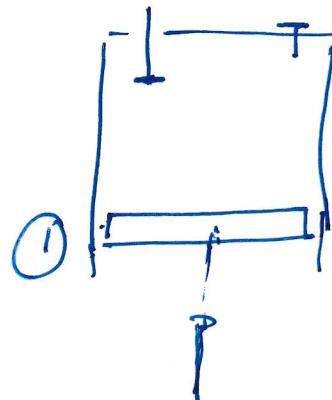
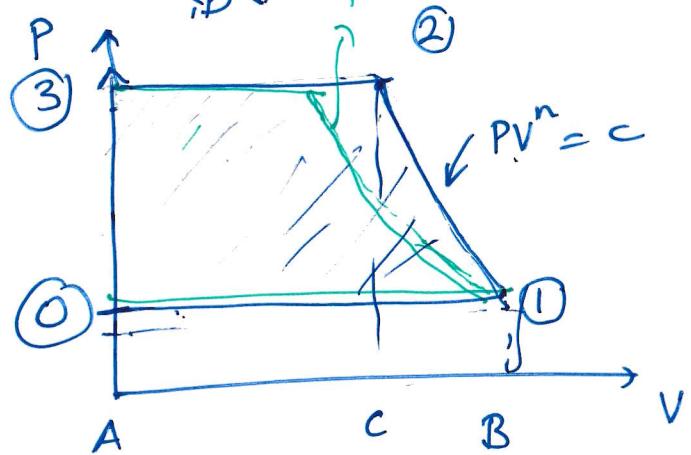
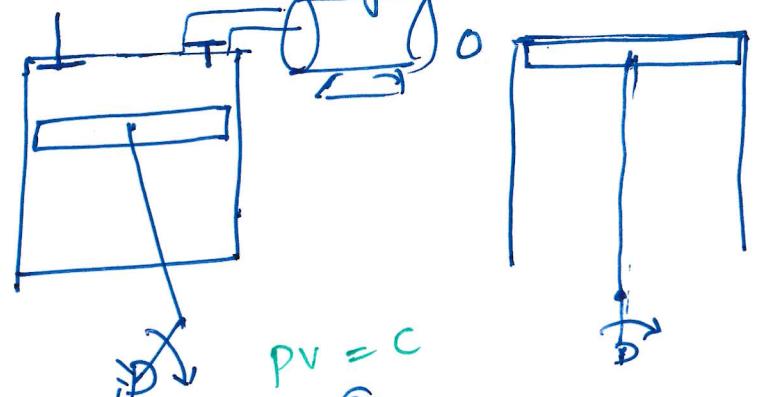


Reciprocating compressor

1

Intake Delivery Tank



$$W = \text{Area } 32CA + \text{Area } 21BC - \text{Area } 01BA$$

$$= p_2 v_2 + \frac{p_2 v_2 - p_1 v_1}{n-1} - p_1 v_1$$

$$= (p_2 v_2 - p_1 v_1) \left[1 + \frac{1}{n-1} \right]$$

$$= \frac{n}{n-1} (p_2 v_2 - p_1 v_1)$$

$$= \frac{n}{n-1} m R (T_2 - T_1)$$

$$= \frac{n}{n-1} m R T_1 \left[\frac{T_2}{T_1} - 1 \right]$$

$$= \frac{n}{n-1} m R T_1 \left[\left(\frac{p_2}{p_1} \right)^{\frac{n-1}{n}} - 1 \right] \quad \left[m = \frac{pV}{RT} \right]$$

$$\text{Define } \gamma_p \triangleq \frac{p_2}{p_1} \text{ (pressure ratio)}$$

$$= \frac{n}{n-1} m R T_1 \left[\gamma_p^{\frac{n-1}{n}} - 1 \right]$$

If compression is isothermal.

$$W = P_2 v_2 + P_1 v_1 \ln \frac{v_2}{v_1} - P_1 v_1 \quad P_2 v_2 + P_1 v_1 \ln \frac{v_1}{v_2} - P_2 v_1$$

