$$dU = \text{đ}Q + \underline{\text{đ}W}\xrightarrow{} \text{on}$$

$$dU = \text{đ}Q - p\,dV$$

$$\frac{\text{đ}Q_{rev}}{T} = dS$$

$$\oint \frac{\text{đ}Q}{T} \leq 0$$

$$dU = T\,dS - p\,dV$$

$$C_V = \left(\frac{\text{đ}Q}{dT}\right)_V = \left(\frac{\partial Q}{\partial T}\right)_V$$

$$\text{đ}Q = C_V\,dT$$

$$dU = C_V\,dT \rightarrow \text{ideal gases}$$

$$\text{đ}Q = dU + p\,dV$$

$$= \left(\frac{\partial U}{\partial T}\right)_V dT + \left[\left(\frac{\partial U}{\partial V}\right)_T + p\right] dV$$

$$\Rightarrow \left(\frac{\text{đ}Q}{dT}\right)_V = \left(\frac{\partial U}{\partial T}\right)_V = C_V$$

$$U \equiv U(T,p), \quad V \equiv V(T,p)$$

$$dU = \left(\frac{\partial U}{\partial T}\right)_p dT + \left(\frac{\partial U}{\partial p}\right)_T dp$$

$$\Rightarrow \text{đ}Q = \left[\left(\frac{\partial U}{\partial T}\right)_p + p\left(\frac{\partial V}{\partial T}\right)_p\right] dT + \left[\left(\frac{\partial U}{\partial p}\right)_T + p\left(\frac{\partial V}{\partial p}\right)_T\right] dp$$

$$C_p = \left(\frac{\partial Q}{\partial T}\right)_p$$

$$C_p = \left(\frac{\partial U}{\partial T}\right)_p + p\left(\frac{\partial V}{\partial T}\right)_p$$

$$C_p = \left(\frac{\partial U}{\partial T}\right)_p + \left(\frac{\partial (pV)}{\partial T}\right)_p$$

$$= \left[\frac{\partial (\underbrace{U+pV}_{H})}{\partial T}\right]_p = \left(\frac{\partial H}{\partial T}\right)_p$$

$$đQ = C_p\,dT$$

$$pV = nRT$$

$$\Rightarrow \left(\frac{\partial V}{\partial T}\right)_p = \frac{nR}{p}$$

$$C_p = C_V + nR$$

$$\Rightarrow C_p - C_V = nR$$

Adiabatic

$$C_V\,dT = dU$$

$$dU = -p\,dV$$

Ideal gas

$$\frac{dT}{T} = (1-\gamma)\,\frac{dV}{V}$$

$$\ln T = \ln V^{(1-\gamma)} + \text{constant}$$

$$\ln T - \ln V^{1-\gamma} = \text{const.}$$

$$\Rightarrow T V^{\gamma-1} = \text{constant}$$

$$\Rightarrow pV^{\gamma} = \text{constant}$$

Isothermal

$$dU = 0 \rightarrow \text{ideal gas}$$

$$đQ = p\,dV$$

$$\Delta Q = \int nRT\,\frac{dV}{V}$$

$$\Delta Q = nRT \ln\left(\frac{V_2}{V_1}\right)$$

$$= N k_B T \ln\left(\frac{V_2}{V_1}\right)$$

Carnot cycle

$$\eta = \frac{\Delta Q}{Q_{in}} = \frac{|Q_h| - |Q_l|}{|Q_h|}$$

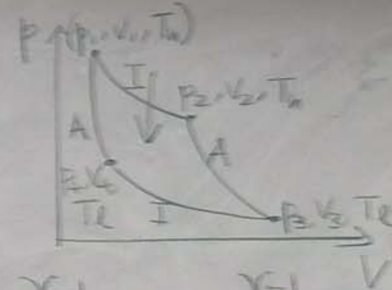
$$= 1 + \frac{Q_l}{Q_h} = 1 - \frac{|Q_l|}{|Q_h|}$$

Ideal gas

$$\eta = 1 - \frac{\cancel{nR}T_l \cancel{\ln\left(\frac{V_4}{V_3}\right)}}{\cancel{nR}T_h \cancel{\ln\left(\frac{V_1}{V_2}\right)}}$$

$$T_h V_2^{\gamma-1} = T_l V_3^{\gamma-1}$$

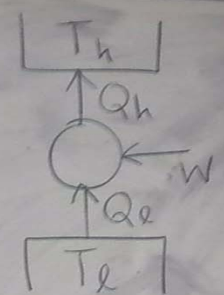
$$\Rightarrow \frac{T_h}{T_l} = \left(\frac{V_3}{V_2}\right)^{\gamma-1}$$



$$T_l V_4^{\gamma-1} = T_h V_1^{\gamma-1}$$

$$\Rightarrow \frac{T_h}{T_l} = \left(\frac{V_4}{V_1}\right)^{\gamma-1} \Rightarrow \frac{V_4}{V_1} = \frac{V_3}{V_2} \Rightarrow \frac{V_4}{V_3} = \frac{V_1}{V_2}$$

$$\eta = 1 - \frac{T_l}{T_h}$$



$$\eta_{fridge} = \frac{Q_l}{W}$$

$$\eta_{pump} = \frac{Q_h}{W}$$

$$= \frac{|Q_h|}{|Q_h| - |Q_l|} = \frac{1}{1 - \frac{|Q_l|}{|Q_h|}} = \frac{T_h}{T_h - T_l}$$

$$|W| = |Q_h| - |Q_l|$$