

DC-2) II חלק - ישר, סדר, זרם, מתח

40

$$E = 24V \quad \text{זרם}$$

$$I_T = 6A$$

$$R_T = \frac{E}{I_T} = \frac{24}{6} = 4\Omega$$

$$P_0 = 12W \quad \text{זרם}$$

$$U_0 = 6V$$

חשבו את ההתנגדות הממוצעת:

$$R_0 = \frac{U^2}{P} = \frac{6^2}{12} = 3\Omega$$

$$R_T = R + R + (R_0 \parallel R)$$

$$4 = R + R + \left(\frac{3 \cdot R}{3 + R} \right) \quad | \cdot (3 + R)$$

$$4(3 + R) = 2R(3 + R) + 3R$$

$$12 + 4R = 6R + 2R^2 + 3R$$

$$2R^2 + 5R - 12 = 0$$

$$R_1 = 1.5\Omega$$

$$R_2 = -4 \quad \text{— ריגור, איננו יכול}$$

41

$$R_{2,5,6} = R_2 + (R_5 \parallel R_6) = 3 + (3^{-1} + 6^{-1})^{-1} = 5\Omega$$

$$R_{2,3,5,6} = (R_3 \parallel R_{2,5,6}) = (5 \parallel 5) = 2.5\Omega$$

$$R_{1,2,3,5,6} = R_1 + R_{2,3,5,6} = 3.5 + 2.5 = 6\Omega$$

R_A — זרם

$$R_{1,2,3,5,6,7} = R_A \parallel R_7 = (6^{-1} + 12^{-1})^{-1} = 4\Omega$$

R_B — זרם

$$R_T = R_4 + R_B = 4 + 8$$

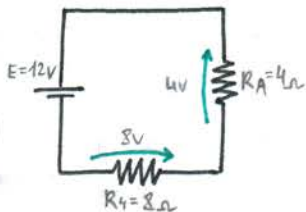
$$R_T = 12\Omega$$



41

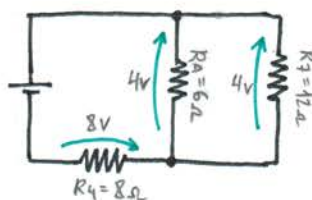
$$U_{R_B} = E \cdot \frac{R_B}{R_4 + R_B} =$$

$$U_{R_B} = 12 \cdot \frac{4}{8 + 4} = 4V$$



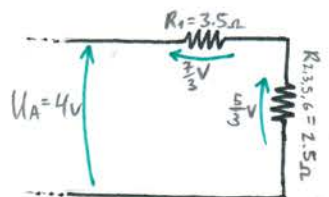
$$U_{R_A} = U_{R_7} = U_{R_B} \quad \text{זרם}$$

$$U_{R_7} = 4V$$



41

$$U_{R_1} = U_A \cdot \frac{R_1}{R_1 + R_{2,3,5,6}} = 4 \cdot \frac{3.5}{3.5 + 2.5} = \frac{7}{3}V$$



$$I_{R_1} = \frac{U_{R_1}}{R_1} = \frac{\frac{7}{3}}{3.5} = \frac{2}{3}$$

$$I_{R_1} = 0.666A$$



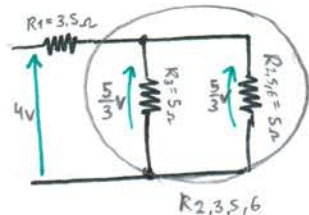
41

$$U_R = U_{R_{2,3,5,6}} = (U_A - U_{R_1}) = (4 - \frac{7}{3})$$

$$U_R = \frac{5}{3}V$$

$$P_{R_3} = \frac{U_{R_3}^2}{R_3} = \frac{(\frac{5}{3})^2}{5} = \frac{5}{9}$$

$$P_{R_3} = 0.555W$$



1

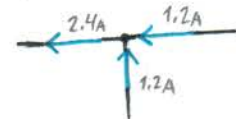
42

$$\underline{I_{R_4}} = \frac{U_{R_4}}{R_4} = \frac{36}{30} = \frac{6}{5} = \underline{1.2 \text{ A}}$$

$$\underline{R_{5,6}} = R_5 + R_6 = 10 + 20 = \underline{30 \Omega}$$

$$\left. \begin{array}{l} R_4 = R_{5,6} \\ U_{R_4} = U_{R_{5,6}} \end{array} \right\} \Rightarrow \underline{I_{R_{5,6}}} = I_{R_4} = \underline{1.2 \text{ A}}$$

$$I_{R_3} = I_{R_4} + I_{R_{5,6}} = 1.2 + 1.2 \quad : [\text{KCL}] \text{ 28}$$

$$\underline{I_{R_3}} = \underline{2.4 \text{ A}}$$


$$\underline{U_{R_3}} = I_{R_3} \cdot R_3 = 2.4 \cdot 5 = \underline{12 \text{ V}}$$

$$\underline{U_{R_{3-6}}} = U_{R_4} + U_{R_3} = 12 + 36 = \underline{48 \text{ V}}$$

$$\underline{U_{R_2}} = U_{R_{3-6}} = \underline{48 \text{ V}}$$

$$\underline{I_{R_2}} = \frac{U_{R_2}}{R_2} = \frac{48}{30} = \frac{8}{5} = \underline{1.6 \text{ A}}$$

