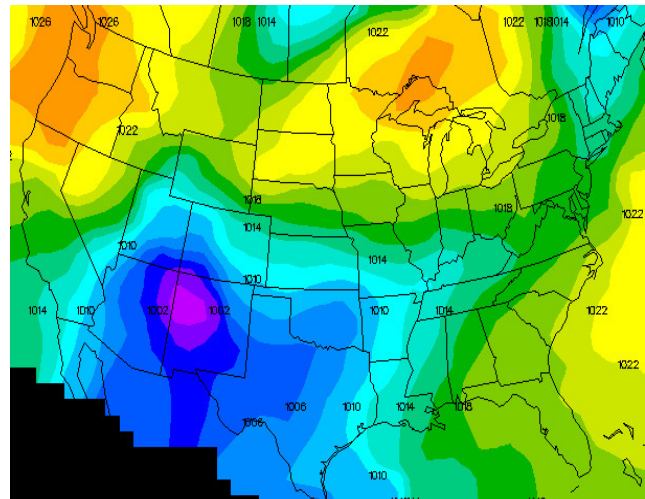




## Pressure in Fluids

### Introduction

In this laboratory we begin to study another important physical quantity associated with fluids: pressure. For the time being we will concentrate on static pressure: pressure exerted by fluids at rest. Atmospheric pressure is a good example of static pressure if we neglect the effect of wind, as is the water pressure at the bottom of a swimming pool. It is worth mentioning that the ultimate source of static pressure is gravity.



**Fig. 1: Relative air pressure (NASA Explores)**

### Biological Systems

Knowledge of static pressure is essential for understanding of the plant vascular systems that serve to distribute water and nutrients throughout a plant. Xylem of vascular plants consists of dead cells placed end to end that form tunnels through which water and minerals move upward from the roots to the rest of the plant. The major mechanism by which water is carried upward is called transpiration, or evaporation of water from the leaf that results in a pressure differential that pulls water from the roots upward. Some plants (but not all) also use a mechanism of root pressure (osmotic pressure in xylem sap). Although the root pressure is not enough to account for the water transport in most plants. The highest root pressure is usually detected in the spring when the transpiration is low and decreases in the summer when transpiration rate is high.



## Experiment

When object is submerged in a fluid, fluid exerts a force on the object. The force is perpendicular to the surface of the object at each point of the surface. Force per unit area is called the pressure of the fluid:

$$P = F/A \quad (1)$$

where

$P$  is the pressure of the fluid,  
 $F$  is the force exerted by the fluid on the object, and  
 $A$  is the area of the object.

Pressure in a static fluid increases with depth. For a fluid whose density remains approximately constant throughout, the pressure increases linearly with depth:

$$P = P_0 + \rho_F g h \quad (2)$$

where

$P$  is the pressure at the bottom of the column of the fluid,  
 $P_0$  is the pressure at the top of the column,  
 $g$  is the acceleration due to gravity,  
 $\rho_F$  is the density of the fluid, and  
 $h$  is the height of the column of the fluid.

Static pressure is isotropic, which means that its magnitude is the same independent of direction.

Note that the relationship between pressure and depth is far more complicated for gasses since the density of gas does not stay constant throughout the column.

In this laboratory we will first experimentally verify the linear dependence of the fluid pressure upon depth of the fluid column. In the second part of the experiment we will experimentally measure the density of the unknown liquid by using variation of pressure vs. depth measurements as described below.

It follows from the Equation (1) that the slope of the pressure vs. depth of the water column graph ( $m_w$ ) is related to the density of water and the acceleration due to gravity:

$$m_w = g \rho_w \quad (3)$$



Similarly, the slope of the pressure vs. depth of the column in the unknown fluid graph ( $m_F$ ) is related to the density of the unknown fluid and the acceleration due to gravity:

$$m_F = g \rho_F \quad (4)$$

By combining Equations (3) and (4) we derive the following expression for the density of the unknown fluid:

$$\rho_F = (m_F / m_W) \rho_W \quad (5)$$

### Procedure



**Fig. 3: Low pressure sensor (Pasco)**

1. Secure the necessary equipment (computer with computer interface, low pressure sensor, graduated cylinder, and ruler).

2. Fill the reservoir with 5.00 cm of water and take a pressure reading at the bottom of the cylinder. Record your reading in the data table below.

3. Repeat the measurements 9 more times adding 1-2 centimeters of water to the cylinder at each trial.

4. Pour out water and replace it with the unknown fluid. Repeat steps (2)-(3).

### Data analysis

Use Microsoft Excel™ to plot pressure readings vs. water depth for water and the unknown fluid. Add linear regression line with the equation displayed on the plot. Calculate the density of the unknown fluid by using Formula (3). Compare your experimental result to the accepted value by calculating percent discrepancy.





Pressure vs. depth of the column in unknown fluid

Water depth (cm)	P (kPa)

Slope (unknown fluid) = \_\_\_\_\_

Density of the unknown fluid = \_\_\_\_\_

Accepted density of the unknown fluid = \_\_\_\_\_

Percent discrepancy = \_\_\_\_\_



1. Make a statement on the dependence of the pressure in a fluid vs. the depth of the column.
2. Assess the accuracy of your experiment
3. Is your experiment precise?
4. What are the sources of random error in your experiment?
5. What are some of the systematic errors in this experimental set-up?

