The Second Law of Thermodynamics

First Law $\longrightarrow$ Conservation of energy

$$dU = đQ + đW$$

$\rightarrow$ Places no limitation of the possibility of transforming ~~of~~ one form of energy to another

1st. Law $\quad$ heat $\rightarrow$ work or work $\rightarrow$ heat

ok ✓ provided total amt of heat = total work

It turns out

work to heat ✓ ok heat by friction

electric current - resistance

heat to work $\longrightarrow$ severe limitations

Kelvin- Planck Statement of Second Law:

A transformation whose only final result is to transform into work heat extracted from a source at a given temperature is impossible.

"only" is critical. $\exists$ transformations that convert heat completely to work. $\longrightarrow$ e.g. Isothermal expansion of an ideal gas

$$đQ = \underbrace{\cancel{dU}}_{U(T)}{}^{\to 0} + đW \quad \Rightarrow \quad đQ = đW$$

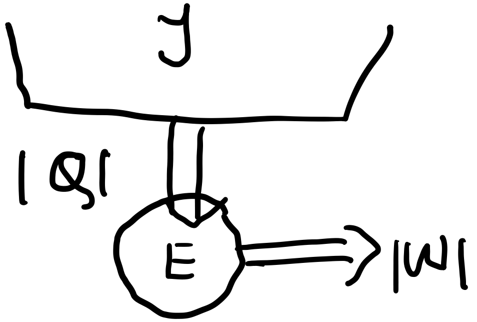
not sole result $\longrightarrow$ volume is affected

state changes

Kelvin statement $\longrightarrow$ no "perfect" heat engine exists

perfect engine $\longrightarrow$ operating in a cycle takes heat from a source $\longrightarrow$ work $\longrightarrow$ returns to original state ready to start again

$$\text{efficiency} = \eta = \frac{\text{output}}{\text{input}} = \frac{W}{Q} = 1 \times \text{ not possible}$$



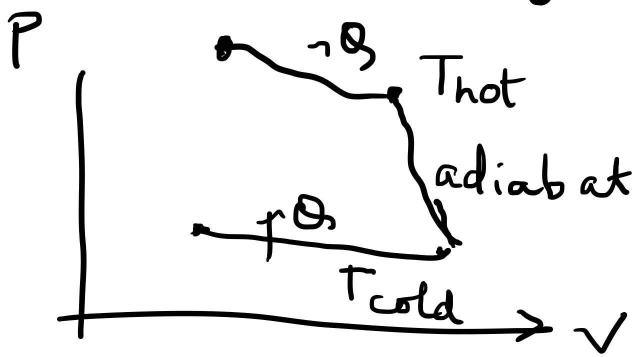
where $|Q| = |W|$

$\rightarrow$ impossible!!

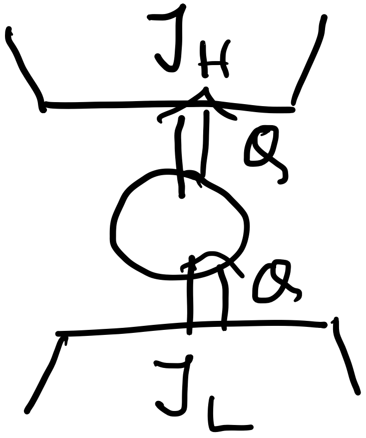
Clausius Statement:
A transformation whose only result is to transfer heat from a cooler to a hotter body is impossible.

"only"

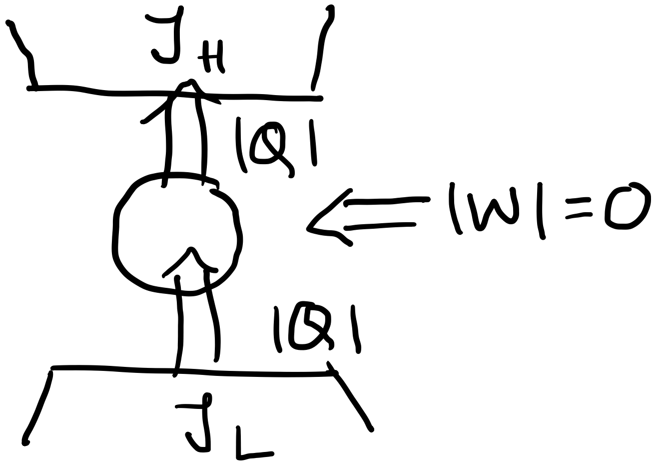
- gas expanded at const temp T_{cold}
  - extracting heat Q from cold source.
- adiabatic compression to temp T_{hot}
- isothermal compression delivering Q to the source at T_{hot}



$\rightarrow$ no violation of 2^{nd} Law because system did not return to same state!!



impossible!



