Series 10 (9 May 2025)

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7.13 The drag, $\mathscr{D}$, on a washer-shaped plate placed normal to a stream of fluid can be expressed as:

$$\mathscr{D} = f(d_1, d_2, V, \mu, \rho)$$

where d_1 is the outer diameter, d_2 the inner diameter, V the fluid velocity, μ the fluid viscosity, and ρ the fluid density. Some experiments are to be performed in a wind tunnel to determine the drag. What dimensionless parameters would you use to organize these data?

7.19 Under certain conditions, wind blowing past a rectangular speed limit sign can cause the sign to oscillate with a frequency ω. (See **Fig. P7.19** and Video V9.9.) Assume that ω is a function of the sign width, b, sign height, h, wind velocity, V, air density, ρ, and an elastic constant, k, for the supporting pole. The constant, k, has dimensions of FL. Develop a suitable set of pi terms for this problem.

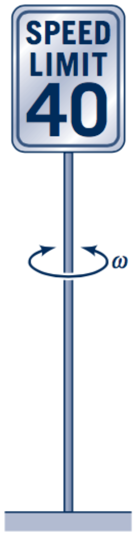


Figure P7.19

7.22 The pressure drop, Δp, along a straight pipe of diameter D has been experimentally studied, and it is observed that for laminar flow of a given fluid and pipe, the pressure drop varies directly with the distance, L, between pressure taps. Assume that Δp is a function of D and L, the velocity, V, and the fluid viscosity, μ. Use dimensional analysis to deduce how the pressure drop varies with pipe diameter.

7.28 As shown in **Fig. P7.28** and Video V5.6, a jet of liquid directed against a block can tip over the block. Assume that the velocity, V, needed to tip over the block is a function of the fluid density, ρ, the diameter of the jet, D, the weight of the block, W, the width of the block, b, and the distance, d, between the jet and the bottom of the block.
(a) Determine a set of dimensionless parameters for this problem. Form the dimensionless parameters by inspection. **(b)** Use the momentum equation to determine an equation for V in terms of the other variables. **(c)** Compare the results of parts (a) and (b).

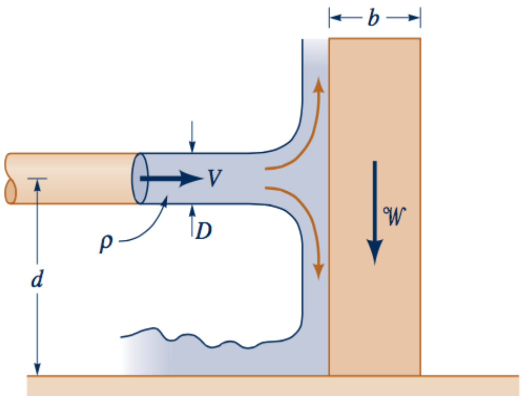


Figure P7.28

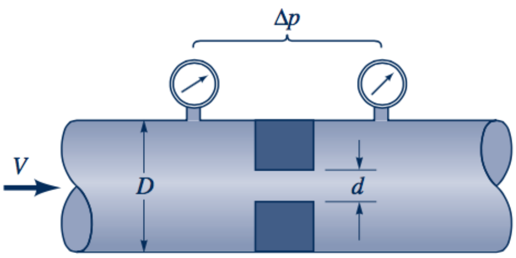
7.34 The pressure drop across a short hollowed plug placed in a circular tube through which a liquid is flowing (see Fig. P7.34) can be expressed as:

$$\Delta p = f(\rho, V, D, d)$$

where ρ is the fluid density, and V is the mean velocity in the tube. Some experimental data obtained with D = 0.06 m, ρ = 1030 kg/m^3, and V = 0.6 m/s are given in the following table:

d (m)	0.01	0.02	0.03	0.04
Δp (kPa)	24	7.5	3	0.6

Plot the results of these tests, using suitable dimensionless parameters, on a log–log scale. Use a standard curve-fitting technique to determine a general equation for Δp. What are the limits of applicability of the equation?

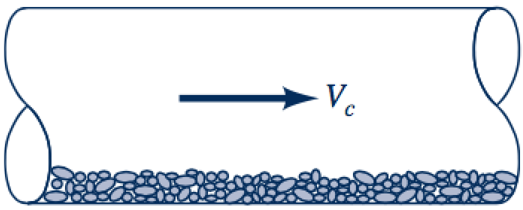


■ Figure P7.34

7.69 A thin layer of particles rests on the bottom of a horizontal tube as shown in Fig. P7.69. When an incompressible fluid flows through the tube, it is observed that at some critical velocity the particles will rise and be transported along the tube. A model is to be used to determine this critical velocity. Assume the critical velocity, Vc, to be a function of the pipe diameter, D, particle diameter, d, the fluid density, ρ, and viscosity, μ, the density of the particles, ρ_P, and the acceleration of gravity, g.

(**a**) Determine the similarity requirements for the model, and the relationship between the critical velocity for model and prototype (the prediction equation).

(**b**) For a length scale of ½ and a fluid density scale of 1.0, what will be the critical velocity scale (assuming all similarity requirements are satisfied)?



■ Figure P7.69