**Department of Mechanical & Automation Engineering**
**Maharaja Agrasen Institute of Technology , Delhi**
**Tutorial Sheet 2011-2012**

ETME 205 | Thermal Science | Sheet No. 3

**I Law of Thermodynamics for Open System** | **due: Aug.26, 2011**

1. Air enters a nozzle steadily at 2.21 kg/m$^3$ and 40 m/s and leaves at 0.762 kg/m$^3$ and 180 m/s. If the inlet area of the nozzle is 90 cm$^2$, determine (*a*) the mass flow rate through the nozzle, and (*b*) the exit area of the nozzle. [0.796 kg/s, 58 cm$^2$]

2. A 1-m$^3$ rigid tank initially contains air whose density is 1.18 kg/m$^3$. The tank is connected to a high-pressure supply line through a valve. The valve is opened, and air is allowed to enter the tank until the density in the tank rises to 7.20 kg/m$^3$. Determine the mass of air that has entered the tank. [6.02 kg]

3. A desktop computer is to be cooled by a fan whose flow rate is 0.34 m$^3$/min. Determine the mass flow rate of air through the fan at an elevation of 3400 m where the air density is 0.7 kg/m$^3$. Also, if the average velocity of air is not to exceed 110 m/min, determine the diameter of the casing of the fan. [0.238 kg/min, 0.063 m]

4. Air enters an adiabatic nozzle steadily at 300 kPa, 200°C, and 30 m/s and leaves at 100 kPa and 180 m/s. The inlet area of the nozzle is 80 cm$^2$. Determine (a) the mass flow rate through the nozzle, (*b*) the exit temperature of the air, and (*c*) the exit area of the nozzle. [0.5304 kg/s, 184.6°C, 38.7 cm$^2$ ]

5. Nitrogen gas at 60 kPa and 7°C enters an adiabatic diffuser steadily with a velocity of 200 m/s and leaves at 85 kPa and 22°C. Determine (*a*) the exit velocity of the nitrogen and (*b*) the ratio of the inlet to exit area *A*1/*A*2.

6. Helium is to be compressed from 120 kPa and 310 K to 700 kPa and 430 K. A heat loss of 20 kJ/kg occurs during the compression process. Neglecting kinetic energy changes, determine the power input required for a mass flow rate of 90 kg/min.

7. Argon gas enters an adiabatic turbine steadily at 900 kPa and 450°C with a velocity of 80 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 250 kW, determine the exit temperature of the argon.

8. A hot-water stream at 80°C enters a mixing chamber with a mass flow rate of 0.5 kg/s where it is mixed with a stream of cold water at 20°C. If it is desired that the mixture leave the chamber at 42°C, determine the mass flow rate of the cold-water stream. Assume all the streams are at a pressure of 250 kPa. [ 0.865 kg/s]

9. A vertical piston–cylinder device initially contains 0.25 m$^3$ of air at 600 kPa and 300°C. A valve connected to the cylinder is now opened, and air is allowed to escape until three-quarters of the mass leave the cylinder at which point the volume is 0.05 m$^3$. Determine the final temperature in the cylinder and the boundary work during this process.

10. The turbocharger of an internal combustion engine consists of a turbine and a compressor. Hot exhaust gases flow through the turbine to produce work and the work output from the turbine is used as the work input to the compressor. The pressure of ambient air is increased as it flows through the compressor before it enters the engine cylinders. Thus, the purpose of a turbocharger is to increase the pressure of air so that more air gets into the cylinder. Consequently, more fuel can be burned and more power can be produced by the engine.

    In a turbocharger, exhaust gases enter the turbine at 400°C and 120 kPa at a rate of 0.02 kg/s and leave at 350°C. Air enters the compressor at 50°C and 100 kPa and leaves at 130 kPa at a rate of 0.018 kg/s. The compressor increases the air pressure with a side effect: It also increases the air temperature, which increases the possibility of a petrol engine to experience an engine knock. To avoid this, an after-cooler is placed after the compressor to cool the warm air by cold ambient air before it enters the engine cylinders. It is estimated that the after-cooler must decrease the air temperature below 80°C if knock is to be avoided. The cold ambient air enters the after-cooler at 30°C and leaves at 40°C. Disregarding any frictional losses in the turbine and the compressor and treating the exhaust gases as air, determine (*a*) the temperature of the air at the compressor outlet and (*b*) the minimum volume flow rate of ambient air required to avoid knock.