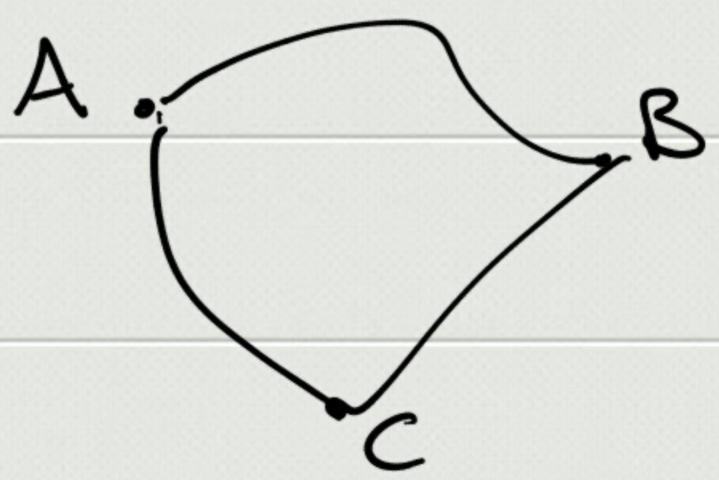
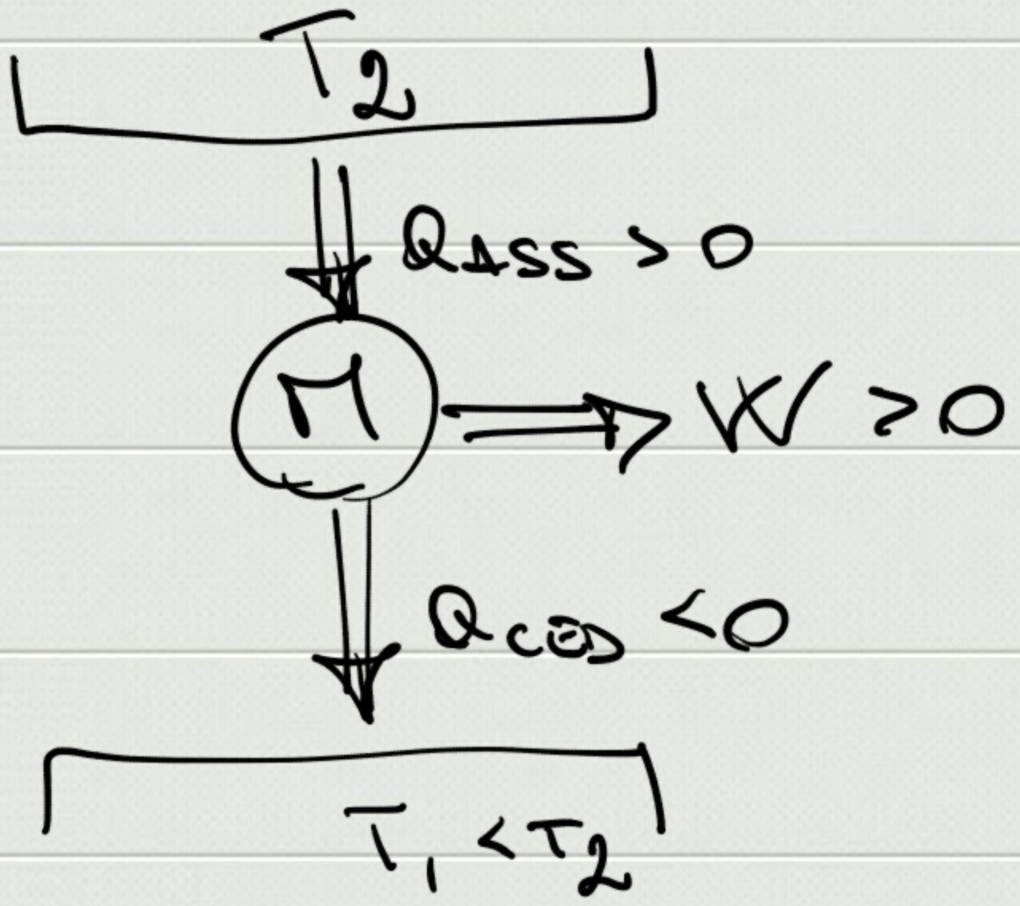
Ciclo

