1 Matter & Energy At-a-Glance:

In 4th grade, students are scientists and engineers as they answer questions and solve problems. In this unit, students discuss how matter has different properties depending on the number and kind of atoms that make it up. They observe how forces act on matter, focusing on how unbalanced forces cause objects to move. They then use that knowledge to analyze how moving objects have energy and transfer that energy in a collision.

Common Misconceptions:

- Misconception: Weight and mass are the same thing.
  - ✓ Fact: Weight and mass are two different measurements. Mass measures the amount of matter in a substance, while weight is a gravitational force exerted on an object by a planet or moon.
- Misconception: If something isn't moving, there are no forces acting on it.
  - ✓ Fact: Forces act on objects all the time. When all of the forces acting on an object are balanced, the object will not change its motion.


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A Breakdown of the Lesson Progression:

1 Properties of Matter

As scientists conduct experiments to gain knowledge, they follow a process to guide them through investigations. All science begins with a basic understanding of matter and how the number and kind of atoms that make it up determine a substance's properties. Scientists are interested in the properties of different kinds of matter because properties can be used to identify different substances.

2 Balanced vs. Unbalanced Forces

Once students understand how all matter is made up of atoms, which determine their properties, they compare two properties: mass and weight. They then discuss how forces act on matter, focusing on gravity, which is an attractive force between all matter. They use that knowledge to analyze how objects change their motion when acted on by an unbalanced force, and apply their analysis to motion in the solar system.

3 Energy and Collisions

Students apply their knowledge of matter, mass, and gravity to evaluate how energy and matter interact. They compare the different forms of energy and describe how energy is conserved. They then analyze how all moving objects have energy, which is transferred when objects collide.

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Unit 1: Matter and Energy

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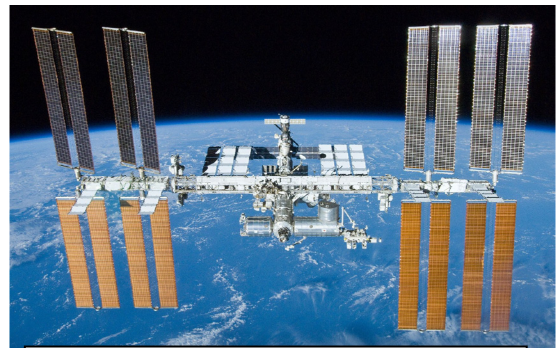
Matter and Energy

Unit Overview:



the International Space Station

Three hundred and eighty six kilometers (240 miles) above Earth, a group of astronauts from around the world sees the sun rise and set 16 times every day. They see this because they live together in a moving science laboratory called the International Space Station, which orbits Earth at a speed of about 28,164 kilometers (17,500 miles) per hour.

These astronauts are scientists, seeking new knowledge by conducting experiments on a range of subjects, including human biology, astronomy, and meteorology.

In this unit, students are introduced to science as they analyze matter, forces, and energy. They conduct an experiment to compare the masses of two different substances, analyzing the different properties that make up matter. They build on that knowledge to compare the effects of unbalanced versus balanced forces on objects. They then evaluate how matter interacts with and is changed by energy, which transfers from one object or system to another.

Unit Goals:

1. Describe how matter is made up of atoms, and the number and kind of atoms that make up a substance determine that substance's properties.
2. Observe how unbalanced forces cause movement.
3. Analyze how moving objects have energy, and how energy transfers in a collision.

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Applying Next Generation Science Standards

This unit covers the following **Next Generation Science Standards**. Each standard includes where it is found in the unit, as well as how it applies the relevant crosscutting concepts (listed in green) and disciplinary core ideas (listed in orange). **Note: Science and engineering practices are listed separately because all of the practices are incorporated into every unit.*

Grade-Specific Standards:

4-PS3	**Energy**
4-PS3-1.	**Use evidence to construct an explanation relating the speed of an object to the energy of that object.** ▪ **Definitions of Energy:** Students investigate the relationship between an object's speed and its energy, using evidence from an experiment to make a claim about whether fast-moving objects transfer more energy in a collision compared to slow-moving objects. Lesson 3 ▪ **Energy and Matter:** Students discuss how matter and energy interact, analyzing how all matter has energy and can only change when enough energy is present. Lesson 3
4-PS3-3.	**Ask questions and predict outcomes about the changes in energy that occur when objects collide.** ▪ **Conservation of Energy and Energy Transfer:** Students predict how energy will change in a collision between a moving marble and a cup at rest. They then evaluate their prediction with an investigation into how energy transfers from one object to another, and how some energy changes into other forms of energy such as sound. Lesson 3 ▪ **Energy and Matter:** Students discuss the interconnectedness of energy and matter, evaluating how moving objects transfer energy during a collision. Lesson 3

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Supporting Standards:

3-PS2	Motion and Stability: Forces and Interactions
3-PS2-1.	**Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object.** ▪ **Forces and Motion:** Students analyze how the sun's gravity produces an unbalanced force that causes Earth to change its motion, and how Earth's gravity pulls down on all objects near Earth's surface. Lesson 2 ▪ **Cause and Effect:** Students compare the effect of an unbalanced force on an object (pan balance) with the effect of a balanced force on the same object. Lesson 2 ▪ **Forces and Motion:** Students analyze how the force of friction causes moving objects to slow down by turning mechanical energy into heat. Lesson 3 ▪ **Cause and Effect:** Students observe how a moving marble will eventually slow down because of the force of friction. Lesson 3

5-PS1	Matter and Its Interactions
5-PS1-1.	**Develop a model to describe that matter is made of particles too small to be seen.** ▪ **Structure and Properties of Matter:** Students describe how all matter is made up of tiny particles called atoms and how the structure of matter determines its properties. Lesson 1 ▪ **Scale, Proportion, and Quantity:** Students compare two different kinds of matter and analyze how the bulk matter, which we can see, is made up of tiny particles we cannot see. Lesson 1

5-PS2	Motion and Stability: Forces and Interactions
5-PS2-1.	**Support an argument that the gravitational force exerted by Earth on objects is directed down.** ▪ **Types of Interactions:** Students analyze how all objects near Earth's surface are pulled down toward Earth's center. Lesson 2

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- **Cause and Effect:** Students discuss how the pull of Earth's gravity causes all objects on or near Earth's surface to be pulled toward Earth's center. The effect is that objects stay on Earth, rather than floating off into space. Lesson 2

5-ESS1	**Earth's Place in the Universe**
5-ESS1-1.	**Support an argument that the apparent brightness of the sun and stars is due to their relative distances from Earth.** ▪ **The Universe and its Stars:** Students discuss the structure of the solar system, analyzing the sun's role as anchor in the solar system as it pulls all objects within its gravitational reach toward it. Lesson 2 ▪ **Scale, Proportion, and Quantity:** Students discuss how the sun is not significantly larger than other stars, but it appears so because it is much closer to Earth than other stars. Lesson 2
5-ESS1-2.	**Represent data in graphical displays to reveal patterns of daily changes in length and direction of shadows, day and night, and the seasonal appearance of some stars in the night sky.** **In this unit, students are introduced to the concept of patterns caused by the relative motions of the sun, moon, and Earth.* ▪ **Earth and the Solar System:** Students describe how Earth's movement around the sun and the moon's movement around Earth causes changes in how the sun and moon appear from Earth. Lesson 2 **Patterns:** Students analyze how the movement of Earth around the sun and the moon around Earth (caused by gravity) result in observable patterns. Lesson 2

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Science and Engineering Practices

Students use the following science and engineering practices in the unit's lessons.

Lesson 1: Properties of Matter

1. Asking questions (for science) and defining problems (for engineering)

- Students are introduced to the scientific process as they develop a question that will help guide them through an investigation that compares the masses of equal volumes of gravel and sand.

2. Developing and using models

- Students create a visual model (scientific diagram) of their experiment-in-progress. Students use the model to visualize how the materials will be used in their properties of matter experiment, and to communicate their experiment to others. They then create a physical model to compare the masses of gravel and sand.

3. Planning and carrying out investigations

- Student teams collaboratively develop a plan, which they then follow to compare the masses of equal volumes of gravel and sand.

4. Analyzing and interpreting data

- Students collect data in a data table on the masses of equal volumes of gravel and sand, analyzing the data for patterns in the measurements. Student teams compare their results with other student teams to highlight similarities and/or differences.

5. Using mathematics and computational thinking

- Students measure and compare the mass of a cup of gravel with the mass of a cup of sand. They calculate the average mass of each after three trials.

6. Constructing explanations (for science) and designing solutions (for engineering)

- Students use the data they gathered in the experiment to construct an explanation (conclusion) that either supports or rejects their hypothesis about how the mass of gravel compares to the mass of sand.

7. Engaging in argument from evidence

- Students come together as a class to compare team results, using their data from the experiment to compare the physical property of mass of gravel and sand.

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8. Obtaining, evaluating, and communicating information

- Students use information from their readers and class dialogue, along with their knowledge of atoms, to evaluate how different kinds of matter have different properties, including mass.

Lesson 2: Balanced vs. Unbalanced Forces

2. Developing and using models

- Students create a pan balance to compare an unknown mass to a known, standard mass.

3. Planning and carrying out investigations

- Students investigate the mass of an unknown substance by using a known, standard mass.

7. Engaging in argument from evidence

- Students use the pan balance activity to analyze how the number of paper clips on one side of the pan balance determined whether the pan balance was balanced or unbalanced.

8. Obtaining, evaluating, and communicating information

- Students use information from their readers and class dialogue, along with their knowledge of balanced and unbalanced forces, to analyze how gravity is an attractive force that provides an unbalanced force in the solar system, causing the objects in the solar system to move.

Lesson 3: Energy and Collisions

1. Asking questions (for science) and defining problems (for engineering)

- Students develop a question that will help guide them through an investigation into the effect of a marble's speed on the amount of kinetic energy it can transfer when it collides with a plastic cup at the base of an inclined plane (ramp).

2. Developing and using models

- Students create a visual model (scientific diagram) of their experiment-in-progress. Students use the model to visualize how the materials will be used in their experiment, and to communicate their experiment to others. They then use marbles and a ramp to model how moving objects have energy, which is transferred during a collision.

3. Planning and carrying out investigations

- Student teams collaboratively develop a plan, which they then follow to investigate the amount of energy transferred from marbles moving at different speeds.

4. Analyzing and interpreting data

- Students collect and analyze data on the distance a target cup moves after a collision with marbles moving at different speeds, looking for patterns that might indicate a relationship between an object's speed and the amount of energy it transfers.

5. Using mathematics and computational thinking

- Students record the distance the target cup moved in 5 trials after a collision with marbles moving at three different relative speeds (fast, medium, and slow). They then calculate the average distance for each speed, and then graph the distance the cup traveled.

6. Constructing explanations (for science) and designing solutions (for engineering)

- Students use the data they gathered in the experiment to construct an explanation (conclusion) that either supports or rejects their hypothesis about how the speed of an object is related to the amount of energy it transfers during a collision.

7. Engaging in argument from evidence

- Students come together as a class to compare team results, using their data from the experiment to analyze any differences in results and to make an argument about the evidence provided by their experiment.

8. Obtaining, evaluating, and communicating information

- Students connect their experiment results with information from their readers and class dialogue to determine the relationship between speed and energy, and how energy is transferred during a collision.

* Unit connections to Common Core Math practices: MP.2 and MP.5.

Unit 1 Pacing Guide Example

All KnowAtom units are designed to take approximately one month. Lessons may span one or two weeks. This pacing guide provides one possible example for how to break down the lessons in this unit over a month. **Breakdown is based on 30- to 45-minute class periods.** Communities that have longer class periods or schedules where science class occurs more frequently can modify this guide accordingly.

Any days in this guide that appear unused take into account months with holidays, vacations, times when a lab and/or investigation takes longer to complete, and/or days when science class does not occur. Note that at the beginning of the school year, when the engineering and scientific processes are new to students, labs may take an extra class period to complete.

Unit 1: Matter and Energy				
Day 1	**Day 2**	**Day 3**	**Day 4**	**Day 5**
Week 1				
Lesson 1 **Start:** As a class, read Section 1 of the KnowAtom student reader. **Final Goal:** Transition to the Socratic dialogue.	**Lesson 1** **Start:** Socratic dialogue **Final Goal:** Transition to Lab 1 question.	**Non-Science Day**	**Lesson 1** **Start:** Recap experiment question. **Final Goal:** Students develop majority of lab with check-ins.	**Non-Science Day**
Week 2				
Lesson 1 **Start:** Teams complete lab development and may begin data collection. **Final Goal:** Students complete lab data collection.	**Non-Science Day**	**Lesson 1** **Start:** Students analyze data and evaluate results. **Final Goal:** Teams complete lab conclusions.	**Lesson 1** **Start:** Lab debrief/wrap-up with class. **Final Goal:** Review assigned assessment questions (optional).	**Non-Science Day**

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Week 3				
Lesson 2 **Start:** As a class, read Section 2 of the KnowAtom student reader. **Final Goal:** Transition to the Socratic dialogue.	**Non-Science Day**	**Lesson 2** **Start:** Socratic dialogue **Final Goal:** Transition to the Balance Investigation.	**Lesson 2** **Start:** Students complete balance Investigation. **Final Goal:** Investigation wrap-up/de-brief.	**Lesson 3** **Start:** As a class, read Section 3 of the KnowAtom student reader. **Final Goal:** Transition to the Socratic dialogue.
Week 4				
Lesson 3 **Start:** Socratic dialogue **Final Goal:** Transition to Lab 2 question.	**Lesson 3** **Start:** Recap experiment question. **Final Goal:** Students develop majority of lab with check-ins.	**Non-Science Day**	**Lesson 3** **Start:** Teams complete lab development and may collect data and analyze results. **Final Goal:** Teams complete lab conclusions.	**Lesson 3** **Start:** Lab debrief/wrap-up with class. **Final Goal:** Review assigned assessment questions (optional).

Science Words to Know:

Use the blank concept map visual to connect vocabulary once the unit is complete. An example concept map is displayed in Appendix 3.

1. **atom** – the smallest piece of matter that has the properties of an element; a combination of three subatomic particles: protons, neutrons, and electrons

2. **cause and effect** – a relationship between events or things, where one is the result of the other

3. **energy** – the ability to do work (move an object, heat up an object, charge an object, etc.)

4. **force** – a push or pull that acts on an object, changing its speed, direction, or shape

5. **friction** – a force that slows motion whenever two objects rub against each other by turning mechanical energy into heat

6. **gravity** – a force of attraction between all matter

7. **mass** – a measure of the amount of matter that makes up an object; measured in grams (g)

8. **matter** – everything that has mass and takes up space

9. **pattern** – something that happens in a regular and repeated way

10. **property** – an observable or measurable characteristic of matter

11. **scale** – the size, extent, or importance (magnitude) of something relative to something else

12. **science** – all knowledge gained from experiments

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13. **speed** – the rate at which an object covers distance in a period of time; measured in meters per second (m/s)

14. **system** – a set of connected, interacting parts that form a more complex whole

15. **volume** – a measure of how much space an object or substance takes up; measured in cubic meters (m^3) or liters (l)

16. **weight** – a gravitational force exerted on an object by a planet or moon; measured in newtons (N)

17. **work** – any change in position, speed, or state of matter due to force

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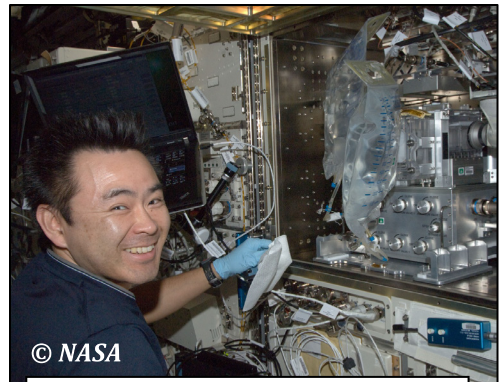
Teacher Background

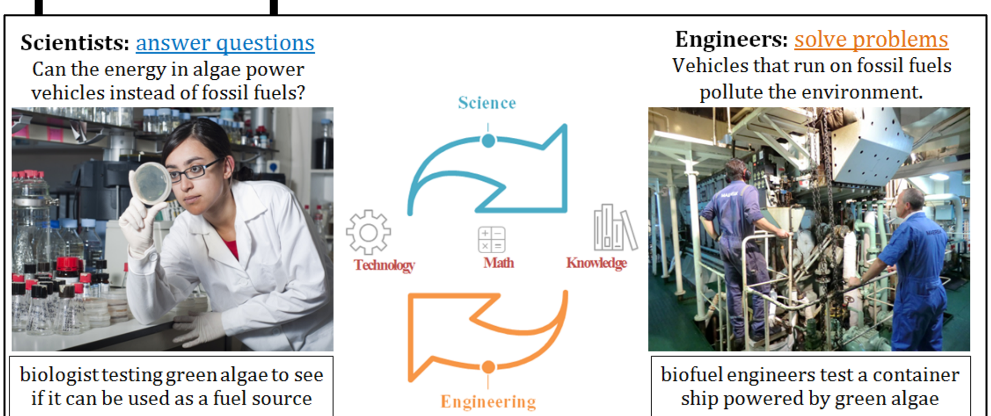
Experiments in Space

The International Space Station provides scientists with a science laboratory in space. Scientists are particularly interested in how matter is affected in a low-gravity environment. For example, scientists have sent zebrafish into space to observe whether they lose muscle mass in low gravity. This research is important because astronauts lose muscle mass in space, and scientists are hoping the zebrafish-in-space experiment will help them understand exactly why and how this happens.



This astronaut prepares for the zebrafish experiment.

Other experiments are exploring how gravity affects the process of regeneration in flatworms and why liquids move differently in space than on Earth. Every experiment seeks to find out new information about the world around us. All knowledge gained from experiments is part of **science**. Science encompasses our collective knowledge about the universe, from the atomic structure of matter to how energy and matter interact in the universe.



Science, technology, engineering, and math are connected in the STEM cycle.

Science is part of a larger cycle that includes engineering, math, and technology. This cycle is called the STEM cycle. Engineers apply scientific knowledge to create new technologies that solve problems. Math is a tool that both scientists and engineers use to capture results and communicate those results to others.

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Following a Scientific Process

Scientists follow a scientific process that provides them with a logical framework to guide them in developing a replicable experiment as they seek out answers to questions about the world around them. There are eight steps that scientists often follow to answer questions using data from experiments.

1. All scientific investigations start with a question—a statement that requires an answer. The question ends in a question mark and does not include words like “I” or “because.” For example, the zebrafish experiment seeks to answer the question: *How does living in space affect a zebrafish’s muscles?*

2. After formulating a question, scientists do background research on their topic. Research is the search for knowledge in books, experts, websites, and other reliable sources. While researching, scientists learn what other experiments have been done on their topic of interest and what else needs to be known. For example, scientists know that astronauts in space tend to lose up to 15 percent of their bone and muscle mass.

3. Based on their research, scientists create a hypothesis about the question they are asking. A hypothesis is a clear and concise statement that can be proved true or false. Hypotheses are written as declarative sentences, such as: *Living in space causes zebrafish to lose muscle mass* or *Living in space does not cause zebrafish to lose muscle mass*. The sentence does not include personal pronoun words like “my” or “I think.”

4. Next, scientists summarize the experiment that will test their hypothesis by briefly describing the controlled testing and data needed to prove the hypothesis true or false. In a controlled experiment, there is usually one variable being tested.

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In the zebrafish example, the variable is the space environment. The experiment also has constants. Constants are conditions that remain the same during each trial. Examples of constants include the amount of water the zebrafish live in and how much food they are given. Finally, a controlled experiment often has a control. The control captures the effect of unknown variables. For example, scientists have a control group of zebrafish on Earth. The constants are the same for both the zebrafish in space and those being tested on Earth. The experiment summary identifies the variables, constants, and controls.

5. Once a scientist has decided on an experiment, he or she vertically lists the materials with quantities and the step-by-step procedure. Information related to safety is also included. Documenting this information is important because scientific results are not valid unless someone can replicate the exact experiment.

