EXAM2 November 8, 2010

1. A jet of alcohol (ρ = 788.42 kg/m^3) strikes the vertical plate in Fig. 1. The (absolute) pressure p_1 = 760 kPa at section 1. Find (a) the alcohol jet velocity V_2 at section 2 and (b) the force F required to hold the plate stationary. For part (a), assume there are no losses in the nozzle flow.

2. Water flows through a vertical pipe, as is indicated in Fig.2. The vertical distance H = 50 cm between the two points marked with dots at the pipe and the mercury (SG = 13.6) manometer height h = 5 cm due to the pressure difference between the two points. (a) What is the head loss h_L between the two points? (b) Is the flow up or down in the pipe? Explain.

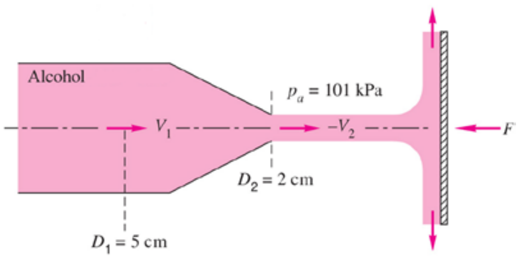

Fig. 1

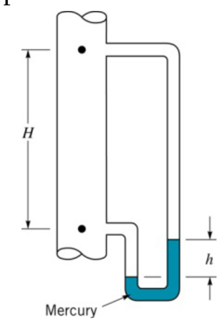

Fig. 2

3. Consider a steady, incompressible, parallel, laminar flow of a viscous fluid falling between two infinite, vertical walls as shown in Fig. 3. The distance between the walls is h, and gravity acts in the negative z-direction ($g_z = -g$, downward in the figure). There is no forced pressure ($\partial p/\partial z$ = 0) driving the flow – the fluid falls by gravity alone. Starting from the following Navier-Stokes equation,

$$\rho\left(\frac{\partial w}{\partial t} + u\frac{\partial w}{\partial x} + v\frac{\partial w}{\partial y} + w\frac{\partial w}{\partial z}\right) = -\frac{\partial p}{\partial z} + \rho g_z + \mu\left(\frac{\partial^2 w}{\partial x^2} + \frac{\partial^2 w}{\partial y^2} + \frac{\partial^2 w}{\partial z^2}\right)$$

(a) drive an expression for w and (b) calculate the centerline velocity (w along the x = 0 line) if h = 2 mm and the fluid is glycerin at 20°C (ρ = 1,260 kg/m^3 and μ = 1.49 N·s/m^2). Assume the flow is purely two-dimensional (v = 0 and $\partial/\partial y$ = 0) and parallel to the walls (u = 0).

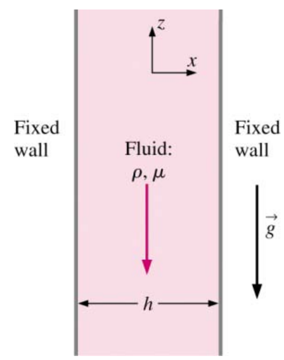

Fig. 3

4. Liquid flows out of a hole in the bottom of a tank as in Fig. 4. Consider the case in which the hole is very small compared to the tank (d << D). Experiments reveal that average jet velocity V is nearly independent of d, D, ρ, or μ. In fact, for a wide range of these parameters, it turns out that V depends only on liquid surface height h and gravitational acceleration g. (a) Using dimensional analysis, generate a dimensionless relationship for V as a function of g and h. (b) If the liquid surface height h is doubled, all else being equal, by what factor will the average jet velocity V increase?

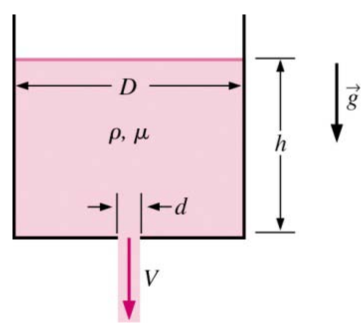

Fig. 4