**ST. ANNE'S COLLEGE OF ENGINEERING AND TECHNOLOGY**

**(Accredited by NAAC, Approved by AICTE, New Delhi. Affiliated to Anna University, Chennai)**
**ANGUCHETTYPALAYAM, PANRUTI – 607 106.**
**DEPARTMENT OF MECHANICAL ENGINEERING**

**UNIT I BASICS, ZEROTH AND FIRST LAW**

Review of Basics – Thermodynamic systems, Properties and rocesses Thermodynamic Equilibrium - Displacement work - P-V diagram. Thermal equilibrium - Zeroth law – Concept of temperature and Temperature Scales. First law – application to closed and open systems – steady and unsteady flow processes.

**PART-A**

| Q. No. | Question | BT Level | Competence |
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| 1. | Express flow Energy. | BT-2 | Understanding |
| 2. | Give the conditions of steady flow process. | BT-2 | Understanding |
| 3. | Summarize thermodynamic equilibrium. | BT-2 | Understanding |
| 4. | Differentiate between point function and path function. | BT-3 | Applying |
| 5. | Define Zeroth Law of thermodynamics. Why it is so called? | BT-1 | Remembering |
| 6. | State the first law for a closed system undergoing a processand a cycle. | BT-1 | Remembering |
| 7. | Why does free expansion have zero work transfer | BT-1 | Remembering |
| 8. | Enlist the similarities between heat and work | BT-1 | Remembering |
| 9. | What is microscopic approach in thermodynamics? | BT-1 | Remembering |
| 10. | Generalize extensive property. | BT-6 | Creating |
| 11. | What is perpetual motion machine of first kind [PMM1]? | BT-1 | Remembering |
| 12. | Give the limitations of first law of thermodynamics. | BT-2 | Understanding |
| 13. | Prove that the difference in specific heat capacities equal to Cp - Cv = R. | BT-5 | Evaluating |
| 14. | Compare homogeneous and heterogeneous system. | BT-4 | Analysing |
| 15. | Compare intensive and extensive properties. | BT-4 | Analysing |
| 16. | Differentiate quasi static and non quasi static process. | BT-3 | Applying |
| 17. | Generalize the term State and Process. | BT-6 | |
| 18. | Prove that for an isolated system, there is no change in internal energy. | BT-5 | Evaluating |
| 19. | Indicate the practical application of steady flow energy equation. | BT-6 | Creating |
| 20. | Illustrate reversible and irreversible process. | BT-3 | Applying |

| PART- B | | | |
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| 1. | Derive the steady flow energy equation and reduce it for aturbine, pump, nozzle and a heat exchanger. (13) | BT-1 | Remembering |
| 2. | Briefly explain the following:<br>(i) Point and path function (ii) Property state process andpath (iii) Quasi-static process. | BT-1 | Remembering |
| 3. | Three grams of nitrogen gas at 6 atm. and 160°C in a frictionless piston cylinder device is expanded adiabaticallyto double its initial volume, then compressed at constantpressure to its initial volume and then compressed again atconstant volume to its initial state. Calculate the net workdone on the gas. Draw the P-V diagram for the processes. | BT-6 | Creating |
| 4. | A stationary mass of gas is compressed without friction froman initial state of $0.3m^3$ and 0.015 MPa to the final state of $0.15m^3$ and 0.105MPa, the pressure remaining constant during the process. There is a transfer of 37.6kJ of heat from the gas during the process. How much does the internal<br>energy of the gas change? | BT-1 | Remembering |
| 5. | A gas undergoes a thermodynamic cycle consisting of the following processes:<br>(i) Process 1-2: constant pressure $P_1$=1.4 bar, $V_1$= $0.028m^3$, $W_{1-2}$=10.5 kJ<br>(ii) Process 2-3: compression with PV=C, $U_3$=$U_2$<br>(iii) Process 3-1: constant volume, $U_1$-$U_3$ = -26.4 kJ.There are no significant changes in the KE and PE.<br>1) Sketch the cycle on a PV diagram. (2)<br>2) Calculate the network for the cycle in KJ. (3)<br>3) Calculate the heat transfer for the process 1-2. (3)<br>4) Show that the sum of heat transfer in the cycle is equal tothe sum of work transfer in the cycle. (5) | BT-5 | Evaluating |
| 6. | A turbine operating under steady flow conditions receives steam at the following state: pressure 13.8 bar, specific volume 0.143 $m^3$/kg, internal energy 2590 KJ/Kg, velocity 30 m/s. The state of the stream leaving turbine is turbine is; pressure 0.35 bar, specific volume $4.37m^3$/Kg, internal energy 2360 KJ/Kg, velocity 90 m/s. Heat is lost to the surroundings at the rate of 0.25 KJ/s. If the rate of steam flow is 0.38 Kg/s, what is the power developed by the<br>turbine? | BT-1 | Remembering |

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| 7. | A thermodynamic system operates under steady flow conditions, the fluid entering at 2 bar and leaving at 10 bar. The entry velocity is 30 m/s and the exit velocity is 10m/s. During the process 25MJ/hr of heat from an external source is supplied and the increase in enthalpy is 5kJ/kg. The exit point is 20m above the entry point. Estimate flow work from the system if the fluid flow rate is 15 Kg/min. | BT-2 | Understanding |

