Chapter

Heat Engine → absorbs heat, produces work

can not convert all of it to work.

Heat comes in increases the entropy of the engine → to start the cycle over, entropy must be taken out of the engine

heat exhausted

$$\Delta U_{cycle} = 0 = Q + W_{gas}$$

$$0 = Q_H - Q_C + W_{gas}$$

Q_H: heat in

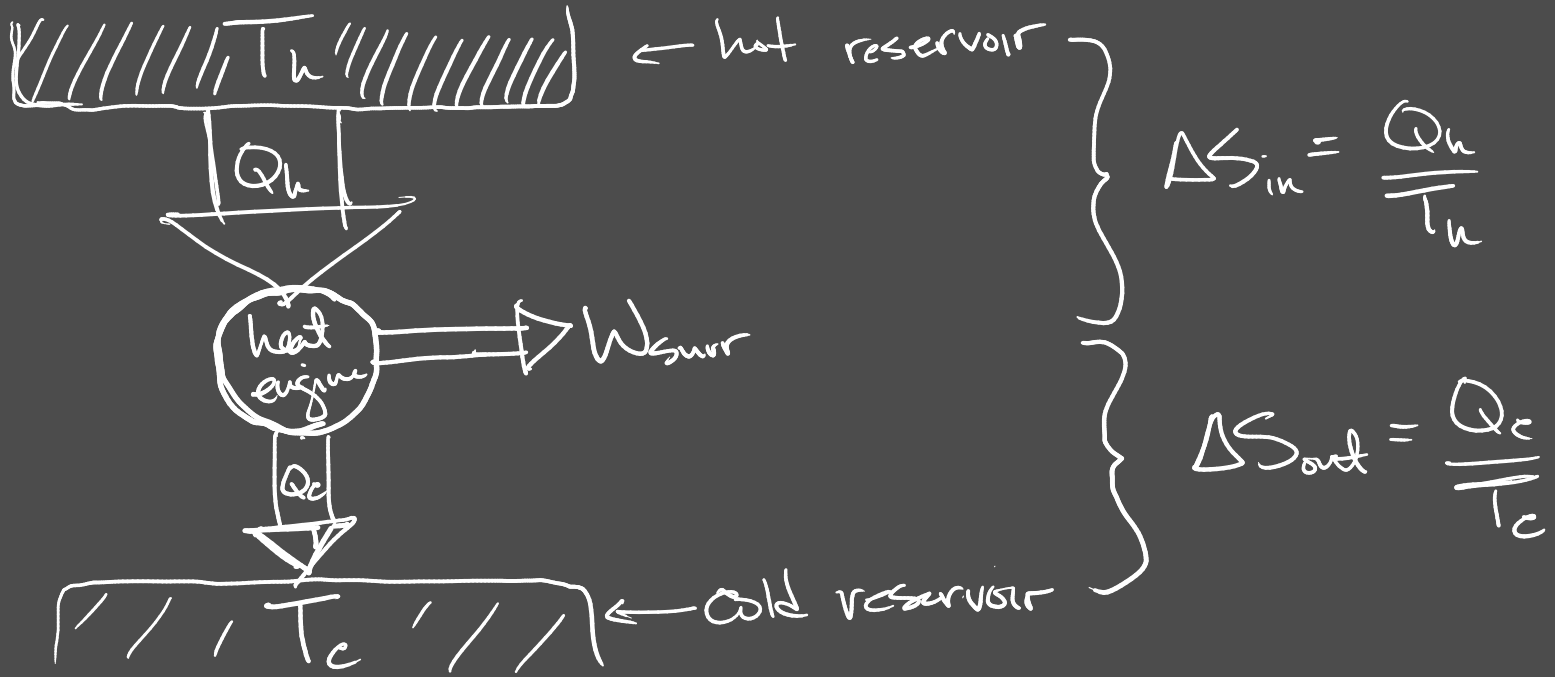
Q_C: heat out

$$-W_{gas} = Q_h - Q_c$$

$$\boxed{W_{surr} = Q_h - Q_c}$$ 1st Law of Thermo

$$\text{efficiency} \equiv \frac{\text{what you get}}{\text{what you pay for}} = \frac{\text{benefit}}{\text{cost}}$$

