at working across different scales and how phenomena observed at one scale may not be observable at another scale. They use proportional relationships (e.g., speed) to gather information about the magnitude of properties and processes.
 - Multiple MS PEs use this CCC, so students will likely have some experience with the MS CCC elements prior to starting Grade 8 and Unit 1.

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- An example of an MS PE that uses the same CCC element (students will have had experience with this CCC if they were previously taught this MS PE) is MS-LS1-1: *Conduct an investigation to provide evidence that living things are made of cells; either one cell or many different numbers and types of cells.*

CCC – Stability and Change

- **Prior learning from 1-2 (NOTE: Stability and change are not referenced by any Grade 3-5 PEs):**
 - In grades 1-2, students learn that some things change while others stay the same, and that change can occur over short and long time periods.
 - Students learn that some systems appear stable, but over long periods of time, they will eventually change. [Appendix G]
- **Prior learning from this grade band (e.g., Grades 6 & 7):** During all MS grades, students are expected to be able to characterize how systems change, including using changes over time and considering forces at different scales. Students learn that changes in one part of a system might cause large changes in another part and how some systems are cases of dynamic equilibrium.
 - Multiple MS PEs use this CCC, so students will likely have some experience with the MS CCC elements prior to starting Grade 8 and Unit 1.
 - An example of an MS PE that uses the same CCC element (students will have had experience with this CCC if they were previously taught this MS PE) is MS-LS2-4: *Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.*

SEP – Planning and Carrying Out Investigations

- **Prior learning from 3-5:** Students should understand how to plan and conduct investigations that provide evidence to support explanations or designs and include the control of variables. They will be able to evaluate methods and/or tools for collecting data.
 - In grades 3-5, students will know how to carry out investigations to produce data to serve as the basis for evidence, using tests in which variables are controlled and the number of trials is considered.
 - Students should be able to make predictions about what would happen if a variable changes. [Appendix F]
- **Prior learning from this grade band (e.g., Grades 6 & 7):** All MS grades will be able to plan and conduct investigations that use multiple variables and provide evidence to support explanations or solutions. This includes making decisions about the best way to get data that provides the evidence to meet the goals of the investigation.
 - Multiple MS PEs use this SEP, so students will likely have some experience with the MS SEP elements, prior to starting Grade 8 and Unit 1.
 - An example of an MS PE that uses the same SEP element (students will have had experience with this SEP if they were previously taught this MS PE) is MS-PS3-4: *Plan an investigation to determine the relationships among the energy transferred, the type of matter, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample.*

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SEP – Analyzing and Interpreting Data

- **Prior learning from 3-5:** Students will have understanding and experience with the collection of data using quantitative approaches to collecting data and conducting multiple trials of qualitative observations. They will be able to carry out the analysis and interpretation of the data using logical reasoning, mathematics, and/or computation.
 - In grades 3-5, students will represent data in tables and/or various graphical displays to reveal patterns that indicate relationships.
 - They will analyze data to refine a problem statement or the design of a proposed object, tool, or process. mathematics, and/or computation. [Appendix F]
- **Prior learning from this grade band (e.g., Grades 6 & 7):** During all MS grades students will build understanding and skills with quantitative analysis of investigations. They will distinguish between correlation and causation and carry out basic statistical techniques of data and error analysis.
 - Multiple MS PEs use this SEP, so students will likely have some experience with the MS SEP elements, prior to starting Grade 8 and Unit 1.
 - An example of an MS PE that uses the same SEP element (students will have had experience with this SEP if they were previously taught this MS PE) is MS-LS2-1: *Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.*

SEP –Engaging in Argument from Evidence

- **Prior learning from 3-5:** Students will have the ability to construct scientific explanations or solutions and to critique those proposed by peers by citing relevant evidence about the natural and designed world(s).
 - In grades 3-5, students will develop understanding and skills for how to construct and/or support an argument with evidence, data, and/or a model.
 - They will be able to distinguish among facts, reasoned judgment based on research findings, and speculation in an explanation.
 - They will use relevant evidence and pose specific questions in the process of respectfully providing and receiving critiques from peers about a proposed procedure, explanation, or model. [Appendix F]
 - **Prior learning from this grade band (e.g., Grades 6 & 7):** During all MS grades, students will progress to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world(s). This will include presenting an oral and written argument 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.
 - Multiple MS PEs use this SEP, so students will likely have some experience with the MS SEP elements, prior to starting Grade 8 and Unit 1.
 - An example of an MS PE that uses the same SEP element (students will have had experience with this SEP if they were previously taught this MS PE) is MS-LS1-3: *Use argument supported by evidence for how the body is a system of interacting subsystems composed of groups of cells.*
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SEP – Constructing Explanations and Designing Solutions

