Examination Number One
Administered: Monday, February 8, 1999

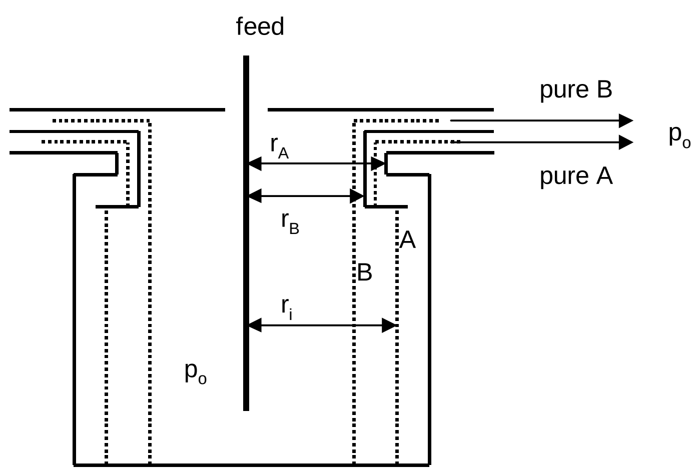
Required Unit Conversions:
1.0 cp = 0.001 kg/m/s
1 hp = 745.7 J/s

Problem 1. Fluid Statics

When the difference in densities of two immiscible fluids is not great, separation by gravity in a decanter is not feasible. One can increase the drive toward separation by increasing the acceleration. To do this, we rely on the centrifugal force of a centrifuge rather than the force of gravity. Consider the centrifuge shown below, employed to separate 2 immiscible fluids A and B where $\rho_A > \rho_B$. If the radial acceleration of the centrifuge is $a = \omega^2 r$ where ω is the angular velocity in radians/sec and r is the position from the center of the centrifuge, then the pressure drop due to the centrifuge is given by:

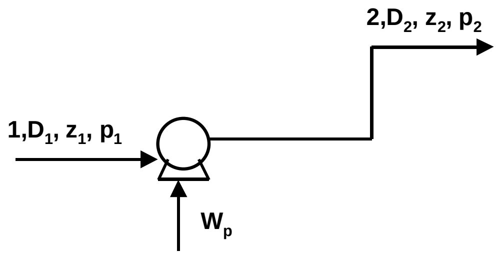
$$\Delta p = p_2 - p_1 = \frac{\rho\omega^2\left(r_2^2 - r_1^2\right)}{2}$$

Using this fact, derive an equation for the location of the A-B interface, r_i in terms of ω, ρ_A, ρ_B, and the overflow positions, r_A, and r_B. Neglect gravity. Carefully indicate on the diagram the location of the two points where you are calculating the pressure to be used in the principle of fluid statics.



Problem 2. Mass balance and mechanical energy balance

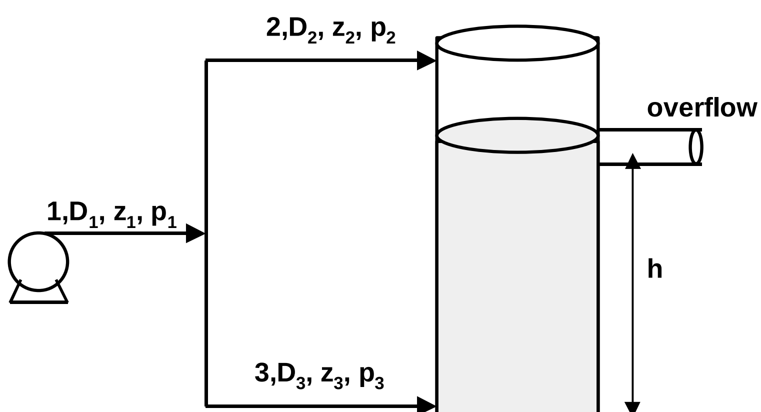
Consider the following flow system:



where the fluid is water. Use a density, $\rho = 1000.0\frac{kg}{m^3}$ and a viscosity, $\mu = 1.0cp$. Assume steady state. The diameters of the lines are: $D_1 = 7.6cm$ and $D_2 = 5.1cm$. The elevations of the lines are: $z_1 = 0.0m$ and $z_2 = 5.0m$. The pressure at the feed to the pump is $p_1 = 1.0atm$ and the pressure at the outlet is $p_2 = 1.0atm$. The volumetric flow rate feeding into the pump is $q_1 = 0.002\frac{m^3}{s}$. The power supplied to the pump is $\hat{\dot{W}}_p = 3.0$ hp. The efficiency of the pump is 80%.

(a) Calculate the inlet and exit velocities in m/s
(b) Calculate total friction loss in J/kg.

Problem 3. Mass balance, mechanical energy balance, and fluid statics
Consider the system shown below, where a pressurized line is split into two lines that empty into the same, open storage tank. The level in the tank is maintained by an overflow.



The fluid is water. Use a density, $\rho = 1000.0\frac{kg}{m^3}$. Assume steady state. Neglect friction. Neglect kinetic energy terms. The diameters of the three lines are: $D_1 = 7.6cm$, $D_2 = 5.1cm$, $D_3 = 6.4cm$. The elevations of the three lines are: $z_1 = 0.0m$, $z_2 = 31.0m$, $z_3 = -6.0m$. The height of the overflow in the tank is $h = 10.0m$. The pressure at the pump is $p_1 = 2.0atm$ and the velocity at the pump is

$\overline{v}_1 = 0.10\frac{m}{s}$. What fraction of the total flow in line #1 enters the tank through line #3? You must write down the complete mass and energy balances.