ENGG 201 Chapter 8

Viscosity of Liquids

Newtonian

$$\tau = -\mu \frac{du}{dy}$$

Non-Newtonian

$$\mu_{app} = \frac{\tau}{\left(\frac{du}{dy}\right)}$$

Power Law

$$\tau = K\left(\frac{du}{dy}\right)^n$$

Kinematic Viscosity

$$\nu = \mu/\rho$$

Temperature Dependence

$$\ln(\mu) = -\frac{A}{T} + C$$

Flow of Fluids in Pipes

$$\mathrm{Re} = \frac{D\bar{u}\rho}{\mu}$$

$$Q = \bar{u}A = \bar{u}\frac{\pi D^2}{4}$$

$$Power = Q\Delta P$$

Ideal (Bernoulli)

$$\frac{P}{\rho} + gh + \frac{u^2}{2} = Const.$$

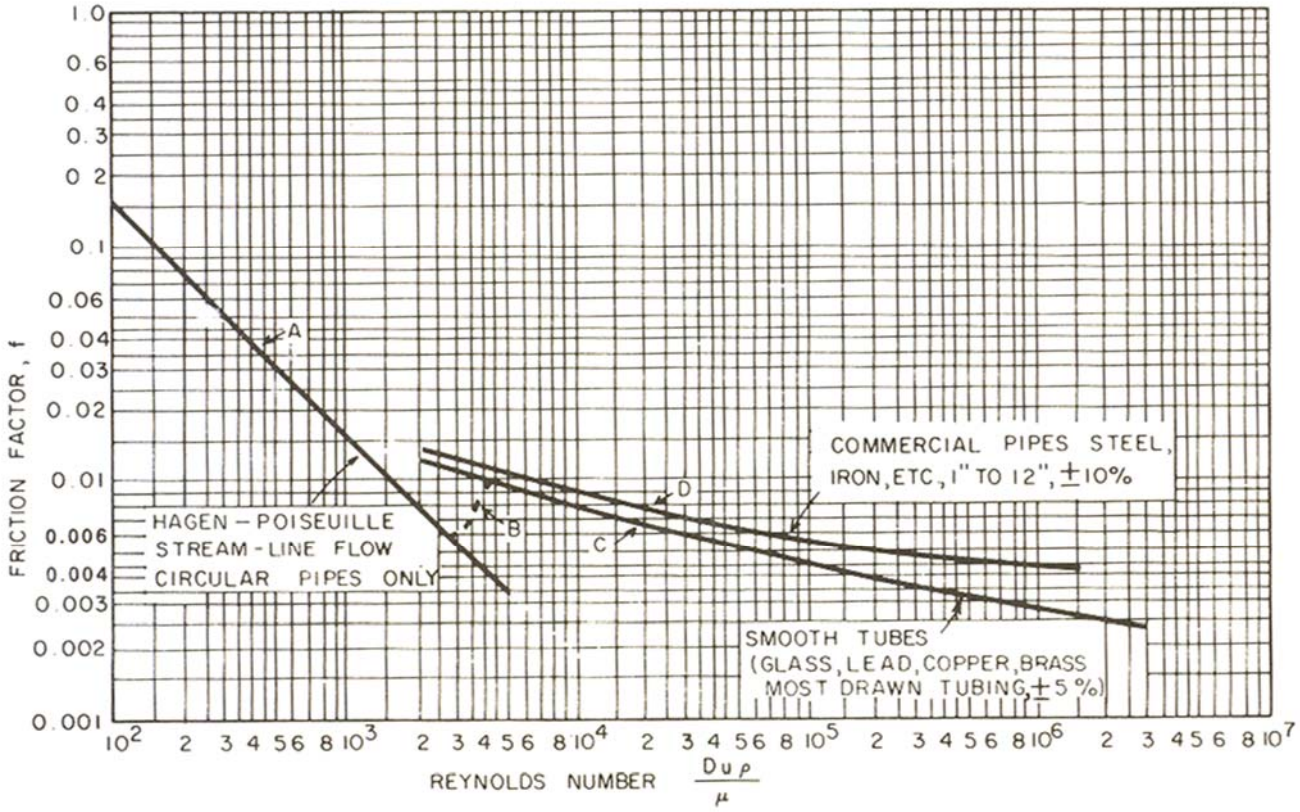
$$\frac{\Delta P}{\rho} + g\Delta h + \frac{\Delta u^2}{2} = 0$$

