1.4.4. Velocity measurements are made along a cross section of a fluid flow field. The velocity at two points (2 cm apart) are 4.8 m/s and 2.4 m/s, respectively. What is the magnitude of the shear stress at this location if the velocity profile is linear and the fluid is water at 20°C?

1.4.5. A very thin plate measuring 6 in. by 18 in. is being pulled between two stationary plates (Figure P1.4.5) at a speed of 1.5 ft/s? The 0.5-in. space between the two plates is filled with lubricating oil with a dynamic viscosity of 0.0065 lb-s/ft^2. How much force (F) is required to pull the thin plate.

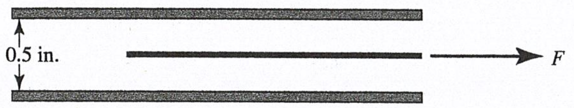

Figure P1.4.5

1.4.6. A flat plate weighing 100 N slides down a 15° incline with a velocity of 2.5 cm/s. A thin film of oil with a viscosity of 1.52 N · s/m^2 separates the plate from the ramp. If the plate is 80 cm by 90 cm, calculate the film thickness in mm.

1.4.7. The 25-cm diameter ram in a hydraulic lift slides in a 25.015-cm diameter cylinder. The viscosity of the oil filling the gap is 0.04 N · s/m^2. If the speed of the ram is 15 cm/s, determine the frictional resistance force when a 3 m length of the ram is engaged in the cylinder.

1.4.8. A liquid flows with velocity distribution $V = y^2 - 3y$, where V is given in ft/s and y in inches. Calculate the shear stresses at $y = 0, 1, 2, 3, 4$ if the viscosity is 8.35×10^{-3} lb-s/ft^2.

1.4.9. A flat circular disk of radius 1.0 m is rotated at an angular velocity of 0.65 rad/s over a fixed flat surface. An oil film separates the disk and the surface. If the viscosity of the oil is 16 times that of water (20°C) and the space between the disk and the fixed surface is 0.5 mm, determine the torque required to rotate the disk.

1.4.10. Fluid viscosity can be measured by a rotating-cylinder viscometer, which consists of two concentric cylinders with a uniform gap between them. The liquid to be measured is poured into the gap between the two cylinders. For a particular liquid, the inner cylinder rotates at 2000 rpm and the outer cylinder remains stationary and measures a torque of 1.10 ft · lb. The inner cylinder diameter is 2.0 in., the gap width is 0.008 in., and the liquid fills up to a height of 1.6 in. in the cylindrical gap. Determine the absolute viscosity of the liquid in lb · s/ft^2.

(SECTION 1.5)

1.5.1. A line force contains the units of force per unit length. This differs from a surface force (like pressure with units of force per unit area) or a body force (like specific weight with units of force per unit volume). Surface tension is considered a line force. Based on the development of Equation 1.3, explain why it is logical to consider surface tension a line force.

1.5.2. Mercury (SG = 13.6) is used in a glass tube to measure pressure. If the surface tension is 0.57 N/m and the contact angle ranges from 40° to 50°, determine the minimum diameter of the tube so that the measurement error in the manometer does not exceed 1.0 mm.

1.5.3. A capillary rise experiment is proposed for a high school physics class. The students are told that for water in clean glass tubes, the contact angle between liquid and glass (θ) is 90°. The students are asked to measure capillary rise in a series of tube diameters (D = 0.02, 0.04, 0.06, 0.08, and 0.10 in.). They are then asked to graph the results and determine the approximate tube diameters that would produce capillary rises of 1.5, 1.0, and 0.5 in. Predict the results if the water used in the experiment is at 20°C.

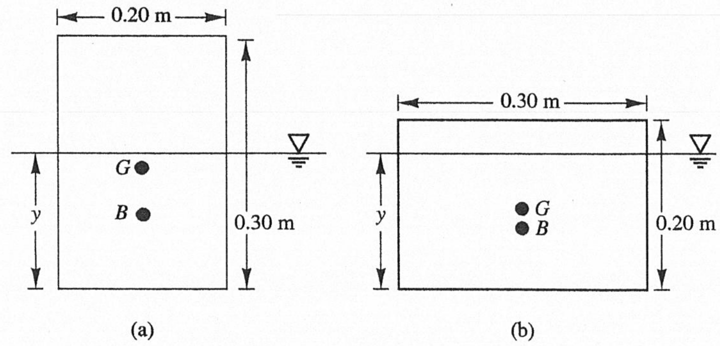

Figure 2.19

For equilibrium, the weight should be equal to the buoyancy force. Then y is determined as $y = 324\ \text{N}/[(0.20\ \text{m})(0.90\ \text{m})(9{,}810\ \text{N/m}^3)] = 0.183\ \text{m}$. Accordingly, the center of buoyancy (point B) is 0.0915 m above the lower edge of the block.

