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## Experiment 1
## Specific Gravity Determination

**Objective:**

The activity aims to determine the specific gravity of fluid using a U – tube manometer.

**Intended Learning Outcomes (ILOs):**

At the end of the activity the students shall be able to:

1. Explain the concept of specific gravity as one of the fundamental properties of fluid.
2. Demonstrate the determination of heights of different fluids inside the U tube manometer.
3. Identify the specific gravity of fluid.

**Discussion:**

Specific gravity of a fluid is the dimensionless ratio of the specific weight y or density p of a fluid to the specific weight $y_s$ or density $p_s$ of the standard substance,

$$s = \frac{y}{y_s} = \frac{p}{p_s}$$

For liquids and solids, the standard substance is pure water at 4ºC at which temperature, its specific weight, $y_s$ = 9.81 KN/$m^3$ and density $p_s$ = 1000 kg/$m^3$ are at their maximum values. With these constants, equation 1.1 may be used to compute the specific weight and density of a fluid given its specific gravity s. For gases, the standard substance is either hydrogen or air at 0ºC and under a pressure of 101.3 KPa. Air at this temperature and pressure has $y_s$ = 12.7 N/$m^3$ and $p_s$ = 1.29 kg/$m^3$.

The specific gravity should not be confused with the density since these are two different properties of a substance, the first one being dimensionless and the second having the dimensions kg/$m^3$ or gm/$cm^3$. In the SI units, however, these two are numerically equal if the density is expressed in gm/$cm^3$. For example, water has specific gravity of unity and a density of 1 gm/$cm^3$.

**Resources/Instruments Required:**

- U – tube manometer
- Scale / Ruler
- Liquids whose specific gravity are to be determined

**Procedure:**

1. Pour an amount of distilled water in the U – tube glass manometer
2. Add an amount of oil in the U – tube glass manometer until it stands
3. Measure the heights of the water and oil inside the U – tube manometer.
4. Evaluate the specific gravity of the unknown liquid using the derived formula below.

$$S_2 = \frac{S_1 h_1}{h_2}$$

5. Perform steps 1 to 4 with other liquids. For heavy fluids, use mercury as standard fluid.

**Laboratory Report:**

Group No.: Section:
Date Performed: Date Submitted:
Group Members:

1. **Data Results:**

| Liquid | h1 (oil) | h2 (liquid) | S |
|---|---|---|---|
| Oil and water | | | |
| Oil and vinegar | | | |
| Water and diesel | | | |
| Diesel and Vinegar | | | |

2. **Observation/s:**

3. **Analysis / Computations:**

4. **Source/s of Error**

5. **Conclusion/s:**

**Assessment (Rubric for Laboratory Performance):**

| CRITERIA | BEGINNER 1 | ACCEPTABLE 2 | PROFICIENT 3 | SCORE |
|---|---|---|---|---|
| **I. Laboratory Skills** | | | | |
| Manipulative Skills | Members do not demonstrate needed skills. | Members occasionally demonstrate needed skills. | Members always demonstrate needed skills. | |
| Experimental Set-up | Members are unable to set-up the materials. | Members are able to set-up the materials with supervision. | Members are able to set-up the material with minimum supervision. | |
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| Safety Precautions | Members do not follow safety precautions. | Members follow safety precautions most of the time. | Members follow safety precautions at all times. | |
| **II. Work Habits** | | | | |
| Time Management / Conduct of Experiment | Members do not finish on time with incomplete data. | Members finish on time with incomplete data. | Members finish ahead of time with complete data and time to revise data. | |
| Cooperative and Teamwork | Members do not know their tasks and have no defined responsibilities. Group conflicts have to be settled by the teacher. | Members have defined responsibilities most of the time. Group conflicts are cooperatively managed most of the time. | Members are on tasks and have defined responsibilities at all times. Group conflicts are cooperatively managed at all times. | |
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| Ability to do independent work | Members require supervision by the teacher. | Members require occasional supervision by the teacher. | Members do not need to be supervised by the teacher. | |
| **Other Comments / Observations:** | | | **TOTAL SCORE** | |
| | | | **RATING** = $\left(\frac{TotalScore}{24}\right)$ x 100% | |

**Questions and Problems**

1. A certain gas weighs 7 $KN/m^3$ at a certain temperature and pressure. What are the values of its density, specific volume, and specific gravity relative to air weighing 12 $N/m^3$?

2. If 5.30 $m^3$ of certain oil weighs 43,860 N, calculate the specific weight, density and specific volume.

3. The density of alcohol is 790 $kg/m^3$. Calculate its specific weight, specific gravity and specific volume.

4. A cubic meter of air at 101.3 kPa and 15ºC weighs 12 N, what is its specific volume?

5. What is the standard fluid used in hydraulics and what are its standard properties?

## Experiment 2
## Measurement of Pressure Head using Manometer

**Objective:**

The activity aims to determine the pressure of liquid at various depths.

**Intended Learning Outcomes (ILOs):**

At the end of the activity the students shall be able to:

1. Define the basic principle of pressure.
2. Demonstrate pressure head measurement using U – tube manometer.
3. Describe pressure and elevation relationships of fluids.
4. Identify pressure of liquid at a certain point.
5. Use the principle of pressure to solve common problems with fluid columns.

**Discussion:**

The intensity of pressure, at any point in a fluid, is the amount of pressure per unit area.

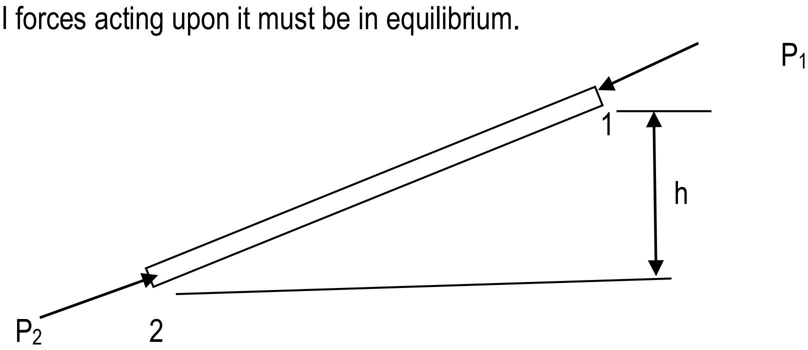
$$P = \frac{Force, F}{Area, A}$$

Pascals Law states:

At any point in a fluid at rest, the pressure is the same in all directions.

