Interview Guidebook

for

Engineering Services Examination,
State Engineering Services, PSUs and
other competitive examinations

Mechanical Engineering

Part-I : Theory

Interview oriented concise theory, definitions,
concepts and formulae

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Interview Guidebook

Part - I : Theory

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Mechanical Engineering

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CHAPTER 1

Thermodynamics

Definition of Thermodynamics

Thermodynamics can be defined as the science of energy. The name thermodynamics stems from the Greek words therme (heat) and dynamics (power). Thermodynamics is broadly interpreted to include all aspects of energy and energy transformation including power generation, refrigeration and relationship among the properties of matter. Energy can be viewed as the ability to cause changes.

Macroscopic Thermodynamics: It is only concerned with the effects of the action of many molecules which can be perceived by human serves senses for example, the pressure is macroscopic quantity which is the average rate of change of momentum due to all the molecular collisions made on a unit area.

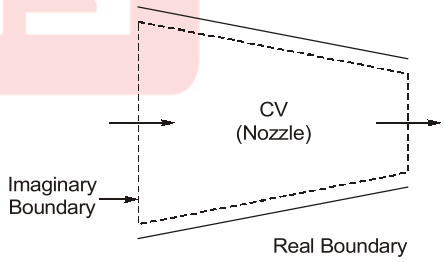
Microscopic Thermodynamics: In this, the matter is composed of myriads of molecules. The behavior of gas is described by summing up the behavior of each molecule. Statistical behavior of each molecule is summed up to give macroscopic viewpoint of thermodynamics. All the result of classical or macroscopic thermodynamics can, however, be derived from the microscopic and statistical study of matter.

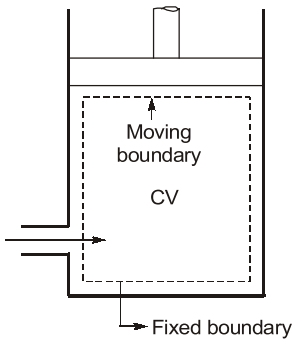
Thermodynamic System: It is defined as a quantity of matter or a region in space upon which attention is concentrated in the analysis of a problem.

Surroundings: The mass or region outside the thermodynamic system is called the surroundings.

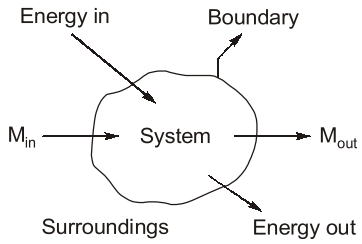
Boundary: The real or imaginary surface that separates the system from its surroundings is called boundary.

Control volume and control surface: An open system or a control volume as it is often called, is a property selected region in space. It usually enclosed a device that involves mass flow such as compressor, turbine or nozzle. The boundaries of a control volume are called a central surface and they can be real or imaginary. Both mass and energy can cross the boundary of a control volume. A control volume can be fixed in size and shape, as in the case of nozzle, or it may involve a moving boundary.



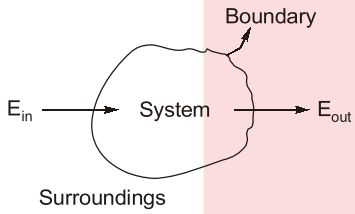


Open system: Open system can exchange both matter and energy with an outside system. Example: Human body, air compressor, turbine



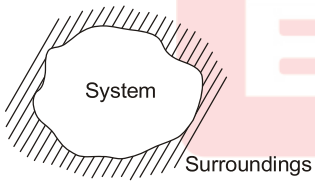
An Open system

Closed system: Closed system exchange energy but not matter with an outside surrounding. Example: Earth, piston cylinder device etc.



A closed system

Isolated system: Isolated system can exchange neither energy nor matter with an outside surrounding. Example: physical universe, closed thermos bottle etc.



An isolated system

Property: Any characteristic of a system is called a property properties are considered to be either intensive or extensive.

- Intensive properties are those that are independent of the mass of a system such as pressure, temperature, viscosity, density etc.
- Extensive properties are those whose values depend on the size of the system such as mass, volume, momentum, energy, enthalpy etc. Extensive properties per unit mass are called specific properties e.g. specific volume, specific energy etc.

Phase: A phase is a quantity of matter which is homogeneous in physical structure and chemical composition e.g. mixture of gases, pure water etc.

State: It is the unique condition of a system of an instant of time described by its properties such as pressure, temperature volume, density etc.

Path: A thermodynamic system passing through a series of states constitutes a path.

Process: A process is defined as a transition in which a system changes from initial state to a final state.

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

Cyclic process: In cyclic process, the system undergoes through a series of processes from one state and ends with the same initial state by forming a complete cycle.

Reversible process: It is a process in which the initial state together with all energies transferred and transform during the process can be completely restored in both system and environment.

Example: extension and compression of spring, evaporation, electrolysis, friction less adiabatic compression and expansion of a fluid etc.\

Irreversible process: A process is said to be irreversible if a system passes through a sequence of non-equilibrium states. Such a system will not retrace the reverse path to restore the original state.

Example: Mechanical & fluid friction, throttling, combustion of fuel in air, free expansion, adiabatic mixing, plastic deformation, convective heat transfer etc.

High Grade Energy: It can be completely transformed into shaft work without any loss e.g. mechanical work, water energy, wind energy, kinetic energy of jet, etc.

