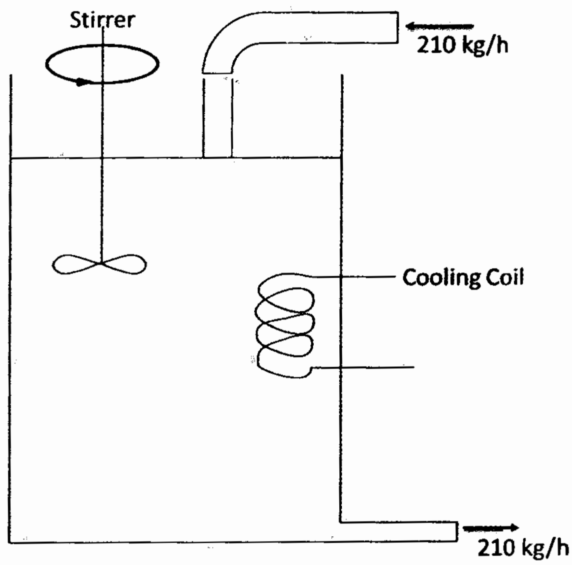
INDIAN INSTITUE OF TECHNOLOGY

Date: .... FN/AN Time: 2 hours Full Marks: 100 No. of Students: 340
Spring Mid-Sem Exam., 2012 Dept. Mechanical Engg. Subject No.: ME22002
2^{nd} Year B.Tech (H) Subject Name: Thermodynamics
Answer all the questions. Marks for the questions are shown on the margin.

Given: Universal Gas Constant, R_u = 8.3145 kJ/kmol-K

1. An insulated liquid bath contains 21 kg of liquid water initially at 21°C. It has one inlet and one exit with equal mass flow rates as shown in the figure. Liquid water enters the bath at 21°C and with a mass flow rate of 210 kg/h. A cooling coil submerged in the bath removes energy at a rate of 4.5 kW. A stirrer is provided for a thorough mixing so that the temperature is uniform throughout the bath. Power input to the water from the stirrer is 0.45 kW. The pressures, both at the inlet and exit, are equal and all the kinetic and potential energy effects may be neglected. The specific heat of water can be approximated as 4.2 kJ/kg-K for the working range of the bath.



Work out the following:

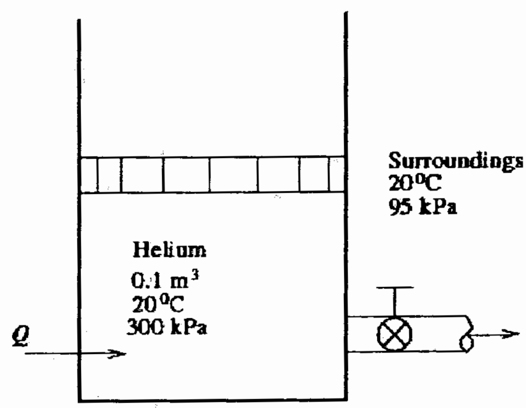
a. Write the first law of thermodynamics as applicable for the system described above.

b. Obtain an expression for the variation of exit temperature of the bath with respect to time.

c. Make a sketch to show the variation of the bath temperature with respect to time.

d. Clearly state the assumptions made by you for this analysis. [5+10+5+5]

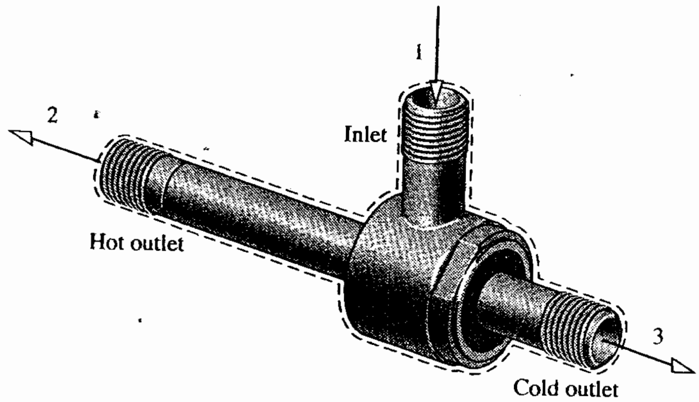
2. A vertical frictionless piston-cylinder device, as shown in the figure, initially contains 0.1 m^3 of helium at 20°C. The mass of the piston is such that it maintains a constant pressure of 300 kPa inside. A valve is now opened, and helium is allowed to escape until the volume inside the cylinder is halved. Heat transfer takes place very slowly between helium and its surroundings at 20°C and 95 kPa so that the temperature of helium in the cylinder remains constant. Determine (a) the maximum work potential (in kJ) of helium at the initial state and (b) the exergy destroyed (in kJ) during this process.



For helium, molecular mass = 4 kg/kmol; c_p = 5.1926 kJ/kg-K and c_v = 3.1156 kJ/kg-K.

[10+15]

3. An inventor claims to have developed a device requiring no energy transfer by work or heat transfer, yet able to produce hot and cold streams of air from a single stream of air at an intermediate temperature. The inventor provides steady-state test data indicating that when air enters at a temperature of 29°C and a pressure of 5 bar, separate streams of air exit at temperatures of −16°C and 84°C, respectively, and each at a pressure of 1 bar. Fifty-five percent of the mass entering the device exits at the lower temperature.



Assume ideal gas behaviour for air (with c_p=1.0 kJ/kgK and R_{air}=0.287 kJ/kgK) and ignore changes in kinetic and potential energies of the streams from inlet to exit. Evaluate the inventor's claim in terms of its feasibility based on first and second law of thermodynamics. Fundamental conservation equations must be clearly written before reducing them employing simplifications applicable for the present configuration.

[10+15]

4. Consider two independent systems, one a frictionless piston-cylinder device and the other, a rigid tank. Initially each system contains 12 kg of an ideal gas at the same temperature, pressure and volume. It is desired to raise the temperature of each of the systems by 20°C.

   Determine which system will require more heat to be supplied and find the difference in heat supplied. Sketch the processes in the piston-cylinder device and in the tank on the *P-V* plane. Assume molecular mass of the gas to be 24 kg/kmol.

[6+11+4+4]