**DHANALAKSHMI SRINIVASAN COLLEGE OF ENGINEERING AND TECHNOLOGY**

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 **DEPARTMENT OF MECHANICAL ENGINEERING**

**QUESTION BANK**


# **Subject Code**: ME8391 **Year / Semester**: II / III

# **Subject Name:** Engineering Thermodynamics

## UNIT – I BASIC CONCEPTS AND FIRST LAW PART – A

1. **Define Thermodynamics.**

Thermodynamics is a science which deals with the relations among heat, work and properties of system which are in equilibrium.

## What is the classical / macroscopic approaches in thermodynamics?

**[NOV/DEC 2013]**

In classical / macroscopic approach, the events occurring at molecular level are not taken into account in arriving at the behavior of the system.

1. **What is statistical / microscopic approach in thermodynamics? [NOV/DEC 2013]** In statistical / microscopic approach, the behavior of a system is arrived at from the events at molecular level.

## Distinguish between stored energies and interaction energies.

**Distinguish between ‘Macroscopic Energy’ and ‘Microscopic Energy’. [DEC 2012]** Stored energies / Microscopic energies are energy stored in the system such as Kinetic Energy, Potential Energy and internal energy (U).

Interaction energies / Macroscopic are energy in transit such as heat and work

## Describe the thermodynamic system

System : A system is a finite quantity of matter or a prescribed region of space Boundary : The actual or hypothetical envelope enclosing the system is the boundary of the system.

Surrounding: Anything outside the system is known as the surrounding Universe : A system and surrounding together comprise a universe

## Classify thermodynamic systems. Give an example for each system.

Open system [e.g. a geyser], Closed system [e.g. a system of steam in a pressure cooker], and Isolated system [e.g. a system of liquid in a thermos flask].

## What is an open system?

A system in which, mass and energy can be transferred across the boundary.

## What is a closed system?

A system in which there is no mass transfer but only energy transfer across the boundary.

## What is an isolated system?

A system in which neither mass nor energy crosses the boundary of the system.

1. **Show that energy of an isolated system is always constant. [NOV/DEC 2011]** For an isolated system, Q =0 and W = 0, Therefore according to first law, E = 0 and hence energy is constant.

## What is meant by Continuum? Identify its importance.

In thermodynamics, material in a system is considered to be continuum that is, it is continuously distributed throughout the system. This assumption allows us to describe a system using only a few measurable properties, thereby making the analysis easier

1. **Using Knudsen number define continuum. [NOV/DEC 2018]** The Knudsen number (Kn) is a [dimensionless number](https://en.wikipedia.org/wiki/Dimensionless_number) defined as the [ratio](https://en.wikipedia.org/wiki/Ratio) of the molecular [mean free path](https://en.wikipedia.org/wiki/Mean_free_path) length to a [representative physical length scale.](https://en.wikipedia.org/wiki/Characteristic_dimension) This length scale could be, for example, the [radius](https://en.wikipedia.org/wiki/Radius) of a body in a fluid. The Knudsen number helps determine whether [statistical mechanics](https://en.wikipedia.org/wiki/Statistical_mechanics) or the [continuum mechanics](https://en.wikipedia.org/wiki/Continuum_mechanics) formulation of [fluid dynamics](https://en.wikipedia.org/wiki/Fluid_dynamics) should be used to model a situation. If the Knudsen number is near or greater than one, the mean free path of a molecule is comparable to a length scale of the problem, and the continuum assumption of [fluid mechanics](https://en.wikipedia.org/wiki/Fluid_mechanics) is no longer a good approximation. In such cases, statistical methods should be used.

## What is meant by control volume approach?

Study of a region in space with fixed volume is known as control volume approach. It is applicable for open systems.

1. **What is meant by control volume and control surface? [NOV/DEC 2018]** Control volume is a volume in space of special interest for particular analysis. The surface of the control volume is referred as a control surface and is a closed surface. The surface is defined with relative to a coordinate system that may be fixed, moving or rotating. Mass, heat and work can cross the control surface and mass and properties can change with time within the control volume
2. **Define thermodynamic equilibrium? [NOV/DEC 2014]** It is a state of balance; a system is said to be thermodynamic equilibrium if the conditions for thermal, mechanical and chemical equilibrium are satisfied.

## What is the thermodynamic property of system?

Thermodynamic property is any characteristic of a substance which is used to identify the state of the system and can be measured, when the system remains in an equilibrium state

1. **Describe intensive and extensive properties [NOV 2013, NOV 2016, NOV 2020]** Intensive properties: These properties do not depend on the mass of the system. Examples: Temperature and pressure.

Extensive properties: These properties depend on the mass of the system. Example: Volume

## Classify the following properties as intensive or extensive or neither. (a) Pressure

**(b) Temperature (c) Volume (d) internal energy (e) Mass (f) Specific Enthalpy**

Extensive property: (c), (d), (e); Intensive property: (a), (b), (f) **[NOV/DEC 2015]**

## Define ‘state’

State is a condition of the system when it has definite values for all its properties

## Define ‘Process’ [APR 2018]

When one or more properties change with time in an operation, it is said to undergo a process.

## istinguish between ‘flow process’ and ‘non-flow process’.

Process undergone by a closed system is a non-flow process and processes undergone by open systems are flow process.

## Define the term cycle.

When a system undergoes a series of processes at the end of which it returns to its initial condition, it is known as cycle.

1. **What is meant by open and closed cycle? [NOV 2019]** In a closed cycle, the same working substance will be undergoing the cycle again and again. In an open cycle, the working substance will be exhausted at the end of a series of processes which will be repeated again and again.
2. **What are point and path function? Give some examples. [APR2018]** Path function: The function whose value is dependent on the path of the process. e.g. work transfer and heat transfer

Point function: The function the change in whose value is independent on the path of the process. e.g. pressure, temperature, etc.

## Classify the following as point or path function: Heat, Enthalpy, Displacement work, Entropy.

Heat and Displacement work – Path functions, Enthalpy and Entropy – point functions.

1. **State Zeroth law of thermodynamics*.* Why is it so called? [NOV 2017,2019,JUL2021]** If a body A is in thermal equilibrium with a body B, and also separately with a body C, then B and C are in thermal equilibrium with each other. It is called so, as it is more basic compared to First law, which was established prior to it.

## What is the requirement for thermal equilibrium? Which law governs it?

**[APR 2018]**

If two systems which are in mechanical, chemical and phase equilibrium do not exchange heat with each other, they will be under thermal equilibrium. Zeroth law governs thermal equilibrium.

## List any five physical properties of matter which can be used for measurement of temperature. [NOV/DEC 2015]

Pressure (in constant volume gas thermometer), Volume (in constant pressure gas thermometer), Length (in mercury-in-glass thermometer), EMF (in thermocouple) and resistance (in electric resistance thermometer).

## Define reversible and irreversible process.

Reversible process: A reversible process is one which can be stopped at any stage and reversed so that the system and surroundings are exactly restored to their initial states. Irreversible process: An irreversible process is one which can be stopped at any stage and reversed but the system and surroundings are not restored to their initial states.

1. **What do you understand by flow work? Is it different from displacement work?** Work transfer process involving open systems or control volumes where flow of mass across the boundary occurs is known as flow work. e.g. Compression of air in an air- compressor. A work transfer in which one or more boundaries of the system is moved is called displacement work or moving boundary work. It is also called pdV work. e.g. compression of a gas in a piston-cylinder arrangement.
2. **State the thermodynamic definition of work. [NOV/DEC 2015]** In thermodynamics work done by a system on its surroundings is defined as that interaction whose sole effect, external to the system is equivalent to raising of a mass through a certain distance.

## Define work and its Sign convention

Work is transient quantity which appears at the boundary when a system changes its state due to the movement of a part of the boundary under the action of a force.

Sign convention:

If the work is done by the system, Work output of the system = + W If the work is done on the system, Work input to system = – W

## Define Heat

Heat is transient quantity which appears at the boundary when a system changes its state due to a difference in temperature between the system and its surroundings.

Heat received by the system = + Q, Heat rejected or given up by the system = – Q.

## Enlist the similarities between work and heat. [NOV/DEC 2014]

|  |  |
| --- | --- |
| **WORK** | **HEAT** |
| Work is ‘something’ which appears at the boundary when a system changes its state due to the movement of a part of the boundary under the action of aforce | Heat is ‘something’ which appears at the boundary when a system changes its state due to a difference in temperature between the system and its surroundings |
| Work output of the system = + W | Heat received by the system = + Q, |
| Work input to system = – W | Heat rejected or given up by the system = – Q |

1. **Define specific heat.**

Amount of heat required to raise a unit mass of a substance through unit rise in temperature.

## Define specific heat at constant volume.

Amount of heat required to raise a unit mass of a substance through unit rise in temperature when the volume remains constant.

## Define specific heat at constant pressure.

Amount of heat required to raise a unit mass of a substance through unit rise in temperature when the pressure remains constant.

## What is a quasi-static process? Give an example.

A process in which the system departs from equilibrium state only by a very small extent is quasi-equilibrium process. Slow compression and slow expansions of a system of gases are quasi-equilibrium processes.

## Isentropic process need not be necessarily an adiabatic process – justify

Entropy increases due to irreversibility and decreases due to heat loss. If these two changes are equal in magnitude, the process would be isentropic without being adiabatic.

## Define an isentropic process.

Isentropic process is a process in which there is no change in entropy. A reversible adiabatic process is isentropic process.

1. **What is the difference between adiabatic and isentropic processes? [MAY 2013]** Adiabatic process is a process without heat transfer. Isentropic process is a process with no change in entropy. A reversible adiabatic process is isentropic.

## What is meant by ‘Hyperbolic’ process? [APR/MAY 2011]

A process in which pV = constant is known as hyperbolic process.

## Which property of a system increases when heat is transferred: [a] At constant volume [b] At constant pressure [APR/MAY 2010]

[a] Pressure increases at constant volume [b] Volume increases at constant pressure

1. **What is a steady flow process? [NOV/DEC 2017]** It is a process in which, properties at any location are constant with respect to time. For a flow process to be steady, there should be no accumulation of mass or energy.

## What are the conditions for steady flow process? [APR/MAY 2013]

There should not be any accumulation of mass or energy in the system.

## Define flow energy. [APR/MAY 2013]

Energy required to introduce a quantity of fluid in a pipe section is flow energy. It is equal to pV.

## Define Internal Energy.

Internal energy of a gas is the energy stored in a gas due to its molecular interactions. It is denoted as U

## Define enthalpy of a system.

It is the sum of internal energy and flow energy. i.e. H = U+ pV

## Define Latent heat.

Amount of heat required to cause a phase change in unit mass of a substance at constant pressure and temperature.

## A Write down the equation for first law for a steady flow process. [ MAY 2016]

𝑪 𝟐

𝟏

+ 𝒈𝒛𝟏

𝟐

**Where,**

+ 𝒖𝟏

+ 𝒑𝟏

𝒗𝟏

𝑪 𝟐

+ 𝑸 = + 𝒈𝒛𝟐

𝟐

𝟐

+ 𝒖𝟐

+ 𝒑𝟐

𝒗𝟐

+ 𝑾

Q = Heat supplied (or entering the boundary) per kg of fluid,

W = Work done by (or work coming out of the boundary) 1 kg of fluid C = Velocity of fluid, Z = Height above datum, p = Pressure of the fluid,

u = Internal energy per kg of fluid, and pv = Energy required for 1 kg of fluid.

## Give the energy equation applicable for an adiabatic nozzle and an adiabatic turbine. [APR/MAY 2016,2018]

**Adiabatic nozzle**

C2 C2

 2 =  1 + (h1 − h2) C2 = √C2 + 2000 (h1 − h2) 𝐶2 = 44.7√+(h1 − h2))

2 2000 2 1

Where, z1 = z2, Q=0, W=0, ℎ1 = 𝑢1 + 𝑝1𝑣1 and ℎ2 = 𝑢2 + 𝑝2𝑣2

## Adiabatic turbine

𝟐 𝟐

𝐂 −𝐂

𝐖 = 𝐦 [ 𝟏 𝟐 + (𝐡 − 𝐡 )]

𝟏𝟐 𝟏 𝟐

𝟐𝟎𝟎𝟎

Where, z1 = z2, ℎ1 = 𝑢1 + 𝑝1𝑣1 and ℎ2 = 𝑢2 + 𝑝2𝑣2, Q = 0

##  Closed system undergoes a cycle consisting of three heat transfers and two work transfers. The heat transfers are: 20 kJ supplied to the system, 40 kJ rejected by the system and 30 kJ supplied to the system and during one of the work transfers, 30 kJ is obtained from the system. What is the magnitude and direction of the other work transfer?

Q1 + Q2 + Q3 = W1 + W2; W2 = 20-40+30-30 =-20 kJ, 20kJ of work is supplied to the system.

## A domestic refrigerator is loaded with food and the door is closed. During certain period the machine consumes 1 kW h of energy and the internal energy of the system drops by 5000 kJ. Find the net heat transfer for the system.

Q = W + E

here, W = -1 kW h = -3600 kJ and E = -5000 kJ , therefore **Q = -8600 kJ**.

## Should the automobile radiator be analysed as a closed system or as an open system? Explain. [NOV/DEC 2016]

The automobile radiator should be analysed as an open system since the mass and energy cross the boundary of the system.

1. **A closed insulated vessel contains 200 kg of water. A paddle wheel immersed in the water is driven at 400 rev/min with an average torque of 500 Nm. If the test run is made for 30 minutes, determine rise in the temperature of water. Take specific heat of water as 4.186 kJ/kg/K. [NOV/DEC 2015]** Given: m = 200 kg, Cp = 4.186 kJ/kg K, N = 400 rpm, t = 30 minutes, T = 500 Nm Applicable concept: paddle wheel work is dissipated as heat into water, raising its temperature.

Paddle wheel work,

W = (2 N t) T = 2 × 400 × 30 × 500 / 1000 = 37699 kJ W = Q = mCpT,

Therefore T = 37699 / (200×4.186) = **45.03 K**

## 56. What is PMM1?

An imaginary machine which supplies work continuously without any other form of energy input is Perpetual Motion Machine of First kind (PMM1).

## PART – B (CO202.1)

1. i) State first law of thermodynamics and list its limitations.
	1. A fluid in a piston and cylinder executes 220 cycles per min with four processes. The net heat transfer during a cycle is -300kJ. Complete the following table showing the method for each item, and compute the net rate of work output in kW. **[NOV 2020]**

|  |  |  |  |
| --- | --- | --- | --- |
| Process | Q(kJ/min) | W(kJ/min) | ΔE(kJ/min) |
| 1-2 | 0 | 4350 | ? |
| 2-3 | 42000 | 0 | ? |
| 3-4 | -4200 | ? | -73500 |
| 4-1 | ? | ? | ? |

1. i) State first law of thermodynamics and specify its applications.
	1. A piston and cylinder machine containing a fluid system has a stirring device as shown in Fig.