Laminar

$$-\left[\frac{\Delta P}{L} + \rho g \frac{\Delta h}{L}\right] = \frac{32\mu\bar{u}}{D^2}$$

Turbulent

$$-\left[\frac{\Delta P}{L} + \rho g \frac{\Delta h}{L}\right] = \frac{2f\bar{u}^2\rho}{D}$$



Viscosity Problems

W2015 Final Exam

A power-law fluid is used to lubricate moving metal on a flat base sliding horizontally. The sliding area between the two metals is 1.2 m^2 and a gap of 1 mm was fixed between the upper and lower metals. Use the following information to answer the questions.

τ (Pa)	du/dy(s^{-1})
50	10
30	5

a) Calculate the apparent viscosity of the fluid at both values of shear stress. (/2)
b) Determine the Power-law parameters (K and n) for the fluid. (/3)
c) If the mass of the sliding metal was 30 kg, what is the sliding velocity of the metal sheet when the initial acceleration is a = 2 m/s^2? (/3)

Winter 2009 Final Exam - PART B –

In a bearing, the gap between the moving surface and a stationary surface is 0.05 mm. The lubrication liquid is at 80°C and has density equal to 870 kg/m^3 and viscosity equal to 140 cP. The moving surface slides past the stationary one at 0.778 m/s. The contact area between the surfaces is 0.78 cm^2.

a) If the flow is laminar between the two surfaces, what is the shear stress exerted by the steel part on the liquid in the gap? ***(/2)***
b) What is the force applied to the steel part to keep it in motion? ***(/2)***
c) The lubricant is mixed with another liquid. Viscometer tests of the liquid mixture yield the following data:

Shear Stress, Pa	Shear Rate, s^{-1}
510.29	10.9
1370.23	38.7

i. Does this liquid exhibit power-law behaviour? ***(/1)***
ii. What is the apparent viscosity at a shear rate of 20 s^{-1}? ***(/3)***

