QUESTION BANK

Name of the Department : **Mechanical Engineering**

Subject Code & Name : **ME 8391 & Engineering Thermodynamics**

Year & Semester : **II & III**

UNIT – I

BASIC CONCEPT & FIRST LAW

PART A

1. **What is heat?**

   Heat is defined as an energy crossing the boundary of the system due to the temperature difference between system and surroundings.
   It is usually expressed by Q and unit is joules.

2. **Prove that C_p-C_v = R.**

   Consider a gas heated at constant pressure
   So, heat supplied, $Q = mC_p (T_2-T_1)$
   Work done, $W = p (V_2-V_1) = m R (T_2-T_1)$
   Change in internal energy $\Delta U = mC_v (T_2-T_1)$
   According to First law of thermodynamics,

   $$Q = W + \Delta U$$

   $$mC_p (T_2-T_1) = mR (T_2-T_1) + mC_v (T_2-T_1)$$

   $$C_p = R + C_v$$

   $$C_p - C_v = R$$

3. **State zeroth law of thermodynamics.**

   Zeroth law of thermodynamics states that, “when two systems are in thermal equilibrium with a third system, then they themselves are in thermal equilibrium with each other”.

4. **Write the corollaries of first law of thermodynamics**.

   There exists a property of a closed system such that a change in the value is equal to the difference between the heat supplied and the work done during any change of state.
   The internal energy of a closed system remains constants if the system is isolated from its surroundings.
   A perpetual motion machine of first kind (PMM-I) is impossible.

5. **What is the convention for positive and negative work?**

   Work done by the system is denoted as positive work and work done on the system is denoted as negative work.

6. What is PMM-I? Why it is impossible?

PMM of first kind delivers work continuously without any input. It violates the first law of thermodynamics.
It is impossible to construct an engine working with this principle.

7. Define cycle.

It is defined as a series of state changes such that the final state is identical with the initial state.

Eg: Air standard cycle, vapour power cycles

8. Define process.

It is defined as the change of state undergone by a gas due to energy flow.
Eg: Constant volume process, adiabatic process

9. Define temperature.

It is defined as the measure of velocity of fluid particles. It is a property of which is used to determine the hotness or cold ness or the level of heat intensity of a body.

10. **Define thermodynamic system**.

A thermodynamic system is defined as a quantity of matter or a region in space, on which the analysis of the problem is concentrated.

11. Define thermodynamic work.

It is the work done by the system when the energy transferred across the boundary of the system. It is mainly due to the intensive property difference between the system and surrounding.

12. What is the difference between classical and the statistical approaches to thermodynamics?

The properties of matter such as pressure, velocity position and energy of the individual molecule at a given instant or at a particular time studied. This approach is known as statistical thermodynamics.

Instead of studying parameters at molecular level, the behavior of the total system in terms of properties such as pressure, volume, temperature etc. are studied. These properties at every instant can be easily measured called classical thermodynamics.

13. State first law of thermodynamics.

It states that, “when a system undergoes a cyclic process, the net heat transfer is equal to work transfer”.

$$\oint Q = \oint W$$

14. Define point function.

The quantity which is independent on the process or path followed by the system is known as point function.
Eg: pressure, volume, temperature

15. Define path function.

The quantity which is dependent on the process or path followed by the system is known as path function.
Eg: Heat transfer, Work transfer

16. **Define thermodynamic equilibrium.**

If a system is in mechanical, thermal and chemical equilibrium then the system is in thermodynamically equilibrium.
(Or)
If the system is isolated from its surrounding there will be no change in the macroscopic property, then the system is said to exist in a state of thermodynamic equilibrium.

17. What is the difference between closed system and open system?

Sl.no	Closed system	Open system
1.	18. No mass transfer	Mass transfer takes place.
2.	19. Only work and heat transfer	In addition to the heat and work transfer.
3.	20. System boundary is fixed one.	System boundary may or may not change.
4.	21. Eg: piston &cylinder arrangement	Eg: Air compressor, boiler

22. **Name and explain the two types of properties.**

The two types of properties are intensive property and extensive property.
Intensive property: It is independent of the mass of the system.
Example: pressure, temperature, specific volume, specific energy.
Extensive property: It is dependent on the mass of the system.
Example: Volume, Energy. If the mass is increased the values of the extensive properties also increase.

23. Show that the energy of an isolated system is always constant.

For any isolated system, there is no heat, work and mass transfer.
$Q = W = 0$
According to first law of thermodynamics,
$Q = W + \Delta U$
$\Delta U = 0$; $U_1 = U_2$.

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PART B

1. Derive the expression for polytrophic process.
2. Derive the expression for isochoric and isothermal process.
3. Derive expression for isentropic process.
4. A piston and cylinder machine contains a fluid system which passes through a complete cycle of four processes. During a cycle, the sum of all heat transfer is -170kJ. The system completes 100 cycles per min. Complete the following table showing the method for each item, and computes the net rate of work output in kW.

5. Process	6. Q (kJ/min)	7. W (kJ/min)	8. ΔE (kJ/min)
9. a-b	10. 0	11. 2170	12. -
13. b-c	14. 21000	15. 0	16. -
17. c-d	18. -2100	19. -	20. -36600
21. d-a	22. -	23. -	24. -

25. The internal energy of certain substance is given by the following equation u=3.56pV+84, where u is given in kJ/kg, p is in kPa, and v is in m^3/kg. A system composed of 3 kg of this substance expands from an initial pressure of 500 kPa and a volume of $0.22m^3$ to a final pressure 100 kPa in a process in which pressure and volume are related by $pv^{1.2}$= constant.
    a. If the expansion is quasi-static, find Q, ΔU, and W for the process.
    b. In another process the same system expands according to the same pressure volume relationship as in part (a), and form the same initial state to the same final state as in part (a), but the heat transfer in this case is 30 kJ. Find the work transfer for this process. Explain the difference in work transfer in parts (a) and (b).

