SEEd Swap Workshop

2017

7th Grade
Welcome to the 2017 SEEd Swap Teacher Workshop

It’s an exciting time for the world of science instruction; advances in cognitive and pedagogical research are reshaping the way we think about engaging students in science and engineering. The state of Utah has reflected these improvements in the new 6-8th grade SEEd (Science and Engineering Education) Standards, which will be implemented across the state during the 2017-2018 school year. While this change is exciting, it also poses significant challenges. The SEEd standards are built on Disciplinary Core Ideas, as were the previous standards. The new components include the explicit integration of Science and Engineering Practices into every single standard, and the framing of ideas within Crosscutting Concepts to allow instructors to help students organize their thoughts. These three components, called ‘dimensions,’ when anchored to instruction that allows students to explore phenomena they encounter in the world, allows students to act as sense-makers and science/engineering practitioners.

In order to provide 6-8th grade teachers with professional learning support to successfully implement the new standards, the Center for Science and Mathematics Education (CSME) is offering a week-long workshop focusing on the content that has ‘swapped,’ or is new to each grade – the “SEEd Swap.”

USBE Credit:
80% documented attendance, taken 2x daily by your instructor, as well as an accurate CACTUS ID number on record, are required to earn 3 USBE credits.

Supply Stipend
A $150 check will be issued to each attendee who
Completed the pre-assessment by the July 29th deadline
Attend 100% of the workshop
Complete the post-assessment between noon on Aug. 4 and midnight Aug. 8th.

Curricular Resources
The majority of the resources found in this book will be available online at the Center for Science and Mathematics Education website: https://csme.utah.edu/resources/k12curriculum/
Megan Black

Megan Black is an elementary science curriculum specialist in Granite School District. She taught science for twelve years working with students in grades 4 - 9, but most often 6th grade. Megan was on the 6th grade SEEd standards writing committee and has been involved with developing the 6th Grade SEEd OER textbook. She is interested in developing curriculum and instructional strategies that engage students as scientists as they explore and figure out the natural world around them.

Sarah Braden

Sarah K. Braden started her career in education as a high school biology, physics, and English as a Second Language (ESL) teacher. Dr. Braden is currently an Assistant Professor of English Language Learner education in The School of Teacher Education and Leadership at Utah State University. Her research centers on understanding language socialization phenomena and promoting equity the sciences.

Brad Carroll, Professor Emeritus - Physics, Weber State University

Brad Carroll began his career as a high school math and physics teacher in Bakersfield, California. After receiving his Ph.D. in astrophysics from the University of Colorado, Brad spent time as a postdoc at the University of Rochester before joining the Physics Dept. at Weber State University in 1985. At WSU, Brad collaborated with faculty in the Dept. of Chemistry to develop a unique physical science course for elementary education majors. He also co-authored An Introduction to Modern Astrophysics, the standard undergraduate astrophysics text. Brad retired in 2015 after 30 years at WSU, 10 of them as chair of the Physics Department. In retirement, he continues to teach with the Physics Department and Honors Program, and is working on the third edition of his astrophysics text.
Holly Godsey
Dr. Holly Godsey is the Director of Student Success and Teacher Development at the CSME and an Associate Professor (Lecturer) in the Department of Geology and Geophysics. She has a BS and PhD in Geology from the University of Utah and an MS in Oceanography (Marine Geology and Geochemistry) from the University of Michigan. Since 2004, she has been involved with several science education projects that connect faculty, graduate and undergraduate students to K-12 teachers and students to inspire, empower and educate learners from across generations and disciplines.

Maura Hanenberger
Maura Hahnenberger is an Assistant Professor in the Geosciences Department at Salt Lake Community College. At SLCC she teaches and advises in the Atmospheric Sciences and Geography programs in both face to face and online settings. Maura is the founder of the WaterGirls outreach program which provides middle school girls with field experiences conducting water science. She also serves on the boards of the SLCC Chapter of the Utah Women in Higher Education Network, Utah Chapter of the American Meteorological Society, and the Earth Science Women’s Network.

Emily Harward, 7th & 8th Grade Science & Biology Teacher at Granite Schools
Emily was lucky to grow up in the Salt Lake Valley, with opportunities to spend time exploring nature. She graduated from the University of Utah in 2004, and has been teaching science at Evergreen Junior High in Granite District ever since. For Emily, the most rewarding part of teaching is developing lessons and activities that provide a pathway for students to develop their own understanding and make sense of the world they live in.
Patrice Kurnarth

Patrice received her B.S. in Biology from Ithaca College and worked in academia for a few years at Yale University and UC Berkeley. She earned her Ph.D. in Biology from the University of Utah in 2016. During her doctoral thesis, Patrice worked with middle school science teachers in the Salt Lake valley for two years as part of a GK-12 graduate school fellowship funded by the National Science Foundation. This experience was truly transformative because she learned about pedagogical theory and experienced first-hand the set-backs and successes of teaching.

Candace Penrod, District Science Supervisor at SLC School District

Candace’s teaching career began in California in elementary education. Upon moving to Utah, she transitioned to secondary science teaching, followed by several years as instructional coach. She is currently the District Science Supervisor for Salt Lake City School District. Candace obtained a Master in Education from the University of Utah in 2009 and a Master of Science in Earth Science Teaching from the University of Utah. Candace is passionate about K-12 science education and continually seeks for opportunities to improve science teaching and student learning at all levels.

Scott Roskelley, Science Assessment Specialist at Utah State Board of Education

Scott was born and raised in Chicago, Illinois and from a young age loved science. He holds degrees in wildlife biology, marine biology, teaching and learning, and educational administration. Never expecting to work in education, Scott fell into teaching in 2001 as he entered the alternative route to licensure in Utah. Scott worked for 15 years in the Jordan School District, mostly teaching middle school. Now as the state science assessment specialist, he is responsible for working with Utah teachers to develop the new end-of-year assessment for the new SEEd standards.

James Ruff

I am an evolutionary biologist studying basic evolutionary topics including sexual selection, and the forces maintaining genetic diversity in populations; furthermore, I apply evolutionary principles and techniques to questions concerning nutrition, toxicology, and pharmaceutical safety assessment. I am passionate about science education and prefer to focus on the process of science relative to the ‘fruits’ of the process. In this vein, I incorporate study designs, data analysis and writing into each of my courses. I have been a teaching fellow at both elementary and middle schools in SLCSD.
Heather Waite

I received my degree and teaching certificate from Weber State University in 2006 in Biology. I’ve been recently teaching 7th and 8th grade science at South Ogden Jr. High for 10 years. This summer I have taken the opportunity to write assessment pieces for the state. I have also worked on a District Level to develop assessments for test review and teacher evaluation. I am currently serving as department chair at SOJH. I also served on the School Transformation Team (Assessment to Achievement) for 2 years.

Tamara Young, Academic Advisor in the Department of Physics & Astronomy

Tamara’s interest in physics began in high school. As an undergraduate at Utah State University, Tamara’s studies focused on nuclear and particle physics. Tamara taught science and math for several years in the public education system. For the last couple years, Tamara has taught astronomy at SLCC, participated in course curriculum development with CSME, and taught a computational astronomy course for Master’s students in Physics Teaching. Tamara is the academic advisor in the Department of Physics & Astronomy at the University of Utah. She also engages in public outreach and education, and loves to talk about physics.
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Strand: 7.1.5

**Emphasis:** Gravity and Mass

**Anticipated Time Required (assuming 50 minute class periods):** 5-6 days
- LE 1 - 50 min
- LE 2 - 50 min
- LE 3 - 50 min
- LE 4 - 50 min
- LE 5 - 50 min
- LE 6 - 50 min

**Dominant CCC:** Systems and System models

**Dominant SEP:** Arguing From Evidence

**Management Strategies** to support equitable access to content:
- Voice and Pen
- “Things I Learned/Things I Thought”
- Role Rotation
- Claim Scaffolding

**Shopping list:**
BINDERS, DIVIDERS with POCKETS for each table group or even each partner pair.
### Storyline Overview 7.1.5d

**Anchor Phenomenon:** New Planets Being Formed in another Solar System

**Student Performance Expectation:** Engage in argument from evidence to support the claim that gravitational interactions within a system are attractive and dependent upon the masses of interacting objects.

<table>
<thead>
<tr>
<th>Dominant DCI</th>
<th>Dominant CCC</th>
<th>Dominant SEP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical Science</td>
<td>Systems</td>
<td>Engage in argument from evidence</td>
</tr>
</tbody>
</table>

### Science Experiences

<table>
<thead>
<tr>
<th>CCC/SEP</th>
<th>What are students doing? (This should match your SEP!)</th>
<th>What specific understandings should students get from this experience?</th>
<th>New questions students have to propel us to the next science experience</th>
<th>Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Students observe star formation in a nebula video: Complete OEQ template Students observe images taken of a developing planetary system Students observe models of development cycle of solar systems Students match the hubble images with the models and put the images in order. What forces do you think are working here?</td>
<td>We can see solar systems forming in other places in the universe and they look similar. There is a lot of heat there. The solar system started as a huge dust and gas cloud that formed into planets and a sun.</td>
<td>What causes this to occur? Gravity? Electric charge? Did electric and gravitational forces build the planets? How does a dust cloud become a solar system?</td>
<td>Start OEQ template Make observations Ask Questions Compare images to models Complete a pre-write of how gravitational and electromagnetic forces helped to form the solar system.</td>
</tr>
<tr>
<td></td>
<td>Students read about the role of gravity in formation of stars</td>
<td>Recognize that gravity pulls dust and gases together with such force that it starts the process of nuclear fusion in the sun.</td>
<td>How do the planets form? Why aren’t they all pulled into the sun?</td>
<td>Students discuss and respond to Claim A.</td>
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<td>2</td>
<td></td>
<td></td>
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<td>Ask Questions</td>
</tr>
<tr>
<td>3</td>
<td>Cause and effect/engage in argument</td>
<td>Students watch clip from how the earth was made about how electric forces cause dust particles to stick together in space and that as those clumps increased in size gravity became the greater force.</td>
<td>Electric charge of minerals can cause them to stick together. At first electric charges pulled matter together, but as the objects gained mass gravity starts to matter together into planets.</td>
<td>Does mass affect gravitational force? How do we measure gravitational force?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Students are given data on the effect of Mass and distance on Gravitational attraction.</td>
<td></td>
<td>Students discuss and respond to Claim B.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Students observe animation showing the effect of mass and on planetary attraction Students are shown explanation of orbits.</td>
<td></td>
<td>Ask Questions</td>
</tr>
<tr>
<td>4</td>
<td>Cause and effect/obtaining evaluating information. Engage in argument</td>
<td>Students are given data sets from different planets including mass, diameter, weight, gravity and asked to find correlations.</td>
<td>Objects with more mass have more gravitational attraction. Weight is mass x acceleration</td>
<td>Students Discuss and Respond to Claim C Ask Questions</td>
</tr>
<tr>
<td>5</td>
<td>System and system models/analyzing and interpreting data and engage in argument</td>
<td>Students are shown video of astronauts on moon and earth and construct an understanding of the difference between mass and weight through data.</td>
<td>Students will write their own claim about the role of forces in the formation of the universe.</td>
<td>Recognize that the solar system is a complex system that has electromagnetic and gravitational forces acting all the time. Recognize that these forces are universal.</td>
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<tr>
<td>6</td>
<td>Cause and effect/communicating information and developing model.</td>
<td>Direct instruction. Discussion Graphic organizer on BIG IDEAS</td>
<td>We measure mass with balance and measure weight with scales. Weight measures the force of gravity pulling on an object. Recognize that though mass doesn’t change, weight does change. Isaac Newton and the apple, Newton recognized that gravity is a universal law and that it affects planets and stars just like it affects objects on earth, everything, even the smallest</td>
<td>Will the planets fall into the sun eventually? How do things in space keep moving? What is acceleration? What</td>
</tr>
</tbody>
</table>
particle has gravity.

Recognize that they don't have a very satisfactory evidence for the behavior of orbiting bodies.
7.1.5 Learning Episode 1

Student Science Performance

<table>
<thead>
<tr>
<th>Topic: Universal Law of Gravitation</th>
<th>Title: Newton’s Big Idea</th>
</tr>
</thead>
</table>

Overarching Performance Expectations (Standard) from State Standards or NGSS:
Engage in argument from evidence to support the claim that gravitational interactions within a system are attractive and dependent upon the masses of interacting objects. Examples of evidence for arguments could include mathematical data generated from various simulations.

Lesson Performance Expectations: Students support claims about the development of the solar system and the role of gravity and electromagnetic forces in making planetary bodies. The evidence provided supports their understanding of the Universal Law of Gravity and the effect of distance and mass on gravitational force. They will recognize that the force of gravity changes with mass and distance and that gravity changes cause weight changes on different planets.

CCC: System and System models
SEP: Engaging in argument from evidence. Obtaining and evaluating and communicating information

Students Will . . To Construct Meaning

Student Prompt:
Build a OEQ template in your journal, and use it to answer this question:
“Are the effects of charges and the force of gravity the same all over the universe and are they responsible for forming the earth?”

Students watch video of developing planetary systems and the birth of stars.

Students engage in class discussion and complete their notes.

Teacher Will . . To Support Students

Guiding Question from 7.1.3 if desired:
“Are the effects of charges and the force of gravity the same all over the universe?” “Are these forces responsible for forming the earth?”

Step 1 Organize Learning Groups

Management Strategy:
This episode is language-heavy and challenging. Depending upon the time of year and the classroom culture, teachers may want to group students by ability, or in heterogeneous pairs so that one student can support another.

Step 2 Present students with the guiding questions
“Are the effects of charges and the force of gravity the same all over the universe and are these forces responsible for forming the earth?”

Step 3 Prepare students to engage with the phenomenon by constructing OEQ journal page for notes. They should be focusing on EVIDENCE or OBSERVATIONS that might help to answer the guiding question. They should also be ASKING QUESTIONS that might lead them to answers.

Step 4 Phenomenon:
Students receive **Resource Binders**
Each student should start a “**Things I Learned/Things I Thought**” sheet.

Students observe images taken of a developing planetary system
Students observe models of development cycle of solar systems
Students should attempt to **match** the **TELESCOPE IMAGES** with the **MODELS** and look for **GRAVITY** or **ELECTRIC** or **MAGNETIC FORCES** in the story.

Show students video of a developing planetary system and the birth of stars.
https://www.youtube.com/watch?v=dhsocKtAI8

**Step 5** Have a brief discussion with students about their observations, questions and connections to the guiding questions.
“Did you see evidence of gravity in that story?”
“Did you see evidence of electric or magnetic charges in that story?”
“What questions did this bring up for you?”

**Step 6** Pass Out Student Binders with resource materials

**Management Strategy: Managing Evidence**
This particular SEP requires large amounts of data, graphics, and reading resources. To help manage this, give each group (or pair) a binder. Each episode can have its own pocket for holding all of the resources necessary for that particular episode. They could be color coded. It’s helpful if all resources are laminated so that they are reusable, and so that students may write on them with overhead markers. Or, if possible, upload images to files if students have access digital media devices.

**Step 7** Students Begin “**Things I learned, Things I thought**” Sheet that will be used throughout the storyline. Copies of this information organizer could be contained in the Binder. Each students should have their own sheet. This should be collected with the Assessment piece and returned to students every day.

**Management Strategy: How do students manage the information they get from resources?**
Most of the information students receive will be factual in the form of data because it is the evidence that will support the claim they are given. Students should complete a “**Things I learned, Things I Thought**” sheet as they move through the episodes

**Example:**
I learned that...gravity increases as mass decreases
I thought that...was interesting because it explains why the moon has less gravity than earth.

**Step 8 Obtaining Information:**
Pictures cards with descriptions should be organized into
Students begin **VOICE AND PEN** protocol and complete FIRST WRITE form.

Sets with NASA’s graphic organizer on development of the solar system.

Here’s another one with less description:

Ask students to match the actual images from the HUBBLE SPACE TELESCOPE with the stages of solar system development from the GRAPHICs.

**Shows images of developing planetary system**
http://hubblesite.org/search/?query=protoplanet+images
(Some of these images are found below)

**Show model images of development cycle of solar Systems**
https://spaceplace.nasa.gov/review/solar-system-formation/infographic.en.png (this is NOT a great graphic, but the best I found online. You may be able to find a better one in an EARTH SCIENCE textbook)

**Management strategy:** *Members of the group should take turns reading and managing resource materials each day. This could occur in rotation based on color or number assignment. This could be as simple as placing colored sticker dots on the desks.*

“Today Yellow is the reader and Blue is the resource manager”

**Step 9** After they’ve had some time to look at these
When students are done they should:
- Return materials to the folder.
- Turn in their First Write for Assessment
- Turn in their “Things I Learned/Things I Thought” organizer.
- Questions should be put on sticky notes and brought to the PARKING LOT.

Management Strategy: **VOICE AND PEN**
For this protocol, paired students take turns holding the pencil. One person will speak (voice), and the other person will dictate (pen). Teacher directions to switch roles will ensure that students spend equal amounts of time speaking and listening.

**Step 10** When students are done they should:
- Return materials to the folder.
- Turn in their First Write for Assessment
- Turn in their “Things I Learned/Things I Thought” organizer.
- Questions should be put on sticky notes and brought to the PARKING LOT.

**Assessment**: First Write and Things I Learned forms should be turned in to the teacher and assessed for participation and effectiveness of the protocol. You should be giving feedback on their ability to relate evidence to the claim.

**Assessment of Student Learning**
Assessment will be the FIRST WRITE FORM turned in at the end of the activity. Informal assessment occurs as the teacher travels between groups and helps them to work through the question, the evidence, and the protocol. First Write should have several ideas about the role of gravity and charges in formation of the planet and the solar system. Ideas might be a little crazy and that’s ok!
Overarching Question: Are Gravitational Forces and Electromagnetic Forces the same all over the universe, and did these forces form the Earth?

Assignment: Explain the role of Gravity and electric and magnetic forces in producing the planets of the solar system including earth.

- You may use drawings to help you construct your explanation.
- You should also include any evidence you have from observation or experience to backup your claim.
- Ask Questions
Above: Gas plumes in Orion Nebula are formed by new stars as they collapse under their own gravity.
Below: Protoplanetary disc. Sun is in the center of the hole and the empty space is where a planet is forming and gathering material.
Proto planetary disk image and model of the image the bright spots are planets

"Simulations also suggest that these spiral arms have rich information about the unseen planet, revealing not only its position but also its mass," Zhu said. The simulations show that if there were no planet present, the disk would look smooth. To make the grand-scale spiral arms seen in the SAO 206462 and MWC 758 systems, the unseen planet would have to be bulky, at least 10 times the mass of Jupiter, the largest planet in our solar system.”

About this image

These are Hubble Space Telescope images of four newly discovered protoplanetary disks around young stars in the Orion nebula, located 1,500 light-years away. Gas and dust disks, long suspected by astronomers to be an early stage of planetary formation, can be directly seen in visible light by Hubble.
Disks around young stars (also known as circumstellar or protoplanetary disks) are thought to be made up of 99% gas and 1% dust. Even that small amount of dust is enough to make the disks opaque and dark at visible wavelengths. The dark disks are seen in these images because they are silhouetted against the bright backdrop of the hot gas of the Orion nebula.

The red glow in the center of each disk is a young, newly formed star, roughly one million years old (compared to the 4.5 billion year age of the Sun). The stars range in mass from 30% to 150% of the mass of our own Sun. As they evolve, the disks may go on to form planetary systems like our own. While only a handful of these dark silhouette disks have been discovered so far, they seem to belong to a much larger family of similar objects, and current indications are that protoplanetary disks are common in the Orion nebula.

Mark McCaughrean of the Max-Planck-Institute for Astronomy, Heidelberg, Germany, and his collaborator C. Robert O'Dell from Rice University, Houston, Texas, spotted the new disks in large-scale survey images of the Orion nebula that O'Dell had taken with Hubble between January 1994 and March 1995. A detailed study of the disk images has been submitted for publication to the Astronomical Journal.

Each image is 167 billion miles, or 257 billion kilometers, across (30 times the diameter of our own solar system). The disks range in size from two to eight times the diameter of our solar system. The researchers explain the different circular elliptical shapes as being due to the fact that each disk is tilted toward Earth by different degrees.

Side view of protoplanetary disc with sun in the middle. The prototype of a young star surrounded by a thin, dark disk and emitting powerful gaseous jets. The disk extends 40 billion miles from left to right in the image, dividing the nebula in two. The central star is hidden from direct view, but its light reflects off the upper and lower surfaces of the disk to produce the pair of reddish nebulae. The gas jets are shown in green.
Obtaining Information: Things I Learned, Things I Thought

Name ________________________

Example:
I learned...that cows had 5 stomachs
I thought...that was weird, why does a cow need 5 stomachs when I only have one. Isn’t one enough?

<table>
<thead>
<tr>
<th>Episode</th>
<th>Things I Learned, Things I thought</th>
<th>put as much detail in these statements as possible so that you can use this information to support your claims later</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>I learned …</td>
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<td>I thought…</td>
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### 7.1.5 Episode 2

#### Student Science Performance

<table>
<thead>
<tr>
<th>Topic: Universal Law of Gravity</th>
<th>Title: Newton’s Big Idea</th>
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**Overarching Performance Expectations from Standard:**
Engage in argument from evidence to support the claim that gravitational interactions within a system are attractive and dependent upon the masses of interacting objects. Examples of evidence for arguments could include mathematical data generated from various simulations.

**Lesson Performance Expectations:**
Students will engage with evidence to help answer the guiding questions. They will use evidence to support a given claim. They will engage in argument to determine if the guiding question has been adequately answered through the claim or if more evidence is required.

- **CCC:** Stability and change, System and system models
- **SEP:** Obtaining and evaluating information, Engaging in argument from evidence.

#### Students Will . . . To Construct Meaning

- Read feedback from previous episode
- Engage in brief classroom discussion on last episode and review Parking Lot questions.
- Review Guiding Question
- Reading and resource management responsibilities should rotate.

#### Teacher Will . . . To Support Students

- **Step 1** Pass back First Write forms and “Things I Learned/Things I thought” forms and allow students time to reflect on feedback.
- **Step 2** Have brief class discussion on previous episode by reviewing question in the PARKING LOT.
- You should also review the Guiding Question by reading it out loud to the group. The question is in their journals or could be posted on the board.

**Guiding Question**
“Are the effects of charges and the force of gravity the same all over the universe and are these forces responsible for forming the earth?”

- **Step 3** Student roles for reading and resource management should be rotate.

**Management Strategy:** Rotate

Resource reading and resource management can be rotated by having a different number or different color distinction for each student. This could be as simple as placing colored sticker dots on the desks.

“Today out loud reading will be done by Green and Resource Management will be done by Pink.”

Post the reading and resource management assignments on the board or in their resource binder.
Students receive resource binder and take out materials for Episode 2 in the storyline.

**Step 4.** For this next episode students should take out the materials for this episode from their binders

- How stars form

  [http://science.howstuffworks.com/star5.htm](http://science.howstuffworks.com/star5.htm)

**Management Strategy: Obtaining Information**

Students will look at data with their table group (4) and fill out “Things I learned/Things I thought” form and discuss what they are learning with their peers.

Each student should have their own page to work on.

**Step 5** students should **actively engage** with this text for the purpose of answer the guiding question.

**Management Strategy: Active engagement looks like**

- students using markers to circle, cross out, and make connections to the text. Different colored markers could be used for different types of information.

  It also looks like student discussion (see notes above) about the EVIDENCE in the text that might be used to help answer the QUESTION.

*Students should also be ASKING QUESTIONS and posting those on sticky notes that can be used to respond to the claim and motivate the next episode.*

*Students should see evidence of gravity acting on matter as stars and solar systems develop. They will not see evidence of electromagnetic forces in this dialogue. Give students about 10 minutes to engage with the data (longer if necessary).*
**Step 6** Pass out CLAIM A

Remind students that the VOICE AND PEN roles have been reversed. Review rules.

**Management Strategy: Responding to a Claim**

Student Reader for this episode should read the claim OUT LOUD and then VOICE should look for evidence that supports the claim while PEN writes that evidence down.

Students should also acknowledge parts of the claim that have weak or inadequate evidence meaning that it is stated as an assumption or is not quantified. **Every statement should be justified which means students should be asking “How do they know that?” or “Why did they say that?” “What do we know or did we see that suggests that is a true statement?” in response to the statements made in the claim.**

If they don’t have an answer to those questions, they may need to ask more questions or look for more evidence. **A few suggestions:** Students could ‘color code’ their evidence to the claim it supports. So as students write their evidence, they could use **colored pencils** of different colors, to match claim to evidence. Any claim that doesn’t have a **color match** needs further investigation. This will also help you with assessment. Teacher should **model** this behavior with the class for first reading.

**Step 7 Assessment:** Have student turn in claim A and “Things I learned/Things I thought” sheets. Review and prepare for next episode.

### Assessment of Student Learning

Students ask questions about the forces that pull earth materials together and the variables that affect those forces. Students respond to CLAIM A by recognizing the evidence that supports the claim and looking for claims that have NOT been supported by evidence and writing them down. In assessing student work, teacher should be looking for evidence statements that match the claim. Feedback on student thought processes and questioning and inferences should be given.
Claim A - The solar system formed from a cloud of gas and dust called a Nebula. The force of gravity pulled the Hydrogen gas and dust particles together because the force of gravity is attractive. This pull of gravity caused an increase in speed of the particles and increased the temperature of the particles until eventually the hydrogen atoms smashed into each other with enough force to start producing Helium. This process is called nuclear fusion. The sun continued to pull in matter until eventually there was a collapse and gas and dust were shot out and away from the sun. Planets formed as gravity pulled particles of dust together that were not pulled into the sun. The bigger the planets grew, the more matter they pulled in because bigger objects have more gravity than smaller objects.

