9-88

$P_r = 10$

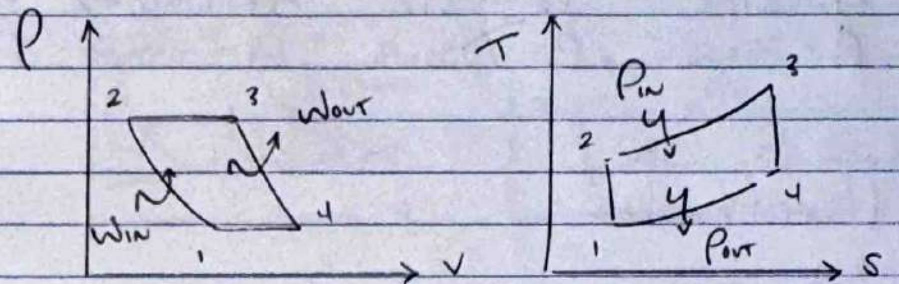
$c_p = 1.005\ kJ/kg\text{-}K$

$k = 1.4$

$q_{IN} = 500\ kJ/kg$

$P_1 = 70\ kPa$

$T_1 = 0°C \rightarrow 273\ K$



ISENTROP. P = CONST. ISENTROP. P = CONST.

1 → 2 $q_{IN} = 500\ kJ/kg$ 3 → 4

$T_1 = 273\ K$

$P_1 = 70\ kPa$

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}} \rightarrow (P_r)^{\frac{k-1}{k}} = T_2 = T_1 \cdot (P_r)^{\frac{k-1}{k}}$$

$$T_2 = 273\,(10)^{\frac{1.4-1}{1.4}} = 527\ K$$

$$P_2 = P_r \cdot P_1 = (10)(70\ kPa) = 700\ kPa$$

$$q_{IN} = c_p\,(T_3 - T_2) \rightarrow \frac{q_{IN}}{c_p} + T_2 = T_3$$

$$\frac{500\ kJ/kg}{1.005\ kJ/kg\text{-}K} + 527\ K$$

$$T_3 = 1024.5\ K$$

$$\frac{T_4}{T_3} = \left(\frac{P_4}{P_3}\right)^{\frac{k-1}{k}} \rightarrow T_4 = T_3\left(\frac{P_4}{P_3}\right)^{\frac{k-1}{k}}$$

$$= 1024.5\left(\frac{70}{700}\right)^{\frac{1.4-1}{1.4}}$$

$$T_4 = 530.6\,K$$

$1 \rightarrow 2 \rightarrow 3 \rightarrow 4$

1	2	3	4
$T_1 = 273\,K$	$T_2 = 527\,K$	$T_3 = 1024.5\,K$	$T_4 = 530.6\,K$
$P_1 = 70\,kPa$	$P_2 = 700\,kPa$	$P_3 = 700\,kPa$	$P_4 = 70\,kPa$

POWER PRODUCED

$$w_{1-2} = C_p(T_2 - T_1)$$

$$= 1.005(527 - 273) = 255.3\ kJ/kg$$

$$w_{3-4} = C_p(T_3 - T_4)$$

$$= 1.005(1023.5 - 530.6) = 495.4\ kJ/kg$$

$$Power = m(w_{3-4} - w_{1-2})$$

$$= 1(495.4 - 255.3)$$

$$\boxed{= 240.1\ kW}$$

THERMAL EFFICIENCY

$$\eta_{TH} = \frac{Power}{P_{IN}} = \frac{240.1}{500} = \boxed{0.4802 \rightarrow 48.02\%}$$

