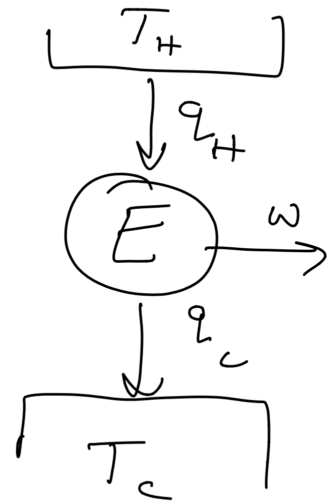
$$\eta_{carnot} = 1 + \frac{q_c}{q_H}$$



T_c, T_H

$$\left(\frac{V_2}{V_1}\right) = \left(\frac{V_3}{V_4}\right)$$

$$\frac{V_4}{V_3}$$

$$\eta_{Carnot} = 1 - \frac{T_c}{T_H}$$

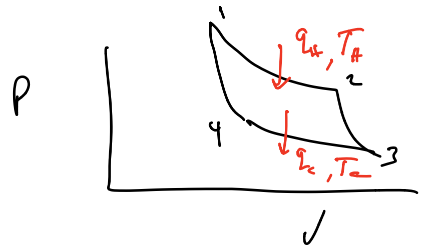
Break Even at 0 Kelvin

all heat → work

$$\eta_{carnot} = 1 + \frac{q_c}{q_H} = 1 - \frac{T_c}{T_H} = \eta_{carnot}$$

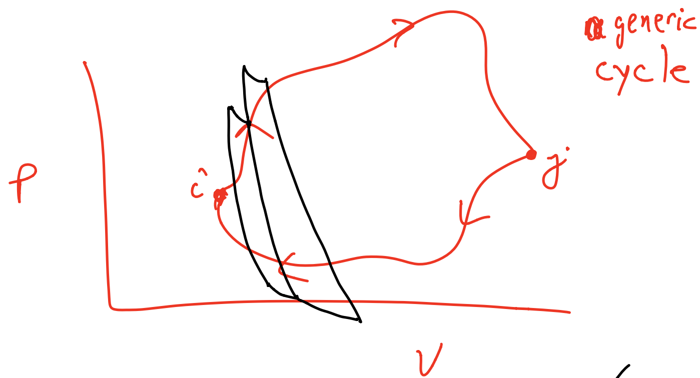
$$\frac{q_c}{q_H} = \frac{-T_c}{T_H}$$

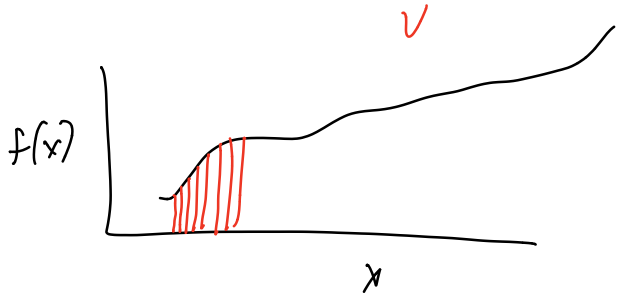
$$\longrightarrow \frac{q_c}{T_c} + \frac{q_H}{T_H} = 0$$



$\frac{q}{T}$ looks like a state function

Turns out!





$$\frac{q_c}{T_c} + \frac{q_H}{T_H} = 0$$

$$\Downarrow$$

$\oint dT = 0$ $\qquad$ $\oint \frac{đq_{reversible}}{T} = 0$

$$dS = \frac{đq_{reversible}}{T} \quad \text{definition!}$$

~~$dS \neq \frac{đq}{T}$~~

$$\oint \frac{đq_{reversible}}{T} = 0$$

$$\oint \frac{đq_{reversible}}{T} \text{ vs } \oint \frac{đq_{irrev}}{T}$$

$$đq_{reversible} > đq_{irrev}$$

$$\oint \frac{đq_{rever}}{T} > \oint \frac{đq_{irrev}}{T}$$

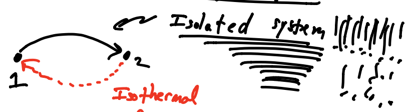
Clausius Inequality
$$\oint \frac{đq}{T} \leq 0 \quad *$$

$\oint \frac{đq}{T} = 0$ Reversible Process

$\oint \frac{đq}{T} < 0$ Irreversible Process

Let's use Clausius Inequality:

system ← Isolated system



$$\oint \frac{đq}{T} = \underbrace{\int_1^2 \frac{đq}{T}}_{=0} + \int_2^1 \frac{đq}{T} < 0$$

$$\int_2^1 \frac{đq_{reversible}}{T} < 0$$

$$\int_2^1 dS < 0$$

$$S_1 - S_2 = \Delta S_{2\to 1} < 0$$

$$S_1 - S_2 < 0$$

$$S_1 < S_2$$

$$S_2 > S_1 \quad \text{process } 1 \to 2$$

ΔS for Irreversible Process in **Isolated** System > 0 $\quad \Delta S > 0$

System = Salt + H_2O

$\Delta S < 0$ (salt), $\Delta S > 0$ (H_2O)

$$\Delta S_{universe} = \Delta S_{system} + \Delta S_{surroundings}$$

Irreversible : $\Delta S_{universe} > 0$

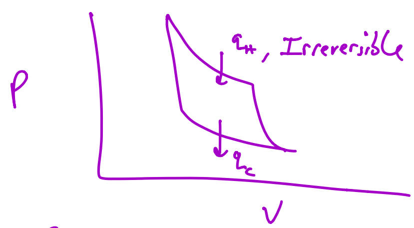
$$\Delta S_{system} > -\Delta S_{surroundings}$$

Reversible :

$$\Delta S_{universe} = 0$$

$$\Delta S_{system} = -\Delta S_{surroundings}$$

Efficiency of Irreversible Engine vs Reversible Engine.



$$\eta^{Rev}_{Carnot} = 1 + \frac{q_c}{q_H^{rev}} \qquad 1 + \frac{q_c}{q_H^{IRREV}} = \eta^{IRREV}$$

$$q_H^{rev} > q_H^{Irre}$$