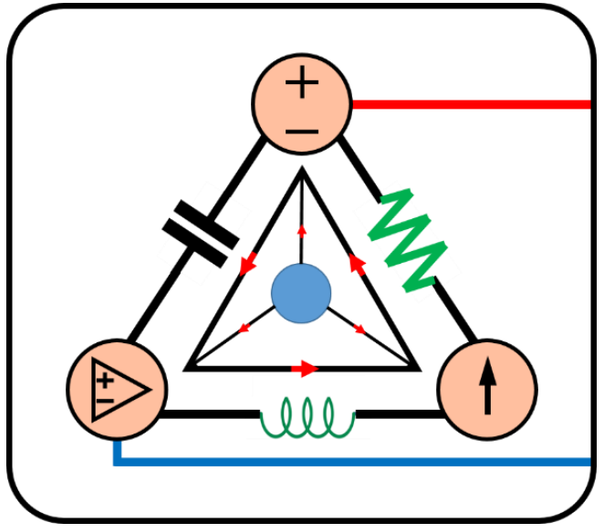
# 2-Mavzu: Elektr zanjiriga oid asosiy qonunlar.

(Lecture-2: Basic Laws)

## 2-Mavzuning 2-qismi

*(Part 2 of the Lecture-2)*



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# 2-Mavzu: Elektr zanjiriga oid asosiy qonunlar.

(Lecture-2: Basic Laws)

**O‘quv rejasi:**

2.1. Om qonuni.

2.2. Tugun, shaxobcha va kontur.

**2.3. Kirxgof qonunlari.**

**2.4. Ketma-ket ulangan qarshiliklar va kuchlanishni bo‘linish qoidasi.**

2.5. Parallel ulangan qarshiliklar va tok kuchini bo‘linish qoidasi.

2.6. Qarshiliklar yulduzini qarshiliklar uchburchagiga (Wye-Delta) o‘zgartirish.

2.7. Qo‘llanilishi.

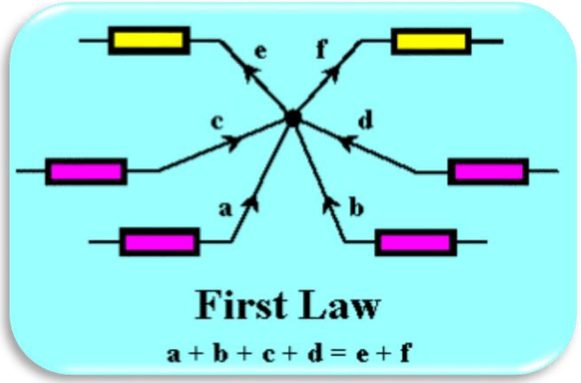
# 2.3. Kirxgof qonunlari.

Om qonunining o‘zi zanjirlarni tahlil qilish uchun yetarli emas.

Biroq, u Kirxgofning ikkita qonuni bilan birlashtirilganda, bizda juda ko‘p turli xil elektr zanjirlarini tahlil qilish uchun yetarlicha imkoniyat va hisoblash usullariga ega bo‘lamiz.

Kirxgof qonunlari birinchi marta 1847 yilda nemis fizigi Gustav Robert Kirxgof (1824-1887) tomonidan kiritilgan.

Kirxgofning birinchi tok kuchiga oid qonuni *(KCL-Kirchhoff’s current law)* deb nomlanadi.



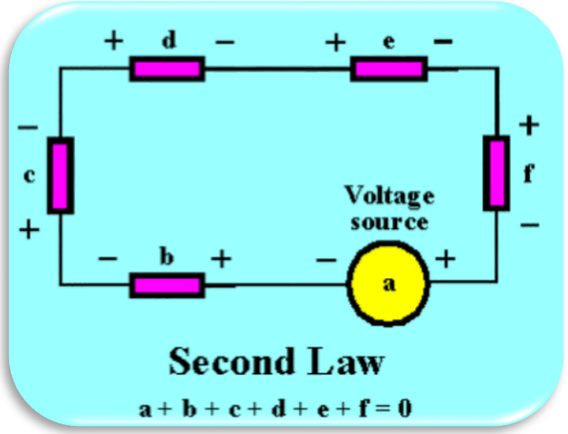




**Photo source:** [34] - https://kaiserscience.files.wordpress.com/2015/10/kirchhoffs-first-law.gif

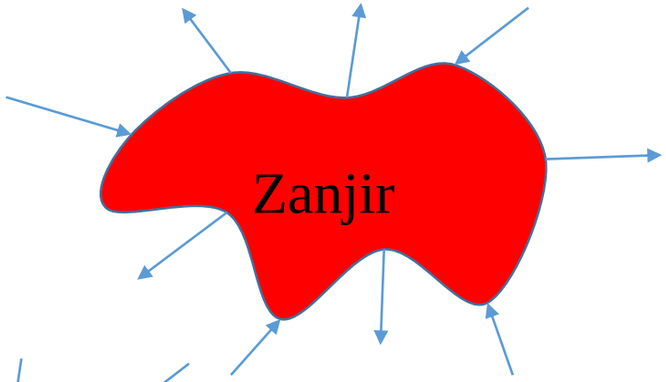
Kirxgofning ikkinchi kuchlanishga oid qonuni *(KVL-Kirchhoff’s voltage law)* deb nomlanadi.

Kirxgof qonunlari elektr tok zanjirlarini hisoblashda asosiy qonunlardan biri bo‘lib, barcha hisoblash usullarning ham negizi hisoblanadi.

