Answer Key

Air Standard Power Cycles

1

OTTO CYCLE

$$c = 0.10 V_D$$

$$r_k = \frac{V_1}{V_2} = \frac{0.10 \cancel{V_D} + \cancel{V_D}}{0.10 \cancel{V_D}} = 11$$

$$e_{oc} = 1 - \frac{1}{r_k^{k-1}} * 100\%$$

$$= 1 - \frac{1}{11^{1.4-1}} * 100\%$$

$$\boxed{e_{oc} = 61.68\%}$$

CARNOT CYCLE

$$e_{cc} = \frac{T_H - T_L}{T_H} * 100\% = \frac{(473 - 301)k}{473k} * 100\%$$

$$\boxed{e_{cc} = 36.36\%}$$

CARNOT CYCLE

$$e_c = \frac{W_{NET}}{Q_{in}} * 100\% = \frac{25\ kW}{45\ KJ/s} * 100\%$$

$$e_c = 55.56\%$$

Then;

$$e_c = 1 - \frac{T_L}{T_H} * 100\%$$

$$0.5556 = 1 - \frac{298\ K}{T_H}$$

$$T_H = 670.5671\ K$$

$$\boxed{t_H = 397.5671°C}$$

CARNOT CYCLE

$$e_c = \frac{W_{NET}}{Q_A} * 100\% = \frac{Q_A - Q_R}{Q_A} * 100\%$$

$$e_c = \frac{(120 - 50)\ Btu}{120\ Btu} * 100\%$$

$$e_c = 58.33\%$$

then;

$$e_c = \frac{T_H - T_L}{T_H} * 100\% = 1 - \frac{T_L}{T_H} * 100\%$$

$$0.5833 = 1 - \frac{T_L}{1080\ °R}$$

$$T_L = 450.036\ °R$$

$$\boxed{t_L = -9.964\ °F}$$

Carnot Cycle

$$e_c = 1 - \frac{T_c}{T_H} * 100\% = 1 - \frac{760\,°R}{1960\,°R} * 100\%$$

$$\boxed{e_c = 61.22\,\%}$$

CARNOT CYCLE

$$e_c = 1 - \frac{T_L}{T_H} * 100\% = 1 - \frac{523\ K}{1573\ K} * 100\%$$

$$\boxed{e_c = 66.75\%}$$

7

exponential LEAP ONLINE REVIEW

OTTO cycle

$W_{NET} = 320\ kW$

$C = 0.10$

$r_k = \frac{C+1}{C} = \frac{0.10+1}{0.10} = 11$

$e_{cl} = 1 - \frac{1}{r_k^{k-1}} * 100\% = 1 - \frac{1}{11^{1.4-1}} * 100\%$

$e_{cl} = 61.68\%$

then;

$e_{cl} = \frac{W_{NET}}{Q_A} * 100\%$

$0.6168 = \frac{320\ kW}{Q_A}$

$Q_A = 518.8197\ kW$

therefore;

$W_{NET} = Q_A - Q_R$

$320\ kW = 518.8197\ kW - Q_R$

$\boxed{Q_R = 198.8197\ kW}$

Exponential LEAP ONLINE REVIEW

DIESEL CYCLE

$r_k = 16$ $\quad P_1 = 110$ kPa

$r_c = 4$ $\quad t_1 = 32°C$

$$e_{DC} = 1 - \frac{1}{r_k^{k-1}}\left[\frac{r_c^k - 1}{k(r_c - 1)}\right] * 100\%$$

$$e_{DC} = 1 - \frac{1}{16^{1.4-1}}\left[\frac{4^{1.4} - 1}{1.4(4-1)}\right] * 100\%$$

$$e_{DC} = 53.15\%$$

then;

$$e_{DC} = \frac{W_{NET}}{Q_A} * 100\%$$

$$Q_A = mC_p(T_3 - T_2)$$

$$r_c = \frac{T_3}{T_2} \; ; \; \left(\frac{T_2}{T_1}\right)^{1/k-1} = r_k$$

$$\left(\frac{T_2}{305\,K}\right)^{1/1.4-1} = 16$$

$$T_2 = 924.5871\ K$$

subst;

$$4 = \frac{T_3}{924.5871\,K}$$

$$T_3 = 3698.3484\ K$$

then;

