Focused Learning Lesson
Science
Grades 9-12
PS-H-E1

Overview:
This lesson is designed to review the characteristics of the four fundamental forces of nature: the strong force, weak force, electromagnetic force, and gravitational force. This lesson will also review the differences between mass and weight. Student handouts and answers are included along with teacher instructions. The student should have prior knowledge of the compositional particles of matter: protons, neutrons, electrons, atoms and molecules. Teacher Background attachment include background information and websites for more information.

Approximate Duration: 45 minutes (may be expanded to two 45-minute sessions)

Benchmarks:
PS-H-E1 recognizing the characteristics and relative strength of the forces of nature (gravitational, electrical, magnetic, nuclear)
PS GLEs:
29. Differentiate between mass and weight.
30. Compare the characteristics and strengths of forces in nature (e.g., gravitational, electrical, magnetic, nuclear).

Benchmark:
SI-H-A4 formulating and revising scientific explanations and models using logic and evidence
SI GLE: 7. Choose appropriate models to explain scientific knowledge or experimental results.

Objectives:
1. The student will define and differentiate mass and weight.
2. The student will compare the characteristics of the four fundamental forces.

Teacher Preparation:
- The teacher should gather the needed materials listed below prior to the lesson and review the lesson handouts and answer sheets.
- A copy of the lesson handouts should be prepared for each student.

Materials/Equipment:

Pencil/Pen	Tape	String or yarn
Scissors	Glue	Sewing thread

Lesson Procedures:
Set or Opener:
Introduce the topic by asking the students, "What holds the different particles of matter together?" If a transparency of an atom is available show it as you pose the question. Allow students to provide their answers and write them on the board. Allow 3-5 minutes for discussion.

Body of the Lesson:

1. Review the relationship of quarks making up electrons, protons, and neutrons, which make up atoms and atoms making up molecules. See Attachment 4.
2. Give each student Handout 1, "Basic Definitions." Review the definition of each term and have the students write these on their handout. Allow 5-10 minutes.
3. Give each student Handout 2, "Connecting Particles of Matter." Read the directions to the students as you model how to connect the P's, N's. and E's by drawing on the board or a transparency. Allow each student to construct the figures as directed in Step 1 on Handout 2. Explain that the student is making models of the neutrons and protons in the nucleus of the atom. Have them identify which force is being used to hold the parts of protons and neutrons together. Allow five minutes to construct the model.
4. Model and then have the students construct a model of the atom according to Step 2. Explain that each student is making a model of one atom. Have the student identify which force(s) is being used to hold the atom together. Explain that the strong force holds the neutrons and protons together in the nucleus and electromagnetic force to holds the electrons in orbit around the nucleus. Have students also identify their atom's charge.
5. Next have all the students connect their atom-models into a long molecule with positives connected to negatives according to step 3 using thread. Have them identify which force is being used. *(electromagnetic force)*
6. Next have the students identify the force that holds the entire model, atom, or any object having mass to Earth is the gravitational force.
7. Explain at this point the difference between mass of matter and weight. Explain that the mass of an object is the amount of mass the object has and that the mass does not change. Then explain that the weight of an object is the gravitational pull the Earth has on an object and that the pull varies as with the distance of the object from the center of the Earth. Also emphasize that the farther away the object is, the less the pull of gravitational force, and therefore, the less the weight of the object.

Closure:

Give each student Attachment 3 (Sample quiz) as a review quiz. Divide students into groups of two to four and allow them five minutes to complete the worksheet as a review. Go over the answers in class and discuss any disagreements.

Attachments:

Attachment 1: Handouts 1 and 2.
Attachment 2: Key for Student Handouts
Attachment 3: Quiz samples
Attachment 4: Teacher Background

Sample Assessment Items:

Formative assessment is through observation of student completions of definitions and construction of model atoms based on a rubric of your design. Handout 3 may also be used as an assessment tool.

Reference Links and Technology Connections:

http://imagine.gsfc.nasa.gov/docs/ask_astro/answers/980127c.html
http://csep10.phys.utk.edu/astr162/lect/cosmology/forces.html

Attachment 1: The Forces of Nature: Basic Definitions Handout 1

DIRECTIONS: Write the definitions for each of the following terms in the space provided.