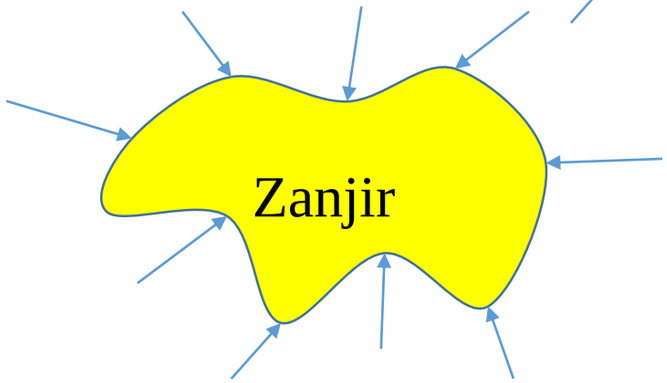
**Kirxgofning 1 – qonuni *(KCL)*:** zaryadning saqlanish qonuniga asoslanadi, u tizimdagi zaryadlarning algebraik yig‘indisi o‘zgarmasligini talab qiladi. Ya’ni, tugunga (yoki yopiq konturga) kiruvchi tarmoq toklarining algebraik yig‘indisi nolga teng ekanligini bildiradi.

$$\sum_{n=1}^{N} i_n = 0 \qquad (2.14)$$

bu yerda: $N$ - tugunga ulangan shaxobchalar soni va $i_n$ - tugunga kiruvchi (yoki undan chiquvchi) $n$-tok kuchlari.

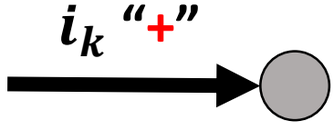


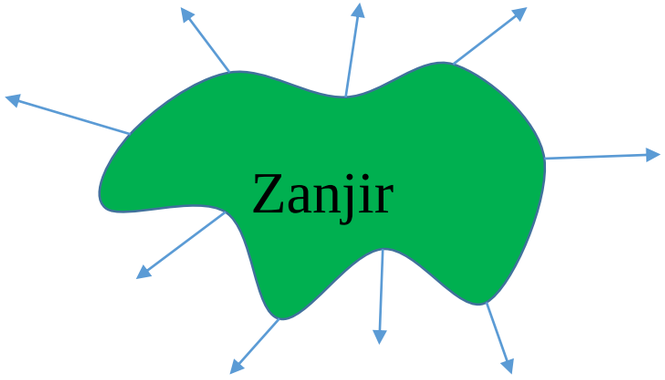

$$\sum_{j=1}^{j=N} i_k = \sum_{k=1}^{k=M} i_{ch}$$




$$\sum_{r=1}^{r=Q} i_k = 0$$

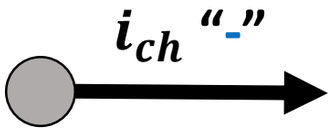
Ushbu qonunga ko‘ra, tugunga kiradigan tok kuchlari ijobiy (musbat) deb,




$$\sum_{m=1}^{m=Q} i_{ch} = 0$$

tugundan chiquvchi tok kuchlar esa salbiy (manfiy) deb hisoblanadi.



KCLni isbotlash uchun bir qator tok kuchlari $i_k(t), k = 1, 2, \ldots$ , tugunga oqib o‘tadi deb faraz qiling. Tugundagi tok kuchlarining algebraik yig‘indisi:

$$i_T(t) = i_1(t) + i_2(t) + i_1(t) + \cdots \tag{2.15}$$

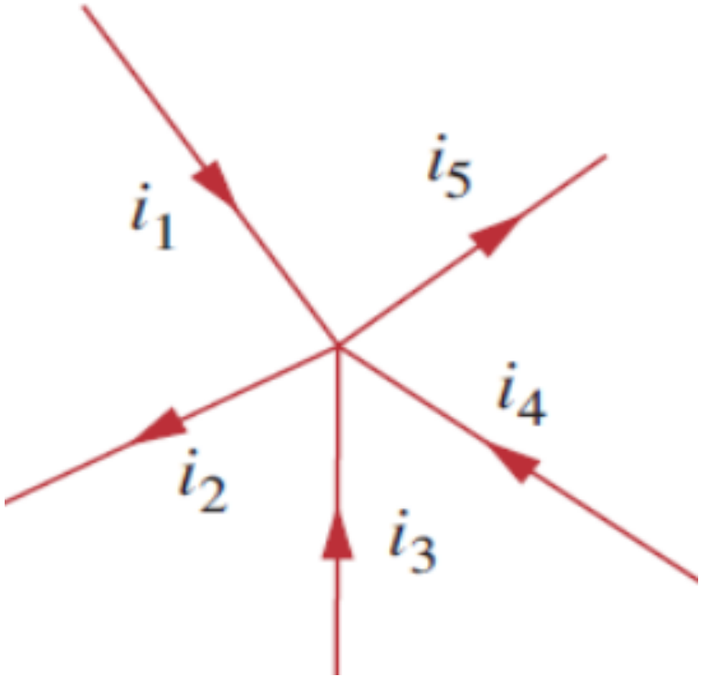
(2.15) tenglamaning ikkala tomonini integrallasak quyidagi hosil bo‘ladi:

$$q_T(t) = q_1(t) + q_2(t) + q_1(t) + \cdots \tag{2.16}$$

bu yerda: $q_k(t) = \int i_k(t)dt$ va $q_T(t) = \int i_T(t)dt$.

