

עבודת הביתה - נגדים חילופיים (AC)

AC - בעל הספק 1:

10

100

$$X_{C1} = (-j8) \Omega$$

$$X_{C2} = (-j12) \Omega$$

$$X_L = +j6 \Omega$$

$$Z_T = X_L + (X_{C1} \parallel X_{C2})$$

$$Z_T = j6 + (-j8 \parallel -j12)$$

$$Z_T = (0 + j1.2) = (1.2 \angle 90) \Omega$$

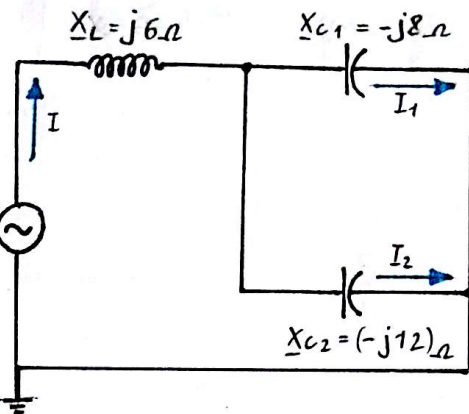
2

$$\underline{I} = \frac{E}{Z} = \frac{12 \angle 0}{1.2 \angle 90}$$

$$\underline{I} = (10 \angle -90) A$$

3

$$\underline{I}_1 = \underline{I} = (10 \angle -90) A$$



3

החוק של קרנל - [KVL]:

$$\underline{I}_2 = \underline{I} \cdot \frac{X_{C1}}{X_{C1} + X_{C2}} = 10 \angle -90 \cdot \frac{-j8}{-j8 - j12}$$

$$\underline{I}_2 = (4 \angle -90) A$$

$$\underline{I}_3 = \underline{I} - \underline{I}_2 = (10 \angle -90) - (4 \angle -90)$$

$$\underline{I}_3 = (6 \angle -90) A$$

7

$$V_L = U_{X_L} = \underline{I} \cdot X_L = (10 \angle -90) \cdot j6$$

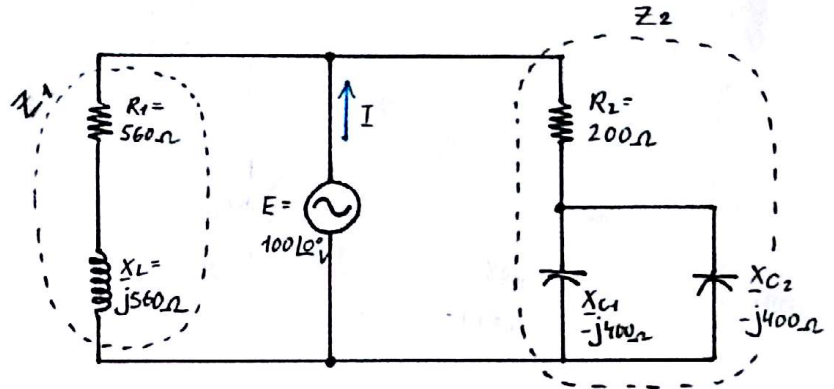
$$U_{X_L} = (60 \angle 0) V$$

100

$$X_L = +j560 \Omega$$

$$X_{C1} = (-j400) \Omega$$

$$X_{C2} = (-j400) \Omega$$



1. $X_{CT} = (X_{C1} \parallel X_{C2}) = (-j400 \parallel -j400)$

$$X_{CT} = (-j200) \Omega$$

100

$$Z_1 = R_1 + X_L$$

$$Z_1 = (560 + j560) = 791.96 \angle 45^\circ \Omega$$

$$Z_2 = R_2 + X_{CT}$$

$$Z_2 = (200 - j200) = 282.843 \angle 45^\circ \Omega$$

$$Z_T = (Z_1 \parallel Z_2) = [(560 + j560) \parallel (200 - j200)]$$

$$Z_T = (240.723 - j114.03) = 266.365 \angle -25^\circ \Omega$$

$$I = \frac{E}{Z_T} = \frac{100 \angle 0}{266.365 \angle -25^\circ}$$

$$I = 375.4 \angle 25.35^\circ \text{ [mA]}$$

2

כח אלקטרוני : [KVL]

$$U_C = E \cdot \frac{X_{CT}}{X_{CT} + R_2} = 100 \angle 0 \cdot \frac{-j200}{-j200 + 200}$$

$$U_C = (70.71 \angle -45^\circ) \text{ [V]}$$

■

3

$$S = \underline{I}^* \cdot \underline{U} = 0.375 \angle -25.35 \cdot 100 \angle 0$$

$$S = 0.375 \angle -25.35 \cdot 100 \angle 0$$

$$S = (33.928 - j16.071) \text{ [VA]}$$

$$P \text{ [W]}$$

(כח אלקטרוני)

$$Q \text{ [VAR]}$$

(כח היציב)