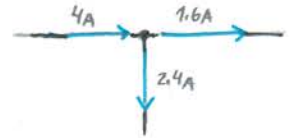
$$I_{R_1} = I_{R_2} + I_{R_3} = 1.6 + 2.4$$

$$\underline{I_{R_1}} = \underline{4 \text{ A}}$$

$$\underline{U_{R_1}} = I_{R_1} \cdot R_1 = 4 \cdot 13 = \underline{52 \text{ V}}$$

$$E = U_{R_1} + U_{R_2} = 52 + 48$$

$$\underline{E = 100 \text{ V}}$$



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$$\underline{U_{R_4}} = U_{AB} = \underline{9.6 \text{ V}}$$

$$\underline{I_{R_4}} = \frac{U_{AB}}{R_4} = \frac{9.6}{6} = \underline{1.6 \text{ A}}$$

$$\underline{R_{5,6}} = R_5 + R_6 = 3 + 1 = \underline{4 \Omega}$$

$$\underline{U_{R_{5,6}}} = U_{R_4} = \underline{9.6 \text{ V}} \quad \text{10.22 x}$$

$$\underline{I_{R_{5,6}}} = \frac{U_{R_{5,6}}}{R_{5,6}} = \frac{9.6}{4} = \underline{2.4 \text{ A}}$$

$$I_{R_3} = I_{R_4} + I_{R_{5,6}} = 1.6 + 2.4$$

$$\underline{I_{R_3}} = \underline{4 \text{ A}}$$

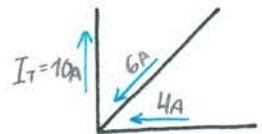

$$\underline{U_{R_3}} = I_{R_3} \cdot R_3 = 4 \cdot 0.6 = \underline{2.4 \text{ V}}$$

$$\underline{U_{R_2}} = U_{R_3} + U_{AB} = 2.4 + 9.6 = \underline{12 \text{ V}}$$

$$I_{R_2} = \frac{U_{R_2}}{R_2} = \frac{12}{2} = \underline{6 \text{ A}}$$

$$\underline{I_{R_1}} = I_{R_2} + I_{R_3} = 6 + 4 = \underline{10 \text{ A}} \quad : [\text{KCL}] \text{ 28}$$

$$\underline{I_T} = I_{R_1} = \underline{10 \text{ A}}$$



$$U_{R_1} = I_{R_1} \cdot R_1 = 10 \cdot 0.8 = \underline{8 \text{ V}}$$

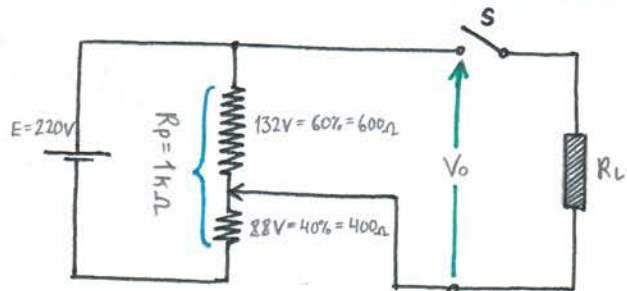
$$E = U_{R_1} + U_{R_2} = 8 + 12$$

$$\underline{E = 20 \text{ V}}$$

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נבדוק את חלוקת המתח וההתנפזות
היחסית של נגד הכוונתיות:

המתח במצב S פתוח (S):



חלוקת ההתנפזות:

חלוקת המתח:

$$\frac{132}{E} \% = \left(\frac{132}{240} \cdot 100\% \right) = 60\% = 132V$$

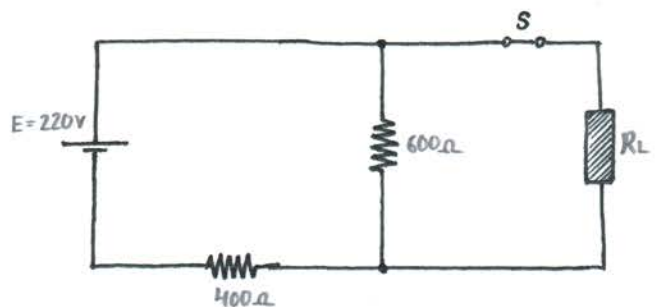
$$\Downarrow$$

$$40\% = 88V$$

$$60\% \cdot R_p = 0.6 \cdot 1 \cdot 10^3 = 600\Omega$$

$$40\% \cdot R_p = 0.4 \cdot 1 \cdot 10^3 = 400\Omega$$

המתח במצב S סגור (S):



$$R_T = 400\Omega + (600\Omega \parallel R_L)$$

$$R_T = 400 + \left(\frac{600 \cdot R_L}{600 + R_L} \right)$$

$$P_T = 88W$$

$$P_T = \frac{E^2}{R_T}$$

$$88 = \frac{220^2}{400 + \left(\frac{600 R_L}{600 + R_L} \right)}$$

$$550 - 400 = \frac{600 R_L}{600 + R_L}$$

$$150(600 + R_L) = 600 R_L$$

$$600 R_L - 150 R_L = 90,000$$

$$R_L = \frac{90000}{450}$$

$$R_L = 200\Omega$$

3

45 $\underline{U_{R4}} = I_{R4} \cdot R_4 = 2 \cdot 60 = \underline{120 \text{ V}}$

