

INDIAN INSTITUTE OF TECHNOLOGY KANPUR

ESO 201A: Thermodynamics

(2023-24 I Semester)

Instructor: Dr Avinash Kumar Agarwal

Tutorial 2

Question 1: Consider a U-tube whose arms are open to the atmosphere. Now water is poured into the U-tube from one arm, and light oil ($\rho = 790 \text{ kg/m}^3$) from the other. One arm contains 70-cm-high water, while the other arm contains both fluids with an oil-to-water height ratio of 4. Determine the height of each fluid in that arm.

(Ans: water height = 0.168m, oil height = 0.673m)

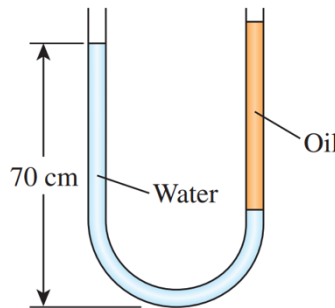


Fig 1

Question 2: It is well-known that the temperature of the atmosphere varies with altitude. In the troposphere, which extends to an altitude of 11 km, for example, the variation of temperature can be approximated by $T = T_0 - \beta z$, where T_0 is the temperature at sea level, which can be taken to be 288.15 K, and $\beta = 0.0065 \text{ K/m}$. The gravitational acceleration also changes with altitude as $g(z) = g_0 \left(1 + \frac{1}{6370320} z\right)^2$ where $g_0 = 9.807 \text{ m/s}^2$ and z is the elevation from sea level in m. Obtain a relation for the variation of pressure in the troposphere (a) by ignoring and (b) by considering the variation of g with altitude.

Ans: (a) $P = P_0 \left(1 - \frac{\beta z}{T_0}\right)^{\frac{g_0}{\beta R}}$

(b) $P = P_0 \exp \left[-\frac{g_0}{R(\beta + kT_0)} \left(\frac{1}{1 + 1/kz} + \frac{1}{1 + kT_0/\beta} \ln \frac{1 + kz}{1 - \beta z/T_0} \right) \right]$

Question 3: A water pump that consumes 2 kW of electric power when operating is claimed to take in water from a lake and pump it to a pool whose free surface is 30 m above the free surface of the lake at a rate of 50 L/s. Determine if this claim is reasonable.

(Ans: Claim is false)

Question 4: The driving force for fluid flow is the pressure difference, and a pump operates by raising the pressure of a fluid (by converting the mechanical shaft work to flow energy). A gasoline pump is measured to consume 3.8 kW of electric power when operating. If the pressure differential between the outlet and inlet of the pump is measured to be 7 kPa and the changes in velocity and elevation are negligible, determine the maximum possible volume flow rate of gasoline.

(Ans: 0.543 m³/s)

Question 5: Two sites are being considered for wind power generation. In the first site, the wind blows steadily at 7 m/s for 3000 hours per year, whereas in the second site the wind blows at 10 m/s for 1500 hours per year. Assuming the wind velocity is negligible at other times for simplicity, determine which is a better site for wind power generation. (Hint: Note that the mass flow rate of air is proportional to wind velocity).

(Ans: Second site is better)

Question 6: Freshwater and seawater flowing in parallel horizontal pipelines are connected to each other by a double U-tube manometer, as shown in Fig. 2. Determine the pressure difference between the two pipelines. Take the density of seawater at that location to be $\rho = 1035 \text{ kg/m}^3$. Can the air column be ignored in the analysis?

(Ans: 3.39 kPa, Air column can be ignored)

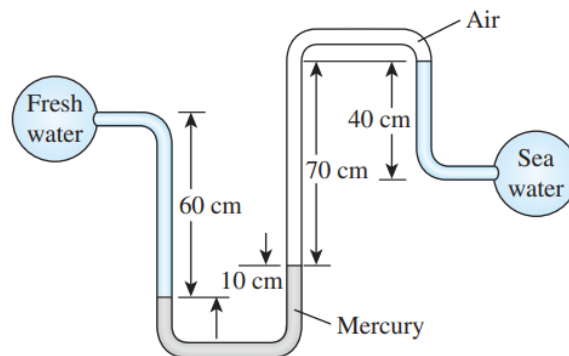


Fig. 2

Question 7: A pressure cooker cooks a lot faster than an ordinary pan by maintaining a higher pressure and temperature inside. The lid of a pressure cooker is well sealed, and steam can escape only through an opening in the middle of the lid. A separate metal piece, the petcock, sits on top of this opening and prevents steam from escaping until the pressure force overcomes the weight of the petcock. The periodic escape of the steam in this manner prevents any potentially dangerous pressure buildup and keeps the pressure inside at a constant value. Determine the mass of the petcock of a pressure cooker whose operation pressure is 100 kPa gage and has an opening cross-sectional area of 4 mm².

Assume an atmospheric pressure of 101 kPa and draw the free-body diagram of the petcock.

(Ans: 40.8 g)

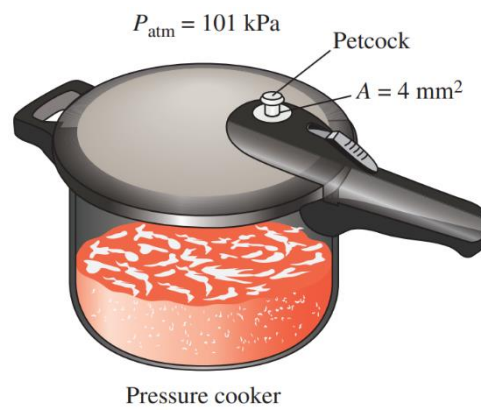


Fig. 3