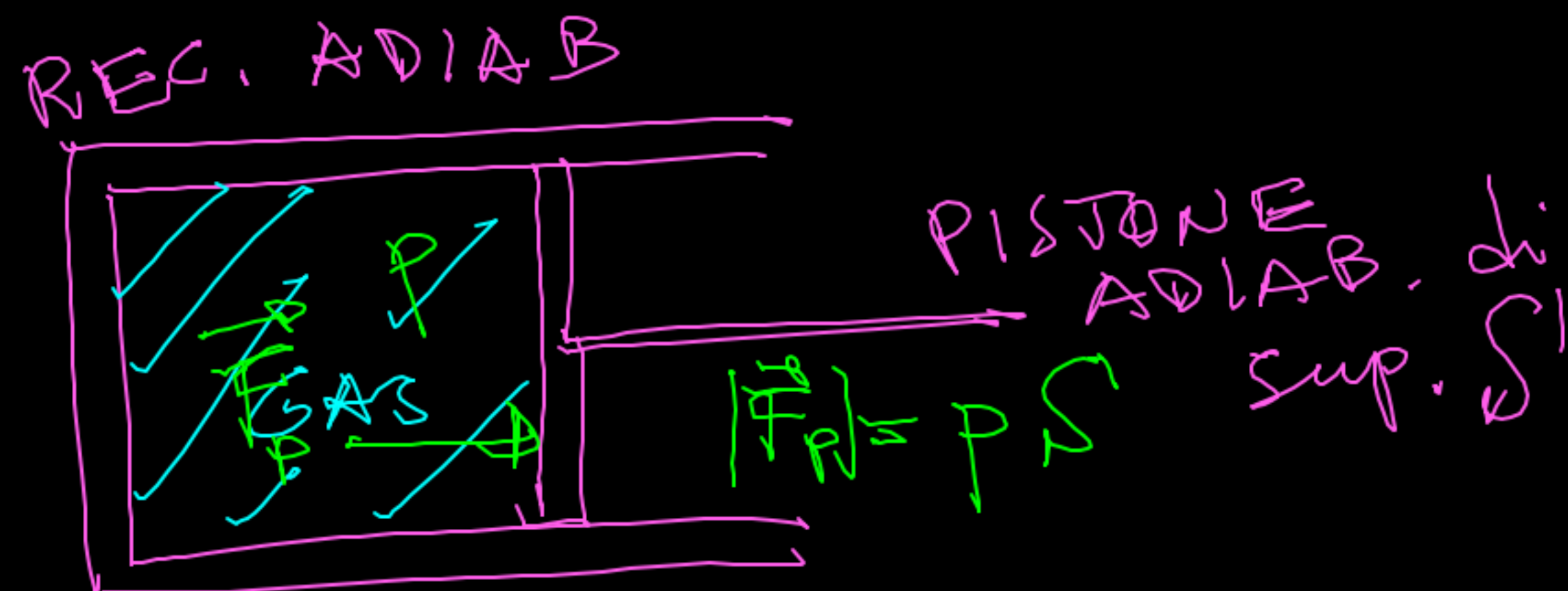


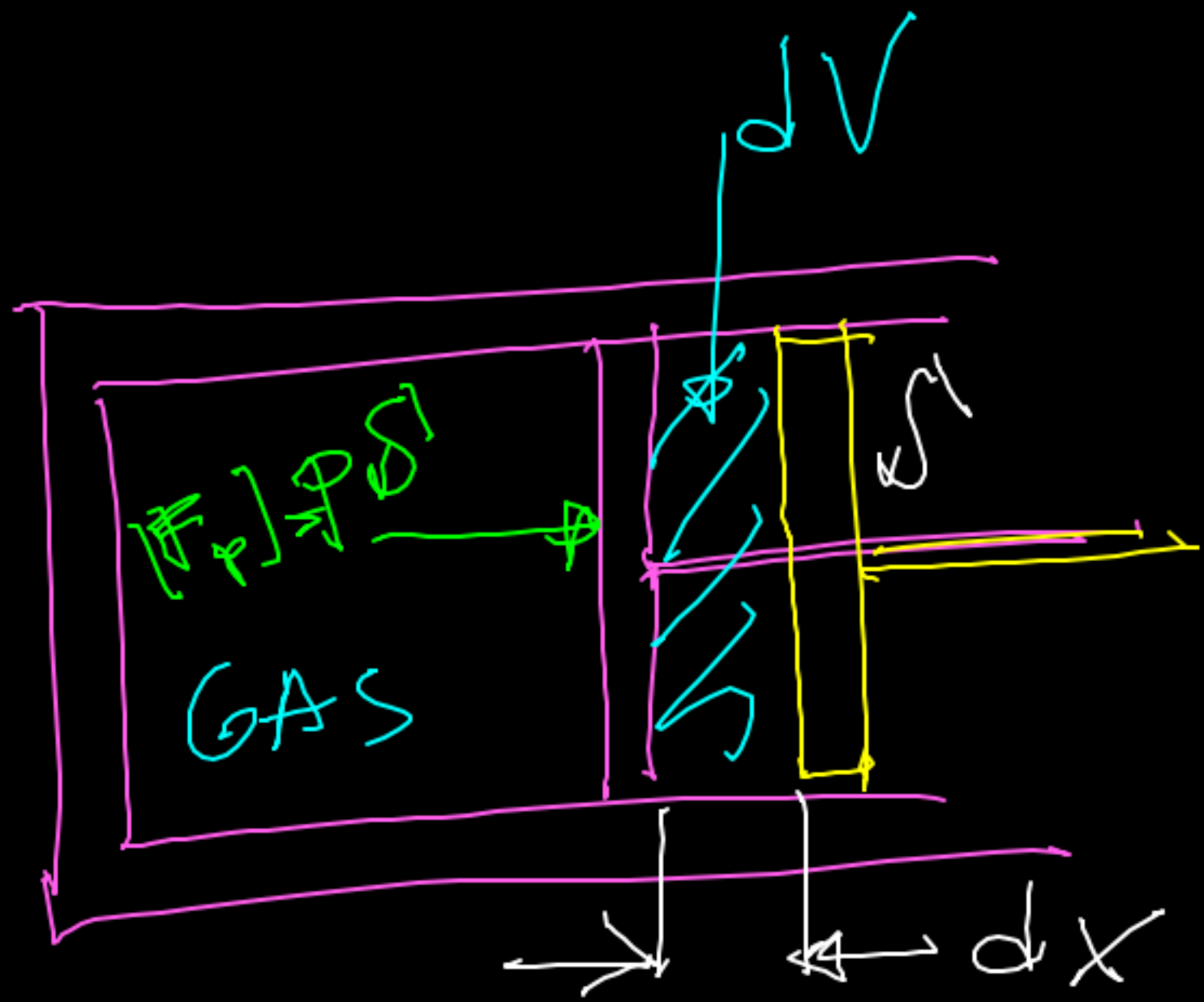
LAVORO IN TERMODINAMICA



CALORE - Energia scambiata
per ΔT

GAS \equiv SISTEMA
TUTTO IL RESTO \equiv AMBIENTE

LAVORO - Energia scambiata
solo attraverso
2 spostamenti meccanici



$$\int dx = dV$$

Variazione di volume del gas

$$dL = p dV$$

LAVORO TERMOD.

(Vale in generale)

