ESO 201A: Thermodynamics

2016-2017-I semester

The Second Law of Thermodynamics: part 2

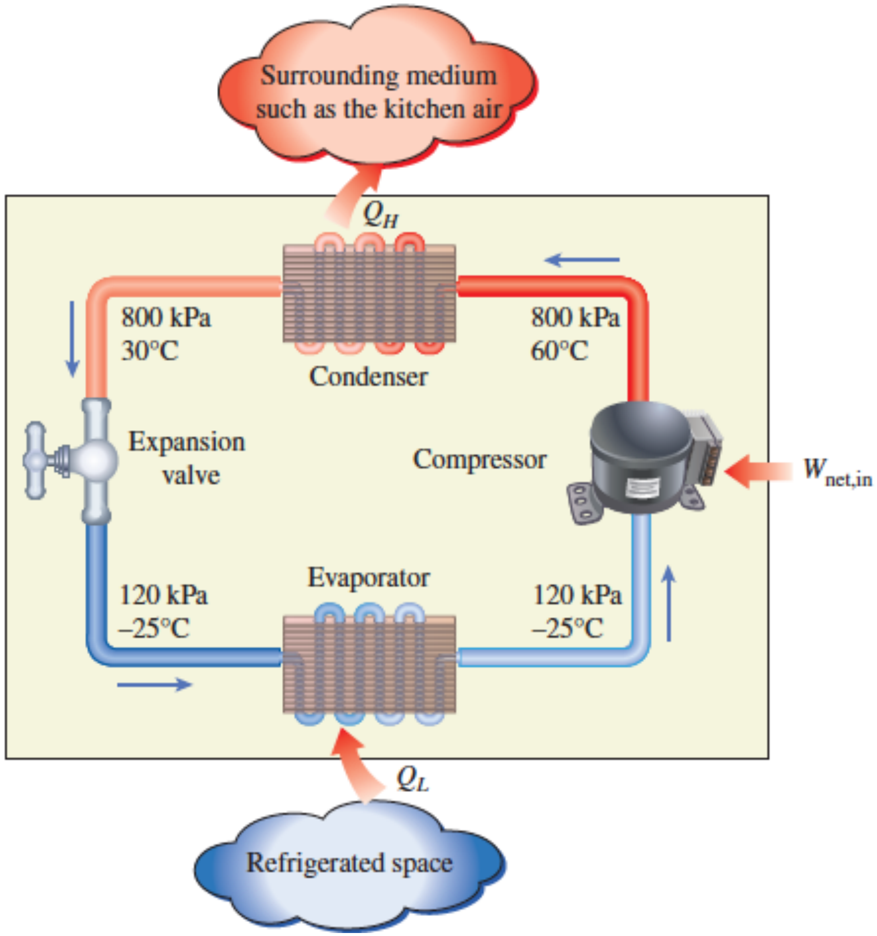
Dr. Jayant K. Singh
Department of Chemical Engineering
Faculty Building 469,
Telephone: 512-259-6141
E-Mail: jayantks@iitk.ac.in
home.iitk.ac.in/~jayantks/ESO201/index.html

Learning objectives

- Introduce the second law of thermodynamics.
- Identify valid processes as those that satisfy both the first and second laws of thermodynamics.
- Discuss thermal energy reservoirs, heat engines
- Describe the Kelvin–Planck statement of the second law of thermodynamics
- Discuss refrigerators, and heat pumps and describe Clausius statement of the second law of thermodynamics
- Determine the expressions for the thermal efficiencies and coefficients of performance for reversible heat engines, heat pumps, and refrigerators.
- Discuss the concepts of perpetual-motion machines, reversible and irreversible processes
- Describe the Carnot cycle, examine the Carnot principles, idealized Carnot heat engines, refrigerators, and heat pumps.
- Apply the second law to develop the absolute thermodynamic temperature scale.

Refrigerator

- Heat from low temperature to high cannot occur by itself
- Requires special device- refrigerator
- Refrigerator maintains the refrigerated space at low T by removing heat from it.
- Cyclic device
- Working fluids- refrigerants
- Most frequent refrigeration cycle: Vapor-compression refrigeration cycle
  - Compressor, condenser, an expansion valve, evaporator