Low Grade Energy: It cannot be completely converted into mechanical work, e.g., heat energy, nuclear energy etc.

Similarities : Heat & Work

- Energy interaction
- Transient phenomenon
- Boundary phenomenon

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- Not the property of system
- Path functions
- In exact differentials

Dissimilarities: Heat & Work

- Heat is low grade energy, where as work is a high grade energy.
- Heat is energy interaction due to difference. All other energy interaction are work interactions.

Thermodynamic Equilibrium: A system is said to be in a state of thermodynamic equilibrium if the value of the property is same at all points of the system. For a system to be in thermodynamic equilibrium, it must be in mechanical, chemical and thermal equilibrium

Point function: When the thermodynamic property has a definite value for a given state, it is called a point function e.g. P, T, V etc. The differentials of point functions are exact.

$$\int_1^2 dV = V_2 - V_1$$

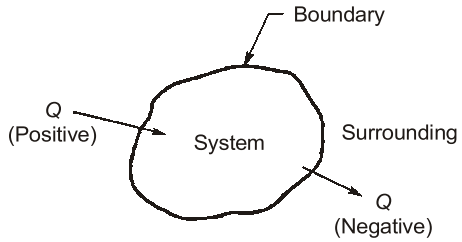
Path function: The quantities which are not thermodynamic properties are called path functions e.g. heat and work. The work and heat are inexact differentials.

$$\int_1^2 \delta W = W_{1-2}$$

and $$\int_1^2 \delta Q = Q_{1-2}$$

Work & Heat Transfer

Heat Transfer



Direction of heat transfer

- Heat is the form of energy that is transferred across a boundary by virtue of temperature difference.
- Heat is transferred by conduction, convection & radiation.
- Heat flow into a system is taken as (+ve) & heat flow act of the system is taken as (–ve).
- It is a boundary phenomenon.
- Heat, like work, is not a conserved quantity, & is not a property of a system.
- A process in which no heat crosses the boundary of the system is called an adiabatic process.
- Heat transfer is a path-function & dQ is an inexact differential.

Specific Heat

- It is defined as the amount of heat required to raise a unit mass of the substance through a unit rise in temperature

$$C = \frac{Q}{m\Delta t} \text{ J/kg K}$$

where
C = specific heat
Q = amount of heat transfer (J)
m = mass of substance (kg)
Δt = rise in temperature (k)

Latent Heat

- It is the amount of heat transfer required to cause a phase change in unit mass of a substance at constant pressure & temperature.

Latent Heat of Fusion (l_{fu})

- Is the amount of heat transferred to melt unit mass of solid to liquid, or to freeze unit mass of liquid to solid.

Latent Heat of Vaporization (l_{vap})

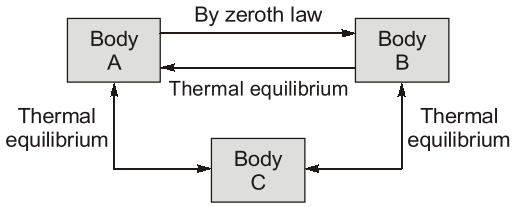
- The quantity of heat required to vaporise unit mass of liquid into vapour, or condense unit mass of vapour into liquid.

Latent Heat of Sublimation (l_{sub})

- The amount of heat transferred to convert unit mass of solid to vapour or vice-versa.
- l_{fu} is not much affected by pressure, where as l_{vap} is highly sensitive to pressure.

Zeroth Law of Thermodynamics

The law states that if two systems are each in thermal equilibrium with a third system, they are also in thermal equilibrium with each other.



Zeroth law of thermodynamics

First Law of Thermodynamics

- Heat & work are different forms of the same entity, called energy which is conserved.
- Energy which enters the system as heat may leave the system is work, or energy which enters the system as work may leave as heat.
- The first law for a closed system undergoing a cycle is

$$\oint dW = J \oint dQ$$

where, $\oint$ = Denotes the cyclic integral for the closed path.

W = Work transfer

Q = Heat transfer

J = Joule's equivalent

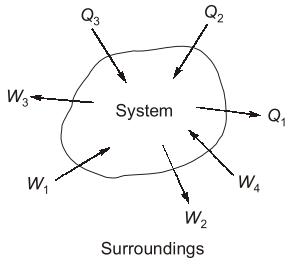
- If the system undergoes a change of state during which both heat transfer & work transfer are involved, the net energy transfer will be stored or accumulated within the system. The energy stored is neither heat nor work & is called energy ΔE.

i.e., $Q - W = \Delta E$

where Q = heat transfer

W = work transfer.

- If there are more energy transfer quantities involved in the process, as shown in fig. the first law gives.



Surroundings

$$(Q_2 + Q_3 - Q_1) = \Delta E + (W_2 + W_3 - W_1 - W_4)$$

Free Expansion

- The expansion of a gas against a vacuum is called free expansion. Since vacuum does not offer any resistance, there is no work transfer involved in free expansion. It is an irreversible process.

