# TUTORIAL-3 (12 Feb 2019)
# Thermodynamics for Aerospace Engineers (AS1300)

1. Air flows at the rate of 0.5 kg/s through an air compressor, entering at 10 m/s velocity, 100 kPa and 1.0 $m^3$/kg volume, and leaving at 8 m/s, 700kPa, and 0.20 $m^3$/kg. The internal energy of the air leaving is 100 kJ/kg greater than that of the air entering. Assume that there is no significant height difference between the inlet at outlet. Cooling water in the compressor jacket absorbs heat from the air at the rate of 58kW. (a) Compute the rate of shaft work input to the air in kW. (b) Find the ratio of the inlet pipe diameter to outlet pipe diameter.

2. In a steam power station, steam flows steadily through a 0.2m diameter pipeline from the boiler to the turbine. After the boiler, the steam conditions are found to be: P=4MPa, T=400deg C, h=3313.6 kJ/kg, and v=0.073 $m^3$/kg. At the turbine inlet, the conditions are found to be: P=3.5 MPa, T= 392 deg C, h=3302.6 kJ/kg, and v=0.084 $m^3$/kg. There is a heat loss of 8.5 kJ/kg from the pipeline. Assume that the pipeline is horizontal. Calculate the steam flow rate.

3. An aircraft with a turbojet engine is in flight with a velocity of 270m/s. Ambient air temperature is -15 deg C. Gas temperature at the outlet of the engine is 600 deg C. Corresponding enthalpy values of air and gas are respectively 260 and 950 kJ/kg. Fuel-air-ratio is 0.02. Chemical energy of the fuel can be assumed to be 45 MJ/kg of fuel. Owing to incomplete combustion only 95% of the heat is released in the engine. Heat loss from the engine is 12 kJ/kg of air. Calculate the exhaust jet velocity.

4. A turbine operates under steady flow conditions, receiving steam at the following state: P=1.2 MPa, T=188 deg C, h=2785 kJ/kg, velocity $u_1$=33.3 m/s and elevation 3m. The steam leaves the turbine at the following state: P=20kPa, h=2512 kJ/kg, $u_2$=100 m/s, and elevation 0m. Heat is lost to the surroundings at the rate of 0.29 kJ/s. If the rate of steam flow through the turbine is 0.42 kg/s, what is the power output of the turbine in kW?

5. A room has two fans each consuming 180W power, and three 100 W lamps. Ventilation air at the rate of 80 kg/h enters with an enthalpy of 84kJ/kg and leaves with an enthalpy of 59kJ/kg. If each person puts out heat at the rate of 630 kg/h, determine the rate at which heat is to be removed by a room cooler, so that a steady state is maintained in the room.

6. A reciprocating air compressor takes in 2m3/min air at 0.11 MPa, 20 deg C, which it delivers at 1.5 MPa, 111 deg C, to an aftercooler where the air is cooled at constant pressure to 25 deg C. The power absorbed by the compressor is 4.15kW. Determine the heat transfer in (a) the compressor, and (b) the cooler. State the assumptions used.

**************************

Tutorial question to be solves by TMM in class.

1. A tank containing 45kg of water initially at 45 deg C, has one inlet and one outlet with equal mass flow rates. Liquid water enters at 45 deg C and a mass flow rate of 270 kg/h. A cooling coil immersed in the water removes energy at a rate of 7.6 kW. The water is well mixed by a paddle wheel with a power input of 0.6 kW. The pressures at the inlet and exit are equal. Ignore the changes in KE and PE. Find the variation of water temperature with time.

2. Air flows steadily at the rate of 0.4 kg/s through an air compressor, entering at 6 m/s with a pressure of 1 bar and a specific volume of 0.85 m3/kg, and leaving at 4.5 m/s with a pressure of 6.9 bar and specific volume of 0.16 m3/kg. The internal energy of the air leaving is 88 kJ/kg greater than that of air entering. Cooling water in a jacket, surrounding the cyllinder absorbs heat from the air at the rate of 59W. Calculate the power required to drive the compressor and the inlet and outlet cross section areas.