NATIONAL MUSEUM
OF THE UNITED STATES AIR FORCE™

Math and Science with a Helium Balloon

Students will learn about motion and forces while experimenting with a helium balloon.

LESSON PLAN

Learning Objectives:

The students will:
- Attach weights to a helium filled balloon and launch it to the ceiling.
- Determine the net upward force caused by a helium filled balloon.
- Determine the area density of a uniformly thick piece of paper.
- Calculate the amount of paper needed to construct a weight for a downward force.

Purpose:

Students determine the upward force of a helium balloon and then use a downward force that allows the balloon to rise a specific distance. The amount of downward force is calculated and measured by using the concept of "area density". In a class contest, the slowest rising balloon is the winner.

Introduction:

Archimedes' Principle applies to bodies immersed in air, just as it does to bodies immersed in liquids. A body which is weighed by means of a spring scale, first in air and then in a vacuum will be found to weigh somewhat less in the air because it is buoyed up by the air about it. The apparent loss of mass of the body when in air is exactly equal to the mass of the air displaced by it. This difference is usually extremely small. However, large, hollow bodies, such as an air ship, actually displace somewhat more than their own mass, which explains why they float in air. Since the air is less dense at higher altitudes, a balloon ultimately stops rising at a level where the mass of the air it displaces is exactly equal to its own mass. The density of air at sea level is 0.001275 g/cm3. The lifting capacity of 10003 feet of helium is equal to about 29.5 kg. The density of helium is 0.0001786 g/cm3. Therefore, helium filled balloons will rise at ground level. Helium is an inert gas and is used in nearly all U.S. meteorological and scientific balloons. Helium is extracted from natural gas. Helium is one of lightest and least dense of all the chemical elements, thanks to the chemical stability and extremely small size of single helium atoms.

Grade Level: 9 - 12

Ohio Learning Standards/Science (2018)
Expectation of Learning
Nature of Science

High School: Physical Science
PS.FM.1: Motion
PS.FM.2: Force
PS.FM.3: Dynamics

High School: Physics
Motion
P.M.1: Motion Graphs
P.M.2: Problem Solving

Forces, Momentum & Motion
P.F.2: Gravitational force & fields
P.F.5: Air resistance & drag

Energy
P.E.1: Gravitational potential energy

Ohio Learning Standards/Mathematics (2017)
Number & Quantity Standards(-vectors)
N.Q.1: Use units as a way to understand problems
N.Q.3: Choose a level of accuracy
(+) N.VM.1: Recognize Vector Quantities

Algebra
A.SSE.1: Interpret expressions
A.REI.1: Explain each step in solving an equation
A.REI.3: Solve linear equations and inequalities

Materials Required:
- 1 balloon for each lab group
- Helium tank (contact a local supplier)
- String, plastic trash bags, masking tape
- Index cards (1st day)
- Colored construction paper (2nd day)
- Calculators, rulers, scissors
- Large paper clips and metal weights
- Triple beam balance, stopwatches

Procedure

A. Warm-up

1. Review the concept of buoyancy and gravity and how they will not be at equilibrium in the contest.

2. Go through the process of finding the area density of a piece of notebook paper.

3. Demonstrate how to determine the upward force of a balloon.

4. Explain the rules for the race and announce the prize for the winning group.

5. Remind the student that helium is escaping through the skin of the balloons so the upward force is always changing. To reduce the loss of helium, try not to handle the balloon or let it touch the surface of any object.

B. Activity

1. Determine the net upward force exerted by the helium filled balloon to which a string and paper clip are attached. A paper clip is at the end of the string exactly 50 cm from the balloon.

2. Put a known mass on a balance. Then attach the balloon to the mass on the balance with the paper clip. The difference between the mass alone and the mass attached to the balloon is the upward force.

3. Determine the area density of the index card that you will be using for a weight. Area density is equal to the mass of the card divided by its area. Record the area in g/cm2.

4. Calculate the amount of paper needed to construct a weight which, when attached to the balloon, can be lifted by the balloon. It is suggested that you take 90-99% of the upward force to ensure a slow rise. Try different percentages of the upward force for the downward force.

5. Construct the weight from the assigned material and verify its mass by using the balance. Paper weights may be bent into any shape. A flat edge must be provided so that it can be attached to the paper clip.

6. If the weight falls from the clip during the rise of the balloon, the student will be permitted to restart the rise.

7. Attach the weight to the paper clip and touch the paper to the floor. On a signal from the timer release the paper and balloon. **No rise time points will be given if:**

    a. The assembly fails to rise.
    b. The balloon does not touch the ceiling within four minutes.
    c. The paper touches the floor after the release.

C. Wrap-up

1. After each lab group has had a turn in the race, complete the data table. Make sure that calculations are correct.

2. Record each group's rise time on the board. Announce the winners (the team with the slowest rise time).

Assessment/Evaluation:

Students will turn in one data sheet per lab group. They will be evaluated by the rise time and the accuracy of calculations.

Extensions:

1. Draw a vector diagram of the forces involved in their balloonrise.

2. Calculate the speed of their balloon. Calculate a class mean.

3. What could you do to make the rise time better (i.e. slower)?

4. What problems did you have with the calculations?

Resources/References:

Helium/Helium Balloons:

https://www.livescience.com/55358-unusual-facts-about-helium.html

https://www.sciencekids.co.nz/sciencefacts/chemistry/helium.html

https://www.chemicool.com/elements/helium-facts.html

Archimedes' Principle:

https://physics.weber.edu/carroll/archimedes/principle.htm

https://courses.lumenlearning.com/boundless-physics/chapter/archimedes-principle/

Helium Balloon Race

Names:____

Lab Group #________

Balloon Race	
Area of paper material – one piece (length x width)	cm^2
Mass of paper material – one piece	g
Area density of paper material – one piece (mass/area)	g/cm^2
Upward fore of the balloon (mass of the metal weight minus the mass of the weight attached to the balloon)	g
Mass of the paper used for a downward force attached to the balloon	g
Area of paper used for the downward force (mass of paper divided by the area density)	cm^2
Rise time	seconds