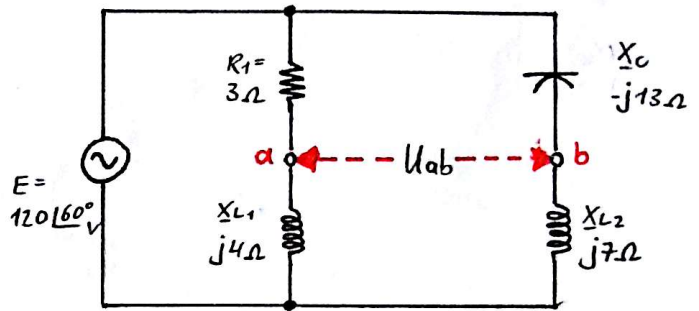
$$P = 33.928 \text{ [W]}$$

■

$$\underline{X}_C = (-j13)\Omega \quad \text{[no]}$$

$$\underline{X}_{L1} = j4\Omega$$

$$\underline{X}_{L2} = j7\Omega$$



(*)

: [KVL] 08-777 7/777

$$\underline{U}_{R1} = E \frac{R_1}{R_1 + \underline{X}_{L1}} = 120\angle 60^\circ \frac{-j13}{3 + j7}$$

$$\underline{U}_{R1} = 72\angle 6.87^\circ \text{ [V]}$$

$$\underline{I}_1 = \underline{I}_{R1} = \frac{\underline{U}_{R1}}{R_1} = \frac{72\angle 6.87^\circ}{3}$$

$$\underline{I}_1 = 24\angle 6.87^\circ \text{ [A]}$$

(*)

: [KVL] 08-777 7/777

$$\underline{U}_{XC} = E \frac{\underline{X}_C}{\underline{X}_C + \underline{X}_{L2}} = 120\angle 60^\circ \frac{-j13}{-j13 + j7}$$

$$\underline{U}_{XC} = 260\angle 60^\circ \text{ [V]}$$

(*)

$$\underline{U}_{AB} = -\underline{U}_{R1} + \underline{U}_{XC} =$$

$$\underline{U}_{AB} = -72\angle 6.87^\circ + 260\angle 60^\circ$$

$$\underline{U}_{AB} = 224.32\angle 74.88^\circ \text{ [V]}$$

$$X_C = (-j60)\Omega$$

$$X_L = j80\Omega$$

Ⓚ

$$Z_1 = (X_L \parallel R_2) + R_1$$

$$Z_1 = (j80 \parallel 20) + 10$$

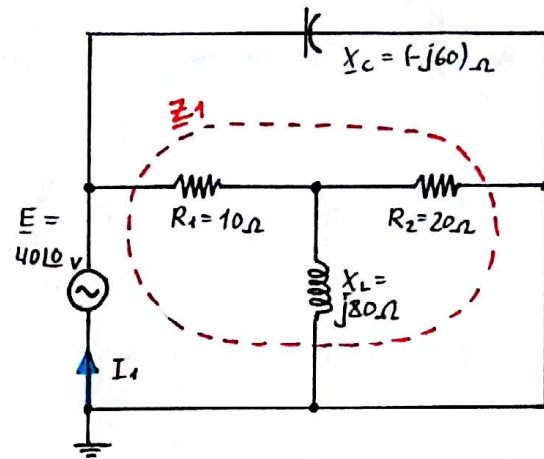
$$Z_1 = (28.824 + j4.706) = 29.21 \angle 9.273^\circ [\Omega]$$