6. To help readers understand the experiment set-up, a scientist makes a scientific diagram of the experiment-in-progress. The diagram is the size of a person's hand, is drawn in pen, includes a title, and labels all of the materials used.

7. Scientists then conduct their experiment. The results of the experiment are data—the measurements and observations gathered from an experiment. Data are typically organized in a table. Graphs can help scientists make sense of data and allow data to be communicated visually among colleagues. For example, scientists look for patterns in data that suggest a **cause-and-effect** relationship, where one event or thing is the result of the other. A **pattern** is something that happens in a regular and repeated way. In order to discover a cause-and-effect relationship, scientists design experiments in a way that show how changes to one thing cause something else to change in a predictable way.

8. The final step is to use the data to develop a conclusion—a summary of what a scientist has learned about the hypothesis, using data from the experiment as evidence. The conclusion is written out in full sentences and uses the data to argue whether the original hypothesis was true, false, or inconclusive. If results are inconclusive, meaning they do not confirm or deny the hypothesis, the scientist needs to design a different test.

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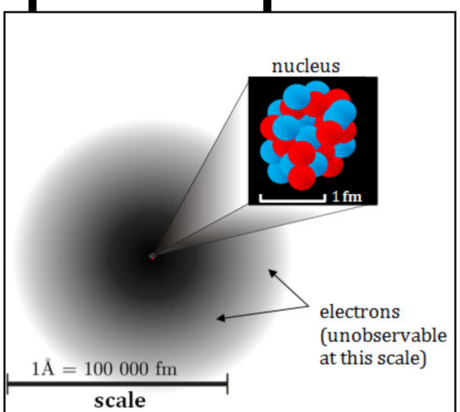
What is Matter?

In every experiment, whether on Earth or on the space station, matter and energy are constantly interacting. In fact, all of science begins with a basic understanding of **matter**—everything that has mass and takes up space. Matter makes up all of the substances in the universe. All matter contains energy, and matter only changes when enough energy is present. For example, zebrafish are matter, but they can only survive and grow when they eat enough food, which has energy.

All matter is made of **atoms**, which are the smallest pieces of matter that have the properties of an element. An element is a substance made up entirely of one kind of atom. Atoms are so tiny that we cannot see them. Just one grain of sand is made up of many millions of atoms. Because of this, scientists use scale to better understand the size of an atom, the parts that make it up, and how it relates to everyday substances. **Scale** is the size, extent, or importance (magnitude) of something relative to something else. For example, think about all of the atoms that make up a grapefruit. If each atom were the size of a blueberry, the grapefruit would have to be the size of Earth. There are so many atoms in just one grapefruit that they are impossible to count. Imagine having to fill up the entire planet with blueberries. That's about how many atoms are in one grapefruit.



This scaled model of an atom shows the size of the atom compared to the particles that make it up.

Atoms themselves are made up of smaller particles, called protons, neutrons, and electrons. These smaller particles are called subatomic particles. These smaller particles are much smaller than the atom itself. For example, the protons and neutrons group together in the atom's core, called the nucleus. If you were to open up the blueberry (representing the atom), the nucleus would be too small to see.

If you were to make the blueberry the size of a football field, you would just be able to see the nucleus. It would be the size of a small marble. The nucleus is very dense because it holds all of the atom's protons and neutrons. The electrons are in constant motion around the nucleus. However, most of the atom is filled with empty space. There are vast regions of space between each of the electrons and between the electrons and the nucleus.

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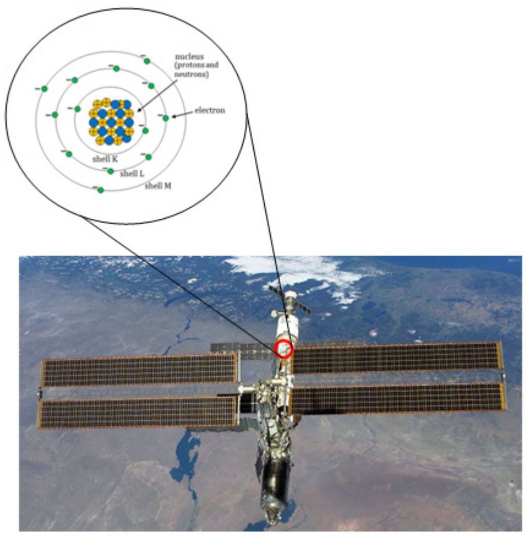
Properties of Matter

As of 2016, scientists have discovered 118 kinds of elements. These 118 elements are the only substances needed to form all of the matter in the universe. For this reason, atoms are called the building blocks of matter, and they can join together in different ways. Two or more atoms joined together are called molecules.

The number and types of atoms that make up matter determine the properties of an object or substance. **Properties** are observable or measurable characteristics of matter. For example, gold atoms conduct electricity, and helium atoms are a gas at room temperature.



The properties of aluminum make it a useful material on the International Space Station.

All matter has both physical and chemical properties. *Physical properties* are characteristics of an object or substance as it exists. Physical properties include color, odor, mass, volume, shape, boiling point, and melting point. Scientists and engineers need to know the properties of various materials when they think about how those materials will be used.

For example, the outer shell of the International Space Station's modules is made of mostly aluminum. Aluminum is light-weight, yet strong, which means it is easier to lift into orbit from Earth. It is also flexible and smooth, so it can be molded into various forms.

Properties also change as atoms form bonds and combine. For example, aluminum oxide is a molecule made from two aluminum atoms and three oxygen atoms. It commonly exists as a gas

Water (H_2O) is a molecule made from two hydrogen atoms and one oxygen atom. The properties of water (H_2O) are different from the properties of the atoms it is made from. For example, at normal room temperature, both oxygen and hydrogen are gases. When atoms of hydrogen and oxygen join as a molecule of water, they change into a liquid.

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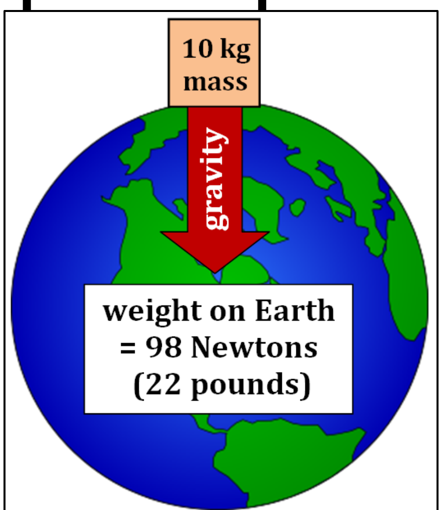
Mass and Weight

Mass is a physical property of matter. **Mass** is the amount of matter an object or substance has packed inside. Scientists measure mass in grams (g). Mass increases as the number and size of atoms increase in an object. An aluminum foil roll is less massive than a gold brick because aluminum atoms have less atomic mass than gold atoms. Pan balances are instruments used to compare a known mass to an unknown mass. Digital or electronic scales can also be used to measure mass.

Mass is an important property for scientists on the space station because an object's mass does not change, regardless of whether it is measured on Earth or on the space station. In contrast, a substance's weight changes significantly. This is because weight is different from mass, even though the two terms are often used interchangeably.



The amount of mass that an object or substance has determines its weight.

The difference between the two terms is **gravity**—the force of attraction between all matter. **Weight** is a gravitational force exerted on an object by a planet or moon. The unit of measurement for weight is the newton (N) because weight reflects the force of gravity.

The distinction between mass and weight is typically ignored by non-scientists because acceleration due to gravity is nearly identical everywhere on Earth (9.8 m/s^2) unless you are using sensitive instruments. On other planets, which have different gravities, an object's weight would noticeably change. The weight would more than double on Jupiter and drop by 85 percent on the moon, while the object's mass would remain the same.

Pan balances offer a good example of the relationship between mass, weight, and gravity. Pan balances measure mass, not weight. This is because here on Earth, the force of Earth's gravity pulls on both sides equally. When the unknown mass of one object is placed in one pan, then known masses can be added to the other side until the two sides are balanced. This would work on other planets as well.

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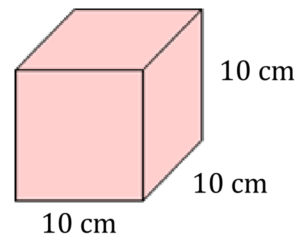
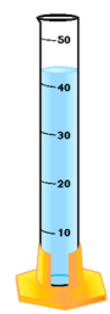
Measuring Volume

Mass's measurement counterpart is **volume**—the measure of how much space an object or substance takes up. Both mass and volume are needed because matter exists in three dimensions. Volume is measured in *cubic meters* or *liters*, depending on which state the matter is in. All matter moves between three states (solid, liquid, and gas), depending on the amount of available heat. (There is a fourth state of matter—plasma—that students learn about in higher grades.)



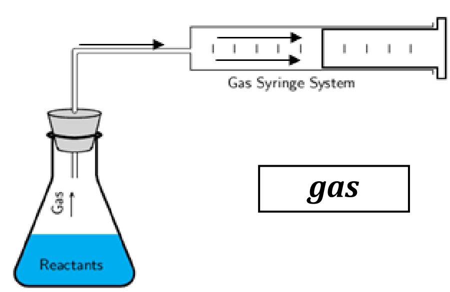
solid

- Matter in a <u>solid</u> state holds its own shape until a force changes it. The atoms of a solid are packed closely together and vibrate in place. A solid's shape determines what instrument is needed to find its volume. For example, to find the volume of a solid rectangular or square, multiply its length, width, and height. The volume of irregular shapes can be calculated by submersing the solid in a graduated cylinder. The volume of a solid is measured in cubic meters (cm^3).



liquid

- Matter in a <u>liquid</u> state takes the shape of its container but has no shape of its own. The atoms in a liquid are close together, but they have enough energy to slide past one another. A liquid's volume is measured using a graduated cylinder. When liquid is poured into the cylinder, a reading can be taken at the top of the liquid near the point where the liquid curves, known as its meniscus. The volume of a liquid is measured in liters (l) or milliliters (mL) .



gas

- Matter in a <u>gas</u> state has no shape and spreads out completely, filling its container. The particles have so much energy that they move far apart and bounce around randomly. Gas particles need to be collected and compressed before a measurement can be made. Scientists use a syringe to capture and measure the volume of gases, which is measured in cubic meters.

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Earth's Gravity and Weight

Understanding a substance's properties is important for scientists on the International Space Station who want to understand how matter changes in a low-gravity environment.

Gravity is known as one of the fundamental forces that govern the interaction of matter. A **force** is a push or pull that acts on an object, changing its speed, direction, or shape. All types of matter, from the smallest grain of dust to the biggest star in the galaxy, have gravity.

The masses of two objects and their distance from one another determine their gravitational attraction. Each time an object's mass doubles, its gravity becomes twice as strong. At the same time, the force of gravity becomes weaker as the distance between two objects increases. For example, astronauts who walk on the moon do not experience Earth's gravity. Instead, they are pulled on by the moon's gravity. However, because the moon is much less massive than Earth, the gravity felt by astronauts on the moon is about 17 percent what it is on Earth.

Low gravity explains why astronauts lose muscle mass when they are on the International Space Station. On Earth, we have to use our muscles just to stand up against the force of gravity, which is constantly pulling on us. This requires our bodies to maintain enough muscle to support our own weight. In the low-gravity environment of space, astronauts lose muscle since it is not required to support their weight.

Astronauts have to exercise regularly on the space station to prevent loss of muscle mass.

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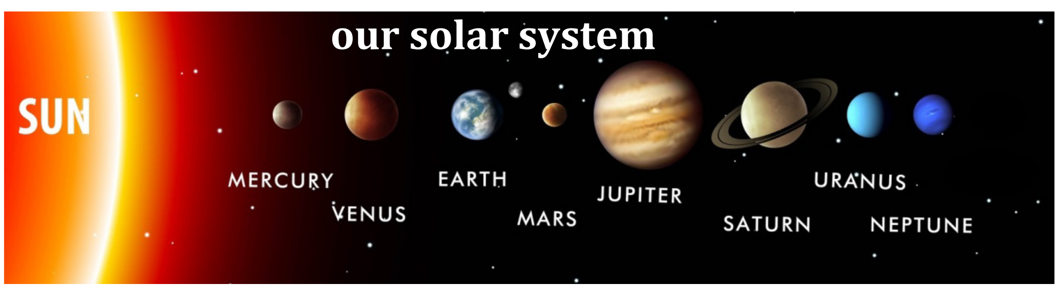
Gravity in the Solar System

The force of gravity is so small on the International Space Station because the space station is in constant movement around Earth. Earth's gravity pulls on the space station. As a result, the space station falls toward Earth. However, the space station is also moving forward rapidly in space, traveling at a speed of roughly 27,600 kilometers (17,150) miles per hour. So it falls around Earth. As the space station falls toward Earth, the planet curves away beneath it. In other words, the space station's forward motion equals the downward pull. It is this phenomenon that causes astronauts to float.

Gravity is the force that determines all movement in the solar system. A solar system is a collection of planets and other objects that orbit (travel in a circle around) a star. Our star, the sun, is the most massive object in our solar system. The force of its gravity is strong enough to pull on Earth and at least seven other planets into orbit around it.

There are eight known planets in our solar system. A planet is a body that orbits the sun, is massive enough for its own gravity to make it round, and has cleared out smaller objects around its orbit. The eight known planets of our solar system are Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune.



The strength of gravitational attraction between two objects also depends on their distance from one another. The force of gravity is cut in half each time two objects double their distance from one another. There are billions of stars in the universe just as massive as our sun. However, these stars are very far away from our solar system. This is why we don't feel their gravity. Our sun seems so large and bright to us because it is so much closer to Earth than any other star.

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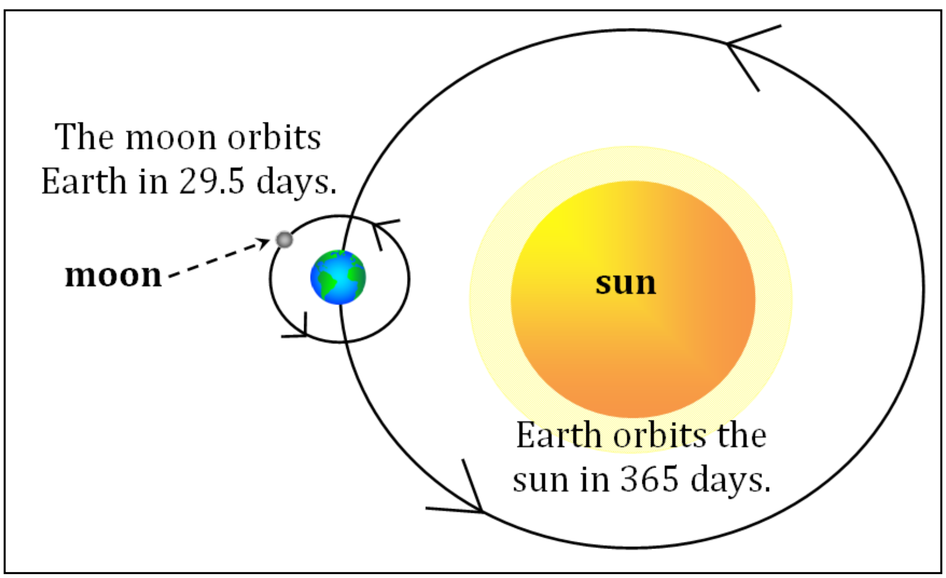
Gravity and Movement

Gravity also plays a role in how long it takes a planet to orbit the sun. The closer a planet is to the sun, the stronger the gravitational pull and the faster the planet moves around the sun. Planets that are farther from the sun have a slower orbit because the gravitational pull weakens. Earth takes 365 days—one Earth year—to orbit the sun.

Here on Earth, the most massive object is Earth itself. For this reason, Earth's gravity is the dominant force, and it pulls all objects near Earth's surface toward the planet's center.

The pull of Earth's gravity also keeps the space station, as well as our moon, in orbit. The space station usually takes about 90 minutes to orbit Earth because of how rapidly it travels. This is why astronauts aboard the space station see the sun rise and set 15 times every day.

Far above the space station, 384,000 kilometers (239,000 miles) above Earth, the moon also orbits Earth. The moon orbits Earth for the same reason that the planets orbit the sun. Earth is so massive that its gravity pulls the moon toward it. The moon takes about 29.5 days to orbit Earth, which equals one Earth month. These predictable motions cause patterns that we can see from Earth, and that astronauts can see from space.



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Balanced vs. Unbalanced Forces

Scientists who study space must consider how gravity affects objects on Earth and in space. Gravity is a force, which means that it can cause an object to move when it provides a greater pull than the other forces acting on the object. This is because unbalanced forces are needed to change an object's motion. Unbalanced forces occur when the forces acting on an object are not equal. The sun's gravity is so strong that it exerts an unbalanced force on the eight planets of the solar system, pulling them into orbit around it.

Here on Earth, the force of Earth's gravity pulls you toward the center of Earth. However, the ground has its own force that pushes back with an equal and opposite force. This keeps you from sinking into the ground. The forces acting on you are balanced.

If you want to move, there must be an unbalanced force acting on you. This is because all events, including motion, require a cause. Picture a swing. If you just sit on the swing, you won't move. However, if someone pushes you, you will start to move. That person provided an unbalanced force. More massive objects need greater force to make them move than less massive objects.

This rocket is carrying experiments, equipment, and supplies to the International Space Station. It needs enough force to overcome the pull of Earth's gravity.

When astronauts travel to the International Space Station, they ride in a rocket that lifts off of Earth with enough force to overcome the pull of Earth's gravity. Rockets that are launched into space apply a tremendous amount of force. As the rocket pushes combustion exhaust downward, the exhaust pushes the rocket upward with enough force to overcome the pull of Earth's gravity.

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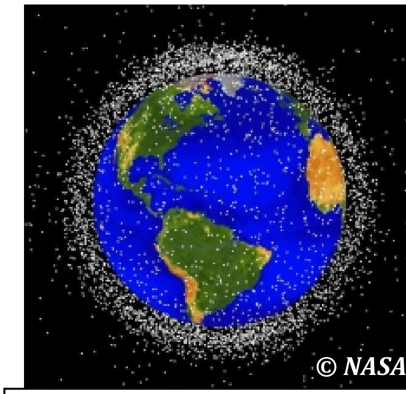
Avoiding Collisions with Space Debris

In 2014, a rocket that had launched from Earth was still attached to the space station when astronauts realized they needed to move the space station to avoid a collision with a hand-sized piece of space debris. The rocket fired its thrusters for four minutes, which provided enough of an unbalanced force to raise the 463-ton space station by 1 kilometer, enough to avoid the space debris.



NASA tracks the more than 500,000 pieces of space debris that orbit Earth.

Space debris is an ongoing challenge for astronauts in space. More than 500,000 pieces of space debris orbit Earth. The most common space debris orbiting Earth comes from human-made sources, including old spacecraft that are no longer in use.

Space debris poses a risk because most debris travels at speeds of up to 28,164 kilometers per hour (17,500 miles per hour). **Speed** is the rate at which an object covers distance in a period of time. It is measured in meters per second (m/s). At those speeds, even tiny paint flecks can damage structures. This is because moving objects have energy. **Energy** is the ability to do work. **Work** is any change in position, speed, or state of matter due to force. The faster an object is moving, the more energy it has.

There are different forms of energy. Energy is always either being stored or doing work. Energy that is being stored is called potential energy. For example, all matter has a form of potential energy called chemical energy. This energy is stored in the bonds that hold together atoms and molecules. The reason we eat food is because food contains chemical energy. Our bodies need that chemical energy to survive.

The energy of motion is called kinetic energy. The more kinetic energy something has, the more work it can do. All moving objects, from speeding space debris to a moving car, have a form of kinetic energy called mechanical energy.

