ME 209
Basic Thermodynamics (Lecture-10)

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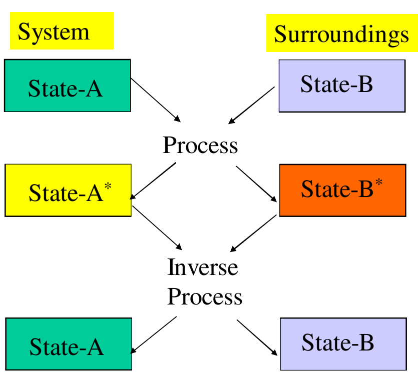
Review of Lecture 9

- Understood the concept of an engine, heat pump and refrigerator.
- Understood the Clausius Statement and Kelvin Planck Statement, and showed that they are equivalent.
- Now we shall look at reversibility and understand that reversible engines, heat pumps and refrigerators perform better than their irreversible counter parts.
- Then we shall move towards definition of thermodynamic temperature scale and show that it is equivalent to Kelvin scale

Reversible Process-I

- Let us now define the Reversible Process



If after a process the system and surroundings can be identically taken to their original states then the original process is reversible.

Reversible Process-II

- Quasitatic adiabatic compression/expansion, Isothermal heat addition/rejection are reversible process
- Causes of Irreversibility
  - Lack of Equilibrium
    - Heat transfer with finite temperature difference
    - Free expansion (mixing of gases with $p_1 > p_2$)
  - Dissipative Work
    - Friction in system
    - Friction in surroundings
- In all the irreversible processes, either there is dissipative work or opportunity to extract work is lost

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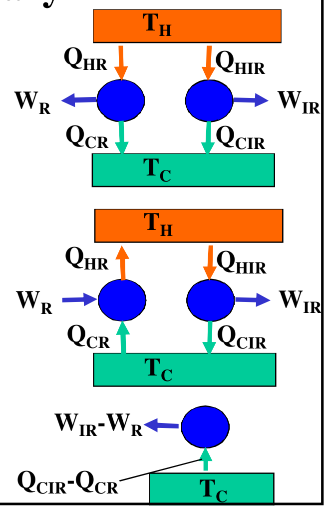
Carnot Corollary-1 - I

- Corollary-1 states that the efficiency of a reversible engine is greater than the efficiency of the irreversible engine
- Let the corollary be violated and let $Q_{HR} = Q_{HIR}$. This will imply $W_R < W_{IR}$
- Reverse the reversible engine and consider the combined system
- Violates K-P statement



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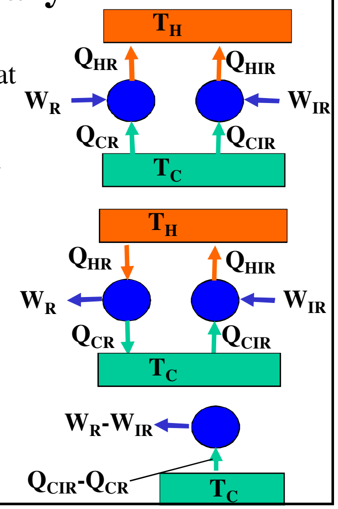
Carnot Corollary-1 - II

- Corollary-1 also states that the $COP_R > COP_{IR}$ For a heat pump/refrigerator
- Let the corollary be violated and let $Q_{HR} = Q_{HIR}$. This will imply $W_R > W_{IR}$
- Reverse the reversible HP/REF and consider the combined system
- Violates K-P statement



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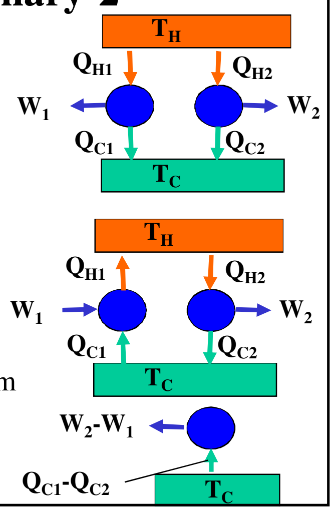
Carnot Corollary-2

- This states that all reversible engines operating between same temperatures have the same efficiency
- Let this be not true and let engine 2 produce more work output for the same Q_H
- Reverse the first engine and consider the combined system
- Violates K-P statement



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Themodynamic Temperature Scale-I

- For the sake of distinction, let us call the hot and cold temperatures in thermodynamic scale as θ_H and θ_C

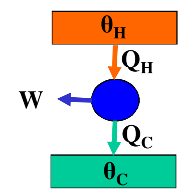
$$\eta = f(\theta_H, \theta_C)$$

- The above is independent of working fluid in the engine

$$\eta(\theta_H, \theta_C) = 1 - Q_C / Q_H$$

$$Q_C / Q_H = 1 - \eta(\theta_H, \theta_C) = f(\theta_H, \theta_C)$$

- Simplest conceivable function is $\dfrac{Q_C}{Q_H} = \dfrac{\theta_C}{\theta_H}$



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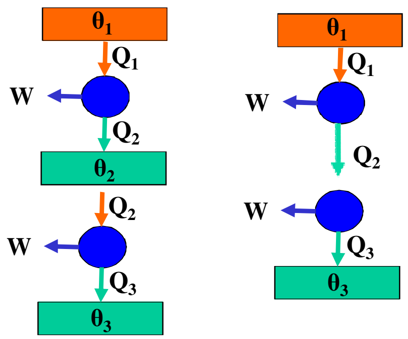

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Themodynamic Temperature Scale-II

- Thus we can use heat engine to construct a thermometer with supplied or rejected as a thermometric property (work remaining the same)

$$\theta = 273.16 \frac{Q}{Q_{Ref}}$$

- We have seen that isothermal heat transfer and frictionless adiabatic process as reversible
- An engine that operates on this cycle is called a Carnot Engine and we shall use this to relate the thermodynamic scale to Absolute Gas Scale (Kelvin Scale)

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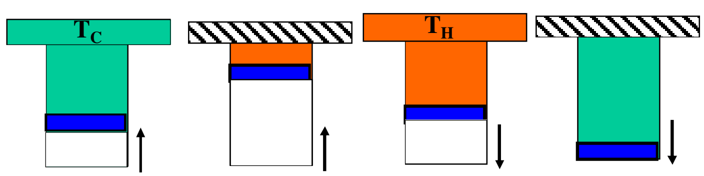
Carnot Engine



1. Isothermal Compression (1-2)
2. Adiabatic Compression (2-3)
3. Isothermal Expansion (3-4)
4. Adiabatic Expansion (4-1)