

Exercises: 20.3, ~~20.8~~, 20.11, 20.16, 20.27, 20.35

Challenge Problem (Extra Credit): 20.63

Ex. 20.3: $Q_H = 1.61 \times 10^4 \text{ J}$, $W = 3.700 \times 10^3 \text{ J}$ per cycle.
 $L = \text{heat of combustion} = 4.60 \times 10^4 \text{ J/g}$.

$$a) e = \frac{W}{Q_H} = \frac{3.700 \times 10^3 \text{ J}}{1.61 \times 10^4 \text{ J}} = \boxed{0.230} \Rightarrow 23\%$$

$$b) |Q_C| = |Q_H| - |W| = (\cancel{1.61} \times 10^4 - 3.70 \times 10^3) \text{ J} = \boxed{1.24 \times 10^4 \text{ J}}$$

$$c) Q_H = mL, \text{ so } m = Q_H/L = \frac{1.61 \times 10^4 \text{ J}}{4.60 \times 10^4 \text{ J/g}} = \boxed{0.350 \text{ g}}$$

$$d) P = W \cdot 60.0 \text{ cycles/s} = (3.700 \times 10^3 \text{ J})(60.0 \text{ cps}) = \boxed{2.22 \times 10^5 \text{ W}}$$

$$= \frac{2.22 \times 10^5 \text{ W}}{746 \text{ W/h.p.}} = \boxed{298 \text{ H.P.}}$$

Ex. 20.8: $r = 8.8$, $\gamma = 1.40$ a) $e = 1 - \frac{1}{r^{\gamma-1}} = 1 - \frac{1}{8.8^{0.4}}$

$$a) \text{ so } \boxed{e = 0.58} \text{ ideal.}$$

$$b) r = 9.6, e = 1 - \frac{1}{9.6^{0.4}} = \boxed{0.60} \text{ so a } \boxed{0.02} \text{ increase.}$$

Ex. 20.11: $|Q_C| = 9.80 \times 10^4 \text{ J}$ per minute.

$$|Q_H| = 1.44 \times 10^5 \text{ J per minute.}$$

$$a) |W| = |Q_H| - |Q_C| = 4.60 \times 10^4 \text{ J per 60 seconds.}$$

$$\text{Hence, } |W| = \frac{4.60 \times 10^4 \text{ J}}{60.5} = \boxed{767 \text{ W}}$$

$$b) \text{EER} = 3.413 \cdot \frac{|Q_C|}{|W|} = 3.413 \cdot \frac{9.80 \times 10^4 \text{ J/min.}}{4.60 \times 10^4 \text{ J/min.}} = \boxed{7.27 \frac{\text{BTU/hr.}}{\text{W}}}$$

Ex. 20.16: $T_H = 320 \text{ K}$, $T_C = 270 \text{ K}$, $|Q_C| = 415 \text{ J}$ per cycle.

$$K_{\text{Carnot}} = \frac{T_C}{T_H - T_C} = \frac{270 \text{ K}}{320 \text{ K} - 270 \text{ K}} = 5.40 = \frac{|Q_C|}{|W|}. \text{ Hence,}$$

$$a) |W| = \frac{|Q_c|}{K} = 76.85 \text{ J/cycle}. |Q_H| = |Q_c| + |W| = \boxed{492 \text{ J/cycle}}$$

$$b) P = |W| \cdot \frac{165 \text{ cycles}}{\text{min.}} \cdot \frac{1 \text{ min.}}{60.5} = \boxed{212 \text{ W}}$$

$$c) K = \frac{|Q_c|}{|W|} = \frac{415 \text{ J}}{76.9 \text{ J}} = \boxed{5.40} \text{ as calculated above.}$$

Ex. 20.27: 1.00 kg of H_2O @ $T = 20.0^\circ\text{C}$ mixed with 2.00 kg of H_2O @ $T = 80.0^\circ\text{C}$. Not a reversible process -- see Example 20.10 on p. 778.

$$T_{\text{final}} = \frac{(1.00 \text{ kg})(293 \text{ K}) + (2.00 \text{ kg})(353 \text{ K})}{3.00 \text{ kg}} = \underline{333 \text{ K}}$$

$$\Delta S_{\text{Hot}} = mc \int_{353 \text{ K}}^{333 \text{ K}} \frac{dT}{T} = (2.00 \text{ kg})(4190 \text{ J/kgK}) \ln\left(\frac{333 \text{ K}}{353 \text{ K}}\right) = -489 \text{ J/K}$$

$$\Delta S_{\text{Cold}} = mc \int_{293 \text{ K}}^{333 \text{ K}} \frac{dT}{T} = (1.00 \text{ kg})(4190 \frac{\text{J}}{\text{kgK}}) \ln\left(\frac{333 \text{ K}}{293 \text{ K}}\right) = 536 \text{ J/K}$$