- **Prior learning from 3-5:** Students will use variables that describe and predict phenomena in order to construct explanations and to design multiple solutions to design problems.
 - In grades 3-5, students will be able to identify evidence that supports particular points in an explanation.
 - They will be able to generate and compare multiple solutions to a problem based on how well they meet the criteria and constraints of the design solution. [Appendix F]
- **Prior learning from this grade band (e.g., Grades 6 & 7):** During all MS grades, students will construct explanations and design solutions that are supported by multiple sources of evidence consistent with scientific ideas, principles, and theories.
 - Multiple MS PEs use this SEP, so students will likely have some experience with the MS SEP elements, prior to starting Grade 8 and Unit 1.
 - An example of an MS PE that uses the same SEP element (students will have had experience with this SEP if they were previously taught this MS PE) is MS-ESS2-2: *Construct an explanation based on evidence for how geoscience processes have changed Earth’s surface at varying time and spatial scales.*

Key Vocabulary

Students build conceptual meaning with and use key tier II and tier III vocabulary terms as they make sense of phenomena and phenomena-based design problems. This is not an exhaustive list of terms and should be reviewed and modified by educators, as appropriate.

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|------------------------|--------------|--------------|
| ● Force | ● Mass | ● Linear |
| ● Acceleration | ● Experiment | ● Inverse |
| ● Independent Variable | ● Procedure | ● Trend line |
| ● Dependent Variable | ● Conclusion | |

Targeted Stage 1 Learning Goals

Acquisition Goals (AG)

A5. Interpret data on how forces sum to give a single force to affect change in motion.
A7. 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. [MS-PS2-2]
A9*. Use and/or develop a model of all the forces acting on an object to show how the object’s motion will change.
A12. Use mathematical and computational thinking to calculate the sum of forces on an object to give a single force that will affect a change in the object’s motion.

Common Core State Standards (CCSS):

RST.6-8.3	MP.2
RST.6-8.7	8.EE.A.2
WHST.6-8.1	8.F.A.3

Enduring Understandings (EU)/ Essential Questions (EQ):

EU/EQ2	EU/EQ5
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Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
<input checked="" type="checkbox"/> Analyze & Interpret Data <input type="checkbox"/> Ask Questions <input checked="" type="checkbox"/> Construct Explanations <input type="checkbox"/> Define Problems <input type="checkbox"/> Design Solutions <input type="checkbox"/> Develop & Use Models <input checked="" type="checkbox"/> Engage in Argument from Evidence <input checked="" type="checkbox"/> Mathematics & Computational Thinking <input type="checkbox"/> Obtain, Evaluate, & Communicate Information <input checked="" type="checkbox"/> Plan & Carry Out Investigations	<input checked="" type="checkbox"/> PS2.A Forces and Motion	<input type="checkbox"/> Cause & Effect <input type="checkbox"/> Energy & Matter <input type="checkbox"/> Patterns <input checked="" type="checkbox"/> Scale, Proportion, & Quantity <input checked="" type="checkbox"/> Stability & Change <input type="checkbox"/> Structure & Function <input type="checkbox"/> Systems & System Models

 **Formative Assessment Opportunities**

Monitoring	Success Criteria	Possible Instructional Adjustments
<ul style="list-style-type: none"> • While students are creating their experimental design, the teacher may want to ask questions such as: <ul style="list-style-type: none"> ○ What is your independent variable? ○ What is your dependent variable? ○ How are you keeping everything else the same? ○ Is the mass changing or is it the same? How can we make sure it stays the same? ○ How will you measure the force? How will you measure the acceleration? • To support students and understand their thinking during the data analysis, the teacher may want to ask: <ul style="list-style-type: none"> ○ What does your data show? 	<p>Students can:</p> <ul style="list-style-type: none"> • Create an experiment with one independent and one dependent variable • Conduct their experiment to find the relationship between force, mass, and the change in motion/acceleration • Examine data collected and recognize linear and inverse relationships in data. • Explain how their data supports their conclusion • Listen to other presentations and connect their findings with student’s own findings • Calculate the net force acting on an object through analysis of forces acting upon it • Interpret data to determine the motion of an object is determined by the sum of the forces acting on it 	<ul style="list-style-type: none"> • Provide equipment options for students to select from when designing their experiment to either challenge or simplify the task • Use guiding questions to ensure that students’ experimental procedures will result in a successful learning experience • Utilize heterogeneous grouping to allow students to learn from and support each other

