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The differences in analysing strategy of viscosity experiment between freshmen and laboratory assistant

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Abstract. The viscosity is defined by dimension of a fluid that resists the force tending to motive the fluid to flow. The aim of viscosity experiment is to determine the fluid viscosity coefficient value. By using graphical analysis, the result of oil viscosity coefficient value which performed by laboratory assistant showed: (1) 0.20 Pa.s using solid ball with accuracy 99.64% and (2) 0.21 Pa.s using smaller solid ball with accuracy 99.17%. Meanwhile, the result of oil viscosity coefficient value which performed by freshmen showed: (1) 0.44 Pa.s using solid ball with accuracy 87.85% and (2) 0.32 Pa.s using smaller solid ball with accuracy 89.84%. The differences result of the freshmen and assistant laboratory viscosity experiment are caused by the freshmen calculated the coefficient viscosity value without velocity correction factor and they used small range fluid so the times are not identified well.

1. Introduction

The viscosity of a fluid reflects the property of being able to transmit friction forces between particles or to exhibit resistance to shearing flows. For a quantitative characterisation of viscosity of a fluid, the laminar flow is considered when the relative motion between two adjacent layers generates shear stresses [1]. The viscosity is defined by a dimension of a fluid that resistant force tending to motive the fluid to flow [2]. Liquids with a high viscosity flow slowly and vice versa [3]. For example, we are easier to pour water from a bottle than pour honey. This is due to the viscosity of honey greater than the water viscosity [4]. The viscosity coefficient value shows the degree of viscosity of a fluid. In physics teaching, the conventional method for measuring the viscosity of liquids, called the falling ball method, is based on the fall of an object through a liquid. The experiment is realized using a setup called the falling ball viscometer, which typically measures the viscosity [3]. There is important to determine the viscosity coefficient value because the value shows the ability of the current fluid [9], and developing the scientific process for us. The scientific process are attitudes include curiosity, respect for proof, critical thinking, creative thinking, speaking based on concrete evidence or data, and care about the environment [10]. Additionally, this scientific process triggers conception of learning physics [11].

For determining the fluid viscosity coefficient one can drop a ball which known the density and then measure the terminal velocity of the ball [5]. The object which is moving in a fluid always gets a friction force in the opposite direction of the motion of the object (Figure 1). The magnitude of the friction force depends on the relative velocity of the object in the fluid and the shape of the object. For ball-shaped objects, the magnitude of the frictional force satisfies Stokes's Law.



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where, r is the radius of the ball; and v is the ball velocity

$$F = 6\pi\eta rv \quad (1)$$


Figure 1 (a) The ball which is moving in a fluid always gets a friction force in the opposite direction of the motion of the object, (b) The force which is acting on the ball when falls into the fluid. (adaptation from [5])

If the ball is dropped in the fluid then the ball moves down with an increasing velocity due to the acceleration of gravity. But, at a point the velocity does not change anymore. This velocity called the terminal velocity [3]. The forces which act on the falling object are the gravity force, the Archimedes force, and the Stokes force. When the ball reaches in the terminal velocity, the three forces are balance. Based on the ball terminal velocity, we can determine the coefficient viscosity value of fluid. Equation (2), (3), and (4) describes the third of the forces.

The Gravity Force

$$w = m_b g = \rho_b V g = \rho_b \left(\frac{4}{3} \pi r^3 \right) g \quad (2)$$

The Archimedes Force

$$F_A = \rho_f g V = \rho_f g \left(\frac{4}{3} \pi r^3 \right) \quad (3)$$

The Stokes Force

$$F_S = 6\pi\eta rv \quad (4)$$

Applying Newton's second law, we can write the following equation of motion for the falling ball:

$$m \frac{dv}{dt} = w - F_A + F_S \quad (5)$$

where v is the instantaneous velocity of the falling ball at a time t [3].