$\underline{U_{4,5,6}} = U_4 = U_5 = U_6 = \underline{120 \text{ V}}$
המתח זהה בכל המסלולים

$\underline{R_{4,5,6}} = R_4 \parallel R_5 \parallel R_6 = (60^{-1} + 56^{-1} + 166^{-1})^{-1}$

$\underline{R_{4,5,6}} = 24.525 \Omega$

$\underline{I_{R_{4,5,6}}} = \frac{U_{4,5,6}}{R_{4,5,6}} = \frac{120}{24.525} = \underline{4.892 \text{ A}}$

$\underline{I_{R3}} = I_{R_{4,5,6}} = \underline{4.892 \text{ A}}$

$\underline{U_{R3}} = I_{R3} \cdot R_3 = 4.892 \cdot 6 = \underline{29.357 \text{ V}}$

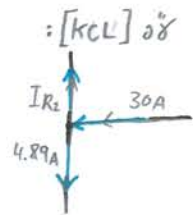
$\underline{U_{R2}} = (U_{R3} + U_{R_{4,5,6}}) = (29.357 + 120)$

$\underline{U_{R2}} = 149.35 \text{ V}$

$I_{R2} = I_{R1} - I_{R3}$

$I_{R2} = 30 - 4.892$

$\underline{I_{R2}} = 25.1 \text{ A}$



$R_2 = \frac{U_{R2}}{I_{R2}} = \frac{149.35}{25.1}$

$\underline{R_2} = 5.948 \Omega$



$I_{R1} = 30 \text{ A}$ המתח

$\underline{U_{R1}} = I_{R1} \cdot R_1 = 30 \cdot 3 = \underline{90 \text{ V}}$

$E = (U_{R1} + U_{R2}) = (90 + 149.35)$

$\underline{E} = 239.35 \text{ V}$



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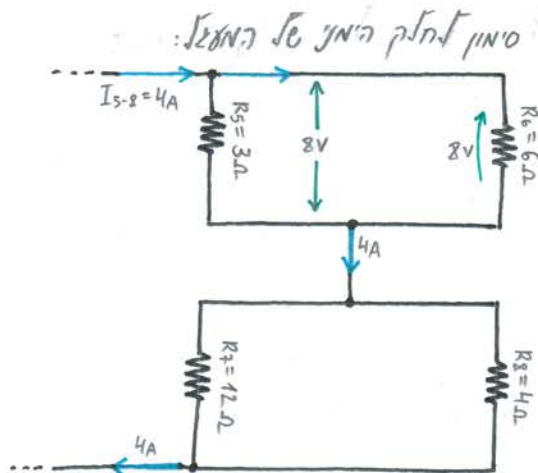
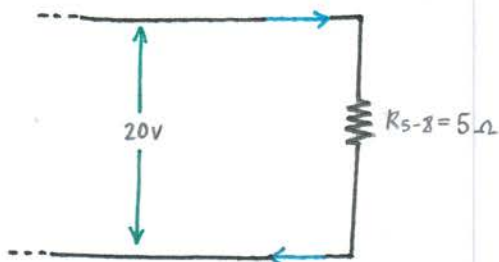
$$U_{R5} = U_{R6} = I_{R6} \cdot R_6 = \frac{4}{3} \cdot 6 = 8V$$

$$R_{5,6} = R_5 \parallel R_6 = \frac{3 \cdot 6}{3+6} = 2\Omega$$

$$I_{5-8} = I_{5,6} = \frac{U_{R5}}{R_{5,6}} = \frac{8}{2} = 4A$$

$$R_{5-8} = R_{5,6} + (R_7 \parallel R_8) = 2 + \frac{12 \cdot 4}{12+4} = 5\Omega$$

$$U_{5-8} = (I_{5-8} \cdot R_{5-8}) = 4 \cdot 5 = 20V$$



$$R_{2,3,4} = R_2 + (R_3 \parallel R_4) = 4 + \frac{15 \cdot 10}{15+10} = 10\Omega$$

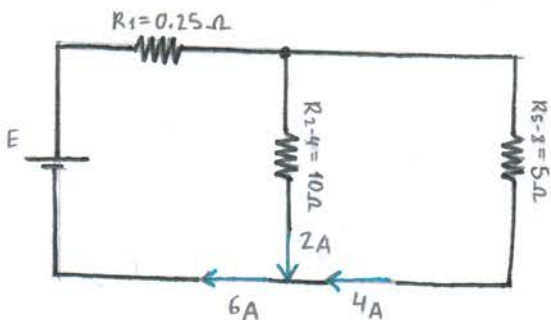
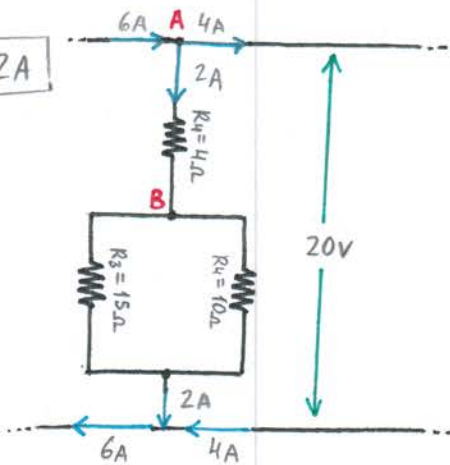
$$U_{2,3,4} = U_{5-8} = 20V$$

