熱力学 4回目

[1] (1) 熱力学第一法則より, 断熱変化より,

$dq = du + pdv = 0$

$C_v dT + pdv = 0$ —①

理想気体の状態方程式より, $pv = RT \rightarrow RdT = pdv + vdp$

$\frac{R}{\kappa-1}dT + pdv = 0$

$pdv + vdp + (\kappa-1)pdv = 0$

$vdp = -\kappa pdv$

$\frac{dp}{p} = -\kappa\frac{dv}{v}$

$\log p = -\kappa \log v + C$

$\log pv^{\kappa} = C$

$pv^{\kappa} = const$ より,

$p_1 v_1^{\kappa} = p_2 v_2^{\kappa}$ //

(2) $pv^n = const$

$W_{12} = \int_1^2 pdv = p_1 v_1^n \int_1^2 v^{-n}dv = \frac{p_1 v_1^n}{1-n}(v_2^{1-n} - v_1^{1-n})$

$= \frac{p_1 v_1^n}{n-1}\left(\frac{1}{v_1^{n-1}} - \frac{1}{v_2^{n-1}}\right) = \frac{1}{n-1}\left\{p_1 v_1 - p_1 v_2\left(\frac{v_1}{v_2}\right)^n\right\}$

$= \frac{1}{n-1}(p_1 v_1 - p_2 v_2) \quad \left(\because \left(\frac{v_1}{v_2}\right)^n = \frac{p_2}{p_1}\right)$

熱力学第一法則より, $dq = du + pdv$

$Q_{12} = C_v(T_2 - T_1) + W_{12}$

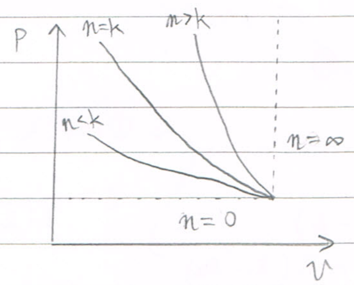
$= C_v(T_2 - T_1) + \frac{1}{n-1}(p_1 v_1 - p_2 v_2) = C_v(T_2 - T_1) - \frac{R}{n-1}(T_2 - T_1)$

$= C_v(T_2 - T_1) - \frac{\kappa-1}{n-1}C_v(T_2 - T_1)$

$= \frac{n-\kappa}{n-1}C_v(T_2 - T_1) \longrightarrow C = \boxed{\frac{n-\kappa}{n-1}C_v}$

(3)

n	変化	比熱
0	定圧	C_p
1	等温	∞
κ	断熱	0
∞	定容	C_v



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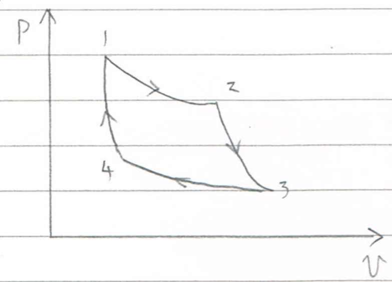
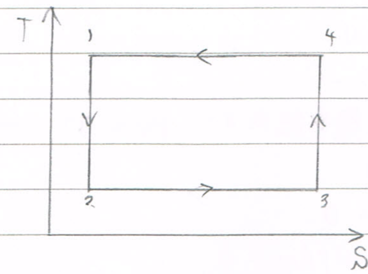
[2] (1)





(2) ・2→3；等温変化より，$dT=0$

$dq = du + p\,dv$ より，$dq = p\,dv$

$$\therefore Q_{23} = \int_2^3 P\,dv = p_2 v_2 \int_2^3 \frac{dv}{v} = p_2 v_2 \ln\left(\frac{v_3}{v_2}\right) = \boxed{mRT_2 \ln\left(\frac{v_3}{v_2}\right)}$$

・4→1；等温変化より，$dT=0$

$$\therefore Q_{41} = \int_4^1 P\,dv = P_4 v_4 \int_4^1 \frac{dv}{v} = P_4 v_4 \ln\left(\frac{v_1}{v_4}\right) = \boxed{mRT_4 \ln\left(\frac{v_1}{v_4}\right)}$$

(3) ・1→2；断熱変化より，$dq=0$

$dq = T\,ds$ より，　$s_{12} = \boxed{0}$

・2→3；等温変化より，$dT=0$

$dq = du + p\,dv$ より，$dq = p\,dv = T\,ds$

$$ds = \frac{p\,dv}{T} = mR\frac{dv}{v} \longrightarrow s_{23} = mR\int_2^3 \frac{dv}{v} = \boxed{mR\ln\left(\frac{v_3}{v_2}\right)}$$

・3→4；断熱変化より，$dq=0$

$s_{34} = \boxed{0}$

・4→1；等温変化より，$dT=0$

$$s_{41} = mR\int_4^1 \frac{dv}{v} = \boxed{mR\ln\left(\frac{v_1}{v_4}\right)}$$

(4)
$$\varepsilon = \frac{Q}{W} = \frac{Q_{41}}{Q_{41} - Q_{23}} \quad \text{— ①}$$

TS線図より，

$$\begin{cases} Q_{23} = T_2(s_3 - s_2) \\ Q_{41} = -T_1(s_1 - s_4) = T_1(s_4 - s_1) \end{cases}$$

$s_1 = s_2$，$s_3 = s_4$ より，　$Q_{41} = T_1(s_3 - s_2)$

→ ①に代入

$$\varepsilon = \frac{T_1(s_3 - s_2)}{T_1(s_3 - s_2) - T_2(s_3 - s_2)} = \boxed{\frac{T_1}{T_1 - T_2}}$$

[3] (1) ・熱効率が上がる
・蒸気の乾き度を上げ，タービンの腐食を防ぐ

(2) $w_{th} = (h_1 - h_a) + (h_b - h_c) + (h_d - h_2) - (h_4 - h_3) = \boxed{h_1 - h_2 + h_3 - h_4 - h_a + h_b - h_c + h_d}$

(3) 加熱量 ; $q_1 = (h_1 - h_4) + (h_b - h_a) + (h_d - h_c)$

$$\therefore \eta_{th} = \frac{w_{th}}{q_1} = \boxed{\frac{h_1 - h_2 + h_3 - h_4 - h_a + h_b - h_c + h_d}{h_1 - h_4 - h_a + h_b - h_c + h_d}}$$

ランキンサイクル ; $\eta = \dfrac{w_T(-w_p)}{q_1 \cancel{- q_2}}$

1 : 加熱 , 2 : 放熱

再熱サイクル ; $\eta = \dfrac{w_T(-w_p)}{q_1}$