26. A fluid is confined in a cylinder by a spring loaded frictionless piston so that the pressure in the fluid is a linear function of volume p=a+bV. The internal energy of the fluid is given by following equation u=34+3.15pV, where u in kJ, p in kPa, V in m^3, if the fluid changes from the initial state of 170 kPa, $0.03m^3$ to final state of 400 KPa and $0.06m^3$, with no other work done on the piston, find the direction and magnitude of work and heat transfer.

27. A piston cylinder device operates 1 kg of fluid at 20 atm.pressure. The initial volume is 0.04 m^3. The fluid is allowed to expand reversibly following a process $pV^{1.45}$=constant so that the volume becomes double. The fluid is then cooled at constant pressure until the piston comes back to the original position. Keeping the piston unaltered, heat is added reversibly to restore it to the initial pressure. Calculate the work done in the cycle.
28. A mass of air is initially at 260°C and 700 kPa occupies a volume of $0.028m^3$. The air is expanded at constant pressure to $0.084m^3$. A polytropic process with n=1.5 is then carried out, followed by constant temperature process. All the process is reversible. Sketch the cycle in p-V and Ts diagram, find the heat received and rejected from the cycle and efficiency of the cycle.
29. Air flows steadily at a rate of 0.5 kg/s through an air compressor, entering at 7 m/s velocity, 100 kPa pressure, and 0.95 m^3/kg volume and leaving at 5 m/s, 700 kPa, 0.19 m^3/kg volume. The internal energy of air leaving is 90 kJ/kg greater than that of air entering. Cooling water in the compressor jackets absorbs heat from the air at the rate of 58 kW. (a) Compute the rate of shaft work input to the air in kW. (b) Find the ratio of inlet pipe diameter to outlet pipe diameter.
30. In a 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 0.37 m^3/kg, 600 kPa, and 16 m/s. The inlet is 32 m above the floor, and the discharge pipe is at floor level. The discharge conditions are 0.62 m^3/kg, 100 kPa, and 270 m/s. the total heat loss between

the inlet and discharge is 9 kJ/kg of fluid. In flowing through is apparatus, does the specific internal energy increase or decrease, and by how much?

31. In a steam power station, steam flows steadily through a 0.2 m diameter pipeline from the boiler to the turbine. At the boiler end, the steam conditions are found to be: p=4 MPa, T=400°C, h=3213.6 kJ/kg and v=0.073 m^3/kg. At the turbine end, the conditions are found to be: p=3.5 MPa, T=392°C, h= 3202.6 kJ/kg and v= 0.084 m^3/kg. There is a heat loss of 8.5 kJ/kg from the pipeline. Calculate the steam flow rate.
32. Air at temperature of 15°C passes through a heat exchanger at a velocity of 30m/s where its temperature is raised to 800°C. It then enters a turbine with the same velocity of 30 m/s and expands until the temperature falls to 650°C. On leaving the turbine, the air is taken at a velocity of 60 m/s to a nozzle, where it expands until the temperature has fallen to 500°C. if the air flow rate is 2 kg/s, calculate
    a. Rate of heat transfer to air in the heat exchanger
    b. Power output from the turbine assuming no heat loss
    c. Velocity at the exit if the nozzle, assuming no heat loss.
    d. Take enthalpy of air as h= C_pT, C_p is the specific heat 1.005 KJ/KgK and T is the temperature.

33. In a gas turbine the gas enters at the rate of 5 kg/s with a velocity of 50 m/s and enthalpy of 900 kJ/kg and leaves the turbine with a velocity of 150 m/s and enthalpy of 400 kJ/kg. the loss of heat from the gases to the surroundings is 25 kJ/kg. Assume for gas R=0.285 kJ/kgK and cp=1.004 kJ/kgK and inlet conditions to be at 100 kPa and 28°C. Determine the power output of the turbine and the diameter of the pipe.
34. A room for four persons has two fans, each consuming 0.18 kW power, and three 100 W lamps. Ventilation air at the rate of 80 kg/hr enters with an enthalpy of 84 kJ/kg and leaves with an enthalpy of 59 kJ/kg. If each person puts out heat at the rate of 630 kJ/hr. Determine the rate at which heat is removed by a room cooler, so that a steady state is maintained in the room.
35. Derive the steady flow energy equation with its engineering applications.