Ammo elektr zaryadining saqlanish qonuni tugundagi elektr zaryadlarining algebraik yig‘indisi o‘zgarmasligini talab qiladi; ya’ni tugun sof zaryadni saqlamaydi.

Shunday qilib $q_T(t) = 0 \rightarrow i_T(t) = 0$, KCLning haqiqiyligini tasdiqlaydi.




**2.13-rasm. KCL ni tasvirlaydigan tugundagi tok kuchlar.**

$$i_1 + (-i_2) + i_3 + i_4 + (-i_5) = 0 \qquad (2.17)$$

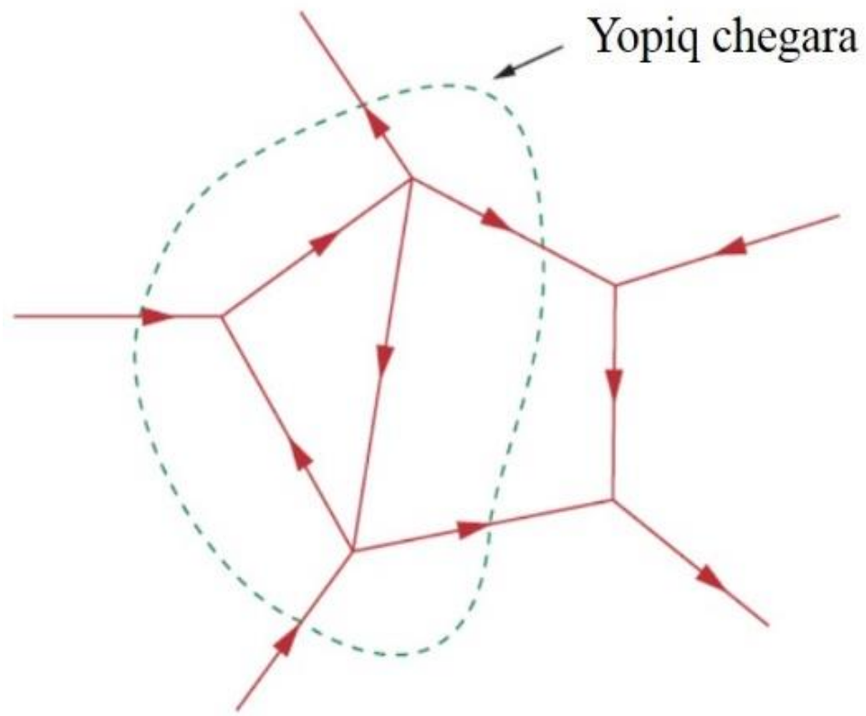
Shartlarni qayta tartibga solish orqali quyidagiga ega bo‘lamiz.

$$i_1 + i_3 + i_4 = i_2 + i_5 \qquad (2.18)$$

(2.18) tenglama KCL ning muqobil shaklidir:

Tugunga kiradigan tok kuchlarning yig‘indisi tugundan chiqadigan tok kuchlarning yig‘indisiga teng.

**Photo source:** [35] - Fundamentals of Electric Circuits, Charles K. Alexander and Matthew N. O. Sadiku / 5th edition, the McGraw-Hill Companies, Inc., - 2013. – p 38.

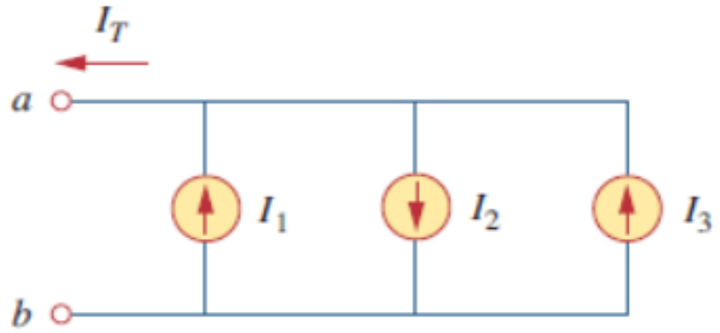



**2.14-rasm. KCL ni yopiq chegarada qo‘llash.**

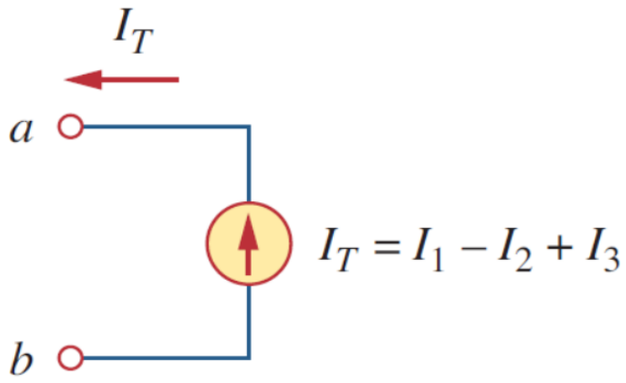
**Photo source:** [35] - Fundamentals of Electric Circuits, Charles K. Alexander and Matthew N. O. Sadiku / 5th edition, the McGraw-Hill Companies, Inc., - 2013. – p 38.

E’tibor bering, KCL yopiq kontur (chegara)ga ham tegishli. Buni umumlashtirilgan holat deb hisoblash mumkin, chunki tugun bir nuqtaga qisqargan yopiq sirt sifatida tushuntiriladi. Ikki o‘lchovda yopiq kontur, yopiq yo‘l *(closed path)* bilan bir xildir.