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| 8. | A vessel of constant volume $0.3m^3$ contains air at 1.5 bar and is connected via a valve to a large main carrying air at a temperature of 38°C and high pressure. The valve is opened allowing air to enter the vessel and raising the pressure therein to 7.5 bar. Assuming the vessel and valve to be thermally insulated, predict the mass of the air entering the vessel. | BT-2 | Understanding |
| 9. | (i) A mass of gas is compressed in a quasi - static process from 80 KPa, $0.1m^3$ to 0.04MPa,0.03 $m^3$.assuming that the pressure and the temperature are related by $PV^{1.35}$=C, Predictthe work done by the gas system. (6)<br><br>**(i)** A milk chilling unit can remove heat from the milk at therate of 41.87MJ/hr. Heat leaks into the milk from the surrounding at an average rate of 4.187MJ/hr. Find the temperature required for cooling a batch of 500 Kg of milk from 45°C to 5°C. Take $C_p$ of milk to be 4.187KJ/kg K.(7) | BT-2 | Understanding |
| 10. | (i) Write the steady flow energy equation of the boiler (6)<br><br>(ii) Air flows steadily at the rate of 0.04 Kg/s through an air compressor, entering at 6m/s with a pressure of 1 bar and specific volume of 0.85 $m^3$/Kg and leaving at 4.5 m/s with a pressure of 6.9 bar and a specific volume of 0.16 $m^3$/Kg. The internal energy of the air leaving is 88 KJ/Kg greater than thatof the entering air. Cooling water surrounding the cylinder absorbs heat from the air at the rate of 59 W. Calculate the power required to drive the compressor and the inlet andoutlet cross sectional areas. | BT-5 | Evaluating |
| 11. | Determine the heat transfer and its direction for a system in which a perfect gas having the molecular weight of 6 is compressed from 101.3 KPa, 20°C to a pressure of 600 KPa following the law $pV^{1.3}$ = C. Take specific heat at constantpressure of a gas is 1.7kJ/Kg-K. | BT-2 | Understanding |

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| 12. | In a gas turbine installation air is heated inside the heat exchanger up to 750°C from the ambient temperature of 27°C. hot air then enters into the gas turbine with a velocity of 50 m/s and leaves at 600°C. Air leaving the turbine enters a nozzle at 60 m/s velocity and leaves the nozzle at the temperature of 500°C. for unit mass of the flow rate of air, Examine the following assuming the adiabatic expansion in the turbine and nozzle.<br>(i) Heat transfer to air in heat exchanger<br>(ii) Power output from turbine<br>(iii) Velocity at the exit of the nozzle. Take $C_p$ of air as 1.005kJ/Kg K | BT-3 | Applying |
| 13. | A three process cycle operating with nitrogen gas as theworking substance has constant temperature compression at 34°C with the initial pressure 100 KPa. Then the gasundergoes a constant volume heating and then polytropic expansion with1.35 as index of compression. The isothermalcompression requires -67 KJ/Kg of work. Point out | | |
| | (i) P, V&T around the cycle. (3)<br>(ii) Heat in and out (4)<br>(iii) Net work (6)<br>For Nitrogen gas $C_v$ = 0.7431KJ/Kg K. | BT-4 | Analysing |
| 14. | In steady flow apparatus, 135 kJ of work is done by each kg of fluid. The specific volume of the fluid, pressure and velocity at the inlet are m$^3$/kg, 600kPa and 16m/s. the inlet is 32m above the floor and the discharge pipe is floor level. The discharge conditions are 0.62m$^3$/kg, 100kPa and 270m/s. the total heat loss between the inlet and discharge is 9 kJ/kg of the fluid. In flowing through this apparatus, does the internal energy increase or decrease and how much? | BT-3 | Applying |
| PART -C | | | |
| 1. | Apply the first law of thermodynamics in human bodies, I.C engines and also compare with them. (15) | BT-5 | Evaluating |
| 2. | Apply and explain the steady flow energy equation conceptfor any two heat transfer devices. (15) | BT-5 | Evaluating |

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| 3. | In water cooling tower air enters at a height of 1 m above theground level and leaves at a height of 7m. The inlet and outlet velocities are 20 m/s and 30 m/s respectively. Water enters at a height of 8m and leaves at a height of 0.8m. The velocity of water at entry and exit are 3 m/s and 1m/s respectively. Water temperatures are 80°C and 50°C at the entry and exit respectively. Air temperatures are 30°C and 70°C at the entry and exit respectively. The cooling tower is well insulated and a fan of 2.25 kW drives the air through thecooler. Find the amount of air per second required for 1 kg/s of water flow. The values of $C_p$ of air and water are 1.005 and 4.187 kJ/kg K respectively. | BT-3 | Applying |
| 4. | A gas of mass 1.5 kg undergoes a quasi-static expansion which follows a relationship $p = a + bV$, where $a$ and $b$ are constants. The initial and final pressures are 1000 kPa and 200 kPa respectively and the corresponding volumes are 0.20m$^3$ and 1.20 m$^3$. The specific internal energy of the gas is given by the relation $u$ = l.5 $pv$ – 85 kJ/kg<br>Where, $p$ is the kPa and $v$ is in m$^3$/kg. Calculate the net heat transfer and the maximum internal energy of the gas attained during expansion. | BT-3 | Applying |

**UNIT II SECOND LAW AND ENTROPY**

Heat Engine – Refrigerator - Heat pump. Statements of second law and their equivalence & corollaries. Carnot cycle - Reversed Carnot cycle - Performance - Clausius inequality. Concept of entropy - T-s diagram – Tds Equations - Entropy change for a pure substance.

**PART-A**

| Q. No. | Question | BT Level | Competence |
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| 1. | State Clausius statement of II law of thermodynamics. | BT-1 | Remembering |
| 2. | Draw a schematic of a heat pump. | BT-6 | Creating |
| 3. | State kelvin Planck's second law statement. | BT-1 | Remembering |
| 4. | Compare difference between adiabatic and isentropic process. | BT-2 | Understanding |
| 5. | Give Carnot theorem and its corollaries. | BT-3 | Applying |
| 6. | An inventor claims to develop an engine which absorbs 100KWof heat from a reservoir at 1000K produces 60 KW of work andrejects heat to a reservoir at 500 K. Will u advise investment in its development? | BT-3 | Applying |
| 7. | What is thermal energy reservoir? Explain the term source andsink. | BT-1 | Remembering |
| 8. | What is reversed heat engine? | BT-1 | Remembering |
| 9. | A turbine gets a supply of 5Kg /s of steam at 7 bar, 250°C and discharges it at 1 bar. Solve the availability. | BT-3 | Applying |

