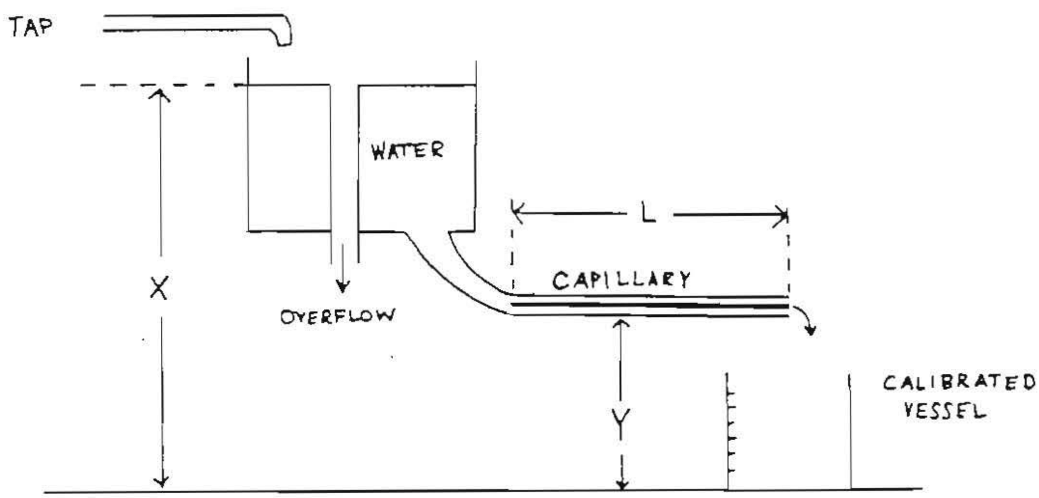
PHYS 2117E Exp. 7 Viscosity of a Liquid

PURPOSE: to measure the viscosity of water by capillary flow method.

REFERENCES: 1) Sears, Zemansky and young, UNIVERSITY PHYSICS, 1982 Edition, Section 13-6.

2) The Physics Teacher, May 1990, pp. 297-299.

APPARATUS: the system components used are shown in the following figure.



THEORY: The rate of flow of a liquid (cm^3/s) through a capillary is directly proportional to the pressure gradient across the capillary:

$$\frac{dV}{dt} = \frac{\pi}{8}\frac{R^4}{\eta}\frac{(P_1-P_2)}{L}$$

$$= \frac{\pi}{8}\frac{R^4 \Delta P}{\eta L}$$

where V is the volume of water
R is the radius of capillary
η is the viscosity of liquid
P_1, P_2 are the pressures at the ends of the capillary
L is the length of the capillary

Note how sensitively the rate of flow depends on the radius of the capillary. As a result for instance, if the human heart is to provide a steady supply of blood to the brain, a 10% reduction is the radius of the capillaries carrying the blood would require the blood pressure to increase by 50% to maintain this supply of blood.

The above equation is known as Poiseuille's Law, which is applied in LAMINAR flow.

Since the rate of flow $\frac{dV}{dt} = dQ$ is linearly proportional to the pressure difference ΔP, we have $\frac{dQ}{d(\Delta P)} = S = \frac{\pi R^4}{8\eta L}$ and the viscosity η can be obtained from $\eta = \frac{\pi R^4}{8SL}$. It is usual to measure R, and L in cm and Q in $\frac{cm^3}{s}$ and ΔP in dynes to obtain η in poises $= \frac{g}{cms}$.

PROCEDURE: In the experiment, a reservoir of water, A, with a constant level x cm above the bench feeds into a capillary of length L which must be set perfectly horizontal using a level. The capillary discharges into a cylinder C with graduations on it.

One measures the rate of flow through the capillary by measuring, with a stop watch, the time it takes until the cylinder C is filled up to a certain mark. This measurement should be repeated 5 times. The pressure difference between both ends of the capillary is expressed in gauge pressure, so it is zero at the open end, and $(x-y)\rho g$ at the other end, $g = 981\frac{cm}{s^2}$, the gravitational constant, ρ the density of water $(= 1g/cm^3)$.

The measurements are repeated at least at 5 different value for y, the height of the capillary above the bench, in order to obtain the rate of flow of water at different pressures. x will be constant.

One then plots $\frac{dV}{dt} = dQ$ vs. the pressure $(x-y)g\rho$ and calculates the slope S from a best-fit straight line:

Note: **viscosity depends on temperature. The temperature of tap water may fluctuate. Start the water flow - through the waste drain - 15 minutes before doing the experiment and keep the thermometer in the reservoir. Record and list the temperature with your result.**

The experiment should be repeated for as many capillaries as possible. The requirement of LAMINAR flow restricts the dimensions of capillaries to specific values. A detailed discussion of this can be found in Ref. 2.