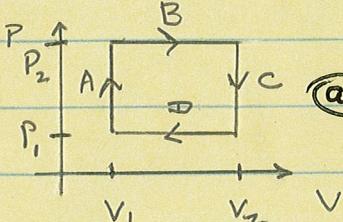


(1) $m = 50 \text{ kg}$ and $L = 334 \text{ kJ/kg} \Rightarrow Q_{\text{out}} = mL = 1.67 \times 10^4 \text{ kJ}$
 $T_{\text{low}} = 0^\circ\text{C} = 273 \text{ K}$, $T_{\text{high}} = 20^\circ\text{C} = 293 \text{ K}$
 $\rightarrow \text{coeff. of perf. } K = T_{\text{low}} / (T_{\text{high}} - T_{\text{low}}) = 13.65$
Now $K = Q_{\text{out}} / W \Rightarrow W = Q_{\text{out}} / K = 1.223 \times 10^3 \text{ kJ}$
 $\Delta t = 1 \text{ hour} = 3600 \text{ sec} \Rightarrow P = W / \Delta t = 340 \text{ W}$

(2) Original efficiency $\rightarrow e = 1 - T_L / T_H$
Increase $T_H \rightarrow T_H + \Delta T \Rightarrow e' = 1 - T_L / (T_H + \Delta T)$
Decrease $T_L \rightarrow T_L - \Delta T \Rightarrow e'' = 1 - (T_L - \Delta T) / T_H$
Ratio of new efficiencies $\rightarrow \frac{e''}{e'} = \left(\frac{T_H - T_L + \Delta T}{T_H} \right) \left(\frac{T_H + \Delta T}{T_H + \Delta T - T_L} \right)$
 $\Rightarrow \frac{e''}{e'} = \frac{T_H + \Delta T}{T_H} > 1 \Rightarrow \underline{\text{decrease } T_L \text{ for greater eff.}}$

[Text 4.1] (3) 
@ $V_2 = 3V_1$ and $P_2 = 2P_1$

Problem 1.34 $\rightarrow W_{\text{done}} = -W_{\text{gas}}$
 $= (P_2 - P_1)(V_2 - V_1) = 2P_1V_1$

Heat flows into system during steps A and B
 $\rightarrow Q_A = \frac{5}{2}(P_2 - P_1)V_1 = \frac{5}{2}P_1V_1$ } $\Rightarrow Q_{\text{in}} = \frac{33}{2}P_1V_1$
 $Q_B = \frac{7}{2}P_2(V_2 - V_1) = 14P_1V_1$ }
 $\Rightarrow e = W_{\text{done}} / Q_{\text{in}} = \frac{4}{33} = 0.12$

(b) Lowest temperature at pressure P_1 , volume V_1
 $\rightarrow T_L = P_1V_1 / nR$

Highest temperature at pressure P_2 , volume V_2
 $\rightarrow T_H = P_2V_2 / nR = 6T_L$
 $\Rightarrow e_{\text{Carnot}} = 1 - T_L / T_H = \frac{5}{6}$

[Text 4.4] (4) a) $T_L = 4^\circ C = 277 K$, $T_H = 22^\circ C = 295 K$

$$\rightarrow e_{max} = 1 - T_L/T_H = 0.061$$

(b) $P = dW/dt = 10^9 W \Rightarrow dQ_{in}/dt = P/e = 1.64 \times 10^{10} W$

For water $C = 4190 J/kg \cdot K$, $\rho = 1000 \text{ kg/m}^3$,

$$\Delta T = 18 K \rightarrow Q_{in} = C m (\Delta T) = c \rho V (\Delta T)$$

$$\Rightarrow dQ_{in}/dt = c \rho (\Delta T) (dV/dt)$$

$$\Rightarrow dV/dt = (dQ_{in}/dt) / [c \rho (\Delta T)] = 217 \text{ m}^3/\text{s}$$

(5) a) Heat pump is an engine run backward

Cannot engine $\rightarrow e = W/Q_{in} = (Q_{in} - Q_{out}) / Q_{in}$
 $= (T_H - T_C) / T_H$

Cannot heat pump $\rightarrow K = Q_{in}/W = 1/e$

$$\Rightarrow K = T_H / (T_H - T_C)$$

(b) $T_C = 0^\circ C = 273 K$, $T_H = 20^\circ C = 293 K$

$$\Rightarrow K = 293/20 = 14.7$$

[Text 3.10] (6) a) $m = 30 g$, $L = 334 J/g \Rightarrow Q = 1.002 \times 10^4 J$

$$T = 0^\circ C = 273 K \Rightarrow \Delta S = Q/T = 36.7 J/K$$

(b) $C = 4.19 J/g \cdot K$, $T_{in} = 273 K$, $T_{fin} = 25^\circ C = 298 K$

$$\Delta S = \int \frac{dQ}{T} = mc \int_{T_{in}}^{T_f} \frac{dT}{T} = mc \ln \frac{T_{fin}}{T_{in}} \rightarrow \Delta S = 11.0 \frac{J}{K}$$