The piston is frictionless, and it is held down against the fluid due to atmospheric pressure of 101.3 kPa. The stirring device is turned 9500 revolutions with an average torque against the fluid of 1.25 Nm. Meanwhile the piston of 0.65 m diameter moves out 0.6 m. Find the network transfer for the system. **[NOV 2019]**

1. i) Prove that for a steady flow system with negligible change in kinetic and potential energy, the shaft work per kg can be expressed as Ws= - vdp

(ii) A working substance flows at a rate of 5kgs/s into a steady flow system at 6 bar 2000kJ/kg internal energy and 0.4 m/kg specific volume with a velocity of 300 m/s. It leaves at 10 bar, 1600 kJ/kg of the internal energy, 1.2 m/kg of specific volume with a velocity of 150 m/s. The inlet is 10m above the outlet. The work transfer to the surroundings is 3 MW. Evaluate the change in enthalpy and estimate the heat transfer and indicate the direction. **[NOV 2019]**

1. (i)Derive the expression for the displacement work.

(ii)Determine the work transfer and heat transfer for a system in which a perfect gas having molecular weight of 16kg/kmol is compressed from 101.3kPa, 20ºC to a pressure of 600kPa following the law pV1.3=Constant. Take specific heat at constant pressure of gas as 1.7kJ/kg.K. **[NOV/DEC 2018]**

1. (i)Derive the expression for workdone for constant volume and polytrophic process.

(ii) Determine the total work done by a gas system following an expansion process as shown in Figure. **[APR/MAY 2018]**



1. A piston-cylinder device contains 0.15 kg of air initially at 2 MPa and 350ºC. The air is first expanded isothermally to 500 kPa, then compressed polytropically with a polytropic exponent of 1.2 to the initial pressure, and finally compressed at the constant pressure to the initial state. Determine the boundary work for each process and the network of the cycle. **[NOV/DEC 2016]**
2. A mass of air is initially at 260 ºC and 700 kPa, and occupies 0.028 m3. The air is expanded at constant pressure to 0.084 m3. A polytropic process with n=1.5 is then carried out followed by a constant temperature process which completes a cycle. All the process are reversible.
3. Sketch the cycle in T-S and P-V planes, (ii) find the heat received and heat rejected in the cycle. (iii)Find the efficiency of the cycle. **[APR/MAY 2016]**
4. A piston-cylinder assembly contains air (ideal gas with 𝛾=1.4) at 200 kPa and occupies a volume of 0.01 m3. The piston is attached to one end of a spring and the other end of the spring is fixed to a wall. The force exerted by the spring on the piston is proportional to the decrease in the length of the spring from its natural length. The ambient atmospheric pressure is 100 kPa. Now, the air in the cylinder is heated till the volume is doubled and at this instant it is found that the pressure of the air in the cylinder is 500 kPa. Calculate the work done by the gas. **[DEC 2015]**
5. Three grams of nitrogen gas at 6 atm and 160°C in a frictionless piston cylinder device is expanded adiabatically to double its initial volume, then compressed again at constant volume to its initial state. Calculate the network done on the gas. Draw the P-V diagram for the processes. **[NOV/DEC 2014]**
6. A three process cycle operating with nitrogen as the working substance has constant temperature compression at 34°C with initial pressure 100 kPa. Then the gas undergoes a constant volume heating and then polytropic expansion with 1.35 as index of compression. The isothermal compression requires -67 kJ/kg of work. Determine (i) P, v and T around the cycle, ii).Heat in and out, iii) Network. (iii)[For nitrogen gas, Cv=0.7431 kJ/kgK] **[APR/MAY 2013]**
7. Air at 1.02 bar, 22°C, initially occupying a cylinder volume of 0.015 m3, is compressed reversibly and adiabatically by a piston to a pressure of 6.8 bar. Calculate: (i) The final temperature; (ii) The final volume; (iii) The work done.
8. A stationary mass of a gas is compressed without friction from an initial state of 0.3 m3 and 0.105 MPa to a final state of 0.15 m3 and 0.105 MPa, the pressure remaining constant during the process. There is a transfer of 37.6 kJ of heat from the gas during the process. How much does the internal energy of the gas change? **[MAY 2017]**
9. A gas undergoes a thermodynamic cycle consisting of three processes beginning at an initial state where p1 = 1 bar, V1 = 1.5 m3 and U1 = 512 kJ. The processes are as follows:

a. Process 1–2: Compression with pV = constant to p2 = 2 bar, U2 = 690 kJ,

b. Process 2–3: W23 = 0, Q23 = –150 kJ, and

c. Process 3–1: W31 = +50 kJ. Neglecting KE and PE changes, Determine the heat interactions Q12 and Q31.

1. A gas undergoes a thermodynamic cycle consisting of the following processes: Process 1–2: Constant pressure p = 1.4 bar, V1 = 0.028 m3, W12 = 10.5 kJ

Process 2–3: Compression with pV = constant, U3 = U2 Process 3–1: Constant volume, U1 – U3 = – 26.4 kJ.

There are no significant changes in KE and PE. (a) Sketch the cycle on a p–V diagram,

(b) Calculate the network for the cycle in kJ (c) Calculate the heat transfer for process 1–2, (d) Show that cycle ΣQ = ΣW.

1. 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 the volume (p=a+bV). The internal energy of the fluid is given by U = (34+3.15pV) where U is in kJ, p in kPa and V in cubic meter. If the fluid changes from an initial state of 170 kPa, 0.03 m3 to a final state of 400 kPa, 0.06 m3, with no work other than that done on the piston, find the direction and magnitude of the work and heat transfer. **[NOV/DEC 12]**
2. 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 0.2 m3 and 1.2 m3. The specific internal energy of the gas is given by the relation u = (1.5 pv-85) kJ/kg, where p is in kPa and V is in m3/kg. Calculate the net heat transfer and the maximum internal energy of the gas attained during expansion. **[NOV 12]**
3. A system of volume V contains a mass m of gas at pressure p and temperature T. The macroscopic properties of the system obey the following relationship:

𝑎

[𝑃 + 𝑉2] (𝑉 − 𝑏) = 𝑚𝑅𝑇

Where a, b, and R are constants. Obtain an expression for the displacement work done by the system during a constant-temperature expansion from volume V1 to volume V2.Calculate the work done by a system which contains 10 kg of this gas expanding from 1 m3 to 10 m3 at a temperature of 293 K. Use the values a = 15.7 ×10 Nm4, b = 1.07 ×10−2m3, and R = 0.278 kJ/kg-K.

1. The properties of a certain fluid are related as follows: i. u = 196 + 0.718t,

ii. pv = 0.287 (t + 273)

Where u is the specific internal energy (kJ/kg), t is in °C, p is pressure (kN/m2), and v is specific volume (m3/kg). For this fluid, find Cv and Cp.

1. A gas contained in a cylinder is compressed from 1 MPa and 0.05 m3 to 2 MPa. Compression is governed by pV1.4 = constant. Internal energy of gas is given by U = (7.5 PV-425) kJ. Where P is pressure in kPa and V is volume in m3. Determine heat, work and change in internal energy assuming compression process to be quasi static. Also find out work interaction, if the 180 kJ of heat is transferred to system between same states. Also explain why it is different from above? **[APR/MAY 2011]**
2. (i) Prove energy as a property of the system.
3. 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 inlet are 0.15 m3/kg, 600 kPa and 16 m/s. The inlet is 32 m above the floor and the discharge pipe is floor level. The discharge conditions are 0.62 m3/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 this apparatus, does the specific internal energy increases or decreases and by how much? **[APR/MAY 2018]**
4. Derive the steady flow energy equation and reduce it for a turbine, pump, nozzle and a heat exchanger. **[NOV/DEC 2017] [NOV/DEC 2018]**
5. i) Derive steady flow energy equation per unit mass and show that shaft work produced by a gas turbine is equal to the enthalpy drop across the gas turbine.
	1. A blower handles 1 kg/s of air at 293 K and consumes a power of 15kW. The inlet and outlet velocities of the air are 100 m/s and 150 m/s respectively. Find the exit air temperature and the pressure ratio, assuming Adiabatic conditions. Take Cp = 1.005kJ/kg. **[NOV 2020]**
6. Air enters the compressor of a gas-turbine plant at ambient conditions of 100 kPa and 25ºC with a low velocity and exits at 1 MPa and 347ºC with a velocity of 90 m/s. The compressor is cooled at a rate of 1500 kJ/min, and the power input to the compressor is 250 kW. Determine the mass flow rate of air through the compressor. Assume Cp=1.005 kJ/kg K. **[NOV/DEC 2016]**
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 exit velocity is 10 m/s. During the process 25 MJ/h of heat from an external source is supplied and the increase in enthalpy is 5 kJ/kg. The exit point is 20 m above the entry point. Determine flow work from the system if the fluid flow rate is 45 kg/min. [**MAY 15]**
8. In a gas turbine installation air is heated inside heat exchanger up to 750°C from ambient temperature of 27°C. Hot air then enters into gas turbine with the velocity of 50 m/s and leaves at 600°C. Air leaving turbine enters a nozzle at 60 m/s velocity and leaves nozzle at temperature of 500°C. For unity mass flow rate of air, determine the following assuming adiabatic expansion in turbine and nozzle,
9. Heat transfer to air in heat exchanger, (ii) Power output from turbine,
10. Velocity at exit of nozzle. Take Cp for air as 1.005 kJ/kgK. **[NOV/DEC 2018]**
11. Air is compressed from 100 kPa and 22°C to a pressure of 1 MPa while being cooled at the rate of 16 kJ/kg by circulating water through the compressor casing. The volume flow rate of air at inlet Condition is 150 m3/min and power input to compressor is 500 kW. Neglecting the gravitational potential energy, determine the mass flow rate and the temperature of air at exit. **[APR/MAY 2012]**
12. Air flows steadily at the rate of 0.4 kg/s through an air compressor, entering at 6 m/s with a pressure of 1 bar and a specific volume of 0.85 m3/kg and leaving at 4.5 m/s with a pressure of 6.9 bar and a specific volume of 0.16 m3/kg. The internal energy of air leaving is 88 kJ/kg greater than that of the air entering. Cooling water in a jacket surrounding the cylinder absorbs heat from the air at the rate of 59 W. Calculate the power required to derive the compressor and the inlet and outlet cross sectional area.
13. Air flows at the rate of 0.5 kg/s through an air compressor, entering at 7 m/s, 100 kPa and 0.95 m3/kg and leaving at 5 m/s, 700 kPa and 0.19 m3/kg. The internal energy of 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.
14. Compute the rate of shaft work input to the air in kW
15. Find the ratio of the inlet pipe diameter to outer pipe diameter. **[DEC 2011]**
16. 90 kJ of heat are supplied to a system at a constant volume. The system rejects 95 kJ of heat at constant pressure and 18 kJ of work is done on it. The system is brought to original state by adiabatic process. Determine : The adiabatic work ;
17. The values of internal energy at all end states if initial value is 105 kJ. A fluid system, contained in a piston and cylinder machine, passes through a complete cycle of four processes. The sum of all heat transferred during a cycle is -340 kJ. The system completes 200 cycles per min.

|  |  |  |
| --- | --- | --- |
| Process | Q (kJ/min) | W (kJ/min) E (kJ/min) |
| 1-2 | 0 | 4340 - |
| 2-3 | 42,000 | 0 - |
| 3-4 | - 4,200 | 0 -73,200 |
| 4-1 | - | - - |

Complete the above table showing the method for each item, and compute the net rate of work output in kW. **[APR/MAY 2012]**

1. A room for four persons has 2 fans, each consuming 0.18 kW power, and three 100W lamps. Ventilation air at the rate of 80 kg/h 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/h. Determine the rate at which heat is removed by a room cooler, so that a steady state is maintained in the room. **[APR/MAY 2016]**
2. An insulated rigid tank of 1.5 m3 of air with a pressure of 6 bar and 100ºC discharges air in to the atmosphere which is at 1 bar through a discharge pipe till its pressure becomes 1 bar. Calculate the velocity of air in the discharge pipe.

Evaluate the work that can be obtained from the frictionless turbine using the kinetic energy of that air. **[APR/MAY 2016]**

1. An insulated rigid tank having 5 kg of air at 3 atm and 30°C is connected to an air supply line at 8 atm and 50°C through a valve. The valve is now slowly opened to allow the air from the supply line to flow into the tank until the tank pressure reaches 8 atm, and then the valve is closed. Determine the final temperature of the air in the tank. Also, find the amount of air added to the tank. **[NOV/DEC 2015]**
2. A vessel of constant volume 0.3 m3 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, find the mass of air entering the vessel. **[APR/MAY 2015]**
3. A rigid tank containing 0.4 m3 of air at 400 kPa and 30°C is connected by a valve to a piston cylinder device with zero clearance. The mass of the piston is such that a pressure of 200kPa is required to raise the piston. The valve is opened slightly and air is allowed to flow into the cylinder until the pressure of the tank drops to 200 kPa. During this process, heat is exchanged with the surrounding such that the entire air remains at 30°C at all times. Determine the heat transfer for this process.

## PART – C (CO202.1)

1. 680 of fish at 5°C are to be frozen and stored at – 12°C. The specific heat of fish above freezing point is 3.182, and below freezing point is 1.717 kJ/kg K. The freezing point is – 2°C, and the latent heat of fusion is 234.5 kJ/kg. How much heat must be removed to cool the fish, and what per cent of this is latent heat?
2. 25 people attended a farewell party in a small room of size 10x8m and have a 5m ceiling. Each person gives up 350 kJ of heat per hour. Assuming that the room is completely sealed off and insulated, calculate the air temperature rise occurring in 10 minutes. Assume Cv of air 0.718 kJ/kgK and R=0.287 kJ/kgK and each person occupies a volume of 0.05 m3. Take p=101.325 kPa and T=20°C
3. 0.1m3 of an ideal gas at 300 K and 1 bar is compressed adiabatically to 8 bar. It is then cooled at constant volume and further expanded isothermally so as to reach the condition from where it started. Calculate: (i) Pressure at the end of constant volume cooling. (ii) Change in internal energy during constant volume process. (iii) Net work done and heat transferred during the cycle. Assume Cp=14.3 & Cv=10.2 kJ/kgK.
4. A mass of 8 kg gas expands within a flexible container so that the p–v relationship is of the form pVl.2 = constant. The initial pressure is 1000 kPa and the initial volume is 1 m3. The final pressure is 5 kPa. If specific internal energy of the gas decreases by 40 kJ/kg, find the heat transfer in magnitude and direction.
5. Air at a temperature of 20°C passes through a heat exchanger at a velocity of 40 m/s where its temperature is raised to 820°C. It then enters a turbine with same velocity of 40 m/s and expands till the temperature falls to 620°C. On leaving the turbine, the air is taken at a velocity of 55 m/s to a nozzle where it expands until the temperature has fallen to510°C. If the air flow rate is 2.5 kg/s, calculate :
	1. Rate of heat transfer to the air in the heat exchanger
	2. The power output from the turbine assuming no heat loss
6. At the inlet to a certain nozzle the enthalpy of fluid passing is 2800 kJ/kg, and the velocity is 50 m/s. At the discharge end the enthalpy is 2600 kJ/kg. The nozzle is horizontal and there is negligible heat loss from it.
	1. Find the velocity at exit of the nozzle.
	2. If the inlet area is 900 cm2 and the specific volume at inlet is 0.187 m3/kg, find the mass flow rate.
	3. If the specific volume at the nozzle exit is 0.498 m3/kg, find the exit area of nozzle

## UNIT – II SECOND LAW AND AVAILABILITY ANALYSIS PART – A (CO202.2)

1. **List the limitations of First law of Thermodynamics.**

First law does not indicate whether a process is possible or not. It does not give any information regarding the extent of conversion of heat into work.