ideal/perfect refrigerator

coeff of performance κ

$$= \frac{\text{output}}{\text{input}} = \frac{Q}{W} \quad , \quad \text{perfect } \kappa \to \infty$$

Equivalenice of K-P and Clausius

K = truth of K-P

$-K$ = falsity of K-P

C = truth of C

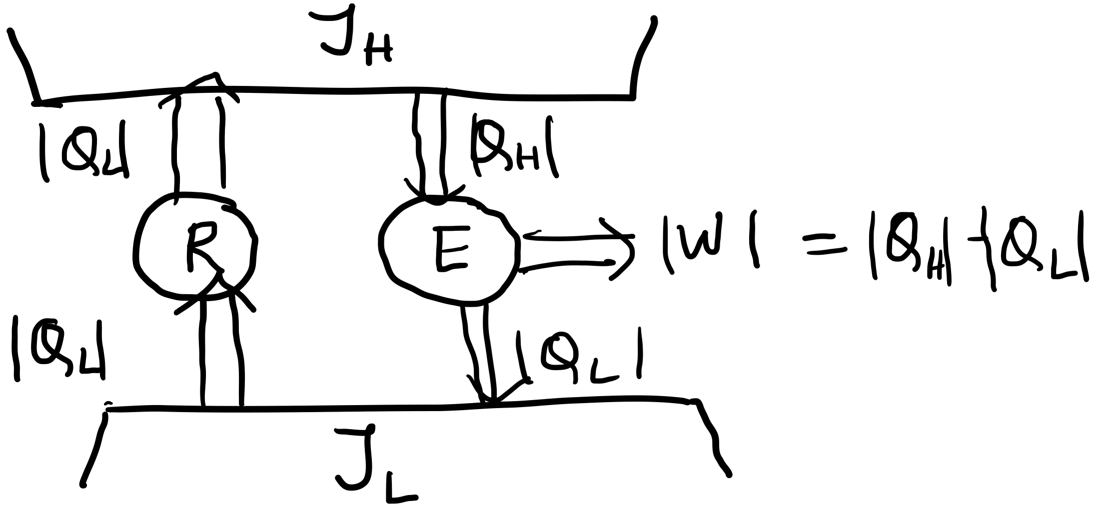
$-C$ = falsity of C

must show $K \equiv C$

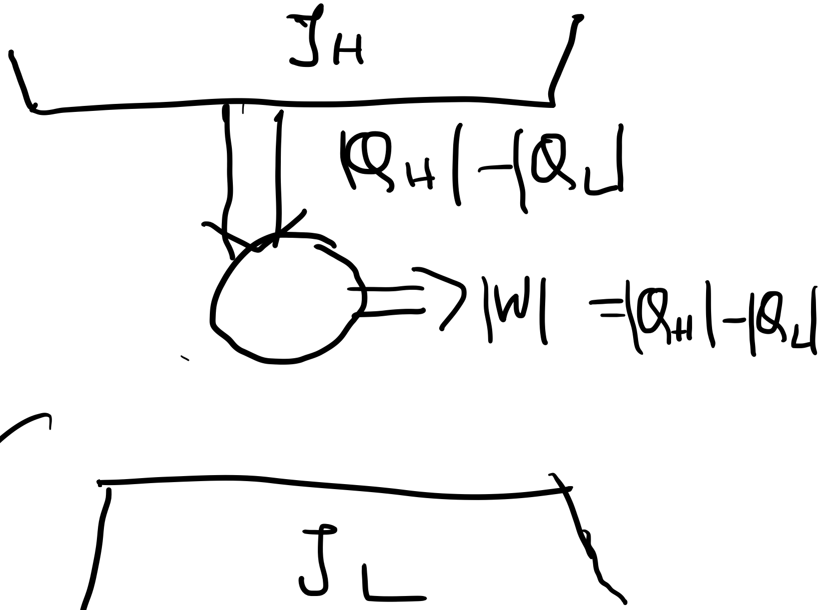
$K \Rightarrow C \qquad C \Rightarrow K$

