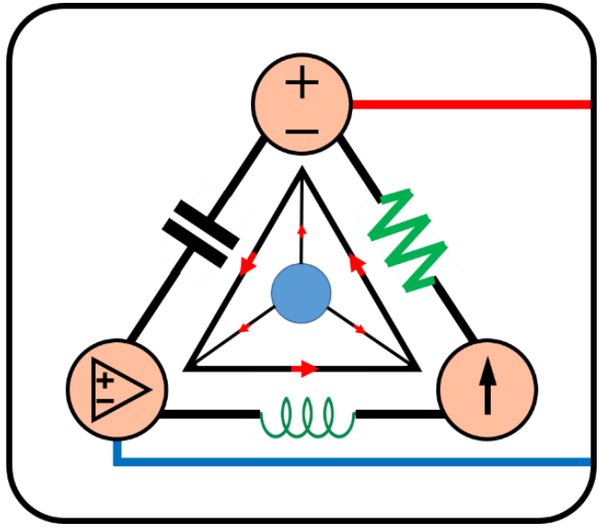
4-Mavzu: Elektr zanjir teoremalari.

(Lecture-4: Circuit Theorems)

4-Mavzuning 3-qismi

(Part 3 of the Lecture-4)



Lecturer: Ph.D., Yusupov Sarvarbek

Toshkent Kimyo Xalqaro Universiteti
"Mashinasozlik texnologiyasi" kafedrasi
Toshkent shahri, Usmon Nosir, 156-uy.

4-Mavzu: Elektr zanjir teoremalari.

(Lecture-4: Circuit Theorems)

O‘quv rejasi:

4.1. O‘zgarmas elektr tok zanjirlarining chiziqli xossalari.

4.2. Superpozitsiya.

4.3. Manbani o‘zgartirish.

4.4. Tevenin teoremasi.

4.5. Norton teoremasi.

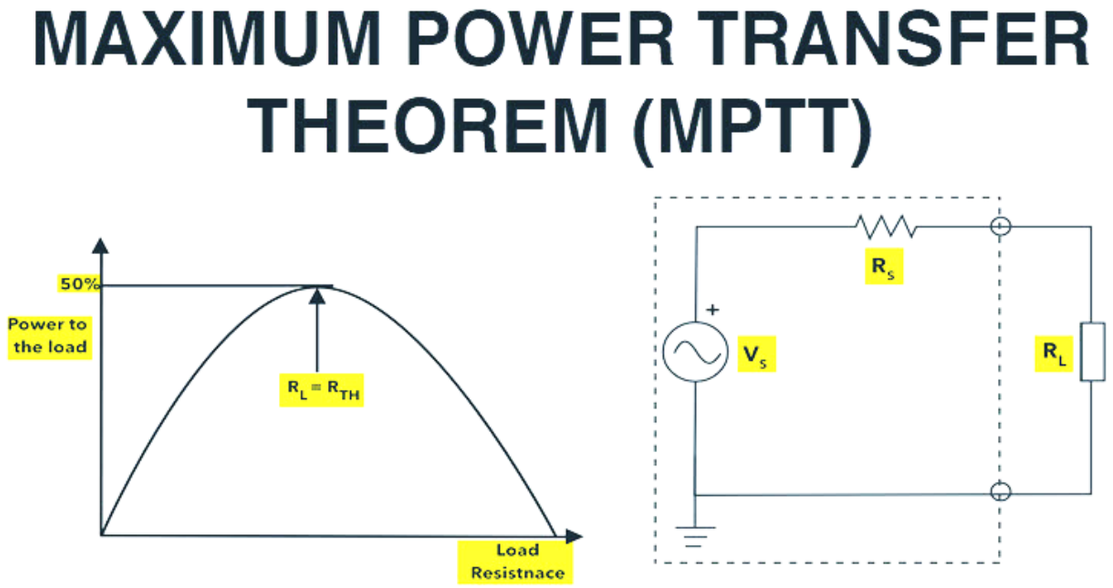
4.6. Maksimal quvvat uzatish.

4.7. Qo‘llanilishi.

4.6. Maksimal quvvat uzatish.

Ko‘p vaziyatlarda zanjir yuklama quvvat bilan ta’minlash uchun loyihalanadi. Aloqa sohalarida yuklamaga yetkazilgan quvvatni maksimal darajada oshirish zarur bo‘ladi.

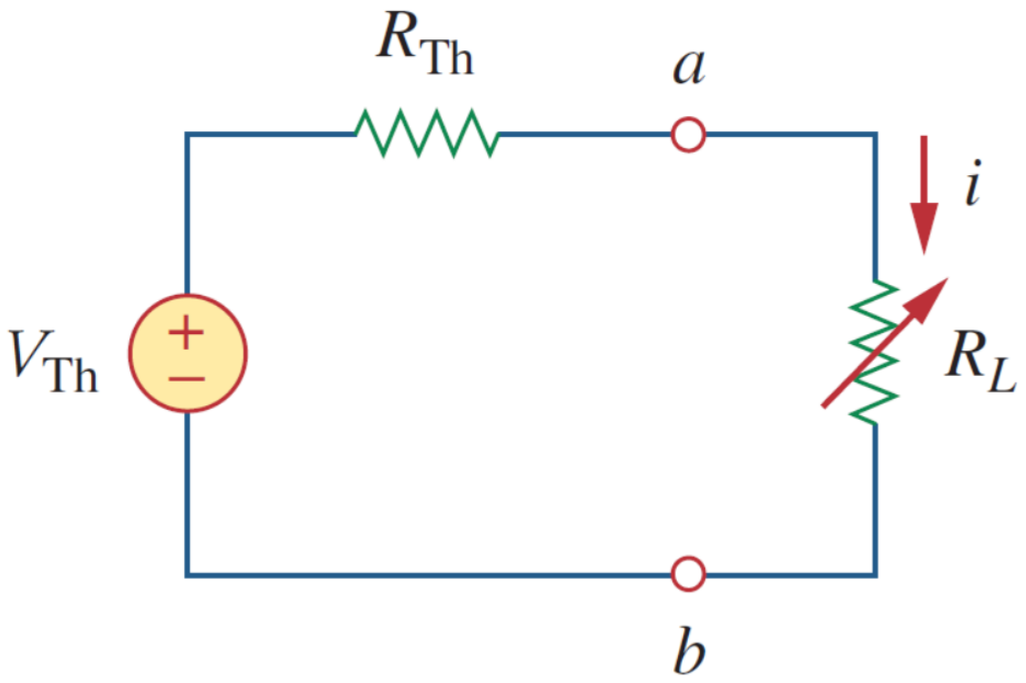
Bu yerda biz ichki yo‘qotishlar ma’lum bo‘lgan tizim berilganda yuklamaga maksimal quvvatni yetkazib berish muammosini hal qilamiz.