$$Z_T = (Z_1 \parallel X_C) = (29.21 \angle 9.273^\circ \parallel -j60)$$

$$Z_T = (26.686 - j8.805) = 28.1 \angle -18.26^\circ [\Omega]$$

$$I_1 = \frac{E}{Z_T} = \frac{40 \angle 0}{28.1 \angle -18.26}$$

$$I_1 = 1.423 \angle 18.56^\circ [A]$$



Ⓛ

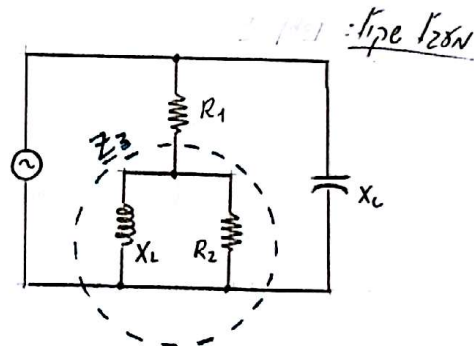
$$Z_3 = (R_2 \parallel X_L) = (20 \parallel j80)$$

$$Z_3 = (18.824 + j4.706) = 19.4 \angle 14.04^\circ$$

החלק הזה - זכור [KVL]

$$V_1 = U_{X_L} = E \cdot \frac{Z_3}{Z_3 + R_1} = 40 \angle 0 \cdot \frac{19.4 \angle 14.04}{19.4 \angle 14.04 + 10}$$

$$V_1 = 26.574 \angle 4.764^\circ [V]$$



Ⓜ

$$S = I^* \cdot E$$

$$S = 1.423 \angle -18.56 \cdot 40 \angle 0$$

$$S = (54.07 + j17.84) [VA]$$

$$P [W]$$

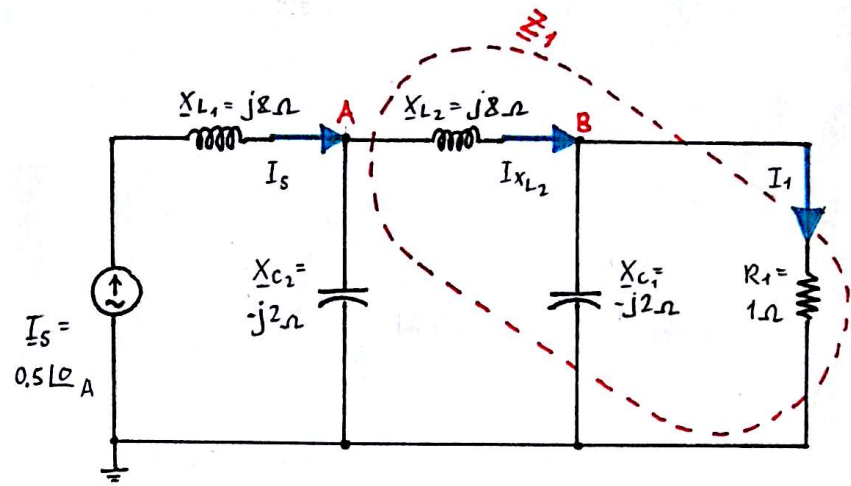
$$Q [VAR]$$

$$P = 54.07 [W]$$

Ⓨ

$$\underline{X}_{L1} = \underline{X}_{L2} = j8\Omega$$

$$\underline{X}_{C1} = \underline{X}_{C2} = (-j2)\Omega$$



$$\underline{Z}_1 = (R_1 \parallel \underline{X}_{C1}) + \underline{X}_{L2} = (1 \parallel -j2) + j8$$

$$\underline{Z}_1 = (0.8 + j7.6) = (7.642 \angle 84^\circ) [\Omega]$$

מחלקה $\underline{I}_{X_{L2}}$ - A נמצא $\underline{I}_{X_{L2}}$:

$$\underline{I}_{X_{L2}} = \underline{I}_s \cdot \frac{\underline{X}_{C1}}{\underline{X}_{C1} + \underline{Z}_1} = 0.5 \cdot \frac{-j2}{-j2 + (0.8 + j7.6)} = (-0.175 - j0.025)$$

$$\underline{I}_{X_{L2}} = (-0.176 \angle -171.869^\circ) [A]$$

מחלקה $\underline{I}_1$ - B נמצא $\underline{I}_1$:

$$\underline{I}_1 = \underline{I}_{X_{L2}} \cdot \frac{\underline{X}_{C2}}{\underline{X}_{C2} + R_1} = (-0.176 \angle -171.869^\circ) \cdot \frac{-j2}{-j2 + 1} = (-0.15 + j0.05)$$

