Archimedes' Principle
(Density of Solids and Liquids)

Object:

To determine the density and specific gravity of sample solids and liquids, by the use of Archimedes' principle.

Apparatus:

Suitable weighing scale, one beaker, solid samples, thread and sinker, liquid such as saturated salt solution, Vernier caliper, hydrometer, cylinder, small soft brush and paper towels.

Theory:

Density (without adjective) is defined as mass per unit volume. **Weight density** means weight per unit volume. In c.g.s. units, density is in grams per cubic centimeter. The weight density (seldom used here) would be in what units? In English engineering practice, it is customary to specify the weight density; for fresh water this is about 62 lb/ft^3.

Specific Gravity is the ratio of the density of a substance to the density of water, or it is the ratio of the weight of a body to the weight of an equal volume of water. Since the density of water is very close to one gram/cm^3 at ordinary temperatures, density and specific gravity are numerically equal in c.g.s. units. (Specific gravity, however, does not have dimensions).

Archimedes' Principle (which is derivable from mechanics) states that a body immersed in a fluid is buoyed up by a force equal to the weight of the displaced fluid.

Consider now a body which sinks in water. If its "true" weight in air is W_a, while its apparent weight is W_w when it is hung from the balance by a thread, but submerged in water, then its buoyancy is (W_a -W_w). This buoyancy is due to a volume of water equal to the volume of the submerged solid. Hence, what is the specific gravity of the solid?

In **Part 1**, we use this method to obtain the specific gravity, and hence the c.g.s. density, of one or more regular and irregular solids. Bubbles should of course be brushed off the body before recording the weight in water. In the case of a regular solid, the result may be checked by computing the density using the mass divided by the volume. The loss of weight in water is (W - W_1), where W is the weight in air and W_1 is the weight in water. Thus the specific gravity "S" will be:

$$S = \frac{W}{W - W_1}$$

In **Part 2**, the same method is used to find the specific gravity of a body that is less dense than water. A sinker must be used in this case. The specific gravity of a solid lighter than water, as obtained by the sinker method, is given by:

$$S = \frac{W}{W_1 - W_2}$$

where W is the weight of the solid in air; W_1 is the weight of the solid and the sinker, with the sinker alone immersed; and W_2 is the weight when both solids are immersed in water.

In **Part 3,** the specific gravity of a liquid is measured by weighing an object in air, in water, and in the liquid. (W_a-W_w) is the buoyancy of water on the submerged body, while (W_a-W_L) is the buoyancy of the liquid. Hence, what is the specific gravity of the liquid?

$$S = \frac{W_a - W_L}{W_a - W_w}$$

Procedure:

Part 1. Show the weighings in air (W_a) and in water (W_w), and give the density as found from Archimedes' principle. A tabular form is advised. For the regular solids, give also the mass and dimensions, and the density computed from "mass/volume". Compare with the density from weighings.

Part 2. Proceed similarly, but include a diagram to show how the weighings with sinker were made.

Part 3. Show the weighings W_a, W_w and W_L, and indicate how the specific gravity (equals c.g.s. density), was found. Compare the result with the reading of the calibrated hydrometer. The body weighed, and the beaker which held the liquid, should be rinsed and dried. Try to avoid spillage, especially on the balance, in any case, wash and dry any spots of the liquid found on the apparatus or table.