Odatda 2.14-rasmdagi sxemada ko‘rsatilganidek, yopiq sirtga kiradigan umumiy tok kuchi sirtdan chiqadigan umumiy tok kuchiga teng.




a)




b)

**2.15-rasm. Elektr zanjirida parrallel manbalar:**

a) elektr zanjirini parrallel ulanishi;

b) b) elektr zanjirini ekvivalenti.

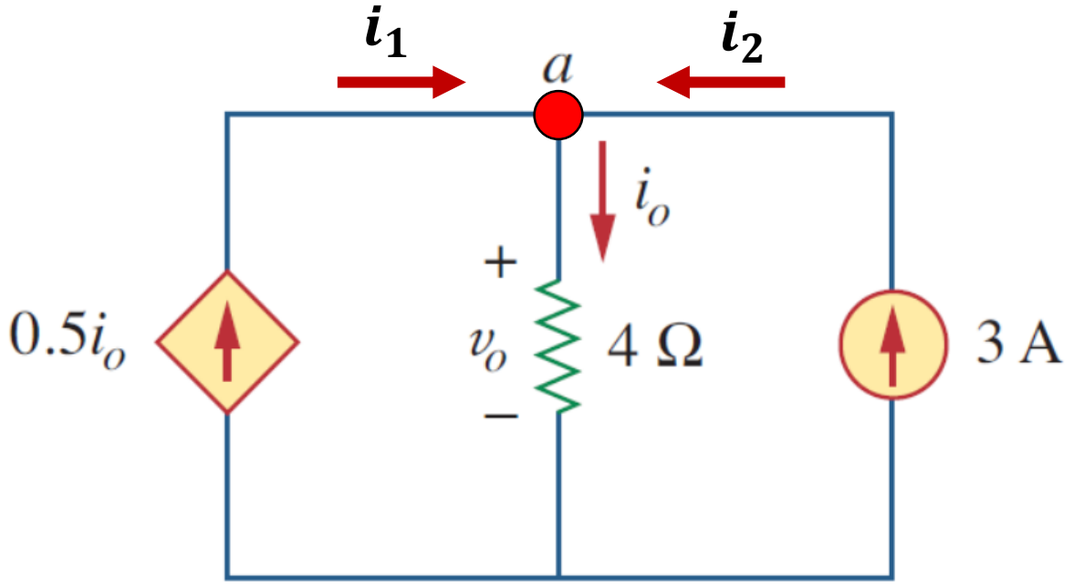
KCL ning oddiy qo‘llanilishi tok kuchi manbalarini parallel ravishda birlashtiradi. Birlashtirilgan tok kuchi - bu alohida manbalar tomonidan ta’minlangan tok kuchining algebraik yig‘indisidir.

Ikkita manba agar ular bir juft terminalda bir xil $i$ - $u$ munosabatlariga ega bo‘lsa, **EKVIVALENT** deb ataladi.

$$I_T + I_2 = I_1 + I_3 \quad \text{yoki} \quad I_T = I_1 - I_2 + I_3 \qquad (2.19)$$

Zanjirda ketma-ket ikkita turli tok kuchlari $I_1$ va $I_2$ bo‘lishi mumkin emas, agar $I_1 = I_2$ bo‘lmasa. Aks holda KCL buziladi.

***2.3.1-masala:*** 2.16-rasmdagi zanjir uchun tok kuchi $i_o$ va kuchlanish $u_o$ ni toping.




**2.16-rasm.**

4 Ω rezistor uchun, Om qonunini qo‘llab $u_o$ ni topamiz.
Demak,

$$U = IR$$

$$u_o = 4i_o$$

$$\boldsymbol{u_o = 4 \cdot 6 = 24\ V}$$

***Yechish:*** $a$ tugun uchun KCLni qo‘llaymiz.

$$\sum i_k = \sum i_{ch}$$

$$i_1 + i_2 = i_o$$

$$i_1 = 0{,}5i_o$$

$$i_2 = 3$$

$$i_o = ?$$

$$3 + 0{,}5i_o = i_o$$

$$3 = i_o - 0{,}5i_o$$

$$3 = 0{,}5i_o$$

$$\boldsymbol{i_o = \frac{3}{0{,}5} = 6\ A}$$

**Kirxgofning 2 – qonuni (KVL):** zanjirdagi berk kontur bo‘ylab olingan kuchlanish tushuvlari yig‘indisi nolga teng ekanligini bildiradi.

Matematik jihatdan, KVL quyidagiga teng bo‘ladi.