The distance between G and B is then $0.15 - 0.0915\ \text{m} = 0.0585\ \text{m}$. Let point M denote the metacenter. The location of M is unknown. By using Equation 2.17, the distance between M and B is calculated as

$$\overline{MB} = \frac{(0.90\ \text{m})(0.20\ \text{m})^3/12}{(0.90\ \text{m})(0.20\ \text{m})(0.183\ \text{m})} = 0.0182\ \text{m}$$

Then point M is 0.0182 m above point B but $0.0585 - 0.0182\ \text{m} = 0.0403\ \text{m}$ below point G. Since the center of gravity is above the metacenter, the equilibrium is unstable and the block will tilt over due to a disturbance.

(b) In this case, the center of gravity (point G) is 0.10 m above the lower edge of the block. Once again for equilibrium, the weight should be equal to the buoyancy force. Then y is determined as $y = 324\ \text{N}/[(0.30\ \text{m})(0.90\ \text{m})(9{,}810\ \text{N/m}^3)] = 0.122\ \text{m}$. Therefore, the center of buoyancy (point B) is 0.061 m above the lower edge of the block.

Accordingly, point G is $0.10 - 0.061\ \text{m} = 0.039\ \text{m}$ above point B. The distance between M and B is calculated as

$$\overline{MB} = \frac{(0.90\ \text{m})(0.30\ \text{m})^3/12}{(0.90\ \text{m})(0.30\ \text{m})(0.122\ \text{m})} = 0.0615\ \text{m}$$

Then point M is 0.0615 m above point B and $0.0615 - 0.039\ \text{m} = 0.0225\ \text{m}$ above point G. Since the center of gravity is below the metacenter, the equilibrium is stable.

PROBLEMS
(SECTION 2.2)

2.2.1. A cylindrical water tank is suspended as shown in Figure P2.2.1. The tank has a 10-ft diameter and contains 20°C water that weighs 14,700 pounds. Determine the depth of water in the tank and the pressure (in lb/ft^2) on the bottom of the tank by two different methods (using the weight of the water and the depth of the water).

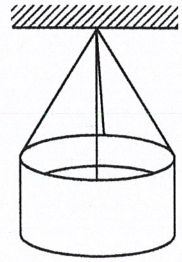

Figure P2.2.1

2.2.2. The collapse (crush) depth of a certain diving bell is an absolute pressure greater of 5 atm. How deep (in meters and feet) can the diving bell go in seawater (S.G. = 1.03) before it is in danger of being crushed?

2.2.3. A simple barometer to measure atmospheric pressure is depicted in Figure P2.2.3. Atmospheric pressure on the water surface in the cup causes the water to rise in the inverted test tube. Determine the magnitude of the atmospheric pressure (in kN/m^2) assuming that there is some vapor pressure (based on the water temperature; 30°C) in the closed end of the test tube but negligible surface tension effects. Also determine the percentage error introduced if the vapor pressure was ignored.

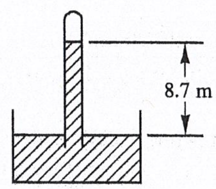

Figure P2.2.3

2.2.4. The gauge pressure at the bottom of a water tank reads 30 mm of mercury (S.G. = 13.6). The tank is open to the atmosphere. Determine the water depth (in cm) above the gauge. Find the equivalency in N/m^2 of absolute pressure at 20°C.

2.2.5. A cube-shaped storage tank, measuring 10 ft in length, width, and height, is filled with water. Determine the force on the tank bottom and sides. *Hint*: The average pressure on the sides of the tank can be determined.

2.2.6. The two containers of water shown in Figure P2.2.6 have the same bottom areas (2 m × 2 m), the same depth of water (10 m), and are both open to the atmosphere. However, the L-shaped container on the right holds less water. Determine hydrostatic *force* (in kN), not the pressure, on the bottom of each container.