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| <ul style="list-style-type: none">○ What kind of graph will best show your data and why?○ What does it mean when we connect dots on a graph?○ What trend line does this look like? | <ul style="list-style-type: none">● Interpret data to describe forces at different scales acting upon an object |
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| <ul style="list-style-type: none">● Encourage students to examine other students' models and consider how they might incorporate their thinking into their own explanation● Support students in giving constructive feedback to each other on their models | Students can: <ul style="list-style-type: none">● Revise their explanatory models to incorporate new learning from the experiments | <ul style="list-style-type: none">● Utilize heterogenous grouping to allow students to support each other |
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Instructional Plan

Lesson Overview

In this lesson, students design and conduct two experiments to derive Newton's second law. Students select from an assortment of equipment, create a design, gather data, analyze that data, and then draw conclusions based on that data. After exploring the concept, students add to their explanations for the anchoring event.

Materials & Set-Up

Experiment materials:



- Board (ramp)
- Timer
- Meter stick
- Spring scales or probe ware for measuring force
- Rolling objects
- Masses with hanger
- Pullies
- [Experiment template handout examples](#)

[<https://ambitiousscienceteaching.org/design-an-experiment-template/>]

Anchor or Investigative Phenomenon: In this unit, the anchor phenomenon is about collisions. These compelling situations can be used to start a discussion about collisions in various situations, the effects of those collisions on an object's motion, and the factors that affect the forces and corresponding changes in motion. The chosen collision is up to the teacher. Options are provided in the unit map.

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Driving Question: How can we predict changes in motion when forces are applied to an object?

Teacher Does	Students Do
Engage	
<ul style="list-style-type: none"> ☑ Introduce object, event, phenomenon, problem, or question ☑ Build background knowledge ☑ Facilitate connections 	
Explore	
<ul style="list-style-type: none"> ☑ Explore object, event, phenomenon, problem, or question ☑ Guided exploration with hands-on activities 	<p>The teacher presents the challenge for the day to find out what exactly is the impact of applying force to an object.</p> <p>The teacher provides students with a variety of materials and the experimental design template (optional). Potential options are listed in the materials list, but the teacher can modify this list based on what is available. The teacher tasks students with creating an experiment to test changing forces on an object with a constant mass.</p> <p>While students are working, the teacher walks around the room and checks in with students and provides feedback on their designs. The teacher uses scaffolding questions to encourage students to consider other options and to challenge students’ errors in their design (for example, the design results in a changing mass).</p> <p>Two simple designs work well for this experiment. One is using a constant object such as a car and changing the angle of the ramp. Students can measure the net force pulling the car down the ramp using the force meter or the spring scale and then release the car and find the acceleration from $acceleration = \frac{2d}{t^2}$, or to simplify the</p>
	<p> Students review the list of materials and then develop a diagram and experimental plan to determine the relationship between force and the change in motion or acceleration on an object. “Change in motion” can be qualitatively explored by comparing the time it takes to reach the bottom between trials. Calculating acceleration from the time is above grade level but could be included as a differentiation strategy to increase the complexity of the activity. Students could either find the acceleration using motion equations or the teacher could provide students with the formula to calculate acceleration.</p> <p>Students present their diagram and plan to the teacher for approval and then conduct their experiment.</p> <p> After conducting their experiment, students analyze their data by graphing the data in a scatterplot and adding a trend line. Students compare the trend line and shape to other graphs to help determine the type of relationship between force and “change in motion” (the greater the force, the less time to the bottom, so more force means more change in motion) or acceleration (a linear relationship, the</p>

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experiment, students can just compare the “change in motion” as described by the length of time it takes to reach the bottom of the ramp.

