INDIAN INSTITUTE OF TECHNOLOGY

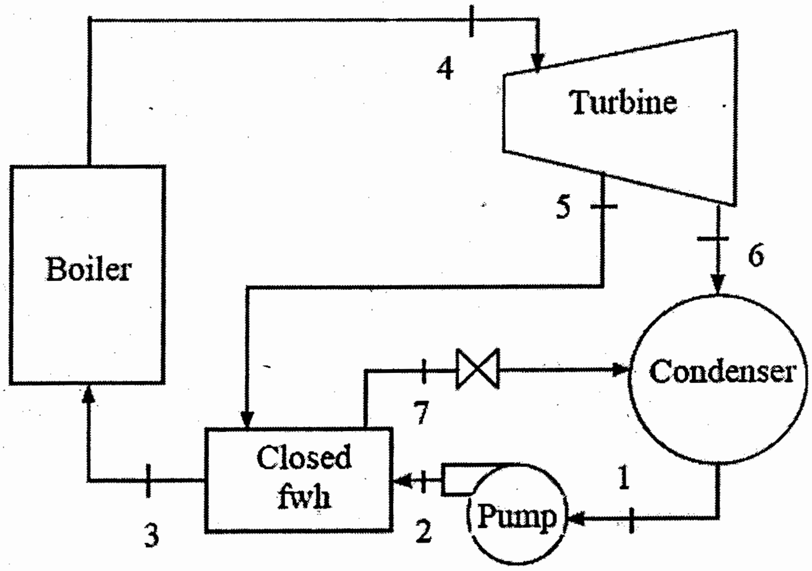
Date: .... FN/AN   Time: 3 hours   Full Marks: 100   No. of Students: 340

Spring End-Semester Exam, 2012   Dept. Mechanical Engg.   Subject No.: ME22002

2nd Year B.Tech (H)   Subject Name: Thermodynamics

Answer all the questions.   Marks for the questions are shown on the margin.

1. A regenerative ideal Rankine cycle operates (as shown in the figure) with a closed feedwater heater (FWH). The turbine inlet is at 3 MPa and 350 °C, while the condenser pressure is 20 kPa. Steam is extracted at 1 MPa to serve the closed FWH, which discharges into the condenser after being throttled (employing an expansion valve) to the condenser pressure.



Consider an ideal closed FWH, where the feedwater (from the condenser) is heated to the exit temperature of the extracted steam, which ideally leaves the heater as a saturated liquid at the extraction pressure.

a) Show the cycle on the T-s plane clearly indicating state points 1 through 7 along with the saturation lines.
b) Determine the pump work (kJ/kg) and clearly state any assumption that you make to do this estimation.
c) State the value of P_5, P_6 and P_7 in kPa.
d) Estimate the turbine work output per unit boiler flow rate (kJ/kg)
e) Estimate the boiler heat input per unit boiler flow rate. **[5+4+3+7+6]**

2. The conditions at the beginning of compression in an air-standard Diesel cycle are fixed at P_1 = 200 kPa, T_1 = 380 K. The compression ratio is 20 and heat addition per unit mass is 900 kJ/kg. Determine:

(a) the cut-off ratio
(b) the net work per unit mass of air, in kJ/kg
(c) the thermal efficiency (in %)
(d) the mean effective pressure, in kPa.
(e) Draw the *P-v* and *T-s* diagrams indicating the state points. **[3+3+3+3+4]**

