Lesson Title	Boyle's Law
Length of Lesson	30 minutes
Created By	Lucas Pounders
Subject	Physical Science
Grade Level	9^{th} - 12^{th}
State Standards	1b,c,g; 2b,c
DOK Level	1,2,3,4
DOK Application	Recognize, observe, conclude, connect
National Standards	9-12 Science as Inquiry
Graduate Research Element	Pressure and Volume

Student Learning Goal:
This lesson is designed to help students to understand the significance of pressure and volume as it pertains to Boyle's Law. This will be done through the use of visual aids and lecture with discussion.

State Standards
INQUIRY
1. Apply inquiry-based and problem-solving processes and skills to scientific investigations.
- b. Identify questions that can be answered through scientific investigations.
- c. Identify and apply components of scientific methods in classroom investigations.
- g. Communicate effectively to present and explain scientific results, using appropriate terminology and graphics.

2. Describe and explain how forces affect motion.
- b. Explain the connection between force, work, and energy.
- c. Describe (with supporting details and diagrams) how the kinetic energy of an object can be converted into potential energy (the energy of position) and how energy is transferred or transformed (conservation of energy).

National Standards
9-12: Science as Inquiry Standards: Understanding about scientific inquiry
*Boyle's Law is an established law explaining the relationship between volume and pressure.

Materials Needed (supplies, hand-outs, resources):
For all of the experiments you will need:
- A working knowledge of Boyle's Law (P*V=constant for given gas.)
- A vacuum glass and vacuum
- Balloon or rubber glove for replacement

- 2 colors of food coloring
- water
- 2 pipets
- beaker
- Isopropyl Alcohol (an ounce for each experiment)
- Shaving Cream

Lesson Performance Task/Assessment:
Start off by asking the students what they know about pressure and volume. Then ask the students what they know about Boyle's Law. After receiving their answers to these questions and explain to them a generic problem of P1V1=P2V2. This is also a good time to provide the students with connections between Boyle's law and other aspects of force, pressure and volume such as kinetic and potential energy, Charles law and Bernoulli's Principle. Pull out the vacuum and vacuum glass. If you do not have access to a vacuum and glass you can also use a closed end syringe, or T-bar with hose and an Erlenmeyer flask. Lightly blow up the balloon or rubber glove and secure it to hold the air. Place it in the vacuum and ask them to draw this. Turn on the vacuum and allow the balloon to expand when fully expanded ask the students to draw this. Next move on to the colored water experiment. Mixed food coloring and water and draw the water into two separate pipets. Take the beaker and place a centimeter or two of water in the bottom. Show the students the pipets and the little bit of air in the bulb of the pipets. Ask the students what they think will happen with the water when placed in the vacuum. Place the pipets in the beaker with water and into the vacuum. Turn on the vacuum. Allow the vacuum to epand the air in the pipets and pull some of the air out of the pipets after the water. After the experiment is complete ask the students to record what they saw with the water and air. Ask them to then take it one step farther and ask them to provide a P2V2=P3V3 when the pressure is let back into the vacuum glass. Moving onto the Alcohol experiment. Pour an ounce or two of unused alcohol into a beaker and place it into the vacuum. Ask the students what they believe will happen when the pressure is taken off of the alcohol. Start the vacuum and allow the alcohol to boil. Explain to the students that the pressure keeping the molecules together in the alcohol is released making gas escape from the alcohol. Ask the students to draw what they have seen in terms of Boyle's Law. In the next experiment, explain to the students that Boyle's Law is at work in the shaving cream already being pressurized in the can. Shoot some foamy shaving cream into a beaker and place it into the vacuum. Ask the students what will happen to the shaving cream in the vacuum. By now they should be able to guess that the shaving cream will fill the vacuum. Perform the experiment and ask them to record their findings. After adding the pressure back into the system show the students the change in consistency in the foam and the current state of the cream.

Lesson Relevance to Performance Task and Students:
This lesson is designed to allow the students to ask questions and make their own assumptions about what is happening in the presented scenarios. It is then to be followed

up with facts about how the systems and how they work. In the end the students should have an understanding of the true correlations between pressure and volume as defined by Boyle's law.

Anticipatory Set/Capture Interest:
The anticipatory set used in this lesson comes in the from the questions asked at the beginning of the lesson. It also provides exciting visual for the students to allow them to see the effects that Boyle's law can have on in different systems.

Guided Practice:
This activity is done in a way that allows students to ask questions about the problem at hand as needed and come up with their own questions to find the answers.

Independent Practice:
Students can be given handouts associated with Boyle's law from their textbooks or other resources. They are also asked to write down and draw their own opinions of what is happening in each experiment as they are happening for discussion. These opinions are to be turned in at the end of the lesson or after elaborating on their opinions.

Remediation and/or Enrichment:
Follow Student IEP.

Check(s) for Understanding:
Ask the students both at the beginning and end of class for their understandings of pressure, volume and Boyle's Law. Their answers to these questions should show insight into their understanding of the subject material.

Closure:
Closure comes in the form of class discussion where the answer to questions asked for understanding can be left somewhat open ended or have a correct and definite answer. Also the students are to turn in their own opinions of the experiments and how Boyle's Law applies. These should be applicable interpretations.

Possible Alternate Subject Integrations:
Most all areas of science.

Teacher Notes:
Always be sure to run experiments before trying to attempt them in class.