BIRLA INSTITUTE OF TECHNOLOGY & SCIENCE, PILANI (RAJ)
First Semester (2023-24)
BITS F111 Thermodynamics
Comprehensive Examination (Closed book)

Max Mark =120 **Friday, 11th December 2023** **Duration 180 min**

- The Question paper has two parts**: Part A (5x6M = 30 M) + Part B (2x20M+2x25M = 90 M).**
- Solve Part A in the space provided in the question paper and Part B on separate answer sheet.
- Use of Thermodynamics table booklet is permitted.
- **Underline the answer and write in proper units.**

Part A

a) Heat is lost through a plane wall steadily at a rate of 800 W. If the inner and outer surface temperatures of the wall are 20°C and 5°C respectively, and the environment temperature is 0°C, what is the lost work in W?

Solution:

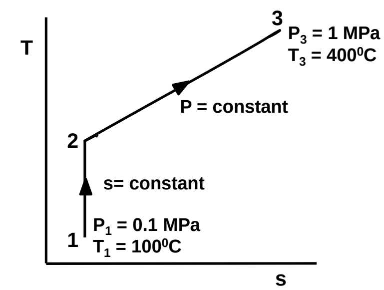
b) A piston-cylinder (A) has piston mass such that it contains mass m_A of helium at P_{1A} and T_{1A}. Another piston-cylinder (B) contains mass m_B of helium at P_{1B} and T_{1B} and water is filled up to the brim on the top of the insulated massless piston. Both these setups were heated so that the temperature of each control mass (Helium) increases to T_2. In which control mass in A or B would entropy change be greater? Justify your answer with the relevant equation. Given conditions: $P_{1A}=P_{1B}$; $T_{1A}=T_{1B}$; $m_A=m_B$

c) Consider an insulated control volume with two openings, A and B. A steady stream of air flows through the control volume, and following temperature and pressure measurements are obtained:

Control volume opening	Temperature (K)	Pressure (kPa)
A	300	100
B	420	400

Identify the direction of flow of air through the control volume, and justify your answer with calculation.

d) One kilogram of water in a piston-cylinder assembly undergoes two internally reversible processes in series as shown in figure. For each process, determine the heat transfer and the work (in kJ).



e) Consider two cases for increasing the COP of a Carnot refrigerator: (a) decreasing the temperature of the high-temperature reservoir (T_H) by ΔT while the temperature of the low-temperature reservoir (T_L) is constant, (b) increasing the temperature of the low-temperature reservoir (T_L) by ΔT while the temperature of the high-temperature reservoir (T_H) is constant. Find which of these two cases has higher COP.

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- **If the values match up to the first three decimals, then avoid doing interpolation.**

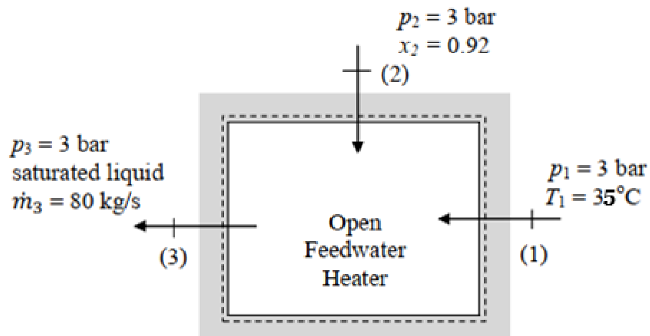
Part B

Q 1. Refrigerant-134a enters an adiabatic compressor at -30^{0}C as a saturated vapor at a rate of 0.50 m^3/min and leaves at 1000 kPa and 60^{0}C. Determine

a) the actual power input to the compressor in kW
b) the rate of entropy generation in kW/K during the process
c) the work input to the compressor in kW if the process is reversible (isentropic work)
d) the isentropic efficiency of the compressor [20M]

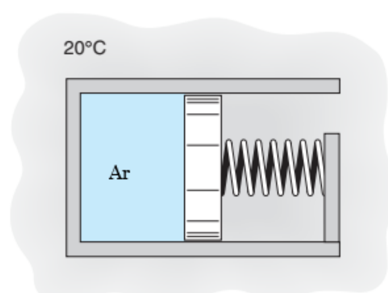
Q 2. Consider a direct mixing type of heat exchanger also known as open feed water heater. Such a heat exchanger is used in a power plant, where two fluid streams of water mix at a steady state as shown in figure. The states of the streams are mentioned in the figure. Stream 1 is having a mass flow rate of 60% of the exit mass flow rate. Assuming the surrounding temperature as 27^{o}C, calculate the following.

a) Mass flow rate of streams 1 and 2 in kg/s.
b) Rate of heat transfer in kW to the surroundings during the process.
c) Rate of entropy generation in kW/K.



[20M]

Q 3. A piston/cylinder as shown in figure, has Argon (Ar) at 200 kPa, 400^{o}C with a volume of 0.1m^3. The piston, having a cross-sectional area of 0.2 m^2, is loaded with a linear spring (compressed initially). The Argon now cools down in such a way that the final volume is half of the initial volume. The spring constant is 15 kN/m. Assuming the process is internally reversible and ambient is at 20^{o}C, calculate the following:



a) total work in kJ
b) the heat transfer in kJ
c) entropy change of Argon in kJ/K
d) the total entropy generation in the process in kJ/K [25M]

Q 4. An insulated piston/cylinder contains 0.1 m^3 air at 250 kPa, 300 K and it maintains constant pressure. More air flows in through a valve from a line at 300 kPa, 400 K so the volume increases by 60%. Using constant specific heat, calculate the following:

1. Final temperature in K
2. the total entropy generation in kJ/K [25M]