1. A *force* is _____
2. *Mass* is _____
3. The s*trong force* is an _____ force that acts between _____ with _____ strength that over a _____ distance.
4. The *weak force* is an _____ force with _____ strength that acts on and changes _____ over a _____ distance.
5. *Electromagnetic force* is the force that acts between _____ and _____ particles and has _____ strength over a _____ distance. It is both _____ and _____.
6. *Gravitational force* is an _____ force that acts over a _____ distance with _____ strength between _____ objects.
7. *Weight* is _____ and depends on the _____ of the object and its _____ from the center of the Earth.
8. The strongest force is the _____ force while the force that is weakest is _____.

The Forces of Nature: Connecting Particles of Matter
Handout 2

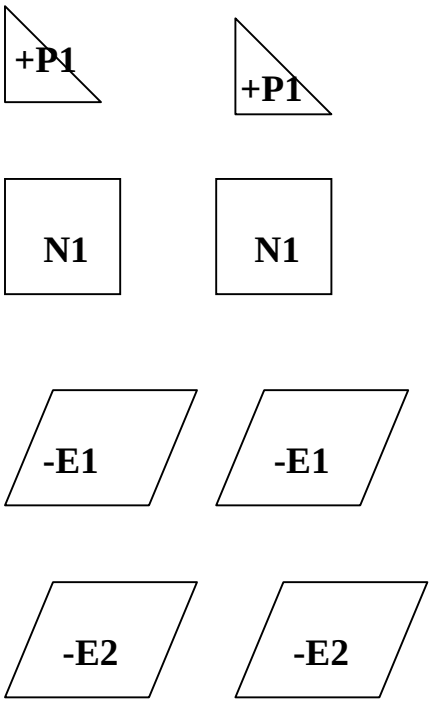
DIRECTIONS: Your teacher will assign which column you are to cut from. Follow each step as directed.

Step 1: Cut out the figures labeled P and N and E. Tape the pieces with the same letter and number together. Wait for teacher instructions.

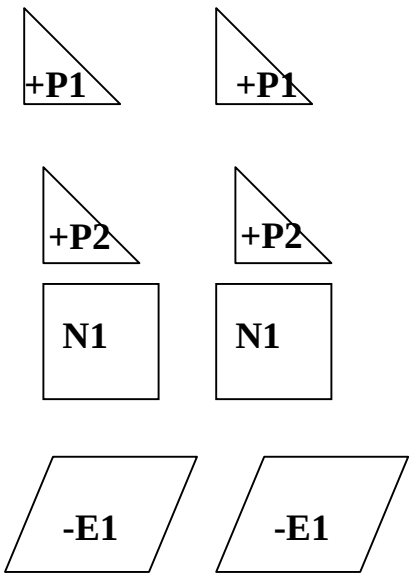
Step 2: Glue the pieces labeled P and N pieces in the center of Figure 1 and the E pieces on the outer circle. Count the number of P's and E's in your atom model and write here which you have more of: _____. If you have more P's, you have a positive atomic model; if you have more E's, you have a negative model. Label your model as positive or negative. Wait for the teacher's instructions.

Step 3: Following teacher instructions, connect your atom model to another student's model of the opposite charge of your model with yarn.

Column 1



Column 2



P = protons (+)
N = neutrons
E = electons (-)

