4.1 Explain the terms 'Heat' and 'Temperature.

Answer:

Heat:

Hear is the transfer of kinetic energy from one medium or object to another,
Or from an energy source to a medium or object.
Such heat or energy transfer can occur in three ways: radiation, conduction, convection.

Temperature:

Temperature is the measure of hotness or coldness expressed in terms of any several scales.For example, kelvin,celsius and fahrenheit scale. Temperature indicates the direction in which heat energy will spontaneously flow from a hotter body to a colder body.

4.8 What is the internal energy of a system? "Internal energy is a state function and not a path function. "

Answer:

The internal energy of a system is the sum of kinetic and potential energy associated with the vibrational motion and electric energy of atoms within molecules. Internal energy also includes the energy in all the chemical bonds.

4.9 Explain The terms:

i) Isochoric process

In thermodynamics, an isochoric process is a type of thermodynamics process in which the volume of the system stays constant $dV=0$;

ii) Isobaric process

In thermodynamics, an isobaric process is a type of thermodynamics process in which the pressure of the system stays constant $dP=0$

iii) Cyclic process

The process in which the initial and final states are the same is known as a cyclic process. It is a sequence of processes that leave the system in the same state in which it started.

iv) Isothermal process

In thermodynamics, an isothermal process is a type of thermodynamics process in which the temperature of the system remains constant $dT=0$;

v) Adiabatic process

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In thermodynamics, an adiabatic process is a type of thermodynamics process in which the transfer of heat is equal to zero;

4.12) Explain the concepts of reversible and irreversible processes.

Ans: Reversible Process:

A reversible process is a theoretical idealized process in thermodynamics that can be reversed without leaving any trace on the surroundings or the system. In a reversible process, both the system and its surroundings can be restored to their original states by reversing the process exactly.

Irreversible Process:

An irreversible process is a thermodynamic process that cannot be reversed to return the system and its surroundings to their original states. Irreversible processes involve energy dissipation, such as the generation of heat, changes in entropy, or other forms of irreversible transformations.

4.19) Definition of the 1st law of Thermodynamics. What are the limitations of the first law of thermodynamics?

The first law of thermodynamics states that the energy entering a system in the form of heat is equal to the sum of the increase in the system's internal energy and the energy leaving from the system in the form of work done by the system on its surroundings. Mathematically, it can be expressed as:

$dQ = dU + dW$.

Limitation of first law of thermodynamics:

1) It does not tell us about the direction of the flow of heat.
2) It fails to explain why heat cannot be spontaneously converted into work.

4.21. explain how first law of thermodynamics leads in the concept of internal energy

Ans:

The first law of thermodynamics states that the energy entering a system in the form of heat is equal to the sum of the increase in the system's internal energy and the energy leaving from the system in the form of work done by the system on its surroundings.. Mathematically, it can be expressed as:

$\Delta U = Q - W$

The internal energy of a system is the sum of kinetic and potential energy associated with the vibrational motion and electric energy of atoms within molecules. Internal energy also includes the energy in all the chemical bonds.

The first law of thermodynamics helps to understand the relationship between internal energy, heat, and work. here's how:

Heat transfer (Q): Heat transfer is the transfer of energy between a system and its surroundings due to a temperature difference. When heat is added to a system ($Q > 0$), it increases the internal energy of the system. The energy from heat is used to increase the kinetic energy of the particles, raising the temperature of the system.

Work done (W): Work is the energy transferred to or from a system as a result of mechanical forces acting on it. When work is done on a system ($W > 0$), it increases the internal energy of the system. Work can increase the potential energy of the particles or change the volume of the system, resulting in a change in internal energy.

Change in internal energy (ΔU): The change in internal energy of a system (ΔU) is the net result of the heat transfer and work done. If more heat is added to the system than the work done by the system, the internal energy increases ($\Delta U > 0$). Conversely, if more work is done by the system than the heat added, the internal energy decreases ($\Delta U < 0$).

4.22) What is the first law of thermodynamics that shows that this law is a particular form of general law of conservation of energy?

Ans:

he first law of thermodynamics states that energy cannot be created or destroyed within a closed system. It can only be transferred from one form to another or converted from one form to another. This law is a specific application of the general law of conservation of energy, which states that the total energy of an isolated system remains constant.

Mathematically, it can be expressed as:

$\Delta U = Q - W$

This equation shows that the change in internal energy (ΔU) is determined by the difference between the heat transfer (Q) and the work done (W). Heat transfer refers to the transfer of energy due to a temperature difference, while work refers to the transfer of energy due to mechanical forces.

The first law of thermodynamics is a specific form of the general law of conservation of energy

4.33)Explain why gas has two specific heat. Why Cp>Cv. Prove, Cp-Cv = R

A solid or a liquid when heated does not undergo any change in the volume or pressure. But in case of gas, both the pressure and volume changes on heating. That's why specific heat of a gas in defined for at constant volume and constant pressure.

