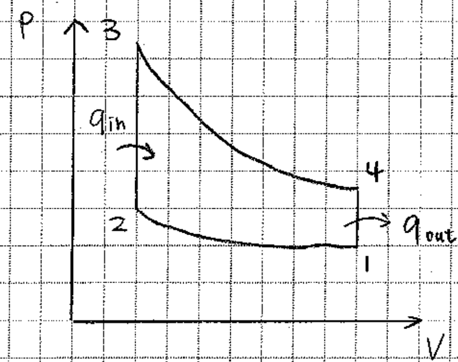
## Q1 Otto Cycle




$P_1 = 100$ kPa

$T_1 = 60°C = 333K$

$P_3 = 8000$ kPa

$n = 1.3$

@ 850 K

$C_p = 1.11$

$C_v = 0.823$

$R = 0.287$

Find:

(a) $T_4$

(b) $W_{net}$

$\eta_{th}$

Sol:

$1 \to 2$: $P_2 = P_1 \left(\frac{V_1}{V_2}\right)^{1.3} = (100)(10)^{1.3} = 1995$ kPa

$T_2 = T_1 \left(\frac{V_1}{V_2}\right)^{0.3} = (333)(10)^{0.3} = 664.4K$

$2 \to 3$: $\frac{P_2}{T_2} = \frac{P_3}{T_3} \Rightarrow T_3 = T_2\left(\frac{P_3}{P_2}\right) = (664.4)\frac{8000}{1995} = 2664K$

$3 \to 4$: $P_4 = P_3 \left(\frac{V_3}{V_4}\right)^{1.3} = 8000\left(\frac{1}{10}\right)^{1.3} = 400.9$ kPa

$T_4 = T_3 \left(\frac{V_3}{V_4}\right)^{0.3} = 2664\left(\frac{1}{10}\right)^{0.3} = \underline{1335 K}$ ※

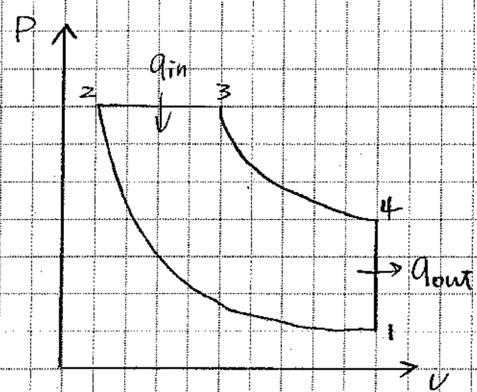
$q_{in} = u_3 - u_2 = C_v(T_3 - T_2) = (0.823)(2664 - 664.4) = 1646$ kJ/kg

$q_{out} = u_4 - u_1 = C_v(T_4 - T_1) = (0.823)(1335 - 333) = 824.8$ kJ/kg

$W_{net} = q_{in} - q_{out} = 1646 - 824.8 = \underline{820.9 \text{ kJ/kg}}$ ※

$\eta_{th} = \frac{W_{net}}{q_{in}} = \frac{820.9}{1646} = \underline{0.499}$ ※

2. Ideal Diesel Cycle




$T_1 = 55°C = 328 K$

$P_1 = 97 kPa$

$r = 17 = \frac{V_1}{V_2}$

$r_c = 2.2 = \frac{V_3}{V_2}$

$C_p = 1.005 \quad C_v = 0.718$

$R = 0.287 \quad k = 1.4$

Sol: $1 \to 2$: $T_2 = T_1\left(\frac{V_1}{V_2}\right)^{0.4} = (328)(17)^{0.4} = 1019 K$

$2 \to 3$: $\frac{P_2 V_2}{T_2} = \frac{P_3 V_3}{T_3} \Rightarrow T_3 = T_2\left(\frac{V_3}{V_2}\right) = 1019(2.2) = 2241 K$

$3 \to 4$: $T_4 = T_3\left(\frac{V_3}{V_4}\right)^{0.4} = T_3\left(\frac{2.2V_2}{V_1}\right)^{0.4} = 2241\left(\frac{2.2}{17}\right)^{0.4} = 989.2 K$

