**5. SECOND LAW OF THERMODYNAMICS**

**THERMAL ENERGY RESERVOIRS:**

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| **HEAT SOURCE:** It’s a thermal energy reservoir which supplies heat at constant temperature. E.g. Hot Gas in IC engine, Fission in nuclear reactors, Hot gases in boiler furnace. | **HEAT SINK:** It’s a thermal energy reservoir which absorbs heat at constant temperature. E.g. Atmosphere, River Water, Ocean. |

**STATEMENT OF SECOND LAW:**

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| **KELVIN-PLANK’S STATEMENT:** It’s impossible to construct a device which is operating on a cycle and producing work continuously and exchanging heat with single reservoir. | **CLAUSIUS STATEMENT:** It’s impossible to construct a device which operates on a cycle and transferring heat from low temperature body to high temperature body without any external work input. |

**PERPETUAL MOTION MACHINE OF SECOND KIND (PMM-II):** It’s impossible to have 100% efficiency of engine. And It violates the second law of thermodynamics.

**HEAT ENGINE:**

It works on cycle and takes heat from higher energy medium and converts in to work and transfers remaining heat to lower energy medium. E.g. IC Engine, Steam Power Plant, Gas Turbine Power Plant.

**FIRST LAW OF THERMODYNAMICS TO HEAT ENGINE:** It’s valid for reversible and irreversible process.

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| For Cycle, | = Heat Supplied to Engine,  = Heat Rejected from Engine,  = Work Done by Engine, | |  |  | | --- | --- | |  |  | |  |  | |  |  | |

**CARNOT CYCLE:**

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| 1. It’s reversible cycle. 2. It’s work producing cycle (Clockwise Dir.)   Processes:  **1-2:** Rev. Isothermal Heat Supply Expansion  **2-3:** Rev. Adiabatic Expansion  **3-4:** Rev. Isothermal Heat Rejection Compression  **4-1:** Rev. Adiabatic Compression. | 4 stages of carnot cycle improving thermal efficiency - MechanicalTutorial | Carnot's Theorem and Cycle - Physics 298 |
| Here,   |  |  | | --- | --- | |  |  | |  |  |   Process 1-2:  Process 3-4: | | From process 2-3 & 4-1: |

**IMPORTANT POINTS:**

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| * Two Rev. isothermal and Two Rev. adiabatic process. * Ideal Cycle for H.E. and gives . * Not Practical cycle since Rev. isothermal and Rev. Adiabatic are difficult to achieve in practice. * depends only on temperature Limits. * doesn’t depend on working fluid (E.g. gas or Vapour or etc…) | * For exam problems,  |  |  | | --- | --- | |  |  | |  |  |  * For Cyclic Rev. Process, * Carnot cycle is used to compare practical H.E. Efficiency.  |  |  | | --- | --- | | Only Temp. Given or Rev. H.E. or Carnot Cycle | Simple H.E. or T1, T2 & Q1, Q2 given or Irreversible or Practical H.E. | |  |  | |

**TWO REVERSIBLE HEAT ENGINES IN SERIES:**

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| **Efficiencies are same:** | **Work Outputs are Same,** | **Overall Efficiency in terms of Temp.,** | |  |  | | --- | --- | |  |  | |  |  | |  |  | |  |  | |  |  | |

**REFRIGERATOR:**

It works on cycle and absorbs heat from lower energy medium and rejects heat to higher energy medium by consuming work. E.g. Domestic Refrigerator, Air Conditioner, Water Cooler, Ice Plant.

