PHYS 1220, Engineering Physics, Chapter 20 – The Second Law of Thermodynamics

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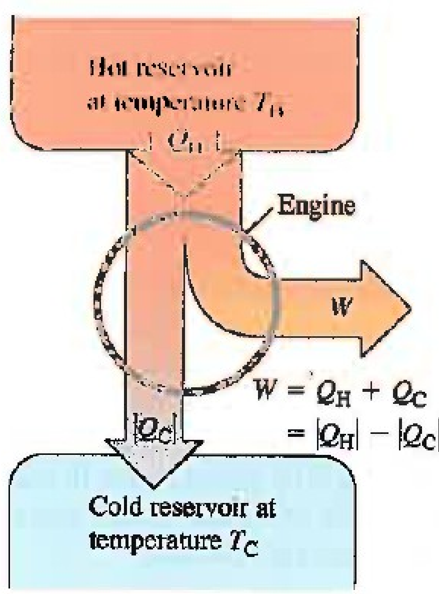
Goal of this chapter is to learn how an engine and a refrigerator operates in different cycle patterns, and their efficiency.

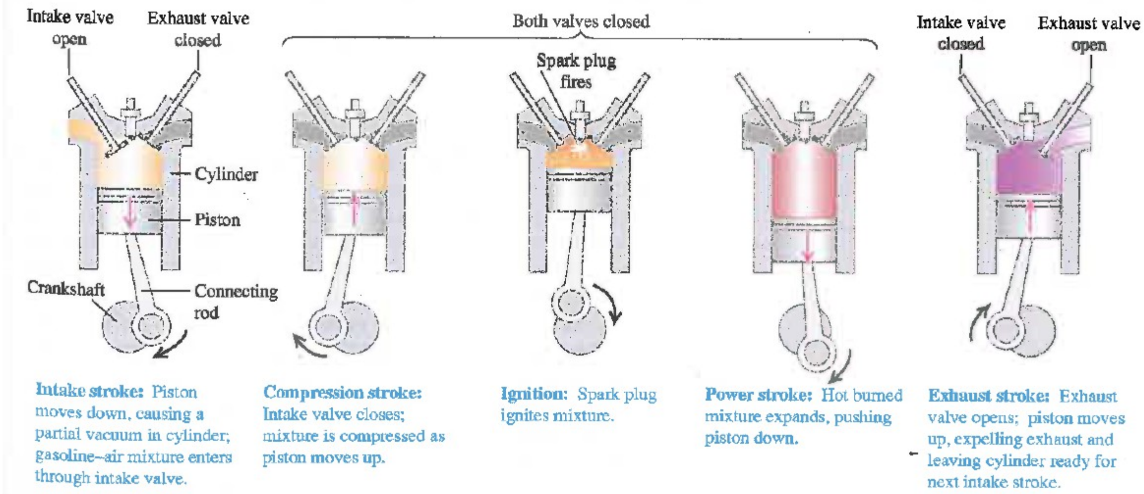
- In real world, all the processes have one preferential direction.
  - They are all irreversible processes.
  - They tend to increase the disorder/randomness.

- Both heat engine and refrigerator perform in **cyclic processes**. In other words, the initial and final states are the same.
  - $\Delta U = U_2 - U_1 = 0 = Q - W$, thus: $Q = W$

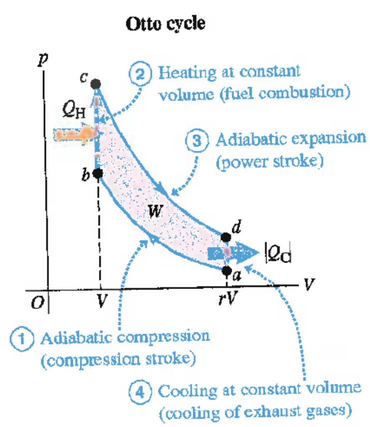
- Heat Engine
  - It's not possible to convert all the heat into mechanical energy (work).
  - $Q = Q_H + Q_C = |Q_H| - |Q_C|$
  - Efficiency is defined as: $e = \frac{W}{|Q_H|}$
  - $e = \frac{W}{|Q_H|} = 1 + \frac{Q_C}{Q_H} = 1 - \left|\frac{Q_C}{Q_H}\right|$