What evidence do you have that supports this claim?

What part of this claim has not been adequately supported by evidence?

What questions do you have?
As you read this, remember the QUESTION you are trying to answer about the role of FORCES in space. Circle words or ideas that you think might be IMPORTANT or might be used as EVIDENCE to support a CLAIM you might make in answer to the guiding question. Ask questions about words you don't understand.

PHOTO COURTESY OF NASA
Gas pillars in a star-forming region - M16 (Eagle Nebula)

Stars are large balls of gases. New stars form from large, cold (10 degrees Kelvin) clouds of dust and gas (mostly hydrogen) that lie between existing stars in a galaxy.

1. Usually, some type of gravity disturbance happens to the cloud such as the passage of a nearby star or the shock wave from an exploding supernova.
2. The disturbance causes clumps to form inside the cloud.
3. The clumps collapse inward drawing gas inward by gravity.
4. The collapsing clump compresses and heats up.
5. The collapsing clump begins to rotate and flatten out into a disc.
6. The disc continues to rotate faster, draw more gas and dust inward, and heat up.
7. After about a million years or so, a small, hot (1500 degrees Kelvin), dense core forms in the disc's center called a protostar.
8. As gas and dust continue to fall inward in the disc, they give up energy to the protostar, which heats up more.
9. When the temperature of the protostar reaches about 7 million degrees Kelvin, hydrogen begins to fuse to make helium and release energy.
10. Material continues to fall into the young star for millions of years because the collapse due to gravity is greater than the outward pressure exerted by nuclear fusion. Therefore, the protostar's internal temperature increases.
11. If sufficient mass (0.1 solar mass or greater) collapses into the protostar and the temperature gets hot enough for sustained fusion, then the protostar has a massive release of gas in the form of a jet called a bipolar flow. If the mass is not sufficient, the star will not form, but instead become a brown dwarf.
12. The bipolar flow clears away gas and dust from the young star. Some of this gas and dust may later collect to form planets.

7.1.5 Episode 3

<table>
<thead>
<tr>
<th>Student Science Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Topic:</strong> Newton’s First and Second Law</td>
</tr>
</tbody>
</table>

**Overarching Performance Expectations (Standard) from State Standards or NGSS:**
Engage in argument from evidence to support the claim that gravitational interactions within a system are attractive and dependent upon the masses of interacting objects. Examples of evidence for arguments could include mathematical data generated from various simulations.

**Lesson Performance Expectations:**
Students will engage with evidence to help answer the guiding questions. They will use evidence to support a given claim. They will engage in argument to determine if the guiding question has been adequately answered through the claim or if more evidence is required.

**CCC:** stability and change, system and system models

**SEP:** Obtaining and evaluating information, engaging in argument from evidence.

<table>
<thead>
<tr>
<th>Students Will... To Construct Meaning</th>
<th>Teacher Will... To Support Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students read through Claim A and discuss feedback.</td>
<td>Pass back First Write and Claim A forms and “Things I Learned/Things I thought” forms and allow students time to reflect on feedback.</td>
</tr>
<tr>
<td>Students participate in class discussion from previous episode</td>
<td>Have brief class discussion on previous episode by reviewing question in the PARKING LOT.</td>
</tr>
<tr>
<td>Students review guiding question and purpose of research.</td>
<td>You should also review the Guiding Question by reading it out loud to the group. The question is in their journals or could be posted on the board. <strong>Guiding Question</strong></td>
</tr>
</tbody>
</table>

"Are the effects of charges and the force of gravity the same all over the universe and are these forces responsible for forming the earth?"

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 3</strong> Student roles for reading and resource management should <strong>rotate</strong>.</td>
<td><strong>Step 4.</strong> For this next episode students should take out the materials for this episode from their binders. Students should continue to use “Things I Learned/Things I Thought sheet that was returned to them, or get a new one if necessary.</td>
</tr>
<tr>
<td><strong>Step 5 Obtain Information:</strong> Students should watch a clip from this video from Nat’l Geographic called “How the Earth was Formed” <a href="https://video.search.yahoo.com/search/video?fr=tightro">https://video.search.yahoo.com/search/video?fr=tightro</a></td>
<td></td>
</tr>
</tbody>
</table>

**Students Should fill out Things I learned/Things I wondered template while watching the video.**
Students should share the things they learned and the things they thought from the video that they wrote on their template with their neighbor. Then Students participate in class DISCUSSION of the things they learned and the things they thought and ask motivating QUESTIONS about the relationship between gravity and mass.

Does gravity increase with mass?
- “If objects with more mass have more gravity, then why doesn’t the earth fall into the sun, it should have the most gravity?”
- “Why doesn’t the moon orbit the earth instead of just the sun?”
- “Do little things have gravity?”
- “Does distance affect gravity?”
- “Why do planets orbit?”

Students Receive Resource Binders
Students continue filling out Learned/Thought sheets

petb&p=how+the+earth+was+formed%3F#id=1&vid=2856ee196fde099983df2453e87adb89&action=click
(time 2:30-7:14)
The research referenced in the video can also be found in an article:

*The clip shows evidence that Electromagnetic forces between charged particles found in the dust cloud surrounding the new sun were able to ‘accrete’ or stick together and form into clumps. It also shows that as mass increased, that gravity increased until eventually the earth became the most massive object in the neighborhood.

Step 6 Management Strategy: Think/Pair/Share:
Students should write in their “Learned/Thought” form individually, and then discuss the evidence with their group and prepare observations and questions as a group to share with the class.
A class discussion with students would be appropriate to help students recognize that the video is suggesting that objects with more mass have more gravity.

*In recognizing this, students will be confronted with some interesting QUESTIONS that could arise from this video and should be used to motivate their research from this point to move closely align with core standard:
- “If objects with more mass have more gravity, then why doesn’t the earth fall into the sun, it should have the most gravity?”
- “Why doesn’t the moon orbit the earth instead of just the sun?”
- “Do little things have gravity?”
- “Does distance affect gravity?”
- “Why do planets orbit?”

Step 7 Students should continue to use “Learned/Thought” forms while they are presented
With animation: Ideally each student pair would have access to a computer and be able to manipulate the animation themselves.
Students are given data on the effect of Mass and distance on Gravitational attraction.

Step 8 Students should continue to use “Learned/Thought” forms while they are presented with the following data sets on the effect of Mass (M) and distance (d) on Gravitational Force. Students should again actively engage with the evidence. Allow students to look at the evidence for 10 minutes (or more if needed)

EXTENSION: Students can also explore the interesting physics of orbiting bodies. Quora has a great animation on the idea of ‘falling’ around the earth. (doc below)


One of the best documents on this is found on wikipedia page called Newton’s Cannonball

https://en.wikipedia.org/wiki/Newton%27s_cannonball

Newton’s cannonball.

However, I would save that animation for direct instruction on Newton’s big idea at the end of the storyline.
Students will switch VOICE and PEN roles
Students will respond to Claim B

**Step 8** VOICE and PEN roles switch. Students should be given CLAIM B and complete. Color coded matching of claims and evidence should be continued.

**Management Strategy: Redundant Claims**
Recognize again that most of the claim is repeated from previous episodes.
Should students repeat evidence from previous episodes? Not necessarily. All of the previous evidence will be used for the final assessment. Students should focus on new evidence and new claims. Students should keep past claims. If you are concerned they may get lost, collect them after with new claim.

**Step 9** Assessment: Turn in Claim B for assessment, “Learned/Thought” sheets

---

**Assessment of Student Learning**

Students are able to identify evidence that supports the claim and claims that are not supported by the evidence. Claims should be collected, read and feedback on their response should be given. Assessments should be returned before the next episode.

---

**VOICE ________________________________  PEN ____________________________**

**Claim B** - The solar system formed from a cloud of gas and dust called a Nebula. The force of gravity pulled the Hydrogen gas and dust particles together because the force of gravity is attractive. This pull of gravity caused an increase in speed of the particles and increased the temperature of the particles until eventually the Hydrogen atoms smashed into each other with enough force to start producing Helium.
This process is called nuclear fusion. The sun continued to pull in matter until eventually there was a collapse and gas and dust were shot out and away from the Sun.

The dust cloud surrounding the sun at a distance was full of charged particles that were attracted to each other and could stick to each other at high speeds. This formed little rocks of aggregated material. As these little rocks crash into each other and stuck together they formed larger and larger rocks until they were big enough that they drew in all of the rocks around them because objects with more mass have more gravity. This process formed all of the planets and rocks in the solar system. Even though these particles were falling towards the sun, their distance meant that they could only fall around the sun causing them to orbit.

What evidence do you have that supports this claim?

What part of this claim has not been adequately supported by the evidence?

What questions do you have?

Source: physics.weber.edu (yes, I bleed purple! Go wildcats! )
The force of gravity varies with distance from the Earth

Earth

<table>
<thead>
<tr>
<th>Distance from Earth (miles)</th>
<th>Acceleration due to Gravity (feet per second per second)</th>
</tr>
</thead>
<tbody>
<tr>
<td>32 (9.75)</td>
<td>0.9 (0.27)</td>
</tr>
<tr>
<td>8 (2.44)</td>
<td>1.3 (0.39)</td>
</tr>
<tr>
<td>400 (6.437)</td>
<td>2 (0.61)</td>
</tr>
<tr>
<td>800 (12.874)</td>
<td>3.6 (1.09)</td>
</tr>
<tr>
<td>1,200 (19.312)</td>
<td>6.25 (1.8)</td>
</tr>
<tr>
<td>1,600 (25.749)</td>
<td>9 (2.77)</td>
</tr>
<tr>
<td>2,000 (32.186)</td>
<td>100 (45.4)</td>
</tr>
<tr>
<td>2,400 (38.623)</td>
<td>25 (11.3)</td>
</tr>
<tr>
<td>3,200 (51.36)</td>
<td>11 (5)</td>
</tr>
<tr>
<td>4,000 (64.64)</td>
<td>6.25 (2.8)</td>
</tr>
<tr>
<td>5,000 (80.9)</td>
<td>4 (1.8)</td>
</tr>
<tr>
<td>6,000 (97.2)</td>
<td>2.77 (1.3)</td>
</tr>
<tr>
<td>7,000 (113.5)</td>
<td>2 (0.9)</td>
</tr>
</tbody>
</table>

distance in miles (kilometers) from the Earth's surface

amount a 100-pound (45.4-kilogram) person would weigh at each location in pounds (kilograms)

© 2011 Encyclopædia Britannica, Inc.
Gravity: Why doesn't the Earth fall into the Sun or the Moon fall into the Earth?

Jesse Berezovsky, Professor of Physics, Case Western Reserve University

Answered Nov 17, 2012 · Upvoted by Robert Frost, Engineer with specialization in spacecraft operations, orbital mechanics, and guidance, navigation …

The earth is constantly trying to fall into the sun, but it keeps missing. That is essentially what an orbit is. The sun exerts an attractive force on the earth, accelerating the earth directly towards the sun. This acceleration is constantly taking place. However, the earth also has some sideways momentum (perpendicular to the direction towards the sun). So as it falls towards the sun, it also moves to the side. As long as that sideways motion is enough to "side-step" the sun, the earth will orbit instead of crashing. You can see this more clearly in a more elliptical orbit:

![Diagram of elliptical orbit](image)

The planet (green) appears to be falling towards the sun (blue), but it has just enough sideways momentum to miss the sun and swing around. The earth and moon have an amount of sideways motion so that the orbits are nearly circular. In other words, we are moving sideways fast enough to so that we maintain a nearly constant distance to the sun, despite constantly accelerating towards it.
# 7.1.5 Episode 4

## Student Science Performance

<table>
<thead>
<tr>
<th>Topic: Newton’s First and Second Law</th>
<th>Title: Newton’s Big Idea</th>
</tr>
</thead>
</table>

**Overarching Performance Expectations (Standard) from State Standards or NGSS:**
Engage in argument from evidence to support the claim that gravitational interactions within a system are attractive and dependent upon the masses of interacting objects. Examples of evidence for arguments could include mathematical data generated from various simulations.

**Lesson Performance Expectations:**
Students will engage with evidence to help answer the guiding questions. They will use evidence to support a given claim. They will engage in argument to determine if the guiding question has been adequately answered through the claim or if more evidence is required.

- **CCC:** stability and change, system and system models
- **SEP:** Obtaining and evaluating information, engaging in argument from evidence, analyzing and interpreting data.

### Students Will... To Construct Meaning

- **Students read through Claim B and discuss feedback.**
- **Students participate in class discussion from previous episode.**
- **Students review guiding question and purpose of research.**

**Reading and Resource Management roles rotate.**

- **Students Receive Resource Binders**
- **Students continue filling out Learned/Thought sheets**

### Teacher Will... To Support Students

**Step 1** Pass back First Wright, Claim A and B forms and “Things I Learned/Things I thought” forms and allow students time to reflect on feedback.

**Step 2** Have brief class discussion on previous episode by reviewing question in the PARKING LOT.

You should also review the guiding question by reading it out loud to the group. The question is in their journals or could be posted on the board.

**Guiding Question**
“Are the effects of charges and the force of gravity the same all over the universe and are these forces responsible for forming the earth?”

**Step 3** Student roles for reading and resource management should be rotated.

**Step 4.** For this next episode students should take out the materials for this episode from their binders
Students should continue to use “Things I Learned/Things I Thought sheet that was returned to them, or get a new one if necessary.
Students watch videos on olympics on the moon.

Students are given worksheet called “Thinking Quantitatively about Gravity” and study data sets. Students will receive support for activity through class discussion and direct instruction.

Step 5 Phenomenon: Olympics on the moon.
https://video.search.yahoo.com/search/video?fr=tightrope&b=&p=olympics+on+the+moon#id=4&vid=4cdee32c67657843192c1792ab36c963&action=click

Questions: “Is there gravity on the moon?” “Why are they able to jump so high when they weigh so much?” “Do they weigh the same?”

Phenomenon extension:
https://video.search.yahoo.com/search/video?fr=tightrope&b=&p=olympics+on+the+moon#id=12&vid=c16b131b183baaa4f4cef4dfcc6b23bc&action=view

Students start to question the effect of gravity on weight and confront misconceptions about the amount of gravity on the moon and other planets.

Step 6
Students should be given worksheet called “Thinking Quantitatively About Gravity”. This could be an actual worksheet that students turn in, or it could be laminated and reused. I recommend individual worksheets so that each student gets experience GRAPHING data from a data set.

Management Strategy: Analyzing and Interpreting Data
Students should have some time to ANALYZE DATA and discover the data that best supports the idea that Mass effects gravity as measured by acceleration rates.
*7th grade students are familiar with plotting points on an x/y plane. However, they will struggle to construct ordered pairs from data and set up a point line graph. This activity will need support. This could be provided by helping students to construct ordered pairs and marking and labeling axis as a group after time is given for analysis of data.

Data Extrapolated from:
http://www.aerospaceweb.org/question/astronomy/q0227.shtml
https://nssdc.gsfc.nasa.gov/planetary/factsheet/planet_table_ratio.html
If the student was the voice during the last episode, then they should take the pen and the claim form and start listening to the voice.

Students turn in Claims, Notes, and Worksheet for Assessment.

*From this activity students should recognize that all matter has gravity, just different quantities and that we can perceive difference in gravity by measuring weight in this strange unit called the Newton (N). Students should be prepared to take on the entirety of CLAIM C.

**Step 7** VOICE and PEN roles switch. Students should be given CLAIM C and complete. Color coded matching of claims and evidence should be continued.

**Management Strategy: Redundant Claims**
Recognize again that most of the claim is repeated from previous episodes.

Should students repeat evidence from previous episodes? Not necessarily. All of the previous evidence will be used for the final assessment. Students should focus on new evidence and new claims. Students should keep past claims. If you are concerned they may get lost, collect them after with new claim.

**Step 8** Assessment: Turn in Claim C for assessment, “Learned/Thought” sheets and Thinking Quantitatively about Gravity assignment.

**Assessment of Student Learning**
Students should complete data analysis worksheet and turn in for feedback. Look for good graphing technique including labeling of axes, identification of ordered pairs from data, correct scaling of graph, etc. Students are able to identify evidence that supports the claim and claims that are not supported by the evidence. Claims should be collected, read and feedback on their response should be given. Assessments should be returned before the next episode.
Claim C- The solar system formed from a cloud of gas and dust called a Nebula. The force of gravity pulled the Hydrogen gas and dust particles together because the force of gravity is attractive. This pull of gravity caused an increase in speed of the particles and increased the temperature of the particles until eventually the Hydrogen atoms smashed into each other with enough force to start producing Helium. This process is called nuclear fusion. The sun continued to pull in matter until the system collapsed and gas and dust were shot out and away from the Sun.

The dust cloud surrounding the sun at a distance was full of charged particles that were attracted to each other and could stick to each other at high speeds. This formed little rocks of aggregated material. As these little rocks crashed into each other and stuck together they formed larger and larger rocks until they were big enough that they drew in all of the rocks around them because objects with more mass have more gravity. This process formed all of the planets and rocks in the solar system. Even though these particles were falling towards the sun, their distance meant that they could only fall around the sun causing them to orbit.

Gravity is a universal law. Every particle of matter in the universe has gravity. Electromagnetic forces are also act throughout the universe. These two forces continue to form new stars and planets today.

Traveling to other planets is difficult because of distances and because of the effects of gravity on different planets. Weight is a measure of the force of gravity pulling on an object. Weight is calculated by taking Mass x Acceleration due to gravity and is measured in Newtons (N). Our changing weights on different planets would make life on that planet impossible.

What evidence do you have that supports this claim?

What part of this claim has not been adequately supported by the evidence?

What questions do you have?
Thinking Quantitatively- What is the affect of mass on gravity?  Name _________________________________

<table>
<thead>
<tr>
<th>Planet</th>
<th>Mass stated as Percentage of Earth’s mass</th>
<th>Acceleration due to gravity (m/s²)</th>
<th>Number of Moons</th>
<th>Magnetic Field</th>
</tr>
</thead>
<tbody>
<tr>
<td>Earth</td>
<td>100% (1.0)</td>
<td>9.81</td>
<td>1</td>
<td>Yes</td>
</tr>
<tr>
<td>Moon</td>
<td>1.23 % (.0123)</td>
<td>1.62</td>
<td>0</td>
<td>No</td>
</tr>
<tr>
<td>Mars</td>
<td>10 % (.10)</td>
<td>3.77</td>
<td>2</td>
<td>No</td>
</tr>
<tr>
<td>Neptune</td>
<td>112% (1.12)</td>
<td>10.67</td>
<td>14</td>
<td>Yes</td>
</tr>
<tr>
<td>Jupiter</td>
<td>236% (2.36)</td>
<td>25.95</td>
<td>67</td>
<td>Yes</td>
</tr>
<tr>
<td>Venus</td>
<td>98% (.98)</td>
<td>8.87</td>
<td>0</td>
<td>No</td>
</tr>
<tr>
<td>Pluto</td>
<td>.03% (.0025)</td>
<td>.42</td>
<td>5</td>
<td>unknown</td>
</tr>
<tr>
<td>Mercury</td>
<td>5% (.05)</td>
<td>3.59</td>
<td>0</td>
<td>Yes</td>
</tr>
<tr>
<td>Saturn</td>
<td>92 % (.916)</td>
<td>11.08</td>
<td>62</td>
<td>Yes</td>
</tr>
<tr>
<td>Uranus</td>
<td>89% (.889)</td>
<td>10.67</td>
<td>27</td>
<td>yes</td>
</tr>
<tr>
<td>Outer Space</td>
<td>1 atom/ square meter</td>
<td>Almost 0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Graph the data that shows that mass affects gravity. Label the axis

Ordered Pairs: ( , )
Weight is a measure of the force of gravity acting on an object. Because the force of gravity is affected by mass, different planets have different amounts of gravity. This means that even though mass (the number of atoms) you are made of does NOT change, your weight (how much gravity is pulling on you) will change.

In physics, weight is measured in the unit of force, THE NEWTON (N).

Example: You stand on the scale and find that you weigh 100 lbs. To find your mass in kg, you took your weight in lbs and divided it by 2.2. You did this because 1kg = 2.2 lbs.

1. Calculate your mass by taking your weight (100 lbs) ÷ 2.2 = ______________
2. Enter your mass in the chart by EVERY planet because YOUR MASS will NOT change on other planets.
3. Use the data table above to find the acceleration due to gravity on each planet listed enter it in the table
4. Calculate your weight on other planets by using this equation: Weight (N) = Mass X Acceleration
5. Use a calculator to help you.

<table>
<thead>
<tr>
<th>Location</th>
<th>Your Mass (kg) (calculate using equation in number 1)</th>
<th>Acceleration due to Gravitational pull (m/s²) (from data chart on last page)</th>
<th>Weight (N) Calculate Weight (N) = Mass X Acceleration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mercury</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Venus</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Earth</td>
<td></td>
<td>9.81</td>
<td>445</td>
</tr>
<tr>
<td>Outer space</td>
<td></td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Moon</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mars</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jupiter</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Saturn</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Uranus</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Neptune</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pluto</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

If you are curious to see how much you weigh in pounds (lbs) on different planets, go to this website http://www.thecalculatorsite.com/conversions/massandweight.php

1. Enter your WEIGHT (N)
2. Convert from Newtons (N) to POUNDS (avoir) lb.

Analysis
A. What happens to weight as gravity changes?
B. What happens to Mass as gravity changes?
## 7.1.5 Episode 5

### Student Science Performance

<table>
<thead>
<tr>
<th>Topic: Newton’s First and Second Law</th>
<th>Title: Newton’s Big Idea</th>
</tr>
</thead>
</table>

**Overarching Performance Expectations (Standard) from State Standards or NGSS:**
Engage in argument from evidence to support the claim that gravitational interactions within a system are attractive and dependent upon the masses of interacting objects. Examples of evidence for arguments could include mathematical data generated from various simulations.

**Lesson Performance Expectations:**

Students will engage with evidence to help answer the guiding questions. They will use evidence to support a given claim. They will engage in argument to determine if the guiding question has been adequately answered through the claim or if more evidence is required. They will also think critically of their claim by addressing counterclaims and rebuttals.

- **CCC:** stability and change, system and system models
- **SEP:** Obtaining and evaluating information, engaging in argument from evidence.

### Students Will... To Construct Meaning

*Students receive feedback and ask questions in preparation for final assessment.*

*Students receive FINAL CLAIM form. Students should be told that their claims will be assessed using color matching.*

*Students will participate in a peer edit. Peers will color match claim to evidence. Then they will submit to instructor.*

### Teacher Will... To Support Students

**Step 1** Pass back First Write, Claim A and B and C and and “Things I Learned/Things I thought” forms and allow students time to reflect on feedback.

You should also review the Guiding Question by reading it out loud to the group. The question is in their journals or could be posted on the board.

**Guiding Question**

“Are the effects of charges and the force of gravity the same all over the universe and are these forces responsible for forming the earth?”

**Step 2** Have brief class discussion on previous episode by reviewing question in the PARKING LOT.

**Step 3** Assessment: FINAL CLAIM

Students will be given the FINAL CLAIM form. This should be completed by every student independently, however they can discuss evidence and use past claims to help them to construct their own answer to the overarching question.

“Are the effects of charges and the force of gravity the same all over the universe and are these forces responsible for forming the earth?”
<table>
<thead>
<tr>
<th>Management Strategy:  Peer Editing and Assessing their claim</th>
</tr>
</thead>
<tbody>
<tr>
<td>It makes sense that their final claim should be assessed using color matching so that students are able to recognize the effectiveness of their evidence in supporting their claim. Student should do a peer edit before submitting. Take some time to model evaluation of a strong vs a weak claim where a strong claim has many legs of valid evidence to support it along with well supported inferences.</td>
</tr>
</tbody>
</table>

| Assessment of Student Learning:  Final Claims should be assessed by instructor using color to connect claim to evidence. Claims should also be evaluated for accuracy based on evidence. Feedback should be given. |
Assessment- Newton’s Big Idea

Name ______________________________

Using the previous claims you have analyzed, make your own claim that answers the overarching question.

**Overarching Question:** “Are the effects of charges and the force of gravity the same all over the universe and are these forces responsible for forming the earth?”

This sounds like: “I think….because…”
Make a counterclaim (rebuttal) to your claim.

This sounds like: “Other people think…because…but I disagree with them because…”

Questions I still have on this topic.

This sounds like: “I am still confused about..” or “I wonder…” or “I wish I understood more about…”
## 7.1.5 Episode 6

### Student Science Performance

<table>
<thead>
<tr>
<th>Topic: Newton’s First and Second Law</th>
<th>Title: Newton’s big Idea</th>
</tr>
</thead>
</table>

**Overarching Performance Expectations (Standard) from State Standards or NGSS:**
Engage in argument from evidence to support the claim that gravitational interactions within a system are attractive and dependent upon the masses of interacting objects. Examples of evidence for arguments could include mathematical data generated from various simulations.

**Lesson Performance Expectations:**
Students will participate in class discussion and obtain information regarding mass and gravity. They will construct a graphic organizer demonstrating an understanding in words and images the relationship between mass, gravity and weight.

- **CCC:** Cause and effect
- **SEP:** Obtaining and communicating information, developing models.

### Students Will... To Construct Meaning

- **Students receive feedback from Final Claim Assessment**

### Teacher Will... To Support Students

**Step 1** Pass back First Write, Claim A and B and C and FINAL CLAIM forms and “Things I Learned/Things I thought” forms and allow students time to reflect on feedback. You should also review the Guiding Question by reading it out loud to the group. The question is in their journals or could be posted on the board.

