19.1



$P_1 = 1 \times 10^5 \, Pa$
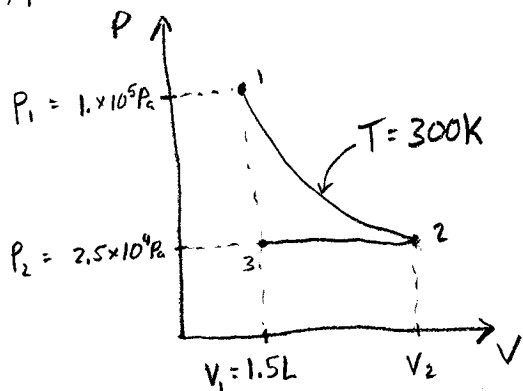
$T = 300K$

$P_2 = 2.5 \times 10^4 \, Pa$

$V_1 = 1.5L$  $V_2$

1) Since the first process is isothermal,

$pV = const$, so

$$P_1 V_1 = P_2 V_2 \Rightarrow V_2 = \frac{P_1 V_1}{P_2} = \frac{(1.0 \times 10^5 Pa)(1.5 \times 10^{-3} m^3)}{2.5 \times 10^4 Pa}$$

$$\boxed{V_2 = 6.0 L}$$

2) The second process is isobaric, so $\boxed{P_2 = P_3 = 2.5 \times 10^4 \, Pa}$

3) Since the pressure is constant in the second process,

$$p = \frac{nRT}{V} = const. \Rightarrow \frac{nRT_2}{V_2} = \frac{nRT_3}{V_3} \Rightarrow$$

$$T_3 = \frac{T_2 V_3}{V_2} = 300K \frac{1.5L}{6.0L} = \boxed{75K}$$

4) For an isothermal process: $pV = nRT = const \Rightarrow$

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

So, $W = \int_{V_1}^{V_2} p \, dV = nRT \int_{1.5L}^{6.0L} \frac{1}{V} dV = nRT \ln\left(\frac{6.0L}{1.5L}\right)$

$$= P_1 V_1 \ln\left(\frac{6.0L}{1.5L}\right)$$
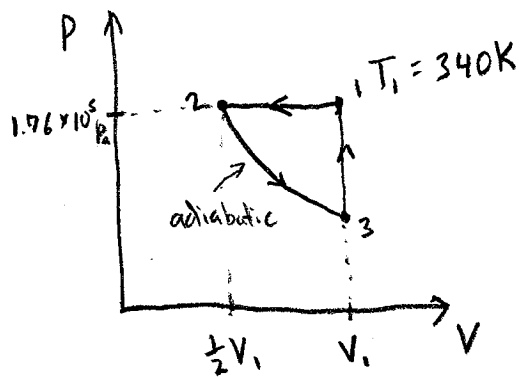
$$= (1.0 \times 10^5 Pa)(1.5 \times 10^{-3} m^3) \ln 4$$

$$\boxed{W_{1 \to 2} = 208 \, J}$$

5) In an isobaric process, $W = p(V_f - V_i) = (2.5 \times 10^4 Pa)(1.5 \times 10^{-3} m^3 - 6.0 \times 10^{-3} m^3)$

$$\boxed{W_{2 \to 3} = -112.5 \, J}$$

19.2



1) For an isobaric process, $p = const = \dfrac{nRT}{V} \Rightarrow$

$$\dfrac{nRT_1}{V_1} = \dfrac{nRT_2}{V_2} = \dfrac{nRT_2}{\frac{1}{2}V_1} \Rightarrow$$

$$\boxed{T_2 = \tfrac{1}{2}T_1 = 170\,K}$$

2) For an adiabatic process $TV^{\gamma-1} = const. \Rightarrow$

$$T_2 V_2^{\gamma-1} = T_3 V_3^{\gamma-1}$$

now, $\gamma = \dfrac{C_p}{C_v} = \dfrac{C_v + R}{C_v}$ and since nitrogen is diatomic, $C_v = \tfrac{5}{2}R$

$$\therefore \gamma = \dfrac{\tfrac{5}{2}R + R}{\tfrac{5}{2}R} = \dfrac{\tfrac{7}{2}R}{\tfrac{5}{2}R} = \dfrac{7}{5} = 1.4$$

then $\quad (170k)\left(\tfrac{1}{2}V_1\right)^{0.4} = T_3 V_1^{0.4}$

$$\boxed{T_3 = 170k\left(\tfrac{1}{2}\right)^{0.4} = 129\,K}$$

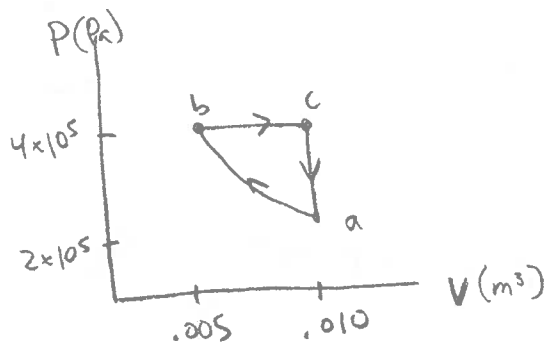3) The minimum pressure is just the pressure at state 3, so

$$P_3 V_3 = nRT_3 \Rightarrow P_3 = \dfrac{nRT_3}{V_3}$$

but, $V_3 = V_1 = \dfrac{nRT_1}{P_1}$ $\quad \therefore P_3 = \dfrac{nRT_3 P_1}{nRT_1} = \dfrac{(129k)(1.76\times10^5 P_a)}{(340K)}$

$$\boxed{P_3 = 6.67\times10^4 P_a}$$

20.1

$P(Pa)$



$4 \times 10^5$

$2 \times 10^5$

.005    .010    $V(m^3)$

(1) For isothermal process $Q = W = nRT \ln\left(\frac{V_b}{V_a}\right)$

ab

since $V_b < V_a \implies$ W = negative $\implies Q < 0$

$P_a V_a = 2 \times 10^3 \implies P_a V_a = P_b V_b$  so heat is __rejected__   * ab = compression