$$\frac{Q_A}{m} = (1.0062\ KJ/kg\text{-}K)(3698.3484 - 924.5871)K$$

$$\frac{Q_A}{m} = 2790.9586\ KJ/kg$$

Hence;

$$0.5315 = \frac{W_{NET}}{2790.9586\ KJ/kg}$$

$$\boxed{W_{NET} = 1483.3945\ KJ/kg}$$

$$e_c = \frac{W_{NET}}{Q_A}$$

$$W_{NET} = \left(1600\ \frac{J}{s} - hr\right)\left(\frac{3600\ s}{1\ hr}\right)\left(\frac{1\ kJ}{1000\ J}\right)$$

$$W_{NET} = 5760\ kJ$$

Then;

$$0.48 = \frac{5760\ kJ}{Q_A}$$

$$\boxed{Q_A = 12000\ kJ}$$

10

Otto cycle

$P_1 = 100\ kPa$ $\quad r_k = 12$

$t_1 = 32°C$ $\quad t_3 = 1200°C$

$$e_{oc} = 1 - \frac{1}{r_k^{k-1}} * 100\% = 1 - \frac{1}{12^{1.4-1}} * 100\%$$

$$e_{oc} = 62.99\%$$

since $r_k = r_e$

$$r_e = \left(\frac{T_3}{T_4}\right)^{1/k-1}$$

$$11 = \left(\frac{1473\ K}{T_4}\right)^{1/1.4-1}$$

$$T_4 = 564.4762\ K$$

Then; $e_{oc} = \frac{W_{NET}}{Q_A}$

$$W_{net} = mC_v(T_3 - T_2 - T_4 + T_1)$$

$$r_k = \left(\frac{T_2}{T_1}\right)^{1/k-1}$$

$$12 = \left(\frac{T_2}{305\ K}\right)^{1/1.4-1}$$

$$T_2 = 824.0856\ K$$

Then;

$$W_{NET} = \left(0.7186\ \frac{kJ}{kg\text{-}K}\right)(1473 - 824.0656 - 564.4762 + 305)$$

$$W_{NET} = 279.8503\ kJ/kg$$

Subst;

$$0.6299 = \frac{279.8503\ kJ/kg}{Q_A}$$

$$\boxed{Q_A = 444.2773\ kJ/kg}$$

11

OTTO CYCLE

$P_1 = 101\ kPa$ $\quad r_k = 12$

$t_1 = 32°C$ $\quad t_3 = 1300°C$

$$P_m = \frac{e_{oc}\, Q_A}{(V_1 - V_2)}$$

$$Q_A = m C_v (T_3 - T_2)$$

$$r_k = \left(\frac{T_2}{T_1}\right)^{1/k-1}$$

$$12 = \left(\frac{T_2}{305K}\right)^{1/1.4-1}$$

$$T_2 = 824.0856\ K$$

subst;

$$\frac{Q_A}{m} = (0.7186\ KJ/_{kg-K})(1573 - 824.0856)K$$

$$\frac{Q_A}{m} = 538.1698\ KJ/_{kg}$$

for $\bar{v}_1$; $P_1 V_1 = m R T_1$

$$100\ kPa\left(\frac{V_1}{m}\right) = (0.287\ KJ/_{kg-K})(305\ K)$$

$$\frac{V_1}{m} = \bar{v}_1 = 0.8754\ m^3/_{kg}$$

for $\bar{v}_2$; $r_k = \frac{V_1}{V_2}$

$$12 = \frac{0.8754\ m^3/_{kg}}{\bar{v}_2}$$

$$\bar{v}_2 = 0.07295\ m^3/_{kg}$$

for e_{oc};

$$e_{oc} = 1 - \frac{1}{r_k^{\,k-1}} * 100\% = 1 - \frac{1}{12^{\,1.4-1}} * 100\%$$

$$e_{oc} = 62.99\ \%$$

therefore;

$$P_m = \frac{(0.6299)(538.1698\ KJ/_{kg})}{(0.8954 - 0.07295)\ m^3/_{kg}}$$

$$\boxed{P_m = 422.4477\ kPa}$$

OTTO cycle

$Q_A = 1200\ Btu$

$W_{NET} = 610\ Btu$

$e_{OC} = \frac{W_{NET}}{Q_A} * 100\% = \frac{610\ Btu}{1200\ Btu} * 100\%$

$e_{OC} = 50.83\%$

then;

