FLUIDS

OBJECTIVE: To determine the densities of several solids and a liquid; to measure buoyant force; to become acquainted with Archimedes' Principle.

THEORY:

1. **Density** is simply defined as the mass per unit volume. It is the mass, m, of a certain quantity of material divided by the volume, V, it occupies:

$$\rho = m / V \, . \quad (1)$$

2. **Pressure** is defined to be the perpendicular force, $F_\perp$, on an area divided by the area, A:

$$P = F_\perp / A \, . \quad (2)$$

Any gas or liquid confined to a volume is going to exert a force on the walls of its container as it tries to spread out. This force will then cause a pressure. In the absence of gravity (real or artificial), the pressure will be the same everywhere in the gas or liquid under static conditions.

3. In the presence of gravity, the material (whether liquid or gas) will push down on the material below because of its weight, causing more force and hence more pressure. It is shown in your text that a simple formula describes this: the difference in pressure (ΔP) due to a difference in height (Δh) is equal to the density of the material (ρ) times the acceleration due to gravity (g) times the difference in height:

$$\Delta P = \rho \, g \, \Delta h \, . \quad (3)$$

4. An object placed in a gas or liquid will then experience a buoyant force (F_B) because the pressure on its lower surface will be greater than the pressure on its upper surface. This difference in pressure will cause a net upward force which is the buoyant force. It is shown in your text that the net buoyant force on an object in a gas or liquid is equal to the weight of the gas or liquid displaced by the object:

$$F_B = m_{fluid} \, g = \rho_{fluid} \, V_{object} \, g \, . \quad (4)$$

This is **Archimedes' Principle**.

Part 1: Density

PROCEDURE:

1. There are four cylinders: one of copper, one of brass, one of steel, and one of aluminum. Using the balance and calipers and definition of density above (Eq. (1)), determine the density of each cylinder.

2. There are two liquids available: water and an unknown (a cleaning solution). Determine the densities of these two liquids using the definition above (Eq. (1)) together with the balance and - instead of the calipers which don't work well for a fluid - the graduated cylinder. [Caution: Be sure you determine the mass of the fluid only, not the mass of the fluid and container!]

Part 2: Buoyant Force and Archimedes' Principle

PROCEDURE:

1. For each of the four cylinders, find the "apparent weight" while the cylinder is immersed in water using the following procedure. First, be sure the cylinder does not touch the sides or the bottom of the flask holding the water as this will introduce a contact force on the cylinder. Tie a thread around the cylinder and attach the other end of the thread to the hook below the top of the balance arm. The flask of water should be placed on the platform that swings out from the base of the balance. The scale in effect then measures the tension, T, in the thread holding the cylinder in the water and this tension can be interpreted as the "apparent weight in water". See Fig. 1 on page 4.

2. Now knowing the real weight and the "apparent weight in water", determine the buoyant force on each of the cylinders provided by the water:

$$F_B = W_{real} - W_{in\ water} \,. \qquad (5)$$

3. For each cylinder, compare the buoyant force so calculated with the theoretical buoyant force from the theory (Eq. (4)) where the fluid is water and the object is the cylinder, i.e.:

$$F_B = \rho_{water} V_{cylinder}\, g \,.$$

Part 3: Applications

PROCEDURE:

1. Determining the density of the rock provides a challenge since we cannot use the calipers to easily find the volume. We can, however, use the combination of real weight and "apparent weight in water" to determine the density. [HINT: use Eqs. (5), (4), and (1).] Do this for the rock on your table.

2. Determining the density of an odd shaped piece of wood provides a further challenge since we cannot use the calipers to determine the volume and the wood will not sink to allow a complete determination of the buoyant force. If the piece of wood supplied is not odd-shaped, determine the density of the wood by the scale and caliper method. Now determine the density of the wood by the real weight and "apparent weight in water" method.

Caution: Since the wood does not sink, we must make it sink. Can you figure out how to do this? Refer to Fig. 2 on page 4 and consider this: To sink the wood we must weigh it down. We can do this with one of our cylinders. We know the apparent weights in water of the cylinders from Part 2. We can then find the apparent weight in water of the combination of the wood and one of the cylinders. This will be less than the apparent weight in water of the cylinder alone since the wood will tend to float. This difference will be due to the buoyant force of the wood minus the real weight of the wood. Thus the buoyant force of the wood is:

$$F_B(\text{wood}) = W_{in\ water}(\text{cylinder}) - W_{in\ water}(\text{combo}) + W_{real}(\text{wood}) \,. \qquad (6)$$

Once the buoyant force is known, the density of the wood can be found in the same way as we did for the rock above.

3. We can further use the real weight and "apparent weight in a liquid" (Archimedes' Principle) to determine the density of a fluid. Determine the density of the unknown fluid by this method using one of the four cylinders and compare with the value you found in Part 1.

REPORT:

Report on your results for each of the 3 parts and make comparisons wherever appropriate. Be sure to discuss the major sources of error in this experiment. In particular, where the same quantity was determined by two different methods, comment on which method gives the more accurate results.

For comparison purposes, the following standard densities are provided:

aluminum:	2.7 gm/cc	copper:	8.9 gm/cc
steel:	7.9 gm/cc	brass:	8.7 gm/cc
lead:	11.3 gm/cc	gold:	19.3 gm/cc

MORE INTERESTING QUESTIONS:

Q: When you have a drink with ice in a glass, and the glass if filled to the rim so that the ice floats above the surface and hence above the rim, will the glass overflow when the ice melts if you do not drink any of the liquid?

