1. Величине РС

- интензивне (не зависе од m): p, T
- екстензивне (зависе од m): U, H, S, E_k, E_p, V
- специфичне: $v = \frac{V}{m}$, $u = \frac{U}{m}$...

$$\dot{m} = \frac{\Delta m}{\Delta t} \qquad \dot{V} = w \cdot A \qquad v = \frac{\dot{V}}{\dot{m}}$$

*** Температура**

$$T = t + 273 \qquad \Delta t = \Delta T$$

*** Притисак**

$$p = \frac{F}{A} \rightarrow F = pA$$

1. атм. пр. $p_b = 101325\ Pa$
2. манометарски пр. → $p_m (> p_b)$, $p_v (< p_b)$
3. апсолутни пр. → $p = p_b + p_m$, $p = p_b - p_v$; $p_m = p - p_b$, $p_v = p_b - p$

- статички: $p_{st} = \rho \cdot g \cdot H$

$(\rho_1 \Delta x_{12} - \rho_3 x_3) g$

2. Ј-на стања

- Идеални гас: $c_p = const$; $c_v = const.$ } ТАБЕЛА 3.1.5 СТР. 13

M, R_g, c_p, c_v, κ — M $\left[\frac{kg}{mol}\right]$; R_g, c_p, c_v $\left[\frac{J}{kgK}\right]$; κ $[-]$

*** Ј-на стања:**

1. $pV = mR_gT$ /:m →
2. $pv = R_gT$
3. $pV = nMR_gT \Rightarrow pV = nRT$
4. $pV = mR_gT$ /:V ⇒ $\frac{p}{\rho} = R_gT$

* → $m_{A1} + m_{B1} = m_{A2} + m_{B2}$

*** Гасни закони:**

1. $T = const. \rightarrow p_1V_1 = p_2V_2$
2. $p = const. \rightarrow$
3. $V = const. \rightarrow$

- за свако стање и сваки резервоар се пише ј-на стања

↳ поступак: $p_1V_1 = p_2V_2 \Rightarrow p_1(x_0 - x_1)A = p_2(x_0 - x_2)A$ и једнакост притиска + $m = \frac{pV}{R_gT}$

3. I ЗТД

I Затворени ТДС → $m = const.$, Q_{12}, W_{12} → $Q_{12} + W_{12} = U_2 - U_1$; $\delta Q + \delta W = dU$

* УΔU: $dU = U_2 - U_1 = mc_v(T_2 - T_1)$ за ИГ! $c_v = const$

* Q_{12} и W_{12}:

1. $p = const \rightarrow Q_{12} = mc_p(T_2 - T_1)$; $W_{12} = -p(V_2 - V_1)$
2. $V = const. \rightarrow Q_{12} = mc_v(T_2 - T_1)$; $W_{12} = 0$
3. $T = const. \rightarrow Q_{12} = m(s_2 - s_1)T$
4. $pv^{\kappa} = const. \rightarrow Q_{12} = 0$

(3., 4.) } $W_{12} = \int_1^2 p\,dV$, $p = f(V)$

II Отворени ТДС → $m \neq const.$

$\dot{m} = \frac{\Delta m}{\Delta t}$; $\dot{Q}\left[\frac{J}{s} = W\right]$, $\dot{W}_t [W]$

I ЗТД:

$$\dot{Q}_{12} + \dot{W}_{t12} = \dot{H}_2 - \dot{H}_1 + \dot{E}_{k2} - \dot{E}_{k1} + \dot{E}_{p2} - \dot{E}_{p1}$$

$$\dot{H}_2 - \dot{H}_1 = \dot{m}c_p(T_2 - T_1) \qquad \dot{E}_{p2} - \dot{E}_{p1} = \dot{m}g(z_2 - z_1) \approx 0$$

$$\dot{E}_{k2} - \dot{E}_{k1} = \frac{\dot{m}}{2}(w_2^2 - w_1^2)$$

$c_p, c_v, M, R_g \rightarrow$ 3.1.5 !

Мајерова формула: $c_p - c_v = R_g$

$$V = \frac{d^2\pi}{4} \cdot x \qquad w_{sr} = \frac{\Delta x}{\tau}$$

1. $p = const.$	$\dot{Q}_{12} = \dot{m}c_p(T_2 - T_1)$	$\dot{W}_{t12} = 0$
2. $V = const.$	$\dot{Q}_{12} = \dot{m}c_v(T_2 - T_1)$	$\dot{W}_{t12} = V(p_2 - p_1)$
3. $T = const.$	$\dot{Q}_{12} = \dot{m}T(s_2 - s_1)$	$\dot{W}_{t12}$ } $\int V dp$
4. $pv^{\kappa} = const.$	$\dot{Q}_{12} = 0$	$\dot{W}_{t12}$ } $\int V dp$