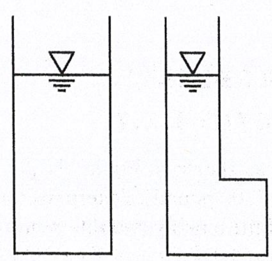

Figure P2.2.6

in the sealed left tank

2.4.12. For the system of manometers shown in Figure P2.4.12, determine the differential reading h.

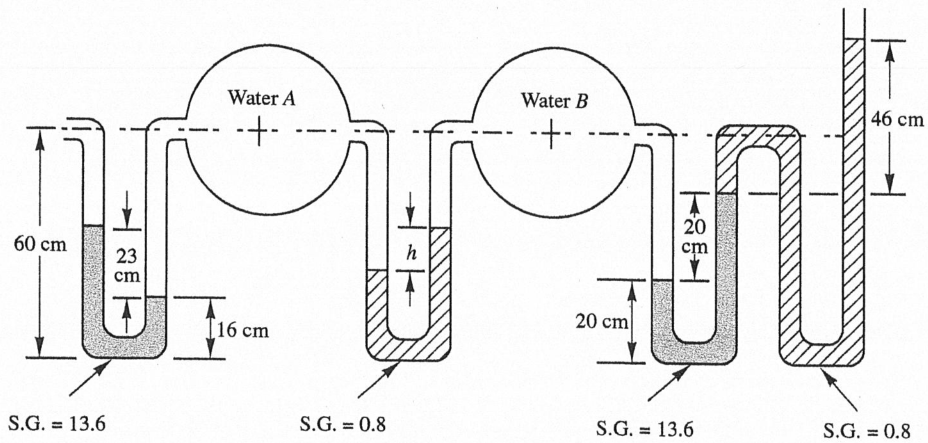

Figure P2.4.12

(SECTION 2.5)

2.5.1. A vertical, semicircular gate (Figure P2.5.1) that is hinged at the top keeps water from flowing in a semicircular channel that has a 2-ft radius (r). Determine the magnitude of the hydrostatic force on the gate and its location when water rises to the full 2-ft depth. Is the center of hydrostatic pressure deeper than the centroid of the gate?

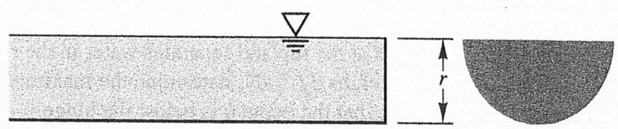

Figure P2.5.1

2.5.2. A concrete dam with a triangular cross section (Figure P2.5.2) is built to hold 9 m of water. Determine the hydrostatic force on a unit length (i.e., 1 m) of the dam and its location. Also, if the specific gravity of concrete is 2.78, determine if the dam is safe. That is, determine the moment generated with respect to the toe of the dam, A. Note that the hydrostatic pressure tends to *overturn* the dam and the weight acts to *stabilize* the dam.

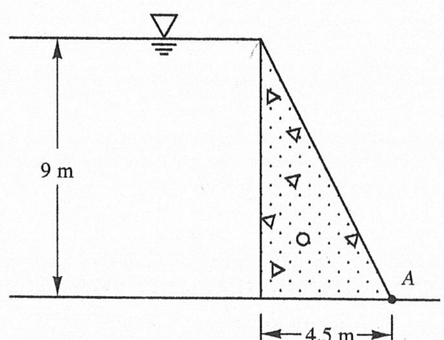

Figure P2.5.2

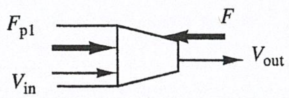

Figure P3.3.4

3.3.5. The force (F) holding a nozzle connection at the end of a 0.6-m-diameter pipe is 63.5 kN. The pipe is connected to a 0.3-m-diameter nozzle. If the flow rate is 1.1 m^3/s in the positive x-direction (Figure P3.3.4), determine the water pressure (F_{P1}) in the pipe just upstream of the nozzle.

3.3.6. Water flowing in a positive x-direction passes through a 90° elbow in a 6-in.-diameter pipeline and heads in a positive y-direction (Figure P3.3.6). If the flow rate is 3.05 ft^3/s, compute the magnitude and direction of the reaction force (F). The pressure upstream of the elbow is 15.1 psi; just downstream it is 14.8 psi.

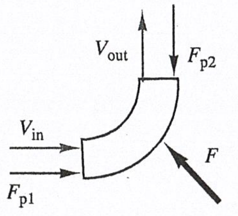

Figure P3.3.6

3.3.7. A 1-m-diameter pipe is carrying 1 m^3/s of water in a positive x-direction and passes through a 90° bend into the positive y-direction (Figure P3.3.6). Entrance and exit pressures in the bend are measured in water column heights of 42 and 41 m. Determine the magnitude and direction of the bend's reaction force (F).

3.3.8. Water flows through a reducing pipe bend and is deflected 30° in the horizontal plane. The velocity is 4 m/s entering the bend (15-cm diameter) with a pressure of 250 kPa. The pressure leaving the bend is 130 kPa (7.5-cm diameter). Determine the anchoring force required to hold the bend in place. (Assume that the water if flowing in a positive x-direction entering the bend and continues in a positive x-direction and a positive y-direction after the bend.)

(SECTION 3.5)

3.5.1. Water at 4°C flows at the rate of 3.5 cms (m^3/s) through a corrugated metal pipe (CMP). If the diameter of the pipe is 2.25 m, determine the friction factor and flow type (i.e., laminar, critical zone, turbulent—transitional zone, turbulent—smooth pipe, or turbulent—rough pipe).