UNIT II – SECOND LAW, ENTROPY & AVAILABILITY

PART A

1. Deduce the relation between the COP of heat pump and the refrigerator.

$COP_{ref} = \frac{Q_2}{Q_1 - Q_2}$

Adding 1 on both sides,

$$1+ COP_{ref} = 1+\frac{Q_2}{Q_1-Q_2}$$

$$= \frac{Q_1-Q_2+Q_2}{Q_1-Q_2} = \frac{Q_1}{Q_1-Q_2}$$

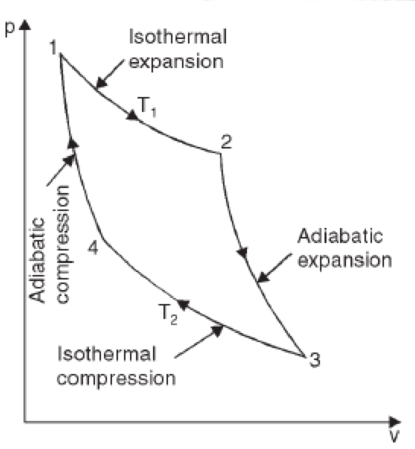
We know that, $COP_{hp} = \frac{Q_1}{Q_1-Q_2}$

Hence, $COP_{hp} = 1+COP_{ref}$

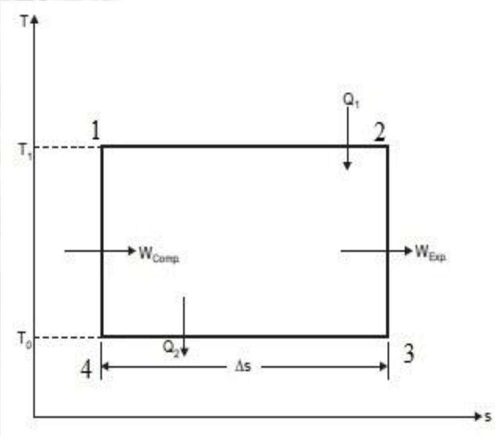
1. **What is meant by thermodynamic temperature scale?**

   A temperature scale that is independent of the properties of the substances that are used to measure temperature is called thermodynamic temperature scale.

2. **What is the process involved in a Carnot cycle? Sketch the P-V and T-S diagram.**



3. P-V diagram



4. T-S diagram

PATH	PROCESS
1-2	Isothermal process with heat addition
2-3	Adiabatic expansion process
3-4	Reversible isothermal heat rejection
4-1	Reversible adiabatic compression process

5. **State the Kelvin Planck statement of II law of thermodynamics.**

   It is impossible to construct a heat engine to produce network in a complete cycle, if it exchanges heat from a single reservoir at single fixed temperature.

6. **Why the II law of thermodynamics is called a directional law of nature?**

   In addition to first law of thermodynamics, it governs the direction in which a process can take place. This principle is known as II law of thermodynamics.

7. **What do you understand by concept of entropy?**

   i. Entropy is a function of a quantity of heat which shows the possibility of conversion of that heat into work.

i. (Or)
ii. Entropy is an index of unavailability or degradation of energy.

8. What is loss of availability? How it is related to entropy of universe?

1. The portion of the energy supplied as heat, which cannot be converted into work due to friction is called as unavailable energy.
2. Unavailable energy, U.A.E = Total heat energy – Available energy
   i. = Q – A.E
   ii. = Q- [Q-T_0.ΔS]
   iii. = T_0. ΔS [because, ΔS = Entropy of universe]

9. Give Clausius statement of II law of thermodynamics.

"Heat cannot flow from cold reservoir to hot reservoir without any external aid. But, heat can flow from hot reservoir to cold reservoir without any external aid".

10. What is the principle of increase of entropy?

For any infinitesimal process undergone by a system, $dS \geq \frac{dQ}{T}$

For reversible, dQ = 0, hence, dS = 0
For irreversible, dS >0.
So, the entropy of an isolated system can never decrease. It always increases and remains constant only when the process is reversible. This is known as principle of increase in entropy or entropy principle.

11. What is the difference between a refrigerator and a heat pump?

1. A refrigerator is a device which operating in a cycle process, maintains the temperature of cold body lower than the temperature of the surrounding.
2. Heat pump is a device which operating a cyclic process maintains the temperature of a hot body higher than the temperature of the surrounding.

12. A reversible heat engine works between the temperature limits of 600 K and 300 K. find the efficiency.

$\eta_{HE} = \frac{T_1 - T_2}{T_1} = \frac{600-300}{600} = 50\%$

13. What is internal irreversibility and external irreversibility?

The irreversibility is in the process due to thermodynamic properties alone is called internal irreversibility. **Eg**: Unrestricted expansion of gas, viscosity and inertia of gas.
The irreversibility is in the process due to external source alone is called external irreversibility. **Eg**: heat dissipation from system to surrounding.

14. What is a cyclic heat engine?

A cyclic heat engine is a device, which is used to convert the thermal energy into mechanical energy.

15. What is absolute entropy?

The entropy measured for all perfect crystalline solids at absolute zero temperature is known as absolute entropy.

16. Define - PMM of second kind.

A heat engine, which converts whole of the heat energy into mechanical work, is known as Perpetual motion machine of the second kind.

