BACHELOR OF PRODUCTION ENGINEERING EXAMINATION, 2024
[3rd Year 1st Semester (5th Semester)]

ENERGY PRODUCTION SYSTEMS

Time: Three hours **Full Marks: 100**

Answer **any FIVE** questions.

All parts of a question (***a, b, c* etc**) should be answered at one place.
Marks allotted for each question are given **at the right side below** the questions.
Assume any missing data with proper justification.

1.(a) A gas turbine power plant consisting of two compressor stages and two turbine stages develops **5000 kW**. The two compressors are driven by the HP turbine whereas the LP turbine runs a generator. The temperature of the gases at entry to the HP turbine is **650° C** and the gases are reheated to **650° C** after expansion in the first turbine. The exhaust gases leaving the LP turbine are passed through a heat exchanger to preheat the air leaving the HP stage compressor. The compressors have equal pressure ratios of **3:1** and the inter-cooling is completed perfectly between the compression stages. The ambient air temperature and pressure are **15° C** and **1.01 bar** respectively.

Isentropic efficiencies of each compressor stage = **80%,**
Isentropic efficiencies of each turbine stage = **85%,**
Heat exchanger efficiency = **75%,**
Combustion efficiency = **95%,**
Air-fuel ratio = **80:1,**
Calorific value of fuel = **42000 kJ/ kg**
C_p for air = **1.015 kJ/kg-K**
C_p for gas = **1.15 kJ/kg-K**
γ for air = **1.4**
γ for gas = **1.33**

Neglecting changes in kinetic energy calculate (i) the overall pressure ratio, (ii) the work ratio, (iii) the cycle thermal efficiency and (iv) the mass flow rate of air.

20

2.(a) Derive an expression of volumetric efficiency in terms of clearance ratio and pressure ratio if the suction and free air conditions are non-identical.

(b) A single cylinder double acting reciprocating air compressor has **20 cm** bore and **25 cm** stoke. Calculate the free air delivery (FAD) at **300 rpm** when clearance volume is **600 cm^3** and delivery pressure is **5 bar**. Assuming that **n=1.3** and suction pressure and temperature are **1 bar** and **30° C** respectively find also the power required to drive the compression. Take free air conditions are **1.013 bar** and **15° C**.

8+12=20

3.(a) Differentiate between nozzle and diffuser. What is the nozzle efficiency?

(b) Define the Mach No. What is the importance of Mach No. used in nozzle?

(c) What is critical pressure? Find out the critical pressure ratio for a nozzle if the steam is expanded isentropically according to $pv^n = C$.

(4+2)+(2+4)+(2+6)=20

4.(a) Distinguish between the impulse turbine and reaction turbine.

(b) What do you mean by Reheat factor and Wilson line?

(c) What do you mean by diagram efficiency and gross stage efficiency?- Explain

(d) Steam is expended from **14 bar** and **300° C to 6 bar** while it is passed through in a convergent-divergent type nozzle. If the flow rate is **1 kg/s** find the throat area and exit area of the nozzle.

6+4+5+5=20

5.(a) In a single-stage impulse turbine, the steam velocity at nozzle mouth is **300 m/s**, the nozzle angle is **18°** and the mean blade velocity is **144 m/s**. Draw to a suitable scale the diagram of relative velocities for steam assuming that the outlet angle of blades is **3°** less than inlet angle and that the relative velocity of the steam at outlet from the blade is **0.84** of the relative velocity at entrance. If the power to be developed is **1000 kW** calculate the mass of steam that must pass through the turbine per sec. Neglect disc friction and leakage loss.

(b) The mean diameter of the rotor, which rotates at **3000 rpm** of a single stage reaction turbine is **1.4** m. Determine the diagram efficiency and the blade inlet angle if the blade outlet angle is **20°** and the speed ratio is **0.7**. Also find the percentage increase in diagram efficiency and rotor speed if the rotor is designed to run at the best theoretical speed, the exit angle being **20°**.

10+10=20

6.(a) Show that for a single stage impulse turbine the optimum blade speed ratio is given by $\rho = \frac{\cos\alpha}{2}$; where, α= nozzle angle.

(b) In a Rankine cycle working between **50 bar** and **500°C** and **0.1 bar** the turbine efficiency of expansion is **0.8**. Determine the cycle efficiency and the dryness fraction of steam after expansion. Compare these with the ideal cycle.

8+12= 20

7.(a) What are the different types of condenser used in thermal power plant? – Discuss.

(b) Write a short note on cooling tower.

(c) Discuss about the working of Jet type condenser with neat sketch.

5+5+10=20

8.(a) Explain with neat sketch the working of Lancashire boiler.

(b) Differentiate between the accessories and mountings of boiler.

(c) What do you mean by vacuum efficiency and condenser efficiency?

8+7+5=20

9. Answer any **FOUR** from the following:

(a) Illustrate the working principle of flat plate solar collector for generation of electricity.

(b) Discuss about the Geothermal energy system with a neat sketch.

(c) Describe the principle of Wind power generation with a neat sketch.

(d) State the working principle of Magneto Hydrodynamic (MHD) systems.

(e) Discuss about the Nuclear power plant cycle with a neat sketch.

5x4=20