Released: 05.03.2025
Exercise Class: 12.03.2025
Solutions: 12.03.2025

Problem Set 2: Hydrostatics and the Bernoulli Equation

1 Archimedes

The homogeneous timber AB in Figure 1 has a cross section of $0.15\,m$ by $0.35\,m$. Determine the specific weight of the timber and the tension in the rope.

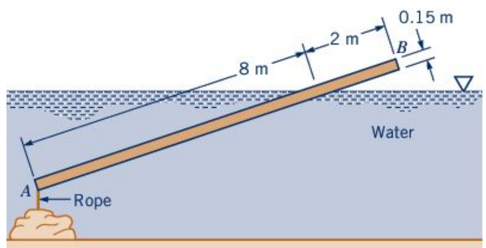

Figure 1: see problem 1

2 Hydrostatic pressure

2.1 Blood pressure

(a) Determine the change in hydrostatic pressure in a giraffe's head as it lowers its head from eating leaves $6\,m$ above the ground to getting a drink of water at ground level (Figure 2). Assume that the absolute pressure in the giraffe's heart does not change, and the specific gravity of blood is $SG = 1$.

(b) Blood pressure is measured by two numbers in units of millimeters of mercury (mmHg): The first number, called *systolic* pressure, measures the blood pressure in the arteries when the heart beats; and the second number, called *diastolic* pressure, measures the pressure in the arteries when the heart rests between beats. What systolic blood pressure is considered high for our hearts? Express the pressure difference calculated in part (a) in units of mmHg, and compare it to a high blood pressure in human's heart.

(See also "Giraffe's blood pressure", Section 2.3.1. in Munson *et al.*)

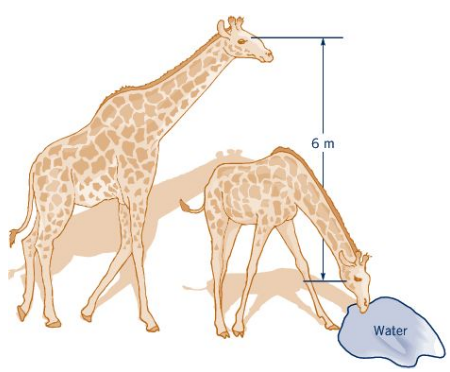

Figure 2: see problem 2.1

2.2 Manometry

(a) A mercury manometer is connected to a large reservoir of water as shown in the left part of Figure 3. Determine the ratio, h_w/h_m, of the heights h_w and h_m indicated in the figure ($SG_m = 13.56$).
(b) Determine the elevation difference, Δh, between the water levels in the two open tanks shown in the right of Figure 3.
(c) Why is the water not flowing from the left to the right tank? How can you change the setup to make the water flow?

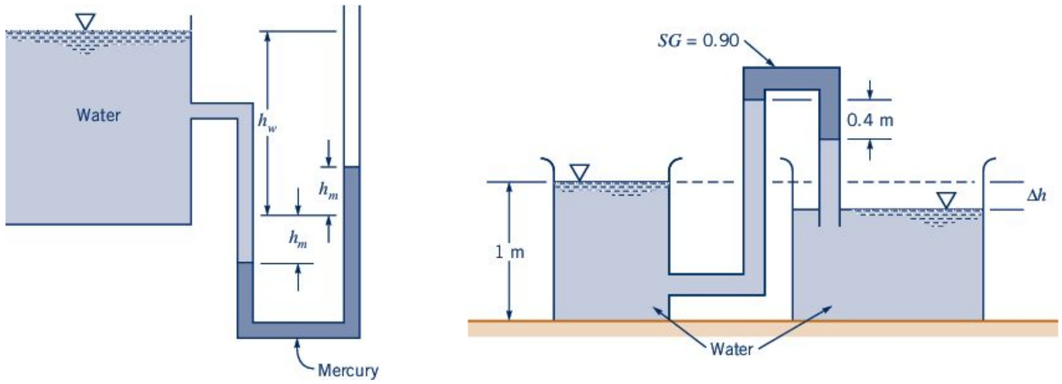

Figure 3: see problem 2.2a (left) and problem 2.2b/c (right)

2.3 Water dam

(a) The concrete dam in Figure 4 weighs $23.6\,kN/m^3$ and rests on a solid foundation. Determine the minimum coefficient of friction between the dam and the foundation required to keep the dam from sliding at the water depth shown. Assume no fluid uplift pressure along the base. Base your analysis on a unit length of the dam.
(b) Determine the horizontal hydrostatic force on the $2309\,m$ long *Three Gorges Dam* when the average depth of the water against it is $175\,m$. (See also "The Three Gorges Dam", Section 2.8. in Munson *et al.*)
(c) If all of the 6.4 billion people on Earth were to push horizontally against the *Three Gorges Dam*, could they generate enough force to hold it in place? Support your answer with appropriate calculations.

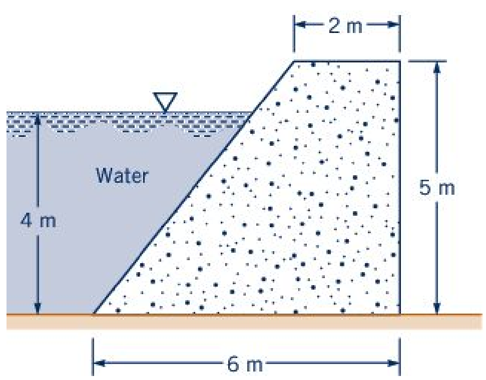

Figure 4: see problem 2.3

3 Water supply

Water flows from the faucet on the first floor of the building shown in Figure 5 with a maximum velocity of $6\,m/s$. For steady inviscid flow, determine the maximum water velocity from the basement faucet and from the faucet on the second floor when all three faucets are open (assume each floor is $3.6\,m$ in height).

