Measurement of the Density of a Given Liquid

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Measurement of density of a liquid is very simple if one has equipment to determine mass and volume. But there are other ways to measure the density, and one such method is by using a hygrometer. The ~~same~~ principles of a hygrometer can be used in a classroom using two test tubes and some other infrastructure that is readily available in a school laboratory, even if the laboratory is ill-equipped.

When a test tube that has been filled with liquid #2 is inserted in a denser liquid #1 (as compared to ~~the~~ liquid #2) contained in a measuring cylinder, the test tube will float in the denser liquid. The depth attained by the test tube that is immersed in the denser liquid will depend on the densities of the two liquids and volume of the two liquids involved. Here the weight of the empty test tube is **not** to be neglected.

This experiment requires very simple set of apparatus, as listed below.

1) 100 ml Measuring cylinder
2) test-tube
3) A retort stand
4) A string 1m in length and about 1 mm diameter
5) 10 ml measuring cylinder
6) Liquids L_1 density ρ_1 and L_2 with density ρ_2 (unknown).

Here $\rho_1 > \rho_2$. [Note: if the condition is reversed, then the liquid in test tube along with the test tube **may** become heavier than the liquid in the cylinder to let the test tube sink in the liquid in measuring cylinder]

In order to ensure that $\rho_1 > \rho_2$ is achieved, one can use a sugar solution as L_1, which can have densities higher than that of water. Similarly, it is possible to measure densities using other common liquids like milk, fruit juices, etc. If $\rho_1 >> \rho_2$ the displacement of the test tube, with addition of more L_2, will not be easily measureable.

L_1 is poured into the measuring cylinder and a test tube filled with L_2 is immersed into the liquid L_1. Since mass of L_2 and test tube is less than the volume of L_1 displaced, the test tube will float in L_1. As more and more L_2 is added, the test tube will begin to sink deeper, but will still be floating. Since mass of L2 added is known, by measuring the extent of sinking of the test tube, the density of the L2 can be determined using the simple steps described below.

Procedure:

1) Fill liquid L_1, about 60 ml, in the measuring cylinder. Let ρ_1 be the density of the liquid L_1.
2) Note down the reading V_0 on the cylinder.
3) Tie the test-tube with the given thread to the retort stand in such a way that when released fully, inside the measuring cylinder, the top of the test tube does not go below the 80 ml mark on the cylinder. [Note: If this condition becomes impossible to accomplish, then reduce the level of liquid L_1 in the measuring cylinder]
4) Insert the empty test tube into measuring cylinder so that the test tube floats on liquid L_1.
5) Note the reading on the cylinder V_b.
6) Take liquid L_2 in the smaller measuring cylinder. Let ρ_2 be the (unknown) density of the liquid L_2.
7) With the help of a dropper pour 1 ml of L_2 into the empty test tube.

CAUTION: Ensure that the L_2 does not spill into L_1. In case of mix up, the experiment has to be started again. [This condition can be modified by the teachers on a case to case basis]

8) After the liquid L_2 has been introduced into the test tube, tap the test tube lightly with the dropper. [This is required so that in case the test tube is sticking to the walls of the cylinder, it may be released. NOTE. This point may be dropped by the teachers if the intention is to test the skills of the students]
9) Note the level of liquid L_1 on the big measuring cylinder. Let this be denoted V_1. Repeat the procedure increasing the liquid L_2 in the test tube by 1 ml each time. This is to be repeated 9 times. (8 marks)

   $\Delta V_1 = W_t/\rho_1 + V_2 \rho_m/\rho_1$. Plot a graph of ΔV_1 vs V_2 where W_t is the weight of the test tube. [Note teacher may decide not to give this equation to the students in case teacher wishes to test the conceptual skill of students. In which case point 2, below, may be included.]

1) Calculate the increase in the level of liquid L_1: $\Delta V = (V_1 - V_0)$. (2 marks)

2) Derive a relation of ΔV with V_2, the volume of L_2 poured in the test tube. (Take W_t as mass of the test tube) (2 marks)

Observation Table:

Sr No.	Volume of liquid L_2 in test tube V_2	Level of liquid in the measuring cylinder V_1	Increase of volume of liquid L_1 is $\Delta V_1 = V_1 - V_o$

Plot a graph of ΔV_1 against V_2. (5 marks)

Determine the following from the graph:

The mass of the test tube is W_t = (2 marks)

The density of the liquid L_2 is = (2 marks)

Q 1) Can you always perform this experiment with the given set up when $\rho_2 \geq \rho_1$? Give reason. (2 marks)

[Here if $\rho_2 \geq \rho_1$ then it is possible that the combined weight of the test tube and the liquid in the test tube may be much larger than the weight of the volume of the liquid displaced, thus sinking the test tube in liquid L_1.]

Q 2) Can you perform this experiment with a measuring cylinder which has diameter 5 times of the given diameter? Give reason. (2 marks)

[This is a little difficult because as the radius/diameter of the outer cylinder increases the increase in volume of L_1 is represented by very small increase in height of L_1. These small increases may not be very easily measureable thus increasing the error in measurements.]

Note: number of marks are only indicative. Techers are free to change the weightage of each question as per their own requirements.