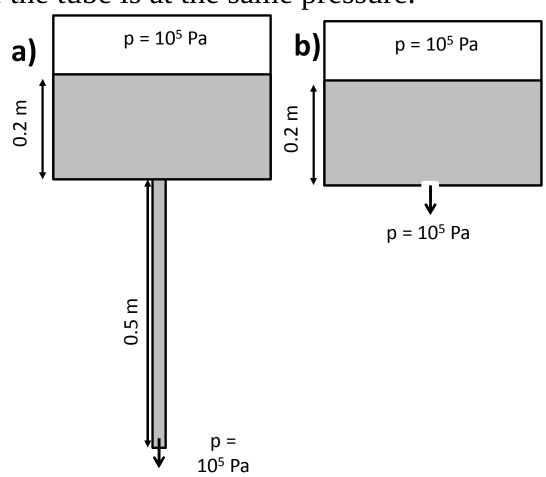
AESB2320, 2017-18

Part 1 Examination - 29 June

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. A large tank is filled with water (density $\rho = 1000$ kg/m^3, viscosity $\mu = 0.001$ Pa s) to a depth of 20 cm. At the bottom of the tank is a sudden contraction at the entrance to a tube with 1 cm inner dia., 50 cm long. The roughness along the tube wall is of height 0.04 mm. Above the water in the tank the pressure is atmospheric (10^5 Pa), and the outlet of the tube is at the same pressure.
   a. What is the velocity of water out the tube? If you are unable to finish the problem, for partial credit give an equation the velocity must satisfy.
   b. Suppose the tube were gone; water simply poured through the hole (sudden contraction), 1 cm in diameter, out of the bottom of the tank. What would be the velocity of the water out the hole in the bottom of the tank in this case?

   (35 points)



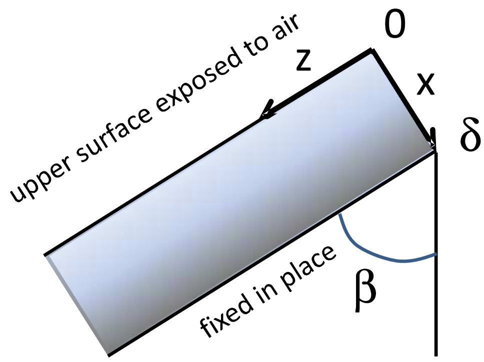
2. A film of Newtonian fluid of thickness δ is flowing down an inclined plane as shown below. The upper surface is exposed to air and the bottom surface lies on a solid that is fixed in place. The fluid viscosity μ is uniform, but its density varies with position according to

   $\rho = a + bx$

   where x is position in the film. (The shading illustrates schematically how density varies in the film.)
   a. Derive a formula for the shear stress τ_{xz} as a function of x in the film.
   b. Derive a formula for the velocity of the fluid in the film, $v_z(x)$.

   The pages of BSL1 for the falling film are attached to the end of this exam. If you use any of that derivation, make clear what equation(s) you are using.

   (25 points)



3. A colleague wants to see the effect of turbulence on fluids injected to enhance oil recovery. He wants therefore to create turbulence as the Newtonian fluid (density 1000 kg/m^3, viscosity 0.005 Pa s) flows through the narrow tubing in our laboratory apparatus. The flow rate Q is 10 ml/min (1.67 x 10^{-7} m^3/s).

(Don't be alarmed if you get unreasonable numbers; this is an impractical idea. I posed this problem to see if it is at all practical.)

   a. What tube diameter should he choose so that he will go just past the transition to turbulent flow?
   b. What would be the pressure gradient ($\Delta\mathcal{P}/L$) along the tubing with this diameter? If you are unable to finish part (a), choose a tube diameter, make clear what you are assuming, and answer this question.

   (25 points)

4. An engineer pumps a liquid through a tube of radius R and length L at a volumetric flow rate Q_1 and measures a pressure difference between inlet and outlet Δp_1. (Note this is pressure difference, not flow-potential difference.) He then pumps at a flow rate ($2Q_1$), and the pressure difference is ($2\Delta p_1$). Which of the following statements could possibly be true about this experiment? There may be more than one correct answer; indicate all correct answers ***on your answer sheet***. The answer could be one, more than one, or none of the following:

   A. It is a Newtonian fluid in laminar flow. The tube is horizontal.
   B. It is a Newtonian fluid in highly turbulent flow. The tube is horizontal.
   C. It is a Bingham plastic flowing in laminar flow. The tube is horizontal.
   D. It is a shear-thinning power-law fluid ($n<1$) in laminar flow. The tube is horizontal.
   E. It is a shear-thickening power-law fluid ($n>1$) in laminar flow. The tube is horizontal.
   F. It is a shear-thinning power-law fluid ($n<1$) in laminar flow. The tube is vertical, with the outlet higher than the inlet.
   G. It is a shear-thinning power-law fluid ($n<1$) in laminar flow. The tube is vertical, with the outlet lower than the inlet.

   (15 points)