Variations in Pressures

Consider any two points (1 & 2), whose difference in elevation is h, to lie in the ends of an elementary prism having a cross sectional area dA and a length of L. Since this prism is at rest, all forces acting upon it must be in equilibrium.




$$P_2 - p_1 = wh$$

Therefore, the difference in pressure between any two points in a homogeneous fluid at rest is equal to the product of the unit weight of the fluid (w) to the vertical distance (h) between the points.

Also,

$$P_2 = P_1 + wh$$

Meaning any change in pressure at point 1 would cause an equal change at point 2. Therefore, a pressure applied at any point in a liquid at rest is transmitted equally and undiminished to every other point in the liquid.

Consider that point 1 lies at the FLS (p1 = 0), then;

$$P = wh$$

A free liquid surface (FLS) is the surface which is subject to the atmospheric pressure (no gage pressure)

Consider that points 1 and 2 lies on the same elevation so that h = 0, then;

$$P_1 = P_2$$

Therefore, the pressure along the same horizontal plane in a homogeneous fluid at rest is equal.

Note: w = unit weight of the liquid

h = height of the fluid

**Resources/Instruments Required:**

- U – Tube manometer
- Mercury
- Rubber tubing
- Funnel
- Prophylactic or thin sheet of rubber
- Water
- Colored Liquid

**Procedures:**

1. Cover the large end of the thistle tube/funnel with a piece of thin sheet of rubber.
2. Attach a piece of rubber tubing over the smaller end of the funnel while the other ends to the U – tube manometer that has two different liquid.
3. Measure the height of the fluids in the U tube manometer.
4. Tabulate the results.
5. Repeat step 2 to 4 with other liquids.

**Laboratory Report:**

Group No. :

Section:

Date Performed:

Date Submitted:

Group Members:

1. **Data Results:**

| Trials (Fluid/s) | h1 (left tube) | h2 (right tube) | Pressure |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |

2. **Observation:**

3. **Analysis:**

**4. Source/s of Error:**

**5. Conclusion:**

**Assessment (Rubric for Laboratory Performance):**

| CRITERIA | BEGINNER<br>1 | ACCEPTABLE<br>2 | PROFICIENT<br>3 | SCORE |
|---|---|---|---|---|
| **I. Laboratory Skills** | | | | |
| Manipulative Skills | Members do not demonstrate needed skills. | Members occasionally demonstrate needed skills. | Members always demonstrate needed skills. | |
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| Safety Precautions | Members do not follow safety precautions. | Members follow safety precautions most of the time. | Members follow safety precautions at all times. | |
| **II. Work Habits** | | | | |
| Time Management / Conduct of Experiment | Members do not finish on time with incomplete data. | Members finish on time with incomplete data. | Members finish ahead of time with complete data and time to revise data. | |
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| Ability to do independent work | Members require supervision by the teacher. | Members require occasional supervision by the teacher. | Members do not need to be supervised by the teacher. | |
| **Other Comments / Observations:** | | | **TOTAL SCORE** | |
| | | | **RATING** $= \left(\frac{TotalScore}{24}\right) \times 100\%$ | |

**Questions and Problems:**

1. If the pressure 3m below the free surface of a liquid is 140 Kpa, calculate its specific weight and specific gravity.

2. An open vessel contains carbon tetrachloride (s=1.50) to a depth of 2 m and waters to a depth of 1.30 m. what is the pressure at the bottom?

3. How many meters of water are equivalent to a pressure of 100 Kpa? How many cm of mercury?

4. What is the equivalent pressure in Kpa corresponding to one meter of air at 15ºC under standard atmospheric conditions?

5. What are other methods/instruments used in measuring pressure?

# Experiment 3
# Manometer and Boyle's Law

**Objective:**

The activity aims to discuss the concept and principle of Boyle's Law in the determination of pressure with the aid of the U – tube manometer.

**Intended Learning Outcomes (ILOs):**

At the end of the activity the students shall be able to:

1. Discuss the concept of Boyles law
2. Demonstrate the use of manometer in the determination of pressure of a fluid.
3. Solve problems involving the principles of Boyle's law.

**Discussion:**

**A. Manometer**

The term manometer is given to a wide variety of devices that measure the pressure by balancing the pressure against to column of liquid in static equilibrium/ the most common types of manometer are:

1. Open manometer- it has an atmospheric surface in one leg and capable of measuring relative or gage pressure.
2. Differential Manometer- it does not have any atmosphere surface and used for measuring pressure difference.

Basically, the use of manometer in measuring pressure or difference in pressure is relatively a good technique in as much as the instrument is simple tube bent in the form of a u and gives precise measurement.

Boyle's Law, a principle that describes the relationship between the pressure and volume of a gas. According to this law, the pressure exerted by a gas held at a constant temperature varies inversely with the volume of the gas. For example, if the volume is halved, the pressure is doubled; and if the volume is doubled, the pressure is halved.

Boyle's Law actually applies only to an ideal, theoretical gas. When real gases are compressed at a constant temperature, changes in the relationship between pressure and volume occur. However, the law is accurate enough to be useful in a number of practical applications. It is used, for example, in calculating the volume and pressure of internal-combustion engines and steam engines.

The law was first stated in 1662 by Robert Boyle. In 1676, Edme Mariotte of France independently stated the same law, and it is sometimes called Mariotte's Law.

Stated as a formula, Boyle's Law reads:

$$P_1V_1 = P_2V_2 \text{ (at constant temperature)}$$

where $V_1$ equals the original volume, $V_2$ equals the new volume, $P_1$ the original pressure, and $P_2$ the new pressure.

