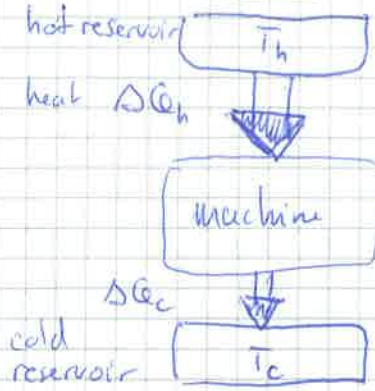
heat machine : reversible process converting heat into work



reversible process

$\Delta S = 0$

$\Delta U = \Delta Q_{in} + \Delta W_{on} = 0$

heat absorbed — work done on system

$\Delta Q - \Delta W = 0$

$\Delta Q = \Delta Q_h - \Delta Q_c$

work done by system, that can be used to do mechanical work

and (1) $\Delta Q_h - \Delta Q_c = \Delta W$

entropy: $\Delta S = 0 = \Delta S_h + \Delta S_c$ total entropy change

$$-\frac{\Delta Q_h}{T_h} + \frac{\Delta Q_c}{T_c} = 0$$

and

(2) $$\frac{\Delta Q_c}{\Delta Q_h} = \frac{T_c}{T_h}$$

- efficiency of machine $\eta = \frac{\Delta W}{\Delta Q_h} \overset{(1)}{=} 1 - \frac{\Delta Q_c}{\Delta Q_h} \overset{(2)}{=} 1 - \frac{T_c}{T_h}$

$$\| \quad \eta = 1 - \frac{T_c}{T_h}$$ Carnot's efficiency

- for an irreversible process:

$$\Delta S_{total} > 0$$

following the argument above;

$$-\frac{\Delta Q_h}{T_h} + \frac{\Delta Q_c}{T_c} > 0 \quad \text{and} \quad \frac{\Delta Q_c}{\Delta Q_h} > \frac{T_c}{T_h}$$

for $\eta := 1 - \frac{\Delta Q_c}{\Delta Q_h}$

we get $$\| \quad \eta < 1 - \frac{T_c}{T_h}$$ real efficiency of a thermal machine

exp: steam machine
stirling engine

- steam machin : James Watt

  regulator ball : adjust steam admission (decrease / to decrease rotation speed

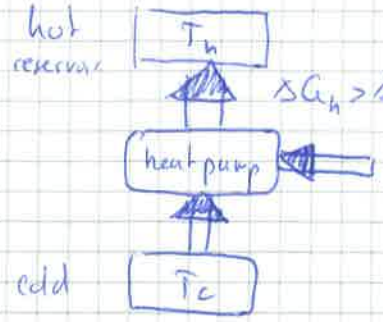
- stirling engine low power - to - weight ratio, but quick, efficient

  slide

  1) keybold version, 1 cylinder

  2) stirling engin as cooling machine

heat machine using work (inverted)
for instance heat pump



$\Delta W = \Delta Q_h - \Delta Q_c$ as seen before

reversible system: $\Delta S = 0 = \Delta S_h + \Delta S_c$

hence $\frac{\Delta Q_h}{T_h} - \frac{\Delta Q_c}{T_c} = 0$, $\frac{\Delta Q_h}{\Delta Q_h} = \frac{T_c}{T_h}$

efficiency of the heat pump: $\eta_{hp} = \frac{\Delta Q_h}{\Delta W}$ (we inject work ΔW and receive heat ΔQ_h)

$$= \frac{\Delta Q_h}{\Delta Q_h - \Delta Q_c}$$

$$\frac{1}{\eta_{hp}} = \frac{\Delta Q_h - \Delta Q_c}{\Delta Q_h} = 1 - \frac{\Delta Q_c}{\Delta Q_h} = 1 - \frac{T_c}{T_h} = \frac{T_h - T_c}{T_h}$$

$$\eta_{hp} = \frac{T_h}{T_h - T_c}$$

irreversible heat pump

$$\eta_{hp} < \frac{T_h}{T_h - T_c}$$