NAME: _____ STUDENT #_____

AESB2320, 2015-16

Part 1 Examination - 8 March

Turn in this exam with your answer sheet.

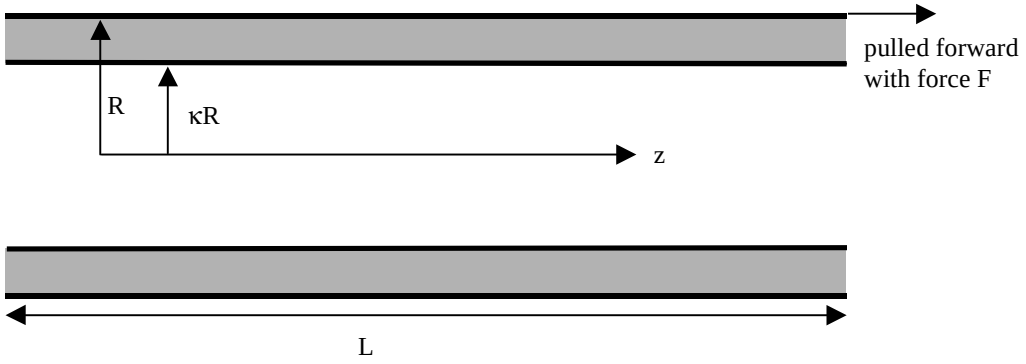
Write your solutions *on your answer sheet*, not here. In all cases ***show your work***. Beware of unnecessary information in the problem statement.

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 (BSL2 or BSLK).

1. Rocky injects a Newtonian liquid of viscosity 0.01 Pa s (10 cp) and density 800 kg/m^3 through a tube of radius R and measures the potential gradient $\Delta\mathcal{P}/L$ and the flow rate Q. He doesn't know the viscosity of the fluid. He *calculates* the viscosity from his measurements with the tube, with the *assumption* that the flow is laminar. Actually, however, the Reynolds number for this flow in this tube is 3000. The tube is "hydraulically smooth." Based on his measurements, what does Rocky (incorrectly) conclude is the viscosity of his fluid? Briefly justify your answer.
(20 points)

2. A Newtonian fluid fills the annulus between two pipes, both of length L (L is very long), that are laid horizontally. The outer pipe has inner radius R and the inner pipe has outer radius κR, with $\kappa < 1$. There is no applied pressure drop across the fluid. The outer pipe is pulled forward (in the z direction) with force F, resulting in a velocity V. The inner pipe is held fixed in place. For the purpose of this problem, don't worry about the outer pipe being pulled beyond the inner pipe; assume they are both so long this is not significant.
   a. Derive a formula for the shear stress τ_{rz} as a function of r in the fluid in the annulus.
   b. Derive a formula for the velocity v_z as a function of r in the fluid.
   c. Derive a formula for the force F required on the outer pipe as a function of the velocity V of the outer pipe.

(25 points)



3. What is the permeability of a packing of sand grains 0.5 mm in diameter, with porosity 35%?
(10 points)

4. A piping system is constructed as illustrated below. Liquid (density 1100 kg/m^3, viscosity 0.003 Pa s) resides in a tank; the liquid level in the tank is 3 m and the pressure above the liquid is p_o. There is a sudden contraction to a pipe 2 cm in diameter at the bottom of the tank. This pipe leads down 1 m, then there is a square (i.e., not rounded) 90°elbow, and it leads horizontally for 3 m. At this point there is a sudden expansion in the pipe diameter; beyond this there is 5 m of horizontal pipe 5 cm in diameter, and then the liquid is released into the air (at 10^5 Pa pressure). The volumetric flow rate Q through this piping system is 0.003 m^3/s. The scale of roughness k is 80 μm (8 x 10^{-5} m) in both pipes. What is the pressure p_o in the tank?

The solution here involves many calculations. For full credit, make each step of your calculations clear.
(45 points)