Bu yuklamaga yetkazilgan quvvatdan kattaroq yoki unga teng bo‘lgan sezilarli ichki yo‘qotishlarga olib keladi.

Photo source: [16] - https://www.electronicshub.org/wp-content/uploads/2021/04/Maximum-Power-Transfer-Theorem-Featured.jpg

Tevenin ekvivalenti chiziqli zanjirda maksimal quvvatni topishda foydalidir. Biz yuklama qarshiligi $\boldsymbol{R_L}$ ni sozlashimiz mumkin.

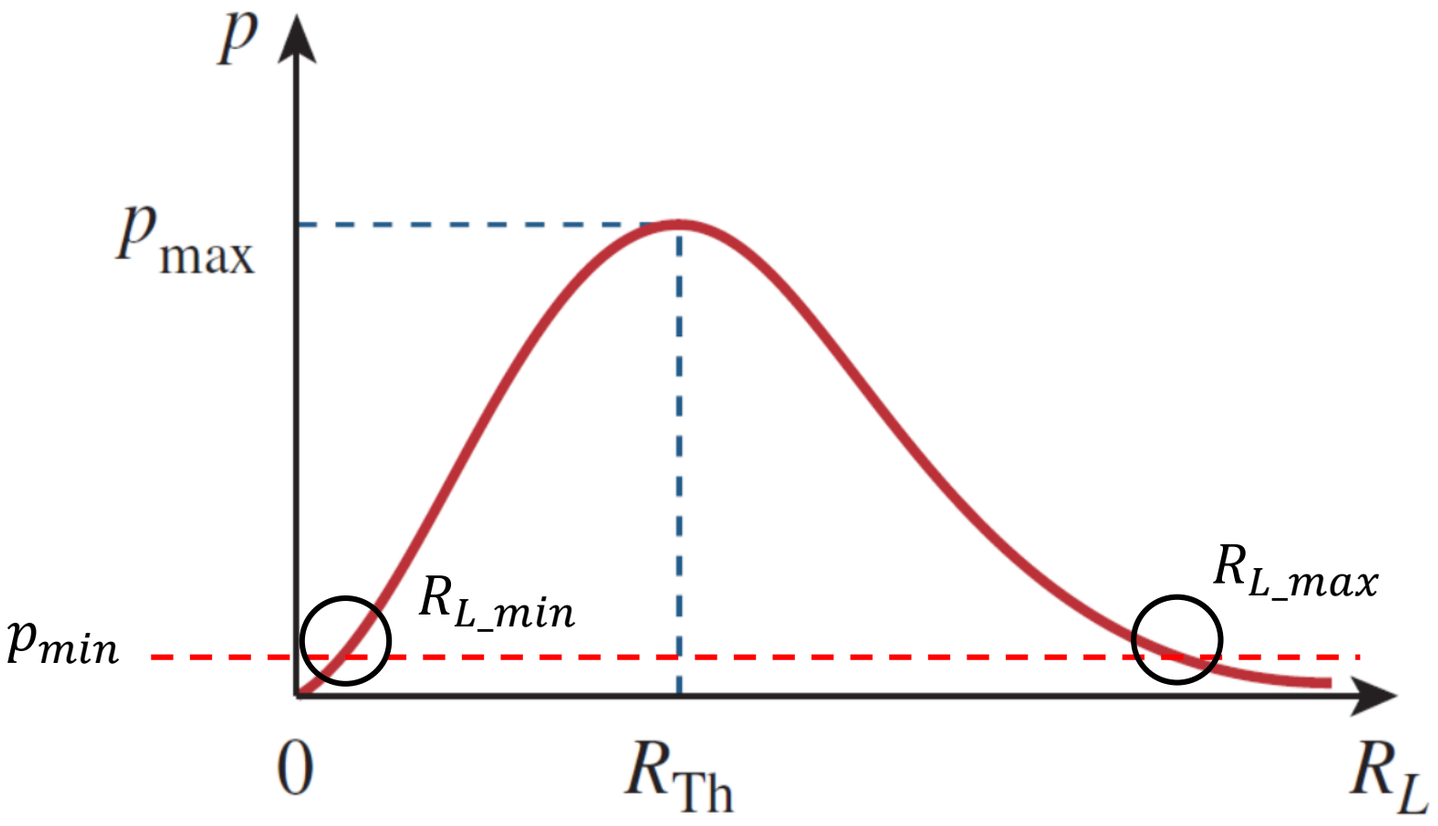


4.21-rasm. Maksimal quvvat uzatish uchun ishlatiladigan zanjir.

Agar butun zanjir yuklamadan tashqari uning Tevenin ekvivalenti bilan almashtirilsa, yuklamaga yetkazilgan quvvat quyidagicha yoziladi.