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| 10. | A closed insulated vessel contains 200kg of water. A paddle wheel immersed in the water driven at 400rev/min with an average torque of 500 Nm. If the test run is made of 30 minutes, determine the rise the temperature of the water. A heatengine is supplied with 2512KJ/min of heat at 650°C. heat rejection takes place at 100°C. Specify which of the following heat rejection represents a reversible, irreversible or impossible result<br>a) 867 KJ/min<br>b) 1015 KJ/min | BT-3 | Applying |
| 11. | Compared available energy and unavailable energy. | BT-5 | Evaluating |
| 12. | What is meant by dead state? | BT-1 | Remembering |
| 13. | Sketch the p-V and T - s diagrams for Carnot cycle | BT-6 | Creating |
| 14. | Describe Carnot theorem. | BT-2 | Understanding |
| 15. | In an isothermal process 1000 KJ of work is done by the system at a temperature of 200°C, evaluate entropy change of the process. | BT-5 | Evaluating |
| 16. | What is the principle of increase in entropy? | BT-1 | Remembering |
| 17. | Give Clausius statement. | BT-2 | Understanding |
| 18. | What is the difference between Refrigerator and heat pump? | BT-1 | Remembering |
| 19. | Give reversed Carnot heat engine. What are the limitations of Carnot cycle? | BT-2 | Understanding |
| 20. | Point out the purpose of second law of thermodynamics. | BT-4 | Analysing |

| PART- B | | | |
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| 1. | (i) A reversible heat pump is used to maintain a temperature of 0°C in a refrigerator when it rejects the heat to the surroundings at 25°C. if the heat removal rate from the refrigerator is 1440kJ/min, determine the COP of the machine and the work input required. (6)<br>(ii) If the required input to run the pump is developed by a reversible engine which receives heat at 380°C and rejects heat to the atmosphere and then determines the overall COP of the system. | BT-1 | Remembering |
| 2. | (i) A drug shop is required to maintain certain essential items at - 23°C in a refrigerator. If a Carnot refrigerator having 200W of compressor is used for this purpose, estimate the fraction of time for the compressor would run in a cold country for a cooling rate of40000 kJ/day, where the ambient temperature is 18°C. If the same refrigerator is used in a tropical country where the ambient temperature is 37°C. What shall be the fraction of the compressor run?<br>(ii) Prove Carnot theorem. | BT-1 | Remembering |
| 3. | Three Carnot engines A, B and C working between the temperatureof 1000K and 300K are in a series combination. The works produced by these engines are in the ratios 5:4:3. Make calculationsof temperature for the intermediate reservoirs. | BT-4 | Analysing |

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| 4. | One kg of ice at -5°C is exposed to the atmosphere which is at 20°C. The ice melts and comes in to thermal equilibrium with the atmosphere.<br>A) Determine the entropy increase of the universe.<br>b) What is the maximum amount of work necessary to convert the water back to ice at -5°C.?<br>$C_p$ of ice is 2.093kJ/kg K and latent heat of fusion of ice is 333.3kJ/kg. | BT-5 | Evaluating |
| 5. | A reversible heat engine operates between two reservoirs a temperature of 600°C and 40°C. the engine drives a reversible refrigerator which operates between the reservoirs at temperatures of 40°C and -20°C. the heat transfer to the heat engine is 2000 KJ and the network output for the combined engine refrigerator is 30 KJ. Evaluate the heat transfer to the refrigerant and the net heat transfer to the reservoir at 40°C. | BT-5 | Evaluating |
| 6. | (i) Describe the Carnot cycle and examine the Carnot principles, idealized Carnot heat engine, refrigerators and heat pumps.<br>(ii) Determine the expression for the thermal efficiencies and coefficient of performance for reversible heat engines, heat pump and refrigerators. | BT-3 | Applying |
| 7. | (i) Two Carnot engines A and B are operated in series. The first one receives heat at 870°C and rejects to a reservoir at T. B receives heat rejected by the first engine and in turn rejects to a sink 300 K. calculate the temperature T for<br>(i) Equal work output of both engines (4)<br>(ii) Same efficiencies (4)<br>(iii) Mention Clausius inequality for open, closed and isolated systems. (5) | BT-3 | Applying |

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| 8. | (i) Prove that increase in entropy is a polytrophic process is<br>$\Delta s = mC_v \frac{\gamma - n}{n} \ln(\frac{p_1}{p_2})$ (5)<br>(ii) An irreversible heat engine with 66 % efficiency of the maximum possible is operating between 1000K and 300K. If it delivers 3KW of work, determine the heat extracted from the high temperature reservoir and the heat rejected to the low temperature reservoir. | BT-4 | Analysing |
| 9. | (i) Helium enters an actual turbine at 300KPa and expands to 100 KPa, 150°C. Heat transfer to atmosphere at 101.325KPa, 25°C amounts to 7KJ/Kg. Calculate the entering stream availability, leaving stream availability and the maximum work. For helium, $C_p$=5.2 KJ/Kg and molecular weight= 4.003 Kg/Kg-mol. (8)<br>(ii) List out and explain various caused of irreversibility (5) | BT-1 | Remembering |
| 10. | 5 $m^3$ of air at 2 bar, 27°C is compressed up to 6 bar pressurefollowing $PV^{1.3}$= C. it is subsequently expanded adiabatically to 2 bar. Considering the two processes to be reversible determine the network, net heat transfer, and change in entropy. Also plot the process on PV and TS diagram. | BT-1 | Remembering |