$m = \frac{PV}{RT} = \frac{(97)(0.0024)}{(0.287)(328)} = 2.473 \times 10^{-3} kg$

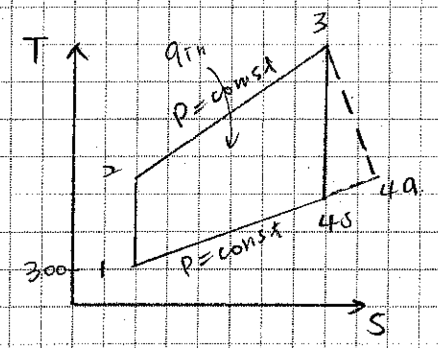
$Q_{in} = m(h_3 - h_2) = mC_p(T_3 - T_2) = (2.473\times10^{-3})(1.005)(2241-1019) = 3.038$

$Q_{out} = m(u_4 - u_1) = mC_v(T_4 - T_1) = (2.473\times10^{-3})(0.718)(989.2 - 328) = 1.174$

$W_{net} = Q_{in} - Q_{out} = 1.864 \ kJ/rev$

$\dot{W}_{net} = \dot{n} W_{net} = (1500/60 \ rev/s)(1.864 \ kJ/rev) = \underline{46.6 \ kW}$ ∦

3. Gas-turbine




$T_1 = 300$
$P_1 = 100$
$P_2 = P_3 = 700$
$T_2 = 580$
$q_{in} = 950$

Find:

Sol:

$$q_{in} = C_p (T_3 - T_2) \Rightarrow 950 = 1.005(T_3 - 580) \Rightarrow T_3 = 1525.27$$

$$\frac{P_{4s}}{P_3} = \frac{P_1}{P_2} \Rightarrow P_{4s} = \frac{P_1}{P_2} P_3 = \frac{100}{700} \cdot 700 = 100 = P_{4s}$$

$$\frac{P_3 V_3}{T_3} = \frac{P_{4s} V_{4s}}{T_{4s}} \Rightarrow T_{4s} = \frac{P_{4s}}{P_3} \cdot T_3 \cdot \frac{V_{4s}}{V_3}$$

$$\because \left(\frac{V_{4s}}{V_3}\right)^k = \frac{V_1^k}{V_2} = \frac{P_2}{P_1} \Rightarrow \frac{V_{4s}}{V_3} = \left(\frac{P_2}{P_1}\right)^{\frac{1}{k}} = \left(\frac{700}{100}\right)^{\frac{1}{1.4}} = 4.01$$

$$\Rightarrow T_{4s} = \frac{100}{700} \times 1525.27 \times 4.01 = 873.76$$

$$q_{out,s} = C_p (T_{4s} - T_1) = 1.005(873.76 - 300) = 576.63$$

$T_1 = 300 \Rightarrow h_1 = 300.19$
$T_2 = 580 \Rightarrow h_2 = 586.04$
$T_3 = 1525.27 \Rightarrow h_3 = 1666.63$
$T_{4s} = 873.76 \Rightarrow h_{4s} = 904.73$

$$W_{c,in} = h_2 - h_1 = 586.04 - 300.19 = 285.85$$

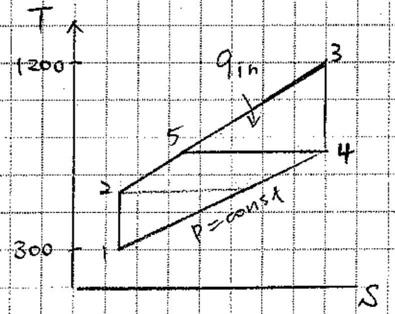
$$W_{t,out} = \eta_T (h_3 - h_{4s}) = 0.86(1666.63 - 904.73) = 655.23$$

$$\frac{W_{c,in}}{W_{T,out}} = \frac{285.85}{655.23} = 0.4362 \quad \divideontimes$$

