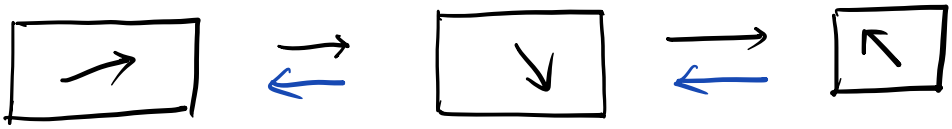
many facets of 2nd Law :

1°

hot T_H → cold T_L

heat flow

2°



看上去没有不同

$$\vec{F} = m\vec{a} = m\frac{d^2\vec{r}}{dt^2}$$

$t \to -t$

one particle → many particles

牛奶都在杯子里

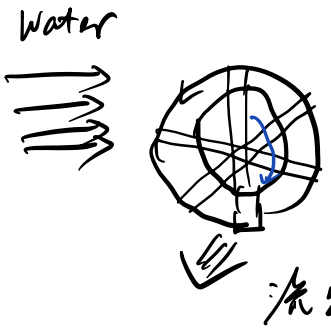
but 没看到牛奶聚拢 (覆水难收)

{ energy transfer
  information transfer

1712 Newcomen → steam engine

1763 - 1782 Watt → industrial revolution

Carnot → what is the optimal efficiency of a heat engine ?

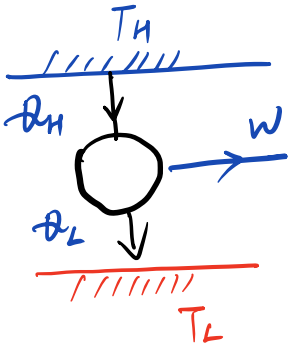


水的重力势能

流出 "水磨" watermill

Water filled at some height → discharged at low level

What a great observation !!



Caloric filled at some high T reservoir → discharged into low T

H / L
high / low T

$W = Q_H - Q_L$ (1st law)

(吸) (排)

$$\eta \equiv \frac{W}{Q_H} = 1 - \frac{Q_L}{Q_H} \quad (< 1)$$

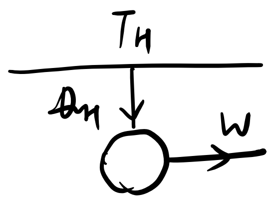


Fig (★)

perfect heat engine :

→ against 2nd law

本行是热力学，不小心成了量子爸爸 ^_^

Kelvin - Planck statement :

Fig (★) is impossible !

Joule : 1卡 = 4.2 焦耳

功 → 热（天纵英明呀 ^_^）

反过来，试图做 热 → 功，还能建立

热功当量吗 ^^

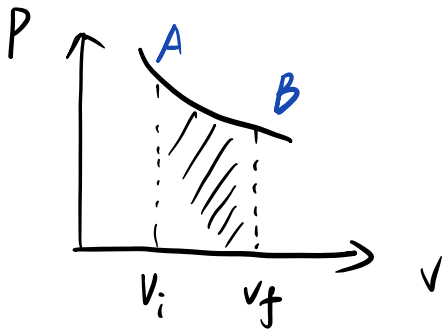
能量的 quality : （资用能）

直流电 → 交流电

烧煤 → 发电

heat flow diagram → Carnot cycle

"cycle"

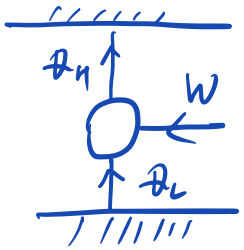


$Q = W$

it is not a cycle !!

把热完全转化为功，but 系统变了！

问题是在循环

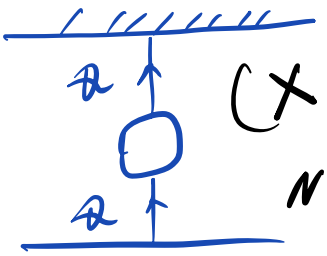


coefficient of performance = cop

$$= \frac{Q_L}{W} = \frac{Q_L}{Q_H - Q_L} = \frac{1}{\frac{Q_H}{Q_L} - 1}$$

冰箱：5

宾馆：2~3



Clausius statement:

(X)

