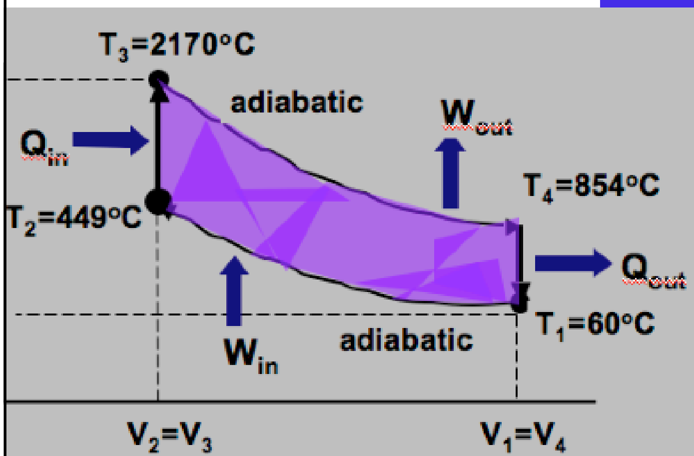
Reminders 02-06-08:
-Heat Engine Worksheet Due today
-4th Homework due Feb 12.
-Read Ch. 20 and Chapters 4&5 of Understanding Thermodynamics
-Exam 1 February 13
-POW 3 due Feb 13

Outline:
-2nd Law of Thermodynamics
-Carnot Engine and Theorem
-Entropy



Otto Cycle (1876)

$$w = q_H - q_C$$

$$q_H = nC_V(T_3 - T_2);\; q_C = nC_V(T_4 - T_1)$$

$$e = W/Q_H = 1 - q_C/q_H$$

$$e = 1 - (T_4 - T_1)/(T_3 - T_2)$$

$$T_1 V_1^{\gamma-1} = T_2 V_2^{\gamma-1};\; T_3 V_3^{\gamma-1} = T_4 V_4^{\gamma-1}$$

$$V_2 = V_3;\; V_1 = V_4$$

$$T_2 = T_1\left(\frac{V_1}{V_2}\right)^{\gamma-1};\quad T_3 = T_4\left(\frac{V_4}{V_3}\right)^{\gamma-1} = T_4\left(\frac{V_1}{V_2}\right)^{\gamma-1}$$

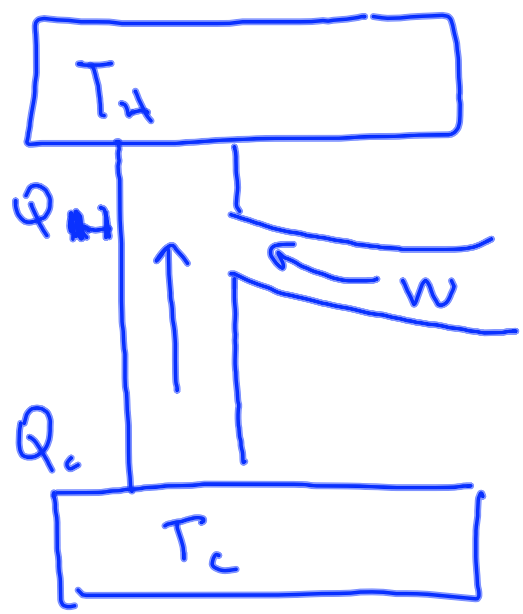
$$e = \frac{Q_H - Q_C}{Q_H} = 1 - \frac{Q_C}{Q_H}$$