9-99 GAS TURBINE w/ REGENERATOR

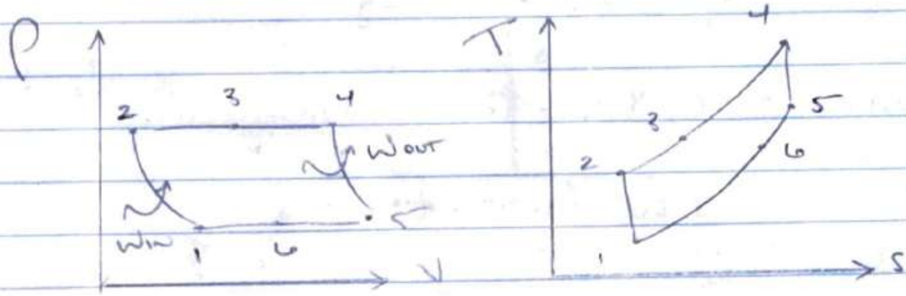
$\frac{P_2}{P_1} = 10$ $\qquad P_{rc} = 10$

$\qquad P_1 = 100\text{ kPa}$

$\frac{P_4}{P_5} = 10$ $\qquad T_1 = 30°C \rightarrow 303\text{ K}$

$\qquad T_4 = 800°C \rightarrow 1073\text{ K}$

$\qquad W_{NET} = 115\text{ kW}$



$\rightarrow 1 \xrightarrow{\text{ISENTROP}} 2 \xrightarrow{P = \text{CONST.}} 3 \xrightarrow{P = \text{CONST.}} 4 \xrightarrow{\text{ISENTROP.}} 5 \xrightarrow{P = \text{CONST.}} 6 \xrightarrow{P = \text{CONST.}}$

1	2	3	4	5	6
$P_1 = 100\text{ kPa}$	$P_2 = 1000\text{ kPa}$	$P_3 = P_2$	$P_4 = P_2$	$P_5 = P_1$	$P_6 = P_1$
$T_1 = 303\text{ K}$	$T_2 = \_\_$	$T_3 = \_\_$	$T_4 = 1073\text{ K}$	$T_5 = \_\_$	$T_6 = \_\_$

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}} \rightarrow 585\text{ K}$$

$$\frac{T_4}{T_5} = \left(\frac{P_4}{P_5}\right)^{\frac{k-1}{k}} \rightarrow 555.76\text{ K}$$