Second Law of Thermodynamics

- Work is said to be high grade energy & heat a low grade energy.
- The complete conversion of low grade energy into high grade energy in a cycle is impossible.
- The second law states that there exists a useful state variable called entropy *S*. The change in entropy delta S is equal to the heat transfer delta *Q* divided by the temperature *T*.
- An example of a reversible process is ideally forcing a flow through a constricted pipe. Ideal means no boundary layer losses. As the flow moves through the constriction, the pressure, temperature and velocity change, but these variables return to their original values downstream of the constriction. The state of the gas returns to its original conditions and the change of entropy of the system is zero. Engineers call such a process an isentropic process. Isentropic means constant entropy.
- The second law states that if the physical process is irreversible, the combined entropy of the system and the environment must increase. The final entropy must be greater than the initial entropy for an irreversible process.
- A hot object is put in contact with a cold object. Eventually, they both achieve the same equilibrium temperature. If we then separate the objects they remain at the equilibrium temperature and do not naturally return to their original temperatures. The process of bringing them to the same temperature is irreversible.
- The first law of thermodynamics indicates that the total energy of a system is conserved. Total energy includes the potential and kinetic energy, the work done by the system, and the transfer of

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heat through the system. The second law of thermodynamics indicates that, while many physical processes that satisfy the first law are possible, the only processes that occur in nature are those for which the entropy of the system either remains constant or increases.

Energy Reservoirs

- **Thermal energy reservoirs (TER):** is a large body of infinite heat capacity, which is capable of absorbing or rejecting an unlimited quantity of heat without suffering appreciable changes in thermodynamic coordinates.
- **Mechanical energy reservoir (MER):** is a large body enclosed by an adiabatic impermeable wall capable of storing work as potential energy or kinetic energy.

Clausius Statement

- It is impossible to construct a device which, operating in a cycle, will produce no effect other than the transfer of heat from a cooler to a hotter body.
- No process is possible whose sole result is the transfer of heat from a cooler to a hotter body.

Kelvin-plank Statement

- It is impossible for heat engine to produce net work in a complete cycle if it exchange heat only with bodies at a single fixed temperature.
- No process is possible whose sole result is the absorption of heat from a reservoir and the conversion of this heat into work

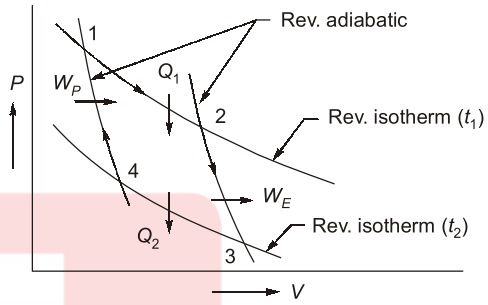
Reversibility & Irreversibility

- A reversible process is one which is performed in such a way that at the conclusion of the process, both the system & the surroundings may be restored to their initial states, without producing any change in the rest of the universe.
- Any natural process carried out with a infinite gradient is an irreversible process.

Causes of Irreversibility

- Heat transfer through a finite temperature difference.
- Lack of pressure equilibrium within the interior of the system or between the system & the surroundings.
- Free expansion
- Friction
- Paddle - wheel work transfer
- Transfer of electricity through a resistor.

Carnot Cycle



Cornet cycle

- Carnot cycle is a reversible cycle.
- It consists of
  - Two reversible isothermal process
  - Two reversible adiabatic process

Carnot's Theorem

- All heat engines operating between a given constant temperature source & a given constant temperature sink, none has a higher efficiency than a reversible engine.
- The efficiency of all reversible heat engines operating between the same temperature level is the same.

$$\eta_A = \eta_B$$

Efficiency of the Reversible Heat Engine

- The efficiency of a reversible heat engine in which heat is receive solely at T_1 is found to be

$$\eta_{rev} = \eta_{max} = 1 - \left(\frac{Q_2}{Q_1}\right)_{rev} = 1 - \frac{T_2}{T_1}$$

  where T_1 & T_2 are temperature of source & sink.
- Efficiency of the reversible cycle increases when T_2 decreases or T_1 increases.
- The more effective way to increase the efficiency of a carnot engine is to decrease T_2 keeping T_1 constant.

Entropy

Entropy is an index of the unavailable or degraded energy. Heat always flow from the hot bodies to cold bodies which becomes degraded or unavailable. When applied to processes, the second law of thermodynamics lead to the definition of a properties, known as entropy.

- For a reversible transfer of heat, change in entropy:

$$\Delta S = S_2 - S_1 = \int \frac{dQ}{T}$$

- Entropy is a point or state function i.e. exact function.
- Entropy is the property of a substance like pressure, volume or internal energy.
- Clausius Inequality:

$$\oint \frac{dQ}{T} \le 0$$

If $\oint \frac{dQ}{T} = 0$, the cycle is reversible

$\oint \frac{dQ}{T} < 0$, the cycle is irreversible and possible.

$\oint \frac{dQ}{T} > 0$, the cycle is impossible.

- The Clausius inequality is valid for refrigeration and heat pumps.
- Entropy of an isolated system can never decrease.
- The entropy of the world (universe) is constant.
- The entropy of the world tends towards a maximum.
- The entropy of an isolated system always increases and becomes a maximum at the state of equilibrium.
- Any thermodynamic process is accompanied by entropy generation.
- A process always occurs in such a direction as to cause an increase in the entropy of the universe.
- The entropy of a system is a measure of the degree of molecular disorder existing in the system.

Exergy, Irreversibility and Gouy Stodola theorem

The exergy (available energy) of a system at a given state is the maximum work that can be extracted from it till it reaches the state of thermodynamic equilibrium with its surroundings.