**Guiding Question**
“Are the effects of charges and the force of gravity the same all over the universe and are these forces responsible for forming the earth?”

**Step 2** Have brief class discussion on previous episode by reviewing question in the PARKING LOT.

**Step 3- Engage** Students should use journals and complete a OEQ template for Engagement Activity. They should write “Isaac Newton’s Big Idea” at the top.

- **Students complete OEQ template for engagement activity on Isaac Newton. They should title the page, Isaac Newton’s Big Idea.**
Students take out the images (page following) of Isaac Newton with the apple. Students should discuss the images and the question. After they have had a chance to discuss bring them together for a class discussion and direct instruction.

**Step 4 : Class Discussion**

**Questions for conversation:**

“What did you notice about the picture? Similarities? Differences?”
“What can you learn about Isaac Newton by looking at these pictures When did he live? How old was he?”
“What do you think he was thinking about?”
“Why is the moon in every picture?”
“What do you think he figured out?”
“Why did the apple help him understand gravity in space?”

**Step 5: Direct Instruction- Students should take notes in their journal.**

The conversation about gravity was not new. Since Aristotle people had marveled that things always fell down and seemed to do it at the same rate, falling faster and faster as they fell. Isaac Newton was fascinated by the motion of the planets.

His experience with the apple was a ‘lightbulb moment; where he recognized that the moon was just like the apple, it was falling towards the earth, but because of its speed and distance it never hits the earth it just keeps falling AROUND the earth. But he was certain that gravity was the explanation for ALL planetary motion and even invented CALCULUS to express the ELLIPTICAL motion of planets and moons.

Teacher Note: One of the best documents on this is found on wikipedia page called Newton's Cannonball

https://en.wikipedia.org/wiki/Newton%27s_cannonball

Galileo had explored the motion of projectiles extensively and Newton had read his work. Newton extended Galileo’s ideas when he recognized that if a Cannon was large enough and could shoot the cannonball fast enough it would fall past earth's' surface before it had a chance to begin its downward descent and would just continue to fall forever.

Newton also recognized that the earth was not the only thing with gravity, but that ALL objects possess gravity but that those objects with the greater mass have more of it.

Newton had never seen men walk on the moon, but understood that weight was related to gravity and INFERRED that weight would change as gravity changed. Of course, now we are certain.

Because of Newton’s contribution to our understanding of FORCES, the unit for force was named after him. (Newton, N)

To help students with difference between weight and mass I show them this model.
We measure mass using weight, but mass is the amount of matter we have no matter where we are in the universe and we measure it with a balance. (kg)
Weight is measured using SCALES.

I include a FORCE PLATE because weight is a measure of FORCE. Scales measure the FORCE of gravity pulling on an object. (N)
Isaac Newton wasn’t the last great mind to explore gravity. Albert Einstein took scientists to the next level by explaining that gravity fields existed because of the ‘FABRIC of the UNIVERSE’ He calls this fabric “SPACE TIME” He helped to construct a model of gravitational fields that is very helpful.

**Demonstration:**
https://www.youtube.com/watch?v=2JOf1ub9US0&feature=youtu.be

To prepare students for their assessment explicitly state:
1. As mass increases, gravitational force increases.
2. As gravity increases, weight also increases.
3. As distance increases, gravity decreases.
4. Mass is a measure of how much matter an object is made of and does not change. Weight is a measure of the force of gravity pulling on a mass and changes depending on the gravity force exerted on that object.
5. Every particle of matter in the universe has gravity and exerts a force on everything else in the universe.

This last statement is called the Universal Law of Gravity.

“What is the relationship between Laws and Forces? “
“Are there other Laws besides gravity? “

Students may have heard of Newton’s Laws of Motion.

Scientific Laws are the mathematical and verbal expression of the behaviors we experience because of forces. There are laws for gravity, but also laws for magnetism, electric charge, and the strong and weak forces that make the atom. Even though we do not understand why these forces occur, we have a pretty good grasp on how they affect matter which makes it possible for us to use these forces.

Let’s explore Newton’s Laws of motion. 7.1.1 and 7.1.2

It was through his exploration of gravity and motion on earth and in space that he was able to construct his Laws of Motion which is where this conversation is going.

**Step 6:** Assessment:
Students construct a graphic showing:
- The relationship between mass and gravity attraction.
- The relationship between gravitational force and weight.
- The relationship between gravitational force and distance
- The difference between mass and weight

Rubric following
Assessment of Student Learning
Students will take notes from direct instruction. Students should be assessed on graphic organizer showing an understanding between mass and gravity, gravity and weight, gravity and distance, and the difference between mass and weight.

These are images of Sir Isaac Newton at the moment he recognize that forces were the same in space as they are on earth. Can you figure out how that occurred for him by looking at the pictures?
### Rubric for Assessment

<table>
<thead>
<tr>
<th>Required Element</th>
<th>Description</th>
<th>Value</th>
<th>Comments/Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>One panel describing in words and model the relationship between mass and gravitational force (attraction)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>One panel describing in words and model gravity and weight</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>One panel describing in words and model the relationship between gravitational force and distance</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>One panel describing in words and model the difference between mass and weight.</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>
Examples of Models for these concepts: These can be shown to your students (or not..) but might help with assessment and expectations.

Gravity Model

Illustration of the Gravity Model
Earth: Mass = 63.5 kg
Weight = 623 N (140 lbs)

Moon: Mass = 63.5 kg
Weight = 103 N (23 lbs)

Jupiter: Mass = 63.5 kg
Weight = 1582 N (355 lbs)

Sun: Mass = 63.5 kg
Weight = 17418 N (3914 lbs)
Strand: 7.1.1

Emphasis: Forces and Motion

Anticipated Time Required (assuming 50 minute class periods):
E. 1 50 min
E  2 100 min
E  3 50 min
E  4- 100-150 min
E  5- 100-150 min
E  6  50-70 min

Dominant CCC: Stability and change
Dominant SEP: Design and conduct investigations

Management Strategies to support equitable access to content: Rainbow labs and Rainbow Quizzes

Shopping list:
E. 2     Whiteboards, raw and hard boiled eggs (1 each per pair), tug of war rope, pie pans or shallow boxes or plates, spheres of different mass (glass marbles, steel marbles, wooden marbles)

E.3     Brick of styrofoam or florist foam the same size as a regular brick, a regular brick, 2 Batteries of different sizes (old is fine), something to make a rmap (board)

E. 4   rulers with grooves in them, styrofoam cups, marbles of different masses (that can roll through the groove on the rulers), or cups of different masses (or both)
Craters:  9x13 pan or a box, flour, cocoa powder, rocks or marbles of different masses, meter sticks, tarp if working indoors.

E. 5  red/green cards, copies of strips for activity on constructing newton’s 2nd in color if possible, straws, balls of different masses, cars, string, board, cup, pennies, pulleys (attached to board)

E. 6   Screw eyes, blocks of wood, different materials to glue to the block (sandpaper, cloth, plastic, silicon sheets, etc.) , ramps, spring scales (Newtons)
### Storyline Planner 7.1.1

**Anchor Phenomenon:** Some very large meteors have hit earth and changed the earth dramatically when they exploded.

**Student Performance Expectation:** Carry out an investigation which provides evidence that a change in an object’s motion is dependent on the mass of the object and the sum of the forces acting on it. Various experimental designs should be evaluated to determine how well the investigation measures an object's motion. Emphasize conceptual understanding of Newton’s First and Second Laws.

<table>
<thead>
<tr>
<th>Dominant DCI</th>
<th>Dominant CCC</th>
<th>Dominant SEP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical Science</td>
<td>Stability and Change</td>
<td>Carry out an investigation</td>
</tr>
</tbody>
</table>

### Science Experiences

<table>
<thead>
<tr>
<th>CCC/SEP</th>
<th>What are students doing? (This should match your SEP!)</th>
<th>What specific understandings should students get from this experience? (What pieces of the performance expectation does the experience provide?)</th>
<th>New questions students have to propel us to the next science experience</th>
<th>Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Cause and effect, systems and system models/ asking questions</td>
<td>Observing the Barringer Crater and other craters on earth. How did this happen? Observe image of the solar system that includes the asteroid belt Students observe the animation of near earth objects from NASA Completing a O/E/Q template</td>
<td>The meteor that made the crater has exploded. There are many asteroids spinning around the sun just like the planets and their behavior is strange.</td>
<td>How were the craters formed? Where do meteors come from? Could they come again? Why do some of them fall? Why do they change direction? When do things move? When do they stop moving? What keeps them in orbit?</td>
<td>Students Ask question Students participate in class discussion. Think/Pair/Share</td>
</tr>
<tr>
<td></td>
<td>Stability and Change/ carrying out an investigation</td>
<td>Tug of war activity</td>
<td>Things do not move unless unbalanced forces act on them. Objects will keep moving unless a force acts on them. Recognize that when a substance is at rest it will stay at rest and a substance in motion will stay in motion unless acted on by a force. An object will not change direction unless acted on by a force.</td>
<td>When do things stop? Will things just go forever unless something stops them? What effect do forces have on motion? Is this why meteors keep moving? What forces act on objects besides gravity? Is friction a force? (table that question for later)</td>
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<tr>
<td>2</td>
<td>Stability and Change/ carrying out investigations</td>
<td>Students will engage in demonstrations and direct instruction on inertia mass and momentum</td>
<td>Mass is a measure of an object’s inertia. Momentum is Mass x speed (velocity)</td>
<td>How do scientists know how big the meteor was that made the crater?</td>
</tr>
<tr>
<td>3</td>
<td>Stability/ change Carry out an investigation</td>
<td>Look at different impact crater sites and ask questions about the asteroids that made them. Students will design a proof of concept experiment with marbles and rules and cups to see if mass and speed affect force.</td>
<td>Students will recognize that rocks with more mass and speed make larger craters.</td>
<td>What is the difference between speed and acceleration?</td>
</tr>
<tr>
<td>Students will design and conduct an investigation on the variables that might affect the size of the crater.</td>
<td>Models of the mathematical relationship between mass and acceleration and force acceleration.</td>
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</tr>
<tr>
<td>Lab Report: Newton's 2nd Law</td>
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<tr>
<td>Students will observe the acceleration of falling objects. Students will construct a mathematical understanding of Newton's 2nd Law by matching models. Students will design and conduct experiments to quantify and prove Newton's 2nd Law.</td>
<td>Students will recognize that work and energy are ways to observe the amount of force that is being exerted on an object.</td>
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<tr>
<td>Lab Report: Friction Test</td>
<td></td>
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</tr>
<tr>
<td>Students will observe I fly ballet and objects falling in a vacuum and recognize that when a force is applied (gravity) acceleration will continue to occur until balance is achieved. Then acceleration will slow even though motion will continue.</td>
<td>Students recognize that when an unbalanced force is applied consistently to an object that its motion will constantly change until the forces balance. With gravitational force we see objects acceleration towards earth. Friction is a very important force on earth that acts against motion. Caused by attraction between</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>What if there was no friction?</td>
<td></td>
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</tbody>
</table>

**What is friction?**

Friction is a force that opposes the motion of objects in contact. It is caused by the attraction between molecules and can be reduced by using lubricants or altering surface texture. Friction affects the motion of objects in various ways, including stopping objects from sliding or changing the direction of motion. Understanding friction is crucial in many areas, such as transportation, manufacturing, and sports.
| formal Assessment on Newton's first and second laws. | opposite charges on atomic level. |   |   |
# 7.1.1 episode 1

<table>
<thead>
<tr>
<th>Student Science Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Topic:</strong> Newton’s First and Second Law</td>
</tr>
</tbody>
</table>

**Overarching Performance Expectations (Standard) from State Standards or NGSS:**
Carry out an investigation which provides evidence that a change in an object’s motion is dependent on the mass of the object and the sum of the forces acting on it. Various experimental designs should be evaluated to determine how well the investigation measures an object’s motion. Emphasize conceptual understanding of Newton's First and Second Laws. Calculations will only focus on one-dimensional movement, the use of vectors will be introduced in high school.

**Lesson Performance Expectations:** Students will engage with phenomenon of meteors and ask questions about their motion through the universe. Students will generate questions about moving bodies in space for investigation

CCC: Cause and Effect
SEP Ask Questions

<table>
<thead>
<tr>
<th>Students Will . . . To Construct Meaning</th>
<th>Teacher Will . . . To Support Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students will construct OEQ chart while they observe these craters.</td>
<td>Overarching Phenomenon: Earth’s surface is covered in craters.</td>
</tr>
</tbody>
</table>

**Step 1:** Students can be organized into Lab Groups or this could be done with table partners.

**Step 2:** Phenomenon: The earth is covered in craters.
Students will complete OEQ template in their journal and make observations, construct explanations, ask questions.

Show students printed images of craters
Students should prepare to observe phenomenon by drawing an OEQ template in their journals.

Students should be warned that they will be RANDOMLY SELECTED to share something they've observed, a question they've had, or an inference they've made.

Writing Prompt: Make Observations, Construct Explanations and Ask Questions about these images.

**Step 3 Management Strategy: think/pair/share**

Students should discuss the OE and Q with their partner. Randomly Generate students names to share thoughts.

**Possible questions include:**

Were these made by meteors? Where did they come from? How big are these craters? Where do meteors come from?

**Question for exploration:** “Where do meteorites come from?

**Step 4 Phenomenon extension:**

Students should prepare to observe phenomenon by using OEQ template in their journals.

**Warn students** that they will be RANDOMLY SELECTED to share something they've observed, a question they've had, or an inference they've made (explanation).

https://www.universetoday.com/19616/earth-10-most-impressive-impact-craters/
Management strategy: Random Student Generator

There are some online generators, however popsicle sticks with names on them drawn randomly from a jar are also very effective if you keep your eyes closed! You may also have student names drawn out of a hat however, keep the names out of the hat until everyone has had a chance to be selected.

Show printed image of ASTEROID BELT

http://www.crystalinks.com/asteroidbelt.html

*Help students to recognize that this is a model of a system.

Question: Which parts of the model are Accurate? Which are inaccurate? What is surprising? What looks familiar?

Allow students to write observations and questions quietly before progressing to animation.

Step 5 Animation

https://www.nasa.gov/asteroid-and-comet-watch

This link brings you to NASA website called “comet and asteroid watch” Click on “How does NASA spot a near earth asteroid?” There are a lot of interesting resources, but the phenomenon for this
episode is “NASA asteroids and comets: 3 years of Neowise data”.

This is a memorizing and somewhat terrifying animation of all the near earth objects recorded by NASA for the last 3 years. Students will need to watch the animation at least 3 times. I recommend stopping the video occasionally to allow students to understand what they are looking at.

Allow some time to discuss their ideas with their table partners before selection.

Construct an OEQ template on the board and RANDOMLY SELECT students to share their Observations, Explanations and Questions.

Students have some understanding that gravity pulls things together and that forces created the universe. They may even have some idea about the interaction of speed, distance and gravity and why things orbit, but..

Investigation Questions for next episode:

How do bodies in space keep moving? When do they change motion?

<table>
<thead>
<tr>
<th>Assessment of Student Learning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assessment at this point is formative as students interact with the phenomenon: Journals may be checked for participation and assessment.</td>
</tr>
</tbody>
</table>
### Topic: Newton’s First and Second Law

#### Title: Force and Motion

### Overarching Performance Expectations (Standard) from State Standards or NGSS:

Carry out an investigation which provides evidence that a change in an object's motion is dependent on the mass of the object and the sum of the forces acting on it. Various experimental designs should be evaluated to determine how well the investigation measures an object's motion. Emphasize conceptual understanding of Newton’s First and Second Laws. Calculations will only focus on one-dimensional movement, the use of vectors will be introduced in high school.

### Lesson Performance Expectations:

Students should investigate the phenomena associated with Newton’s First Law of motion. Students should engage in argument as they construct Newton’s First Law of motion. They should understand that when an unstable force is applied to an object in stable motion, that the motion of that object will change. Change in motion is stopping, starting, slowing down, speeding, or changing direction.

They should use Newton’s First Law of motion to answer a question on motion of objects.

**CCC:** Stability and Change  
**SEP:** Constructing a model, Carry out an investigation

### Students Will... To Construct Meaning

*Students should do a QUICK READ and REVIEW question from last episode and review the phenomenon*

### Teacher Will... To Support Students

**Overarching Question:** What are Newton’s Laws of motion and how do they relate to forces? From 7.1.5

**Investigation Questions for this episode:**

- “How do objects in space keep moving?:
- “When do objects change motion?”

**Miniepisode 1** Have students do a QUICK READ AND REVIEW from the notes they took during the last episode.

**Management Strategy:** QUICK READ and REVIEW  
When students come to class they can engage in journaling and review. students can do a QUICK READ. Students are given 1-2 minutes of silence to review their notes from the day before. Randomly generate names and call on individuals to tell you "What do you remember from last time.“ This review helps teachers and students to assess student understanding that has 'stuck’ and allows students to review a lot of material quickly. It also gives motivation for clear and well written notes.

**Review student generated questions from last episode:**

*Students Investigate the difference in motion between a raw egg and a cooked egg.*
<table>
<thead>
<tr>
<th>Students construct an explanation of the phenomenon on whiteboards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students are instructed in appropriate language for engaging in argument with their peers.</td>
</tr>
<tr>
<td>Students engage in Think Tank protocol and determine the best explanation of the behavior of the eggs based on evidence.</td>
</tr>
</tbody>
</table>

**Student prompt:**

Use language tools to communicate scientifically:

*Language tools for SHARING IDEAS:*

My idea is...

---

**Miniepisode 2**

**Engage with Investigation: Is it raw or cooked?**

Students should complete OEQ template and prepare for investigation.

Student Lab Pairs are given **2 eggs, one raw and one hard-boiled.** They are not told which one is which.

Students should be told to **discover which egg is raw** without breaking it or using any tool besides their hands.

Students should discuss the problem with their partners and then ask questions if they need help.

If they get stumped, here is the procedure:

**The procedure:** If students spin a raw egg and then stop it suddenly with their finger and then move their finger away, the egg will start spinning again.

A hard-boiled egg will stop spinning entirely when stopped.

**Step 5** Once the desired observations have been made have students consider these questions:

- Why does this occur?
- How does this tell us which egg is raw and which is cooked?

Students should return to their template and discuss possible explanations with their partners.

Students should be given **whiteboards** and construct a **MODEL and EXPLANATION** of how they know which eggs is raw and which is cooked and why.

**Management Strategy: THINK TANK**

Count off lab partners so that you end up with 3 partner pairs in a discussion group. (so if you have 36 students in 18 pairs, count to 6, 3 times to form 6 groups)

They should meet up with their number group and share their ideas and their models. Each group should select the best model or should produced a modified model to share with the class. Each group gets 3 minutes to present.

Presentations to the class will begin 10 minutes after strategy begins.

**Management Strategy: SET an ALARM.** An egg timer or your phone can be used to time any activity. A timer could be selected in each group as well.

**Management Strategy: Respectful Language**

Review with students the language scientists use when

---
I think that...
We could draw a picture to show...
I think it looks like...

**Language tools for CLARIFICATION**
I notice that you wrote _______ can you explain?
Can you explain why you _______?
Can you draw what you mean?
Can you say more about _________?
Can you say more about _________?
Do you have evidence for __________?

**Language tools for VALIDATION:**
What I heard you say was.....?
What do you think?
What is your idea?
When you said __________ I thought of ________?

---

Students participate in tug of war
Students observe images of tug of war and answer the question: Who is going to win and why?

Students answer Question about images in their journals and engage in Think/Pair/Share protocol. 
Students participate in class discussion

---

‘arguing from evidence’.
These language tools should be posted or reviewed before allowing students to critique student work in a student led group.

**Student Understanding:**
Students should start constructing the idea that until something actually makes something stop, it doesn’t stop. Possible explanations sound like:
“the cooked egg is solid and so all of the egg stops at once, but the raw egg inside the shell doesn’t STOP MOVING at the same time as the shell. It also doesn’t START MOVING inside the shell as quickly.”

Students may find themselves wanting to use the word FORCE. This should be noticed and encouraged.

**Miniepisode 3 Activity - Tug of War**
You may want to attempt a tug of war contest in your class, if conditions do not allow then just proceed to step 2.

**Think/Pair/Share**
Show students this image
Have them answer the question in their journal: "Who is going to win and why?" Use the word FORCE in your answer. Give them 1 min to write


Then show them this image and have them answer the same question. Give them 1 min to think and write

http://media.gettyimages.com/photos/tug-of-war-150
Students observe picture and try to tell the STORY of the picture. How did the story start and how will the story end. They should use arrows to show motion and forces.

Students watch Nitrocircus video and compare to their prediction. Students should recognize that the bike and the rider keep moving at the same speed and direction even though they are not touching. Students should do a THINK/PAIR/SHARE on the image.

Students should take turns with their table partners offering their answers and explanations. They should be reminded of proper dialogue for argument.

Bring discussion to the class.

*Student Understanding:
Students should recognize that no movement would occur because the man is pulling against himself with (we assume) equal force. Things only change motion when forces are unbalanced.

Follow up question:
"What does this tell us about motion? Is it always true that motion only changes when forces are unbalanced?"

Miniepisode 4: Objects in Motion: Nitrocircus

Show students this image:


With your lab partner, discuss the story of this picture:
- "How did this happen?"
- "What's going to happen next?"

Students should be given time to consider the question. Have the students use Whiteboards to draw the scenario. Tell them to use Arrows to indicate DIRECTION of MOTION and ANY FORCE that is acting on the 'object'. Walk around and find a few drawings to share with the class and bring it to the class for discussion.

Show students this incredible video of 'objects' in motion.

http://nitrocircus.com/ Extended Highlights: Nitro World Games 2017 in SLC.
Rewind the motion and stop at 2:24 and freeze the frame.

Or show: https://video.search.yahoo.com/search/video;_ylt=AwrSbnPTdGIZ0_wANUhXNyAo;_ylu=X3oDMTEyOWwxY3RzBGNvbG8DZ3ExBHByQwMxBAHZ0aWQDQJoVcMTRjMQRzZWMDc2M-
p=nitro+circus+world+games+2017+best+tricks&fr=tightropetb#id=80&vid=8e3b37c2d9b6df2aabc8ef18a982b0a8&action=view

Freeze at 1:18

Questions for discussion: Discuss with table partner, then with class.

Was your story correct? What did you get wrong? How is the man moving forward if he is no longer attached to his bike?

Class conversation: STABILITY AND CHANGE

Pass out a piece of paper with the following questions:

- “What does it mean to be stable?”
- “What does it mean for motion to be stable?”
- “Is moving in a circle stable motion?”

Have students engage THINK/PAIR/SHARE

Students should respond to the questions individually and then share with their lab partner and then share with the class.

Miniepisode 5: Investigation: Don’t lose your marbles

Give lab partners a pie tin, a large marble and a small marble or a styrofoam ball and a small styrofoam ball. (I recommend two rolling objects with different masses because they will also begin to construct understanding of Newton’s 2nd Law as well which leads to the next episode)

Students should put the balls into the pie pan and play with the motion of the pan and the different balls and construct RULES that describe

- WHEN IS AN OBJECT’S MOTION STABLE and
- WHEN DOES AN OBJECT’S MOTION CHANGE?

Students must use the phrase UNBALANCED FORCE in their rules.

Encourage students to stop and start the pan and move it quickly in a circle or change the pans direction and carefully observe what the ball does. They will need to make good observations and take good notes.

When they think they have a set of rules, they should come to the front and GRAFFITI SPLASH

Students investigate moving objects (solid balls or marbles of different masses in a pie tin) with intent to construct rules for motion.
Students will write their inferences on the board in GRAFFITI SPLASH protocol.

Learn slogans for vocabulary: unbalanced force, balanced force, stable, change

Student prompt:
Students take Quick Quiz - When do objects change motion?

Students receive QUICK WRITE form.
As a class, students are asked to construct a list of vocabulary words that would be necessary to answer the question:
Why do we wear seatbelts in cars?”
Using Newton’s first Law of motion.
Students answer the question using the vocabulary list they constructed. They may also use models to explain the answer.

Management Strategy: Graffiti Splash
Students come to the class whiteboard and write sentences or responses or ideas in different colored markers.
When everyone has had a chance to contribute, lead a reading of the Graffiti and ask students to explain or support their statements with evidence from their observations.

*Student Understanding:
Students should recognize that an object will not start moving or stop moving or change direction unless acted on by an unbalanced FORCE. An object does not need a force to KEEP moving just CHANGE movement. Students will also notice that a bigger or heavier object requires more force to change its motion.

Vocabulary Study: slogans! See supplemental Words: unbalanced force, balanced force, stable, change

Assessment: Quick Quiz - When do objects change motion?

Assessment: Newton’s First Law
Pass out a Quick Write form.
Show students the question: 
“Why do we wear seatbelts in cars?”
Ask students to construct a list of words they would need to use to answer this question using Newton’s First Law of Motion.

The list must include:
- Motion
- Change
- Inertia
- Force
- Stable
- Balanced
- Unbalanced

List may include:
- Stop
- Start
Students consider the question. Does mass affect the amount of force it takes to move an object?

- Brakes
- Seatbelt
- Crash
- Fly
- Car

Students will write an explanation of why we use seatbelts in cars that MUST have the vocabulary that they have selected.

**Management Strategy: Creating a Vocabulary List**

This is a very effective way to get students thinking, before they write, about the language they need to use in order to construct an explanation. They are always very surprised when they are expected to USE the list. *Tricky Teacher.* :)

Question for next episode: “Does mass affect the amount of force it takes to move an object?”

