# Experiment No. 02:
## Measurement of Temperature and Viscosity of Oils

### Experimental Objective

1. To measure viscosity of oil at various temperatures.
2. To calibrate a thermocouple and measure its time constant.

## I Viscometer

Viscosity is a fluid property whose effect is understood when the fluid is in motion.In a flow of fluid, when the fluid elements move with different velocities, each element will feel some resistance due to fluid friction within the elements.

Viscosity is a measure of the ratio of shearing stress to shear strain.

$$Viscosity\,(\eta) = \frac{Shearstress\,(\tau)}{Strainrate\,(\dot{\gamma})} \tag{1}$$

### Viscometer Working Principle

The Brookfield viscometer (FIG.(a))is of the rotational type. It measures the torque required to rotate an immersed spindle in a fluid. The spindle is driven by a motor through a calibrated spring; deflection of the spring is indicated by a pointer and dial. By proper selection of spindles and speed, the desired viscosity of the fluid can be determined. For a given viscosity, the viscous drag, or resistance to flow (indicated by the degree to which the spring winds up), is proportional to the spindle's speed of rotation and is related to the spindle's size and shape. The drag will increase as the spindle size and rotational speed increases. It follows that for a given spindle geometry and speed, an increase in viscosity will be indicated by an increase in deflection of the spring.

### Cylindrical Spindles

The following equations apply to cylindrical spindles only, on any Brookfield Viscometer (see FIG.(b)).

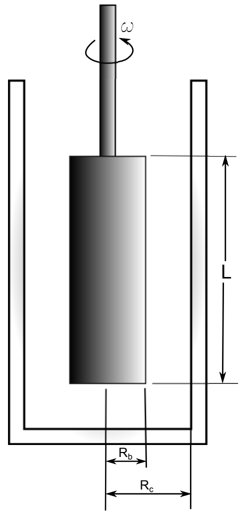
$$Shear\,rate\,(sec^{-1}) \qquad \dot{\gamma} = \frac{2\omega R_c^2 R_b^2}{x^2({R_c}^2 - {R_b}^2)} \tag{2}$$

$$Shear\,stress\,(dynes/cm^2) \qquad \tau = \frac{M}{2\pi {R_b}^2 L} \tag{3}$$

$$Viscosity\,(Poise) \qquad \eta = \frac{\tau}{\dot{\gamma}} \tag{4}$$

where, $\omega$= Angular velocity of spindle (rad/sec)
$N$= Speed in RPM
$R_c$ = radius of container (cm)
$R_b$ = radius of spindle (cm)
$x$ = radius at which shear rate is being calculated (cm)
$M$ = torque input by instrument (dyne-cm)
L = effective length of spindle (cm)

(a) Brookfield Viscometer




(b) Spindle

## Procedure for operating the viscometer

1. Fill the beaker with the oil for which the viscosity has to be measured.
2. Confirm that the viscometer is level using the bubble level on the top of the instrument.
3. For the Brookfield DV-II, remove the spindle (if any already mounted) and press any button so that it will automatically AUTO-ZERO and set the speed as 100% .
4. Choose an appropriate spindle and enter the spindle code.
5. Attach the spindle to the viscometer. Immerse the spindle designated in the product specification into the sample to the groove on the spindle shaft. Do not allow air bubbles to be formed. The spindle should not touch the bottom or sides of the container and should be centered. Reconfirm that the viscometer is level.
6. See that the percentage torque is between 10% and 100%. If it is lower than 10% adjust the speed of rotation or change the spindle type.
7. Once the percentage is within the agreeable limits, you can record the variation of viscosity of the given liquid with temperature.
8. For the DV-II, choose the units by pressing the desired unit key (CPS for centipoises).
9. When done, turn motor and power off. Remove the spindle carefully, clean it and place in the spindle holder.