**Procedures:**

1. Set up a manometer with a liquid inside the tube.
2. Connect the rubber tubing at one end of the manometer while the other end at the smaller end of the funnel.
3. Slowly immerse the glass funnel down to the water (in the container) allowing the water to enter.
4. Take note of the difference in height of the surface of the mercury in the manometer. Designate it as h.
5. Also take note the height of water that enters into the glass funnel, designate that as $h_{1.}$, record as well the diameter of the water surface that enters the funnel. Designate it as d.
6. Repeat set up 1 to 5 with other liquids.
7. Evaluate pressure using the formula below

$$p_1 v_1 = p_2 v_2$$

$$V = (\frac{\pi}{3})\ (R^2 + r + Rr)$$

$$p_1 = 101.3\ kpa$$

$$V_2 = (\frac{\pi}{3})\ (R^2 + r_1^2 + r r_1)(h - h_1)$$

$$p_2 = p_o + y_{h2o} S_g H_g h_g$$

Newton's Law of approximation 3rd degree

$$h = h - p(h_1)/p(h_1)$$

$$x = \frac{h-h_1}{h}(R - r)$$

$$r_1 = r + x\ (h - h_2)/h(R - r)$$

$$\frac{x}{h-h_1} = \frac{r-r}{h}$$

**Laboratory Report:**

Group No.: Section:

Date Performed: Date Submitted:

Group Members:

1. **Data and Results:**

| **Fluid** | **d (cm)** | **h (cm)** | **h1** | **P2 (kPa)** |
|---|---|---|---|---|
| | | | | |
| | | | | |
| | | | | |
| | | | | |

**2. Observation:**

**3. Analysis:**

### 4. Source/s of error

### 5. Conclusion:

**Assessment (Rubric for Laboratory Performance):**

| CRITERIA | BEGINNER<br>1 | ACCEPTABLE<br>2 | PROFICIENT<br>3 | SCORE |
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| **II. Work Habits** | | | | |
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| Ability to do independent work | Members require supervision by the teacher. | Members require occasional supervision by the teacher. | Members do not need to be supervised by the teacher. | |
| **Other Comments / Observations:** | | | **TOTAL SCORE** | |

| | | |
|---|---|---|
| | **RATING** = $\left(\frac{TotalScore}{24}\right)$ x 100% | |

**Question and Problems:**

1. A glass 1.60 m long and having a diameter of 2.50 is inserted vertically into tank oil (y= 0.80) with the open end down and the closed end uppermost. If the open end is submerged 1.30 m from the oil surface, determine the height to which the oil will raise bin the tube. Assume barometric pressure is 100 kPa and neglect vapor pressure.

2. The manometer in the figure is taped to a pipeline carrying oil (y= 0.85). Determine the pressure at the centerline of the pipe. (h= 0.30m)

3. Give the common types of manometer and discuss their usage and differences.

## Experiment 4
## Determination of the Density of a Fluid

**Objective:**

The activity aims to determine the density of a fluid.

**Intended Learning Outcomes (ILOs):**

At the end of the activity the students shall be able to:

1. Demonstrate ability to measure, collect and record data accurately.
2. Demonstrate ability to use data in a formula to solve for density.
3. Identify the density of water and compare with common liquids.
4. Identify if there is a relationship between the volume and mass of the volume in solving for density.

**Discussion:**

Density is a physical property of matter, as each element and compound has a unique density associated with it. Density defined in a qualitative manner as the measure of the relative "heaviness" of objects with a constant volume.

Density is the mass of the fluid contained in a unit volume. The specific weight and density of a fluid both decrease with an increase in temperature, which causes the molecular activity and spacing to likewise increase. On the other hand, with the application of additional pressure which tends to increase the amount of molecules in the fluid, it is possible to increase the specific weight and density of the fluid.

More commonly, the specific weight of a gas is computed through the combination of the Boyle and Charle's Laws, which gives

$$\gamma = \rho g = \frac{Pg}{RT}$$

Where:
Y = Specific Gravity
P = Density in kg/m$^3$
G = acceleration due to gravity in m/s$^2$
P = absolute pressure in Pa
R = gas constant in N-n/kg-$^0$K
T = temperature in $^0$K

**Resources/Instruments Required:**

- Graduated Cylinder
- Hydrometer Cylinder
- Scale or Triple Beam Balance
- Liquids whose properties are to be measured
- Block of wood

**Procedure:**

Method 1

1. Weigh an empty graduated cylinder or beaker.
2. Weigh a known volume of a liquid using a graduated cylinder or beaker.
3. Identify the density of the liquid from the difference in weight divided by the volume.

Method 2

1. Weigh a block of wood in air.
2. Weigh a block of wood in liquid
3. Identify the buoyant force acting on the object from the difference of its weight.
4. Identify the density of the liquid from the difference in volume of the liquid displaced which is equivalent to the weight per unit volume.

**Laboratory Report:**

Group No.: Section:
Date Performed: Date Submitted:
Name of Members:

**1. Data and Results:**

Method 1

| **Data needs to be gathered** | **Water (g)** | **Oil (g)** |
|---|---|---|
| Mass of the graduated cylinder | | |
| Mass of the graduated cylinder and liquid | | |
| Mass of the liquid | | |
| Volume of liquid | | |

Method 2

| **Data needs to be gathered** | **Water (g)** | **Oil (g)** |
|---|---|---|
| Mass of the graduated cylinder | | |
| Mass of the graduated cylinder and liquid | | |
| Mass of liquid | | |

| Data needs to be gathered | Water (g) | Oil (g) |
|---|---|---|
| Mass of the wood in air | | |
| Mass of the graduated cylinder + liquid + wood | | |
| Mass of the wood in liquid | | |
| Volume of liquid | | |
| Total volume of the wood | | |
| Volume of the wood submerged | | |
| Volume of the liquid (displaced) | | |

**2. Observation:**

**3. Analysis:**

### 4. Source/s of Error/s

### 5. Conclusion:

**Assessment (Rubric for Laboratory Performance):**

| CRITERIA | BEGINNER 1 | ACCEPTABLE 2 | PROFICIENT 3 | Score |
|---|---|---|---|---|
| **I. Laboratory Skills** | | | | |
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| **II. Work Habits** | | | | |
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| **Other Comments / Observations:** | | | **TOTAL SCORE** | |
| | | | **RATING** $= \left(\frac{TotalScore}{24}\right) \times 100\%$ | |

**Questions and Problems:**

1. Are the results of all density measurement in agreement?

2. How does the buoyant force vary with the depth of the submerged object? Why?

3. An ice berg weighing 8.96 $kN/m^3$ floats in seawater (y=10.10 $kN/m^3$) with a volume $m^3$ above the surface. What is the total volume of the iceberg?

