Lab 13: Density and Bouyancy

Objectives:
- To practice estimating and combining uncertainties
- To understand density
- To understand the buoyant force
- To be able to measure the buoyant force

Equipment:
- Ruler
- Balance
- Meter stick
- Vernier calipers
- Graduated cylinder or beaker
- Ping-pong ball
- Superball
- Clay
- Spill can
- Spring scale
- String

Investigation 1 Density measurement

In Lab 1, you learned how to make a precise measurement of density. You first measured the mass and volume of an object, including an appropriate estimate of the uncertainty. Then you then calculated the density, ρ, by dividing the mass by the volume, $\rho = m/V$, and combined uncertainties as in Section 3.5 in the Introduction to the Lab Manual to report the density as ρ +/- $\Delta\rho$.

Investigation 1.1 Carry out the same kind of measurement to calculate the density, including the uncertainty, of the two balls at your table: one is a ping-pong ball and the other is a superball, both of the same volume (within uncertainty). Record your measurements and show your work below and on the next pages.

The volume of a sphere is $V = 4/3\ \pi\ r^3$.

Measurements for ping-pong ball

Mass measurements: ____________ ____________

____________ ____________

____________ ____________

____________ ____________

____________ ____________

average mass ping-pong ball _____________ uncertainty in mass _______________

diameter measurements: ____________ ____________

____________ ____________

____________ ____________

____________ ____________

____________ ____________

average diameter ping-pong ball __________ uncertainty in radius _______________

average radius ping-pong ball ____________ uncertainty in radius _______________

average volume ping-pong ball ___________ uncertainty in volume ______________

density of ping-pong ball_____________ uncertainty in density_______________

Measurements for superball

Mass measurements: ___________ ___________

___________ ___________

___________ ___________

___________ ___________

___________ ___________

average mass superball ____________ uncertainty in mass ______________

radius measurements: ___________ ___________

___________ ___________

___________ ___________

___________ ___________

___________ ___________

average diameter superball _________ uncertainty in radius ______________

average radius superball ___________ uncertainty in radius ______________

average volume superball __________ uncertainty in volume _____________

density of superball____________ uncertainty in density______________

Exploration 1 Bouyancy

Exploration 1.1 Take a graduated cylinder or some other graduated container (beaker, plastic pitcher, etc.) and measure its mass empty. Then fill it to a designated level and measure the mass. Calculate the density of water and compare it to the densities of the balls. Predict what will happen to the balls if they are placed in water. Write your conclusions in the space below.

Exploration 1.2 Using a beaker or other container large enough to hold both balls at once, place the balls in water to test your prediction. Was your prediction correct?

Exploration 1.3 Draw a force diagram of all the forces acting on each of the balls in the space below.

Superball Ping-pong ball

The upward force of the water on the ball is called the buoyant force.

Exploration 1.4

Determine the net force on each ball. Show your work or explain your reasoning.

Determine the magnitude of the buoyant force on each ball, if possible. If not possible, explain why. Show your work or explain your reasoning.

Exploration 1.5

Hang the superball in air from a string from a spring scale. Determine the weight of the superball.

Hang a superball from a string from a spring scale with the superball submerged in water.

Draw a force diagram for the superball hanging from the spring scale and submerged in the water in the space below.

From your force diagram and the two scale readings (in and out of the water), determine the buoyant force on the superball in this case.

Exploration 1.6 Do your answers to exploration 1.4 and 1.5 agree for the superball? Explain.

Exploration 1.6 Can you think of another way to measure the buoyant force than in Exploration 5?

Exploration 2

Exploration 2.1 Can you change the buoyant force on each ball? Explain how.

Exploration 2.1 Press down on one of the balls in the water. Does the buoyant force change? Explain. Note that as you press down more water is displaced.

Exploration 2.3 Submerge increasingly greater portions of the ping-pong ball in the water and then release it release. Does this tell you anything about the buoyant force? Can you conclude anything about the buoyant force in terms of the water displaced?

Investigation 2 Bouyant force

We're going to explore the relationship between the buoyant force and the amount of water displaced.

Fill a spill can to the top and gently lower (not dropping) one of the balls into the spill can. Make sure that the water is at the end of the spout of the spill can and is being held in place by surface tension to minimize error. Catch the overflow in a graduated cylinder and calculate the mass of the overflow water.

Calculate the weight of the overflow water.

Compare the weight of the overflow water the weight of the pin-pong ball. Are they equal? (Should they be, base don Exploration 1.4?)

Because this activity requires some patience and skill it tends to have a high error. Do the experiment a number of times and calculate the uncertainty in your measurement. Show your measurements and calculations on the next page.

	Volume of overflow water	Mass of overflow water	Weight of overflow water
Trial 1			
Trial 2			
Trial 3			
Trial 4			
Trial 5			
Trial 6			
Trial 7			
Trial 8			

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average weight of overflow water___________ uncertainty in weight_______________

Archimedes' Principle states: *The buoyant force is equal to the weight of the fluid displaced*.

Are your data in agreement with Archimedes' Principle?

Investigation 3 Don't rock the boat

Each group needs a large glass beaker. Along one side of the beaker attach a piece of masking tape to the side of the beaker. The tape should be vertical. Fill the beaker about half to three-quarters full of water and mark the water level on the tape.

Get a small amount of clay. Make a small boat from the clay and place it in the water. Be sure that the boat doesn't leak or take on water in any way. Once again mark the level of the water on the tape.

Discuss among you group what will happen to the water level if the boat were to sink. Record your prediction in the space below.

Once you have reached a consensus, sink the boats and mark the water. Did the water level rise, drop, or remain the same? Explain why.