Cv is the molar specific heat capacity at constant voulume, it increase the internal energy of the system. On the other side, when gas is heated at constant pressure both volume and internal energy of the system increases. That's why Cp>Cv.

prove of Cp -Cv = R;
We know, $q = ncdT$
At constant pressure,$Q_p = n\ C_p\ dT = dQ$
At constant volume, $Q_v = n\ C_v\ dT = dU$
We know, $dW = p\ dV = n\ R\ dT$
again, We Know,
$dQ = dU + dW$
$C_p = C_v + R$

4.41. Distinguish between isothermal and adiabatic process.:

Ans:

An isothermal process and an adiabatic process are two different types of thermodynamic processes that occur in systems. Here are the main distinctions between them:

Temperature Change:

Isothermal Process: In an isothermal process, the temperature of the system remains constant throughout the process. This means that the system is in thermal equilibrium with its surroundings, and any heat added to or removed from the system is perfectly balanced by an equal amount of heat transfer.

Adiabatic Process: In an adiabatic process, there is no heat transfer between the system and its surroundings. The system is thermally insulated, so there is no exchange of heat. Consequently, the temperature of the system can change during an adiabatic process.

Heat Transfer:

Isothermal Process: In an isothermal process, heat transfer occurs to maintain the constant temperature. If the system absorbs heat, it releases an equal amount of heat to maintain equilibrium. If the system loses heat, it absorbs an equal amount of heat from the surroundings.

Adiabatic Process: In an adiabatic process, there is no heat transfer between the system and its surroundings. The process is thermally isolated, meaning that the system neither gains nor loses heat to or from its surroundings.

Work Done:

Isothermal Process: In an isothermal process, work can be done on or by the system. The work done is a result of the expansion or compression of the system while maintaining constant temperature. The amount of work done depends on the pressure and volume changes of the system.

Adiabatic Process: In an adiabatic process, work can also be done on or by the system. However, the work done is a result of changes in pressure and volume without any heat transfer. The specific relationship between pressure, volume, and work can vary depending on the specific adiabatic process (e.g., adiabatic expansion or adiabatic compression).

Efficiency:

Isothermal Process: In an isothermal process, the system operates at maximum efficiency because heat is added or removed at the same temperature. This allows for a complete conversion of heat energy into work.

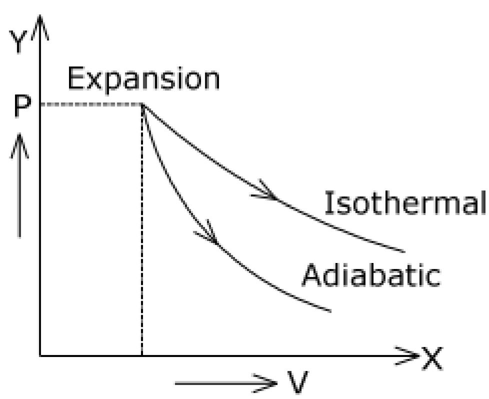
Adiabatic Process: In an adiabatic process, the efficiency can be lower compared to an isothermal process. This is because some energy is inevitably lost due to the temperature change during the process.

4.42. Draw P-V diagrams representing isothermal and adiabatic processes.

Ans:

Isothermal Process:

In an isothermal process, the temperature remains constant. As a result, the graph on the P-V diagram is a rectangular hyperbola, indicating that the pressure and volume are inversely proportional.



In the diagram, the curve represents the isothermal process. The initial and final points of the process are labeled as A and B, respectively. The area under the curve represents the work done during the process.

Adiabatic Process:

In an adiabatic process, there is no heat transfer between the system and its surroundings. As a result, the graph on the P-V diagram is steeper compared to an isothermal process. The exact shape of the adiabatic curve depends on the specific adiabatic process (e.g., expansion or compression).

In the diagram, the curve represents the adiabatic process. The initial and final points of the process are labeled as A and B, respectively. The steepness of the curve indicates the rapid change in pressure and volume during the adiabatic process.

4.51. Calculate the work done in a Carnot's cycle of operations. Deduce the efficiency of a Carot's engine in terms of the temperature between which it works.

Ans:

In a Carnot cycle, the work done by the engine can be calculated by finding the area enclosed by the PV diagram. The efficiency of the Carnot engine can be deduced by comparing the work done with the heat input.

The Carnot cycle consists of four reversible processes: two isothermal processes and two adiabatic processes. Let's denote the high-temperature reservoir as TH and the low-temperature reservoir as TL.