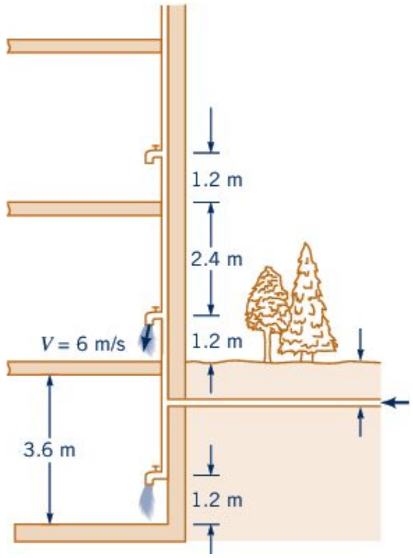

Figure 5: see problem 3

4 Siphon

Water is siphoned from a large tank and discharges into the atmosphere through a $5.08\,cm$ diameter tube as shown in Figure 6. The end of the tube is $0.9\,m$ below the tank bottom, and viscous effects are negligible.
(a) Determine the volume flow rate from the tank.
(b) Determine the maximum height, H, over which the water can be siphoned without cavitation occurring. Atmospheric pressure is $101.3\,kPa$, and the water vapor pressure is $1.8\,kPa$.

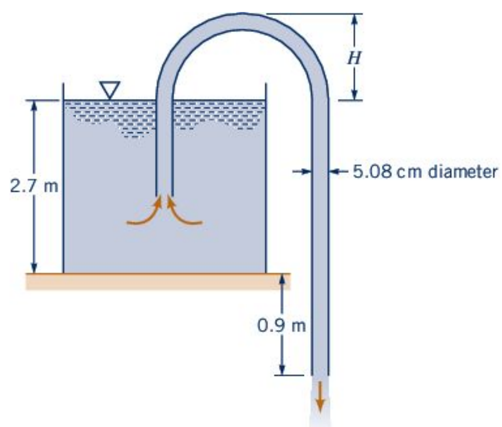

Figure 6: see problem 4

5 Soda bottle

Soda (with the same properties as water) flows from a 10.16 cm diameter soda container that contains three holes as shown in Figure 7. The diameter of each fluid stream is 0.38 cm and the distance between holes is 5.08 cm. If viscous effects are negligible and quasi-steady conditions are assumed, determine the time at which the soda stops draining from the top hole. Assume the soda surface is 5.08 cm above the top hole when $t = 0$. (The final integral can be evaluated numerically.)

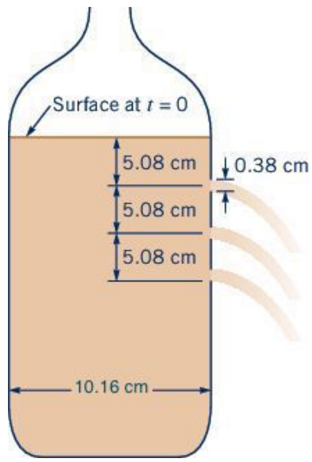

Figure 7: see problem 5

6 Normal to a streamline

Water flows around the vertical two-dimensional bend with circular streamlines and constant velocity as shown in Figure 8. If the gauge pressure is 40 kPa at point (1), determine the pressure at points (2) and (3). Assume that the velocity profile is uniform as indicated.

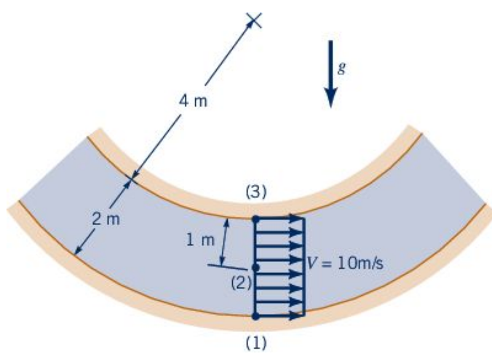

Figure 8: see problem 6

7 Vaporizer

Air flows through the device shown in Figure 9. If the flow rate is large enough, the pressure within the constriction will be low enough to draw the water up into the tube. Determine the flow rate, Q, and the pressure needed at section (1) to draw the water into section (2). Neglect compressibility and viscous effects.

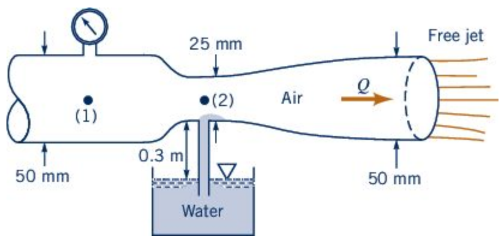

Figure 9: see problem 7

8 Ball in a funnel

Observations show that it is not possible to blow the table tennis ball from the funnel shown in Figure 10a. In fact, the ball can be kept in an inverted funnel, Figure 10b, by blowing through it. The harder one blows through the funnel, the harder the ball is held within the funnel. Explain this phenomenon (no explicit calculation is required).

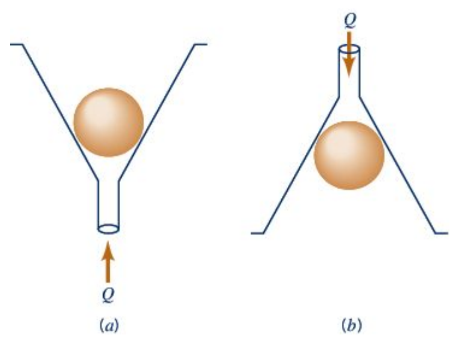

Figure 10: see problem 8