OBJECTIVES

- Determine the density of a solid sample, using geometry
- Determine the density of a solid sample, using displacement
- Calibrate a volumetric pipet, using water as a standard
- Determine the density of a liquid sample, using a calibrated pipet

INTRODUCTION

Mass is a measure of how much matter a sample is composed of. In this lab mass will be measured with an analytical balance and will be reported in units of grams, g.

Volume is the amount of space a sample occupies. In this lab, volume of solids will be measured by using geometry or displacement of a liquid. The volume of liquids will be measured using volumetric glassware. Volume will be reported in units of cubic centimeters, cm^3, or milliliters, mL. These units are equivalent and interchangeable. There is a tendency to use units of cubic centimeters if the volume is determined from geometric measurements. Units of milliliters are typically used for volumes related to volumetric glassware.

$$1cm^3 = 1mL \qquad (1)$$

Density is a measure of how much mass is packed into a given volume. It is expressed as

$$\text{density} = \frac{\text{mass}}{\text{volume}} \qquad (2)$$

In this lab, density will be reported in units of g/cm^3 or g/mL.

Determination of Volume by Geometry The volume of a solid object can be determined by geometry if the sample has a regular geometric shape. See Table 1. This method involves measuring geometric features of the object, such as length, width, radius, etc. and then plugging those dimensions into the corresponding geometric formula for volume. This method is limited to objects with regular geometry.

Table 1 – Volume formulas for some simple geometric solids.

Geometric Shape	Volume
Rectangular bar	$V = l \times w \times h$
Cylinder	$V = \pi r^2 h$
Sphere	$V = \frac{4}{3}\pi r^3$

Determination of Volume From Displacement The volume of a solid object can be determined by measuring the volume of water the object can displace. See Figure 1. This method involves fully immersing the object in water within a graduated cylinder and measuring the volume of water the object displaces.

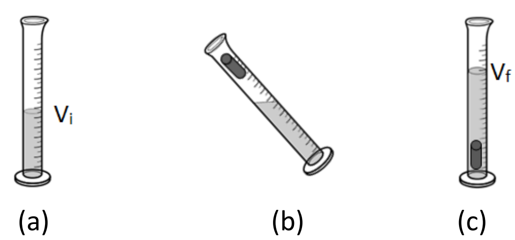


Figure 1 – Measuring volume by the displacement method. (a) Measure the initial volume, V_i. (b) Carefully slide the object into the water, (c) Measure the final volume, V_f.

$$V_{object} = V_f - V_i \qquad (3)$$

A **volumetric pipet** is used to *deliver* a specific volume of a liquid. It has a single *calibration line* that corresponds to its specified volume. A pipet pump is used to fill the pipet to the line. See Figure 2.

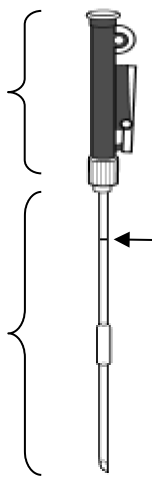


Figure 2 Volumetric pipet, fitted with a pipet pump.

Calibration of a volumetric pipet is the accurate determination of the volume of water the pipet ***delivers***. The pipet is filled to its calibration line and then drained into a weighing beaker. The mass of the water delivered is determined.

$$\text{mass of water delivered} = \mathrm{m_f} - \mathrm{m_i} \qquad (4)$$

The volume of water delivered by the pipet is then calculated from the mass and density of the water delivered.

$$\text{volume delivered} = \frac{\text{mass of water delivered}}{\text{density of water @ T°C}} \qquad (5)$$

Generally speaking, water has a density of about 1g/mL. However, the true density of water depends on temperature. For calibration purposes, a more accurate value for the density of water should be used. See Table 2.

Table 2 – Density of water at various temperatures.