$$\underline{I}_1 = (158.1 \angle 161.57^\circ) [mA]$$

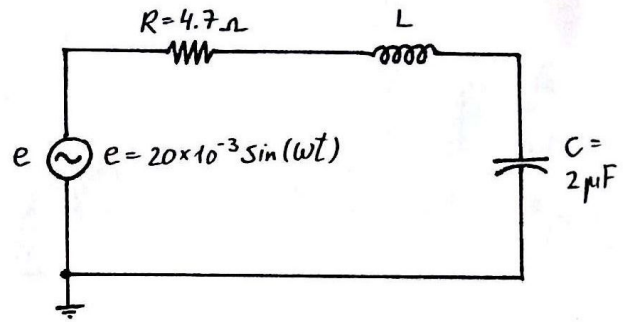
$$u(t) = 20 \times 10^{-3} \cdot \sin(\omega t + 0^\circ)$$

$$U_{\max} = U \cdot \sqrt{2}$$

$$U = \frac{U_{\max}}{\sqrt{2}} = \frac{20 \times 10^{-3}}{\sqrt{2}}$$

$$U = 14.142 \angle 0^\circ \text{ [V]}$$

AC - $\sqrt{f} \cdot R$ ג' 6



$$\textcircled{a} f_0 = 1800 \text{ Hz}$$

$$\omega_0 = 2\pi f = 2\pi \cdot 1800$$

$$\omega_0 = 3600\pi = 11.3 \times 10^3 \text{ [rad/sec]}$$

$$\omega_0 = \sqrt{\frac{1}{LC}}$$

$$3600\pi = \sqrt{\frac{1}{L \cdot 2 \times 10^{-6}}}$$

$$L = 3.91 \text{ mH}$$

$$\textcircled{b} X_C = -j \frac{1}{\omega C} = -j \frac{1}{(3600\pi) \cdot 2 \times 10^{-6}}$$

$$X_C = (-j44.21) \Omega$$

מכיוון שהמעגל בתדודה אחידה, מתקבל:

$$[X_L = X_C] \Rightarrow X_L = (+j44.21) \Omega$$

מכיוון שהמעגל בתדודה אחידה, מתקבל:

$$Z_T = R = 4.7 \Omega$$

$$I = \frac{U}{Z_T} = \frac{14.142 \angle 0^\circ}{4.7}$$

$$I = 3 \angle 0^\circ \text{ [mA]}$$

$$\textcircled{c} S_T = I^* \cdot U = 3 \times 10^{-3} \angle 0^\circ \cdot 14.142 \angle 0^\circ$$

$$S_T = (42.55 \times 10^{-6} + j0) \text{ VA}$$

$$P \text{ [W]}$$

$$Q \text{ [VAR]}$$

$$P = 42.55 \text{ [mW]}$$

$$\textcircled{d} S_T = (42.55 \times 10^{-6} + j0) \text{ המכונה P הקצו}$$

$$S_T = 42.55 \angle 0^\circ \text{ [mVA]}$$

$$\textcircled{e} [\varphi = 0^\circ] \Rightarrow \cos \varphi = \cos 0 = 1$$

$$\textcircled{f} Q_0 = \frac{\omega_0 L}{R} = \frac{(3600\pi) \cdot 3.91 \times 10^{-3}}{4.7}$$

$$Q_0 = 9.406$$

$$BW = \frac{R}{2\pi L} = \frac{4.7}{2\pi \cdot 3.91 \times 10^{-3}}$$

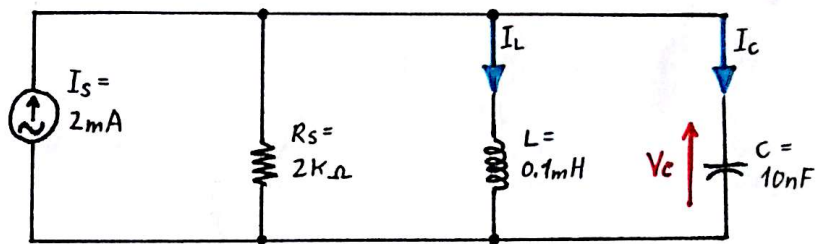
$$BW = 191.36 \text{ [Hz]}$$

$$\textcircled{g} \omega_{1,2} = \pm \left(\frac{R}{2L} \right) + \sqrt{\left(\frac{R}{2L} \right)^2 + \omega_0^2} \quad * \text{ ערך הנמוך הוא 25 במוסאין מ"ר}$$