**Assessment of Student Learning**

*QUICK WRITE* should be assessed to determine student understanding of Newton’s First Law. Students will answer the question using a constructed list of vocabulary. Then students must answer the question using specific language and correctly answer the question using the principles of Newton’s first law.
Quick Write- Newton’s 1st Law of Motion
Question: Why do we wear seatbelts in cars?

1. What vocabulary words must you have to answer this question using Newton’s 1st Law of motion.

2. Answer the question using ALL of the vocabulary above. Underline the vocabulary words in your explanation. You may use the backside of this paper if necessary. You may also draw a model of your explanation.
Quick Quiz- When do objects change motion

Fill in the blank

<table>
<thead>
<tr>
<th>Force</th>
<th>Unbalanced Forces</th>
<th>Balanced Forces</th>
<th>Stable</th>
<th>Changed</th>
<th>Motion</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>If an object experiences a change in its motion, we know it was affect by ________________________</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>2</td>
<td>If an object is not experiencing a change in its motion, we know it is experiencing ________________________</td>
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<td></td>
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</tr>
<tr>
<td>3</td>
<td>If an object is moving at a constant speed then its motion is ________________________</td>
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</tr>
<tr>
<td>4</td>
<td>If an object suddenly slows down it is because the forces acting on that object ________________________</td>
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<td></td>
<td></td>
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</tr>
<tr>
<td>5</td>
<td>An object in motion will stay in motion unless acted upon by an unbalanced ________________________. An object at rest will stay at rest unless acted upon by an unbalanced ________________________.</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>The statement above is called Newton’s First Law of ________________________</td>
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</tr>
</tbody>
</table>
7. **Question:** How do objects in space (planets, asteroids, comets) keep moving in the same way?

**Vocabulary List:**

**Explanation:**

8. **Question:** When do objects change motion (slow down, speed up, start, stop, or change direction)?

**Vocabulary List:**

**Explanation:**

**Quick Write- Newton’s 1st Law of Motion**

**Name _____________________________**

**Question:** Why do we wear seatbelts in cars?

1. What vocabulary words must you have to answer this question using Newton’s 1st Law of motion.

   Inertia, change, motion, force, stable, balanced, unbalanced (required), stop, start, brakes, seat belt, crash, fly

2. Answer the question using **ALL of the vocabulary** above. Underline the vocabulary words in your explanation. You may use the backside of this paper if necessary. You may also draw a model of your explanation.

   We wear a seatbelt when we drive because when our bodies are in motion inside of our cars we are traveling at the same speed as our car and we don’t feel like we are moving because the forces are balanced. But if the car suddenly stops because you have to push on the brake, to avoid a crash, then the motion of the car changes and the forces acting on our bodies become unbalanced. Then our inertia will keep us moving in a straight line until some force, like the steering wheel or the windshield, stops us.
Quick Quiz—When do objects change motion

1. Unbalanced forces
2. Balanced forces
3. Stable
4. Changed
5. Force, force
6. Motion
7. How do objects in space keep moving in the same way?

Vocab: inertia, motion, balanced forces, unbalanced forces, orbit, planets, asteroids, gravity, change

Explanation: When the universe was forming the dust and debris that formed the planets started moving together because of the unbalanced forces acting on them like gravity. All of material was pulled into the sun, but some made planets and asteroids and because the forces on them are currently stable, they don’t change motion and won’t change until an unbalanced force is applied.

8. When do objects change motion?

Vocab: unbalanced force, exerted, change, motion, stop, start, speed up, slow down, balanced force, newton’s First Law of motion

Newton’s First Law of motion states that an object’s motion will not change unless acted on by an unbalanced force. Changing motion looks like speeding up or slowing down, stopping, starting or even changing direction. If forces are balanced then motion remains stable. Stable means unchanging, not stopped.
<table>
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<tr>
<th><strong>Student Science Performance</strong></th>
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</thead>
<tbody>
<tr>
<td><strong>Topic</strong></td>
</tr>
</tbody>
</table>

**Overarching Performance Expectations (Standard) from State Standards or NGSS:**
Carry out an investigation which provides evidence that a change in an object’s motion is dependent on the mass of the object and the sum of the forces acting on it. Various experimental designs should be evaluated to determine how well the investigation measures an object’s motion. Emphasize conceptual understanding of Newton’s First and Second Laws. Calculations will only focus on one-dimensional movement, the use of vectors will be introduced in high school.

**Lesson Performance Expectations:** Students will understand that Inertia is a property of matter related to mass, that mass x speed = momentum. Students will quantify the momentum of moving objects and begin constructing Newton’s 2nd Law of motion.

**CCC:** Cause and Effect

**SEP:** Obtaining Information, use Mathematics and computational thinking

<table>
<thead>
<tr>
<th><strong>Students Will... To Construct Meaning</strong></th>
<th><strong>Teacher Will... To Support Students</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Students will take notes on Newton’s First Law of motion</em></td>
<td><strong>Overarching Question:</strong> What are Newton’s Laws of motion and how do they relate to forces? From 7.1.5</td>
</tr>
<tr>
<td><em>Students learn the definition of INERTIA.</em></td>
<td><strong>Investigation question:</strong> “Does mass affect the amount of force it takes to move an object?”</td>
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</table>

**Quick Read/Review**

**Direct Instruction:**
Isaac Newton recognized that the motion of planets and other objects on earth followed consistent rules. Newton’s First Law of motion states:

- An object in motion tends to stay in motion unless acted on by a FORCE (push or a pull)
- An object at rest tends to stay at rest unless acted on by a FORCE (push or a pull)

Newton explained that all matter has INERTIA. INERTIA is a property of matter (Bill Nye is right) INERTIA is the property of matter that makes it RESIST changes in motion. (like a student resisting homework)
The law means that a force MUST be applied for an object to stop, start, slow down (decelerate), speed up (accelerate), or change direction.
Students respond to a writing prompt; Use the word INERTIA while explaining why the raw egg kept spinning after it was stopped.

Students watch demonstrations on relationship between inertia and mass

Students respond to writing prompt: “Does understanding this concept help us to understand why we see lots of small objects falling towards earth, like shooting stars, but not very many large ones? (thank goodness). How does this concept help us to understand why this happens?”

Writing Prompt: Students should answer the following question in their journals. Randomly generate students to share. “Use the word INERTIA while explaining why the raw egg kept spinning after it was stopped.”

Demonstration:
1 building brick
1 styrofoam brick
A student is asked to come up and change the motion of the bricks (push on them with a force)
Which brick has more inertia? (which one RESISTS a change in its motion the most?)

Direct instruction:
Mass is determined by the amount of inertia an object has, the more resistant an object is to change in its motion, the more inertia it possesses.

Demonstration:
Rolling 2 batteries (see note) or other rolling objects of different masses but similar sizes down a ramp and onto the floor.
Which one resists a change in its motion the most? (which one takes the longest time to stop rolling)

Student understanding:
Note: The physics of rolling objects is a little nuts because of what is called the “The moment of inertia” which is affected by the position of mass in a rolling bodies. For example: Solid objects will roll faster than hollow objects so choosing a golf ball and a ping pong ball for example is not an accurate representation of the effect of mass on inertia.

Writing Prompt: Have students explore the following questions in their journals. Randomly generate students to share.

Question: “Does understanding this concept help us to understand why we see lots of small objects falling towards earth, like shooting stars, but not very many large ones like asteroids? (thank goodness). How does the concept of inertia help us to understand why this happens?”

Direct Instruction:
When an object with mass is moving, the object acquires MOMENTUM which is calculated:
Learn slogans for inertia, resist, momentum, speed with class. Call and response.

**THINK PAIR SHARE**

Students respond to writing prompt by:
- Calculating the MOMENTUM of the Asteroid that made Barringer Crater.
- Deciding if momentum is energy?
- Considering what happened to all of that momentum when the asteroid hit the earth?
- What happened to the earth when it was hit with an object that had that much momentum?

Students should discuss their answers with their neighbors and then with the class...however don’t expect them to have these answers, let them guide you to the next episode.

Mass x Speed = Momentum

When an object has more MOMENTUM, it takes a greater force to change its motion in any way.

**Vocabulary study:** slogans! See supplemental on vocab. Words: inertia, resist, momentum, speed

**Management Strategy:** THINK/PAIR/SHARE

**RANDOM STUDENT GENERATOR**

**Assessment:** Quick Quiz-Inertia, Mass, Speed and momentum.

Here we are at Barringer Crater again. We have some understanding now of how a random asteroid could leave its potential endless cycle through the sky and suddenly head towards earth.

Think/Pair/Share

**Writing Prompt:** Scientists estimate that the asteroid that made this crater was moving at 12,800 m/s (28,800 miles/hour) and has a mass of 45,000 kg. I’ve included the answers here though you don’t need to answer their questions, many will be answered in the next episode.

- How much momentum did it have? A lot (576,000,000 kg/m/s)
- Is momentum energy? No, changes in momentum like the sudden deceleration of the asteroid when it hit the earth, can be used to calculate force (mass x deceleration) and force can be used to determine energy (next episode)
- What happened to all of that momentum when the asteroid hit the earth? *It was turned into force, which turned into work* (like the work of
digging a hole ¾ across and throwing the material 5 miles in every direction)

- , and then expressed as a quantity of energy. What happened to the earth when it as hit with an object that had that much momentum? It was altered as that force did work on it.

Investigation Questions for next episode:
Do bigger asteroids make bigger craters? What happens to momentum when an object contacts another object?

Assessment of Student Learning
Assessment: Quick quiz score students should be able to use a formula and recognize that the formula is a quantitative way to predict the behavior of objects when they interact. Students should be able to connect understanding to original phenomenon and construct an explanation of asteroid behaviors stating that more massive objects like comets and large asteroids will not be pulled off course by earth’s gravity as easily as smaller objects, it would require a tremendous force to change their motion in a noticeable way. Students should also recognize that inertia of the egg yolk cause the raw egg to keep spinning in engagement activity.
Quick Quiz- Inertia, Mass, Speed and Momentum

Name _______________________

1. Define Inertia _________________________________________________________

2. Which has more inertia a 10 kg object or a 20 kg object?

3. Which will require more force to change its motion, a 100 kg human or a 10,000 kg truck?

4. Define momentum _____________________________________________________

Which has more momentum?

6. A mosquito hitting your car at 60 miles/hour
   A train hitting your car at 60 miles/hour

7. Which has more momentum?
   60 kg football player running at 10 miles/hour
   60 kg football player running at 5 miles/hour

8. Which will require more force to GET MOVING?
   A box weighing 50 N
   A box weighing 100 N

9. Which will more force to STOP once its moving?
   A box weighing 50 N
   A box weighing 100 N

10. Which requires a great force to CHANGE ITS MOTION?
    A 10,000 kg asteroid at 56,000 miles/hour
    A 2 kg meteorite at 56,000 miles/hour

11. How much momentum does an asteroid have if it has a mass of 100 kg and is moving at a ridiculous speed of 108,000 km/h
    Calculate: Momentum = Mass x speed

12. How much moment does a train have if it has a mass of 9,000 kg and is not moving?

Draw models of the following scenarios. Use arrows to show the direction force is exerted and the direction of motion if applicable.
13. You push on the left side of a box that weighs 50 N with a 60 N force. Will the box move? Which way will it move?

14. You push on your car that weighs 1000 N with 100 N of force. Will the car move? Which way will it move?

15. You weigh 100 kg and your friend weighs 150 kg. You decide to play a rough game of tag and you accidentally run into each other. You are both running at 6 km/hour. Who is going to get knocked over, you or your friend? Draw a model showing the scene.

16. **QUESTION:**
Why don’t all near earth asteroids fall towards earth?

**Vocabulary List:**

**Explanation:**
__________________________________________________________________________________________________________________
__________________________________________________________________________________________________________________
__________________________________________________________________________________________________________________
__________________________________________________________________________________________________________________
__________________________________________________________________________________________________________________
Quick Quiz: Inertia, Mass, Speed and Momentum

Name ______________________

1. Define Inertia ____________
   Tendency of matter to Resist Change

2. Which has more inertia a 10 kg object or a 20 kg object? ____________
   20 kg - More Mass

3. Which will require more force to change its motion, a 100 kg human or a 10,000 kg truck? ____________
   10,000 kg Truck

4. Define momentum ____________
   Mass x Speed

Which has more momentum?

6. A mosquito hitting your car at 60 miles/hour
   A train hitting your car at 60 miles/hour
   A train hitting your car at 60 miles/hour

7. Which has more momentum?
   60 kg football player running at 10 miles/hour
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    A 10,000 kg asteroid at 56,000 miles/hour
    A 2 kg meteorite at 56,000 miles/hour
    A 2 kg meteorite at 56,000 miles/hour

11. How much momentum does an asteroid have if it has a mass of 100 kg and is moving at a ridiculous speed of 108,000 km/h
    Calculate: Momentum = Mass x speed
    \[ 10,800,000 \]

12. How much moment does a train have if it has a mass of 9,000 kg and is not moving?
    0 - has no speed if it's not moving

Draw models of the following scenarios. Use arrows to show the direction force is exerted and the
13. You push on the left side of a box that weighs 50 N with a 60 N force. Will the box move? Which way will it move?

\[ 60 \text{ N} \rightarrow \text{ East} \]
\[ 10 \text{ N to the Right.} \]

14. You push on your car that weighs 1000 N with 100 N of force. Will the car move? Which way will it move?

\[ \text{NOPE!} \]

15. You weigh 100 kg and your friend weighs 150 kg. You decide to play a rough game of tag and you accidentally run into each other. You are both running at 6 km/hour. Who is going to get knocked over, you or your friend?

Draw a model showing the scene.

This guy (100 kg) is gonna fly.
Hey that's me!!! Oh no.

16. QUESTION:
Why don't all near earth asteroids fall towards earth?

Vocabulary List:
mass, Inertia, Force, Gravity, more, less, move

Explanation: All matter has Inertia and resists changes in motion. Matter won't speed up, slow down, stop, start, or change direction unless acted on by a force. This is Newton's First Law of Motion. Because Inertia is a property of matter, more massive objects (made of more matter) have more Inertia. This means that an asteroid with more mass will be able to resist Earth's gravitational pull more than a less massive meteorite-sized object and won't be pulled into Earth.
**Making Craters**

**Observation/ scientific phenomena**
There are different sized craters all over the earth. What makes some craters so much bigger than others?

**Research Question:**
What is the effect of mass and acceleration on the force that object exerts on other object? (Acceleration is a word that describes a CHANGE IN MOTION)

<table>
<thead>
<tr>
<th><strong>Independent Variable</strong></th>
<th>What will you change?</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dependent Variable</strong></td>
<td>What will you measure?</td>
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<tr>
<th><strong>Control</strong></th>
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<tbody>
<tr>
<td><em>Normal situation for comparison</em></td>
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<tr>
<th><strong>Constants</strong></th>
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</thead>
<tbody>
<tr>
<td><em>What must be kept the same?</em></td>
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<table>
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<tr>
<th><strong>Hypothesis</strong></th>
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<tbody>
<tr>
<td><em>If...then...because...</em></td>
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<tr>
<td>Experiment</td>
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<tr>
<th>Procedures/steps</th>
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Get your teacher’s permission before proceeding.
Create a table to record your data here.

<table>
<thead>
<tr>
<th>Data:</th>
<th>Conclusions</th>
<th>Questions</th>
</tr>
</thead>
<tbody>
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7.1.1 episode 5

### Student Science Performance

<table>
<thead>
<tr>
<th>Topic</th>
<th>Title: forces and motion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Newton’s First and Second Law</td>
<td></td>
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</tbody>
</table>

**Overarching Performance Expectations (Standard) from State Standards or NGSS:**

Carry out an investigation which provides evidence that a change in an object’s motion is dependent on the mass of the object and the sum of the forces acting on it. Various experimental designs should be evaluated to determine how well the investigation measures an object’s motion. Emphasize conceptual understanding of Newton’s First and Second Laws. Calculations will only focus on one-dimensional movement, the use of vectors will be introduced in high school.

**Lesson Performance Expectations:**

Students will engage in activities to help them understand the concept of acceleration. They will construct using mathematical reasoning, Newton’s 2nd Law. They will design, conduct and write about an experiment testing Newton’s 2nd law and the effect of changing mass on acceleration when a constant force is exerted.

CCC: stability and change
SEP: Developing and using models, Planning and carrying out investigations, Using mathematics and computational thinking.

<table>
<thead>
<tr>
<th>Students Will. . . To Construct Meaning</th>
<th>Teacher Will. . . To Support Students</th>
</tr>
</thead>
</table>
| Students will review questions from previous episode. | **Overarching Question:** What are Newton’s Laws of motion and how do they relate to forces? From 7.1.5 **Overarching Phenomenon:** Meteor Craters are found on earth. **Question for the Episode:**
  - How much force was required to stop that asteroid?
  - How do we calculate the force that is transferred between objects when they collide?
  - Can we use that information to make predictions about how things will respond when they come in contact with each other? |
| **Engage:** Students get engaged in the episode by trying to identify when a car is accelerating and when the motion is stable by holding up a red card when they think the card is stable and a green card when they think the cars is accelerating. (video shows the accelerometer of several super fast cars) | **Engage:** Students are given a red card and a green card. Have them watch the video and hold up the Green Card when they think the car is ACCELERATING Red Card when they think the car is STABLE |
| Students will be instructed that ACCELERATION means ANY change in motion, which can include speeding up, slowing down, or changing direction. | **https://www.youtube.com/watch?v=PLGJk79Aa2w** |
| **Gather:** | **Direction Instruction:** Students will be confused about which card to hold up when the car is slowing down. That’s because we typically think of speeding up |
As a table group, students will receive a Quick Quiz and a Whiteboard and 4 different Marker. Each student will write 1 their answer to their question on the whiteboard. They will choose a spokesman to present their whiteboard to the teacher/class and discuss the logic behind their answers.

Students will construct Newton’s 2nd Law by using mathematical reasoning. Students will receive a set of paper strips that have Mass/Acceleration Ratios and Forces and study them until they recognize a pattern. The pattern is Newton’s 2nd Law- Force = Mass x Acceleration. When they recognize the pattern, they should write it on a sticky note and bring it to the teacher and be prepared to explain how they came up with the Law.

Students take notes in their journal and learn about Newton’s 2nd Law in preparation for Lab Report and Assessment:

Students prepare by recognizing proof of concept test results (crater experiment, blowing on balls with straws) and applying them to the phenomenon of Barringer Crater.

when we think of acceleration, HOWEVER, in physics, ACCELERATION is speeding up, slowing down, or changing direction. If motion is not stable, then the object is accelerating. You can have (+) acceleration or (-)acceleration, but they are both acceleration when it comes to Newton’s 2nd law. If you have time, have them try it again.

Discussion:
Students should use a whiteboard and answer

Management Strategy: Rainbow answers
Each student in group is given a different color marker and are assigned one of the questions on the quiz to write on the whiteboard.

QUICK QUIZ- see below.
THINK/PAIR/SHARE -Teacher will go around and have students show their whiteboards to the class and discuss their answers looking for any misconceptions.

Group Activity: constructing Newton’s 2nd Law
Pass out the strips of paper in activity page below. Have students use the strips to determine Newton’s 2nd Law. When students think they understand what the law is, have them write it on a sticky note and bring it to the front. Don’t tell them if they’re right or wrong until everyone’s done.

Sort the answers into groups. Explain what people wrote to the class and ask a representative from each category to share their logic and what they learned from the strips of paper.

Direction Instruction: Newton’s 2nd Law.
Newton’s 2nd Law of Motion is the expression of the mathematical relationship we observe between Force, Mass and Acceleration. Force (N) = Mass (kg) x Acceleration (m/s. This relationship is observed in the following ways:

1. If Acceleration is constant, then A more massive object will have greater force than a less massive object

Proof of concept: Crater Experiment.
Reason

Design an investigation to test Newton’s 2nd law by observing the effect of changing mass on acceleration when acted on by a constant force.

2. If Force is constant, then a more massive object will accelerate less than a less massive object.

Proof of concept demonstrations:
Blowing on different massed spheres with straws and observing their acceleration.
This could easily be demonstration with 3 students, 3 straws and 3 different sized balls (ping pong, golf ball, Wooden Ball or Metal Ball)

Force is also calculated by measure the change in momentum over change in time. For Example:
If an asteroid went from 56,000,000 kg/m/s of momentum to 0 in 4 seconds as it smashed into the earth, then the acceleration( - ) of the asteroid is
\[
\frac{56,000,000}{4} = 14,000,000 \text{ kg of mass } = 630,000,000,000
\]
Newton’s of Force which can get a LOT of work done in a very short period of time. A LOT of energy. About 10 nuclear bombs worth...

Design an investigation: Students are going to test Newton’s 2nd Law and answer the following question with by conducting an experiment:

Question: If I change mass, will I change acceleration with a CONSTANT force?

Students can test Newton’s 2nd Law using an apparatus similar to this one. Several different examples of how to do this experiment exist online. Many of them require photo gates or speedometers. I believe students could evaluate time my observing with slow motion cameras on their phones, though it may be more difficult.

Vocabulary study: Slogans! See supplemental on vocabulary. Words: Acceleration, Newton’s 2nd Law
Communicate
Students will fill out a FINAL FULL LAB report according to the provided RUBRIC.

Assessment: Lab Report
The complexity of the concept requires students to complete a FULL LAB REPORT, which would be assessed using a rubric.

There are interactives on Newton’s laws available, this one worked...
http://www.physicsclassroom.com/Physics-Interactives/Newtons-Laws/Force/Force-Interactive

Assessment of Student Learning
Students will be assessed on their understanding of the word acceleration. Students will construct Newton’s 2nd Law by looking for mathematical patterns. Students will test Newton’s 2nd Law by designing an experiment to test the effect of changing mass on acceleration when a constant force is applied. Full Lab Report Should be completed and graded according to the rubric provided which includes a description of all essential elements of each stage of design, activity, and communication.

Quick Quiz - Acceleration
Write your answers on a WHITEBOARD. Prepare to share your answers and models.
Part 1
1. Which picture shows ACCELERATION
http://www.kshitij-iitjee.com/Study/Physics/Part1/Chapter2/22.jpg
2. How could you tell which model represented acceleration? What pattern do you observe when objects are accelerating?

3. What is causing acceleration in these pictures?

4. Draw a model that shows stable motion and then show 2 ways things can accelerate. (students can use dots)

5. Which truck would take more force to accelerate? Inertia?

Part 2

Show students two strobe images of falling objects:
Here are 2 images of falling objects: What patterns do you observe. What does the pattern tell us?

Key: Quick Quiz
1. Top picture is stable. Bottom two pictures show acceleration
2. I can tell when something is accelerating because the car travels a different distance in the same time. (space between them changes)
3. Changes in motion are always caused by forces.

4. . . . . . . . . . . . . . . . is stable
   . . . . . . . . . . . . . . . is acceleration
   . . . . . . . . . . . . . . . . . is also acceleration

5. The little truck will take less force to speed up or slow down than the big truck because it has less inertia and will not resist changes in its motion as much.

Part 2
I see that they are speeding up when they fall and slowing down when they bounce up. There are forces acting on the object. Gravity causes things to speed up as they fall! That's because gravity is a force! I get it.

Constructing Newton’s 2nd Law

Make a copy for each partner pair or for each group. Cut them out and pass out as a set.
<table>
<thead>
<tr>
<th>Mass</th>
<th>Acceleration</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 kg</td>
<td>9 m/s²</td>
</tr>
<tr>
<td>6 kg</td>
<td>3 m/s²</td>
</tr>
<tr>
<td>1 kg</td>
<td>18 m/s²</td>
</tr>
<tr>
<td>9 kg</td>
<td>4 m/s²</td>
</tr>
<tr>
<td>2 kg</td>
<td>18 m/s²</td>
</tr>
<tr>
<td>Mass</td>
<td>Acceleration</td>
</tr>
<tr>
<td>----------</td>
<td>--------------</td>
</tr>
<tr>
<td>6 kg</td>
<td>6 m/s²</td>
</tr>
<tr>
<td>16 kg</td>
<td>3 m/s²</td>
</tr>
<tr>
<td>2 kg</td>
<td>24 m/s²</td>
</tr>
<tr>
<td>8 kg</td>
<td>6 m/s²</td>
</tr>
</tbody>
</table>

1. What is the force (N) of an object that is accelerating at 3 m/s² and has a mass of 2 kg?

Equation set up_________________  Force __________________

Model:
2. What is the force of a football player with a mass 100 kg accelerating at 6 m/s²?

Equation set up ____________________  Force ____________________

Model:

3. What is the mass of a truck that is hit with 40,000 N of force while accelerating 10 m/s²?

Equation set up ____________________  Mass ____________________ kg

Model:

4. Which will accelerate faster? Circle the answer.

5. Which will be able to move the barrier? Big truck has mass of 2 kg and little truck has mass of 0.5 kg and they are both accelerating at 3 m/s² towards the blocks that weigh 3 N. Circle the truck.
Key:

1. \(2 \text{kg} \times 3 \text{m/s}^2 = 6 \text{N}\)  
   \(\overset{2\text{kg}}{\Rightarrow} 3\text{m/s}^2\)

2. \(100 \text{ kg} \times 6 \text{m/s}^2 = 600 \text{N}\)

3. \[
\begin{align*}
\text{mass} &= \frac{40,000 \text{ N}}{10} \\
&= 4000 \text{ kg} \\
\rightarrow 10 \text{m/s}
\end{align*}
\]

4. 5g gram ball will go slower than 2g ball (2g) should be used.