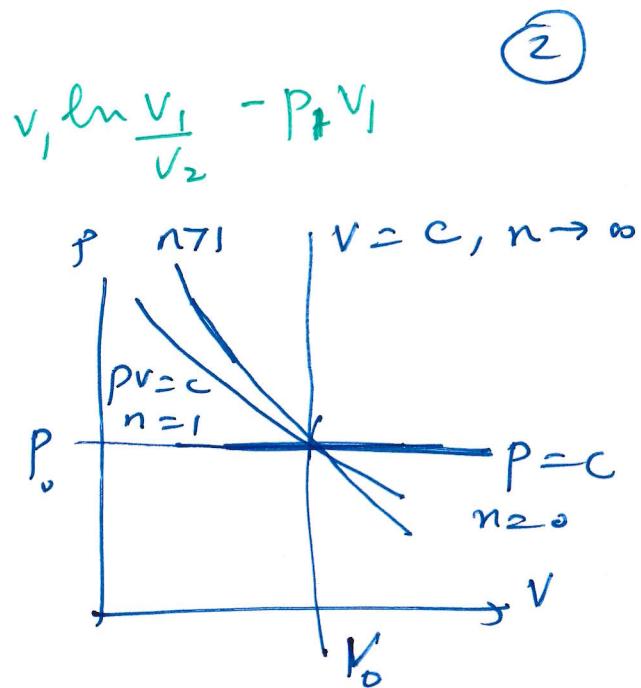
Since $P_1 v_1 = P_2 v_2$ (isothermal)

$$W = P_1 v_1 \ln \frac{v_2}{v_1} \quad P_1 v_1 \ln \frac{v_1}{v_2}$$

$$W = m R T \ln \frac{P_2}{P_1}$$

$$W_{iso} < W_{polytropic}$$

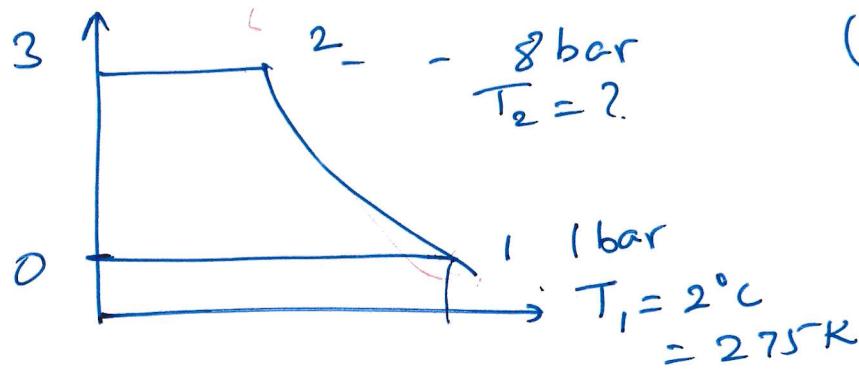
$$\eta_{\text{isothermal}} = \frac{W_{iso}}{W_{\text{polytropic}}} \quad (\text{Isothermal efficiency})$$



(3)

A single acting reciprocating compressor is required to compress $1.5 \text{ m}^3/\text{min}$ of R-134 refrigerant ($\gamma = 1.31$, $MW = 102$) with initial temperature 2°C from 1 bar to 8 bar. Assume compression is polytropic $n = 1.12$. Determine:

- 1) Temperature at the end of the compression
- 2) Power required to operate the compressor
- 3) Heat transferred during compression
- 4) Isothermal efficiency
- 5) Mass of the refrigerant compressed per minute



$$(1) \quad \frac{T_2}{T_1} = \left(\frac{P_2}{P_1} \right)^{\frac{n-1}{n}} \Rightarrow \frac{T_2}{275} = \left(\frac{8}{1} \right)^{\frac{0.12}{1.12}}$$

$$= 343.6 \text{ K} = 70.6^\circ\text{C}$$

$$(2) \quad W = \frac{n}{n-1} m R T_1 \left[\frac{n-1}{n} - 1 \right]$$

$$= \left(\frac{0.12}{0.12} \right) (100) \left(\frac{1.5}{60} \right) \left[8^{\frac{0.12}{1.12}} - 1 \right]$$

$$= 5.82 \text{ kW}$$

$$(3) \quad Q = \Delta u + W = \underline{\underline{m c_v \Delta T + W}}$$

$$m = \frac{P V}{R T} \quad R = \frac{8.314}{102} = 0.0815 \text{ kJ/kg K} ; \quad c_v = \frac{R}{r-1} = \frac{0.0815}{1.31-1} = 0.263 \text{ kJ/kg K}$$

$$\therefore m = \frac{(100)(1.5/60)}{(0.0815)(275)} = \underline{\underline{0.11 \text{ kg/s}}}$$

$$\therefore Q = \underline{\underline{(0.11)(0.263)(70.6 - 2)}} - \cancel{5.82}^{5.125} = \cancel{-3.84 \text{ kW}} \quad -3.14 \text{ kW}$$

