Second Law of Thermodynamics

Heat engine

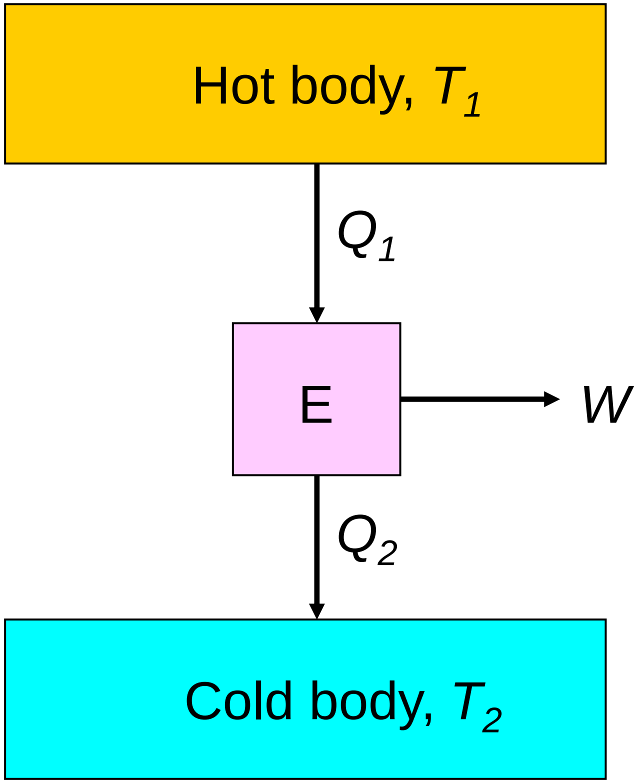
A heat engine converts heat into work in a **cyclic process** in which the working substance is unchanged.

The efficiency, $\zeta = W/Q_1$

In a cyclic process $\Delta U = 0$

First law gives $W = Q_1 - Q_2$

Hence, $\boldsymbol{\zeta = 1 - Q_2/Q_1}$



Second Law of Thermodynamics

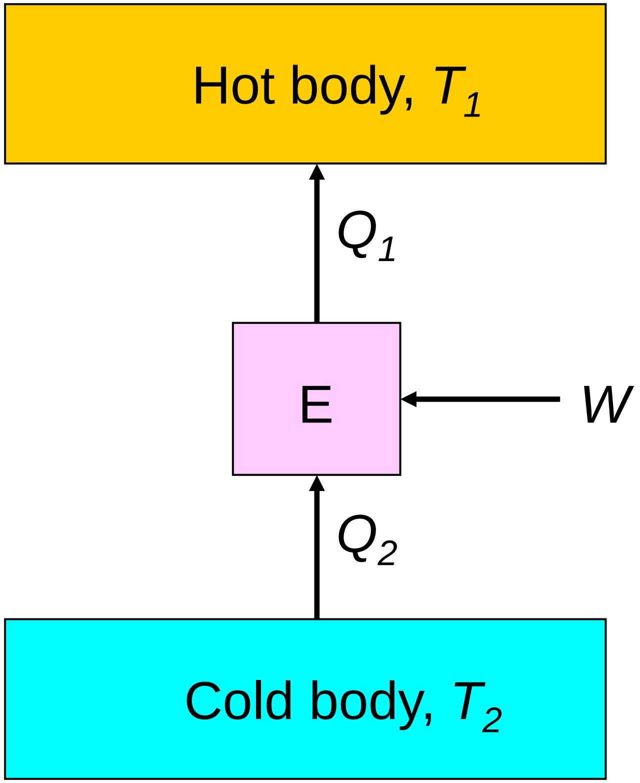
Refrigerator & Heat Pump

A refrigerator extracts heat from a body at lower temperature than surroundings.

$$\zeta^{R} = \frac{Q_2}{W}$$

A heat pump delivers heat to a body at a higher temperature than surroundings

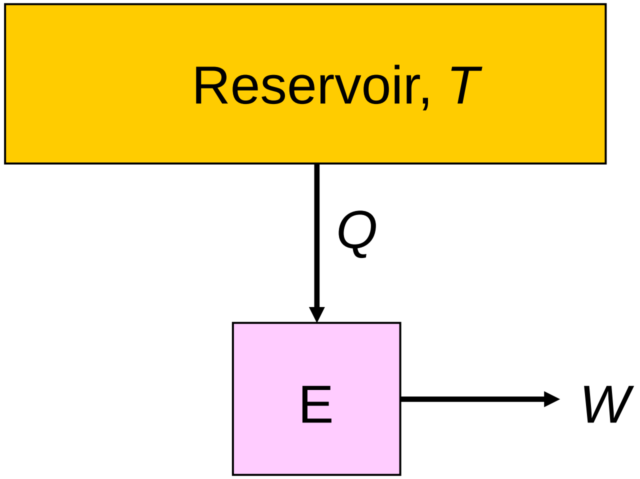
$$\zeta^{HP} = \frac{Q_1}{W}$$



Second Law of Thermodynamics

Kelvin-Planck Statement

It is impossible to construct a device operating in a cycle, which will produce no effect other than the extraction of heat from a single body at a uniform temperature and the performance of an equivalent amount of work.

