Circle your division:
7:30 Joglekar 9:30 Wassgren 10:30 Gore 12:30 Chen 2:30 Woodland 4:30 Sircar

Question 1 (30 Points): The question consists of 2 problems. Show your work including schematics, graphs, detailed derivation from the basic equations, property relations, and efficiency and cycle relations as provided on the attachments and calculation procedures and place your answers in boxes.

(a) (15 Points): A machine extracts 10 kW of energy from a low temperature reservoir and delivers 11 kW of energy to a high temperature reservoir in a cyclic manner. Find COP for this machine: (I) operated as a refrigerator and (II) operated as a heat pump.

![Diagram with COP calculations]

(I) $COP_R = 10$

(II) $COP_{HP} = 11$

(b) (15 Points) 0.5 kg of acetylene ($C_2H_2$) ($M = 26$ kg/kmol, $P_c = 62.8$ bar absolute, $T_c = 309$ K) is to be stored at a pressure of 125 bar absolute and $T = 402$ K, find the volume in Liters (L) of the tank.

![Diagram with volume calculation]

Volume = 3.6 L
Question 2 (30 Points): Given: Cold air (2 lbm/s) at T=540°F flows into the inner tube of a heat exchanger and is heated to 640°F. Hot air (1 lbm/s) at T=1080°F enters the shell of the heat exchanger and flows out at T= 860°F. The heat exchanger has no insulation and the ambient temperature is 540°F. Show your work including schematics, graphs, assumptions, detailed derivation from the basic equations as provided on the basic equation sheet and calculation procedures and place your answers in boxes.

Find:
(a) (10 Points) Draw control volume(s) in the sketch above that is (are) suitable for finding the heat loss to the ambient through the faulty insulation.
(b) (20 Points) Find the heat loss (Btu/h) to the ambient considering that the specific heat of air varies with temperature.

\[
\dot{Q} = \sum m_i \left( h_i + \frac{V_i^2}{2} + gh_i \right) - \sum m_i \left( h_i + \frac{V_i^2}{2} + gh_i \right) + \dot{m}_3 \Delta h
\]

\[
\dot{Q} = \left[ 2 \left( h(640) + h(1080) \right) - \left( h(540) + h(860) \right) \right] = \left[ 2 \left( 530.09 \right) + 260.97 \right] = 23220 \text{ Btu/h}
\]

(b) Heat Loss to the Ambient = 23220 Btu/h
Circle your division:
7:30 Joglekar 9:30 Wassgren 10:30 Gore 12:30 Chen 2:30 Woodland 4:30 Sircar

**Question 3 (40 Points) Given:** A steam turbine power cycle consists of an adiabatic pump (P), a steam generator (SG) and an adiabatic turbine (T) as shown in the sketch below. Water enters the pump at 1 bar absolute and 4°C (state 1) and leaves it at 20 bar absolute and 20°C (state 2). Steam enters the turbine at 20 bar absolute and 240°C (state 3) with 100 m/s velocity (V3) and expands to a saturated vapor state at 100°C (state 4) and 1 m/s velocity (V4). The turbine supplies total power of 5 MW including the power required for driving the pump (\(\dot{W}_P\)). Please complete the tasks in (a), (b) and (c) below. *Kinetic energy can be ignored at states: 1 and 2. Potential energy changes can be ignored at all states.* Show your work from the basic equations, assumptions, property relations, and efficiency and cycle relations as provided on the basic equation sheet.

**Find:**

(a) **6 Points** Draw appropriate control volumes (on schematic below) for analysis of pump (P) and turbine (T).

(b) **10 Points** Complete the T-v diagram with labels and units on the axes, the vapor dome and show the relevant constant pressure curves. Also show states 1, 2, 3, and 4 and processes 1-2, 2-3, and 3-4 on this diagram.

(c) **24 Points** Find in SI Units that you must enter at appropriate locations in your answers: (c1) the work interaction for the pump per unit mass of \(\text{H}_2\text{O} \); (c2) the work interaction for the turbine per unit mass of \(\text{H}_2\text{O} \) and (c3) the mass flow rate of \(\text{H}_2\text{O} \). Show calculation procedures and place your answers in boxes on page 5.
\[ \frac{dE_{cv}}{dt} = \dot{Q} - \dot{W} + \dot{m}_i \left( h_i + \frac{v_i^2}{2} + g z_i \right) - \dot{m}_e \left( h_e + \frac{v_e^2}{2} + g z_e \right) \]

\[ \frac{dE_{me}}{dt} = -\dot{m}_e - \dot{m}_i \]

\[ \text{Losses, no H-T. for pump & turbine } \Delta E \text{ neglected} \]

\[ \text{for pump, } \Delta P E \text{ neglected for both.} \]

\[ W_p = \dot{m}_1 h_1 - \dot{m}_2 h_2 \implies \frac{W_p}{m} = 16.87 - 85.95 = -69.08 \]

\[ W_T = \dot{m}_3 (h_3 + \frac{v_3^2}{2}) - \dot{m}_4 \left( h_4 + \frac{v_4^2}{2} \right) \]

\[ \text{(state)} \quad \begin{array}{c}
1 \quad 16.87 \\
2 \quad 85.95 \\
3 \quad 2876.5 \\
4 \quad 2676.1 \\
\end{array} \]

\[ h_1 = u_1 + \rho \frac{v_1^2}{2} \]
\[ = 16.77 + 100 \times 10^{-3} \]
\[ = 16.87 \text{ KJ/kg} \]

\[ h_2 = u_2 + \rho \frac{v_2^2}{2} \]
\[ = 83.95 + 2 \]
\[ = 85.95 \text{ KJ/kg} \]

\[ \dot{W}_T = \dot{m} (h_3 - h_4) = \dot{m} 205.4 = 5000 \quad \Rightarrow \dot{m} = \frac{5000}{205.4} \approx 24.34 \text{ kg/s} \]