A no cost method for finding the density of liquids

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Abstract

In this article, a simple and no cost method, which is based on Archimedes' principle and moment of force and which does not require measurement of mass and volume of the liquid, is described for the determination of the density of liquids. The experimental set up for this purpose is very simple. A meter scale is hung by a string from a rigid support at center point. A solid substance of unknown mass is hung from the left side of the meter scale with a string and to balance the system, another solid body of unknown mass is hung from a string at the right side of the scale. The balancing length is measured. A beaker containing a liquid of known density is placed underneath the mass at right side of the scale such that it is immersed completely in the liquid. Due to upthrust the weight of the mass decreases and to make the system in balance it is moved to another point and the balancing length is measured. Now that mass is immersed completely in another liquid whose density is to be determined. The new balancing length is measured. From these three balancing length the density of the unknown liquid can be found out.

Keywords: Density of liquid, no cost apparatus, meter scale.

Resumen

En este artículo, un método simple y económico, el cual se basa en el principio de Arquímedes y el momento de fuerza y que no requiere la medición de la masa y volumen del líquido, se describe para la determinación de la densidad de líquidos. El experimento establecido para este propósito es muy simple. Una escala métrica se cuelga de una cadena de un soporte rígido en el punto central. Una sustancia sólida de masa desconocida se cuelga del lado izquierdo de la escala métrica con una cadena y para equilibrar el sistema, otro cuerpo sólido de masa desconocida se cuelga de una cadena del lado derecho de la escala. La longitud de equilibrio es medida. Un vaso de precipitados que contiene un líquido de densidad conocida se coloca debajo de la masa del lado derecho de la escala, de tal manera que se sumerge completamente en el líquido. Debido al empuje hacia arriba el peso de la masa disminuye y hace que el sistema en equilibrio se mueva a otro punto y la longitud de equilibrio es medida. Ahora que la masa se sumerge completamente en otro líquido cuya densidad ha sido determinada. La nueva longitud de equilibrio es medida. De estas tres longitudes de equilibrio de la densidad del líquido desconocido puede ser encontrada fuera.

Palabras clave: Densidad de líquido, aparatos no costosos, escala métrica.

I. INTRODUCTION

Besides the common method of measuring density of an object many other alternative methods have been developed by Koenigs [1], Hughes [2, 3], Sing [4, 5], Mumba & Tsige [6] and Chattopadhyay [7, 8]. Koenigs [1], Hughes [3] and Chattopadhyay [7] have developed their methods for the determination of liquid density. For the determination of density of liquids using Koenigs [1] and Hughes [3] methods the volume of the body must be known. But for the method developed by Chattopadhyay [7] the density of liquid can be determined without measuring its mass and volume. The method developed by Chattopadhyay [7] is very simple, accurate and of almost now cost. In this paper, another almost now cost method for the determination of liquid density is described. This method is based on Archimedes' principle and moment of forces and which does not require the measurement of mass and volume of the liquid.

II. METHOD

The experimental set up is shown in Fig. 1. The materials needed are: one meter rule, three pieces of string of negligible mass and volume, a solid substance of any shape and of unknown mass, a liquid of known density (*e.g.* water), an another liquid whose density is to be determined and another solid substance of unknown mass and of higher density than water and the liquid used in the experiment, and one beaker. The meter rule is hung by a string from a rigid support at center point O. The solid substance is hung

from the left side of the meter rule with a string at point A and to balance the system, another solid substance is hung from a string at the right hand side of the rule at point B. If the masses of the two solid substances are M and m respectively and the distances of points A and B from point O are L and l respectively, then from the principle of moments of forces we can write:

$$MgL = mgl. \qquad (1)$$

FIGURE 1: The balancing of the 2nd solid substance with the first one
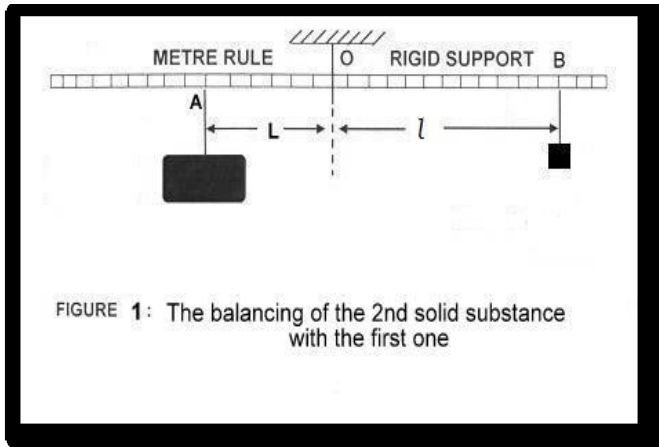
Then a beaker containing a liquid of known density (*e.g.* water) is placed underneath the solid substance of mass m. The beaker is then moved upward until the solid substance is completely immersed in the liquid making sure that the substance is freely suspended in the liquid. As the weight of the solid substance decreases due to upthrust acting on it, the system becomes unbalanced. To make the system in balance one moves the substance to point C while it is freely suspended and completely immersed in the liquid (Fig. 2). The positions of the solid substance at A and the pivot O are not changed throughout the experiment.

