Workshop Tutorials for Introductory Physics

PI2: **Buoyancy and Density**

A. Review of Basic Ideas:

Use the following words to fill in the blanks:
higher, volume, flow, gases, mass, equal, buoyant, liquids.

Fluids, floating bodies and density

Fluids play an important role in our everyday life. We drink them, breathe them, swim in them; they circulate through our bodies, they control our weather, aeroplanes fly through them, ships float in them. The list goes on and on. A fluid is any substance that can _______; we use the term for both _______ and _______. We usually think of a gas as easily compressed and a liquid as nearly incompressible.

The density of any material is defined as its_______ divided by _______. Measuring density is an important analytical technique. For example, we can determine the charge condition of a storage battery by measuring the density of its electrolyte, a sulfuric acid solution. As the battery discharges the density decreases from about 1.30×10^3 kg.m^{-3} for a fully charged battery to 1.15×10^3 kg.m^{-3} for a discharged battery.

This measurement is performed routinely in service stations with the aid of a hydrometer, which measures density by observation of the level at which a calibrated body floats in a sample of the solution. The solution exerts an upward force, on the hydrometer, called the _______ force. The calibrated float sinks into the fluid until the weight of the fluid it displaces is _______ to its own weight which is also equal to the buoyant force. This is Archimedes' principle for floating bodies. The hydrometer floats _______ in denser liquids than in less dense liquids. It is heavier at its bottom end so that the upright position is stable, and a scale in the top stem permits direct density readings.

B. Activity Questions:

1. Archimedes and the king's crown

Repeat the experiment done by Archimedes. Use the overflow of water to measure the volume of the crown to find its density. A table of densities of different materials is provided.
Do you have a gold crown in your hands? What do you hold in your hands?

2. Buoyant force

An object is suspended from a spring balance. Will the reading on the spring balance be different when the object is in air compared to when the object is immersed in water? Draw a diagram showing the forces acting on the object to help explain your answer.

3. Hydrometers

There are hydrometers and several liquid samples on the activity benches. Walk over and take a few measurements. Can you identify the samples from the table of densities given below?

a. Why does a hydrometer float higher in denser liquids?

b. Identical hydrometers are placed in three different liquids. They float at different levels. Is the buoyant force on the hydrometers the same or different? Why?

c. Say you are using a hydrometer that has been designed so that the lowest density it can measure is that of water. This hydrometer sinks in kerosene. Why?

d. How would you alter this hydrometer to measure the density of kerosene?

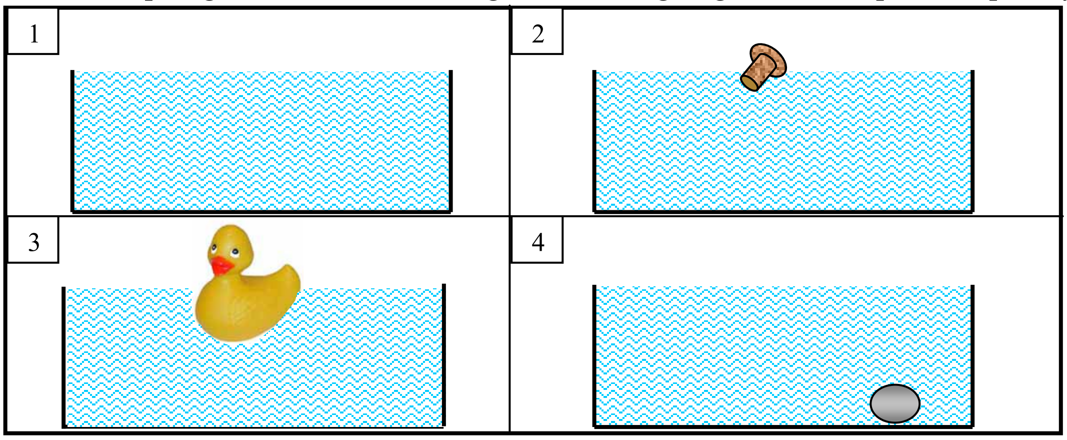
4. Cartesian diver
What happens to the diver as you push on the bottle? Why?
What controls the motion of the diver?

C. Qualitative Questions:

1. When you join a gym you may have a skin fold test done to tell you how much of your body is fat. A more accurate, but less pleasant, means of measuring body composition is via submersion in water. The person is weighed in air and then weighed again when completely submerged in water. (Don't try this at home!)

a. Explain how this process can be used to measure average density.
b. Why is it important to breathe out as much as possible when doing such a test?
c. In general, women float better than men. Why do you think this is the case?
d. Why is it easier to float in very salty water, for example the Dead Sea, than in fresh water.

2. The figure below shows four identical open-top containers. One container has just water. A cork floats in another container and a toy duck floats in the third. The fourth container has a steel marble in it. All four containers are filled to the brim with water. The containers are now placed on separate weighing scales without spillage. How do the readings on the weighing scales compare? Explain your answer.



D. Quantitative Question:

In February 1995, an iceberg so big the entire Sydney region from the coast to the Blue Mountains could fit on its surface broke free of Antarctica. The iceberg was approximately rectangular with a length of 78 km, a width of 37 km and 200 m thick.

a. What fraction of this iceberg was underwater?
b. Do you actually need the shape and size of the iceberg to determine this fraction?
c. The "unsinkable" Titanic was sunk by an iceberg. Why do icebergs present such a problem for shipping?
d. Would icebergs be a problem if water density increased on freezing, like most other liquids?

TABLE OF DENSITIES

Ice	917 kg.m^{-3} (at 1 atm and 0 °C)
Sea water	1024 kg.m^{-3} (at 1 atm and 20 °C)
Water	998 kg.m^{-3} (at 1 atm and 20 °C)