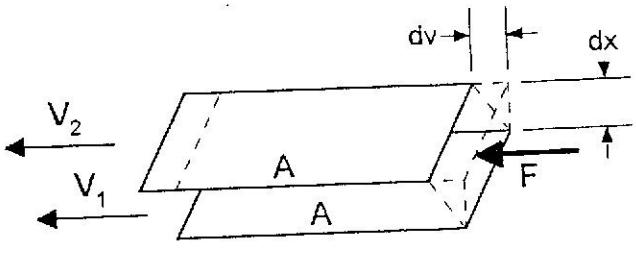
Rheometer Experiment 1

Objective:

To gain an understanding of the property - viscosity, and to become familiar with a device used to measure this property - the rheometer.

Discussion:

A fluid is defined as a substance that deforms continuously under the action of a shear stress, no matter how small the shear stress may be. Without shear stress, there will be no deformation. Fluids are generally classified by the relation between the applied shear stress and the rate of deformation. Fluids in which the shear stress is directly proportional to the rate of deformation are called "Newtonian" fluids (after Isaac Newon). The term non-Newtonian is used to classify all fluids in which shear stress is not directly propotional to the shear rate. This proportionality constant is called viscosity, and can also be thought of as a measure of the internal friction of a fluid. This friction becomes apparent when a layer of fluid is made to move in relation to another layer. The greater the friction, the greater the amount of force required to cause this rate of movement.



Isaac Newton defined viscosity by considering the model represented above. Two parallel planes of fluid of equal area "A" are separated by a distance "dx" and are moving in the same direction at different velocities V_1 and V_2. Newton assumed that the force required to maintain this difference in speed was proportional to the difference in speed (velocity gradient). Newton surmised:

$$\frac{F}{A} = \eta \frac{dv}{dx}$$

Where η is a constant for a given material and is called its <u>viscosity</u>. The velocity gradient, dv/dx, is a measure of the speed at which the intermediate layers move respect to each other. It describes the shearing the liquid experiences and thus is called the "shear rate". The F/A term indicates the force per unit area required to produce the shearing action, and is therefore referred to as "shear stress." Rearranging the above equation, we have:

$$\eta = \text{viscosity} = \frac{F/A}{dv/dx} = \frac{\text{shear_stress}}{\text{shear_rate}} = \frac{\tau}{S}$$

The fundamental unit of viscosity is the <u>poise</u> and is represents one dyne-second per square centimeter. Other units sometimes used are centipoise [cp] (= poise/100), Pascal-seconds [Pa·s] (= 10 poise), and milli-Pascal-seconds [mPa·s] (= 1 cp).