$$\sum_{m=1}^{M} U_m = 0 \qquad (2.20)$$

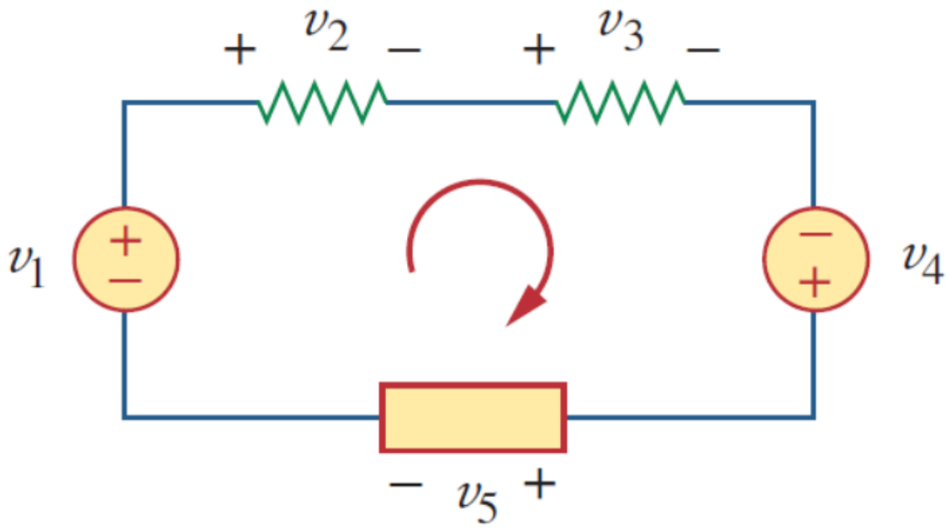
bu yerda: $M$ - konturdagi kuchlanishlar soni (yoki konturdagi shaxobchalar soni) va $U_m$ $m$-chi kuchlanishdir.

Ya’ni, KVLda kontur bo‘ylab kuchlanish ko‘tarilishlarining yig‘indisi kuchlanish tushishlarining yig‘indisiga teng.

$$\sum U_{ko'tarilishi} = \sum U_{tushishi} \qquad (2.20\ a)$$

KVL ni tasvirlash uchun 2.17-rasmdagi zanjirni ko‘rib chiqaylik.



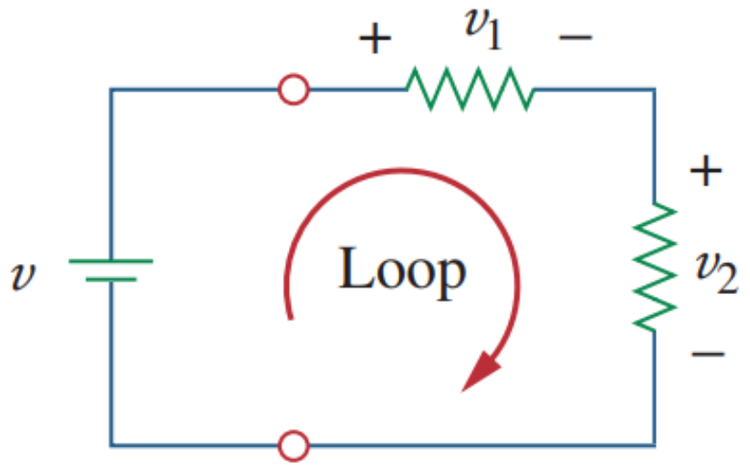




**Photo source:** [36] - https://qph.cf2.quoracdn.net/main-qimg-4a955105009cda5459e3c6507f95a5a7

**2.17-rasm. KVL ni aks ettiradigan bitta konturli zanjir.**

$$KVL: -v + v_1 + v_2 = 0$$

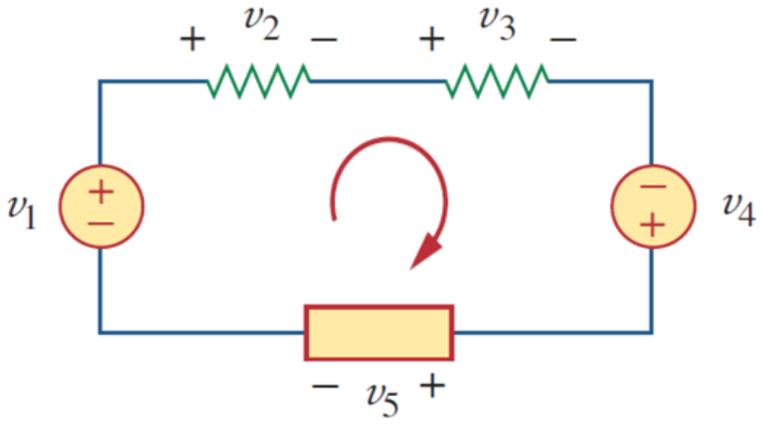
Agar konturni aylanib chiqish yo‘nalishi bilan tok kuchi yoki kuchlanish yo‘nalishi bir xil bo‘lsa, u holda yig‘indiga tegishli tashkil etuvchilar **“musbat”** ishora bilan, aks holda esa **“manfiy”** ishora bilan kiradi.

KVL ikki yo‘l bilan qo‘llanilishi mumkin:

kontur bo‘ylab soat milining yo‘nalishi bo‘yicha yoki aksincha.

**Photo source:** [37] - https://www.shutterstock.com/image-vector/rotate-clockwise-counterclockwisevector-icon-260nw-1646384518.jpg

Qanday bo‘lmasin, kontur atrofidagi kuchlanishlarning algebraik yig‘indisi nolga teng.




$$\sum U = 0$$

Kuchlanishlar

$-u_1,$

$+u_2,$

$+u_3,$

$-u_4$ va $+u_5$ shu tartibda bo‘ladi.