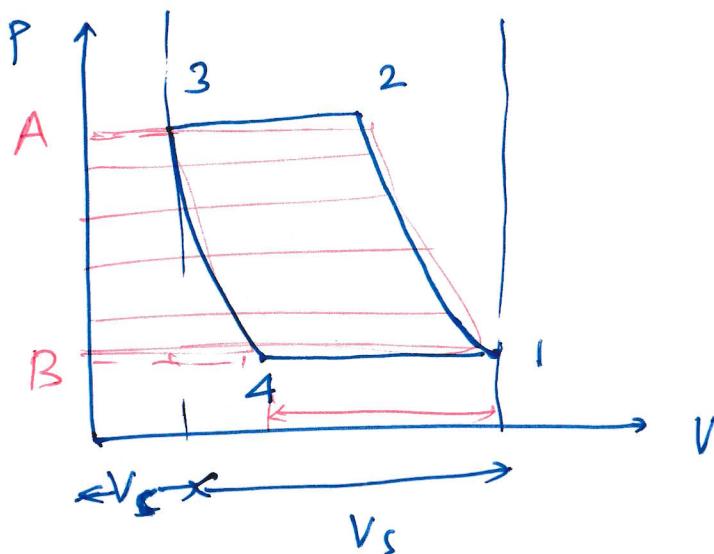
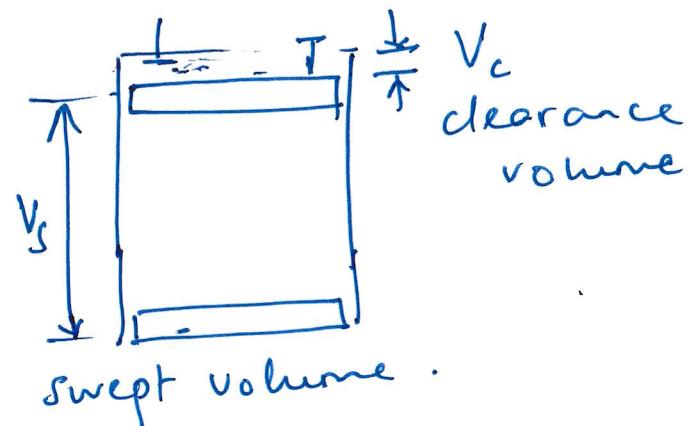
$$(4) \quad \therefore W_{iso} = P_1 V_1 \ln \frac{P_2}{P_1}$$

$$= (100) \left(\frac{1.5}{60} \right) \ln 8/1 = 5.2 \text{ kW}$$

$$\eta_{iso} = \frac{5.2}{5.82} = 89\%$$

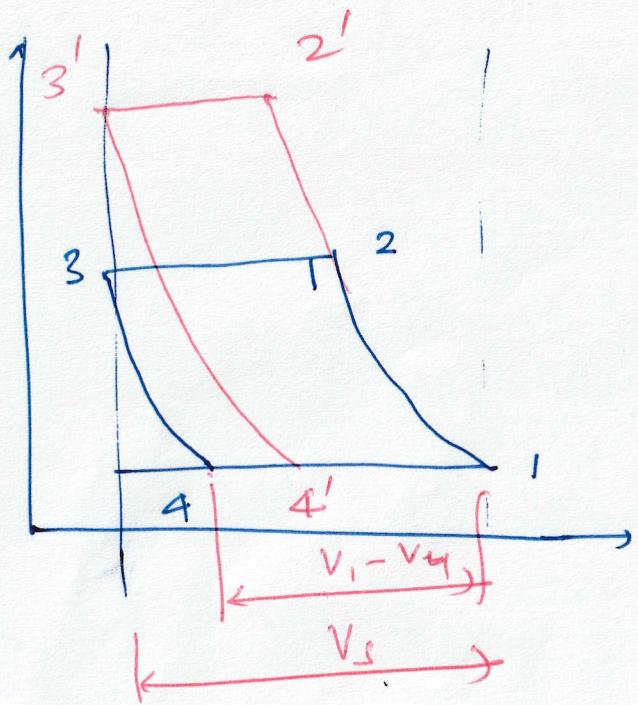
$$W = \frac{m R(T_2 - T_1)}{n-1} = \frac{(0.11)(0.0815)(70.6 - 2)}{1.12 - 1} \\ \text{(Compression)} \quad \therefore 5.125 \text{ kW.}$$

(4)



$$W = \text{Area } A B 1 2 - \text{Area } A B 3 4 \\ = \frac{n}{n-1} m_1 R T_1 \left[r^{\frac{n-1}{n}} - 1 \right] - \frac{n}{n-1} m_4 R T_1 \left[r^{\frac{n-1}{n}} - 1 \right] \\ = \frac{n}{n-1} (m_1 - m_4) R T_1 \left[r^{\frac{n-1}{n}} - 1 \right]$$

(S)



$$\eta_{vol} \triangleq \frac{V_1 - V_4}{V_s}$$