**How Does Viscosity of a Fluid Affect the Time Taken to Hit the Bottom of a Graduated Cylinder?**

**IA Proposal - Arsh Mobeen**

**Introduction:**

Projectile motion and kinematics are concepts that we constantly see all around us on a daily basis. We would likely go insane trying to measure everything that happens around us, but doing an experiment with one or two of these unique circumstances and phenomenon would without a doubt provide us with more awareness of our world. At the end of the day, learning how nature works around us is something not many choose to do, but doing it would enlighten us. That is my reason for choosing this experiment. Essentially, I will be dropping a ball bearing into five different fluids contained in a graduated cylinder, each with their unique viscosities, and then measure the time it takes for the ball bearing to hit the bottom of the graduated cylinder. Stokes law alongside the concept of updrift will be used to determine the forces acting upon the ball.

**Hypothesis:**

As the viscosity of a fluid increases, the time taken to hit the bottom of a graduated cylinder increases as well.

**Aims and Objectives:**

To measure the time taken for the ball bearing to hit the bottom of the graduated cylinder experimentally.

To measure the time taken for the ball bearing to hit the bottom of the graduated cylinder theoretically with the help of derived formula.

Comparison of the two methods to check the accuracy of the results.

**Methodology**

1. **Time Measurement using the derived formula**

**Derivation of the Formula:**

The theoretical formula for this experiment is given below:

**Thus:**

In order to derive the formula of time from the velocity, we will use separation of variables technique i.e.

Where:

v = Velocity (terminal)

r = Radius of Ball Bearing

g = Force of Gravity (9.8ms-2)

Pb = Density of Ball Bearing

Pf = Density of Fluid

η = Viscosity Coefficient of Fluid

∆d = Displacement (Traveled by Ball Bearing after hitting the surface of the fluid)

(∆d will now be s according to equation A)

t = Time

V = volume

Viscosity is the frictional force between particles of a substance, and that same viscosity creates viscous drag, a motion like air resistance that opposes the general motion of an object. Now, when the ball bearing will be dropped into the graduated cylinder, three forces will act upon it, the force of gravity acting down, the force of viscous drag, and the force of upthrust caused by the fluid it displaces. Both viscous drag and upthrust oppose and equate the downwards force of gravity. Thus we can say:

Fg = Fv + Fu

Fg (Force of Gravity) = mg

m = PbV

v = 4/3πr3

Fg  = PbVg

∴ Fg =Pb4/3πr3g

The force of gravity is equal to mass times gravity, mass equals to density times volume. Volume is 4/3πr3. Thus we can say that force of gravity equals the density of the ball bearing multiplied by 4/3 pi times radius cubed times gravity. This gives us the theoretical formula for the force of gravity.

Fv  (Force of Viscous Drag) = 6πηrv (Stokes Law)

According to Stokes law, which gives us the magnitude of viscous drag applied to a ball in a given fluid, the force of viscous drag is 6 times pi times the coefficient of viscosity times radius of the ball bearing times velocity.

Fu (Force of Upthrust) = Weight of Fluid Displaced

= Pf 4/3πr3g

Therefore:

Fg = Fv + Fu

Pb4/3πr3g = 6πηrv + Pf 4/3πr3g

After canceling the variables π,r and factoring we get the formula:

6ηv = 4/3r2g(Pb - Pf)

Isolating for v gives us:

Since we know that the forces are opposite and equal, we know that by newton’s second law, the acceleration will be 0, thus we can simply put the above equation into a velocity, displacement and time formula, giving us:

Viscosity is the main independent variable, however, updrift is a factor that will be impacted by the varying viscosity coefficients, leading to the inclusion of density in the theoretical equation.

1. **Experimental Measurement of Measurement**

**Experiment:**

In my experiment, I will fill five identical graduated cylinders with an equal amount of five different fluids, each with their own unique viscosities and densities. I will then drop a steel ball bearing into each cylinder from a height of 10 centimeters (0.1 m) above the opening of the beaker three times each, all while keeping track of the time it takes for the ball to hit the bottom of the cylinder from release. These five fluids will be Water, Canola Oil, Hand Soap, Maple Syrup and Honey. These fluids may be subject to change. I anticipate that the velocity will differ between each liquid based upon differing viscosity. A meter stick will be set up beside each cylinder. Prior to the ball drop, temperature will be noted and made sure to all be the same.

Cameras, recording in slow motion will be set up. Note that in the theoretical equation, the time and distance will be after the ball makes contact with the surface. Thus more specifically, I will be measuring the total time, but then going back to slow motion video recordings and determining the exact time it spent in the fluid. The diagram below shows a rough model of my experiment.

Fluid (n)

Time measured (Total time - time to hit surface)

Steel Ball Bearing

**Variables:**

**Control Variables:**

Temperature (℃)

Distance

Volume of Fluid within the graduated Cylinder

**Independent Variable:**

Viscosity

**Dependant Variable:**

Time

**Equipment Required:**

* 5 Identical Graduated Cylinders - Lab Provided
* Meter Stick - Lab Provided
* Water - Self Provided
* Maple Syrup - Self Provided
* Olive Oil - Self Provided
* Hand Soap - Self Provided
* Honey - Self Provided
* Camera - Self Provided

I recommend you to keep the headings A and B under the methodology section but you can change the headings A and B as per your choice.

**Results**

Compare the results under this heading in the form table.

**Bibliography**

Mention reference to a book, paper, or author you have used in this proposal.

**Challenges & Conditions:**

One of the largest challenges I will face is keeping the temperature the same and still knowing the viscosity. The viscosity coefficients will be researched about and noted down ahead of time.

However, these coefficients are given in a specific temperature. So finding all viscosity coefficients and temperatures the same will be a challenge. (If you are doing this experiment at room temperature (**21–22 °C (70–72 °F)**) then the viscosity value of five different fluids can be searched and there is no need to measure the viscosity just make sure to keep temperature of lab at room I recommend to measure the temperature of the laboratory ahead of final day of experimentation and then note down the values of viscosity according to that.)

Another challenge, or rather uncertainty that I will have to account for is the major margin for human error. Through testing, I have determined that for fluids with low viscosity such as water, the ball bearing falls at a high velocity, so stopping that stopwatch at relatively accurate times will be a challenge. Yet this can be overcome by taking multiple trials and choosing the three in which I am most confident. (To overcome the human error, take the average of multiple trials instead of choosing the best from the three trials).

Precision in the data collecting portion of the experiment is key, as many fluids will have similar viscosity coefficients and will depend on accurate time tracking to show their differences.

For environment specific temperatures, I ask that no one be heating the classroom environment and that on that day no one uses a wind blowing fan in the classroom. Heating can cause variance in temperature, my control variables, and wind blowing can throw the tiny ball bearing off course.