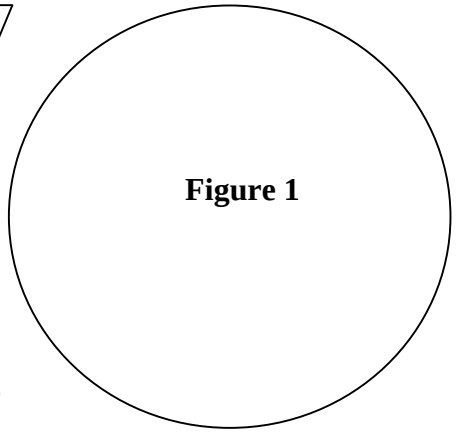


Figure 1

Attachment 2: The Forces of Nature: Basic Definitions
Handout 1 Key

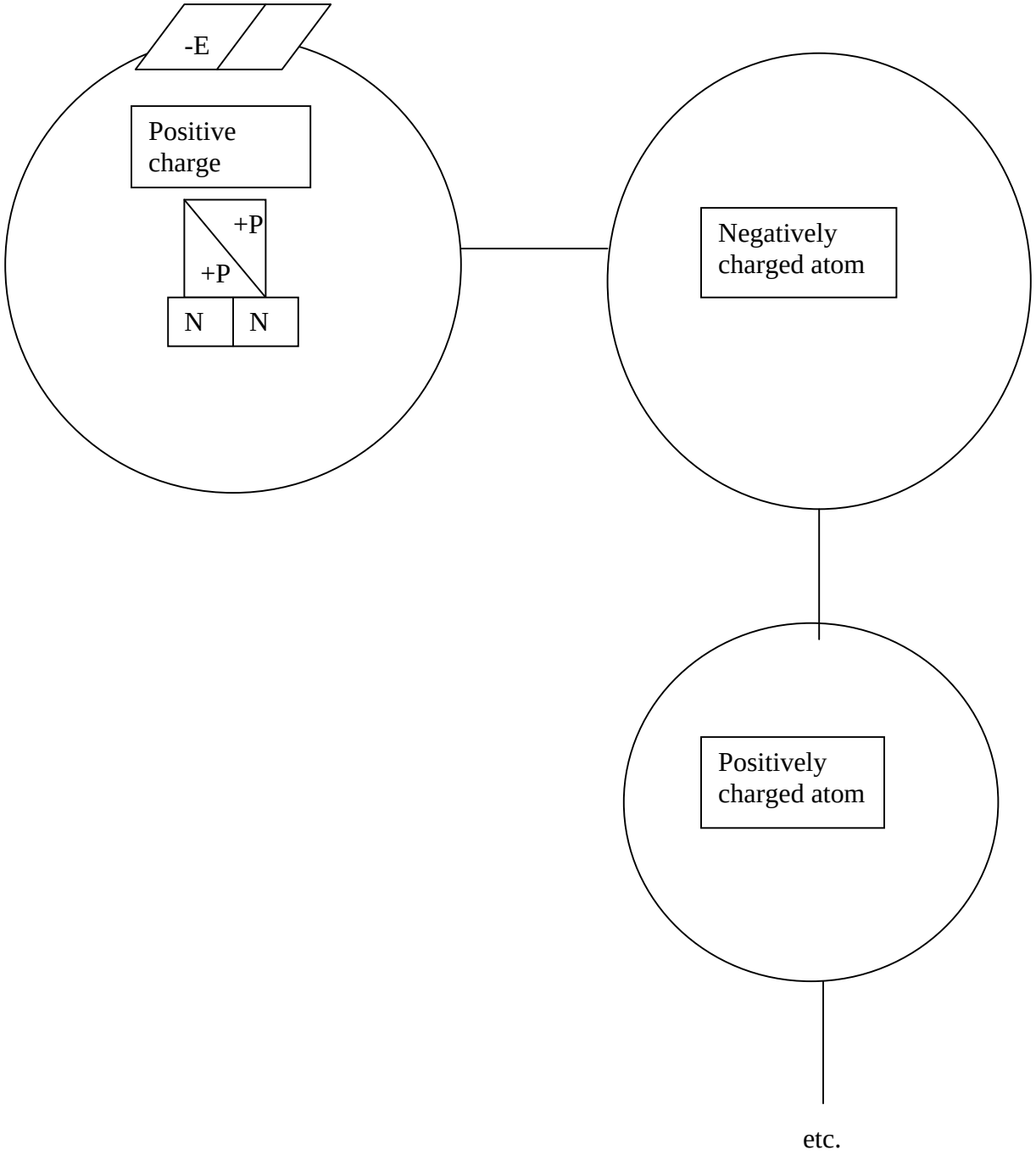
DIRECTIONS: Write the definitions for each of the following terms in the space provided.

