Fluid Mechanics (ME 201)

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Tutorial 7 – Flow through pipes

1. Prandtl has suggested that the velocity distribution of a turbulent flow in a pipe may be approximated by $v = v_{max}\left(\frac{r}{r_0}\right)^{1/7}$, where r_0 is the pipe radius, and r is the distance from the pipe wall. Determine the expression of average velocity in terms of centre line velocity. Compute kinetic energy correction coefficient, and compare this value with that of laminar flow. $[v_{avg} = 0.933v_{max}]$

2. Water flows through a viscometer having a circular pipe configuration of diameter 0.5 mm. The volume flow rate and the pressure drop per unit length, respectively, are 880 mm^3/s and 1 Mpa/m. Compute the kinematic viscosity of water. Justify your result.
. $[1.74 \times 10^{-3}$ kg/ms]

3. Using method of repeating variable, obtain an expression for head loss for a laminar/turbulent flow through a pipe. Explain the appearance of Darcy friction factor. Derive an expression for Darcy friction factor for a fully developed laminar flow through a pipe.

4. A horizontal pipe carries fluid in fully developed turbulent flow. The static pressure difference measured between two sections is 35 kPa. The distance between sections is 10 m and the pipe diameter is 150 mm. Calculate the shear stress at the wall. [131.25 N/m^2]

5. Kerosine is pumped through a smooth tube with inside diameter 30 mm at close to critical Reynolds number. The flow is unstable and fluctuates between laminar and turbulent states, causing the pressure gradient to intermittently change from approximately -4.5 kPa/m to -11 kPa/m. Which one corresponds to laminar state? For each flow compute shear stress at the tube wall, and sketch shear stress distributions.

6. A 6 cm diameter horizontal water pipe expands gradually to a 9 cm diameter pipe. The walls of the expansion section are angled 30^o from the horizontal. The average velocity and pressure of water before the expansion section are 7 m/s and 150 kPa, respectively. Determine the head loss in the expansion section and the pressure in the larger-diameter pipe. (loss coefficient for this configuration $K_L = 0.07$, $\alpha \approx 1.06$.) [169 kPa]

7. Determine the Darcy friction factor when water of kinematic viscosity $\nu = 1.14 \times 10^{-6}$ m^2/s flows through a 300 m long galvanised steel pipe having averaged surface roughness of 0.15 mm and diameter of 150 mm. The flow rate is 0.05 m^3/s. Also calculate the pumping power required for this flow rate, and when the flow rate is reduced to 0.00025 m^3/s.
. [0.02,8.009 kW, 0.00172 W]

8. A 100 m length of smooth horizontal pipe having diameter 75 mm is attached to a large reservoir. The reservoir has water level of 10 m. A pump is attached to the end of the pipe

to pump water into the reservoir at a volume flow rate of 0.01 m^3/s. What pressure must the pump produce at the pipe to generate this flow rate? Take $\mu = 10^{-3}$ kg/ms, $\alpha \approx 1.06$, and loss coefficient at the exit, $K_L = 1.0$. [152.595 kPa]

9. The flow rate of methanol (ρ =788.4 kg/m^3 and $\mu = 5.857 \times 10^{-4}$ kg/ms) through a 4 cm diameter pipe is to be measured with a 3 cm diameter orifice meter equipped with a mercury manometer across the orifice place. If the differential height of the manometer is read to be 11 cm, determine the flow rate of methanol through the pipe and the average flow velocity. Assume $C_d = 0.61$, and density of mercury to be 13,600 kg/m^3.
   . [3.09 $\times 10^{-3}$ m^3/s]