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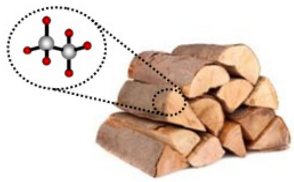
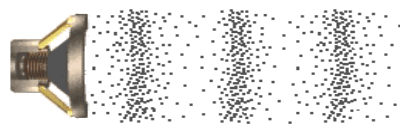
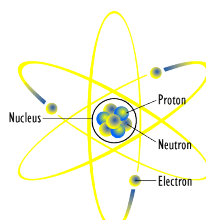
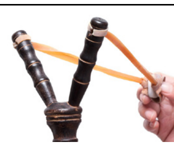
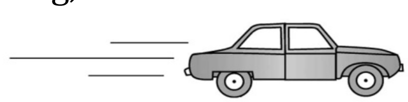
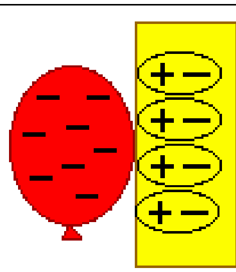
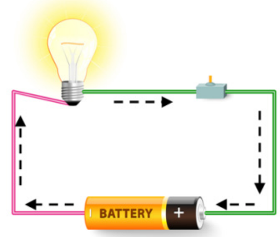
Forms of Energy

Forms of Potential Energy	Forms of Kinetic Energy
chemical: energy stored in the bonds of atoms and molecules (e.g., food, wood, gasoline) 	**heat:** the motion of atoms and molecules in a substance or object as its temperature increases (e.g., boiling water) 
gravitational: stored energy related to an object's height above the ground (e.g., a roller coaster at the top of the track) 	**sound:** energy produced by sound vibrations moving through a substance in waves (e.g., music, talking) 
nuclear: energy stored in the nucleus of an atom (e.g., energy that holds the nucleus together) 	**light:** the movement of energy in a wave-like pattern that comes from light (e.g., visible light, X-rays) 
elastic: energy stored in objects when stretched (e.g., compressed springs, stretched rubber bands) 	**mechanical:** the energy of a substance or system due to its motion (e.g., car moving, windmill blades turning) 
static electricity: energy stored in an electric charge (e.g., static charged balloons) 	**current electricity:** the movement of charged particles through a conductor (e.g., electricity, lightning) 

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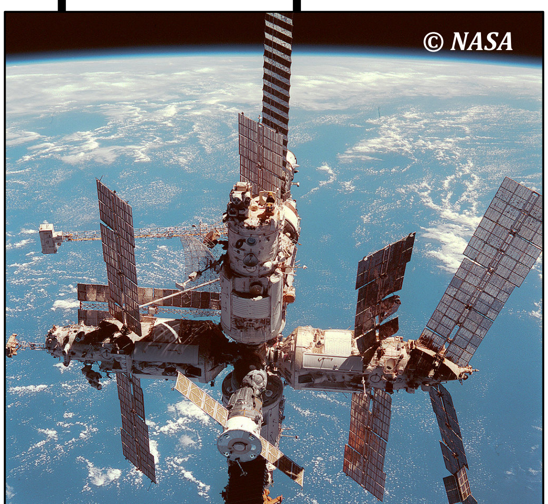
Energy Transfers in a Collision

Energy is never created or destroyed. Instead, it can transfer from one object or system to another. A **system** is a set of connected, interacting parts that form a more complex whole. When energy is transferred, it moves into or out of an object or system. The reason that even tiny paint flecks can damage the International Space Station is that when two objects collide, the force of that collision causes energy to transfer from one object to another.

Whenever two objects come into contact with each other, both objects exert a force on each other. These forces cause energy to transfer. For example, whenever two objects rub against one another, they create friction. **Friction** is a force that slows motion when two objects rub against each other by turning mechanical energy into heat. Friction is why your hands feel hot after you rub them together.



These solar panels on the right have been damaged because of collisions with space debris.

When a moving object hits another object, the force of the collision transfers some of the mechanical energy of the moving object to the other object. This transfer of energy changes the motion of both objects. If a paint fleck hits the International Space Station, it transfers some of its energy to the space station. This transfer of energy is what causes damage because the energy can change the position of matter. Astronauts have had to repair or replace the windows in various space shuttles because of damage caused by paint flecks.

The force of the collision also transfers energy out of the system by changing it to other forms of energy, such as sound. This is why collisions often make loud noises.

If a larger piece of space debris, traveling at the same speed as the paint fleck in the earlier example, collided with the space station, its force will transfer more energy because more massive objects exert a greater force. However, the total amount of energy of the system, which is made up of the two interacting objects (the International Space Station and debris), will remain the same.

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Lesson 1: Properties of Matter

Objective: Students set up laboratory notebooks and carry out an experiment to compare the masses of equal volumes of gravel and sand.

Materials:

Consumable
A. Goggles – 1 per student
B. Laboratory notebooks – 1 per student
C. Gravel – shared
D. Sand – shared
E. Small measuring cups (30-mL graduated) – 1 per team

Non-Consumable
F. Bowls – shared
G. Digital scales – 1 per team
H. STEM Cycle Visual – (not shown)
I. Scientific Process Visual – (not shown)
J. Who is a Scientist Poster – (not shown)
K. Matter Visual – (not shown)
L. Properties Visual – (not shown)

A


B


C


D


E


F


G


Teacher Preparation:

- Download the visuals from the KnowAtom Interactive website.
- To save time, prepare photocopies of the Blank Data Table for each student using the copy master on page 49.

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- Add equal amounts of gravel to half the bowls and equal amounts of sand to the remaining bowls.
- Arrange pick-up stations for teams to collect materials to use at their desks. For example:
  - <u>Pick-Up Station 1</u>: goggles and laboratory notebooks
  - <u>Pick-Up Station 2</u>: digital scales and small cups (30-mL graduated)
  - <u>Pick-Up Station 3</u>: bowls of gravel and bowls of sand

NOTE: To operate the digital scale, first remove the black cover and place the scale on a smooth, level surface. Press the ON button. Use the mode button to select the units you wish to use for your experiment (grams [g]).

Press the *Tare* button to calibrate the scale before using (it will reset to 0). To automatically exclude the mass of the container holding a liquid or solid, press the Tare button with the empty container on the scale. Any readings on the scale after will be just the mass of the solid or liquid added to the container. Keep the scale clear of debris and do not exceed 1,000 g.

scale with cover

<u>Student Reading Preparation</u>:

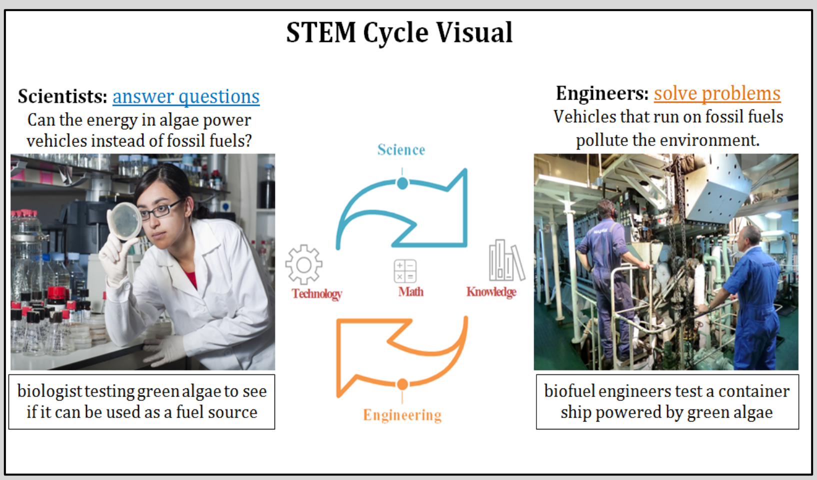
- Read Section 1 of the student reader together as a class before the Socratic dialogue and activity portion of the lesson. Model how to read closely for understanding. For example:
  - Emphasize connections between examples in the reading and broader concepts. For example, ask why a certain example was used to support the reading's main point.
  - Use "why" and "how" questions to connect ideas in the reading to student experiences.

Socratic Dialogue:

- The Socratic dialogue serves as the bridge between the nonfiction reading and the lab portion of the lesson.
- The example Socratic dialogue below describes one possible progression of ideas to engage students in higher order thinking. Blocks are used to divide the dialogue according to key organizing concepts. Note that in a Socratic dialogue, the teacher is not the only one asking questions and challenging ideas. Students should be actively engaged in proposing questions, challenging assumptions, and using evidence to support their arguments. *Not sure how to set up a Socratic dialogue? Check out www.knowatom.com/socratic for an in-depth look at how to hold a next generation Socratic dialogue in the classroom.*

Block 1-1: Introduction to Science

1. Display *STEM Cycle Visual*. Use Socratic dialogue to pre-assess student understanding of **science**, which is all knowledge gained from experiments.



- ☐ **Big Idea 1**: Begin a dialogue with students about how science is the search for explanations about the natural world. For example:
  - *Ask one student how scientists on the space station are helping to build scientific knowledge. (Scientists on the*

space station are conducting many experiments to answer different questions, including how the space environment affects the muscles of zebrafish.)

- *Connect questioning with experiments, asking another student to explain why evidence is important in science, and how scientists gather evidence. (Experiments play a critical role in the search for knowledge because experiments are procedures designed to test whether a hypothesis is true, false, or inconclusive. Experiments are how scientists answer questions about the world around them, providing data that can support or disprove a hypothesis.)*
- *Ask another student to use any personal experiences with gathering evidence. For example, some students may have experience with experiments, while others are new to it. Some students may have had a question about something they observed, which they investigated to find an answer.*

- **Big Idea 2:** Coach students toward an understanding of the relationship between science and engineering. Both are part of the STEM (science, technology, engineering, and math) cycle. They are connected and interact with one another, but they are also different. For example:
  - *Ask a student to compare science and engineering, providing concrete details for how they are different. (Scientists gain knowledge through experiments, while engineers apply that scientific knowledge to create new technologies that solve problems.)*
  - *Ask another student to expand on the first student's answer by explaining what the primary clue is as to whether something is science or engineering. (Science always begins with a question, while engineering begins with a problem that needs to be solved.)*

2. Display *Scientific Process Visual*. Have a dialogue with students about how **scientists** follow a scientific process that provides a systematic, logical framework for investigating the answers to their questions.

Scientific Process Visual

1	**Question**	End with a question mark and do not include words such as "I" or "because."
2	**Research**	Include a minimum of three facts relevant to the question.
3	**Hypothesis**	Write a concise statement that answers the question and can be proved true or false.
4	**Summarize Experiment**	Describe in 2-3 sentences the experiment you will do to test whether your hypothesis is true or false. Identify the independent and dependent variables, constants, and controls of the experiment. The independent variable is the variable changed. The dependent variable is what happens as a result of the independent variable. Constants of the experiment are conditions unchanged during each trial. A control in the experiment captures the effect of unknown variables
5	**Materials and Procedure**	Vertically list all materials needed for your experiment with quantities. Next, vertically list the numbered steps of your procedure. Note safety precautions.
6	**Scientific Diagram**	Draw a diagram of the experiment set-up that is at least the size of your hand. Title it and include labels for all materials on the materials list.
7	**Data**	Follow your test procedure and gather data (both observations and numbers) to determine whether the hypothesis is true, false, or inconclusive. Use proper units, title data tables, and tape into lab notebooks.
8	**Conclusion**	Use the data collected in the experiment to explain why the hypothesis is true, false, or inconclusive. Every conclusion must contain a minimum of 3 elements: 1. Restate your hypothesis. 2. Make a claim (true/false/inconclusive). 3. Use key points of data as evidence to support and explain your claim.

- ☐ **Big Idea 3**: Assess student understanding of the importance of using a process in science and engineering. A process is any series of steps designed to meet a goal. For example:
  - *Ask one student what would happen if scientists tried to conduct an experiment without first asking a question. (The scientific process provides scientists with a logical way to work from a question to a data-based conclusion. Without a question, scientists wouldn't know how to set up the experiment because they wouldn't be able to form a hypothesis.)*
  - *Ask another student why data are important in an experiment. (Data are the measurements and observations gathered from an experiment. Data will be used as evidence in the conclusion to determine whether a hypothesis is true, false, or inconclusive. This evidence is necessary to support a claim in a conclusion, which is more reliable than forming a conclusion based on opinion or subjective observation.)*

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<u>**Laboratory Notebook Set-Up**</u>:

> **NOTE**: This lesson is the only lesson in which students should be directed step by step because they are setting up their lab notebooks. In all future labs, student teams should use the scientific process to guide them from a question to a data-based conclusion in their lab notebooks.

1. Each student collects 1 laboratory notebook. Students write their name, class, grade, and subject on the cover and on the first page of their notebooks. Students should also number each right-hand page up to 10. Page numbers are written in the top right corner, and writing is only done on right-hand pages.

2. Students title page 2: "The Scientific Process." Use the <u>*Scientific Process Visual*</u> to discuss how scientists use a process to help them answer their questions, while students list each step with brief descriptions in their lab notebooks:

- <u>question</u> – a statement that requires an answer; ends in a question mark; does not include words such as "I" or "because"
- <u>research</u> – the search for existing knowledge using books, experts, websites, and/or personal observations; includes a minimum of three facts relevant to the question
- <u>hypothesis</u> – a clear and concise statement that answers the question; can be proved true or false
- <u>experiment summary</u> – one or two sentences describing an experiment that tests if the hypothesis is true or false; lists the variables, constants, and controls
- <u>list materials and procedure</u> – a vertical list of all materials with quantities needed for the experiment; a vertical list of the numbered steps of the procedure; includes safety precautions
- <u>scientific diagram</u> – a diagram of the experiment set-up that is at least the size of your hand and titled; labels all materials on the materials list

- <u>data</u> – the measurements and observations gathered from the experiment; evidence that proves if the hypothesis is true, false, or inconclusive; titled; taped into lab notebooks; uses proper units
- <u>conclusion</u> – a summary of what a scientist learned about the hypothesis using data from the experiment as evidence; uses the data collected in the experiment to explain why the hypothesis is true, false, or inconclusive; must contain a minimum of three elements:
    1. Restate the hypothesis.
    2. Make a claim (true, false, or inconclusive).
    3. Use key points of data as evidence to support and explain the claim.

3. Students title page 3: "Engineering Process." Students will record the steps of an engineering process on this page later in the year.

4. Students title page 4: "Table of Contents." When students fill this in, each entry will include the lab number, title, date, and first page number. Leave pages 5-7 blank for the Table of Contents.

page 4

Table of Contents

Lab #	Lab Title	Date	Page #
1	Properties of Gravel and Sand	9/10/13	8

5. For each new lab entry, students write the title of the experiment, date, and partner's name (if applicable) under the page number. Explain that the lab title, date, and page number of each lab are also entered in the table of contents chronologically. Remind students that lab notebooks should be neat, written in pen, and that all errors must be crossed out, never erased or scribbled.

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page 8

Properties of Gravel and Sand, 9/10/13, T. Rogers

Lab 1:Properties of Gravel and Sand

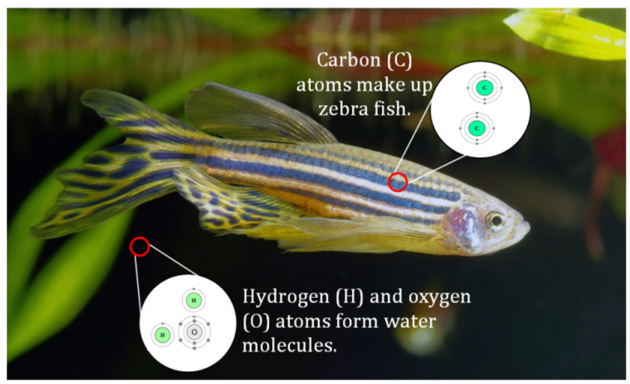
Question: Which has more mass in the same volume, gravel or sand?

Socratic Dialogue:

Block 1-2: Properties of Matter

1. Display *Matter Visual*. Continue the dialogue from the previous block about science, assessing student understanding of how all of the matter in the universe is made up of different kinds of atoms, which determine the properties of matter.

Matter Visual



- ☐ **Big Idea 4**: Coach students toward the idea that **matter** is everything that has mass and takes up space. This means that all matter is made up of **atoms**, which are the smallest pieces of matter that have the properties of an element. An element is a substance made up entirely of one kind of atom. For example:
  - *Ask one student why zebrafish and water are two kinds of matter. (Both the zebrafish and water are matter because they have mass and take up space. They have mass because they are made up of tiny parts called atoms. For example, some of the atoms that make up the zebrafish are carbon atoms. Water is made up of hydrogen and oxygen atoms.)*

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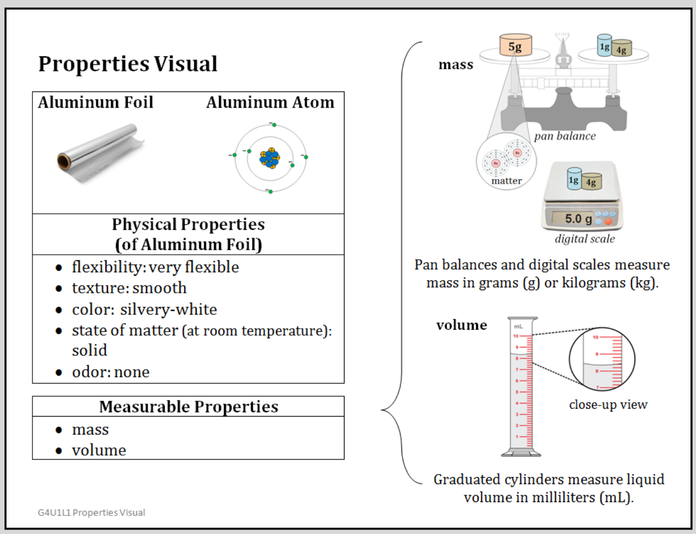
- *A common misconception is that atoms are separate from matter, when in reality, atoms are themselves matter that make up larger kinds of matter. Challenge this misconception by asking another student to explain what would happen to the zebrafish or water (or other matter being discussed) if all of the atoms were removed. (Substances are made up of atoms, so nothing would remain if all of the atoms were removed.)*
- *Transition to Big Idea 5 by asking the first student how, if both water and zebrafish are made up of atoms, they can be so different from each other. (The zebrafish and water are made up of different kinds of atoms. The specific kinds of atoms that make up a substance determine the characteristics of that substance.)*

2. Display <u>*Properties Visual*</u>. Continue the dialogue with students about how matter has different **properties**—observable and measurable characteristics of matter. A substance's properties depend on the number and kind of atoms that make it up.



☐ **<u>Big Idea 5</u>:** Coach students toward the idea that a substance's properties depend on the number and kind of atoms that make it up. For example:

- *Ask one student why each element has a unique set of properties. (Each element is made up entirely of one kind of atom. Elements have the properties they do because of the kind of atoms that make them up.)*
- *Ask another student to describe an object in the classroom using its properties. (For example, a desk is matter because*

it has mass and takes up space. It is solid and smooth. Desks are often brown, but they can be different colors. Desks are often rigid because they aren't flexible.)

- *Ask the first student why mass is an example of a property. (**Mass** is a measure of the amount of matter that makes up an object. It is measured in grams (g) with a digital scale or pan balance.)*
- *Assess student understanding of the relationship between mass and atoms by asking another student what makes a substance more massive than another substance. (Objects that have more atoms or larger atoms have a greater mass than objects with fewer atoms or smaller atoms.)*

<u>Experiment</u>: Lab 1 – Properties of Gravel and Sand

SAFETY: Students should wear goggles during this activity.

