Homework 4  
CM4650 Spring 2015

Due: Wednesday 4 March 2015, in class

Please do not write on the back side of the page. Please write legibly and large. Thank you.

1. (20 points) For honey, a Newtonian fluid, please address the following:
   a. What is the viscosity as a function of shear rate at room temperature? (use the internet). Please provide a reference and a printout/photocopy of your source.
   b. Using Excel or another program, plot \( \eta(\dot{\gamma}) \) for honey two ways: log-log \( (10^{-2}s^{-1} \leq \dot{\gamma} \leq 10^2s^{-1}; \) model your graph on Figure 6.1) and linear-linear.
   c. What is the material function \( \eta^+(t) \) for honey at \( \dot{\gamma}_0 = 0.020 \text{ s}^{-1} \)?
   d. Using Excel or a comparable program, plot \( \eta^+(t) \) from part c) two ways: log-log \( (10^{-2}s \leq t \leq 10^2s; \) model your plot on Figure 6.49) and linear-linear.

2. (20 points) For high molecular weight polydimethylsiloxane, a non-Newtonian fluid, please address the following:
   a. What is the viscosity as a function of shear rate at room temperature? (use the internet; if you have trouble finding it, let’s discuss search strategies). Please provide a reference and a printout/photocopy of your source.
   b. Using Excel or another program, plot the answer from part a); model your graph on Figure 6.1.
   c. Sketch (by hand) likely curves for \( \eta^+(\dot{\gamma},t) \) for your PDMS. Include curves for several values of \( \dot{\gamma} \).

3. (10 points) Text 5.3 (compare and contrast various quantities related to the rate-of-deformation).

4. (20 points) 3.18 Newtonian tangential annular flow. Calculate the functions \( v \) and \( p \) and the torque; also, when calculating the torque, develop the equation for torque from the general equation:

\[
T_{\text{on}} = \iint_S \left[ R \times \left( \hat{n} \cdot \left(-P \right) \right) \right]_{\text{surface}} dS
\]

5. (20 points) For problem 7.27 (pressure-driven flow of a power-law GNF between parallel plates), begin the solution of the problem. Do not assume Newtonian fluid; rather assume an unknown constitutive equation \( \chi(v) \). Simplify the continuity equation and the Cauchy momentum equation as far as you can. Write \( \dot{\gamma} \) for the problem as far as you can. Calculate the magnitude of the shear rate tensor \( \dot{\gamma} = \left| \dot{\gamma} \right| \) in terms of velocity gradients. Write the boundary conditions.

6. (10 points) For the kinematics associated with steady shear and shear start-up, calculate the strain function \( \gamma_{21}(t, t’) \), where \( t \) and \( t’ \) are two times (they will appear in your answer). The time \( t \) varies but is always positive, i.e. it goes between zero and \( \infty \). The time \( t’ \) varies also and may be positive or negative, i.e. it ranges between \(-\infty \) and \( t \). Note that \( t \) is the (variable) reference time for the strain.

\[
0 \leq t \leq \infty \quad \quad -\infty \leq t’ \leq t
\]