$$= \pm \left(\frac{4.7}{2 \cdot 3.91 \times 10^{-3}} \right) + \sqrt{\left(\frac{4.7}{2 \cdot 3.91 \times 10^{-3}} \right)^2 + (3600\pi)^2}$$

$$\omega_1 = 10742 \text{ [rad/sec]}$$

$$\omega_2 = 11927 \text{ [rad/sec]}$$



1

$$\omega_0 = \sqrt{\frac{1}{LC}} = \sqrt{\frac{1}{0.1 \times 10^{-3} \cdot 10 \times 10^{-9}}}$$

$$\omega_0 = 1000 \times 10^3 \left[\frac{\text{rad}}{\text{sec}} \right]$$

$$f_0 = \frac{\omega_0}{2\pi} = \frac{1000 \times 10^3}{2\pi}$$

$$f_0 = 159 \text{ [kHz]}$$

2

המתקן: תהודה מתקין

$$\underline{Z}_T = R_s = 2k\Omega$$

$$V_c = I_s \cdot \underline{Z}_T = 2 \times 10^{-3} \cdot 20 \times 10^3$$

$$V_c = 4V$$

3

$$Q_0 = \omega_0 RC = 1000 \times 10^3 \cdot 2000 \cdot 10 \times 10^{-9}$$

$$Q_0 = 20$$

4

$$U_c = U_L = V_c = 4V$$

$$X_L = \omega L = 1000 \times 10^3 \cdot 0.1 \times 10^{-3} = 100\Omega$$

$$\downarrow$$

$$X_L = X_C$$

$$X_L = (+j100)\Omega$$

$$I_L = \frac{U_L}{X_L} = \frac{4 \angle 0}{j100}$$

$$I_L = 40 \angle -90^\circ \text{ mA}$$

$$I_L = -40 \text{ [mA]}$$

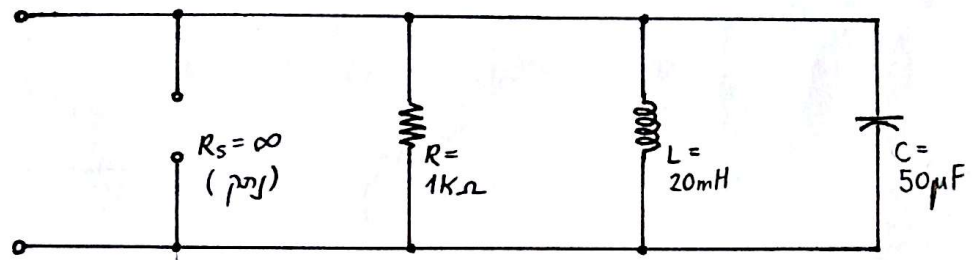
$$X_C = (-j100)\Omega$$

$$I_C = \frac{U_C}{X_C} = \frac{4 \angle 0}{-j100}$$

$$I_C = 40 \angle 90^\circ \text{ mA}$$

$$I_C = 40 \text{ [mA]}$$

7



א) $\omega_0 = \sqrt{\frac{1}{LC}} = \sqrt{\frac{1}{20 \times 10^{-3} \cdot 50 \times 10^{-6}}}$

$\omega_0 = 1000 \left[\frac{\text{rad}}{\text{sec}} \right]$

ב) $Q_0 = \omega_0 RC$

$Q_0 = 1000 \cdot 1000 \cdot 50 \times 10^{-6}$

$Q_0 = 50$

ג) $BW = \frac{1}{2\pi RC} = \frac{1}{2\pi \cdot 1000 \cdot 50 \times 10^{-6}}$

$BW = 3.183 \left[\text{Hz} \right]$

ד)

כל הערכים אשר בנוסחה לחישוב מוכיח "R" - ישתנו!



$\omega_0 = \sqrt{\frac{1}{LC}}$ - המהירות הזוויתית תשאר כפי שניתן.