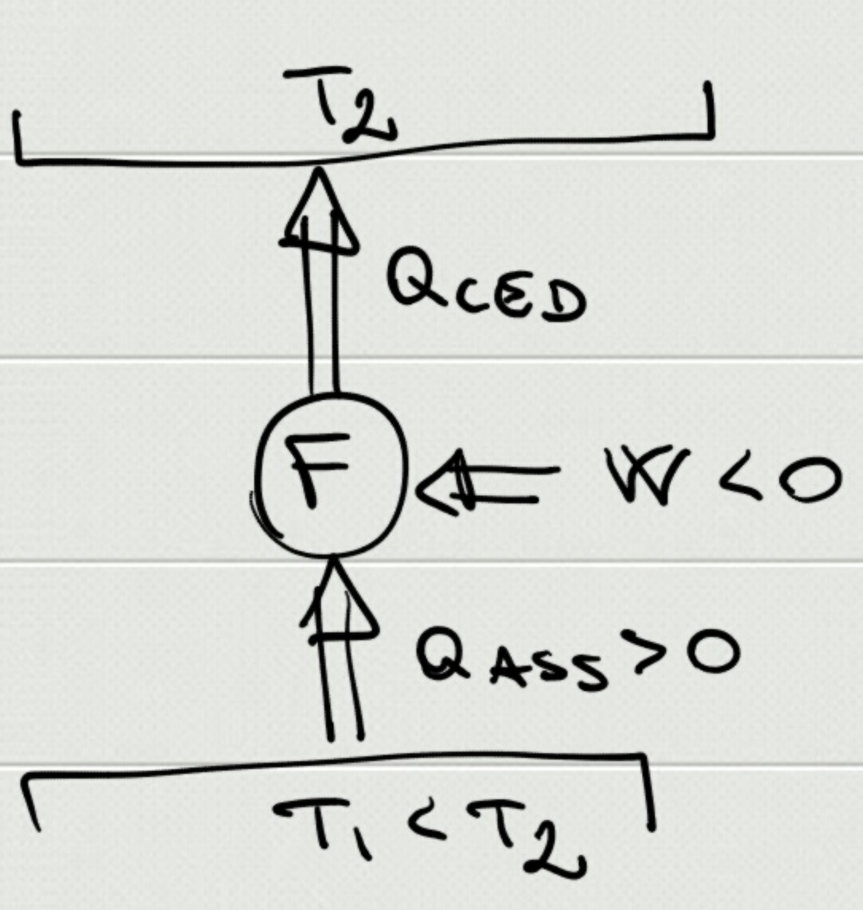


$Q = \Delta U + W$ $\quad \Delta U = 0 \Rightarrow \boxed{Q = W}$

$Q = W \begin{cases} > 0 & \text{macchina termica} \\ < 0 & \text{macchina frigorifera} \end{cases}$



Macchina termica



Macchina frigorifera

Rendimento

$$\boxed{\eta = \frac{W}{Q_{ASS}}}$$

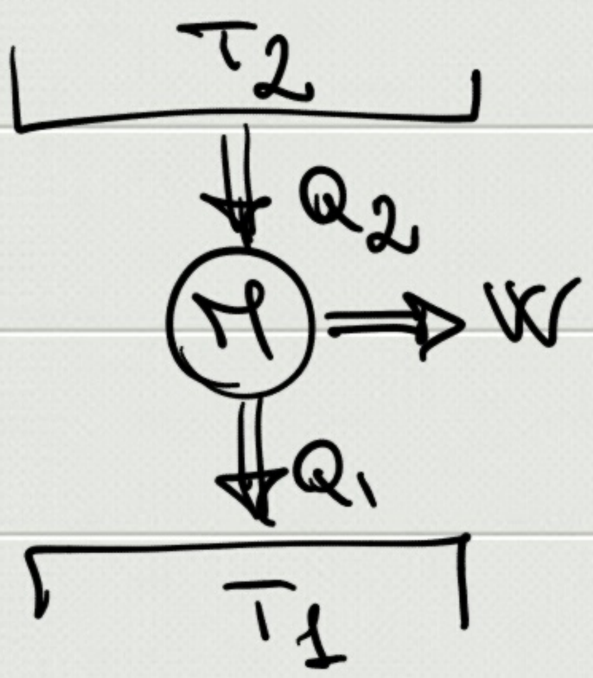
$\Delta U = 0$

$$\eta = \frac{W}{Q_{ASS}} \overset{!}{=} \frac{Q_{ASS} + Q_{CED}}{Q_{ASS}} = 1 + \frac{Q_{CED}}{Q_{ASS}} = 1 - \frac{|Q_{CED}|}{Q_{ASS}}$$

