**Third Semester Mechanical Engineering**
**ENGINEERING THERMO DYNAMICS (ME 2201)**
**UNIT I**

**1. Define system.**

It is defined as the quantity of the matter or a region in space upon which we focus **attention to study** its property.

**2. Name the different types of system.**

1. Closed system (**only energy transfer** and no mass transfer)
2. Open system (**Both energy and mass** transfer)
3. Isolated system (**No mass and energy transfer**)

**3. 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.

**4. What do you mean by quasi-static process?**

Equilibrium state
Quasi-static process
Infinite slowness is the characteristic feature of a quasi-static process. A quasistatic process is that a **succession of equilibrium states**. A quasi-static process is also called as reversible process.

**5. Define Path function.**

The work done by a process does **depend upon the path** of the process. It depends on the path of the system follows from state 1 to state 2. Hence work is called a path function.

**6. Define point function.**

Thermodynamic properties are point functions. The change in a thermodynamic property of a system is **independent of the path** and depends
only on the initial and final states of the system.

**7. 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, density.
**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.

**8. Explain homogeneous and heterogeneous system.**

The system consist of **single phase** is called homogeneous system and the system consist of **more than one phase** is called heterogeneous system.

10. What is a steady flow process?

Steady flow means that the rates of flow of mass and energy across the control surface are constant.

**9. Prove that for an isolated system, there is no change in internal energy.**

In isolated system there is no interaction between the system and the surroundings. There is no mass transfer and energy transfer. According to first law of thermodynamics as $dQ = dU + dW$; $dU = dQ - dW$; $dQ = 0$, $dW = 0$, There fore $dU = 0$ by integrating the above equation $U =$ constant, therefore the internal energy is constant for isolated system.

**10. Indicate the practical application of steady flow energy equation.**

1. Turbine, 2. Nozzle, 3. Condenser, 4. Compressor.

**11. Define cycle.**

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

**12. Explain Mechanical equilibrium.**

If the **forces are balanced** between the system and surroundings are called Mechanical equilibrium

Explain Chemical equilibrium.

If there **is no chemical reaction** or transfer of matter form one part of the system to another is called Chemical equilibrium

**13. Explain Thermal equilibrium.**

If there is **no temperature difference** between the system and surroundings it is in Thermal equilibrium.

**14. Define Zeroth law of Thermodynamics.**

When two systems are separately in thermal equilibrium with a third system then they themselves are in thermal equilibrium with each other.

**15. What are the limitations of first law of thermodynamics?**

1. According to first law of thermodynamics heat and work are mutually convertible during any cycle of a closed system. But this law does not specify the **possible conditions** under which the heat is converted into work.
2. According to the first law of thermodynamics it is impossible to transfer heat from **lower temperature to higher temperature.**
3. It does not give any information regarding change of state or whether the process is possible or not.
4. The law does not specify the **direction of heat and work.**

**16. What is meant by perpetual motion machine of first kind?**

The machine, which continuously delivers **work without any input**, is called perpetual motion machine of first kind. This is corollary to first law of thermodynamics.

# UNIT II

**1. What is perpetual motion machine of first kind?**

It is defined as a machine, which **produces work energy without consuming energy** from other source. It is impossible to obtain in actual practice, because no machine can produce energy of its own without consuming any other form of energy.

**2. Define Clausius statement.**

It is impossible for a self-acting machine working in a cyclic process, to transfer **heat from a body at lower temperature to a body at a higher temperature** without the aid of an external agency.

**3. What is Perpetual motion machine of the 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.

**4. Define Kelvin Planck Statement.**

It is **impossible** to construct a heat engine to produce **all the heat supplied into work** if it exchanges heat from a single reservoir at single fixed temperature.

**5. Define Heat pump.**

A heat pump is a device, which maintains the **temperature of the system greater than the surroundings.**

**6. Define Heat engine.**

Heat engine is a machine, which is used to **convert the heat energy into mechanical work** in a cyclic process.