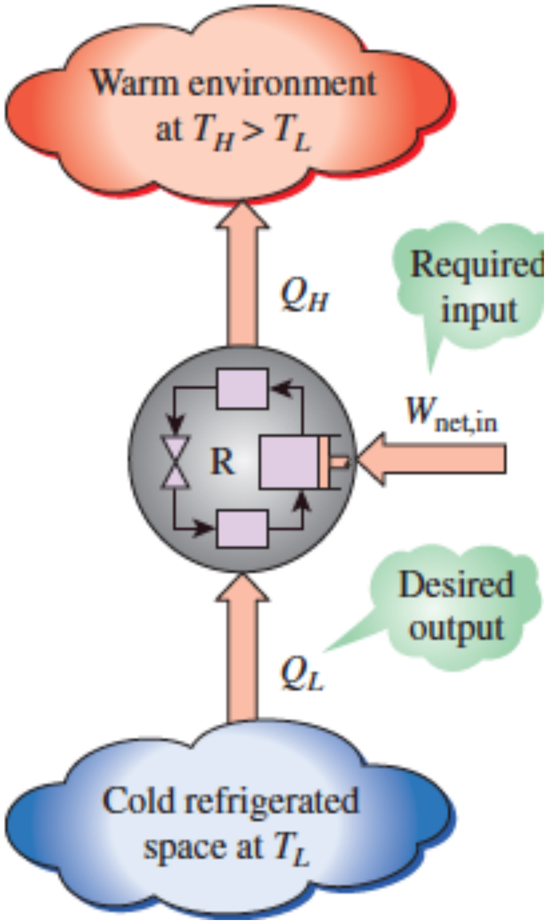


Enters compressor as vapor, compressed to condenser pressure, cools down to saturated liquid, expands further, to lower pressure and temperature, uses heat from ref. space to evaporate to vapor

Refrigerator

The *efficiency* of a refrigerator is expressed in terms of the **coefficient of performance** (COP).

The objective of a refrigerator is to remove heat (Q_L) from the refrigerated space.



$$\text{COP}_\text{R} = \frac{\text{Desired output}}{\text{Required input}} = \frac{Q_L}{W_{\text{net,in}}}$$

The conservation of energy principle for a cyclic device requires that

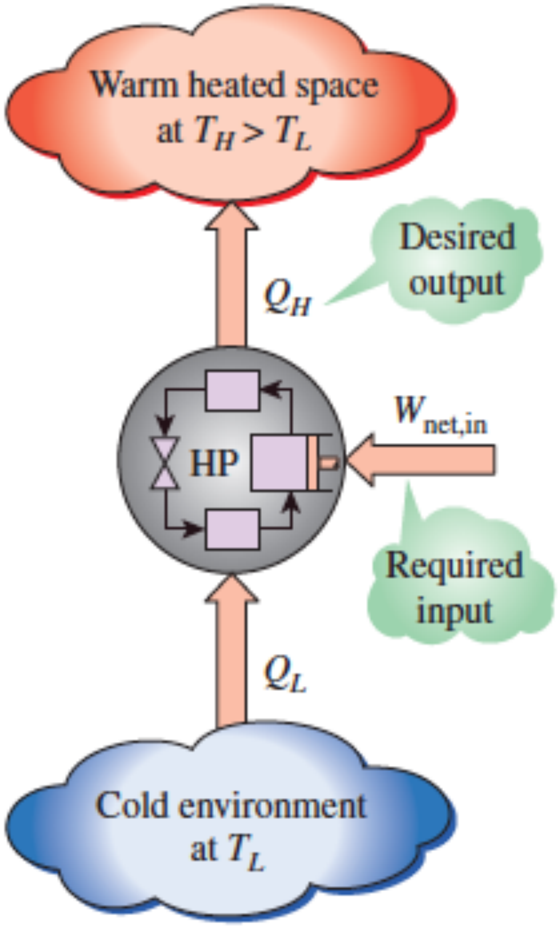
$$W_{\text{net,in}} = Q_H - Q_L \quad \text{(kJ)}$$

$$\text{COP}_\text{R} = \frac{Q_L}{Q_H - Q_L} = \frac{1}{Q_H/Q_L - 1}$$

Can the value of COP_R be greater than unity?

Air conditioners –basic refrigerator.

Heat pumps



Another device that transfer from a low T medium to high T medium.