$$p = i^2 R_L = \left(\frac{U_{Th}}{R_{Th}+R_L}\right)^2 R_L \qquad (4.21)$$

Maksimal quvvat teoremasi



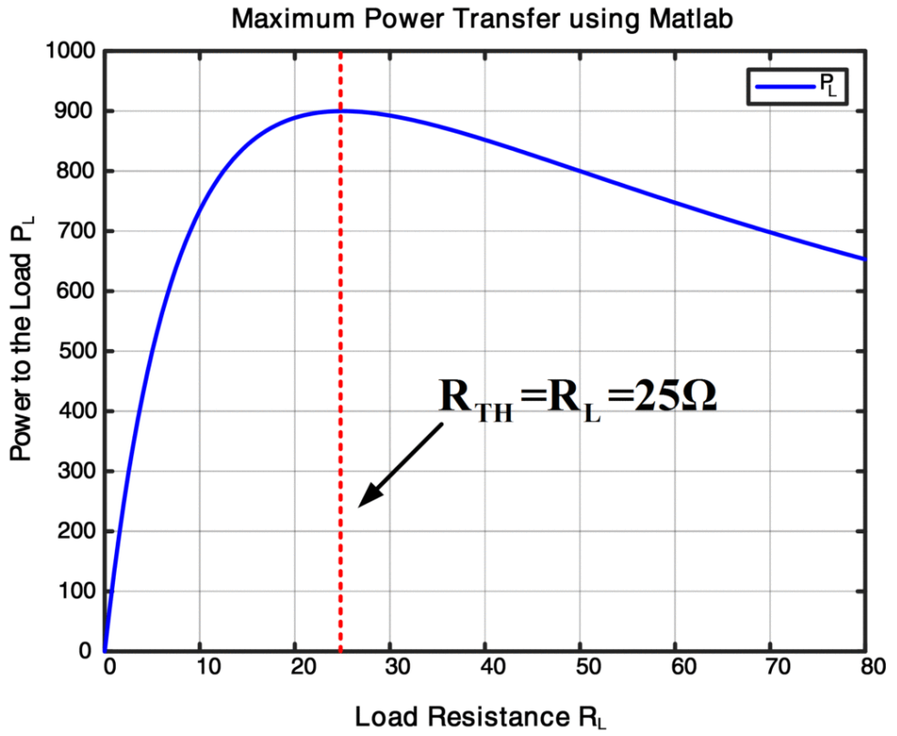


Photo source: [17] - https://electricalacademia.com/wp-content/uploads/2017/01/Maximum-Power-Transfer-Matlab-768x637.gif

4.22-rasm. R_L funksiyasi sifatida yuklamaga yetkazilgan quvvat.

Maksimal quvvat yuklamadan ko‘rinib turganidek, yuklama qarshiligi Tevenin qarshiligiga teng bo‘lganda yuklamaga o‘tkaziladi ($R_L = R_{Th}$).

Maksimal quvvat uzatish teoremasini isbotlash uchun tenglamada p ni farqlaymiz. (4.21) R_L ga nisbatan va natijani nolga tenglashtirib quyidagi tenglamani olamiz.

$$\frac{dp}{dR_L} = U_{Th}^2 \left[\frac{(R_{Th}+R_L)^2 - 2R_L(R_{Th}+R_L)}{(R_{Th}+R_L)^4}\right] =$$

$$= U_{Th}^2 \left[\frac{R_{Th}+R_L-2R_L}{(R_{Th}+R_L)^3}\right] = 0$$

Bu shuni anglatadiki,

$$0 = (R_{Th}+R_L-2R_L) = (R_{Th}-R_L) \qquad (4.22)$$

$$R_L = R_{Th} \tag{4.23}$$

yuklama qarshiligi R_L Tevenin qarshiligi R_{Th} ga teng bo‘lganda maksimal quvvat uzatish sodir bo‘lishini ko‘rsatadigan haddir.

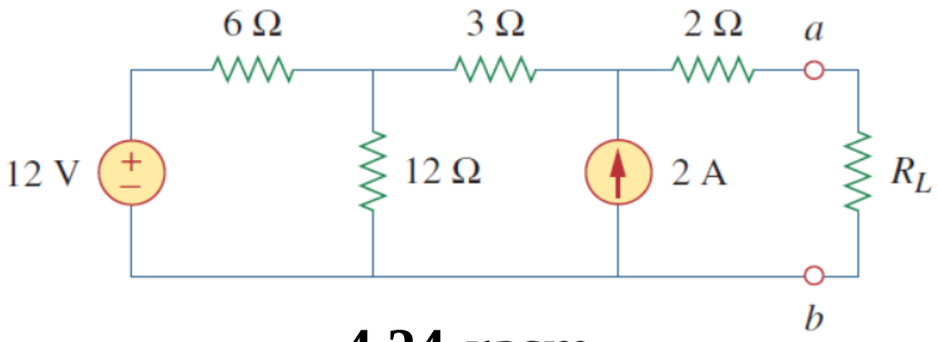
(4.23) tenglama maksimal quvvatni berishini $\frac{d^2p}{dR_L^2} < 0$ ko‘rsatish orqali osongina tasdiqlashimiz mumkin. O‘tkazilgan maksimal quvvat tenglama (4.23) ni (4.21) tenglamaga almashtirish orqali olinadi.

$$\boldsymbol{p_{max} = \frac{U_{Th}^2}{4R_{Th}}} \tag{4.24}$$

(4.24) tenglama faqat $R_L = R_{Th}$ hollarda qo‘llaniladi. $R_L \neq R_{Th}$ bo‘lganda, biz (4.21) tenglamadan foydalanib, yukga yetkazilgan quvvatni hisoblaymiz.

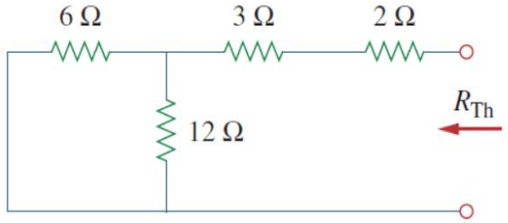
4.6.1-masala: 4.23-rasmdagi zanjir maksimal quvvat uzatish R_L qiymatini toping.

Maksimal quvvatni toping.



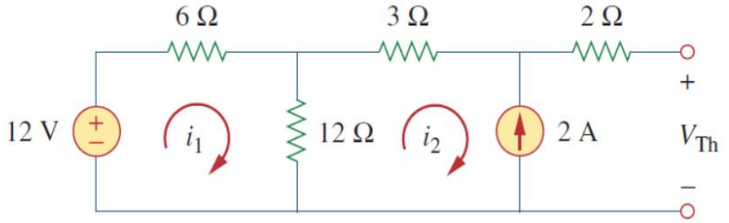
4.24-rasm.