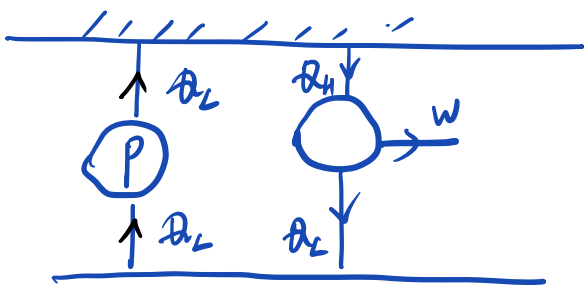
NO "perfect" refrigerator

cop → ∞

K - P statement ≡ C - statement

反证法：

(A) assume clausius is wrong



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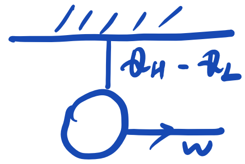
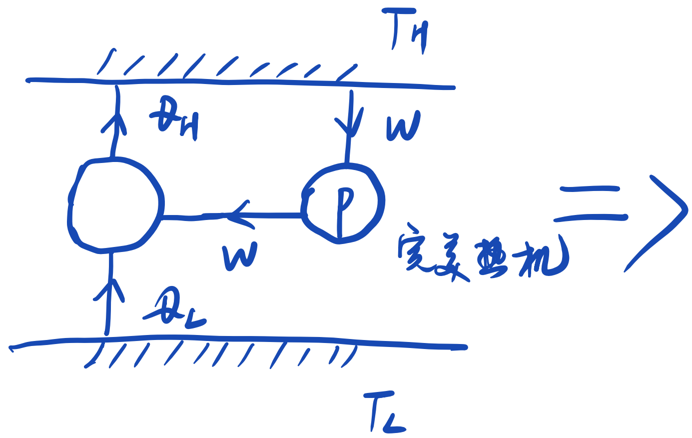
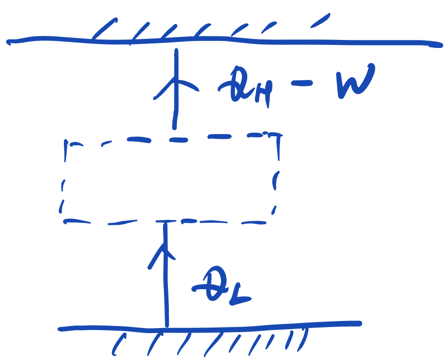


完美冰箱 ⇒ 完美热机

(b) assume K-P is wrong





完美热机 ⇒ 完美冰箱

Otto vs Carnot (周期很长)

Otto ↓ 1秒很多 cycle

Carnot ↓ 效率很好，功率很差

细水流长

人生苦短 → （水滴石穿但不会用水来穿石，你等不了）

Otto 循环被选为汽车引擎

Carnot theorems :

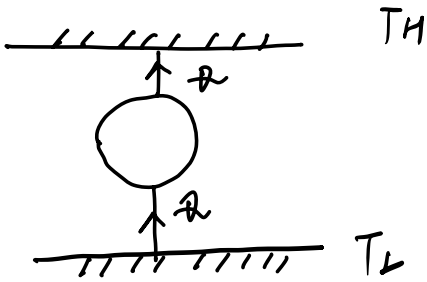
(A) All revisible heat engine working between T_H & T_L have the same efficiency （反证法）

(B) no heat engine is better than Carnot engine.

(irreversible in a real heat engine)

ideal engine is not perfect engine

科学告诉我们你造不出完美热机
不完美不是由于什么摩擦力之类的东西，Q、T、S 从这种形式实现做功伴随"能量质量"的问题
即做功的能力的问题。



perfect R

impossible

如果发生：

(吸热为正) $-\frac{Q_L}{T_L}+\frac{Q_H}{T_H}+0<0$

(cycle：S是状态参量)

合为孤立系统 ← (热源 + 工质)

$\Delta S<0$

但是不可能 → 结论要反过来

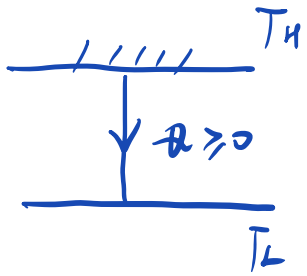
2nd Law Clausius statement

→ no perfect refrigerator

⇓

$\Delta S\geq 0$ (熵增原理)

能发生的过程：



$-\frac{Q_H}{T_H}+\frac{Q_L}{T_L}\geq 0$

学习是减熵过程：

答案非题，没学，可是可非

学了，这是对非

在熵的意义上并无差别

学得好与不好，S 无差

学与不学，S 差很大

（学了将做出一种选择）

比较 square cycles 的状态和 S 大小。

the measure of disorder：