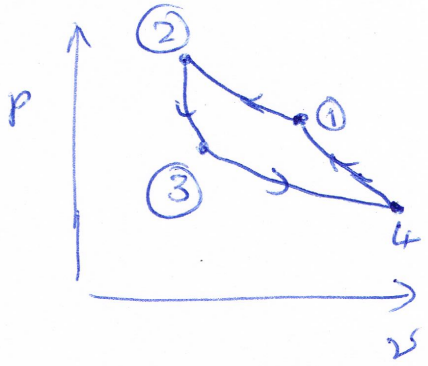
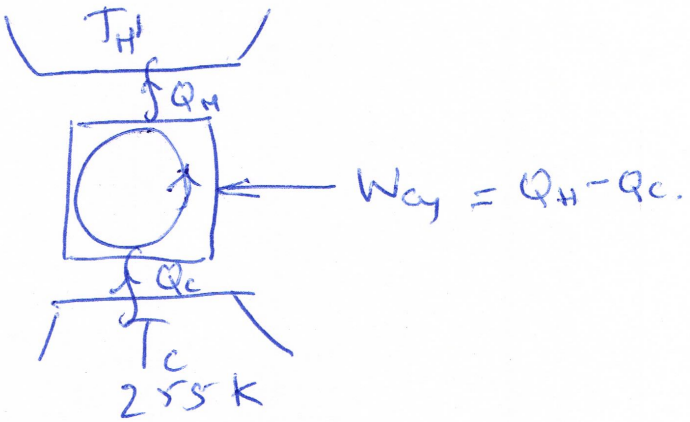
QUIZ 5

CARNOT REFRIGERATION CYCLE:

Air as an ideal gas.





(a) ① → ② Isothermal compression $p_1 = 135$ kPa

$m = 0.4$ kg. $V_1 = 0.3 m^3$

$$T_1 = \frac{p_1 V_1}{mR} = \frac{135.10^3 \frac{N}{m^2} . 0.3 m^3}{0.4 kg . \frac{8314}{28.97} \frac{J}{kg K}} = 352.8 K.$$

(b) Coefficient of Performance $\beta = \frac{Q_c}{W_{cy}} = \frac{Q_c}{Q_H - Q_c}$.

$$\frac{Q_c}{Q_H} = \frac{T_c}{T_H} \quad \therefore \beta = \frac{\left(\frac{T_c}{T_H}\right)}{\left(1 - \frac{T_c}{T_H}\right)} = \frac{\left(\frac{255}{352.8}\right)}{\left(1 - \frac{255}{352.8}\right)}$$

$$\left[\frac{Q_c}{Q_H - Q_c}\right] = \left[\frac{\left(\frac{Q_c}{Q_H}\right)}{1 - \left(\frac{Q_c}{Q_H}\right)}\right] \qquad \beta = 2.607.$$

(c) Isothermal compression: $pV = mRT = \text{const}$

① - ②

$\therefore$ polytropic with $n = 1$

$$\therefore W_{12} = \int_1^2 p\,dV = p_1 V_1 \ln\frac{V_2}{V_1} = 135\,\frac{kN}{m^2} \cdot 0.3\,m^3 \ln\left(\frac{0.06}{0.3}\right)$$

$$\therefore W_{12} = -65.18\ kJ$$

$$Q_{12} - W_{12} = m(u_2 - u_1)$$

Isothermal ideal gas $\therefore u_2 = u_1$

$$\therefore Q_{12} = W_{12} = \underline{\underline{-65.18\ kJ}}.$$

$$Q_{12} = -Q_H \qquad Q_{34} = Q_C.$$

$$\frac{Q_C}{Q_H} = \frac{T_C}{T_H} \quad \therefore \quad Q_{34} = \left(\frac{T_C}{T_H}\right)(-Q_{12}).$$

$$\therefore Q_{34} = \left(\frac{255}{352.8}\right) \cdot 65.18\ kJ = 47.11\ kJ.$$

(d) $$W_{cy} = Q_H - Q_C = (65.18 - 47.11)\ kJ$$

$$= \underline{\underline{18.07\ kJ}}.$$

(e) $$\beta = 2.5 = \frac{Q_C}{Q_H - Q_C} \quad \therefore \beta(Q_H - Q_C) = Q_C$$

$$Q_C = \frac{\beta Q_H}{1+\beta} \qquad Q_H = 70\ kJ.$$

$$Q_C = \frac{2.5}{3.5} \cdot 70\ kJ = 50\ kJ.$$

$$-\sigma_{cy} = -\frac{Q_H}{T_H} + \frac{Q_C}{T_C} = \frac{50}{255} - \frac{70}{352.8} = -0.00233\,\frac{kJ}{K}$$

$\therefore \sigma_{cy} = +2.33 \frac{J}{K}.$