dx è lo spostamento del pistone

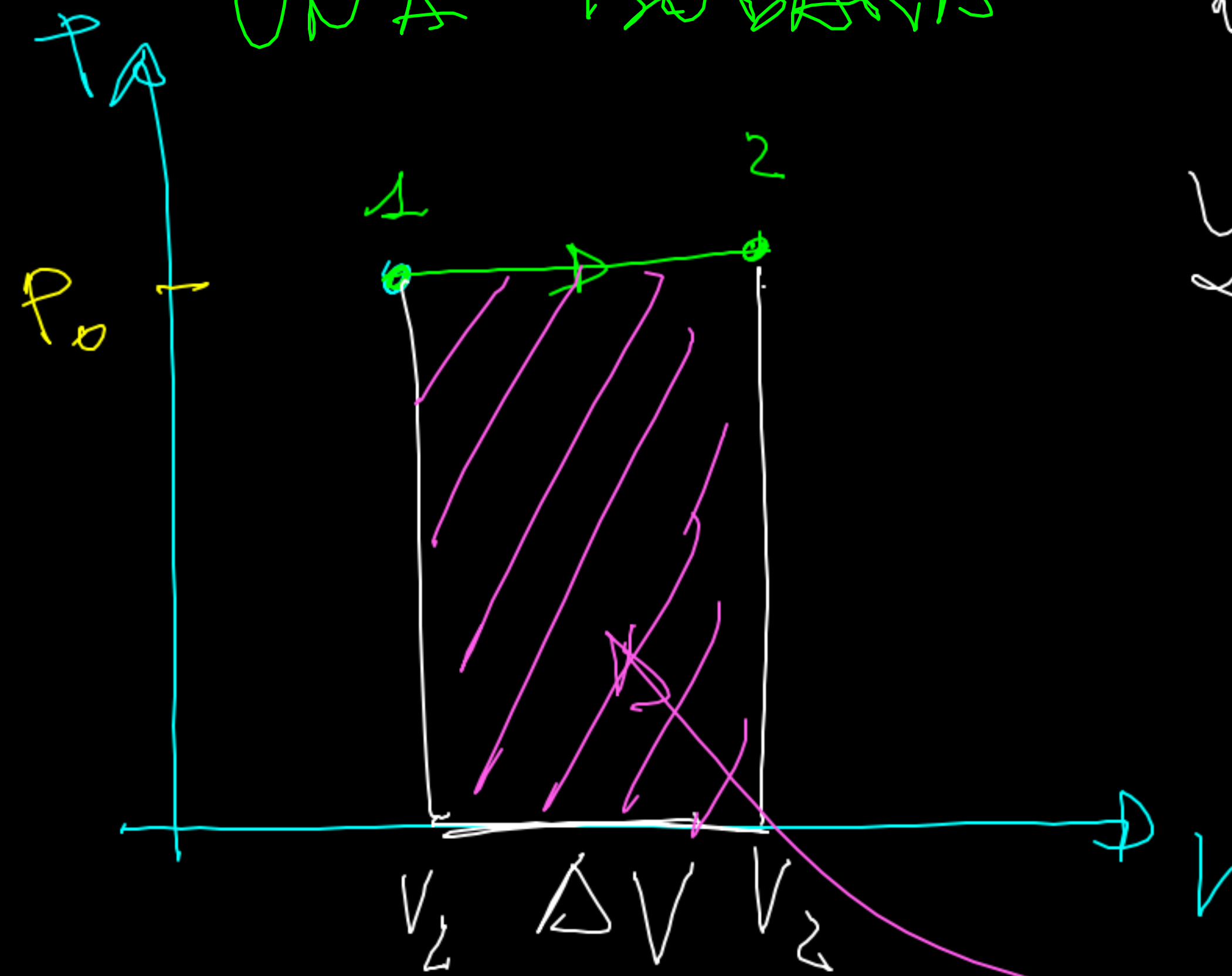
$\vec{F}_p \parallel dx$

$$dL = |\vec{F}_p| dx = p dV$$

$dV > 0 \Rightarrow dL > 0$
 il sistema fa lavoro sull'ambiente

$dV < 0 \Rightarrow dL < 0$
 il sistema "riceve" lavoro dall'amb.

LAVORO IN UNA ISOBARA



$$dL = p dV$$

$$L_{1 \rightarrow 2} = \int_1^2 p dV$$

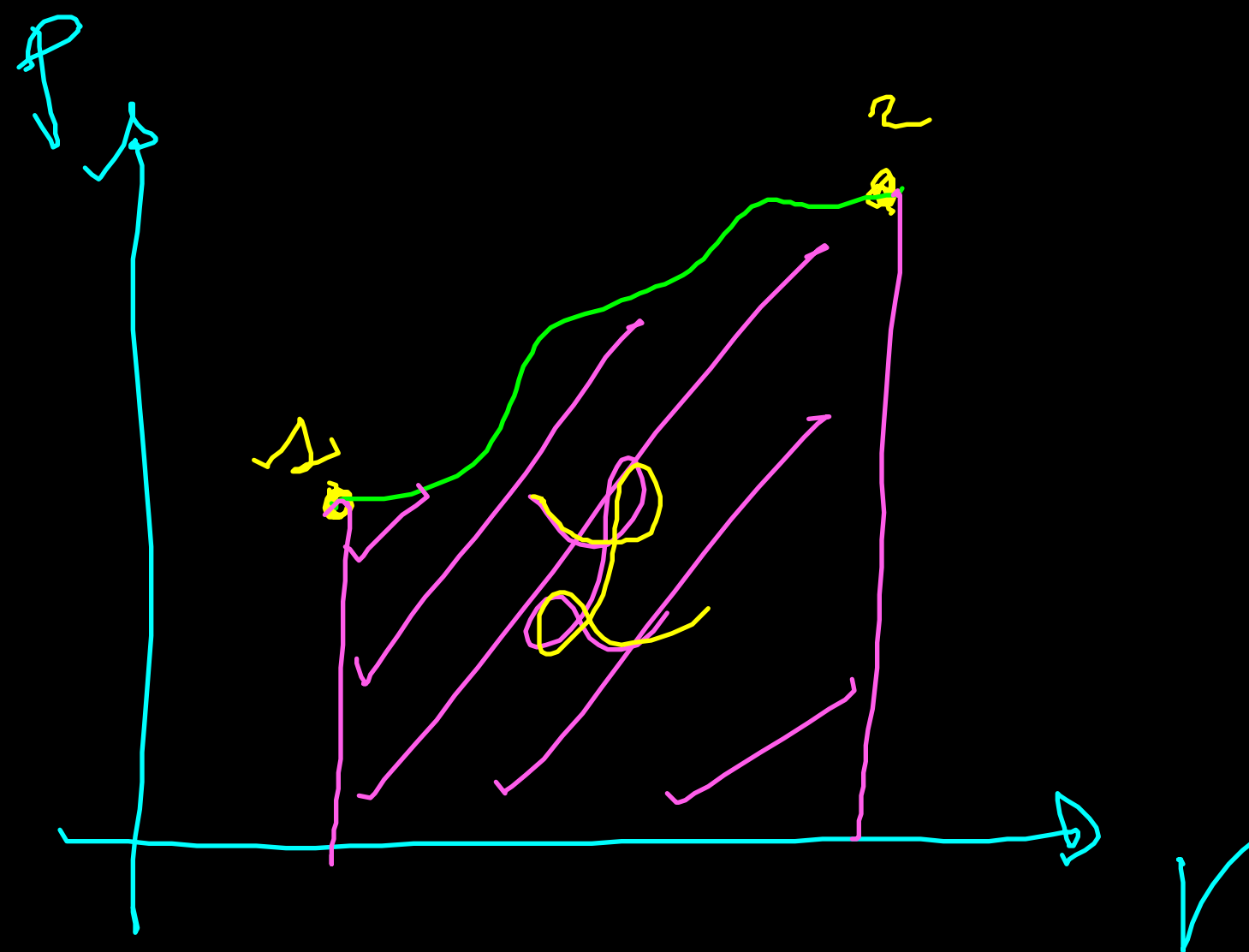
$$L_{1 \rightarrow 2} \text{ (ISOB.)} = p_0 \int_1^2 dV = p_0 \Delta V$$

$$= p_0 (V_2 - V_1)$$

$L_{1 \rightarrow 2}$

IN GENERALE

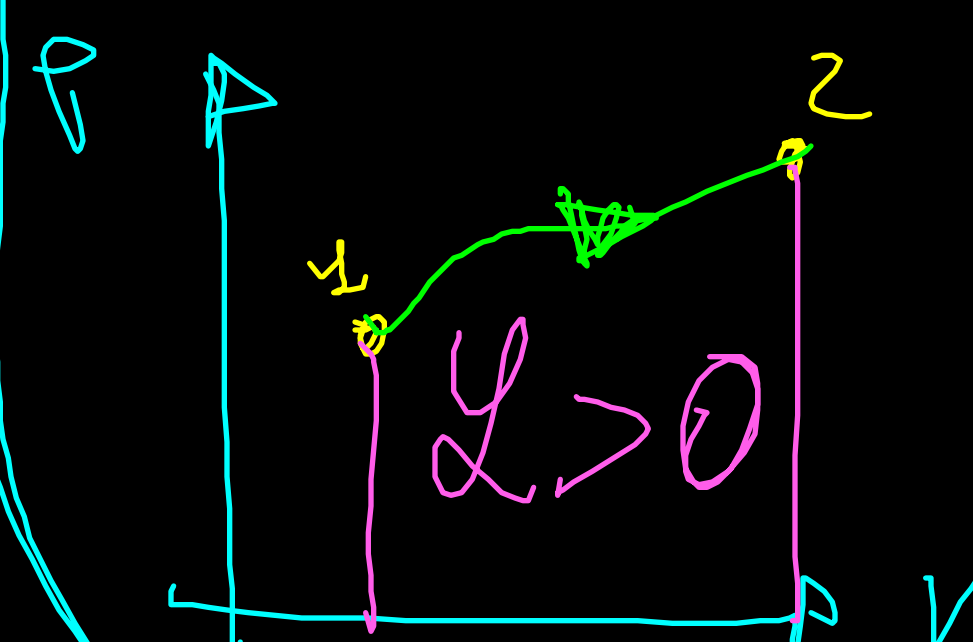
$$\int_{1 \rightarrow 2} p \, dV \Rightarrow$$



