

# 1 Yechim:

A)  $0 \rightarrow 1$  qism aralashmaning izobar sōrilishini ifodalaydi.

$1 \rightarrow 2$  qism uning adiabatik siqilishini ifoda etadi.

$2 \rightarrow 3$  qism aralashma yongach bosimning izoxorik ortishini

$3 \rightarrow 4$  qism adiabatik kengayish „ishchi yurish“

$4 \rightarrow 1$  qism gazlarning izobarik chiqarilishini

$1 \rightarrow 0$  qism aralashmaning slindrdan izobar chiqarilishini ifodalaydi.

B)  $T_1 = T_0 = 300 \text{ (K)}$

$$P_1 = P_0 = 10^5 \text{ (Pa)}$$

$1 \rightarrow 2$  jarayon adiabatik ekanligi uchun Puasson tenglamasidan foydalanamiz.

$$P_1 V_1^\gamma = P_2 V_2^\gamma \quad (1)$$

$$P_2 = P_1 \left( \frac{V_1}{V_2} \right)^\gamma \quad (2)$$

$$P_2 = P_1 \epsilon^\gamma = 2,34 \text{ (MPa)}$$

Izoh: Bu yerda „ $\epsilon$ “ siqilish darajasi:

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

Klapeyron tenglamasidan

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

$$T_2 = T_1 \cdot \frac{P_2 V_1}{P_1 V_2} \quad \left( \epsilon = \frac{V_1}{V_2} \right)$$

$T_2 = T_1 \cdot \frac{P_2}{P_1} \cdot \frac{1}{\epsilon}$  tenglikni hosil qilib (2) ni hisobga olsak

$$T_2 = T_1 \cdot \epsilon^{\gamma-1}$$

$T_2 = 740 \text{ (K)}$  ekanligi kelib chiqadi.

Shartga kōra yonish boshlangan paytda bosim 2 marta ortadi ya'ni

$$P_3 = 2P_2$$

$$P_3 = 4,68 \text{ (MPa)}$$

2 → 3 izoxorik jara-  
yon ekanligi uchun

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

hosil qilamiz. Bundan  
„T<sub>3</sub>“ ni topsak quyida-  
gicha kōrinish oladi

$$T_3 = T_2 \cdot \frac{P_3}{P_2} \quad \langle P_3 = 2P_2 \rangle$$

$$T_3 = 2T_2 \Rightarrow T_3 = 1480(K)$$

3 → 4 adiabatik jara-  
yon shuning uchun

$P_3 V_3^\gamma = P_4 V_4^\gamma$  ni  
yozishimiz mumkin.  
Bundan

$$P_4 = P_3 \cdot \left(\frac{V_3}{V_4}\right)^\gamma \quad \langle \epsilon = \frac{V_2}{V_1} \rangle$$

$$P_4 = P_3 \cdot \epsilon^{-\gamma} \Rightarrow$$

$P_4 = 0,2$  (MPa) ekanligi  
kelib chiqadi.

$$\frac{P_3 V_3}{T_3} = \frac{P_4 V_4}{T_4} \quad \text{Klapeyron}$$

tenglamasidan

$$T_4 = \frac{P_4}{P_3} \cdot \frac{V_3}{V_1} \cdot T_3$$

$$\left\langle \frac{V_2}{V_1} = \epsilon \quad \frac{P_4}{P_3} = \epsilon^{-\gamma} \right\rangle$$

$$T_4 = T_3 \cdot \epsilon \cdot \epsilon^{-\gamma}$$

$$T_4 = T_3 \cdot \epsilon^{1-\gamma}$$

$T_4 = 600$  (K) ekanli-  
gi kelib chiqadi.

4 → 1 izoxorik jara-  
yon, shuning uchun

$$\frac{P_4}{P_1} = \frac{T_4}{T_1} \Rightarrow T_1 = T_4 \cdot \frac{P_1}{P_4}$$

$$T_1 = 300$$
 (K)

Kutilganidek  $T_1 = T_1'$ .