- Objective to maintain a heated space at high T by supplying heat (desired output) to it.

$$COP_{HP} = \frac{\text{Desired output}}{\text{Required input}} = \frac{Q_H}{W_{net,in}}$$

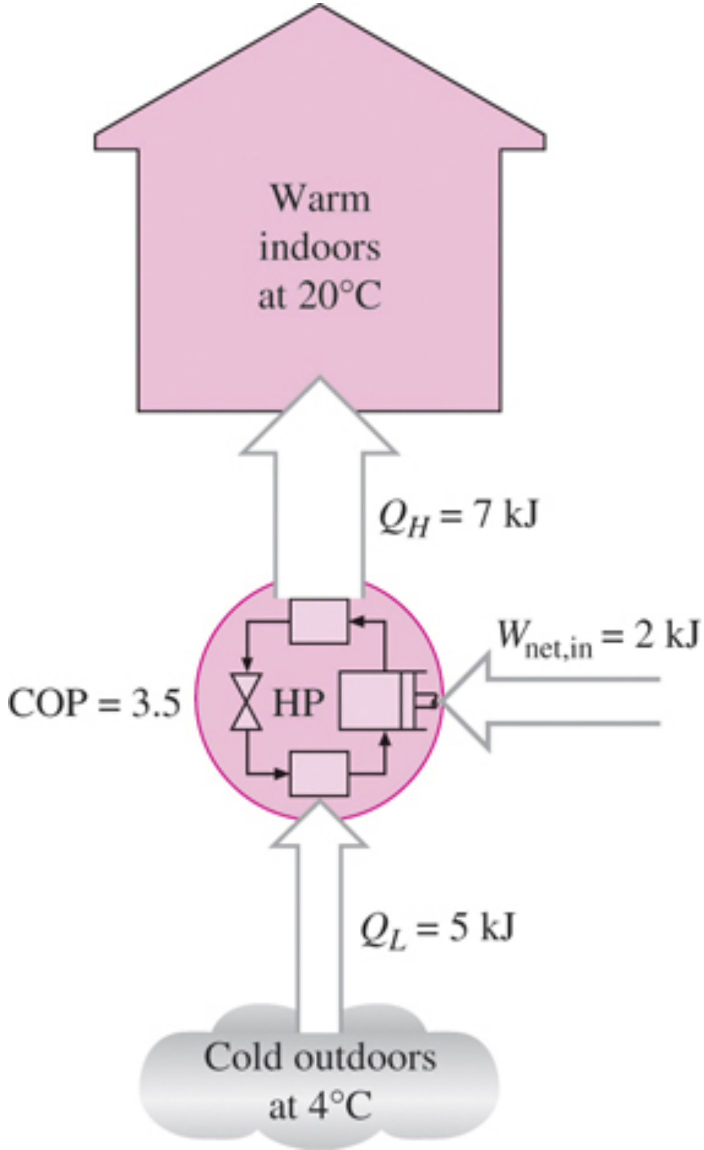
$$COP_{HP} = \frac{Q_H}{Q_H - Q_L} = \frac{1}{1 - Q_L/Q_H}$$

$$COP_{HP} = COP_R + 1$$

Air conditioners –if installed backwards can act like HP

Heat pumps

The work supplied to a heat pump is used to extract energy from the cold outdoors and carry it into the warm indoors.



Can the value of COP_{HP} be lower than unity?

$$COP_{HP} = \frac{\text{Desired output}}{\text{Required input}} = \frac{Q_H}{W_{net,in}}$$

Refrigerator and HP

When installed backward, an air conditioner functions as a heat pump.

- Most heat pumps in operation today have a seasonally averaged COP of 2 to 3.
- Most existing heat pumps use the cold outside air as the heat source in winter (*air-source* HP).
- In cold climates their efficiency drops considerably when temperatures are below the freezing point.
- In such cases, *geothermal* (*ground-source*) HP that use the ground as the heat source can be used.
- Such heat pumps are more expensive to install, but they are also more efficient.
- **Air conditioners** are basically refrigerators whose refrigerated space is a room or a building instead of the food compartment.
- The COP of a refrigerator decreases with decreasing refrigeration temperature.
- Therefore, it is not economical to refrigerate to a lower temperature than needed.

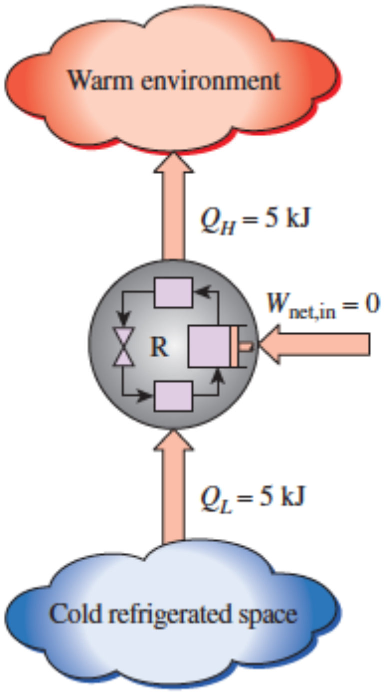
Revisit the second law of thermodynamics

Kelvin-Plank-relates to heat engines

It is impossible for any device that operates on a cycle to receive heat from a single reservoir and produce a net amount of work.