$$= 1 - \frac{nC_v(T_4 - T_1)}{nC_v(T_3 - T_2)}$$

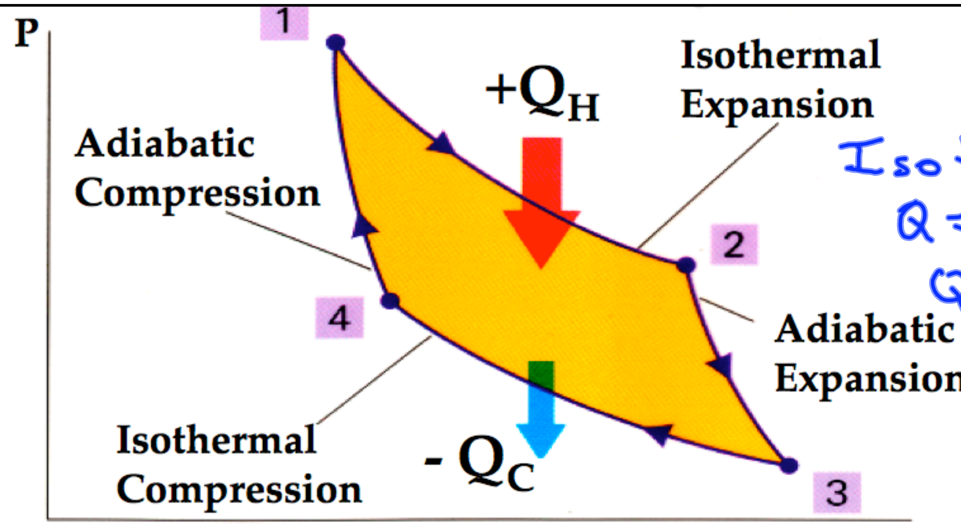
$$e = 1 - \frac{T_4 - T_1}{T_4\left(\frac{V_1}{V_2}\right)^{\gamma-1} - T_1\left(\frac{V_1}{V_2}\right)^{\gamma-1}}$$

$$= 1 - \frac{T_4 - T_1}{\left(\frac{V_1}{V_2}\right)^{\gamma-1}(T_4 - T_1)} = 1 - \frac{1}{\left(\frac{V_1}{V_2}\right)^{\gamma-1}}$$

$$e = 1 - \frac{1}{r^{\gamma-1}}$$



Refrigerator



Isoth.

$Q = W$

$Q_H = W_{12}$

$Q_c = W_{34}$

$$Q_h = W_{12} = nRT_H \ln(V_2/V_1)$$

$$Q_c = W_{34} = nRT_C \ln(V_4/V_3) = -nRT_C \ln(V_3/V_4)$$

$$\frac{Q_C}{Q_H} = -\frac{T_C}{T_H}\frac{\ln\left(V_3/V_4\right)}{\ln\left(V_2/V_1\right)}$$

$$T_H V_2^{\gamma-1} = T_C V_3^{\gamma-1}$$

$$T_H V_1^{\gamma-1} = T_C V_4^{\gamma-1} \quad \Rightarrow V_2/V_1 = V_3/V_4$$

$$\frac{Q_C}{Q_H} = -\frac{T_C}{T_H} \quad or \quad \left|\frac{Q_C}{Q_H}\right| = \frac{T_C}{T_H} \quad \Rightarrow e_c = 1 - \frac{T_C}{T_H}$$

$$Q_h = W_{12} = nRT_H \ln(V_2/V_1)$$

$$Q_c = W_{34} = nRT_C \ln(V_4/V_3) = -nRT_C \ln(V_3/V_4)$$

$$\frac{Q_C}{Q_H} = -\frac{T_C}{T_H}\,\frac{\ln\left(V_3/V_4\right)}{\ln\left(V_2/V_1\right)}$$

$$T_H V_2^{\gamma-1} = T_C V_3^{\gamma-1}$$

$$T_H V_1^{\gamma-1} = T_C V_4^{\gamma-1} \quad \Rightarrow V_2/V_1 = V_3/V_4$$

$$\frac{Q_C}{Q_H} = -\frac{T_C}{T_H} \quad or \quad \left|\frac{Q_C}{Q_H}\right| = \frac{T_C}{T_H} \quad \Rightarrow e_c = 1 - \frac{T_C}{T_H}$$

- A certain refrigerator has a motor power rating of 88J. Consider it an ideal reversible refrigerator. If the outside temperature is 26° C, how long will it take to freeze 2.5 kg of water if we put it in at room temperature? Do you expect time to be larger or smaller for a real refrigerator? How should we define the efficiency of the refrigerator? Show we define in terms of the desired output/desired input, or should we define it in terms of the Carnot heat engine? Does it matter?

$$Q = mc\Delta T \pm mL_f$$

$$= (2.5\,kg)(4186\,J/kg\,C°)(-26) - (2.5\,kg)(3.34\times10^5\,J/kg)$$

$$= -1.1\times10^6\,J$$

Power Rating of motor 88W

$$e = 1 - \frac{T_c}{T_H} = 1 - \frac{273}{299} = .087$$

$$\frac{P_w}{P_H} = .087 \qquad P_H = \frac{88W}{.087} = 1011W$$

$$P_c = 1011W - 88W = 923W$$

$$t = \frac{1.10\times10^6\,J}{923\,J/s} = 1200s = \frac{1}{3}\text{ hour}$$