1. A force is *a push or pull on an object*
2. Mass is *the amount of matter that makes up an object.*
3. The strong force is an *attractive* force that acts between *quarks of the protons and neutrons in the nucleus* with *very great* strength that acts over a *very short* distance.
4. The weak force is an *attractive* force with *great* strength that acts on and changes *quarks* over a *short* distance.
5. The electromagnetic force is the force that acts between *positive* and *negative* particles and has *fairly strong* strength over a *somewhat short* distance. It is both *attractive* and *repulsive*.
6. The gravitational force is an *attractive* force that acts over a *very long* distance with *very weak* strength between *all* objects in the universe.
9. Weight is *the measure of the gravitational pull on an object by the Earth* and depends on the *mass* of the object and the *distance* from the center of the Earth.
7. The strongest force is the *strong* force while the force that is weakest is *gravity* .

Handout 2
Key

Constructed models should look similar to the following:

An example of one fully constructed atom is below. Linking is illustrated below.



Attachment 3
Quiz Samples

Below is a sample of quiz questions:

1. The electromagnetic force is
   A) attractive
   B) repulsive
   C) both
   D) neither

2. Explain why weight is not a force.

3. Molecules consist of atoms connected together by _____ forces.

4. True or False: Gravitational force is the strongest of the four forces.

5. When water is coming out of a faucet, the water molecules tend to form a stream. Explain which of the four fundamental forces is most likely to account for the formation of the stream of water.

Key

1. *C*
2. *Weight is a measurement of gravitational force. It results from the effect of a force on a mass.*
3. *Electromagnetic*
4. *F*
5. *Electromagnetic*

Attachment 4
Teacher Background

The Forces of Nature

There are four fundamental forces in nature.

1. Electromagnetism
2. Strong
3. Weak
4. Gravity

These four forces all occur because of the exchange of force carrier particles.

What is a "force carrier particle"?

Well, pretend you want to knock a bird out of a tree 100 yards away. You must exert a force to do this, but the bird is out of your reach. So, you take throw a stone at the bird. If you're good enough, you will successfully exert a force on the bird and knock it down from its perch, with the stone being the **force carrier.**

Not all types of matter though are affected by all force carrying particles. For example, the proton and electron are affected by the force carrier particle of the electromagnetic force, the photon. They can emit and absorb photons. The neutrino, on the other hand, is a mass particle without charge, and is thus not affected by the photon and will not emit or absorb one.

A brief overview:

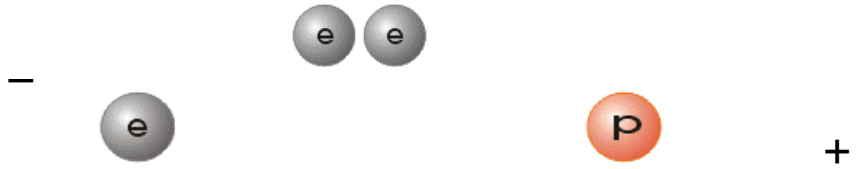
From http://imagine.gsfc.nasa.gov/docs/ask_astro/answers/980127c.html

- **Electromagnetic Force**: This acts between electrically charged particles. This force produces electricity, magnetism, and light and it has infinite range.
- **The Strong Force:** This force binds neutrons and protons together in the cores of atoms. It is a very strong, short-range force.
- **Weak Force:** The weak force allows changes in the quarks and thus causes radioactivity in the form of Beta decay (the conversion of a neutron to a proton, an electron and an antineutrino) plus various particles are formed by strong interactions, but decay is via weak interactions. Like the strong force, the weak force is also short range.
- **Gravity:** This force acts between all mass in the universe, and it has infinite range. The amount of force exerted is dependent on the masses of the objects and the distance between the objects.

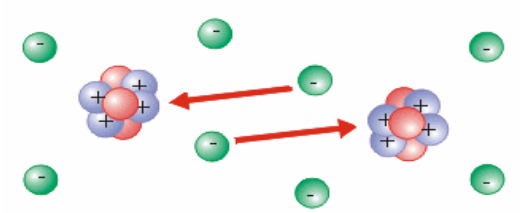
Let's look at each force individually.

First stop, **Electromagnetism**.

Electromagnetism is one of the two forces that dominate our everyday lives (the other one being gravity). The words you are reading are a result of electromagnetism. The electromagnetic force acts between all particles that have electric charge. It is attractive for oppositely charged particles, and repulsive for particles of the same charge.



