Ref. No. Ex/PE/PE/H/T/324A/2025

B.E. POWER ENGINEERING THIRD YEAR SECOND SEMESTER EXAM 2025

SUBJECT: ***ADVANCED POWER CYCLES (HONS.)***

Time: Three Hours **100 Marks**

CO I: Answer any one (20 Marks)

1.

a) What are the ideal properties of a working fluid for a vapor power cycles? How do the following working fluids meet these criteria: Mercury, Water, and Organic Fluid? **6+4=10**

b) Draw a neat sketch of an ORC and explain their salient advantages over vapor power cycles. **6+4=10**

2.

A binary vapor cycle operates on mercury (Hg) and steam. Dry saturated mercury vapor at 4.5 bar is supplied to the mercury turbine, from which it exhausts at 0.04 bar. The mercury condenser generates saturated steam at 15 bar, which is expanded in a steam turbine to 0.04 bar. The heat released by the mercury condensing at 0.04 bar is used to impart only the latent heat of vaporization part to the water in the steam cycle a) Determine the efficiency of the Mercury cycle, b) the efficiency of the Steam cycle, and c) the overall efficiency of the Binary cycle. The following saturation properties of Hg are supplied

p_{sat} (bar)	T_{sat} (°C)	h_f (kJ/kg)	h_g(kJ/kg)	S_f(kJ/kgK)	s_g(kJ/kgK)	v_f (m^3/kg)	v_g (m^3/kg)
4.5	450	62.93	355.98	0.1352	0.5397	79.9×10^{-6}	0.068
0.04	217	9.9832	9.85	0.0808	0.69257	6.5×10^{-6}	5.178

CO II: Answer any two (40 Marks)

3.

A steam power plant operates on an ideal reheat– regenerative Rankine cycle and has a TG gross power output of 110 MW. Steam enters the high-pressure turbine at 10 MPa and 500°C and leaves at 0.8 MPa. Some steam is extracted at this pressure to heat the feedwater in an open feedwater heater. The rest of the steam is reheated to 500°C and is expanded in the low-pressure turbine to the condenser pressure of 10 kPa. Show the cycle on a T-s diagram with respect to saturation lines, and determine (a) the mass flow rate of steam through the boiler and (b) the extraction flow the feedwater heater. (c) Also calculate the net and gross heat rates of the cycle as per ASME PTC 6-A if the TG excitation power is 1.2 MW and other turbine auxiliary power consumption is 800 kW. **20**

4.

a) Show that for a simple GT cycle, the maximum specific work output is related to the maximum and minimum temperatures as $w_{max} = C_p[\sqrt{T}_{max} - \sqrt{T}_{min}]$.

b) A GT plant consists of 2 stage compressor and single stage turbine with regeneration. Air is taken into the compressor at 20° and 1 bar. Maximum temperature of the cycle is limited to 700°C while the pressure ratio is 6. Regenerator effectiveness is 0.7. Assuming the following data, find out (i) the air:fuel ratio, (ii) thermal efficiency of the cycle, and (iii) S.F.C. of the plant. Consider airflow through the plant = 200 kg/s, compressor efficiency of 88% for both the stages, turbine efficiency of 92%, combustion efficiency of 96%, mechanical efficiency of 96%, generator efficiency of 95%, GCV of fuel is 36960 kJ/kg, Cp = 1.008 kJ/kgK and γ = 1.4 for both air and flue gas. Assume perfect intercooling and neglect any pressure drop in the line. **10+10=20**

5.

Consider a coal-fired steam power plant that produces 300 MW of electric power. The power plant operates on a simple ideal Rankine cycle with turbine inlet conditions of 5 MPa and 450°C and a condenser pressure of 25 kPa. The coal has a heating value (energy released when the fuel is burned) of 29,300 kJ/kg. Assuming that 75 percent of this energy is transferred to the steam in the boiler and that the electric generator has an efficiency of 96 percent, determine (*a*) the overall plant efficiency (the ratio of net electric power output to the energy input as fuel) and (*b*) the required rate of coal supply, (*c*) the specific steam consumption, and (*d*) the NHR and GHR. **20**

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Time: Three Hours **100 Marks**

CO III: Answer any one (30 Marks)

6.

a) What do you mean by IGCC? Write down the basic steps of gasification process. **2+6 =8**

b) What are the three basic types of gasifiers used in IGCC power plants? Explain briefly their salient features. **2+8 = 10**

c) With a neat sketch of the basic building blocks, explain the working procedure of an IGCC cycle. What is the salient merit of IGCC over a GTCC plant? **8+4=12**

7.

A GTCC plant operates with simple GT cycle with a HRSG. The GT, HRSG and ST operating parameters are as follows:

GT Cycle: Temperature ratio =4, T_{amb} = 300 K, r_p = 5, Assume isentropic processes for the compressor and gas turbine. GT output = 150 MW

HRSG: Pinch point temperature difference 10 ºC, Acid dew point = 170 ºC. Exit gas temperature is to be maintained at least 10 ºC above the acid dew point.

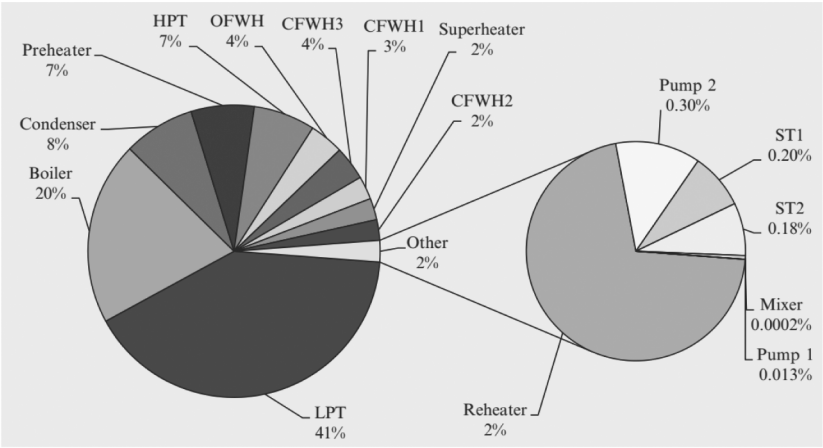
Steam Cycle: Simple Rankine cycle with boiler and condenser back pressures of 20 bar and 0.08 bars, respectively. Assume steam turbine expansion isentropic, and neglect pump work.

Draw the cycle arrangement and the T-Q diagram for the HRSG. Also determine, (i) GT cycle efficiency, (ii) mass flow rates of the GT and ST cycles, (iii) ST cycle output, and (iii) Overall plant efficiency **30**

Part IV Answer any one (10 Marks)

8.

What are the salient reasons of exergy destruction in a thermodynamic process? The figure below shows the exergy destruction in the major components of a reheat-regenerative power plant. State the reasons of the exergy destructions (Legend: HPT = High Pressure Turbine, OFWH= Open Feedwater Heater, CFWH = Closed Feedwater Heater). **3+7=10**



9.

Liquid water at 200 kPa and 20°C is heated in a chamber by mixing it with superheated steam at 200 kPa and 300°C (see Fig. on the right). Liquid water enters the mixing chamber at a rate of 2.5 kg/s, and the chamber is estimated to lose heat to the surrounding air at 25°C at a rate of 600 kJ/min. If the mixture leaves the mixing chamber at 200 kPa and 60°C, determine (a) the mass flow rate of the superheated steam and (b) the wasted work potential during this mixing process. **10**