A: Since the density of frozen water (ice) is less than that of liquid water (drink), ice will float. But as it melts, it goes from the lower density of ice to the higher density of liquid water. But since the mass of the water, be it frozen or liquid, must remain the same, its volume must shrink as it changes from ice to liquid water . Thus, the liquid water will take up less volume than it did when it was ice and therefore no liquid will spill over the rim of the glass as the ice melts!

Q: What about the fear concerning the melting of the polar ice cap? If that were to happen, would the ocean surface rise and inundate vast areas of land?

A: If the ice is floating (as it is in the Arctic), the answer is NO. If the ice is resting on ground (as it is in Antarctica and in Greenland), the answer would be yes. However, the ice that is resting on land would not melt very quickly since it is touched only by air. A good demonstration of this is the snow on Mt. Kilimanjaro which is present all year round even though the mountain is located near the equator!

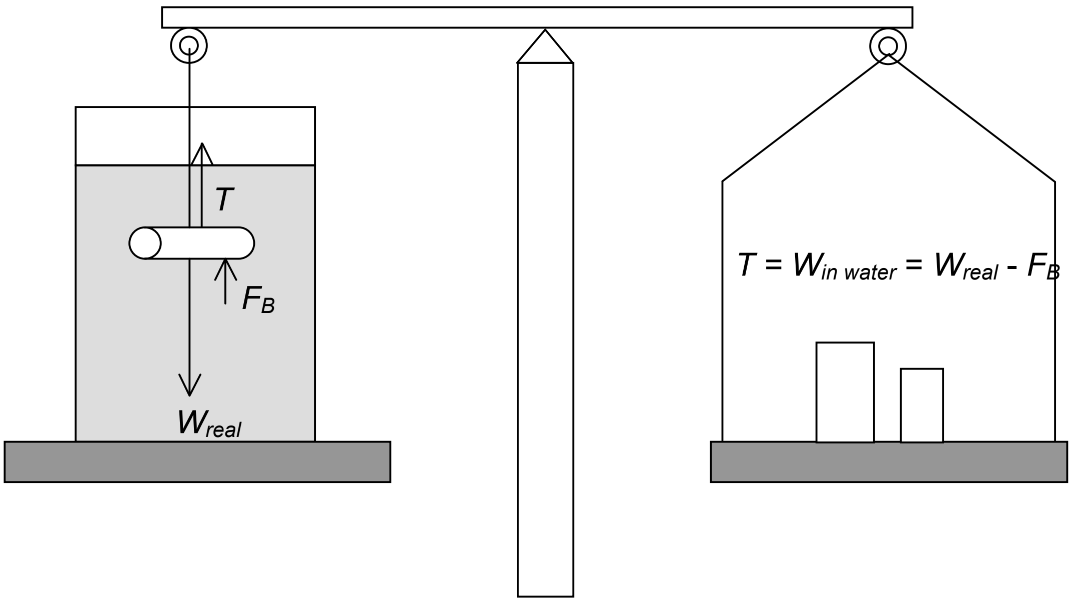

FIGURE 1

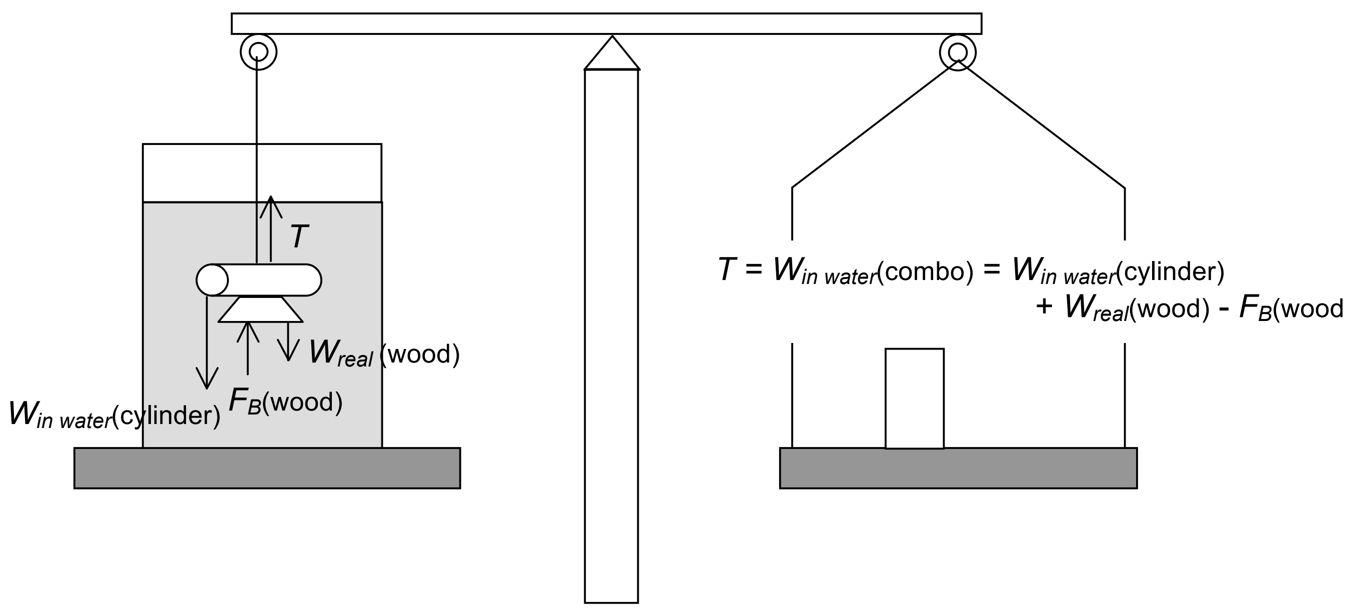

FIGURE 2