**7. What are the assumptions made on heat engine?**

1. The source and sink are maintained at constant temperature.
2. The source and sink has infinite heat capacity.

**8. State Carnot theorem.**

It states that **no heat engine** operating in a cycle between two constant temperature heat reservoir can be **more efficient than a reversible engine** operating between the same reservoir.

**9. Explain entropy?**

It is the measure of molecular disorder. It is denoted by S. It is the amount of **unavailable energy** present in the system.

**10. What is absolute entropy?**

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

**11. Define availability.**

**The maximum useful work** obtained during a process in which the final condition of the system is the same as that of the surrounding is called availability of the system.

**12. Define available energy and unavailable energy.**

Available energy is the maximum thermal useful work under ideal condition. The remaining part, which cannot be converted into work, is known as unavailable energy.

**13. What do you understand by the entropy principle?**

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.

**14. What are the important characteristics of entropy?**

1. If the heat is supplied to the system then the entropy will increase.
2. If the heat is rejected to the system then the entropy will decrease.
3. The entropy is constant for all adiabatic frictionless process.
4. The entropy increases if temperature of heat is lowered without work being done as in throttling process.
5. If the entropy is maximum, then there is a minimum availability for conversion in to work.

**15. What is reversed carnot heat engine? What are the limitations of carnot cycle?**

1. No friction is considered for moving parts of the engine.
2. There should not be any heat loss.

**16. Define refrigerator.**

Refrigerator is a device which maintains the **temperature** of the system **lower than the surroundings.**

**17. Define C.O.P of refrigerator.**

Coefficient of performance of refrigerator is the ratio of **heat removed from the system to the work supplied** to the system. Its value is always greater than one.

**18. Define C.O.P of Heat pump.**

It is defined as the ratio of **heat supplied to the high temperature body to the work supplied.** $C.O.P_{HP} = C.O.P_{Ref} + 1$

## UNIT III

**1. Define efficiency ratio.**

The ratio of **actual cycle efficiency to that of the ideal cycle efficiency** is termed as efficiency ratio.

**2. Define overall efficiency.**

It is the **ratio of the mechanical work to the energy supplied in the fuel**. It is also defined as the product of combustion efficiency and the cycle efficiency.

**3. Define specific steam consumption of an ideal Rankine cycle.**

It is defined as the **mass flow of steam required per unit power** output.

**4. What are the effects of condenser pressure on the Rankine Cycle?**

By lowering the condenser pressure, we can **increase the cycle efficiency**. The main disadvantage is lowering the back pressure **increases the wetness** of steam. Isentropic compression of a very wet vapour is very difficult.

**5. Mention the improvements made to increase the ideal efficiency of Rankine cycle.**

1. Lowering the condenser pressure.
2. **Superheated steam** is supplied to the turbine.
3. **Increasing the boiler pressure** to certain limit.
4. Implementing **reheat and regeneration** in the cycle.

**6. What are the advantages of reheat cycle?**

1. It increases the **turbine work.**
2. It increases the heat supply.
3. It increases the **efficiency of the plant.**
4. It **reduces the wear** on the blade because of low moisture content in LP state of the turbine.

**7. Explain the term critical point, critical temperature and critical pressure.**

In the T-S diagram the region left of the waterline, the water exists as liquid. In right of the dry steam line, the water exists as a super heated steam. In between water and dry steam line the water exists as a wet steam.

At a particular point, the **water is directly converted into dry steam** without formation of wet steam. The point is called **critical point.**

The critical temperature is the temperature above which a substance cannot exist as a liquid, the critical temperature of water is 374.15°C. The corresponding pressure is called critical pressure.

**8. Define dryness fraction (or) What is the quality of steam?**

It is defined as the ratio of **mass of the dry steam to the mass of the total steam.**

**9. How do you determine the state of steam?**

If V>vg then super heated steam, V= vg then dry steam and V< vg then wet steam.

**10. Define triple point.**

The triple point is merely the point of intersection of **sublimation** and vapourisation curves.

**11. Explain the terms, Degree of super heat, degree of sub-cooling.**

The **difference** between the temperature of the superheated vapour and the saturation temperature at the same pressure.

