Tutorial Sheet-4

First Law Applied to Flow Process

1. Air (1100 K/101.32 kPa) is passing through a converging nozzle and leaves it at 300 K. Determine the velocity of air at the nozzle outlet. The Nozzle is laid horizontal. The inlet velocity of the air can be ignored. $C_{P\ air}$ = 1 kJ/kg K. **[Ans. V_2 = 1265 m/s]**

2. An air compressor compresses air from 100 kPa to 700 kPa whereupon the internal energy of air is increased by 90 kJ/kg. The jacket cooling water extracts 100 kW of heat developed due to the compression.

   Determine:

   (i) The rate of the shaft work input to the compressor.

   (i)) the ratio of the inlet to outlet pipe diameter.

   Take air flow rate = 18.000 kg/h

   Air velocity at inlet = 7 m/s and at outlet = 5 m/s

   Specific volume of air at inlet = 0.95 m^3/kg and at outlet = 0.19 m^3/kg. **[Ans. 739.4, 1.89]**

3. Air (288 K/100 KPa) enters the diffuser blades of a jet engine with a velocity of 200 m/s. Determine

   (i) mass flow rate of air.

   (ii) temp. of the diffuser-exit air.

   Given: Diffuser inlet air = 0.4 m^2, Ignore the exit velocity of air w.r.t. its velocity at the diffuser inlet. **[Ans. 96.7866 kg/s, 307.9 K]**

4. An air compressor compresses 3600 kg/h of air from 1 bar to 8 bar. Neglecting the PE, Determine

   (i) the power input.

   (ii) the pipe cross-section at the entry and exit of the compressor.

   [Ans. 155 kW, 0.1583 m^2, 0.02 m^2]

5. Consider steady flow of air (C_P = 1.005 kJ/kg K) in an adiabatic passage. Air enters the passage at 100 kPa. 500 K at velocity of 150 m/s and exit the passage at 510 K. Assume air to be ideal gas and neglect potential energy changes, find the velocity at the exit and identify the device whether is nozzle or diffuser.

   [Ans. 49 m/s , Diffuser]

6. A completely evacuated rigid tank fully insulated is filled with 10 kg of air passing through a charging line maintained at a pressure of 1000 kPa and enthalpy of 400 kJ/kg. Final equilibrium state in the tank is 1000 kPa. Enthalpy of 600 kJ/kg and sp. volume of 0.17 m^3/kg. The air in the vessel is heated by a heating coil. Find the heat transfer in kJ. **[Ans. 300 kJ]**

7. An ideal gas at 20 bar and 40°C is contained in a small cylinder having a volume of 15 cm^3. This cylinder is placed in a large container having a volume of 1500 cm^3. The large container is perfectly evacuated and insulated. By an appropriate means, the gas is allowed to discharge and fill the large container. Find the final pressure after entire assembly reaches equilibrium**.**

[Ans. 0.2 bar]

8. An insulated rigid pressure vessel is divided into two portions by a movable partition. If one part of the vessel is occupied by an ideal gas at a pressure (P_1), Volume (V_1) and Temperature (T_1). The other part is occupied by same ideal gas at pressure (P_2), volume (V_2) and temperature (T_2). The partition is removed and two partitions mixed adiabatically. Show that the final pressure (P_3) and final temp. (T_3) are given by:

$$P_3 = \frac{P_1V_1+P_2V_2}{V_1+V_2}$$

$$T_3 = \frac{P_1V_1+P_2V_2}{\frac{P_1V_1}{T_1}+\frac{P_2V_2}{T_2}}$$

9. Air at a temperature of 20°C passes through a heat exchanger at a velocity of 40 m/s where its temperature is raised to 820°C. It then enters a turbine with same velocity of 40 m/s and expands till the temperature falls to 620°C. On leaving the turbine, the air is taken at a velocity of 55 m/s to a nozzle where it expands until the temperature has fallen to 510°C. If the air flow rate is 2.5 kg/s. Calculate:

(i) Rate of heat transfer to the air is in the heat exchanger.

(ii) The power output from the turbine assuming no heat loss.

(iii) The velocity at exit from the nozzle, assuming no heat loss.

Take the enthalpy of air as $h = C_Pt$, where C_P is the specific heat equal to 1.005 kJ/kg°C and t is the temperature. **[Ans. 2010 kJ/s, 504.3 kW 473.4 m/s]**

10. Two streams of air, one at 1 bar, 27°C and velocity of 30 m/s and the other at 5 bar, 227°C and 50 m/s velocity, mix in equal proportion in a chamber from which heat at the rate of 100 kJ/kg is removed. The mixture is then passed through an adiabatic nozzle. Find the velocity of the stream issuing out of the nozzle. The temperature of air leaving the nozzle is 27°C and its C_P = 1.005 kJ/kg K. **[Ans. 51.96 m/s]**

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