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3431 *Your Roll No.* .....

M.Tech. / II Sem. **A**

NUCLEAR SCIENCE AND TECHNOLOGY

Paper NST–606— Applied Thermodynamics

Time : 3 hours *Maximum Marks* : 70

(Write your Roll No. on the top immediately on receipt of this question paper.)

Attempt all the questions. All notations are usual.

1. (a) A housewife, on a warm summer day, decides to beat the heat by closing the windows and doors in the kitchen and opening the refrigerator door. At first, she feels cool and refreshed, but after a while the effect begins to wear off. Evaluate the situation as it relates to first law of thermodynamics, considering the room including the refrigerator as the system? (3 marks)

(b) 1 Kg of ethane (perfect) gas is compressed from 1.1 bar, 27 ^{0}C according to a law $pV^{1.3}$ =constant, until the pressure is 6.6 bar. Calculate the heat flow to or from the cylinder walls (Given: molecular weight of ethane=30 and $c_p = 1.75\ kJ/kg\,K$). (3 marks)

(c) A movable frictionless piston closes a fully insulated cylinder on one side and offers a constant resistance during its motion. A paddle work is drawn into the cylinder and does work on the system. Prove that the paddle work is equal to change in enthalpy? (3 marks)

(d) What entropy change occurs when a partition is removed to allow two perfect gases at the same temperature to diffuse through one another? (2 marks)

(e) Explain the following: two stroke cycle engines find wider applications either in small two-wheelers or in large marine propulsion engines? (2 marks)

(f) Consider a sphere and a cylinder of equal volume made of copper. Both the sphere and the cylinder are initially at the same temperature, and are exposed to convection in the same environment. Which do you think will cool faster, the sphere or the cylinder? Why? (2 marks)

(g)What is the difference between wet steam and superheated steam? What advantages are obtained if superheated steam is used in steam plant? (3 marks)

(h) Explain the advantages of multistage compression? (2 marks)

(i) What is the function of superheater in boiler? Discuss its advantage to use in a boiler. (3 marks)

Turn over

(j) State Stefan-Boltzmann law of total radiation from a black body. How this law can be modified to take into account radiation from a non-black body? (2 marks)

(k) A current of 200 A is passed through a stainless-steel wire (K=19 W/m K) of 3 mm diameter. The resistivity of the steel may be taken as $70\,\mu\Omega.cm$, and the length of the wire is 1 m. The wire is submerged in a liquid at 110 ^{0}C and experiences a convection heat-transfer coefficient of 4 kW/m^{2}K. Calculate the center temperature of the wire. (4 marks)

(l) Justify the sentence that the specific heat of a gas may vary from zero to infinity. (1 marks)

2. (a) Give the Kelvin-Planck's and Clausius statements of second law of thermodynamics and show that violation of either statement implies violation of the other.

(b) Prove the following for an ideal gas:

$$ds = \frac{dV}{V} + c_v \frac{dp}{p}.$$

Using this result show that for an ideal gas undergoing an isoentropic change of state with constant specific heat, $pV^{\gamma} = \text{constant}$. (5+5=10 marks)

3. Is it better to arrange for the flow in a heat exchanger to be parallel or counter flow? Explain the answer. In a counter flow heat exchanger, oil ($c_p = 3\ kJ/kg\,K$) at the rate of 1400 kg/hr is cooled from 100 ^{0}C to 30 ^{0}C by water that enters the exchanger at 20 ^{0}C at the rate of 1300 kg/hr. Determine the heat exchanger area for an overall heat transfer coefficient of 3975 $kJ/m^2 - hr - K$. Also derive a relationship between oil and water temperatures at any section of the heat exchanger.

OR

What is thermal resistance? Explain its analogy with electrical resistance. A furnace wall consists of 200 mm layer of refractory bricks, 6 mm layer of steel plate and a 100 mm layer of insulation bricks. The maximum temperature of the wall is 1500 ^{0}C on the furnace side and the minimum temperature is 40 ^{0}C on the outermost side of the wall. An accurate energy

balance over the furnace shows that the heat loss from the wall is 400 W/m^2. It is known that there is a thin layer of air between the layers of refractory bricks and steel plate. Thermal conductivities for the three layers are 1.52, 45 and 0.138 $W/m\,^0C$, respectively. To how many millimeters of insulation brick is the air layer equivalent? What is the temperature of the outer surface of the steel plate? (10 marks)

4. Prove that the work done in two-stage compressor per kg of air delivered with perfect inter-cooling is given by

$$W/kg = \frac{2n}{n-1} RT_1 \left[\left(\frac{p_4}{p_1} \right)^{\frac{n-1}{2n}} - 1 \right].$$

Using this result calculate the condition for minimum work done by the compressor. An air compressor takes in air at 1 bar and 20°C and compresses it according to $pV^{1.2} = \text{constant}$. It is then delivered to a receiver at a constant pressure of 10 bar (where R=0.287 kJ/kg K). Determine the air temperature at the end of compression.

OR

Describe a simple vapor compression cycle giving clearly its flow diagram. Discuss the effect of sub-cooling of liquid on the performance of a vapor compression system. Why, in practice, is a throttling valve used in a vapor compression refrigerator rather than in an expansion cylinder to reduce the pressure between the condenser and evaporator? In an open cycle gas turbine plant, air enters the compressor at 27 ^{0}C and 1 kgf/cm^2 and leaves it at a pressure 4.5 kgf/cm^2. The maximum temperature in the cycle is 950 ^{0}C. There is a pressure drop of 0.15 kgf/cm^2 between the compressor and the turbine. Assuming the efficiency of both the compressor and the turbine as 85%, determine per kg of air (a) the net work output and (b) the thermal efficiency of the cycle. Assume specific heats of the working fluid to be constant ($c_p = 0.24\ kJ/kg\,K$). (10 marks)

5. In what respect four stroke diesel cycles (compression ignition) engine differs from four-stroke cycle spark ignition engine? Why is the thermal efficiency of petrol engine lower as

compared to diesel engine? In an ideal cycle for an internal combustion engine, the pressure and temperature at the beginning of compression are 15 bar and 260.5 ^{0}C, respectively. The pressure at the end of compression is 450 bar and the maximum pressure of the cycle is 750 bar. During combustion, half of the heat is added at constant volume and half at constant pressure. Both the compression and expansion curves are adiabatic and heat is rejected at constant volume ($c_p = 0.238\ kJ/kg\,K$ and $c_v = 0.17\ kJ/kg\,K$ throughout the cycle). Taking the entropy at the beginning of compression as zero, tabulate, for one kilogram of the working substance, the values of pressure, volume, absolute temperature and entropy at the four points of the cycle making the principal changes of condition up to the end of combustion. Sketch the pressure-volume and temperature-entropy diagram for the cycle.

(10 marks)