Electromagnetic force gets weaker and weaker, the further apart the particles are, but its range is infinite. The carrier of this force is the photon, most commonly observed as light. In addition, electromagnetic forces are responsible for binding atoms together to form molecules. Although most atoms have a net neutral charge, the positive charge from within one atom can attract a negative charge within another atom, thus binding the two atoms together. This is called the "residual electromagnetic force."



The next force we will look at is the strong force.

The Strong Force:

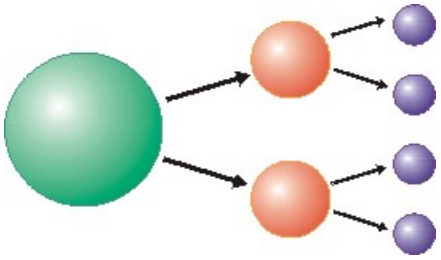
In addition to electric charge, quarks also contain something called "color charge." The force between color charged particles is very powerful, thus it is called the "strong force."

The strong force is strictly an **attractive force** that acts between nucleons (protons and neutrons). It attracts any combination of protons and neutrons, i.e., neutrons attract neutrons and protons attract neutrons, etc. This is the force that overcomes the repulsive force within an atom due to the electromagnetic force and holds the nucleus together.

The **strong force actually acts between quarks**, and it's the residual strong force (similar to the residual electromagnetic force) that causes nucleons (particles in the nucleus of the atom) to attract. The carrier of this force is the gluon.

The next force we'll look at is the weak force.
The Weak Force:

All the stable matter in the universe appears to be made up of one type of lepton (the electron) and two quarks (the up and down), which compose the neutron and the proton. However, there have been six types of each that have been predicted and observed.



The reason why we don't observe these more massive quarks and leptons is due to the weak force. It is the weak force that causes massive leptons and quarks to decay into lighter leptons and quarks.

One more force to go, gravity.
Gravity:

Gravity acts between all particles that have mass. Mass will attract other mass with a force that gets weaker as the distance between them gets larger. Gravity is responsible for the large-scale structure of the universe. Here's a pretty picture of a galaxy, which, of course, is held together by gravity.

Although gravity appears to be a very powerful force, it is the weakest of the four fundamental forces.

Summary of Properties of the Fundamental Forces

See http://csep10.phys.utk.edu/astr162/lect/cosmology/forces.html

There are four fundamental forces that have been identified. In our present universe, they have rather different properties.

- The ***electromagnetic force*** causes electric and magnetic effects such as the repulsion between like electrical charges or the interaction of bar magnets. It is long-ranged, but much weaker than the strong force. It can be attractive or repulsive, and acts only between pieces of matter carrying electrical charge.
- The ***strong force interaction*** is very strong, but very short-ranged. It acts only over ranges of order 10^{-13} centimeters and is responsible for holding the nuclei of atoms together.
- The ***weak force*** is responsible for radioactive decay and neutrino interactions. It has a very short range and, as its name indicates, it is very weak.
- The ***gravitational force*** is weak, but very long ranged. Furthermore, it is always attractive, and acts between any two pieces of matter in the universe since mass is its source.

Additional information about quarks:

Until the early part of the nineteenth century, it was generally thought that what we now call the atom was the smallest constituent of matter. The word "atom" comes from the Greek for "uncuttable." The work of Wilhelm Roentgen, Marie Curie, Joseph Thomson, Ernest Rutherford, Niels Bohr and others led to the discovery of even smaller particles: the electrons, protons, and neutrons.

Recent work carried out at the sites of the largest particle accelerators has confirmed that these three atomic particles are themselves composed of combinations of even smaller constituents, which we call "quarks." (The name quark comes from the novel *Finnegan's Wake*, by James Joyce.)

Quarks:

There are six quarks that combine to make sub-atomic particles. They are named: up, down, charm, strange, top and bottom. If you think the names show that physicists have a sense of humor, you should also know that the unit of nuclear neutron-cross-section is the barn, because hitting tiny nuclei with neutrons is as easy as hitting the broad side of a barn. Quarks are studied in high-energy physics.

See http://www.essex1.com/people/speer/quark.html.

See http://www2.slac.stanford.edu/vvc/theory/quarks.html.