The temperature between the saturation temperature and the temperature in the sub cooled region of liquid.

**12. Define latent heat of vaporization.**

The amount of **heat added to convert water into steam** at saturation temperature is called the latent heat of vaporization.

**13. Define superheated steam.**

The steam heated **above saturation temperature** is called the superheated steam.

## UNIT IV

**1. State Boyle's law.**

It states that volume of a given mass of a perfect gas varies inversely as the absolute pressure when temperature is constant.

**2. State Charle's law.**

It states that if any gas is heated at constant pressure, its volume changes directly as its absolute temperature.

**3. Explain the construction and give the use of generalized compressibility chart.**

The general compressibility chart is plotted with Z versus Pr for various values of Tr. This is constructed by plotting the known data of one of mole gases and can be used for any gas. This chart gives best results for the regions well removed from the critical state for all gases.

**4. Explain law of corresponding states.**

If any two gases have equal values of reduced pressure and reduced temperature, then they have same values of reduced volume.

**5. Explain Dalton's law of partial pressure.**

The pressure of a mixture of gases is equal to the sum of the partial pressures of the constituents. The partial pressure of each constituent is that pressure which the gas would expect if it occupied alone that volume occupied by the mixtures at the same temperatures. m = mA+mB+mC+....... = _mi

mi = mass of the constituent.

P=PA+PB+PC+....... = _Pi, Pi – the partial pressure of a constituent.

**6. State Avogardo's Law.**

The number of moles of any gas is proportional to the volume of gas at a given pressure and temperature.

**7. What is Joule-Thomson coefficient?**

The temperature behaviors of a fluid during a throttling (h=constant) process is described by the Joule-Thomson coefficient defined as

$\mu = [dT/dP]n$

**8. What is compressibility factor?**

The gas equation for an ideal gas is given by (PV/RT) = 1, for real gas (PV/RT) is not equal to 1 (PV/RT) = Z for real gas is called the compressibility factor.

**9. What is partial pressure?**

The partial pressure of each constituent is that pressure which the gas would exert if it occupied alone that volume occupied by the mixtures at the same temperature..

**10. How does the Vander Waal's equation differ from the ideal gas equation of state?**

The ideal gas equation pV=mRT has two important assumptions,

1. There is little or no attraction between the molecules of the gas.
2. That the volume occupied by the molecules themselves is negligibly small compared to the volume of the gas. This equation holds good for low pressure and high temperature ranges as the intermolecular attraction and the volume of the molecules are not of much significance.

As the pressure increases, the inter molecular forces of attraction and repulsion increases and the volume of the molecules are not negligible. The real gas deviate considerably from the ideal gas equation

[p+(a/V2)](V-b) = RT

**11. State Helmholtz function.**

Helmholtz function is the property of a system and is given by subtracting the product of absolute temperature (T) and entropy (S) from the internal energy (U).

Helmholtz function = U – TS

# UNIT V

**1. What is humidification and dehumidification?**

The addition of water vapour into air is humidification and the removal of water vapour from air is dehumidification.

**2. Differentiate absolute humidity and relative humidity.**

Absolute humidity is the mass of water vapour present in one kg of dry air. Relative humidity is the ratio of the actual mass of water vapour present in one kg of dry air at the given temperature to the maximum mass of water vapour it can with hold at the same temperature. Absolute humidity is expressed in terms of kg/kg of dry air. Relative humidity is expressed in terms of percentage.

**3. Define specific humidity.**

It is defined as the ratio of the mass of water vapour (ms) in a given volume to the mass of dry air in a given volume (ma).

**4. Define degree of saturation.**

It is the ratio of the actual specific humidity and the saturated specific humidity at the same temperature of the mixture.

**5. What is dew point temperature?**

The temperature at which the vapour starts condensing is called dew point temperature. It is also equal to the saturation temperature at the partial pressure of water vapour in the mixture. The dew point temperature is an indication of specific humidity.

**6. What is meant by dry bulb temperature (DBT)?**

The temperature recorded by the thermometer with a dry bulb. The dry bulb thermometer cannot affected by the moisture present in the air. It is the measure of sensible heat of the air.