PART B

1. Acyclic heat engine operates between a source temperature of 800°C and sink temperature of 30°C. What is the least rate of heat rejection per kW net output of the engine?
2. A domestic food freezer maintains a temperature of -15°C. The ambient air temperature is 30°C. If heat leaks into the freezer at the continuous rate of 1.75 kJ/s, what is the least power necessary to pump this heat out continuously?
3. A Carnot heat engine takes heat from an infinite reservoir at 550°C and rejects to sink at 275°C. Half of the work delivered by the engine is used to run generator and other half is used to run heat pump which takes heat at 275°C and rejects it at 440°C. Express the heat rejected at 440°C by the heat pump as % of heat supplied to the engine at 550°C. If the operation of the generator is 500KW, find the heat rejected per hour by the heat pump at 440°C.
4. A reversible heat engine operates between two reservoirs at temperatures of 600°C and 40°C. The engine drives a reversible refrigerator operating between reservoirs of temperatures of 40°C and -20°C. The heat transfer of the heat engine is 2000 kJ and the network output of the combined engine refrigerator plant is 360 kJ.
   i. Evaluate the heat transfer to the refrigerant and the net heat transfer to the reservoir at 40°C.
   ii. Reconsider (a) given that the efficiency of the heat engine and the COP of the refrigerator are each 40% of their maximum possible values.
5. A heat engine is used to drive a heat pump. The heat transfer from the heat engine and heat pump is used to heat the water circulating through the radiators of buildings. The efficiency of heat engine is 27% and COP of heat pump is 4. (i) Draw the neat diagram and (ii) evaluate the ratio of heat transfer to the circulating water to the heat transfer to the heat engine.
6. An inventor claims that his new engine will develop 30KW for a heat addition of 240 KJ/min. The highest and the lowest temperature of the cycle are 1527°C and 327°C respectively. Would you agree his claim? Use Clausius inequality method.

7. Three identical bodies of A, B and C has constant heat capacity at temperatures of 300, 300 and 100K. A heat engine is operated between A and B. And a heat pump working as refrigerator is operated between B and C. The heat pump is operated by the output of heat engine. If no work or heat supplied from outside, find the highest temperature to which any one of the body can be raised by the operation of heat engine or refrigerator.
8. Two reversible heat engines A and B are arranged in series. A rejecting heat directly to B, A engine receives 200 KJ at a temperature of 421°C from a hot source, while engine B is in communication with cold sink at a temperature of 4.4°C. If the work output of engine A is twice that of engine B, find(i) the intermediate temperature between A and B (ii) the efficiency of each engine (iii) the heat rejected to the cold sink.
9. A household refrigerator is maintained at a temperature of 275K. Every time the door is opened, warm material is placed inside, introducing an average of 420 KJ, but making only small change in the temperature of the refrigerator. The door is opened 20 times a day, and the refrigerator operates at 15% of ideal COP. The cost of work is Rs 2.50/KWhr. What is the bill for the month of April for this refrigerator? The atmosphere is at 303K.
10. A reversible engine operates between a source of 972°C and two sinks, one at 127°C and another at 27°C. The energy rejected is same at both sinks. What is the ratio of heat supplied to heat rejected? Also calculate the efficiency.
11. (a) One kg of water at 273K is brought into contact with a heat reservoir at 373 K. When the water is reached 373 K. Find the entropy change of the water, of the heat reservoir, and of the universe.
12. (b) If water is heated from 273 to 373 K by first bringing it in contact with a reservoir at 323 K, and then with a reservoir at 373 K, what will be the entropy change of the universe?
13. (c) Explain how water might be heated from 272 to 373 K with almost no change in the entropy of the universe.
14. One kg of ice at -5°C is exposed to the atmosphere which is at 20°C. The ice melts and comes into thermal equilibrium with the atmosphere. (i) Determine the entropy increase of the turbine (ii) what is the minimum amount of work necessary to convert the water back to ice at -5°C? Assume Cp for ice as 2.093 kJ/kgK and the latent heat of fusion of ice as 333.3KJ/kg.
15. 50 kg of water is at 313K and enough ice at -5°C is mixed with water in an adiabatic vessel such that the end of the process all the ice melts and water at 0°C is obtained. Find the mass of ice required and the entropy change of water and ice. Given Cp of water = 4.2 KJ/kgK, Cp of ice = 2.1 KJ/kgK and latent heat of ice = 335 KJ/kg.
16. A heat engine operating between two reservoirs at 1000K and 300K is used to drive heat pump which extracts heat from the reservoir at a rate twice that at which rejects heat to it. If the efficiency of engine is 40% of maximum possible and COP of pump is 50% of maximum possible, make calculations for the temperature of the reservoir

to which heat pump rejects heat. Also work out the rate of heat rejection from heat pump if the rate of supply of heat to engine is 50 KW.

17. One kg of air is contained in a piston cylinder assembly at 10 bar pressure and 500K temperature. The piston moves outwards and the air expands to 2 bar pressure and 350K temperature. Determine the maximum work obtainable. Assume environmental conditions to be 1 bar and 290K. Also calculate the availability in the initial and finial states.
18. In a steam boiler, hot gases from a fire transfer heat to water which vaporizes at constant temperature. In a certain case, the gases are cooled from 1100°C to 500°C while the water evaporates at 220°C. The specific heat of gases is 1.005 kJ/kgK, and the latent heat of water at 220°C, is 1858.5 kJ/kg. All the heat transferred from the gases goes to the water. How much does the total entropy of the combined system of gas and water increase as a result of irreversible heat transfer? Obtain the result on the basis of 1 kg of water evaporated. If the temperature of the surrounding is 30°C, find the increase in unavailable energy due to irreversible heat transfer.
19. Derive the expression for Carnot and reversed Carnot cycle with P-V and T-s diagram.
20. Explain the principle of increase of entropy.
21. Derive the Clausius Inequality.
22. Derive the expression for change in entropy for ideal gas and change in entropy for different processes.