KVL quyidagi hadlarni hosil qiladi.

$$-u_1 + u_2 + u_3 - u_4 + u_5 = 0 \qquad (2.21)$$

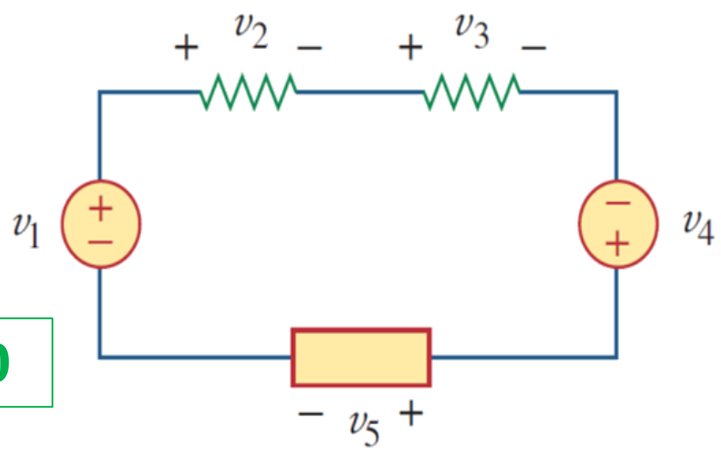
Ishoralarni qayta tartibga solish orqali quyidagini talqin qilinishi mumkin.

$$u_2 + u_3 + u_5 = u_1 + u_4 \qquad (2.22)$$

yoki,

**Kuchlanish tushuvi yig‘indisi = kuchlanishning ko‘tarilishi yig‘indisi**

E’tibor bering!




$-u_1 + u_2 + u_3 - u_4 + u_5 = 0$

$u_2 + u_3 + u_5 = u_1 + u_4$

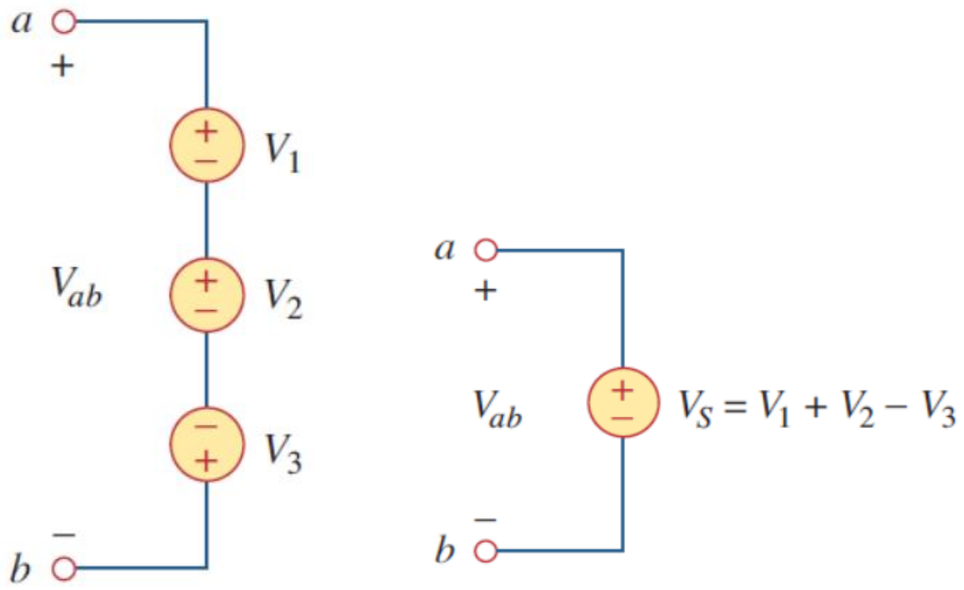
$-u_5 + u_4 - u_3 - u_2 + u_1 = 0$

$u_4 + u_1 = u_5 + u_3 + u_2$

Demak, (2.21) va (2.22) tenglamalar o‘zgarishsiz qoladi.

Kuchlanish manbalari ketma-ket ulanganda, umumiy kuchlanishni olish uchun KVL qo‘llanilishi mumkin.

Kombinatsiyalashgan kuchlanish - bu alohida manbalarning kuchlanishlarining algebraik yig‘indisidir.




a) b)

**2.18-rasm. Kuchlanish manbalari ketma-ket joylashgan:**

a) asl zanjir; b) ekvivalent zanjiri.

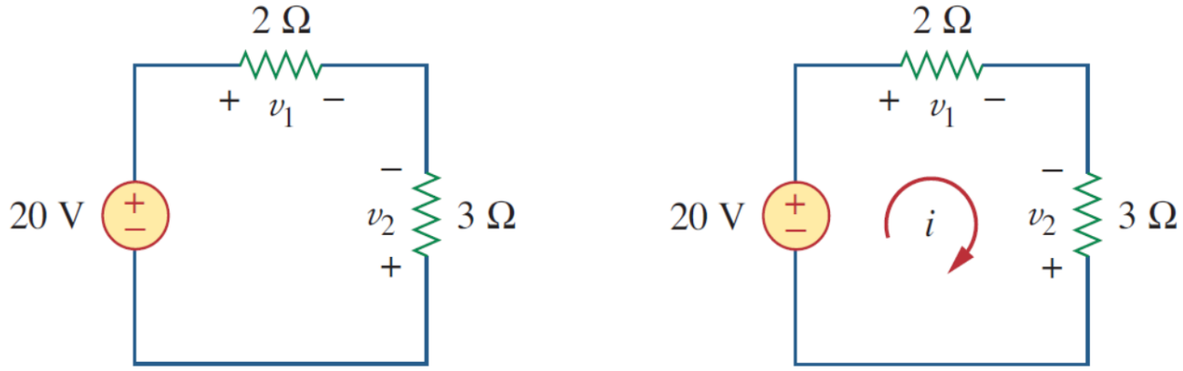
$$-U_{ab} + U_1 + U_2 - U_3 = 0$$

yoki,

$$U_{ab} = U_1 + U_2 - U_3 \qquad (2.23)$$

KVLning qoidasi buzmasligi uchun, $U_1 = U_2$ bo'lmasa, zanjir ikkita turli $U_1$ va $U_2$ kuchlanishlari parallel bo‘lishi mumkin emas.