5. The Big Truck can push the barrier with 4N of force - little guys can't only 1N.
Overarching Performance Expectations (Standard) from State Standards or NGSS:
Carry out an investigation which provides evidence that a change in an object's motion is dependent on the mass of the object and the sum of the forces acting on it. Various experimental designs should be evaluated to determine how well the investigation measures an object's motion. Emphasize conceptual understanding of Newton's First and Second Laws. Calculations will only focus on one-dimensional movement, the use of vectors will be introduced in high school.

Lesson Performance Expectations: Students will engage in argument from evidence about the role of friction and opposing forces on motion. Students will learn that friction is a force that acts between all matter and acts opposite to forward motion. Students will design and conduct an experiment on the effect of friction on the force required to move an object and report. Students will model friction
CCC: Cause and effect, stability and change
SEP: Carry Out and Investigation, Argue from evidence

Students Will. . . To Construct Meaning

Students engage with phenomenon of "I fly ballet" and terminal velocity with an OEQ template.

Students should be going crazy with questions about motion and forces. What is going on here? How are they doing that? Why are they falling sometimes and flying other? Does their body position change the way the forces at on their bodies? What's keeping them up?

Students Play Talking Tag: The first student is chosen to start the game with an Observation, Explanation, or Question. They can only say one complete thought, then they have to tag someone else to keep the idea moving ahead. Students should be talking about the interaction of forces and the acceleration (change in motion) that is constantly occurring.

Students write this statement in their journals.

Teacher Will. . . To Support Students

Overarching Question: What are Newton's Laws of motion and how do they relate to forces?
From 7.1.5

Students prepare an OEQ template

Phenomenon:
I fly ballet -
https://www.youtube.com/watch?v=RdZAk3j -YM
Long- but the guy in black at 5:21 shows terminal velocity perfectly.
https://www.youtube.com/watch?v=-Aw-qjG2zEl

Engaging in argument from evidence; I fly
Management Strategy: Talking TAG
Randomly Choose one student to start the conversation. The rules are that the one I call on can only say one things. Then anyone can respond (kindly) to what they are saying, but only if the speaker calls on them. Each person can only speak once until everyone's had a turn.

Teacher Note: I fly tanks have huge fans at the bottom and the air speed is perfectly calibrated to exert a force on the person that is proportional to their mas x acceleration in gravity (their weight in Newtons - force) Through the movement of their hands, feet and body the fliers are able to manipulate the aerodynamic qualities of their body and the amount of AIR RESISTANCE their bodies experience. Air
Students Write an argument to the statement by providing evidence that the statement is NOT true. Examples could include, feathers or pieces of paper, frisbees, parachutes, etc. Students could even use paper to demonstrate their ideas. Then they will discuss their ideas with their neighbors and with the class.

Students learn the word Vacuum. The word describes a space that has all of the air removed. No air molecules at all.

Students observe the video of the bowling ball and the feather in a vacuum chamber and observe that all matter falls at the same speed when there is no friction to stop it.

resistance is a type of friction called FLUID friction caused by the force of accelerating little mass particles of air pushing with a force against the motion of falling bodies (or flying bodies) Unless an object is in a vacuum, touching nothing, friction is always present. Friction keeps our feet on the floor! Without friction we couldn't move. (Newton’s 3rd).

When the game runs down hit them with this idea by writing it on the board. Have them write it in their journals.

‘Everything on earth falls at the same rate of acceleration regardless of mass.’

Engage students by asking them to prove that the statement is NOT true, because you can prove that it IS true.

Give students a minute or two to write, then talk to their neighbors or lab groups about evidence that proves that statement untrue.

Randomly Generate Names to begin the discussion.

Galileo was the first to prove that falling objects are pulled down at the same acceleration rate even if they have different MASSES!! (did he really drop things from the tower of Pisa? We really don’t know).

A VACUUM is a space where all atoms have been removed...not a cleaning device...it’s called a vacuum because it pumps air out of a space to create a vacuum, that is what causes the ‘suction’.

https://video.search.yahoo.com/search/video/fr=tightropetb&p=bowling+ball+and+feather+in+vacuum#id=1&vid=bd51f5379cd2027b9064e09306f850f7&action=view
Students do a turn and talk about friction. What is it?

Students will design an experiment to study the effects of different surfaces on friction force. They will get experience working with spring scales and the Newton as a measure of force. They will complete a MINI LAB REPORT as a group.

Students take notes on Direct Instruction: (There may be some textbook material on this topic as well if you are interested in a reading assignment)

Students attempt a model of friction before engaging with the content instruction.

Shows a bowling ball and feather being dropped in a vacuum chamber.

They will need to recognize that air is matter and slows down the feather when it falls because of FRICITION.

Ask students to do a TURN and TALK about friction. Randomly Generate Students to share their ideas.

Investigation:
Students will complete a MINI LAB REPORT with their lab groups to investigate the question:
What is the effect of friction on the force it takes to change the motion of an object (cause it to accelerate)?

Materials:
- Piece of Wood with different surfaces glued to each side (sandpaper, cloth, wax paper, plastic etc.) and a hook screwed into the end
- Spring Scales
- Ramp
- Books or blocks of wood for the ramp
- Lab Report

Student Understanding: Students should use the spring scale to measure the force it takes to move the block of wood up the ramp with different surfaces facing the ramp.
Students should construct an understanding that rougher surfaces have more friction. The evidence is the amount of force (measured with the spring scale in Newtons) required to move the block up the ramp.

Direct Instruction: Have students infer a model of friction and the way it acts in relation to forward motion.
Students recognize that friction is caused by opposite charge forces. It is caused as matter that is attracted to each other is pulled against their attractive forces and RESIST changes in their motion.

Friction is caused by Electric and Static Forces (almost forgot about that huh?)
It is caused by the force of attraction that occurs between atoms and molecules within a substance and between objects.

Matter doesn’t like to move away from other matter because all matter is made up of positive and negative charges so there is always some attraction between atoms. When a force pulls matter away from each other, they RESIST the change.
Friction is a force that acts opposite to the direction of motion.

Draw Examples:
Boat in water
Car on the Road

Have students work in their groups to produce a single model on a piece of paper that they can show to the class.

Vocabulary Study: Slogans! See supplemental guide to vocabulary. Words: Friction, Vacuum, Terminal Velocity (maybe)

Direct Instruction: Quantifying Forces
Question: A ball is rolling forward with a force of 20 N
Students participate in rainbow response and class discussion with a quick quiz. Students practice calculating Net force when friction acts on an object.

and the friction force between the ball and the ground is exerting a force of 5 N. What is the NET force of the ball?
How to answer this question:
The force of friction is subtracted from the force of the ball
20 N (force of the ball) - 5 N (friction force acting in a negative direction to the ball) = 15 N of NET FORCE
(the word net is used to describe when two opposing values have been combined: example: net income = pay-taxes)

Quick Quiz- Friction and Motion
See below
Rainbow Response would also work well here. Each student uses a pen color and answers 1 question for group on whiteboard. Scan the room as they work and help students prepare to share their answers and models.

Quick Write Assessment: Forces that act against motion
Pass Out Quick Write Form
Scenario: You roll a ball across the floor. The ball begins to slow down after a while, and eventually comes to a stop.
Question: “Why did the ball stop?”
Vocabulary List:
The list MUST include:
Motion
Change
Stable
Force
Inertia
The list MAY include:
Roll
Stop
Friction
Against
Exert
Net Force

Assessment: Assignment - Explaining Felix Baumgartner’s famous fall. (see below)
Thoughts: Could also make a similar assignment about the meteorite that exploded over Russia.
Assessment of Student Learning: Students will complete a minilab report with their group according to the rubric provided that details all of the essential elements of each section of the report including quality of design, constants, variables, measurement and analysis of results. Students will complete quick quiz on friction and forces and a quick write on friction and motion. These should demonstrate an understanding of how to calculate Net Force and how to apply an understanding of opposing forces in a system to explain the phenomenon of friction changing motion of an object.
Quick Write - Forces that act against motion  Name ____________________________

Scenario: You roll a ball across the floor. The ball begins to slow down after a while, and eventually comes to a stop.

Question: “Why did the ball stop?”

1. What vocabulary words must you have to answer this question using Newton’s 1st Law of motion.

2. Answer the question using ALL of the vocabulary above. Underline the vocabulary words in your explanation. You may use the backside of this paper if necessary. You may also draw a model of your explanation.

_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________

Quick Write - Forces that act against motion  Name ____________________________

Scenario: You roll a ball across the floor. The ball begins to slow down after a while, and eventually comes to a stop.

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_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________

Quick Write - Forces That Act Against motion
1. Friction, opposite, against, force, charges, motion, balanced, stop, roll, ball, Newton’s first Law, inertia

2. Explanation: When the ball is rolled, it has inertia and could continue to move at a stable speed and direction, but the floor is made of matter that is attracted to the ball and it acts against the forward momentum of the ball. When the force of friction and the force of the mass x acceleration of the ball are balanced then the ball will stop moving and become stable unless some other force acts on it to change it. The arrow showing friction points in the opposite direction to the motion of the ball.
Quick Quiz - Friction and Motion

1. A ball is rolling forward with a force of 25 N. The friction force between the ball and the floor is 10 N. What is the net force acting on the bag?

Calculate the net force: ____________________________

Draw a model:

2. A man jumps out of a plane and falls without a parachute with 1000 N of force, the air without a parachute, exerts a force of only 50 N. When the parachute jumper hits the ground, what will be his net force?

Calculate the net force: ____________________________

Draw a model:

3. A woman jumps out of a plane and falls with 1000 N of force. She has a parachute and when it fills, it exerts 800 N of force. What will be her net force when she lands on the ground?

Calculate the net force: ____________________________

Draw a model:

4. Look at the diagram below of two students pulling a bag of volleyball equipment. The friction force between the bag and the floor is 15 N. What is the net force acting on the bag?

Calculate the net force: ____________________________

5. If a boat traveling 30 mph has 500 N of force and the water exerts 500 N of friction force, what will their speed be? Will the boat still have momentum? Will it still have force if it hits another object that is not moving?

Key - Quick Quiz - Friction and Motion
(1) \(250 - 10 = 240 \text{ N} \) Net Force.

Ball 250 N → Friction 10 N

(2) 1000 N → 50 N → Whoa! 950 N!

(3) 1000 N - 800 N = 200 N Net Force.

(4) 60 N + 45 N = 105 N Force Taped students are exerting on the bag.

105 N - 15 N (Friction) = 90 N of Net Force the students are exerting.

(5) Tricky. A speed stays 30 mph because forces are balanced so speed will not change. Boat still has a lot of momentum. If it hits another object will unbalanced force then its motion will change.

Constructing an Explanation - Felix Baumgartner's Famous Fall  Name _________
Watch Video: Felix Baumgartner's jump and flat spin scene- you tube.

https://video.search.yahoo.com/search/video?fr=tightropetb&p=felix+baumgartner+jump+and+flat+spin+scene#id=1&vid=ba77ddc2f917c5fecbb3e1d7fe13247c&action=view

Felix was the first man to fly supersonic (faster than the speed of sound 690 mph) without a car or a jet. He jumped from an astounding 128,000 feet above sea level (23 miles up). **Terminal velocity** is achieved when Friction forces and gravitational forces acting on falling object are balanced.

Graph the data from his fall. Make sure to label the axis and define the units

<table>
<thead>
<tr>
<th>Time spent falling (seconds)</th>
<th>Speed (mph)</th>
<th>freefall/parachute</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>freefall</td>
</tr>
<tr>
<td>21</td>
<td>433</td>
<td>freefall</td>
</tr>
<tr>
<td>34</td>
<td>693</td>
<td>freefall</td>
</tr>
<tr>
<td>50</td>
<td>843.6</td>
<td>freefall</td>
</tr>
<tr>
<td>64 (1 min 4 seconds)</td>
<td>648</td>
<td>freefall</td>
</tr>
<tr>
<td>180 (3 minutes)</td>
<td>285</td>
<td>freefall</td>
</tr>
<tr>
<td>260 (4 min 20 seconds)</td>
<td>191.5</td>
<td>Deploys parachute</td>
</tr>
<tr>
<td>Lands 9 min 18 seconds</td>
<td>1 mile/hour</td>
<td>parachute</td>
</tr>
</tbody>
</table>

1. Why does the graph look like this?

2. What is happening to his speed when the graph is increasing (upward slope)?
3. What does it mean if he is accelerating (his motion is changing?)
4. What force is causing this to occur?
5. What is happening to his speed when the graph is decreasing (downward slope)?
6. What does it mean if he is accelerating (his motion is changing)?
7. What force is causing this to occur?
8. Felix had tried to break the sound barrier before by jumping from lower altitudes, but had been unable to do it. Why not? Why did he have to go so high into the atmosphere?
9. Let’s say (because I’m not sure) that Felix has a mass of about 80 kg (175 lbs). The acceleration due to gravity on earth is 9.8 m/s². How much force (N) did he have?
10. For him to reach Terminal Velocity and stop speeding up how much force would air resistance have to have?
11. How much force would air resistance have to slow him down?
12. Draw a model of Felix, showing him and the forces acting on him when he reached terminal velocity (stable motion)
13. What vocabulary would you need to explain this to someone else?
Strand: 7.1.2

Emphasis: Newton’s 3rd Law

Anticipated Time Required (assuming 50 minute class periods):
- E. 1 50 min
- E. 2 50 min
- E. 3 120 min
- E. 4 50-80 min

Dominant CCC: Systems and System models

Dominant SEP: Engineer a solution to a problem

Management Strategies to support equitable access to content: Ninja Turtle Engineer Teams

Shopping list:
E. 2- per 2 teams
- 2 rolling carts (skateboards, chairs, or boards with wheels)
- 1 rope
- 1 big ball (soccer ball or heavier)
- Smaller balls (tennis ball)

E.3- per team
- 1- 3 oz cup
- Golf Ball
- 2 Plastic grocery Bags
- 1 m String
- 8 straws
- You may decide if they have limits on tape or other materials.
- Provide scissors, rulers, etc.

For: 6- 8 groups per class.

E. 4
- String
- Balloons
- Straws
- Clothes pins
### 7.1.2 Storyline Overview

**Anchor Phenomenon:** Rockets, bullets, dancers, and drops of water go up or shoot out.

**Student Performance Expectation:** Apply Newton’s third Law to design solution to a problem involving the motion of two colliding objects in a system. Examples could include collisions between two moving objects or between a moving object and a stationary object.

<table>
<thead>
<tr>
<th>Dominant DCI</th>
<th>Dominant CCC</th>
<th>Dominant SEP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical Science</td>
<td>Systems and system models</td>
<td>Design and engineer a solution to a problem</td>
</tr>
</tbody>
</table>

### Science Experiences

<table>
<thead>
<tr>
<th>CCC/SEP</th>
<th>What are students doing? (This should match your SEP!)</th>
<th>What specific understandings should students get from this experience? (What pieces of the performance expectation does the experience provide?)</th>
<th>New questions students have to propel us to the next science experience</th>
<th>Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Forming into Engineering Teams</td>
<td>Students recognize that when forces exerted on an object, that the object exerts a force in the opposite direction.</td>
<td>Why couldn't he get any work done? How did they solve his problem.</td>
<td>Journal notes</td>
</tr>
<tr>
<td></td>
<td>Finding patterns in the behavior of different objects</td>
<td>Action/Reaction pairs</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Listening to direct instruction</td>
<td>How to draw a free body diagram</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Observe George Cernan video from first work in space</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Engage in activity on rolling carts</td>
<td>Action/Reaction pairs do occur, but friction is another</td>
<td>How do we solve other problems related to</td>
<td>Complete assignment based on observation</td>
</tr>
<tr>
<td>Action/reaction pair that prevents us from seeing the full effects of the force.</td>
<td>Designing a solution is tricky.</td>
<td>Engineering requires patience, diligence, teamwork.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Work as a team to produce ideas to solve the problem of work in space.</td>
<td>Teams will construct a device to slow an ‘astronaut’ down while in his pod and land rightside up.</td>
<td>Recognize that action/reaction pairs are important</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Design a solution assignment.</th>
<th>APT journal Press Release</th>
<th>Assignment: Newton’s Laws</th>
</tr>
</thead>
<tbody>
<tr>
<td>Systems/models; design a solution, carry out an investigation</td>
<td>Video of swimming, flying, walking, Rocket Balloon races</td>
<td>Assignment: Newton’s Laws</td>
</tr>
</tbody>
</table>

| 3 Systems/models; design a solution, carry out an investigation | 4 System/models; construct models, conduct investigation | Assignment: Newton’s Laws |

| 195 | 195 | 195 |
7.1.2 Learning Episode 1

### Student Science Performance

<table>
<thead>
<tr>
<th>Topic: Newton’s 3rd law</th>
<th>Title: Getting a reaction from action.</th>
</tr>
</thead>
</table>

### Overarching Performance Expectations (Standard) from State Standards or NGSS:

Apply Newton’s Third Law to design a solution to a problem involving the motion of two colliding objects in a system. Examples could include collisions between two moving objects or between a moving object and a stationary object.

### Lesson Performance Expectations:

Lesson Performance Expectations: Students look for patterns in the behavior of matter when affected by contact forces. Students model forces in systems using free body diagrams. Students construct an understanding of Newton’s 3rd Law and recognize how it applies to systems.

- **CCC:** Patterns, Systems and system models
- **SEP:** Obtain Information, Ask Questions

### Students Will. . . To Construct Meaning

Get organized into groups by moving into 1 of four corners based on personality statements of these Ninja Turtles

**Leonardo:** I like to get things done and make sure everyone is safe. “A true Ninja is a master of himself and his environment, so don’t forget: We’re turtles!”

**Leader in charge of selecting team:** presents choices to the group and helps them come to a final decision, keep track of assignment sheets, keeps track of time and supply budget, helps wherever needed.

**Raphael:** I don’t give up when things get tough and I like to do things with my hands. “Oh, so that’s the plan from our ‘great leader’, huh? Just sit here on our butts?”

**Head contractor:** in charge of physically building the product and making sure it works.

**Donatello:** I like to draw plans and figure out how things work. “Question: Do you like penicillin on your pizza?”

**Technical Advisor:** in charge of writing description of design and drawing iterations of product.

**Michelangelo:** I like to talk and help others while they work. “I LOVE being a turtle!”

**Supply manager:** in charge of making sure materials for construction are available including anything brought from home. In charge of maintaining safe, clean work environment,

### Teacher Will. . . To Support Students

Assign students an engineering Team

**Management Strategy:** Ninja Engineering Teams

Similar to rainbow lab groups, but different personality traits required. I have some Teenage Mutant Ninja turtle stickers so I thought I’d use the personality types of this famous foursome to help students take on roles for an engineering project which are a little different than lab groups. Most famous groups (power rangers, fantastic 4, fast and furious (kidding-but not) Ron, Hermione, Harry and Seamus, Hogwarts houses) have a typical set of personalities geared towards powerful problem solving. They make good models of how engineering groups might work.

**Leonardo:** Get it?
**Donatello:** Got it.
**Raphael:** Good.
**Michelangelo:** I don't get it.

Splinter: “Cowabunga dude. Ha! I made a funny!”

**Once students have selected a group, pass out cards with descriptions of responsibilities:**

**Leonardo:** **Leader in charge of selecting team:** presents choices to the group and helps them come to a final decision, keep track of assignment sheets, keeps track of time and supply budget, helps wherever needed.

**Raphael:** **Head contractor:** in charge of physically building the
listens carefully and helps with writing, drawing, and building as needed.

Choose your role. Leonardo will choose the rest of his team from each of the groups.
All members of the team are responsible to make sure the product works and is completed on time and within constraints.
Your teacher is Master Splinter and is available as advisor, guide and disciplinarian (if necessary)

Engage with a Phenomenon:
What do these phenomena have in common?
Use journal to take notes on patterns you observe
1. I observe this
2. I observed this, and it reminds me of the last one because of this...
Get together with team and images of the phenomenon you observed and look for patterns. Do those patterns imply a rule? What is the rule?

Donatello writes the patterns and rules
Michelangelo presents them to the class.

Gather: Use journals to take notes on Newton’s 3rd Law.
Learn the term ACTION/REACTION pair.

Product and making sure it works.
Donatello: Technical Advisor: in charge of writing description of design and drawing iterations of product.
Michelangelo: Supply manager: in charge of making sure materials for construction are available, including anything brought from home. In charge of maintaining safe, clean work environment, listens carefully and helps with writing, drawing, and building as needed.

Teacher: You are Master Splinter and should make yourself available as advisor, guide and disciplinarian (if necessary) Once students are in teams have them use their journals and observe these videos by looking for patterns in behavior.

Preparation to view phenomenon:
On the board show them a template that looks like
Video #1- I observed……
Video #2- I observed…. And it reminded me of…..
Video #3- I observed… And it reminded me of….
Video #4- I observed… And it reminded me of….
Video #5- observed...and it reminded me of.…

Phenomenon: There are patterns in the way matter behaves when force is applied.

Show videos of all of these.

Ask: What patterns do you observe in these phenomenon (how are they similar, how are they different)
- Drop of water
- Bouncing ball
- Recoiling gun
- Dancer Leaping
- Space shuttle launching
Give students an image sheet to remind them of the phenomena they’ve observed and let them discuss the patterns and see if they can construct a rule. Donatello will write the patterns and rules and Michaelangelo will present them to the class.

Ask: Teams send representative to present their findings.

Student Understanding: The goal is to help students construct Newton’s 3rd Law which states that “For every action, there is an equal and opposite reaction.”

Direct Instruction:
We have learned that forces are interactions between
Learn that for every action there is an EQUAL and OPPOSITE reaction.
Learn how to model action/reaction pairs using free body diagrams.
Learn that interactions between matter and forces can be at a distance or contact

Reason:
What are examples of the 2 different types of force interactions?

Use Free Body Diagrams to analyze the images we looked at to start the episode.

Communicate: Draw the free body diagrams of phenomena observed earlier with their teams. Leonardo should prepare to present to the class.

For practical purposes we say that forces can interact with matter in two ways:
- Forces that act at a distance (without touching)
- Forces that act when objects touch

Question: “Can you give an example of the types of forces or that fit into these categories?”

*Students should recognize that gravity and charged particles can act at a distance while friction, Pushing, bouncing and DEFORMING (changing shape) occurs where surfaces touch

Teacher Note: of course, the irony here is that even friction or the perceived solidness or two colliding objects is really the interactions that occur between repelling and attractive forces of charged particles (protons, electrons).

Newton Observed as you have observed. That when a force is applied in one direction that there is movement in the opposite direction. Newton was able to quantify the ACTION and REACTION behaviors you have identified and stated his observations and calculations as Newton’s Third Law of Motion which states;

“For every action there is an EQUAL and OPPOSITE reaction”

Model: Use the examples given in phenomenon to demonstrate ACTION/REACTION pairs in these SYSTEMS. Show one or two and have them work in their teams to figure out the rest of them. Have Leonardo come up and share team models.
Remember that there is a lot of elastic potential energy (in contracted muscles) being converted into force, that’s why we bend our knees and use our muscles. It’s not just our weight that the earth pushes us up with. Otherwise, we’d never get off the ground.

Teacher Note: This is a little hard to grasp because our experience does not always match unless we analyze these contact forces with a tool called a ‘FREE BODY DIAGRAM’. We have already been using free body diagrams without really talking about it because they are pretty intuitive, but there are some important aspects of free body diagrams we need to understand to construct a CORRECT understanding of contact interactions. This video: by bozeman science on Newton’s 3rd Law explains the rules very well. https://www.youtube.com/watch?v=9lOYouih4bQ

Recognize that the most important aspect of drawing free body diagrams is that only 1 ‘body’ is considered at a time and the diagram NEVER shows the ‘body’ acting on the objects around it, just the other objects exerting forces ON THE “BODY”.
I think this is important to recognize so that misconceptions about action/reaction pairs don’t cause problems.

Example: If I am the object then the earth acts on me by pulling on my mass with a specific acceleration rate. This force that is acting on me is measured as my weight so if I have a mass of 100 kg and gravity is accelerating me at 9.8 m/s² then the force the earth exerts on me is 980 N and THAT is how much force I am exerting BACK on the earth. If I tried to show the force I exerted on the earth by calculating the mass of the earth times my acceleration I would get the mistaken impression that I was exerting a HUGE force on the earth, if the earth exerted that much force BACK on me I’d end up on jupiter!

If the rule above is followed, then problems like this can be avoided. ONLY DRAW FORCES ACTING ON THE BODY (depending on the object being analyzed) and then recognize that the body is reacting with EQUAL force in the OPPOSITE direction.

I recommend giving students some guidelines on drawing basic free body diagrams. When the core states that calculations only focus on one-dimensional movement it can be inferred that this is also true of any modeling which means that students should focus on the pushing and pulling that is occurring at contact points. It is not necessary to show the ‘NORMAL’ force and Gravity in the model, but...it could happen. Just don’t make it the focus.

See picture below:
(normal force is the red line pointing straight up from the ground and represents the earth’s reaction force to his weight (blue line pointing down) not necessary for one dimensional analysis of the reaction pairs of pushing on the wall and pushing against the ground.)
Before watching this video, prepare a OEQ template in your journal.

With your team discuss your observations, explanations, questions.

Show students video of Astronauts in space

**Prepare:** Students prepare to engage in phenomenon by completing OEQ template.

**Phenomenon:**
- NOVA: Newton’s Third Law of Motion

Only play video until 3:00 because we want students to consider the problem.

Students should discuss their observations, explanations and questions with their teams and bring questions to the PARKING LOT for review in next episode.