C) Ta'rifga kōra  
issiqlik dvigateli  
siklining F.I.K'i

$$\eta = \frac{A_{\text{foy}}}{Q_1} = \frac{Q_1 - Q_2}{Q_1} \text{ ga}$$

teng.

Bu yerda „A<sub>foy</sub>“ dvi-  
gatel tomonidan bir  
sikl davomida bajaril-  
gan foydali ish.

$Q_1 \rightarrow$  isitkichdan olin-  
gan issiqlik miqdori

$Q_2 \rightarrow$  sovutkichga berilgan issiqlik miqdori.

$1 \rightarrow 2$  va  $3 \rightarrow 4$  jarayonlar issiqlik almashinuvrisiz yuz bergani uchun issiqlik berilishi va olib ketilishi faqat  $2 \rightarrow 3$  va  $4 \rightarrow 1$  qismlarda amalga oshiriladi.

$$Q_1 = C_v m (T_3 - T_2)$$

$$Q_2 = C_v m (T_4 - T_1)$$

$C_v \Rightarrow$  gazning o'zgar-mas hajmdagi so-lishtirma issiqlik sig'imi.

$$\eta = \frac{Q_1 - Q_2}{Q_1}$$

$$\eta = \frac{C_v m [(T_3 - T_2) - (T_4 - T_1)]}{C_v m (T_3 - T_2)}$$

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

$$\eta = 1 - \frac{600 - 300}{1480 - 740}$$

$$\eta = 1 - \frac{300}{740}$$

$$\eta \approx 0,6$$



## 2 Yechim:

$$1) \Delta Q = \Delta U + A$$

$$\langle \Delta U = \nu C_v \Delta T \rangle$$

$$\langle A = P \cdot \Delta V \rangle$$

$$C = \frac{1}{\nu} \cdot \frac{\Delta Q}{\Delta T} = \frac{1}{\nu} \cdot \left( \frac{\nu C_v \Delta T}{\Delta T} + \frac{P \Delta V}{\Delta T} \right) =$$

$$= C_v + \frac{P}{\nu} \cdot \frac{\Delta V}{\Delta T} \quad (1)$$

$C \rightarrow$  motyar issiq sig'imi  $Q = C \nu \cdot \Delta T$  dan topildi.

$C_v - V = \text{const}$  bo'lgandagi gazning motyar issiqlik sig'imi ikki atomli gaz uchun  $C_v = \frac{5}{2}R$  ga teng.

Gaz bosimi Laplas bosimiga teng. Sorun pufagi vakuumda bo'lgani uchun 2 ta sirtga ega. Laplas bosimi:  $P = \frac{4\sigma}{r}$  bo'ladi.

$\sigma = \text{const}$   $r \sim V^{\frac{1}{3}}$  bo'lganligidan holat tenglamasini quyidagicha yozamiz.

$$P \sim \frac{1}{V^{\frac{1}{3}}} \Rightarrow P V^{\frac{1}{3}} = \text{const}$$

$$P V^{\frac{1}{3}} = \text{const}$$

Ideal gaz uchun

$$P V = \nu R T \quad \text{bundan,}$$

$$P = \frac{\nu R T}{V} \quad \text{ni} \quad P^{\frac{1}{3}} V =$$

$$= \text{const} \quad \text{ga qo'yib,}$$

$$\frac{T^{\frac{1}{3}}}{V^{\frac{1}{3}}} = \text{const} \quad \text{ekani}$$

gini topamiz.

$$T^{\frac{1}{3}} = \text{const} \cdot V^{\frac{1}{3}}$$

$$V^{\frac{1}{3}} = \frac{T^{\frac{1}{3}}}{\text{const}} \Rightarrow$$

$$V^{\frac{2}{3}} = \frac{T^{\frac{2}{3}}}{\text{const}} \Rightarrow$$

$$V = \frac{T^{\frac{3}{2}}}{\text{const}}$$

$$\frac{dV}{dT} = \frac{3}{2} \cdot \frac{1}{\sqrt{\text{const}}} \cdot T^{\frac{1}{2}} = \frac{3}{2} \cdot$$

$$\frac{1}{\sqrt{T^{\frac{3}{2}}}} \cdot T^{\frac{1}{2}} = \frac{3}{2} \cdot \frac{V}{T^{\frac{3}{2}}} \cdot T^{\frac{1}{2}} = \frac{3}{2} \cdot \frac{V}{T}$$