Temperature (°C)	**Density** (g/mL)
10	0.999 702 6
11	0.999 608 4
12	0.999 500 4
13	0.999 380 1
14	0.999 247 4
15	0.999 102 6
16	0.998 946 0
17	0.998 777 9
18	0.998 598 6
19	0.998 408 2
20	0.998 207 1
21	0.997 995 5
22	0.997 773 5
23	0.997 541 5
24	0.997 299 5
25	0.997 047 9
26	0.996 786 7
27	0.996 516 2
28	0.996 236 5
29	0.995 947 8
30	0.995 650 2

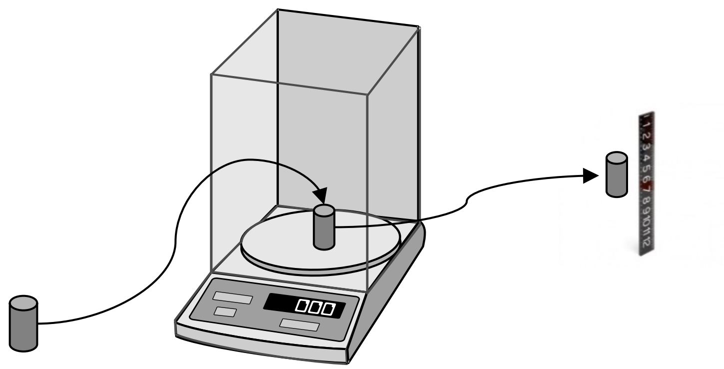
The **Density of a liquid** is determined from the mass and volume of the liquid delivered from a calibrated pipet.

$$mass\ of\ liquid\ delivered = m_f - m_i \qquad (6)$$

$$density = \frac{mass\ of\ liquid\ delivered}{volume_{(calibrated)}} \qquad (7)$$

Note: Any time the density of a sample is determined, it should be report at the temperature, T°C, that the measurements were made.

PROCEDURE 1 - DENSITY OF AN OBJECT (geometric method)



1. Obtain an object with cylindrical geometry and record its ID #.

2. Weigh the object and record its mass.

3. Use a metric ruler to measure the object. Record its height and radius.

$$\text{Volume of object} = \pi r^2 h$$

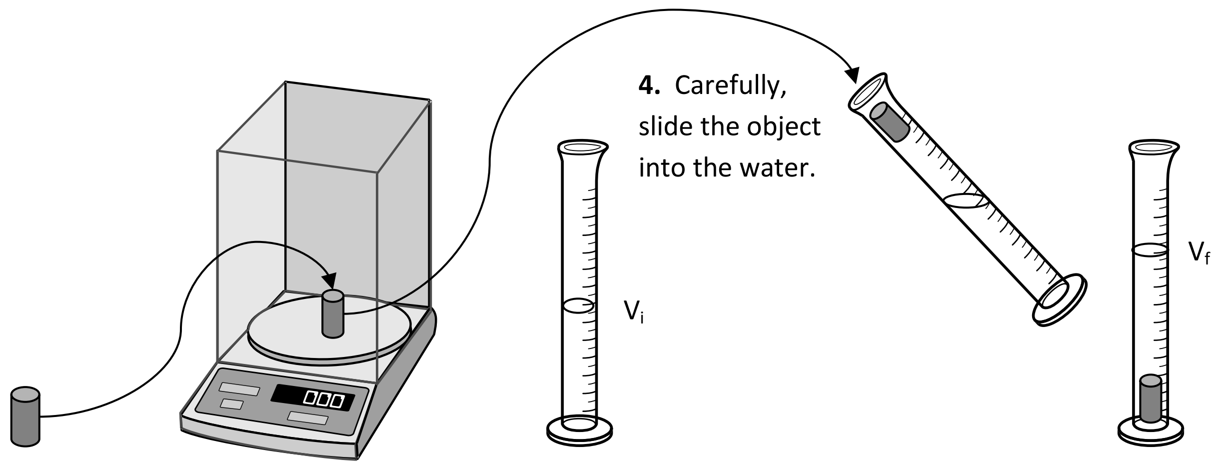
$$\text{Densityof object} = \frac{\text{mass of object}}{\text{volume of object}}$$

Table 3 – Density of an object (geometric method)

ID #	
Mass of object (g)	
Height of object (cm)	
Radius of object (cm)	
Volume of object (cm^3)	
Density of object (g/cm^3)	

PROCEDURE 2 - DENSITY OF OBJECT (displacement method)

