LAB 4: Viscosity measurement

(Due by 5 pm *one week* after the lab day)

The members of our group are: ____

____

____

Objectives:

- ☐ Measure the viscosity of different fluids using a viscometer and choosing appropriate spindle/rotational speed combinations.
- ☐ Develop proportional relationships (qualitative) between the size of the spindle, the rotational speed of the spindle, the viscosity of the fluid and the torque needed to turn the spindle.
- ☐ Demonstrate an understanding of units.

Activity 1: Viscometers and getting a feel for viscosity

Background: rotational dial viscometers

One instrument used to measure viscosity is a **rotational dial viscometer**. A schematic diagram of such a viscometer is shown in Fig. 1.

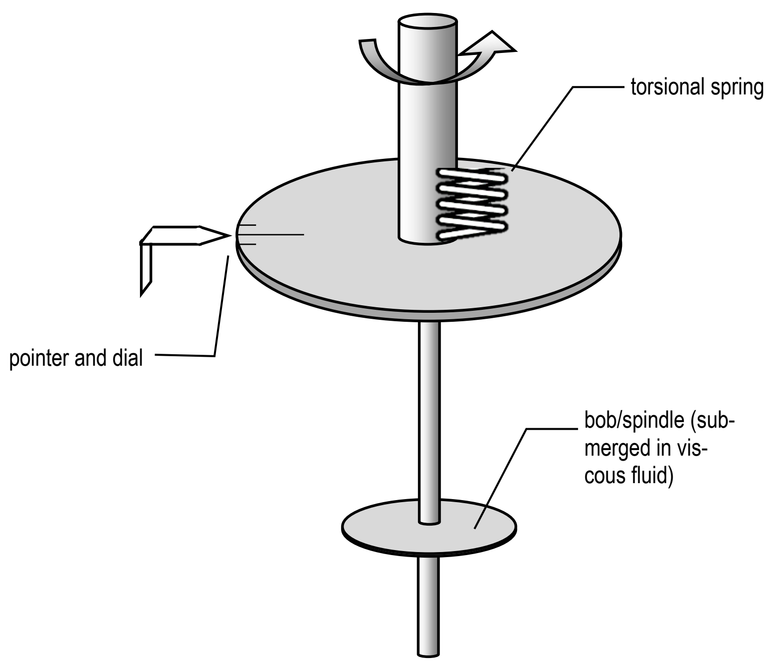

Figure 1: Schematic diagram of dial viscometer

In this type of viscometer, a motor turns the spindle (bob) submerged in the fluid. The viscosity of the fluid resists the motion, applying a torque to the spindle. One end of a calibrated spring with a known spring constant is connected to the motor while the other is connected to the bob/spindle. Likewise, a dial is connected to the motor side and a pointer is connected to the bob/spindle side. At steady state, the relative angular distance between the dial and the pointer is proportional to the torque.

Since both the dial and the pointer are rotating under normal operation, taking a measurement requires you to use a clutch in order to fix the pointer at the given location relative to the dial. You can then turn off the motor so as to get a dial reading.

The motor speed can be changed along with using a number of available spindle sizes. This allows for a large range of viscosities to be measured. (In general, smaller spindle numbers correspond to larger surface areas.)

Equation (1) shows the relationship between the measured torque and rotational speed readings and the viscosity:

$$\mu = \frac{F}{\omega} T, \tag{1}$$

where μ is viscosity in units of cP (centipoise) , ω is rotational speed in RPM, and T is torque. The "units" on the torque are a percent of the full-range torque (the fraction of the maximum torque that the device can read). That is, a value between 0 and 100. The scaling factor F depends on the spindle size. Manufacturer supplied values are given in Table 1.

Table 1: Scaling factors for different RV-Series spindles

Spindle #	**1**	**2**	**3**	**4**	**5**	**6**	**7**
F	100	400	1,000	2,000	4,000	10,000	40,000

Procedure

There should be two beakers at the lab station, one filled with corn syrup and the other filled with an unknown fluid. Using the beaker with the corn syrup, pick two different spindles of significantly different size and place the spindles (one at a time) in the fluid and turn them by hand.

Questions

1. What effect does using a spindle with a larger surface area have on the relative effort it required to turn it?

2. What effect does increasing the rotational speed of the spindle have on the relative effort it required to turn it?

3. Viscosity is a fluid property that is related to friction. Compare and contrast the effects of friction due to viscosity with the Coulomb friction model used in solid body mechanics. How are they different? How are the similar?

Activity 2: Measuring the viscosity of corn syrup

Procedure

1. Using the same beaker of corn syrup as in Activity 1, choose up to two different spindle/rotational speed combinations to get *reasonable* full range torque readings ("reasonable" meaning between 20% and 90%) on the dial. You may want to look up the approximate value of the viscosity of corn syrup to make informed decisions of the spindle/speed combinations to try. Record your results in Table 2.

Table 2. Collected data for different spindle/rotational speed combinations to get the same % FRT for measuring viscosity of corn syrup

Spindle #	Rotational speed (RPM)	% FRT (0-100)	Viscosity [cP]

2. After taking your data, calculate the measured viscosities and record them in the same table.

3. Before moving onto the next activity, make sure to clean and dry the spindles.

Sample calculation

Show your sample calculations for calculating μ, using your second set of data from Table 2. Include all unit conversions.

Activity 3: Measuring the viscosity of an unknown fluid

In this activity, we will measure the viscosity of the unknown fluid.

Procedure:

1. Using the beaker of the unknown fluid, place the spindles into the fluid and turn them with your fingers. Is the fluid more or less viscous than honey? Record any observations below:

2. Using the insights gained related to spindle size, rotational speed, viscosity, and the torque required to turn the spindle from Activities 1 and 2, pick a spindle/rotation speed combination. You may need to try different spindle/speed combinations to get it to work. *You should limit your speeds to be between 5 to 100 RPM.* Also remember that to get an accurate reading, the %FRT should be between 20% to 90%.
3. Record your measurements, even the failed ones, in Table 3. For any failed measurement, explain what you think contributed to the failure.
4. Once you get at least two spindle/speed combinations that work, you are ready for data processing. Make sure to clean and dry the spindles before you leave your lab station so that the next group is ready to do their experiment.

Table 3. Collected data for different spindle/rotational speed combinations

Spindle #	**Rotational speed [RPM]**	**% FRT [0-100]**	**Reason for failure**	**Viscosity [cP]**
				X
				X
			Success	
			Success	

Sample calculation

Show your sample calculations for calculating μ, using your last set of data from Table 3. Include all unit conversions.

Activity 4: Units

In this activity, we will get a physical sense of some common units that we have encountered.

Procedure:

Using the provided artifacts, find and/or demonstrate the units in Tables 4-6. You may need to combine several masses or be creative to show some of these using the provided artifacts. You should also describe what you did to demonstrate each of these in the tables.

Table 4. SI and USCS weight/mass comparison

Unit	Description	Rank
kg		
Newton		
Pounds-force		
Slug-force		
Pound mass		

Table 5. SI and USCS pressure comparison

Unit	Description	Rank
1 kPa		
0.25 psi		
1 in water		
50 mm of Bromine (*SG* = 3.12)		

Table 6. Work and power

Unit	Description
1 J	
1 ft-lbf	
1 W	

To be turned in

This completed lab handout is due at 5:00 pm one week after your lab day. Only one copy should be turned in for each group.