Lesson Plan 2

**Title: Pressure, Buoyancy, and Archimedes’ Principle Lecture and Activity**

* Subject: Physics
* Estimated Time: 45minutes
* Grade Level: 9,10,11,12
1. Overview
* Summary of Events:

Students will perform a short lab activity which investigates the fundamental physics behind pressure in fluids, buoyancy forces, and Archimedes’ principle. After a short lecture the students will be tasked with discovering which shapes of cardboard provide the most buoyancy in water. A large piece of cardboard, a series of masses, and a container of water will be given to each lab group. The students must use the principles of buoyancy, pressure, and force to investigate how area is related to the buoyant force of an object floating in water. The lab activity involves taking measurements of the area of small cardboard cutouts and the mass of steel weights to illustrate how the buoyant force of a cardboard cutout floating on water changes with area. The steel weights vary from 1-100g. The students will place steel weights on their floating cardboard cutouts until they sink and from this determine the buoyant force. This lab activity allows the students to predict and verify the optimum mass to area ratio of cardboard floating on water in order to prepare them for designing a large scale cardboard boat for a card board boat race.

* Materials List: (for each group)
* Box of paper clips or steel masses from 1-100g
* Mass scale
* Meter Stick
* Medium size (6inx6inx6in) Tupperware containers
* Access to water
* Scissors or box cutters
* Cardboard sheet, 2x2ft
* Incorporated Standards:
* Safety Issues:
* Scissors and box cutter blades are very sharp, students should use extreme caution when cutting the cardboard. Remind them to always cut away from themselves.
1. Useful Information
* Background

Archimedes of Syracusewas a Greek mathematician, physicist, engineer, inventor, and astronomer. Although few details of his life are known, he is regarded as one of the leading scientists in classical antiquity. Among his advances in physics are the foundations of hydrostatics, statics, and an explanation of the principle of the lever. He is credited with designing innovative machines, including siege engines and the screw pump. He is also known for a principle involving the buoyant force of a fluid known as Archimedes’ Principle. Objects immersed in a fluid such as water appear to weigh less than they do when they are not in the water. This is due to the buoyant force exerted by the liquid on the immersed object. Archimedes is credited with discovering that the buoyant force on an object is equal to the weight of the displaced fluid. It is said that he discovered this principle while taking a bath and trying to think of a way to determine whether the new crown of King Hiero II was pure gold or if some silver had been substituted in the gold’s place. He noticed that the level of the water in his bath tub rose as he got in and realized that this could be used to determine the volume of the crown. One can assume in most cases that water is incompressible and thus the submerged crown should displace an amount of water equal to its own volume. The mass of the crown could be divided by the volume resulting in the crown’s density. If this density was less than that of gold then the metal would be something other than pure gold. It is said that once Archimedes discovered this principle he took to the streets naked with so much excitement he began shouting Eureka!(meaning “I have found it!”). Archimedes’ Principle is so important that all ship and boat designers still employ it heavily to this day.

Archimedes’ Principle may be stated as:

*The buoyant force on an object immersed in a fluid is equal to the weight of the fluid displaced by that object.*

Some useful equations and constants:(see derivation sheet for explanations)

1. ρ=m/V
2. F=ma
3. P=F/A
4. P=ρgh
5. P=Po+ρgh
6. FB=mg
7. FB=ρH2OVg
8. Vdispl/Vo=ρo/ρF
9. ρH2O=1000kg/m3
10. ρair=1.29kg/m3
11. ρHe=0.179kg/m3
12. ρHg=13.6x103kg/m3
13. 1lb=4.448N
14. 1mm-Hg=133N/m2
15. 1bar=1x105N/m2
16. 1atm=760mm-Hg
17. Po=1atm=1.013x105N/m2=101.3kPa

