2 October 2023

CHE 260 – Thermodynamics and Heat Transfer

Quiz 1 – 2023

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) A piston–cylinder device contains helium gas initially at 100 kPa, 10°C, and with a volume of 0.2 m^3. The helium is now compressed in a polytropic process (PV^n= constant) to 700 kPa and 290°C. Determine the heat loss or gain during this process.

(30 Marks)

2) Air is contained in a piston-cylinder device equipped with a paddle wheel. Initially, the air is at 400 kPa and 17°C. The paddle wheel is now turned by an external electric motor until 75 kJ/kg of work has been transferred to the air. During this process, heat is transferred to the air in the cylinder to maintain a constant air temperature while allowing the gas volume to triple. Calculate the required amount of heat transfer, in kJ/kg of air.

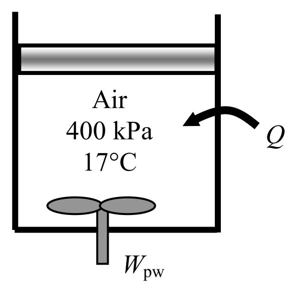

Figure 1

(35 Marks)

3) An adiabatic gas turbine expands air at 1300 kPa and 800 K to 100 kPa and 400 K. Air enters the turbine through a 0.2 m^2 opening with an average velocity of 40 m/s, and exhausts through a 1 m^2 opening. Determine (*a*) the mass flow rate of air through the turbine and (*b*) the power produced by the turbine. Neglect potential energy changes but do not neglect kinetic energy changes.

(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

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

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

	Air		
Temp (K)	c_p (kJ/kgK)	c_v (kJ/kgK)	$\gamma=c_p/c_v$
250	1.003	0.716	1.401
300	1.005	0.718	1.400
350	1.008	0.721	1.398
400	1.013	0.726	1.395
450	1.020	0.733	1.391
500	1.029	0.742	1.387
550	1.040	0.753	1.381
600	1.051	0.764	1.376
650	1.063	0.776	1.370
700	1.075	0.788	1.364
750	1.087	0.800	1.359
800	1.099	0.812	1.354
900	1.121	0.834	1.344
1000	1.142	0.855	1.336

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