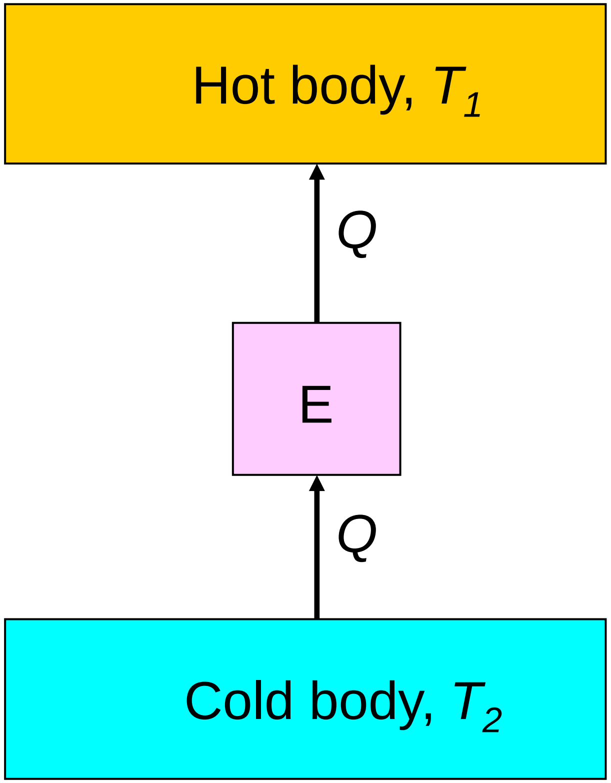


IMPOSSIBLE!

Second Law of Thermodynamics

Clausius Statement

It is impossible to construct a device operating in a cycle, which will produce no effect other than the transfer of heat from a colder to a hotter body.



IMPOSSIBLE!

Second Law of Thermodynamics

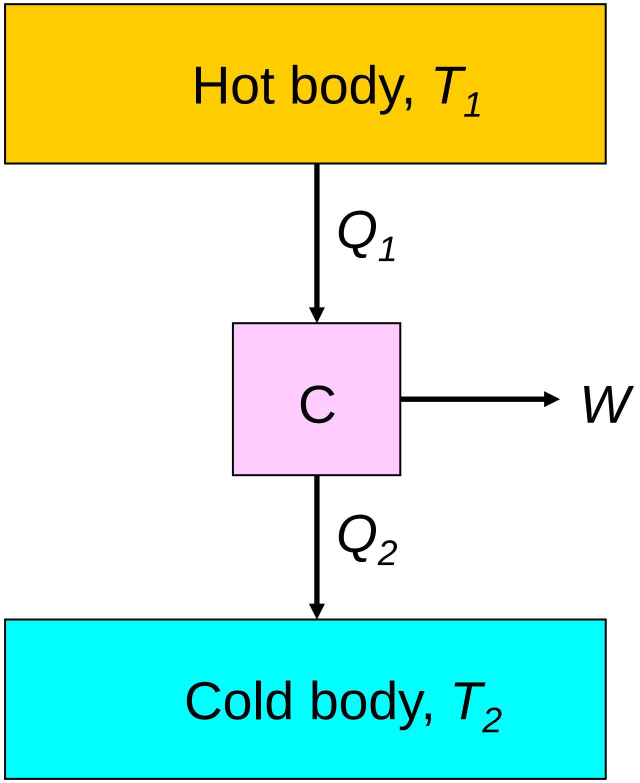
Carnot engine

A Carnot engine, C, is a **reversible** engine operating between only **two temperatures**.