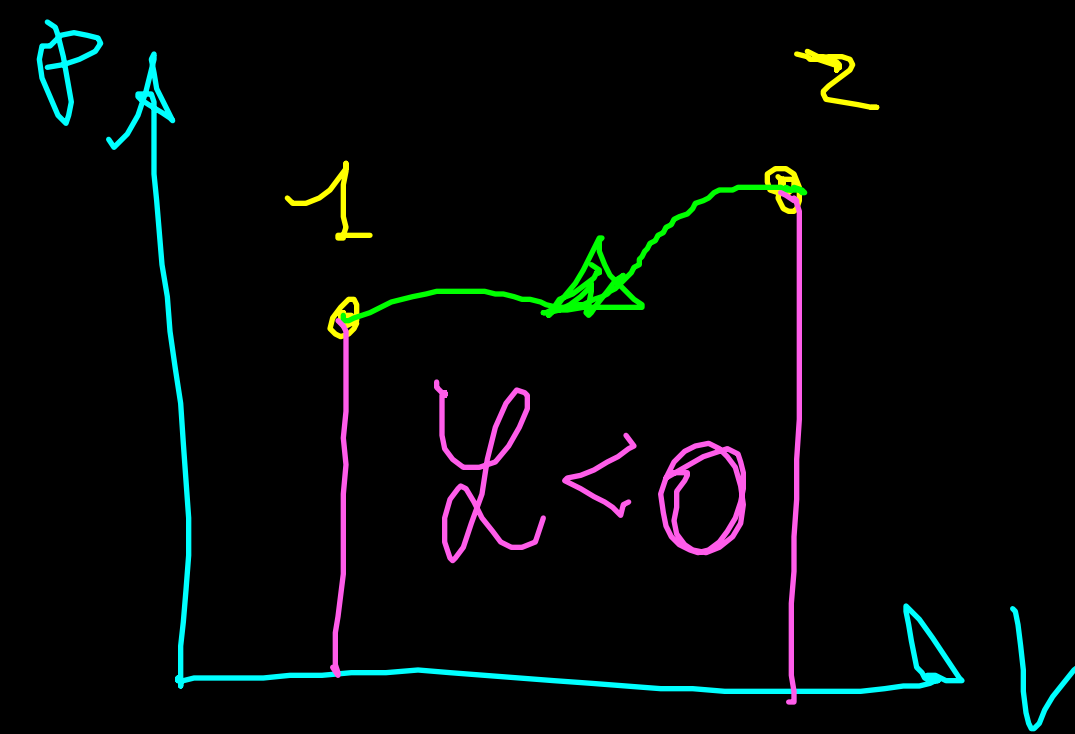
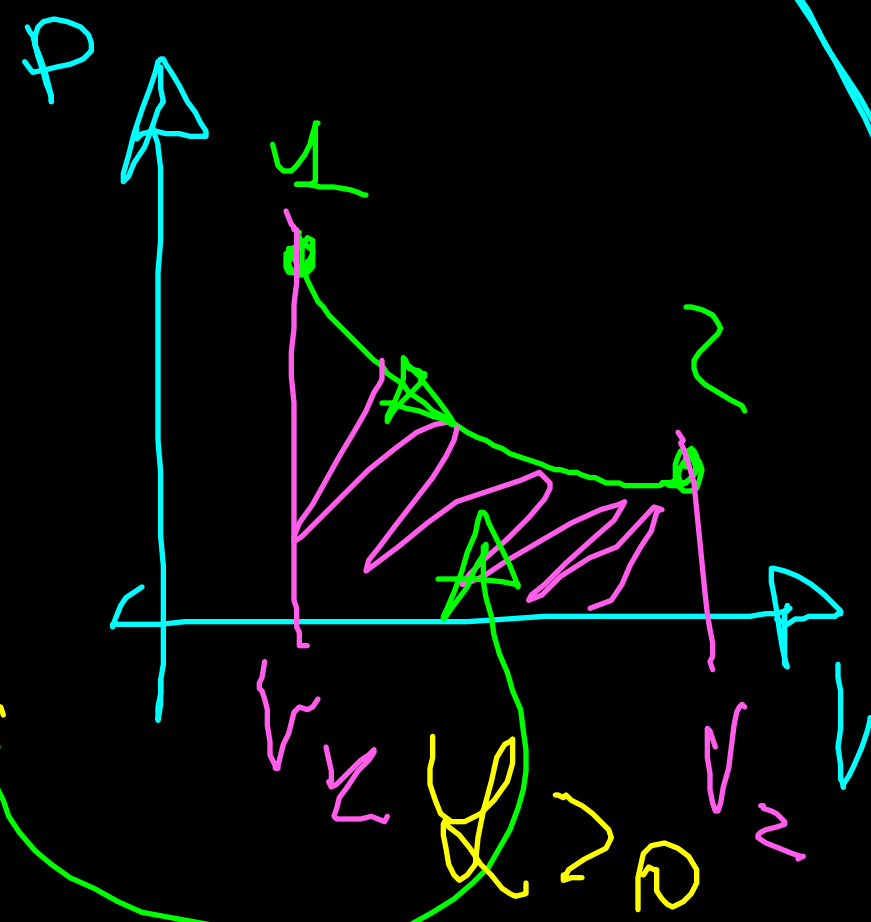
ESEMPIO: GAS PERFETTO