4. A log 1m long and having a diameter of 30 cm floats in fresh water. If its specific gravity is 0.75, what is the depth of floatation?

# Experiment 5
# Specific Gravity by Archimedes Principle

**Objective:**

The activity aims to determine the specific gravity of fluid using Archimedes Principle.

**Intended Learning Outcomes (ILOs):**

At the end of the activity, the students shall be able to:

1. Discuss the concept of Archimedes principle.
2. Demonstrate the proper use of hydrometer.
3. Identify the correct measurement of the specific gravity of a fluid using hydrometer.

**Discussion:**

Buoyancy is an upward force exerted by a fluid that opposes the weight of an immersed object. In a column of fluid, pressure increases with depth as a result of the weight of the overlying fluid. Thus a column of fluid, or an object submerged in the fluid, experiences greater pressure at the bottom of the column than at the top. This difference in pressure results in a net force that tends to accelerate an object upwards. The magnitude of that force is proportional to the difference in the pressure between the top and the bottom of the column, and (as explained by Archimedes' principle) is also equivalent to the weight of the fluid that would otherwise occupy the column, i.e. the displaced fluid.

For this reason, an object whose density is greater than that of the fluid in which it is submerged tends to sink. If the object is either less dense than the liquid or is shaped appropriately (as in a boat), the force can keep the object afloat. This can occur only in a reference frame which either has a gravitational field or is accelerating due to a force other than gravity defining a "downward" direction (that is, a non-inertial reference frame). In a situation of fluid statics, the net upward buoyancy force is equal to the magnitude of the weight of fluid displaced by the body.

Operation of the hydrometer is based on “Archimedes Principle” that a solid suspended in a fluid will be buoyed up by a force equal to the weight of the fluid displaced by the submerged part of the suspended solid. Thus, the lower the density of the substance, the farther the hydrometer will sink.

$$F_b = \gamma_f V_s$$

Where,

$F_b$ = Buoyant Force

$\gamma_f$ = specific weight of fluid

$V_s$ = Volume submerged

**Resources / Instruments Required:**

- Graduated Cylinder
- Hydrometer
- Liquids

**Procedures:**

1. Pour an amount of liquid into the graduated cylinder.
2. Place the graduated cylinder on a level surface.
3. Gently lower the hydrometer into the graduated cylinder. If there are bubbles clinging to the hydrometer, flick it to knock them off. If this does not get rid of the bubbles, remove the hydrometer and lower it again. Bubbles throw off the hydrometer reading.
4. Move the hydrometer to the middle of the graduated cylinder so it is floating freely and not attached to the sides.
5. Take the measurement at the lowest point of the curved surface of the liquid.

**Laboratory Report:**

Group No: Section:
Date Performed: Date Submitted:
Group Members:

**1. Data and Results:**

| LIQUID | SPECIFIC GRAVITY |
| --- | --- |
| | |
| | |
| | |
| | |

**2. Observation/s:**

## 3. Analysis:

## 4. Source/s of Error

## 5. Conclusion:

**Assessment (Rubric for Laboratory Performance):**

| CRITERIA | BEGINNER<br>1 | ACCEPTABLE<br>2 | PROFICIENT<br>3 | SCORE |
|---|---|---|---|---|
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| **Other Comments / Observations:** | | | **TOTAL SCORE** | |
| | | | **RATING** $= \left(\frac{TotalScore}{24}\right) \times 100\%$ | |

**Questions and Problems:**

1. A rectangular solid piece of wood 30 $cm^2$ and 5 cm thick floats in water to a depth of 3.25 cm. How heavy an object must be placed on the wood (s=0.50) in such a way that it will just be submerged?

2. The specific gravity of rock used as concrete aggregate is often desirable to know. If a rock weighed 6.50 N in the air and 3.80 N submerged in water, what would be the specific gravity of the rock?

3. A piece of wood weighs 17.80 N in air and a piece of metal weighs 14.80 N in water. Together the two weighs 13.35 N in water. What is the specific gravity of the wood?

4. How does buoyant force vary with the depth of submerged fluid? Why?

# Experiment 6
# Fluid Viscosity Determination

**Objective:**

The activity aims to determine the specific gravity of fluid using a U – tube manometer.

**Intended Learning Outcomes (ILOs):**

At the end of the activity the students shall be able to:

1. Discuss the concept of fluid viscosity.
2. Identify the settling time of spheres in a quiescent fluid.
3. Solve the viscosity of a fluid using Stokes' law and the terminal velocity of a sphere in this fluid.
4. Evaluate the diameter effects of fluid container on the determination of fluid viscosity using a "falling ball" viscometer.

**Discussion:**

Viscosity is a measure of a fluid's resistance to flow. It describes the internal friction of a moving fluid. A fluid with large viscosity resists motion because its molecular makeup gives it a lot of internal friction. A fluid with low viscosity flows easily because its molecular makeup results in very little friction when it is in motion.

**Falling Ball Viscometers**

The falling ball viscometer is based on Stokes' Law, and is what we will use in this laboratory investigation. This type of viscometer consists of a circular cylinder containing the fluid and a smooth ball. The ball is placed in the fluid and the time that it takes to fall the length of the cylinder is recorded. This time is then utilized to back the viscosity out of the velocity relationship that we derived using Stokes' Law and summing forces. As the ball is dropped into the fluid it accelerates as a result of the gravitational field until the ball reaches terminal velocity. Terminal velocity occurs when the viscous and buoyancy forces equal the weight of the ball. At this point the velocity of the ball is maximum, or terminal. To simplify our approach, we will allow the ball to reach terminal velocity prior to making the time measurements. The forces acting on a sphere, for example, that are falling at terminal velocity through the liquid are:

**Weight – Buoyancy – Drag = 0**

$$\frac{4}{3}\pi R^3 \rho_s g - \frac{4}{3}\pi R^3 \rho g - 6\mu V R = 0$$

$$\rho V D \leq 1$$

Where D is the sphere diameter. Once the viscosity of the liquid is found, the above ratio should be calculated to be certain that the mathematical model gives an accurate description of a sphere falling through the liquid.