Yechish:



a)

a) R_{Th} ni topish zanjiri;



b)

b) U_{Th} ni topish zanjiri.

$$R_{Th} = 2 + 3 + 6 \,||12 = 5 + \frac{6 \cdot 12}{6 + 12} = 9\ Om$$

U_{Th} ni *a*-*b* terminallari bo‘ylab olish uchun tashqi halqa bo‘ylab KVLni qo‘llaymiz.

$$-12 + 6i_1 + 3i_2 + 2(0) + U_{Th} = 0, \quad \rightarrow \quad U_{Th} = 22\ V$$

$$-12 + 18i_1 - 12i_2 = 0, \quad \rightarrow \quad i_2 = -2\ A$$
$$i_1 = -2/3$$

Maksimal quvvat uzatish uchun,

$$\boldsymbol{R_L = R_{Th} = 9\ \Omega}$$

Maksimal quvvat:

$$\boldsymbol{p_{max} = \frac{U_{Th}^2}{4R_{Th}} = \frac{22^2}{4 \cdot 9} = 13,44\ W}$$

4.7. Qo‘llanilishi.

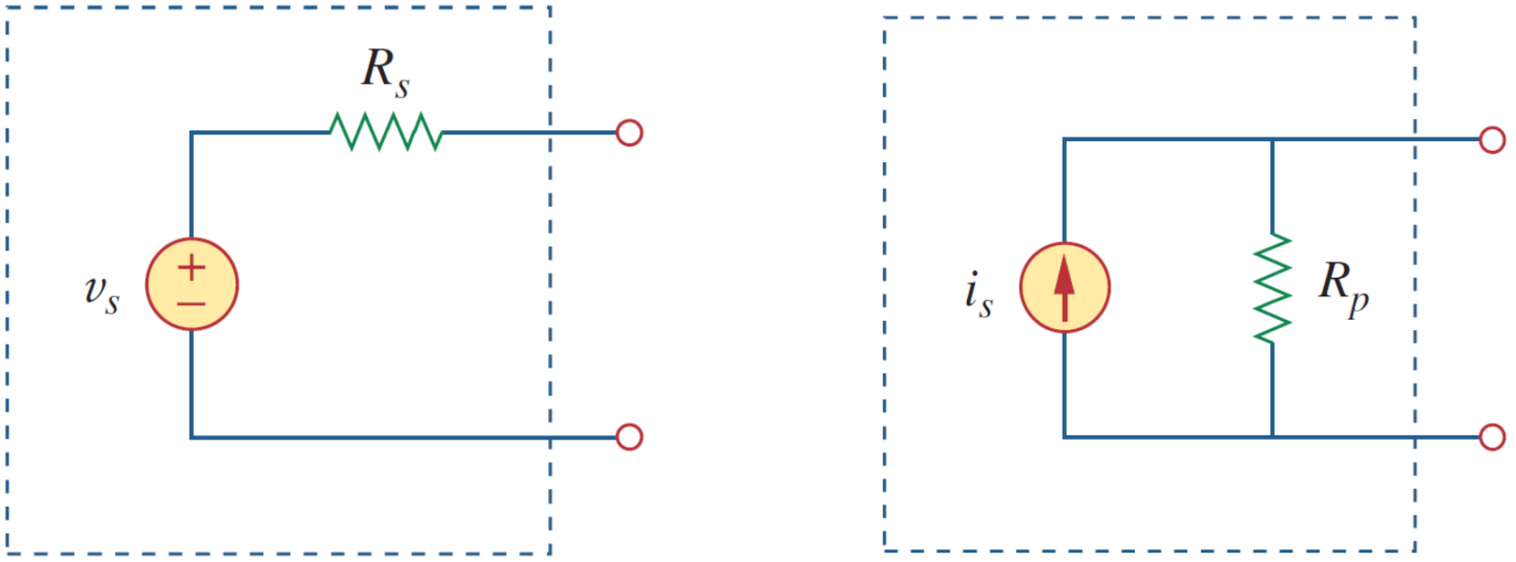
Ushbu mavzu doirasida biz ko‘rib chiqilgan tushunchalarning ikkita muhim amaliy qo‘llanilishini muhokama qilamiz: ***manbani modellashtirish*** va ***qarshilikni o‘lchash***.

4.7.1. Manbani modellashtirish.

Manba modellashtirish Tevenin yoki Norton ekvivalentining foydaliligiga misol keltiradi. Batareya kabi faol manba odatda Tevenin yoki Norton ekvivalent zanjiri bilan tavsiflanadi.

Ideal kuchlanish manbai yuklama tomonidan chiqarilgan tok kuchidan qat’i nazar, doimiy kuchlanishni ta’minlaydi, ideal tok kuchi manbai esa yuklama kuchlanishidan qat’i nazar, doimiy tok kuchini ta’minlaydi.

4.26-rasmda ko‘rsatilganidek, amaliy kuchlanish va tok kuchi manbalari ichki qarshiliklari yoki manba qarshiligi R_s va R_p tufayli ideal emas. Ular $R_s \to 0$ va $R_p \to \infty$ sifatida idealga aylanadi.



a) b)

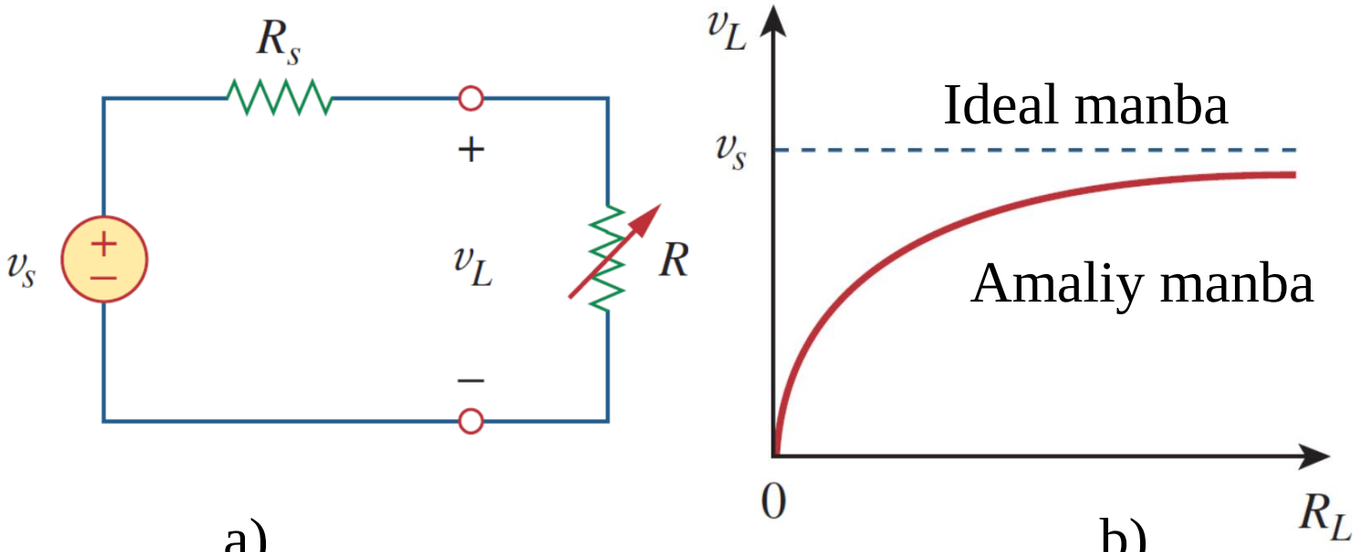
4.26-rasm.

a) kuchlanish manbai; b) tok kuchi manbai.