4. II ЗТД

$\Delta S_{AIS} > 0$ → неравенство
$\Delta S_{AIS} = 0$ → равнище

$\Delta S_{AIS} \geq 0 \rightarrow \Delta S_{AIS} = \Delta S_{RS} + \Delta S_{Ti} + \Delta S_{TP}$

$\Delta S_{Ti} = \frac{Q_{Ti}}{T_{Ti}}$

$\Delta S_{TP} = \frac{Q_{TP}}{T_{TP}}$

*Аналитично

1. Адиабатен обратим процес:

$\Delta S_{12} = m\left(C_v \ln\frac{T_2}{T_1} + R_g \ln\frac{V_2}{V_1}\right)$

$\Delta S_{12} = m\left(C_p \ln\frac{T_2}{T_1} - R_g \ln\frac{P_2}{P_1}\right)$

$\Delta S_{12} = m\left(C_p \ln\frac{V_2}{V_1} + C_v \ln\frac{P_2}{P_1}\right)$

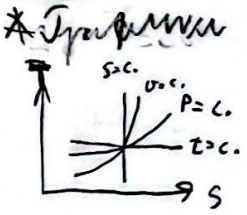
2. $P = const$:

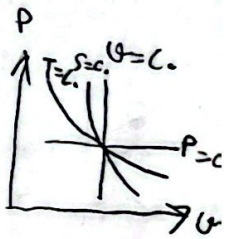
$\Delta S_{12} = m C_p \ln\frac{T_2}{T_1}$

3. $V = const$:

$\Delta S_{12} = m C_v \ln\frac{T_2}{T_1}$

*Графично





4. $T = const$.

$\Delta S_{12} = \frac{Q_{12}}{T}$

5. $PV^k = const$.

$\Delta S_{12} = 0$

5. Политропа

1. Общи данни:

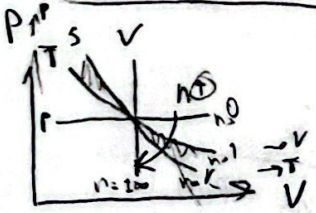
$PV^n = const.$

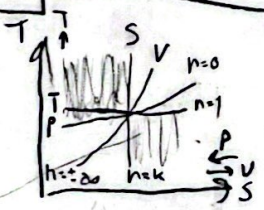
$k = \frac{C_p}{C_v}$

$n = \frac{C_n - C_p}{C_n - C_v}$

$Q_{12} = m C_n (T_2 - T_1)$

$C_n = C_v \frac{n-k}{n-1}$





2. $P = const.$

$n = 0$

$Q_{12} = m C_p (T_2 - T_1)$

3. $T = const.$

$n = 1$

$Q_{12} = mT(S_2 - S_1)$

4. $S = const.$

$n = k$ $PV^k = const.$

$Q_{12} = 0$

5. $V = const.$

$n = \pm\infty$

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

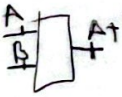
6. Смесване

- Смесване винаги не ИГ!

*Смесване при $V = const.$ (задължително ТДС)

A B → A+B

*Смесване при $P = const.$ (задължително ТДС)



$P_A = P_B = P_{sm}$

- Смесва смеси:

$g_i = \frac{m_i}{m_{sm}}$ $r_i = \frac{V_i}{V_{sm}}$ $\gamma_i = \frac{n_i}{n_{sm}}$

За ИГ! ⇒ $r_i = \gamma_i$

$r_i = g_i \frac{M_{sm}}{M_i} = g_i \frac{R_i}{R_{sm}}$

- Задължителни формули:

$M_{sm} = \frac{1}{\sum_{i=1}^{n} \frac{g_i}{M_i}}$

$R_{sm} = \frac{8314}{M_{sm}}$

$C_p = \sum_{i=1}^{n} g_i C_{pi}$

$C_v = \sum_{i=1}^{n} g_i C_{vi}$

ТД 2. КЛК

7. Деснокружни процеси
- произведено и предато стање је једнако, смер кретања на сату

*** Carnot**

$Q_{PK} = -W_{PK}$

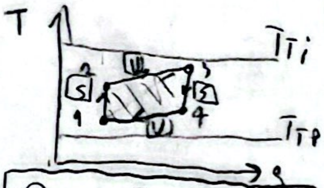
$Q_{dov} = Q_{12} + Q_{23}$
$Q_{odv} = Q_{34} + Q_{41}$

$Q_{kor} = Q_{dov} - |Q_{odv}| = W_{kr}$

$\eta = 1 - \frac{|Q_{odv}|}{Q_{dov}}$

$\Delta S_{RS} = 0$

*** ОТО**



$Q_{dov} = Q_{23} = m c_v \Delta T_{32}$
$Q_{odv} = Q_{41} = m c_v \Delta T_{41}$