(1) ifodadan foydalanamiz.

$$C = C_v + \frac{P}{\nu} \cdot \frac{\Delta V}{\Delta T} = C_v + \frac{P}{\nu} \cdot \frac{dV}{dT} =$$

$$= \left\langle \frac{dV}{dT} = \frac{3}{2} \cdot \frac{V}{T} \right\rangle = C_v + \frac{P}{\nu} \cdot \frac{3}{2} \cdot \frac{V}{T}$$

$$\langle P V = \nu R T \rangle \Rightarrow$$

$$C = C_v + \frac{3}{2} \cdot \frac{\nu R T}{\nu T} = C_v + \frac{3}{2} \cdot R =$$

$$= \left\langle C_v = \frac{5}{2} R \right\rangle = \frac{5}{2} R + \frac{3}{2} R =$$

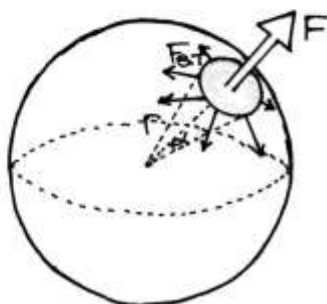
$$= \frac{8}{2} R = 4 R$$

$$\langle R = 8,31 \left( \frac{\text{J}}{\text{mol} \cdot \text{K}} \right) \rangle$$

$$C = 4 \cdot 8,31 = 33,24 \left( \frac{\text{J}}{\text{mol} \cdot \text{K}} \right)$$

$$\text{Jarobas } C = 33,24 \left( \frac{\text{J}}{\text{mol} \cdot \text{K}} \right)$$

2) Sorun pufagining yuzasidan kichik bir qismni ajratib olamiz va uni tebratishlarini topamiz.



$F \rightarrow$  Gaz tomonidan taʼsir etuvchi kuch

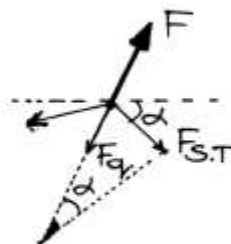
$F_{st} \rightarrow$  sirt taranglik kuchi

Sorun pufagining radiusi „x“ ga ortib, kamayib tebratayotgan deb faraz qilamiz. Radiusi „x“ ga ortsin. Bu hol uchun dinamikaning asosiy masalasiga tenglama-

sinini yozamiz.

$$m \cdot \ddot{x} = F - F_q$$

( $F_q$  - qaytaruvchi kuch)



$$F_q = 2 F_{st} \cdot \sin \alpha$$

$\alpha$  juda kichik ekanligidan  $\sin \alpha \approx \alpha$

$$\Rightarrow F_q = 2 F_{st} \cdot \alpha$$

$$F_{st} = \sigma \cdot l = \sigma \cdot 2\pi r$$

$$r = (r+x) \sin \alpha \approx \alpha (r+x)$$

$$\Rightarrow F_{st} = 2\pi \sigma \cdot \alpha (r+x)$$

$$F_q = 2 \cdot 2\pi \sigma \cdot \alpha (r+x) \cdot \alpha = 4\pi \sigma \cdot \alpha^2 (r+x)$$

Ajratilgan qism yuzasi  $S = \pi \cdot (\alpha \cdot r)^2$

Radiusi „x“ ga ortgandan soʻng

$$S' = \pi (\alpha \cdot (r+x))^2 \Rightarrow$$

$$S' = S \cdot \left(1 + \frac{x}{r}\right)^2 = \langle x \ll r \rangle =$$

$$= S \cdot \left(1 + 2 \cdot \frac{x}{r}\right)$$

$$F = P \cdot S' \quad (1)$$

$P = \text{const}$ . Sababi

Savolda Termodinamik muvozanatda ya'ni issiqlik muvozanatida deyilgan.