$$e = \frac{W_{surr}}{Q_h} = \frac{Q_h - Q_c}{Q_h} = 1 - \frac{Q_c}{Q_h}$$



at best, w/ no new entropy created

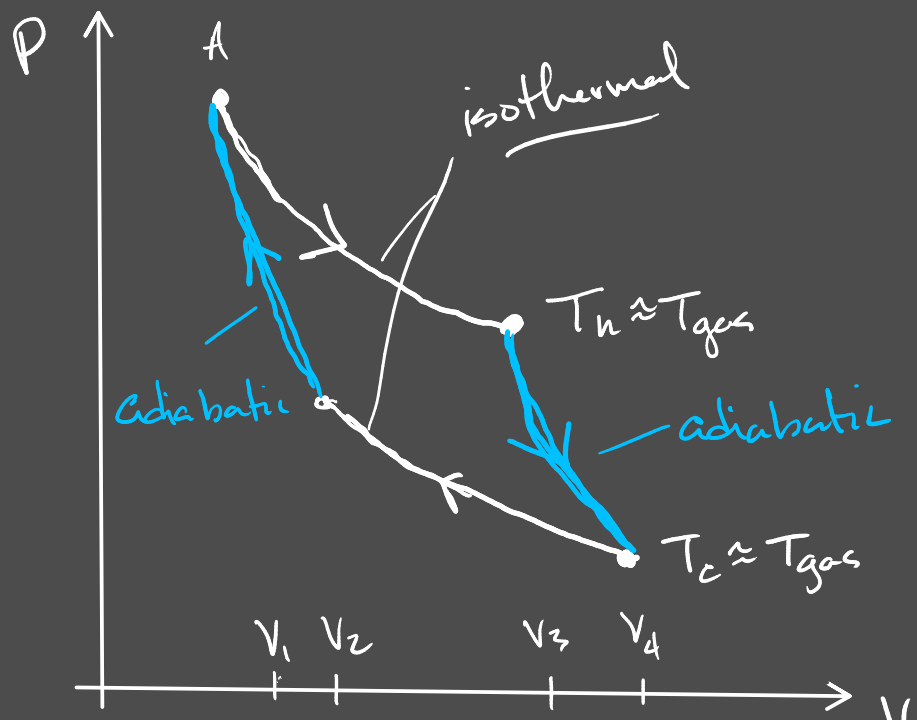
$$\Delta S_{in} = \Delta S_{out}$$

$$\frac{Q_h}{T_h} = \frac{Q_c}{T_c}$$

more realistically

$$\frac{Q_h}{T_h} \leq \frac{Q_c}{T_c}$$

$$\frac{T_c}{T_h} \leq \frac{Q_c}{Q_h} \Rightarrow e \leq 1 - \frac{T_c}{T_h}$$



- Carnot cycle → $e = 1 - \frac{T_c}{T_h}$

⇒ how can we achieve max efficiency

$$\frac{Q_h}{T_h} = \frac{Q_h}{T_{gas}}$$

Q_h removed from res

Q_h gained by working substance

$T_h = T_{gas}$

no heat will transfer

$T_{gas} + dT = T_h$

↓

keep this T_{gas} constant

isothermal expension

for exhaust,

$$\frac{Q_c}{T_c} = \frac{Q_c}{T_{gas}}$$

4.5 isothermal expansion

$$\cancel{dU}^{0} = \text{đ}Q + \text{đ}W$$

$$\text{đ}Q = -\text{đ}W = p\,dV$$

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

$$Q = Nk_BT\int_{V_i}^{V_f}\frac{dV}{V} = Nk_BT\ln\left(\frac{V_f}{V_i}\right)$$

$$Q_h = Nk_BT_h\ln\left(\frac{V_3}{V_1}\right)$$

$$Q_c = Nk_BT_c\ln\left(\frac{V_2}{V_4}\right)$$

$$e = 1 - \frac{Q_c}{Q_h} \stackrel{?}{=} 1 - \frac{T_c}{T_h}$$

$$1 - \frac{T_c\ln\left(\frac{V_2}{V_4}\right)}{T_h\ln\left(\frac{V_3}{V_1}\right)} = 1 - \frac{T_c}{T_c} \quad \text{only if} \quad \underbrace{\frac{V_2}{V_4} = \frac{V_3}{V_1}}_{\text{prove this}} \quad \checkmark$$

adiabatic expansion

$$V_f T_f^{f/2} = V_i T_i^{f/2}$$