30 September 2021

CHE 260 – Thermodynamics and Heat Transfer

Quiz 1 – 2021

You have 60 minutes to do the following three problems. You may use the aid sheet provided and any type of non-communicating calculator.

1) An insulated cylinder is divided into two parts with volume 1 m^3 each by an initially locked piston, as shown in Fig. 1. Side *A* has air at 200 kPa, 300 K, and side *B* has air at 1.0 MPa, 1000 K. The piston is now unlocked so that it is free to move, and it conducts heat so that the air comes to a uniform temperature $T_A = T_B$. Find the mass of air in both *A* and *B* and the final temperature and pressure in the cylinder.

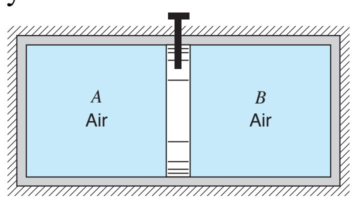

Figure 1 (30 Marks)

2) A 10-m-high cylinder, with a cross-sectional area of 0.1 m^2, has a massless piston at the bottom with water at 20°C on top of it, as shown in Fig. 2. Air under the piston, initially at 300 K with a volume of 0.3 m^3, is heated so that the piston moves up, spilling the water out over the side. Find the total heat transfer to the air when all the water has been pushed out. Assume atmospheric pressure P_0=101.3 kPa, the density of water is 1000 kg/m^3, and acceleration due to gravity g=9.81 m/s^2.

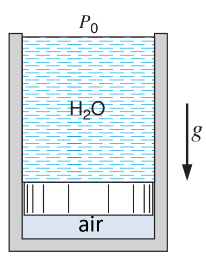

Figure 2 (35 Marks)

3) An air compressor takes in air at 100 kPa, 17°C, (state 1 in Fig. 3) and delivers it at 1 MPa, 600 K (state 2) to a constant-pressure cooler, which the air exits at 300 K (state 3). Find the work supplied to the compressor and the heat transfer in the cooler per unit mass of air flowing through the system.

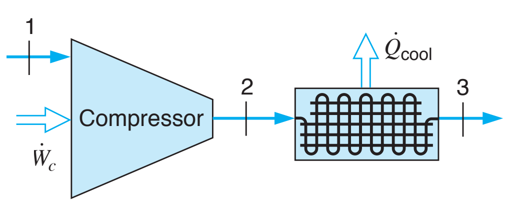

Figure 3 (35 Marks)

Ideal gas equation

$PV = NR_uT$ $\quad$ R_u =8.314 kJ/kmol K

$PV = mRT$ $\quad$ $R=R_u/M$

Boundary Work

$$W_{12} = -\int_{V_1}^{V_2} P\,dV$$

For a constant pressure process

$W_{12} = P_1(V_1 - V_2) = P_1V_1 - P_2V_2$

For a polytropic process $PV^n = C$

$$W_{12} = P_1V_1 \ln\frac{V_1}{V_2} = P_2V_2 \ln\frac{V_1}{V_2} \quad \text{for } n=1$$

$$W_{12} = \frac{P_2V_2 - P_1V_1}{n-1} \quad \text{for } n \neq 1$$

Flow work per unit mass of fluid

$w_{\text{flow}} = Pv$

Spring Work

$$W_{\text{spring}} = \int_{x_1}^{x_2} F dx = \int_{x_1}^{x_2} Kx dx = \frac{1}{2}K(x_2^2 - x_1^2)$$

First law $Q + W = \Delta E$

Enthalpy $h = u + Pv$

Specific heats

$$c_v(T) \equiv \left(\frac{\partial u}{\partial T}\right)_v \text{ and } c_p(T) \equiv \left(\frac{\partial h}{\partial T}\right)_P$$

For an ideal gas

$c_p = c_v + R$

$\Delta u = u_2 - u_1 = c_{v,avg}(T_2 - T_1)$

$\Delta h = h_2 - h_1 = c_{p,avg}(T_2 - T_1)$

Specific heat ratio $\gamma = \dfrac{c_p}{c_v} = \dfrac{\overline{c_p}}{\overline{c_v}}$

For a liquid or solid

$$\Delta h = h_2 - h_1 = c(T_2 - T_1) + v(P_2 - P_1)$$

For a control volume

$$\dot{m} = \frac{AV}{v}$$

$$\dot{Q} + \dot{W} = \dot{m}\left[(h_2 - h_1) + \frac{V_2^2 - V_1^2}{2} + g(z_2 - z_1)\right]$$

Formula	Molar Mass (M kg/kmol)
H_2	2.016
O_2	31.999
H_2O	18.015
NH_3	17.031
N_2	28.013
C	12.01
CO_2	44.01
CH_4	16.043
He	4.0026

Gas	R (kJ/kgK)	c_p (kJ/kg K)	c_v (kJ/kg K)
He	2.07703	5.1926	3.1156
Ar	0.20813	0.5203	0.3122
H_2	4.12418	14.2091	10.0849
CO	0.29683	1.0413	0.7445
N_2	0.29680	1.0416	0.7448
O_2	0.25983	0.9216	0.6618
H_2O	0.46152	1.8723	1.4108
CO_2	0.18892	0.8418	0.6529
NH_3	0.48819	2.1300	1.6418
Air	0.2870	1.0035	0.7165