$$\Rightarrow P \cdot V = P' \cdot V'$$

$$\langle V \propto r^3 \rangle \Rightarrow$$

$$P' = P \cdot \left(\frac{r}{r'}\right)^3 = \langle r' = r + x \rangle =$$

$$= P \cdot \left(\frac{r}{r+x}\right)^3 = P \cdot \frac{1}{\left(1+\frac{x}{r}\right)^3} \approx$$

$$\approx P \cdot \frac{1}{\left(1+\frac{3x}{r}\right)} \approx P \cdot \left(1 - \frac{3x}{r}\right)$$

(1) ifodaga ko'ra,  
 $F = P' \cdot S' = P \cdot \left(1 - \frac{3x}{r}\right) \cdot S.$

$$\cdot \left(1 + 2 \cdot \frac{x}{r}\right) \approx \left(1 - \frac{x}{r}\right) P \cdot S$$

$$m \cdot \ddot{x} = F - F_q$$

Ajratib olingan  
 qism massasi

$$m = \rho \cdot S \cdot h \quad \langle S = 4\pi(\alpha \cdot r)^2 \rangle$$

$$\Rightarrow \rho \cdot S \cdot h \cdot \ddot{x} = \left(1 - \frac{x}{r}\right) \cdot P \cdot S -$$

$$- 4\pi\sigma \cdot \alpha^2 (r+x)$$

$$\text{Dastlab, } P \cdot S = \frac{4\sigma}{r}.$$

$$\cdot \pi \cdot (\alpha r)^2 = 4\pi\sigma \cdot \alpha^2 \cdot r$$

$$\langle S = \pi \cdot \rangle \Rightarrow$$

$$\rho = \frac{4\pi\sigma \cdot \alpha^2 \cdot r}{\alpha^2 \pi r^2} = \frac{4\sigma}{r} \text{ edi.}$$

bundan,

$$\rho \cdot S \cdot h \cdot \ddot{x} = -\frac{x}{r} \cdot \frac{4\sigma}{r} \cdot S -$$

$$- 4\pi \cdot \sigma \cdot \alpha^2 \cdot \frac{x}{r^2} \cdot \rho$$

$$\langle S = \pi \alpha^2 \cdot r^2 \rangle$$

$$\rho \cdot h \cdot \ddot{x} = -\frac{\sigma \cdot x}{r^2}$$

$$\rho \cdot h \cdot \ddot{x} = -\frac{8\sigma \cdot x}{r^2} \Rightarrow$$

$$\ddot{x} + \frac{8\sigma}{\rho \cdot h \cdot r^2} x = 0$$

$$\left\{ \ddot{x} + \omega^2 x = 0 \rightarrow \text{kichik} \right. \\ \left. \text{tebranishlar tenglamasi} \right\}$$

$$\text{Demak, } \omega = \sqrt{\frac{8\sigma}{\rho \cdot h \cdot r^2}} =$$

$$= 108 \text{ s}^{-1}$$

$$\text{Javob: } \omega = 108 \text{ s}^{-1}$$



### 3. Yechim:

Borning atom modeliga kōra elektro-magnit nurlanish (yoki yutilish) uning bir statsionar holatdan ikkinchi statsionar holatga o'tishida yuz beradi.

$$E_k - E_n = h\nu_{kn}$$

$$h\nu_{kn} = hR \left( \frac{1}{n^2} - \frac{1}{k^2} \right)$$

Bu yerda

$R \rightarrow$  Ridberg doimiysi  
 $h \rightarrow$  Plank doimiysi

Vodorod atomining ionlashish energiyasi  $n=1$  asosiy holatdan  $k=\infty$  holatga o'tishdagi o'tish energiyasiga teng.

$$E_{ion} = hR \left( \frac{1}{1} - \frac{1}{\infty} \right)$$

$$E_{ion} = hR \quad (1)$$

Masala shartiga kōra vodorod atomi asosiy holatda turgani sababli minimal qozgotish energiyasi  $E_q$  bolib

$$E_q^{(min)} = E_2 - E_1 = hR \left( 1 - \frac{1}{4} \right)$$

$$E_q^{(min)} = \frac{3}{4} hR$$

(1) ifodani hisobga olsak

$$E_q^{(min)} = \frac{3}{4} E_{ion} \quad \langle hR = E_{ion} \rangle$$

$$E_q^{(min)} = \frac{3}{4} E_{ion} \quad (2) \text{ teng-}$$

likni hosil qilishimiz mumkin.