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| 11. | (i) Give available energy and unavailable energy with reference to the thermodynamic cycle. (4)<br>(ii) A fluid undergoes a reversible adiabatic compression from 0.5 MPa, 0.2 $m^3$ to 0.05$m^3$, according to the law $PV^{1.3}$=C. determine the change in enthalpy and entropy and the heat transfer and work transfer during the process. (9) | BT-4 | Analysing |
| 12. | Two kg of air at 500 KPa, 80°C expands adiabatically in a closed system until its volume is doubled and its temperature becomesequal to that of the surroundings which is at 100 KPa, 5°C. forthis process determine:<br>The maximum work<br>The change in availability<br>The irreversibility | BT-3 | Applying |
| 13. | (i) 5 Kg of air at 550 K and 4 bar is enclosed in a closed vessel. Examine the availability of the system if the surrounding pressure and temperature are 1 bar and 290°C. (6)<br>(ii) If the air is cooled at constant pressure to the atmospheric temperature, determine the availability and effectiveness. (7) | BT-3 | Applying |
| 14. | (i) 3 Kg of air at 500 KPa, 90°C expands adiabatically in a closed system until its volume is doubled and its temperature becomes equal to that of the surroundings at 100KPa and 10°C. calculate themaximum work, change in availability and irreversibility. (8)<br>(ii) Briefly discuss about the concept of entropy. (5) | BT-1 | Remembering |
| | **PART-C** | | |
| 1. | The food compartment of refrigerator is maintained at 4°C by removing heat from it at a rate of 360kJ/min. if the required power input to the refrigerator is 2kW, determine the COP of the refrigerator, rate of heat rejection to the room that houses the refrigerator. | BT-6 | Creating |

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| 2. | An air preheater is used to cool the products of combustion from a furnace while heating the air to be used for combustion. The rate offlow of products is 12.5kg/s and the products are cooled from 300°C and 200°C and for the products at this temperature $C_p$=1.09kJ/kg K. the rate of air flow is 1.15kg/s. the initial temperature is 40°C and the air $C_p$=1.005kJ/kg K.<br>Estimate the initial and final availability of the products.What is the irreversibility for the products?<br>If the heat transfer from the product occurs reversibly through heat engine, what is the power developed by the heat engine?<br>Take $T_o$=300K and neglect pressure drop both the fluids and heat transfer to the surroundings. | BT-6 | Creating |

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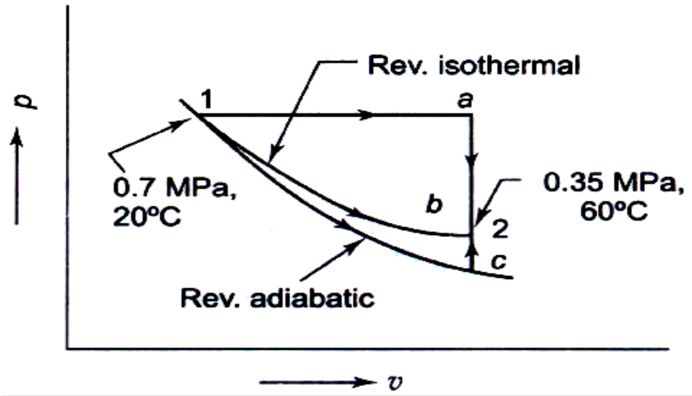
| 3. | One kg of air initially at 0.7 MPa, 20°C changes to 0.35 MPa, 60°Cby the three reversible non-flow processes, as shown in Figure. Process 1: *a*-2 consists of a constant pressure expansion followed by a constant volume cooling, process 1: *b*-2 an isothermal expansion followed by a constant pressure expansion, and process 1: *c*-2 an adiabatic. Expansion followed by a constant volume heating. Determine the change of internal energy, enthalpy, and entropy for each process, and find the work transfer and heat transfer for each process. Take *Cp* = 1.005 and cv = 0.718 kJ/kg K and assume the specific heats to be constant. Also assume for air *pv*= 0.287 T, where *p* is the pressure in kPa, *v* the specific volume in $m^3$/kg, and *T* the temperature in K. (15)   | BT-4 | Analysing |
| 4. | A pressure vessel has a volume of 1 m3 and contains air at 1.4 MPa, 175°C. The air is cooled to 25°C by heat transfer to the surroundings at 25°C. Calculate the availability in the initial and final states and the irreversibility of this process. Take *P*0 = 100 kPa. | BT-5 | Evaluating |

| UNIT III AVAILABILITY AND APPLICATIONS OF II LAW | | | |
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| Ideal gases undergoing different processes - principle of increase in entropy. Applications of II Law. High and low-grade energy. Availability and Irreversibility for open and closed system processes - I and II law Efficiency | | | |
| PART-A | | | |
| **Q. No.** | **Question** | **BT Level** | **Competence** |
| 1. | Define Exergy. | BT-1 | Remembering |
| 2. | What is meant by dead state? | BT-1 | Remembering |
| 3. | Draw P-T (Pressure-Temperature) diagram of a pure substance. | BT-6 | |
| 4. | Give the possible ways to increase thermal efficiency of Rankinecycle. | BT-2 | Understanding |
| 5. | Superheated steam at 30 bar and 300°C enters a turbine and expanded to 5 bar and quality 0.974 dryness, compute the loss in availability for the adiabatic process if the atmospherictemperature is 270°C. | BT-3 | Applying |
| 6. | Define second law of thermodynamics. | BT-1 | Remembering |
| 7. | What is meant by dryness fraction of the steam? | BT-1 | Remembering |
| 8. | Draw the standard Rankine cycle on P-V and T-S coordinates. | BT-6 | Creating |
| 9. | Draw the P-T diagram for water and label all salient points. | BT-6 | Creating |
| 10. | Summarize the advantages of using superheated steam in turbines. | BT-5 | Evaluating |
| 11. | Define pure substance. | BT-1 | Remembering |
| 12. | Give triple point represented in P-V diagram. | BT-2 | Understanding |
| 13. | Define triple point. | BT-1 | Remembering |
| 14. | Explain the terms, Degree of super heat, degree of sub-cooling. | BT-4 | Analysing |
| 15. | Calculate the mass of 0.7 $m^3$ of wet steam at 150°C and 90% dry. | BT-3 | Applying |
| 16. | Analysis the effects of condenser pressure on the Rankine Cycle. | BT-4 | Analysing |
| 17. | Show Carnot cycle cannot be realized in practice for vapourpower cycles. | BT-3 | Applying |
| 18. | Discuss latent heat of vaporization. | BT-2 | Understanding |
| 19. | Name the different components in steam power plant working onRankine cycle. | BT-1 | Remembering |
| 20. | Why is excessive moisture in steam undesirable in steamturbines? | BT-4 | Analysing |