$$I_{2,3,4} = \frac{U_{2,3,4}}{R_{2,3,4}} = \frac{20}{10} = 2A$$

$$I_{R2} = I_{2,3,4} = 2A$$

$$U_{AB} = I_{R2} \cdot R_2 = 2 \cdot 4$$

$$U_{AB} = 8V$$



$$R_T = R_1 + (R_{2,3,4} \parallel R_{5-8}) = 0.25 + \left(\frac{10 \cdot 5}{10+5} \right)$$

$$R_T = 3.588\Omega$$

$$I_T = I_{5-8} + I_{2,3,4} = 4 + 2 = 6A$$

$$E = I_T \cdot R_T = 6 \cdot 3$$

$$E = 21.5V$$

: [KCL] օր

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$$R_{5-8} = R_5 + R_6 + (R_7 \parallel R_8) = 2 + 1 + \left(\frac{6 \cdot 3}{6 + 3}\right) = 5 \Omega$$

$$R_{4-8} = R_4 \parallel R_{5-8} = 5 \parallel 5 = 2.5 \Omega$$

$$R_{2-8} = R_2 \parallel (R_3 + R_{4-8}) = 5 \parallel (2.5 + 2.5) = \frac{5}{2} = 2.5 \Omega$$

$$R_T = R_1 + R_{2-8} = 2.5 + 2.5$$

$$R_T = 5 \Omega$$

$$I_T = \frac{E}{R_T} = \frac{20}{5}$$

$$I_T = 4 A$$

$$I_{R_1} = I_T = 4 A$$

$$U_{R_1} = I_{R_1} \cdot R_1 = 4 \cdot 2.5 = 10 V$$

$$U_{R_2} = E - U_{R_1} = 20 - 10 = 10 V$$

$$U_{R_{3-8}} = U_{R_2} = 10 V$$

$$U_{R_{4-8}} = U_{R_3} = U_{R_4} = \frac{U_{R_{3-8}}}{2} = \frac{10}{2} = 5 V$$

$$U_{R_{5-8}} = U_{R_4} = 5 V$$

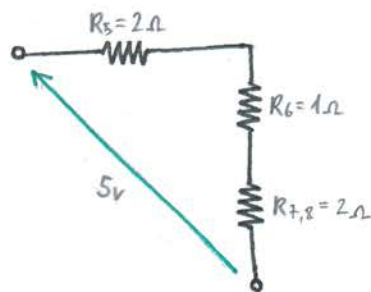
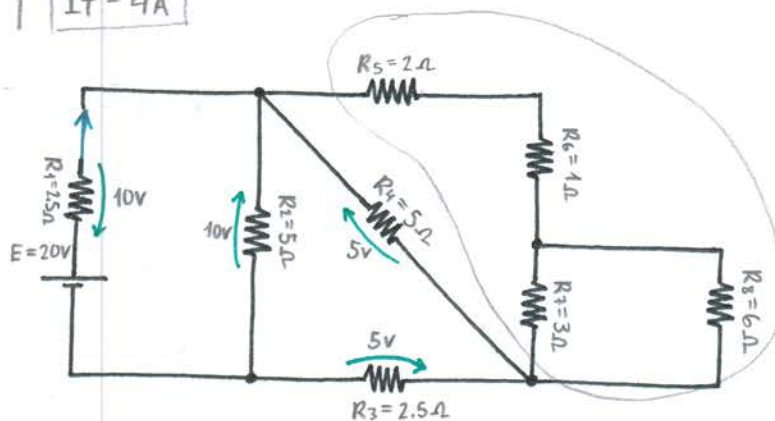
$$R_{7,8} = R_7 \parallel R_8 = \left(\frac{6 \cdot 3}{6 + 3}\right) = 2 \Omega$$

$$U_{R_{7,8}} = U_{R_{3-8}} \cdot \frac{R_{7,8}}{R_5 + R_6 + R_{7,8}} = 5 \cdot \frac{2}{2 + 1 + 2} = 2 V$$

$$U_{R_8} = U_{R_{7,8}} = 2 V$$

$$P_{R_8} = \frac{(U_{R_8})^2}{R_8} = \frac{2^2}{6} = \frac{2}{3}$$

$$P_{R_8} = 0.666 W$$



48

$$R_{1,2,3} = R_1 \parallel R_2 \parallel R_3$$

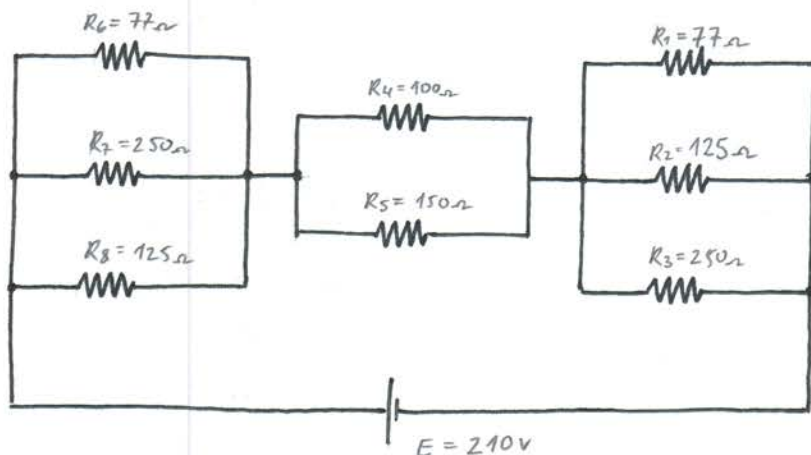
$$R_{1,2,3} = (77^{-1} + 125^{-1} + 250^{-1})^{-1}$$