- The dead state of a system is defined as the state of stable equilibrium of the system within the atmosphere, i.e., its capacity to do work ceases and the available energy becomes zero.
- The exergy of a system decreases as its temperature or pressure decreases and approaches that of the dead state where its value is zero.
- The degradation of energy of the system is more when heat loss occurs at a higher temperature than that occurring at lower temperature.
- Quantity wise the energy loss may be the same, but quality wise the losses are different.
- While the first law states that energy is always conserved quality wise, the second law emphasizes that energy is always degraded quality wise.
- Energy is always conserved, but its quality is always degraded.
- The exergy of an isolated system can never increase but always decreases.
- The exergy of an isolated system can never increase but always decreases.
- Second law efficiency,

$$\eta_{II} = \frac{\text{Minimum exergy intake to perform the given task}}{\text{Actual exergy intake to perform the same task}}$$

Irreversibility and Gouy-Stodola theorem: The actual work done by a system is always less than the idealized reversible work and the difference between the two is called irreversibility (I) of the process.

($I = \omega_{rev} - \omega$ = degradation of energy). According to Gouy-stodola theorem, the rate of loss of exergy in a process is proportional to the rate of entropy generation.

$$\dot{I} = \dot{\omega}_{cost} = T_0(\Delta \dot{S})_{univ.} = T_0 \dot{S}_{gen}$$

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Note:

- **Exergy of a finite body at temperature *T*:** The exergy of any finite body of heat capacity *C* at temperature *T* is given as

$$X = C\left[T - T_0 - T_0 \ln\frac{T}{T_0}\right]$$

- **Exergy of a closed system :** Exergy function of a closed system is given by

$(\phi = U + P_0V - T_0S)$

So, $(\omega_{max} = \phi_1 - \phi_2)$

- **Exergy of a steady flow system:** Exergy function of a steady flow system is given by

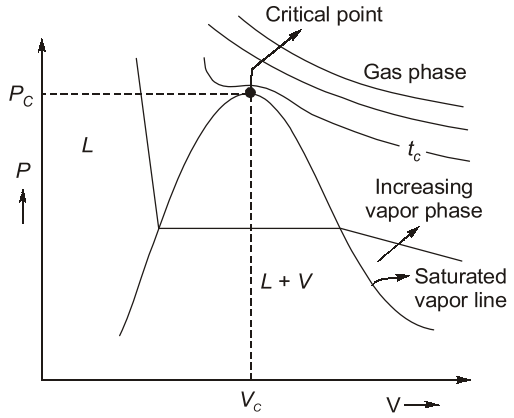
$(\phi = H - T_0S)$

$\omega_{max} = (H_1 - T_0S_1) - (H_2 - T_0S_2) = \phi_1 - \phi_2$

Properties of Pure Substance

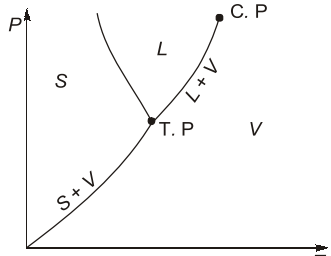
- A pure substance is one which has homogeneous molecular structure and is also invariable in chemical composition. It may exist in one or more phases.
- Example of pure substance: atmospheric air, steam-water mixture, combustion, products of a fuel.
- **Dryness fraction:** The term 'dryness fraction' is related to wet steam which evaporates and used to find the state in the transition zone of saturation curve on p-v diagram.

$$x = \frac{m_g}{m_g + m_f}$$

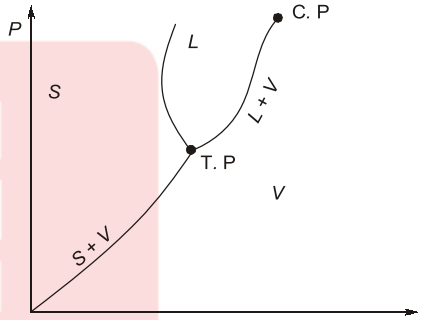


- For water at critical point:

$p_c = 221.2$ bar,
$t_c = 374.15°$ C,
$v_c = 0.00317$ m^3/kg

- 

Substance that expands on freezing



Substance that contract on freezing

- The point where all the three phases coexist simultaneously is called the triple point.
- The triple point for water is 0.611 kPa and 0.01° C.
- The internal energy of saturated water at the triple point (t = 0.01° C) is arbitrarily chosen to be zero.
- The entropy of saturated water is taken as zero at the triple point.

Properties of Gases

- A hypothetical gas which obeys the law $p\bar{v} = \bar{R}T$ at all pressures and temperatures is called an ideal gas.
- At $P \to 0$ or $T \to \infty$, the real gas approaches the ideal gas behavior.
- For an ideal gas: $h = f(T)$ only
  $u = f(T)$ only
- $\gamma = \frac{5}{3}$ for monoatomic gases
  $= \frac{7}{5}$ for diatomic gases
  $= \frac{4}{3}$ for polyatomic gases

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Mechanical Engineering

Part-II

Topicwise Bifurcated
Previous Interview Questions
and Practice Questions

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UNIT 1

Thermodynamics

1. Basic Concepts, Work and Heat

1.1 Which concept does the Zeroth Law of thermodynamics give?

Ans: Temperature

1.2 What is heat and work in a thermodynamic system?

Ans: **Work:** The work is said to be done by a system if the sole effect on the things external to the system can be reduced to the raising of a weight.

