Maximum work. Perpetuum mobile of second kind

(Perpetual motion machine)

All machines

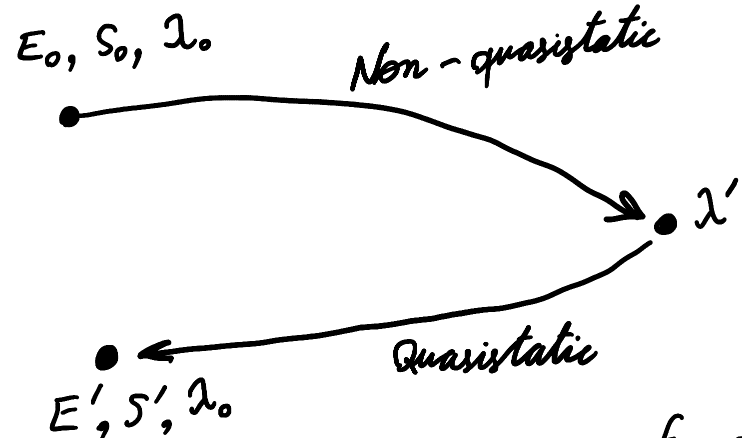
Cyclic
(Turbines, internal combustion engines, steam engines, ...)

Non-cyclic
(Anything that involves chemical reaction: batteries, rockets, etc...)

Focus on cycles

Is it possible to convert internal energy to work?

Consider a thermally isolated system.



Because the entropy grows for an isolated system, $S' \geqslant S_0$. Because $\left(\frac{\partial E}{\partial S}\right)_\lambda = T > 0$
$E' \geqslant E_0$.

The increase of energy $E_0 \to E'$ may come only from work done on the system

Thus, to increase the entropy of a thermally isolated system one has to do work on it.
[illegible] extract work from it.

isolated system one has to do work on it.
Thus, it's impossible to extract work from it.

To extract tork from a system one needs at least two bodies at temperatures T_1 and T_2

$$\delta Q = \delta E + \delta W$$

in an arbitrary not necessarily reversible process. Consider a reversible process with the same change of energy δE

$$T \delta S = \delta E + \delta W'$$

$$\delta W' - \delta W = T \delta S - \delta Q > 0$$

→ Maximal work is done in a reversible process

Because contact between 2 systems with different temperatures leads to an irreversible heat transport, we will need at least 3 elements:

1) Heater with $T = T_2$
2) Cooler with $T = T_1$
3) A <u>system</u> which may pass heat from the heater to the cooler without any direct contact between them

When contacting the heater and the cooler, the temperature T of the system must match the temperatures of the heater cooler, the [illegible] of the heater must match the temperatures of the heater and the cooler respectively

Work $\delta W = \delta Q_1 + \delta Q_2 = T_1 \delta S_1 + T_2 \delta S_2$

$\delta S = \delta S_1 + \delta S_2$, due to reversibility

$$\delta W = \delta S_2 (T_2 - T_1) = \frac{T_2 - T_1}{T_2} \delta Q_2$$

<u>Efficiency</u> = the ratio of work to the heat received from the heater

$$\boxed{\eta_{max} = \frac{T_2 - T_1}{T_2}}$$

In the considered reversible process

$$\frac{\delta Q_2}{T_2} + \frac{\delta Q_1}{T_1} = 0$$

The cycle which maximises efficiency for a system between a heater at T_2 and a cooler at T_1 is called <u>Carnot cycle</u>

In a generic reversible process $\oint \frac{\delta Q}{T} = 0$

Historically, $\frac{\delta Q}{T}$ was called the change of entropy