$$\eta_{th} = \frac{655.23 - 285.85}{950} = 0.3888 \quad \divideontimes$$

## Q4

4 gas-turbine engine




$r_p = 10 = \frac{P_2}{P_1} = \frac{P_3}{P_4}$

$\eta_{th,regen} = 100$

Find: $W_{net}$

$\eta_{th}$

Sol/

$$T_1 V_1^{k-1} = T_2 V_2^{k-1}$$
$$P_1 V_1^{k} = P_2 V_2^{k}$$
$$\Rightarrow \frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{k-1} \text{ \& } \frac{P_2}{P_1} = \left(\frac{V_1}{V_2}\right)^{k} \Rightarrow \left(\frac{T_2}{T_1}\right)^{\frac{1}{k-1}} = \left(\frac{P_2}{P_1}\right)^{\frac{1}{k}}$$

$$\Rightarrow T_2 = T_1 \left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}} = 300\,(10)^{\frac{0.4}{1.4}} = 579.21$$

also $\Rightarrow T_4 = T_3 \left(\frac{P_4}{P_3}\right)^{\frac{k-1}{k}} = 1200\left(\frac{1}{10}\right)^{\frac{.4}{1.4}} = 621.54$

$T_1 = 300 \Rightarrow h_1 = 300.19$

$T_2 = 579.21 \Rightarrow h_2 = 585.21$

$T_3 = 1200 \Rightarrow h_3 = 1277.79$

$T_4 = 621.54 \Rightarrow h_4 = 629.7$

$q_{in} = h_3 - h_5 = h_3 - h_4 = 1277.79 - 629.7 = 648.09$

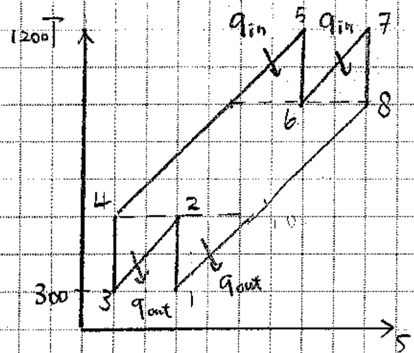
$q_{out} = h_4 - h_1 = 629.7 - 300.19 = 329.51$

$W_{out} = (h_3 - h_2) - (h_4 - h_1) = (1277.79 - 585.21) - (629.7 - 300.19)$

$= \underline{363.07 \text{ kJ/kg}}$ ※

$\eta = \frac{363.07}{648.09} = \underline{0.56}$ ※

5. Ideal gas-turbine w/ 2 stages of compression & expansion




$r_p = 3 = \frac{P_2}{P_1} = \frac{P_4}{P_3} = \frac{P_5}{P_6} = \frac{P_7}{P_8}$  Find: $r_{bw}$, $\eta_{th}$

$T_1 = T_3 = 300$

$T_5 = T_7 = 1200$

Sol:

$T_2 = T_1\left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}} = 300(3)^{\frac{.4}{1.4}} = \underline{410.62 = T_2 = T_4}$ ※

$T_6 = T_5\left(\frac{P_6}{P_5}\right)^{\frac{k-1}{k}} = 1200\left(\frac{1}{3}\right)^{.4/1.4} = \underline{876.72}$ ※

$T_1 = 300 \Rightarrow h_1 = 300.19$

$T_2 = 410.62 \Rightarrow h_2 = 411.75$

$T_5 = 1200 \Rightarrow h_5 = 1277.79$

$T_6 = 876.72 \Rightarrow h_6 = 906.90$

$W_{c,in} = 2(h_2 - h_1) = 2(411.75 - 300.19) = 223.12$

$W_{T,out} = 2(h_5 - h_6) = 2(1277.79 - 906.90) = 741.78$

$r_{bw} = \frac{223.12}{741.78} = \underline{0.3008}$ ※

$q_{regen} = (0.75)(h_8 - h_4) = 0.75(876.72 - 411.75) = 348.73$

$q_{in,old} = (h_5 - h_4) + (h_7 - h_6) = (1277.79 - 411.75) + (1277.79 - 906.90)$
$= 1236.93$

$q_{in,new} = 1236.93 - 348.73 = 888.2$

$\eta_{th} = \frac{741.78 - 223.12}{888.2} = \underline{0.5839}$ ※