AME 101 Fall 2017
Problem Set #4
Assigned: 10/27/2017
Due: 11/3/2017, 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 (15 points)

The Froude number (Fr) of the flow around an object such as a sailboat is defined by $Fr = g\lambda/v^2$, where g = acceleration of gravity, λ = characteristic length of the object, and v = velocity of the object.

(a) Calculate the Froude number of the flow around a 40 foot long sailboat (that is, λ = 40 ft) cruising through the water at 25 miles per hour.
(b) Calculate the Reynolds number of the flow of the water around the sailboat, again using λ = 40 ft as the characteristic dimension (see Table 4 in the lecture notes for the properties of water).
(c) It is desired to simulate the flow around this sailboat in a laboratory experiment with mercury (see Table 4 in the lecture notes for mercury properties) (do not attempt this at home!) What model length (λ) (in feet) and fluid speed (v) (in feet per second) would be required to have the same Froude and Reynolds numbers as determined in parts (a) and (b)?

Problem #2 (20 points)

A cylindrical balloon 1 ft in diameter and 5 ft in length is released into the atmosphere. It rises (with the axis of the cylinder horizontal) and reaches a terminal velocity of 5 ft/s. The density of air is 1.18 kg/m^3 and its kinematic viscosity (ν) is 0.15 cm^2/s. The density of the gas inside the balloon is unknown. The mass of the balloon itself is negligible.

(a) What is the Reynolds number of the flow around the balloon?
(b) What is the drag force acting on the balloon?
(c) When the balloon is at terminal velocity, the buoyant force is equal in magnitude and opposite in direction to the drag force. What density of the gas inside the balloon would be required to obtain drag force = -buoyant force?

Problem #3 (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 #4 (20 points)

Air initially at rest ($M_1 = 0$) with an initial pressure $P_1 = 1$ atm and temperature $T_1 = 300K$ flows through a nozzle into a partial vacuum with $P_2 = 0.2$ atm. There is no elevation change.

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

Problem #5 (25 points total)

Ronney Chemicals, Inc. has invented a new fluid, called PDR™, that has **all** the same properties as water except that **its density (ρ) is twice that of water**. In particular, the dynamic viscosity (μ) 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 (i.e. Problem 3a above).
(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_d (i.e., laminar flow) (same diameter (d), length (L), roughness (ε) and velocity (v) for both fluids)
(g) Pressure drop (ΔP) in a rough pipe at very high Re_d (same d, L, ε and v for both fluids)