**7. What is meant by wet bulb temperature (WBT)?**

It is the temperature recorded by a thermometer whose bulb is covered with cotton wick (wet) saturated with water. The wet bulb temperature may be the measure of enthalpy of air. WBT is the lowest temperature recorded by moistened bulb.

**8. What is psychrometric chart?**

It is the graphical plot with specific humidity and partial pressure of water vapour in y axis and dry bulb temperature along x axis. The specific volume of mixture, wet bulb temperature, relative humidity and enthalpy are the properties appeared in the psychrometric chart.

**9. Define sensible heat and latent heat.**

Sensible heat is the heat that changes the temperature of the substance when added to it or when abstracted from it. Latent heat is the heat that does not affect the temperature but change of state occurred by adding the heat or by abstracting the heat.

**10. What are the important psychrometric process?**

1. Sensible heating and sensible cooling, 2. Cooling and dehumidification, 3. Heating and humidification, 4. Mixing of air streams, 5. Chemical dehumidification, 6. Adiabatic evaporative cooling.

# TUTORIAL_-I

## FIRST LAW

1. During the working stroke of an engine the heat transferred out of the system was 150 KJ/Kg of the working substance. Determine the work done, when the internal energy is decreased by 400 kJ/Kg. Also state whether the work done on or by the engine.

   **Result : Work output W=250KJ/Kg**

   **(Positive work indicates that the work done is by the engine.)**

2. 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 the following equation u=34+3.15pV, where u is kJ, p is in kPa and V in $m^3$. if the fluid changes from an initial state of 170 kPa, 0.01$m^3$ to a final state of 400 kPa, 0.06$m^3$, with no other work that that done on the piston, find the direction and magnitude of the work and heat transfer.

   **Result:**

   **Work transfer, W= 8.55 kJ**

   **(+ve sign indicates that the work is done by the system.)**

   **Heat transfer , Q=68.085 kJ**

   **(+e heat transfer indicates that the heat is transferred into the system)**

3. A piston and cylinder machine contains a fluid system which passes through a complete cycle of four processes. During the cycle, the sum of all heat transfers is – 170 kJ. The system completes 100 cycles per minute. Complete the following table showing the method for each item, and compute the net rate of work output in kW.

| Process | Q(kJ/min) | W(kJ/min) | ΔE(kJ/min) |
|---|---|---|---|
| a-b | 0 | 2,170 | – |
| b-c | 21,000 | 0 | – |
| c-d | –2,100 | - | -36,600 |
| d-a | - | - | - |

**Result:**

| Process | Q(kJ/min) | W (kJ/min) | ΔE(kJ/min) |
|---|---|---|---|
| a-b | 0 | 2,170 | -2,170 |
| b-c | 21,000 | 0 | 21,000 |
| c-d | –2,100 | 34,500 | -36,000 |
| d-a | -35900 | -53670 | 17770 |

## NON FLOW PROCESS

4. Five kg of air is compressed polytropically (n = 1.3) from 1 bar and 27° C to 3 bar. Find (i) work transfer (ii) heat transfer (iii) change in internal energy.

   **Work transfer, W = -82.82kJ/kg.**

   **Heat transfer, Q = -20.705 kJ/kg.**

   **Change in internal energy, U = 62.115 kJ/kg.**

5. 5 kg of air at 40°C and 1 bar is heated in a reversible non-flow constant pressure until the volume is doubled. Find (a) change in volume (b) work done (c) change in internal energy and (d) change in enthalpy

   **Change in volume, $V_2$-V1 = 4.49m$^3$**

   **Work done, W = 449kJ**

   **Change in internal energy, ΔU = 1117.41kJ**

   **Change in enthalpy, ΔH = 1572.83 kJ**

6. A gas whose original pressure, volume and temperature were 140 kN/m$^3$, 0.1m$^3$ and 25°C respectively. It is compressed such that new pressure is 700 kn/m2 and its new temperature is 60°C. Determine the new volume of the gas.