Clausius statement

It is impossible to construct a device that operates in a cycle and produces no effect other than the transfer of heat from a lower-temperature body to a higher-temperature body.



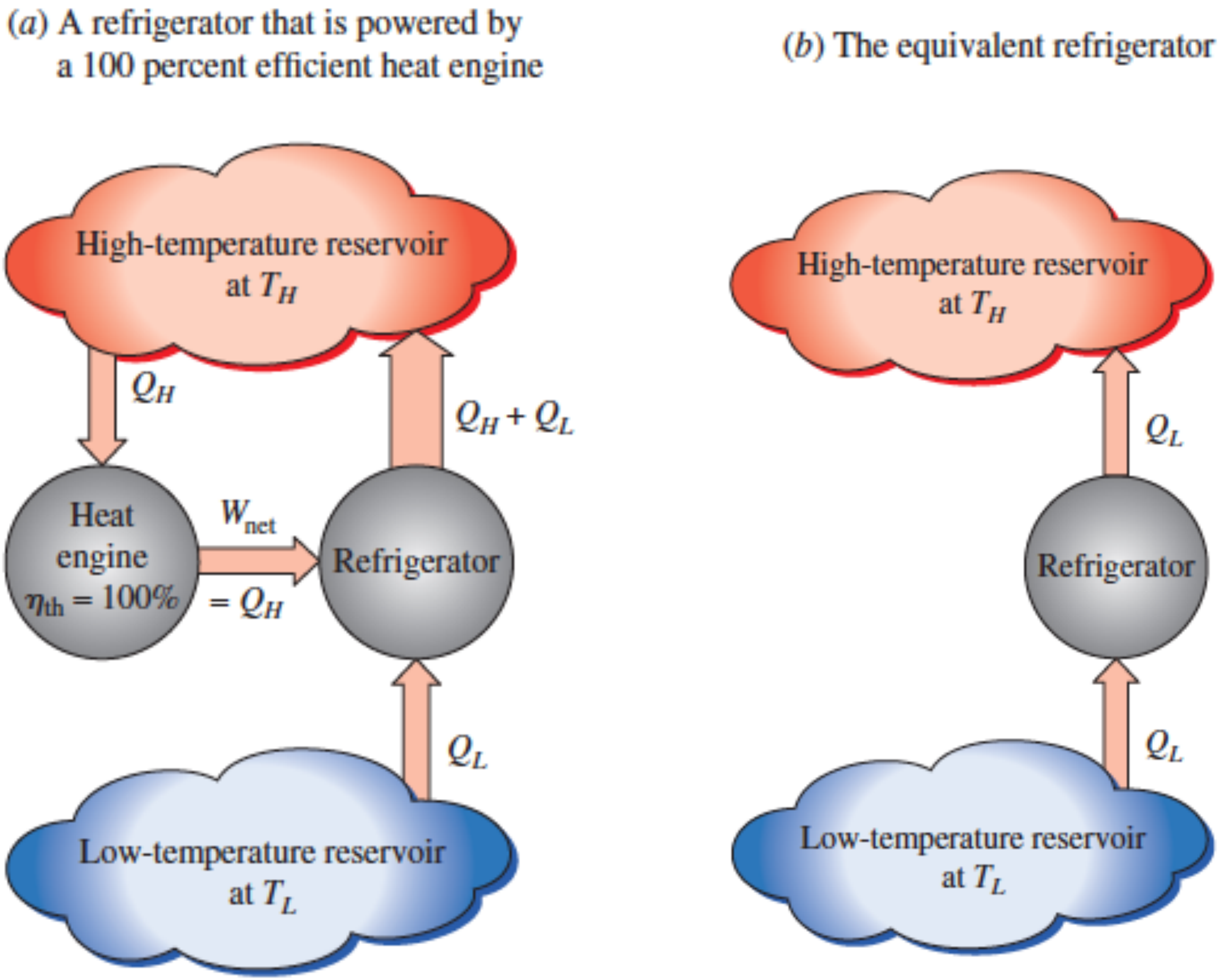
A refrigerator that violates the Clausius statement of the second law.

External work is needed!

2nd law based on experiments- till date it has not been voilated

Equivalence of the two statements

Any device that violates Kelvin-Planck statement also violates the Clausius statement, and vice-versa



Next lecture

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