So $\Delta S = \Delta S_{\text{Hot}} + \Delta S_{\text{Cold}} = (536 - 489) \text{ J} = \boxed{47 \text{ J/K}}$

Ex. 20.35: a) No. Since the gas expands isothermally $T = \text{constant}$, so the velocity distribution, v_{rms} , etc. are unchanged. $w_2 = 3^N w_1$ (See example 20.11, p. 782).

$$b) \Delta S = k \ln\left(\frac{w_2}{w_1}\right) = k \ln(3^N) = kN \ln 3.$$

Now we have 2.00 moles, so $N = 2N_A$. $\Delta S = 2kN_A \ln 3 = \boxed{2R \ln 3}$

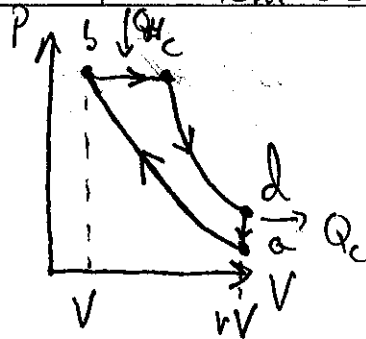
$$c) \Delta S = \frac{Q}{T}, \quad PV = nRT, \text{ so } PV = \text{constant. Since } T = \text{const.}, \Delta U = 0 \text{ and hence } W = Q.$$

$$W = \int_V^{3V} p dV = \int_V^{3V} \frac{nRT}{V} dV$$

$$W = nRT \ln\left(\frac{3V}{V}\right) = nRT \ln(3). \quad n = 2.00 \text{ moles, so}$$

$$Q = 2RT \ln(3). \quad \Delta S = \frac{Q}{T} = \frac{2RT \ln(3)}{T} = \boxed{2R \ln 3}, \text{ same as in part b.}$$

Figure 20.6:
The Diesel Cycle:



$$Q_H = nC_p(T_c - T_b)$$

$$= n(C_v + R)(T_c - T_b) > 0$$

$$Q_C = nC_v(T_a - T_d) < 0$$

$$e = \frac{Q_H + Q_C}{Q_H} = \frac{n(C_v + R)(T_c - T_b) + nC_v(T_a - T_d)}{n(C_v + R)(T_c - T_b)}$$

$$= 1 + \frac{C_v}{C_p} \cdot \frac{T_a - T_d}{T_c - T_b} = 1 + \frac{1}{\gamma} \cdot \frac{T_a - T_d}{T_c - T_b}$$

Adiabatic Strokes:

$$T_c V_c^{\gamma-1} = T_d (rV)^{\gamma-1}, \quad T_a (rV)^{\gamma-1} = T_b V^{\gamma-1}$$

Need V_c : Isobaric, so $p = \text{const} = \frac{nRT}{V}$, hence:

$$\frac{T_B}{V} = \frac{T_c}{V_c}, \text{ so } V_c = V \cdot \frac{T_c}{T_B}$$

$$\Rightarrow T_c \left(V \frac{T_c}{T_B} \right)^{\gamma-1} = T_d (rV)^{\gamma-1} \quad T_a r^{\delta-1} = T_b = \frac{T_b}{T_a} = r^{\gamma-1}$$

$$\frac{T_c^\gamma}{T_B^{\gamma-1}} = T_d r^{\gamma-1}, \text{ so } \frac{T_c^\gamma}{T_b^{\gamma-1}} = \frac{T_c^\gamma}{T_a^{\gamma-1} (r^{\gamma-1})^{\gamma-1}} = T_d r^{\gamma-1}$$

$$e = 1 + \frac{1}{\gamma} \frac{1 - T_d/T_a}{\frac{T_c}{T_a} - T_b/T_a} = \frac{1 - T_d/T_a}{\frac{T_c}{T_a} - r^{\gamma-1}}$$

$$e = 1 + \frac{1}{\gamma} \frac{1 - (T_c/T_a)^\gamma / r^{\gamma^2 - \gamma}}{\frac{T_c}{T_a} - r^{\gamma-1}}$$

substitute $\gamma = 1.40$
 $r = 21.0$

$$e = 0.708 = 70.8\%$$

$\frac{T_c}{T_a} = 3.167$

Much more efficient than the Otto Cycle!

22-141 50 SHEETS
22-142 100 SHEETS
22-144 200 SHEETS