   **New Volume, V2 = 0.0223m$^3$**

7. 0.25 kg of air at a pressure of 1 bar occupies a Volume of 0.3 m$^3$. If this air expands isothermally to a volume of 0.9m$^3$. Find (i) The initial temperature, (ii) The final temperature (iii) External work done, (iv) Heat absorbed by the air , (v) Change in internal energy. Assume R =0.29kJ/K.
8. A mass of air is initially at 260°C and 700kPa and occupies 0.28m$^3$. The air is expanded at constant pressure to 0.084m$^3$. A polytropic process with n=1.5 is then carried out, followed by a constant temperature process. All the processes are reversible.

   Sketch the cycle in the p-V and T-s planes.

Find the heat received and heat rejected in the cycle.

Find the efficiency of the cycle.

9. A room for four persons has two fans, each consuming 0.18kW power and three 100W lamps. Ventilation air at the rate of 80kg/hr enters with an enthalpy of 84kJ/kg and leaves with an enthalpy of 59kJ/kg. If each person puts out heat at the rate of 630kJ/hr, determine the rate at which heat is to be removed by a room cooler so that a steady state is maintained in the room.

10. A system receives 200kJ of energy as heat, at constant volume. Then it is cooled at constant pressure when 50kJ of work was done on the system while it rejects 70kJ of heat. Supposing the system is restored to the initial state by an adiabatic process, how much work will be done by the system

## FLOW PROCESS

11. A turbine operates under steady flow conditions receiving steam at the following state: Pressure =1.2MPa, temperature =188°C. Enthaply =2785kJ/kgt, Velocity = 33.3 m/s and elevation =3m. The steam leaves the turbine at the following state: Pressure = 20kpa, Enthaply =2512 kJ/kg, Velocity = 100m/s and elevation = 0m. Heat is lost to the surroundings at the rate of 0.29kJ/s. If the rate of steam flow through the turbine is 0.42 kg/s, what is the power output of the turbine in kW?

12. Air flow steadily at the 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 5m/s, 700 kPa and 0.19$m^3$/kg. The internal energy of the air leaving is 90 kJ/kg greater than that of the 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 ration of the inlet pipe diameter to the outlet pipe diameter.

13. In a steady flow system, a working substance flows at a rate of 4kg/s enters a pressure of 620 kN/$m^2$ at a velocity of 300 m/s. The internal energy is 2100lJ/kg and specific volume 0.37$m^3$/kg. It leaves the system at a pressure of 130 kN/$m^2$, a velocity of 150 m/s, internal energy of 1500 kJ/kg and specific volume of 1.2 $m^3$/kg. During in passage in the system, the substance has a heat

transfer of loss of 30 kJ/kg to its surroundings. Determine the power of the system. State that it is from (or) to the system.

14. Air at a temperature of 15°C passes through a heat exchange 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 60m/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:

    (i) The rate of heat transfer to the air in the heat exchange.

    (ii) The power output from the turbine assuming no heat loss, and

    (iii) The velocity at exit from the nozzle, assuming no heat loss.

Take the enthalpy of air as $h = C_p t$, where $C_p$ is the specific heat equals to 1.005 kJ/kgK and 't' the temperature.

15. Air flows steadily at the rate of 0.5kg/s through an air compressor entering at 7m/s velocity, 100kPa pressure, and 0.95m$^3$/kg specific volume, and leaving at 5m/s, 700kPa, and 0.19m$^3$/kg. The internal energy of air leaving is 90kJ/kg greater than that of the air entering. Cooling water in the compressor jackets absorb heat at the rate of 58kW. Calculate the rate of shaft work input to the compressor.

16. A gas flows steadily through compressor. The gas enters the compressor at a temperature of 16°C, a pressure of 100kPa, and an enthalpy of 391.2kJ/kg. The gas leaves the compressor at a temperature of 245°C, a pressure of 0.6MPa, and an enthalpy of 534.5 kJ/kg. There is no heat transfer to or from the gas as it flows through the compressor. Evaluate the external work done per unit mass of gas when the velocity at entry 80m/s and that at exit is 160m/s.

