INDIAN INSTITUTE OF TECHNOLOGY

Date: .... FN/AN   Time: 2 hours   Full Marks: 100   No. of Students: 350

Spring Mid-Sem Examination, 2013   Dept. Mechanical Engineering   Subject No.: ME22002

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

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

In situations involving air, air can be assumed as an ideal gas with constant specific heats of c_p=1.004 kJ/kgK and c_v=0.717 kJ/kgK.

Use of steam table, supplied with the question paper, is permitted.

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1. A cylinder with a cross sectional area of 7.012 cm^2 has two pistons mounted, as shown in the figure. The upper one has mass of 100 kg, and it initially rests on the stops. The lower piston is virtually massless, and has 2 kg of water below it, with a linear spring in vacuum connecting the two pistons. The spring force is zero when the lower piston stands at the bottom and when the lower piston hits the stops the volume of water is 0.056 m^3. The water, initially at 50 kPa, volume = 0.00206 m^3 is then heated to saturated vapour.
   (a) What is the initial temperature of water?
   (b) At what pressure will both the pistons move together, assuming that they move in a quasiequilibrium process?
   (c) Find the final temperature, pressure, volume, and the net work done and heat transfer during the process, with the identification of an appropriate system.
   (d) Sketch the process in a p-v diagram.

3+6+17+6=32

2.
   (i) Mention whether the following statements are TRUE or FALSE. There is no credit for a correct identification of TRUE/FALSE statement without appropriate justification.

   (a) Air is a pure substance at atmospheric pressure and temperature.
   (b) A control volume within which intensive properties are not functions of time essentially represents a steady state steady flow device.
   (c) 1 Litre of a capsule of water is in state 1 (900 kPa, 175°C), and is kept in a large, insulated, and otherwise evacuated vessel. The capsule breaks and water fills up the entire volume. The final pressure is 200 kPa. The final state of water, in this scenario, may be specified by its specific internal energy and pressure.
   (d) Entropy of a fixed mass of ideal gas decreases in every isothermal compression.

3+5+4+4=16

   (ii) State the major assumptions/ restrictions under which the following expressions are valid:
   (a) $TdS = dU + \delta W$
   (b) $w_{12} = -\int_1^2 v dp$
   (c) $w_{12} = \int_1^2 p dv$

4+4+4=12

3. A combination of heat engine driving a heat pump takes waste energy from a source at 50^0 C as shown in the given figure. Both the devices are reversible. The heat engine receives Q_{w1} while the heat pump takes Q_{w2}. The heat engine rejects Q_L amount of heat at 30^0 C and the heat pump delivers Q_H at 150^0 C. If the total waste energy taken by the combination is 5 MW, find the following:
   (a) The efficiency and the COP of the heat engine and the heat pump respectively.
   (b) The rate of energy delivered at the high temperature.
   (c) The combined device works in a cycle and delivers heat to a high temperature body from a low temperature one at a finite rate without requiring work input from any external agency. Is this a violation of the **Second Law of Thermodynamics**? Justify your answer.

(4+4)+7+5=20

4. Air is compressed steadily by a compressor from 100 kPa and 27°C to 700kPa at a flow rate of 5 kg/min. Determine:
   (a) the power input required if the process is reversible adiabatic.
   (b) the power input and the heat transfer if the process is reversible isothermal.

You may use the first and the second law of thermodynamics and the property relation. Derive it, if you use any other relation. Assume air to be an ideal gas with constant specific heat, and neglect changes in kinetic and potential energy.

20

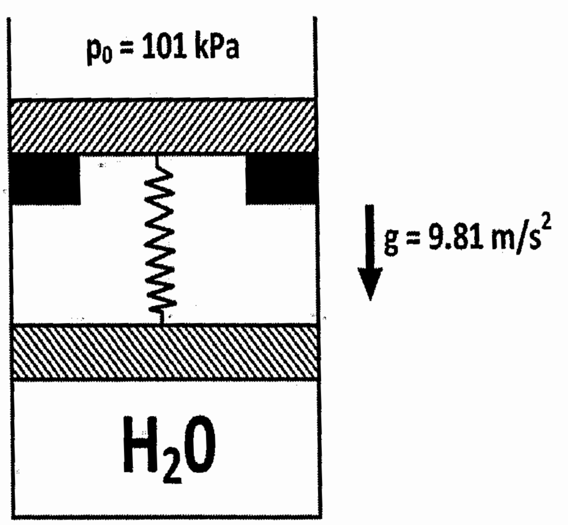

Figure for Problem 1.

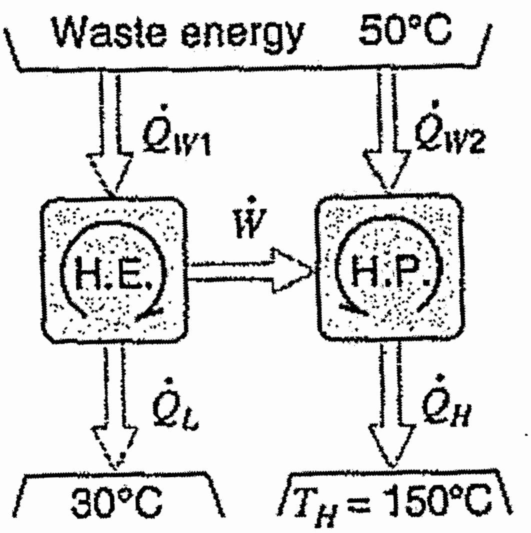

Figure for Problem 3(a).