$$R_{1,2,3} = 40 \Omega$$

$$R_{6,7,8} = R_{1,2,3}$$

סימטריה
במקרה זה

$$R_{6,7,8} = 40 \Omega$$

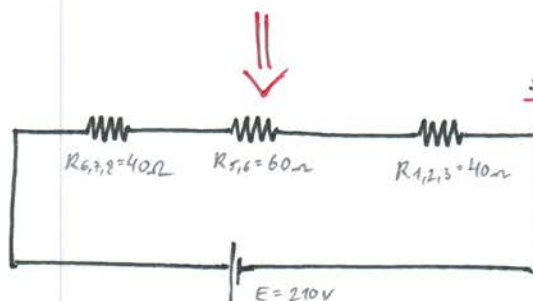


טיפה לזכור

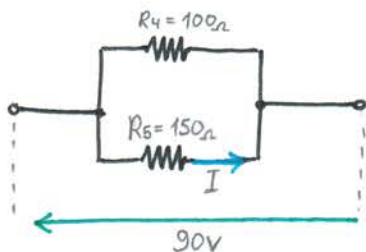
$$R_{4,5} = R_4 \parallel R_5 = (100^{-1} + 150^{-1})^{-1} = 60 \Omega$$

$$U_{R_{4,5}} = E \cdot \frac{R_{4,5}}{R_{1,2,3} + R_{4,5} + R_{6,7,8}} = 210 \cdot \frac{60}{40 + 60 + 40}$$

$$U_{R_{4,5}} = 90V$$



טיפה לזכור



$$U_{R5} = U_{R_{4,5}} = 90V$$

$$I = I_{R5} = \frac{U_{R5}}{R5} = \frac{90}{150} = 0.6A$$

49

$$I(10000 + R_x) = 50$$

$$I(R_x + 5000) = 40$$

$$I = \frac{50}{(10000 + R_x)}$$

$$I = \frac{40}{(R_x + 5000)}$$

I=I)

$$\left(\frac{50}{10000 + R_x} \right) = \left(\frac{40}{R_x + 5000} \right) \quad / : 10$$

$$4(10000 + R_x) = 5(R_x + 5000)$$

$$40000 + 4R_x = 5R_x + 25000$$

$$5R_x - 4R_x = 40000 - 25000$$

$$R_x = 15 k\Omega$$

עם חיסוב נקל להתחיל
2 סימטריה

49 $I = \left(\frac{50}{10000 + 15000} \right) = 2mA$ ($R_x = 15k\Omega$)
בהשוואה השתאף.

$$U_{R_x} = I \cdot R_x = (2 \times 10^{-3}) \cdot (15 \times 10^3)$$

$$U_{R_x} = 30V$$

49 $R_T = (10 + 15 + 5) \times 10^3 = 30k\Omega$

$$E = I \cdot R_T = 2 \times 10^{-3} \cdot 30 \times 10^3$$

$$E = 60V$$

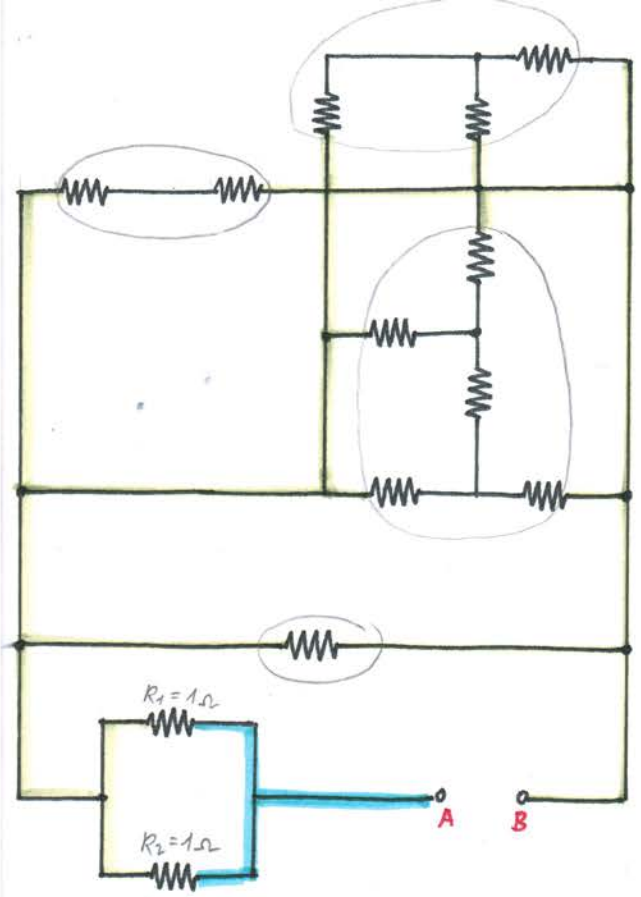
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50