## What is Perpetual motion machine of the second kind?

Perpetual motion machine of second kind draws heat continuously from single reservoir and converts it into equivalent amount of work. Thus it gives 100% efficiency

1. **Define Kelvin Planck Statement. [APR/MAY 2014]** It states that it is impossible to construct an engine, which while operating in a cycle produces no other effect except to extract heat from a single reservoir and do equivalent amount of work.

## Define Clausius state

It states that it is impossible to construct a device which operating in a cycle will produce no effect other than the transfer of heat from a lower temperature region to higher temperature region.

## Define heat reservoir and source.

As it can act as a source and sink of heat, it is often also referred to as a heat reservoir or heat bath. Lakes, oceans and rivers often serve as thermal reservoirs in geophysical processes, such as the weather. In atmospheric science, large air masses in the atmosphere often function as thermal reservoirs

## Define Heat engine.

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

1. **Explain the term source and sink or thermal energy reservoirs. [NOV/DEC 2017]** Source is a thermal reservoir, which supplies heat to the system and sink is a thermal reservoir, which takes the heat from the system.

## What is a cyclic heat engine?

A cyclic heat engine is a thermodynamic system working on a cycle having net heat input and network output.

## Draw a schematic of a heat engine and expression of efficiency

|  |  |
| --- | --- |
|  | **Efficiency:**𝜼 = 𝑸𝟏−𝑸𝟐𝑬𝑵𝑮𝑰𝑵𝑬 𝑸𝟏 |

1. **A reversible heat engine operates between a source at 800ºC and a sink at 30ºC. What is the least rate of heat rejection per KW network output of the engine?**

## [APR/MAY 2016]

Efficiency:

𝜂𝐸𝑁𝐺𝐼𝑁𝐸

= 1 − 𝑇2

𝑇1

𝜂𝐸𝑁𝐺𝐼𝑁𝐸

= 1 − 303

1073

𝜂𝐸𝑁𝐺𝐼𝑁𝐸

= 71.8%

𝜂𝐸𝑁𝐺𝐼𝑁𝐸

= output

input

𝜂𝐸𝑁𝐺𝐼𝑁𝐸

= 1

𝑄𝑠

𝐐𝐬

= 𝟏. 𝟑𝟗𝐤𝐖

QR = Qs − W QR = 1.39 − 1 𝐐𝐑 = 𝟎. 𝟑𝟗𝐤𝐖

## A heat engine with a thermal efficiency of 45 percent rejects 500 kJ/kg of heat. How much heat does it receive? [NOV/DEC 2016]

ηENGINE

= 1 − QR

QS

0.45 = 1 − 500

QS

𝐐𝐒

= 𝟗𝟎𝟗. 𝟏𝐤𝐉/𝐤𝐠

## A heat engine is supplied with 2512 kJ/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. (a) 867 kJ/min (b) 1015 kJ/min

**[APR/MAY 2015]**

Maximum thermal efficiency of his engine possible

𝜂 = 1 − 𝑇2

𝑇1

𝜂 = 1 − 373

923

𝜂 = 54.68%

(a)𝜂 = 1 − 𝑄2 = 1 − 867

= 65.48 % max , it is impossible

𝑄1

2512

(b) 𝜂 = 1 − 𝑄2 = 1 − 1015 = 59.59 % max , it is impossible

𝑄1

2512

## An inventor claims to have developed an engine which absorbs 100 kW of heat from a reservoir at 1000 K produces 60 kW of work and rejects heat to a reservoir at 500 K. Will you advise investment in its development? [NOV/DEC 2014] Maximum thermal efficiency of his engine possible

𝜂 = 1 − 𝑇2

𝑇1

𝜂 = 1 − 500

1000

𝜂 = 50%

Also, thermal efficiency of the engine,

𝜂 = 𝑊𝑜𝑟𝑘 𝑑𝑜𝑛𝑒

𝐻𝑒𝑎𝑡 𝑆𝑢𝑝𝑝𝑙𝑖𝑒𝑑

𝜂 = 60

100

𝜂 = 60%

Which is not feasible as no engine can be more efficient than that working on Carnot cycle? Hence claims of the inventor is not true

## Define the term COP? [NOV 2019]

Co-efficient of performance is defined as the ratio of heat extracted or rejected to work input.

Heat extracted or rejected COP =

Work input

## Define Heat pump.

A heat pump is a device, which is working in a cycle and transfers heat from a lower temperature region to higher temperature region.

## Draw a schematic of a heat pump and expression of COP. [NOV/DEC 2013]

|  |  |
| --- | --- |
|  | **COP of Heat Pump:**𝑸𝟏𝑪𝑶𝑷𝑯𝑷 = 𝑸 − 𝑸𝟏 𝟐 |

1. **Define refrigerator. [NOV 2019]**

A refrigerator is a device which operating in a cyclic process, maintains the temperature of a cold body at a temperature lower than the temperature of the surroundings.

## Draw a schematic of a heat pump and expression of COP.

|  |  |
| --- | --- |
|  | **COP of Refrigerator:**𝑸𝟐𝑪𝑶𝑷𝑯𝑷 = 𝑸 − 𝑸𝟏 𝟐 |

1. **Write the expression for COP of a reversible heat pump and a refrigerator?**

|  |  |
| --- | --- |
| **Reversible Heat Pump** | **Reversible Refrigerator** |
| 𝑇2𝐶𝑂𝑃𝐻𝑃 = 𝑇 − 𝑇2 1 | 𝑇1𝐶𝑂𝑃𝑅𝑒𝑓 = 𝑇 − 𝑇2 1 |

## What is the relation between COPHP and COP ref?

COP of Heat Pump = COP of Refrigeration + 1= (COPHP = COPref+1)

## Why the COP of a heat pump is higher than that of a refrigerator, if they both operate between the same temperature limits?

The heat supplied by the heat pump into the space includes the work input required whereas the heat extracted by a refrigerator from a space does not include the work input

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

The rate of heat leakage into the freezer must be equal to the rate of heat removal Q2 from it. For least power requirement, the COP is to be maximum, i.e. The refrigerator is to be reversible.

COP of a reversible refrigerator

Therefore,

COP of refrigerator

𝐶𝑂𝑃𝑅𝑒𝑓,𝑟𝑒𝑣 =

𝑇1

𝑇2

− 𝑇2

258

= = 5.733

45

𝐶𝑂𝑃𝑅𝑒𝑓

= 𝑄2

𝑊

W = 1.75 / 5.733 = **0. 3052 kW**

1. **Carnot refrigerator requires 1.25 kW per ton of refrigeration to maintain the temperature of 243 K. Find the COP of Carnot refrigerator. [APR/MAY 2015]** COP = Q2/W, here Q2= 1 Ton of Refrigeration, which is equal to 3.5 kW

Therefore COP = 3.5/1.25 = 2.8

1. **Ice is formed at 0°C from water at 20°C. The temperature of the brine is -10°C. Find the ice formed per kW hour. Assume that the refrigeration cycle used is perfect reversed Carnot cycle. Latent heat of ice = 80 kcal/kg. [APR/MAY 2015]** The heat removed from one kg of water at 20°C to convert it into ice at 0°C,

Q = 1× 4.186 × (20-0) + 1× 80×4.186 = 418.6 kJ/kg

Mass of ice formed per kW hour = 3600 /418.6 = 8.6 kg.

## What is the difference between a heat pump and a refrigerator? [APR/MAY 2012]

|  |  |
| --- | --- |
| Heat pump is a device which operating in cyclic process, maintains the temperature of a hot body at a temperature higher than thetemperature of surroundings. | A refrigerator is a device which operating in a cyclic process, maintains the temperature of a cold body at a temperature lower than thetemperature of the surroundings. |

1. **What are the processes involved in Carnot cycle**
	* Reversible isothermal compression
	* Isentropic compression
	* Reversible isothermal expansion
	* Isentropic expansion
2. **State Carnot theorem. [APR/MAY 2014, 2018]** No heat engine operating in a cyclic process between two fixed temperatures, can be more efficient than a reversible engine operating between the same temperature limits.

## What are the Corollaries of Carnot theorem? [APR/MAY 2014]

* The efficiency of any reversible heat engine operating between two reservoirs is independent of the nature of the working fluid and depends only on the temperature of the reservoirs.
* All the reversible engines operating between the two given thermal reservoirs with fixed temperatures, have the same efficiency.

## Write the expression for efficiency of the Carnot cycle.

𝑇2 − 𝑇1

ɳ =

𝑇2

## Why a heat engine cannot have 100% efficiency?

For all the heat engines there will be a heat loss between system and surroundings.

Therefore we can’t convert all the heat input into useful work.

## Name two alternative methods by which the efficiency of a Carnot cycle can be increased.

* Efficiency can be increased as the higher temperature T1 increases. i.e. temperature of heat added
* Efficiency can be increased as the lower temperature T2 decreases. i.e. temperature of heat rejection

## What is reversed Carnot heat engine?

The cycle consists of two isothermal and two isentropic process but this cycle is used to extract heat from cold body and reject it into hot body. Therefore, the same cycle is performed in the reverse direction.

## What are the limitations of Carnot cycle?

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

## Why Carnot cycle cannot be realized in practical?

* In a Carnot cycle all the four process are reversible but in actual practice there is no process reversible.
* There are two processes to be carried out during compression and expansion. For isothermal process the piston moves very slowly and for adiabatic process the piston moves as fast as possible. This speed variation during the same stroke of the piston is not possible.
* It is not possible to avoid friction moving parts completely.

## Why Carnot cycle on T-s plot is a rectangle?

Because it consists of two reversible isothermal processes (horizontal line in T-s plot) and two reversible adiabatic processes (vertical line in T-s diagram).

## What is meant by irreversible process?

A irreversible process is one, which is performed in such a way that at the end of the process, system and surroundings are not restored to its initial state and produces changes in the universe.

## Define irreversibility. [APR/MAY 2016]

The actual work which a system does is always less than the idealized reversible work, and the difference between the two is called the irreversibility of the process. Thus, Irreversibility, I = Wmax – Wact

This is also sometimes referred to as ‘degradation’ or ‘dissipation’.

## List the causes of Irreversibility

* + Lack of equilibrium during the process (ex: Heat transfer through a finite temperature difference)
	+ Involvement of dissipative effects. (ex: Free Expansion)

## Explain the throttling process.

When a gas or vapour expands and flows through an aperture of small size, the process is called as throttling process.

## How is the absolute scale independent of the working substance?

Two temperatures in absolute scale (Kelvin’s scale) bear the same relationship as do the heats absorbed and rejected by a Carnot engine operating between these temperature limits. Therefore absolute scale is independent of the working substance.

## What do you understand by dissipative effects? When work is said to be dissipated?

When energy is degraded in a process, it is referred to as dissipative effect. Work is dissipated in the form of heat.

## Why the second law is called directional law of nature?

It specifies the direction in which heat transfer takes place in a process.

## Give the criteria of reversibility, irreversibility impossibility of a thermodynamic cycle.

 *dQ* < 0 irreversible cycle,  *dQ* = 0 reversible cycle,  *dQ* > 0, impossible.

*T T T*

## State Clausius theorem.

*dQ* 0 for reversible cycle



*T*

## What is absolute entropy?

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

## 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.

## How is entropy related to molecular disorder of the system?

As molecular disorderliness increases entropy increases.

## What are the causes of entropy increase? [NOV/DEC 2017]

* by external heat addition, by internal irreversibility

## What are the important characteristics of entropy?

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

## 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.

## Energy is always conserved but its quality is always degraded. Explain

Energy is never destructed but whenever energy is transformed from one form to another, its availability decreases as a result of increase in entropy.

## 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

1. **When a system is adiabatic, what can be said about the entropy change of the substance in the system? [NOV/DEC 2016]** When a system is adiabatic, the entropy change of the substance in the system is constant.

## Express Clausius inequality for various processes. [NOV/DEC 2015]

When the system performs reversible cycle, then

𝜕𝑄

∑ (

𝑇

𝐶𝑦𝑐𝑙𝑒

) = 0

When the cycle not reversible, then

𝜕𝑄

∑ (

𝑇

𝐶𝑦𝑐𝑙𝑒

) < 0

## Define Second law efficiency [NOV/DEC 2015]

Availability recoverd

η =

Availability supplied

1. **What is Helmholtz free energy function? [NOV/DEC 2018]** In [thermodynamics](https://en.wikipedia.org/wiki/Thermodynamics), the Gibbs free energy (IUPAC recommended name: Gibbs energy or Gibbs function; also known as free enthalpy[[1]](https://en.wikipedia.org/wiki/Gibbs_free_energy#cite_note-1) to distinguish it from [Helmholtz free energy](https://en.wikipedia.org/wiki/Helmholtz_free_energy)) is a [thermodynamic potential](https://en.wikipedia.org/wiki/Thermodynamic_potential) that can be used to calculate the [maximum](https://en.wikipedia.org/wiki/Maximum) of reversible [work](https://en.wikipedia.org/wiki/Work_%28physics%29) that may be performed by a thermodynamic system a constant [temperature](https://en.wikipedia.org/wiki/Temperature) and [pressure](https://en.wikipedia.org/wiki/Pressure) ([isothermal](https://en.wikipedia.org/wiki/Isothermal), [isobaric](https://en.wikipedia.org/wiki/Isobaric_process)).

## What is meant by dead state? [APR/MAY 2013]

The state at which the system will be incapable of delivering a work output.

## PART – B

1. State that the efficiency of the reversible heat engine depends only on the maximum and minimum absolute temperature in the cycle. **[NOV/DEC 2018]**
2. State and prove Carnot theorem. **[NOV/DEC 2018]**
3. Describe the Carnot cycle and examine the Carnot principles, idealized Carnot heat engine, refrigerators and heat pumps. **[NOV/DEC 2017, APR/MAY 2018]**
4. Determine the expression for the thermal efficiencies and coefficient of performance for reversible heat engine, heat pumps and refrigerators. **[NOV/DEC 2017]**
5. A reversible heat engine operates between two reservoirs at temperatures 700°C and 50°C. The engine drives a reversible refrigerator which operates between reservoirs at temperatures of 50°C and – 25°C. The heat transfer to the engine is 2500 kJ and the network output of the combined engine refrigerator plant is 400 kJ. (i) Determine the heat transfer to the refrigerant and the net heat transfer to the reservoir at 50°C (ii) Reconsider (i) given that the efficiency of the heat engine and the C.O.P. of the refrigerator are each 45 per cent of their maximum possible values.
6. A heat engine operating between two reservoirs at 1000 K and 300 K is used to drive a heat pump which extracts heat from the reservoir at 300 K at a rate twice that at which the engine rejects heat to it. If the efficiency of the engine is 40% of the maximum possible and the cop of the heat pump is 50% of the maximum possible, what is the rate of heat rejection from the heat pump if the rate of heat supply to the engine is 50 kW? **[APR/MAY 2016]**
7. A heat engine receives 800 kJ of heat from the reservoir at 1000 K and rejects 400 kJ at 400 K. If the surrounding is at 300 K, calculate the first and the second law efficiency, and the relative efficiency of the heat engine. **[APR/MAY 2016]**
8. State the Carnot principles and prove the first principle with relevant sketches.