Atomlar massalar markazi bilan boglangan sanoq sistemasida ikkala vodorod atomi  $v/2$  ga teng bir xil tezlikka ega.

Energiyani saqlanish qonunini qollaymiz

$$2 \cdot \frac{m}{2} \left( \frac{v}{2} \right)^2 = E_k + E_q$$

Bu yerda  
 $E_k \rightarrow$  atomlarning  
 tōqnashishdan keyin-  
 gi kinetik energiyasi ( $E_k \geq 0$ )

$E_q \rightarrow$  vodorod atomi-  
 ning qōzğatish  
 energiyasi.

Tōqnashish elastik  
 bōlishi uchun

$$2 \cdot \frac{m}{2} \left( \frac{v}{2} \right)^2 < E_q^{(\min)}$$

$$\left\langle E_q^{(\min)} = \frac{3}{4} E_{ion} \right\rangle$$

$$2 \cdot \frac{m}{2} \left( \frac{v}{2} \right)^2 < \frac{3}{4} E_{ion}$$

shart bajarilishi  
 kerak. Demak

$$\frac{mv_0^2}{4} = \frac{3}{4} E_{ion} \text{ tenglik-}$$

dan chegaraviy  
 tezlik  $v_0$  dan ki-  
 chik tezliklarda  
 tōqnashishlar elastik  
 bōladi.

$$\frac{mv_0^2}{4} = \frac{3}{4} E_{ion} \text{ dan}$$

" $v_0$ " ni topsak

$$v_0 = \sqrt{\frac{3E_{ion}}{m}} \text{ kelib chiqadi.}$$

Son qiymatlarini  
 qōyib hisoblasak

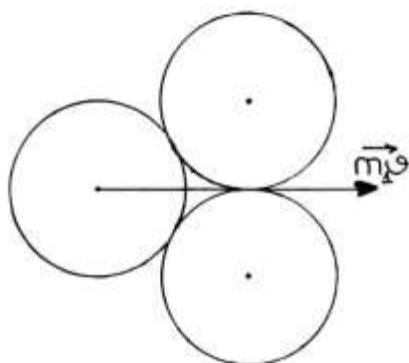
$v_0 = 6,26 \cdot 10^4 \text{ (m/s)}$   
 ekanligi ma'lum bōla-  
 di.

Javob: Atomlarning  
 elastik tōqnashishi  
 yuz beradigan tezlik-  
 ning chegaraviy  
 qiymati  $v_0 = 6,26 \cdot 10^4 \text{ (m/s)}$   
 ga teng.



#### 4. Yechim:

Uchta bir xil sharchalarni yopiq sistema deb qabul qilamiz. Boshlang'ich paytda vertikal yo'nalishda og'irlik kuchi ipning taranglik kuchi bilan muvozanatda bo'ladi.



To'qnashuvchi shar bilan qolgan ikkita sharning gorizontal tekislikdagi vaziyatini rasmda ko'rsatilgandek tasavvur qilish mumkin. U holda impuls saqlanish qonunini quyidagicha yozish mumkin:

$$\begin{cases} \vec{P}_{um} = \vec{m}_1 \vec{u} \\ \vec{P}_{um} = \vec{m}_1 \vec{u}_1 + \vec{m}_2 \vec{u}_2 + \vec{m}_3 \vec{u}_3 \end{cases}$$

$$\vec{P}_{um} = \vec{P}_{um}$$

$$\vec{m}_1 \vec{u} = \vec{m}_1 \vec{u}_1 + \vec{m}_2 \vec{u}_2 + \vec{m}_3 \vec{u}_3$$

