**Thermo and Fluid Dynamics of a Homemade “Lava Lamp”:**

By: Dan Miller

Overview:

Lava lamps are just cool, that’s all there is to it. Most everyone has spent at least an hour of their life just staring at a lava lamp. While the experiment outlined here isn’t really the same as a commercial lava lamp it does demonstrate many of the important fluid and thermodynamic properties. Most importantly it provides students with an interesting and fun visual demonstration intended to motivate thought about the physics behind the experiment itself.

The “lava lamp” created in the following experiments displays a multitude of important fluid and thermodynamic concepts. Concepts such as convection, surface tension, buoyancy, density, fluid drag, and the differences between heat convection and other convective processes are evident simply by observation.

Experiments:

Equipment:

* 1x 800ml Beaker
* 1x 100ml Graduated Cylinder
* 1x Hotplate

Supplies (per experiment):

* 10ml Fountain Pen Ink (I used Higgins Eternal Black Ink but any will do)
* 90ml Water (Graduated Cylinder)
* 600ml Vegetable Oil (Beaker)
* Alka-Seltzer Tablets

Heated Convection Procedure:

1. Fill the beaker with 600ml of Vegetable Oil.

2. Fill the graduated cylinder with 90ml of water.

3. Mix the water with the vegetable oil in the beaker and allow the water to settle to the bottom.

4. Fill the graduated cylinder with 10ml of ink and then pour that with the oil/water mixture.

5. The ink droplets then settle down on top of the oil/water barrier but won’t break through due to the surface tension caused by the hydrophobic barrier.

6. Place the beaker on a hotplate and heat until shortly after the ‘lava lamp’ begins to convect. If the hotplate has an adjustable temperature dial you can maintain the beaker at a constant temperature and keep this reaction going for some time.

Unheated Convection Procedure[[1]](#footnote-2):

1. Fill the beaker with 600ml of Vegetable Oil.

2. Fill the graduated cylinder with 90ml of water.

3. Mix the water with the vegetable oil in the beaker and allow the water to settle to the bottom

4. Fill the graduated cylinder with 10ml of ink and then mix that with the oil/water mixture.

5. The ink droplets then settle down on top of the oil/water barrier but won’t break through due to the surface tension caused by the hydrophobic barrier.

6. An Alka-Seltzer is then dropped into the middle of the beaker. When the Alka-Seltzer hits the oil/water barrier it breaks the surface tension and the ink mixes with the water. Once the Alka-Seltzer is in the water it begins to react and release gas triggering the convection process.

Explanations and Exercises:

Buoyancy and Convection:

It should be clear to anyone who observes these two experiments that they are remarkably similar. This demonstrates the connection between buoyancy and density as well as indicating that there are other methods of convection aside from heat convection.

Traditionally students are often introduced to heat convection in schools. Heat convection occurs when a liquid is heated causing the density of the liquid at the bottom to be less than the density of the liquid on the top. The less dense liquid flows to the top because it is more buoyant than the colder liquid. While the colder liquid on top flows downward because it is more dense and therefore less buoyant. This process continues as the liquid undergoes convective flow.

In the unheated experiment the gas created by the Alka-Seltzer reaction is responsible for the buoyant force lifting droplets of water/ink to the surface. The low density gas bubbles form on droplets of water/ink and cause the droplets to be more buoyant. Once the droplets reach the surface the gas bubbles escape from the mixture and the dense water/ink droplets fall back down to the oil/water barrier.

Students can demonstrate their understanding by solving for the necessary droplet volume (radius) required to balance the force of buoyancy (F­b) with the force due to gravity (Fg).

(1)

Thus this droplet will simply float in place neither moving upwards nor falling.

The force due to buoyancy can be determined given the following equation:

(2)

Where is the density of the fluid the droplet is in, is the volume of fluid displaced by the droplet (same as the volume of the droplet) and g is the acceleration due to gravity on the surface of earth (9.81m/s 10m/s).

The force of gravity given by:

(where mass is ) (3)

From these two equations students should be able to rearrange and solve for volume.

The volume of a spherical drop is given by the equation:

Hydrophobia:

The oil used in these experiments forces the water/ink mixture to bead into droplets as it moves throughout the oil. This occurs because the oil is hydrophobic. Hydrophobic sounds exactly as it means; the water/ink mixture does not “want” to mix with the oil.

In a more scientific sense the water molecules are minimizing the energy of interaction by bonding to themselves rather than the water. Water can very easily forms hydrogen bonds with itself because it is a very polar molecule but the oil which is non-polar is not capable of forming these bonds with water. The water molecules therefore favor interaction between themselves and form into droplets to minimize contact with the oil surrounding it.

Drag:

Droplets *moving* through the oil experiencing fluid drag among other forces[[2]](#footnote-3). Fluid drag is a force that opposes the movement of the droplets in the oil due to friction between the droplet and the oil surrounding it. In the buoyancy problem above the drag force was zero because the droplet wasn’t moving. Drag is something most people have heard of in reference to the aerodynamics of cars. If the car is not shaped properly a lot of drag force will be resisting it as it moves quickly due to the air moving around it.

Keywords:

advection, convection, buoyancy, hydrophobic, thermodynamics, fluid, surface tension, density

1. An experiment similar to this one can be found here… <http://www.sciencebob.com/experiments/lavalamp.php> [↑](#footnote-ref-2)
2. Students could be asked to draw a force vector diagram or list all of the forces involved in the motion of the droplet and their relative magnitudes (eg. ). (Forces: Gravity, Buoyancy, Drag) [↑](#footnote-ref-3)