Drexel-SDP GK-12 ACTIVITY

Subject Area: Science

Associated Unit: Weather and Aeronautics

Lesson Title: Up, Up and Away! Introduction to Density and the Forces of Flight

Grade Level _6_ (_5_-_8_)

Lesson # _2_ of _10_

Lesson Dependency Lessons 1 through 10 of the Weather and Aeronautics Lesson and Activity Group

Time Required: 2 Hours

Summary

We continue our discussion of the foundations of aviation by investigating the principles of density and buoyancy. In particular, we manipulate the density fraction by changing the volume of a PVC pipe and observing that it will float. Alternatively, one can manipulate density and buoyancy by changing the density of the water, for example, by adding salt to it as in the ocean. This has connections to the movie *An Inconvenient Truth*, in which the global ocean current is illustrated as sinking cold, salty, dense water and rising warm, fresh water. Students will explore at what point an object will float in water.

After that, we extend the properties of water into a discussion of the properties of air. We will explore Bernoulli's Principle with the ping-pong ball experiment, and demonstrate the forces involved with keeping a wing afloat. Props can be as simple as pieces of paper and as elaborate as actual wing structures.

Engineering Connection

The aeronautics course is intended as a multi-disciplinary course in physics, math and history of aviation. Navigation, forces of flight, principles of flight, history of flight, and environmental factors (including weather and landforms) are specifically investigated. The core curricular items are emphasized, and aviation is considered an underlying theme. The intent is to provide grounding to the curriculum components learned in a typical K-12 school year. Aviation easily generates a lot of excitement among this age group, and as a result, measurable results are expected in these subjects.

Keywords

- Aeronautics
- Weather
- Aviation
- Flight
- Bernoulli's Principle
- Air
- Cloud Formations

PA Science Educational Standards

- 3.1.7A Explain the parts of a simple system and their relationship to each other.
- 3.1.7B Describe the use of models as an application of scientific or technological concepts.
- 3.2.7A Explain and apply scientific and technological knowledge.
- 3.2.7C Identify and use the elements of scientific inquiry to solve problems.
- 3.4.7C Identify and explain the principles of force and motion.
- 3.5.7C Describe basic elements of meteorology.
- 3.5.7D Explain the behavior and impact of the earth's water systems.

Pre-Requisite Knowledge

None

Learning Objectives

After this lesson, students should be able to:

- Manipulate density by changing volume or mass to cause one object to float within another.
- Identify the general motion from high pressure to low pressure.
- Apply Bernoulli's Theorem to practical situations, such as a garden hose or airplane wing.

- Identify the source of the forces of lift in flight, as a result of the properties of air as a fluid.

Introduction / Motivation

The purpose of this lesson is to use a series of experiments and activities to discover the properties of water and air as fluids. Once the analogy is drawn between water and air, students explore one of the basic forces of flight: lift, as provided in part by Bernoulli's Principle.

Lesson Background & Concepts for Teachers

Density. Let's review the concepts from the introductory lesson, in which we used aluminum foil to wrap a PVC pipe so that it floats in water. What made it suddenly float in water? By adding tin foil, we caused the pipe to displace its own weight in water. But how? This doesn't tell us anything about how this was possible. Let's look instead at the density fraction. Recall that an item of smaller density will float in a fluid of higher density. So the density (weight / volume) of the unwrapped PVC pipe was higher than that of the water. But when we wrapped it up, the density became less. How can we make a fraction like density smaller? By either decreasing its numerator (weight) or increasing its denominator (volume). Which did we change by wrapping it up? We didn't change the weight very much, in fact we made it slightly heavier! So we must have decreased the volume. Surely, by covering the holes, we create a higher volume cylinder than with the donut we had before.

Buoyancy. How about making the coke can float in water? We can't really change its weight or its volume, since it is sealed. Changes to the water's volume won't help us too much unless we add a *lot* of water, and this will add to its weight! But we can change the water's weight by adding salt, which would not change its volume. Salt changes the density of the water by increasing it. Eventually, the can of soda will become less dense than the salty water, and it will float.