## [NOV/DEC 2015]

1. Draw the Carnot cycle on p-V and T-s Diagram to derive its efficiency and explain the major inference from Carnot cycle efficiency. **[NOV 2019]**
2. Two Carnot engines work in series between the source and sink temperature of 550 K and 350 K. If both engines develop equal power, draw the schematic and label them properly and also determine the intermediate temperature. **[NOV 2019]**
3. Three Carnot engines A, B and C working between the temperature of 1000 K and 300 K are in a series combination. The work produced by these engines are in the ratio of 5:4:3. Make calculations of temperature for the intermediate temperatures.

## [APR/MAY 2015]

1. Two heat engines operating in series are giving out equal amount of work. The total work is 50 kJ/cycle. If the reservoirs are at 1000 K and 250 K. Find the intermediate temperature and the efficiency of each engine. Also, find the heat extracted from the source. **[NOV/DEC 2014]**
2. (a) Two Carnot engines A and B are operated in series. The first one receives heat at 870 K and rejects heat to a reservoir at T. B receives heat rejected by the first engine and in turn rejects to a sink at 300K. Find the temperature T for (i) Equal work outputs of both engines (ii) Same efficiencies
3. Mention the Clausius inequality for open, closed and isolated systems.

## [NOV 2013,2017]

1. Prove that increase in entropy in a polytropic process is ∆s = mC

γ−n P1

v ln ( )

n P2

1. An irreversible heat engine with 66% efficiency of the maximum possible is operating between 1000K and 300K. If it delivers 3 kW of work, determine the heat extracted from the high temperature reservoir and heat rejected to low temperature reservoir.

## [APR/MAY2013]

1. Two reversible heat engines A and B are arranged in series. Engine A rejecting heat directly to engine B, receives 200 kJ 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 (i) The intermediate temperature between A and B

(ii) The efficiency of each engine and (iii) The heat rejected to the cold sink.

1. A reversible engine operates between temperatures T1 and T (T1 > T). The energy rejected from this engine is received by a second reversible engine at the same temperature T. The second engine rejects energy at temperature T2 (T2 < T). Show that.
	1. Temperature T is the arithmetic mean of temperatures T1 and T2 if the engines produce the same amount of work output (**b)** Temperature T is the geometric mean of temperatures T1 and T2 if the engines have the same cycle efficiencies. **[APR 2015]**
2. A heat engine is used to drive a heat pump. The heat transfers from the heat engine and from the heat pump are used to heat the water circulating through the radiators of a building. The efficiency of the heat engine is 27% and the COP of the heat pump is 4. Evaluate the ratio of the heat transfer to the circulating water to the heat transfer to the heat engine.
3. A heat pump is run by a reversible heat engine operating between reservoirs at 800°C and 50°C. The heat pump working on Carnot cycle picks up 15 kW heat from reservoir at 10°C and delivers it to a reservoir at 50°C. The reversible engine also runs a machine that needs 25 kW. Determine the heat received from highest temperature reservoir and heat rejected to reservoir at 50°C.
4. (i) A heat pump operates on a Carnot heat pump cycle with a COP of 8.7. It keeps a space at 24ºC by consuming 2.15 kW of power. Determine the temperature of the reservoir from which the heat is absorbed and the heating load provided by the heat pump.

(ii) An inventor claims to have developed a refrigeration system that removes heat from the closed region at – 12ºC and transfer it to the surrounding air at 25ºC while maintaining a COP of 6.5. Is this claim reasonable? Why? **[NOV/DEC 2016]**

1. A reversible heat pump is used to maintain a temperature of 0C in a refrigerator when it rejects the heat to the surrounding at 25C. If the heat removal rate from the refrigerator is 1440 kJ/min, determine the COP of the machine and work input required.

If the required input to run the pump is developed by a reversible engine which receives heat at 380C and rejects heat to atmosphere, then determine the overall COP of the system**. [APR/MAY 2014]**

1. A drug shop is required to maintain certain essential items at -23C in a refrigerator. If a Carnot refrigerator having 200 W of compressor is used for this purpose, estimate the fraction of time the compressor would run in a cold country for a cooling rate of 4000 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 runs. **[APR/MAY 2018]**
2. A certain water heater operates under steady flow conditions receiving 4.2kg/s of water at 75C temperature, enthalpy 313.93 kJ/kg. The water is heated by mixing with steam which is supplied to the heater at temperature 100.2C and enthalpy 2676 kJ/kg. The mixture leaves the heater as liquid water at temperature 100C and enthalpy 419 kJ/kg. How much steam must be supplied to the heater per hour?

## [NOV/DEC 2017]

1. A fluid undergoes a reversible adiabatic compression from 4bar, 0.3 m3 to 0.08m3 according to the law pV1.25=C. Determine the change in enthalpy, the change in internal energy and change in entropy. **[NOV/DEC 2018]**
2. 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.
3. Determine the entropy increase of the universe.
4. What is the minimum amount of work necessary to convert the water back into ice at -15C?

Cp of the ice is 2.093 kJ/kg K and latent heat fusion of ice is 333.3 kJ/kg. **[MAY 2018]**

1. A metal block with m=5 kg, C=0.4 kJ/kg K at 40°C is kept in a room at 20°C. It is cooled in the following two ways: (i) Using a Carnot engine (executing internal number of cycles) with the room itself as the cold reservoir; (ii) Naturally. In each case, calculate the change in entropy of the block, of the air of the room and of the universe. Assume that the metal block has constant specific heat **[NOV/DEC 2012]**
2. (a) 2 kg of water at 90°C is mixed with 3 kg of water at 10°C in an isolated system. Calculated the change of entropy due to the mixing process.
3. Derive an expression for the change in entropy of a perfect gas during polytropic process in terms of T1 and T2. **[APR/MAY 2012]**
4. Air at 20°C and 1.05 bar occupies 0.025 m3. The air is heated at constant volume until the pressure is 4.5 bar, and then cooled at constant pressure back to original temperature. Calculate: (i) The net heat flow from the air. (ii) The net entropy change.
5. An insulated cylinder of volume capacity 4 m3 contains 20 kg of nitrogen. Paddle work is done on the gas by stirring it till the pressure in the vessel gets increased from 4 bar to 8 bar. Determine : (i) Change in internal energy, (ii) Work done, (iii) Heat transferred, and (iv) Change in entropy
6. Find the change in entropy of steam generated at 400ºC from 5 kg of water at 27ºC and atmospheric pressure. Take specific heat of water to be 4.2 kJ/kg K, heat of vaporization at 100ºC as 2260 kJ/kg and specific heat for steam given by; Cp = R (3.5

+ 1.2T + 0.14T2), J/kgK.

1. (i) A 30 kg iron block and a 40 kg copper block, both initially at 80 ºC, are dropped into a large lake at 15 ºC. Thermal equilibrium is established after a while as a result of heat transfer between the blocks and the lake water. Determine the total entropy change for this process.

(ii)How much of the 100 kJ of thermal energy at 650 K can converted to useful work? Assume the environment to be at 25 ºC. **[NOV/DEC 2016]**

1. 50kg of water is at 313k and enough ice at -5ºC is mixed with water in an adiabatic vessel such that at the end of the process all the ice melts and water at 0ºC is obtained. Find the mass of ice required and the entropy change of water and ice. Given Cp of water = 4.2kJ/kgK, Cp of ice=2.1 kJ/kgK and latent heat of ice=335 kJ/kg. **[APR 2016]**
2. One kilogram of water at 273 K is brought into contact with a heat reservoir at 373 K.
3. When the water has reached 373 K, find the change in entropy of the water, of the heat reservoir, and of the universe. (ii) If the water had been heated from 273 K to 373 K by first bringing it in contact with a reservoir at 323 K and then with a reservoir at 373 K, what would have been the change in entropy of the universe? **[NOV 2015]**
4. i) State and derive Clausius inequality.

ii) A reversible engine operates between a source at 972°C and two sinks, one at 127°C and another at 27°C. The energy rejected is same at both the sinks. Compute the engine efficiency. Also calculate the power and rate of heat supply if the rate of heat rejected to each sink is100 kW. **[NOV 2020]**

1. 5 m3 of air at 2 bar, 27 C is compressed up to 6 bar pressure following pV1.3= C. It is subsequently expanded adiabatically to 2 bar. Considering the two process to be reversible, determine the network, net heat transfer and change in entropy. Also plot the processes on T-S and P-V diagrams. **[APR/MAY 2014]**
2. (a)Helium enters an actual turbine at 300 kPa, 300°C and expands to 100 kPa, 150°C. Heat transfer to atmosphere at 101.325 kPa, 25°C amounts to 7 kJ/kg. Calculate the entering stream availability, leaving stream availability and the maximum work. For helium, Cp=5.2 kJ/kg and molecular wt=4.003 kg/kg mol
3. List out and explain various causes of irreversibility. **[APR/MAY2013]**
4. Air flows through an adiabatic compressor at 2kg/s. The inlet condition are 100kPa and 310K, and exit conditions are 700kPa and 560K. Consider To to be 298K. Determine the change of availability and the irreversibility. **[NOV/DEC 2018]**
5. 5 kg of air at 550 K and 4 bar is enclosed in a closed vessel. Determine the availability of the system if the surrounding pressure and temperature are 1 bar and 290 K. (b) If the air is cooled at constant pressure to the atmospheric temperature, determine the availability and effectiveness. **[NOV/DEC 2014]**
6. (a) 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 surroundings at 100 kPa and 10C. Find maximum work, change in availability and irreversibility (b)Briefly discuss about the concept of entropy. **[NOV/DEC 2013]**
7. In a Carnot cycle the maximum pressure and temperature are limited to 18 bar and 410°C. The volume ratio of isentropic compression is 6 and isothermal expansion is

1.5. Assume the volume of the air at the beginning of isothermal expansion as 0.18 m3. Show the cycle on p-V and T-s diagrams and determine (i) The pressure and temperature at main points (ii) Thermal efficiency of the cycle. **[DEC 2012]**.

1. i) Draw the Carnot cycle on p-V and T-s diagram and derive the efficiency of Carnot cycle based on T-s diagram.

ii) Air flows through an adiabatic compressor at 2 kg/s. The inlet conditions are 100 kPa and 310 K, and the exit conditions are 700 kPa and 560 K. Consider T0 to be 298K. Determine the net rate of energy transfer and irreversibility. **[NOV 2020]**

## PART – C

1. Two tanks A and B are connected through a pipe with valve in between. Initially valve is closed and tanks A and B contain 0.6 kg of air at 90°C, 1 bar and 1 kg of air at 45°C, 2 bar respectively. Subsequently valve is opened and air is allowed to mix until equilibrium. Considering the complete system to be insulated determine the final temperature, final pressure and entropy change.
2. (i) A household refrigerator that has a power input of 450 W and a COP of 1.5 is to cool 5 large watermelons, 10kg each, to 8ᵒC. If the watermelons are initially at 28ᵒC, determine how long it will take for the refrigerator to cool them. The watermelons can be treated as water whose specific heat is 4.2kJ/kgK. Is your answer realistic or optimistic? Explain.

(ii) What are the desirable characteristics of a working fluid most suitable for vapour power cycles?

1. Determine the change in entropy of universe if a copper block of 1 kg at 150ºC is placed in a sea water at 25ºC. Take heat capacity of copper as 0.393 kJ/kg K.
2. 1 kg of ice at – 5°C is exposed to the atmosphere which is at 25°C. The ice melts and comes into thermal equilibrium. (i) Determine the entropy increase of the universe (ii) What is the minimum amount of work necessary to convert the water back into ice at

– 5°C? Take : Cp of ice = 2.093 kJ/kg°C, Latent heat of fusion of ice = 333.33 kJ/kg

1. Two Carnot engines A and B are connected in series between two thermal reservoirs maintained at 1000 K and 100 K respectively. Engine A receives 1680 kJ of heat from the high-temperature reservoir and rejects heat to the Carnot engine B. Engine B takes in heat rejected by engine A and rejects heat to the low-temperature reservoir. If engines A and B have equal thermal efficiencies, determine. (a) The heat rejected by engine B, (b) The temperature at which heat is rejected by engine, A (c) The work done during the process by engines, A and B respectively. If engines A and B deliver equal work, determine, (d) The amount of heat taken in by engine B, (e) The efficiencies of engines A and B.
2. i) A Carnot heat engine works between two temperatures of source at 900 K and sink at 300 K. It operates a Carnot refrigerator working between two temperatures of 300 K and 250 K. The heat engine is supplied with 50 kJ/s and it not only operates refrigerator, but also delivers a net power of 10 kW.

ii) Determine the heat transferred to the refrigerant in the refrigerator and the net heat transfer to the sink maintained at 300 K. ii) Recalculate the above, if the actual efficiency of the heat engine is 50% of the maximum value and COP of the refrigerator is 50% of the maximum value. **[NOV 2019]**UNIT – III PROPERTIES OF PURE SUBSTANCE AND STEAM POWER PLANT

**PART – A**

**Define a pure substance. Give examples. [NOV/DEC 2013]** A pure substance is a substance of constant chemical composition throughout its mass. A pure substance does not have to be of a single chemical element. A mixture of various chemical elements is also called as pure substance as long as the mixture is homogeneous in composition, homogeneous in chemical aggregation and invariable in chemical aggregation. e.g. H2O.

## What are saturation states?

A saturation state is a state from which a change of phase may occur without a change of pressure or temperature. The state of a substance at which a phase transformation begins or ends.

1. **What is meant by latent heat of vaporization? [NOV 2019]** The amount of heat transfer required to cause evaporation of unit mass of a substance from saturated liquid state to saturated vapour state is known as latent heat of vaporization
2. **Define saturation temperature and pressure and saturated liquid.[NOV/DEC 2017]** The temperature at which vaporization takes place at a given pressure is called the saturation temperature

The pressure at which vaporization takes place at a given temperature is called the saturation pressure.

Liquid at a state in which a phase transformation begins or ends is known as saturated liquid.

## Define sub cooled liquid.

The state of a pure substance at which the temperature is less than the saturation temperature corresponding to the pressure is known as sub-cooled liquid state

1. **Define compressed liquid. [NOV/DEC 2017]** The pressure on the liquid water is greater than the saturated pressure at a given temperature. In this condition, the liquid water is known as the compressed liquid.

## What do you understand by the terms ‘super heating’ and ‘subcooling’?

Heating steam beyond its saturation temperature and cooling of liquid below saturation temperatures are known as superheating and subcooling.

1. **What is the Degree of superheat? [NOV/DEC 2015]** The difference between the superheated temperature and the saturated temperature at the given pressure is called the degree of superheat.

## What is critical state? Define the term critical pressure, critical temperature, and critical volume of water. [NOV/DEC 2018]

The state at which the transition from liquid to vapour phase suddenly takes place. The specific volume of the saturated liquid and of the saturated vapour is the same.

Such a state of the substance is called the critical state. The properties like pressure, temperature and volume at critical state are known as critical pressure, critical temperature, and critical volume. The corresponding values for water are: 221.2 bar, 374.15°C and 0.00317 m3/kg

## What is normal boiling point of a substance?

Boiling point of a substance at a pressure of 760mmHg.

## What is triple point? For a pure substance, how many degrees of freedom are there at triple point? [APR/MAY 2015]

The state at which all the three phases-solid, liquid and vapour coexist in equilibrium is called the triple point. At the triple point, C=1, P=3 and application of the phase rule gives F=C+2-P=1+2-3+0. Hence, the number of degrees of freedom at the triple point is equal to zero. In other words the triple point is invariant (F=0). One cannot arbitrarily assign either temperature or pressure for the triple point. The triple point exists at u definite pressure and temperature. For example, the triple point of water is P=0.611kPa and t=0.01°C.

