JME 3700
April 8, 2017

Homework #11

1. (10 pts) Water drains from a large tank through a system made of $D = 0.2\,m$ inner diameter pipe having a surface roughness of $\varepsilon = 0.00026\ m$ (Fig. 1). Discharge to the atmosphere is $H = 4.5\,m$ below the free surface and the volume flow rate is $Q = 0.05\ m^3/s$. If the four right–angle pipe components each have a loss coefficient of $K_a = 0.25$ and the exit itself has a loss coefficient of $K_e = 1$, calculate the total length of the straight pipe sections. (We assume that the inlet to the pipe is "well–rounded" so that its losses are negligible.) Assume a water viscosity and density of $\nu = 1.2 \times 10^{-6}\,m^2/s$ and $\rho = 1000\,kg/m^3$, respectively.

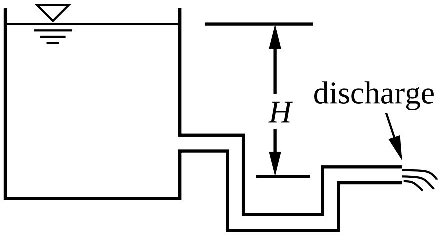

Fig. 1: *Piping system.*

2. (10 pts) A water company is considering replacing a long section of a very old 0.5 m inner diameter "main". This pipe has a relative roughness of $\varepsilon/D = 0.02$. One option is to dig the whole system up, but this would be very expensive. A junior engineer suggests pushing a hydrodynamically smooth plastic liner of inner diameter 0.4 m through the old pipe instead. Although this would be much cheaper, this new configuration would still need to carry the same volume flow rate $Q = 1\,m^3/s$ as the older, larger pipe. If there is to be no net increase in pressure drop, will this approach work? Assume a water viscosity of $\nu = 1.2 \times 10^{-6}\ m^2/s$.

3. (10 pts) A pump moves water into a very large tank at a flow rate of $Q = 0.01\ m^3/s$ through $L = 100\ m$ of hydrodynamically smooth pipe (Fig. 2, not shown to scale). The pipe is horizontal and has an inner diameter of $D = 0.075m$. At the instant shown, there is an $h = 10\ m$–deep column of water already in the tank. What pressure, P_p, must the pump step the flow up to at its outlet? Assume $\nu = 1 \times 10^{-6}\,m^2/s$ and $\rho = 1000\,kg/m^3$ and that the viscous losses due to the flow entering the tank are characterized by the loss coefficient $K = 1$.

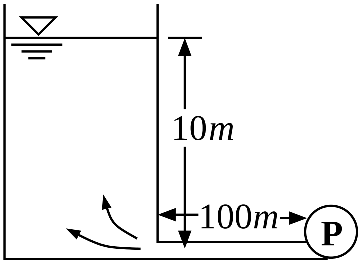

Fig. 2: *Pumping water.*

4. (10 pts) Oil flows steadily in a horizontal pipe of constant diameter $D_1 = 0.2\,m$ at an average velocity of $\overline{u}_1 = 1\ m/s$ (Fig. 3). Oil viscosity is $\nu = 0.001\ m^2/s$ and the flow is fully–developed. The flow eventually reaches a smooth contraction and enters into a smaller pipe of diameter $D_2 = 0.1\ m$, quickly becoming fully developed. Determine the respective friction factors f_1 and f_2 in the larger and smaller pipes.

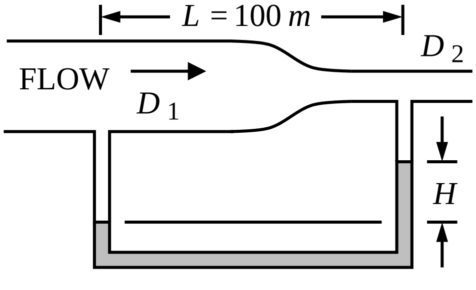

Fig. 3: *Oil flow in a pipe.*

5. (10 pts) The configuration in Question 4 is exactly horizontal and two static ports are separated by $L = 100\ m$, as measured along the pipe. These ports are connected by a liquid

mercury manometer (also shown in Fig. 3), whose fluid density is $\rho_m = 13500\ kg/m^3$. Here, the contraction is halfway between the static ports and is very short compared to the overall length of $L = 100\ m$. Therefore, taking as a first approximation that f_1 applies over the first $50m$ of pipe length and f_2 applies over the subsequent $50m$ of length, determine the manometer reading, H. Gravitational acceleration is $g = 9.8\,m/s^2$ and oil density is $\rho_o = 900\,kg/m^3$. From a design perspective, comment whether this manometer configuration would be a good method for measuring pressure drop.