Basic Thermodynamics

Handout 3

Carnot's theorem

No engine operating between two given temperatures can be more efficient than a Carnot engine.

A proof of Carnot's theorem was given in lectures.

Refrigerators and heat pumps

The efficiency of refrigerators and heat pumps is measured by the **coefficient of performance** (CoP).

A **refrigerator** has CoP

$$\mathrm{CoP} = \frac{Q_2}{W},$$

where Q_2 is the heat drawn from the colder reservoir (at T_2), and W is the work done on the system. A refrigerator built from a Carnot engine operating in reverse has CoP

$$\mathrm{CoP}_{\mathrm{Carnot}} = \frac{T_2}{T_1 - T_2}.$$

A **heat pump** has CoP

$$\mathrm{CoP} = \frac{Q_1}{W},$$

where Q_1 is the heat transferred to the hotter reservoir (at T_1), and W is the work done on the system. A heat pump built from a Carnot engine operating in reverse has CoP

$$\mathrm{CoP}_{\mathrm{Carnot}} = \frac{T_1}{T_1 - T_2} > 1.$$

Clausius' theorem

For any closed cycle,

$$\oint \frac{đQ}{T} \leq 0,$$

where equality necessarily holds for a reversible cycle.

A proof of Clausius' theorem was given in lectures.