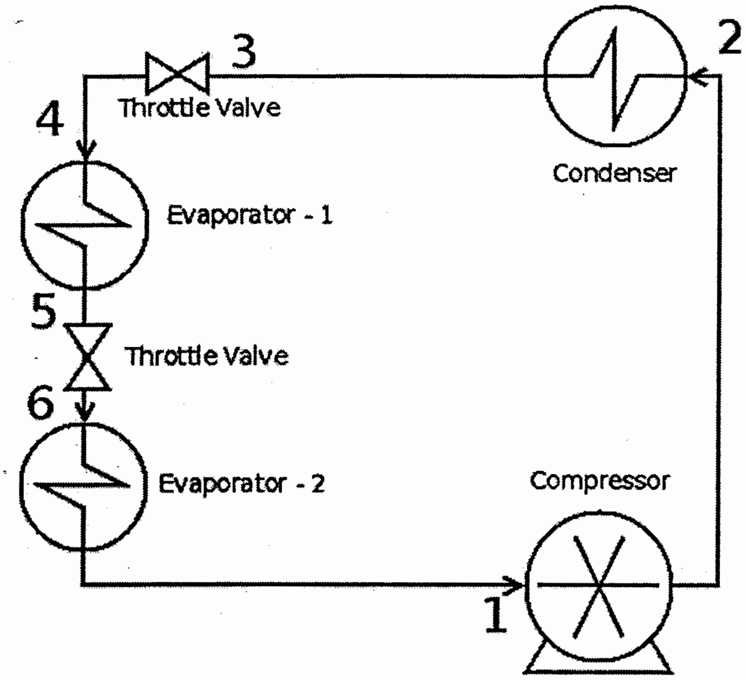
3. The Clapeyron equation is given by: $\left(\frac{dP}{dT}\right)_{sat} = \frac{h_{fg}}{Tv_{fg}}$ where the symbols have their usual meaning.

Hence derive the Clapeyron-Clausius equation:

$$\ln\left(\frac{P_2}{P_1}\right)_{sat} \cong \frac{h_{fg}}{R}\left(\frac{1}{T_1}-\frac{1}{T_2}\right)_{sat}$$

Using this relation, estimate the saturation pressure of refrigerant-134a at –50°C with the data at –40°C; P=51.25 kPa and h_{fg} = 225.86 kJ/kg. For 134a, R = 0.08149 kJ/kg-K. **[4+5]**

4. A two-evaporator vapour compression refrigeration system (figure shown) uses refrigerant 134a as the working fluid. The refrigerant which is saturated vapour at −26°C at the entrance to the compressor is compressed isentropically to 800 kPa and then condensed in the condenser at 800 kPa until it becomes saturated liquid. Then it is evaporated in evaporator-1 at 0°C and further evaporated in evaporator-2 at −26°C until it becomes saturated vapour. The mass flow rate through the compressor is 0.1 kg/s. The cooling power of the low temperature evaporator is twice that of the cooling power of the high temperature evaporator.



a) Draw the thermodynamic cycle in a T-s plot showing state points 1-6.

b) State the pressure in each of the evaporators.

c) Calculate the cooling power in kW for evaporator-1.

d) Calculate the cooling power in kW for evaporator-2.

e) Find the entropy generation rate (kW/K) in each of the throttle valves. **[5+4+5+5+6]**

5. A gaseous mixture contained in a rigid vessel of volume 0.4 m^3, has the following composition on a molar basis: O_2: 15%, N_2: 60%, CO_2: 25%. It is heated to a temperature of 120^{0}C by heat transfer from a thermal-energy reservoir having a temperature of 300^{0}C. The environment is at 25^{0}C and 100 kPa. Determine the following:

   a) the composition of the mixture on a mass basis
   b) the partial pressure of each component (kPa) if the total pressure is 150 kPa and the temperature is 30^{0}C before the process of heating
   c) the apparent gas constant of the mixture (kJ/kg-K)
   d) the mass of the mixture (kg)
   e) the final pressure (kPa)
   f) the heat transfer during the process (kJ)
   g) the irreversibility for the process (kJ)

Given, universal gas constant (R_u) = 8.314 kJ/kmol-K, molecular mass of O_2, N_2, and C are 32, 28 and 12 kg/kmol, respectively. Do the analysis based on ideal gas assumption. An approximate value of the specific heat (molar) at constant pressure for the mixture can be taken as 35 kg/kmol-K.
[3+3+3+3+3+4+6]