INDIAN INSTITUE OF TECHNOLOGY

Date: Feb 17, 2014 FN/AN | Time: 2 hrs | Full Marks: **60** | No. of Students: **350**

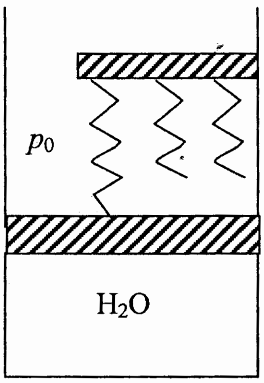
Spring Mid-Semester, 2013-14 | Mechanical Engineering | Subject Number: **ME22002**

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

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

In problems involving steam, properties may be obtained from the Steam Tables supplied during the Examination.

1. A piston/cylinder arrangement has 3 linear springs (each of the same stiffness) and the outside atmosphere acting on the piston (p_0 = 100 kPa), as shown in the figure. It contains water at 3 MPa, 400 °C, with the volume being 0.1 m^3. At this stage, only one spring touches the piston. The system now cools until the pressure reaches 1 MPa. At a hypothetical state on which the piston would have been at the extreme bottom, the spring would exert a force such that a pressure of 200 kPa inside the cylinder would be required to balance the forces.



i. Identify a system for your analysis.

ii. Find the mass of water in the identified system.

iii. What is the specific volume at the final state?

iv. Determine the work done during the process, using the expression $\int pdV$. Under what assumptions can this expression be used?

v. Determine the heat transfer during the process. State the assumptions that you make.

[1+2+2+5+5=15]

2a. A rock bed of volume 2 m^3 is heated to 380 °C using solar energy. A reversible heat engine receives heat from the bed and rejects to the ambient at 27 °C till the bed is cooled to the ambient temperature. Find the followings:

i. The work delivered by the heat engine.

ii. The efficiency of the heat engine at the beginning and at the end of the process.

Density and specific heat of the bed material are 2600 kg/m^3 and 0.8 kJ/kgK respectively.

2b. A cyclic device can be used both as a refrigerator and as a heat pump. "If the temperatures of the two thermal reservoirs between which the device works are fixed, the COP of the heat pump will be greater than the COP of the refrigerator only for reversible cycles" – comment on this statement.

2c. The wife in a family puts a cup of hot water (50 °C) inside the refrigerator for cooling. Her action is criticized by her thermodynamicist husband. Why?

[5+2.5+2.5]+[2.5]+[2.5]=15

3. A control volume receives an amount of heat Q_H from a thermal reservoir at a temperature $T_H \neq T_0$, where T_0 is the ambient temperature. The control surface temperature at all states is different from T_0. The control volume undergoes a steady state steady flow process with inlet state 'i' and exit state 'e'. Because of the difference in temperature between the ambient and the control surface, an amount of heat Q_0 is also transferred from the ambient to the control volume. Assume inlet specific enthalpy, velocity, specific entropy, elevation as h_i , V_i , s_i , z_i and exit specific enthalpy, velocity, specific entropy as h_e , V_e , s_e , z_e.

i. What is the work transfer across the control surface during the process?

ii. If all processes would have occurred reversibly, derive an expression for the work delivered in the process. Schematically describe an idealized arrangement for the situation in order to derive your expression.

iii. If S_{gen} be the entropy generation during the process, derive an expression for the total irreversibility in the process.

iv. Deduce an expression for the maximum possible reversible work that can be derived from the process, by choosing an appropriate exit state.

[2+6+5+2=15]

4. Steam enters a turbine at 3 MPa, 400 °C and with a velocity of 160 m/s. Saturated vapour at 100 °C exits the turbine with a velocity of 100 m/s. At steady-state, the turbine develops work equal to 540 kJ/kg of steam flowing through the turbine. Heat transfer between turbine and its surroundings occurs at an average outer surface temperature of 350 K. Change in potential energy across the turbine may be assumed to be negligibly small. Determine:

i. Rate at which entropy enters the turbine (in kJ/kgK)

ii. Rate at which entropy exits the turbine (in kJ/kgK)

iii. Entropy generation rate during the process in the turbine (in kJ/kgK)

iv. Heat transfer between the turbine and its surroundings (in kJ/kg) and its direction.

[4+4+3+4=15]

END OF PAPER