$$p = \frac{nRT}{V}$$

Per una transf. isoterma $T = T_0$

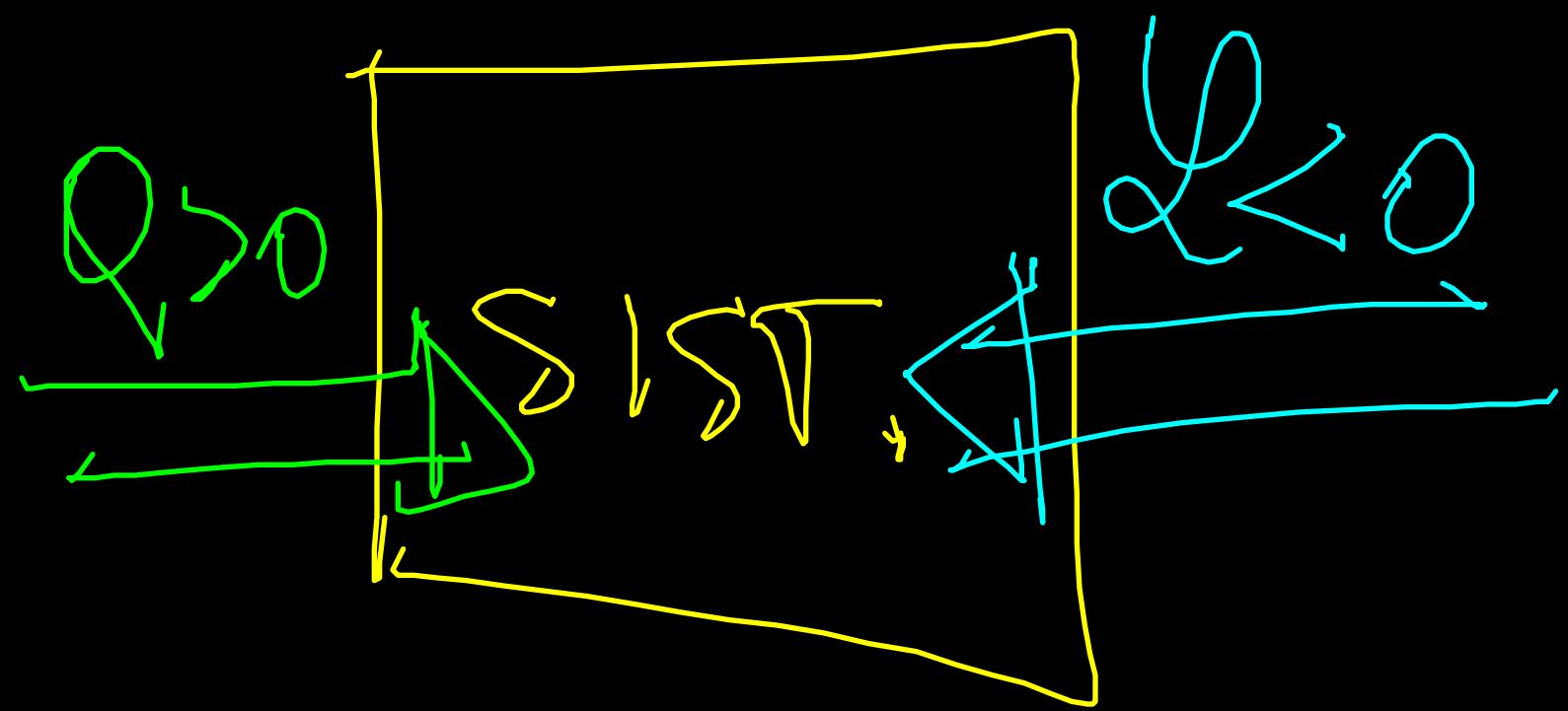
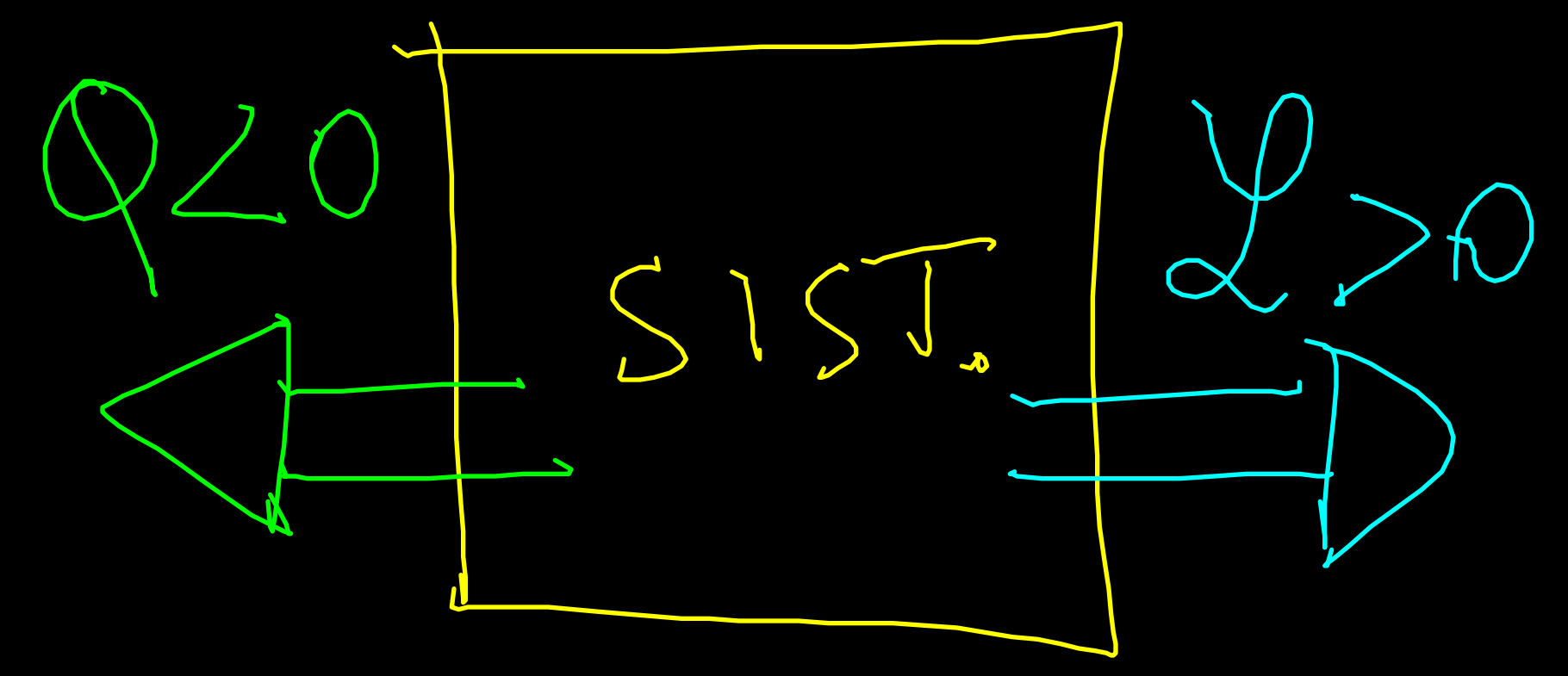
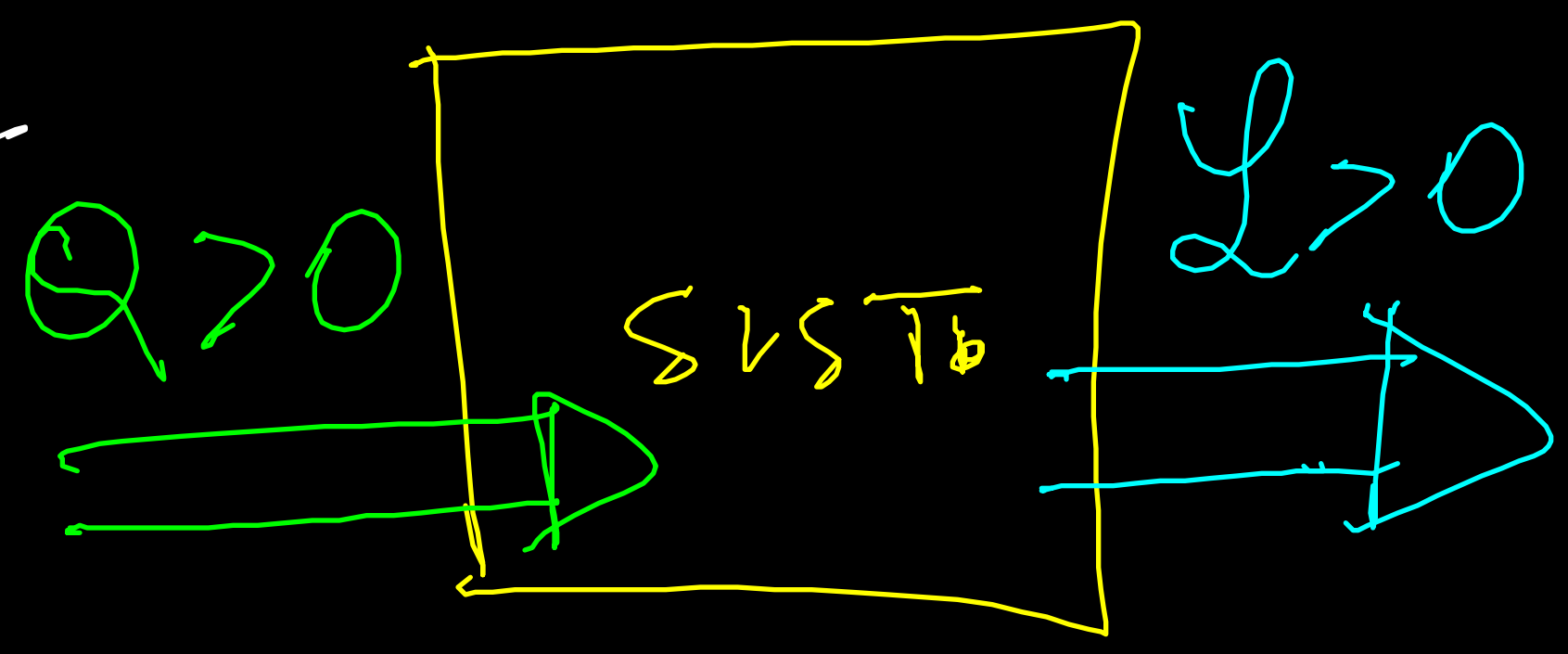


$$\int_{1 \rightarrow 2} p \, dV \stackrel{\text{isot}}{=} \int_{V_1}^{V_2} \frac{nRT_0}{V} dV = nRT_0 \ln \frac{V_2}{V_1}$$