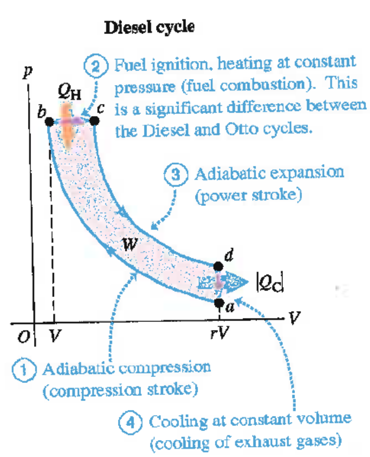
- Internal-Combustion Engine



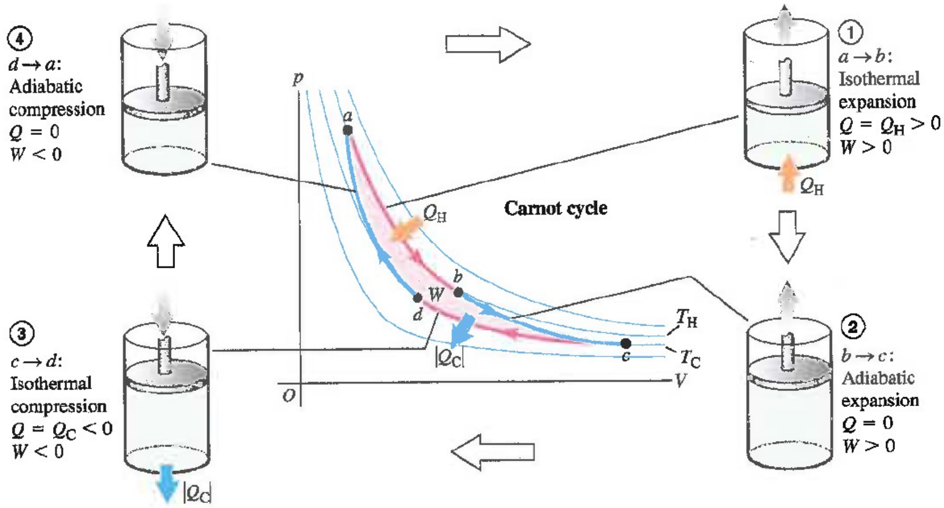
- **Otto Cycle** (two adiabatic processes and two isochoric processes)
- $e = 1 - \frac{1}{r^{\gamma-1}}$; where r = compression ratio, which represent the ratio between the largest volume and smallest volume (~ 8 to 10 for today's automobile engine)



- **Diesel Cycle** (two adiabatic processes, one isochoric process, and one isobaric process)

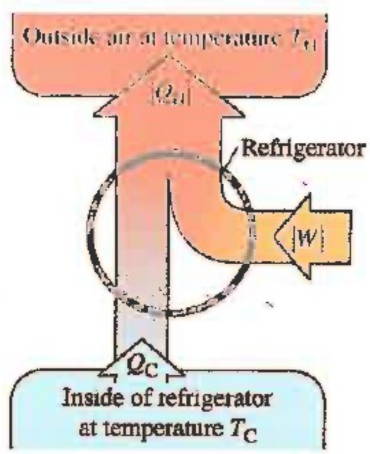


- **Carnot Cycle**, an ideal cycle that maximize the heat engine efficiency (two adiabatic processes and two isothermal processes)
- $e_{Carnot} = \frac{T_H - T_C}{T_H}$



- Refrigerator (pump heat from low to high temperatures)

- $K = \frac{|Q_C|}{|W|} = \frac{|Q_C|}{|Q_H| - |Q_C|}$
- $K = \frac{|Q_C|}{|W|} = \frac{H}{P}$; typical air conditioners have heat removal rates H of 5,000 to 10,000 Btu/h (~1,500 – 3,000 W); and require electric power input of about 600 to 1,200 W. Thus, typical K = ~3.



- The Second Law of Thermodynamics

- It is impossible for any system to undergo a process in which it absorbs heat from a reservoir at a single temperature and converts the heat completely into mechanical work, with the system ending in the same state in which it began.

- It is impossible for any process to have as its sole result the transfer of heat from a cooler to a hotter body.

- Entropy (a quantity to measure *disorder*)
  - $dS = \frac{dQ}{T}$ (infinitesimal reversible process)
  - $\Delta S = \int_1^2 \frac{dQ}{T}$ (entropy change in a reversible process)
  - **The second law of thermodynamics**: for all the processes, $\Delta S \geq 0$ including all the systems involved in the processes.
  - Microscopic interpretation of entropy: $S = k \ln w$, where w represents the number of possible microscopic states.