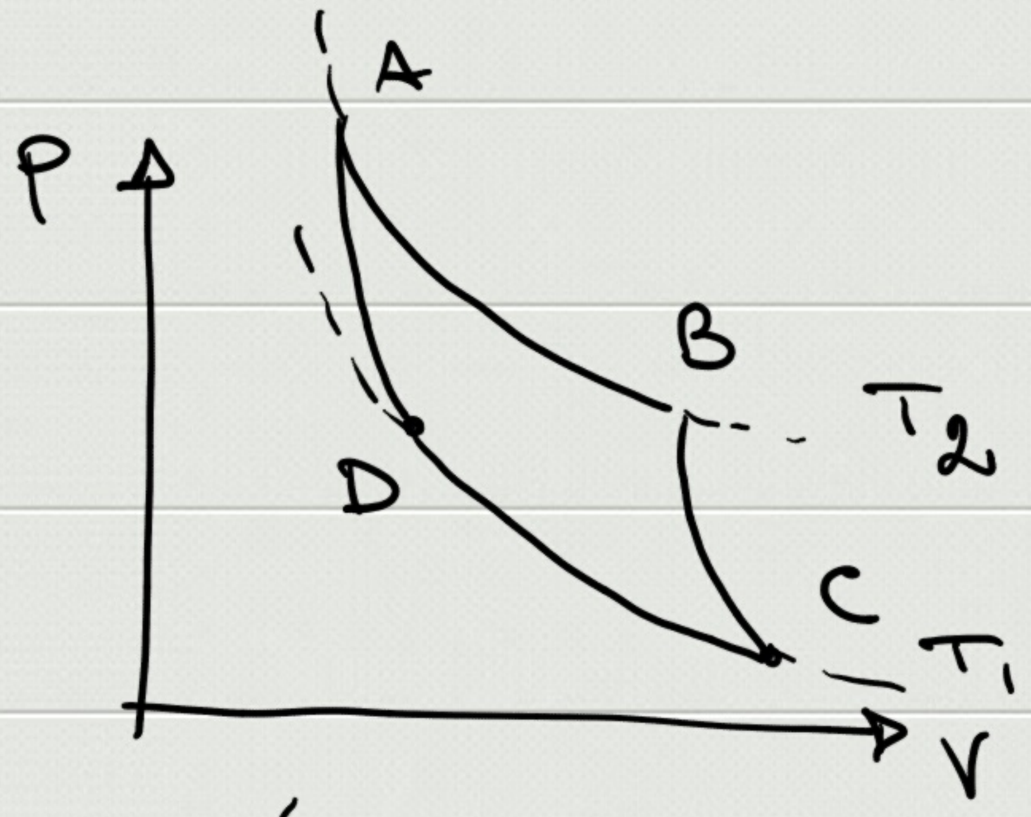
$$\Rightarrow \boxed{0 \leq \eta < 1}$$

Macchine di Carnot (ciclo di Carnot)

↳ reversibile



$\Rightarrow$ η_{MAX}



AB : isot. esp.

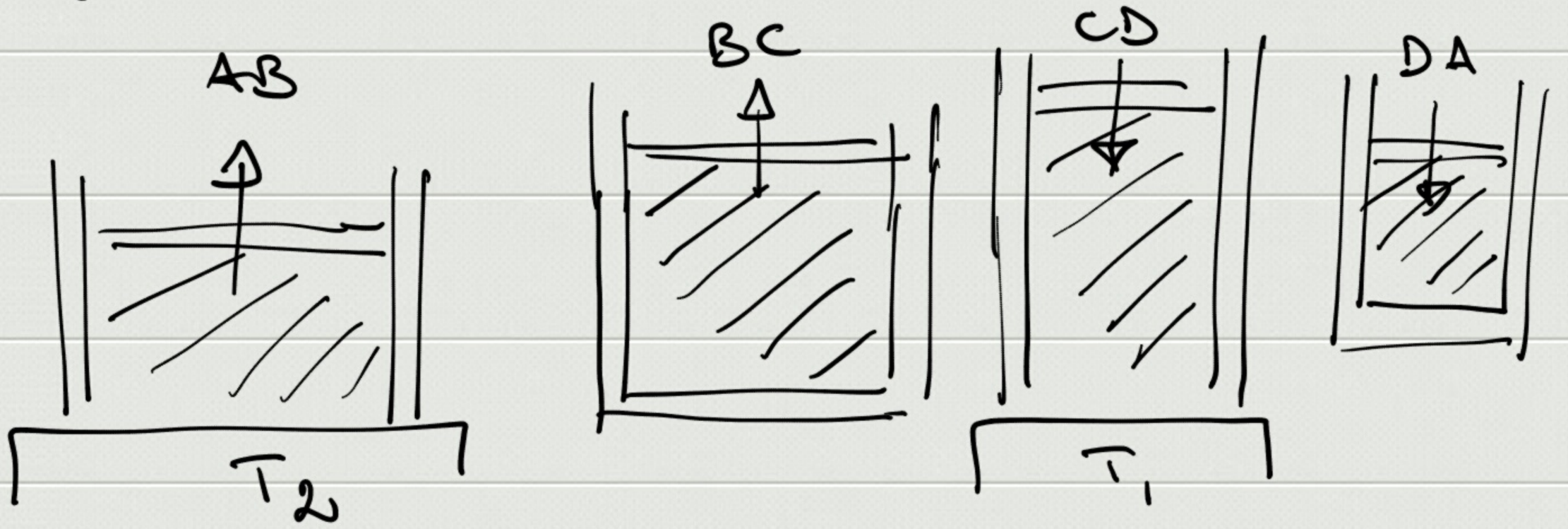
BC : adiab. esp.