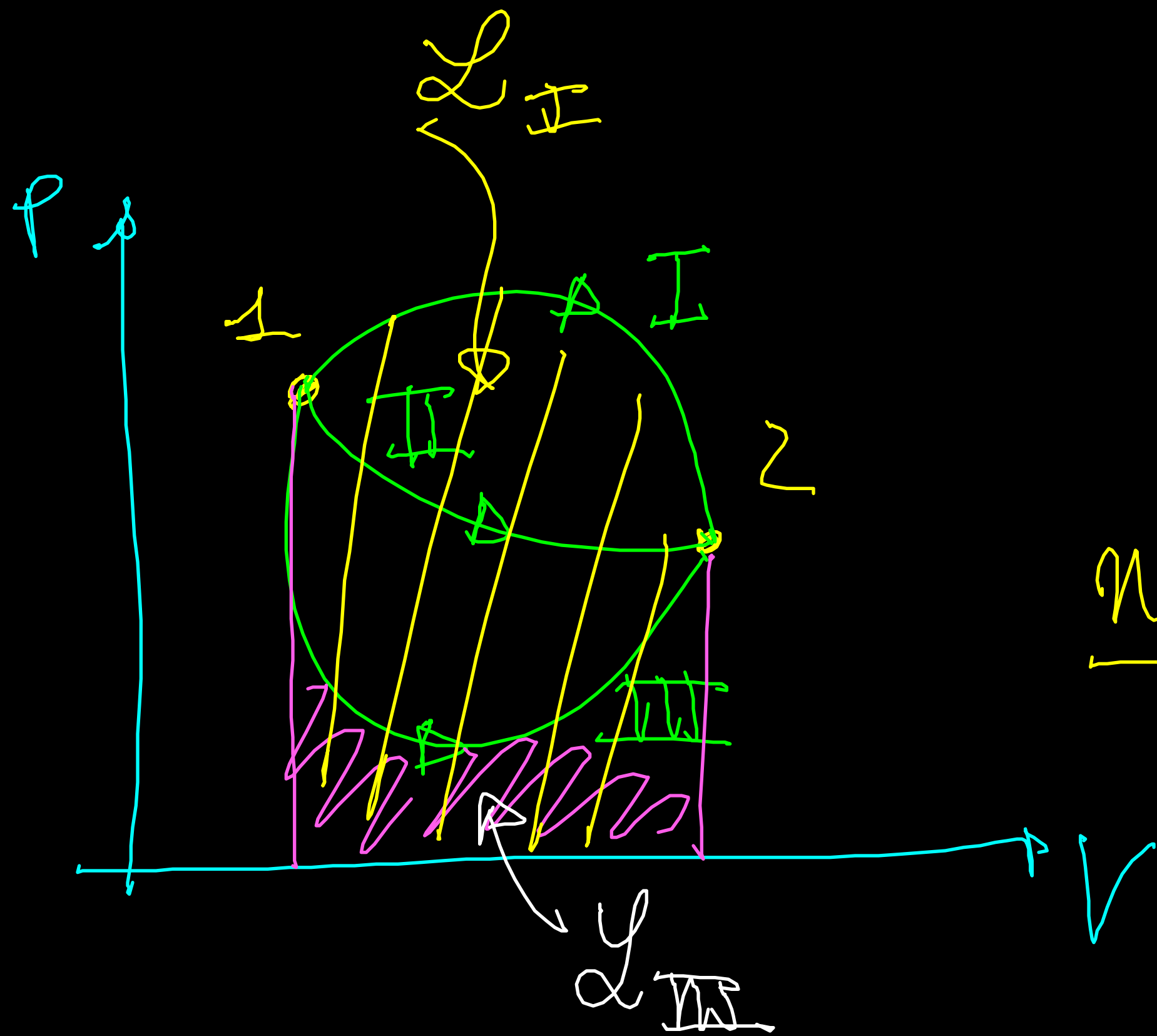


SCAMBI ENERGETICI SIST. ~~AD~~AMB.

AMB



ENERGIA NETTA TRASF. AL SISTEMA $Q - L$

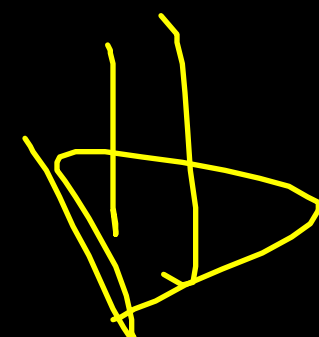


$$L_I \neq L_{II} \neq L_{III}$$

$$Q_I \neq Q_{II} \neq Q_{III}$$

Ma

$$Q_I - L_I = Q_{II} - L_{II} = Q_{III} - L_{III}$$



ESISTE UNA
FUNZIONE DI STATO
 $U(P, V, T, \dots)$

ENERGIA INTERNA

L'energia netta trasferita dipende solo dagli stati iniziale e finale e NON dalle trasformazioni

IN UNA TRASF. $i \rightarrow f$

$$Q - L = \Delta U = U(p_f, T_f, V_f) - U(p_i, T_i, V_i)$$

PRIMO PRINCIPIO DELLA TERMODINAMICA

↳ PRINCIPIO GEN. DI CONSERVAZIONE DELL'ENERGIA

In forma "infinitesimale"

$$\delta Q - \delta L = dU$$

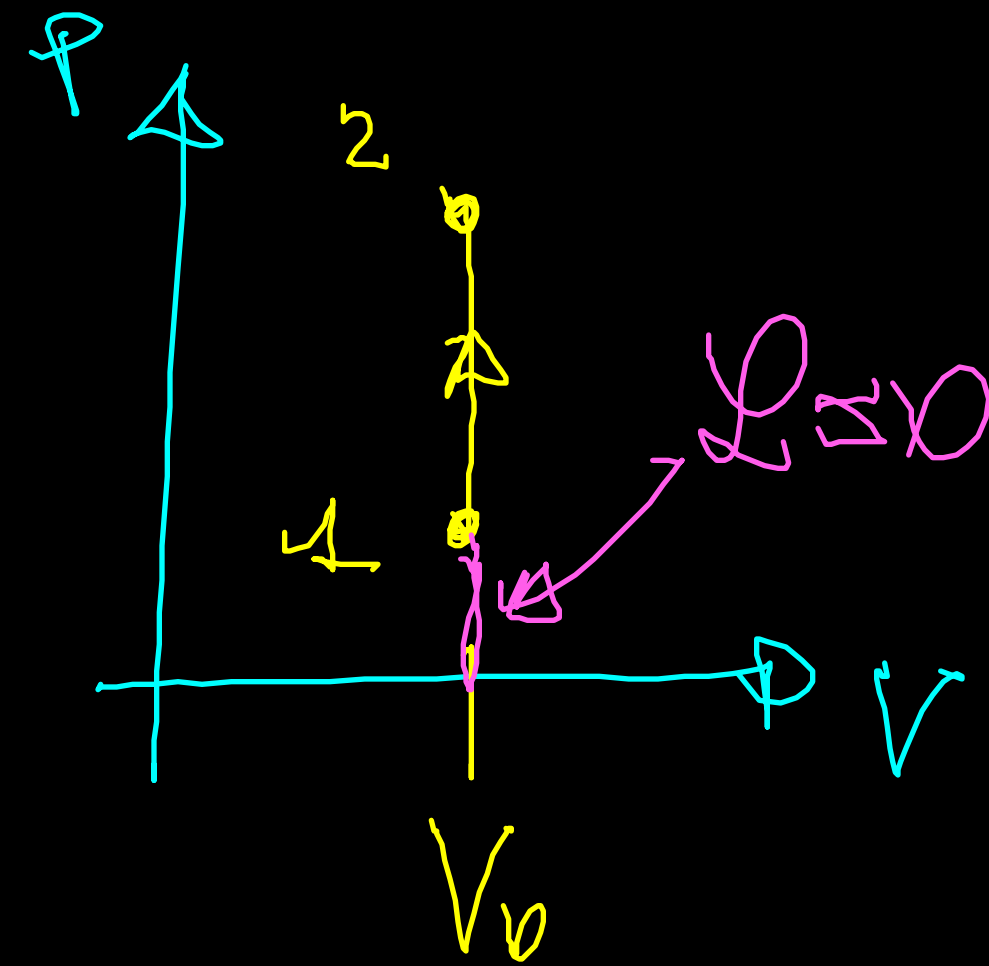
↳ DIFF. "ESATTO"