Another option is to use a pulley with hanging masses on a flat surface. A string connecting the hanging mass is connected to the rolling object (a car) to provide an applied force across the table. To minimize friction, the string runs over a pulley. The weight of the hanging mass provides a constant force. However, adding mass to the hanger requires mass to be taken away from the car to keep the mass that is accelerating constant.

Students may generate other designs as well. What is most important is to ensure that the mass is constant, and that friction is as small as possible.

After students conduct their experiments, the teacher monitors and provides guidance as they analyze their data. This may include guiding selecting a graph type and recognizing that scatter plots are not line graphs and that students should develop a trend line that does not connect the dots. The teacher should not tell students the relationship or equations but allow students to find the relationship and support that through scaffolding questions.

After students find the relationship between force and change in motion/acceleration ($a = F/m$) they modify their experiment to find the relationship between a constant force and a changing mass.

greater the force the greater the acceleration).

Next, students modify their experiment to find the relationship between change in motion/acceleration and mass when the applied force is constant. Again, they share their diagram and plan with the teacher for approval and feedback.

After their design is approved, students conduct their experiment and collect data. Then, they graph their data and analyze the data to find the relationship between change in motion/acceleration and changing mass (inverse). They may compare their data to a series of graphs of data to help see the relationship.

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As students work on changing their experimental design, the teacher walks around the room and monitors student progress. Again, the teacher provides feedback to students as they make their changes. The teacher needs to support students by ensuring that students' designs have different masses but constant forces. This can be more challenging with the ramp situation, as changing the mass will change the gravitation pull, meaning that the ramp angle needs to be changed to keep the net force the same. The pulley with a hanging mass setup may work better here but recognize that the mass includes both the mass of the car and the hanging mass.

After students collect their data, the teacher cycles around the room to assist students in plotting their data points and recognizing the trend. Here the relationship is an inverse relationship, $a = F/m$, and as m grows the a will get smaller, but never actually reach 0. The curved shape will be an issue for some students. A potential scaffold would be to provide students with a series of graphs and relationships ahead of time to compare their graphs to.

Explain

- Explain understanding of concepts and processes
- Introduce new concepts and skills to seek conceptual clarity

Following the collection of data from the two experiments, the teacher again walks around the room and provides support as students work on explaining their results and, ideally, finding the equation for Newton's second law, $a=F/m$. Or, identifying the relationship that the greater the force, the greater the change in motion, and the larger the mass, the



Students write a conclusion based on their data, share their findings with the class, and as a class discuss a consensus model for the relationship between force, mass, and acceleration related to an object's motion.

After conducting the experiments and the class discussion, students return to their explanatory model for the anchoring event. Students revise their

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smaller the change in motion. In this situation, students have changed force and mass, which resulted in the change in motion/acceleration changing, therefore a is the dependent variable. However, Newton's second law is often presented as $F = ma$, even though acceleration is not the independent variable.

explanations and add information from the activity to improve their explanations.

After the class has written their experimental conclusions, the teacher facilitates a class discussion of the results where students share their findings. Students create a way of presenting their data that makes sense for them and then share their learning with the classroom.

Finally, after all students have shared their findings, students should revisit their explanatory model for the anchoring event and refine their explanation and add information related to the two experiments.

Elaborate

- Build on or extend understanding and skill
 - Apply concepts in new or related contexts
-

Evaluate

- Self-assess knowledge, skills, and abilities
 - Evaluate student development and lesson effectiveness
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Closing

Ask students to answer the following prompt as an exit ticket: *Reflect on your findings today, how do your findings relate to Newton's Third Law which we learned about earlier? How might the findings from today connect to action/reaction pairs?*

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Differentiation Strategies and Resources

“Universal Design for Learning (UDL) is a framework to improve and optimize teaching and learning for all people based on scientific insights into how humans learn” (CAST, 2022). Taking time to reflect on prior instruction when planning for accessible, differentiated, and culturally responsive instruction for diverse learners and culturally diverse classrooms serves to identify ways to improve future instructional practices. The UDL Guidelines provide a framework for this reflection. The guidelines include three principles as ways to focus on variety and flexibility in instructional practices:



Multiple Means of Engagement




Multiple Means of Representation



Multiple Means of Action & Expression

By examining instruction and instructional materials through the lens of each of these principles, the teacher can identify and thus reduce or remove barriers to diverse learners.