When the object reaches in the terminal velocity, the three forces satisfy

$$\begin{aligned} w &= F_A + F_S \\ \rho_b \left(\frac{4}{3} \pi r^3 \right) g &= \rho_f g \left(\frac{4}{3} \pi r^3 \right) + 6\pi\eta rv \\ \eta &= \frac{2r^2 g (\rho_b - \rho_f)}{9v} \end{aligned} \quad (6)$$

The measured viscosity of a suspension appears to depend upon the diameter of the tube of the capillary viscometer used in determining it [6]. The metal ball is dropped into a cylinder which is containing the fluid will tend to be forced to move away from the cylinder wall. This condition is called the wall effect [6, 7]. The terminal velocity will be achieved if the ball is far from the initial location when it's released in the fluid. Therefore, we need the velocity correction factor because the tube which is used in this experiment has limited diameter and length.

The velocity correction factor based [8]

$$v = v' \left(1 + 2.4 \frac{r}{R} \right) \left(1 + 3.3 \frac{r}{L} \right) \quad (7)$$

Where, v' is the ball terminal velocity; R is the radius of the tube; and L is the length of fluid. The unit of coefficient viscosity value is $Pa.s$ with **1 poise** = $1 \frac{dyne.s}{cm^3} = 10^{-1} \frac{N.s}{m^3} = 10^{-1} Pa.s$.

The errors that can reduce the accuracy of measurements in this experiment are the inaccuracy in determining the constant point and the inaccuracy in measuring travel time of the ball falling [7]. From the results of viscosity experiments that have been done in basic physics laboratories, there are significant results differences between physics major and non-physics major. Therefore, it is necessary to do research on the viscosity experiment to find the cause of the differences result.

In this article, we discuss about the differences of analysis strategy of the viscosity experiment result by freshmen and laboratory assistant. The purpose of the viscosity experiment is to determine the value of oil viscosity coefficient.

2. Method

Based on the research aim, this research is a descriptive research using the quantitative descriptive method in explaining the differences of analytical strategies on viscosity experiment between freshmen and laboratory assistant. In this case, the subject research is the freshmen in majoring mathematic, physics, chemistry, and biology of the faculty of mathematics and natural sciences of The State University of Surabaya. The method of this experiment is falling a ball which known the density and then measure the terminal velocity of the ball. For measuring the ball terminal velocity is manipulating the travel of the ball and then measuring the times. The fluid of this experiment is oil with two methods, they are using a solid ball and using a smaller solid ball [8].

3. Result and Discussion

The viscosity experiment we got some data, there are the mass of the ball, the diameter of the ball, the diameter of the tube, the density of the fluid, the length of fluid, and the terminal velocity. For calculating the terminal velocity is dividing between the long travel of the ball and the times. In this experiment, we manipulated the long travel of the ball and measuring the times. The long travel manipulation used distance after constant point, the meaning is the measuring the terminal velocity when the ball move with constant velocity in the fluid. After we got the data, we can calculate use the viscosity equation. Based the viscosity experiment which performed by freshmen, the oil viscosity coefficient value as follows

Table 1. The result of oil viscosity coefficient value which performed by freshmen.

Major	Department	The Coefficient Viscosity value, η (Pa.s)	
		Solid Ball	Smaller Solid Ball
Physics Major	Physics	0.0760	0.0285
Non Physics Major	Mathematic	0.5153	0.4870
	Chemistry	0.9424	0.6398
	Biology	0.2130	0.1140

The result of the viscosity coefficient value above is obtained from calculate using equation 5 at each distance manipulation then determine the viscosity coefficient value average. The result of oil viscosity coefficient value which performed by freshmen showed: (1) 0.44 Pa.s using solid ball with accuracy 87.85% and (2) 0.32 Pa.s using smaller solid ball with accuracy 89.84%. Meanwhile, the viscosity experiment which performed by laboratory assistant, the oil viscosity coefficient value using graphical analysis as follows