הערכים שכן ישתנו:

מכיוון שחיבור נעזרים במקביל, מקטין את ערך ההתנגדות הכוללת (R_T) במעגל:

$R_T < R$

$R_T = (R_s \parallel R)$

$R_T < 1000 \Omega$

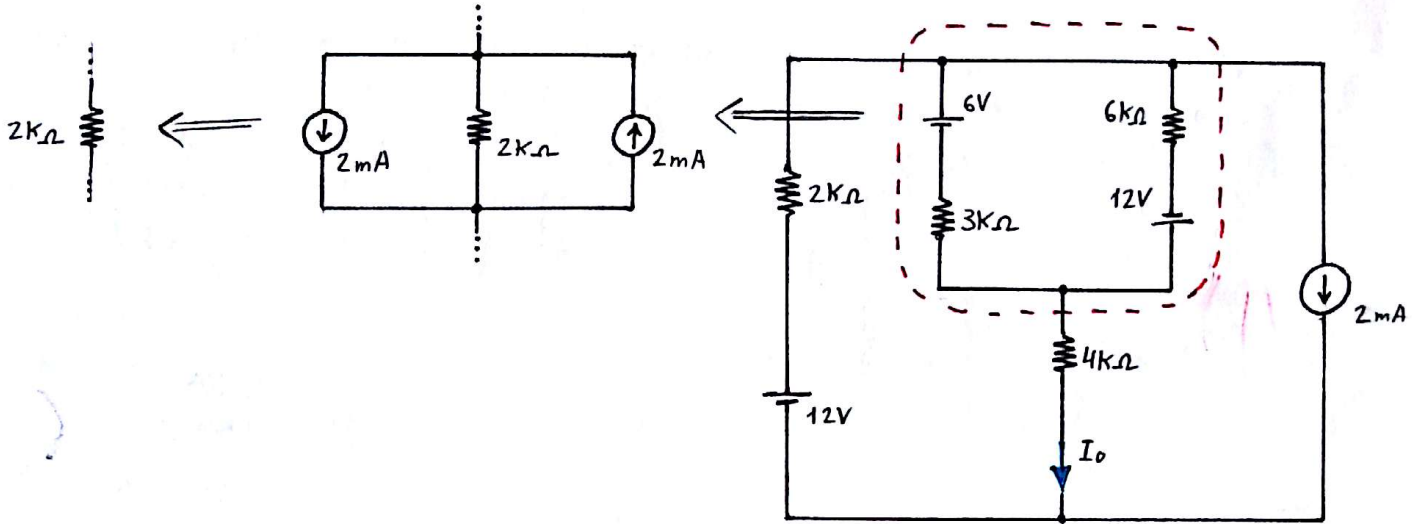


מתקבל ש:

$Q_0 = \omega_0 R_T C$ - זורם הסיב (Q_0) - יקטן!
(יחס מתמטי יש בין Q_0 ל- R_T)

$BW = \frac{1}{2\pi R_T C}$ - רוחב הפס (BW) - יגדל!
(R_T במכנה - יחס מתמטי הפוך ל-BW)

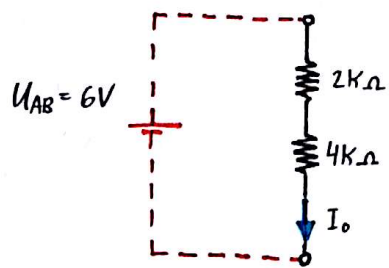
שאלת תשובה DC - עכ"ל 1:



נמצא את U_{AB} :

$$U_{AB} = \frac{\sum I_{sc}}{\sum G} = \frac{\frac{12}{2000} - 2 \times 10^{-3}}{2000^{-1} + 6000^{-1}} =$$

$$U_{AB} = 6V$$

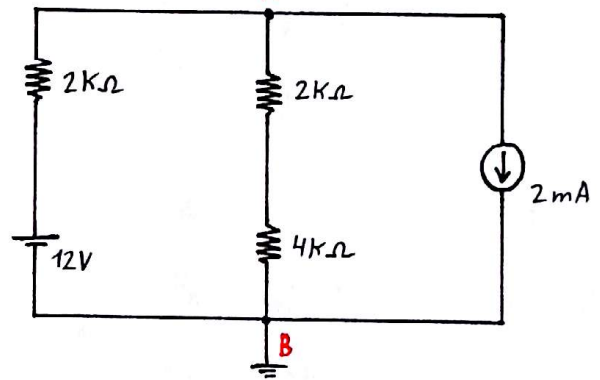


$$I_o = \frac{U_{AB}}{(2000 + 4000)}$$

$$I_o = \frac{6}{6000}$$

$$I_o = 1mA$$

נמצא את I_o :



(K)