$e_{OC} = 1 - \frac{1}{r_k^{k-1}} * 100\%$

$0.5083 = 1 - \frac{1}{r_k^{1.4-1}}$

$r_k = 5.8986$

therefore;

$r_k = \frac{C+1}{C}$

$5.8986 = \frac{C+1}{C}$

$C = 0.2041$

$\boxed{C = 20.41\%}$

OTTO CYCLE

$P_1 = 110\ kPa$

$P_2 = 760\ kPa$

$$r_k = \left(\frac{P_2}{P_1}\right)^{1/k} = \left(\frac{760\ kPa}{110\ kPa}\right)^{1/1.4} = 3.9773$$

therefore;

$$e_{oc} = 1 - \frac{1}{r_k^{\,k-1}} * 100\%$$

$$e_{oc} = 1 - \frac{1}{3.9773^{1.4-1}} * 100\%$$

$$\boxed{e_{oc} = 42.43\%}$$

Diesel cycle

$$e_{DC} = 1 - \frac{1}{r_k^{k-1}}\left[\frac{r_c^{k} - 1}{k(r_c - 1)}\right] * 100\%$$

$$e_{DC} = 1 - \frac{1}{10^{1.4-1}}\left[\frac{3^{1.4} - 1}{1.4(3-1)}\right] * 100\%$$

$$\boxed{e_{DC} = 48.02\%}$$

EXPONENTIAL LEAP ONLINE REVIEW

DIESEL CYCLE

$$e_{DC} = 1 - \frac{Q_R}{Q_A} * 100\%$$

$$e_{DC} = 1 - \frac{1}{r_k^{k-1}}\left[\frac{r_c^k - 1}{k(r_c - 1)}\right] * 100\%$$

$$e_{DC} = 1 - \frac{1}{8^{1.4-1}}\left[\frac{2^{1.4} - 1}{1.4(2-1)}\right] * 100\%$$

$$e_{DC} = 49.04\%$$

Therefore;

$$0.4904 = 1 - \frac{Q_R}{1450 \text{ kJ}}$$

$$\boxed{Q_R = 738.9025 \text{ kJ}}$$

DIESEL CYCLE

$$t_1 = 28°C$$

$$r_k = 15$$

$$r_c = 6$$

$$r_c = \frac{T_3}{T_2} \; ; \quad r_k = \left(\frac{T_2}{T_1}\right)^{1/k-1}$$

$$15 = \left(\frac{T_2}{301\,k}\right)^{1/1.4-1}$$

$$T_2 = 889.2073\ k$$

$$6 = \frac{T_3}{889.2073\ k}$$

$$T_3 = 5335.2436\ k$$

$$\boxed{t_3 = 5062.2436\ °C}$$

17

Diesel cycle

$P_1 = 110\ kPa \qquad r_k = 13 \text{ to } 1$

$T_1 = 320\ k \qquad T_3 = 1800\ k$

$r_c = \frac{T_3}{T_2}\ ; \quad r_k = \left(\frac{T_2}{T_1}\right)^{1/k-1}$

$13 = \left(\frac{T_2}{320\ k}\right)^{1/1.4-1}$

$T_2 = 892.7448\ k$

$r_c = \frac{1800k}{892.7448k} = 2.0163$

Therefore;

$e_{DC} = 1 - \frac{1}{r_k^{k-1}}\left[\frac{r_c^{k}-1}{k(r_c-1)}\right] * 100\%$

$e_{DC} = 1 - \frac{1}{13^{1.4-1}}\left[\frac{2.0163^{1.4}-1}{1.4(2.0163-1)}\right] * 100\%$

$\boxed{e_{DC} = 57.95\%}$

DIESEL CYCLE

$c = 7\%$

$P_1 = 110 \text{ kPa}$

Fuel is injected 6% of the stroke

$V_3 - V_2 = 0.06 V_D$

└→ Fuel is injected at this process

$V_2 = 0.07 V_D$ (clearance)

Subst;