1. **State the phase rule for pure substance. [APR/MAY 2016]** Phase rule gives F=C+2-P, Hence, the number of degrees of freedom at the triple point is equal to zero. F Degree of freedom, C No. of elements, P No. of Phases

## Define superheated steam.

The supply of heat to the dry or saturated steam is continued at constant pressure, there will be increase in temperature and volume of steam. The steam so obtained is called superheated steam and it behaves like a perfect gas.

## What is heat of superheat?

The additional amount of heat supplied to the steam during superheating is called as heat of superheat. It can be calculated by using the specific heat of superheated steam at constant pressure.

## List the advantages of superheated steam.

* + Its heat content and hence its capacity to do work is increased without having to increase its pressure
	+ High temperature of superheated steam results in an increase in thermal efficiency
	+ Superheating is done in a superheater which obtains its heat from waste furnace gases.

## Define latent heat

The heat being supplied does not show any rise of temperature but results in change of state is known as latent heat.

## Define sensible heat of water.

It is defined as the quantity of heat absorbed by 1 kg of water when it is heated from 0°C to boiling point. It is also called total heat of water.

## What is meant by dryness fraction?

The term dryness fraction is related with wet steam. It is defined as the ratio of the mass of actual dry steam to the mass of steam containing it. It is expressed by the symbol ‘x’.

## Draw the phase equilibrium diagram on T-v coordinates for water with relevant constant property lines.

1. **Draw the phase equilibrium diagram for a pure substances on T-S plot with relevant constant property line.**

## Draw the p-T diagram for water and label all salient points. [APR/MAY 2014] [NOV/DEC 2014]



1. **Why cannot a throttling calorimeter measure quality of steam, if the steam is very wet?**

If the steam is very wet, even after throttling it may remain wet and the state can’t be located with pressure and temperature measurement. Therefore the quality can’t be found.

## A vessel of 2 m3 contains a wet steam of quality 0.8 at 210 °C. Determine the mass of the liquid and vapour present in the vessel. [APR/MAY 2015]

From the steam table at 210°C

𝑣𝑓 = 0.0011726 𝑚3/𝑘𝑔, 𝑣𝑔 = 0.1042 𝑚3/𝑘𝑔

The specific volume of the wet steam of quality 0.8

𝑣 = 𝑥𝑣𝑔 + (1 − 𝑥)𝑓 = 0.8(0.1042) + 0.2(0.0011726) = 0.0836𝑚3/𝑘𝑔

Mass of steam (m) in the vessel =𝑣 = 2

= 23.923 𝑘𝑔

𝑣 0.0836

Where y=volume of the vessel

Mass of vapour (𝑚 ) = 𝑚𝑥 = 0.8 × 23.923 = 19.138𝑘𝑔

Mass of liquid (𝑚 ) = 𝑚(1 − 𝑥) = 0.2 × 23.923 = 4.785𝑘𝑔

## Determine the enthalpy and sp. volume of steam at a pressure of 6 bar having a quality of 0.85.

h = hf + x hfg = 1213.35+.85x1571.0 = 2548.7 kJ/kg ; v = x X vg = 0.85x 0.03244 = 0 .027574 m3/kg

## Draw the phase equilibrium diagram on p-v coordinates with relevant constant property lines for water. / How is Triple point represented in the P-v diagram?

**[NOV/DEC 2013]**

1. **Find the mass of 0.7 m3 of wet steam at 150ºC and 90% dry. [APR/MAY 2013]** The specific volume of dry steam at 150°C, vg = 0.3928 m3/kg ; The mass of 0.7 m3 of wet steam at 150°C and 90% dry is: 0.7 / (0.3928×0.9) = 1.98 kg.
2. **Is iced water a pure substance? Why? [NOV/DEC 2016]** Yes, iced water is a pure substance. The chemical composition of ice is H2O even if the phase changes.

## Name the different components in steam power plant working on Rankine cycle.

Boiler, Turbine, Cooling Tower or Condenser and Pump.

## List the process involved in Rankine cycle

Process 1-2 : Reversible adiabatic expansion in the turbine (or steam engine). Process 2-3 : Constant-pressure transfer of heat in the condenser.

Process 3-4 : Reversible adiabatic pumping process in the feed pump. Process 4-1 : Constant-pressure transfer of heat in the boiler.

## Draw the schematic diagram of Rankine cycle

1. **List the improvement of Rankine cycle efficiency.**
2. Increasing the average temperature at which heat is supplied.
3. Decreasing/reducing the temperature at which heat is rejected.

This can be achieved by Increasing boiler pressure, Superheating, Reducing condenser pressure

## Show Rankine cycle on T-s diagram.

1. **Why Rankine cycle is modified?**

The work obtained at the end of the expansion is very less. The work is too inadequate to overcome the friction. Therefore the adiabatic expansion is terminated at the point before the end of the expansion in the turbine and pressure decreases suddenly, while the volume remains constant.

## How to improve thermal efficiency of the Rankine cycle.

* + Reheating of steam
	+ Regenerative feed water heating
	+ By water extraction
	+ Using binary vapour

## List the advantages of Reheating of steam. [NOV 2020]

* + There is an increased output of the turbine.
	+ Erosion and corrosion problems in the steam turbine are eliminated/avoided.
	+ There is an improvement in the thermal efficiency of the turbines.
	+ Final dryness fraction of steam is improved.
	+ There is an increase in the nozzle and blade efficiencies.

## What are the advantages of reheating? [NOV/DEC 2014]

* + It increases the turbine work.
	+ It increases the heat supply.
	+ It increases the efficiency of the plant.

## Draw the block diagram of reheat Rankine cycle

1. **Show Reheat Rankine cycle on T –S diagram. [APR, NOV 2018]**

## List the disadvantages of Reheating of steam

* + Reheating requires more maintenance.
	+ The increase in thermal efficiency is not appreciable in comparison to the expenditure incurred in reheating.

## What is the purpose of reheating?

The purpose of reheating is to increase the dryness fraction of the steam passing out of the later stages of the turbine.

## Why reheat cycle is not used for low boiler pressure?

At the low reheat pressure the heat cycle efficiency may be less than the Rankine cycle efficiency. Since the average temperature during heating will then be low.

## What is the effect of reheat on (a) the network output, (b) the cycle efficiency and

1. **steam rate of steam power plant? [NOV/DEC 2016]** The network output is increases, the cycle efficiency is increases and steam rate of steam power plant is decreases.

## Write down the expression for efficiency of Rankine cycle without considering pump work.

h1 − h2

η =

h1 − h4

## What is regeneration in Rankine cycle?

Using a part of steam bled at an intermediate pressure for heating the feed water to reduce heat input.

## Draw the block diagram of regeneration Rankine cycle.

1. **List the advantages of Regenerating of steam**
	* The heating process in the boiler tends to become reversible.
	* The thermal efficiency is improved because the average temperature of heat addition to the cycle is increased.
	* Heat rate is reduced.
	* Due to many extractions there is an improvement in the turbine drainage and it reduces erosion due to moisture.

## List the disadvantages of regeneration of steam

* + The plant becomes more complicated.
	+ Because of addition of heaters greater maintenance is required.
	+ For given power a large capacity boiler is required.

## What are the methods of improving the performance of Rankine cycle? [MAY 14]

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

## Compare Rankine Cycle and Carnot Cycle. [NOV 2019]

* + Between the same temperature limits Rankine cycle provides a higher specific work output than a Carnot cycle, consequently Rankine cycle requires a smaller steam flow rate resulting in smaller size plant for a given power output. However, Rankine cycle calls for higher rates of heat transfer in boiler and condenser.
	+ Since in Rankine cycle only part of the heat is supplied isothermally at constant higher temperature T1, therefore, its efficiency is lower than that of Carnot cycle. The efficiency of the Rankine cycle will approach that of the Carnot cycle more nearly if the superheat temperature rise is reduced.

## Define efficiency ratio.

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

## 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.

## Define specific steam consumption of an ideal Rankine cycle.

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

## 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 in release the wetness of steam. Isentropic compression of a very wet vapour is very difficult.

## Define heat rate. [NOV/DEC 2018]

The rate of heat input required to produce unit power output.

## State the advantages of using superheated steam in turbine.

Superheated steam’s greatest value lies in its tremendous internal energy that can be used for kinetic reaction through mechanical expansion against turbine blades and reciprocating pistons, that produces rotary motion of a shaft.

1. **What is binary vapour cycle? [NOV/DEC 2017]** A binary vapor cycle is defined in thermodynamics as a power cycle that is a combination of two cycles, one in a high temperature region and the other in a lower temperature region.

## Mention the two working fluids used in binary vapour cycle. [APR/MAY 2016]

Water and Mercury, Water and Organic compounds.

1. **Superheated steam at 30 bar and 300°C enters a turbine and is expanded to 5 bar and quality 0.974 dryness. Compute the loss in availability for the adiabatic process if the atmospheric temperature is 27°C. [APR/MAY 2015]** Loss in availability = Irreversibility, I = T0 (Ssystem + Ssurroundings)

For adiabatic process Ssurroundings = 0, Therefore here, I = 300 [Cp ln (T2/T1) – R ln (p2/p1)]

I = 300 [1.616 × ln (393/573 – 0.461 × ln (5/30)] = **65.01 kJ/kg**

## What do you understand by specific steaming rate? State its unit.[APR/MAY 2012]

The rate of steam required to produce unit power output. Its unit is kg/kW h

## Why are the temperature and pressure dependent properties in the saturated mixture region? [NOV/DEC 2010]

During the phase transformations of a pure substance, the pressure and temperature remain constant. Therefore, in the saturated mixture region, the temperature and pressure are dependent properties.

1. **What is the effect of regeneration of a steam power plant? [APR/MAY 2009]** Regeneration does not affect work output, however the efficiency of the plant increases as the temperature of heat addition is increased.

## Why is excessive moisture in steam undesirable in steam turbine? [DEC 2009]

It may erode the turbine blades.

## PART – B (CO202.3)

1. Explain steam formation with relevant sketch and label all salient points and explain every point in detail. **[NOV/DEC 2018] [NOV/DEC 2014] [NOV2019]**
2. A pressure cooker contains 1.5 kg of saturated steam at 5 bar. Find the quantity of heat which must be rejected so as to reduce the quality to 60% dry. Determine the pressure and temperature of the steam at the new state. **[NOV2019]**
3. (i) State the advantages of using super-heated steam in vapour power cycles.

(ii) A vessel with a capacity of 0.05m3 contains a mixture of saturated water and saturated steam at a temperature of 245°C. The mass of the liquid present is 10kg. Find the following. (i)The pressure,(ii) The mass,(iii) The specific volume,(iv) The specific enthalpy,(v) The specific entropy, and (vi) The specific internal energy.

## [NOV/DEC 2015] [APR/MAY 2014]

1. (i) Define specific steam consumption, specific heat rate and work ratio.

(ii) Steam enters the turbine at 3 MPa and 400°C and is condensed at 10kPa. Some quantity of steam leaves the turbine at 0.5 MPa and enters feed water heater. Compute the fraction of the steam extracted per kg of steam and cycle thermal efficiency.

## [NOV/DEC 2012]

1. i) Explain the use of Throttling Calorimeter to determine dryness fraction.

ii) Steam flows through a small turbine at the rate of 500 kg/h entering at 15 bar, 300°C and leaving gat 0.1 bar with 4% moisture. The steam enters at 80 m/s at a point 2 m 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. Calculate the areas of the inlet and discharge tubes. **[NOV 2020]**

1. Define the following terms pertaining to pure substances like water: i)Sensible heating, ii)Latent heating, iii)Saturation states, iv)Saturation pressure, v)Saturation temperature, vi)Triple point, vii)Dryness fraction, viii)Superheated steam and Degree of super heat. **[APR/MAY 2012]**
2. 3kg of steam at 18bar occupy a volume of 0.2550m3. During a constant volume process, the heat rejected is 1320kJ. Determine final internal energy also find initial dryness and work done. **[NOV/DEC 2018]**
3. 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.

## [APR/MAY 2018, NOV/DEC 2017]

1. (i) Steam initially at 0.3 MPa, 250°C is cooled at constant volume. At what temperature will the steam become saturated vapour? What is the steam quality at 80°C? Also find what is the heat transferred per kg of steam in cooling from 25oC to 80°C.

(ii) When will you call a vapour superheated? Give example. Also when will you call a liquid as compressed liquid? Give example. **[NOV/DEC 2013]**

1. (i) Steam at 30 bar and 350 °C is expanded in a non-flow isothermal process to a pressure of 1 bar. The temperature and pressure of the surroundings are 25 °C and 100 kPa respectively. Determine the maximum work that can be obtained from this process per kg of steam. Also find the maximum useful work.
2. With the aid of T-v diagram explain various phases of conversion of ice at -20°C to steam at 125°C. **[APR/MAY 2013]**
3. A large vessel is divided into two chambers, one containing 5 kg of dry saturated steam at 0.2 MPa and the other 10 kg of steam, 0.8 quality at 0.5 MPa. If the partition between the chambers is removed and the steam is mixed thoroughly and allowed to settle, find the final pressure, steam quality and entropy change in the process.

## [APR/MAY 2016]

1. A steam boiler initially contains 5 m3 of steam and 5 m3 of water at 1 MPa. Steam is taken out at constant pressure until 4 m3 of water is left. What is the heat transferred during the process? **[NOV/DEC 2016]**
2. i) Draw Rankine Cycle on T-s and H-s diagram with steam at superheated condition at the entry of turbine and explain the effect of super heated steam on network and efficiency, compared to saturated steam based Rankine cycle.

ii)Steam enters the turbine at 3 MPa and 400°C and is condensed at 10 KPa. Some quantity of steam leaves the turbine at 0.6 MPa and enters open feed water heater. Compute the fraction of the steam extracted per kg of steam and cycle thermal efficiency. **[NOV 2020]**

1. Calculate the internal energy per kg of superheated steam at a pressure of 10 bar and a temperature of 300°C. Also find the change of internal energy if this steam is expanded to 1.4 bar and dryness fraction 0.8.
2. Draw the P-V, T-S, h -s, diagrams and theoretical lay out for Rankine cycle and hence deduce the expression for its efficiency. **[NOV/DEC 2015] [NOV/DEC 2018]**
3. In a Rankine cycle, the steam at inlet to turbine is saturated at a pressure of 35 bar and the exhaust pressure is 0.2 bar. Determine (i) The pump work (ii) The turbine work
4. The Rankine efficiency (iv) The condenser heat flow (v) The dryness at the end of expansion. Assume flow rate of 9.5 kg/s. **[NOV/DEC 2014]**
5. A simple Rankine cycle works between pressures 28 bar and 0.06 bar, the initial condition of steam being dry saturated. Calculate the cycle efficiency, work ratio and specific steam consumption.
6. (i) Why is Carnot cycle not practicable for a steam power plant?

(ii) In a steam power plant the condition of steam at inlet to the steam turbine is 20 bar and 300ᵒC and the condenser pressure is 0.1 bar. Two feed water heaters operate at optimum temperatures. Determine: (1) The quality of steam at turbine exhaust, (2) network per kg of steam, (3) cycle efficiency, (4) the steam rate. Neglect pump work.