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| For Cycle,  It’s Valid for Rev.& Irreversible Cycle.  If Refrigerator Door is Open in room, Room temperature increase. | = Heat Rejected to Refrigerator,  = Heat Absorbed by Refrigerator,  = Work Supplied to Refrigerator, |

**REVERSIBLE CARNOT CYCLE:**

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| 1. It’s reversible cycle. 2. It is work consuming cycle (Anti-Clockwise Dir.) 3. It gives maximum .   Processes:  **1-2:** Rev. Adiabatic Compression (Compressor Work)  **2-3:** Rev. Isothermal Heat Rejection. (Heat Exchanger)  **3-4:** Rev. Adiabatic Expansion. (Throttling)  **4-1:** Rev. Isothermal Heat absorption. (Refrigerating effect). | COP Of Air Refrigerator Working On Reversed Carnot Cycle with PV and Ts  Diagram | Mecholic | |
| Here,   |  |  | | --- | --- | |  |  | |  |  |   Process 2-3:  Process 4-1: | | From process 1-2 & 3-4: |

**IMPORTANT POINTS:**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| * Two Rev. isothermal and Two Rev. adiabatic process. * Ideal Cycle for Refrigerator and gives . * Not Practical cycle since Rev. isothermal and Rev. Adiabatic are difficult to achieve in practice. | * depends only on temperature Limits. * doesn’t depend on working fluid (E.g. gas or Vapour or etc…) * For exam problems,  |  |  | | --- | --- | |  |  | |  |  | |

**TWO REVERSIBLE REFRIGERATORS ENGINES IN SERIES:**

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| **COPs are same:** | **Work Inputs are Same,** | **Overall COP,** | |  |  | | --- | --- | |  |  | |  |  | |  |  | |  |  | |  |  | |

**HEAT PUMP (HEAT TRANSFORMER):** It’s same as refrigerator only concern medium is higher temperature whereas in refrigerator concern medium is lower temperature medium.

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| For Cycle,  It’s Valid for Rev.& Irreversible Cycle.   * Derivations are same as refregerator only COP equation changes. | = Heat Rejected to Cabin,  = Heat Absorbed by Atmosphere,  = Work Supplied to Heat Pump, | |  |  | | --- | --- | |  |  | |  |  | |  |  | |
| It’s Valid for Reversible Cycle only. | |

**IMPORTANT POINTS:**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| * Two Rev. isothermal and Two Rev. adiabatic process. * Ideal Cycle for Refrigerator and gives . * Not Practical cycle since Rev. isothermal and Rev. Adiabatic are difficult to achieve in practice. | * depends only on temperature Limits. * doesn’t depend on working fluid (E.g. gas or Vapour or etc…) * For exam problems,  |  |  | | --- | --- | |  |  | |  |  | |

**RELATION BETWEEN REFRIGERATOR & HEAT PUMP:**

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| From & Energy Balance, |  |

**RELATION BETWEEN HEAT ENGINE & HEAT PUMP:**

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| From Equations, |  |
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**ELECTRICAL HEATING COIL OR ELECTRIC RESISTANCE HEATER:**

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| **HEAT PUMP** | **ELECTRIC HEATER** |
| It’s better than electric heater because energy consumption is less () | Energy consumption is high ()in comparison so it’s not better to use. |

**SPECIAL CASE OF REFRIGERATOR:**

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| **REFRIGERATED SPACE WITH VENTILATION:** Room is opened to atmosphere. Hence, it’s constant Pressure process. |  |
| **REFRIGERATED SPACE WITH PERFECTLY SEALED & INSULATED:** Room is Insulated & Closed System (Room with no opening). Hence, it’s constant Volume process. |  |

**CALCULATION OF POWER BILL FOR REFRIGERATION MACHINE:**

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**COMBINED HEAT ENGINE & REFRIGERATORS:**

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**COMBINED HEAT ENGINE & HEAT PUMP:**

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| **CLAUSIUS INEQUALITY:** It’s Valid for H.E., Refrigerator & H.P. |  | = Heat Transfer (in J),  = Absolute Temp. (in K), |
| If , Reversible Cycle. | If , Irreversible Cycle. | If , Impossible Cycle. |

**HEAT ENGINES WITH MULTIPLE RESERVOIRS:**

**PERPETUAL MOTION MACHINE OF THIRD KIND (PMM-III):** The continual motion of a movable device in absence of friction.