Masala shartiga ko'ra,

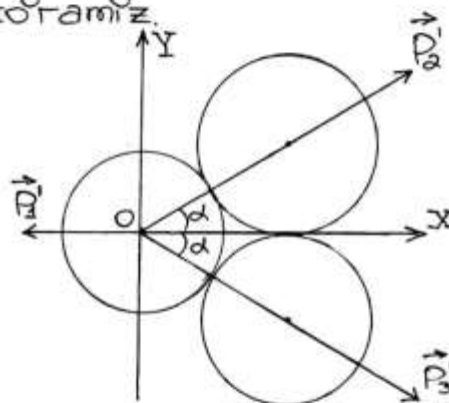
$$m_1 = m_2 = m_3 = m \Rightarrow$$

$$\vec{m} \vec{u} = \vec{m} \vec{u}_1 + \vec{m} \vec{u}_2 + \vec{m} \vec{u}_3$$

$$\vec{u} = \vec{u}_1 + \vec{u}_2 + \vec{u}_3$$

ko'rinishdagi tenglik hosil bo'ladi.

Sharlarning impuls-larini Ox va Oy o'qlariga proyeksiyalarini ko'ramiz.



1-shar uchun,

$$P_1^{(x)} = m_1 u_1 = m u_1$$

2-shar uchun,

$$\begin{cases} P_2^{(x)} = m_2 u_2 \cos \alpha = m u_2 \cos \alpha \\ P_2^{(y)} = m_2 u_2 \sin \alpha = m u_2 \sin \alpha \end{cases}$$

3-shar uchun,

$$\begin{cases} P_3^{(x)} = m_3 u_3 \cos \alpha = m u_3 \cos \alpha \\ P_3^{(y)} = -m_3 u_3 \sin \alpha = -m u_3 \sin \alpha \end{cases}$$

Impuls saqlanish qonuniga ko'ra,



$\alpha$  ni (4) ga olib bo-  
rib qo'yamiz.

$$\begin{aligned} U_2 &= \frac{29 \cos \alpha}{1 + 2 \cos^2 \alpha} = \frac{29 \cos 30^\circ}{1 + 2 \cos^2 30^\circ} \\ &= \frac{29 \cdot \frac{\sqrt{3}}{2}}{1 + 2 \cdot \frac{3}{4}} = \frac{\frac{\sqrt{3} 29}{2}}{\frac{5}{2}} = \frac{2\sqrt{3}}{5} 9. \end{aligned}$$

$U_1$  ni topish uchun  
(3) tenglamadan foy-  
dalanamiz.

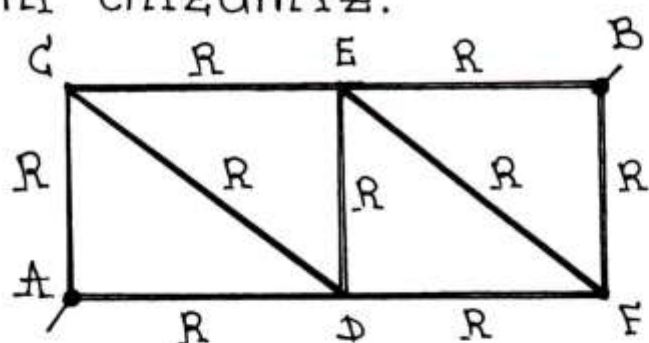
$$\begin{aligned} U_1 &= \frac{U_2}{\cos \alpha} - 9 = \frac{\frac{2\sqrt{3}}{5} 9}{\frac{\sqrt{3}}{2}} - 9 = \\ &= \frac{4}{5} 9 - 9 = -\frac{1}{5} 9 \end{aligned}$$

Yuqoridagi xulosalar-  
dan  $U_2 = U_3 = \frac{2\sqrt{3}}{5} 9$

$$\begin{aligned} \text{Javob: } U_2 &= U_3 = \frac{2\sqrt{3}}{5} 9 \\ U_1 &= -\frac{1}{5} 9 \end{aligned}$$

