**Department of Mechanical Engineering**

**Thermodynamics (ESC209)**

**Tutorial Sheet I**

1. A spherical balloon of 1m diameter contains a gas at 200 kPa and 300 K. The gas inside balloon is heated until the pressure reaches 500 kPa. During the process of heating the pressure is proportional to the diameter of balloon. Determine the work done by the gas inside the balloon.
2. A piston–cylinder device contains 0.05 m3 of a gas initially at 200 kPa. At this state, a linear spring that has a spring constant of 150 kN/m is touching the piston but exerting no force on it. Now heat is transferred to the gas, causing the piston to rise and to compress the spring until the volume inside the cylinder doubles. If the cross-sectional area of the piston is 0.25 m2, determine (*a*) the final pressure inside the cylinder, (*b*) the total work done by the gas, and (*c*) the fraction of this work done against the spring to compress it.
3. One kg of air at 1 bar and 300 K is compressed adiabatically till its pressure becomes 5 times the original pressure. Then it is expanded at constant pressure and finally cooled at constant volume to return to its original state. Calculate heat transfer, work transfer and change in internal energy for each process and for the cycle.
4. Air at 100 kPa and 280 K is compressed steadily to 600 kPa and 400 K. The mass flow rate of the air is 0.02 kg/s, and a heat loss of 16 kJ/kg occurs during the process. Assuming the changes in kinetic and potential energies are negligible, determine the necessary power input to the compressor.
5. Air at 288 K passes through a heat exchanger at a velocity of 30 m/s where its temperature is raised to 1073 K. It then enters a turbine with the same velocity of 30 m/s and expands until the temperature falls to 923 K. On leaving the turbine, air is taken at a velocity of 60 m/s to a nozzle where it expands until the temperature has fallen to 773 K. Calculate for the air flow rate of 2 kg/s- (a) the rate of heat transfer to the air in the heat exchanger (b) the power output from the turbine assuming no heat loss and (c) the velocity at exit from the nozzle assuming no heat loss.
6. An insulated rigid tank is initially evacuated. A valve is opened, and atmospheric air at 95 kPa and 17°C enters the tank until the pressure in the tank reaches 95 kPa, at which point the valve is closed. Determine the final temperature of the air in the tank. Assume constant specific heats.

**Tutorial Sheet II**

1. During some integral number of complete cycles a reversible heat engine absorbs 2800 kJ from a heat reservoir at 1000 K and performs 800 kJ of mechanical work. The engine exchanges heat with two other heat reservoirs one of which is 5400 K and the other at 600 K. Determine the heat exchanged (whether absorbed or rejected) with these two reservoir, the change in entropy of each of the three reservoirs and the change in the entropy of the universe. Draw a neat sketch of the system.
2. A perfect gas of molecular weight 29.79 occupies a volume of at 8 bar and. The gas is allowed to expand against a piston in the cylinder till 1 bar in the following manners: (a) Hyperbolically (b) Adiabatically (c) Polytropically 

What will be the amount of heat transfer and change in entropy during expansion? Represent the above process on P-V and T-S planes.

1. Consider steady heat transfer through a 5-m 7-m brick wall of a house ofthickness 30 cm. On a day when the temperature of the outdoors is 0\_C, the house is maintained at 27\_C. The temperatures of the inner and outer surfaces of the brick wall are measured to be 20\_C and 5\_C, respectively, and the rate of heat transfer through the wall is 1035 W. Determine the rate of entropy generation in the wall, and the rate of total entropy generation associated with this heat transfer process.
2. A 50-kg block of iron casting at 500 K is thrown into a large lake that is at a temperature of 285 K. The iron block eventually reaches thermal equilibrium with the lake water. Assuming an average specific heat of 0.45 kJ/kg · K for the iron, determine (*a*) the entropy change of the iron block, (*b*) the entropy change of the lake water, and (*c*) the entropy generated during this process.
3. An inventor claims to have designed an engine which receives 2.5 kJ of heat and produces 0.625 kJ of work between source at 333 K and sink at 263 K. Is this claim valid?
4. A 500-kg iron block is initially at 200°C and is allowed to cool to 27°C by transferring heat to the surrounding air at 27°C. Determine the reversible work and the irreversibility for this process.

**Tutorial Sheet III**

1. A cylinder contains one kg of water and steam at a pressure of 4 bar and 0.4 dry. Heat is supplied at constant volume until the pressure reaches to 10 bar. The steam is then expanded according to the law PV= constant, until the pressure is 2 bar. Calculate (i) heat transfer during constant volume heating, (ii) heat transfer during PV= constant and (iii) temperature of steam after the expansion.
2. A vessel of volume contains a mixture of saturated water and saturated steam at a temperature of . The mass of the liquid present is 9 kg. Find the pressure, mass, specific volume, enthalpy, entropy and internal energy.
3. What are the Gibbs function and Helmholtz function? Derive Maxwell relations.
4. Derive the Clapeyron and Clausius-Clapeyron equations and explain the physical significance of these equations.
5. Steam at 20 bar; is expanded in a steam turbine to 0.08 bar. It then enters a condenser, where it is condensed to saturated liquid water. The pump feeds back the water into the boiler. (a) Assuming ideal processes, find per kg of steam the net work and the cycle efficiency. (b) if the turbine and the pump have each 80% efficiency, find the percentage reduction in the net work and cycle efficiency.
6. A cyclic steam power plant is to be designed for a steam temperature at turbine inlet ofand an exhaust pressure of 0.08 bar. After isentropic expansion of steam in the turbine, the moisture content at the turbine exhaust is not to exceed 15%. Determine the greatest allowable steam pressure at the turbine inlet and calculate the Rankine cycle efficiency for these steam conditions. Estimate also the mean temperature of heat addition.

A steam power station uses the following cycle:

**Tutorial Sheet IV**

1. With the help of p-v and T-s diagram, compare the efficiency of Otto, Diesel and Dual cycle on the basis of (a) same compression ratio and (b) same maximum pressure & temperature.
2. A Diesel cycle has compression ratio 14 and heat supply up to 5% of the stroke; calculate the air-standard efficiency of the cycle. If the compression ratio is increased from 14 to 19 and the cut-off is adjusted to give the same air standard efficiency obtained above, find the required change in the cut-off.
3. An insulated rigid tank is divided into two compartments by a partition. One compartment contains 7 kg of oxygen gas at 40°C and 100 kPa, and the other compartment contains 4 kg of nitrogen gas at 20°C and 150 kPa. Now the partition is removed, and the two gases are allowed to mix. Determine (*a*) the mixture temperature and (*b*) the mixture pressure after equilibrium has been established.
4. Consider a room that contains air at 1 atm, 35°C, and 40 percent relative humidity. Using the psychrometric chart, determine (*a*) the specific humidity, (*b*) the enthalpy, (*c*) the wet-bulb temperature, (*d*) the dew-point temperature, and (*e*) the specific volume of the air.
5. Saturated air leaving the cooling section of an air-conditioning system at 14°C at a rate of 50 m3/min is mixed adiabatically with the outside air at 32°C and 60 percent relative humidity at a rate of 20 m3/min. Assuming that the mixing process occurs at a pressure of 1 atm, determine the specific humidity, the relative humidity, the dry-bulb temperature, and the volume flow rate of the mixture.