1. Divide the class into teams of two. Show students the materials for the lesson (bowls of gravel and sand). Have a dialogue about the different observable properties of gravel and sand. Ask questions such as:

- If you didn't know what was in each bowl, how could you begin to identify each substance? [*You could start to list each substance's properties (observable or measurable characteristics of a substance).*]
- Which properties can be used to describe the gravel? [*For example, it is yellowish-brown in color. It has a rounded irregular shape, it is hard, and it is larger in size relative to the sand.*]
- Which properties can be used to describe the sand? [*For example, it is brown and white in color, and the grains have a round shape. It is also smaller relative to the gravel.*]
- How were you able to come up with these properties? [*They are all observable properties. We can look at the gravel and sand and see the size, shape, and color.*]

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- How else can scientists identify a substance? [*There are some properties that can be measured. For example, mass is measured with a digital scale or pan balance, and length is measured with a ruler.*]

2. Using the materials for the lesson (digital scales, gravel/sand bowls, and small graduated measuring cups), guide students toward asking a testable question that will allow them to compare one measurable property of gravel and sand (its mass). For example: "Do equal volumes of gravel and sand particles have the same mass?" or "Which has more mass in the same volume, gravel or sand?"

Question
As a class, discuss the possible questions for the experiment and decide which question to explore for the lab. For example: "Which has more mass in the same volume, gravel or sand" Once the experiment question is established for the lab, students should record it in their lab notebooks. Students create a title for the new lab entry that is relevant to the question. A relevant title for this lab would be "Properties of Gravel and Sand."

> **NOTE**: Use the *Who is a Scientist* poster and the *Scientific Process Visual to* help guide students through the scientific process.

Research
For research, students list up to three facts relevant to the experiment question. For this experiment, students can record three different observable properties between the gravel and the sand particles. Teams may wish to collect a sample of each material to evaluate at their desks. For example:

- Gravel particles are larger than sand particles.
- There is more empty space between pieces of gravel in a measuring cup than between pieces of sand in a measuring cup.

- Gravel is harder than sand.

Hypothesis

Students form their own hypothesis and record it in their lab notebooks. For example:

- "Gravel has more mass than sand in the same volume."
- "Sand has more mass than gravel in the same volume."
- "Gravel and sand have equal mass in the same volume."

Checkpoint #1: After Question, Research, and Hypothesis

As teams are ready, they should check in with the teacher to review their question, research, and hypothesis. Do the lab notebooks of both team members match and meet expectations? Can both students within the team explain their reasoning? If not, ask for areas of clarification or correction before they advance further. Not all teams will arrive at the lab check-points at the same time, so teams independently receive the go-ahead to move on in their lab after they have made the necessary modifications. Student lab notebook entries within the class will most likely have the same question, but variations from team to team in the remaining steps of the process are expected and encouraged.

Summarize Experiment

Stand by the materials station(s) and explain how the materials function, as well as proper handling of tools (digital scales). Facilitate a discussion that will help students arrive at a testable experiment. Students summarize the experiment in their lab notebooks. For example: "Our experiment will compare the masses of equal volumes of gravel and sand for three separate trials each. The variables in the experiment are the gravel and sand samples. The constant is the volume of the gravel and sand samples. There is no control in this experiment because we are comparing two substances to each other."

NOTE: There is no control group in this experiment because students are using the experiment to compare two substances. A control group would be needed if the experiment wanted to investigate the effect of one factor (such as water absorption) on the mass of gravel and sand in a given volume.

Checkpoint #2: After Experiment Summary
As teams are ready, they should check in with the teacher to review the experiment summary of their lab. Do the lab notebooks of each team member match and meet expectations? Can students explain their reasoning? The summary should not include a detailed procedure or material quantities.

- ✓ Students describe what data will be collected to serve as evidence to address the lab question. The summary should include the basics of the data to be collected, the number of trials students will conduct, the variables, and the parts of the experiment they will keep constant in each test or trial.

List Materials and Procedure
Students list materials and all relevant safety precautions in their notebooks.

- 1 small measuring cup (30 mL)
- 1 digital scale
- 1 small measuring cup of gravel
- 1 small measuring cup of sand

Safety

- goggles

Work with the class to develop a standardized list of steps for the procedure. For example:

Step 1: Mass the empty small cup and record.

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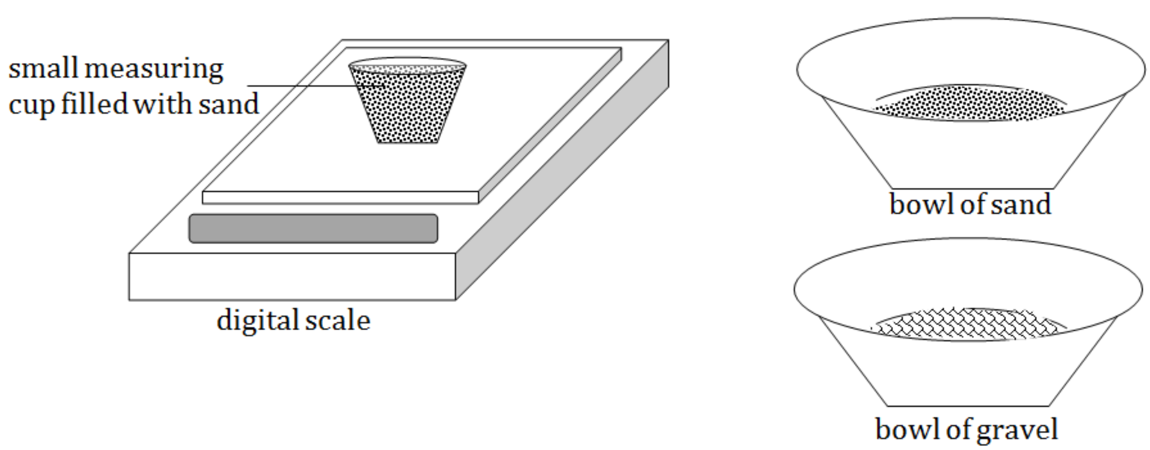
Step 2: Fill the small cup with gravel, record its mass, and discard the gravel.
Step 3: Repeat steps 1-2 for two more trials.
Step 4: Repeat steps 1-3 using sand in place of gravel.

Checkpoint #3: After Materials and Procedure
As teams are ready, they should check in with the teacher to review the materials and procedure steps of their lab. Are the materials and procedure in vertical lists and quantities included with all materials? Can you follow each team's procedure? Are the materials and quantities under "materials" all required by the procedure? Is it clear, concise, and specific? If not, clarify expectations. Students make corrections or any modifications and return to the checkpoint for the go-ahead.

Scientific Diagram

Students draw a titled scientific diagram of their experiment-in-progress. For example:

Comparing Mass of Gravel and Sand Diagram



Checkpoint #4: After Scientific Diagram
As teams are ready, they should check in with the teacher to review their lab scientific diagram. Are the diagrams complete? Diagrams should be titled and materials labeled. If complete, students pick up blank data tables and graphs to tape inside their lab notebooks and then proceed to collect the materials needed to conduct their experiment after meeting at this checkpoint.

Data
Each team collects the materials from the pick-up stations to begin the experiment. Gravel and sand bowls are shared among teams. Students record data in their data tables as the experiment progresses. Photocopy and distribute blank data tables to save time.

Table 1: Comparing Mass of Gravel and Sand

Trials	Empty Cup (g)	Gravel & Cup (g)	Gravel Only (g)	Empty Cup (g)	Sand & Cup (g)	Sand Only (g)
1	1.5	53.9	52.4	1.5	58.1	52.4
2	1.5	57.1	55.6	1.5	58.2	56.7
3	1.5	57.3	55.8	1.5	58.7	57.2
Average	**1.5**	**56.1**	**54.6**	**1.5**	**58.3**	**55.4**

NOTE: Example data represent one possible outcome. For the “Gravel Only” column, subtract the mass of the cup from the “Gravel & Cup” amounts (e.g., 53.9 g – 1.5 g = 52.4 g). For the “Sand Only” column, subtract the mass of the cup from the “Sand & Cup” amounts (e.g., 58.1 g – 1.5 g = 52.4 g).

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Conclusion
Each student writes a conclusion that summarizes their findings and tells how the data did or did not support the hypothesis. For example: “Our hypothesis that gravel has more mass than sand in the same volume is false. Our data show that a cupful of sand has 0.8 grams more mass on average than an equal volume of gravel. We believe the gravel had less mass than the sand in the same volume because the gravel’s large size and irregular shape created large open spaces between the gravel particles in the cup, preventing it from completely filling the cup. The sand filled the entire cup because its particles are small and round. This allowed more sand particles to fit in the cup compared to the gravel particles.”

<u>Final Checkpoint</u>: After Data and Conclusion
As teams are ready, they should check in with the teacher to review the data and conclusion steps of their lab. One team member reads the team’s conclusion aloud to you while you review the other team member’s lab notebook. Do they restate the hypothesis? Have they made a true/false/inconclusive claim? Look for key data points that students used to form their conclusion. Is it clear? Is it persuasive? Do the data support the claim? If the results are contrary to their research, what might be responsible? How could they test for that in the future?

<u>Wrap-Up</u>:

1. Have a dialogue with students about the results of the experiment. For example:

- Ask students from one team to present their conclusion to the class.
- Ask students from another team to respectfully critique the conclusion of the first team, using their own data and conclusion to question the first team about any differences.

- Give students from the first team a chance to respond and either respectfully agree or disagree with the second team.
- Ask students from another team if they experienced any challenges in conducting this experiment, and if so, what they were. [*Answers will vary. Challenges are a part of conducting experiments, and discussing them can help students think through their process, comparing their method with other student teams. It can be challenging in the beginning to develop a procedure that will allow for an experiment that tests the hypothesis.*]
- Ask students from the first team why it was important to have an equal volume of gravel and sand in the experiment. [*Volume is a measure of how much space an object or substance takes up. If the volumes were not equal for both gravel and sand, the experiment would not be controlled because we wouldn't be able to draw any conclusions about how the masses of each substance compared to the other.*]

2. Continue the dialogue with students to review concepts of science, matter, and properties covered in the experiment. For example:

- Ask one student why both the gravel and sand are examples of matter. [*Both gravel and sand are kinds of matter because they both have mass (a measure of the amount of matter that makes up an object) and take up space. In other words, they are both made up of atoms, which are particles that are so small we cannot see them.*]
- Ask another student how atoms are connected to a substance's properties, and why scientists care about a substance's properties. [*The number and kind of atoms that make up a substance determine its properties. Properties help scientists identify unknown substances.*]
- Ask the first student why the mass of a substance is a property. [*It is a measurable feature of a substance, which is why it is a*

property. It is a measure of the amount of matter that makes up a substance, and it is measured in grams.]

- Ask another student why all matter has mass. [*Mass is a measure of the amount of matter that makes up an object or substance. All matter is made up of atoms, so all matter has mass.*]

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Unit 1: Lesson 1 – Sample Laboratory Notebook

This complete lab notebook entry is intended to be used as an exemplar for teacher use only. It is not intended for student use.

Lab 1:Properties of Gravel and Sand

Question: Which has more mass in the same volume, gravel or sand?

Research: Gravel particles are larger than sand particles. There is more empty space between pieces of gravel in a measuring cup than between pieces of sand in a measuring cup. Gravel is harder than sand.

Hypothesis: Gravel has more mass than sand in the same volume.

Summarize Experiment: Our experiment will compare the masses of equal volumes of gravel and sand for three separate trials each. The variables in the experiment are the gravel and sand samples. The constant is the volume of the gravel and sand samples. There is no control in this experiment because we are comparing two substances to each other.

Materials:
- 1 small measuring cup (30 mL)
- 1 digital scale
- 1 small measuring cup of gravel
- 1 small measuring cup of sand

Safety:
- goggles

Procedure:

Step 1: Mass the empty small cup and record.

Step 2: Fill the small cup with gravel, record its mass, and discard the gravel.

Step 3: Repeat steps 1-2 for two more trials.

Step 4: Repeat steps 1-3 using sand in place of gravel.

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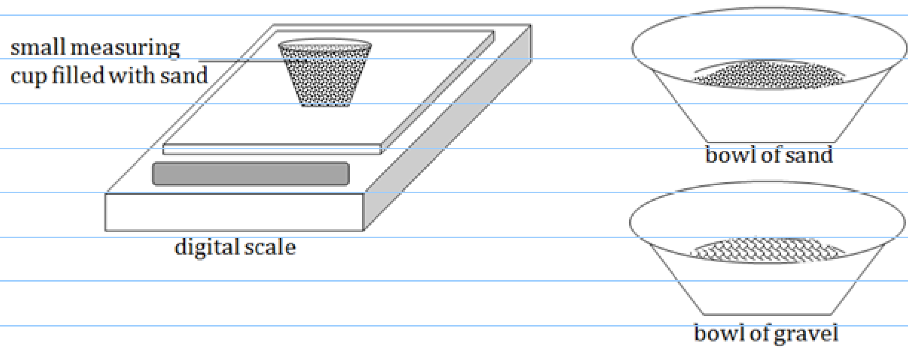
Unit 1: Lesson 1 – Sample Laboratory Notebook

This complete lab notebook entry is intended to be used as an exemplar for teacher use only. It is not intended for student use.

Scientific Diagram:

Comparing Mass of Gravel and Sand Diagram



Data:

Table 1: Comparing Mass of Gravel and Sand						
Trials	Empty Cup (g)	Gravel & Cup (g)	Gravel Only (g)	Empty Cup (g)	Sand & Cup (g)	Sand Only (g)
1	1.5	53.9	52.4	1.5	58.1	52.4
2	1.5	57.1	55.6	1.5	58.2	56.7
3	1.5	57.3	55.8	1.5	58.7	57.2
Average	**1.5**	**56.1**	**54.6**	**1.5**	**58.3**	**55.4**

Conclusion: Our hypothesis that gravel has more mass than sand in the same volume is false. Our data show that a cupful of sand has 0.8 grams more mass on average than an equal volume of gravel. We believe the gravel had less mass than the sand in the same volume because the gravel's large size and irregular shape created large open spaces between the gravel particles in the cup, preventing it from completely filling the cup. The sand filled the entire cup because its particles are small and round. This allowed more sand particles to fit in the cup compared to the gravel particles.

<u>Unit 1: Lesson 1</u> – Blank Data Table

Table 1: Comparing Mass of Gravel and Sand						
Trials	Empty Cup (g)	Gravel & Cup (g)	Gravel Only (g)	Empty Cup (g)	Sand & Cup (g)	Sand Only (g)
1						
2						
3						
Average						

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Lesson 2: Balanced vs. Unbalanced Forces

Objective: Students build and use pan balance models to compare an unknown mass to a known, standard mass.

Materials:

Consumable

A. Goggles – 1 per student
B. "Balance Activity" sheets
– 1 per student (student reader)
C. Small paper clips – shared
(for testing balances only)
D. Long dowels
– 1 per student
E. Short dowels
– 1 per student
F. Cardboard tubes with holes
– 1 per student
G. Cardboard bases – 1 per student
H. Portion cups – 2 per student
I. Clothespins – 3 per student
J. Rubber bands – 6 per student
K. Large paper clips – 6 per student

Non-Consumable

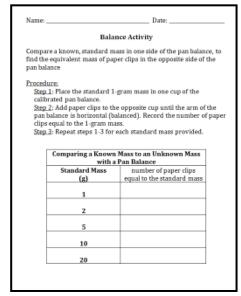
L. Mass sets – shared
M. Gravity in Space Visual – (not shown)
N. Balanced and Unbalanced Forces
Visual – (not shown)

Teacher Tool Kit

O. Hole punches – shared
P. Invisible tape – 1 per student
Q. Glue gun/glue – shared
R. Extension cord – teacher use
S. Power strip – teacher use

A

B



Name: ______ Date: ______

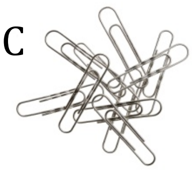
Balance Activity

Compare a known, standard mass in one side of the pan balance, to find the equivalent mass of paper clips in the opposite side of the pan balance

Procedure:
Step 1: Place the standard 1-gram mass in one cup of the calibrated pan balance.
Step 2: Add paper clips to the opposite cup until the arm of the pan balance is horizontal (balanced). Record the number of paper clips equal to the 1-gram mass.
Step 3: Repeat steps 1-3 for each standard mass provided.

Comparing a Known Mass to an Unknown Mass with a Pan Balance	
Standard Mass (g)	number of paper clips equal to the standard mass
1	
2	
5	
10	
20	

C



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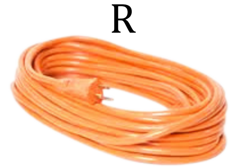

S

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Teacher Preparation:

- Download the visuals from the KnowAtom Interactive website.
- Glue the cardboard tubes with holes to the center of the cardboard bases using hot glue.

- Arrange a glue station using the glue guns with glue, power strip, and extension cord for students to access during the activity.
- Arrange several pick-up stations for teams to pick up materials to use at their desks during the activity. For example:
    - Pick-Up Station 1: goggles, pre-glued cardboard tubes with bases, short dowels, clothespins, invisible tape, and long dowels
    - Pick-Up Station 2: hole punches, portion cups, large paper clips, and rubber bands
    - Pick-Up Station 3: small paper clips, mass sets, and student readers

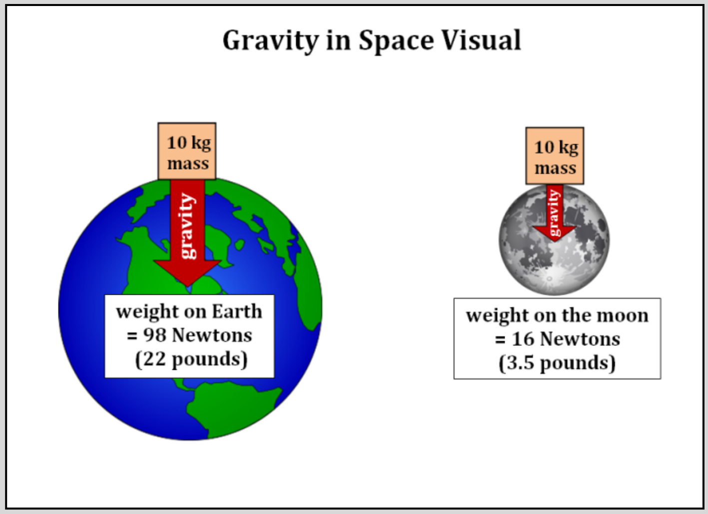
Student Reading Preparation:

- Read Section 2 of the student reader together as a class before the Socratic dialogue and lab portion of the lesson. Model how to read closely for understanding. For example:
    - Emphasize connections between examples in the reading and broader concepts. For example, ask why a certain example was used to support the reading's main point.
    - Use "why" and "how" questions to connect ideas in the reading to student experiences.

<u>Socratic Dialogue</u>:

<u>Block 2-1: The Force of Gravity</u>

1. Display *<u>Gravity in Space Visual</u>*. Dialogue with students about how **gravity** is a force of attraction between all matter.



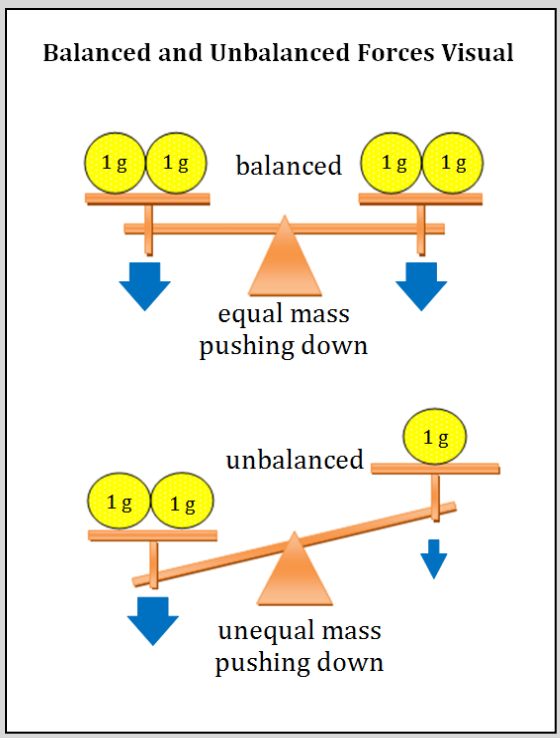
- **<u>Big Idea 6</u>:** Coach students toward the idea that because gravity is an attractive force, it pulls objects toward one another. For example:
  - *Ask one student why gravity is a force. (**Forces** are pushes or pulls that act on an object, changing their speed, direction, or shape. Gravity is a force because it pulls on all of matter.)*
  - *Ask another student why Earth's gravity keeps them and all other objects near Earth's surface from floating off into space. (Earth's gravity pulls everything near Earth's surface downward toward Earth's center. This downward pull keeps you from floating off into space.)*
  - *Contradict student answer to probe more deeply. For example, ask the first student why, given that all matter has gravity, we don't feel the pull of other objects' gravity here on Earth. (More massive objects have more gravity. On Earth, you always experience the pull of Earth's gravity because Earth is so massive.)*
  - *Ask another student to describe the relationship between gravity, mass, and weight. (Mass is the measure of the amount of matter that makes up a substance. **Weight** is the gravitational force exerted on an object by a planet or*

moon. Here on Earth, weight is calculated by multiplying the object's mass by the force of Earth's gravity.)