UNIT 3

Properties of Pure Substances & Steam Power Cycle

PART A

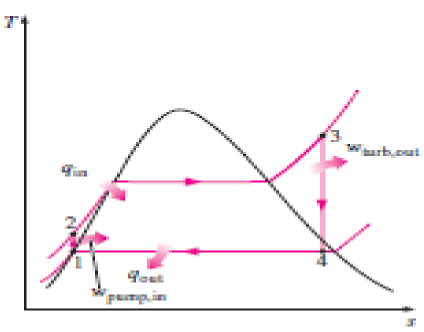
1. **What do you understand by pure substance? Give some typical examples**.
   a. Pure substance is a substance which has a fixed chemical composition throughout its mass.
   b. A pure substance does not to be of a single chemical element or compound. A mixture of various chemical elements or compounds is also called as pure substances.
   c. Eg: Water, mixture of ice and water

2. **What is critical point? What are the properties of water at critical point?**
   a. It represents the highest pressure and temperature at which the liquid and vapour coexist in equilibrium. At critical point, liquid is directly converted into vapour.
   b. The critical pressure, temperature and volume of water are 221.2 bars, 374.15°C and 0.00317 m^3/ kg.

3. **Define critical pressure and temperature of water**.
   a. The pressure at which water is directly converted into vapour without formation of liquid vapour mixture is called as critical pressure.

   The corresponding temperature is called critical temperature.

4. **Sketch the rankine cycle on a p-V plane and name the various processes.**

5. 

6. 1-2 Isentropic compression in a pump
   2-3 Constant pressure heat addition in a boiler
   3-4 Isentropic expansion in a turbine
   4-1 Constant pressure heat rejection in a condenser

7. **Define saturation state of a system.**
   a. The state of the substance at which the phase changes is called saturation state.

   Eg: Phase change from liquid to steam.

8. Why Carnot cycle is not possible for a steam power plant? (or) Why the Carnot cycle not a realistic model for steam power plants?

a. The main difficulty to attain the cycle in practice is that isothermal condensation is stopped before it reaches to saturated liquid condition. The compressor has to deal with non-homogeneous mixture of water and steam. Due to the large specific volume of liquid vapour mixture before compression require large compressor and high work input. The higher power requirements reduce efficiency as well as work ratio.

9. If water is at 65°C at 1 atm, what is the state of water? What is its specific enthalpy?

Corresponding to 65°C, saturation pressure, p_{sat}= 0.2503
Since $p_{sat} < p$, the water is steam which is in super-heated condition.
Specific enthalpy, h= 2621.07 kJ/kg

10. Define quality of steam. What are the methods to determining the quality of steam?

Dryness fraction is defined as ratio of the mass of dry steam actually present to mass of total steam.
It is denoted by "x"
x= $\frac{m_g}{m_f + m_g}$ where m_g - mass of dry steam in kg; m_f- mass of water vapour in suspension.
This term presents only for wet steam.
For dry steam, m_f= 0, therefore x= 1

11. Why excessive moisture in steam undesirable in steam turbines?

a. The expansion ratio in the turbine is increased due to increase in pressure; leads to steam become wet at the end of expansion. Increasing in moisture of the steam cause erosion in the turbine blades and increases the losses.

12. Why are the temperature and pressure dependent properties in the saturated mixture region?

a. The temperature cannot be varied while holding the pressure constant. When the pressure changes, the temperature will also vary.

13. What are four processes that make up the simple ideal rankine cycle?

a. The four processes are-

Constant pressure heat addition in the boiler.

Isentropic expansion in the turbine.\
Constant pressure and temperature heat rejection in the condenser.
Pressure increase at constant temperature by pumping the boiler.

14. The water is at 2.5 bar and 120 °C. Find the state of water.

a. Corresponding to 2.5 bar and 120°C, from steam table:
b. T_{sat}= 127.4 °C: T_{sat}> T, So, steam is wet condition.

15. What is the effect of reheat on the cycle efficiency?

a. The effect of reheat on cycle efficiency are-

Reduces the heat supply to the boiler.
Increases turbine work.
Reduces moisture in the turbine to avoid corrosion.
Increases thermal efficiency of the cycle.

16. What is the effect of regeneration on the cycle efficiency?

a. The temperature of the feed water is raised to the saturation temperature corresponding to the boiler pressure before it reaches into the boiler, the cycle efficiency will also close as Carnot cycle.

17. **What is meant by cogeneration?**

a. The process of producing both heat and work at the same time in power generation cycle is called cogeneration.
b. Eg: Rankine regenerative cycle.

PART B

1. Find the saturation temperature, the changes in specific volume and entropy during evaporation, and the latent heat of vaporization of steam at 1MPa.
2. Find the enthalpy, entropy, and volume of steam at 1.4 MPa, 380°C.
3. A vessel of volume contains 0.04m^3 contains a mixture of saturated water and saturated steam at a temperature of 250°C. The mass of the liquid present is 9 kg. Find the pressure, the mass, the specific volume, the enthalpy, the entropy and the internal energy.
4. Steam initially at 0.3 MPa, 250°C is cooled at constant volume. (a) At what temperature will the steam become saturated vapour? (b) What is the quality at 80°C? What is the heat transferred per kg of steam in cooling from 250°C to 80°C?
5. Steam initially at 1.5 MPa, 300°C expands reversibly and adiabatically in a steam turbine to 40°C. Determine the ideal work output of the turbine per kg of steam.

6. Steam at 0.8 MPa, 250°C and flowing at a rate of 1 kg/s passes into a pipe carrying wet steam at 0.8 MPa, 0.95 dry. After adiabatic mixing the flow rate is 2.3 kg/s. determine the condition of steam after mixing. The mixture is now expanded in a frictionless nozzle isentropically to a pressure of 0.4 MPa. Determine the velocity of steam leaving the nozzle. Neglect the velocity of steam leaving the nozzle. Neglect the velocity of steam in the pipeline.
7. The following data were obtained with a separating and throttling calorimeter.