Heat: It is defined as the form of energy that is transferred across a boundary by virtue of a temperature difference.

1.3 What is intensive and extensive property in a thermodynamic system?

Ans: Properties which are independent of mass are known as intensive properties. Extensive properties are mass dependent properties. Examples:

Intensive property: Pressure, temperature, density, specific energy.

Extensive property: Volume, energy.

1.4 What is Charle's law?

Ans: The volume of a given mass varies directly as its absolute temperature, if the pressure remains unchanged.

$\Rightarrow \quad V \propto T$ where P is constant.

1.5 What is quasi-static process or quasi-equilibrium process?

Ans: When a process proceeds in such a manner that the system remains infinitesimally close to an equilibrium state at all times, it is called a quasi-static process. It can be seen as a sufficiently slow process that allows the system to adjust itself internally so that properties in one part of the system do not change any faster than those at other parts.

1.6 How will you get work done by a water pump? (Assuming flow process)

Ans: Flow work = $\int vdp$.

where, v = volume, dp = change in pressure.

1.7 What is difference between vdp and *pdv*?

Ans: Both are used for the calculation of work done in thermodynamic system. *pdv* is used for a closed system; and vdp is used for a open system i.e., flow work.

1.8 What is constant internal energy process in thermodynamics?

Ans: Isothermal process.sw

1.9 What is thermometric property? **[BHEL-2007]**

Ans: A thermometric property is any physical property that changes measurably with temperature. Examples are length of column of liquid, electrical resistance, pressure, volume, etc.

1.10 What is work done in isothermal process? **[BHEL-2008]**

Ans: Work done in isothermal process:

$$W = mRT \ln \frac{V_2}{V_1}$$

1.11 What is Thermodynamics? **[ESE-2013]**

Ans: Thermodynamics is a macroscopic science which studies various interactions amongst energy, notably heat and work transfer, with matter that brings about significant changes in the macroscopic properties of a substance that are measurable. The laws of thermodynamics govern energy behaviour.

There are four basic laws of thermodynamics :

- Zeroth law of thermodynamics
- First law of thermodynamics
- Second law of thermodynamics
- Third law of thermodynamics

1.12 Is the boiler a closed system?

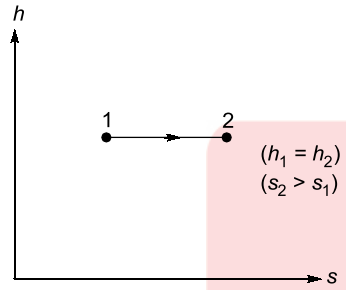
[ESE-2013]

Ans: Yes, the boiler is a closed system.

1.13 What is throttling? Draw it on h-s diagram. Where is it practically used?

[ESE-2016]

Ans: When a fluid passes through a restriction such as a porous plug, a capillary tube, or an ordinary valve, its pressure decreases. During this process, enthalpy of the fluid remains constant. This process is known as throttling.



It is practically used in vapour compression refrigeration cycle (VCR cycle).

1.14 What is point and path function?

[ESE-2016]

Ans: A point function is one which depends on the state only and not on how a system reaches that state. Whereas path function is that whose magnitudes depends on the path followed during a process as well as the end states.

1.15 What is isochoric process?

[ESE-2016]

Ans: It is a thermodynamics process during which the volume of the closed system undergoing such a process remains constant.

1.16 What is ideal gas and real gas?

[ESE-2016]

Ans: An ideal gas is a theoretical gas composed of randomly moving particles that do not interact except when they collide elastically. Real gases are non-hypothetical gases whose molecules occupy space and have interactions. These gases behave as ideal gases at low pressure and high temperature.

1.17 What are c_P and c_V? [ESE-2018]

Ans: c_p is specific heat at constant pressure i.e heat energy per unit mass require to raise the temperature by one degree celsius keeping pressure constant. c_v is the specific heat at constant volume i.e. heat energy per unit mass required to raise the temperature by one degree celsius keeping the volume constant.

1.18 What is relation between c_P and c_V? Which one is larger?

[ESE-2018]

Ans: Relation is given by Meyer's relation i.e. $c_p - c_v = R$. c_p is larger than c_v.

1.19 Give a practical example of adiabatic process?

[ESE-2018]

Ans: Adiabatic process is a process in which there is no heat transfer, and for that the process has to be very very fast, which is not practically feasible. So, in reality no process is adiabatic process.

1.20 What is specific heat?

[ESE-2018]

Ans: It is the amount of heat energy per unit mass which is required to raise the temperature by one degree celsius.

1.21 What is ideal gas? Give examples of ideal gas.

[ESE-2021]

Ans: An ideal gas is defined as the one in which all collisions between atoms or molecules are perfectly elastic and there are no intermolecular forces. It consequently follows ideal gas law. It is only a theoretical concept, and no gas is actually ideal.

However, helium behaves like ideal gas being monoatomic gas and interatomic forces being very low. Several gases and mixture of gases behave like ideal at low densities like O_2, N_2, air etc.

1.22 What is turbine?

[ESE-2021]

Ans: A turbine is a machine that transforms rotational energy from a fluid that is picked up by the rotor system into usable form of energy or work.