$$T_3 = T_5 - 10\text{ K} = 545.76\text{ K}$$

$$T_6 = T_5 - (T_3 - T_2) = 595\text{ K}$$

HEAT ADDITION + REJECTION

$$W_{1-2} = C_p (T_2 - T_1)$$

$$= 1.005 (585 - 303)$$

$$= 283.41 \ kJ/kg$$

$$W_{4-5} = C_p (T_4 - T_5)$$

$$= 1.005 (1073 - 555.76)$$

$$= 519.83 \ kJ/kg$$

$$W_{NET} = (W_{4-5} - W_{1-2}) = 519.83 - 283.41$$

$$= 236.42 \ kJ/kg$$

$$\dot{m} = \frac{\dot{W}_{NET}}{W_{NET}} = \frac{115}{236.42} = 0.4864 \ kg/s$$

$$\dot{Q}_{IN} = \dot{m} C_p (T_4 - T_3)$$

$$= 0.4864 (1073 - 545.76)$$

$$\boxed{= 256.5 \ kW}$$

$$\dot{Q}_{OUT} = \dot{m} C_p (T_6 - T_1)$$

$$= 0.4864 (598 - 303)$$

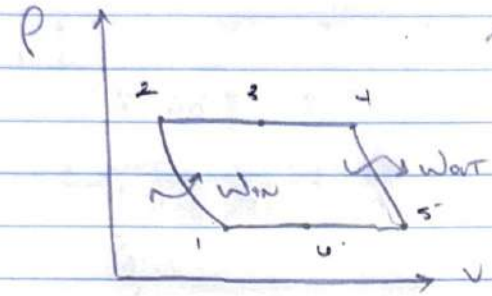
$$\boxed{= 142.03 \ kW}$$

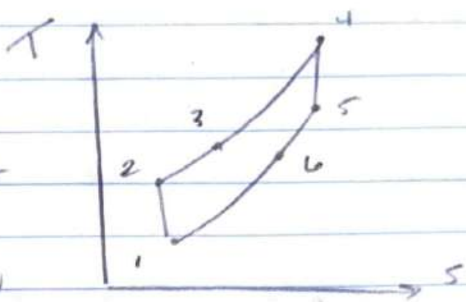
9-107 Brayton cycle w/ Regeneration

$P_r = 7$

$T_{MIN} = 310K$ $\quad \eta_c = 0.75$ $\quad \epsilon = 0.65$

$T_{MAX} = 1150K$ $\quad \eta_T = 0.82$





1	2	3	4	5	6
P = CONST → ISENTROP. →	P = CONST →	P = CONST. →		ISENTROP. →	P = CONST. →
$T_1 = 310K$ $h_1 = 310.24 \frac{kJ}{kg}$ $P_{r_1} = 1.5546$	$P_2 = 7P_1$	$P_3 = P_2$	$T_4 = 1150K$ $h_4 = 1219.3 \frac{kJ}{kg}$ $P_{r4} = 200$ $P_4 = P_1$	$P_5 = P_2$	$P_6 = P_1$

$P_{r_2} = P_r \cdot P_{r_1} \rightarrow (7)(1.5546) = 10.8822$

$h_{2s} = 541.296 \frac{kJ}{kg}$

$$\eta_c = \frac{h_{2s} - h_1}{h_2 - h_1} \rightarrow h_2 = \frac{(h_{2s} - h_1)}{\eta_c} + h_1$$

$$= 618.3 \; kJ$$

$$P_{r5} = \frac{1}{P_r} \cdot P_{r4} = 28.57 \rightarrow h_{5s} = 711.846 \frac{kJ}{kg}$$

$$\eta_T = \frac{h_4 - h_{5s}}{h_4 - h_5} \rightarrow h_5 = h_4 - \frac{(h_4 - h_{5s})}{\eta_T}$$

$$= 803.3 \frac{kJ}{kg}$$

$$\epsilon = \frac{h_3 - h_2}{h_5 - h_2} \rightarrow h_3 = \epsilon(h_5 - h_2) + h_2 = 738.4$$

a. TEMP. @ TURBINE

$\boxed{T_5 = 782.984\ K}$

b. W_{NET}, OUTPUT

$W_{OUT} = (h_4 - h_5) \rightarrow (1219.3 - 803.3)$

$= 416\ kJ/kg$

$W_{IN} = (h_2 - h_1) \rightarrow (618.3 - 310.24)$

$= 308.06\ kJ/kg$

$W_{NET} = (W_{OUT} - W_{IN}) = \boxed{107.94}\ kJ/kg$

c. THERMAL EFFICIENCY

$Q_{IN} = h_4 - h_3 \rightarrow 1219.3 - 738.4$

$= 480.9\ kJ/kg$

$\eta_{TH} = \frac{W_{NET}}{Q_{IN}} = \frac{107.94}{480.9} = \boxed{0.225 = 22.5\%}$