Note: Use the same cylindrical object as in Procedure 1



1. Obtain an object with regular geometry and record its ID #.

2. Weigh the object and record its mass.

3. Half-fill a 100mL graduated cylinder with water. Record the volume, V_i.

4. Carefully, slide the object into the water.

5. Record the volume, V_f.

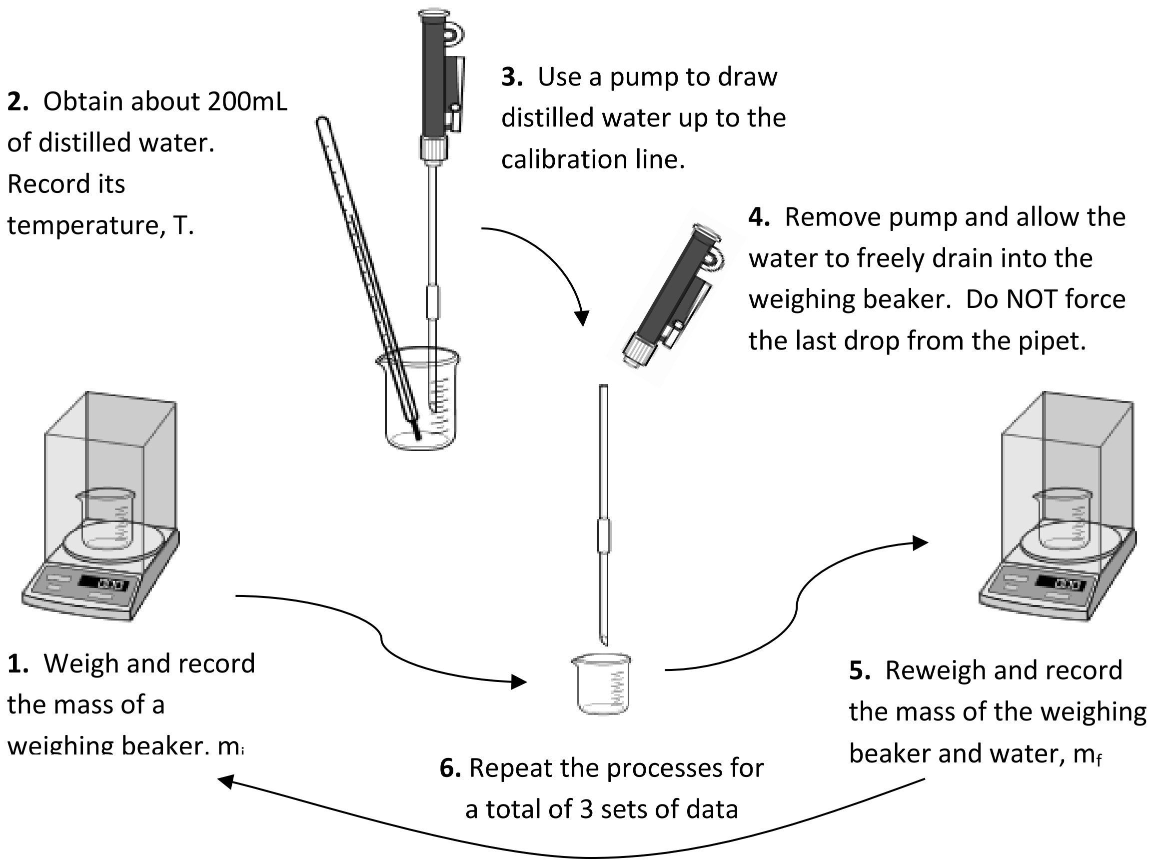
$$\text{Volume of object} = V_f - V_i$$

$$\text{Density of object} = \frac{\text{mass of object}}{\text{volume of object}}$$

Table 4 – Density of an object (displacement method)

ID #	
Mass of object (g)	
V_f (mL)	
V_i (mL)	
Volume of object (mL)	
Density of object (g/mL)	