$\delta Q_1 \neq \delta Q_2$, $\delta L_1 \neq \delta L_2$, ma $dU_1 = dU_2$

TRASF. ISOCORA

$V = \text{constante}$

$$\underline{Q = \int p dV \approx 0}$$

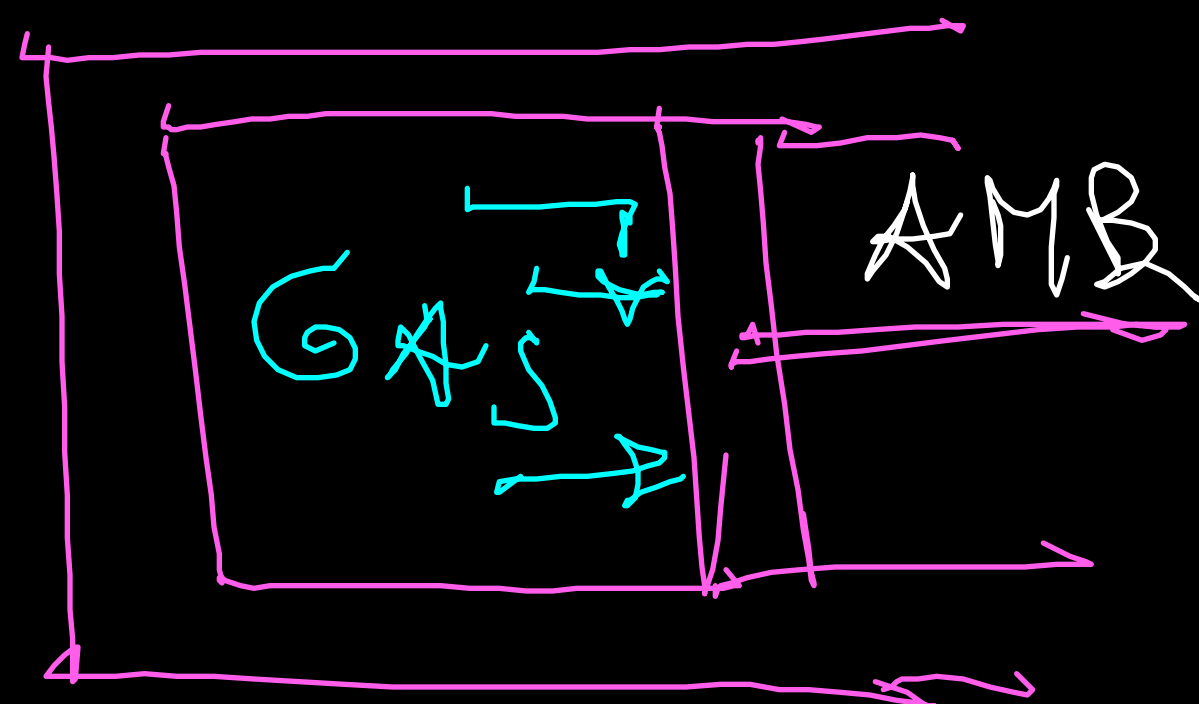
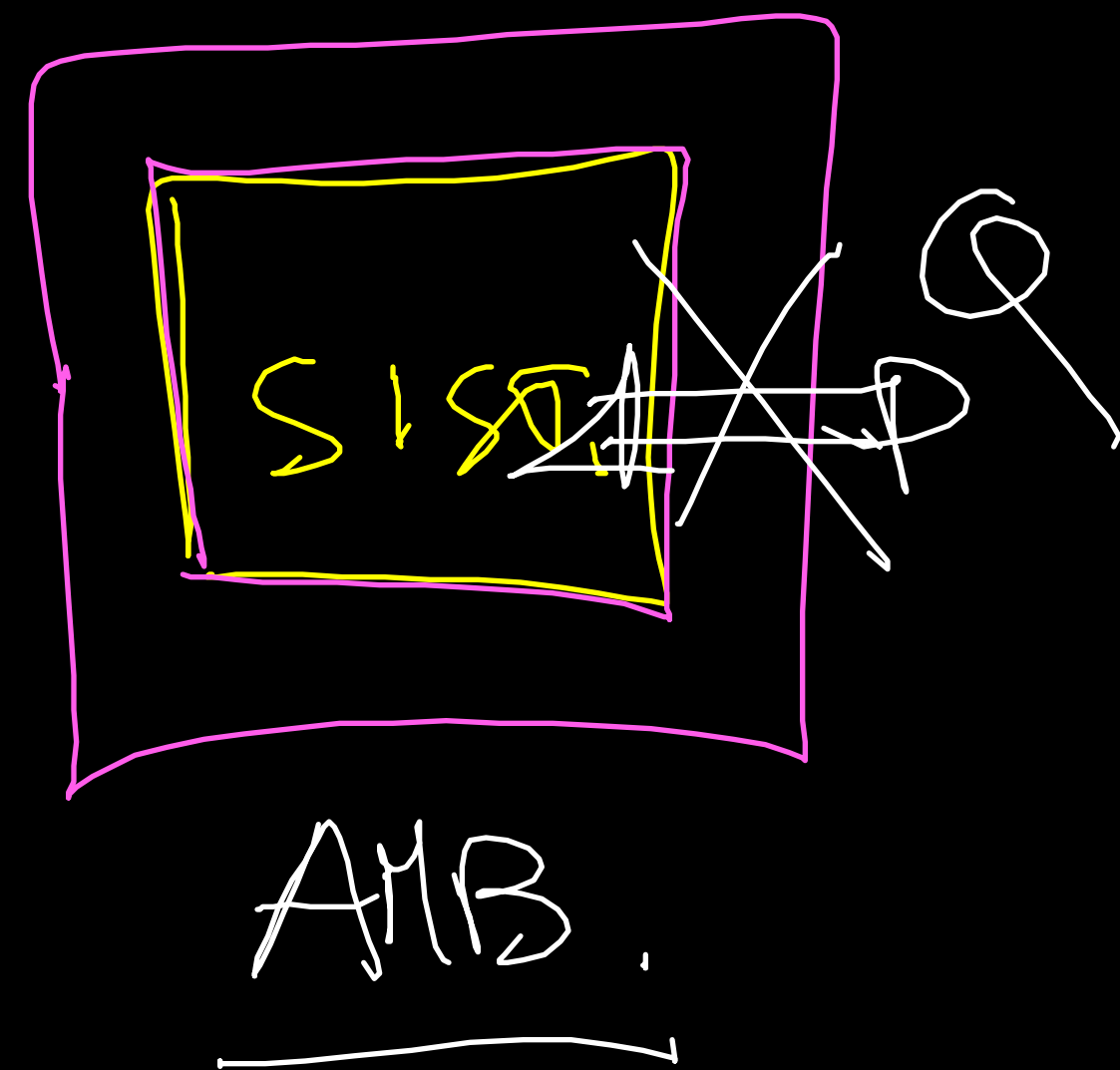


$$Q = 0$$

$$Q = \Delta U$$

ISOCORA

TRASF. ADIABATICA



$$Q = 0$$

$$-L = \Delta U$$

TRASF. ADIAB.

⇒ SI PUÒ DIMOSTRARE
CHE PER UN GAS PERFETTO

$$\text{ADIAB.} \rightarrow PV^\gamma = \text{cost}, \quad \gamma = \frac{C_p}{C_v}$$