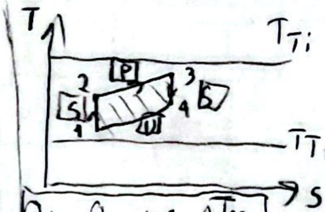
$\Delta S_{23} = -\Delta S_{41}$

$\frac{T_3}{T_2} = \frac{T_4}{T_1}$

$\eta = 1 - \frac{|T_1 - T_4|}{T_3 - T_2}$

$\varepsilon = \frac{V_{max}}{V_{min}} = \frac{V_4}{V_3} = \frac{V_1}{V_2}$

*** ДИЗЕЛ**



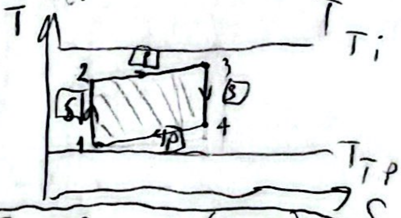
$Q_{dov} = Q_{23} = m c_p \Delta T_{23}$
$Q_{odv} = Q_{41} = m c_v \Delta T_{41}$

$\left(\frac{T_3}{T_2}\right)^k = \frac{T_4}{T_1}$

$\eta = 1 - \frac{|c_v(T_1 - T_4)|}{c_p(T_3 - T_2)}$

$\varepsilon = \frac{V_4}{V_2}$

*** Џулов**



$Q_{dov} = Q_{23} = m c_p (T_3 - T_2)$
$Q_{odv} = Q_{41} = m c_p (T_1 - T_4)$

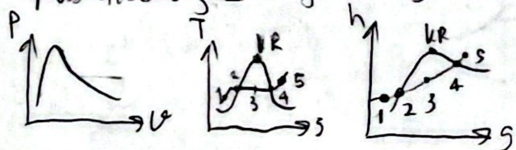
$\frac{T_3}{T_2} = \frac{T_4}{T_1}$

$\eta = 1 - \frac{|T_1 - T_4|}{T_3 - T_2}$

ТД појављивања: $T_3 = T_{Ti}$; $T_1 = T_{TP}$

8. Водена пара

1 - течност ; 2 - кључала т. ; 3 - влажна пара ; 4 - сува пара ; 5 - прегрејана пара

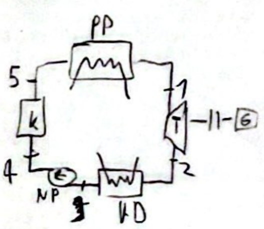


1, 5 - 4.4.8. (61. стр)
2, 4 - 4.4.5 - 7. (52. - 57. стр)

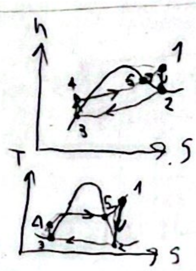
3 - $x = \frac{h - h'}{h'' - h'} \rightarrow h = h' + x(h'' - h')$ (h, u, s, v)

$x = \frac{m''}{m' + m''}$

9. ТД са радним ф. (Ренкин Клаузијусов)



1-2 - адиј. експанзија
2-3 - изоб. одв. Q
3-4 - адиј. компресија
4-5 - изоб. дов. Q
5-1 - изоб. дов. Q



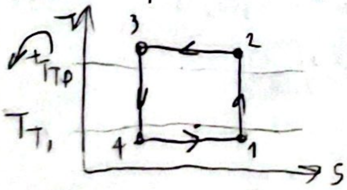
$\eta = 1 - \frac{|h_3 - h_2|}{h_1 - h_4}$

$y = y_1 + \frac{y_2 - y_1}{x_2 - x_1}(x - x_1)$

$q_{dov} = q_{45} + q_{51} = h_1 - h_4$
$q_{odv} = q_{23} = h_3 - h_2$

$w_{t12} = h_2 - h_1$
$\hookrightarrow P_{tur} = \dot{m}(h_2 - h_1)$
$w_{t34} = h_4 - h_3$
$\hookrightarrow P_{NP} = \dot{m}(h_4 - h_3)$

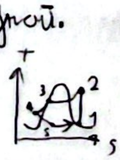
10. Левокретни (расхладни)



$Q_{odv} = Q_{23} \rightarrow Q_{TP} = -Q_{23}$
$Q_{dov} = Q_{41} \rightarrow Q_{T1} = -Q_{41}$