Yuklamaning kuchlanish manbalariga ta’sirini aniqlash uchun kuchlanishni bo‘linish qoidasidan foydalanamiz.

$$u_L = \frac{R_L}{R_s + R_L} u_s \qquad (4.25)$$

R_L ortishi bilan yuk kuchlanishi 4.27-rasm, *b* da ko‘rsatilganidek, manba kuchlanishiga u_s yaqinlashadi.



a) b)

4.27-rasm. a) R_L yuklamaga ulangan amaliy kuchlanish manbai; b) yuklama kuchlanishi R_L kamayishi bilan kamayadi.

(4.25) tenglamadan shuni ta’kidlashimiz kerak:

1. Agar manbaning ichki qarshiligi R_s nolga teng bo‘lsa yoki hech bo‘lmaganda $R_s \ll R_L$ bo‘lsa, yuklama kuchlanishi doimiy bo‘ladi.

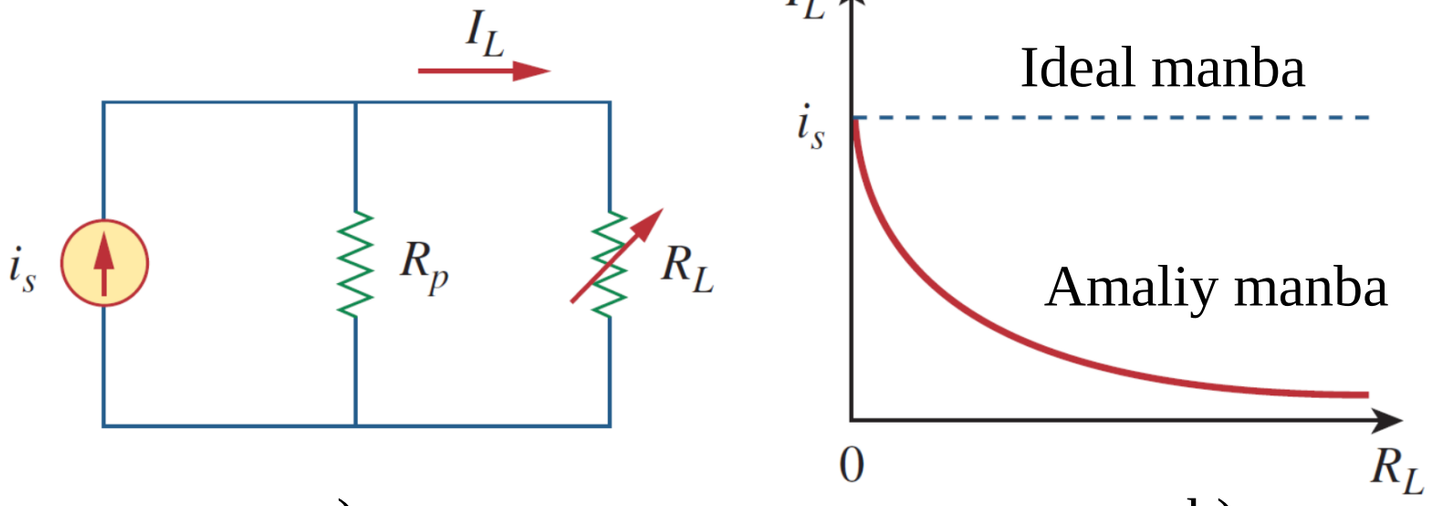
Boshqacha qilib aytganda, kichikroq R_s R_L bilan taqqoslansa, kuchlanish manbai idealga qanchalik yaqin bo‘ladi.

2. Yuklama uzilganda (ya’ni, manba ochiq zanjirli $R_L \to \infty$ bo‘lishi uchun), $u_{oc} = u_s$. Shunday qilib, u_s yuklanmagan manba kuchlanishi sifatida qaralishi mumkin.

Yuklamani ulash terminal kuchlanishining pasayishiga olib keladi. Bunday hodisa ***yuklanish effekti*** sifatida tanilgan.

Xuddi shu argument 4.28-rasm, *a* da ko‘rsatilganidek, yuklamaga ulanganda amaliy tok kuchi manbai uchun ham keltirilishi mumkin. Tok kuchini bo‘linish qoidasiga ko‘ra,

$$i_L = \frac{R_p}{R_p + R_L} i_s \qquad (4.26)$$



a) b)

4.28-rasm.

R_L - ortishi bilan

I_L - o‘zgarishini ko‘rsatadi.

a) R_L yuklamaga ulangan amaliy tok kuchi manbai;
b) yuklama tok kuchi R_L ortishi bilan kamayadi.

Shunga qaramay, biz yuklama (*yuklanish effekti*) tufayli tok kuchining pasayishini sezamiz va ichki qarshilik juda katta bo‘lganda (*ya’ni,* $R_p \to \infty$ *yoki, hech bo‘lmaganda,* $R_p \gg R_L$) yuklama tok kuchi doimiy (*ideal tok kuchi manbai*).

a) b)

4.29-rasm.

a) u_{oc} ni o‘lchash; b) u_L ni o‘lchash.

u_s yuklanmagan manba kuchlanishi va R_s kuchlanish manbasining ichki qarshiligini bilish uchun

4.29-rasmda ko‘rsatilgan jarayonga amal qilamiz.

$$u_s = u_{oc} \qquad (4.27)$$

Keyin, terminallar bo‘ylab o‘zgaruvchan yuk R_L ni ulaymiz.