TRASF. ISOBARA

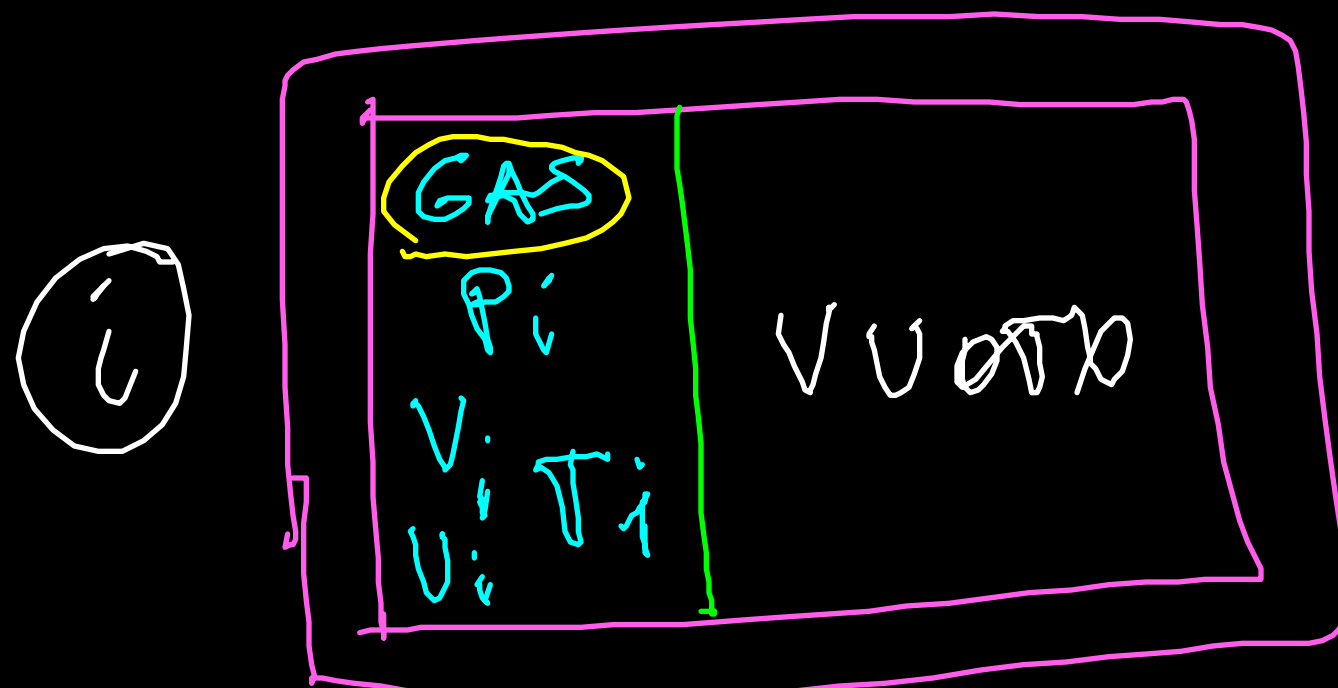
$$p = \text{cost.}$$

$$L = \int p dV \neq 0$$

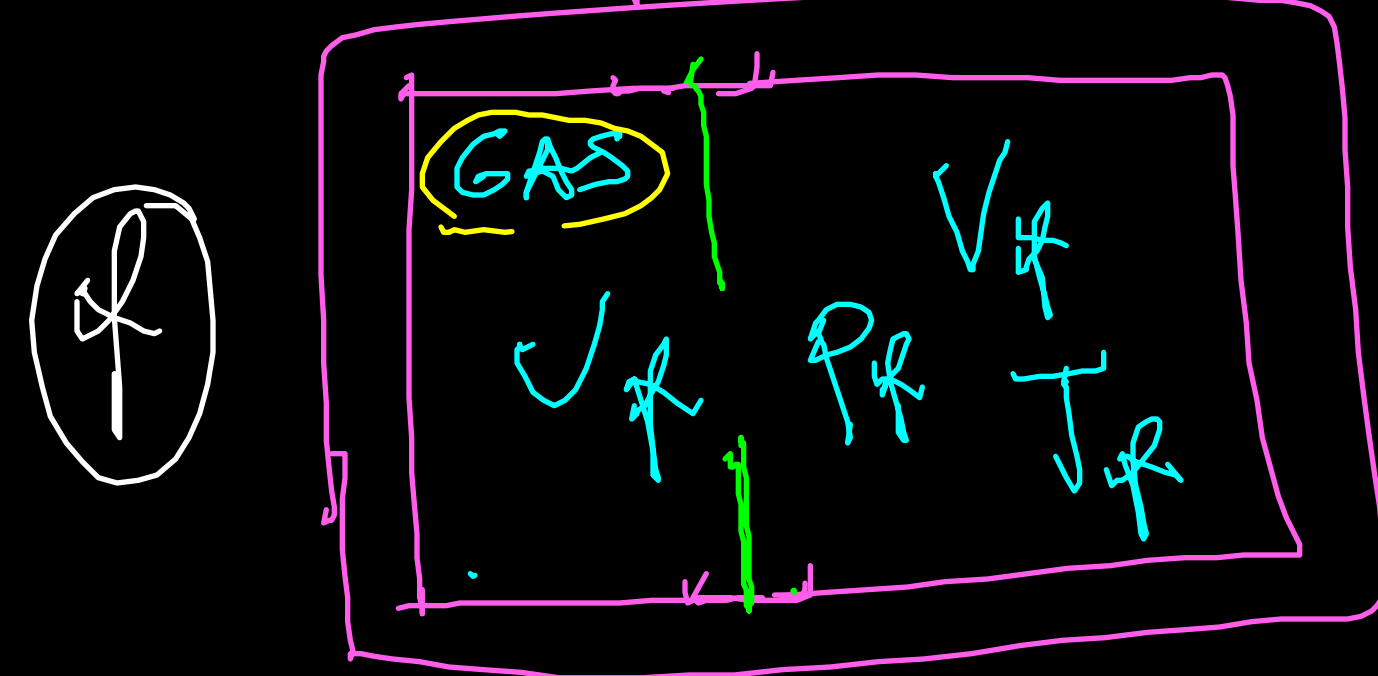
$$Q \neq 0$$

$$Q - L = \Delta U$$

ESPANSIONE "LIBERA" DI UN GAS



ADIAB.



2 var. indip, ed. es. V, T

$$L = 0 ; Q = 0 \Rightarrow \Delta U = 0$$

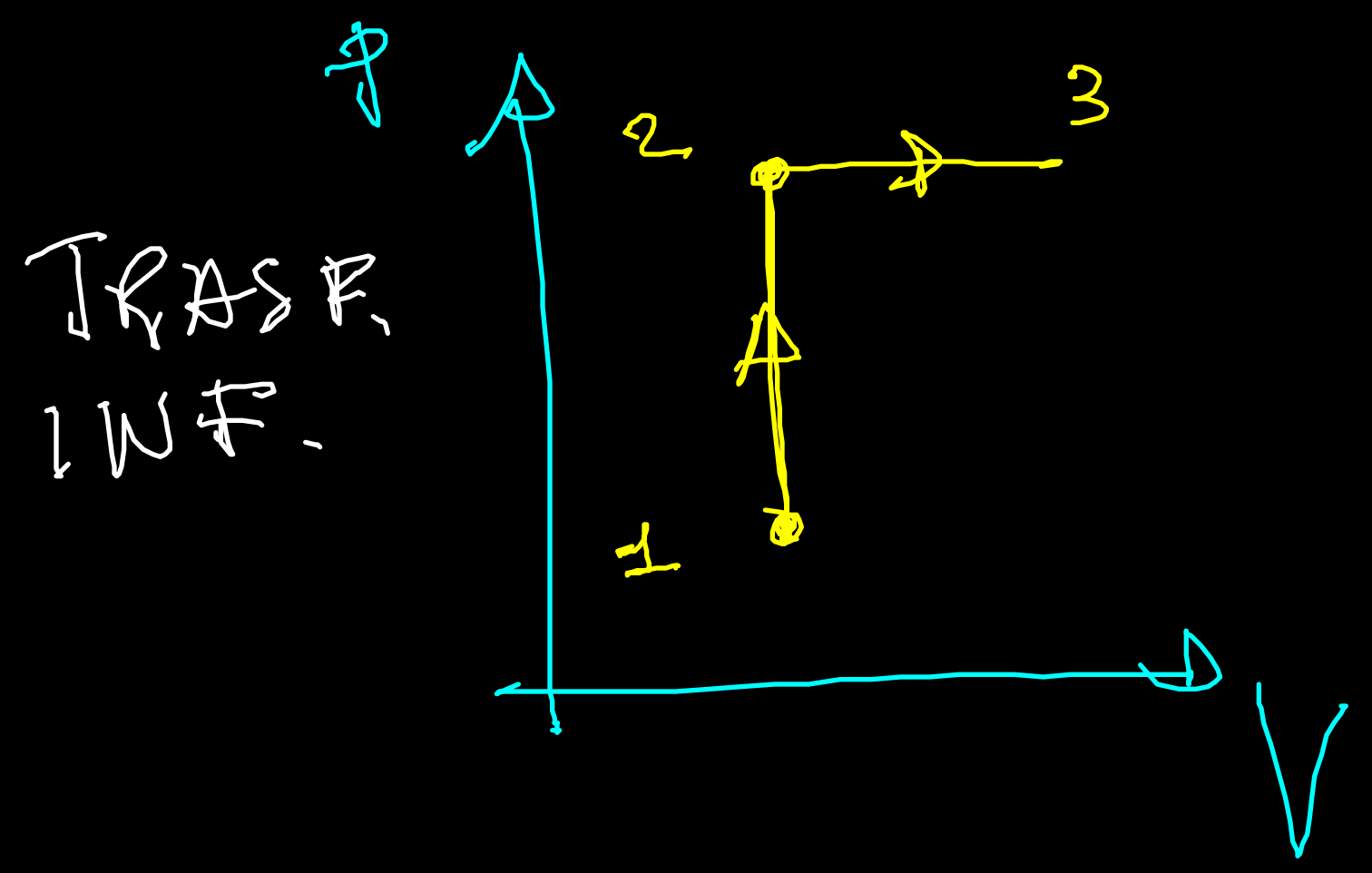
$$U_f = U_i \Rightarrow U_f(V_f, T_f) = U_i(V_i, T_i)$$

\Rightarrow SPERIM. $T_f \approx T_i$ (GAS PERFETTO $T_f = T_i = T$)

$$U_f(V_f, T) = U_i(V_i, T)$$

\Rightarrow U (GAS PERFETTO) DIPENDE SOLO DA T

→ n moli di gas perfetto $\delta Q - \delta Y = dU$



$1 \rightarrow 2$ Trasf. a V costante

$$\delta Q = n C_V dT$$

dal I principio $\delta Q - \delta Y = dU \Rightarrow \delta Q = dU$

$$dU = n C_V dT \Rightarrow U_{\text{GAS}} = n C_V T + \text{cost}$$

$2 \rightarrow 3$ Trasf. a p costante

$$\delta Q = n C_p dT$$

$$C_p = \frac{1}{n} \frac{\delta Q}{dT} = \frac{1}{n} \left(\frac{dU + \delta Y}{dT} \right)$$

$$C_p = \frac{1}{n} \left(\frac{dU}{dT} + \frac{\delta Y}{dT} \right) = \frac{1}{n} \left(n C_V dT + \frac{p dV}{dT} \right)$$

$$C_p = C_V + \frac{1}{n} \frac{p dV}{dT}$$

$$d(pV) = d(nRT) \Rightarrow p dV + V dp = nR dT$$

p è costante

$$C_p = C_V + \frac{1}{n} n R dT = C_V + R$$

$$C_p - C_V = R$$

RELAZ. DI MAYER

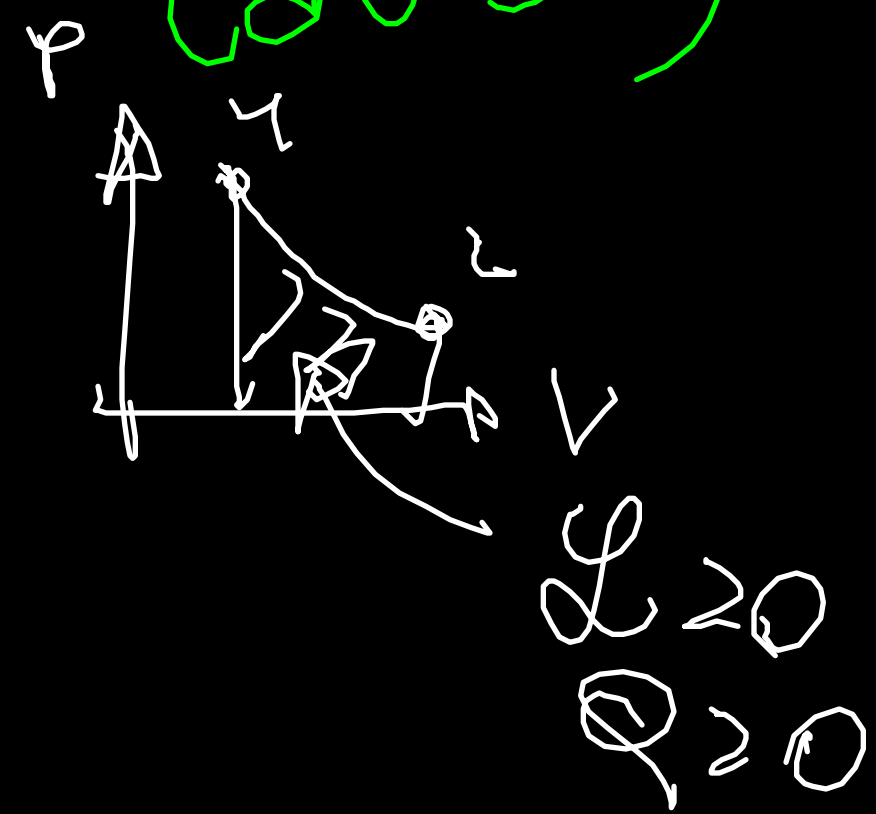
PER UN GAS PERFETTO

$$\delta Q - \delta L = dU \Rightarrow \delta Q = \delta L + n C_V dT = p dV + n C_V dT$$