8. Pressure in pipeline	9. 1.5 MPa
10. Condition after throttling	11. 0.1 MPa, 110°C
12. During 5 min moisture collected in the separator	13. 0.150 litre at 70°C
14. Steam condensed after throttling during 5 min	15. 3.24 kg

16. Find the quality of steam in the pipeline.

17. A 280 mm diameter of cylinder fitted with a frictionless leak proof piston contains 0.02 kg of steam at a pressure of 0.6 MPa and a temperature of 200°C. As the piston moves slowly outwards through a distance of 305 mm, the steam undergoes a fully-resisted expansion during which the steam pressure p and the steam volume V are related by pV^n= constant, where n is a constant. The final pressure of the steam is 0.12 MPa. Determine (a) the value of n, (b) the work done by the steam, and (c) the magnitude and sign of heat transfer.
18. Steam generated at a pressure of 6 MPa and a temperature of 400°C is supplied to a turbine via throttle valve which reduces the pressure to 5 MPa. Expansion in the turbine is adiabatic to a pressure of 0.2 MPa, the isentropic efficiency being 82%. The surroundings are at 0.1 MPa, 20°C. Determine the availability of steam before and after the throttle valve and at the turbine exhaust, and calculate the specific work output from the turbine. The K.E and P.E changes are negligible.

Steam Power Cycles

19. Steam at 20 bar, 360°C is expanded in a steam turbine to 0.08 bar. It then enters a condenser, where it condensed to saturated liquid water. The pump feeds back the water into the boiler. (a) Assume ideal processes; find per kg of steam the network and the cycle efficiency. (b) If the turbine and the pump have each 80% efficiency, find the percentage reduction in the net work and cycle efficiency.
20. Steam boiler generates steam at 30 bar, 300°C at the rate of 2 kg/s. this steam is expanded isentropically in a turbine to a condenser pressure of 0.05 bar, condensed at constant pressure and pumped back to boiler. (a) Draw the schematic arrangement of the above plant, and (b) Find the heat supplied in the boiler per hour, (c) determine the

quality of steam after expansion, (d) what is the power generated by the turbine? (e) Estimate the Rankine efficiency considering pump work.

21. In a steam power plant operating on an ideal reheat rankine cycle, the steam enters the HP turbine at 3 MPa and 400°C. After expansion to 0.6 MPa, the steam is reheated to 400°C and then expanded in the LP turbine to the condenser pressure of 10 KPa. Determine the thermal efficiency of the cycle and the quality of the steam at the outlet of the LP turbine.
22. A steam power station uses the following cycle: steam at boiler outlet is 150 bar, 550°C, reheated at 40 bar to 550°C and condenser at 0.1 bar. Using mollier chart and assuming ideal processes, find the (a) quality of steam at turbine exhaust, (b) cycle efficiency, and (c) steam rate.
23. A reheat cycle operating between 30 and 0.04 bar has a super heat and reheat temperature of 450°C. The first expansion takes place till the steam is dry saturated and then reheat is given. Neglect feed pump work determine the ideal efficiency.
24. In a regenerative cycle, the steam pressure at turbine inlet is 30 bar and the exhaust is at 0.04 bar. The steam is initially saturated. Enough steam is bled off at the optimum pressure of 3 bar to heat the feed water. Determine the cycle efficiency, neglecting pump work.
25. In a steam power plant the condition of steam at inlet to the steam generator is 20 bar and 300°C and the condenser pressure is 0.1 bar. Two feed water heaters operate at optimum temperature. Determine: (a) the quality of steam at turbine exhaust, (b) network per kg of steam, (c) cycle efficiency, and (d) the steam rate. Neglect pumps work.
26. Describe and derive the efficiency of rankine cycle and also draw the P-V & T-s diagram.
27. Derive the efficiency relation for reheat cycle with P-V and T-s diagram.
28. Describe the regenerative rankine cycle with neat sketch.
29. Briefly explain combined and binary cycles.

Unit 4 – Ideal & Real Gases, Thermodynamic Relations

PART A

1. What are the unique features of Vander Waals equation of state?

Intermolecular attractive study is made.

Shape factor is considered.

i. These assumptions are not made in ideal gas equation of state.

2. What is compressibility factor? What does it signify? What is its value for Van der Waals gas at critical point?

a. For real gas, the correction factor is introduced in the perfect gas equation due to the deviation of real gas from perfect gas equation.
b. pV= ZRT
c. Z is called as compressibility factor.

Intermolecular attractive study is made.
Shape factor is considered.

d. At critical point, the Van der Waals equation
e. $\frac{p_c V_c}{RT_c} = 1$ for ideal gasas.

3. **State the Avagadro's law.**

a. Avagadro's law states, "Equal volumes of different perfect gases at the same temperature and pressure, contain equal number of molecules".

4. **Write the Maxwell's relations.**

a. $(\frac{\partial T}{\partial v})_s = -(\frac{\partial p}{\partial s})_v$
b. $(\frac{\partial T}{\partial p})_s = (\frac{\partial v}{\partial s})_p$
c. $(\frac{\partial p}{\partial T})_v = (\frac{\partial s}{\partial v})_T$
d. $(\frac{\partial v}{\partial T})_p = -(\frac{\partial s}{\partial p})_T$
e. These are known as Maxwell's relations.