If V and d_1 be the volume of the solid substance at B and density of the known liquid respectively then the upthrust (buoyant force) acting on the solid substance is Vd_1g. So, applying Archimedes' principle and moments of force we can write:

$$MgL = (m - Vd_1)gl_1, \qquad (2)$$

where l_1 is the new balancing length (OC) of the solid substance.

FIGURE 2: The balancing of tne second substance of mass 'm' when dipped in water
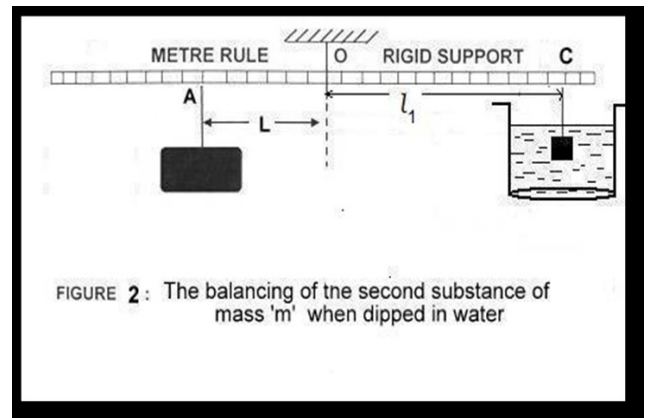
The solid substance is then taken out from the beaker and is dried. The known liquid should then be emptied from the beaker and the beaker is dried. Now the beaker is then filled with the unknown liquid, whose density is to be determined, keeping the solid substance at A and the pivot 'O' in their original position. The solid substance on the right hand side is immersed completely in the unknown liquid. To balance the system again, the solid substance is moved to the point 'D' (Fig. 3). If this balancing length (OD) be l_2 and the density of the unknown liquid be d_2, then applying Archimedes' principle and principle of moment of force we can write:

$$MgL = (m - Vd_2)gl_2. \qquad (3)$$

FIGURE 3: The balancing of the 2nd substance when dipped in the liquid
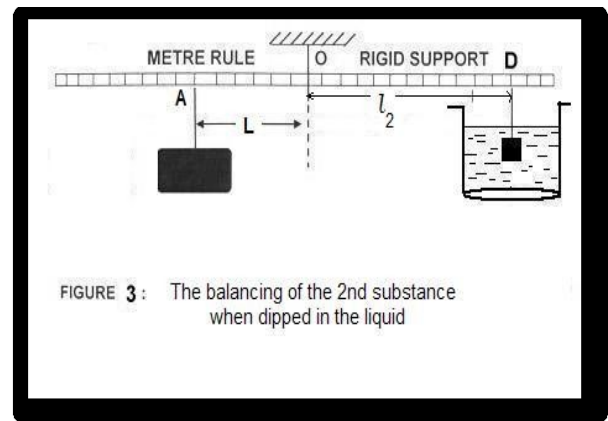
Now from Eqs. (1) and (2) we can write:

$$Vd_1 = m(1 - l/l_1). \qquad (4)$$

And from Eqs. (1) and (3) we can write:

$$Vd_2 = m(1 - l/l_2). \qquad (5)$$

From Eqs. (4) and (5) we have:

$$d_2/ d_1 = (1 - l/l_2) / (1 - l/l_1). \qquad (6)$$

From the above Eq. d_2 can be found out easily as d_1 is known.

The method described above for the determination of density of liquid has many advantages as follows: i) it is very simple; ii) a physical balance for measuring mass and a measuring cylinder for measuring volume are not necessary; iii) only measurable quantities are the three moment arms, iv) it is almost a no cost method.

We have neglected the mass and volume of the thread used for binding the solid substance; it is a source of error. But it can be minimized by taking the thread very thin and short. Measurement of the moment arms should be done very carefully. In this method the solid substance at B should be so chosen that it has no chemical or other reaction with the liquid and it immerses completely in the liquid. This method is not suitable for the determination of density of mercury because it is difficult to find a solid substance which immerses in mercury.

We have measured densities of many liquids using this method and the experimental results agree well with already known values.

This simple method is useful for teachers and students of schools and undergraduate colleges.

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