| PART- B | | | |
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| 1. | Steam at 480°C, 90 bar is supplied to a Rankine cycle. It is reheated to 12 bar and 480°C. the minimum pressure is 0.07 bar.Calculate the work output and the cycle efficiency using steam tables with and without considering the pump work. | BT-2 | Understanding |
| 2. | (i)Steam initially at 0.3MPa, 250°C is cooled at constant volume. At what temperature will the steam becomes saturated vapour? What is the steam quality at 80°C. also find what is the heat transferred per kg of steam in cooling from 250°C to 80°C. | BT-1 | Remembering |
| | (ii)When will u call a vapour superheated? Give examples. Also when will you call a liquid as compressed liquid? Give examples. | | |
| 3. | Explain the steam formation with relevant sketch and label all salient points and explain every point in detail. | BT-4 | Analysing |
| 4. | In a Rankine Cycle, the steam at inlet to the turbine is saturatedat a pressure of 35 bar and the exhaust pressure is 0.2 bar.<br>Determine<br>i. The pump work<br>ii. The turbine work<br>iii. The condenser heat flow<br>iv. The dryness at the end of expansion. Assume flow rate of 9.5kg/s. | BT-3 | Applying |
| 5. | Steam initially at 1.5Mpa 300°C expands reversibly and adiabatically to a steam turbine to 40°C. Determine the ideal work output of the turbine per kg of steam. | BT-3 | Applying |
| 6. | A steam power station uses the following cycles.<br>Steam boiler outlet 150 bar and 550°C, Reheat at 40 bar to 550°C, Condenser at 0.1 bar. Using the Mollier chart and assuming ideal processes, find the a) Quality ant turbine exhaust, b) Cycle efficiency,<br>c) Steam rate. Derive the first and second Tds equation. | BT-1 | Remembering |
| 7. | A certain water heater operates under steady flow conditions receiving 4.2 kg/s of water at 75°C, enthalpy 313.93kJ/kg. The water is heatedby mixing with steam which is supplied to the heater at temperature 100.2°C and enthalpy 2676kJ/kg. The mixture leaves the heater as liquid water at temperature 100°C and enthalpy 419kJ/kg. How much steam must be supplied to the heater per hour? | BT-2 | Understanding |
| 8. | A steam power plant operates on a theoretical reheat cycle.Steam at 25 bar pressure and 400°C is supplied to a highpressure turbine. After its expansion to dry state the steam isreheated to a constant pressure to its original temperature.Subsequent expansion occurs in the low pressure turbine to acondenser pressure of 0.04 bar. Considering feed pump work,make calculation to determine (i) quality of steam at the entry tothe condenser (ii) thermal efficiency (iii) specific steam consumption. | BT-2 | Understanding |

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| 9. | (i) Steam initially at 1.5MPa, 300ºC expands reversibly and adiabatically in a steam turbine to 40ºC. Determine the ideal work output of the turbine per kg of steam.<br>(ii) Explain mercury water binary vapor cycle. | BT-2 | Understanding |
| 10. | A vessel having a capacity of 0.05 $m^3$ contains a mixture of saturated water and saturated steam at a temperature of 245°C. the mass of the liquid present is 10 Kg. Calculate the pressure,mass, specific volume, specific enthalpy, specific entropy, andspecific internal energy. | BT-5 | Evaluating |
| 11. | A steam power plant operates on theoretical reheat cycle. Steam in boiler at 150 bar, 550°C expands through the high pressure turbine. It is reheated to a constant pressure of 40 bar to 550°C and expands through the low pressure turbine to a condenser at bat. Draw T-s and h-s diagram. Find:<br>i. Quality of the steam at the turbine exhaust. | BT-2 | Understanding |

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| | ii. Cycle efficiency<br>iii. Steam rate in kg/kW-hr | | |
| 12. | (i) Steam at 30 bar and 350°C is expanded in a non-flow isothermal process to a pressure of 1 bar. The temperature andthe pressure of the surroundings are 25°C and 100KParespectively. Determine the maximum work that can be obtainedfrom this process per kg of steam. Also find the maximum usefulwork.<br>(ii) Write the aid of T-v diagram explain various phases of conversion of ice at -20°C to steam at 125°C. | BT-6 | Creating |
| 13. | (i) With the help of the schematic diagram, explain the regenerative Rankine cycle and derive the expression for its efficiency. Also represent the process in p-v and T-s diagrams.<br><br>**(i)** Steam at 50 bar and 400°C expands in a Rankine cycle to 0.34 bar. For a mass flow rate of 150 Kg/s of steam, determine<br>Power developed<br>Thermal efficiency<br>Specific steam consumption | BT-1 | Remembering |

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| 14. | Consider a steam power plant that operates on a reheat Rankine cycle and has a net power output of 80MW. Steam enters the high pressure turbine at 10 MPa and 500˚C and the low pressure turbine at 1 MPa and 500˚C. Steam leaves the condenser as a saturated liquid at a pressure of 10 KPa. The isentropic efficiency of the turbine is 80 percent, and that of the pump is 95percent. Show the cycle on a T-s diagram with respect to saturation lines, and determine,<br>(i) The quality (or temperature, if superheated) of the steam atthe turbine exit,<br>(ii) The thermal efficiency of the cycle, and<br>(iii) The mass flow rate of the steam. | BT-5 | Evaluating |
| PART- C | | | |
| 1. | Steam at a pressure of 15 bar and 300ºC is delivered to the throttle of an engine. The steam expands to 2 bar when releaseoccurs. The steam exhaust takes place at 1.1 bar. A performancetest gave the result of the specific steam consumption of 12.8kg/kWh and a mechanical efficiency of 80 percent. Determine:<br>i. Ideal work or the modified Rankine engine work per kg.<br>ii. Efficiency of the modified Rankine engine (or) ideal thermal efficiency.<br>iii. The indicated and brake work per kg.<br>iv. The brake thermal efficiency.<br>v. The relative efficiency on the basis of indicated work and brake work. | BT-5 | Evaluating |