**Resources / Instruments Required:**

- Graduated cylinder
- Scale
- Stopwatch
- Test Fluids
- Several Small Spheres with Weight and Diameter to be measured

## Procedures

### Equipment Measurements

1. Weigh each sphere on an electronic scientific scale and record on a sheet of paper the mass of each sphere (in kilograms). Measure each sphere for diameter then divide that by two to equal the radius. Record each radius value on the paper.
2. Calculate the volume of each sphere using the formula $v= (4\pi r^3)/3$, where "v" represents volume and "r" represents the sphere's radius. π equals 3.14.
3. Determine the density of each sphere by dividing the mass found in Step 1 by the volume found in Step 2. Record the density of each sphere.
4. Place an empty beaker on the scale and record its weight. Remove the beaker and fill it with 10 ml of the liquid. Subtract the weight of the empty beaker from the weight of the full beaker and divide the answer by 10 to calculate the density of 1 ml of that liquid.

### Determine Viscosity

5. Prepare your workstation with a graduated cylinder, the spheres, liquids, paper, stopwatch and tape. Carefully pour liquid into a graduated cylinder until it is nearly full. Leave about a half inch of space between the liquid and the top of the cylinder.
6. Mark off a spot, using the tape, about 2 cm below the liquid's surface and another about half an inch from the bottom of the cylinder. These marks will help determine the distance of the sphere's fall. Use either the top or the bottom of the tape as a guide, but remain consistent. Measure the exact distance between the tape marks and record it.
7. Hold the sphere on the surface of the liquid. Simultaneously start the stopwatch and drop the sphere. Stop the watch when the sphere reaches the second tape mark. Record the data. Repeat the drop using the other spheres and record their data. Repeat Steps 1 through 4 with the other liquid.
8. Calculate the velocity of the spheres by dividing the distance between the tape marks by the time it took for the sphere to reach the second mark.
9. Calculate the viscosity of the fluid

## Laboratory Report:

Group No.: Section:
Date Performed: Date Submitted:
Group Members:

1. **Data and Results:**

**Sphere Data**

| Materials | Diameter (mm) | Volume (m3) | Weight (g) | Density (g/m3) |
|---|---|---|---|---|
| Marble | | | | |
| Metal sphere | | | | |

**Viscosity Data**

| Liquids | Specific gravity | Trials | Sphere Used | Distance (cm) | Time (s) | Velocity (m/s) | Viscosity (Pa – s) |
|---|---|---|---|---|---|---|---|
| | | 1 | Marble | | | | |
| | | 2 | Metal | | | | |
| | | 1 | Marble | | | | |
| | | 2 | Metal | | | | |
| | | 1 | Marble | | | | |
| | | 2 | Metal | | | | |

**2. Observation:**

**3. Analysis:**

**4. Source/s of Error/s:**

**5. Conclusion:**

**Assessment (Rubric for Laboratory Performance):**

| CRITERIA | BEGINNER<br>1 | ACCEPTABLE<br>2 | PROFICIENT<br>3 | SCORE |
|---|---|---|---|---|
| **I. Laboratory Skills** | | | | |
| Manipulative Skills | Members do not demonstrate needed skills. | Members occasionally demonstrate needed skills. | Members always demonstrate needed skills. | |
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| Safety Precautions | Members do not follow safety precautions. | Members follow safety precautions most of the time. | Members follow safety precautions at all times. | |
| **II. Work Habits** | | | | |
| Time Management / Conduct of Experiment | Members do not finish on time with incomplete data. | Members finish on time with incomplete data. | Members finish ahead of time with complete data and time to revise data. | |
| Cooperative and Teamwork | Members do not know their tasks and have no defined responsibilities. Group conflicts have to be settled by the teacher. | Members have defined responsibilities most of the time. Group conflicts are cooperatively managed most of the time. | Members are on tasks and have defined responsibilities at all times. Group conflicts are cooperatively managed at all times. | |
| Neatness and Orderliness | Messy workplace during and after the experiment. | Clean and orderly workplace with occasional mess during and after the experiment. | Clean and orderly workplace at all times during and after the experiment. | |
| Ability to do independent work | Members require supervision by the teacher. | Members require occasional supervision by the teacher. | Members do not need to be supervised by the teacher. | |
| **Other Comments / Observations:** | | | **TOTAL SCORE** | |
| | | | **RATING** = $\left(\frac{TotalScore}{24}\right)$ x 100% | |

**Questions and Problems:**

1. Should the terminal velocity of two different size spheres be the same?

2. Does a larger sphere have a higher terminal velocity?

3. Should the velocity found for two different size spheres be the same? Why or why not?

4. If different size spheres give different results for the viscosity, what are the error sources?

5. What are the shortcomings of this method?

6. Why should temperature be recorded?

7. Can this method be used for gases?

8. Can this method be used for opaque liquids?

9. Can this method be used for something like peanut butter, or grease of flour dough?
   Why or why not?

# Experiment 7
## Center of Pressure on Submerged Plane surface

**Objective:**

The activity aims to determine the center of pressure of a vertical submerged plane surface.

**Intended Learning Outcomes (ILOs):**

At the end of the activity the students shall be able to:

1. Identify safe operating practices and requirements for laboratory experiments.
2. Review the concepts and equations for calculating pressure forces on plane surfaces.
3. Identify the center of pressure of plane surface submerged in a fluid.
4. Measure the pressure force acting on the plane surface for two water depths, and compare the measured forces with calculated forces.

**Discussion:**

Submerged surfaces can be found in many engineering applications. Dams, weirs and water gates are familiar examples of submerged surfaces used to control the flow of water. From the design viewpoint, it is important to have knowledge of the forces that act on the submerged surfaces.