R_L qarshiligini rostlab ochiq zanjirli kuchlanishning to‘liq yarmiga teng yuklama kuchlanishini o‘lchagunimizcha, $u_L = u_{oc}/2$, chunki hozir $R_L = R_{Th} = R_s$.

Shu paytda R_L ni ajratamiz va uni o‘lchaymiz.

$$R_s = R_L \qquad (4.28)$$

a) b)

4.29-rasm.

a) u_{oc} ni o‘lchash; b) u_L ni o‘lchash.

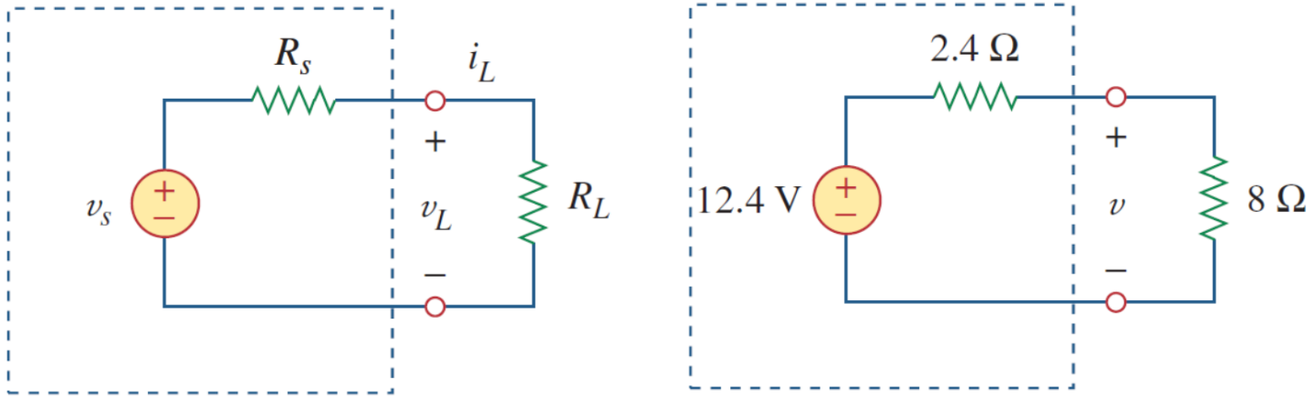
Misol uchun, avtomobilning batareyasi $u_s = 12\ V$ va $R_s = 0{,}05\ \Omega$.

4.7.1-masala: 2 W yuklama ulanganda kuchlanish manbasining terminal kuchlanishi

12 V ni tashkil qiladi. Yuklama uzilganda, terminal kuchlanish 12,4 V ga ko‘tariladi.

a) Manba kuchlanishini u_s va ichki qarshilik R_s ni hisoblang.

b) Yuklama manbaga ulanganda kuchlanishni aniqlang.



a) b)

4.30-rasm.

a) $\boldsymbol{u_s = u_{oc} = 12,4\ V}$

yuklama ulanganda $u_L = 12\ V$ va $p_L = 2\ W$. Demak,

$$p_L = \frac{u_L^2}{R_L} \quad \rightarrow \quad R_L = \frac{u_L^2}{p_L} = \frac{12^2}{2} = 72\ \Omega$$

Yuklama tok kuchi.

$$i_L = \frac{u_L}{R_L} = \frac{12}{72} = \frac{1}{6}\ A$$

R_s dagi kuchlanish manba kuchlanishi u_s va u_L o‘rtasidagi farq

$$12,4 - 14 = 0,4 = R_s i_L, \qquad \boldsymbol{R_s = \frac{0,4}{I_L} = 2,4\ \Omega}$$

b)

$$\boldsymbol{u = \frac{8}{8 + 2,4}(12,4) = 9,538\ V}$$

4.7.2. Qarshilikni o‘lchash.

Ommetr usuli qarshilikni o‘lchashning eng oddiy usulini taqdim etsa-da, Veatstone ko‘prigi yordamida aniqroq o‘lchovlarni olish mumkin.

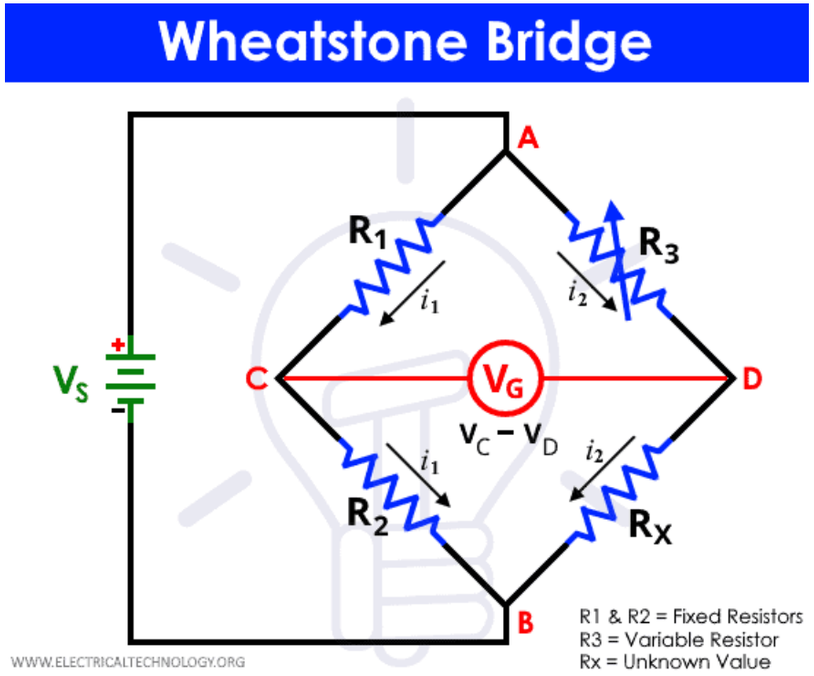
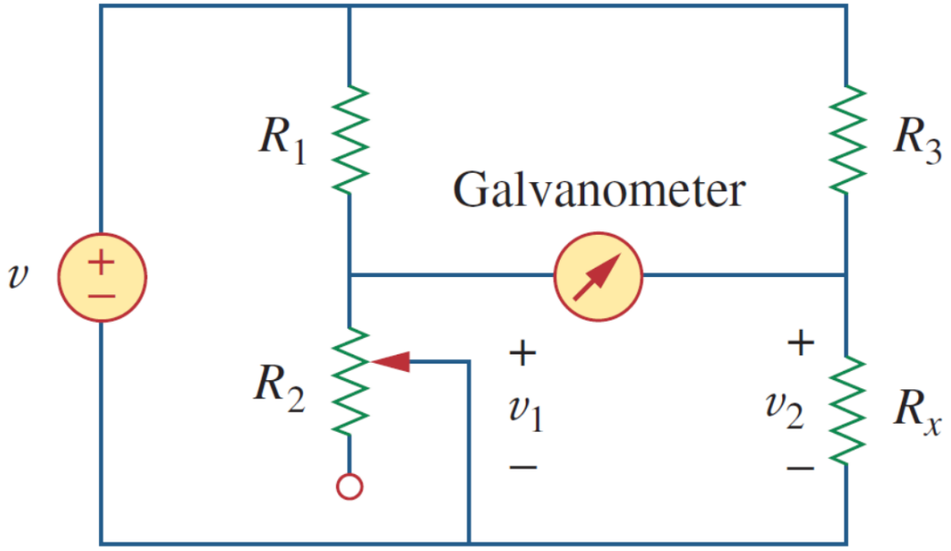