***2.3.2-masala:*** 2.19-rasmdagi zanjir uchun $u_1$ va $u_2$ kuchlanishlarini toping.




**2.19-rasm.**

***Yechish:*** $u_1$ va $u_2$ larni topish uchun zanjirning bir qismi uchun Om qonuni va Kirxgofning kuchlanishga oid qonunidan foydalanamiz.

Om qonuni bo‘yicha,

$$u_1 = 2i$$

$$u_2 = -3i$$

Kontur bo‘yicha KVL ni qo‘llaymiz,

$$-20 + u_1 - u_2 = 0$$

$$-20 + 2i + 3i = 0$$

$$5i = 20 \quad \rightarrow \quad i = 4\ A$$

$i$ ning qiymati bo‘yicha

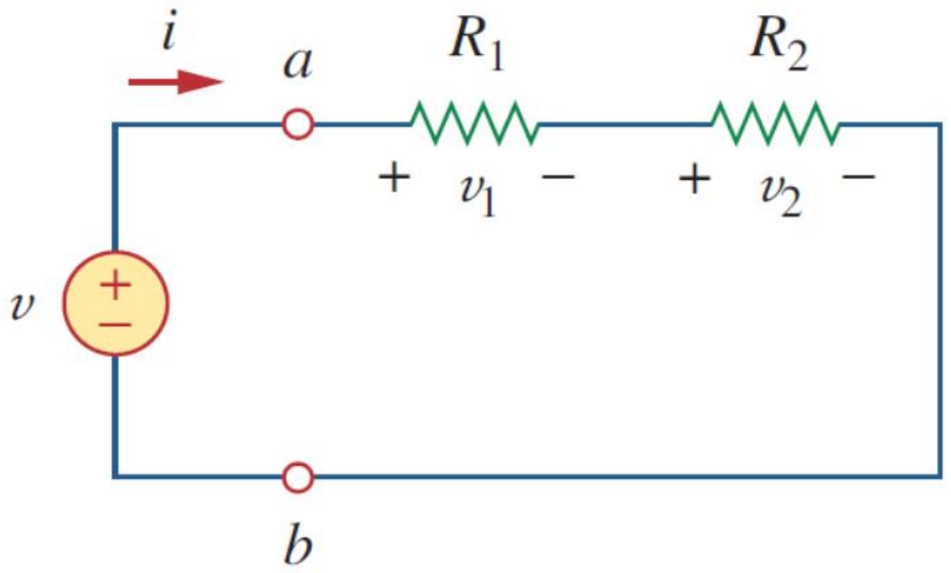
$$u_1 = 8\ V$$

$$u_2 = -12\ V$$

# 2.4. Ketma-ket ulangan qarshiliklar va kuchlanishni bo‘linish qoidasi.

Rezistorlarni ketma-ket yoki parallel ravishda birlashtirish zarurati tez-tez sodir bo‘ladi, bu alohida e’tibor talab qiladi.

Ikkala rezistor ketma-ket joylashgan, har ikkalasidan bir xil tok kuchi *i* oqadi.




**2.20-rasm. Ikkita rezistor ketma-ket ulangan bitta konturli zanjir.**

Rezistorlarning har biriga Om qonunini qo‘llash orqali biz quyidagilarni olamiz:

$$u_1 = iR_1, \quad u_2 = iR_2 \tag{2.24}$$

KVLni zanjir konturiga qo‘llash orqali quyidagilarni olamiz:

$$-u + u_1 + u_2 = 0 \tag{2.25}$$

(2.24) va (2.25) tenglamalarni birlashtirish orqali quyidagiga ega bo‘lamiz:

$$(u = u_1 + u_2 = i(R_1 + R_2) \tag{2.26}$$

yoki

$$i = \frac{u}{R_1 + R_2} \tag{2.27}$$

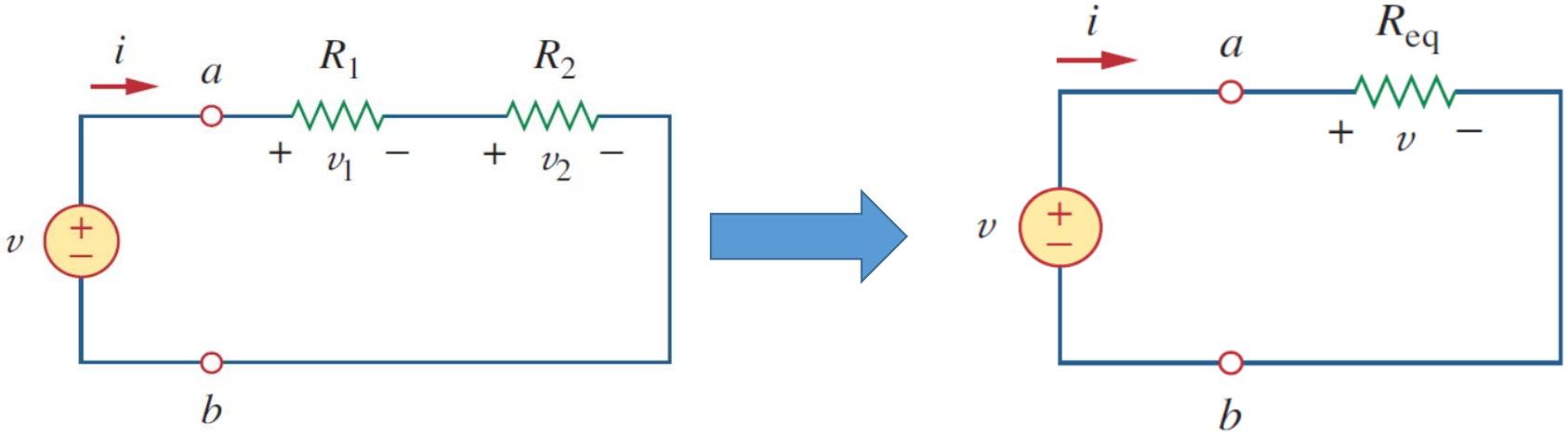
$$(\boldsymbol{u = u_1 + u_2 = i(R_1 + R_2)}$$