- *Assess student understanding of this relationship between mass, weight, and gravity by asking the first student why the 10-kilogram object in the visual weighs less on the moon than on Earth, but the mass remains the same. (The moon's gravity is much weaker than Earth's gravity because the moon is much less massive than Earth. Because weight is the gravitational force exerted on an object by a planet or moon, it changes when the force of gravity changes. However, mass is intrinsic to a substance because it doesn't depend on any external factors such as the force of gravity.)*
- *One at a time, give multiple students a chance to respond to this question, evaluating each other's answers as they explore mass, gravity, and weight. Redirect if student misconceptions arise by asking a student to analyze specific parts of the misconception.*

2. Display *Balanced and Unbalanced Forces Visual*. Use the pan balances in the visual to have a dialogue with students about how unbalanced forces cause movement.

- **Big Idea 7**: Coach students toward the idea that when the forces acting on an object are balanced, the object's motion will not change. An unbalanced force is necessary to cause movement. For example:
  - *Ask one student why we aren't all in constant*



motion if Earth's gravity is always pulling down on us. (When you stand on Earth's surface, gravity pulls you down toward the center of Earth. In reaction, the ground has its own force that pushes back up with the same amount of force. This keeps you from sinking into the ground. These forces are balanced because they are equal. When all of the forces acting on an object are balanced, the object will not change its motion.)

- *Challenge student understanding of action-reaction forces by presenting the scenario of a person leaning against a wall. Ask another student to imagine that they are leaning against a wall. Why don't they fall through the wall, given that they are exerting a force on the wall? (The wall is pushing back with the same amount of force. If the wall weren't strong enough to push back with the same amount of force, the person leaning would fall through the wall because there would be an unbalanced force.)*
- *Ask the first student to give an example of an unbalanced force causing movement from their own life. (All movement occurs because of unbalanced forces, so there are many different examples. For example, if you push a book across the desk, you are providing an unbalanced force that causes the book to move.)*

- **Big Idea 8:** Assess student understanding of the effects of the balanced and unbalanced pan visual in the visual. For example:
  - *Students sometimes have trouble with the idea that Earth's gravity pulls down on all objects with the same amount of force, thinking that gravity pulls more on more massive objects. Challenge this misconception by asking one student why the pan balance measures mass and not weight. (Earth's gravity pulls down on both sides of the pan balance equally, so the difference between the objects on each side of the pan is due to their mass.)*

- *Probe more deeply by asking another student to predict how the two pan balances in the visual would change if they were on the moon, rather than on Earth. (The moon has less gravity than Earth. However, the moon's gravity would still pull on both sides of the pan balance equally, so the pan balance would still compare the mass of the two sides to each other.)*
- *Ask another student why the pan balance in the top diagram of the visual is balanced. (In the top visual, the pan balance is balanced because each side has the same amount of mass (2 grams.)*
- *Ask the first student why the pan balance diagram in the bottom part of the visual is unbalanced. (The mass on one side of the pan balance is greater than the mass on the other side. One side holds 1 gram, while the other side holds 2 grams. These masses are unequal; therefore, the pan balance is unbalanced.)*

Investigation:

SAFETY: Students should wear goggles during this activity.

1. Divide students into teams of two. Each student will assemble their own pan balance individually and then test both of their pan balances as a team. Stand by each pick-up station and explain how the materials will be used and the amount each student will receive. Students should go to the stations to pick up materials they will use at their desks.

Pick-Up Station 1:

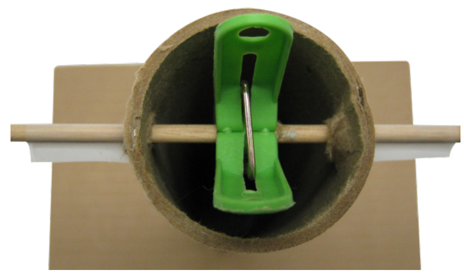
- goggles – 1 per student
- pre-glued cardboard tube with base – 1 per student
- short dowels – 1 per student
- clothespins – 3 per student
- invisible tape – 1 per student

- long dowels – 1 per student

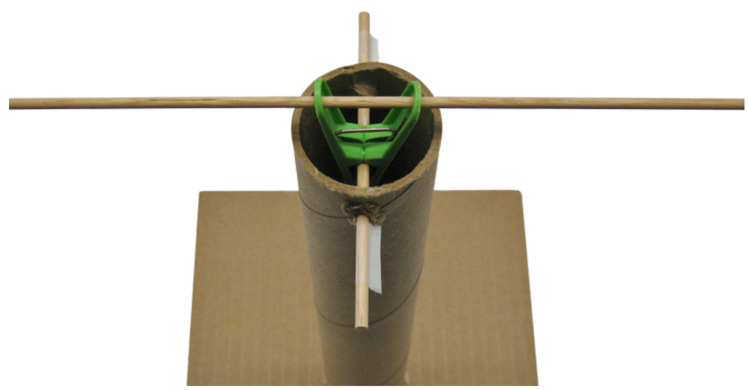
Glue Station:
- glue guns with glue – shared

Explain that each student will:

- ☐ Assemble the pivot point for the pan balance:
  1. Slide the short dowel through the pre-drilled holes in the cardboard tube.
  2. Fold a piece of tape over the ends of the dowel to prevent it from sliding out.
  3. Clip the clothespin onto the dowel and secure with hot glue. Let the glue dry for at least 2 minutes.



- ☐ Assemble the arm of the pan balance:
  1. Slide the long dowel through the holes of the clothespin glued to the short dowel.
  2. Balance the long dowel on the clothespin so it stays horizontal.
  3. Secure the balanced long dowel in place by taping the dowel on each side of the clothespin.



Pick-Up Station 2:
- hole punches – shared (1 per 2 students)
- portion cups – 2 per student
- large paper clips – 6 per student
- rubber bands – 6 per student

Explain that each student will:

- ☐ Assemble the pan balance cups:
  1. Use the hole punch to punch three evenly spaced holes around the rim of each cup. Hook one paper clip through each hole in the cups.
  2. Attach a rubber band to each paper clip.
  3. Use one clothespin on each cup to gather up the rubber bands.

- ☐ Attach one cup assembly to each end of the pan balance arm.
  1. Slide the clothespins with cups attached onto each end of the long dowel.
  2. Tape the <u>ends</u> of the long dowel to prevent the clothespins holding the cups from sliding off.
  3. Calibrate the cups so they are balanced by moving the cups several millimeters to the left or right along the dowel until the pan balance arm hangs in equilibrium horizontally.
  4. Secure the calibrated clothespins holding the cups to the dowel with tape to prevent the clothespins from sliding toward the cardboard tube.

NOTE: Attaching the cups to the pan balance arm is often the most challenging part of the assembly process. The pan balances may become uncalibrated after use. As students compare masses, remind them to check their pan balances between tests to ensure they are still calibrated. If not, they should recalibrate by adjusting or adding more tape to either side of the clothespins.

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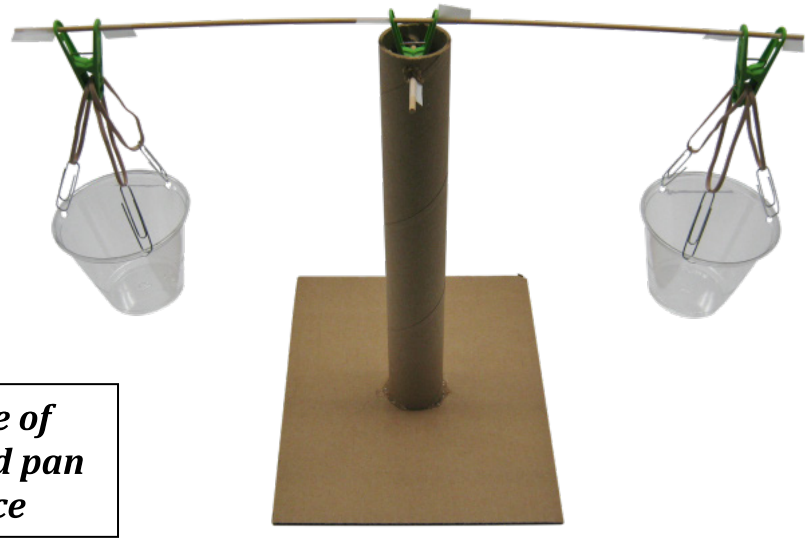

example of assembled pan balance

<u>Pick-Up Station 3</u>:

- small paper clips – shared
- mass sets pieces – shared
- “Balance Activity” sheet – 1 per student (student reader page 25)

Explain that each team will:

- Use the “Balance Activity” sheet and one calibrated pan balance to record the number of paper clips equivalent to each standard mass provided.
  1. Place the standard 1-gram mass in one cup of the calibrated pan balance.
  2. Add paper clips to the opposite cup until the arm of the pan balance is horizontal (balanced). Record the number of paper clips equal to the 1-gram mass.
  3. Repeat steps 1-3 for each standard mass provided.

2. Students/teams collect their materials from the pick-up stations in order to assemble the pan balances. Shared materials should be returned to the station after use for other students/teams to access.

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Circulate throughout the class to help troubleshoot and to facilitate the glue station.

Wrap-Up:

1. Have a dialogue with students to review the results of the activity. For example:

- Ask students from one team what evidence they used to determine if the mass of the paper clips on one side of the pan balance was equal to the standard mass on the opposite side. [*The pan balance arm was balanced (stayed horizontal) when equal masses were in both cups*.]
- Ask students from another team how they knew when the mass of the paper clip sample was greater than the standard mass in the opposite cup. [*The pan balance arm became unbalanced when the mass in one cup was greater than the mass of the opposite cup*. *The pan balance arm with more mass moved downward*.]
- Ask students from the first team to describe how the force of gravity pulled on each side of the pan balance according to how much mass was on each side. [*The force of gravity pulls down on all objects on Earth with a nearly identical pull. So Earth's gravity pulled down with the same amount of force regardless of the amount of mass on each side.*]

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Name: ______________________________________ Date: ____________________

Balance Activity

Use a known, standard mass on one side of the pan balance to find the equivalent mass of paper clips on the opposite side of the pan balance

Procedure:

Step 1: Place the standard 1-gram mass in one cup of the calibrated pan balance.

Step 2: Add paper clips to the opposite cup until the arm of the pan balance is horizontal (balanced). Record the number of paper clips equal to the 1-gram mass.

Step 3: Repeat steps 1-3 for each standard mass provided.

Comparing a Known Mass to an Unknown Mass with a Pan Balance	
Standard Mass (g)	number of paper clips equal to the standard mass
1	
2	
5	
10	
20	

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Lesson 3: Energy and Collisions

Objective: Students use the scientific process to see if fast-moving objects transfer more energy in a collision compared to slow-moving objects.

Materials:

Consumable

A. Goggles – 1 per student
B. Laboratory notebooks
– 1 per student
C. Medium plastic cups
– 2 per team
D. Pipe insulation
– 1 section per team

Non-Consumable

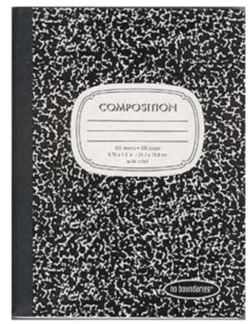
E. Large plastic cups
– 1 per team
F. Small plastic cups
– 1 per team
G. Marbles – 1 per team
H. Forms of Energy Visual
– (not shown)
I. Transferring Energy Visual
– (not shown)

Teacher Tool Kit

J. Masking tape – shared
K. Measuring tape – 1 per team
L. Scissors – 1 per team

A

B



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D

E

F

G

J

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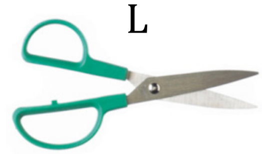
L



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Teacher Preparation:

- Download the visuals from the KnowAtom Interactive website.
- To save time, prepare photocopies of the Blank Data Table, Facilitated Set-Up Procedure, and the Blank Graph for each student using the copy masters on pages 79-80.
- Arrange pick-up stations for teams to collect materials to use at their desks. For example:
  - Pick-Up Station 1: goggles and laboratory notebooks
  - Pick-Up Station 2: large plastic cups, medium plastic cups, and small plastic cups
  - Pick-Up Station 3: pipe insulation, marbles, and masking tape
  - Pick-Up Station 4: scissors and measuring tapes

Student Reading Preparation:

- Read Section 3 of the student reader together as a class before the Socratic dialogue and lab portion of the lesson. Model how to read closely for understanding. For example:
  - Emphasize connections between examples in the reading and broader concepts. For example, ask why a certain example was used to support the reading's main point.
  - Use "why" and "how" questions to connect ideas in the reading to student experiences.

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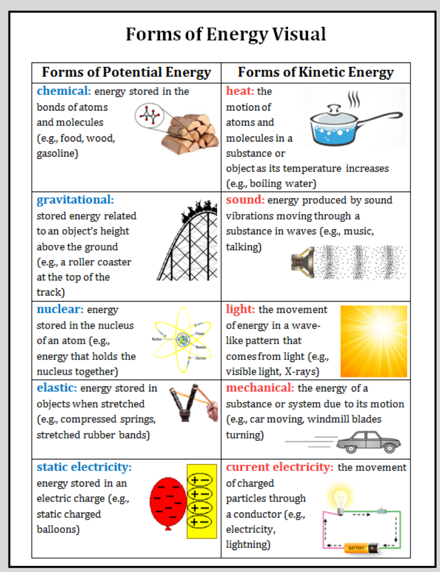
Socratic Dialogue:

Block 3-1: Introduction to Energy

1. Continue the conversation from the last lesson, beginning a dialogue with students about the difference between matter and energy.

- **Big Idea 9**: Coach students toward the idea that energy is not matter, but it is related to matter because matter can only change when enough energy is present. For example:
  - *Ask one student how energy is different from matter. (Matter is anything that has mass and takes up space. Unlike matter, energy is not made up of atoms. Instead,* ***energy*** *is the ability to do* ***work*** *(any change in position, speed, or state of matter due to force).)*
  - *Ask another student how energy interacts with matter. (Matter and energy are constantly interacting. Matter can only change when enough energy is present. For example, energy can make an object (matter) move, heat up, change shape, etc.)*


Forms of Energy Visual

Forms of Potential Energy	Forms of Kinetic Energy
chemical: energy stored in the bonds of atoms and molecules (e.g., food, wood, gasoline)	**heat:** the motion of atoms and molecules in a substance or object as its temperature increases (e.g., boiling water)
gravitational: stored energy related to an object's height above the ground (e.g., a roller coaster at the top of the track)	**sound:** energy produced by sound vibrations moving through a substance in waves (e.g., music, talking)
nuclear: energy stored in the nucleus of an atom (e.g., energy that holds the nucleus together)	**light:** the movement of energy in a wave-like pattern that comes from light (e.g., visible light, X-rays)
elastic: energy stored in objects when stretched (e.g., compressed springs, stretched rubber bands)	**mechanical:** the energy of a substance or system due to its motion (e.g., car moving, windmill blades turning)
static electricity: energy stored in an electric charge (e.g., static charged balloons)	**current electricity:** the movement of charged particles through a conductor (e.g., electricity, lightning)

2. Display *Forms of Energy Visual*. Have a dialogue with students about how there are different forms of energy, but all energy is always either being stored or doing work. Energy that is being stored is called potential energy, and energy of motion is called kinetic energy. [Note: This unit introduces energy and discusses a few of the forms (chemical, mechanical, heat, and sound). Later units will explore other forms of energy in more detail.]

- **Big Idea 10**: Coach students toward the idea that energy can change from one form to another in an

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energy system. A **system** is a set of connected, interacting parts that form a more complex whole. For example:

- *Ask one student why chemical energy is a form of potential energy. (Potential energy is energy that is stored or has the ability to do work. Chemical energy is a form of potential energy because it is energy stored in the bonds of atoms and molecules.)*
- *Ask another student why food has chemical energy. (Food is matter, so it is made up of atoms and molecules. The joined atoms are held together with bonds. It is those bonds that store energy.)*
- *Ask the first student to apply what they know about potential energy and gravity to explain why gravitational energy is a form of potential energy. (Gravitational energy is potential energy is because it is stored energy related to an object's height above the ground.)*
- *Ask another student to contrast kinetic energy with potential energy, explaining why mechanical energy is kinetic, not potential, energy. (Kinetic energy is the energy of motion. Mechanical energy is the energy of a substance due to its motion.)*
- *Ask another student to use a detail from the nonfiction reading that supports the idea that they are an energy system. (The reading describes how people are energy systems because we eat food, which contains chemical energy. Our bodies change some of that chemical energy into other forms of energy, including mechanical energy.)*
- *Ask the first student whether or not they agree with what the other student said, using their own observations and/or examples from the reading to support their analysis. Give the other student a chance to respond, so that both are evaluating each other's answers as they explore the concept of energy and energy systems.*

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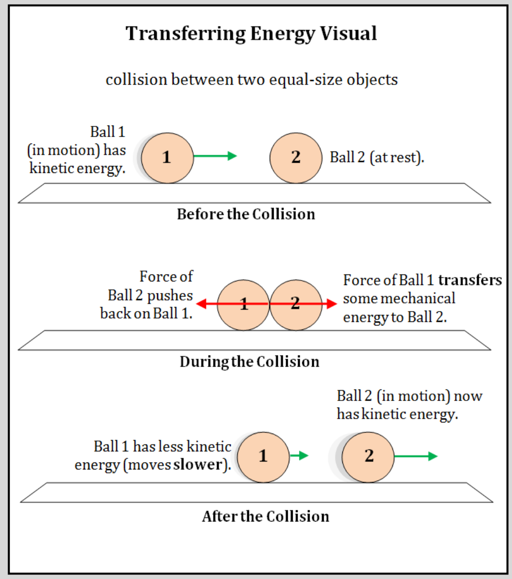
<u>Block 3-2: Energy Transfers</u>



1. Display <u>*Transferring Energy Visual*</u>. Have a dialogue with students about how energy is never created or destroyed, but it can be transferred into or out of objects or systems.

- ☐ <u>**Big Idea 11**</u>: Coach students toward the idea that energy can also be transferred from one object or system to another. When energy is transferred, it moves into or out of an object or system. For example:
  - *Ask one student how objects transfer energy. (Whenever two objects come into contact with one another, they both exert force on each other. That force transfers energy.)*
  - *Ask another student why Ball 2 in the visual starts to move after Ball 1 collides with it. (Ball 1 has mechanical energy because it is moving. When it collides with Ball 2, it exerts a force on Ball 2 that transfers some of Ball 1's mechanical energy to Ball 2.)*
  - *Ask the first student why the movement of Ball 1 changes after it collides with Ball 2. (Ball 2 exerts a force back on Ball 1 when they collide. This force changes the motion of Ball 1.)*
  - *Ask another student why Ball 1 moves more slowly than Ball 2 after the collision. (Ball 1 has transferred some of its mechanical energy to Ball 2. Because energy is never created or destroyed, it means that Ball 1 now has less mechanical energy, so it moves more slowly.)*
  - *Ask the first student why collisions between two objects often result in a loud sound. (Sound is a form of kinetic energy. When two objects collide, some of the mechanical*

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energy is transferred out of the system and changed into other forms of energy, including sound energy.)