The steps of the Carnot cycle are as follows:

Isothermal Expansion (Step 1-2):

In this step, the working substance (ideal gas) expands isothermally at temperature TH, absorbing heat (QH) from the high-temperature reservoir. The work done (W12) during this expansion can be calculated using the equation:

W12 = QH - QH' (where QH' is the heat lost during the process)

Adiabatic Expansion (Step 2-3):

In this step, the gas expands adiabatically, meaning there is no heat transfer. The temperature of the gas decreases from TH to TL. The work done (W23) during this expansion can be calculated using the equation:

W23 = (QH' - QL') (where QL' is the heat lost during the process

Isothermal Compression (Step 3-4):

In this step, the gas is compressed isothermally at temperature TL, releasing heat (QL) to the low-temperature reservoir. The work done (W34) during this compression can be calculated using the equation:

W34 = QL - QL' (where QL' is the heat lost during the process)

Adiabatic Compression (Step 4-1):

In this step, the gas is compressed adiabatically back to its initial state. The temperature of the gas increases from TL to TH. The work done (W41) during this compression can be calculated using the equation:

W41 = (QH' - QL') (where QH' is the heat lost during the process)

The net work done (Wnet) in the Carnot cycle is the sum of the work done in each step:

Wnet = W12 + W23 + W34 + W41

The efficiency of the Carnot engine (η) can be calculated by comparing the net work done with the heat input:

η = Wnet / QH

= (W12 + W23 + W34 + W41) / QH

Now, let's deduce the efficiency of the Carnot engine in terms of the temperatures TH and TL.

For the isothermal processes, the heat absorbed or released can be calculated using the equation:

Q = nRT ln(V2/V1)

where n is the number of moles, R is the gas constant, and V2/V1 is the ratio of volumes during the process.

For the adiabatic processes, the relationship between pressure and volume can be expressed as:

P * V^γ = constant

where γ is the heat capacity ratio (Cp/Cv) for the working substance.

4.53. State the Second Law of thermodynamics. Describe Carol's cycle and deduce the efficiency of an ideal heat engine.

Ans:

The Second Law of Thermodynamics states that the entropy of an isolated system always increases over time, or in a reversible process, it remains constant. This law encompasses several important principles:

Kelvin-Planck Statement: It is impossible to create a heat engine that operates in a cycle and extracts heat from a single reservoir and converts it entirely into work.

Clausius Statement: It is impossible to have a heat transfer from a cooler body to a hotter body without the aid of external work or energy input.

The Carnot cycle is a theoretical thermodynamic cycle that represents the most efficient operation of a heat engine between two temperature reservoirs. It consists of four reversible processes:

Isothermal Expansion: The working substance (usually an ideal gas) expands while in thermal equilibrium with the high-temperature reservoir, absorbing heat and doing work.

Adiabatic Expansion: The gas continues to expand without any heat exchange, resulting in a decrease in temperature.

Isothermal Compression: The gas is compressed while in thermal equilibrium with the low-temperature reservoir, releasing heat and doing work.

Adiabatic Compression: The gas continues to be compressed without any heat exchange, resulting in an increase in temperature.

4.54. Describe Camot's cycle and obtain an expression for the efficiency of an ideal heat engine in terms of temperatures.

Ans:

The Carnot cycle is a theoretical thermodynamic cycle that represents the most efficient operation of a heat engine between two temperature reservoirs. It consists of four reversible processes: two isothermal processes and two adiabatic processes.

Isothermal Expansion:

In this process, the working substance (typically an ideal gas) expands while in thermal equilibrium with the high-temperature reservoir (TH). The temperature of the gas remains constant, and it absorbs heat (QH) from the reservoir. The expansion occurs at the high temperature TH.

Adiabatic Expansion:

In this process, the gas continues to expand without any heat exchange with its surroundings. The temperature of the gas decreases as it expands. This expansion is adiabatic, meaning no heat is transferred. The expansion continues until the gas reaches the low temperature TL

Isothermal Compression:

In this process, the working substance is compressed while in thermal equilibrium with the low-temperature reservoir (TL). The temperature of the gas remains constant, and it releases heat (QL) to the reservoir. The compression occurs at the low temperature TL.

Adiabatic Compression:

In this process, the gas continues to be compressed without any heat exchange. The temperature of the gas increases as it is compressed. The compression continues until the gas reaches the high temperature TH.

4.56. What is the principle used in the working of a refrigerator. Define coefficient of performance. Is it greater than 1? Explain

Ans:

The principle used in the working of a refrigerator is based on the Second Law of Thermodynamics. It utilizes the transfer of heat from a low-temperature reservoir (inside the refrigerator) to a high-temperature reservoir (outside the refrigerator), against the natural direction of heat flow. This process is achieved by utilizing work input from an external source.

A refrigerator operates using a refrigeration cycle, which typically involves a working fluid (refrigerant) that undergoes compression, condensation, expansion, and evaporation. The basic components of a refrigerator include a compressor, condenser, expansion valve, and evaporator.

The refrigeration cycle works as follows:

Compression: The refrigerant is compressed by the compressor, which raises its pressure and temperature.

