7.5 EXERCISES

Steady flow

Ex 7.5.1. Water flows through a cylindrical pipe of internal diameter 1 cm. (a) If 100 L of water flows per minute, what is the velocity of flow in m/s? (b) What is the mass rate of flow in kg/s?

Ans: (a) 21 m/s; (b) 1.67 kg/s.

Ex 7.5.2. A water supply pipe to a house has an internal diameter of 4 cm. The second floor of the house has water pipe of diameter 2 cm. (a) What is the volume rate of flow? (b) If water flows at the speed of 10 m/s from the pipe at the second floor, what is the speed of flow in the supply line? (c) What does current equal to?

Ans: (a) $3.14 \times 10^{-3}\text{m}^3/\text{s}$, (b) 2.5 m/s, (c) 3.14 kg/s.

Ex 7.5.3. Rate of mass flow per unit area is also called current density J. Find the current density of water flowing through a cylindrical pipe of diameter 5 cm at the rate of 100 L per second.

Ans: $50,900\ \text{kg}/\text{m}^2.\text{s}$.

Bernoulli's equation

Ex 7.5.4. A water tank is drained by a pipe that varies in cross-section, with 5 cm diameter at the tank (point 2) and a diameter of 1 cm at the exit (point 1). Point 2 is 30 cm above point 1. The surface of water in the tank is 50 cm above point 1. (a) Find the speed of flow at point 1. (b) Find volume rate of flow. (c) Find rate of flow at point 2 . (d) Find pressure at point 2.

Ans: (a) 3.13 m/s; (b) 246 cc/s; (c) 12.5 cm/s; (d) P_{atm} + 1,950 Pa.

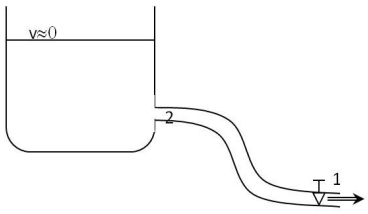


Figure 7.15: Example 7.5.4

Ex 7.5.5. Water is pumped from the ground floor of a high-rise building to a 10th floor apartment 25 meters above. A gauge pressure at the pump reads 400 kPa and the pipe on the 10th floor is open to atmosphere. While the pipe on the ground floor is 5 cm in diameter, that in the apartment is only 2 cm in diameter. Find speeds of flow at (a) the ground floor and (b) the tenth floor.

Ans: (a) 2.85 m/s. (b) 17.8 m/s.

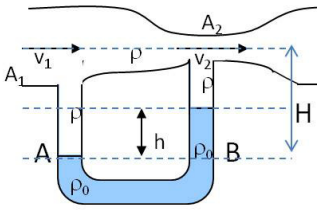
Ex 7.5.6. A large water tank is filled with water to the top, and sealed off at the top so that it is not exposed to the atmospheric pressure. A small orifice is opened at the bottom. Determine the minimum water height in the tank for the water to leak at all.

Ans: 10.34 m.

Ex 7.5.7. On a windy day wind blows on top of a roof at a speed of 110 km/hr. The air under the roof is quiet but can flow freely. If the density of air is 1.3 kg/m^3, what is the lift force per unit m^2 area of the roof.

Ans: 607 N.

Ex 7.5.8. A venturi flow meter is used to measure the flow rate of water by inserting the flow meter in the tube. One side of the Venturi meter has a diameter of 5 cm and the other side has a diameter of 1.5 cm. The Venturi meter is filled with oil of density 1.8 g/cc.



Find the speed of flow of water in the pipe at the 5 cm-diameter place if the oil on the two sides of the venturi manometer has a height difference of 2 cm.

Ans: 58.7 cm/s.

Viscosity

Ex 7.5.9. One liter of blood flows per day through a narrow vein of length 5 cm which has a pressure difference of 0.5 atm across its length. What is the diameter of the vein?

Ans: 224 μm.

Ex 7.5.10. A spherical steel ball of mass 200 grams is dropped in glycerin (glecerol) from rest. After some time, the ball drops with a steady terminal speed. What is the value of the terminal speed? Ignore the force of buoyancy. (Density of the steel is 7.8 g/cc; Viscosity of glycerine 1.49 Pa.s.)

Ans: 3.81 m/s.

Ex 7.5.11. A spherical ball of radius R and density ρ is dropped from rest in a fluid of density ρ_0 and viscosity η. Derive a formula for the time it takes to reach the terminal speed.

Ans Hint: Suppose, we say the terminal speed has reached if the acceleration is below some value ϵg, then the time to reach that state will be $T = -\frac{\ln(\epsilon)}{\gamma}$, where $\gamma = 6\pi\eta R/m$.

Turbulence

Ex 7.5.12. Determine which of the following flows will be turbulent. (a) mercury flowing at $20°C$ through a tube of inner radius 1 cm and length of 1 m carrying 30 liters per hour, (b) water flowing in the same tube at the same volume rate, and (c) olive oil flowing in the same tube at the same volume rate.

Ans: (a) turbulent, (b) & (c) not turbulent.

Ex 7.5.13. Blood flows through an artery of diameter 3 mm. What is the volume rate of flow if Reynolds number of the flow is 400? $\eta_{\text{blood}} = 2.7 \times 10^{-3}$ Pa.s.

Ans: 2.5 ml/s.