THE INSTITUTION OF ENGINEERS, SRI LANKA

PART I EXAMINATION - AUGUST 2007

105 THERMODYNAMICS

Answer any FIVE Question only Time: 03 hours

Tables of Thermodynamics and Transport properties will be provided.

State clearly the Thermodynamic principles used in all solutions attempted.

Q1. A windmill drives an electric generator that produces an average power output of 4kW. The power is subsequently stored as chemical energy by charging a battery. Heat transfer from the battery to the surroundings occurs at a constant rate of 0.5 kW during charging. Determine the amount of energy stored in the battery during 8 hours of continuous operation of the total system.

Q2. A closed system undergoes a thermodynamic cycle comprised of the following processes:

Process 1-2: adiabatic compression following $pv^{1.4}$=constant, from 3 bar, 0.1 m3 to 0.05 m3.
Process 2-3: constant volume
Process 3-1: constant pressure with ΔU of 50 kJ

Sketch the cycle on a schematic p-v diagram and calculate the net work and net heat of the cycle. Also make a comparison of these two values and with a discussion.

Q3. A rigid well insulated vessel contains 2 kg of H_2O as a mixture of liquid and vapour at 1.0 MPa and 90% dryness fraction. An electric resistance heater in the tank transfers energy to the mixture at a constant rate of 50 kW. Draw the process on a schematic p-v diagram and determine the time required for the water to reach 200°C.

Q4. A perfect gas flows through a convergent nozzle attached to a part of a heat engine, at a mass flow rate of 1 kg/s. The pressure, temperature and velocity of the gas are 8 bar, 850 K and 165 m/s, at entry to the nozzle. The gas temperature at the exit is found to be 250 K. If the specific heat c_p= 1125 J/(kgK) and the gas constant is 287 J/(kgK) for the gas, calculate the cross-sectional areas of the nozzle at inlet and at exit, assuming isentropic expansion. What would be the exit temperature and pressure if the internal surface condition of the nozzle is changed so that nozzle isentropic efficiency is 0.85?

Q5. An inventor develops a system that undergoes a thermodynamic cycle re from a tank that contains liquid water at 90°C and rejecting heat to its surro 30°C. The preliminary testing carried out by the inventor shows that the produces 150 MJ of net work. The temperature of the water in the tank drops to 3 during this period. Determine the minimum mass of water required in the tank for this purpose, describing a possible layout with assumptions.

Q6. A small scale electricity generating plant in an industry, working on steam, has a power output of 10 MW. The plant takes chemically treated water at 30°C from a large open tank at atmospheric pressure and is pumped to the boiler maintained at 15 bar. The boiler generates saturated vapour that is then supplied to the power generating turbine which has an isentropic efficiency of 85%. The exhaust steam from the turbine is at 1 bar and is subsequently released to the nearby river after cooling it to 35°C. Making suitable assumptions, estimate the overall efficiency of the plant. Also draw a schematic layout of the arrangement.

Q7. Air standard Diesel cycle takes air at 1 bar and 300 K. At the end of the heat addition the pressure and temperature of the working fluid is 6.5 MPa and 2100 K respectively. Determine the:

i. Compression ratio
ii. Fuel cut off ratio
iii. Cycle thermal efficiency
iv. Mean effective pressure

Q8. A vapour compression heat pump unit uses R134a as the refrigerant. The refrigerant enters the compressor at 2.4 bar & 0°C with a volumetric flow rate of 0.5 m^3/min. After an adiabatic compression to 9 bar, the discharge temperature of the refrigerant from the compressor if found to be 60°C. The condenser delivers saturated liquid at 9 bar to the expansion device before it is fed to the evaporator. Determine the:

i. Power input to the compressor
ii. Cooling capacity of the unit
iii. The COP of the system