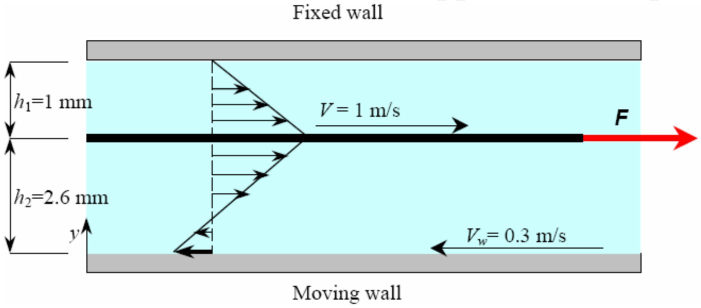
057:20 TEST # 3 Fall 2005

1. A thin 20-cm×20-cm flat plate is pulled at 1 m/s horizontally through a 3.6-mm-thick oil layer sandwiched between two plates, one stationary and the other moving at a constant velocity of 0.3 m/s, as shown in the figure. The dynamic viscosity of oil is 0.027kg/m·s. Assuming the velocity in each oil layer to vary linearly, determine the force that needs to be applied on the plate to maintain this motion.



2. A 90° elbow is used to direct water flow at a rate of 25 kg/s in a horizontal pipe upward. The diameter of the entire elbow is 10cm. The elbow discharges water into the atmosphere, and thus the pressure at the exit is the local atmospheric pressure. The elevation difference between the centers of the exit and the inlet of the elbow is 35 cm. The weight of the elbow and the water in it is considered to be negligible. Take the momentum-flux correction factor to be 1.03. Determine
(a) the gage pressure at the center of the inlet of the elbow and
(b) the anchoring force needed to hold the elbow in place.
(Water density ρ=1000kg/m^3)

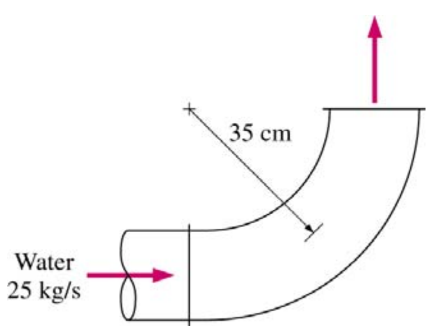


Figure 2 for problem 2

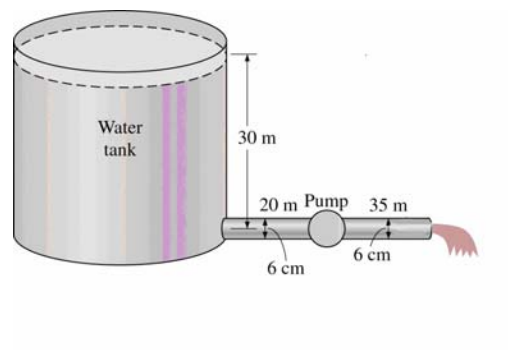
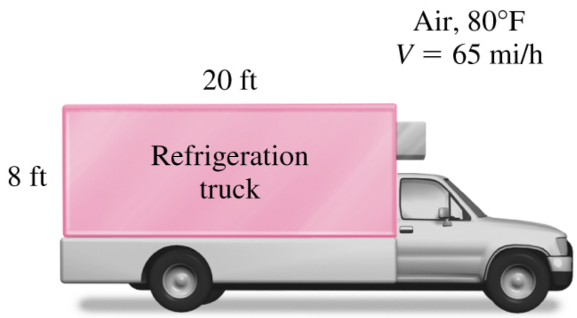


Figure 3 for problem 3

3 Water at 15°C is to be discharged from a reservoir at a rate of 18 L/s using two horizontal cast iron pipes connected in series and a pump between them. The first pipe is 20 m long and has a 6-cm diameter, while the second pipe is 35 m long and has the same diameter. The water level in the reservoir is 30 m above the centerline of the pipe. The pipe entrance is sharp-edged, and losses associated with the connection of the pump are negligible (i.e., the minor loss exists only at the pipe entrance). Neglecting the effect of the kinetic energy correction factor, determine the required pumping head to maintain the indicated flow rate.
(Water dynamic viscosity $1.138\times10^{-3}\ kg/m\cdot s$; density $999.1 kg/m^3$)
(1 L/s = 0.001 m^3/s)

4. Air flows through the test section of a small wind tunnel at speed V = 7.5 ft/s. The length of the wind tunnel test section is 1.5 ft. Assume that the boundary layer thickness is negligible prior to the start of the test section. Determine the flow is laminar or turbulent at the end of the test section. The critical Reynolds number is $\mathrm{Re}_{x,critical} = 1\times10^5$. Estimate the boundary layer thickness, the displacement thickness, and the momentum thickness of the boundary layer at the end of the test section.
(Air kinematic viscosity $1.697\times10^{-4}\ ft^2/s$)

5. Consider a refrigeration truck traveling at 65 mi/h at a location where the air temperature is at 1atm and 80°F. The refrigerated compartment of the truck can be considered to be a 9-ft-wide, 8-ft-high, and 20-ft-long rectangular box. Assuming the airflow over the entire outer surface to be turbulent and attached (no flow separation), i.e. turbulent flat plate boundary layer, determine the drag force acting on the top and side surfaces and the power required to overcome this drag.
(Air kinematic viscosity $1.697\times10^{-4}\ ft^2/s$; density $0.0735\, lbm/ft^3$)
($1\, mi/h = 1.46667\ ft/s$; $1\, lbf = 32.2\, lbm\cdot ft/s^2$; $1\, kW = 737.57\, lbf\cdot ft/s$)



6. A submarine can be treated as an ellipsoid with a diameter of 5 m and a length of 25 m. Determine the power required for this submarine to cruise horizontally and steadily at 40 km/h in seawater whose density is 1025 kg/m^3. Also determine the power required to tow this submarine in air whose density is 1.30 kg/m^3. Assume the flow is turbulent in both cases.
($1\, m/s = 3.6\, km/h$)