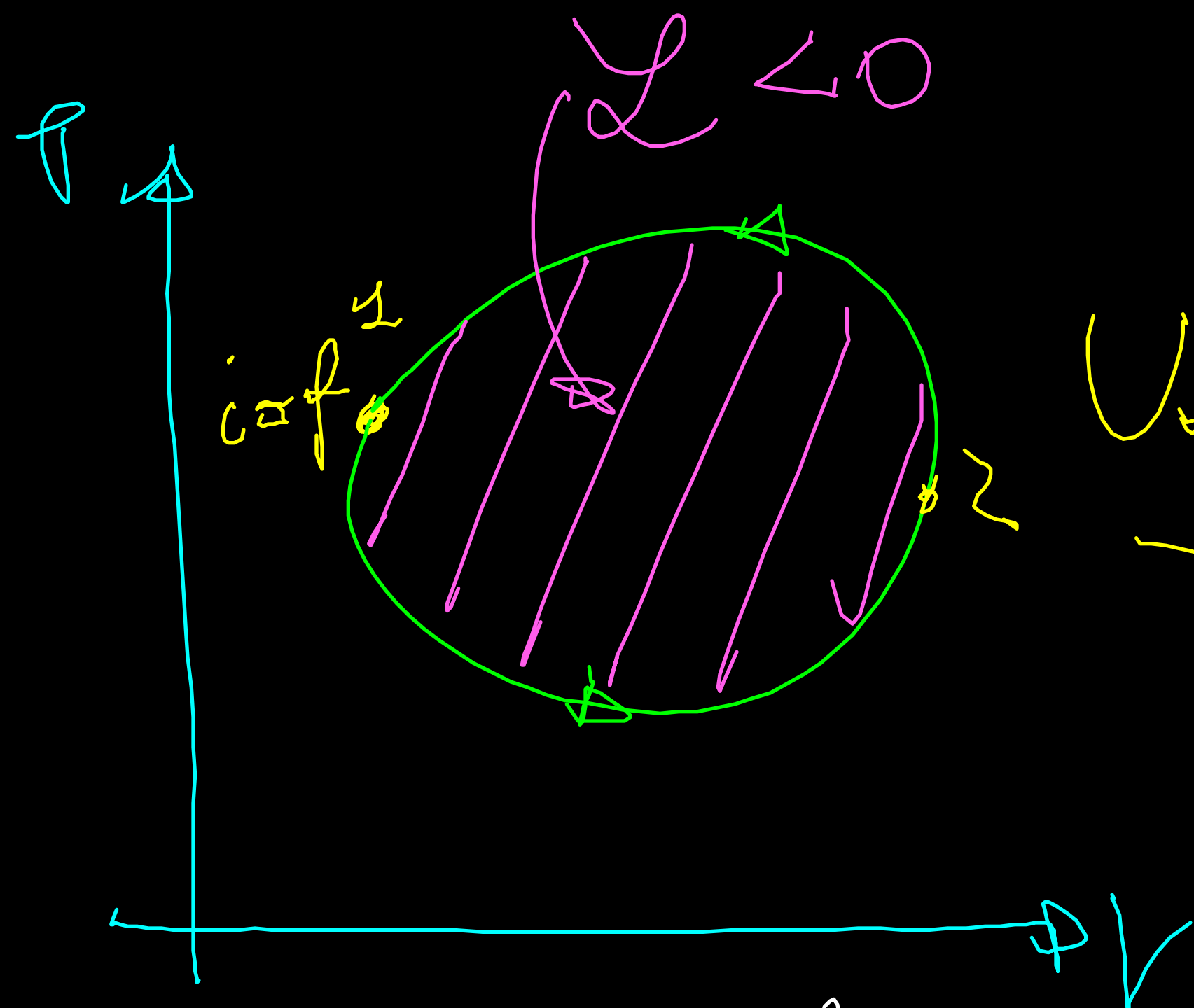
$$\delta Q = -V dp + n C_p dT$$

ISOTERMA DI UN GAS PERFETTO $\Rightarrow \delta Q = \delta L$
($dU = 0$)

$1 \rightarrow 2$, T costante $L = nRT \ln \frac{V_2}{V_1} = Q$



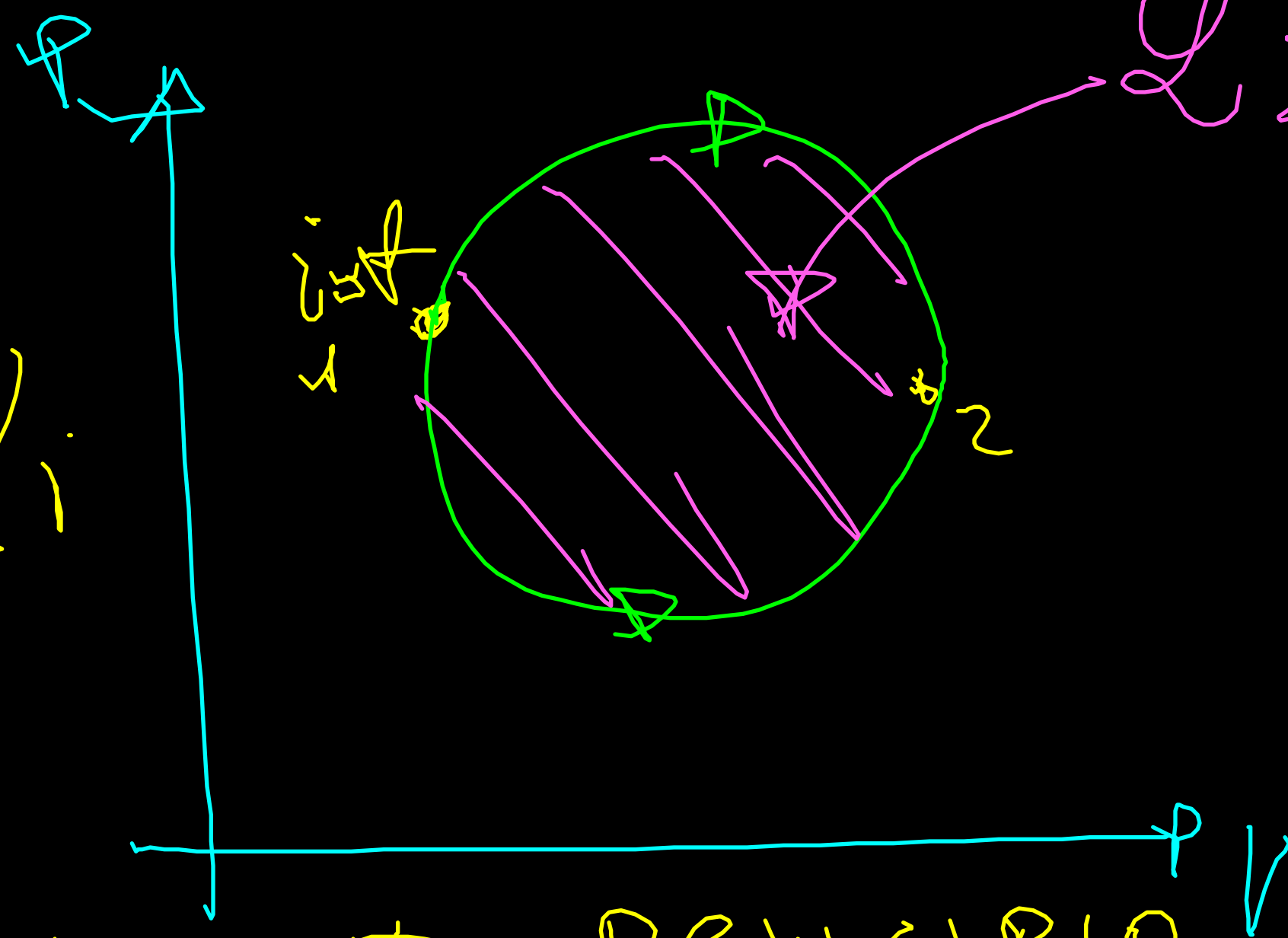
TRASFORMAZIONI CICLICHE



$$Q_{TOT} = Q_{1 \rightarrow 2} + Q_{2 \rightarrow 1} < 0$$

$$|Q_{12}| < |Q_{21}|, \quad \begin{matrix} Q_{21} < 0 \\ Q_{12} > 0 \end{matrix}$$

$$U_f = U_i$$



DAI PRINCIPII

$$Q - Q = \Delta U = 0$$

$$Q = Q$$