5. **What is meant by equation of state?**

a. The equation of state for real gases becomes
   i. pV= ZRT where Z is compressibility factor.

6. **State the Dalton's law of partial pressure.**

a. The total pressure of a mixture of gases is equal to the sum of partial pressures exerted by individual gases if each one of them occupied separately in the total volume of the mixture at mixed temperature.
b. $p= p_1 + p_2 + p_3 +.....p_k$

7. **Have you ever encountered any ideal gas? If so, where?**

a. No. In actual practice, there is no ideal gas which strictly follows the gas laws over entire range of temperature and pressure. However H2, O2, N2 and air behave as an ideal gas under certain temperature and pressure limits.

8. **What is coefficient of expansion?**

a. Co-efficient of expansion is defined as the change in volume with change in temperature per unit volume keeping pressure constant. It is denoted by β.
   i. $\beta = \frac{1}{v}\left(\frac{\partial v}{\partial T}\right)_p$

9. Explain the following terms: (a) Mass fraction (b) Mole fraction

a. (a)Mass fraction:
   i. Mass fraction of any component is defined as the ratio of mass of a component to the mass of the mixture. The mass of a mixture is the sum of mass of component gases.
   ii. $x_i = \frac{m_i}{m_m}$ Where m_i is the mass of individual component; m_m is the mass of mixture.

b. (b)Mole fraction:
   i. It is the mole number of a component to mole number of the mixture. The total number of moles of a mixture is the sum of number of its component.
   ii. $y_i = \frac{N_i}{N_m}$

10. What does the Joule- Thomson coefficient represent?

a. Joule –Thomson co-efficient is defined as the change in temperature with change in pressure, keeping enthalpy remains constant. It is denoted by μ.
   i. $\mu = \left(\frac{\partial T}{\partial p}\right)_h$

11. **What is meant by reduced properties?**

a. Reduced properties mean, it is the obtaining the relationship of thermodynamic properties in terms of one or more than one thermodynamic properties such as pressure, volume, temperature, specific heat, internal energy, enthalpy and entropy.

12. **Write down the Clausius-Clapeyron equation.**

a. Clausius-Clapeyron equation which involves relationship between saturation pressure, saturation temperature, the enthalpy of evaporation and the specific volume of the two phases involved.
b. $\frac{dp}{dT} = \frac{S_g - S_f}{v_g - v_f} = \frac{S_{fg}}{v_{fg}} = \frac{h_{fg}}{T v_{fg}}$

13. **What is the partial pressure of carbon dioxide in a container that holds 5 moles of carbon dioxide, 3 moles of nitrogen and 1 mole of hydrogen and has a total pressure of 1.05 atmospheres**.

   a. The mole fraction is given by
   b. $y_{co_2} = \frac{N_{co_2}}{N_{co_2}+N_{N_2}+N_{H_2}} = \frac{5}{5+3+1} = 0.56$
   c. The partial pressure of CO_2, $p_{co_2} = y_{co_2} * p$ = 0.56 *1.05 = 0.588 atm
      a. = 0.588*1.013 = **0.596 bar**

PART B

1. Derive the Maxwell's equations.
2. Derive the entropy relations.
3. From First law of thermodynamics, derive the enthalpy relations.
4. What is Clapeyron equation? Derive the expression for Clapeyron equation.
5. What is Joule-Thomson co-efficient? Briefly explain about it.
6. Derive the energy equations.

UNIT 5 – Gas Mixtures & Psychometry

PART A

1. **What is dew point temperature? How it is related to dry bulb temperature and wet bulb temperature at the saturation condition?**

   a. It is the temperature at which the water vapour present in the air begins to condense when the air is cooled.

   For saturated air, the dry bulb, wet bulb and dew point temperature are all same.

2. **Define specific humidity.**

   a. It is the ratio of mass of water vapour (m_v) to the mass of dry air (m_a) in the given volume of mixture. It is denoted by ϖ.

   $\varpi = \frac{m_v}{m_a}$

3. **What is adiabatic mixing and write the equation for that?**

   a. The mixing of two air streams suddenly by merging to make a single air stream is called adiabatic mixing.

4. The equation for adiabatic mixing is given by

   a. $\frac{m_1}{m_2} = \frac{h_2-h_3}{h_1-h_3} = \frac{\omega_2-\omega_3}{\omega_1-\omega_3}$
   b. Where h, ω denotes enthalpy and specific humidity respectively.

5. If the relative humidity of air is 60% at 30°C, what is the partial pressure of water vapour?

From steam tables, corresponding to dry bulb temperature of 30°C,
p_{sat} =4.246 kPa

6. $\Phi = \frac{p_v}{4.246}$ = **2.548 kPa**

7. What is thermodynamic wet bulb temperature?

i. It is the temperature of air measured by a thermometer when its bulb is covered with wet cloth and exposed to current rapidly moving air. It is denoted by t_w.

8. What is dry bulb temperature?

i. The temperature which is measured by an ordinary thermometer is known as dry bulb temperature. It is generally denoted by t_d.

9. What is the difference between dry air and atmospheric air?

i. Dry air consists of air without water vapour by atmospheric air contains both dry air and water vapour.

10. Moist air passed through a cooling section where it is cooled and dehumidified. How do the specific humidity and relative humidity of air change during the process?

i. During cooling, dry bulb temperature from Φ_1 to Φ_2 but specific humidity is constant. During dehumidification, specific humidity decreases but relative humidity is constant.