$V_3 - 0.07 V_D = 0.06 V_D$

$V_3 = 0.13 V_D$

and;

$$r_c = \frac{V_3}{V_2} = \frac{0.13 \cancel{V_D}}{0.07 \cancel{V_D}} = 1.8571$$

$$r_k = \frac{c+1}{c} = \frac{0.07+1}{0.07} = 15.2857$$

Therefore;

$$e_{DC} = 1 - \frac{1}{r_k^{k-1}}\left[\frac{r_c^{k}-1}{k(r_c-1)}\right] * 100\%$$

$$e_{DC} = 1 - \frac{1}{15.2857^{1.4-1}}\left[\frac{1.8571^{1.4}-1}{1.4(1.8571-1)}\right] * 100\%$$

$$\boxed{e_{DC} = 61.39\%}$$

OTTO CYCLE

$$e_{OC} = \frac{W_{NET}}{Q_A} \times 100\%$$

$$0.70 = \frac{W_{net}}{450\ kJ}$$

$$\boxed{W_{NET} = 315\ kJ}$$

OTTO cycle

$$e_{C} = \frac{W_{NET}}{Q_A} * 100\% = 1 - \frac{Q_R}{Q_A} * 100\%$$

$$0.65 = \frac{650 \text{ kJ}}{Q_A}$$

$$Q_A = 1000 \text{ kJ}$$

Therefore;

$$W_{net} = Q_A - Q_R$$

$$650 \text{ kJ} = (1000 - Q_R) \text{ kJ}$$

$$\boxed{Q_R = 350 \text{ kJ}}$$

OTTO cycle

$$e_{c} = 1 - \frac{Q_R}{Q_A} * 100\%$$

$$0.50 = 1 - \frac{1200 \text{ Btu}}{Q_A}$$

$$\boxed{Q_A = 2400 \text{ Btu}}$$

OTTO CYCLE

$P_1 = 101$ kPa

$t_1 = 30°C$

$r_k = 9$

$Q_A = 1100$ kJ/kg

$$P_m = \frac{e_{oc}\, Q_A}{(V_1 - V_2)}$$

$P_1 V_1 = mRT$

$$(101\text{ kPa})\,\frac{V_1}{m} = (0.287\text{ kJ/kg-K})(303\text{ K})$$

$$\frac{V_1}{m} = \bar{v}_1 = 0.861\text{ m}^3/\text{kg}$$

And;

$$r_k = \frac{V_1}{V_2}$$

$$9 = \frac{0.861\text{ m}^3/\text{kg}}{\bar{v}_2}$$

$$\bar{v}_2 = 0.09567\text{ m}^3/\text{kg}$$

for e_{oc};

$$e_{oc} = 1 - \frac{1}{r_k^{\,k-1}} * 100\% = 1 - \frac{1}{9^{1.4-1}} * 100\%$$

$$e_{oc} = 58.48\%$$

Therefore;

$$P_m = \frac{(0.5848)(1100\text{ kJ/kg})}{(0.861 - 0.09567)\text{ m}^3/\text{kg}}$$

$$\boxed{P_m = 840.4636\text{ kPa}}$$

Otto cycle

$$r_k = 10$$

$$t_3 = 1300°C$$

$$\left(\frac{T_3}{T_4}\right)^{1/k-1} = r_e = r_k$$

$$\left(\frac{1573\ K}{T_4}\right)^{1/1.4-1} = 10$$

$$T_4 = 626.2226\ K$$

$$\boxed{t_4 = 353.2226°C}$$

24

exponential LEAP ONLINE REVIEW

OTTO CYCLE

$t_1 = 30°C$

$P_1 = 100\ kPa$

$r_k = 8$

$Q_A = 1400\ KJ/kg$

$Q_A = mC_v(T_3 - T_2)$

$$r_k = \left(\frac{T_2}{T_1}\right)^{1/k-1} = \left(\frac{P_2}{P_1}\right)^{1/k}$$

$$8 = \left(\frac{T_2}{303\ K}\right)^{1/1.4-1} = \left(\frac{P_2}{100\ kPa}\right)^{1/1.4}$$

$T_2 = 696.1112\ K$

$P_2 = 1837.9174\ kPa$

subst;

$$1400\ KJ/kg = (0.7186\ KJ/kg\text{-}K)(T_3 - 696.1112\ K)$$

$T_3 = 2644.3439\ K$

therefore;

$$\frac{T_3}{T_2} = \frac{P_3}{P_2}$$

$$\frac{2644.3439\ K}{696.1112\ K} = \frac{P_3}{1837.9174\ kPa}$$

$$\boxed{P_3 = 6981.7662\ kPa}$$

DIESEL CYCLE

$$e_{DL} = \frac{W_{NET}}{Q_A} * 100\%$$

$$0.60 = \frac{W_{NET}}{1700\ KJ/kg}$$

$$\boxed{W_{NET} = 1020\ KJ/kg}$$

DIESEL CYCLE

$r_k = 10$

$t_1 = 35°C$

$T_3 = 2200\ k$

$r_c = \frac{T_3}{T_2}$; $r_k = \left(\frac{T_2}{T_1}\right)^{1/k-1}$

$10 = \left(\frac{T_2}{308\ k}\right)^{1/1.4-1}$

$T_2 = 773.6610\ k$

$r_c = \frac{773.6610\ k}{308\ k} = 2.5119$

therefore ;