1.23 What is the importance of thermodynamics?

[ESE-2021]

Ans: Thermodynamics has very wide application as basis of thermal engineering. Almost all processes and engineering industries, agriculture, transport, commercial and domestic activities use thermal engineering. But energy technology and power sector are fully dependent on laws of thermodynamics.

1.24 Is the statement "For every action, there is an equal and opposite reaction", applicable to laws of thermodynamics?

[ESE-2021]

Ans: Newton's laws can't describe thermodynamic cycles. Newton's laws have not any attention to the irreversibility and the same concepts.

1.25 What is heat engine?

[ESE-2021]

Ans: A device which converts heat into work.

1.26 What is the difference between polytropic and adiabatic process?

[ESE-2016, ESE-2021]

Ans: Adiabatic processes are those in which no heat transfer takes place across the boundaries, whereas polytropic process is a general process, given by the equation (PV^n = constant) and 'n' can take any value. In polytropic process both heat and work transfer takes place across the boundary.

1.27 What is an isothermal process?

[BHEL-2008, ESE-2021]

Ans: An isothermal process is the one in which the temperature remains constant.

1.28 Difference between thermodynamic cycle and heat transfer.

[ESE-2017, 2023]

Ans: Thermodynamic cycle means its initial and final states are same. If the energy interaction occurs due to temperature difference, it is called heat transfer.

1.29 What is thermodynamic equilibrium?

[ESE-2013, 2022, 2023]

Ans: A system as an isolated system is said to be in thermodynamic equilibrium when no change is observed in the macroscopic properties of the system like entropy, internal energy etc. Mechanical equilibrium, chemical equilibrium and thermal equilibrium are to be maintained for the system which is in thermodynamic equilibrium.

1.30 What is zeroth law of thermodynamics and why its name is zeroth?

[ESE-2016, 2018, 2022, 2024]

Ans: The zeroth law of thermodynamics states that if two thermodynamic systems are each in thermal equilibrium with a third one, then they are in thermal equilibrium with each other. Since, zeroth law of thermodynamics is nothing but statement about "thermodynamic equilibrium" which is one of the most basic law in thermodynamics and was added as a law of thermodynamics after "first law of thermodynamic" was established. So it was named zeroth.

1.31 What is the difference between heat transfer and thermodynamics?

[ESE-2013, 2024]

Ans: Heat transfer deals with the energy analysis which is in transition and depends on the modes of heat transfer like conduction, convection and radiation or combination of any of these modes. Heat transfer deals in non equilibrium domain and conditions while thermodynamics deals with study of system at equilibrium and does not depend on how heat transfer has occurred.

1.32 How many laws of thermodynamics are there?

[ESE-2021, 2024]

Ans: There are four laws of thermodynamics:

1. Zeroth law of thermodynamics.
2. First law of thermodynamics.
3. Second law of thermodynamics.
4. Third law of thermodynamics.

2. First Law of Thermodynamics

2.1 What is the statement of the first law of thermodynamics?

Ans: The first law of thermodynamics states that "energy can neither be created nor be destroyed during a process; it can only change forms";

or

"During a cyclic process, the net work interaction and net heat interaction have the same value".

2.2 Write expression for steady flow energy equation.

Ans:

$$\dot{m}\left[h_1+\frac{v_1^2}{2}+gz_1\right]+\dot{Q}=\dot{m}\left[h_2+\frac{v_2^2}{2}+gz_2\right]+\dot{W}$$

Subscript 1 is for inlet of the system and 2 for outlet of the system.

2.3 What is polytropic process?

Ans: Polytropic process follows the following law : $PV^n = C$ where n is polytropic index.
The slope of this process is in between the isothermal and isentropic process.

2.4 What is its physical significance? (Continuation of previous question)

Ans: It is almost impossible to maintain both isothermal and isentropic process for a gaseous substance, hence most of the isentropic process is idealised as a polytropic process to get close analysis of a system.

2.5 What are the drawbacks of first law of thermodynamics?

[ESE-2016]

Ans: First law doesn't differentiate between heat and work. It considers the aspect of conservation of energy quantitatively but does not take qualitative aspect into consideration.

2.6 What is a system and control volume?

[ESE-2016]

Ans: The word 'system' refers to a fixed mass with a boundary. However, with time, the boundary of the system may change but the mass remains same.
A control volume is often called as a properly selected region in space. It usually encloses a device that involves mass flow such as a compressor, turbine, or nozzle. Both mass and energy can cross the boundary of a control volume.

2.7 Why specific heat of gas at constant volume is lower than at constant pressure?

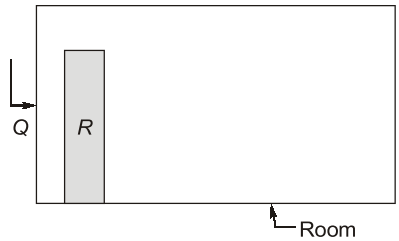
[ESE-2018]

Ans: When a gas is heated at constant volume, all the added heat is used to increase the internal energy of the gas whereas at constant pressure condition some part of heat goes in external work to maintain constant pressure.

2.8 If I leave the door of refrigerator open, then what will happen to room temperature? Will it increase or decrease and why?

[ESE-2019]

Ans: Considering room as a system, net heat is getting added to the system, hence temperature of room will rise.