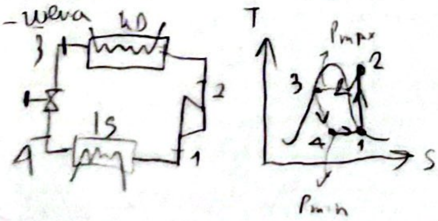
$\varepsilon_h = \frac{\dot{Q}_h}{P_h} \rightarrow \dot{Q}_h = Q_{dov} = \dot{m}(h_1 - h_4)$
$P_h = \dot{m} w_{t12} = \dot{m}(h_2 - h_1)$

- Пумпа



$P_{kom} = \dot{m}(h_2 - h_1)$
$\dot{Q}_h = \dot{m}(h_1 - h_5)$
$\varepsilon_h = \frac{h_2 - h_5}{h_1 - h_5}$

- шема



1-2 - адиј. комп.
2-3 - изобарско - Q
3-4 - адиј. пригуш. ($h_3 = h_4$)
4-1 - изобарско + Q

$\hookrightarrow$ 4 - кључала течност

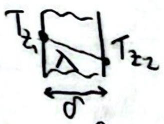
11., 12. Простирање топлоте

$\dot{Q} = \frac{Q}{\tau}\,[W]$; $\dot{q} = \frac{\dot{Q}}{A}\,[\frac{W}{m^2}]$; $q_L = \frac{\dot{Q}}{L}\,[\frac{W}{m}]$

* Кондукција (провођење)

- Фуријеова једначина: $\vec{q} = -\lambda\, grad\, T$

1. Раван зид:



$$\dot{q} = \frac{T_{z1} - T_{z2}}{\delta/\lambda} = \frac{T_{z1} - T_{z2}}{R_{\lambda,A}}$$

вишеслојни: $$\dot{q} = \frac{T_{z1} - T_{z2}}{\sum R_{\lambda,A}} = \frac{T_{z1} - T_{z2}}{\sum^{i} \frac{\delta_i}{\lambda_i}}$$

2. Цилиндрични:

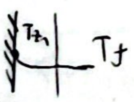
$$\dot{q}_L = \frac{\dot{Q}}{L}$$

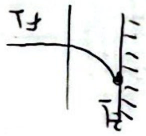
$$\dot{q}_L = \frac{T_{z1} - T_{z2}}{\frac{1}{2\pi\lambda} \ln\frac{d_2}{d_1}}$$

вишеслојни: $$\dot{q}_L = \frac{T_{z1} - T_{z2}}{\sum \frac{1}{2\pi\lambda_i} \ln\frac{d_{2i}}{d_{1i}}}$$

* Конвекција (прелажење)

са зида на флуид ~ са флуида на зид





- Њутнов закон

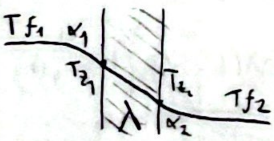
$\dot{q} = \alpha (T_z - T_f)$ $\alpha = [\frac{W}{m^2 K}]$

1. Раван зид: $\dot{q} = \frac{T_z - T_f}{\frac{1}{\alpha}}$ → R_α

2. Цил. зид: $\dot{q} = \frac{T_z - T_f}{\frac{1}{d\pi\alpha}}$ → R_α

* Пролажење (комбинација 1. и 2.)

1. Раван зид



$$\dot{q} = \frac{T_{f1} - T_{f2}}{R_{\alpha1} + R_{\lambda,A} + R_{\alpha2}}$$

$R_{\alpha1} = \frac{1}{\alpha_1}$; $R_{\alpha2} = \frac{1}{\alpha_2}$; $R_{\lambda,A} = \frac{\delta}{\lambda}$ → $\frac{1}{k}$ - коеф. пролажења

2. Цилиндрични зид

$$\dot{q}_L = \frac{T_{f1} - T_{f2}}{R_{\alpha1} + R_{\lambda,L} + R_{\alpha2}}$$

$R_{\alpha1} = \frac{1}{d_1\pi\alpha_1}$; $R_{\alpha2} = \frac{1}{d_2\pi\alpha_2}$; $R_\lambda = \frac{1}{2\pi\lambda} \ln\frac{d_2}{d_1}$

* Радијација

$$\dot{Q} = C_{12} H_{12} \left(\left(\frac{T_1}{100}\right)^4 - \left(\frac{T_2}{100}\right)^4 \right) [W]$$ T_1, T_2 у K!

$C_{12} = C_0 \cdot \varepsilon_{red}$ $[\frac{W}{m^2 K^4}]$

$C_0 = 5{,}67$

$\varepsilon_{red} = \varepsilon_1 \varepsilon_2$

$H_{12} = A_2 > A_1$

R_λ - отпор (провођењу) $[\frac{m^2 K}{W}]$

α - коеф. прелажења Q $[\frac{W}{m^2 K}]$

λ - коеф. провођења Q $[\frac{W}{mK}]$

δ - дебљина зида