$e_{DC} = 1 - \frac{1}{r_k^{k-1}}\left[\frac{r_c^{k} - 1}{k(r_c - 1)}\right] * 100\%$

$e_{DC} = 1 - \frac{1}{10^{1.4-1}}\left[\frac{2.5119^{1.4} - 1}{1.4(2.5119 - 1)}\right] * 100\%$

$\boxed{e_{DC} = 50.52\%}$

Brayton Cycle

$$e_{BC} = 1 - \frac{1}{r_p^{\frac{k-1}{k}}} * 100\% = 1 - \frac{1}{12^{\frac{1.4-1}{1.4}}} * 100\%$$

$$\boxed{e_{BC} = 50.83\%}$$

BRAYTON CYCLE

$$\frac{T_2}{T_1} = r_p^{\frac{k-1}{k}}$$

$$\frac{T_2}{305\,k} = 13^{\frac{1.4-1}{1.4}}$$

$$T_2 = 634.7013\ k$$

$$W_c = m C_p (T_2 - T_1)$$

$$\frac{W_c}{m} = (1.0062\ kJ/kg\text{-}k)(634.7013 - 305)k$$

$$\boxed{\frac{W_c}{m} = 331.7454\ kJ/kg}$$

BRAYTON CYCLE

$$Q_A = m\,C_p\,(T_3 - T_2)$$

$$\frac{T_2}{T_1} = r_p^{\frac{k-1}{k}}$$

$$\frac{T_2}{303\,K} = 9^{\frac{1.4-1}{1.4}}$$

$$T_2 = 567.6535\,K$$

$$\frac{Q_A}{m} = \left(1.0062\,kJ/kg\text{-}K\right)\left(1773 - 567.6535\right)K$$

$$\boxed{\frac{Q_A}{m} = 1212.8196\ kJ/kg}$$

Brayton Cycle

$$W_T = mC_p(T_3 - T_4)$$

$$\frac{T_3}{T_4} = r_p^{\frac{k-1}{k}}$$

$$\frac{1973\,K}{T_4} = 8^{\frac{1.4-1}{1.4}}$$

$$T_4 = 1089.1843\ K$$

$$\frac{W_T}{m} = (1.0062\ KJ/kg\text{-}K)(1973 - 1089.1843)K$$

$$\boxed{\frac{W_T}{m} = 889.2954\ KJ/kg}$$

BRAYTON CYCLE

$$e_{BC} = 1 - \frac{1}{r_k^{k-1}} * 100\% = 1 - \frac{1}{12^{1.4-1}} * 100\%$$

$$\boxed{e_{BC} = 62.99\%}$$

BRAYTON CYCLE

$$e_{BC} = 1 - \frac{T_4 - T_1}{T_3 - T_2} * 100\%$$

$$= 1 - \frac{(383 - 305)K}{(1593 - 693)K} * 100\%$$

$$\boxed{e_{BC} = 91.33\%}$$

BRAYTON CYCLE

$$BWR = \frac{W_c}{W_T} = \frac{T_2 - T_1}{T_3 - T_4}$$

$T_1 = 303\ K$

$T_3 = 1773\ K$

for T_4;

$$\frac{T_3}{T_4} = r_p^{\frac{k-1}{k}}$$

$$\frac{1773\ K}{T_4} = 9^{\frac{1.4-1}{1.4}}$$

$$T_4 = 946.3854\ K$$

For T_2;

$$\frac{T_2}{T_1} = r_p^{\frac{k-1}{k}}$$

$$\frac{T_2}{303\ K} = 9^{\frac{1.4-1}{1.4}}$$

$$T_2 = 567.6535\ K$$

Hence;

$$BWR = \frac{(567.6535 - 303)\ K}{(1773 - 946.3854)\ K}$$

$$\boxed{BWR = 32.02\ \%}$$