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| 2. | A steam power plant equipped with regenerative as well as reheat arrangement is supplied with steam to the H.P. turbine at 80 bar 470ºC. For feed heating, a part of steam is extracted at 7 bar and remainder of the steam is reheated to 350ºC in a reheaters and then expanded in L.P. turbine down to 0.035bar. Determine: 1. Amount of steam bled-off for feed heating. 2. Amount of steam supplied to L.P. turbine. 3. Heat supplied in the boiler and reheater.4. Cycle efficiency and 5. Power developed by the system. The steam supplied by the boiler is 50 kg/s. | BT-5 | Evaluating |
| 3. | Steam flows through a small turbine at the rate of 5000 kg/h entering at 15 bar, 300°C and leaving at 0.1 bar with 4% moisture. The steam enters at 80 m/s at a point 2 in above the discharge and leaves at 40 m/s. compute the shaft power assuming that the device is adiabatic but considering kinetic and potential energy changes. How much error would be made if these terms were neglected? Calculate the diameters of the inlet and discharge tubes. | BT-6 | Creating |

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| 4. | The net power output of an ideal regenerative-reheat steam cycle is 80MW. Steam enters the H.P. turbine at 80 bar, 500°C and expandstill it becomes saturated vapor. Some of the steam then goes to an open feed water heater and the balance is reheated to 400°C, after which it expands in the I.P. turbine to 0.07 bar. Compute (a) the reheat pressure, (b) the steam flow rate to the H.P. turbine, and (c) the cycle efficiency. Neglect pump work. | BT-6 | Creating |

**UNIT IV Ideal And Real Gases, Thermodynamic Relations**

Properties of Ideal gas- Ideal and real gas comparison- Equations of state for ideal and real gases-Reduced properties-.Compressibility factor-.Principle of Corresponding states. -Generalized Compressibility Chart and its use-. Maxwell relations, Tds Equations, Difference and ratio of heat capacities, Energy equation, Joule-Thomson Coefficient, Clausius Clapeyron equation, Phase Change Processes. Simple Calculations

PART-A

| Q. No. | Question | BT Level | Competence |
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| 1. | Define Avogadro's law. | BT-1 | Remembering |
| 2. | What is real gas? Give examples. | BT-1 | Remembering |
| 3. | What is known as equation of state and when it can be used forengineering calculations? | BT-3 | Applying |
| 4. | What are known as thermodynamic gradients? | BT-1 | Remembering |
| 5. | What is Joule-Thomson coefficient? Why is it zero for an ideal gas? | BT-1 | Remembering |
| 6. | What is the law of corresponding states? | BT-1 | Remembering |
| 7. | A domestic food freezer maintains a temperature of -15°C. Theambient air temperature is 30°C. If the heat leaks in to the freezer 1.75 KJ/s continuously, calculate the least powernecessary to pump this heat out continuously. | BT-2 | Understanding |
| 8. | One Kg of ideal gas is heated from 18°C to 93°C. TakingR=269Nm/Kg -K and $\gamma$=1.2 for the gas. Calculate the change in internal energy | BT-2 | Understanding |
| 9. | Give are the assumptions made to derive ideal gas equationanalytically using the kinetic theory of gases. | BT-2 | Understanding |
| 10. | Using Clausius-Clapeyron equation, estimate the enthalpy of vaporization at 200°C. $V_g$=0.1274 $m^3$/Kg; $V_f$= 0.01157 $m^3$/Kg;dp/dt= 32KPa/K. | BT-2 | Understanding |
| 11. | Find the mass of 0.7 $m^3$ of wet steam at 150°C and 90% dry. | BT-2 | Understanding |
| 12. | How does the Vander Waal's equation differ from the ideal gas equation of state? | BT-2 | Understanding |
| 13. | Draw a generalized Compressibility Chart and its significance. | BT-1 | Remembering |
| 14. | What is Coefficient of Volume of Expansion? | BT-5 | Evaluating |
| 15. | Write down two Tds relations. | BT-1 | Remembering |
| 16. | What is equation of state and write the same for ideal gas? | BT-1 | Remembering |

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| 17. | Determine the molecular volume of any perfect gas at 600 $N/m^2$ and 30°C. Universal gas constant may be taken as 8314 J/Kgmole- K. | BT-2 | Understanding |
| 18. | Write the Maxwell's equations and its significance. | BT-6 | Creating |
| 19. | What is compressibility factor? | BT-1 | Remembering |
| 20. | Define isothermal Compressibility. | BT-1 | Remembering |
| PART- B | | | |
| 1. | (i) Derive Clausius Clapeyron equation. What are theassumptions made in this equation?<br>(ii) Consider an ideal gas at 303 K and $0.86m^3/Kg$. As a resultof some disturbance the state of gas changes to 304 K and $0.87m^3/Kg$. Estimate the change in pressure of the gas as the result of this disturbance. | BT-6 | Creating |