Photo source: [18] - https://www.electricaltechnology.org/wp-content/uploads/2021/03/Wheatstone-Bridge.png

Ommetrlar past, o‘rta yoki yuqori diapazonda qarshilikni o‘lchash uchun mo‘ljallangan bo‘lsa-da, Veatstone ko‘prigi o‘rta diapazondagi qarshilikni o‘lchash uchun ishlatiladi, aytaylik, 1 Ω va 1 MΩ.

Qarshilikning juda past qiymatlari ***milliommetr*** bilan o‘lchanadi, lekin juda yuqori qiymatlar ***Megger tester*** bilan o‘lchanadi.

Veatstone ko‘prigi (*yoki qarshilik ko‘prigi*) zanjir bir qator amaliyotlarda qo‘llaniladi. Bu yerda biz noma’lum qarshilikni o‘lchash uchun foydalanamiz. Noma’lum qarshilik R_x 4.31-rasmda ko‘rsatilgandek ko‘prikka ulangan.



4.31-rasm. Veatstone ko‘prigi;

R_x - o‘lchanadigan qarshilik.

O‘zgaruvchan qarshilik galvanometrdan tok kuchi o‘tguncha o‘rnatiladi, bu aslida mikroamper diapazonida ampermetr kabi sezgir tok kuchini ko‘rsatuvchi qurilma sifatida ishlaydigan d'Arsonval harakatidir.

Bu shartda $u_1 = u_2$ va ko‘prik muvozanatli deyiladi.

Galvanometrdan tok kuchi o‘tmaganligi sababli, R_1 va R_2 o‘zlarini xuddi ketma-ket bo‘lgandek tutadilar; R_3 va R_x ham shunday. Galvanometrdan tok o‘tmasligi ham $u_1 = u_2$ ekanligini bildiradi. Kuchlanishni bo‘linish qoidasini qo‘llash orqali quyidagiga ega bo‘lamiz.

$$u_1 = \frac{R_2}{R_1+R_2}u = \; u_1 = \frac{R_x}{R_3+R_x}u \qquad (4.29)$$

Demak, qachon galvanometrdan tok kuchi o‘tmaydi

$$\frac{R_2}{R_1+R_2} = \frac{R_x}{R_3+R_x} \quad \rightarrow \quad R_2R_3 = R_1R_x$$

yoki

$$R_x = \frac{R_3}{R_1}R_2 \qquad (4.30)$$

Agar galvanometrdan tok o‘tmaguncha $R_1 = R_3$ va R_2 o‘rnatilsa, u holda $R_x = R_2$ bo‘ladi.

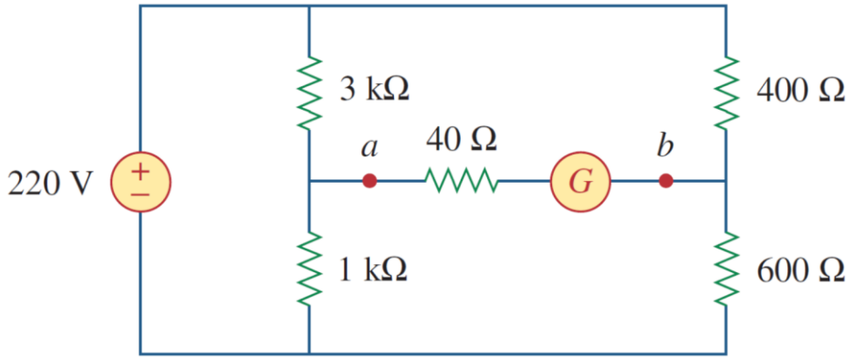
Veatstone ko‘prigi muvozanatsiz bo‘lsa, galvanometr orqali tok kuchini qanday topamiz? Galvanometr terminallariga nisbatan Tevenin ekvivalentini (U_{Th} va R_{Th}) topamiz.

Agar galvanometrning qarshiligi R_m bo‘lsa, muvozanatsiz holatda u orqali o‘tadigan tok kuchi quyidagiga tenglama orqali topiladi.

$$I = \frac{U_{Th}}{R_{Th}+R_m} \tag{4.31}$$

4.7.2-masala: 4.32-rasmdagi zanjir muvozanatsiz ko‘prikni ifodalaydi.

Agar galvanometrning qarshiligi 40 Ω ga teng bo‘lsa, galvanometrdan o‘tgan tokni toping.



4.32-rasm.

