BIRLA INSTITUTE OF TECHNOLOGY & SCIENCE, PILANI (RAJ)

First Semester (2023-24)

Course No: BITS F111 Thermodynamics; Mid-semester test (Open book)

Max Marks 90 **Wednesday, October 11, 2023 (11 am to 12:30 pm)** **Duration: 90 min**

- The Question paper has two parts**: Part A (30 marks) and Part B (60 Marks)**
- Answer **Part A** in the **question paper** itself, in the space provided**. (maximum duration 45 min)**
- **After submitting Part A, question paper of Part B will be given.**
- Answer **Part B** in the answer book.
- **Please highlight the answers with box** ☐

Name: **Id:** **Section No:**

PART A

Q 1.

A. If a bullet of mass 16.0 g, traveling at a velocity of 950 m/s, hits a small hard oak wooden block of mass 1 kg, determine the rise in temperature (ΔT) of the hard oak wooden block. **[6M]**

B. If P = 150 bar and T = 600 °C, find the specific volume of water. What is the percentage error in calculating the specific volume using a compressibility chart (D.1)? **[6M]**

C. Helium (He) is at a pressure and temperature of 2 MPa and 2000 K (state 1), respectively. It is throttled to a pressure of 100 kPa. Represent the process on the T-h plot. Label the process systematically. **[6M]**

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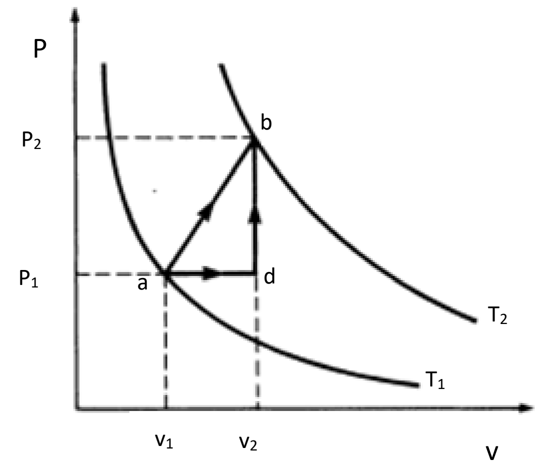
D. Consider the two processes in the sketch **(ab** and **adb)**. What is the difference between the heat transferred (Q_{ab}-Q_{adb}) to control mass system containing an ideal gas and executing the given processes if $P_2 = 2P_1$ and $v_2=2v_1$? Express your answer in terms of the gas constant R and T_1. **[6M]**



E. A sealed rigid vessel has a volume of 30 L and contains a mixture of saturated liquid and vapor of water at atmospheric pressure of 100 kPa so that the water passes exactly through the critical state when the container is heated. Find the mass of saturated liquid and the quality of the mixture at the initial state. **[6M]**

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PART B

Q 2. Tank *A* (volume=0.1 m^3) contains 2 kg of ammonia at -30 °C. It is connected to cylinder *B* through a valve that is initially closed. Cylinder *B* contains an insulated massless piston (area=0.1 m^2) connected to a linear spring (k=5 kN/m) immersed in water (assuming the density of water as 1000 kg/m^3), as shown in the fig. 1. The volume of tank B is 0.1 m^3 and atmospheric pressure is P_0=100 kPa. Cylinder *B* also has a stop at a height of 0.75 m. Initially, the piston is at the bottom and the spring is unrestrained. The valve is opened slowly, and heat is transferred to ammonia until the temperature of the ammonia reaches to 5 °C. (Assume a quasi-equilibrium process and g=10 m/s^2, neglect the piston's thickness, the ammonia volume in the connecting pipe, and the volume of the spring).

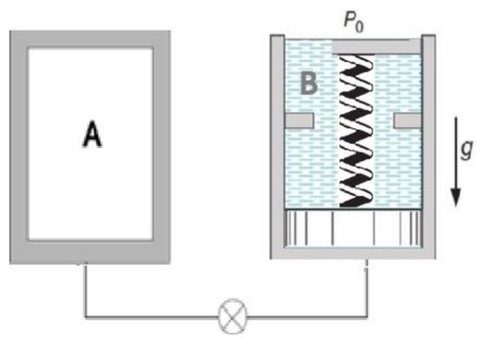

Fig 1

a) Find whether the piston is against the stops.
b) Find the final pressure in kPa and the total volume of ammonia (m^3).
c) Calculate the total work done by ammonia in the process (kJ).
d) Calculate the total heat supplied to ammonia (kJ).
e) Represent the process on P-v plot. **[20M]**

Q 3. Two kilograms of air, initially at 6 bar, 400 K, and 4 kg of carbon monoxide (CO) initially at 3 bar, 550 K are confined to opposite sides of a rigid, well-insulated container by a partition, as shown in Fig 2. The partition is free to move and allows heat transfer from one gas to the other without energy storage in the partition itself. The air and CO behave as ideal gases with a constant specific heat ratio of k= 1.395.

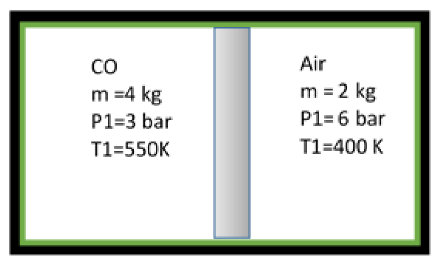

Fig 2.

Determine at equilibrium

a) the final temperature, (K)
b) the final pressure, (bar) and
c) the volume occupied by each gas at the final state, (m^3).

Assuming constant specific heat $C_v = \frac{R}{k-1}$, where R is the specific gas constant. **[20M]**

Q 4. As shown in Fig 3. steam at 80 bar, 440 °C, enters in an insulated turbine, with negligible inlet velocity, operating at steady state with a volumetric flow rate of 236 m^3/min. Twenty percent of the entering mass flow exits through a diameter of 0.25 m at 60 bar, 400 °C. The rest exits through a diameter of 1.5 m with a pressure of 0.7 bar and a quality of 90%. Determine

a) the velocity at each exit duct, (m/s).
b) the mass flowrate at each exit (kg/s).
c) Power generated (kW). **[20M]**

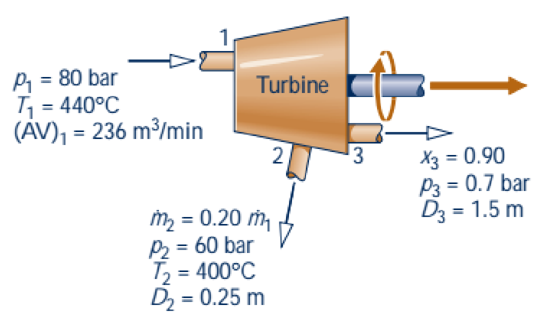

Fig 3.