3.5.2. A wrought iron pipe, 1.50 ft in diameter and 100 ft long, carries 12 cfs (ft^3/s) of water at 68°F. Determine the friction factor and the type of flow that exists in the pipeline (i.e., laminar, critical zone, turbulent—transitional zone, turbulent—smooth pipe, or turbulent—rough pipe).

3.5.3. A horizontal, commercial steel pipe, 1.5 m in diameter, carries 3.5 m^3/s of water at 20°C. Calculate the pressure drop in the pipe per kilometer length. Assume that minor losses are negligible.

3.5.4. A 15-in. galvanized iron pipe is installed on a 1/50 slope (uphill) and carries water at 68°F (20°C). What is the pressure drop in the 65-ft-long pipe when the discharge is 18 cfs (ft^3/s)? Assume that minor losses are negligible.

3.5.5. The commercial steel pipeline depicted in Figure P3.5.5 is 200 m long and has a diameter of 0.45 m. Determine the height of the water tower (h) if the flow rate is 0.85 m^3/s. Assume that minor losses are negligible and a water temperature is 4°C.

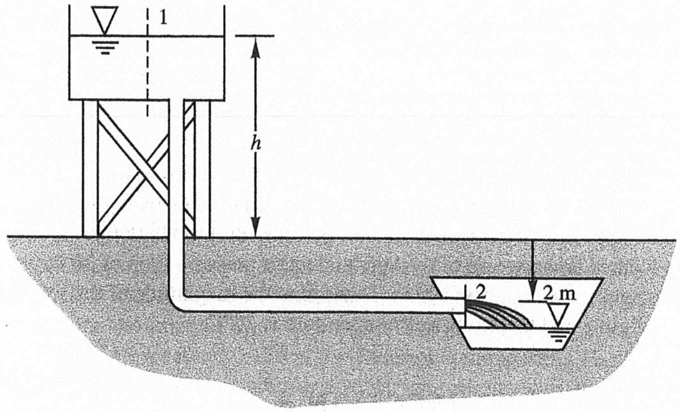

Figure P3.5.5

3.5.6. Determine the flow rate of water (20°C) that will cause a pressure drop of 17,250 N/m^2 in 350 m of horizontal, cast-iron pipe (D = 60 cm). Ignore minor losses.

3.5.7. The pressure heads are measured at two sections in a pipeline and are found to be 8.3 m at point A and 76.7 m at point B. The two sections are 5.5 km apart along a 4.5-m-diameter riveted-steel pipe (best condition). A is 100 m higher than B. If the water temperature is 20°C, what is the flow rate? Minor losses are negligible.

3.5.8. A smooth concrete pipe (1.5-ft diameter) carries water from a reservoir to an industrial treatment plant 1 mile away and discharges it into the air over a holding tank. The pipe leaving the reservoir is 3 ft below the water surface and runs downhill on a 1:100 slope. Determine the flow rate (in cfs, ft^3/s) if the water temperature is 40°F (4°C) and minor losses are negligible.

3.5.9. Two pressure gauges measure a pressure drop of 16.3 psi ($lb/in.^2$) at the entrance and exit of an old buried pipeline. The original drawings have been lost. If the 6-in. galvanized iron pipe carries water at 68°F with a flow rate of 1.64 cfs (ft^3/s), determine the length of the horizontal underground line ignoring minor losses.

3.5.10. Determine the diameter of a 400-m-long wrought iron pipe required to convey water (15°C) at a flow rate of 45 L/s with a head loss not to exceed 9.8 m.

3.5.11. A 2,500-ft long pipeline is required to carry 21.5 cfs (ft^3/s) of water to an industrial client. The limiting pressure drop mandated by the client is 40 psi ($lb/in.^2$). Determine the pipe size required if the material available is polyvinyl chloride (PVC) and the pipeline is level (horizontal). Assume that minor losses are negligible and the water temperature is 68°F.

3.5.12. City officials want to transport 1,800 m^3 of water per day to a water treatment plant from a reservoir 8 km away. The water surface elevation at the reservoir is 6 m above the entrance of the pipe, and the water surface in the receiving tank is 1 m above the exit of the pipe. The pipe will be laid on a 1/500 slope. What is the minimum required diameter of a concrete pipe (good joints) if the water temperature varies between 4°C and 20°C? Assume that minor losses are negligible.

3.5.13. Equation (3.19) defines the mean velocity for laminar flow using the Hagen–Poiseuille law. Equation (3.20) gives the Darcy–Weisbach equation applied to a horizontal uniform pipe. Derive Equation (3.20a) showing all steps in the process.

3.5.14. A cast-iron pipeline was installed 20 years ago with a friction factor (measured) of 0.0195 and a roughness height (e) of 0.26 mm. The horizontal pipeline is 2,000 m long and has a diameter of 30 cm. Significant tuberculation has occurred since it was installed, and field tests are run

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