Air Properties. How do these ideas extend to the air around us? When you push on your desk, you can feel the pressure exerted from your hand and from the desk. When you fill a bottle of water, the water expands, in other words, it fills the bottle as completely as it can. If the bottle were wider, the liquid would fill it, too. This is because the water is pushing on the sides of the bottle, or exerting pressure, just like your hand on the desk.

Air has pressure, too. You see this every day as well, but may not notice it as readily as you would with the examples above because you cannot see air. Take a water bottle and pretend to drink it, but use air to keep the water in the bottle. Here, you are using air to push against the water, just like you used your hand to push against the desk. The water stays in the bottle because the air is holding it there. Release the air, and the water flows through the bottle.

We demonstrate this principle by trapping air in a bottle with clay, and then sucking the air from the bottle through a straw. We say that the bottle is "empty," when it is really full of air! When we take air out of the bottle, room is made for the water to flow into the bottle through a funnel.

When we took air out of the bottle, the air density inside the bottle decreased. What does this mean? Basically, there are less air molecules (because we took some out!) inside the bottle, which means that they can spread out more. As a result, they won't push as hard on the sides of the bottle, meaning that the pressure inside the bottle has decreased as well.

This is why the water rushed into the bottle -- the pressure was lower inside the bottle, and things move from areas of high pressure to lower pressure. In other words, the water wants to take up the extra space left over from when we took out some of the air. How much water will go in?

Take a look at the funnel to see. The water goes into the bottle until the pressure goes back to what it was before.

As we will see in the next experiments, we can take advantage of pressure to make things move for us. Does this give you any clues about what makes things fly?

1. Put the funnel into a bottle that is otherwise sealed with clay, trapping air inside the bottle. Now suck some of the air out of the bottle.
2. Take a piece of paper and hold it up to your lower lip. What do you think will happen when you blow over the top of the paper? Why? Blow over the top of the paper. What happens?
3. Take a ping pong ball and hang it from a string. What do you think will happen when you blow on the front of it? The side? Actually do this, what happens?
4. Now take the two ping pong balls, tape each one to a piece of string, and hang them from a desk or something else. What do you think will happen when you blow between the ping pong balls? Why? Blow between the ping pong balls. What happens?

The paper actually blows upward when you blow on it. This is not what you might expect. Not only that, but the ping pong balls move towards each other when you blow between them, only moving away if they actually bounce off of one another. So why did this happen?

Bernoulli. Bernoulli's Principle says that when something like air or water flows over a surface, it exerts less pressure the faster it goes. You might say that it's going so fast, that it doesn't have time to stop and push on the surface.

So now we can use this to make an airplane wing that can lift through the air. But air passes above *and* below a wing, so we're going to have to deal with that somehow. Let's take a look...

Extensions to Flight. Airplane wings come in all different shapes and can fly for a number of reasons. Let's look at one popular reason common to most airplanes.

This wing is curved along the top and straight on the bottom. Which path is longer, the line over the top or the line below the wing? The line over the top is longer. So if you blow onto this wing like you blew on the piece of paper earlier, you would expect the air to move faster over the top. Why? Because it has to move further over the curve (remember the shortest distance between two points is a straight line!).

That’s great, but now remembers that when air moves faster, it creates less pressure. And you remember that things want to move from low pressure to high pressure. So the wing is going to want to push upward because of all this. That's lift! And that's part of the story of what makes airplanes fly. In later lessons we will learn how to control airplanes, and how they navigate through our skies each day. We will even model and build our own airplane to test in a wind tunnel that simulates blowing air over the wing surfaces.

To test the idea, take the same piece of paper you used earlier and shape it like this wing. Blow on it and notice that it moves upwards!

Lesson Summary Assessment

1. Given an egg, a bottle, and heat we will provide, how can you make an egg pull into a bottle? (Fire removes oxygen from the inside of the bottle, reducing density and pressure, causing the egg resting on the bottle to pull inside.)

2. Given a plate of water, a glass, and heat we provide, how can you make the plate pull into the glass? (Same as above.)

References

AOPA Path: Pilot's and Teacher's Handbook. http://www.aopa.org/path/.

SynergyLearning: http://cf.synergylearning.org/displayarticle.cfm?selectedarticle=225.

AIAA Activity Book. http://www.aiaa.org/kidsplace/kidsplacepdfs/sciact.pdf.

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