A plane surface located beneath the surface of a liquid is subject to a pressure due to height of liquid above it. Increasing pressure varies linearly with increasing depth resulting in a pressure distribution that acts the submerged surface. The analysis of this situation involves determining the force, which is equivalent to the pressure and finding the location of this force.

For this case, it can be shown that the equivalent forces is,

$$F = YcPgA$$

Where:

P = is the liquid density

Yc = the distance from the free surface of the liquid to the centric of the plane

A = the area of the plane in contact with the liquid.

Further, the location of this force $Y_f$ below the free surface is,

$$Y_f = \frac{Y_g}{Y_c A} + Y_c$$

Where:

Ig = the centroidal moment of inertia of the area

**Resources/Instruments Required:**

- Center of pressure apparatus
- Set of weights
- Water
- basin

**Procedure:**

**Counterbalancing the Water Vessel**

1. Set the water vessel (1) to an angle of $\alpha = 0^0$ using the detent (2) as shown.
2. Mount the rider (6), set the lever arm on the scale (e.g. l = 150 mm).
3. Counterbalance the unit with a rotating slier (3): The stop pin (4) must be precisely in the middle of the hole for this.

**Performing the Experiment**

1. Top up with water until the unit is balanced (stop pin (4) at the center of hole).
2. Read off the water level s and enter it in the prepared worksheet.
3. Increased the appended weights (7) in increments of 0.5 – 1 N and repeat the measurement.

**Evaluating the experiments**

S = water level reading
l = Lever arm of the force due to weight
Fg = Force due to weight of the appended weights

**Laboratory Report:**

Group No.: Section:
Date Performed: Date Submitted:
Group Members:

1. **Data and Results:**

| Trials | W (N) | l (mm) | S (mm) | $l_D$ (mm) | $F_{exp}$ (N) | Ft (N) | % error |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |

**Where:**

ID is the distance to center of motion of the unit
= 200 mm – s/3

Fexp is a force of a balance of moments around the center of motion O

$$\Sigma M_o = 0$$
$$F_g \cdot l = F_{exp} \cdot l_D$$
$$F_{exp} = \frac{F_g \cdot l}{l_D}$$

Ft is the resultant force

$$F_t = P_c A_{act}$$

Or $$F_t = w h A_{act}$$

Where,
$$h = \frac{s - s_t}{\cos \alpha}$$

$$A_{act} = s \cdot b$$

$$b = 75 \text{ mm}$$

**2. Observation:**

**3. Analysis**

**4. Source/s of Error/s:**

**5. Conclusion:**

**Assessment (Rubric for Laboratory Performance):**

| CRITERIA | BEGINNER<br>1 | ACCEPTABLE<br>2 | PROFICIENT<br>3 | SCORE |
|---|---|---|---|---|
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| **II. Work Habits** | | | | |
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| Ability to do independent work | Members require supervision by the teacher. | Members require occasional supervision by the teacher. | Members do not need to be supervised by the teacher. | |
| **Other Comments / Observations:** | | | **TOTAL SCORE** | |
| | | | **RATING** $= \left(\frac{TotalScore}{24}\right) \times 100\%$ | |

**Questions and Problems:**

1. Why isn't the weight of the torus and the balance arm taken into account?

2. What is the significance effect of hydrostatic pressure in civil engineering?

3. A vertical rectangular plane of height d and base b is submerged in a liquid with its top edge at the liquid surface. Determine the total force P acting on one side and its location from the liquid surface.

4. A vertical rectangular plate is submerged half in oil (sp.gr. = 0.8) and half in water such that its top edge is flushed with the oil surface. What is the ratio of the force exerted by water acting on the lower half to that by oil acting on the upper half?

5. A 30 m long dam retains 9 m of water as shown in the figure. Find the total resultant force acting on the dam and the location of the center of pressure from the bottom.

## Experiment 8
## Force and Forced Vortex Apparatus

**Objective:**

The activity aims to plot the surface of various forced vortices formed under different speed conditions.

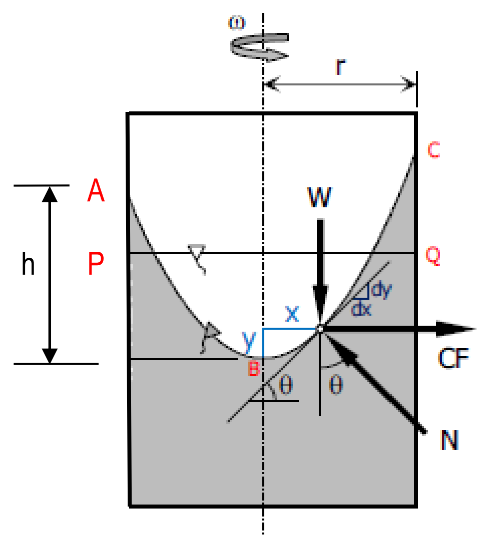
**Intended Learning Outcomes (ILOs):**

At the end of the activity, the students shall be able to:

1. Demonstrate the free and forced vortices.
2. Identify the surface profile of a free and forced vortex.
3. Locate and describe the total head variation in free and forced vortex.
4. Sketch the shape of a free vortex by measurement of the surface profile coordinates..

**Discussion:**

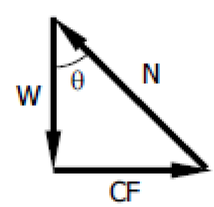
When at rest, the surface of mass of liquid is horizontal at PQ as shown in the figure. When this mass of liquid is rotated about a vertical axis at constant angular velocity ω radian per second, it will assume the surface ABC which is parabolic. Every particle is subjected to centripetal force or centrifugal force CF = $m\omega^2 x$ which produces centripetal acceleration towards the center of rotation. Other forces that acts are gravity force W = mg and normal force N.




$$\tan\theta = \frac{CF}{W}$$

$$\tan\theta = \frac{m\omega^2 x}{mg}$$

$$\tan\theta = \frac{\omega^2 x}{g}$$




Where tan θ is the slope at the surface of paraboloid at any distance x from the axis of rotation.