- *Ask another student why moving objects eventually slow down. (Moving objects eventually slow down because of friction.* ***Friction*** *is a force that slows motion when two objects rub against each other. Friction slows motion by turning mechanical energy into heat.)*

- ☐ **Big Idea 11**: Transition to the experiment by coaching students toward the idea that moving objects have energy, and the faster an object is moving, the more energy it has. **Speed** is the rate at which an object covers distance in a period of time. For example:
  - *Ask one student whether a ball has more kinetic energy when it is moving at a fast speed or a slow speed. (The faster an object is moving, the more kinetic energy it has.)*
  - *Ask another student why even tiny objects such as paint flecks damage structures such as the International Space Station. (Most space debris travels at very high speeds. Because speed is related to energy, that moving paint fleck has a tremendous amount of energy. If it hits the International Space Station, it transfers some of its mechanical energy to the space station. This transfer of energy is what causes damage because the energy can change the position of matter, such as by denting windows.)*

Experiment – Lab 2 Marble Speed and Collisions

SAFETY: Students should wear goggles during the activity.

1. Divide students into teams of two. To help students visualize the ramp model for the lab, use the materials to show a basic ramp set-up. Prop one end of the pipe insulation up on the large plastic cup to create a ramp/inclined plane. Position one of the medium plastic cups upside down against the lowest end of the pipe insulation. (Students will need to cut an opening in this cup for the marble to

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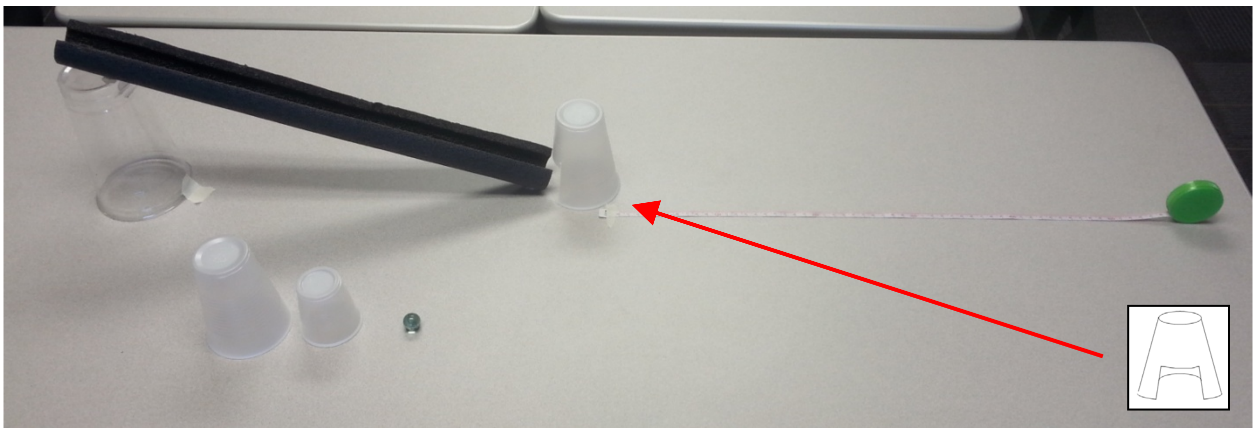
roll into.) The speed of a marble rolling down the ramp can be changed by decreasing or increasing the steepness of the ramp using the small and medium plastic cups in place of the large plastic cup. Use Socratic dialogue, the ramp model, marble, and a measuring tape to guide students toward asking a question about the effect of a marble's speed on the amount of kinetic energy it can transfer when it collides with a plastic cup at the base of the inclined plane. For example: "If a marble rolls down an inclined plane and collides with a cup, how does the speed of the marble affect how far the cup moves?"



example ramp system with "target" cup diagram on far right

Question

As a class, discuss the possible questions for the experiment and decide which question to explore for the lab. For example: "If a marble rolls down a ramp and collides with a cup, how does the speed of the marble affect how far the cup moves?" Once the experiment question is established for the lab, students should record it in their lab notebooks. Students create a title for the new lab entry that is relevant to the question. A relevant title for this lab would be "Marble Speed and Collisions."

NOTE: Use the *Who is a Scientist* poster and the *Scientific Process Visual to* help guide students through the scientific process.

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Research
For research, students list up to three facts relevant to the experiment question, using information from the student reader and/or discussion. For example:

- *A force is a push or a pull that acts on an object, changing its speed, direction, or shape*.
- *Energy is the ability to do work (move an object, heat up an object, change an object, etc.).*
- *When two objects collide, they each exert a force on each other. The force of the collision transfers some of the mechanical energy from one object to the other.*

Hypothesis
Students form their own hypothesis and record it in their lab notebooks. For example:

- "Increasing the speed of a marble increases the distance a cup moves when the marble collides with it."
- "Increasing the speed of a marble decreases the distance a cup moves when the marble collides with it."
- "The speed of the marble has no effect on the distance a cup moves when the marble collides with it."

<u>Checkpoint #1</u>: After Question, Research, and Hypothesis
As teams are ready, they should check in with the teacher to review their question, research, and hypothesis. Do the lab notebooks of both team members match and meet expectations? Can both students within the team explain their reasoning? If not, ask for areas of clarification or correction before they advance further. Not all teams will arrive at the lab check-points at the same time, so teams independently receive the go-ahead to move on in their lab after they have made the necessary modifications. <u>At this point in the year, student lab notebook entries within the class will most likely have the same question, but variations from team to team in the remaining steps of the process are expected and encouraged</u>.

Summarize Experiment
Stand by the materials stations and explain how the materials function (measuring tape, pipe insulation, small-, medium- and large plastic cups, etc.) and the general amounts each team can use. Facilitate a discussion that will help students arrive at a testable experiment. Students summarize the experiment in their lab notebooks. For example: “Our experiment will test how the speed of a marble affects the distance a target cup moves when marbles with fast, medium, and slow speeds collide with it for five separate trials each. The constants in the experiment are the size of the marble and the size of the plastic “target” cup. The variable in the experiment is the speed of the marble, which we will change by increasing the height of the ramp using small, medium, and large plastic cups. There is no control in this experiment because all objects need a force to move.”

Checkpoint #2: After Experiment Summary
As teams are ready, they should check in with the teacher to review the experiment summary of their lab. Do the lab notebooks of each team member match and meet expectations? Can students explain their reasoning? The summary should not include a detailed procedure or materials quantities.

- ✓ Students describe what data will be collected to serve as evidence to address the lab question. The summary should include the basics of the data to be collected, the number of trials students will conduct, the variables, and the parts of the experiment they will keep constant in each test or trial.

List Materials
Students list materials and all relevant safety precautions in their notebooks.

- 2 medium cups
- 1 large plastic cup
- 1 small plastic cup

Safety

- goggles

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- 1 marble
- 1 section of pipe insulation
- 1 pair of scissors
- 1 measuring tape
- masking tape (shared)

Procedure

Due to the precision required in this experiment, students will not derive steps of the ramp and target-cup set-up procedure on their own. In this lesson, the set-up procedure is facilitated by the teacher. A copy master of the facilitated set-up procedure is located at the end of the lesson (with the blank data table on page 76). Discuss the facilitated set-up procedure first, and then distribute a copy for each student to add to his or her lab notebook under 'procedure.' Work with the class to develop a standardized list of steps for the testing procedure. Student testing procedures should include a level of detail comparable to the example testing procedure below:

Ramp and Target Cup Set-Up (FACILITATED)

Step 1: Cut out a large, 5-cm x 4-cm section from the rim of one medium plastic cup for the marble to roll into/collide with. This will be the "target" cup.
Step 2: Tape the large plastic cup upside down on a flat, level surface. Lean one end of the pipe insulation against the top edge of the large plastic cup to create a ramp. Secure the pipe insulation to the cup with masking tape.
Step 3: Position the "target" cup upside down against the lowest end of the ramp. The hole in the cup should line up with the channel in the pipe insulation.

Testing Procedure:

Step 1: Release the marble from the highest point of the ramp so it rolls down the channel and collides with the cup. Record the

distance the target cup moved. Return the target cup to its starting position.
Step 2: Repeat Step 1 for four more trials.
Step 3: Repeat steps 1-2 for two more tests, replacing the large plastic cup holding up the ramp with the medium plastic cup, and then the small plastic cup.

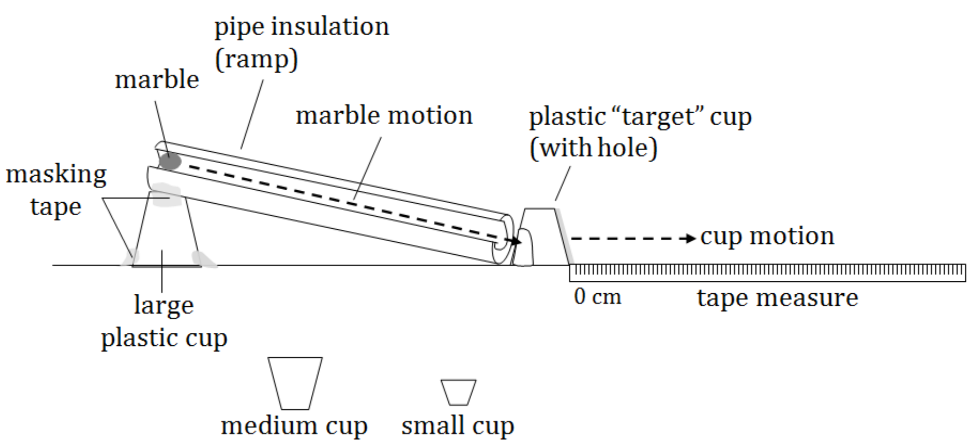
NOTE: Students may need to set up their ramps on a level floor to allow enough room for the target cup to move.

Checkpoint #3: After Materials and Procedure
As teams are ready, they should check in with the teacher to review the material and procedure steps of their lab. Are the materials and procedure in vertical lists and quantities included with all materials? Can you follow each team's testing procedure? Are the materials and quantities under "materials" all required by the procedure? Is it clear, concise, and specific? If not, clarify expectations. Students make corrections or any modifications and return to the checkpoint for the go-ahead.

Scientific Diagram

Students draw a titled scientific diagram of their experiment system-in-progress. All materials should be labeled. Arrows can be used to indicate the predicted motion of the marble and cup in the diagram. For example:

Marble Speed and Collisions Diagram



Checkpoint #4: After Scientific Diagram
As teams are ready, they should check in with the teacher to review their lab scientific diagram. Are the diagrams complete? Diagrams should be titled and materials labeled. If complete, students pick up blank data tables and graphs to tape inside their lab notebooks and then proceed to collect the materials needed to conduct their experiment after meeting at this checkpoint.

Data
Teams collect the materials from the pick-up stations to carry out their experiment. Students record data in their data tables as the experiment progresses. Students then create a titled bar graph to compare the average distance the target cup moved (on the y-axis) vs. the relative speed of the marble (on the x-axis). Students should create a scale for the graph's y-axis and labels for the x-axis. Photocopy and distribute blank data tables and graphs to save time.

Table 1: Comparing Distance Target Cup Moved vs. Marble Speed

Relative Marble Speed	Distance Target Cup Moved (cm)					
	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Average
High Ramp Marble (fast)	27.5	26.5	24	32	29.5	27.9
Medium Ramp Marble (medium)	17	18	16	16	17.5	16.9
Low Ramp Marble (slow)	8	9	7	6	6.5	7.3

NOTE: Example data table represent one possible outcome.

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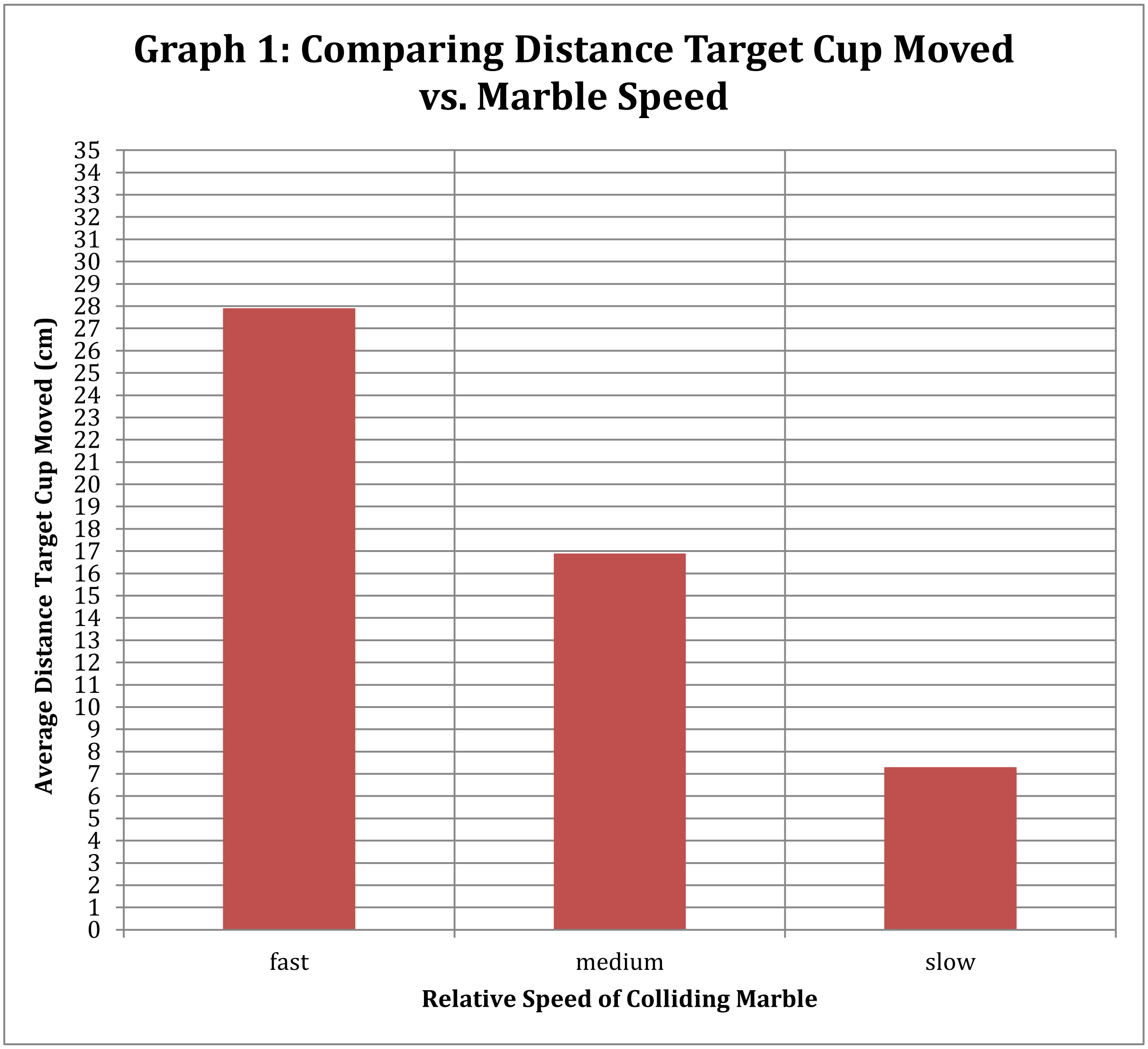

Conclusion

Each student writes a conclusion that summarizes his or her findings and tells how the data did or did not support the hypothesis. For example: "Our hypothesis that the speed of the marble has no effect on the distance a cup moves when the marble collides with it is false. Our data show that as the relative speed of the marble decreased, the distance the target cup moved after the collision decreased. The average distance the target cup moved when a fast marble collided with it was between 11 and 20.6 centimeters more than the distance the target cup moved when the slow- and medium-speed marbles collided with it. We can conclude fast-moving objects transfer more energy during a collision compared to slow-moving objects."

Final Checkpoint: After Data and Conclusion
As teams are ready, they should check in with the teacher to review the data and conclusion steps of their lab. One team member reads the team's conclusion aloud to you while you review the other team member's lab notebook. Do they restate the hypothesis? Have they made a true/false/inconclusive claim? Look for key data points that students used to form their conclusion. Is it clear? Is it persuasive? Do the data support the claim? If the results are contrary to their research, what might be responsible? How could they test for that in the future?

Wrap-Up:

1. Have a dialogue with students to review team results from the experiment. For example:

- Ask students from one team to present their conclusion to the class.
- Ask students from another team to respectfully critique the conclusion of the first team, using their own data and conclusion to question the first team about any differences.
- Give students from the first team a chance to respond and either respectfully agree or disagree with the second team.
- Ask students from another team if they experienced any challenges in conducting this experiment, and if so, what they were. [*Answers will vary. One challenge might be creating a procedure that effectively investigates the question of how the speed of a marble affects how far the cup moves after a collision. One at a time, allow teams to analyze challenges they faced and how they overcame those challenges.*]

2. Continue the dialogue with students about the results of the experiment, focusing on how the experiment provided evidence for the transfer of energy and the relationship between an object's speed and the amount of energy it transfers during a collision. For example:

- Ask one student at what point energy transferred in this experiment. [*When the marble collided with the plastic "target" cup, the force of the moving marble transferred mechanical energy to the cup at rest.*]
- Ask another student why the fast moving marble transferred more energy to the "target cup" during the collision compared to the slower-moving marbles. [*The faster an object is moving, the more energy it has. Therefore, when it collides with another object, the force from the collision transfers more energy.*]
- Ask the first student why sound was produced when the marble collided with the cup. [*Sound is a form of energy. When the marble collided with the cup, some of the mechanical energy of the moving marble was transferred out of the system and changed into sound energy. This is why the collision made a noise.*]
- Ask the first student what evidence this experiment provided about the relationship of the speed of an object and its energy. [*The experiment provided evidence that speed is related to energy, and that the faster an object is moving, the more energy it has. We saw evidence of this when marbles moving at different speeds collided with a cup at rest: when the marble moved faster, it transferred more energy to the plastic cup, causing it to move farther.*]
- Ask another student why raising the height of the ramp increased the speed of the marble when it rolled down the ramp. [*Increasing the height of the ramp increased the gravitational potential energy of the marble when placed at the top of the ramp. Gravitational potential energy is energy related to an object's height above the ground. The higher an object is above the ground the more gravitational potential energy it has.*]

This complete lab notebook entry is intended to be used as an exemplar for teacher use only. It is not intended for student use.

Page

Marble Speed and Collisions, Date, Partner Name

Lab #2: Marble Speed and Collisions

Question: If a marble rolls down a ramp and collides with a cup, how does the speed of the marble affect how far the cup moves?

Research: Energy is the ability to do work (move an object, heat up and object, or charge an object etc.). When two objects collide, they each exert a force on each other. The force of the collision transfers some of the mechanical energy from one object to the other. A force is a push or pull that acts on an object, changing its speed, direction or shape.

Hypothesis: The speed of the marble has no effect on the distance a cup moves when the marble collides with it.

Summary of Experiment: Our experiment will test how the speed of a marble affects the distance a target cup moves when marbles with fast, medium, and slow speeds collide with it for five separate trials each. The constants in the experiments are the size of the marble and the size of the plastic "target" cup. The variable in the experiment is the speed of the marble, which we will change by increasing the height of the ramp using small, medium, and large plastic cups. There is no control in this experiment because all objects need a force to move.

Materials:

- 2 medium cups
- 1 large plastic cup
- 1 small plastic cup
- 1 marble
- 1 section of pipe insulation
- 1 pair of scissors
- 1 measuring tape
- 1 masking tape

Safety:

- goggles

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Unit 1 Lesson 3: Example Laboratory Notebook

This complete lab notebook entry is intended to be used as an exemplar for teacher use only. It is not intended for student use.

Ramp Set-Up Procedure:

Step 1: Cut out a large, 5-cm x 4-cm section from the rim of one medium plastic cup for the marble to roll into/collide with. This will be the "target" cup.