**Assessment:** Journal Notes

Assessment of Student Learning
Students journals may be assessed for participation.
# 7.1.2 Episode 2

## Student Science Performance

<table>
<thead>
<tr>
<th>Topic: Newton’s 3rd Law</th>
<th>Title: Getting a reaction from my action.</th>
</tr>
</thead>
</table>

### Overarching Performance Expectations (Standard) from State Standards or NGSS:

Apply Newton’s Third Law to design a solution to a problem involving the motion of two colliding objects in a system. Examples could include collisions between two moving objects or between a moving object and a stationary object.

### Lesson Performance Expectations:

Students will make observations through investigation of behaviors associated with Newton’s 3rd law. Students will work with design team to solve a problems by defining problem, identifying tasks, considering best materials, modeling the solution and communicating to the class.

**CCC:** Systems, System models, Cause and Effect  
**SEP:** Carry Out an Investigation, Design a solution to a problem

### Students Will . . . To Construct Meaning

**Engage with a Phenomenon:**
Combine with another team and gather materials. Pick up a copy of the assignment. If you are not engaged in the lab, you should be sitting quietly, writing the assignment. Leonardo is in charge of choosing the participation order. (take turns)  
Donatello reads the instructions out loud to the group(s). (take turns kids)

Bring the assignment back to your desk and your team. Discuss each question carefully. Help each other with difficult problems. Fix your answers if necessary. Raphael will present to the class.

Your group will receive a copy of Solving Problems through Engineering worksheet.

### Teacher Will . . . To Support Students

**Read and Review**
Review questions in the parking lot from the video on George Cernan’s problem in space.

**Management strategy:**
Mass is a variable in today’s activities, but body mass for middle school students can be sensitive. Pair students by size well before the lesson, and when you announce pairs, do not call attention to this pairing strategy.

**Engage:**
Have students combine with another Team for the next activity so that there are eight people per group. (Four groups)

**Materials:**
- Provide groups with  
  - Two rolling carts (skateboards, chairs, or boards with wheels)  
  - One rope  
  - One big ball (soccer ball or heavier)  
  - Smaller balls (tennis ball)  
  - Set of instructions for experiments and observation requirements. Assignment- Newton’s 3rd Law really? See below  
  - And a partridge in a pear tree.

Students should meet with teams at their desk and help each other complete their assignments and discuss their answers. Randomly Generate student names to drive discussion.
Michelangelo reads the instructions out loud. Each member of the team responds to the questions with a specific color of pen or pencil.

Prepare to present solutions to the class. Michelangelo will present.

from the assignment:

Pass out one copy of “Solving Problems through Engineering” Assignment to each team.

Raphael reads the instructions out loud to the team. **Challenge:** You have been asked to design a solution to the problems George Cernan was encountering in space. You and your team need to complete the following assignment and be prepared to share your solution with the class. Solving Problems through engineering Assignment. See below.

Discuss student questions brought up during presentations. Next episode on why things break when they collide and the effect of equal and opposite forces on different materials and distribution of force.

When discussion is over allow students to finish viewing the video and see if they agree with their choices.

**Assessment of Student Learning:** Assessment on Newton’s third Law activity should be graded according to completeness and effort. The assignment should be used to evaluate student understanding of the concept at this point and engagement. Assessment: Designing solutions to problems worksheet should be completed by the team. Each team member should show contribution by responding to one prompt. Assessment should be focused on team compatibility and effectiveness/ Should be used to determine any interventions or helps that are needed before larger engineer project.
Use your notes from the video and the activity to design a solution to George Cernan’s problem on his first space walk.

Constraints: Consider all of the problems of space travel including the problems of adding mass to the rocket, space and the cost of materials.

Each member of the team will write for a specific section. Use different colored pens to show your contribution to the work. All colors should be represented.

1. Given. List the important information given in the problem. - Leonardo - blue

2. Required. Summarize the task(s) required to solve the problem. If there is more than one task, then number them in order that they will be accomplished. Donatello - purple

3. Explanation List all materials used throughout the tasks and how they would be used and WHY you choose them. - Raphael - red

4. Solution. Show the solution to the problem in a logical, well-organized, and neat manner. Michelangelo - orange
Newton’s 3rd Law...really?

Instructions

1. Teams should pair up according to teacher instruction.

2. Each member should have a copy of this assignment and sit quietly and make observations and take notes while watching the other members of their team. You are not required to take notes during your own turn. You should relate the questions to yourself BY OBSERVING the behavior of your teammates while they do the activities and match that to your own experience. Tricky.

3. Leonardo (s) will take turns choosing who goes first. Donatello will read the instructions out loud.

1. Sit on the rolling platform, push gently against the wall a few times with different force.
   - What is the effect of different forces on your acceleration?
   - Do the same activity without the rolling cart. How was the reaction to your action different?
   - Why do you think it was different?
   - Draw a free body diagram of the forces acting on you in this system. Show A/R pairs

2. Sit across from each other and take turns throwing the ball back and forth.
   - What happens to your acceleration?
   - What happens to the ball’s acceleration?
   - What happens to your partner’s acceleration?
   - Do the same thing standing on the ground without the carts. How was the reaction to your action different?
   - Draw a free body diagram of the forces acting on you in this system. Show A/R pairs

3. Sit across from each other and hold the rope between you. Only ONE of you pull on the rope.
   - What happens to your acceleration?
   - What happens to your partners acceleration?
   - Do the same thing sitting on the ground. How was the reaction to your action different?
   - Draw a free body diagram of the forces acting on you in this system. Show A/R pairs

4. Sit across from each other on the rolling platforms. One person pushes against the other person’s hands. Make sure only one of you pushes.
● What happens to your acceleration?
● What happens to your partner’s acceleration?
● Do the same thing standing on the ground. How was the reaction to your action different?
● Draw a free body diagram of the forces acting on you in this system. Show A/R pairs

5. Invite one person to join ONE of you on the back of your board. (trying to see if different masses are affected by action/reaction pairs differently).
   ● What is the effect of mass on the acceleration of the more massive cart.
   ● What is the effect on the less massive cart?
   ● Which Law describes this behavior?
   ● Draw a model of this activity indicating the effects of increasing mass on acceleration.

6. Briefly describe the purpose of these activities. Don’t tell me they were fun, tell me what you DID in three sentences or more. Prepare to share with your team.

7. Questions: At least three really good questions are required. Prepare to share with your team.
7.1.2 Episode 3

**Student Science Performance**

<table>
<thead>
<tr>
<th>Topic: Newton’s 3rd Law</th>
<th>Title: Getting a reaction from action</th>
</tr>
</thead>
</table>

**Overarching Performance Expectations (Standard) from State Standards or NGSS:**
Apply Newton’s Third Law to design a solution to a problem involving the motion of two colliding objects in a system. Examples could include collisions between two moving objects or between a moving object and a stationary object.

**Lesson Performance Expectations:**
Students will design and engineer an object that uses Newton’s 3rd law to slow down the speed of a falling object and land the contents upright on the ground.
They will complete a team journal that involves all members and at least 2 iterations of their design and good use of supplies.

- **CCC:** Systems and System models
- **SEP:** Design a solution to a problem

**Students Will. . . To Construct Meaning**

*Watch video of Felix Baumgartner’s famous fall in the Red Bull Stratos. Why do you think they wanted to accomplish this? How can this benefit people to see if people can survive a fall from such a tremendous height? What do you think we could learn from this experience?*

**Teacher Will. . . To Support Students**

*Phenomenon: Felix Baumgartner's famous fall with Red Bull Stratos Team*

&p=felix+baumgartner+jump+and+flat+spin+scene#id=1&vid=ba77ddc2f917c5fecbb3e1d7fe13247c&action=view

- Turn and Talk and discuss.
- Ask students to consider why this would be important? What we can learn from them?.
- Pass Out journals to the Teams and have them read the first page.

**Design a solution to a problem:**

*When Felix Baumgartner made his famous fall, he didn’t do it alone. Many Engineers and Scientists and Physicians and Trainers helped him to prepare his mind, his body, and his equipment. Their goal was to test methods and equipment that would allow astronauts to survive a fall from earth’s upper atmosphere in case of problems during space travel. Students are going to create a device that uses Newton’s 3rd law of motion to safely land an astronaut back on earth from a very high altitude using air resistance. The pilot cannot be knocked out of his ‘pod’*

**Rules:**
Leonardo: **Leader** in charge of selecting team, presents choices to the group and helps them come to a final decision, keep track of assignment sheets, keeps track of time and supply budget, helps wherever needed.

Raphael: **Head contractor**, in charge of physically building the product and making sure it works.

Donatello: **Technical Advisor** in charge of writing description of design and drawing iterations of product.

Michelangelo: **Supply manager**, in charge of making sure materials for construction are available including anything brought from home. In charge of maintaining safe, clean work environment, listens carefully and helps with writing, drawing, and building as needed.

Take 4 or 5 sticky notes and write down your thoughts on these 3 BIG IDEAS before you start your project. We call this developing NORMS.

**Big Idea 1** - What do you think the goals of the assignment are.
**Big Idea 2** - How do you think people should act when working on a group project?

Write one response per sticky note and put it in the center of your table.

- Michelangelo will read sticky notes aloud and organize them.
- Leonardo will write a rough draft of Team Goals and Team Rules with input from the team.
- Donatello writes them in the team journal
- Raphael Reads them at the beginning of every day that they are working as a team.

Work together to fill out the entire journal completely. Including the PRESS release which should be written by the whole team. Divided up the content and each person take on a little bit.

- The astronaut must stay in the pod after being dropped from a height of six feet.
- The other materials are used to cushion the landing and keep the astronaut in the pod.
- The pod may not have any type of lid, covering, or roof that intersects the vertical plane of the cup rim.
- Can only put up to four holes in the cup
- Taping or gluing the astronaut into the cup is not allowed
- You may change your design as many times as you like, but no changes can be made once official testing has started.
- The astronaut must still be in the pod and the pod undamaged.
- Designs that survive six foot drop will be tested at greater height to determine best design.

**Supplies:**

- 1-3 oz cup
- Golf Ball
- 2 Plastic grocery Bags
- 1 m String
- 8 straws

You may decide if they have limits on tape or other materials.
Provide scissors, rulers, etc.

Students will perform tasks as outlined by their character. Students should read through those expectations: Each person reads their card aloud.
Have students construct Norms.

**Management strategy: Norms**

Working in a group can be stressful unless everyone is clear of the expectations and the rules. Setting up norms can be pretty simple. Give sticky notes to everyone in the group (4 o4 5) and have them write down their thoughts on

- What they think the goals of the assignment are.
- The way they think people should act when working on a group project

Have Michelangelo organize the notes into categories. Then have the students write down a list TEAM GOALS and TEAM RULES before they engage the project.

These goals and rules should be written on the first page of their APT journal document.

**Assessment: Astronaut Protection Team (APT):**
Journal and Press Release

---

**Assessment of Student Learning**

*Students journals may be assessed for participation.*
When Felix Baumgartner made his famous fall, he didn’t do it alone. Many Engineers and Scientists and Physicians and Trainers helped him to prepare his mind, his body, and his equipment. Their goal was to test methods and equipment that would allow astronauts to survive a fall from earth’s upper atmosphere in case of problems during space travel.

Students are going to create a device that uses Newton’s 3rd law of motion to safely land an astronaut back on earth from a very high altitude using air resistance. The pilot cannot be knocked out of his ‘pod’

Rules:
- The astronaut must stay in the pod after being dropped from a height of 6 ft.
- The other materials are used to cushion the landing and keep the astronaut in the pod.
- The pod may not have any type of lid, covering, or roof that intersects the vertical plane of the cup rim.
- Can only put up to 4 holes in the cup
- Taping or gluing the astronaut into the pod is not allowed
- You may change your design as many times as you like, but no changes can be made once official testing has started.
- The astronaut must still be in the pod and the pod undamaged.
- Designs that survive 6 ft drop will be tested at greater height to determine best design.
- Extra supplies will have to be purchased with service to the Team COMMANDER.

Supplies:

- 1-3 oz cup
- Golf Ball
- 2 Plastic grocery Bags
- 1 m String
- 8 straws
- Golf Ball

Time Frame: You have 75 min to test and complete your project before final testing and 20 the next day to complete your APT JOURNAL. Only show your best work in the APT journal. Use your class journals for brainstorming.

TEAM GOALS:

TEAM RULES (norms):

Brainstorm: In your class journals. Define the problem and consider solutions.
Draw a model of what your project will look like.

Draw a Free Body Diagram of how ACTION/REACTION forces will act on this Object (system) using your understanding of Newton’s 3rd law.

On this page: Record your test and design another ITERATION of your model (iteration means another version or another try). Try again.
Test 1

- Drop your pod from six feet. Record your observations:
- Did your ‘astronaut’ and pod survive the six foot drop? ________________
- If yes, drop the astronaut from a greater height. How high were you able to go before the system failed? ______________

Redesign: How can you make your lander better? Brainstorm in your classroom journals and make some changes.

<table>
<thead>
<tr>
<th>Changes that need to be made</th>
<th>Draw new design here</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Test 2-

- Drop your lander from the higher and higher points until the system fails. Record your observations
• How high was your lander able to fall from without spilling the ‘astronaut’

Can you make it even better? Brainstorm in your classroom journals and make some changes.

<table>
<thead>
<tr>
<th>Changes that need to be made</th>
<th>Draw new design here</th>
</tr>
</thead>
</table>

Communication: Design a Press Release describing your attempts at a successful product to help astronauts land safely from extreme altitudes, maybe even from orbit. Each team member write about 1-2 of these items and then combine them.

Include the following details:
● Names of your team.
● The purpose of your engineering project
● A description of at least two iterations of your product
● The results of at least two tests including the most successful test.
● Successes the team had.
● Problems that still need to be solved.
● Future design ideas.
### 7.1.2 Episode 4

**Student Science Performance**

<table>
<thead>
<tr>
<th>Topic: Newton’s Laws</th>
<th>Title: Getting a reaction out of action.</th>
</tr>
</thead>
</table>

**Overarching Performance Expectations (Standard) from State Standards or NGSS:**
Apply Newton’s Third Law to design a solution to a problem involving the motion of two colliding objects in a system. Examples could include collisions between two moving objects or between a moving object and a stationary object.

**Lesson Performance Expectations:**
Students will engage with Newton’s 3rd Law and how it helps us to do work like walk, swim, and fly. Students will construct balloon rockets and complete and assessment showing that they recognize ACTION/REACTION pairs in many different systems.

- **CCC:** Cause and Effect, Systems
- **SEP:** Construct a model, plan and carry out an investigation

<table>
<thead>
<tr>
<th>Students Will . . . To Construct Meaning</th>
<th>Teacher Will . . . To Support Students</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Quick Write in Journals:</em></td>
<td><em>Quick Write in Journals:</em> What would life be like without action/reaction pairs and friction? Are contact interactions all bad?*</td>
</tr>
<tr>
<td><em>What would life be like without action/reaction pairs and friction? Are contact interactions all bad?</em></td>
<td>Phenomenon: Watch rocket Launch (any video will be fine)</td>
</tr>
<tr>
<td><em>How do we use contact interactions like friction and thrust to do work?</em></td>
<td>People swimming</td>
</tr>
<tr>
<td></td>
<td>Airplanes flying</td>
</tr>
</tbody>
</table>

The effects of Newton’s 3rd Law are not all negative. Most of them are extremely positive important. Without action/reaction pairs we couldn’t walk, swim, fly, stand up, sit down, well...really anything.

We tend to focus on friction as a negative, but without friction we would look like this.

[https://www.youtube.com/watch?v=nTkM9zFQd4c](https://www.youtube.com/watch?v=nTkM9zFQd4c)

Just show the first minute and give the kids some time to laugh at the silly people. :)

---

215
Leonardo’s pick a new team

Design and build a balloon rocket.

Complete assignment Newton’s Third Law

Of course, without ACTION/REACTION pairs, it might not hurt as much!

**Rotate Leaders**

**Activity:** Balloon rockets

**Materials:**
- String
- Balloons
- Straws
- Clothes pins

Assessment: Seedstorylines.org has a great activity and assessment on Newton’s 3rd.

https://www.seedstorylines.org/7-1-2

Will take you to the home page. Go to 7th grade-

7.1: 7.1.2: Episode 2

The assignment link: Newton’s Third Law

https://docs.google.com/document/d/1H4AuaVpzM0ozMWCvk1rjSIHUGQzIbI0E Au_V3gy30/edit

**Raphael’s switch**

Assessment of Student Learning

Proficient students can model the action/reaction pairs acting within a system and describe that forces within a system are EQUAL in magnitude and OPPOSITE in direction.
Strand: 7.1.4 (and a lot of 7.1.3)

**Emphasis:** Magnets

**Anticipated Time Required** (assuming 50 minute class periods):
- Episode 1 - 100 min
- Episode 2 - 50 min
- Episode 3 - 70 min
- Episode 4 - 50-80 min depends on quality of writing desired
- Episode 5 - 50 min

**Dominant CCC:** Cause and effect
**Dominant SEP:** Collect and analyze data, construct models

**Management Strategies** to support equitable access to content:

**Shopping list:**

**Episode 1**
- Round ceramic magnets
- Bar magnets or other shapes
- Nails
- Thread
- Paper clips (small and large)
- Pieces of cardboard or other materials (used to understand that magnetic fields can penetrate through matter)
- Rulers
- Magnets of different strengths (some of those old worn out magnets you got laying around…)
- Pins
- Leaves or pieces of wax paper
- Markers
- Bowl of water

**Episode 2**
- At least 1 small compass per pair.
- Paper
- Ruler
- Bar magnets
- Pencil
- Iron filings
- Small tray or box

**Episode 3**
- Battery
- Alligator clips and wire
- 22-30 gauge enamel coated (insulated) copper wire
- Nail or bolt to wrap wire around
- Battery
- Sand paper to strip the insulation off the wire
- Paperclips or staples

**Episode 4**
- Materials list will depend on variables you choose to have students test.
### 7.1.4 Storyline Planner

**Anchor Phenomenon:** Aurora Borealis

Student Performance Expectation: Students explore magnets and electromagnets and construct models and explanations of why things are magnetic from data. Students will be able to use their models and data to construct an understanding of the cause other aurora phenomena.

<table>
<thead>
<tr>
<th>Dominant DCI</th>
<th>Dominant CCC</th>
<th>Dominant SEP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical Science</td>
<td>Cause and effect</td>
<td>Collect and analyze data</td>
</tr>
</tbody>
</table>

### Science Experiences

<table>
<thead>
<tr>
<th>CCC/SEP</th>
<th>What are students doing? (This should match your SEP!)</th>
<th>What specific understandings should students get from this experience? (What pieces of the performance expectation does the experience provide?)</th>
<th>New questions students have to propel us to the next science experience</th>
<th>Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Cause and effect/ making models</td>
<td>View aurora borealis video. Ask questions Engage with lab exploring magnetism. Construct first try model of how magnets work. Compare models to peers and construct a group model.</td>
<td>Magnets produce forces that act at a distance. Magnetic forces can travel through objects. Magnetic forces attract sometimes and repel other times. Compasses are little floating magnets. How to draw things that</td>
<td>First try and second try models. Lab notes</td>
</tr>
<tr>
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<td></td>
</tr>
<tr>
<td>2</td>
<td>Cause and effect/ making models</td>
<td>Construct models of magnetic fields using a compass and iron filings.</td>
<td>Magnetic fields make magnetic field lines. They have different shapes depending on the magnet, but similarities too.</td>
<td>Why are things magnetic?</td>
</tr>
<tr>
<td>3</td>
<td>Cause and effect/ making models, asking questions</td>
<td>Receive direct instruction on the causes of magnetism. Explore electricity and EMF using gaussmeter. Construct electromagnets and ask questions.</td>
<td>Electricity and magnetism are related. That magnetic fields are produced when electrons are able to move or spin in one direction.</td>
<td>What affects the strength of a magnetic field? Why is the earth magnetic?</td>
</tr>
<tr>
<td>4</td>
<td>Cause and effect/ conduct investigation collect and analyze data</td>
<td>Conduct investigation on variables that affect magnetic field strength using electromagnets.</td>
<td>Number of coils, strength of electrical force, type of materials all affect the strength of magnetic field.</td>
<td>Why is the earth magnetic? What causes the aurora borealis? How is it related to magnetism</td>
</tr>
<tr>
<td>5</td>
<td>Cause and effect, argue from evidence</td>
<td>Gather information from models, images, and articles on the formation of the auroras.</td>
<td>The auroras are a phenomena related to the interaction of earth’s magnetic field with the sun’s magnetic field and the solar wind.</td>
<td>What would happen if we didn’t have a magnetosphere?</td>
</tr>
</tbody>
</table>
### 7.1.4 Episode 1 (from sara’s plan- floating paperclip)

#### Student Science Performance

<table>
<thead>
<tr>
<th>Topic: Magnetism</th>
<th>Title: Shock and Awe</th>
</tr>
</thead>
</table>

#### Overarching Performance Expectations (Standard) from State Standards or NGSS:

**7.1.3**

Construct a model using observational evidence to describe the nature of fields existing between objects that exert forces on each other even though the objects are not in contact. Emphasize the cause and effect relationship between properties of objects (such as magnets or electrically-charged objects) and the forces they exert.

**7.1.4**

Collect and analyze data to determine the factors that affect the strength of electric and magnetic forces. Examples could include electromagnets, electric motors, or generators. Examples of data could include the effect of the number of turns of wire on the strength of an electromagnet, or of increasing the number or strength of magnets on the speed of an electric motor.

#### Lesson Performance Expectations:

Students will develop and revise models of magnetism anchored in a particular phenomenon (floating paper clip). Students will then test their models’ ability to account for new phenomena (generators, electromagnets, or iron filings) Students will use appropriate language (made explicit by the teacher in sentence frames) for describing their models and asking questions of peers to extend their thinking. Students will share leadership responsibilities required for consensus modeling. Students will participate in whole class discussions by repeating/rephrasing, adding new ideas, asking questions, providing counter evidence or a counter argument.

#### Students Will... To Construct Meaning

Engage with a Phenomenon: Fill out an OEQ template while watching the video on the AURORA BOREALIS turn and talk to your neighbor about your observations, explanations and questions. Prepare to share those with the class if called on.

#### Teacher Will... To Support Students

From 7.1.3

Prepare to engage with phenomenon: OEQ template

Phenomenon: Aurora Borealis Aurora Borealis at Magnetic Midnight.

After quiet writing time, have students turn and talk about their observations, explanations and questions.

Management Strategy: Randomly generate students to share.

Write their questions on the board.

To learn about this beautiful phenomenon we need to learn about magnets!
Gather and Reason:
Sort into lab groups based on color. Perform group responsibilities based on your number.

Receive a copy of the lab packet. Start by going to stations and filling out the I learned/I wondered template. Write down your inferences and the evidence that supports them.
For examples: I saw that magnetic attract things because I saw things moving towards the magnet.

Travel with your lab group. You will have 5 minutes at each station.

Management strategy: Numbered Heads Together
Organize students into lab groups of 4 students by using colored Number stickers or colored cards with numbers written on them. The level of science language/skills difficulty for this standard is moderate to difficult. Take that into consideration as you pass out your cards and look for good combinations based on your understanding of student needs.

Guiding Question: How do magnets work? (what is the cause of the effect)

Students will engage with the lab by completing I Learned... because... /I wondered template. This could be written into their journals or passed out as worksheet (below) along with ‘modeling magnetic fields’ worksheet.

Management Strategy: What to ASSESS!
I have thought a lot about when students should journal vs when they should complete an assignment. One thought I had was that I should grade anything that demonstrates use of the SEP, so in this case I should be grading their ability to ‘CONSTRUCT A MODEL’ or ‘COLLECT AND ANALYZE DATA’. Since I find journal grading difficult, and worksheet grading a little easier (for both time, space, and providing feedback) I have chosen to create a worksheet and address both the content (DCI) and the SEP.

Goal: Students will construct a model of fields coming from within magnets and fields between magnets based on their experience with 9 stations:

see descriptions below
Return to group tables
Communicate:
Read worksheet ‘Constructing a model of how magnets work’
Learn slogans for new words.

Read task expectations on worksheet with instructor

Quick Write on what it means to be invisible. Why are things invisible. How can we show things that are invisible?

Be prepared to share your thoughts with the class.

Complete first try of model of how magnets work.

Share models and explanations with group

As students are working circulate especially to students who may need help. Ask them probing questions like “What do you see (observe)?” “What does it feel like?” “How do you explain what you see or feel?” “If you were to draw what this feels like, what might it look like?”

When students have completed their observations, they should return to their group tables.

Students are introduced to new vocabulary through a class reading of the introduction to the worksheet. Constructing a model of how magnets work-

Students construct slogans for the words, FORCE, FIELD, EXERT, ATTRACT and REPEL and share with the class. Choose a slogan for each and write it down for later review.

(This may not be necessary if you already explored vocabulary with the other 7.1.3 section, either section can work as an introduction to forces and fields)

Read: TASK EXPECTATIONS with students before they begin the ‘working independently’ section.

Direct Instruction:
Setting Students up to Succeed on assessment:
Help students to recognize that there is a lot going on here that is INVISIBLE.

Quick write

Question: Why are things invisible? How can we show things we’ve observed or inferred but that we can’t see?

Have students suggests ways that they could show things

Number 1 will ask:
What are the similarities/differences in our models?
•I noticed X# have……
•I noticed only X’s has…. 