11. Define sensible heat and latent heat.

The heat added with air by heating without moisture is called sensible heat.
The heat due to the addition of moisture is known as latent heat.

12. What is relative humidity?

i. It is the ratio of mass of water vapour (m_v) in a certain volume of moist air at a given temperature to the mass of water vapour (m_{vs}) in the same volume of saturated air at the same temperature.

It is denoted by $\Phi = \frac{m_v}{m_{v_s}}$

13. Define psychrometry.

a. The science which deals with the study of behavior of moist air (mixture of dry air and water vapour) is known as psychrometry.

14. State Dalton's law of additive pressure.

i. The pressure of a gas mixture is equal to the sum of the pressures which each gas would exert if it is existed alone at the temperature and volume of the mixture.

$P_m = \sum_{i=1}^{k} P_i(T_m, V_m)$

Where P_m is pressure of mixture, P_i is pressure of component.

15. State Amagat's law of additive volume.

a. The volume of a gas mixture is equal to the sum of the volume of each gas would exert if the existed alone at the temperature and pressure of the mixture.

b. $V_m = \sum_{i=1}^{k} V_i(T_m, P_m)$

Where V_m is volume of mixture, V_i is component volume

PART B

1. A gas mixture consists of 0.5 kg of carbon monoxide and 1 kg of CO_2. Determine (a) the mass fraction of each component, (b) the mole fraction of each component, and (c) the average molar mass and the gas constant of the mixture.
2. A gas mixture of 5 kg mass at 135°C consists of 20 percent O_2, 70 percent N_2, and 10 percent CO_2 by volume. If the pressure of the mixture is 300 kPa, determine the gravimetric analysis and the partial pressures of the gases in the mixture. If the mixture is cooled to 20°C at constant pressure, find the final volume of the mixture.
3. A rigid tank contains 0.35 kg of steam of quality 0.2 and 0.1 kg of nitrogen gas. If the temperature of the mixture is 90°C, determine the volume of the tank and the pressure of the mixture.
4. Atmospheric air at 1.0132 bar has a dry bulb temperature of 32°C and a wet bulb temperature. Compute (i) The partial pressure of water vapour, (ii) the specific humidity, (iii) the dew point temperature, (iv) the relative humidity, (v) the degree of saturation, (iv) the density of air in the mixture, (vii) the density of vapour in the mixture and (viii) the enthalpy of the mixture. Use thermodynamic table only.
5. Air at 760 mm of Hg has 45°C dry bulb temperature and 30°C wet bulb temperature. Using psychrometric chart, calculate the following (a) Relative humidity (b) Humidity ratio (c) Dem point temperature (d) Enthalpy (e) Specific volume of air.
6. Atmospheric air at 1 bar pressure has 25°C dry bulb temperature and 75% relative humidity. Using psychrometric chart, calculate dew point temperature, enthalpy and vapour pressure.

7. The air in a room has a dry-bulb temperature of 22°C and a wet-bulb temperature of 16°C. Assuming a pressure of 100 kPa, determine (a) the specific humidity, (b) the relative humidity, and (c) the dew-point temperature. Use psychrometric chart only.
8. An air conditioning system is designed under the following conditions:

9. outdoor conditions - 30°C DBT, 75% RH
10. Required indoor conditions - 22°C DBT, 70% RH
11. Amount of free air circulated – 3.33 m^3/s
12. Coil dew point temperature – 14°C
    a. The required condition is achieved first by cooling and dehumidification, and then by heating. Estimate (a) the capacity of the cooling coil in tonnes, (b) the capacity of the heating coil in kW, and (c) the amount of water vapour removed in kg/s.

13. Air at 20°C 40% RH is mixed adiabatically with air at 40°C, 40% RH in the ratio of 1 kg of the former with 2 kg of the latter (on dry basis). Find the final condition of air.
14. Two airstreams are mixed steadily and adiabatically. The first stream enters at 32°C and 40 % relative humidity at a rate of 20 m^3/min, while the second stream enters at 12°C and 90 percent relative humidity at a rate of 25 m^3/min. Assuming that the mixing process occurs at a pressure of 1 atm, determine the specific humidity, the relative humidity, the dry-bulb temperature, and the volume flow rate of the mixture.
15. Saturated air at 21°C is passed through a drier so that its final relative humidity is 20%. The drier uses silica gel adsorbent. The air is then passed through a cooler until its final temperature is 21°C without a change in specific humidity. Find out (a) the temperature of air at the end of the drying process, (b) the heat rejected in kJ/kg dry air during the cooling process, (c) the relative humidity at the end of the cooling process, (d) the dew point temperature at the end of the drying process, and (e) the moisture removed during the drying process in kg vapour/ kg dry air.
16. For a hall to be air conditioned, the following conditions are given
17. Outdoor condition - 40°C DBT, 20°C WBT
18. Required comfort condition - 20°C DBT, 60% RH
19. Seating capacity of hall – 1500
20. Amount of outdoor air supplied – 0.3 m^3/min per person.
21. If the required condition is achieved first by adiabatic humidification and then by cooling, estimate (a) the capacity of the cooling coil in tonnes, and (b) the capacity of humidifier in kg/hr.
22. Briefly explain the different types of psychrometric process with neat sketch.
23. Describe adiabatic evaporative cooling process.
24. Explain and derive expression for adiabatic mixing of air streams.
25. Write a brief note on adiabatic saturation process.