Step 2: Tape the large plastic cup upside down on a flat, level surface. Lean one end of the pipe insulation against the top edge of the large plastic cup to create a ramp. Secure the pipe insulation to the cup with masking tape.

Step 3: Position the "target" cup upside down against the lowest end of the ramp. The hole in the cup should line up with the channel in the pipe insulation.

Testing Procedure:

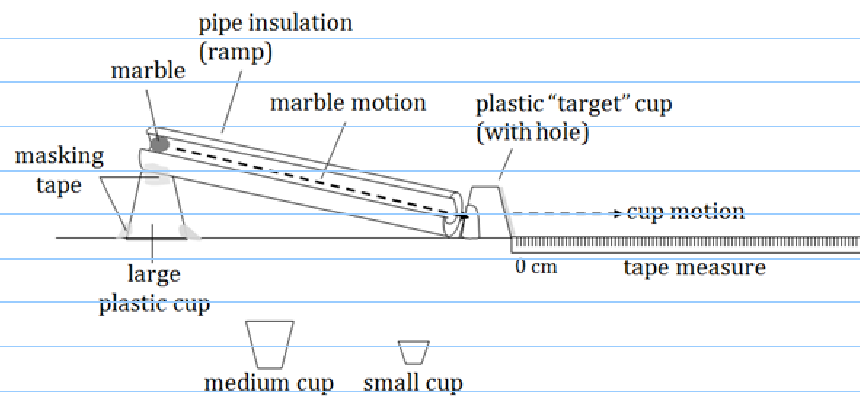
Step 1: Release the marble from the highest point of the ramp so it rolls down the channel and collides with the cup. Record the distance the target cup moved. Return the target cup to its starting position.

Step 2: Repeat Step 1 for four more trials.

Step 3: Repeat Steps 1-2 for two more tests, replacing the large plastic cup holding up the ramp with the medium plastic cup, and then the small plastic cup.

Scientific Diagram:

Marble Speed and Collisions Diagram



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<u>Unit 1 Lesson 3</u>: Example Laboratory Notebook

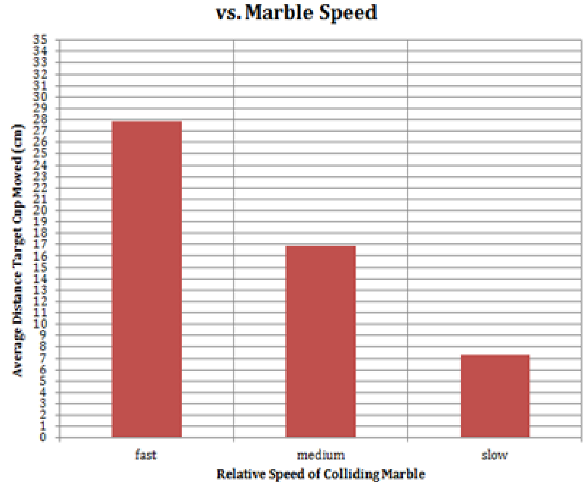
This complete lab notebook entry is intended to be used as an exemplar for teacher use only. It is not intended for student use.

<u>Data</u>:

Table 1: Comparing Distance Target Cup Moved vs. Marble Speed

Relative Marble Speed	Distance Target Cup Moved (cm)					
	Trial 1	**Trial 2**	**Trial 3**	**Trial 4**	**Trial 5**	**Average**
High Ramp Marble (fast)	27.5	26.5	24	32	29.5	27.9
Medium Ramp Marble (medium)	17	18	16	16	17.5	16.9
Low Ramp Marble (slow)	8	9	7	6	6.5	7.3

Graph 1: Comparing Distance Target Cup Moved vs. Marble Speed



<u>Conclusion</u>: Our hypothesis that the speed of the marble has no effect on the distance a cup moves when the marble collides with it is false. Our data show that as the relative speed of the marble decreased, the distance the target cup moved after the collision decreased. The average distance the target cup moved when the fast marble collided with it was between 11 and 20.6 centimeters more than the distance the target cup moved when the slow- and medium-speed marbles collided with it. We can conclude that fast-moving objects transfer more energy during a collision compared to slow-moving objects.

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Unit 1: Lesson 3 – Facilitated Set-Up Procedure and Blank Data Table

Ramp and Target Cup Set-Up Procedure

1. Cut out a large, 5-cm x 4-cm section from the rim of one medium plastic cup for the marble to roll into/collide with. This will be the "target" cup.
2. Tape the large plastic cup upside down on a flat, level surface. Lean one end of the pipe insulation against the top edge of the large plastic cup to create a ramp. Secure the pipe insulation to the cup with masking tape.
3. Position the "target" cup upside down against the lowest end of the ramp. The hole in the cup should line up with the channel in the pipe insulation.

Table 1: Comparing Distance Target Cup Moved vs. Marble Speed

Relative Marble Speed	**Distance Target Cup Moved (cm)**					
	Trial 1	**Trial 2**	**Trial 3**	**Trial 4**	**Trial 5**	**Average**
High Ramp Marble (fast)						
Medium Ramp Marble (medium)						
Low Ramp Marble (slow)						

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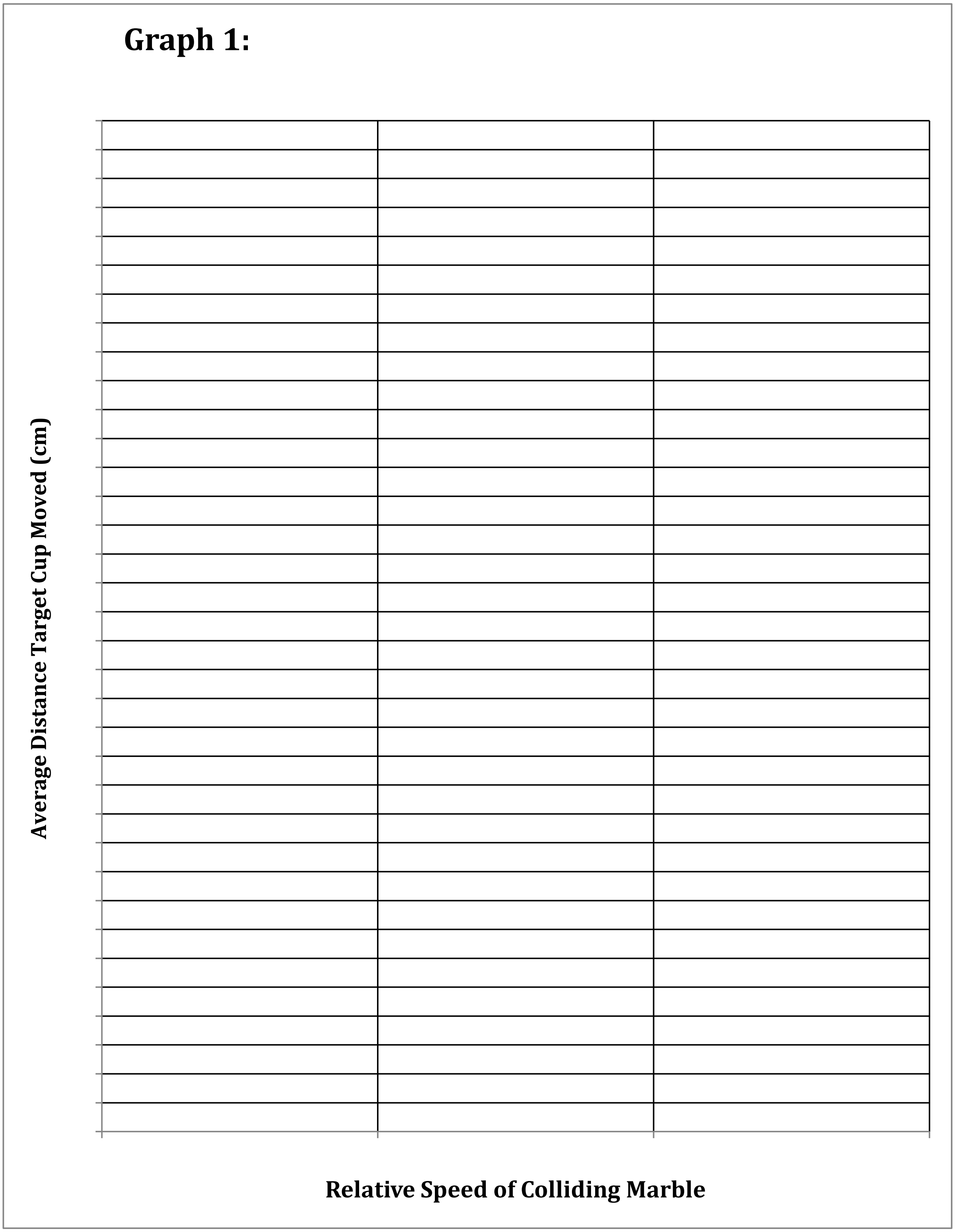
<u>Unit 1: Lesson 3</u> –Blank Graph

Graph 1:



Name: ________________________________ Date: ____________

Unit 1: Matter and Energy

Vocabulary Check

Directions: For questions 1-5, circle the best answer.

1. Fish and water are both made up of ______________________.

A. energy B. atoms

C. forces D. work

2. The faster an object is moving, the more ________________ it has.

A. energy B. volume

C. mass D. all of the above

3. ______________and ____________ are examples of measurable properties.

A. volume and shape B. mass and volume

C. mass and color D. an atom

4. Earth's ___________ keeps the International Space Station in orbit by pulling down on it toward Earth's center.

A. gravity B. properties

C. mass D. electrons

5. The gravitational force exerted on an object by a planet or moon is called _______________.

A. weight B. density

C. mass D. matter

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Name: ____ Date: _________________

Unit 1: Matter and Energy

Concept Check

Part I: For questions 1-3, circle the best answer.

1. Which of the following causes a ball thrown up in the air to fall back to the ground?

A. the moon's gravity
B. the sun's gravity
C. the ball's gravity
D. Earth's gravity

2. There are two cars traveling down the same road. One car is traveling at a faster speed than the other car. Which of the following statements is true?

A. The slower car has more energy than the faster car.
B. The faster car has more energy than the slower car.
C. The two cars have the same amount of energy.

3. Leon fills out a data table showing how many times his dog Fluffy does a trick compared to the number of treats Fluffy receives.

Fluffy Treats vs. Tricks	
Treats	Tricks
1	5
2	7
3	8
4	7

What question is Leon most likely trying to answer with the data?

A. Does Fluffy like to do tricks?
B. Does Fluffy eat a lot of treats?
C. Does Fluffy do more tricks when she gets more treats?
D. Is Fluffy a lazy dog?

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Part II: Use the Collisions scenario to answer the following questions.

Word Bank
mass – a measure of the amount of matter that makes up an object
force – a push or pull that acts on an object, changing its speed direction or shape
energy – the ability to do work (move an object heat up an object, charge and object, etc.)
mechanical energy – the energy of an object due to its motion
controlled experiment – an experiment where scientists change one thing at a time

Collisions

Mr. Payton's class is learning about speed and collisions. They are using a ramp and marbles to model how the motion of a target cup changes after a collision with a marble.

The students reviewed the materials for the investigation and noticed that some of the marbles were larger than the others. They were curious if the mass of the marble might affect how far the target cup at the base of the ramp would move after a collision. Mr. Payton asks his students to think of a question they can investigate scientifically about the distance the target cup moved when marbles of different masses collided with it. So the class came up with the following question for their experiment.

If a marble rolls down a ramp and collides with a cup, how does the mass of the marble affect how far the cup moves?

Each team of students collects the following materials for the investigation.

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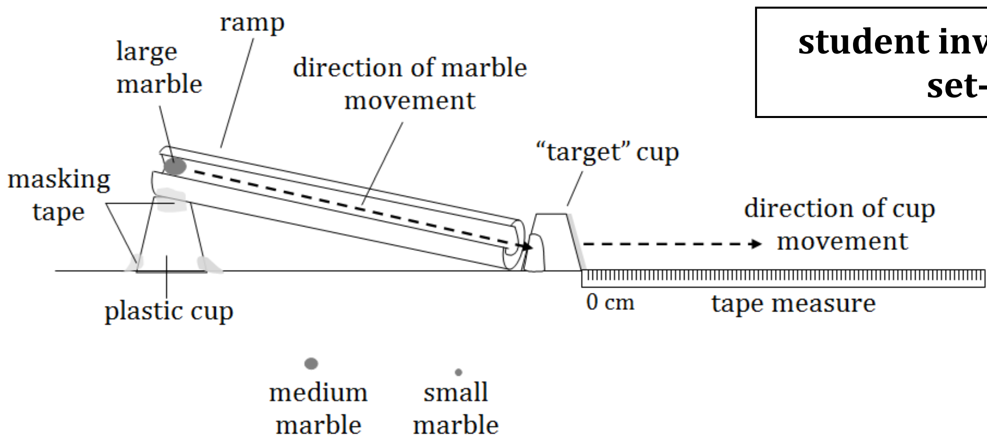
- 1 large marble
- 1 medium marble
- 1 small marble
- 1 ramp
- 1 measuring tape
- 1 plastic cup
- 1 "target" cup
- tape

The students set up a model to investigate their question. The diagram below shows how they set up their model:



student investigation set-up

Make a Prediction

If a marble rolls down a ramp and collides with a cup, how does the mass of the marble affect how far the cup moves?

1. Write a prediction for the question in the spaces below.
Tip: This question is most similar to the **hypothesis** in the scientific process.

____

____

____

____

____

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2. Explain your prediction using what you know about forces, energy, and mass.

____

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____

The students from Mr. Payton's class carried out their investigation using the following procedure.

Testing Procedure

Step 1: Mass the large marble.

Step 2: Release the large marble from the highest point of the ramp so it rolls down the channel and collides with the cup. Record the distance the target cup moved. Return the target cup to its starting position.

Step 3: Repeat Step 2 for four more trials.

Step 4: Repeat steps 1-3 for two more tests, first with the medium marble, then the small marble.

Table 1: Comparing Distance Target Cup Moved vs. Marble Mass

Marble Mass (g)	**Distance Target Cup Moved (cm)**					
	Trial 1	**Trial 2**	**Trial 3**	**Trial 4**	**Trial 5**	**Average**
Large Marble 20.7	37.1	42	34.3	39.2	37.6	**38**
Medium Marble 3.5	11.7	10	11.8	9.6	12.1	**11**
Small Marble 1.5	3.4	3.7	3.4	3.5	3.5	**3.5**

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Graph the Data

3. Use the data from Table 1 to create a bar graph to compare the average distance the target cup moved (on the y-axis) vs. the mass of the marble (on the x-axis). Title the graph, create a scale for the graph, and label the x- and y-axis.

Graph 1:

Analyze the Results

4. Describe any patterns you notice in the data.

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5. Look at the prediction you wrote for Question 1. Check one of the following statements based on your prediction:

- ☐ The data **supported** the prediction.
- ☐ The data **did not support** the prediction.

Explain how the data did or did not support your prediction.
Tip: This question is most similar to the **conclusion** step in the scientific process.

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6. The following definition was listed in the word bank at the beginning of the story.

Controlled experiment: an experiment where scientists change one thing at a time

Do you think that the investigation carried out by Mr. Payton's class was a controlled experiment? Use one example from the investigation to explain your thinking.

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Unit 1: Appendix 1
Answer Keys

Vocabulary Check

1. B. atoms [Fish and water are both made up of atoms because they are both matter. Atoms are the smallest pieces of matter that have the properties of an element. Energy is the ability to do work, while work is any change in position, speed, or state of matter due to force. A force is a push or pull on an object, changing its speed, direction, or shape]
2. A. energy [The faster an object is moving, the more energy it has. Energy is the ability to do work. Mass is a measure of the amount of matter that makes up an object. It is measured in grams (g). Volume is a measure of how much space an object or substance takes up and it is measured in cubic meters (m^3) or liters (l). Both mass and volume are properties of matter.]
3. B. mass and volume [Mass and volume are examples of measurable properties of matter. Mass is a measure of the amount of matter that makes up an object. It is measured in grams (g). Volume is a measure of how much space an object or substance takes up and it is measured in cubic meters (m^3) or liters (l). Color and shape are two examples of observable (not measurable) properties of matter.]
4. A. gravity [Earth's gravity attracts all objects on or near Earth's surface, pulling them downward toward Earth's center. Mass is a measure of the amount of matter that makes up an object. Properties are observable or measurable characteristics of matter. Electrons are one of three subatomic particles that make up atoms. They orbit the nucleus because they are attracted to the positive charge of protons.]
5. A. weight [The gravitational force exerted on an object by a planet or moon is called weight. Mass is a measure of the amount of matter that makes up an object. Non-scientists often use the terms weight and mass interchangeably, but mass is an intrinsic property of matter, which means it is not dependent on any external factors. In contrast, an object's weight depends on the force of gravity. Density is another physical property of matter.]

Concept Check

Part I

1. D. Earth's gravity [Earth's gravity causes a ball thrown up in the air to fall back to the ground. Gravity is an attractive force between all matter. On Earth, the pull of Earth's gravity is the dominant force because Earth is so much more massive than anything else on the planet. Earth's gravity affects objects near Earth by pulling them downward toward Earth's center. This is why objects that are thrown into the air fall back to Earth. The moon and the ball are both much smaller than Earth, so their gravities do not influence the movement of the ball. The sun is more massive than Earth, but it is much farther away, and the force of gravity becomes weaker as the distance between two objects increases.]
2. B. The faster car has more energy than the slower car. [If two cars are traveling along the same road and moving at different speeds, the faster car has more energy than the slower car. This is because moving objects have mechanic (kinetic) energy, and faster-moving objects have more mechanical energy than slower-moving objects]
3. C. Does Fluffy do more tricks when she gets more treats? [The data show that as Fluffy eats more treats, the amount of tricks she does levels off. This question can be answered if Leon forms a conclusion based on this data. Whether Fluffy likes to do tricks, eat a lot of treats, or is lazy cannot be answered with this data.]

Part II

*This assessment asks students to analyze an experiment that investigates how the speed of a marble changes after a collision with a large marble compared to a small marble. These questions assess the NGSS standards **4-PS3-1** and **4-PS3-3**.*

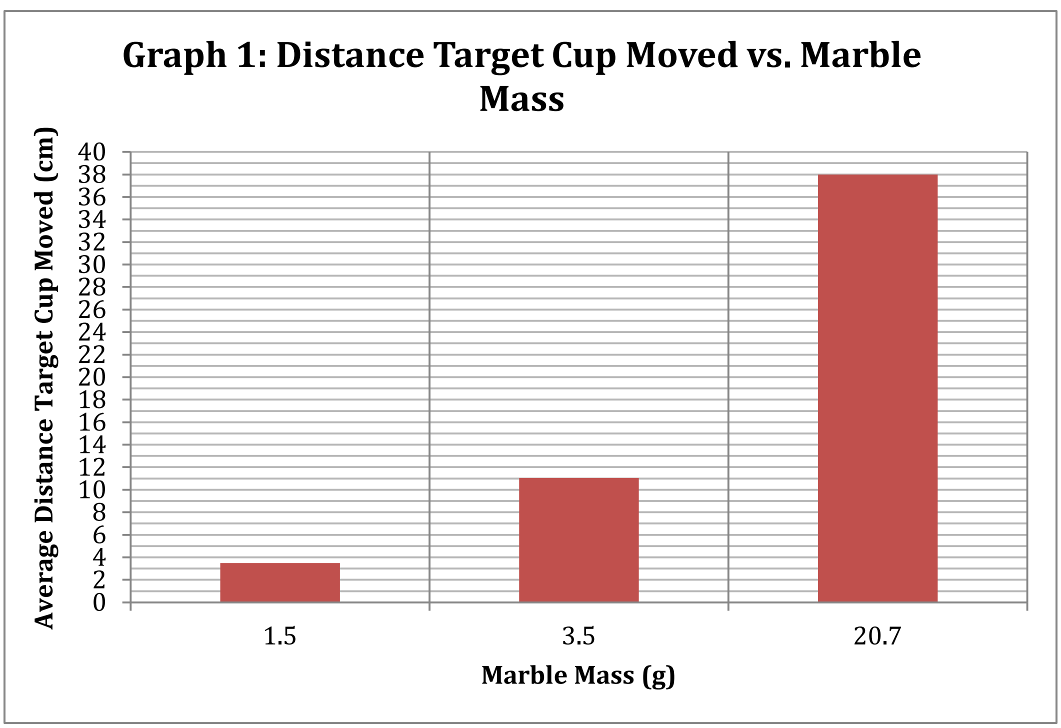
1. By developing a prediction about how the mass of the marble affects how far the target cup moves after a collision, students are partially assessed on the science and engineering practice of **Asking Questions and Defining Problems**. Students are also partially assessed on the disciplinary core idea of **Relationship Between Energy and Forces**, as well as the crosscutting concept of **Energy and Matter**.
   - Student answer should demonstrate an understanding of how questions guide an investigation. In this example, the prediction should demonstrate that students understand what the investigation is seeking to show. It should also demonstrate an awareness of the

scientific principles that will help to answer the question. The prediction is most similar to the hypothesis in the scientific process, which is a clear and concise statement that can be proved true or false, and it should be a declarative sentence that does not include personal pronoun words like "my" or "I think."