Number 2 will ask:

• Materials:
  • Round ceramic magnets
  • Bar magnets or other shapes
  • Nails
  • Thread
  • Paper clips (small and large)
  • Pieces of cardboard or other materials (used to understand that magnetic fields can penetrate through matter)
  • Rulers
  • Magnets of different strengths (some of those old worn out magnets you got laying around…)
  • Pins
  • Leaves or pieces of wax paper
  • Markers
  • Bowl of water
What do we agree should be in our model?
• I think we should include…. because…..
• I agree/disagree because…….
  I felt this in the lab and I think we could show it by...

Number 3 will ask:
Are we ready to draw? How should we start?
• I think we should draw….because/for example

Number 4 will ask:
Is there anything missing in our drawing?
• We need to add……

Number 1 will ask:
What’s our evidence for this model?
  ● Our evidence is……
  ● I think it’s like this because...

Number 2 will draw group model
Number 3 and 4 will write group description and explanation

Present models to the class. Choose a spokesperson to speak for the group. Post model on the board.

Participate in respectful discussion while learning from the models produced by the class.

---

that they’ve observed that we can’t actually see with our eyes because it's too small or because it's a force acting between between things that we can’t see..

Give students 5-10 minutes to complete the FIRST TRY worksheet in their lab packet.
Students should take turns sharing their models (choose a number to start) and explanations. Each student should take 1 minute. (Designate a timekeeper)

**Pass Out** Group Task Instructions sheet. Read instructions aloud. Students should follow the protocol of taking turns reading questions and leading the discussion in an effort to come to consensus. This will take at least 20-30 min.

Students should complete SECOND TRY- Draw group model. Assignment.

Have students bring their models to the front as a group and chose a voice to present their model. Tell students to hold their comments until everyone's done. They may take notes in their journals to keep track of their thoughts.

Post the models on the board and lead a group discussion.

(poster: types of participation)

• Make comparisons between the models
• Encourage students to point out similarities, differences, consistencies, inconsistencies.
• Provide counter evidence to challenge student thinking
• Ask questions that probe students’ thinking.
• Asks students to rephrase or repeat others’ thinking/ideas
• Build consensus, “Who else thought XYZ?”, “Do we agree or disagree with QRS idea and why?” (focus on ideas not people).
• List ideas on the board to guide talk (be sure to be inclusive, as in don’t hesitate to add incorrect ideas to the ongoing list of options)
List student generated questions for further exploration.

**Assessment of models:**
Rubric for Assessing models and informing instruction in
Ask questions
Respond to questions and comments with journal reflection

next episode.

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</tr>
<tr>
<td>Is the model showing progression</td>
<td>From Static/macroscopic --- to Dynamic/microscopic</td>
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</table>

If their models are still too static and too macroscopic, then they require more evidence/instruction.

Reflection Questions:
“I like your model, do we understanding what is going on in the magnet that is making it act like this?”
“Would you change your model after listening to your peers?”
“Would you like more evidence?”
“What do you think this has to do with the Aurora Borealis?”
“How well did you participate in this process?”

Assessment of Student Learning
Assessment is based on rubric for assessing models and informing instruction. Proficient students are engaged in constructing models and explaining them individually and as a group. Proficient students will be asking questions and looking for evidence to help perfect their models. Keep notes on how students participate in small group and whole class discussions & have students complete reflections on their participation. Can be in checklist form to streamline recording!
How do magnets work?
Making Observations, constructing explanations: Name _________________________

<table>
<thead>
<tr>
<th>Station</th>
<th>I learned that...because i saw...</th>
<th>I wondered about...</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
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<tr>
<td>8</td>
<td></td>
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</tbody>
</table>
Modeling Magnetic Fields

Read along with the instructor:

The word FIELD in science means an area where an object can EXERT a FORCE. A FORCE is a push or a PULL. We observed magnetic FORCE today. EXERT means to ACT on something with a force. Magnetic force was exerted anytime something in lab was PULLED together or PUSHED apart. When a force pulls things together we say they ATTRACT. When a force pushes things apart we say they REPEL.

As a group decide on a SLOGAN for these vocabulary words, be prepared to share them with the class.

FORCE:

EXERT:

FIELD:

ATTRACT:

REPEL:

Task: You are required to CONSTRUCT A MODEL of HOW MAGNETS WORK.

**Explanation of Science Practice:**
Constructing a model has several components. Constructing a model means that you must use the **inferences** you made from your **observations** in lab to:

- Draw (with pictures, words, and arrows)
- Describe (tell what the model represents in words)
- Explain (tell why you think this is true)

Task: SHARE your model with your group.

Here are some examples of the language you could use to share your model:

- *In my drawing you can see…….. I included X,Y,Z because…… OR My drawing has…..because……
- *My evidence for this model is……
- *Something I observed today……
- *Something I observed somewhere outside of class……
- *Something I read……
- * Something I learned in another science class……
Working Independently (by yourself) - Use your observations to CONSTRUCT A MODEL that answers the question: How do magnets work? Be prepared to share your model with your group in _________ minutes.

How do magnets work? In lab we noticed that there is a force that comes from within a magnet that affects the way it interacts with other magnets or other objects.

1. FIELDS that come from WITHIN a magnet
2. FIELDS that exist BETWEEN magnets and other objects.

Model of fields that come from within a magnet.

Describe and explain your model

_____________________________________________________________________________________
_____________________________________________________________________________________
_____________________________________________________________________________________ 

Model of fields that exist between magnets

Describe and explain your model

_____________________________________________________________________________________
_____________________________________________________________________________________
_____________________________________________________________________________________
Task: Construct a model as a GROUP that shows magnetic force fields coming from magnets and acting on other objects in that field.

Constructing a model as a group means coming to a CONSENSUS (agreement) on...
- what the model should look like
- how to label it,
- what it means
- why you think that it is a true representation of how magnets work.

*This will be done* by taking turns asking questions. Everyone will help to answer the questions in turn. Pass the sheet around as you take turns asking questions.

**Number 1 will ask:**
What are the similarities/differences in our models?
• I noticed X# have…….
• I noticed only X’s has…..

**Number 2 will ask:**
What do we agree should be in our model?
• I think we should include… because…..
• I agree/disagree because…….  
  I felt this in the lab and I think we could show it by...

**Number 3 will ask:**
Are we ready to draw? How should we start?
• I think we should draw…. because/for example

**Number 4 will ask:**
Is there anything missing in our drawing?
• We need to add……

**Number 1 will ask:**
What’s our evidence for this model?
- Our evidence is……
- I think it’s like this because...

**Number 2 will Draw group model**

**Number 3 and 4 will write group description and explanation**
Describe and Explain Group model here:
<table>
<thead>
<tr>
<th>Station 1</th>
<th>Target observations</th>
</tr>
</thead>
</table>
| **What materials are attracted to a magnet?**  
- String  
- Paper  
- A nut or washer  
- A paper clip  
- Cardboard, other substances  
- Plastic  
- Metal hole-puncher  
- Pick something from your backpack that you are curious about! | **Some materials can be magnetized, others cannot.**  
**Some metals can be magnetized others cannot.** |

<table>
<thead>
<tr>
<th>Station 2</th>
<th>Target observations</th>
</tr>
</thead>
</table>
| **What happens when you put 2 magnets on one side of a pencil and one magnet on the other side?**  
**Test out different ways to put the magnets on the pencil.** | **Magnets are polar (kid language will be different!)**  
**Sometimes magnets attract each other, sometimes they repel each other.**  
**You can make magnets attract or repel by “flipping” one of them**  
**When the magnets push away from each other, what appears to be empty space stays between them.** |

<table>
<thead>
<tr>
<th>Station 3</th>
<th>Target observations</th>
</tr>
</thead>
</table>
| **How many paperclips can you pick up with a magnet through a piece of wood or cardboard?**  
**Variation:**  
- How many paperclips can you pick up with a magnet through a piece of cardboard?  
- What happens when you add pieces of cardboard?  
- How many pieces of cardboard can you use before you can no longer pick up a paperclip | **Magnetic fields (again, this is not in kid language!) can and do travel through materials.**  
**The magnetic field does not extend forever around the magnet, there is a limit to it’s range**  
**Paperclips closer to the magnet experience a greater pull than paper clips farther from the magnet.** |
### Station 4

- **How can you make a paperclip float with magnets?**
  - Try with different #s of magnets!

**Target observations**
- If the magnet is too far away the paperclip will not float.
- You can feel resistance when you hold the paperclip in a floating position.
- You need more than one magnet for the floating trick to work well – more magnets = easier to make magnets float. Note: Ss may or may not work out this relationship on their own, but, the teacher can help draw this out in whole class discussion.

### Station 5

- **How many paperclips can you pick up with a nail with a magnet touching the nail?**

**Target observations**
- Nails can become temporarily magnetized by touching a magnet.
- As Ss will see in the next station, this is different from the cardboard exercise because the cardboard allows the magnetic field to act through it without becoming magnetized, the nail on the other hand becomes magnetized.

### Station 6

- **What happens to your ability to pick up paperclips with a nail after you rub a magnet across the nail 20-30 times?**

**Target observations**
- Nails can become temporarily magnetized by coming into contact with a magnet.
- This temporary magnetization (word? J) will not last long, can wear off and can be dissipated on purpose by tapping the nail. (Ss may not see this on their own but you can point it out during whole class discussion)

### Station 7

- **What happens to the paperclips on the end of a nail when you flip the magnet?**

**Target observations**
- When you initially remove the magnet, the paperclip should stay attached to the nail.
- When you flip the magnet the paperclip should drop as a result of the reversal in polarity.

Note: This station is a little tricky so Ss may need help “seeing” what you want them to see here.
<table>
<thead>
<tr>
<th>Station 8</th>
<th>Target observations</th>
</tr>
</thead>
</table>
| What are the differences between these magnets? | ● Magnets are made of different materials  
● The pull comes from different places  
● Some magnets are stronger than others. |
|                                                                                       |
| Station 9 Can you make a compass with a leaf if you magnetize a needle?               | Target observations                                                                 |
|                                                                                       | ● Compasses are floating magnets                                                      |
### 7.1.4 Episode 2

**Student Science Performance**

<table>
<thead>
<tr>
<th>Topic: Magnetism</th>
<th>Title: Shock and Awe</th>
</tr>
</thead>
</table>

**Overarching Performance Expectations (Standard) from State Standards or NGSS:**

**7.1.3** Construct a model using observational evidence to describe the nature of fields existing between objects that exert forces on each other even though the objects are not in contact. Emphasize the cause and effect relationship between properties of objects (such as magnets or electrically-charged objects) and the forces they exert.

**7.1.4** Collect and analyze data to determine the factors that affect the strength of electric and magnetic forces. Examples could include electromagnets, electric motors, or generators. Examples of data could include the effect of the number of turns of wire on the strength of an electromagnet, or of increasing the number or strength of magnets on the speed of an electric motor.

**Lesson Performance Expectations:**

Students will develop and revise models of magnetism anchored in a particular phenomenon (magnetic interactions). Students will then test their models’ ability to account for new phenomena (compasses or iron filings).

Students will use appropriate language (made explicit by the teacher in sentence frames) for describing their models and asking questions of peers to extend their thinking. Students will share leadership responsibilities required for consensus modeling. Students will participate in whole class discussions by repeating/rephrasing, adding new ideas, asking questions, providing counter evidence or a counter argument.

- **CCC:** Systems and system models, cause and effect
- **SEP:** Developing and using models, Constructing explanations

**Students Will. . . To Construct Meaning**

- Read and review your journal notes and reflections
- Watch interactive model of how electric fields of oppositely charged particles create field lines.
- We will look at
  - positive to positive
  - Negative to negative
  - Positive to negative
- Draw a model of each one of these interactions.

**Teacher Will. . . To Support Students**

**Read/Review**

More Evidence: Constructing magnetic fields with a compass.

Students will work in pairs within their lab group. For example: youngest and oldest together or middles or let them choose.

**Give students exposure to charge field lines with the following interactive:**


**Show students the following combinations:**

- Positive to positive
- Negative to negative
- Positive to negative

Students should draw models of these fields in their journals.

Ask students to consider how this matches their earlier models.
Use the magnet and the compass and see if you can identify any patterns as you move the compass around the magnet.

Take notes in your journal on video plotting magnetic field lines. Watch carefully. We will watch it once and then go through the highlights again.

Work with one of your table partners on Model #3. One of you will hold the pencil, while the other moves the compass. Every 5 minutes you will trade.

Students will map the magnetic field using a compass and a magnet. Model the practice for students and then give them an instruction sheet.

Materials:
- At least 1 small compass per pair.
- Paper
- Ruler
- Magnet
- Pencil
- Iron filings
- Small tray or box

Management Strategy: Voice and Pen
Students should work in pairs and alternate roles. One uses the pencil (pen), the other gives instructions (voice). Set a timer and have them alternate every 5 minutes. Proverbially speaking- Only one pencil should be used. Voice should sound like
“I noticed this so I think we should…”
“I was wondering what would happen if…”

Give students magnets and compasses and let them explore for a bit before showing them the instructions.

There are several videos on how to do this. You choose what works for you.
“Plotting magnetic field lines” (judgeteasowsci)
https://www.youtube.com/watch?v=DMO373nDp8M
https://www.youtube.com/watch?v=JUZC679CwKs
I made a model that wasn’t nearly this neat my first time with no instruction. Don’t laugh. :)

I recommend following these instructions in the video, they will help.
The tricky thing...all magnets have a different magnetic field pattern depending on the shape and how the magnet was polarized. **You will have to explore the magnets you are using before you give them to your students. Practice!**

If you want it to be easy, use labeled bar magnets polarized through the long axis.
**Note:** I noticed that I wasn’t clear about which was the North side of the magnet and which was the south side.

The compass will point toward the south side of the magnet and away from the north side. I got it wrong on my drawing because I was thinking about it like the earth, but the earth’s magnetic north pole is actually the south pole and vice versa...so can’t use that logic.

Students work together to construct a model of the magnet. If they finish early, give them another magnet to work on.

**More evidence:**
To confirm their observations show them the magnetic field using iron filings. These are messy and difficult to work with, so you may want to just do a demonstration. If you are feeling brave, give students a tray or a box and a small container (like the kind they put glitter in) of iron filings.

**Wrap the magnet in plastic wrap** so that you don’t get iron filings directly on the magnet. They don’t come off very well.

Cover the magnet with a piece of paper and sprinkle the iron filings on the paper over the magnet and

---

*Wrap your magnet in plastic wrap...tightly. Place your magnet on the tray or box you are given. Put a clean piece of paper over the magnet. Sprinkle iron filings on the paper over the magnet and observe.*
**On your assignment (or in journals)**

**Model #4- Iron filings**

*Draw a model of like charges repelling and opposite charges attracting with iron filings.*

*Complete the Assessment ‘Reflections on constructing a model of ‘how magnets work.’*

---

Let them experiment with the iron filings and observe how magnets interact with other magnets.

- What does the field look like if we put them together with opposite poles?
- What does it look like if we put them together with like poles.
- Have them draw these interactions in their journals.

**Assessment:** Reflection on constructing a model of How magnets work.

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**Journal Reflection:** We use compasses to find the north and south poles on earth, what does that tell us about the
Reflect in your journal on these questions:
We use compasses to find the north and south poles on earth, what does that tell us about the earth?

How do you think this relates to the Aurora borealis we observed?

What questions do you have?

Be prepared to share with the class.

earth? How does this relate to the Aurora Borealis. Questions:
Give students time to reflect on these questions. Randomly generate names to drive class discussion.
Write new class questions on the board.

Assessment of Student Learning: Student models will be assessed to guide instruction. Proficient students are able to recognize the differences in the mental models they had constructed and the mapping of the magnetic fields they have observed. Their models and explanations should show a comparison to current thinking from past thinking and the role of evidence in changing their understanding.
Model #3  Modeling magnetic fields using a compass. Watch the video carefully and follow instructions as they are given to you. Video if you want to watch at home
https://www.youtube.com/watch?v=DMO373nDp8M&t=6s
Model # 4 - Iron filings- Iron filings hurt eyes! Do not blow them around or rub them into your eyes!!!!!! Be extremely careful!

<table>
<thead>
<tr>
<th>Draw your magnet in plastic wrap. Put in small box. Sprinkle with iron filings.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Draw a model of your magnet with iron filings.</strong></td>
</tr>
<tr>
<td><strong>Draw a model of your magnet with another magnet with opposite poles facing. Make sure to wrap other magnet in plastic wrap!!!!!</strong></td>
</tr>
<tr>
<td><strong>Draw model of your magnet with another magnet with like poles facing. Make sure to wrap other magnet in plastic wrap!!!!</strong></td>
</tr>
<tr>
<td>First model</td>
</tr>
<tr>
<td>-------------------------------------</td>
</tr>
<tr>
<td>Looked like this</td>
</tr>
<tr>
<td>I explained it like this</td>
</tr>
<tr>
<td>Because I didn’t understand</td>
</tr>
</tbody>
</table>
### 7.1.4 Episode 3

<table>
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<tr>
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<th>Title: Shock and Awe</th>
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**Overarching Performance Expectations (Standard) from State Standards or NGSS:**

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**7.1.4** Collect and analyze data to determine the factors that affect the strength of electric and magnetic forces. Examples could include electromagnets, electric motors, or generators. Examples of data could include the effect of the number of turns of wire on the strength of an electromagnet, or of increasing the number or strength of magnets on the speed of an electric motor.

**CCC:** Systems and system models  
**SEP:** Constructing models, analyzing and interpreting data

**Lesson Performance Expectations:**
Students continue to gather information to construct a model and an explanation that includes the macro and micro aspects of electromagnetic forces and explains the behavior of these magnets with model that includes field lines and electron flow. Explanation should also include evidence from past experiences that support the model and explanation.

**CCC:** Systems and System models, Cause and Effect  
**SEP:** Develop a model, carry out an investigation

<table>
<thead>
<tr>
<th>Students Will. . . To Construct Meaning</th>
<th>Teacher Will. . . To Support Students</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Read and review from last episode</strong></td>
<td>Read and Review- Return past models to them</td>
</tr>
<tr>
<td><strong>Think/ Pair /share Prepare an OEQ template and watch video on how magnets are made.</strong></td>
<td>Students continue to work with their lab groups</td>
</tr>
<tr>
<td><strong>Prepare to share your observations, explanations, questions</strong></td>
<td><strong>Prepare:</strong> Students prepare to watch the video by preparing an OEQ template. Generate student names to share observations, explanations, questions.</td>
</tr>
</tbody>
</table>
| **Take notes on when materials become magnetized.** | **How it’s made- magnets**  
[https://www.youtube.com/watch?v=noGGcyPHtdI](https://www.youtube.com/watch?v=noGGcyPHtdI) |

**Direct Instruction:** Magnets are made of metals whose atoms have been lined up to make the magnet polar with opposite charges on either end. Then they are shocked with electricity to make magnetic properties stronger. Before people manufactured magnets they were found in nature, it is believed they were rocks that had become magnetized when they were hit with LIGHTNING. In lab we saw that we could rub a magnet on a nail and make it magnetic temporarily. That was because the electrons in the metal could be lined up and start moving in one
Is electricity related to magnetism? Are magnetic fields found with electrical things? Observe the electromagnetic fields EMF readings of different electrical outlets, wires, and devices. Is there a connection?

Observe video on electromagnets.

Turn and talk
How do you think they made a magnet strong enough to pick up a car?
How does it drop its load?
Why is it called an ELECTROMAGNET?


When a bar of metal is made into a ‘Permanent magnet’ the atoms are ‘pinned’ into a position where their electrons are fixed in the correct position for magnetism to occur. Anything that disrupts that position will make a magnet lose its magnetism. For example, heating a magnet will cause it to lose its magnetism or hitting a magnet repeatedly (or crashing it into another magnet) will weaken the magnetic field over time or make it lose its magnetic force entirely.

Shows magnetic field penetrating bar of iron and inducing a magnetic field in the iron bar.

Teacher Note: magnetic properties are found in elements whose atoms have one unpaired electron. The spin of this unpaired electron creates opportunity for electric force to induce a magnetic field which is perpendicular to the
Prepare to share your answers with the class.

Given supplies and instructions build an electromagnet.
With your table partner

Ask questions about electromagnets.

---

**Student Questions:** Is electricity necessary to make magnets? What is the relationship between magnets and electricity? Does more electricity make a stronger magnet?

**Show** students a Gauss meter if you have one and have them quantify the magnetic field strength of the magnet used in lab. Then see if there are EMF readings coming from electrical outlets, computer, power lines and any other electrical sources.

**Show** students ELECTROMAGNETS used to pick up junk in junk yards. How do you think they make a magnet strong enough to pick up a car? How do they drop the load? Why is that called an ELECTROMAGNET? Randomly generate students to share.

https://www.youtube.com/watch?v=6yhNOXQkMpY

Students will **build** electromagnets and **ask questions** about variables that might affect the strength of the magnetic field.

**Warning:** These electromagnets can get very HOT, especially as students start experimenting with stronger electromagnets. I have seen some people recommending rubber gloves. I tell the kids to be careful and unplug if it gets too hot.

http://www.wikihow.com/Create-an-Electromagnet
Has clear instructions and lists.
Science buddies is also a good source.

**Basic materials to make electromagnets:**
- Battery
- Alligator clips and wire
- 22-30 gauge enamel coated (insulated) copper wire
- Nail or bolt to wrap wire around
- Battery
- Sand paper to strip the insulation off the wire
- Paperclips or staples

---

Read the rubric for your final model. In your journal:
- Write a list of vocabulary words you need to...
describe ‘how magnets work’

- draw a model and an explanation that includes the newest information you have about How Magnets Work.

Show your model to a peer for a peer edit, have them fill out the rubric and help you figure out how to make your model better. Show them your old model.

When you feel like your rough draft is EXCELLENT, then fill out the final ASSESSMENT. TRY AGAIN MODEL #5.

Inquiry: After students have had time to experiment with the simple electromagnet Have students write questions and post them in Parking Lot.

Assessment: Students should complete model #5 of How Magnets Work

Give students the compasses and have them construct a model of the magnetic field produced by their electromagnet.
Model should show that magnetic fields are produced as negative charges (electrons) move through the wire. The magnetic field is perpendicular to the direction of electron flow.

Model of electric force (green) moving perpendicular to
Review questions

http://www.geocities.ws/rjwarren_stm/Physics_Notes/Helix.gif


Prepare to write: Constructing a vocabulary list.
Students write in their journals. What words do you need to use in order to correctly explain a model of “How magnets work.”?
Students construct rough draft of final model and explanation using required vocabulary.
Students should use the rubric for self evaluation and for peer editing BEFORE using the template for the assignment below.

Sentence Stems could be given to help students:
This model shows…..
Arrows are used to show…..
Evidence for this model includes…..
What is not shown in the model is……..

Give students grading rubric and have them peer edit models according to the rubric. If students need to add to their model then they should.

<table>
<thead>
<tr>
<th>Element</th>
<th>Expectation</th>
</tr>
</thead>
</table>

magnetic field (red)
<table>
<thead>
<tr>
<th>Elements that are not observable</th>
<th>Your explanation <strong>talks</strong> about parts of the model that are hard to observe or draw. Required vocabulary used.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evidence included in explanation.</td>
<td>Your explanation describes evidence and observations that helped you make the model.</td>
</tr>
<tr>
<td>Interactions between those unobservable elements</td>
<td>Your model shows • where the parts of the system that are causing this effect are located • how they are arranged • how they are moving</td>
</tr>
<tr>
<td>Interactions or behaviors of those unobservable elements that are microscopic</td>
<td>Are the invisible parts of this system shown in some way including large field lines or small electrons.</td>
</tr>
<tr>
<td>Is the model showing progression</td>
<td>Is this model more clear and accurate than your last model?</td>
</tr>
</tbody>
</table>

**Questions:** What makes an electromagnet stronger? Why is the earth magnetic?

---

**Assessment of Student Learning**

*Proficient students can construct a model of magnetism that includes the flow of electrons leading toward a dynamic/microscopic view of magnetic forces.*

---

**Try Again- Model#5 - How magnets work.**

Name __________________________________________

Construct a rough draft of your model and an explanation in your journal and self evaluate (check your own work) using the **rubric**.

When you feel like the models and explanation are complete, have a peer check your work using the rubric. Then use this template (form) to write your final assignment.
Draw your model. Include electrons and show the direction of the magnetic field that is produced compared to the direction of the flow of electricity in this system.

Describe your model in words and explain the reasons why your model changed from your last model.
<table>
<thead>
<tr>
<th>Expectation</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Your explanation <strong>talks</strong> about parts of the model that are hard to observe or draw.</td>
<td></td>
</tr>
<tr>
<td>Required Vocabulary is used correctly in explanation.</td>
<td></td>
</tr>
<tr>
<td>Your Explanation includes evidence that support the explanation. I think … <strong>because</strong>…</td>
<td></td>
</tr>
</tbody>
</table>
| Your model shows  
  ● where the parts of the system that are causing this effect are located  
  ● how they are arranged  
  ● how they are moving  
  ● how this system interacts with other objects? | |
| Are the invisible parts of this system shown in some way including large field lines or small electrons. | |
| Is this model more clear and accurate than your last model? | |

**Task- Peer Editing**

Quietly read through the rubric and write comments. When you are clear about how might help them improve, give them helpful suggestions and comments. Like: I really like how you did…, I feel like this part would be more clear if…
<table>
<thead>
<tr>
<th>Expectation</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Their explanation <strong>talks</strong> about parts of the model that are hard to observe or draw.</td>
<td></td>
</tr>
<tr>
<td>Required vocabulary used correctly.</td>
<td></td>
</tr>
<tr>
<td>Their Explanation includes evidence that support the explanation.</td>
<td></td>
</tr>
<tr>
<td>I think ….<strong>because</strong>...</td>
<td></td>
</tr>
<tr>
<td>Their model shows</td>
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<td>● where the parts of the system that are causing this effect are located</td>
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<td>Are the invisible parts of this system shown in some way including large field lines or small electrons.</td>
<td></td>
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<tr>
<td>Is this model more clear and accurate than their last model?</td>
<td></td>
</tr>
</tbody>
</table>
Overarching Performance Expectations (Standard) from State Standards or NGSS:

7.1.3 Construct a model using observational evidence to describe the nature of fields existing between objects that exert forces on each other even though the objects are not in contact. Emphasize the cause and effect relationship between properties of objects (such as magnets or electrically-charged objects) and the forces they exert.