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| 2. | What are the properties of ideal gas? What are the major assumptions made in kinetic theory of gases to derive the ideal gas equation? | BT-5 | Evaluating |
| 3. | The gas neon has a molecular weight of 20.183 and its critical temperature pressure and volume are 44.5 K, 2.73 MPa and 0.0416 $m^3/Kg$ mol. Reading from a compressibility chart for areduced pressure of 1.3, the compressibility factor Z is 0.7.<br>What are the corresponding specific volume, pressure,temperature and reduced volume? | BT-1 | Remembering |
| 4. | (i) Under what conditions, a real gas behaves like an ideal gas? why?<br>(ii) Can you use the relation $\Delta H = m\,C_p(T_2 - T_1)$ to calculate the change in total internal energy of an ideal and real gas? if yes, for which process? If no, why? | BT-2 | Understanding |
| 5. | Nitrogen gas is stored at 175 K and 9500 kPa in a container.Calculate the specific volume of the gas if it is considered as<br>(i) ideal gas and (ii) van der Waals gas and (iii) Alsocalculate the compressibility factor. Use the constants: 0.175 kPa. $M^6/Kg^2$ and 0.00138 $m^3/Kg$ | BT-2 | Understanding |
| 6. | Derive any three Maxwell relations. | BT-2 | Understanding |
| 7. | Determine the pressure of nitrogen gas at T=175 K and v = $0.00375m^3/Kg$ on the basis of<br>a. The ideal gas equation of state.<br>b. The van der Walls equation of state.<br>c. The van der Walls constant for nitrogen are$\alpha$=$0.175m^6$-KPa/Kg; b=$0.00138m^3/Kg$ | BT-2 | Understanding |
| 8. | Show that the family of constant pressure lines in the wet region of a Mollier diagram are straight but diverging lines and that the slope of a constant pressure line in the superheat region increase with temperature. | BT-6 | Creating |

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| 9. | (i) Explain Joule Kelvin effect. What is inversion temperature?<br>(ii) A certain gas has $C_p$=1.968kJ/kg K and $C_v$=1.505kJ/kg K. Find its molecular weight and the gas constant. A constant volume chamber of 0.3$m^3$ capacity contains 2kg of this gas at 5°C. Heat is transferred to the gas until the temperature is 100°C. Find the work done, heat transferred and the changes in internal energy, enthalpy and entropy. | BT-6 | Creating |
| 10. | (i) Derive the Clausius Clapeyron equation and discuss itssignificance.<br>(ii) Write down two Tds relation. | BT-4 | Analysing |
| 11. | (i) What are the differences between real and ideal gases?<br>(ii) Write down the Vander Waal's equation of state for real gases and how is it obtained from ideal gas equation by incorporating real gas corrections? | BT-2 | Understanding |

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| 12. | Determine the specific volume of water vapour at 110 bar and 841 K by (i) the ideal gas equation of state, (ii) the principle of corresponding state and (iii) the super heat steam table. (iv) Also calculate the % of error in the volume obtained by ideal gas equation and that by the principle of corresponding state. Take, $p_c$ = 221.2 bar and $T_c$ = 647 C. Use generalized compressibility chart. | BT-1 | Remembering |
| 13. | The pressure and temperature of mixture of 4 kg of $O_2$ and 6 kg of $N_2$ and 4 bar and 27°C respectively. For the mixturedetermine the following;<br>a) The mole fraction of each component<br>b) The average molecular weight<br>c) The specific gas constant<br>d) The volume and density<br>e) The partial pressure and partial volume. | BT-5 | Evaluating |
| PART- C | | | |
| 1. | Show that slope of the sublimation curve at the triple point isgreater than that of vaporization curve on P-T diagram, using<br>(i) latent heat and (ii) entropy change. | BT-3 | Applying |
| 2. | Explain compressibility factor and compressibility chart. | BT-1 | Remembering |
| 3. | A vessel is divided into three compartments (a), (b), and (c) by two partitions. Part (a) contains oxygen and has a volume of 0.1 $m^3$, (b) has a volume of 0.2 $m^3$ and contains nitrogen, while (c) is 0.05 $m_3$ and holds $CO^2$ All three parts are at a pressure of 2 bar and a temperature of 13°C. When the partitions are removed and the gasesmix, determine the change of entropy of each constituent, the final pressure in the vessel and the partial pressure of each gas. The vessel may be taken as being completely isolated from itssurroundings. | BT-2 | Understanding |
| 4. | Prove that Joule – Thomson co-efficient $\mu = \left(\frac{\partial T}{\partial p}\right)_h = \frac{T^2}{C_p}\left[\frac{\partial}{\partial T}\left(\frac{V}{T}\right)\right]_p$ | BT-5 | Evaluating |

| UNIT V GAS MIXTURES AND THERMODYNAMIC RELATIONS<br>Properties of Ideal gas, real gas - comparison. Equations of state for ideal and real gases. Vander Waal's relation - Reduced properties - Compressibility factor - Principle of Corresponding states – Generalized Compressibility Chart. Maxwell relations - TdS Equations - heat capacities relations - Energy equation, Joule Thomson experiment - Clausius-Clapeyron equation. | | | |
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| **PART-A** | | | |
| **Q. No.** | **Quest ion** | **BT Level** | **Competence** |
| 1. | Summarize why humidification of air is necessary. | BT-5 | Evaluating |
| 2. | How the wet bulb temperature does differ from the dry bulbtemperature? | BT-2 | Understanding |
| 3. | Define adiabatic saturation temperature. | BT-1 | Remembering |
| 4. | What is bypass factor? | BT-1 | Remembering |
| 5. | Define dew point temperature. | BT-1 | Remembering |
| 6. | What is chemical dehumidification? | BT-1 | Remembering |
| 7. | Carnot refrigerator requires 1.25 KW per ton of refrigeration tomaintain the temperature of 243 K. Find the COP of Carnot refrigerator. | BT-2 | Understanding |
| 8. | Ice is formed at 0°C from water at 20°C. the temperature of thebrine is -10°C. find the ice formed per KW hour. Assume that refrigeration cycle used is perfect reversed Carnot cycle. Latentheat of ice = 80Kcal/Kg. | BT-2 | Understanding |
| 9. | Analyse is Amagat’s law. | BT-4 | Analysing |
| 10. | What is sensible heating? | BT-1 | Remembering |
| 11. | Define molar mass. | BT-1 | Remembering |
| 12. | Analyse sensible heat factor. | BT-4 | Analysing |
| 13. | Summarize why wet clothes dry in sun faster. | BT-1 | Remembering |
| 14. | Define degree of saturation. | BT-1 | Remembering |
| 15. | Sketch the Cooling and dehumidifying process on a skeleton Psychrometric chart | BT-6 | Creating |
| 16. | Using the definitions of mass and mole fractions, derive a relation between them. | BT-6 | Creating |
| 17. | Point out the process in psychometric chart. | BT-4 | Analysing |
| 18. | What is the difference between the dry air and atmospheric air? | BT-5 | Evaluating |
| 19. | What do you understand by Dew Point Temperature? | BT-5 | Evaluating |