$P_b V_b = 2 \times 10^3$   $T_a = T_b$

(2) bc is @ constant P $\rightarrow Q = nC_p \Delta T = \underbrace{\frac{C_p}{R}}_{const.} P \Delta V$

$\Delta V$ is positive   so $Q > 0 \implies$ heat is absorbed

(3) ca is @ const. V $\rightarrow Q = nC_v \Delta T = \underbrace{\frac{C_v}{R}}_{const} V \Delta P$

$\Delta P < 0$   so $Q < 0$   * heat is rejected

(4) $PV = nRT$

$T_a = \frac{P_a V_a}{nR} = \frac{(2 \times 10^5)(.010)}{(1.8)(8.314)} = 134\,K$

$T_b = \frac{P_b V_B}{nR} = \frac{(4 \times 10^5)(.005)}{(1.8)(8.314)} = 134\,K$

$T_c = \frac{P_c V_c}{nR} = \frac{(4 \times 10^5)(.010)}{(1.8)(8.314)} = 268\,K$

(5) calculate Q for each segment

$Q_T = Q_{ab} + Q_{bc} + Q_{ca}$

$Q_{ab} = nRT \ln\left(\frac{V_b}{V_a}\right) = (1.8)(8.314)(134) \ln\left(\frac{.005}{.010}\right) = -1.39 \times K$

$$Q_{bc} = nC_p \Delta T = (1.8)\left(\frac{7}{2}\right)(8.314)(134) = 7.02 \times 10^3 \, J$$

$= \frac{7}{2}R$ for diatomic

$$Q_{ca} = nC_v \Delta T = (1.8)\left(\frac{5}{2}\right)(8.314)(-134) = -5.01 \times 10^3 \, J$$

$= \frac{5}{2}R$ for diatomic

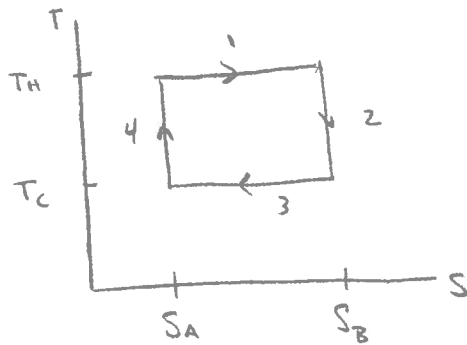$$Q_T = (-1.39 \times 10^3) + (7.02 \times 10^3) + (-5.01 \times 10^3) = \underline{620 \, J}$$

(6) For this cycle $\quad W_{net} = Q_T = \underline{620 \, J}$

(7) $\quad e = \frac{W}{Q_H} = \frac{620 \, J}{7.02 \times 10^3 \, J} = 0.088 = \underline{8.7\%}$

(1) carnot cycle:



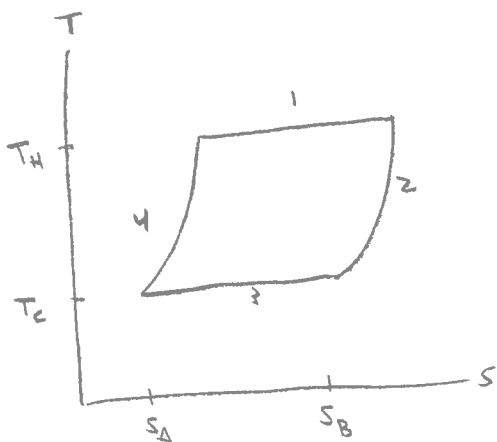(2) For a reversible path $dS = \frac{dQ}{T} \implies dQ = TdS$

$$Q = \int dQ = \int TdS$$

for infinitesimal $\Delta S \to dS$ and $\int TdS$ is the area under the curve in the graph above

(3) based on the graph $Q = T\Delta S$ & $W = Q_H - Q_c$ ($Q_c < 0$ because $\Delta S_3 < 0$)

$$e = \frac{W}{Q_H} = \frac{T_H \Delta S - T_c \Delta S}{T_H \Delta S} = \boxed{1 - \frac{T_c}{T_H}}$$

(4)
Stirling cycle



$$e_{stir} = \frac{W}{Q_H} = \frac{W_{stir}}{Q_{HS}}$$

for Stirling cycle $W_{stir} = W_{carnot}$

but $Q_{HS} > Q_{HC}$ (area under curve 4+1)

because of this
$$\frac{W_{car}}{Q_{HC}} > \frac{W_{car}}{Q_{HS}}$$

$$\implies \underline{\underline{e_{car} > e_{stir}}}$$