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## TUTORIAL_-II

## SECOND LAW

1. An inventor claims to have developed a refrigerating unit which maintains the refrigerated space at - 6°C while operating in a room where temperature is 27°C and has COP 8.5. Find out whether his claim is correct or not.

   **Result: His claim is not correct because COP carnot is less than the Inventor's claimed COP.**

2. A heat engine operates between a source at 600°C and a sink at 60°C. Determine the least rate of heat rejection per kW net output of the engine.

   **Result: $Q_r$ = 0.616 kw.**

3. A domestic food freezer maintains a temperature of -15°C. The ambient air is at 30°C. If heat leaks into the freezer at a continuous rate of 1.75kJ/s, what is the least power necessary to pump the heat out continuously?

   **Result: W= 0.305 kW.**

<u>**PARALLEL CONNECTION**</u>

4. A heat engine is used to drive a heat pump. The heat transfer from the heat engine and from the heat pump is used to heat the water circulating through the radiators of building. The efficiency of the heat engine is 27% and COP of the heat pump is 4. (i) Draw the neat diagram of the arrangement and (ii) evaluate the ratio of heat transfer to the circulating water to the heat transfer to the heat engine.

   **Result: $(Q_{R1}+ Q_{R2}) / Q_{S1}$ =1.81**

5. A cannot heat engine takes heat from an infinite reservoir at 550°C. Half of the work delivered by the engine is used to run generator and the 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 444°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.

   **Result: $Q_{R2} / Q_{S1}$ = 72.7%**

6. Three identical bodies of A,B and C constant heat capacity are at temperature 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.

   **Result: The maximum temperature is 300 K of B.**

## SERIES CONNECTION

7. Two reversible heat engines A and B are arranged in series. A rejecting heat directly to B. engine receives 200kJ at a temperature of 421°C from a hot source, while engine B is in communication with a cold sink at a temperature of 4.4°C. if the work output of A is twice that of B, find:

   The intermediate temperature between A and B

   The efficiency of each engine, and

   The heat rejected to the cold sink.

   **Result: Intermediate temperature T = 143.42°c**

   **Efficiency of A= 40.04%, Efficiency of B = 33.39%**

   **$Q_{R2}$=79.89 KJ**

8. Two Carnot engines A and B are operated in series. The first one receives heat at 870K and rejects to a reservoir at temperature T. The second engine B recives heat rejected by the first engine and in turn rejects to a reservoir at 300K. Calculate the intermediate temperature between the two heat engines if (a) the work output of the two engines are equal. (b) The efficiencies of the two engines are equal.

   **Result: T =312°c. T = 237.88 c.**

## ENTROPY

9. 5 kg of air at 2 bar and 30°C is compressed to 24 bar pressure according to the las $pV^{1.2}$=Constant. After compression air is cooled at constant volume to 30°C. Determine, (i) Volume and temperature at the end of compression, (ii) Change of entropy during compression

(iii) Change in entropy during constant volume cooling. Take Cp = 1.005 kJ/kg K, Cv=0.718kJ/kg K.

**Result: Final volume after compression** = **0.274 $m^3$**

**Final Temperature** =**185.47°c**

**Change of entropy during compression** = **1.483 KJ/K**

**Change of entropy during compression** = **1.487 KJ/K**

10. 0.2kg of air at 1.5bar and 27°C is compressed to a pressure of 15 bar according to the law $PV^{1.25}$=Constant. Determine work done on or by air, heat flow to or from the air, increase or decrease is entropy.

**Result: Work** = **40.29 KJ**

**Heat Transfer** = **15.1088 KJ**

**Change of entropy** = **0.17187 KJ/KGK**

11. Find the change in entropy of 1 kg of ice which is heated from mk -5°C to 0°C. It melts into water at 0°C, Cpice =2.093kJ/kgK. The pressure during heating maintained at 1 atm constant. Latent heat of fusion of ice =334.96kJ/kg.

**Result: Change of entropy** = **1.266 KJ/K**

12. 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/kg K and the latent heat of fusion of ice as 333.3 kJ/kg.