## [APR/MAY 2016]

1. Steam at 50 bar, 400 °C expands in a Rankine cycle to 0.34 bar. For a mass flow rate of 150 kg/sec of steam, determine i) Power developed, ii) Thermal efficiency, iii) Specific steam consumption. **[APR/MAY 2013]**
2. A power generating plant uses steam as a working fluid and operate at a boiler pressure of 50 bar, dry saturated and a condenser pressure of 0.05bar. Determine the cycle efficiency, work ratio and specific steam consumption for Rankine cycle.

## [APR/MAY 2015]

1. (i) In a steam generator compressed liquid water at 10 MPa, 30°C enters a 30 m diameter tube at the Rate of 3 litres/sec. Steam at 9MPa, 400°C exits the tube. Find the rate of heat transfer to the water.

(ii) Steam at 20 bar, 360°C is expanded in a steam turbine to 0.08 bar. It then enters a condenser, where it is condensed to saturated liquid water. The pump feeds back the water into the boiler. i) Assuming ideal processes find the net-work and the cycle efficiency per kg of steam. ii) If the pump and the turbine have 80% efficiency, find the percentage reduction in the net-work and cycle efficiency. **[APR/MAY 2011]**

1. Draw the P-V, T-S, h -s, diagrams and theoretical lay out for Reheat Rankine cycle and hence deduce the expression for its efficiency.
2. A steam power plant operates on a theoretical reheat cycle. Steam at 25 bar pressure and 400 ºC is supplied to the high pressure turbine. After its expansion to dry state the steam is reheated at a constant pressure to its original temperature. Subsequent expansion occurs in the low pressure turbine to a condenser pressure of 0.04 bar. Considering feed pump work, make calculation to determine (i) quality of steam at entry to condenser (ii) thermal efficiency (iii) specific steam consumption. [**MAY 15]**
3. A steam power plant operates on a theoretical reheat cycle. Steam at boiler at 150bar, 550 °C expands through the high pressure turbine. It is reheated at a constant pressure of 40 bar to 550 °C and expands through the low pressure turbine to a condenser at 0.1 bar. Draw T-s and h-s diagram. Find (i) Quality of steam at turbine exhaust (ii) Cycle efficiency (iii) Steam Rate in kg/kWh. **[APR 2014,2018]**
4. 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. Find the work output and cycle efficiency using steam tables with and without considering pump work. **[NOV/DEC 2013]**
5. With the help of a schematic diagram, explain the regenerative Rankine cycle and derive the expression for its efficiency. Also represent the process in p-V and T-s diagram. **[APR/MAY 2013]**
6. A steam power plant operates on an ideal regenerative Rankine cycle. Steam enters the turbine at 6 MPa and 450ºC and is condensed in the condenser at 20 kPa. Steam is extracted from the turbine at 0.4 MPa to heat the feed water in an open feed water heater. Water leaves the feed water heater as a saturated liquid. Show the cycle on a T-s diagram, and determine (i) the network output per kilogram of steam flowing through the boiler and (ii) the thermal efficiency of the cycle. **[NOV/DEC 2016]**
7. Explain mercury-water binary vapour cycle. **[NOV/DEC 2017]**

## PART – C (CO202.3)

1. A pressure cooker contains 1.5 kg of saturated steam at 5 bar. Find the quantity of heat which must be rejected so as to reduce the quality to 60% dry. Determine the pressure and temperature of the steam at the new state. **[NOV2019]**
2. A spherical vessel of 0.9 m3 capacity contains steam at 8 bar and 0.9 dryness fraction. Steam is blown off until the pressure drops to 4 bar. The valve is then closed and the steam is allowed to cool until the pressure falls to 3 bar. Assuming that the enthalpy of steam in the vessel remains constant during blowing off periods, determine :(i) The mass of steam blown off (ii) The dryness fraction of steam in the vessel after cooling

;(iii) The heat lost by steam per kg during cooling.

1. A steam turbine is fed with steam having an enthalpy of 3100 kJ/kg. It moves out of the turbine with an enthalpy of 2100 kJ/kg. Feed heating is done at a pressure of 3.2 bar with steam enthalpy of 2500 kJ/kg. The condensate from a condenser with an enthalpy of 125 kJ/kg enters into the feed heater. The quantity of bled steam is 11200 kg/h. Find the power developed by the turbine. Assume that the water leaving the feed heater is saturated liquid at 3.2 bar and the heater is direct mixing type. Neglect pump work.
2. A steam power plant running on Rankine cycle has steam entering HP turbine at 20 MPa, 500°C and leaving LP turbine at 90% dryness. Considering condenser pressure of 0.005 MPa and reheating occurring up to the temperature of 500°C determine i)The pressure at which steam leaves HP turbine, ii)The thermal efficiency, iii)Work done.

## [NOV/DEC 2018]

1. In a single-heater regenerative cycle the steam enters the turbine at 30 bar, 400°C and the exhaust pressure is 0.10 bar. The feed water heater is a direct contact type which operates at 5 bar. Find: (i) The efficiency and the steam rate of the cycle. (ii) The increase in mean temperature of heat addition, efficiency and steam rate as compared to the Rankine cycle (without regeneration). Pump work may be neglected.
2. Explain the phase transformation that takes place when ice (solid) is heated continuously till superheated steam is obtained. Name the different states involved. Sketch the transformation on a ‘temperature’ Vs ‘heat added’ diagram.
3. A vessel of volume 0.04 m3 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, mass, the specific volume, the enthalpy, the entropy and the internal energy.
4. In a power-station, the saturated steam is generated at 200 ℃ by transferring the heat from hot gases in a steam boiler. The gases are cooled from 1000 ℃ to 500 ℃ and all the heat from gases goes to water. Assume water enters the boiler at saturated condition and leaves as saturated steam. I) Calculate the mass of gas required to produce a kg of steam and ii) Find the increase in total entropy of the combined system of gas and water and increase in unavailable energy due to irreversible heat transfer. Take Cp (for gas) = 1.0 kJ/kg.K,hfg (latent heat of steam at 200 ℃) =1940.7 kJ/kg. **[NOV 2019]**

## UNIT IV IDEAL AND REAL GASES, THERMODYNAMIC RELATIONS PART – A

1. **Define Ideal gas.**

It is defined as a gas having no forces of intermolecular attraction. These gases will follow the gas laws at all ranges of pressures and temperatures.

## Define Real gas.

It is defined as a gas having the forces of attraction between molecules and the gas molecules tend to be very small at reduced pressures and elevated temperatures.

1. **What is equation of state? [NOV/DEC 2015]** The relation between the independent properties such as pressure, specific volume and temperature for a pure substance is known as the equation of state.
2. **What are the reduced properties? Give their significance? [APR/MAY, DEC 2016]** The ratios of pressure, temperature and specific volume of a real gas to the corresponding critical values are called the reduced properties.

## 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,

* + There is little or no attraction between the molecules of the gas.
	+ 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, inter molecular forces of attraction and repulsion increases and the volume of the molecules are not negligible. The real gas deviates considerably from the ideal gas equation [p+ (a/V2)] (V-b) = RT]

## What are the assumptions made in Vander Waal’s equation of state?

1. There is no inter molecular forces between particles.
2. The volume of molecules is negligible in comparison with the gas.
3. **Define Avogadro’s law [NOV/DEC 2013]** Avogadro's law states that, "equal volumes of all gases, at the same temperature and pressure, have the same number of molecules". For a given mass of an ideal gas, the volume and amount (moles) of the gas are directly proportional if the temperature and pressure are constant.

## Define coefficient of volume expansion.

The coefficient of volume expansion is defined as the change in volume with the change in temperature per unit volume keeping the pressure constant.

## 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

## What are known as thermodynamics gradients? [NOV/DEC 2014]

Temperature gradients, pressure gradients, or concentration gradients

## What are the assumptions made to drive ideal gas equation analytically using the kinetic theory of gases? [NOV/DEC 2014]

* + Gases are made up of particles with no defined volume but with a defined mass. In other words their volume is miniscule compared to the distance between themselves and other molecules.
	+ Gas particles undergo no intermolecular attractions or repulsions. This assumption implies that the particles possess no potential energy and thus their total energy is simply equal to their kinetic energies.
	+ Gas particles are in continuous, random motion.
	+ Collisions between gas particles are completely elastic. In other words, there is no net loss or gain of kinetic energy when particles collide.
1. **What is compressibility factor? [NOV/DEC 2017]** The compressibility factor of a gas at a given state is defined as a ratio between the product of pressure and specific volume of the gas and the product of characteristic

gas constant and absolute temperature of the gas as that state.𝑍 = pV , for real gas

RT

(pV/RT) is not equal to 1

1. **Explain law of corresponding states. [NOV/DEC 2018]** If any two gases have equal values of reduced pressure and reduced temperature, then they have same values of reduced volume.
2. **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.

## State the laws of perfect gas.

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

1

𝑃 𝖺

𝑉

Charles' Law, or the law of volumes, states that if any gas is heated at constant pressure, its volume changes directly as its absolute temperature.

𝑉 𝖺 𝑇

## P=\frac{RT}{V_m-b}-\frac{a}{TV_m^2}Write down the Berthelot equation of state for a real gas.

1. **Sketch a skeleton compressibility chart with constant reduced temperature characteristics and indicate uses of this chart.**

The Generalized Compressibility Chart can be used for constant property processes: constant temperature processes follow a TR line, constant pressure processes follow a

vertical PR line, and constant specific volume processes follow a vR' line.



## Define Bulk Modulus

The bulk modulus (K) of a substance is defined as the ratio between the increase in pressure and the corresponding decrease in volume as a fraction of its original volume under isothermal condition.

𝐾 = (

𝑑𝑝

) = (

𝑑𝑝

𝑑𝑝

) = −𝑣 ( )

−𝑑𝑉/𝑉 𝑇

−𝑑𝑣/𝑣 𝑇

𝑑𝑣 𝑇

## Define isothermal compressibility

The isothermal compressibility (KT) of a substance is defined as ratio between the reduction in volume as a fraction of its original volume and the corresponding increase in pressure under isothermal condition.

𝐾𝑇 = (

−𝑑𝑣/𝑣

)

𝑑𝑝 𝑇

1 𝑑𝑣

= − ( )

𝑣 𝑑𝑝 𝑇

## Define isentropic compressibility

The isentropic compressibility (Ks) of a substance is defined as ratio between the reduction in volume as a fraction of its original volume and the corresponding increase in pressure under isentropic condition.

𝐾𝑠 = (

−𝑑𝑣/𝑣

)

𝑑𝑝 𝑠

1 𝑑𝑣

= − ( )

𝑣 𝑑𝑝 𝑠

## What is meant by coefficient of thermal expansion?

The coefficient of expansion of a substance is defined as ratio between the increase in volume as a fraction of its original volume and the corresponding increase in temperature under isobaric condition.

𝛽 = (

𝑑𝑣/𝑣

)

1 𝑑𝑣

= ( )

𝑑𝑇 𝑃 𝑣 𝑑𝑇 𝑃

1. **Expression for Maxwell’s relation. [NOV2019]**

|  |  |
| --- | --- |
| The internal energy expression𝜕𝑇 𝜕𝑝( ) = − ( )𝜕𝑉 𝑆 𝜕𝑆 𝑣 | The enthalpy expression𝜕𝑇 𝜕𝑣( ) = ( )𝜕𝑝 𝑆 𝜕𝑆 𝑝 |
| The Helmnoltz expression𝜕𝑝 𝜕𝑆( ) = ( )𝜕𝑇 𝑣 𝜕𝑣 𝑇 | The Gibbs expression𝜕𝑣 𝜕𝑆( ) = − ( )𝜕𝑇 𝑝 𝜕𝑝 𝑇 |

1. **Write down the two Tds equations. [NOV/DEC 2016,APR/MAY 2018]**

# Tds = cv

dT + T

(∂p)

dv , Tds = cp

# dT − T

(∂v) dp

∂T v ∂T p

## Explain Joule-Kelvin effect. What is inversion temperature?

When a gas (not ideal gas) is throttled, the temperature increases up to a point and then decreases. This is known as Joule Kelvin effect. The temperature at which the slope of a throttling curve in T-p diagram is zero is inversion temperature.

1. **What does the Joule-Thomson coefficient represent? [APR/MAY 2016]** Joule-Thomson coefficient is a measure of the rate of change of temperature with respect to pressure as a gas is expanded through a valve or orifice without any heat transfer to or from the surroundings.

## What is meant by a phase change of first order?

A phase change during which the entropy and volume change and the Gibbs function remains constant but its first order derivatives change discontinuously is called a phase change of first order.

## What is the significance of Clausius – Clapeyron equation?

The Clausius-Clapeyron, which gives the latent heat during phase change in terms of phase change temperature, change in specific volume during the phase change and the rate of change of saturation pressure with the saturation temperature.

1. **State any one application of Clapeyron equation. [NOV/DEC 2018]** Clapeyron equation can be applied in chemistry and chemical engineering for transitions between a gas and a condensed phase. This equation also has its application in climatology and meteorology.

## Write the Clausius-Clapeyron equation and label all the variables.

**[NOV/DEC 2015,2017, APR/MAY 2018]**

dp sg − sf

=

dT vg − vf

sfg

=

vfg

hfg

=

Tvfg

sg = Specific entropy of saturated vapour, sf = Specific entropy of saturated liquid vg = Specific volume of saturated vapour, vf = Specific volume of saturated liquid sfg=Increase in specific entropy, vfg = Increase in specific volume, and

hfg = Latent heat added during evaporation at saturation temperature T

## One kg of an ideal gas is heated from 18°C to 93°C. Taking R = 269 Nm/kg K and 

**= 1.2 for the gas, Find the change in internal energy. [APR/MAY 2015]**

U = m CvT,

**Cv =** R/(-1) = 0.269/0.4 = **0.6725 kJ/kg K**.

**U =** 1× 0.6725×(93-18) = **50.4375 kJ**

## Using Clausius – Clapeyron’s equation, estimate the enthalpy of vaporization at 200°C, vg=0.1274 m3/kg, vf = 0.001157 m3/kg, dp/dt=32 kPa/K [NOV/DEC 2014] For vaporization process

dp = h𝐹g

32 = h𝐹g

𝐡 = 𝟏𝟗𝟏𝟎. 𝟖 𝐤𝐉/𝐤𝐠

dT T(vg−v𝐹)

473(0.1274−0.001157)

𝐟𝐠

1. **Define Joule-Thompson Coefficient. [NOV/DEC 2013]** It is defined as the ratio of change of temperature to change in pressure at any state under constant enthalpy condition.

𝑑𝑇

𝜇𝑗 = (𝑑𝑝)

ℎ

## PART – B

1. Using the ideal-gas equation of state, verify
	1. The cyclic relation and
	2. The reciprocity relation at constant Pressure.
2. Show that the Internal Energy of an ideal gas and an incompressible substance is a function of temperature only, u=u(T)
3. A vessel of volume 0.28m3 contains 10kg of air at 320 k. Determine the pressure exerted by the air using a) perfect gas equation b) Vander walls equation C) Generalised compressibility chart. (Take critical temperature of air as 132.8K and critical pressure of air as 37.7 bar). **[APR/MAY 2016]**
4. Determine the pressure of nitrogen gas at T=175K and V=0.00375 m3/kg on the basis of (i) The ideal gas equation of state, (ii) The van der waals equation of state. The van der waals constant for nitrogen are α=0.175 m6 kPa/kg2, b=0.00138 m3/kg.

