EXPERIMENT 9

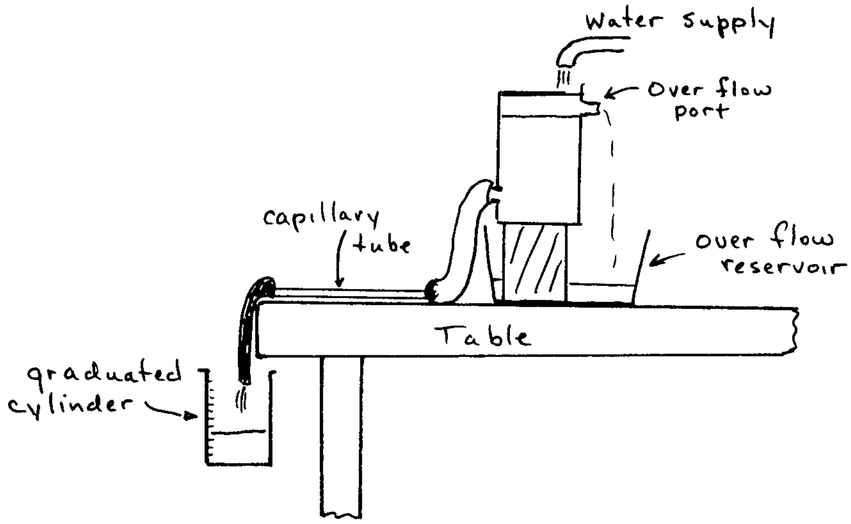
FLUIDS AND MOTION

PART I. FLUID FLOW

Materials - Water container, capillary tubes of different lengths and diameters, overflow bucket, rubber tubing, graduated cylinder, timer, and water.

Exploration:

Set up a water container that will permit you to regulate the flow of water through a variety of glass tubes. Examine the system. List the variables that change the rate of flow. Approximate drawing of a possible system:



Make a list of important variables for flow rate of water and the influence of each variable.

Invention:

Write down Poiseuille's Law and define each variable. (pronounced Pwä-zwēz') What assumptions are made in the derivation of Poiseuille's Law? Are those assumptions correct for the flow of water through a glass tube? Why?

Application:

1. Use your water flow system to determine a rule for your system relating the water flow rate (m^3/s) and the pressure head (N/m^2). Convert a pressure in N/m^2 to pressure in mm of Hg. sp. gr. of Hg = 13.6.
2. Use the system to determine a rule relating flow rate (m^3/sec) and capillary length (m).
3. Use the system to determine a rule relating the flow rate (m^3/sec) and the capillary radius.

PART II. VISCOSITY OF FLUIDS

Materials - Long tube, 4 different radii steel balls, liquid (some kind of oil), a timer, a meter stick, and a vernier caliper.

Application: Falling Sphere Method of Determining the Viscosity of a Fluid

A sphere (radius = a) moving with a constant small velocity, V, through a viscous fluid has a force resisting motion given by Stoke's Equation:

$F = 6\pi\eta aV$, where η = viscosity of fluid

If the sphere falls freely under the action of gravity, we can derive the following equation for uniform velocity conditions in a fluid:

Weight - Buoyant Force = Viscous Force of the Fluid

$$\therefore \rho_s \left(\frac{4\pi}{3} a^3\right) g - \rho_f \left(\frac{4\pi}{3} a^3\right) g = 6\pi\eta a v$$

$$\therefore \eta = (\rho_s - \rho_f)\,\frac{2a^2 g}{9v}$$

ρ_s = density of sphere
ρ_f = density of fluid
g = acceleration due to gravity
$v = \frac{s}{t}$
s = distance of travel
t = time of travel

1. Measure the radius of each sphere provided with a vernier caliper and record these measurements: a_1, a_2, a_3, a_4. Using the spheres provided, make 10 trials for each, recording the falling times for a distance S. Record the distance of travel (s) and the average time of travel (t) for each sphere. Using $\rho_s = 7.8$ gm/cm^3 for steel, calculate the viscosity for each set of data. Are your measurements independent of sphere size? If not, explain.
2. An experimental error for this data is given by the equation below, assuming no errors in density or g values.

$$\frac{\Delta\eta}{\eta} = \frac{2\Delta a}{a} + \frac{\Delta s}{s} + \frac{\Delta t}{t}$$

Determine $\frac{\Delta\eta}{\eta}$ for each set of data. Compare your viscosity values with the table value for your liquid. Are you within experimental error? A correction for the finite radius of the tube gives the following equation:

$$\frac{9\eta}{2(\rho_s - \rho_f)g}\left(1 + \frac{Ka}{r}\right) = \frac{a^2}{v^2}$$

r = radius of the tube
K = -2.104

Find $\frac{Ka}{r}$ for each sphere. Are these corrections significant for your data?

PART III. VISCOUS DRAG

Design an experiment to measure the viscous force on a runner or swimmer.