CD : isot. compr.

DA : adiab. compr.

$(T_1 < T_2)$

$\eta = ?$



$$AB: \quad \Delta U_{AB} = 0 \qquad Q_{AB} = W_{AB} = nRT_2 \ln \frac{V_B}{V_A} > 0$$

$$BC: \quad Q_{BC} = 0 \qquad W_{BC} = -\Delta U_{BC} = -nC_V(T_1 - T_2) > 0$$

$$TV^{\gamma-1} = \text{cost} \quad \Rightarrow \quad T_2 V_B^{\gamma-1} = T_1 V_C^{\gamma-1}$$

$$CD: \quad \Delta U_{CD} = 0 \qquad W_{CD} = Q_{CD} = nRT_1 \ln \frac{V_D}{V_C} < 0$$

$$DA: \quad Q_{DA} = 0 \qquad W_{DA} = -\Delta U_{DA} = -nc_V (T_2 - T_1) < 0$$

$$T_1 V_D^{\gamma-1} = T_2 V_A^{\gamma-1}$$

$$\eta = 1 + \frac{Q_{CED}}{Q_{ASS}} = 1 + \frac{Q_{CD}}{Q_{AB}} = 1 + \frac{\cancel{nRT_1} \ln \frac{V_D}{V_C}}{\cancel{nRT_2} \ln \frac{V_B}{V_A}}$$

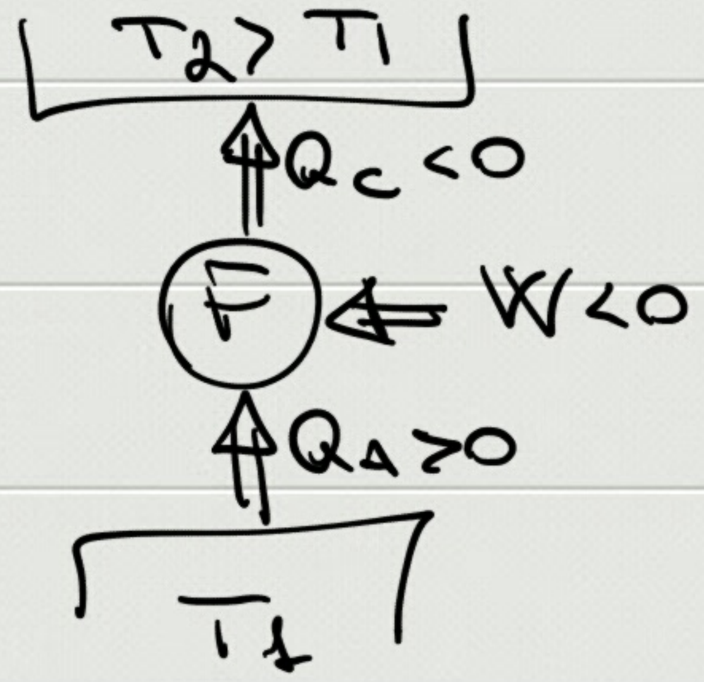
$$\left.\begin{aligned} T_2 V_B^{\gamma-1} &= T_1 V_C^{\gamma-1} \\ T_2 V_A^{\gamma-1} &= T_1 V_D^{\gamma-1} \end{aligned}\right\} \Rightarrow \left(\frac{V_B}{V_A}\right)^{\gamma-1} = \left(\frac{V_C}{V_D}\right)^{\gamma-1}$$

$$\Rightarrow \frac{V_B}{V_A} = \frac{V_C}{V_D} = \left(\frac{V_D}{V_C}\right)^{-1}$$