**Result: Entropy of Universe** = **0.096 KJ/K**

**Minimum amount of work** = **28.373 KJ**

13. 1 kg of ice melts at constant atmospheric pressure and at 0°C to form liquid water. If the latent heat of fusion of ice is 333.3 kJ/kg, calculate the entropy change during process.

14. Ten grammes of water at 20°C is converted into ice at -10°C at constant atmospheric pressure. Assuming the specific heat of liquid water to remain constant at 4.2 J/gK and tat of ice to be half of this value and taking the latent heat of fusion of ice at 0°C as 335 j/g, calculate the entropy change of the system.

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## TUTORIAL_-III
## PURE SUBSTANCES

1. Determine the condition of steam for the following cases
   (i) Steam has a pressure of 10 bar and specific volume 0.22 $m^3$.
   (ii) Steam has a pressure of 15 bar and temperature 225°c.
   (iii) Steam has a temperature of 200°c and enthalpy 2790.9 kj/kg.
   (iv) Steam has a temperature of 120°c and entropy 7 kj/kgk
2. A closed vessel of 0.2 $m^3$ contains steam at 1 MPa and temperature of 250°c. If the vessel is cooled so that pressure falls to 350 KPa. Determine the final temperature, heat transfer, and change of entropy during the process.
3. Steam initially at 400 kpa 0.6 dry is heated in a rigid vessel of 0.1$m^3$. The final condition is 600 kpa. Find the amount of heat added and mass of the steam.
4. 2 kg of steam initially at 5 bar and 0.6 dry is heated at constant pressure until the temperature becomes 350oc. Find the change in entropy and internal energy.
5. One kg of steam at a pressure of 700 kpa and 0.6 dry is heated at constant pressure until it becomes dry saturated. Determine change in internal energy and work done.
6. A mass of 0.9 kg of steam is initially at a pressure of 1.5 MPa and temperature 250°c and expands to 150 kpa. Assume the process is hyperbolic Find the condition of steam and work transfer.
7. A mass of 0.9 kg steam is initially at a pressure of 1.5 Mpa and a temperature of 250°c expands to 150 Kpa. Assume the process is isentropic. Find the condition of the steam and work transfer.
8. Two kg of steam at a pressure of 8 bar occupies a volume of 0.3$m^3$. If the air expands to a volume of 1.5 $m^3$ according to the law $pv^{1.3}$ =c. Calculate the work done and change in entropy during the process.
9. A vessel of volume 0.04$m^3$ contains a mixture of saturated water and steam at a temperature of 250°C. The mass of the liquid present is 9 kgs. Find the pressure, mass, specific volume, enthalpy, entropy and internal energy.
10. In a stream generator compressed water at 10MPa, 30°C enters a 30 mm diameter tube at the rate of 3 litres/sec. steam at 9MPa, 400°C exit the tube. Find the rate of heat transfer.

11. Steam at 0.8MPa, 250°C and flowing at the rate of 1 kg/s passes into a pipe carrying wet steam at 0.08MPa, 0.95 dry. After adiabatic mixing the flow rate is 2.3 kg/s. Determine the properties of the steam after mixing.

## SIMPLE RANKINE CYCLE

1. Find the efficiency of the Prime mover operating on the Rankine cycle between 7bar and 1bar for the following initial conditions.
   (a) The steam has a dryness fraction of 0.8
   (b) The steam is dry and saturated and
   (c) The steam is super heated to 350°C

   Draw the T-s diagram for each case. Neglected the pump work.

2. Determine the Rankine cycle efficiency working between 60bar and 0.4bar when supplied with dry saturated steam. By what percentage is the efficiency increased by supplying superheated steam of 300°C

## REHEAT RANKINE CYCLE

3. Consider steam power plant operating on an ideal reheat Rankine cycle. The steam enters the H.P. turbine at 30bar and 350°C. After expansion to 5bar, the steam is reheated to 350°C and then expanded the L.P. turbine to the condenser pressure of 0.075bar. Determine the thermal efficiency of the cycle and the quality of the steam at the outlet of the L.P. turbine.