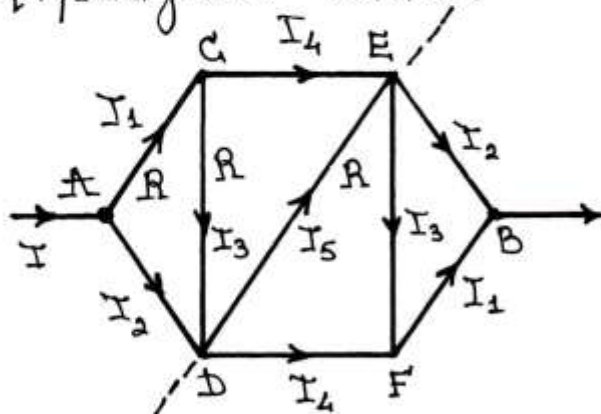
## 5. Yechim:

Rasmida sxema shaklini chizamiz.



Sxema „DE“ o'qiga nisbatan simmetrik bo'lgani uchun tok kuchlarining bir xil bo'lishidan foydalanamiz.

U holda sxema ko'rinishi quyidagicha bo'ladi:



Kirxgof qoidasiga asosan:

- { „A“ nuqta uchun: (1)
- { „D“ nuqta uchun: (2)
- { „F“ nuqta uchun: (3)
- { „E“ nuqta uchun: (4)

$$\begin{cases} I = I_1 + I_2, & (1) \\ I_2 + I_3 = I_4 + I_5, & (2) \\ I_1 = I_3 + I_4, & (3) \\ I_5 + I_4 - I_3 = I_2, & (4) \end{cases}$$

Qo'shimcha tenglamalar:

$$\begin{cases} \varphi_A - \varphi_B = U = R_{AB} \cdot I, & (5) \\ \varphi_A - \varphi_C = I_1 \cdot R, & (6) \\ \varphi_A - \varphi_D = I_2 \cdot R, & (7) \\ \varphi_C - \varphi_D = I_3 \cdot R, & (8) \\ \varphi_C - \varphi_E = I_4 \cdot R, & (9) \\ \varphi_D - \varphi_F = I_4 \cdot R, & (10) \\ \varphi_E - \varphi_F = I_5 \cdot R, & (11) \\ \varphi_E - \varphi_B = I_2 \cdot R, & (12) \\ \varphi_F - \varphi_B = I_1 \cdot R, & (13) \\ \varphi_D - \varphi_E = I_5 \cdot R, & (14) \end{cases}$$

11 va 13 tenglamalarni qo'shib, 12-tenglamaga tenglashtirsak,

$$I_5 R + I_1 R = I_2 R \text{ bunda}$$

$$I_2 = I_1 + I_5 \quad (15)$$

6; 9 va 12 tenglamalarni qo'shib,

$$\varphi_A - \varphi_B = I_1 R + I_2 R + I_4 R = I \cdot R_{AB}$$

ni hisoblaymiz.

8; 14; 9-tenglamalardan:

$$\begin{cases} I_3 R + I_5 R = I_4 R, & I_3 + I_5 = I_4 \\ I_5 = I_4 - I_3 \end{cases}$$

4-tenglamadan:  $2I_5 = I_2$



$I_5 = \frac{1}{2} I_2$  ga teng bo'ladi.  
 1:2 va 3- tenglamalardan  
 foydalanib,  $I_2 = \frac{6}{5} I_1$ ;  
 $I_3 = \frac{1}{5} I_1$ ;  $I_4 = \frac{4}{5} I_1$ .  
 munosabatni aniqlash  
 mumkin.

U holda  $\varphi_A - \varphi_B = I \cdot R_{AB}$   
 $R_{AB} (I_1 + I_2) = R (I_1 + I_2 + I_4)$   
 Toklarning " $I_1$ " orqali  
 ifodalarini " $I_1$ " ga qisqar  
 tirsak zanjirning  
 umumiy qarshiligi.  $R_{AB} = \frac{15}{11} R$   
 Javob:  $R_{AB} = \frac{15}{11} R$ .