## Falling Sphere Experiment

When a sphere is dropped into a vertical column filled with viscous liquid, it initially accelerates due to gravity. After this brief transient period, the sphere achieves a steady settling velocity (a constant terminal velocity). For the velocity to be steady (no change in linear momentum), Newtons second law requires that the three forces acting on the sphere, gravity $F_G = \frac{\pi D^3 \rho_s g}{6}$, buoyancy $F_B = -\frac{\pi D^3 \rho_f g}{6}$, and fluid drag $F_D = -\frac{C_D \pi D^2 \rho_f V^2}{8}$ should be balanced.

$$Re = \frac{\rho_f V D}{\mu} \tag{5}$$

where,
$\rho_f$ is the liquid density (893 $kg/m^3$ at $15^oC$)
$V$ is the terminal velocity of the sphere ($m/s$)
$D$ is the diameter of the sphere ($m$)
For Re<1, from stokes hypothesis, $C_D = \frac{24}{Re}$
from force balance,

$$F_G + F_B + F_D = 0 \tag{6}$$

gives,

$$\mu = \frac{D^2(\rho_s - \rho_f)g}{18V} \tag{7}$$

here,
$\mu$ is the dynamic viscosity of the liquid ($Pa - s$)
$\rho_s$ is the density of spherical ball (7800 $kg/m^3$)
$g$= 9.81($m/s^2$)

# II Thermocouple

## Introduction

When two dissimilar conductors such as copper, and its alloy, constantan (55% Copper and 45% Nickel) are joined together (see FIG.1) and their two junctions are maintained at two different temperatures say one hot and the other cold, a thermo-emf flows through the circuit. This can be observed using a voltmeter connected across the circuit. This effect is known as Seebeck Effect (after Seebeck,1831).

## Procedure for calibration

1. A thermocouple can be calibrated approximately using a two-point calibration.The thermocouple junctions and leads are connected as shown in the Fig.1
2. The milli-Volt meter(Digital or Analog) is checked for ZERO ERROR and is thus manually nullified when the junctions are not under different ambient temperature.
3. First, the cold junction is kept in ice (reference point) and the other junction is kept in the ambient (use a thermometer) .
4. This calibration point along with the one obtained using boiling point of water, gives the two-points for the calibration of thermocouple.
5. Linearity can be verified by measuring the thermo-emf at intermediate temperature values if necessary.

## Procedure for finding the time constant

For obtaining the time constant of a thermocouple (or a liquid-in-glass thermometer), the thermometric device is subjected to a step input. This is achieved by suddenly inserting the thermometric device in hot substance (say boiling water) or by removing it from it. Time constant($\tau$) is calculated from the following equation,

$$\frac{T - T_0}{T_f - T_0} = \exp(-\frac{t}{\tau}) \tag{8}$$

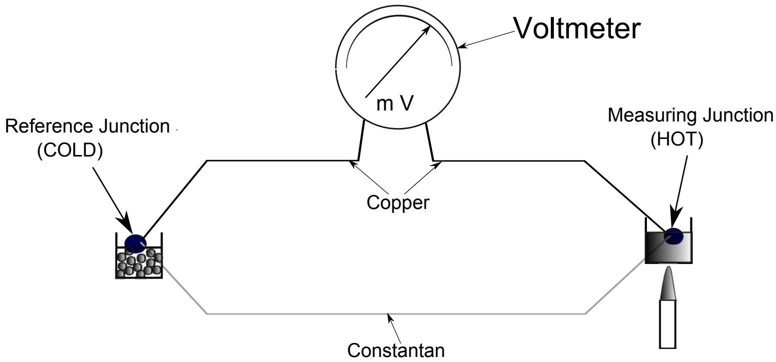



Figure 1: Thermocouple

where $T_f$ is the temperature of the boiling water , $T_0$ is the ambient temperature, and T is temperature at time t.The variation of thermo-emf (in turn the temperature)is noted down at specific intervals of time. Once the data is recorded, a plot between the temperature coefficient $\frac{T-T_0}{T_f-T_0}$ and time $t$ can be used to obtain the time constant $\tau$.

# III Outcome Expected

1. Variation of viscosity of the given oils with respect to temperature.
2. Calibration chart for the thermocouple.
3. Cooling or Heating curve(s) and Time constant.

## Observation Tabulation- Viscometer

| **Spindle Type :** | |
|---|---|
| **Spindle Speed :** | |
| **Temperature (C)** | **Viscosity (mPa-S)** |
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## Observation Tabulation- Thermocouple Calibration and Time constant

| **Thermocouple Calibration** | |
|---|---|
| **Temperature (C)** | **Voltage (mV)** |
| | |
| | |

| **No. of Div(s) in Voltmeter** | **Voltage (mV)** | **Temperature (C)** | **Time (sec)** | | |
|---|---|---|---|---|---|
| | | | **Trial 1** | **Trial 2** | **Trial 3** |
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## Make Sure that your report contains the following

1. Objective
2. Apparatus required
3. Working Principle
4. Procedure
5. Result Tabulation
6. Graphs enumerated in section (III)
7. Observations and Conclusions