Middle East Technical University
Department of Chemical Engineering
ChE204 Thermodynamics I (Section 2)
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PROBLEM SET 4

Problems 6, 7 and 8 are homework due March 28

1) An evacuated chamber with perfectly insulated walls is connected to a steam main through which steam at 1 MPa and 200°C is flowing. The valve is opened and steam flows rapidly into the chamber until the pressure in the chamber is 1 MPa. If no heat is lost to the surroundings or transferred back to the main, find the temperature of the steam when the flow stops.

2) Solve the previous problem for a perfectly insulated chamber of 0.1 m^3 volume which initially contains saturated steam at 0.5 MPa.

3) A tiny hole develops in the wall of a rigid tank whose volume is 0.75 m^3, and air from the surroundings at 1 bar, 25°C leaks in. Eventually the pressure in the tank reaches 1 bar. The process occurs slowly enough to let heat transfer between the tank and the surroundings keep the temperature of air inside the tank constant at 25°C. Determine the amount of heat transferred through the walls of the tank,

a. if the tank is initially evacuated.

b. if the tank initially contains air at 0.7 bar, 25°C.

4) An insulated 0.1 m^3-tank holds air initially at 140 kPa, 15°C. An electrical heating coil is inserted in the tank and steadily dissipates 100 W to the air in the tank. A pressure-regulating valve bleeds air from the tank to the atmosphere to maintain the pressure constant in the tank. Determine the temperature in the tank 5 minutes after the initial conditions.

5) A perfectly insulated rigid cylinder containing an ideal gas is initially at a temperature T_1, a pressure P_1. A valve is opened and the gas starts leaking to the atmosphere. For this process show that

$$\frac{T}{T_1} = \left(\frac{m}{m_1}\right)^{\gamma-1} \qquad and \qquad \frac{T}{T_1} = \left(\frac{P}{P_1}\right)^{(\gamma-1)/\gamma}$$

where $\gamma = c_p/c_v$, m_1 is the original amount of mass in the cylinder, m is the mass of gas in the cylinder at any time, T is the temperature of gas in the cylinder at any time and P is the pressure of the gas in the cylinder at any time.

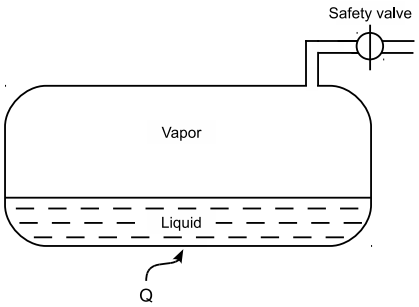
6) The following scheme has been proposed for maintaining a constant temperature in a space capsule that contains electronic equipment. Initially pressurized, the capsule is to be provided with a small but adjustable opening for controlled air leakage. It is contended that the leakage of air will remove the energy added by the dissipation of heat from the electrical equipment, thereby maintaining a constant temperature inside the capsule.

Suppose a capsule with a volume of 0.1 m^3 has an internal heat source of 10.0 Watts. What should be the rate of flow of air from the capsule to maintain the temperature constant at 27°C?

7) The heat capacity of a gaseous mixture of hydrocarbons is required for some process calculations. For this purpose, a sample of the gas is put in a glass flask and is initially at 25.0°C and 910.0 mmHg absolute pressure. A stopcock is then opened momentarily to allow the pressure inside the flask to equalize with that of the atmosphere. Then the stopcock is shut. The flask is next warmed, and when the gas is again at 25.0°C, its pressure is determined to be 780.0 mmHg. Atmospheric pressure is 760.0 mmHg. What is the c_p of the gas mixture in J/mol K?

It may be assumed that the gas mixture is ideal and that the c_p is constant.

8) The 200-L tank shown in the figure initially contains water at 100 kPa and a quality of 1%. Heat is transferred to the water, thereby raising its temperature and pressure. At a pressure of 2 MPa, the safety valve at the top of the tank opens to let saturated vapor at 2 MPa escape from the tank. The process continues, maintaining the pressure inside at 2 MPa until the quality in the tank is 90%, and then stops. Determine the amount of water that remains in the tank and the total heat transferred.



9) At the commercial suppliers of industrial gases, the standard tanks to be recharged are first completely evacuated to remove impurities, then refilled and returned to the customer at 136 bar. What should be the pressure in the large supply tanks to guarantee that we do receive gases at the claimed pressure? Take nitrogen for example.

10) Steam passes through a short hose into a well-insulated barrel of water, at 1 bar, where it condenses, with the following result.

Water in the barrel at the beginning = 180 kg
Water in the barrel at the end = 200 kg
Temperature of water at the beginning = 20°C
Temperature of water at the end = 80°C
Pressure in the steam line = 300 kPa
Heat loss from water during the process including heat needed to warm the barrel = 11500 kJ

Find the condition of the steam in the line (quality and temperature).