1 October 2018

CHE 260 – Thermodynamics and Heat Transfer

Quiz 1 – 2018

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) Air at 200 kPa, 30°C is contained in a cylinder-piston arrangement (see Fig. 1) with initial volume 0.1 m^3. The air pressure in the cylinder balances the ambient atmospheric pressure P_0=100 kPa plus a spring force that is proportional to $V^{0.5}$, where V is the air volume in the cylinder. Heat is transferred to the system until the air pressure reaches 225 kPa. Find the final air temperature and the work done during the process.

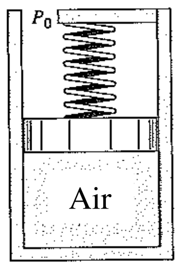

Figure 1 (35 Marks)

2) An insulated cylinder is divided into two parts of 1 m^3 each by an initially locked piston, as shown in Fig. 2. 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 at equilibrium T_A=T_B. Find the mass of air in both A and B and the equilibrium pressure and temperature in the system.

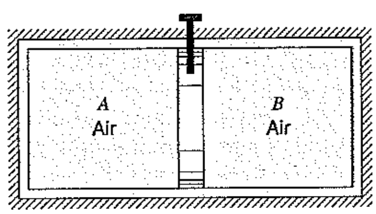

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Figure 2 (35 Marks)

3) The compressor of a large gas turbine receives air from the atmosphere at 95 kPa, 20°C, with a low velocity. At the compressor discharge, air exits at 1.52 MPa, 430°C, with a velocity of 90 m/s. The power input to the compressor is 5000 kW. Determine the mass flow rate of air through the turbine.

(30 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