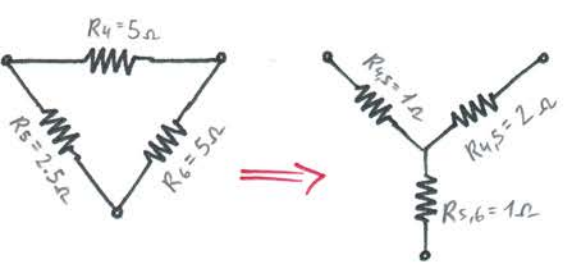
עם סימון הכולליות הנכונות
המשל, מסתבר שכל קבוצות
הנזקים במעגל המקורות העיצוב
והסדר של הכולליות חסות זהה
($\Delta U = 0$)

$$R_T = R_1 \parallel R_2 = \frac{1 \cdot 1}{1 + 1}$$

$$R_T = 0.5 \Omega$$



51



$$\Sigma R = R_4 + R_5 + R_6 = 5 + 2.5 + 5$$

$$\Sigma R = 12.5$$

$$R_{4,5} = \frac{R_4 \cdot R_5}{\Sigma R} = \frac{5 \cdot 2.5}{12.5} = 1 \Omega$$

$$R_{5,6} = \frac{R_5 \cdot R_6}{\Sigma R} = \frac{2.5 \cdot 5}{12.5} = 1 \Omega$$

$$R_{4,6} = \frac{R_4 \cdot R_6}{\Sigma R} = \frac{5 \cdot 5}{12.5} = 2 \Omega$$

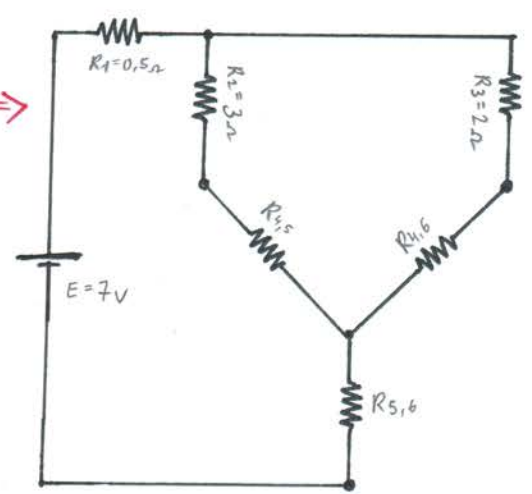
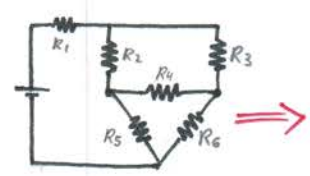
$$R_T = R_1 + R_{5,6} + [(R_2 + R_{4,5}) \parallel (R_3 + R_{4,6})]$$

$$R_T = 0.5 + 1 + [(3 + 1) \parallel (2 + 2)]$$

$$R_T = 3.5 \Omega$$

$$I_T = \frac{E}{R_T} = \frac{7}{3.5} = 2 A$$

(8)



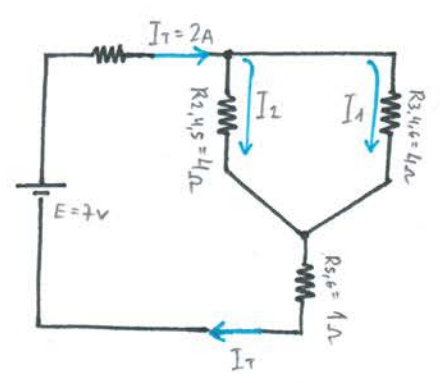
$$R_{2,4,5} = R_{3,4,6}$$

$$I_1 = I_2$$

$$I_1 = \frac{I_T}{2} = \frac{2}{2} = 1 A$$

$$I_{R3} = I_1$$

$$P_{R3} = I_{R3}^2 \cdot R_3 = 1 \cdot 2 = 2 W$$



52

$$R_T = [(R_1 + R_2) \parallel (R_3 + R_4)] + r$$

$$R_T = \left[\left(\frac{30}{12+18} \right) \parallel \left(\frac{20}{12+8} \right) \right] + 0.5$$

$$R_T = 12.5 \Omega$$

1 סלון

$$U_{AB} = U_{R_1} - U_{R_3}$$

$$U_{AB} = R_1 \cdot I_1 - R_3 \cdot I_2$$

$$2.4 = 12 I_1 - 12 I_2 \quad / : 12$$

$$0.2 = I_1 - I_2$$

$$I_1 = (0.2 + I_2)$$

2 סלון

$$U_{AB} = (-U_{R_2}) + U_{R_4}$$

$$U_{AB} = -R_2 I_1 + R_4 I_2$$

$$2.4 = -18 I_1 + 8 I_2 \quad / : 2$$

$$1.2 = -9 I_1 + 4 I_2$$

$$(I_1 - 0.2)$$

$$1.2 = -9(0.2 + I_2) + 4 I_2$$

$$1.2 = -1.8 - 9 I_2 + 4 I_2$$

$$3 = -5 I_2$$

$$I_2 = \left(-\frac{3}{5} \right) A$$

סמן המנוס מצוין שהסרם
בקוביות הפונה למטה
המחנה

$$I_2 = \left(-\frac{3}{5} \right) \rightarrow 3.7$$

$$I_1 = (0.2 + I_2)$$

$$I_1 = 0.2 - \frac{3}{5}$$

$$I_1 = \left(-\frac{2}{5} \right) A$$

כך *

$$\left. \begin{array}{l} I_T = I_1 + I_2 \\ I_T = \frac{3}{5} + \frac{2}{5} \\ I_T = 1 A \end{array} \right\} \Rightarrow$$