Yechish:

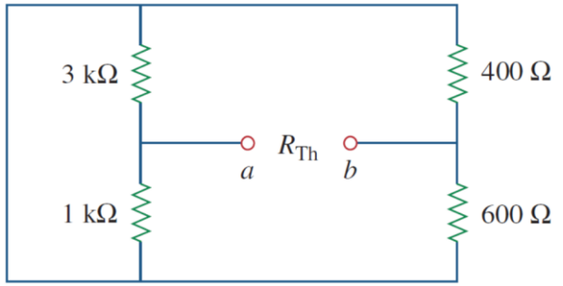
a)

$$R_{Th} = 3000||1000 + 400||600 =$$

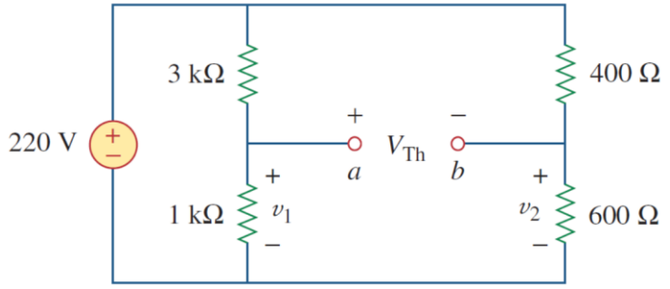
$$= \frac{3000 \cdot 1000}{3000+1000} + \frac{400 \cdot 600}{400+600} =$$

$$= 750 + 240 = 990\ \Omega$$

b)



a)



b)

$$u_1 = \frac{1000}{1000 + 3000}(220) = 55\ V$$

$$u_2 = \frac{600}{600 + 400}(220) = 132\ V$$

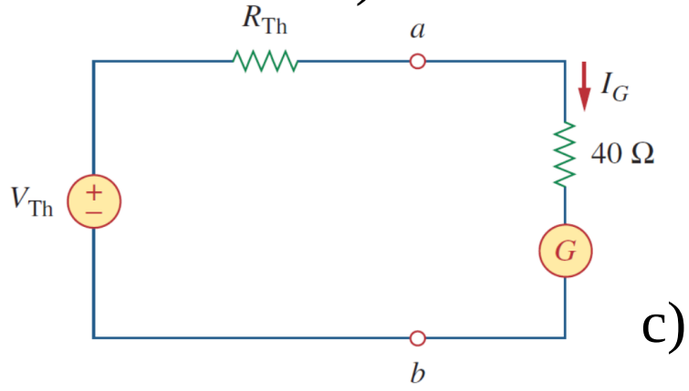
$$-u_1 + U_{Th} + u_2 = 0$$

yoki

$$U_{Th} = u_1 - u_2 = 55 - 132 = -77\ V$$

c)

$$I_G = \frac{U_{Th}}{R_{Th} + R_m} = -\frac{77}{990 + 40} = -74{,}76\ mA$$



c)

4.33-rasm.

a) R_{Th} ni toppish; b) U_{Th} ni topish; c) galvonometrdan o‘tuvchi tok kuchini aniqlash.

FOYDALANILGAN MANBALAR:

16. https://www.electronicshub.org/wp-content/uploads/2021/04/Maximum-Power-Transfer-Theorem-Featured.jpg
17. https://electricalacademia.com/wp-content/uploads/2017/01/Maximum-Power-Transfer-Matlab-768x637.gif
18. https://www.electricaltechnology.org/wp-content/uploads/2021/03/Wheatstone-Bridge.png

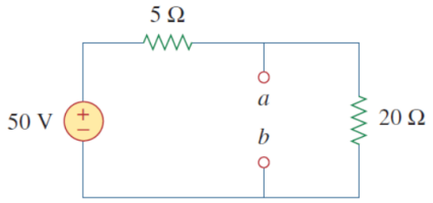
TEKSHIRISH UCHUN SAVOLLAR!

4.1. Kiruvchi manba kuchlanishi 10 V bo‘lganda chiziqli tarmoqdagi shaxobchadan o‘tuvchi tok kuchi 2 A ga teng. Agar kuchlanish 1 V ga kamaytirilsa va qutb teskari bo'lsa, tarmoq orqali o'tadigan tok kuchi:
A) -2 A. B) -0,2 A. C) 0,2 A. D) 2 A. E) 20 A

4.2. Superpozitsiya uchun bir vaqtning o‘zida faqat bitta mustaqil manba ko‘rib chiqilishi shart emas; bir vaqtning o‘zida istalgan miqdordagi mustaqil manbalar ko‘rib chiqilishi mumkin.
A) To‘g‘ri. B) Xato.

4.3. Superpozitsiya prinsipi quvvatni hisoblash uchun qo'llaniladi.
A) To‘g‘ri. B) Xato.

4.4. 4.34-rasmga qarang. *a* va *b* terminallaridagi Tevenin qarshiligi:



4.34-rasm.

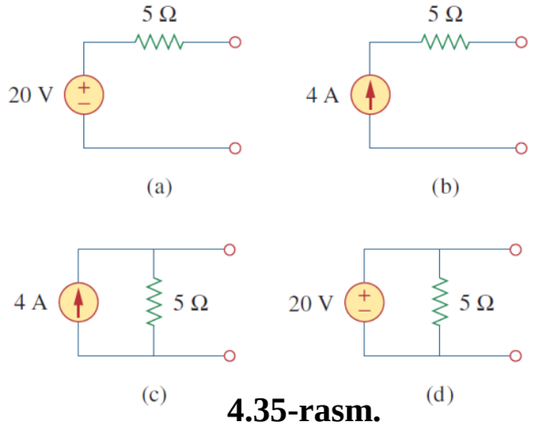
A) 25 Ω
B) 20 Ω
C) 5 Ω
D) 4 Ω

4.5. 4.34-rasmdagi zanjirning *a* va *b* terminallaridagi Tevenin kuchlanishi:
A) 50 V. B) 40 V. C) 20 V. D) 10 V.

4.6. 44.33-rasmdagi zanjirning *a* va *b* terminallaridagi Norton tok kuchi:
A) 10 A. B) 2,5 A. C) 2 A. D) 0 A.

4.7. Norton qarshiligi R_N Tevenin qarshiligi R_{Th} ga tengdir.
A) To‘g‘ri. B) Xato.

4.8. 4.35-rasmdagi qaysi juft zanjirlar ekvivalent hisoblanadi?



4.35-rasm.

A) *a* va *b*.
B) *b* va *d*.
C) *a* va *c*.
D) *c* va *d*.

4.9. Tarmoqqa yuklama ulangan. Yuklama ulangan terminallarda $R_{Th} = 10\ \Omega$ va $U_{Th} = 40\ V$. Yuklam bilan ta’minlangan maksimal quvvat:
A) 160 W. B) 80 W. C) 40 W. D) 1 W.

4.10. Yuklamaning qarshiligi manba qarshiligiga teng bo‘lganda, manba yuklamaga maksimal quvvat beradi.
A) To‘g‘ri. B) Xato.

E'TIBORINGIZ UCHUN RAHMAT!!!