$-K \Rightarrow -C \qquad -C \Rightarrow -K$

① $\sim C \Rightarrow -K$



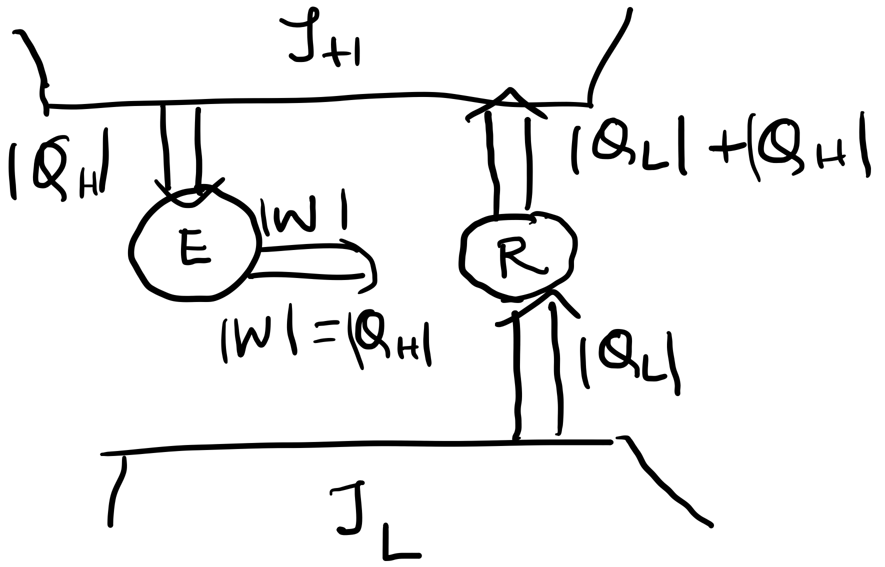
perfect refrigerator
+ real engine



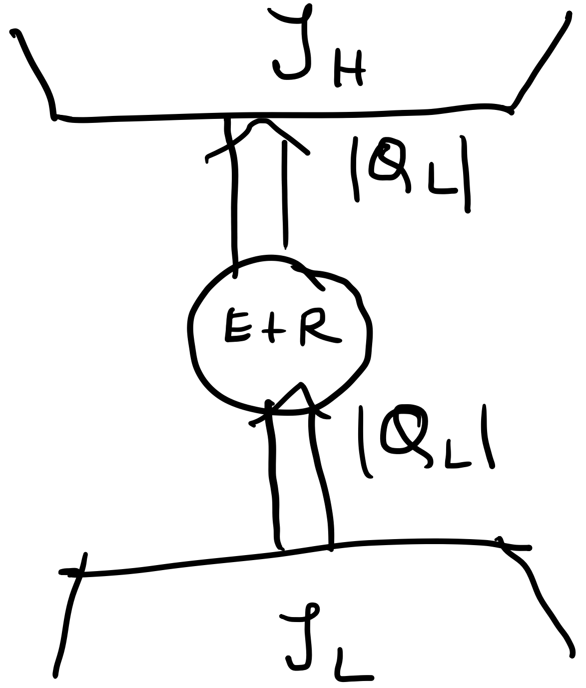
perfect engine
violates K.

$-C \Rightarrow -K$

② $-K \implies -C$



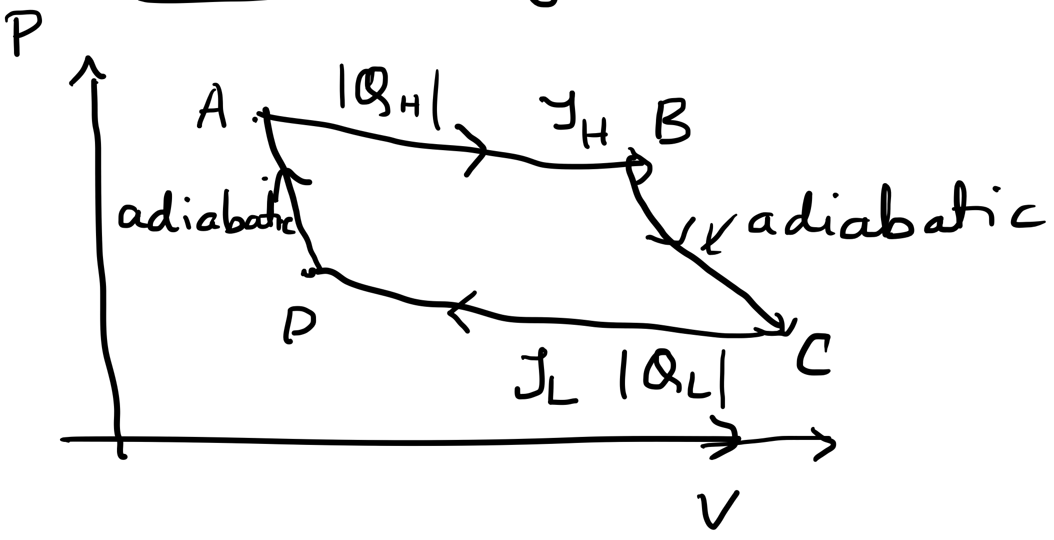
ideal engine + real refrigerator



→ perfect refrigerator violates C

$$\boxed{-K \implies -C}$$

Carnot Cycle / Engine



$$|W| = |Q_H| - |Q_L|$$

- Carnot cycle is reversible
- Heat is always transferred at const temp.
- Independent of working substance.