## [APR/MAY 2015]

1. (i) One kg of CO2 has a volume of 1m3 at 100ºC. Compute the pressure by

(1) Van der Walls’ equation (2) Perfect gas equation. The Van der Waals’ constants

a=362850 Nm4/(kg-mol)2 and b=.0423 m3 /(kg-mol).

(ii) Write the Berthelot and Dieterici equations of state. **[NOV/DEC 2016]**

1. Explain law of corresponding states 2. State the real gas equation of state as virial expansions and deduce an expression for compressibility factor *Z* in terms of virial coefficients. **[NOV/DEC 2018]**
2. Draw a neat schematic of a compressibility chart and indicate its salient features.

## [NOV 2013, APR 2016, NOV 2020]

1. Describe the use of reduced properties, principle of corresponding states and compressibility chart. **[NOV 2019]**
2. Consider an ideal gas at 303 K and 0.86 m3/kg. As a result of some disturbance the state of the gas changes to 304 K and 0.87 m3/kg. Estimate the change in pressure of the gas as the result of this disturbance. **[APR/MAY 2013]**
3. i) Deduce the expression for the change in internal energy with respect to change in volume at constant temperature.

ii) The latent heat of vaporization at 1 bar pressure is 2258kJ/kg and the saturation Temperature is 99.4°C. Calculate the saturation temperature at 2 bar pressure. Verify the same from the steam table data. **[NOV 2020]**

1. One kmol of methane is stored in a rigid vessel of volume 0.6 m3 at 20°C. Determine the pressure developed by the gas by making use of the compressibility chart.

## [NOV/DEC 2015]

1. Deduce Van der Waals equation of state and explain its importance.**[DEC 18, JUL 21]**
2. Derive Maxwell relations. **[NOV/DEC 2017,APR/MAY 2015]**
3. Derive entropy equations (Tds Equations). **[APR/MAY 2018, NOV/DEC 2018]**
4. Derive the Tds relation in terms of T and V and hence deduce the expression for change in the internal energy per unit change in volume at constant temperature.

## [NOV 2019]

1. Derive the difference in heat capacities and specific heat capacities. **[MAY 13,18]**
2. Derive the ratio of heat capacities or specific heat capacities
3. Derive the Energy equation.
4. Derive Joule-Thomson Experiment and Show that the Joule-Thomson coefficient of an ideal gas is zero. **[NOV/DEC 2018]**
5. Explain Joule-Kelvin effect. What is inversion temperature? **[NOV/DEC 2017]**
6. What is Joule-Thomson coefficient? Why is it zero for an ideal gas?**[NOV/DEC 2016]**
7. What is meant by phase change process? Derive Clausius-Clapeyron equation for a phase change process. Give the significance of this equation.

## [MAY 2018,MAY 2016,DEC 2016]

1. Derive expressions(𝜕𝑢⁄ )

𝜕𝑃

𝑇

= (𝜕ℎ⁄𝜕𝑣)

and 𝜕𝑢

𝜕𝑃

( ⁄ )

= (𝜕ℎ⁄𝜕𝑣)

for p, v, T.

𝑇

1. Verify the validity of Maxwell’s relation,

(𝜕𝑠)

= − (

𝜕𝑣)

for Steam at 300°C and 500

𝜕𝑝 𝑇

𝑇

𝑇

𝜕𝑇 𝑝

kPa. **[MAY 2013]**

## PART – C (CO202.4)

1. A container of 3 m3 capacity contains 10 kg of CO2 at 27°C. Estimate the pressure exerted by CO2 by using (a) Perfect gas equation, (b) Vander Waals’ equation, (c) Beattie Bridgeman equation.
2. 1 kg of air at a pressure of 8 bar and a temperature of 100°C undergoes a reversible polytropic process following the law pv1.2 = constant. If the final pressure is 1.8 bar, determine:
	1. The final specific volume, temperature and increase in entropy.
	2. The work done and the heat transfer. Assume R = 0.287 kJ/kg K and γ = 1.4.
	3. Repeat (a), assuming the process to be irreversible and adiabatic between end states.
3. i. Explain how real gases deviate from an ideal gas behaviour.
4. Why does isothermal compression need minimum work and adiabatic compression need maximum work?
5. A certain quantity of air initially at a pressure of 8 bar and 280°C has a volume of

0.035 m3. It undergoes a cycle consisting of the following processes: (a) Expands at constant pressure to 0.1 m3 (b) Follows polytropic process with n = 1.4 and (c) A constant temperature process which completes the cycle. Evaluate the heat received and rejected in the cycle and cycle efficiency.

## UNIT – V GAS MIXTURES AND PSYCHROMETRY PART – A

1. **Define Mole Fraction**

Mole fraction of a gas in a gas mixture is defined as the ratio between the number of mol of that gas and the total number of mol of the gas mixture.

## Define Mass Fraction

Mass fraction of a gas in a gas mixture is defined as the ratio between the mass of that gas and the total mass of the gas mixture.

## What is Partial Pressure?

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

1. **What is Partial Volume? [NOV/DEC 2018]** The partial volume of a constituent gas in a gas mixture is the volume of that gas required to exert the same pressure of the gas mixture, at the same temperature of the mixture.
2. **Explain Dalton’s law of partial pressure. [APR/MAY 2016] [NOV/DEC 2016]** 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+……. = mA, mB - mass of the constituent.

p = pA+pB+pC+……. = pA, pB - partial pressure of the constituent.

1. **Explain Amagat’s law of partial volume [APR/MAY 2018,2015, NOV 2019]** Amagat’s law states that the total volume of a gas mixture is equal to the sum of the partial volumes of all constituent gases.

## State Avogadro’s Law. [NOV/DEC 2017]

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

1. **State Gibbs-Dalton’s law. [NOV/DEC 2015]** This states that as the pressure of a real gas approaches zero, the pressure of each component in the mixture approaches its [Partial Pressure.](http://www.thermopedia.com/content/1010/) The [Joule-Thomson](http://www.thermopedia.com/content/905/) [Coefficient](http://www.thermopedia.com/content/905/) is a notable example of this. It remains nonzero at P = 0, whereas the perfect gas value is identically zero.
2. **Define Molecular mass. [NOV/DEC 2014]** Molecular mass is defined as the ratio between total mass of the mixture to the total number of moles available in the mixture.
3. **What is the difference between dry air and atmospheric air? [NOV/DEC 2009]** The difference between dry air and atmospheric air is that atmospheric air contains water vapor but dry air contains no water vapor. Moisture content is zero in dry air.

## Define Psychrometry.

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

## What is humidification and dehumidification?

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

## 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 the same volume (ma). In other words mass of water vopour associated with unit mass of dry air. It is also called absolute humidity.

## Define relative humidity.

It is defined as the ratio of partial pressure of water vapour (pw) in a mixture to the saturation pressure (ps) of pure water at the same temperature of mixture.

## 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 withhold at the same temperature. Absolute humidity is expressed in terms of kg/kg of dry air. Relative humidity is expressed in terms of percentage

1. **Define Degree of saturation. [NOV/DEC 2015]** It is the ratio of actual mass of water vapour in certain mass of dry air to the mass of water vapour in the same mass of dry air when it is saturated at the same

temperature.

1. **What is meant by wet bulb temperature (WBT)? [NOV/DEC 2017]** 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.
2. **What is meant by dry bulb temperature (DBT)? [NOV/DEC 2017]** The temperature recorded by the thermometer with a dry bulb. The dry bulb thermometer cannot affect by the moisture present in the air. It is the measure of sensible heat of the air.
3. **What is dew point temperature? [NOV/DEC 2016]** 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.

## Define dew point depression

It is the difference between dry bulb temperature and dew point temperature at any point.

## What is effective temperature?

The effective temperature is a measure of feeling warmth or cold to the human body in response to the air temperature, moisture content and air motion. If the air at different DBT and RH condition carries the same amount of heat as the heat carried by the air at temperature T and 100% RH, then the temperature T is known as effective temperature.

## What are the important psychrometric processes?

* 1. Sensible heating and sensible cooling, 2. Cooling and dehumidification,

3. Heating and humidification, 4. Mixing of air streams,

5. Adiabatic evaporative cooling.

1. **What is meant by adiabatic mixing? Write the equation for that? [APR/MAY 2016]** The process of mixing two or more streams of air without any heat transfer to the surrounding is known as adiabatic mixing. It takes place in air conditioning system.



## 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.

## Sketch the sensible heating process on a skeleton psychrometric chart.

**[APR/MAY 2018]**

## When are the dry-bulb and dew-point temperatures identical?

The dry-bulb and dew-point temperatures are identical when the air is saturated.



## What is evaporative cooling? Will it work in humid climates?

It is defined as the reduction in temperature resulting from the evaporation of a liquid, which removes latent heat from the surface from which evaporation takes place and it will not work in humid climates.

1. **Define sensible heat and latent heat. [APR/MAY 2015]** 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.
2. **Define sensible heat factor. [NOV/DEC 2014]** Sensible Heat Factor (SHF) is the ratio of total sensible heating load to that of the total heating load of the air conditioning apparatus. SHF is used in the design process of the air conditioning apparatus.
3. **Define adiabatic saturation temperature [APR/MAY 2014] [NOV/DEC 2018, 2019]** It is the temperature at which the outlet air can be brought into saturation state by passing through the water in the long insulated duct (adiabatic) by the evaporation of water due to latent heat of vapourisation.
4. **What is the by-pass factor [APR/MAY 2014]** The bypass factor of the coil is defined as the ratio of temperature difference between the coil and the exit air to the maximum possible theoretical temperature rise in air.
5. **Why do wet clothes dry in the sun faster? [NOV/DEC 2013]** The heat of sun causes evaporation of water from the wet clothes more rapidly than the evaporation in shade. Due to this, wet clothes dry up quickly in sun than in shade.
6. **When is humidification of air necessary? [APR/MAY 2013]** Humidification of air is the process of adding moisture to the air and it is necessary to provide human comfort, when the ambient air is dry.

## How does the wet bulb temperature differ from the dry bulb temperature?

**[APR/MAY 2013]**

The thermometer on the psychrometer that contains the wet wick is called the "wet bulb". The thermometer on the psychrometer without the wick is called the "dry bulb". The thermometers are then whirled around the dowel by their strings. The thermometers are whirled until the wet bulb is dry. When there is little water vapor present, the water on the wet bulb is able to evaporate. This results in a greater difference between the wet and dry bulbs of the psychrometer. When the air is saturated with water vapor, then the water on the wet bulb cannot evaporate.

## In a gas mixture, which component will have the higher partial pressure - the one with the higher mole number or the one with the larger molar mass?

The one with the larger molar mass will have higher partial pressure.

## C:\Users\SYS\Desktop\Capture.PNGDeduce the expression for the molecular weight of the mixture of two non-reacting ideal gases.

**PART – B**

1. i. Prove that specific humidity of air is 𝜔 = 0.622 𝑃𝑣

𝑃𝑏−𝑃𝑣

ii. With the aid of model psychrometric chart explain the following processes. (a).Adiabatic mixing, (b).Evaporative cooling **[APR/MAY 2013]**

1. A certain gas has CP=1.968 and CV=1.507 kJ/kg K. Find its molecular weight and the gas constant. A constant volume chamber of 0.3 m3 capacity contains 2 kg of this gas at 5 °C. Heat is transferred to the gas until the temperature is 100°C. Find the work done, he heat transferred and the change in internal energy, enthalpy and entropy**.**

## [Nov/Dec 17]

1. The mixture of 2kg of hydrogen and 4kg of nitrogen at initially temperature of 22°C is compressed in a cylinder-piston arrangement so that its temperature rises to 150°C. The mean values of Cp over this temperature range for two constituents are 14.45 kJ/kg K and 1.041 kJ/kg K for hydrogen and nitrogen 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 constituent and the mixture**. [APR/MAY 2018]**
2. A vessel of 0.35 m3 capacity contains 0.4 kg of carbon monoxide (molecular weight=28) and 1 kg of air at 20°C. Calculate:
	1. The partial pressure of each constituent,
	2. The total pressure in the vessel.

The gravimetric analysis of air is to be taken as 23.3% oxygen (molecular weight = 32) and 76.7% nitrogen (molecular weight = 28).

1. A mixture of ideal gases consists of 4 kg of nitrogen and 6 kg of carbon dioxide at a pressure of 4 bar and a temperature of 20°C. Find:
	1. Mole fraction of each constituent,
	2. The equivalent molecular weight of the mixture,
	3. Equivalent gas constant of the mixture,
	4. Partial pressures and partial volumes,
	5. Volume and density of the mixture, and
	6. Cp and Cv of the mixture. **[APR/MAY 2012]**
2. A gas mixture contains 7 kg of nitrogen and 2 kg of oxygen at 4 bar and 27°C. Calculate the mole fraction, partial pressures, molar mass, gas constant, volume and density.

## [APR/MAY 2015]

1. A mixture of hydrogen (H2) and oxygen (O2) is to be made so that the ratio of H2 to O2 is 2:1 by volume. If the pressure and temperature are 1 bar and 25ºC Respectively. Calculate (i) the mass of O2 required, (ii) the volume of the container. **[DEC 2014]**
2. A vessel contains at 1 bar and 20°C a mixture of 1 mole of CO2 and 4 moles of air. Calculate for the mixture:
	1. The masses of CO2, O2 and N2, and the total mass;
	2. The percentage carbon content by mass;
	3. The apparent molecular weight and the gas constant for the mixture;
	4. The specific volume of the mixture.

The volumetric analysis of air can be taken as 21% oxygen and 79% nitrogen.

1. i) State Dalton’s law and prove the same

ii) The exhaust gas of an internal combustion engine is found to have 9.8% CO2, 0.3% CO, 10.6% H2O, 4.5% O2 and 74.8% N2 by volume. Calculate molar mass and gas constant of the exhaust gas. If the volume flow rate of exhaust gas is 2m3/h at 100 kPa and 573 K, calculate its mass flow rate. **[NOV 2019]**

1. i) State Amagat’s Law and Dalton’s Law.
2. ii) A closed vessel has a capacity of 500 litres. It contains 20% nitrogen and 20% oxygen, 60% carbon di-oxide by volume at 100°C and 1 MPa. Calculate the molecular mass, gas constant, mass percentages and the mass of mixture.

## [NOV 2020]

1. A vessel of 1.8 m3 capacity contains oxygen at 8 bar and 50°C. The vessel is connected to another vessel of 3.6 m3 capacity containing carbon monoxide at 1 bar and 20°C. A connecting valve is opened and the gases mix adiabatically. Calculate : The final temperature and pressure of the mixture;

The change of entropy of the system. Take: For oxygen, Cv = 21.07 kJ/mole K. For carbon monoxide, Cv = 20.86 kJ/mole K.

1. A mixture of ideal gas consists of 3 kg of N2 and 5 kg of CO2 at a pressure of 300 kPa and at 20°C. Find

a. The mole fraction of each constituent, b. Equivalent molecular weight of the mixture, c. Equivalent gas constant of the mixture, d. The partial pressures and partial volumes, e. Volume and density of the mixture and Cp and Cv of the mixture. Assume, the value of CP/Cv for CO2=1.286, for N2=1.4.