מציאת הפתרונות - בשיטת טרם חוקים:

$$\begin{pmatrix} R_{11} & R_{12} & R_{13} \\ R_{21} & R_{22} & R_{23} \\ R_{31} & R_{32} & R_{33} \end{pmatrix} \begin{pmatrix} I_1' \\ I_2' \\ I_3' \end{pmatrix} = \begin{pmatrix} E_1' \\ E_2' \\ E_3' \end{pmatrix}$$

חוקי ההתנגדויות בחוקים:

$$R_{11} = 15 + 20 + 20 + 35$$

$$R_{11} = 90 \Omega$$

$$R_{12} = R_{21} = 20 \Omega$$

$$R_{13} = R_{31} = 20 \Omega$$

$$R_{22} = 30 + 50 + 20$$

$$R_{22} = 100 \Omega$$

$$R_{23} = R_{32} = 50 \Omega$$

$$R_{33} = 45 + 20 + 50$$

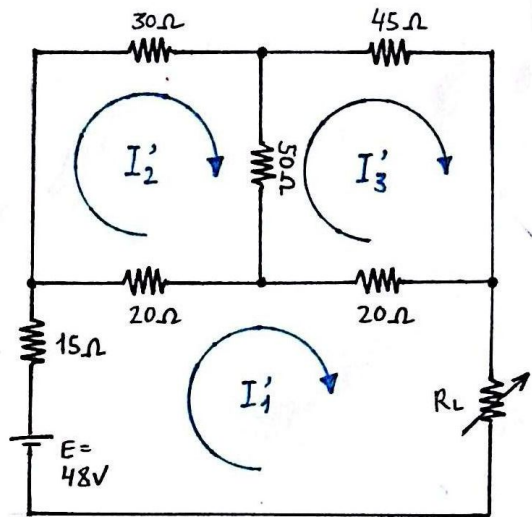
$$R_{33} = 115 \Omega$$

חוקי ה"מתחים":

$$E_1 = 48V$$

$$E_2 = 0$$

$$E_3 = 0$$



הצבת החוקים במערכת:

$$\begin{pmatrix} 90 & -20 & -20 \\ -20 & 100 & -50 \\ -20 & -50 & 115 \end{pmatrix} \begin{pmatrix} I_1' \\ I_2' \\ I_3' \end{pmatrix} = \begin{pmatrix} 48 \\ 0 \\ 0 \end{pmatrix}$$

$$I_1' = \frac{12}{19} = 0.634 [A]$$

$$I_2' = \dots$$

$$I_3' = \dots$$

$$I_{RL} = I_1' = \frac{12}{19} = 0.634 [A]$$

$$P_{RL} = I_{RL}^2 \cdot R_L = \left(\frac{12}{19}\right)^2 \cdot 35 = \frac{5040}{361}$$

$$P_{RL} = 13.961 [W]$$

(D)

חינוכי מעגל קוצים:

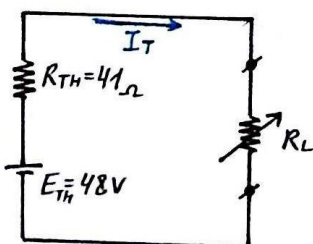
$$R_T = \frac{E}{I_1'} = \frac{48}{\left(\frac{12}{19}\right)} = 76 \Omega$$

$$R_{TH} = R_T - R_L = 76 - 35$$

$$R_{TH} = 41 \Omega$$

$$E_{TH} = E$$

$$E_{TH} = 48V$$



* הכידי למצוא את הזרם המקסימלי של כל שאר הנקודות, כחל - R_L המשתנה ניתן להצטרף בחישוב הזרם הכללי מהמעגל הקוצים ($I_T = I_1'$) ולקבוע ממצב שקול תבנית 'ביחס' - R_L .

לפיכך הספק מקסי:

$$R_L = R_{TH} = 41 \Omega$$

$$I_T = \frac{E_{TH}}{R_{TH} + R_L} = \frac{48}{41 + 41}$$

$$I_T = 0.585 [A]$$

$$P_{RL} = I_T^2 \cdot R_L = 0.585^2 \cdot 41$$

$$P_{RL} = 14.05 [W]$$

(E)