Condensation: The high-pressure and high-temperature refrigerant flows into the condenser, where it releases heat to the surroundings and condenses into a liquid.

Expansion: The condensed liquid refrigerant passes through an expansion valve, which causes a drop in pressure. As a result, the refrigerant becomes a low-pressure, low-temperature mixture of liquid and vapor.

Evaporation: The low-pressure refrigerant enters the evaporator, where it absorbs heat from the interior of the refrigerator, causing the refrigerant to evaporate into a low-temperature vapor.

By absorbing heat from the interior of the refrigerator and releasing it to the surroundings, the refrigeration cycle maintains a lower temperature inside the refrigerator compared to the ambient temperature.

The coefficient of performance (COP) is a measure of the efficiency of a refrigerator or heat pump. It is defined as the ratio of the desired output (heat removed from the low-temperature reservoir) to the required input (work input or energy consumed).

For a refrigerator, the coefficient of performance (COP_refrigerator) is given by:

COP_refrigerator = QL / W

where QL is the amount of heat removed from the low-temperature reservoir (inside the refrigerator) and W is the work input required to drive the refrigeration cycle

The COP of a refrigerator is always greater than 1. This implies that for a given amount of work input, the refrigerator can remove more heat from the low-temperature reservoir than the work input it consumes. In other words, it achieves a cooling effect greater than the work input. This is possible due to the utilization of external work and the transfer of heat against its natural direction.

The COP of a refrigerator indicates its efficiency in providing cooling, with a higher COP value indicating a more efficient refrigerator.

4.67. Write short notes on:

(i) Efficiency of Carnot's Heat Engine:

The efficiency of a Carnot's heat engine is the maximum possible efficiency that can be achieved by any heat engine operating between two temperature reservoirs. It is given by the equation:

Efficiency = 1 - (T_Low / T_High)

where T_Low is the temperature of the low-temperature reservoir and T_High is the temperature of the high-temperature reservoir. The efficiency is always less than 1 (expressed as a decimal or percentage) and represents the fraction of input energy that is converted into useful work.

(ii) Carnot's Theorem:

Carnot's theorem states that no heat engine operating between two temperature reservoirs can be more efficient than a Carnot heat engine operating between the same two reservoirs. It implies that the Carnot cycle, which consists of reversible processes, represents the most efficient operation of a heat engine. Carnot's theorem provides a theoretical limit for the maximum possible efficiency of any heat engine.

(iii) Efficiency of Carnot's Heat Engine:

The efficiency of a Carnot's heat engine is given by the equation:

$$\text{Efficiency} = 1 - (T_{Low} / T_{High})$$

where T_{Low} is the temperature of the low-temperature reservoir and T_{High} is the temperature of the high-temperature reservoir. This efficiency represents the maximum efficiency achievable for a heat engine operating between those two temperatures.

(iv) Second Law of Thermodynamics:

The Second Law of Thermodynamics states that the entropy of an isolated system always increases over time, or remains constant in a reversible process. It provides fundamental principles regarding energy conversion, heat transfer, and the direction of natural processes. It includes concepts such as the impossibility of a perpetual motion machine of the second kind and the concept of entropy as a measure of the disorder or randomness in a system.

(v) Zeroth Law of Thermodynamics:

The Zeroth Law of Thermodynamics establishes the concept of temperature and thermal equilibrium. It states that if two systems are in thermal equilibrium with a third system, they are also in thermal equilibrium with each other. This law forms the basis for temperature measurement and the establishment of temperature scales.

(vi) First Law of Thermodynamics:

The First Law of Thermodynamics, also known as the Law of Energy Conservation, states that energy cannot be created or destroyed in an isolated system. It can only be converted from one form to another or transferred between systems. This law establishes the principle of energy conservation in various thermodynamic processes, including heat transfer, work done, and changes in internal energy.

(vii) Internal Energy:

Internal energy refers to the total energy possessed by a system due to the molecular motion and interactions of its constituent particles. It includes the kinetic energy of particles and the potential energy associated with their interactions. Internal energy is a state function and depends only on the current state of the system, not on the path taken to reach that state.

(viii) Quasi-Static Process:

A quasi-static process, also known as a quasi-equilibrium process, is a theoretical idealization in thermodynamics. It assumes that a system changes its state infinitesimally slowly, maintaining thermodynamic equilibrium at all times. In a quasi-static process, the system is always very close to being in equilibrium, allowing precise calculations and analysis based on the laws of thermodynamics.

(ix) External and Internal Work:

External work refers to the work done by or on a system as a result of the system's volume changing against an external force. It involves mechanical work, such as the expansion or compression of a gas against a piston. Internal work refers to the work done within a system due to molecular interactions, such as the work associated with changes in the internal energy of a substance. Both external and internal work contribute to the overall energy