4. A reheat cycle works between 120bar and 0.035bar. The initial steam temperature is 570°C. After isentropic expansion to dry saturated conditions, the steam is reheated to 500°C. Determine the efficiency of the cycle.

5. In the reheat cycle the steam is at 6MN/m2 and 450°C. The first reheat is done at 1MN/m2 to 370°C. The second reheat is done at 0.2MN/m2 to 320°C. The exhaust pressure is 0.02MN/m2. Determine the thermal efficiency and power developed at a steam rate of 1kg/s.

6. Steam is supplied to a turbine at 4MPa and 450°C and the Condenser is 6kPa. The machine runs at 300 rpm and the power developed 3MW. The expansion is in two stages, the steam being reheated to 410°C between H.P and L.P. stages. If all the stages develop the same power with a same isentropic efficiency, determine reheat pressure, thermal efficiency of the cycle & Steam flow rate.

## REGENARATIVE RANKINE CYCLE

7. A regenerative cycle utilizes steam as the working fluid. Steam is supplied to the turbine at 40bar and 450°C and the condenser pressure is 0.03bar. After expansion in the turbine to 3bar, some of the steam is extracted from the turbine for heating the feed water from the condenser in an open heater. The pressure in the boiler is 40bar and the state of the fluid leaving the heater is saturated liquid water at 3bar. Assuming isentropic heat drop in the turbine and pumps. Compute the efficiency of the cycle.

8. Consider an ideal regenerative cycle in which steam at 60bar, 400°Csupplied to the turbine and the condenser pressure is 0.5bar. There are two feed water heaters in the plant, both are open type and operates at optimum temperatures. Determine the quality of steam at turbine exhaust, network per kg of steam, cycle efficiency and steam flow rate. Neglect pump work.

9. In a regenerative steam cycle employing two open feed water heater, the steam is supplied to the turbine at 30 bar and 500°C and is exhausted to the condenser 0.04bar. The extraction points for two heaters are at 3.5bar and 0.75bar respectively. Calculate the thermal efficiency of the plant.

10. A steam turbine plant working on a single stage of regenerative feed heating receive steam at 30bar and 300°C, the turbine exhausts to a condenser at 0.15bar, while the bled steam is at 3baR. Assuming that the cycle uses actual regenerative cycle. Calculate the thermal efficiency of cycle. Compare this value with a Ranking cycle operating between same boiler and condenser pressures.

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## TUTORIAL _- IV

## PSYCHROMETRY

1. Air at 20°C, 40% RH is mixed adiabatically with air at 40°C, 40% RH in the ratio of 1kg of the former with 2kg of the latter (on dry basis). Find the final condition of air.

2. An air – water vapour mixture at 0.1Mpa, 30°C, 80% RH has a volume of $50m^3$. Calculate the specific humidity, dew point, wet bulb temperature, mass of dry air and mass of water vapour.

3. Air at 16°C and 25% relative humidity passes through a heater and then through a humidifier to reach final dry bulb temperature of 30°C and 50% relative humidity. Calculate the heat and moisture added to the air. What is the sensible heat factor?

4. Saturated air at 20°C at a rate of $1.16m^3$/sec is mixed adiabatically with the outside air at 35°C and 50% relative humidity at a rate of $0.5m^3$/sec. Assuming adiabatic mixing condition at 1 atm, determine specific humidity relative humidity, dry bulb temperature and volume flow rate of the mixture.

5. Dry bulb and we bulb temperatures of 1 atmospheric air stream are 40°c and 30°c respectively. Determine humidity ratio, relative humidity, specific humidity, dew point temperature, enthalpy, and specific volume. (Use formula method as well as chart method.)

6. The atmospheric air at 1 bar, dry bulb temperature 15oc and wet bulb temperature 10oc enters the heating coil whose temperature is 45°c . Assuming by-pass factor of heating coil as 0.45 determine dry bulb temperature wet bulb temperature, relative humidity of air leaving the coil and sensible heat added per kg of air.

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