7.1.4 Collect and analyze data to determine the factors that affect the strength of electric and magnetic forces. Examples could include electromagnets, electric motors, or generators. Examples of data could include the effect of the number of turns of wire on the strength of an electromagnet, or of increasing the number or strength of magnets on the speed of an electric motor.

CCC: Cause and effect
SEP: Carry out an investigation, collect and analyze data

Lesson Performance Expectations:

Students Will . . To Construct Meaning

Quick write on video of car parts being picked up with an electromagnet.

How do you think they make a magnet strong enough to pick up a car?

Teacher Will . . To Support Students

Show students ELECTROMAGNET used to pick up junk in junk yards. How do you think they make a magnet strong enough to pick up a car?

https://www.youtube.com/watch?v=6yhNOXQkMpY

Questions: How is this working? How come it is so strong?

Lab Report: See supplementals on how to design an experiment through writing. Protocol. Assign them lab roles for the experiment on variables that affect the strength of an electromagnet. Pass out cards with roles and an identifier (number, name, shape, character)

Roles

- Leader- In charge of selecting group and keeping group on task and completes the assignment, time keeper for experiment.
- Manager- In charge of materials for the lab including set up and clean up.
- Writer- In charge of anything that is written down data and leading group to complete lab reports.
- Expert - In charge of reading instructions, leading discussion on experiment design and execution.

Students should consider variables that might affect the
Conduct experiment.  
Write about experiment.  
Talk about your experiment.

<table>
<thead>
<tr>
<th>Conduct experiment.</th>
<th>Write about experiment.</th>
<th>Talk about your experiment.</th>
</tr>
</thead>
</table>

strength of the electromagnet, here are a few they might consider.
You can decide what materials you have and where you want them to go.

Independent Variables might be:
- Number of turns on the coil or length of the wire.
- Size of the current by increasing battery size or number
- Different cores steel, copper, aluminum, etc. You can use nails, bolts, pipe, tubing, and more.
- Leads used

Dependent Variables Might be:
- Number or size of paperclips picked up
- Time for the electromagnet to attract the paper clips
- Readings on gaussmeter

Students conduct experiments and prepare to write or present data to the class.

http://miniscience.com/kits/Magnet_Motor_kit/index.html
Making an electric motor
https://www.sciencebuddies.org/science-fair-projects/project_ideas/Elec_p051.shtml
Another one.

Assessment: Lab report graded with rubric

Or another assessment idea may be a mini lab report and then have students create posters and present to the class.

Assessment of Student Learning
Proficient students show an understanding of the relationship between electric force and magnetism through their writing on a lab report or poster presentation. They should also show an understanding of how to collect and analyze data through their discussion. Graded according to rubric.
### Overarching Performance Expectations (Standard) from State Standards or NGSS:

**7.1.3** Construct a model using observational evidence to describe the nature of fields existing between objects that exert forces on each other even though the objects are not in contact. Emphasize the cause and effect relationship between properties of objects (such as magnets or electrically-charged objects) and the forces they exert.

**7.1.4** Collect and analyze data to determine the factors that affect the strength of electric and magnetic forces. Examples could include electromagnets, electric motors, or generators. Examples of data could include the effect of the number of turns of wire on the strength of an electromagnet, or of increasing the number or strength of magnets on the speed of an electric motor.

**CCC:** Systems and system models, cause and effect

**SEP:** Constructing explanations, analyzing and interpreting data, obtaining information, developing and using models.

### Lesson Performance Expectations:

**Students Will. . . To Construct Meaning**

- How does the Aurora Borealis form?
- What does that have to do with magnets?

Use understanding of models and magnets and charges to construct an understanding of the Aurora Borealis (northern lights) from articles, images and models.

“You may not always understand the words, but maybe someone in your group has the evidence or the definition that will help you! Highlight or circle words that don’t make sense. Do the best you can to understand the text with the pictures and models to help you. Read carefully and apply what you have learned about magnets and magnetic fields and charged particles to help you understand. This is how we use past learning to learn new things! It works!"

**Teacher Will. . . To Support Students**

**View Aurora Borealis**

**Group Activity: Using system models to make inferences.**

From experiences with compasses and instruction throughout your life, you understand that the earth is a magnet, that it has a north and south pole. From our labs, you are probably wondering what earth’s magnetic field looks like and what that has to do with the aurora borealis.

Use your understanding of magnets and models to
Construct a model of how the Aurora forms. Each team member will be given a separate colored pen and be asked to contribute to the model.

Participate in gallery stroll and compare the models of other students. Write on their models positive comments or productive questions.

“I like how you showed this”
“I’m not clear what you mean by this.”

construct an understanding of the aurora borealis and earth’s magnetic field from the following pieces of evidence.

Each member of your group will be given a piece of evidence and asked to analyze it and prepare to explain it to your group

Assessment:
Draw a model of how the Auroras of earth form. Each person needs to contribute to the model by using a different color pen. They should contribute to the model in that area in which they became expert.
Example: The student that read about earth’s magnetic field, should draw earth’s magnetic field.

Students will present their models to the class for a graffiti stroll.

When the students have constructed an explanation show them a few of these videos. They are amazing.

The sun is magnetic
https://www.nasa.gov/feature/goddard/2016/understanding-the-magnetic-sun
https://www.youtube.com/watch?v=URN-XyZD2vQ

Earth’s magnetic shield
https://www.youtube.com/watch?v=ReSi_kPTNIc

Why solar storms are so dangerous
https://www.youtube.com/watch?v=GrnGi-q6iWc

Solar Explosion Nasa
http://sci.esa.int/cluster/54022-cluster-helps-to-model-earths-mysterious-magnetosphere/

Cool animation of solar wind pushing on earth’s magnetic field

Exit Ticket: Explain how the aurora borealis formed.
Exit ticket: Why is the earth magnetic?

Journal Reflection: Evidence from the fossil record and
iron intrusion from rock suggests that life started sometime between the time period in which earth’s magnetic field gained strength and the time that rocks started showing evidence that the atmosphere contained oxygen around 3.5 billion years ago. Was the development of earth’s magnetic field necessary for life to develop on earth? What is the cause of earth's’ magnetic field and why does it seem to fluctuate over time? What creates a strong magnetic field versus a weak magnetic field. These questions could take you to 7.2.4 modeling earth, or they could take you to 7.3 and needs of living things.

<table>
<thead>
<tr>
<th>Assessment of Student Learning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short description of the evidence the teacher is willing to accept that a student is proficient with the performance expectations. This may be a rubric, narrative or other set of descriptors that are useful for distinguishing proficient from non-proficient performances.</td>
</tr>
</tbody>
</table>
Explain the role of Earth’s magnetic field, the sun’s magnetic field and charged particles in the Aurora Borealis.

Vocabulary:

Model:

Explanation:
_____________________________________________________________________________________
_____________________________________________________________________________________
_____________________________________________________________________________________
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_____________________________________________________________________________________
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_____________________________________________________________________________________

Exit Ticket- What causes Auroras? Name ____________________________________

Explain the role of Earth’s magnetic field, the sun’s magnetic field and charged particles in the Aurora Borealis.

Vocabulary:

Model:

Explanation:
_____________________________________________________________________________________
_____________________________________________________________________________________
_____________________________________________________________________________________
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_____________________________________________________________________________________
_____________________________________________________________________________________

Exit Ticket - Why is the Earth Magnetic?

Name ___________________________

Vocabulary:

Model:

Explanation:

____________________________________________________________

____________________________________________________________

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____________________________________________________________

Exit Ticket - Why is the Earth Magnetic?

Name ___________________________

Vocabulary:

Model:

Explanation:

____________________________________________________________

____________________________________________________________

____________________________________________________________

____________________________________________________________

____________________________________________________________
# 7.1.4 - Lesson Developed by Dr. Sarah Braden

<table>
<thead>
<tr>
<th>Student Science Performance</th>
<th>Student Science Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade: MS</td>
<td>Grade: MS</td>
</tr>
<tr>
<td>Topic: Magnetism</td>
<td>Topic: Magnetism</td>
</tr>
<tr>
<td>Title: Modeling magnetism: the floating paper clip</td>
<td></td>
</tr>
</tbody>
</table>

## Overarching Performance Expectations (Standard) from State Standards or NGSS:

### Lesson Performance Expectations:
- Ss will develop and revise models of magnetism anchored in a particular phenomenon (floating paper clip). Ss will then test their models’ ability to account for new phenomena (generators, electromagnets, or iron filings)
- Ss will use appropriate language (made explicit by the teacher in sentence frames) for describing their models and asking questions of peers to extend their thinking. Ss will share leadership responsibilities required for consensus modeling. Ss will participate in whole class discussions by repeating/rephrasing, adding new ideas, asking questions, providing counter evidence or a counter argument

### Students Will... To Construct Meaning

**Engage with a Phenomenon: Floating paper clip.**

**Gather:** Observations (drawings & notes) about how magnets interact with different objects under various conditions.

**Reason:** Hypothesize/model HOW the magnets produce the observable properties students collected/noticed at the stations by focusing on the floating paperclip phenomenon. The model must be consistent with the observable evidence.

**Communicate:** Using verbal contributions to both peer group and whole class discussions, students will describe and explain their drawings/models of magnetism & ask questions to clarify their understanding of their peers’ models.

### Teacher Will... To Support Students

- Prep lesson with valued/appropriate language of participation made explicit to students at multiple points throughout the lesson.
- Manage students’ participation in groups using colored cards & explicit instructions for leadership roles & the process of forming consensus models.
- Provide an accessible phenomenon for Ss to work with.
- Circulate while students are working independently and in groups to provide feedback and ask strategic questions to push students’ thinking. Also help individual Ss prepare to share their models – particularly EL students.
- Provide built in wait time by allowing sufficient time for independent work before group work.
- Use strategic talk moves to promote broader participation in whole class discussions and shift classroom culture away from valuing only one correct answer.
- Draw students’ attention to evidence, counter evidence, and additional scenarios strategically to push their thinking about their models (independent, small group, and whole class settings).

If T wants students to model at the micro-level, will need to ask students specifically to think about and draw what is happening inside the magnet and the paperclip to allow this phenomenon to occur.
Assessment of Student Learning

Proficiency will be determined based on whether or not students models show the desired level of specificity at the macro or micro levels, whether the models are static or dynamic, whether they account for observable evidence (experientially provided in class), and whether or not students models demonstrate increased sophistication/change over time. A simple 0/1 scoring could be set up for each of these dimensions if grades must be applied.

Materials Required:
- Station labels & instructions
- Magnets, nails, pencils, string, paper clips, tape.
- Paper for students to draw
- Chart paper for students to depict consensus models
- White board or chart paper to record ideas during whole class discussions.
- T may want a clipboard w/ a chart to keep track of notes on students’ thinking AND notes on Ss participation according to instructions for how to collaborate.

Management Strategies:

<table>
<thead>
<tr>
<th>Teacher Does</th>
<th>Students Do</th>
</tr>
</thead>
<tbody>
<tr>
<td>Present the phenomenon &amp; Q: How does a magnet make a paperclip float in air? Think-Pair-Share T refrains from commenting too much on Ss ideas at this point. Make record of Ss initial ideas on the board.</td>
<td>Ss watch demo &amp; do Think-Pair-Share</td>
</tr>
<tr>
<td>Messing about: T circulates while students visit stations, and listens to student thinking and/or is available to answer procedural Qs. Can ask probing Qs as relevant.</td>
<td>Messing about: Ss visit different stations constructed by the teacher to make observations about how magnets interact with each other and other materials. Ss keep track of ideas with notes and pictures.</td>
</tr>
<tr>
<td>Initial Modeling – Independent work time Circulate and ask probing Qs, help Ss who aren’t sure how to get started, visit EL students (&amp; others) to make sure they are ready to share their models with their classmates.</td>
<td>Initial Modeling – Independent work time Ss generate drawings and initial answers to the anchor question. Ss plan how they will share their drawings with their peers.</td>
</tr>
<tr>
<td>Initial Modeling – Sharing models T circulates to collect info on student thinking – what’s in the models, and to ensure Ss follow the participation framework and that no one student is dominating the conversation or “playing teacher/expert”.</td>
<td>Initial Modeling – Sharing models Ss share their models in a small group using the participation &amp; explanation structure provided by the teacher.</td>
</tr>
<tr>
<td>Consensus Modeling T circulates to monitor Ss participation according to the framework AND to ask probing Qs about Ss thinking – to push Ss thinking.</td>
<td>Consensus Modeling Ss work together using the suggested participation framework to create a consensus model for the anchoring phenomenon.</td>
</tr>
<tr>
<td>Sharing consensus models à building towards class consensus</td>
<td>Sharing consensus models</td>
</tr>
<tr>
<td>-------------------------------------------------------------</td>
<td>-------------------------</td>
</tr>
<tr>
<td>T facilitates science talk about the models. (See notes in PPT)</td>
<td>Ss listen, present, and ask Qs following the participation framework.</td>
</tr>
</tbody>
</table>

Ss revise their models based on whole class discussion (2nd round of small group consensus modeling). Repeat process as above, assign different roles to students.

Ss test their models on a new phenomenon (e.g., electromagnets, generators, and/or behavior of iron filings (if not used in initial stations & depending on T goals))

May have independent and/or small group work here. Activities can/should involve standard 7.1.4.

Ss revise models.

Ss use models to explain or make predictions of a novel scenario.
A closeup of an erupting prominence with Earth inset at the approximate scale of the image. Taken on July 1, 2002. **Credit:** SOHO, ESA & NASA

Solar activity associated with Space Weather can be divided into four main components: solar flares, coronal mass ejections, high-speed solar wind, and solar energetic particles.

- Solar flares impact Earth only when they occur on the side of the sun facing Earth. Because flares are made of photons, they travel out directly from the flare site, so if we can see the flare, we can be impacted by it.
- Coronal mass ejections, also called CMEs, are large clouds of plasma and magnetic field that erupt from the sun. These clouds can erupt in any direction, and then continue on in that direction, plowing right through the solar wind. Only when the cloud is aimed at Earth will the CME hit Earth and therefore cause impacts.
- High-speed solar wind streams come from areas on the sun known as coronal holes. These holes can form anywhere on the sun and usually, only when they are closer to the solar equator, do the winds they produce impact Earth.
- Solar energetic particles are high-energy charged particles, primarily thought to be released by shocks formed at the front of coronal mass ejections and solar flares. When a CME cloud plows through the solar wind, high velocity solar energetic particles can be produced and because they are charged, they must follow the magnetic field lines that pervade the space between the Sun and the Earth. Therefore, only the charged particles that follow magnetic field lines that intersect the Earth will result in impacts.

*Last Updated: July 30, 2015*

*Editor: Holly Zell*
A coronal mass ejection on Feb. 27, 2000 taken by SOHO LASCO C2 and C3. A CME blasts into space a billion tons of particles traveling millions of miles an hour. **Credit:** SOHO ESA & NASA

The outer solar atmosphere, the corona, is structured by strong magnetic fields. Where these fields are closed, often above sunspot groups, the confined solar atmosphere can suddenly and violently release bubbles of gas and magnetic fields called coronal mass ejections. A large CME can contain a billion tons of matter that can be accelerated to several million miles per hour in a spectacular explosion. Solar material streams out through the interplanetary medium, impacting any planet or spacecraft in its path. CMEs are sometimes associated with flares but can occur independently.

*Last Updated: July 30, 2015*

*Editor: Holly Zell*
A solar eruptive prominence as seen in extreme UV light on March 30, 2010 with Earth superimposed for a sense of scale. Credit: NASA/SDO

A solar prominence (also known as a filament when viewed against the solar disk) is a large, bright feature extending outward from the Sun's surface. Prominences are anchored to the Sun's surface in the photosphere, and extend outwards into the Sun's hot outer atmosphere, called the corona. A prominence forms over timescales of about a day, and stable prominences may persist in the corona for several months, looping hundreds of thousands of miles into space. Scientists are still researching how and why prominences are formed.

The red-glowing looped material is plasma, a hot gas comprised of electrically charged hydrogen and helium. The prominence plasma flows along a tangled and twisted structure of magnetic fields generated by the sun's internal dynamo. An erupting prominence occurs when such a structure becomes unstable and bursts outward, releasing the plasma.

Last Updated: July 30, 2015
Editor: Holly Zell
The Sun unleashed a powerful flare on 4 November 2003. The Extreme ultraviolet Imager in the 195A emission line aboard the SOHO spacecraft captured the event. Credit: ESA & NASA/SOHO

A solar flare is an intense burst of radiation coming from the release of magnetic energy associated with sunspots. Flares are our solar system’s largest explosive events. They are seen as bright areas on the sun and they can last from minutes to hours. We typically see a solar flare by the photons (or light) it releases, at most every wavelength of the spectrum. The primary ways we monitor flares are in x-rays and optical light. Flares are also sites where particles (electrons, protons, and heavier particles) are accelerated.

Last Updated: July 30, 2015
Editor: Holly Zell
The sun is a magnetic variable star that fluctuates on timescales ranging from a fraction of a second to billions of years.

Solar flares, coronal mass ejections, high-speed solar wind, and solar energetic particles are all forms of solar activity. All solar activity is driven by the solar magnetic field.

Credit: NASA

Last Updated: July 30, 2015
Editor: Holly Zell
An astronaut aboard the International Space Station adjusted the camera for night imaging and captured the green veils and curtains of an aurora that spanned thousands of kilometers over Quebec, Canada.

Snow and ice in this winter image, acquired on Feb. 3, 2012, reflect enough light from stars, the moon, and the aurora to reveal details of the landscape. On the lower right, we see a circle of ice on the frozen reservoir that now occupies Manicouagan impact crater (70 kilometers in diameter). City lights reveal small settlements, such as Labrador City (an iron-ore mining town) and the Royal Canadian Air Force base at Goose Bay on the Labrador Sea.

The aurora borealis (northern lights) is the light that glows when charged particles from the magnetosphere (the magnetic space around Earth) are accelerated by storms from the sun. The
particles collide with atoms in the atmosphere; the green and red colors, for instance, are caused by the release of photons by oxygen atoms.

The fainter arc of light that parallels the horizon is known as airglow. This is another manifestation of the interaction of the Earth's atmosphere with radiation from the sun.

The atmosphere shields life on Earth from the sun's harmful radiation. It also causes small asteroids to burn up or catastrophically explode before hitting the ground. Larger asteroids can occasionally penetrate the atmosphere and collide with our rocky planet—with dramatic effects.

Geologists know that a large asteroid slammed into Earth roughly 214 million years ago, creating a crater about 100 kilometers (60 miles) across on the landmass that is now part of Canada. The impact caused a shock wave to radiate across Earth's surface, followed closely by high-velocity winds. Near the impact point, wind speeds would have exceeded 1000 kilometers (600 miles) per hour. The shock wave and air blast would have severely damaged and killed plants and animals out to distances of approximately 560 kilometers (350 miles)—as far as Goose Bay. After erosion by glaciers and other processes over millions of years, the Manicouagan crater is now about 60 kilometers (37 miles) wide.

Annotated image: NASA's Earth Observatory

Image Credit: NASA

Caption: D. Kring, Lunar and Planetary Institute, Universities Space Research Association; Michael Trenchard, Barrios Technology, Jacobs Contract at NASA-JSC; and M. Justin Wilkinson, Texas State University, Jacobs Contract at NASA-JSC

Last Updated: Aug. 8, 2016
Editor: Sarah Loff
Storms From the Sun
March 8, 2012

Artist illustration of events on the sun changing the conditions in Near-Earth space.

Image Credit:
NASA

Space weather starts at the sun. It begins with an eruption such as a huge burst of light and radiation called a solar flare or a gigantic cloud of solar material called a coronal mass ejection (CME). But the effects of those eruptions happen at Earth, or at least near-Earth space. Scientists monitor several kinds of space "weather" events -- geomagnetic storms, solar radiation storms, and radio blackouts – all caused by these huge explosions on the sun.

Solar Radiation Storms

A solar radiation storm, which is also sometimes called a solar energetic particle (SEP) event, is much what it sounds like: an intense inflow of radiation from the sun. Both CME's and solar flares can carry such radiation, made up of protons and other charged particles. The radiation is blocked by the magnetosphere and atmosphere, so cannot reach humans on Earth. Such a storm could, however, harm humans traveling from Earth to the moon or Mars, though it has little to no effect on airplane passengers or astronauts within Earth's magnetosphere. Solar radiation storms can also disturb the regions through which high frequency radio communications travel. Therefore, during a solar radiation storm, airplanes traveling routes near the poles – which cannot use GPS, but rely exclusively on radio communications – may be re-routed.

Geomagnetic Storms

Auroras occur primarily near Earth's poles. They are the most common and the only visual result of space weather.
An aurora dances in the atmosphere on August 20, 2014, as the International Space Station flew over North America. This image was captured by astronaut Reid Wiseman from his vantage point on the ISS. In the upper foreground is a portion of the ISS’ robotic arm.

*Credits: NASA/ISS*

On the evening of Aug. 20, 2014, the International Space Station was flying past North America when it flew over the dazzling, green blue lights of an aurora. On board, astronaut Reid Wiseman captured this image of the aurora, seen from above.
This model shows where the aurora was visible at 7:30 p.m. EDT on Aug. 19, 2014, as the International Space Station flew over it. The model is an Ovation Prime model and it is available from the Community Coordinated Modeling Center at NASA's Goddard Space Flight Center in Greenbelt, Maryland.

This auroral display was due to a giant cloud of gas from the sun – a coronal mass ejection or CME – that collided with Earth's magnetic fields on Aug. 19, 2014, at 1:57 a.m. EDT. This event set off, as it often does, what's called a geomagnetic storm. This is a kind of space weather event where the magnetic fields surrounding Earth compress and release. This oscillation is much like a spring moving back and forth, but unlike a spring, moving magnetic fields cause an unstable environment, setting charged particles moving and initiating electric currents. The geomagnetic storm passed within 24 hours or so but, while it was ongoing, the solar particles and magnetic fields caused the release of particles already trapped near Earth. These, in turn, triggered reactions in the upper atmosphere in which oxygen and nitrogen molecules released photons of light.

The result: an aurora, and a special sight for the astronauts on board the space station.

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Editor: Holly Zell
A magnetosphere is that area of space, around a planet, that is controlled by the planet's magnetic field. The shape of the Earth's magnetosphere is the direct result of being blasted by solar wind. The solar wind compresses its sunward side to a distance of only 6 to 10 times the radius of the Earth. A supersonic shock wave is created sun-ward of Earth called the Bow Shock. Most of the solar wind particles are heated and slowed at the bow shock and detour around the Earth in the Magnetosheath. The solar wind drags out the night-side magnetosphere to possibly 1000 times Earth's radius; its exact length is not known. This extension of the magnetosphere is known as the Magnetotail. The outer boundary of Earth's confined geomagnetic field is called the Magnetopause. The Earth's magnetosphere is a highly dynamic structure that responds dramatically to solar variations. Also residing within the magnetosphere are areas of trapped charged particles; These particles travel from the radiation belt to the poles of earth causing the aurora borealis. These particles only appear in a circle around the north pole. Particles don’t go to the north pole directly, they go around it. Credit: NASA/Goddard/Aaron Kaase

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Many technologies of the 21st century are vulnerable to solar storms.

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Schematic illustration of the invisible magnetic field lines generated by the Earth, represented as a dipole magnet field. In actuality, our magnetic shield is squeezed in closer to Earth on the Sun-facing side and extremely elongated on the night-side due to the solar wind.

Earth’s polarity is not a constant. Unlike a classic bar magnet, the matter governing Earth’s magnetic field moves around. Geophysicists are pretty sure that the reason Earth has a magnetic field is because its solid iron core is surrounded by a fluid ocean of hot, liquid metal. The flow of liquid iron in Earth’s core creates electric currents, which in turn creates the magnetic field. Credit/Copyright: Peter Reid, The University of Edinburgh

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Earth’s magnetosphere and the sun’s magnetosphere create a pathway for charged particles like positively charged protons and negatively charged electrons and other forms of radiation to travel to the earth. The same way iron filings line up between two magnets. These particles are produced by explosions on the sun. These explosions cause a wave of particles to fly at the earth so fast, it only takes a few minutes for them to get to earth. This wave of particles is called the solar wind.

Earth’s magnetosphere protects us from MOST of these charged particles and the solar wind blows around us. Some particles get trapped in earth’s magnetic field lines and move towards the north and south poles causing the Aurora Borealis (northern lights) or Aurora Australis (southern lights). These lights show where some radiation leaks through earth’s magnetosphere to earth’s atmosphere.

This energy causes the elements of earth’s atmosphere like oxygen and nitrogen to glow! Different elements glow with different colors. Oxygen glows green and yellow, while Nitrogen glows red and blue.
The stripes that we see when we look at the Aurora are caused by charged particles following earth's' magnetic field lines, the same way that iron filings make lines around a magnet.

Even Saturn has auroras from the sun's solar wind! Does this mean saturn is also magnetic?