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| 20. | Illustrate the need of psychometric process. | BT-5 | Evaluating |

| PART- B | | | |
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| 1. | The mixture of 2kg of $H_2$ and 4kg of $N_2$ at initial temperature of 22°C is compressed in a cylinder-piston arrangement so that its temperature rises to 150°C. The mean values of $C_p$ over this temperature range for two constituents ate 14.45kJ/kg K and 1.041kJ/kg K for $H_2$ and $N_2$ respectively. Assuming the process to be reversible and polytropic with an index of 1.2. Find the heat transfer during the process and change of entropy of each constituents and the mixture. | BT-5 | Evaluating |
| 2. | A tank of $0.2m^3$ capacity contains $O_2$ at 15 bar and 400°C. Asecond tank $0.5m^3$ contains $N_2$ at 20 and 300°C. the two tansare connected together and allowed to mix. The heat lostduring mixing is 50 KJ. Determine the final pressure, final temperature of the mixture and net entropy change due to mixing. | BT-2 | Understanding |
| 3. | Five moles of gas mixture contains 45% $N_2$, 27% He and 28%$C_6H_6$ by mass. Find (i) the analysis by volume and the number of moles of each constituent (ii) the volume of mixture at 3.5bar pressure and 20°C. | BT-2 | Understanding |
| 4. | (i) Write down the Dalton's law of partial pressure and explain its importance. 0.45 Kg of CO and 1 Kg of air is contained in a vessel of volume 0.4 $m^3$ at 15°C. Air has 3.3% of $O_2$ and 76.7% of $N_2$ by mass. Calculate the partial pressure of each constituents and total pressure in the vessel. Molar masses of CO, $O_2$ and $N_2$are 28, 32 and 28 kg/K- mol. | BT-5 | Evaluating |
| 5. | (i) An air water vapour mixture enters an air conditioning unit at pressure of 1.0 bar and 38 °C DBT, and a relative humidity of 75%. The mass of dry air entering is 1Kg/s. The air-vapour mixture leaves the air conditioning unit at 1 bar, 18°C, 85% relative humidity. The moisture condensed leaves at 18°C.<br>(ii) Determine the heat transfer rate for the process. | BT-2 | Understanding |

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| 8. | (i) Explain adiabatic evaporative cooling.<br>(ii) Air at 20°C, 40% relative humidity is mixed adiabatically with air at 40°C, 40% relative humidity in the ratio of 1 Kg of the former with 2 Kg of the latter (on dry basis). Find the condition of air. | BT-2 | Understanding |

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| 9. | (i) Derive the sensible heat factor for cooling and dehumidification process. Also explain the process.<br>(ii) One kg of air at 40°C DBT and 50% RH is mixed with 2Kg of air at 20°C DBT and 20°C dew point temperature. Calculate the temperature and specific humidity of the mixture. | BT-6 | Creating |
| 10. | (i) Prove that specific humidity of air is =0.622<br>(ii) With the aid of model psychrometric chart explain thefollowing process<br>(i) Adiabatic mixing<br>(ii) Evaporative cooling | BT-5 | Evaluating |
| 11. | Atmospheric air at 1.01325 bar has a DBT of 30°C and WBTof 25°C. Compute;<br>i. The partial pressure of the water vapour<br>ii. Specific humidity<br>iii. Dew point temperature<br>iv. Relative humidity<br>v. Degree of saturation<br>vi. Density of air in the mixture<br>vii. Density of vapour in the mixture<br>viii. Enthalpy of the mixture (use thermodynamics tableonly). | BT-3 | Applying |
| 12. | 120 $m^3$ of air per minute at 35°C DBT and 50% relative humidity is cooled to 20°C DBT by passing through coolingcoil. Determine the following<br>a. Relative humidity of out coming air and its WBT.<br>b. Capacity of cooling coils in tones of refrigeration.<br>c. Amount of water vapour removed per hour. | BT-3 | Applying |
| 13. | (i) Briefly discuss about evaporative cooling process.<br>(ii) Explain adiabatic saturation process with a schematic. | BT-5 | Evaluating |
| 14. | Explain the following Air Conditioning Process.<br>a) Sensible cooling and Sensible heating process.<br>b) Cooling and dehumidification process.<br>c) Evaporative cooling. | BT-3 | Applying |
| PART-C | | | |
| 1. | An insulated vessel containing 1 mole of oxygen at a pressure of 2.5 bar and temperature of 293 K is connected through a valve to a second insulated rigid vessel containing 2 mole nitrogen at a pressure of 1.5 bar and a temperature of 301 K. The valve is opened and adiabatic mixing takes place. Assuming that oxygen and nitrogen are prefect gases calculatethe entropy change in the mixing process. Assume Specific heats at $C_v$ for oxygen =0.39 kJ/kg-K and nitrogen=0.446 | BT-6 | Creating |

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| | kJ/kg-K. | | |
| 2. | Atmospheric air at 43°C and 40% RH is to be conditioned to a temperature of 25°C and 50% RH. The method employed is to lower the temperature to dew point of conditioned air and then to raise it to the required temperature. The volume of the conditioned air is $25m^3$/min. Find<br>A) Dew Point<br>b) Mass of water vapor drained out.<br>c) Amount of heat required to raise the temperature from the dewpoint to that of the conditioned air. | BT-6 | Creating |
| 3. | Consider the room contains air at 1 atm, 35°C and 40% RH. Using the psychrometric chart determine, specific humidity, enthalpy, WBT, DPT, specific volume of the air. | BT-2 | Understanding |
| 4. | Discuss the practical application of the adiabatic mixing oftwo streams and derive the expression for mass ratio. | BT-5 | Applying |