From Calculus, y' = slope, thus

$$\frac{dy}{dx} = \tan\theta$$

$$\frac{dy}{dx} = \frac{\omega^2 x}{g}$$

$$dy = \frac{\omega^2}{g} x \, dx$$

$$\int dy = \frac{\omega^2}{g} \int x \, dx$$

$$y = \frac{\omega^2 x^2}{2g}$$

For cylindrical vessel of radius r revolved about its vertical axis, the height h of paraboloid is

$$h = \frac{\omega^2 r^2}{2g}$$

**Other Formulas**
By squared-property of parabola, the relationship of y, x, h and r is defined by

$$\frac{r^2}{h} = \frac{x^2}{y}$$

Volume of paraboloid of revolution

$$V = \tfrac{1}{2} \pi r^2 h$$

Important conversion factor

$$1 \text{ rpm} = 1/30\ \pi \text{ rad/sec}$$

**Resources/Instruments Required:**

- Free and Forced Vortex Apparatus
- Hydraulic Bench
- Water

**Procedure:**

Measurements

1. Radius and Height

   Insert combined radius and height gauge in mount from underneath and secure using star-type nut.
   - For measurement, loosen star-type nut and set new height; then use knurled nut and set new height ; then use knurled nut on cross member to move gauges to surface of vortex.
   - Readings are taken at the following points:
     **Height**: Shoulder of retaining rod; this indicates the height of the gauges above the bottom
     Radius: Left edge of notch of slider; this indicates the radius
2. Height gauge

   - Pull combined radius and height gauge downwards out of mount and insert 10 mm gauge in hole; secure with star-type nut.
   - Insert 3 mm gauges in holes in gland bolts and secure
   - For measurement, position gauges on surface of vortex. As all gauges are of equal length, a rule can be used to measure the distance between the top edge of the mount and the end of the gauge.

Velocity determination by way of number of revolutions

1. Allow a small piece of paper or polystyrene to drop into the surface to measure the velocity of the vortex.

2. Then use a stopwatch to determine the time taken for the piece of paper to perform 10 revolutions with the vortex.
3. Determine the radius on which the paper revolves.

Angular velocity ω is.

$$\omega = 2 . \pi . n \text{ in } 1/s$$

with n in Revolutions/seconds

**Laboratory Report:**

Group No.: Section:
Date Performed: Date Submitted:
Group Members:

**1. Data and Results:**

| Radius r in mm | 0 | 30 | 50 | 70 | 90 | 110 | ω (rpm) | (rad/sec) |
|---|---|---|---|---|---|---|---|---|
| Height h in mm | | | | | | | | |
| Experimental (right) | | | | | | | | |
| Experimental (Left) | | | | | | | | |
| Theoretical | | | | | | | | |

**2. Observations:**

## 3. Analysis

## 4. Source/s of Error/s:

## 5. Conclusions:

**Assessment (Rubric for Laboratory Performance):**

| CRITERIA | BEGINNER<br>1 | ACCEPTABLE<br>2 | PROFICIENT<br>3 | SCORE |
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| **Other Comments / Observations:** | | | **TOTAL SCORE** | |
| | | | **RATING** $= \left(\frac{TotalScore}{24}\right) \times 100\%$ | |

**Questions and Problems:**

1. A rectangular tank 20 ft. long by 6 ft. deep by 7 ft. wide contains 3 ft. of water. If the linear acceleration horizontally in the direction of the tanks length is 8.05 ft./sec$^2$, determine the greatest pressure at the bottom of the tank.

2. If the tank in Problem 1 is filled with water and accelerated in the direction of its length and the rate of 5 ft./sec$^2$, how many gallons of water are spilled?

3. A tank is 1.5 square and contains 1m of water. How high must its sides be if no water is spilled when the acceleration is 4 m/sec$^2$ parallel to a pair of sides?

4. An open cylindrical tank 6 ft high and 3 ft in diameter contains 4.5 ft of water. If the cylinder rotates its geometric axis,
   a. What is the greatest constant angular velocity that will be allowed without spilling the water?

5. A U-tube with right angles bends is 305 mm wide and contains mercury that rises 229 in each leg when the tube is at rest. At what speed must the tube be rotated about an axis 76 mm from one leg so that there will be no mercury in that leg of the tube.

## Experiment 9
## Bernoulli's Principle Demonstrator

**Objective:**

The activity aims the students to understand the Bernoulli's principle.

**Intended Learning Outcomes (ILOs):**

At the end of the activity, the students shall be able to:

1. State Bernoulli's principle.
2. Carry out an experiment to show the effect of Bernoulli's principle using a venture tube.
3. Explain that a resultant force exists due to a difference in fluid pressure.
4. Describe application of Bernoulli's principle.
5. Solve problems involving Bernoulli's principle.

**Discussion:**

Bernoulli's principle, sometimes known as Bernoulli's equation, holds that for fluids in an ideal state, pressure and density are inversely related: in other words, a slow-moving fluid exerts more pressure than a fast-moving fluid. Since "fluid" in this context applies equally to liquids and gases, the principle has as many applications with regard to airflow as to the flow of liquids. One of the most dramatic everyday examples of Bernoulli's principle can be found in the airplane, which stays aloft due to pressure differences on the surface of its wing; but the truth of the principle is also illustrated in something as mundane as a shower curtain that billows inward.

Bernoulli's energy theorem results from the application of the principles of conservation of energy.

$$E_1 = E_2$$
$$\frac{V_1^2}{2g} + \frac{P_1}{\omega} + Z_1 = \frac{V_2^2}{2g} + \frac{P_2}{\omega} + Z_2$$

Bernoulli's Theorem Demonstrator facilitates the students and the industrial professionals to explore the fundamentals of "Bernoulli's Theorem" in Fluid Mechanics. It states that, in a steady flow the sum of all forms of mechanical energy (kinetic, potential and pressure energy) in a fluid along a streamline is the same at all points on that streamline. It consists of classical venture of clear acrylic. A series of wall tapping allows measurement of static pressure distribution of convergent duct, while a total head tube is provide at the centre of throat. These tapping are connected to a bank of manometer tube. This unit has been designed with Hydraulic Bench to study the characteristic flow through convergent and divergent section. During the experiment, the water fed to the venture and the flow rate can be control by the gate valve at the outlet of venture. The venture is used to demonstrate the flow rate measurement and to determine the co-efficient of discharge.

