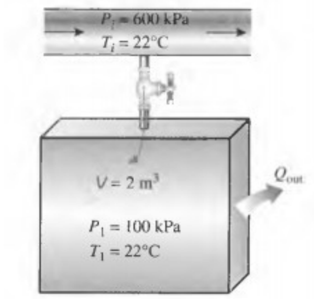
AS1300: Thermodynamics for Aerospace Engineers
Tutorial 4 (13/02/2020)

Note: If not explicitly mentioned, take c_p (air) = 1.018 kJ/kg/K and c_v (air) = 0.718 kJ/kg/K

1. An insulated rigid tank is initially evacuated. A valve is opened, and atmospheric air at 95 kPa and 17 ^oC enters the tank until the pressure in the tank reaches 95 kPa, at which point the valve is closed. Determine the final temperature of the air in the tank. Assume constant specific heats.

2. Consider a 20-L evacuated rigid bottle that is surrounded by the atmosphere at 100 kPa and 27 ^0C. A valve at the neck of the bottle is now opened and the atmospheric air is allowed to flow into the bottle. The air trapped in the bottle eventually reaches thermal equilibrium with the atmosphere as a result of the heat transfer through the wall of the bottle. The valve remains open during the process so that the trapped air also reaches mechanical equilibrium with the atmosphere. Determine the net heat transfer through the wall of the bottle during this filling process.

3. A 2 m^3 rigid tank initially contains air at 100 kPa and 22 ^oC. The tank is connected to a supply line through a valve. Air is flowing in the supply line at 600 kPa and 22 ^0C. The valve is now opened, and air is allowed to enter the tank until the pressure in the tank reaches the line pressure, at which point the valve is closed. A thermometer placed in the tank indicates that the air temperature at the final state is 77 ^oC. Determine (a) the mass of air that has entered the tank and (b) the amount of heat transfer.



4. A balloon initially contains 40 m^3 of He gas at atmospheric conditions of 100 kPa and 17 ^oC. The balloon is connected by a valve to a large reservoir that supplies He gas at 125 kPa and 25 ^oC. Now the valve is opened, and helium is allowed to enter the balloon until pressure equilibrium with the helium at the supply line is reached. The material is such that its volume increases linearly with pressure. If no heat transfer takes place during this process, determine the final temperature in the balloon. c_p (He) = 5.1926 kJ/kg/K and c_v (He) = 3.1156 kJ/kg/K.

5. A rigid insulated pressure cylinder of volume V contains air at pressure p_0 and temperature T_0. It is to be filled from a compressed air line maintained at constant pressure p_1 and temperature T_1. Show the temperature of the air in the cylinder after it has been charged to the pressure of the line is given by :

$$T = \frac{\gamma T_1}{1 + \frac{p_0}{p_1}\left(\gamma \frac{T_1}{T_0} - 1\right)}$$

6. A small reciprocating vacuum pump having the rate of volume displacement V_d is used to evacuate a large rigid vessel of volume V. The air in the vessel is maintained at a constant temperature T by energy transfer as heat. If the initial and final pressures are p_1 and p_2 respectively, find (a) the time taken for the pressure drop and (b) the necessary energy transfer as heat during evacuation. Assume that for air, pV = mRT, where m is the mass and R is a constant, and u is a function of T only.

7. A rigid tank of volume 0.5 m^3 is initially evacuated. A tiny hole develops in the wall, and air from the surroundings at 1 bar and 21 ^{0}C leaks in. Eventually, the pressure in the tank reaches 1 bar. The process occurs slowly enough so that the heat transfer between the tank and the surroundings keeps the temperature of the air inside the tank constant at 21 ^{0}C. Determine the amount of heat transfer.

8. A well-insulated rigid vessel of volume V contains a gas at a pressure P_0 and temperature T_0. Gas from a main suppy line (at T_1 temperature and P_1 pressure) is pumped into the vessel and the inflow rate decreases exponentially with time according to the relation :

$$\mathrm{m} = \mathrm{m}_0 e^{-at}$$

where "a" is a constant, "m" and "m_0" are mass flow rates, "t" is time.
Determine the pressure and temperature of the gas in the vessel as a function of time. Neglect the KE and PE of the gas entering the vessel and assume that the gas follows the relation pV = mRT. Assume constant specific heat capacities.

(i) If the vessel is initially evacuated, show that the temperature inside the vessel is independent of time.
(ii) Determine the charging time when the pressure inside the vessel reaches that of the main supply line.