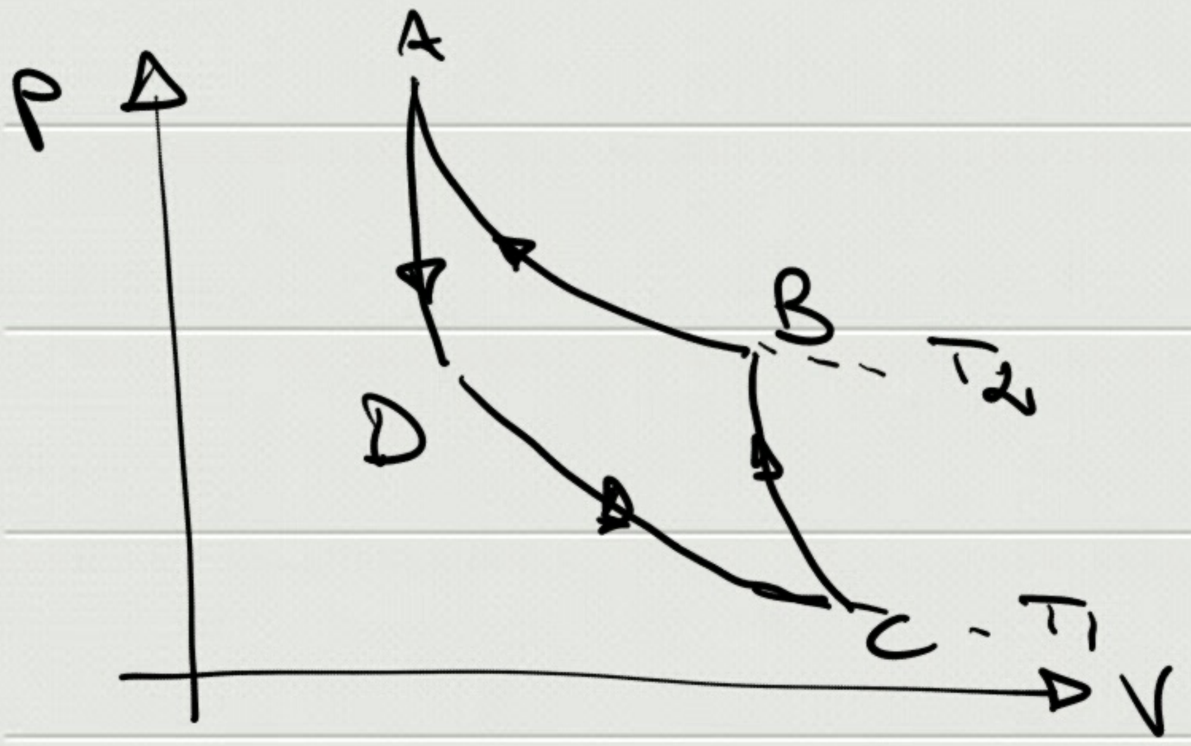
$$\Rightarrow \eta = 1 + \frac{T_1 \ln\left(\frac{V_D}{V_C}\right)}{T_2 \ln\left(\frac{V_D}{V_C}\right)^{-1}} = 1 - \frac{T_1 \ln(\cancel{V_D/V_C})}{T_2 \ln(\cancel{V_D/V_C})}$$

$$\Rightarrow \boxed{\eta = 1 - \frac{T_1}{T_2}} \leftarrow \eta_{max}$$

$$\eta = 1 - \frac{|Q_c|}{Q_A} = 1 - \frac{T_1}{T_2} \Rightarrow \frac{|Q_c|}{Q_A} = \frac{T_1}{T_2}$$



efficienza $\boxed{\xi = \frac{Q_A}{|W|}}$



$$Q_{CD} = \nu R T_1 \ln \frac{V_C}{V_D} > 0$$

$$Q_{BA} = \nu R T_2 \ln \frac{V_A}{V_B} < 0$$

$$\xi = \frac{Q_A}{|Q_A + Q_C|} = \frac{\nu R T_1 \ln \frac{V_B}{V_D}}{\left| \nu R T_1 \ln \frac{V_C}{V_D} + \nu R T_2 \ln \frac{V_A}{V_B} \right|} =$$

$$= \frac{T_1}{|T_1 - T_2|} = \frac{T_1}{T_2 - T_1}$$