AESB2320, 2019-20

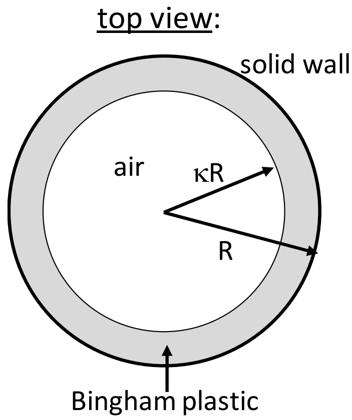
Part 1 Examination - 10 March 2020

Write your solutions *on your answer sheet*, not here. In all cases ***show your work***.
To avoid any possible confusion,
state the equation numbers and figure numbers of equations and figures you use
along with the text you are using (BSL1, BSL2 or BSLK).
Beware of unnecessary information in the problem statement.

1. I would like to repeat a demonstration in the film we watched in class on "Turbulence." Specifically, I will use a horizontal tube, 2 cm in diameter, with a fluid of density 1000 kg/m^3. A pump injects this fluid at a fixed velocity of 0.10 m/s. In a way similar to the film, I will start with a viscosity (call it μ_1), then reduce the viscosity to ($\mu_1/2$), then reduce it again to ($\mu_1/4$). I want pressure difference to decrease when I go from μ_1 to ($\mu_1/2$), then increase when I go to ($\mu_1/4$). What value of μ_1 would you recommend I use?
(10 points)

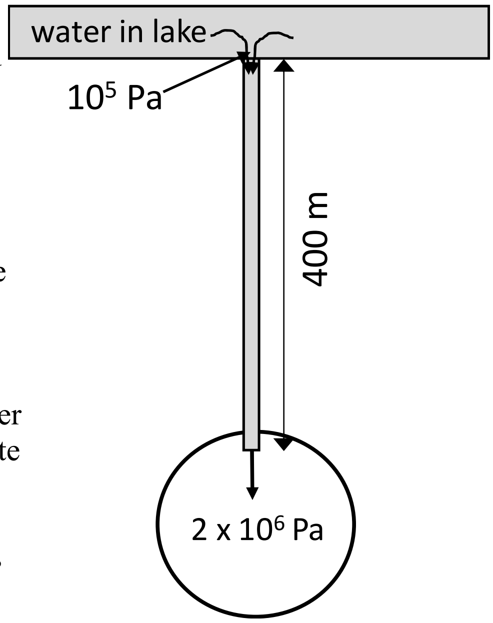
2. A layer of Bingham plastic coats the inside of a pipe. The radius of the inner wall of the pipe is R, and the inner surface of the layer is at radius (κ R) (with $\kappa < 1$). Inside the radius of the plastic layer (i.e., for $r < (\kappa R)$) is air. The plastic has Bingham parameters μ_o and τ_o, and density ρ. The pipe is not moving.
   a. Derive a formula for the shear stress within the Bingham plastic layer ($\tau_{rz}(r)$).
   b. Derive a formula for the minimum value of κ for which the Bingham plastic would stay fixed in place, and not flow down the tube.

   This problem has some similarities to BSL1 Sect. 2.3. I attach some pages from that text.
(30 points)



3. I'm told that researchers in the GRS department are measuring raindrop sizes by measuring raindrop velocities in air. They say that raindrops are fairly sparsely spread out, so they can be treated as isolated spheres in still air (if we ignore gusts of wind, which we will do for this exercise).
   a) If drop diameter doubles, how does its velocity change for creeping flow (low Re)?
   b) If drop diameter doubles, how does its velocity change for highly turbulent flow (very large Re)?
(20 points)

4. In 1980 drillers working in (shallow) Lake Peigneur in Louisiana hit an old salt-mine cavern by mistake. Water from the lake poured into the drill hole and, in a short time, emptied the lake. For the purposes of this problem, use the following parameters: The well is 400 m deep (from the bottom of the lake to the pipe end). Assume water (density 1000 kg/m^3, viscosity 0.001 Pa s) fills the hole. Assume the bottom of the well is a large cavity held at a constant pressure 2 x 10^6 Pa, while just above the entrance to the drill hole pressure is 10^5 Pa. It was estimated that about 1.3 x 10^7 m^3 of water flowed down the hole over two days (a flow rate of about 7.67 m^3/s); assume this flow rate was constant. Assume a roughness factor k/D of 0.004 for the cylindrical hole (probably a gross underestimate, but use it). Assume the top of the hole is an abrupt constriction on the lake bottom (top of the pipe), and assume the hole itself is filled only with water.*



a) Derive an equation that the hole diameter D must satisfy to explain this flow rate with all the parameter values plugged in.
b) Simplify the problem by assuming that the only dissipation that matters is drag along cylindrical wall of the hole, and that kinetic energy is unimportant. Then solve for the diameter with these assumptions. Don't worry if you get a hole size that seems odd; just solve the problem with the parameters and assumptions as given.

* - in reality, there was a drill bit and drill pipe in the hole; for the purposes of this exercise, ignore that.

(40 points)