November 9, 2016

1. A curved nozzle assembly that discharges to the atmosphere is shown in Fig. 1. The nozzle mass is 4.5 kg and its internal volume is 0.002 m^3. The fluid is water (ρ = 999 kg/m^3). Determine (a) the velocity V_2 at the nozzle exit and (b) the vertical component of the reaction force, Ry, exerted by the nozzle on the coupling to the inlet pipe.

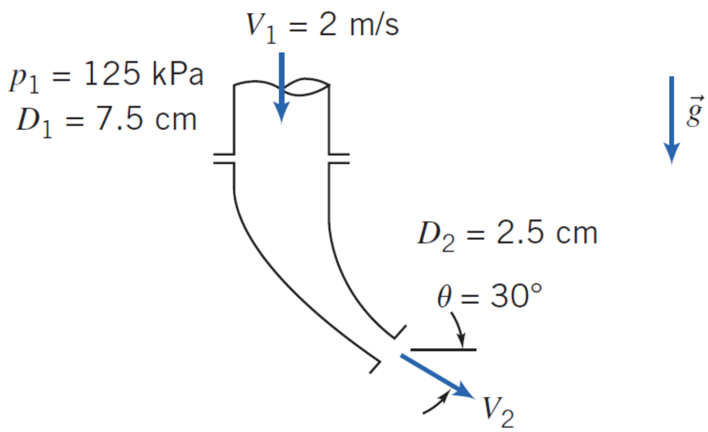

Fig. 1

2. Fig. 2 shows a pump testing setup. Water is drawn from a large sump and pumped through a pipe containing a valve. The water is discharged into a catch tank sitting on a scale. During a test run, 360 kg of water (ρ= 999 kg/m^3) is collected in the catch tank in 15 s. The pump power input to the fluid during this period is 950 W. Calculate (a) the water flow rate Q in the pipe and the velocity V_2 at the exit and (b) the head loss h_L in the pipe and valve.

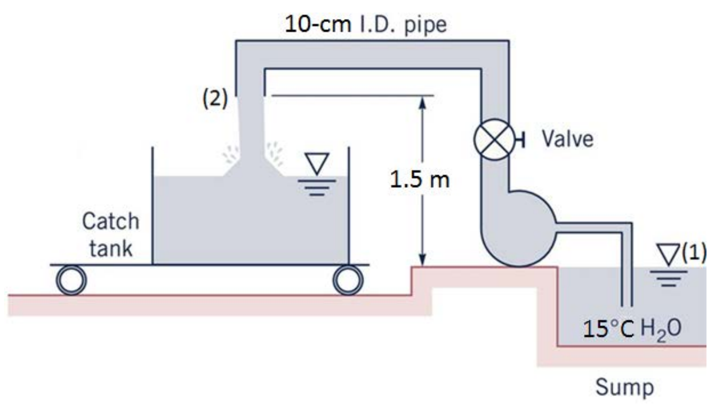

Fig. 2

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3. Consider a steady, incompressible, laminar flow of a Newtonian fluid between two infinite fixed-walls (Fig. 3). The two walls are separated each other at a distance h and both inclined at an angle α. There is no applied pressure gradient ($\partial P/\partial x = 0$). Instead, the fluid flows down the pipe due to gravity alone. We adopt the coordinate system shown, with x down the inclined wall. By assuming the flow is parallel and fully developed, the x-momentum equation reduces as,

$$\frac{d^2u}{dy^2} = -\frac{\rho g \sin\alpha}{\mu}$$

(a) Solve the equation by using appropriate boundary conditions for this problem and (b) if the fluid is an engine oil at 60°C (ρ = 864 kg/m^3 and $\mu = 7.25 \times 10^{-2}$ N·s/m^2) and h = 1 cm and α = 45°, calculate the volume flow rate q per unit depth and the average velocity V between the walls.

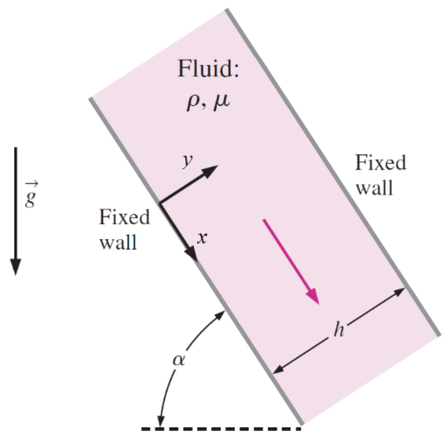

Fig. 3

4. A boundary layer is a thin region (usually along a wall) in which viscous forces are significant and within which the flow is rotational. Consider a boundary layer growing along a thin flat plate (Fig. 4). The flow is steady. The boundary layer thickness δ is a function of downstream distance x, free-stream velocity U, and fluid density ρ and viscosity μ. (a) Use the Buckingham Pi theorem to show how many dimensionless parameters are associated with this problem and (b) use the method of repeating variables to generate a dimensionless relationship for δ as a function of the other parameters. Show all your work.

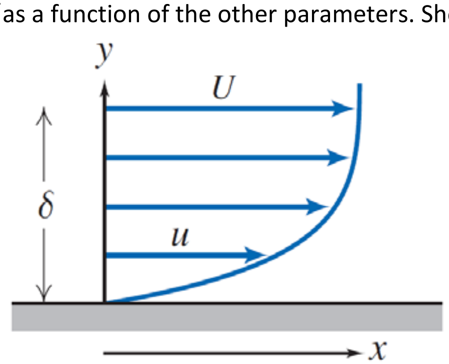

Fig. 4