30 September 2019

CHE 260 – Thermodynamics and Heat Transfer

Quiz 1 – 2019

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 is contained in a piston-cylinder device at 600 kPa and 927°C and occupies a volume of 0.8 m^3 (state 1). The air undergoes an isothermal process until the pressure is reduced to 300 kPa (state 2). The piston is now fixed in place so that it cannot move, and heat transfer takes place until the air temperature reaches 27°C (state 3).

    a. Sketch the process on a *P-V* diagram

    b. Determine the net amount of heat transfer for the combined process (1→3).

(30 Marks)

2) A frictionless piston-cylinder device contains 0.15 kg of air initially at P_1=2 MPa, T_1=350°C. The air is first expanded isothermally to P_2=500 kPa and then compressed in a polytropic process for which $PV^{1.2}$= constant to the initial pressure. It is then compressed at constant pressure to the initial state. Draw this cycle on a *P-V* diagram. Determine (*a*) the boundary work for each process and (*b*) the net work done during this cycle.

(35 Marks)

3) Argon gas enters an adiabatic turbine steadily at 1600 kPa and 450°C with a velocity of 55 m/s and leaves at 150 kPa with a velocity of 150 m/s. The inlet area of the turbine is 60 cm^2. If the power output of the turbine is 190 kW, determine the exit temperature of the argon.

(35 Marks)

Ideal gas equation

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

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

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	$\boldsymbol{R}$ (kJ/kgK)	$\boldsymbol{c_p}$ (kJ/kg K)	$\boldsymbol{c_v}$ (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