Interactions of Quarks and Gluons in a Proton

Document Overview: Students will interact with what the Standard Model is and what has been discovered in science. They will become familiar with the names and classification of the molecules in the Standard Model. Students will investigate the interactions of the forces that hold together quarks. They will use tarp ties and spring scales to look at how more/ less force affects the bonds of the force.

Minnesota State Academic Standards:
9.2.2.2.3 An object's mass and the forces on it affect the motion of an object.
Demonstrate that whenever one object exerts force on another, a force equal in magnitude and opposite in direction is exerted by the second object back on the first object.

9P.2.2.1.1 Forces and inertia determine the motion of objects.
Use vectors and free-body diagrams to describe force, position, velocity and acceleration of objects in two-dimensional space.

Objective:
Students will investigate how forces interact with each other to form bonds to make a quark. A quark is a fundamental element of a proton.

Type of Activity:
Literature analysis
Inquiry Lab

Duration: 2-40 minute class sessions

Connection to Nobel Speaker:
Theoretical physicist Frank Wilczek shared the 2004 Nobel Prize in physics with David Gross and H. David Politzer for their discovery of "asymptotic freedom," which holds that the closer quarks are to each other, the less the strong interaction (or color change) between them (and that when quarks are in extreme proximity, the nuclear force between them is so weak that they behave almost as free particles).

Teacher Tips:

Concepts:
- Overview of "The Standard Model"
- Quarks are "glued" together with gluons
- Closer the quarks are, less force holding them together
- Farther the quarks are, more force holding them together

Description of Activity:
- Students will learn about "The Standard Model" through chart analysis and a short reading exercise. They will gain an understanding of the small particles that make up an atom.

- Students will interact with the forces of a "quarks" and "gluons" to gain an understanding of when the bonds are strong and when they are weak. They will do this through an inquiry lab where they use bungee balls that they pull and measure the force between the bungee balls. (Lab Sheet below)

Materials:
Reading activity printouts
3 Bungee balls
3 Spring scales
3 Meter sticks
Calculator

Sources:
http://www.physik.uni-bielefeld.de/~yorks/www/teaching.html
http://www.livescience.com/13613-strange-quarks-muons-nature-tiniest-particles-dissected.html

Name: Class Hour: Date:

Title: Quarks and Gluons

Purpose: Demonstrate the interactions between quarks and gluons. Describe the change in energy as distance changes.

Vocabulary:
energy:

force:

gluons:

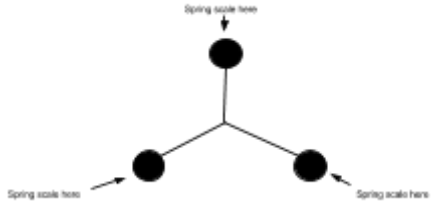
qualitative:

quark:

Procedure:
Note: You will need 3 different people pulling each ball and 1 person to measure distances

1. Attach the bungee balls so they form a triangle. Each bungee ball is a quark.
2. Attach a spring scale to each bungee ball.
3. Put a meter stick next to each ball
4. Pull the balls (at the same time) so all scales read 1N of force. Measure the length of the bungee cord from the center.
5. What qualitative observations can you make? (How does the ball feel as you are holding it? Does the force feel strong or weak? Is the ball pulling or pushing you?)
6. Measure the distance the balls are being pulled using the spring scale
7. Repeat measurements and qualitative measurements for each force on your data table
8. Calculate the energy (You can calculate k or use k=1)

Diagram:



Data:

Force (N)	Distance (cm)	Qualitative Observations	Energy $E=1/2k\Delta x^2$
1N			
2N			
3N			

Graph:

Conclusion: Describe the change in energy and force as distance changes using evidence from the experiment.

The Standard Model

Using the website, find the following information:
http://www.livescience.com/13613-strange-quarks-muons-nature-tiniest-particles-dissected.html

Draw and label the atom, nucleus and proton on the chart. On your drawing describe what each of the drawings is showing.

Explain how the atom, the nucleus, and the proton related in the picture.

Define matter using the website.

Define matter using another website.

What is a boson?

What are the names for the bosons?

What are the 3 forces of bosons called that are apart of the Standard Model?

What is the Higgs boson?

What is the Standard Model?

What are the particles called that make up the quark group?

How many quarks do you need to make up a proton?

What force holds a quark together?

Extensions:

- Have students make their own version of the above infographic
- Draw Helium balloon
- Zoom in and draw Helium atom, labeling subatomic particles
- Zoom on proton to draw quarks, labeling the quarks
- Video on Standard Model: Gives a visual and a description of the model. Show the math of how a proton has a +1 charge. Describes the reading from above and how the standard model works together.
    - http://www.youtube.com/watch?v=d1zaw-KZX1o
- Short Videos on "The Standard Model" in Minute physics
    - Higgs Boson, Part 1 (explains why the Higgs boson exists and why it took a while to discover) http://www.youtube.com/watch?v=9Uh5mTxRQcg
    - How does the Higgs field give mass? Part II http://www.youtube.com/watch?v=ASRpIym_jFM
    - Higggs Boson Part III: How to Discover a particle (Shows how scientists discovered the particle, picture of CERN lab, How scientists determine that a particle might exist) http://www.youtube.com/watch?annotation_id=annotation_540565&feature=iv&index=4&list=PLED25F943F8D6081C&src_vid=ASRpIym_jFM&v=6guXMfg88Z8
    - The theory of everything: (Intro to the model, Shows the math equation and how each part of the equation is more complex than it seems) http://www.youtube.com/watch?v=HVO0HgMi6Lc
    - The theory of Everything: What is Matter? (Describes electron behavior.) http://www.youtube.com/watch?NR=1&feature=fvwp&v=Fxeb3Pc4PA4
    - Every Force in Nature (Theory of Everything, Part III): Theory behind standard Model (Gives a good analogy of how energy can be created and how it relates to force. Not really standard model) http://www.youtube.com/watch?v=3_RhISgoXUs