INDIAN INSTITUTE OF TECHNOLOGY KANPUR

ESO 201A: Thermodynamics

(2023-24 I Semester)

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Practice Problems - Set 2

Question 1: The variation of pressure with density in a thick gas layer is given by $P = C\rho^n$, where C and n are constants. Noting that the pressure change across a differential fluid layer of thickness dz in the vertical z-direction is given as $dP = -\rho g\, dz$, obtain a relation for pressure as a function of elevation z. Take the pressure and density at $z = 0$ to be P_0 and ρ_0, respectively.

(Ans: $P = P_0\left(1 - \frac{n-1}{n}\frac{\rho_0 g z}{P_0}\right)^{n/(n-1)}$ **)**

Question 2: Blood pressure is usually measured by wrapping a closed air-filled jacket equipped with a pressure gage around the upper arm of a person at the level of the heart. Using a mercury manometer and a stethoscope, the systolic pressure (the maximum pressure when the heart is pumping) and the diastolic pressure (the minimum pressure when the heart is resting) are measured in mmHg. The systolic and diastolic pressures of a healthy person are about 120 mmHg and 80 mmHg, respectively, and are indicated as 120/80. Express both of these gage pressures in kPa, psi, and meter water column.

(Ans: 16.0kPa/10.7kPa, 2.32psi/1.55psi, 1.63m/1.09m of water)

Question 3: The 60W fan of a central heating system is to circulate air through the ducts. The analysis of the flow shows that the fan needs to raise the pressure of air by 50 Pa to maintain flow. The fan is located in a horizontal flow section whose diameter is 30 cm at both the inlet and the outlet. Determine the highest possible average flow velocity in the duct.

(Ans: 17.0 m/s)

Question 4: Consider a vertical elevator whose cabin has a total mass of 800 kg when fully loaded and 150 kg when empty. The weight of the elevator cabin is partially balanced by a 400-kg counterweight that is connected to the top of the cabin by cables that pass through a pulley located on top of the elevator well. Neglecting the weight of the cables and assuming the guide rails and the pulleys to be frictionless, determine (a) the power required while the fully loaded cabin is rising at a constant speed of 1.2 m/s and (b) the

power required while the empty cabin is descending at a constant speed of 1.2 m/s. What would your answer be to (a) if no counterweight were used? What would your answer be to (b) if a friction force of 800 N has developed between the cabin and the guide rails?

(Ans: (a) 4.71kW with counterweight; **9.42kW** without counterweight; **(b)2.94kW** friction frictionless pulleys, **3.90kW** if friction is considered)

Question 5: Consider a 1400-kg car cruising at constant speed of 70 km/s. Now the car starts to pass another car, by accelerating to 110 km/h in 5 s. Determine the additional power needed to achieve this acceleration. What would your answer be if the total mass of the car were only 700 kg?

(Ans: 77.8 kW, 38.9 kW)

Question 6: The basic barometer can be used as an altitude measuring device in airplanes. The ground control reports a barometric reading of 753 mmHg while the pilot's reading is 690 mmHg. Estimate the altitude of the plane from ground level if the average air density is 1.20 kg/m^3 .

(Ans: 714 m)

Question 7: (a) Determine the pressure exerted on a diver at 45 m below the free surface of the sea. Assume a barometric pressure of 101 kPa and a specific gravity of 1.03 for seawater. **(b)** Titanic is buried at a depth of about 12500 ft (3800m) under North Atlantic ocean. Estimate the pressure on Titanic Wreck.

(Ans: (a)556 kPa, (b)38485.6 kPa (around 380 atm))