Ushbu (2.26) tenglamani quyidagicha yozishimiz mumkin:

$$\boldsymbol{u = iR_{um}} \tag{2.28}$$

$R_{um}$ ekvivalent rezistorni ikkita rezistor bilan almashtirsak bo‘ladi. Ya’ni,

$$\boldsymbol{R_{um} = R_1 + R_2} \tag{2.29}$$




**2.21-rasm. 2.20-rasmning ekvivalent zanjiri.**

Chunki, ular *a*-*b* terminallarida bir xil kuchlanish-tok kuchi munosabatlarini ifodalaydi. 2.21-rasmdagi ekvivalent zanjir orqali uning tahlilini soddalashtirish uchun foydalidir.

Umuman olganda, ***ekvivalent qarshilik*** bir nechta ketma-ket ulangan qarshiliklar individual qarshiliklarning yig‘indisidir.

Ketma-ket ulangan *N* ta rezistorlar uchun,

$$\boldsymbol{R_{um} = R_1 + R_2 + \cdots + R_N = \sum_{n=1}^{N} R_n} \qquad (2.30)$$

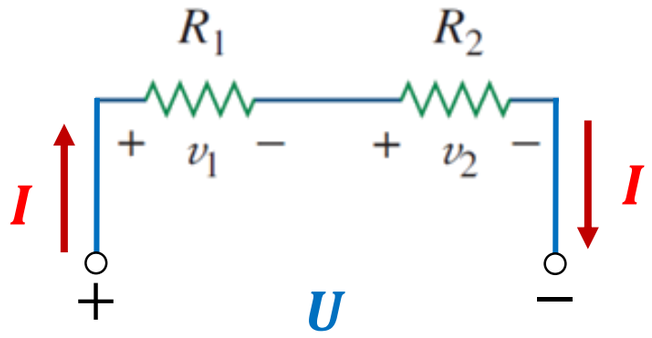
2.20-rasmda har bir rezervatorning kuchlanishini aniqlash uchun (2.26) tenglamani (2.24) tenglamaga almashtiramiz.

$$\boldsymbol{u_1 = \frac{R_1}{R_1+R_2}u,} \qquad \boldsymbol{u_2 = \frac{R_2}{R_1+R_2}u} \qquad (2.31)$$

Manba kuchlanishi *u* rezistorlar o‘rtasida ularning qarshiliklariga to‘g‘ridan-to‘g‘ri mutanosib ravishda bo‘linadi.

Qarshilik qanchalik katta bo‘lsa, **R** kuchlanishning pasayishi shunchalik katta bo‘ladi. **U**

Bu ***kuchlanish bo‘linish prinsipi*** (*principle of voltage division*) deb ataladi va 2.20-rasmdagi zanjir ***kuchlanish bo‘luvchi*** (*voltage divider*) deb ataladi.




$$R_{um} = R_1 + R_2$$

$$I = \frac{U}{R_{um}} = \frac{U}{R_1 + R_2}$$

$$U_1 = I \cdot R_1 = \frac{U}{R_1 + R_2} R_1$$

$$U_2 = I \cdot R_2 = \frac{U}{R_1 + R_2} R_2$$

$$U_3 = I \cdot R_3 = \frac{U}{R_1 + R_2 + \cdots + R_n} R_3$$

Agar kuchlanish bo‘luvchida manba kuchlanishi $u$ bilan ketma-ket $N$ rezistor ($R_1, R_2, \ldots, R_N$) bo‘lsa, $n$-rezistor ($R_N$) kuchlanish pasayishiga ega bo‘ladi.

$$u_n = \frac{R_n}{R_1 + R_2 + \cdots + R_N} u \qquad (2.32)$$

# *FOYDALANILGAN MANBALAR:*


34. https://kaiserscience.files.wordpress.com/2015/10/kirchhoffs-first-law.gif
35. Fundamentals of Electric Circuits, Charles K. Alexander and Matthew N. O. Sadiku / 5th edition, the McGraw-Hill Companies, Inc., -2013. – p 38.
36. https://qph.cf2.quoracdn.net/main-qimg-4a955105009cda5459e3c6507f95a5a7
37. https://www.shutterstock.com/image-vector/rotate-clockwise-counterclockwisevector-icon-260nw-1646384518.jpg

# *E'TIBORINGIZ UCHUN RAHMAT!!!*