Learning Opportunities	UDL Principle	Example Differentiation Strategies & Resources
Explore		
<p><i>Students find out what exactly is the impact of applying a force to an object using a variety of provided materials.</i></p>		<p>Make the work authentic and relevant</p> <ul style="list-style-type: none"> The initial anchoring phenomenon is selected to connect with students at the start of the unit <p>Provide choices</p> <ul style="list-style-type: none"> Allow students to choose how they model force relationships (e.g., drawing, cutting and pasting, animation, using objects, etc.) <p>Describe the meaning of vocabulary and symbols</p> <ul style="list-style-type: none"> Create a word wall or a glossary for science and academic terms such as force, motion, gravity, collide, mass, etc. Describe meaning vs. a formal definition. For example, “When things crash together, they collide.” (Vocabulary.com) Pair vocabulary words with pictures <p>Encourage collaboration with partners and in groups</p> <ul style="list-style-type: none"> Ensure everyone has the means to contribute Contrast between text and the background, describe using alternative text, etc <p>Support transfer and generalization of skills and knowledge</p> <ul style="list-style-type: none"> Include opportunities to review and practice prior knowledge and skills along with new knowledge and skills

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		<p>Use a flexible way to present information</p> <ul style="list-style-type: none"> • Students decide how best to record their data and represent it for analysis • Present example models of force and motion using multimedia so they can easily be enlarged or increased
		<p>Provide options for accessing instructional activities and materials</p> <ul style="list-style-type: none"> • Present example mode • Allow for differences in rate, timing, speed, and range of motion (e.g., allow enough time for all students to process the question and formulate their responses; allow enough time for all students to move from one activity to the next, or to perform a task.)
Explain		
<p><i>Students write and share their conclusion about the relationship between force and mass with the class.</i></p>		<p>Encourage communication about frustrations and guide self-management of the frustrations</p> <ul style="list-style-type: none"> • When students show signs of frustration such as withdrawing or exhibiting distracting behaviors, encourage them to communicate what is frustrating them and what they think might help <p>Support self-reflection and evaluation</p> <ul style="list-style-type: none"> • Provide visual tools to foster independence, prepare students for the next activity, break tasks into smaller steps, and aid transition <p>Provide support for decoding written text and symbols</p> <ul style="list-style-type: none"> • Allow access to screen readers during presentations
<p><i>Students write and share with the class their conclusion about the relationship between force and mass.</i></p>		<p>Vary the ways for students to respond to questions or a task</p> <ul style="list-style-type: none"> • Students write their conclusion and share it with the class in a way that makes sense to them e.g. writing their expression of the relationship between force and mass either quantitatively or qualitatively

Resources

Experiment template handouts

- [Design an Experiment Template | AST \(ambitiousscienceteaching.org\)](https://ambitiousscienceteaching.org/design-an-experiment-template/)
[https://ambitiousscienceteaching.org/design-an-experiment-template/]
- [Microsoft Word - HS ExD Procedure.doc \(ocsef.org\)](https://ocsef.org/)

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[<https://ocsef.org/wp-content/uploads/2020/05/HS-ExD-Procedure.pdf>]

Sample experiments (do not give students the procedure, these are for teacher reference):

- [Investigating Newton's second law of motion | IOPSpark](#)
[<https://spark.iop.org/investigating-newtons-second-law-motion>]
- [Newton's Second Law - College Lab Experiments | PASCO](#)
[<https://www.pasco.com/resources/lab-experiments/1172/1>]

Core Text Connections

Information on Newton's second law

- [Newton's Second Law \(Law of Motion\) | HowStuffWorks](#)
[<https://science.howstuffworks.com/innovation/scientific-experiments/newton-law-of-motion3.htm>]
- [Force, Mass & Acceleration: Newton's Second Law of Motion | Live Science](#)
[<https://www.livescience.com/46560-newton-second-law.html>]
- [STEMonstrations: Newton's Second Law of Motion | NASA](#)
[<https://www.nasa.gov/stemonstrations-newtons.html>]

Information on designing experiments

- [sec6.designexperiment \(longwood.edu\)](#)
[<http://www.longwood.edu/cleanva/images/sec6.designexperiment.pdf>]
-