- Self-contained system
- Simple representation of concept
- Direct measurement of static head
- Seven pressure tapings along with tubes
- Requires minimal installation
- Robust and transparent venturimeter
- All tanks are rust proof

Bernoulli's equation for constant head h:

$$\frac{P_1}{P} + \frac{\omega_1^2}{2} = \frac{P_2}{p} + \frac{\omega_2^2}{2} = \text{constant}$$

Allowance for friction losses and conversion of the pressures $p_1$ and $p_2$ into static pressure heads $h_1$ and $h_2$ yields:

$$h_1 + \frac{\omega_1^2}{2g} = h_2 + \frac{\omega_2^2}{2g} + hv$$

**Resources/Instruments Required:**

- Bernoulli's Principle Demonstrator
- Hydraulic Bench
- Water

**Procedures:**

1. Arrange the experimentation set - up on the HM 150 such that the discharge routes the water into the channel.
2. Make hose connection between HM 150 and HM 150.07.
3. Open discharge of HM 150.
4. Set cap nut (1) of probe compression gland such that slight resistance is felt on moving probe.
5. Open inlet and outlet valves.
6. Switch on pump and slowly open main cock of HM 150.
7. Open vent valves (2) on water pressure gauges.
8. Carefully close outlet valve until pressure gauges are flushed.
9. By simultaneously setting inlet and outlet valve, regulate water level in pressure gauges such that neither upper nor lower range limit (UL, LL) is overshot or undershot.
10. Record pressure at all measurement points. Then move overall pressure probe to corresponding measurement level and note down overall pressure.
11. Determine volumetric flow rate. To do so, use stopwatch to establish time t required for raising the level in the tank of the HM 150 from 201 to 301.

**Laboratory Report:**

Group No.: Section:
Date Performed: Date Submitted:
Group Members:

**1. Data and Results:**

Table 2.2 Pressure Heads and Velocity

| Trial | Volume V ($m^3$) | Time, t (sec) | Discharge Q ($m^3/s$) | Measuring Point | | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | Head , h (mm) | Total | | | | | | |
| | | | | | Static | | | | | | |
| | | | | | Dynamic | | | | | | |
| | | | | Velocity V (m/s) | Measured | | | | | | |
| | | | | | Calculated | | | | | | |
| 2 | | | | Head , h (mm) | Total | | | | | | |
| | | | | | Static | | | | | | |
| | | | | | Dynamic | | | | | | |
| | | | | Velocity V (m/s) | Measured | | | | | | |
| | | | | | Calculated | | | | | | |

Calculation of dynamic pressure head:

$$h_{dyn.} = h_{total} - h_{stat}$$

The velocity $w_{meas}$ was calculated from the dynamic pressure

$$W_{meas} = \sqrt{2 . g . h_{dyn}}$$

## 2. Observation

## 3. Analysis

**4. Source/s of Error/s:**

**5. Conclusion:**

**Assessment (Rubric for Laboratory Performance):**

| **CRITERIA** | **BEGINNER**<br>**1** | **ACCEPTABLE**<br>**2** | **PROFICIENT**<br>**3** | **SCORE** |
|---|---|---|---|---|
| **I. Laboratory Skills** | | | | |
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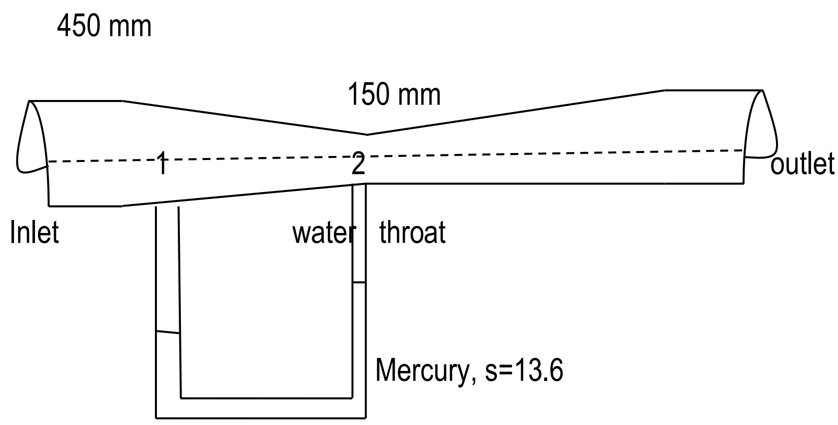
| **Other Comments / Observations:** | | | **TOTAL SCORE** | |
| | | | **RATING** $= \left(\frac{TotalScore}{24}\right) \times 100\%$ | |

**Questions and Problems:**

1. A 150 mm diameter horizontal Venturi meter is installed in a 450 mm diameter water main. The deflection of mercury in the differential manometer connected from the inlet to the throat is 375 mm. (a) Determine the discharge neglecting head loss, (b) Compute the discharge if the head lost from the inlet to the throat is 300 mm of water, and (c) what is the meter coefficient?




2. A horizontal 150 mm diameter pipe gradually reduces its section to 50 mm diameter, subsequently enlarging into 150 mm section. The pressure in the 150 mm pipe at a point just before entering the reducing section is 140 kPa and in the 50 mm section at the end of the reducer, the pressure is 70 KPa. If 600 mm head is lost between the points where the pressure are as above given, compute the rate of flow of water through the pipe.

3. Oil (sp. gr. = 0.8) flows at the rate of 8.5 litres per second through a 25 mm horizontal venturimeter which is attached to a 37.5 mm diameter pipe as shown in the figure. A differential manometer containing mercury is attached from the base of the inlet to the throat and to the base of the outlet. Calculate the deflection of mercury in each tube if the head lost from the inlet to the throat is 5% of the velocity in the throat and from the throat to the outlet is 20% of the velocity head in the throat.