INDIAN INSTITUTE OF TECHNOLOGY

ENERGY CONSERVATION AND WASTE HEAT RECOVERY (ME 60234)
WASTE HEAT RECOVERY (ME 60086)

Spring 2018: End-semester examination

Full marks: 100 | *Attempt all questions* | Time: 3 Hours

Instructions: Clearly mention any assumptions made by you.

---

1. Consider the three sectors of economy – Steel, Food and Energy. To produce 1 unit of steel, we require 0.4 unit of old steel and 0.5 unit of energy. Similarly, 1 unit of Food requires 0.1 unit of food and 0.7 unit of energy, while 1 unit of energy requires 0.1 unit of steel, 0.8 unit of food and 0.1 unit of energy. Determine the production requirement of the three sectors if the annual demand in a small township is 100 units of steel, 400 units of food and 200 units of Energy. How does it change if the demand for food goes up by 10% in a particular year?

10+5 = 15

An energy installation costs Rs. 4 crores. The cash inflow over 5 yrs is expected to be Rs. 100 lakhs for first 2 yrs, 150 lakhs for the next 2 yrs and 250 lakhs in the 5th yr. Assuming a discount rate of 15% and zero salvage value calculate its NPV.

5

2. For an annular disc shaped flywheel, show that the maximum circumferential velocity is given by

$$v_{max} = \sqrt{\frac{2K\sigma_{max}}{\rho}}$$

10

A pumped hydro plant is used to deliver 100 MW of power for 6 hrs. The water is pumped up for 10 hrs consuming 85 MW. Calculate the turnaround efficiency.

5

In a CAES plant, air is compressed from 1 bar, 25 °C to 50 bar. Calculate the compressed air temperature assuming, Cp/Cv of air to be 1.4.

5

3. For a given Thermoelectric Generator (TEG) with given materials and geometry, find the condition under which the work output (W_L) is maximized and derive the expression for the maximum W_L.

10

An electric heater is used to heat a room which is at 25 °C while the outside temperature is -5 °C. It is decided to replace the heater by a heat pump. COP of the heat pump is 80% of ideal COP. The total heat loss from the room is estimated as $C\Delta T$, where ΔT is the temperature difference between the room and outside and C is estimated as 0.5 kW/K. Calculate the saving in electrical energy in kW.

10

4. A base load *1000 MW* power plant is designed with a sensible energy storage system. The thermal energy stored is called upon to produce *4000 MW-hr* of electrical energy daily. The accumulations are *4-m* in diameter each and are well insulated so that $U = 5\ kJ/m^2\text{-}hr\text{-}K$. The storage time is *15-hrs* while the maximum and minimum storage pressures are *2000 kPa* and *200 kPa* respectively. Assume outside ambient temperature is *20°C*, *Cp* of water = *4.35 kJ/kg-K* and the peaking turbine efficiency is *25%*. Calculate (a) the turn-around efficiency of the energy storage system and (b) the accumulator volume.

15

Consider a 30 cm long heat pipe with water having a rating of 20 W in horizontal orientation. The heat pipe is subsequently shortened to 20 cm and the water mixed with additives to reduce its viscosity by 20%. What is the power rating of the modified heat pipe?

5

5. The details of the streams in a process plant are given below.

(Stream No.) Type	Heat capacity, $\dot{m}c_p$ (kW/K)	Temperatuere at inlet (°C)	Temperatuere at exit (°C)
(1) Hot	4	240	40
(2) Hot	10	180	120
(3) Hot	2.5	280	80
(4) Cold	5	50	230
(5) Cold	16	110	160

A designer wants to synthesis a heat exchanger network using a pinch technology. Assuming the minimum temperature difference between the streams to be 20°C, find out the following

a. hot end pinch temperature,
b. cold end pinch temperature,
c. minimum hot utility,
d. minimum cold utility and
e. heat exchange between the streams.

Explain why generally it is not possible to have a network both with minimum number of heat exchangers and minimum use of utility.

5+5+3+3+4 = 20

Saturated Water Properties

Pressure (kPA)	*Temp* (°C)	*Specific volume* (m^3/kg)		*Enthalpy* (kJ/kg)			*Entropy* (kJ/kg-K)		
		v_f	v_g	h_f	h_{fg}	h_g	s_f	s_{fg}	s_g
2000	212	0.001177	0.09959	908.47	1889.8	2798.3	2.4467	3.8923	6.3390
200	120	0.001061	0.88578	504.71	2201.6	2706.3	1.5302	5.5968	7.1270
100	100	0.001043	1.6941	417.51	2257.5	2675.0	1.3028	6.0562	7.3589