Vocabulary

1. Acceleration (**a**): this is the change in velocity per unit time, or how fast the velocity is changing. This is a vector quantity and usually represented in meters per second per second, m/s/s.
2. Acceleration due to gravity (**g**): this is a constant g. On Earth g=9.81m/s/s.
3. Area: a quantity describing the extent of a two dimensional surface, usually in m2.
4. Axis: this refers to the horizontal (x-axis) or the vertical (y-axis) in a two dimensional Cartesian coordinate system.
5. Buoyancy: an upward force exerted by a fluid that opposes the weight of an immersed object.
6. Density(ρ): defined as the mass per unit volume of a substance.
7. Force (**F**): this is the outside influence which causes a mass to change its direction, acceleration, or shape. In this case, direction and acceleration. This is a vector quantity and usually represented in Newtons, which is a kilogram-meter per second per second, N=kg\*m/s/s.
8. Gravitational Force (**F**g): This is the force exerted by the mass of one object on the mass of another object where both objects are separated by a certain distance, in this case the Earth on the steel ball. This is a vector quantity.
9. Gravity: the phenomenon by which all objects with mass are attracted to one another, this is what gives objects with mass weight.
10. Mass: a quantity which represents the amount of matter in a body, also you could say the property of a body which represents the amount of resistance to being accelerated by an external force. This is a scalar quantity and usually represented in kilograms, Kg.
11. Origin: the crossing/intersection of the x-axis with the y-axis.
12. Pressure: defined as the force per unit area exerted on an object, the force is acting perpendicular to the surface area.
13. Scalar: a quantity which is described by a number.
14. Specific gravity: the ratio of the density of an object to the density of water at 40C.
15. Vector: a quantity which is described by a number and a direction.
16. Vertical: the direction which is aligned with the gradient of the gravity field, rather the direction which is aligned with the direction of gravity.
17. Volume: a quantity describing the amount of three dimensional space enclosed by a certain closed boundary.
18. Weight: this is the force on an object due to gravity. One way to define this is **W**=m**g**.
* References/Resources
* Wikipedia, this is a great resource if you want a fast and general understanding of most physical topics.
* Hyperphysics, this is a website about physics created by Georgia State University, also a great website for fast and a bit more detailed physics topics. <http://hyperphysics.phy-astr.gsu.edu/hbase/hframe.html>
* A great book which many undergraduate science majors use and my undergraduate professor helped write is, Physics for Scientist and Engineers, 4th edition, Douglas C. Giancoli, 2008. This will be a higher level of math, but has a lot of good examples and homework problems.
1. Lesson Outline
* General Introduction(5-10min depending on if you use the video)
* Audience and Knowledge Review(5min)
1. In this case just ask if anyone has heard of Archimedes’ Principle
2. If no one has heard of it, ask can anyone tell me what happens to the water level when you get into a bath tub?
3. Why does the water level rise?
4. How much volume of fluid is displaced?
5. What force causes this volume to be displaced?
6. Then ask does anyone know why boats float?
* Whiz Bang: Video on Archimedes Principle by TedEd on Youtube : http://www.youtube.com/watch?v=C-h2W1\_4ptE&feature=player\_embedded
* Transition Sentence

Today we are going to take a look at pressure in fluids, the buoyant force, and Archimedes’ Principle. First I am going to go over some material so you will need to take notes (introduce the boat race during the lecture section). After this you guys are going to do a short lab activity and investigate how the area is related to the buoyant force.

* Instructional Transition
* Lecture(see written notes)
* Density, Specific Gravity, and Force
	+ - * Define density then give the formula, ρ=m/V
			* Define Specific Gravity then give the formula and density of water, SG=ρ/ρH2O, ρH2O=1000kg/m3
			* Define Force, F=ma=mg= ρVg
* Pressure
	+ Define pressure and give formula, P=F/A
	+ Give the units of Pressure, N/m2 or Pascal(Pa)
		- * Show P= ρgh using F= ma=mg= ρVg and P=F/A
	+ Explain how an object in a fluid feels pressure on all sides, pressure exerts a force perpendicular to all surfaces
	+ See derivation of pressure on an object a certain depth below the surface of a fluid
* Buoyancy and Archimedes’ Principle
	+ Define buoyancy and Archimedes’ Principle(see background)
	+ See derivation of buoyant force on submerged object
	+ See derivation of buoyant force on floating object
	+ Explain the density ratio and how this relates to the fraction of object submerged(see derivation)
* Inquiry Activity(30-35min)
1. Transition Sentence: Now that we have gone over some of the ideas behind Pressure and Buoyancy I want you to investigate how the area of a floating object is related to the buoyant force.
2. Worksheet( have the group worksheets already out and then hand them the homework worksheet as they go out the door or sometime towards the end, don’t want to overwhelm them with work before they finish)
3. Assessment
* The assessment questions are included in the introduction of the lecture and at the end of the lab activity, see the Audience section and the lab worksheet and the homework worksheet.
1. Closure(5min)
* This should relate to going over the rules and timeline of the boat race activity see the boat race guidelines sheet.
1. Modifications
* See Extended Time
1. Contingencies
* Drawing on the board is always a good tool for this type of lab
1. Extended Time(5-10min depending on how much time you have left)
* This lab is already is not you could incorporate the following:
* Start the homework sheet early
* Have them investigate which shapes of cardboard travel the fastest across the water
* Start splitting them up into teams for the large scale boat race and have them decide on team names and schedules and go over the boat race rules