(c) From part (a), $Q_{melt} = 1.002 \times 10^4 J$

$$\text{Increase in temp} \rightarrow Q_2 = mc (\Delta T) = 3.14 \times 10^3 J$$

$$\Rightarrow \Delta S_{room} = -Q_{total} / T_{fin} = -(Q_{melt} + Q_2) / T_{fin}$$

$$\Rightarrow \Delta S_{room} = -44.2 J/K$$

(d) $\Delta S_{total} = \Delta S_{water} + \Delta S_{room} = 3.55 J/K$

> 0 as expected

[Text 3.11] (7) Initially, $m_1 = 50 \text{ kg}$ at $T_1 = 55^\circ\text{C} = 328 \text{ K}$
and $m_2 = 25 \text{ kg}$ at $T_2 = 10^\circ\text{C} = 283 \text{ K}$
(note that $\rho = 1 \text{ g/cm}^3 \Rightarrow 1 \text{ liter has mass } 1 \text{ kg}$)
Now total heat transfer = 0
 $\Rightarrow m_1 C_{H_2O} (T_f - T_1) + m_2 C_{H_2O} (T_f - T_2) = 0$
 $\Rightarrow (m_1 + m_2) T_f = m_1 T_1 + m_2 T_2 \Rightarrow T_f = (m_1 T_1 + m_2 T_2) / (m_1 + m_2)$
 $\rightarrow T_f = 313 \text{ K} = 40^\circ\text{C}, C_{H_2O} = 4.19 \text{ kJ/kg-K}$
 $\rightarrow \Delta S = \Delta S_1 + \Delta S_2 = m_1 C_{H_2O} \int_{T_1}^{T_f} \frac{dT}{T} + m_2 C_{H_2O} \int_{T_2}^{T_f} \frac{dT}{T}$
 $= [m_1 \ln(T_f/T_1) + m_2 \ln(T_f/T_2)] C_{H_2O}$
 $\rightarrow \Delta S = -9.807 \text{ kJ/K} + 10.55 \text{ kJ/K} \rightarrow \boxed{\Delta S = 750 \text{ J/K}}$

[Text 3.28] (8) $V_{in} = 10^{-3} \text{ m}^3, V_{fin} = 2V_{in}, T_{in} = 20^\circ\text{C} = 293 \text{ K}$
 $P = 1.013 \times 10^5 \text{ Pa}$

Isochoric process $\Rightarrow T_{fin} = T_{in} (V_{fin}/V_{in}) = 2T_{in}$
Air made of diatomic molecules $\Rightarrow C_p = \frac{7}{2} nR$

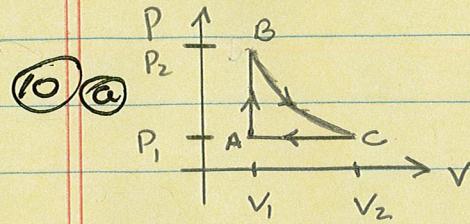
Now $nR = PV_{in}/T_{in} = 0.3457 \text{ J/K}$

$$\rightarrow \Delta S = C_p \int_{T_{in}}^{T_{fin}} \frac{dT}{T} = \frac{7}{2} nR \ln 2 \rightarrow \boxed{\Delta S = 0.839 \frac{\text{J}}{\text{K}}}$$

(9) (a) $R = 20 \Omega, m = 5.0 \text{ g}, \Delta t = 1 \text{ sec}, I = 2.0 \text{ A}$
 $\rightarrow Q = P_R \Delta t = I^2 R (\Delta t) = 80 \text{ J}$
Also $C = 850 \text{ J/kg-K} = 0.850 \text{ J/g-K}$
 $\rightarrow Q = mc (\Delta T) \Rightarrow \boxed{\Delta T = Q/mc = 18.8 \text{ K}}$

(b) $T_{in} = 20^\circ\text{C} = 293 \text{ K} \rightarrow T_{fin} = 312 \text{ K}$

$$\rightarrow \Delta S = mc \int_{T_{in}}^{T_{fin}} \frac{dT}{T} = mc \ln \left(\frac{T_{fin}}{T_{in}} \right) \rightarrow \boxed{\Delta S = 0.267 \frac{\text{J}}{\text{K}}}$$



(b) $A \rightarrow B$ is isochoric

$$\Rightarrow \Delta S_{AB} = nC_V \int_{T_A}^{T_B} \frac{dT}{T} = nC_V \ln\left(\frac{T_B}{T_A}\right)$$

For an isochoric process, $T_B/T_A = P_2/P_1 \Rightarrow \Delta S_{AB} = nC_V \ln(P_2/P_1)$
 $B \rightarrow C$ is adiabatic $\Rightarrow \Delta S_{BC} = 0$

$C \rightarrow A$ is isobaric $\Rightarrow T_A/T_C = V_1/V_2$

$$\Rightarrow \Delta S_{CA} = nC_P \int_{T_C}^{T_A} \frac{dT}{T} = nC_P \ln\left(\frac{T_A}{T_C}\right) \Rightarrow \Delta S_{CA} = nC_P \ln\left(\frac{V_1}{V_2}\right)$$

(c) Adiabatic processes $\rightarrow P_2 V_1^\gamma = P_1 V_2^\gamma \Rightarrow P_2/P_1 = (V_2/V_1)^\gamma$
 $\Rightarrow \ln(P_2/P_1) = \gamma \ln(V_2/V_1) \Rightarrow \Delta S_{AB} = n\gamma C_V \ln(V_2/V_1)$

$$\text{But } \gamma C_V = C_P \Rightarrow \boxed{\Delta S_{\text{total}} = nC_P \ln(V_2/V_1) + nC_P \ln(V_1/V_2) = 0}$$

(11) $C_V = A + BT$

$$\text{Now } dS = nC_V(dT/T) + nR(dV/V)$$

$$\Rightarrow \Delta S = n \int_{T_{in}}^{T_f} \frac{C_V dT}{T} + nR \int_{V_{in}}^{V_f} \frac{dV}{V}$$

$$= nA \int_{T_{in}}^{T_f} \frac{dT}{T} + nB \int_{T_{in}}^{T_f} dT + nR \int_{V_{in}}^{V_f} \frac{dV}{V}$$

$$\rightarrow \boxed{\Delta S = nA \ln\left(\frac{T_f}{T_{in}}\right) + nB(\Delta T) + nR \ln\left(\frac{V_f}{V_{in}}\right)}$$