(1) Assuming an ideal gas

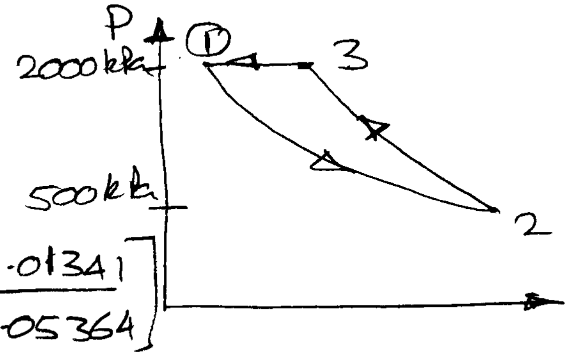
$$V_1 = \frac{mRT_1}{P_1} = \frac{0.15\,kg \times 0.287\,\frac{kJ}{kg\,K} \times 623\,K}{2000\,kPa} = 0.01341\,m^3$$

$$V_2 = \frac{mRT_2}{P_2} = \frac{0.15\,kg \times 0.287\,\frac{kJ}{kg\,K} \times 623\,K}{500\,kPa} = 0.05364\,m^3$$

$$P_2 V_2^{1.2} = P_3 V_3^{1.2}$$

$$\Rightarrow (500\,kPa)(0.05364\,m^3)^{1.2} = (2000\,kPa)(V_3^{1.2})$$

$$\Rightarrow V_3 = 0.01690\,m^3$$



$$W_{12} = P_1 V_1 \ln \frac{V_1}{V_2}$$

$$= 2000\,kPa \times 0.01341\,m^3 \ln \left[\frac{0.01341}{0.05364}\right]$$

$$= -37.18\,kJ$$

$$W_{23} = \frac{P_3 V_3 - P_2 V_2}{n-1}$$

$$= \frac{2000\,kPa \times 0.01690\,m^3 - 500\,kPa \times 0.05364\,m^3}{1.2-1}$$

$$= 34.90\,kJ$$

$$W_{31} = P_3 (V_3 - V_1) = 2000\,kPa\,(0.01690 - 0.01341)\,m^3$$

$$= 6.98\,kJ$$

$$W_{net} = W_{12} + W_{23} + W_{31}$$

$$= -37.18\,kJ + 34.90\,kJ + 6.98\,kJ = 4.7\,kJ$$

(2) For N_2

$R = 0.2968\ kJ/kg\,K \qquad C_v = 0.745\ \frac{kJ}{kg\,K}$

$P_1 = 100\ kPa, \qquad T_1 = 17°C$

$P_2 V_2^{1.3} = P_1 V_1^{1.3}$

$\Rightarrow \quad P_2 = \left(\frac{V_1}{V_2}\right)^{1.3} P_1 = 2^{1.3}(100\ kPa)$

$= 246.2\ kPa$

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

$\Rightarrow \quad T_2 = \frac{P_2}{P_1} \cdot \frac{V_2}{V_1} \cdot T_1 = \frac{246.2\ kPa}{100\ kPa} \times 0.5 \times 290\ K$

$T_2 = 357.0\ K$

$$W_{12} = \frac{P_2 V_2 - P_1 V_1}{n-1} = \frac{mR(T_2 - T_1)}{n-1}$$

$$= \frac{1.5\ kg \times 0.2968\ kJ/kg\,K\ (357 - 290)\,K}{1.3 - 1}$$

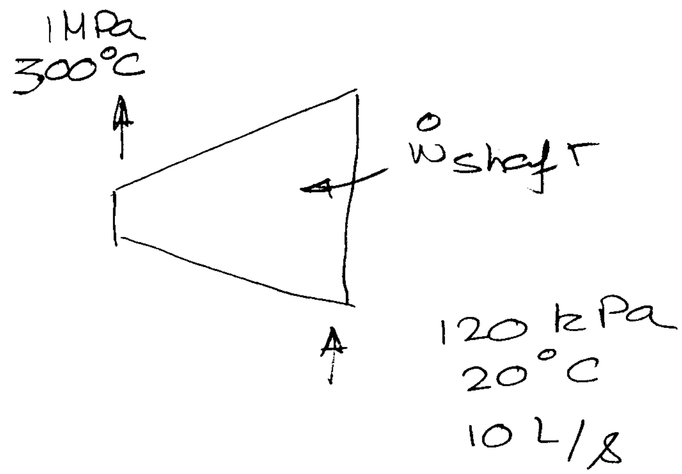
$= 99.4\ kJ$

$W_{12} + Q_{12} = \Delta U = m C_v (T_2 - T_1)$

$Q_{12} = -99.4\ kJ + 1.5\ kg \times 0.745\ \frac{kJ}{kg\,K}\ (357 - 290)\,K$

$= -24.5\ kJ$

3)



Assume $\Delta KE = \Delta PE = 0$

$$\dot{W}_{shaft} = \dot{m}\, c_p\, (T_2 - T_1)$$

Specific volume

$$v_1 = \frac{RT_1}{P_1} = \frac{0.287 \frac{kJ}{kg\,K} \times 293\ K}{120\ kPa}$$

$$= 0.7008\ m^3/kg$$

$$\dot{m} = \frac{\dot{V}}{v_1} = \frac{0.010\ m^3/s}{0.7008\ m^3/kg} = 0.01427\ \frac{kg}{s}$$

Assume c_p for air at 160°C $= 1.018\ \frac{kJ}{kg\,K}$

$$\dot{W}_{shaft} = 0.01427\ \frac{kg}{s} \times 1.018\ \frac{kJ}{kg\,K} \times (300-20)\ K$$

$$= 4.068\ kW.$$