2.9 What is efficiency of a heat engine?

[ESE-2021]

Ans: For any engine,

$$\eta=\frac{W_{out}}{Q_{in}}$$

For Carnot engine,

$$\eta_{carnot}=\frac{T_H-T_L}{T_H}=1-\frac{T_L}{T_H}$$

2.10 If I say there exist a heat engine with 90% efficiency will you agree?

[ESE-2021]

Ans: Practically no, but theoretically yes.

2.11 What is PMM2?

[ESE-2016, 2023]

Ans: Perpetual motion machine (PMM2) is a kind of machine working on thermodynamic cycle that can produce net work output while exchanging heat with a single reservoir.

2.12 What is enthalpy?

[ESE-2024]

Ans: The total heat content of a system is known as enthalpy. It is the sum of internal energy of the system (u) and the flow work (pv).

3. Second Law of Thermodynamics

3.1 Apply second law of thermodynamics on a hot cup of tea.

[ESE-2017]

Ans: Heat rejected by hot cup of tea at T_H = Heat gained by ambient at T_L = Q(say)

Now, $\oint \frac{dQ}{T} = \frac{-Q}{T_H} + \frac{Q}{T_L} = Q\left(\frac{T_H - T_L}{T_H \times T_L}\right) > 0$

So, $(\Delta S)_{\text{universe}} = Q\left(\frac{T_H - T_L}{T_H \times T_L}\right) > 0$

$\Rightarrow$ Process is possible.

3.2 What is Clausius inequality for a reversible and irreversible cycle?

[ESE-2018]

Ans: $\because \oint \frac{dQ}{T} = 0$ for reversible cycle

$\oint \frac{dQ}{T} < 0$ for irreversible cyclex

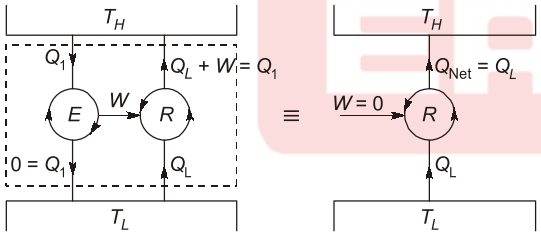
3.3 What is minimum temperature that can be achieved?

[ESE-2018]

Ans: Theoretically minimum possible temperature is 0 K , but practically it is not feasible to achieve.

3.4 Is a perpetual machine possible after having heat engine and refrigerator connected between two reservoir? [ESE-2019]

Ans: Let us assume that the engine is possible which take heat from source and produce work $W = Q_1$, and rejects no heat, which is then connected to refrigerator as shown.



The equivalent system will transfer heat Q_1 from lower temperature to higher temperature without any external work, which violates Clausius statement. Hence, such perpetual motion machines are not possible.

3.5 Why carnot cycle is not possible practically?

[ESE-2021]

Ans: Since in carnot cycle, isothermal processes are much slower and adiabatic processes require higher speed, which is not possible in actual engines.

3.6 Explain 1st and 2nd law of thermodynamics?

[ESE-2016, 2018, 2019, 2024]

Ans: **1st law** is based on the conservation of energy. For a closed system undergoing a thermodynamic cycle, net heat transfer is proportional to the net work transfer.

2nd law: According to Kelvin Planck's statement, it is impossible for a heat engine working on thermodynamic cycle to produce a net work output while exchanging heat with a single reservoir.

4. Entropy

4.1 What is difference in polytropic and isentropic process?

Ans: In isentropic process heat transfer is zero, whereas in polytropic process, it is not zero.

4.2 Why does entropy decrease with increase in temperature?

[ESE-2013]

Ans: $dS = \frac{\delta Q}{T}$

Entropy is inversely proportional to the temperature so, as temperature increases, entropy decreases.

4.3 Name a process in which entropy decreases and what is irreversibility?

[ESE-2014]

Ans: Entropy can decrease in a reversible process. Suppose, source loses heat Q_1 at temperature T_1, so its entropy decreases by $\frac{Q_1}{T_1}$.

Irreversibility can be represented as the difference in maximum possible work and actual work.

4.4 What is second law and entropy relationship?

[ESE-2016]

Ans: $dS \geq \frac{\delta Q}{T}$

According to this law, the total entropy of the universe is continuously increasing.

4.5 Entropy and entropy generation is path or point function?

[ESE-2017]

Ans: Entropy is a property so it is point function whereas entropy generation is a path function.

4.6 How can we calculate the second law efficiency?

[ESE-2017]

Ans: Second law efficiency:

- Work producing devices

$$\eta_{II} = \frac{\eta_{actual}}{\eta_{max}} \Rightarrow \frac{W_{act}}{W_{max}}$$

- Work consuming

$$\eta_{II} = \frac{(COP)_{act}}{(COP)_{max}} = \frac{D.E / W_{act}}{D.E / W_{min}} = \frac{W_{min}}{W_{act}}$$

4.7 What is clausius inequality? Give definition?

[ESE-2018]

Ans: According to this, the cyclic integral of factor $\frac{dQ}{T}$ should be less than or equal to zero.

Clausius inequality: $\oint \frac{dQ}{T} \leq 0$

4.8 When adiabatic process is termed as isentropic?

[ESE-2018]

Ans: When the adiabatic process is reversible then, it is termed as isentropic process.