$$E = I \cdot R_T$$

$$E = 1 \cdot 12.5$$

$$E = 12.5 V$$

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$$R_{AB} = (R + R_L) \parallel R + R = R_L \leftarrow \begin{array}{l} \text{הקריסה} \\ \text{בכמה} \end{array}$$

$$\frac{(R + R_L) \cdot R}{(R + R_L) + R} + R = R_L$$

$$\frac{R^2 + R \cdot R_L}{2R + R_L} + R = R_L \quad / \cdot (2R + R_L)$$

$$R^2 + R R_L + R(2R + R_L) = R_L(2R + R_L)$$

$$R^2 + R R_L + 2R^2 + R R_L = 2R R_L + (R_L)^2$$

$$3R^2 + 2R \cdot R_L = 2R \cdot R_L + (R_L)^2$$

$$3R^2 = (R_L)^2$$

$$R_L = \pm \sqrt{3 \cdot R^2}$$

$$R_L = \sqrt{3} \cdot \sqrt{R^2}$$

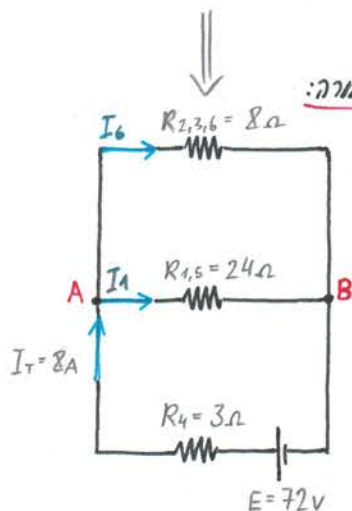
$$R_L = \sqrt{3} \cdot R$$

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$$R_{2,3} = R_2 \parallel R_3 = (6 \parallel 12) = 4 \Omega$$

$$R_{2,3,6} = (R_{2,3} + R_6) = 4 + 4 = 8 \Omega$$

$$R_{1,5} = (R_1 + R_5) = 16 + 8 = 24 \Omega$$

: I_T תאורה

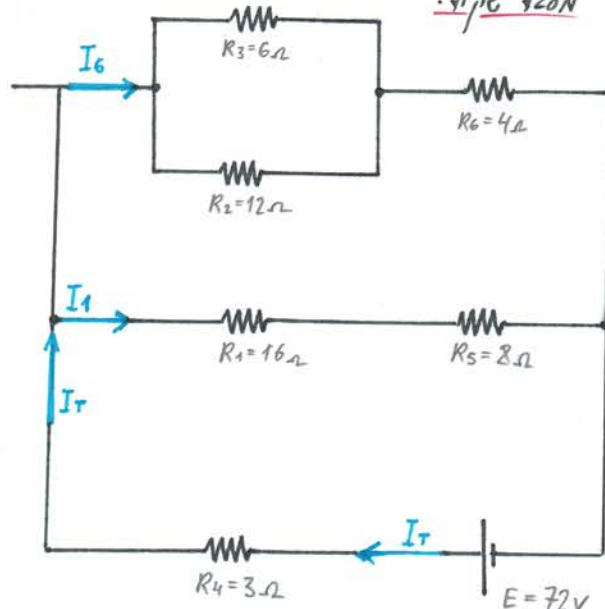
$$R_T = (R_{1,5} \parallel R_{2,3,6}) + R_4$$

$$R_T = (24 \parallel 8) + 3$$

$$R_T = 9 \Omega$$

$$I_T = \frac{E}{R_T} = \frac{72}{9}$$

$$I_T = 8A$$

: I_{R6} I_{R3} 

חשוב: הכוונה וסלילי: הנתון בקצרים:

$$I_{R4} = I_T = 8A$$

$$U_{R4} = I_{R4} \cdot R_4 = 8 \cdot 3 = 24V$$

$$U_{AB} = E - U_{R4} = 72 - 24$$

$$U_{AB} = 48V$$

$$I_1 = \frac{U_{AB}}{R_{1,5}} = \frac{48}{24} = 2A$$

$$I_{R1} = I_1 = 2A$$

$$U_{R1} = I_1 \cdot R_1 = 2 \cdot 16 = 32V$$

$$I_{R5} = I_1 = 2A$$

$$U_{R5} = I_1 \cdot R_5 = 2 \cdot 8 = 16V$$

$$I_6 = \frac{U_{AB}}{R_{2,3,6}} = \frac{48}{8} = 6A$$

$$I_{R6} = I_6 = 6A$$

$$U_{R6} = I_6 \cdot R_6 = 6 \cdot 4 = 24V$$

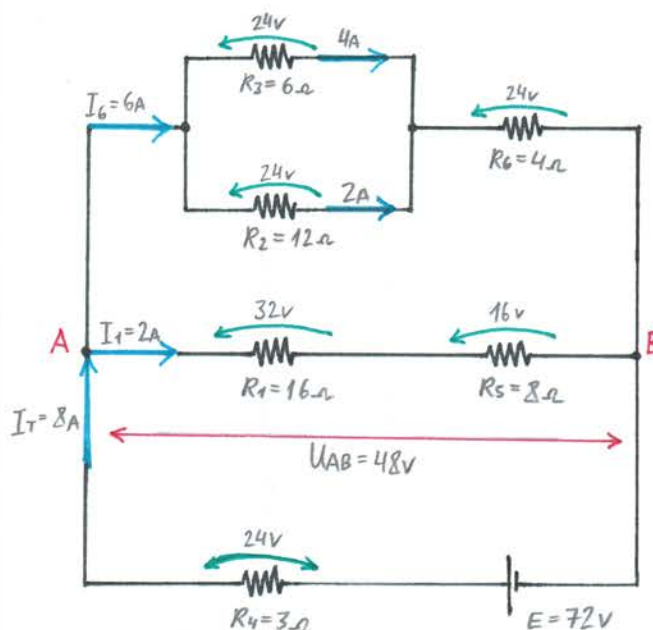
$$U_{R3} = U_{AB} - U_{R6}$$

$$U_{R3} = 48 - 24 = 24V$$

$$I_{R3} = \frac{U_{R3}}{R_3} = \frac{24}{6} = 4A$$

$$U_{R2} = U_{R3} = 24V$$

$$I_{R2} = \frac{U_{R2}}{R_2} = \frac{24}{12} = 2A$$



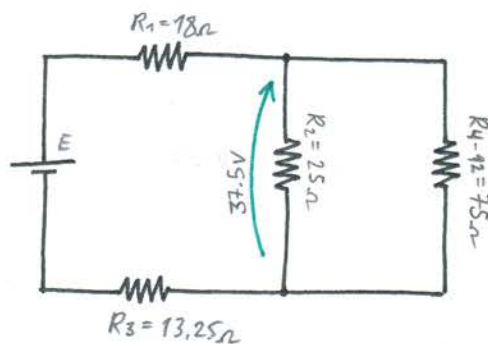
55

$$R_{4,5,6} = (R_4 \parallel R_5 \parallel R_6) = (90 \parallel 45 \parallel 30) = 15 \Omega$$

$$R_{10,11,12} = R_{10} \parallel (R_{11} + R_{12}) = 10 \parallel (\overset{15}{3} + 12) = 6 \Omega$$

$$R_{8-12} = R_8 \parallel (R_9 + R_{10,11,12}) = 10.5 \parallel (\overset{14}{8} + 6) = 6 \Omega$$

$$R_{4-12} = (R_{4,5,6} + R_7 + R_{8-12}) = (15 + 54 + 6) = 75 \Omega$$



$$P_{R_2} = 56.25 \text{ W}$$

$$U_{R_2} = \sqrt{P_{R_2} \cdot R_2} = \sqrt{56.25 \cdot 25}$$

$$U_{R_2} = 37.5 \text{ V}$$

$$I_{R_2} = \frac{U_{R_2}}{R_2} = \frac{37.5}{25}$$

$$I_{R_2} = 1.5 \text{ A}$$

$$U_{R_{4-12}} = U_{R_2} = 37.5 \text{ V}$$

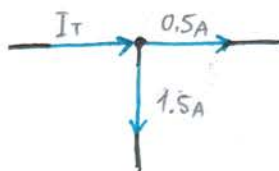
$$I_{R_{4-12}} = \frac{U_{R_{4-12}}}{R_{4-12}} = \frac{37.5}{75}$$

$$I_{R_{4-12}} = 0.5 \text{ A}$$

$$I_T = I_{R_2} + I_{R_{4-12}} \quad \text{[KCL] 28}$$

$$I_T = 1.5 + 0.5$$

$$I_T = 2 \text{ A}$$

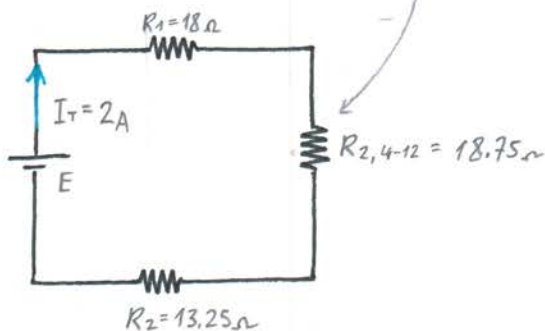


$$R_{2,4-12} = (R_2 \parallel R_{4-12}) = (25 \parallel 75) = 18.75 \Omega$$

$$R_T = R_1 + R_{2,4-12} + R_3$$

$$R_T = 18 + 18.75 + 13.25$$

$$R_T = 50 \Omega$$



$$E = I_T \cdot R_T = 2 \cdot 50$$

$$E = 100 \text{ V}$$