1. Five moles of gas mixture contains 45% N2, 27% He and 28% C6H6 by mass. Find (i) the analysis by volume and the number of moles of each constituent (ii) the volume of mixture at 3.5 bar pressure and 20ºC.
2. If the mixture is heated at constant volume to 50°C, find the changes in internal energy, enthalpy and entropy of the mixture. Find the changes in internal energy, enthalpy and entropy of the mixture if the heating is done at constant pressure. Take γ for CO2 = 1.286 and for N2 = 1.4. **[NOV/DEC 2012]**
3. A rigid tank that contains 2 kg of N2 at 25ºC and 550 kPa is connected to another rigid tank that contains 4kg of O2 at 25ºC, determine the volume of each tank and the final mixture pressure. **[NOV/DEC 2016]**
4. A rigid tank of 5 m3 contains gas mixture comprising 3 kg of O2, 4kg of N2 and 5 kg of CO2 at 290 K. Calculate the molar specific volume, initial pressure of the gas. If it is heated to 350 K, calculate the heat transfer and change in enthalpy. Also verify the Gibbs theorem for entropy. **[APR/MAY 2016]**
5. A tank of 0.2 m3 capacity contains O2 at 15 bar and 400 ºC. A second tank of 0.5 m3 contains N2 at 20 bar and 300 ºC. The two tanks are connected together and allowed to mix. The heat lost during mixing is 50 kJ. Determine the final pressure, final temperature of the mixture and net entropy change due to mixing. **[APR/MAY 2012]**
6. A rigid tank contains 2 kmol of CO2 gases at 300 K and 15MPa. Estimate the volume of the tank on the basis of (a) The ideal-gas equation of state, (b) Compressibility factors and Amagat’s law and (c) Compressibility factors and Dalton’s law.

## [NOV 2010]

1. An insulated rigid tank is divided into two compartments by a partition. One compartment contains 7 kg of Oxygen gas at 40°C and 100 kPa, and the other compartment contains 4 kg of nitrogen gas at 20°C and 150 kPa. Now the partition is removed, and the two gases are allowed to mix. Determine,

The mixture temperature and

The mixture pressure after equilibrium has been established. **[NOV/DEC 2010]**

1. In an engine cylinder a gas has a volumetric analysis of 13% CO2, 12.5% O2 and 74.5% N2. The temperature at the beginning of expansion is 950°C and the gas mixture expands reversibly through a volume ratio of 8:1, according to the law PV1.2= constant. Calculate per kg of gas: (a) The work done, (b) The heat flow, (c) Change of entropy per kg of mixture.

The values of Cp for the constituents CO2, O2 and N2 are 1.235 kJ/kg K, 1.088 kJ/kg K and 1.172 kJ/kg K respectively. **[NOV/DEC 2015]**

1. Two vessels A and B, both containing nitrogen are connected by a valve – which is opened to allow the contents to mix and achieve an equilibrium temperature of 27°C. Before mixing the following information is known about the gases in two vessels.

## Vessel A Vessel B

P = 1.5 MPa P = 0.6 MPa

T = 50 °C T = 20 °C

Contents = 0.5 kg mol Contents = 2.5 kg

Calculate the final equilibrium process, and the amount of heat transferred to the surroundings. If the vessel had been perfectly insulated – Calculate the final temperature and pressure which would have been reached. Take γ = 1.4. **[MAY 2009]**

1. Explain the psychometric properties and process with neat sketch**. [APR/MAY 2018]**
2. Explain the following Air – conditioning process.
3. Sensible cooling and sensible heating
4. Cooling and dehumidification process
5. Evaporative cooling. **[NOV/DEC 2017]**
6. 40 m3 of air at 35°C DBT and 50% R.H. is cooled to 25°C DBT maintaining its specific humidity constant. Determine: (i) Relative humidity (R.H.) of cooled air; (ii) Heat removed from air.
7. 120 m3 of air per minute at 35°C DBT and 50% relative humidity is cooled to 20°C DBT by passing through a cooling coil. Determine the following:
	1. Relative humidity of out coming air and its wet bulb temperature.
	2. Capacity of cooling coil in tonnes of refrigeration.
	3. Amount of water vapour removed per hour.
8. i) Define relative humidity and show on the psychrometric chart how it changes during sensible heating, sensible cooling, humidification and dehumidification.

ii) 120m3 of air per minute at 35°C DBT and 50% relative humidity is cooled to 20°C DBT by passing through a cooling coil. Determine the following: i) Relative humidity of out coming air, ii) Wet bulb temperature of out coming air, iii) Capacity of cooling coil in tonnes of refrigeration, taking 14000 kJ/hr as one tonne of refrigeration. **[NOV 2020]**

1. i) Describe the adiabatic Mixing of Air Streams.

ii) An air-water vapour mixture enters an air-conditioning unit at a pressure of 1.0 bar 38 ℃ DBT, and a relative humidity of 75%. The mass of dry air entering is 1 kg/s. The air-vapour mixture leaves the air-conditioning unit at 1.0 bar, 18 ℃, 85% relative humidity. The moisture condensed leaves at 18 ℃. Determine the heat transfer rate for the process. **[NOV 2019]**

1. Two streams of air 25° C, 50% RH and 25° C, 60% RH are mixed adiabatically to obtain 0.3 kg/s of dry air at 30° C. Calculate the amounts of air drawn from both the streams and humidity ratio of the mixed air.
2. An air-conditioned room requires 30 m3/min of air at 1.013 bar, 20° C, 52.5% RH. The steady flow conditioner takes in air at 1.013 bar, 77%RH, which it cools to adjust the moisture content and reheats to room temperature. Find the temperature to which the air is cooled and thermal loading on both the cooler and heater. Assume that a fan before the cooler absorbs 0.5 kW, and that the condensate is discharged at the temperature to which the air is cooled. i. Explain the process of cooling and dehumidification of air. ii. Draw the psychometric chart and show any two psychrometric process on it. iii. What is moist air and saturated air?
3. It is required to design an air-conditioning plant for a small office room . Outdoor conditions - 14ºC DBT and 10ºC WBT

Required conditions - 20ºC DBT and 60% R.H. Amount of air circulation - 0.30 m3/min./person Seating capacity of office - 60

The required condition is achieved first by heating and then by adiabatic humidifying.

Determine the following: (a) Heating capacity of the coil in kW and surface temperature required if the by pass factor of coil is 0.4. (b) The capacity of the humidifier. Solve the problem by using psychrometric chart. **[NOV/DEC 2016]**

1. A room 7m\*4m\*4m is occupied by an air-water vapour mixture at 38ºC. The atmospheric pressure is 1 bar and the relative humidity is 70%. Determine the humidity ratio, dew point, mass of dry air and mass of water vapour. If the mixture of air-water vapour is further cooled at constant pressure until the temperature is 10ºC. Find the amount of water vapour condensed. **[APR/MAY 2016]**
2. i.A sling psychrometer in a laboratory test recorded the following readings: Dry bulb temperature = 35°C

Wet bulb temperature = 25°C

Calculate the following: (i) Specific humidity (ii) Relative humidity (iii) Vapour density in air (iv) Dew point temperature (v) Enthalpy of mixture per kg of dry. Take atmospheric pressure = 1.0132 bar.

ii. Write short notes on mixing of air streams adiabatically. **[NOV/DEC 2015]**

1. Atmospheric air at 1.0132 bar has a DBT of 30°C and WBT of 25°C. Compute: (a) The partial pressure of water vapour, (b) Specific humidity, (c) Dew point temperature,
2. Relative humidity, (e) Degree of saturation, (f) Density of air in the mixture, (g) Density of vapour in the mixture, (h) Enthalpy of the mixture Use thermodynamic tables only. **[APR 2015]**
3. 120 m3 of air per minute at 35ºC DBT and 50% relative humidity is cooled to 20ºC DBT by passing through a cooling coil. Determine the following (i) relative humidity of out coming air and its wet bulb temperature (ii) capacity of cooling coil in tones of refrigeration (iii) amount of water vapour removed per hour. **[NOV2014]**
4. An air-water vapour mixture enters an air-conditioning unit at a pressure of 1 bar, 38 ºC DBT, and a relative humidity of 75%. The mass of dry air entering is 1 kg/s. The air-vapour mixture leaves the air-conditioning unit at 1 bar, 18 ºC, 85% relative humidity. The moisture condensed leaves at 18 ºC. Determine the heat transfer rate for the process. **[NOV/DEC 2014]**
5. (i) Explain the mole fraction and mass fraction and relation between them. (ii)The exhaust gas of an internal combustion engine is found to have 9.8% CO2,

0.3% CO, 10.6% H2O, 4.5% O2 and 74.8% N2 BY volume. Calculate the temperature and specific humidity of the mixture. **[NOV/DEC 2018]**

1. It is required to design an air-conditioning system for an industrial process for the following hot and wet summer conditions

Outdoor conditions - 32°C DBT and 65% RH Required air inlet conditions - 25°C DBT and 60% RH Amount of free air circulated - 250 m3/min

Coil dew temperature - 13°C

The required condition is achieved by first cooling and dehumidifying and then by heating. Calculate the following (solve this problem with the use of psychrometric chart)

1. The cooling capacity of the cooling coil and its by-pass factor.
2. Heating capacity of heating coil in kW and surface temperature of heating coil if the by-pass factor is 0.3
3. The mass of water vapour removed per hour **[NOV/DEC 2014]**
4. i. Air at 20°C, 40% R.H is mixed with air at 40 °C, 40% R.H in the ratio of (former) 1:2 (later) on dry basis. Determine the final condition of air.

ii. Briefly discuss about evaporative cooling process. **[NOV/DEC 2013]**

1. i. Derive the sensible heat factor for cooling and dehumidification process. Also explain the process.

ii. One kg of air at 40 °C dry bulb temperature and 50% relative humidity is mixed with 2 kg of air at 20°C dry bulb temperature and 20°C dew point temperature. Calculate the temperature and specific humidity of the mixture. **[APR 13, NOV 18]**

1. i. One kg of air at 35°C DBT and 60% R.H. is mixed with 2 kg of air at 20°C DBT and 13°C dew point temperature. Calculate the specific humidity of the mixture.

ii. 90 m3 of air per minute at 20°C and 75% R.H. is heated until its temperature becomes 30°C. Calculate: (i) R.H. of the heated air. (ii) Heat added to air per minute.

1. For the atmospheric air at room temperature of 30ºC and relative humidity of 60% determine partial pressure of air, humidity ratio, dew point temperature, density and enthalpy of air.
2. Show the processes of adiabatic mixing on a skeleton psychrometric chart and explain the process. **[NOV/DEC 2012]**
3. A 5m x 5m x 3m room contains air at 25°C and 100 kPa at a relative humidity of 75 percent. Determine (a) The partial pressure of dry air, (b) The specific humidity, (c) The enthalpy per unit mass of the dry air, and (d) The masses of the dry air and water vapour in the room. **[APR/MAY 2010]**
4. The dry and the wet-bulb temperatures of atmospheric air at 1 atm (101.325 kPa) pressure are measured with a sling Psychrometer and determined to be 25°C and 15°C respectively. Determine
	1. The specific humidity,
	2. The relative humidity and
	3. The enthalpy of the air using thermodynamic relations **[NOV/DEC 2010]**
5. An air-conditioning system is to take in outdoor air at 283 K and 30% R.H at a steady rate of 45 m3/min and to condition it to 298 K and 60% R.H. The outdoor air is first heated to 295 K in the heating section and then humidified by the injection of hot steam in the humidity section. Assuming the entire process takes place at a pressure of 100 kPa, determine (i) the rate of heat supply in the heating section and

(ii) the mass flow rate of the steam required in the humidifying section. **[DEC 2009]**

## PART-C

1. An air pre-heater is used to cool the products of combustion from a furnace while heating the air to be used for combustion. The rate of flow of products is 12.5 kg/s and products cooled from 300°C to 200°C and for the products at this temperature CP=1.09kJ/kg K. The rate of air flow is 11.05 kg/s. The initial temperature is 40°C and the air CP=1.005kJ/kg K.
	1. Estimate the initial and final availability of the products.
	2. What is the irreversibility for the process?
	3. If the heat transfer from the products occurs reversibly through heat engines, what is the final temperature of the air? What is the power developed by the heat engine?

Take T0=300 K and neglect pressure drop both the fluid and heat transfer to the surroundings**. [APR/MAY 2018]**

1. Atmospheric air at 43°C and 40% relative humidity is to be conditioned to a temperature of 25°C and 50% relative humidity. 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 25 m3/min. Find
	1. Dew point
	2. Mass of water vapour drained out
	3. Amount of heat required to raise the temperature from the dew point to the conditioned air. **[APR/MAY 2018]**
2. The food compartment of a refrigerator is maintained at 4°C by removing heat from it at a rate of 360 kJ/min. If the required power input to the refrigerator is 2 kW, determine
	1. The coefficient of performance of the refrigerator and
	2. The rate of heat rejection to the room that houses the refrigerator. **[DEC 17]**
3. Consider a room that contains air at 1 atm, 35°C and 40 percent relative humidity. Using the psychromatric chart, determine,
	1. The specific humidity
	2. The enthalpy
	3. The wet bulb temperature
	4. The dew point temperature and
	5. The specific volume of this air. **[NOV/DEC 2017]**
4. (i) How do you minimize the energy consumed by your domestic refrigerator? (ii)The interior lighting of refrigerators is provided by incandescent lamps whose switches are actuated by the opening of the refrigerator door. Consider a refrigerator whose 40-W light bulb remains on continuously as a result of a malfunction of the switch. If the refrigerator has a coefficient of performance of 1.3 and the cost of electricity is Rs.5 per kWh, determine the increase in the energy consumption of the refrigerator and its cost per year if the switch is not fixed. Assume the refrigerator is opened 20 times a day for an avenge of 30s.
5. State law of conservation of energy and mention few everyday examples of first law of thermodynamics.
6. Categorize your home appliances as closed and open system. Perform thermodynamic analysis on any two. Make suitable assumptions wherever required.
7. Comment on quantity and quality of energy.
8. Apply the concept of non-flow process for a 7.5 litre pressure cooker which uses steam to determine the quantity of LPG required to prepare rice. Assume suitable pressure, volume and temperatures. Take the calorific value of LPG as 46.1 MJ/kg
9. A steam motor company manufactured a lawn mower in 1890 powered by a Rankine cycle steam engine. If it had a boiler outlet state of 7 bar and 260C and a condenser pressure of 0.07 bar, calculate (i) degree of superheat at boiler outlet (ii) Rankine cycle efficiency of lawn mower.(iii) equivalent Carnot cycle efficiency of the lawn mower.
10. If air consists of 77% by weight of nitrogen and 23% by weight of oxygen calculate:
11. The mean molecular weight of air,
12. The mole fraction of oxygen,
13. The concentration of oxygen in mole/m3 and kg/m3 if the total pressure is 1.5 atmospheres and the temperature is 25 °C.
14. A textile dryer is found to consume 4 m3/h of natural gas with a calorific value of 800 kJ/mole. If the throughput of the dryer is 60 kg of wet cloth per hour, drying it from 55% moisture to 10% moisture, estimate the overall thermal efficiency of the dryer taking into account the latent heat of evaporation only.