- For example:
  - "Increasing the mass of a marble increases the distance a cup moves when the marble collides with it."
  - "Increasing the mass of a marble decreases the distance a cup moves when the marble collides with it."
  - "The mass of the marble has no effect on the distance a cup moves when a marble collides with it."

2. Students are partially assessed on the disciplinary core idea of **Relationship Between Energy and Forces**, **Conservation of Energy and Energy Transfer,** as well as the crosscutting concept of **Energy and Matter** as they explain their prediction using what they know about forces, energy, and mass. For example:
   - Large marbles have more mass than small marbles. Large marbles apply a larger force than small marbles. A large force transfers more mechanical energy in a collision compared to a small force.

3. By creating a bar graph that compares the average distance the target cup moved when the mass of the colliding marble increases, students are partially assessed on the science and engineering practice of **Using Mathematics and Computational Thinking**.



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4. In this question, students are asked to describe any patterns they notice in the data. Students are partially assessed on the science and engineering practice of **Analyzing and Interpreting Data**. They are also partially assessed on the crosscutting concept of **Patterns**.
   - Student answer should demonstrate an understanding of how to analyze the graph for patterns.
     - For example: As the mass of the marble increased, the average distance the cup moved also increased.
5. By using the data to analyze their prediction, students are partially assessed on the science and engineering practices of **Constructing Explanations and Designing Solutions**, **Engaging in Argument from Evidence**, and **Obtaining, Evaluating, and Communicating Information**. Students are also assessed on the crosscutting concept of **Energy and Matter** as they explain how the mass of the marbles affects how much energy is transferred during a collision, using the distance the cup moved as evidence.
   - Student response should demonstrate an understanding of how to use evidence (data) to support or refute a prediction or claim.
   - Student response should restate the prediction (from Question 1), identify whether the results of the experiment support or do not support the prediction, and explain their reasoning, using key data points from the table or graph. The response should demonstrate a similar level of detail and reasoning:
     - "**The data supported the prediction**: The prediction that increasing the mass of a marble increases the distance a cup moves when the marble collides with it was true. The data show that when the large marble collided with the cup, it moved the cup 38 centimeters. This was 27 centimeters more than when the medium marble collided with the cup and 34.5 centimeters more than when the small marble collided with the cup. We can conclude that objects with more mass transfer more energy in a collision compared to objects with less mass."
     - Or: "**The data did not support the prediction**: The prediction that the mass of the marble has no effect on the distance a cup moves when a marble collides with it was false. The data show that when the large marble collided with the cup, it moved the cup 38 centimeters. This was 27 centimeters more than when the medium marble collided with the cup and 34.5 centimeters more than when the small marble collided with the cup. We can conclude that objects

with more mass transfer more energy in a collision compared to objects with less mass."

6. Student answer should demonstrate an understanding of controlled experiments. For example:
   - The investigation was a controlled experiment because the only variable that changed in each of the trials was the mass of the marble. The constants, or parts of the experiment that remained the same for reach trial, were the height of the ramp and the size of the cup that the marble collided with.

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Student Reader Answer Key

The section review questions at the end of each section in the reader are designed to use Common Core ELA standards to advance student comprehension of the student reader. Students can answer these questions independently or they can be discussed as a class before the Socratic dialogue portion of the lesson.

Section 1 Reading Comprehension Questions

1. [The main idea of the first section is that science is all knowledge learned from experiments, including the knowledge about matter. All matter is made up of different combinations of atoms, which determine the properties of matter.]
2. [Examples used to support the main idea include some of the experiments on the International Space Station, specifically the study of zebrafish in the space environment. Zebrafish are made up of matter, as is the water in which the fish live.]
3. [The text relates the atoms that make up a piece of matter to its properties by explaining that matter has the properties it does because of the number and kind of atoms that make it up.]
4. [The text uses comparisons to explain the scale of an atom so it is easier to understand how the size of the atom relates to everyday objects, and how the smaller parts of the atom relate to one another. For example, if each atom in the grapefruit were the size of a blueberry, the grapefruit would have to be the size of Earth. The text also explains that if one atom were the size of a blueberry, the nucleus would be too small to see. The atom would have to be the size of a football field to see the nucleus. Even then, the nucleus would be tiny, the size of a marble compared to the football field.]

Section 2 Reading Comprehension Questions

1. [The main idea of Section 2 is that forces are all around us, and are related to an object's motion. Unbalanced forces cause objects to change their motion, while objects don't change their motion if the forces acting on them are balanced.]
2. [The text gives the example of Earth's motion around the sun to explain how the sun's gravity changes the motion of Earth because the pull of the sun's gravity is so strong that it provides an unbalanced force that pulls Earth into orbit around it.]

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3. [The text focuses on the force of gravity here on Earth and in the solar system to explain the relationship between forces and motion. For example, when someone is standing on the ground, gravity pulls down on them. However, the ground pushes back with the same amount of force. This means that the forces acting on the person are balanced, and so the person will remain stationary. If the ground did not push back with the same amount of force, that person would fall into the ground because the forces would be unbalanced. Gravity would pull down with a greater force than the force of the ground pushing back up.]
4. [The text connects the fact that astronauts (and possibly zebrafish) lose muscle mass in space with the force of gravity. On Earth, we have to use our muscles just to stand up against the downward pull of gravity. This requires our bodies to maintain enough muscle to support our own weight. In the low-gravity environment of space, astronauts lose muscle mass since it is not required to support their weight.]

Section 3 Reading Comprehension Questions

1. [The main idea of Section 3 is that energy changes matter, and that moving objects have mechanical kinetic energy. Objects that are moving at a faster speed have more kinetic energy than objects moving at a slower speed. When two objects collide (come into contact with one another), they transfer energy between them. The faster an object is moving, the more energy it transfers.]
2. [The text uses the example of a piece of space debris as small as a paint fleck to explain how objects moving at a fast speed have a lot of kinetic energy, and will transfer some of this energy during a collision. If an object that is more massive than a paint fleck were to collide, it would transfer even more energy to the space station.]
3. [We can infer that astronauts are concerned about collisions in space because objects in space are moving at a very fast speed. Because of this, these objects would transfer a tremendous amount of energy during a collision. This could cause damage to the space station or other objects in space.]

Unit 1: Appendix 2
Common Core Connections

The following Common Core standards are covered in this unit. Questions for the *Reading Informational Texts* standards provide an example of a question that links to a specific ELA standard. Additional questions are included in the section reviews. These types of questions can also be used with other texts. Other ELA and math standards are covered as students work through the reading, class dialogue, and hands-on portion of the lessons.

ELA Standards	Applying ELA Connections to the Student Reader
Reading Informational Texts	
RI.4.1. Refer to details and examples in a text when explaining what the text says explicitly and when drawing inferences from the text.	• How can something as small as a paint fleck damage the International Space Station (pages 30-32)? [*All moving objects contain energy, and the faster the object is moving, the more energy it has. Paint flecks in space move with tremendous speed, so they have a lot of energy. The force of a collision causes energy to transfer from one object to another.*]
RI.4.2. Determine the main idea of a text and explain how it is supported by key details; summarize the text.	• What is the main idea of the text on pages 11-12? [*The main idea is that all of matter is made up of tiny particles too small to be seen called atoms. Millions of atoms make up just one grain of sand, and yet the atom itself is made up of smaller particles. Scientists use scale comparisons to understand how these parts all relate to one another.*]
RI.4.3. Explain events, procedures, ideas, or concepts in a historical, scientific, or technical text, including what happened and why, based on specific information in the text.	• Why do scientists follow a scientific process when they want to find out how zebrafish are affected by a low-gravity environment (pages 4-9)? [*The scientific process guides scientists through an experiment so that knowledge can be generated. People don't know yet how zebrafish will be affected by a low-gravity environment, so scientists need to conduct experiments to generate data so they can determine a conclusion.*]

Writing	
W.4.5. With guidance and support from peers and adults, develop and strengthen writing as needed by planning, revising, and editing.	• Students develop their writing skills as they use their lab notebooks for experiments. In this unit, students practice writing clearly and concisely as scientists. They follow a specific organization that is appropriate for scientific writing. They revise and edit as necessary to ensure their writing is specific and clear.
Language	
L.4.2. Demonstrate command of the conventions of standard English capitalization, punctuation, and spelling when writing.	• In Lessons 1 and 3, students use standard English capitalization, punctuation, and spelling as they work through an experiment, recording their question, research, hypothesis, experiment summary, and conclusion.
L.4.4. Determine or clarify the meaning of unknown and multiple-meaning words and phrases based on grade 4 reading and content, choosing flexibly from a range of strategies.	• Students use the student reader to expand their scientific vocabulary. They use that vocabulary to communicate with others precisely and clearly.
Speaking and Listening	
SL.4.1.A. Come to discussions prepared, having read or studied required material; explicitly draw on that preparation and other information known about the topic to explore ideas under discussion.	• In Lessons 1, 2, and 3, students engage in Socratic dialogue before beginning the activity or experiment. As a class, students read the reader, and then apply what they have read to new situations or real-life scenarios.

SL.4.1.B. Follow agreed-upon rules for discussions and carry out assigned roles.	• In Lessons 1, 2, and 3, students follow agreed-upon rules during the Socratic dialogue portion of the class, as well as during the activity portion of the lesson.
SL.4.1.C. Pose and respond to specific questions to clarify or follow up on information, and make comments that contribute to the discussion and link to the remarks of others.	• In Lessons 1, 2, and 3, students actively engage in dialogue and in the activity portion of the lesson.
SL.4.1.D. Review the key ideas expressed and explain their own ideas and understanding in light of the discussion.	• In Lessons 1, 2, and 3, students contribute to the Socratic dialogue and during the wrap-up portion of the lesson, explaining their experiences and understandings.

Math Standards	Applying Math Connections to the Unit
Measurements & Data	
4.MD.1. Know relative sizes of measurement units within one system of units. Within a single system of measurement, express a larger unit in terms of a smaller unit.	• Students are introduced to the metric system, which allows scientists to express both very small and very large amounts because of its system of using base units and prefixes.
4.MD.2. Use the four operations to solve word problems involving distances, intervals of time, liquid volumes, masses of objects, and money, including problems involving simple fractions or decimals, and problems that require expressing measurements given in a larger unit in terms of a smaller unit. Represent measurement quantities using diagrams such as number line diagrams that feature a measurement scale. ** In this unit, students focus on solving word problems involving masses of objects.*	• In Lesson 1, students engage in their own word problem as they use the scientific process to compare the masses of gravel and sand. They apply math within their experiment as they add, subtract, and divide to find key data that support a claim about their hypothesis to use in their conclusion. • In Lesson 3, students engage in their own word problem as they conduct an experiment in which they measure the distance a cup travels to determine how much energy a fast-moving marble transferred to it compared to marbles that moved more slowly. They apply math within their experiment as they add, subtract, and divide to find key data that support a claim about their hypothesis to use in their conclusion.

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Use this chart to keep track of how you are connecting science to the rest of your curriculum.

Unit Connections to ELA Common Core	Unit Connections to Math Common Core	Unit Connections to History/Social Studies

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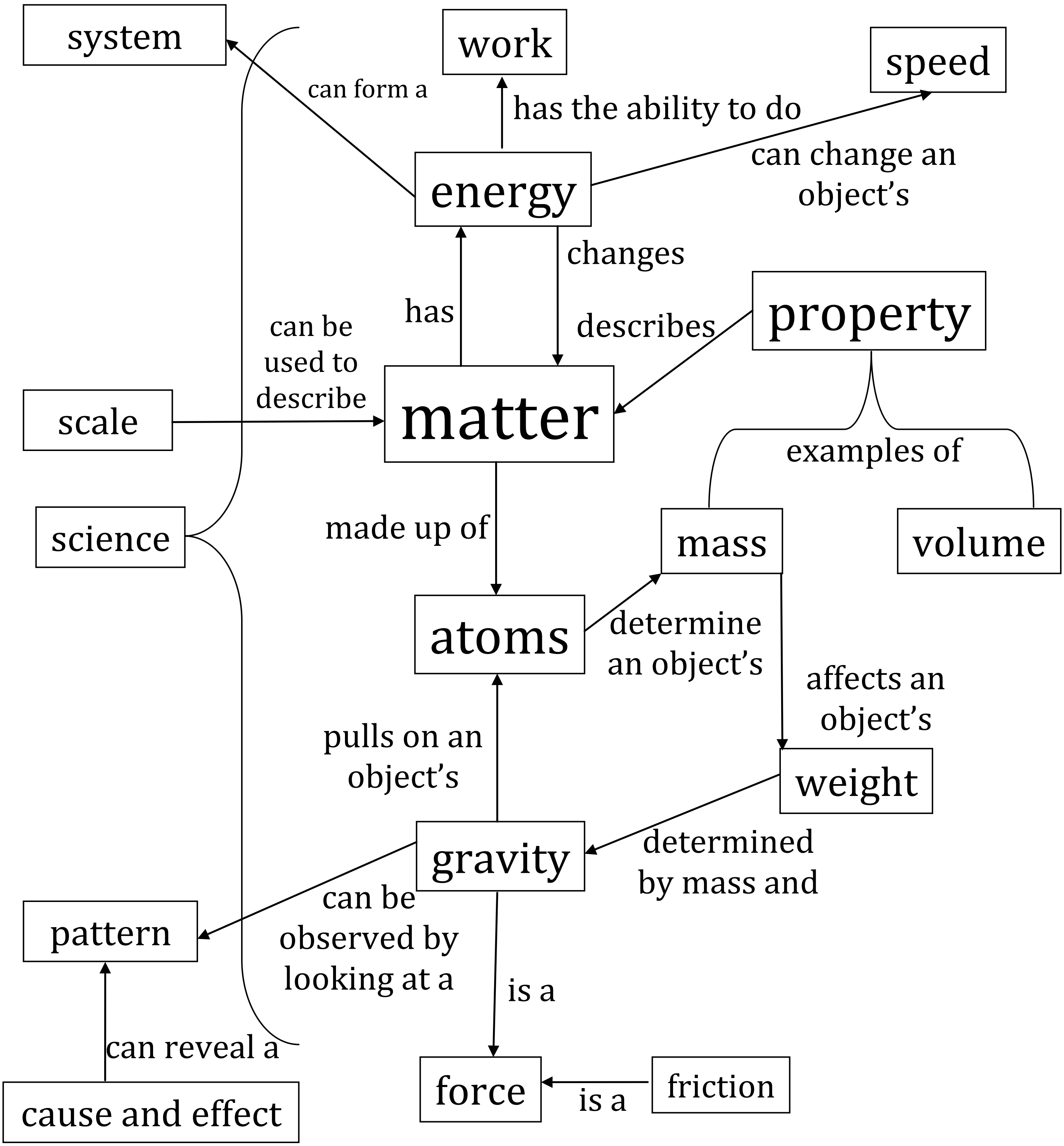
<u>Unit 1: Appendix 3</u>
Sample Concept Map



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<u>Unit 1: Appendix 4</u>
Support for Differentiated Instruction
Next Generation Science Standards

Core Expectation	KnowAtom Assessment Strategies	Possible Primary Evidence
4-PS3-1. Use evidence to construct an explanation relating the speed of an object to the energy of that object.	<u>Low Entry Point</u> • Recognize that motion can indicate the energy of an object. • Recognize that objects can only change position with energy. • Recognize that investigations can provide evidence for the connection between motion and energy. <u>At Grade-Level Entry Point</u> • Describe the relationship between speed and energy. • Recognize that energy transfers between objects and their environments or other objects.	• marble speed and collisions lab notebook entry completed by student • video of student developing and carrying out their procedure to test how the speed of a marble is related to how much energy it transfers during a collision
4-PS3-3. Ask questions and predict outcomes about the changes in energy that occur when objects collide.	<u>Low Entry Point</u> • Identify basic forms of energy. • Demonstrate that objects can move and that changes can occur that effect the movement of objects. <u>At Grade Level Entry Point</u> • Recognize that energy changes forms. • Describe how energy can change from one form to another, and can transfer into or out of objects or systems.	• marble speed and collisions lab notebook entry completed by student • student diagram showing how energy changes during a collision, transferring between objects and out of the system

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Unit 1: Appendix 5
Materials Chart

	Lesson	Quantity	Notes	Used Again
Unit Kit Consumable				
Goggles	all	1 per student	safety	✓
Gravel	1	shared	for the properties lab	
Sand	1	shared	for the properties lab	
Small measuring cups (30 mL)	1	1 per team of 2	for measuring gravel and sand volumes	
Small paper clips	2	shared	for testing pan balance	
Short dowels	2	1 per student	for pan balance model	
Large paper clips	2	6 per student	for pan balance model	
Long dowels	2	1 per student	for pan balance model	
Cardboard tubes with holes	2	1 per student	for pan balance model	
Cardboard bases	2	1 per student	for pan balance model	
Portion cups	2	2 per student	for pan balance model	
Clothespins	2	3 per student	for pan balance model	
Rubber bands	2	6 per student	for pan balance model	
Pipe insulation	3	1 per team of 2	for collisions lab	
Medium plastic cups (10 oz)	3	2 per team of 2	for collisions lab	
Non-Consumable				
Bowls	1	1 per team of 2	for holding gravel/sand	
Digital scales	1	1 per team of 2	for measuring mass	
Mass sets	2	shared	for testing pan balance	
Marbles	3	1 per team of 2	for collisions lab	
Measuring tapes	3	1 per team of 2	for measuring	
Large plastic cups (24 oz)	3	1 per team of 2	for collisions lab	
Small plastic cups (3oz)	3	1 per team of 2	for collisions lab	
Teacher Tool Kit				
Hole punches	2	shared	for punching holes in portion cups	✓
Invisible tape	2	1 per student	for assembling pan balances	✓
Glue gun/glue	2	shared	for assembling pan balances	✓
Extension cord	2	teacher use	for hot glue station	✓
Power strip	2	teacher use	for hot glue station	✓
Rulers	3	1 per team of 2	for collisions lab	✓
Masking tape	3	shared	for taping cups	✓
Measuring tapes	3	1 per team of 2	for measuring	✓
Scissors	3	1 per team of 2	for trimming cups	✓

Nonfiction Reading			
Laboratory notebooks	1, 3	1 per student	for “Lab 1” and “Lab 2”
Matter and Energy student readers	all	1 per student	for “Balance Activity” sheet
Visuals	Downloads/Posters		
Lesson 1	Who is a Scientist Poster, Scientific Process Visual, STEM Cycle Visual, Matter Visual, Properties Visual,		
Lesson 2	Gravity in Space Visual, Balanced and Unbalanced Forces Visual		
Lesson 3	Forms of Energy Visual, Transferring Energy Visual		