Backyard Ballistics Teachers Guide

Lesson Plan: The Jellyfish of the Sky

Objective:

The Jellyfish of the Sky is a project that will serve as a springboard towards investigation into the properties and behavior of fluids. Specifically, this lesson plan illustrates ideas of buoyancy, density and volume. The Jellyfish of the Sky is a hot air balloon with a small heater made from jellied alcohol.

Concepts:

Buoyancy

Buoyancy is the lifting force derived from immersing a body in a fluid of less density. The ancient scientist Archimedes is credited for first explaining the idea. He said that when an object is immersed in a fluid (like a helium balloon in a roomful of air) the upward force on an object is equal to the weight of the fluid the object displaces.

Archimedes Law says that the upward force on an object like a balloon is equal to

Equation 1: $\text{Force}_{\text{buoyant}} = (\text{Volume of Air displaced}) \times (\text{Density of Air})$

The density of air can be calculated from the ideal gas law*

Equation 2: $\text{Density}_{\text{air}} = \text{atmospheric air pressure} / (\text{Gas Constant} * \text{Temperature}_{\text{Air}})$

For example, at atmospheric air pressure of 14.7 psi, an air temperature of 40 degrees F (which is 500 degrees R, which must be used in ideal gas laws), and using the gas constant for air which is 53.3 ft-lbf/lbm-R, the density of air is calculated form equation 2 to be:
$\text{Density}_{\text{air}} = (14.7 \text{ psi} * 144 \text{ inches}^2/\text{feet}^2)/53.3 * 500 = .079 \text{ lbm/ft}^3$

* The ideal gas laws is high school level physics and chemistry topic. Consult appropriate text books if more information is desired.

Field Work

Archimedes Law explains why hot air balloons rise. To illustrate this concept make the dry cleaner bag balloon in accordance with the instructions found in chapter 9 of the book **Backyard Ballistics** by William Gurstelle (Chicago Review Press, 2001).

When the air in the dry cleaner bag is first warmed it is at the same temperature as the surrounding air. There is no buoyant force. After time though, the air inside the bag becomes warmer than the surrounding air.

Assume that after some time, the air inside the bag is warmed to 160 degrees F which is 620 degrees R.

From equation 1, the density of the air inside the balloon is calculated:

$$\text{Density}_{air} = (14.7 \text{ psi} * 144 \text{ inches}^2/\text{feet}^2)/53.3 * 620 = .064 \text{ lbm/ft}^3.$$

Remember, at 40 degrees F, the density of air was .079 lbm/ ft^3. So, the air inside is about 20 % less dense than the air outside.

Measure or estimate the volume of the dry cleaner bag balloon you plan to use. Assuming a volume for a particular bag of 6 cubic feet, then Archimedes Law tells us that the upward force exerted by buoyancy on the balloon is:

$\text{Force}_{buoyant}$ = (Volume of Air displaced) x (Density of Air) = 6 ft^3 X .079 lbm/ft^3 = .474 lb

But the heated air still has its own weight. The downward force due to the weight of the heated air inside balloon is:

$\text{Force}_{gravity}$ = (Volume of Bag) x (Density of Heated Air) = 6 ft^3 X .064 lbm/ft^3 = .384 lb. So, the upward buoyant force is .474 lb up. The downward gravitational force is .384 down.

Subtracting the difference is the net lifting force: .474 - .384 = .09 lb.

So if the dry cleaner bag balloon weighs less than .09 lb the balloon will rise. If the bag weighs more than that, it will not rise. The trick to making the balloon rise is to use very light materials.

Backyard Ballistics (ISBN: 1556523750) is available from most bookstores, online, and from the publisher
Sales: orders@ipgbook.com