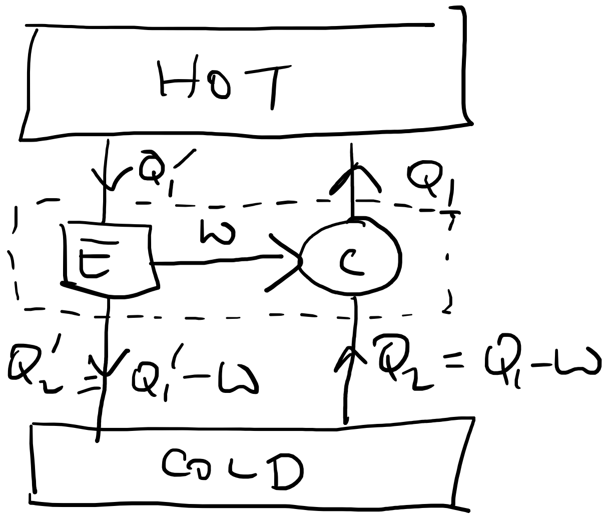
Carnot's Theorem

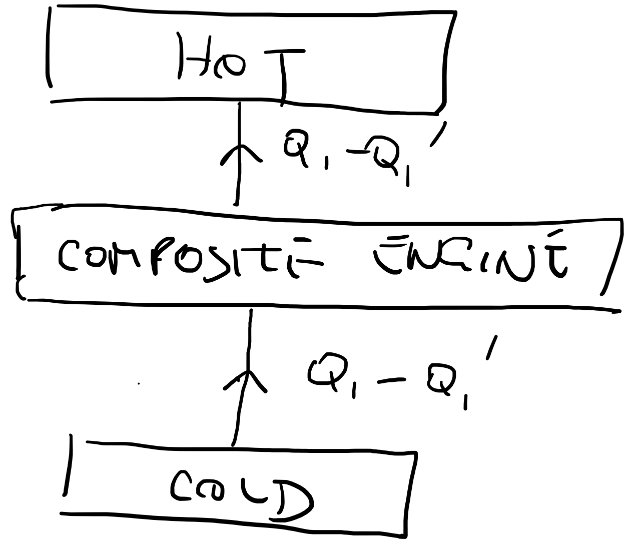
No engine operating between two reservoirs can be more efficient than a Carnot engine operating between those same two temperatures.

Equivalent to 2nd law



Proof by contradiction: Suppose $\eta^{HE} > \eta^{C}$





Efficiency of engine $\eta^{HE} = \dfrac{W}{Q_1'}$; $\eta^{C} = \dfrac{W}{Q_1}$

If $\eta^{HE} > \eta^{C}$, since W same

$$Q_1 > Q_1'$$

VIOLATES CLAUSIUS STATEMENT OF 2ND LAW

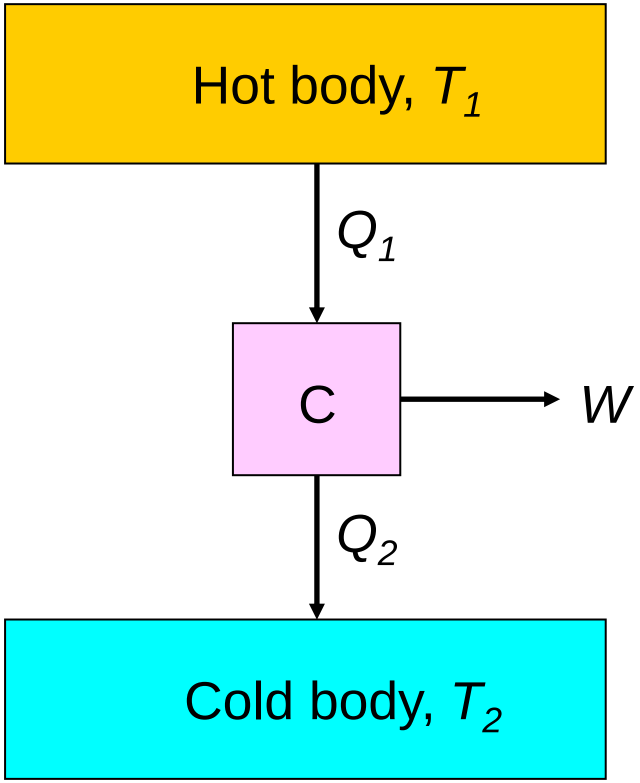
Second Law of Thermodynamics

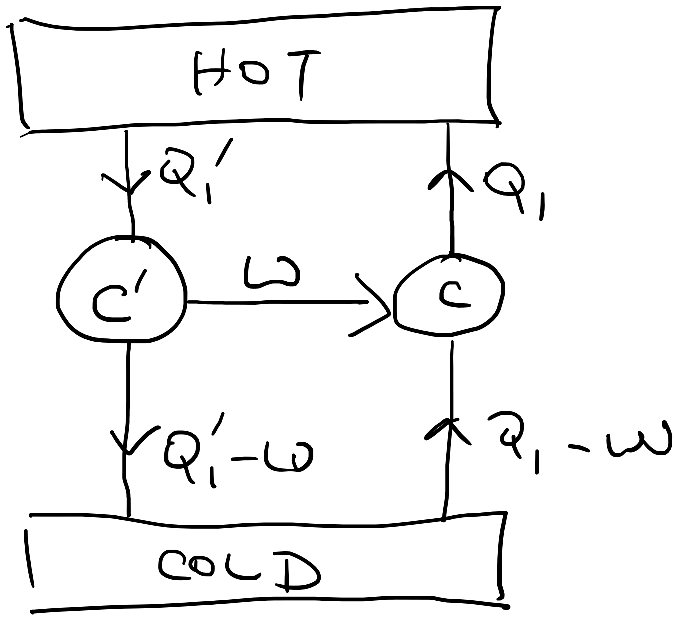
Carnot engine

A Carnot engine, C, is a **reversible** engine operating between only **two temperatures**.

Corollary to Carnot's Theorem

All Carnot engines operating between the same two reservoirs have the same efficiency.





$$\eta^{C'} \leq \eta^{C}$$

Run in opposite direction

$$\eta^{C'} \geq \eta^{C}$$

$$\therefore \quad \eta^{C'} = \eta^{C}$$