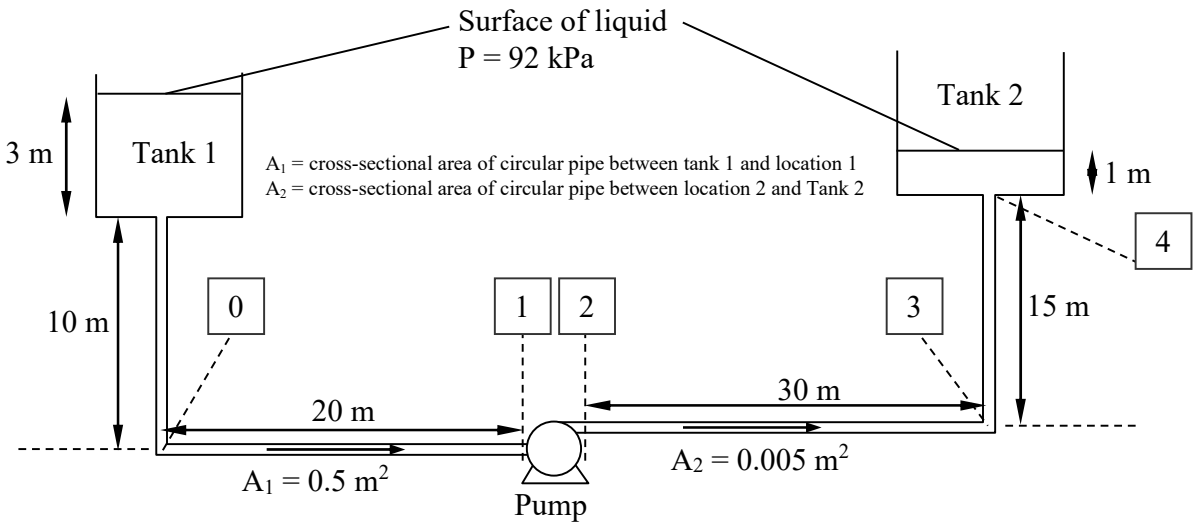
W2005 Final Exam

1. A thin 15 mm layer of oil has spilt on the floor of an auto body shop. This oil is a power law fluid with parameters K=0.58 $Pa.s^{0.4}$ and n=0.4. A piece of sheet metal 5 m by 5 m has fallen on top of the layer of oil. One of the mechanics tries to use the sheet of metal as a surf-board. Assuming he initially launches his entire body weight (100 kg) along the surface of the metal at 2 m/s^2, what is the velocity of the piece of sheet metal as it flies along the oil? *(4 Marks)*
2. What are the main differences between an ideal fluid, a Newtonian fluid, and a non-Newtonian fluid? *(3 marks)*
3. Draw a velocity profile for laminar flow in a pipe (i.e. draw how the velocity changes as you move from the center of the pipe to the pipe wall). *(1 mark)*

Fluid Flow Problems

Winter 2009 Final Exam - PART A

A pumping station is displayed in the following Figure.



The mass flow rate through the system is 1320 kg/h. The density and viscosity of the liquid are 980 kg/m^3 and 1.2 mPa s, respectively. The pipes can be treated as rough commercial steel.

b) Is the flow laminar or turbulent at location 1? ***(/2)***
c) At location 1, what is the maximum velocity in the circular pipe? ***(/1)***
d) Is the flow laminar or turbulent at location 2? ***(/2)***
e) What is the pressure at location 1? ***(/3)***
f) What is the pressure at location 2? ***(/4)***
g) What is the power of the pump? ***(/2)***

WINTER 2005 – FINAL EXAM

4. You have been hired to design a pipeline at Huge Stone Brewery that will be used to transport Cricket Beverage from a fermenter through 150 m of pipeline to a storage tank. The pressure at the inlet of the pipe is 100 kPa (at the fermenter), and pressure at the outlet of the pipeline (at the storage tank) is atmospheric pressure, and the outlet is at a height 5 m above the inlet. The density of the liquid is 1100 kg/m^3, and the viscosity is 0.105 Pa.s. You have two choices of pipe available – a 15 cm diameter smooth plastic pipe, and a 3 cm diameter rough steel pipe. You will also have to install a pump at the beginning of the pipe (i.e. just after the fermenter).

    a. Draw a diagram showing the fermenter, pipe, pump and storage tank. Be sure to label all pressures that are known. *(1 mark)*
    b. Calculate what the velocity of the fluid (m/s) would be for each of the two pipe choices to maintain a volumetric flow rate of 1000 L/min through the pipeline. *(3 marks)*
    c. Calculate the power required for the pump if the smooth plastic pipe is installed, and the volumetric flow rate is 1000 L/min. *(4 marks)*
    d. Calculate the power required for the pump if the rough steel pipe is installed and the volumetric flow rate is 1000 L/min. *(4 marks)*

W2015 Final Exam PART A

A construction company is adding asphalt (bitumen) roof coating to one of the University of Calgary buildings. The asphalt material is supplied in blocks (sold form) and needs to be heated in a heating tank, and then sent to the asphalt spraying machine (pump and hose with nozzle) which is right beside the tank. The pump removes the bitumen from the bottom of the tank, which has 0.75 m (depth) of bitumen. The liquid asphalt is pumped from the heating tank, which is open to atmospheric pressure, through 13 m of pipe to the spray nozzle located 10 m above the pump. The pipe exit spray nozzle is exposed to atmospheric pressure (P_{atm} = 1 atm).

a) Sketch the system indicating the pressure points, tank, pump, pipe and nozzle. (/2)
b) It is required to pump 8 l/min of asphalt at an elevated temperature of 175ºC through 2" (5.08 cm) inside diameter commercial steel pipe. The density and viscosity of the liquid asphalt at 175^{o}C are 900 kg/m^3 and 0.1 Pa.s, respectively. Categorize the liquid asphalt flow (laminar or turbulent flow). (/3)
c) Calculate the pump discharge pressure and pump power consumption for the flow rate in part (b). (/6)
d) After using the system, the machine was drained, charged with solvent for cleaning and the solvent was circulated at a rate of 360 l/min. The density and viscosity of the cleaning solvent are 800 kg/m^3 and 2 mPa.s, respectively. Assume that the liquid height in the tank is 0.75 m as above. Calculate the pump power consumption during the cleaning cycle. (/6)