AME 101 Fall 2016
Problem Set #4
Assigned: 10/24/2016
Due: 11/4/2016, 4:30 pm, in drop-off box in OHE 430N (back room of the OHE 430 suite of offices, where the Xerox machine is located)

Problem #1 (20 points) (from last year's 2nd midterm)

The Weber number (We) is a measure of the relative importance of kinetic energy to surface energy in a flow with an interface (e.g., between liquid water and air in a water droplet.) Its definition is $We \equiv \rho v^2 d / \Sigma$, where ρ = density of liquid, v = flow velocity, d = droplet diameter and Σ is the surface tension (units force/length, e.g. Newtons per meter).

(a) Calculate the value of We for a falling water droplet in a cloud with d = 0.01 inch, v = 10 miles/hr and Σ = 0.070 N/m.
(b) Calculate the Reynolds number based on diameter d of this falling droplet. (Use the viscosity of air, not water, in the calculation for Re.)
(c) It is desired to simulate the flow around this falling droplet in air with mercury (Σ = 0.486 N/m, ρ from the table of fluid properties in Chapter 6) as the liquid in a laboratory experiment. What droplet d (in inches) and fluid speed (v) (in feet per second) would be required to have the same Weber and Reynolds numbers as determined in parts (a) and (b)? (In both cases the liquid droplet is falling in air so use the viscosity of air in the calculation of Re).

Problem #2 (20 points)

A fire hose has a length of 100 feet, is 4 inches in diameter and has a roughness of ¼ inch. The fire hose leads into a nozzle that narrows from 4 inches diameter at the inlet to 2 inches at the outlet. The pressure at the nozzle inlet is 75 lbf/in^2 and atmospheric pressure (14.7 lbf/in^2) at the outlet.

(a) What is the velocity of water at the nozzle outlet? Assume viscous effects are negligible within the nozzle and the elevation change between the nozzle inlet and outlet is negligible.
(b) What is the Reynolds number of water in the hose?
(c) What is the pressure drop over the 100 foot length of the hose leading up to the nozzle?

Problem #3 (20 points)

Air at an inlet pressure of 10 atm and a temperature of 600°C flows through a steel pipe 1 inch inside diameter, 1/8 inch wall thickness and 100 feet long at a speed of 30 m/s. The kinematic viscosity (ν) of the air is 0.1 cm^2/sec, the density (ρ) is 4.0 kg/m^3 and the specific heat ratio (γ) is 1.35. The pipe wall is very very smooth and the pipe mass is 60 kg.

(a) What is the Reynolds number of the air flow inside the pipe?
(b) Compute the pressure drop in the pipe in units of lbf/in^2.
(c) If the pipe were dropped into water and remained horizontal, what would the pipe's terminal velocity be?
(d) At this terminal velocity, would the pipe be sinking or rising? Explain.

Problem #4 (20 points)

Helium (He, molecular mass 4 g/mole, $\gamma = 1.667$) initially at rest ($M_1 = 0$) in a tank at pressure $P_1 =$ 5 atm and temperature $T_1 = 300K$ flows through a nozzle into ambient air at pressure $P_2 = 1$ atm. There is no elevation change. Assuming isentropic flow:

(a) What is the density $\rho_1 = P_1/RT_1$ (in kg/m^3) of the He in the tank?
(b) What is the Mach number of the He at the end of the nozzle (M_2)?
(c) What is the He temperature at the end of the nozzle (T_2)?
(d) What is the sound speed of the He at the end of the nozzle ($c_2 = (\gamma RT_2)^{1/2}$) ?
(e) What is the He velocity (v_2) at the end of the nozzle = c_2M_2?
(f) What is the ratio of throat area (A^*) to exit area (A_2)?
(g) What would the He velocity v_2 be if you had used Bernoulli's equation and assumed that the gas density was constant ($\rho_2 = \rho_1$)?

Problem #5 (20 points) (from last year's 2nd midterm)

Ronney Chemicals, Inc. has invented a new fluid, called PDR™, that has **all** the same properties as water except that **its dynamic viscosity (μ) is twice that of water**. In particular, the density (ρ) of PDR™ is the same as water. If PDR™ were used instead of water, state whether each of the following would increase, decrease or remain the same, and if there is a change, would the change be a factor of more than, less than, or exactly a factor of 2. **No credit without explanation!**

(a) Hydrostatic pressure at the bottom of a 100 m deep lake.
(b) The net buoyant force acting on an object with density (ρ_o) of 500 kg/m^3.
(c) Velocity at the exit of a nozzle decreasing from 4 inches to 2 inches diameter with a pressure decrease of 60 lbf/in^2, assuming Bernoulli's equation applies.
(d) Reynolds number of the flow around a sphere (same sphere diameter (d) and velocity (v) for both fluids)
(e) Drag force on a sphere at very low Re (same sphere diameter (d) and velocity (v) for both fluids)
(f) Pressure drop (ΔP) in a pipe at very low Re (same diameter (d), length (L), roughness (ε) and velocity (v) for both fluids)
(g) Pressure drop (ΔP) in a pipe at very high Re (same d, L, ε and v for both fluids)