4.9 In which process is entropy constant and why it happens?

[ESE-2018]

Ans: Most steady-flow devices operate under adiabatic conditions, and the ideal process for these devices is the isentropic process. Some examples of theoretically isentropic thermodynamic devices are pumps, gas compressors, turbines, nozzles, and diffusers. These devices are assumed to be adiabatic and frictionless. Only work transfer takes place which do not change entropy, so entropy remains constant.

4.10 What do you mean by 2nd law efficiency?

[ESE-2018]

Ans: Second-law efficiency computes the effectiveness of a system relative to its performance in reversible conditions. It is defined as the ratio of the thermal efficiency of an actual system compared to an idealized or reversible version of the system.

4.11 What is the significance of entropy?

[ESE-2012, 2020]

Ans: Entropy is a measure of unavailable energy. In fact, the entropy may be regarded as the unavailable energy per unit temperature i.e.,

$$\text{Entropy} = \frac{\text{unavailable energy}}{\text{temperature}}$$

4.12 What is the difference between first and second law efficiency?

[ESE-2021]

Ans: The first law efficiency tells that how much input energy is converted to desired output (i.e. work) whereas second law efficiency tells that how efficient our system is compared to ideal system (i.e. Carnot engine).

4.13 What is third law of thermodynamics?

[ESE-2016, 2020, 2021,2022]

Ans: It states that entropy of a perfect crystal is zero when the temperature of the crystal is equal to absolute zero (0 K).

4.14 What do you mean by entropy?

[ESE-2013, 2021, 2024]

Ans: A thermodynamic quantity representing the unavailability of a system's thermal energy for conversion into mechanical work, often interpreted as the degree of disorder or randomness of the system.

5. Properties of Pure Substance

5.1 What is critical temperature and critical pressure of a substance?

Ans: **Critical temperature:** It is the temperature at and above which vapor of the substance cannot be liquified, no matter how much pressure is applied.

Critical pressure: It is the pressure required to liquify a gas at its critical temperature.

5.2 What is the critical temperature and pressure of water?

Ans: Critical pressure is 221.2 bar and critical temperature is 374.15°C.

5.3 What is indicated by slope of h-s diagram?

Ans: Temperature.

5.4 What is degree of superheat?

Ans: The degree of superheat can be defined as the amount by which the temperature of a superheated vapor/steam exceeds the temperature of the saturated vapor/steam at the same pressure.

5.5 If a dry saturated steam is passed through an isolated nozzle, what will be output quality of steam?

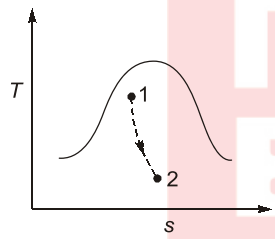
Ans: Since, nozzle is isolated, no heat transfer to the surrounding or assume isentropic process. As steam will move, its pressure will decrease and velocity increases. So, the quality of steam will reduce.

5.6 Does the throttling process improve or reduce quality of steam?

Ans: It improves the quality of steam.

5.7 Draw throttling process for steam on T-s diagram.

Ans:



Process 1-2 is throttling process.

5.8 What is the latent heat of water?

Ans: The latent heat of fusion is 334 J (79.7 calories) per gram and the heat of vaporization is about 2230 J (533 calories) per gram at 0°C and 100°C respectively.

5.9 Out of ice and water, which will have more density? [ESE-2014]

Ans: Water has more density.

5.10 Define latent heat. Explain by example. [ESE-2016]

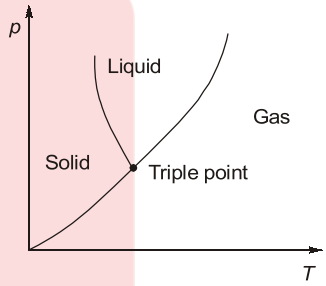
Ans: Latent heat is energy released or absorbed by a body or thermodynamic system, during a constant temperature phase change process. An example is latent heat of fusion for a phase change, melting at specified temperature and pressure.

5.11 What is critical temperature? [ESE-2021]

Ans: The critical temperature of a substance is the temperature at and above which vapour of the substance cannot be liquified, no matter how much pressure is applied.

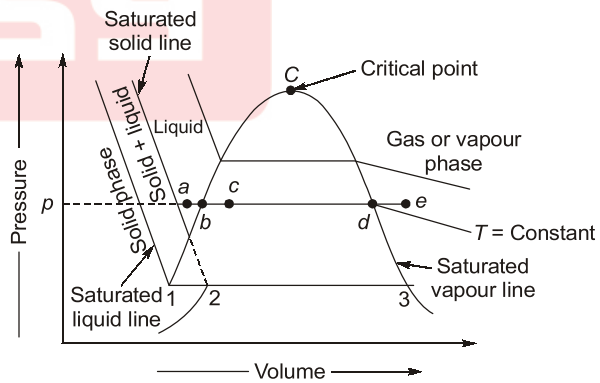
5.12 What is triple point? DOF at triple point? [ESE-2018, 2022]

Ans: It is defined as the point at which three phases (gas, liquid and solid) co-exist in thermodynamic equilibrium. DOF at triple is zero.



5.13 Draw p-V diagram of water. [ESE-2023]

Ans:



5.14 What is Mollier diagram? [ESE-2025]

Ans: Phase diagram of steam on h-s axis is as known Mollier's diagram of steam.