PROCEDURE 3 - CALIBRATION OF 10 mL VOLUMETRIC PIPET



$$\text{mass of water delivered} = m_f - m_i$$

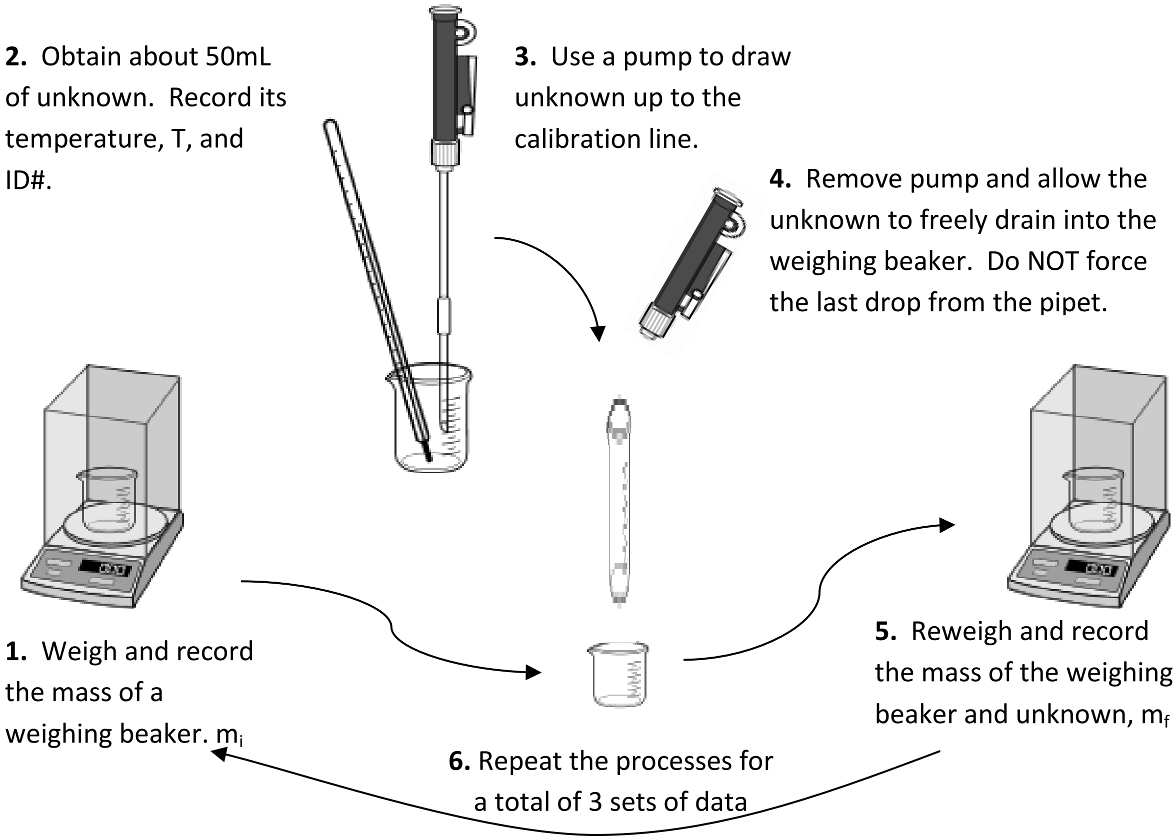
$$\text{Volume of water delivered} = \frac{\text{mass of water delivered}}{\text{density of water @T}}$$

Table 5 – Calibration of volumetric pipet

Trial	T (water) (°C)	Density of water at T°C (g/mL)	m_f (g)	m_i (g)	Mass of water delivered (g)	Volume of water delivered (mL)
1						
2						
3						
					Avg.	
					Std. Dev.	
					95% CI	

Note: The average volume of water delivered is the **calibrated volume** of the pipet. Use this value in Procedure 4.

PROCEDURE 4 - DENSITY OF AN UNKNOWN AQUEOUS SOLUTION



$$\text{mass of unknown delivered} = m_f - m_i$$

$$\text{Density of unknown} = \frac{\text{mass of unknown delivered}}{\text{calibrated volume of pipet}}$$

Unknown #: _____________. T = _________°C

Table 6 – Density of an unknown aqueous solution

Trial	m_f (g)	m_i (g)	Mass of unknown delivered (g)	Calibrated volume of pipet (mL)	Density of unknown (g/mL)
1					
2					
3					
				Avg.	
				Std. Dev.	
				95% CI	