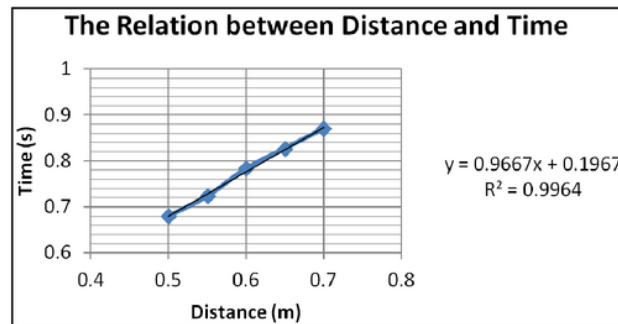


Figure 2. Graphic analysis of the viscosity experiment result using solid ball.

The graph line equation in Figure 2 shows the relation between distance and time. Y-axis shows the times, X-axis shows the times, and the gradient of the line equation is 0.9667. From the gradient we can determine the coefficient viscosity value use equation (7) and R^2 shows the accuracy of this experiment. The accuracy of this experiment is gotten 99.64%.

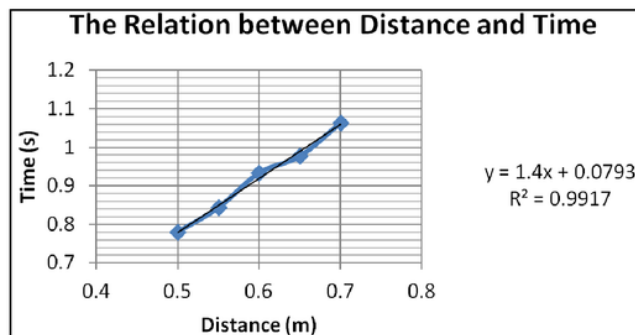


Figure 3. Graphic analysis of the viscosity experiment result using smaller solid ball.

The graph line equation in Figure 3 shows the relation between distance and time. Y-axis shows the times, x-axis shows the times, and the gradient of the line equation is 1.4. From the gradient we can determine the coefficient viscosity value use equation (7). And R^2 shows the accuracy of this experiment. The accuracy of this experiment is gotten 99.17%.

Based the graph of the relation between distance and time above, we can determine the value of the fluid viscosity coefficient through the gradient value of the graph. Using the value of a velocity correction factor in the equation (6), obtained the value of viscosity coefficient using graphical analysis as follows

$$\eta = \frac{2r^2 g m (\rho_b - \rho_f)}{9 \left(1 + 2.4 \frac{r}{R}\right) \left(1 + 3.3 \frac{r}{L}\right)} \quad (8)$$

where, m is the graph gradient [7].

The result of the oil viscosity coefficient value which performed by a laboratory assistant showed: (1) 0.20 Pa.s using solid ball with accuracy 99.64% and (2) 0.21 Pa.s using smaller solid ball with accuracy 99.17%. The result of the oil viscosity value which performed by freshmen is different with the result of oil viscosity coefficient value which performed by laboratory assistant due to the freshmen calculated the viscosity coefficient value without using the velocity correction factor, and they used relatively small distance manipulation so that they couldn't identify the times well.

Based two analytical strategies above, we know that the result analysis of this experiment using graphical analysis based on the equation (7) is better than analysing use equation (5). This is caused by velocity correction factor equation (6) is neglected by the equation (5). In this case, we can't neglect the velocity correction factor because the tube which is used in this experiment has limited diameter and length.

4. Conclusion

The result of this experiment which performed by freshmen got the oil viscosity coefficient value using solid ball and smaller solid ball show different values. It is also showing the different result if it is compared with the viscosity coefficient value of laboratory assistant's result. The differences are caused by the freshmen calculated the viscosity coefficient value without using the velocity correction factor, and they used relatively small distance manipulation so that they couldn't identify the times well. So, if we want to get accuracy result in analysing our data in our experiment, more better if we use graphical analysing, and attention the correction factor the experiment.

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