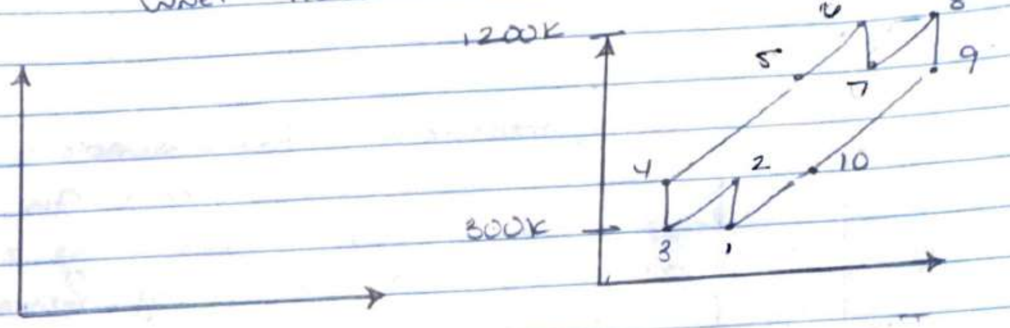
9-119

$r_{p\,overall} = 9 \rightarrow \sqrt{9} = 3$

$T_{in,c} = 300K$

$T_{in,T} = 1200K$

$\dot{W}_{net} = 110\,MW \rightarrow 110{,}000\ kg/s$



$1 \xrightarrow{\text{ISENTROP.}} 2 \xrightarrow{P=\text{CONST.}} 3 \xrightarrow{\text{ISENTROP.}} 4 \xrightarrow{P=\text{CONST.}} 5 \xrightarrow{P=\text{CONST.}} 6 \xrightarrow{\text{ISENTROP.}} 7 \xrightarrow{P=\text{CONST.}} 8 \xrightarrow{\text{ISENTROP.}} 9 \xrightarrow{P=\text{CONST.}} 10$

1	2	3	4	5
$T_1 = 300K$				$T_5 = 1200K$
$h_1 = 300.19\ \frac{kJ}{kg}$				$h_5 = 1277.79\ \frac{kJ}{kg}$
$P_{r1} = 1.3860$				$P_{r5} = 238$

6	7	8	9	10

$$P_{r2} = (P_r)P_{r1} = 3(1.3860) = 4.158$$

$$h_2 = 411.257$$

$$P_{r6} = \frac{P_6}{P_5} P_{r5} = \frac{1}{3}(238.0) = 79.3$$

$$h_6 = 946.247$$

$$(W_{comp})_{in} = 2(h_2 - h_1)$$

$$= 2(411.257 - 300)$$

$$= 222.134 \ kJ/kg$$

$$(W_{turb})_{out} = 2(h_5 - h_6)$$

$$= 2(1277.79 - 946.247)$$

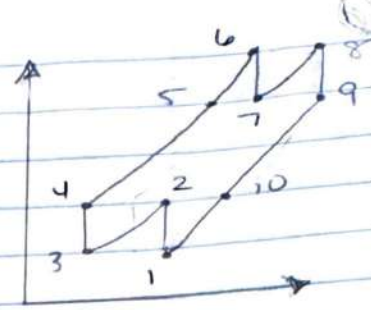
$$= 663.086 \ kJ/kg$$

$$w_{net} = W_{out} - W_{in} = (663.086 - 222.134)$$

$$= 440.952 \ kJ/kg$$

$$\dot{m} = \frac{\dot{W}_{net}}{w_{net}} = \frac{110000}{441} = \boxed{250 \ kg/s}$$

9-121



P = CONST. 1 ISENT. 2 P = CONST. 3 ISENT. 4 P = CONST. 5

P = CONST. 6 ISENT. 7 P = CONST. 8 ISENT. 9 P = CONST. 10

1	2	3	4	5
$T_1 = 300K$				$T_5 = 1200K$
$h_1 = 300.19$				$h_5 = 1277.79$
$P_{r1} = 1.3860$				$P_{r5} = 238$
6	7	8	9	10

$$R_{BW} = \frac{W_{IN}}{W_{OUT}} = \frac{222.134}{663.086} = \boxed{0.335 \rightarrow 33.5\%}$$

$$Q_{IN} = (h_5 - h_4) + (h_7 - h_6)$$

$$(1277.79 - 441.3) + (1277.79 - 946.247)$$

$$= 1198 \ kJ/kg$$

$$\eta_{TH} = \frac{W_{NET}}{Q_{IN}} = \frac{441}{1198} = 0.368 \rightarrow \boxed{36.8\% \quad 37\%}$$

$$\dot{Q}_R = \varepsilon (h_8 - h_4)$$

$$= 0.75 (946.2 - 411.3)$$

$$= 401.2$$

$$\dot{Q}_{INR} = \dot{Q}_{IN} - \dot{Q}_R$$

$$= 1198 - 401.2$$

$$= 796.8$$

$$\eta_{TH} = \frac{W_{NET}}{\dot{Q}_{INR}} = \frac{441}{796.8} = \boxed{0.553 \rightarrow 55.3\%}$$