$$W = P_E \cdot t$$

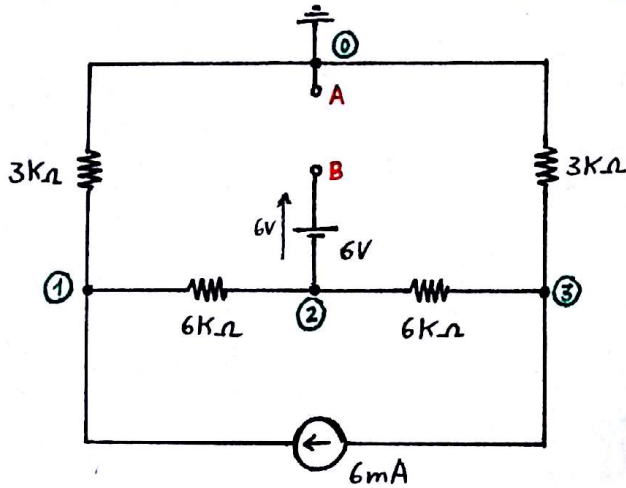
$$W = (I_T \cdot E_{TH}) \cdot t$$

$$W = (0.585 \cdot 48) \cdot 2 = \frac{2304}{41}$$

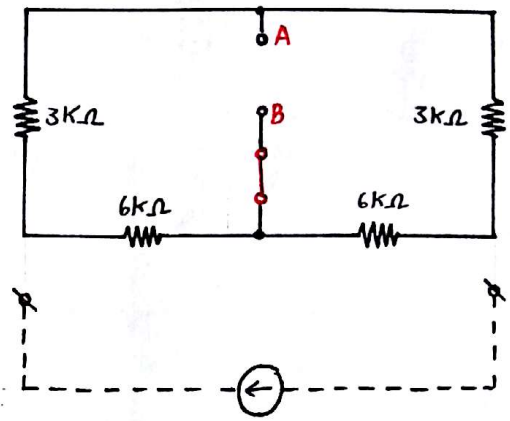
$$W = 56.2 [Wh]$$

שאלת חסרה - DC - שאלה מספר 3:

חישוב E_{TH}



חישוב R_{TH}



$$R_{TH} = (3+6) \parallel (3+6)$$

$$R_{TH} = 4.5 k\Omega$$

מערכת הנתונה - בשל "מתח" צמתים:

אם צמת "0" מ"מ:

$$\begin{pmatrix} +G_{11} & -G_{12} & -G_{13} \\ -G_{21} & +G_{22} & -G_{23} \\ -G_{31} & -G_{32} & +G_{33} \end{pmatrix} \begin{pmatrix} V_1 \\ V_2 \\ V_3 \end{pmatrix} = \begin{pmatrix} I_{SC1} \\ I_{SC2} \\ I_{SC3} \end{pmatrix}$$

חישוב המוליכויות:

חישוב זרמי הקצרי:

$$G_{11} = 3^{-1} + 6^{-1} = 0.5 kS$$

$$I_{SC1} = 6 mA$$

$$G_{12} = G_{21} = 1/6 kS$$

$$I_{SC2} = 0$$

$$G_{13} = G_{31} = 0$$

$$I_{SC3} = (-6) mA$$

$$G_{22} = 6^{-1} + 6^{-1} = 1/3 kS$$

$$G_{23} = G_{32} = 1/6 kS$$

$$G_{33} = 3^{-1} + 6^{-1} = 0.5 kS$$

הצבת המוליכים במערכת:

$$\begin{pmatrix} 0.5 & -1/6 & 0 \\ -1/6 & 1/3 & -1/6 \\ 0 & -1/6 & 0.5 \end{pmatrix} \begin{pmatrix} V_1 \\ V_2 \\ V_3 \end{pmatrix} = \begin{pmatrix} 6 \\ 0 \\ -6 \end{pmatrix} \rightarrow \begin{matrix} V_1 = \dots \\ V_2 = 0 \\ V_3 = \dots \end{matrix}$$

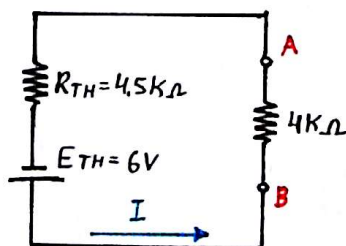
$$V_A = 0$$

$$V_B = V_2 + 6$$

$$V_B = 0 + 6$$

$$V_B = 6V$$

$$U_{AB} = 6V$$



חישוב מתח - ע"פ [KVL]

$$U(4k) = E_{TH} \frac{4}{4+4.5} = 6 \frac{4}{8.5} = \frac{48}{17}$$

$$U(4k) = 2.823 [V]$$

$$V_o = U(4k)$$