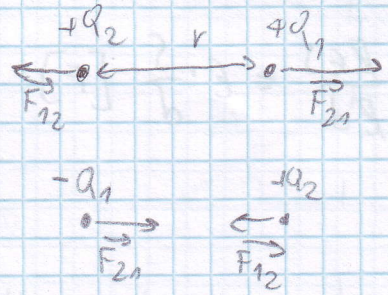
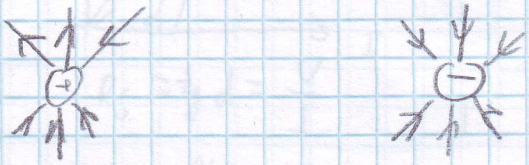
1.

$$F = \frac{Q_1 Q_2}{4\pi\varepsilon_0 r^2}$$



2.

$$\vec{E} = \frac{\vec{F}}{q} = \frac{\frac{Q \cdot q}{4\pi\varepsilon_0 r^2}}{q} = \frac{Q}{4\pi\varepsilon_0 r^2}$$



$$\vec{E} = \lim_{q \to 0} \frac{\vec{F}}{q}$$

3.

$$\varphi = \frac{W_{p1}}{Q}$$

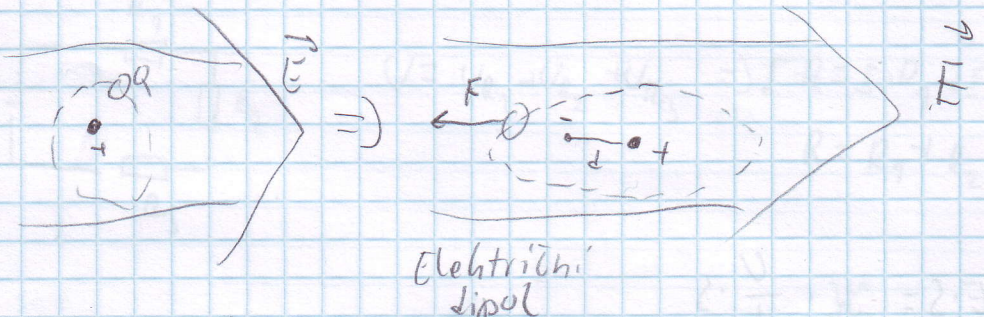
$$W_{p1} = p \cdot q$$

$$U_{AB} = \varphi_A - \varphi_B = \frac{W_{p1}}{Q_A} - \frac{W_{p1}}{Q_B} = \frac{F \cdot s_1}{Q_A} - \frac{F \cdot s_2}{Q_B} = \frac{Q E_A s_1}{Q_A} - \frac{Q E_B s_2}{Q_B}$$

$$= E_A s_1 - E s_2$$

$$= E(s_1 - s_2) = E d$$

4.



$$\varphi = \frac{Q}{V} = \frac{As}{m^3}$$

$$\varepsilon = \varepsilon_0 \varepsilon_r$$

5.

$$C = \frac{Q}{U} = \frac{\sigma S}{U} = \frac{\sigma S}{Ed} = \frac{E\varepsilon S}{Ed} = \varepsilon \cdot \frac{S}{d} \; [F]$$

$$\sigma = \frac{q}{S}$$

$$E = \frac{\sigma}{\varepsilon\varepsilon} \Rightarrow \sigma = E \cdot \varepsilon$$

$$W_c = F \cdot s = E \cdot q \cdot s = \frac{\sigma}{2\varepsilon} \cdot q \cdot s = \frac{\frac{q}{S}}{2\varepsilon} \cdot q \cdot s = \frac{Q^2 S}{2\varepsilon S} = \frac{q^2}{2\varepsilon \frac{S}{S}} = \frac{q^2}{2C} = \frac{U^2 C}{2} = \frac{qU}{2}$$

6.

7.

$$\Delta Q = N q \cdot S \cdot v \cdot \Delta t$$

$$I = \frac{\Delta Q}{\Delta t} = \frac{N q S v \Delta t}{\Delta t} = N q S v = [A]$$

$$i(t) = \frac{dq}{dt} \Rightarrow dQ = i(t) \cdot dt \Rightarrow Q = \int_0^t i(t)\, dt$$

$$J = \frac{\Delta I}{\Delta S}$$

8.

$$\gamma = \frac{J}{E}$$

$$I = J \cdot S = \gamma \cdot E \cdot S = \gamma \cdot \frac{U}{d} \cdot S$$

$$G = \frac{I}{U_{AB}} = \gamma \cdot \frac{S}{d}$$

$$R = \frac{1}{G} = \frac{1}{\gamma} \cdot \frac{d}{S} = \rho \cdot \frac{d}{S} \Leftarrow 9.$$

(10)

$R = R_{20}(1 + \alpha(T - 20))$

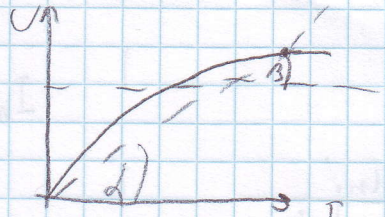
$R = R_{20} + R_{20}\alpha(T - 20)$

(11)

Linearni

$R = U/I$

Nelinearni



$R_S = \operatorname{tg}\alpha = \frac{U}{I}$

$R_d = \frac{\Delta U}{\Delta I} = \operatorname{tg}\beta$

(12)

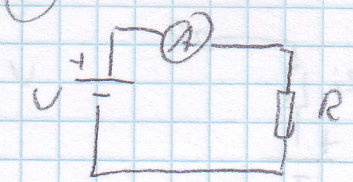
Joulejeva toplina

$\Delta W = \Delta q(\varphi_1 - \varphi_2) = F \cdot s = EAR \cdot s = \frac{U}{s} \cdot \Delta Q \cdot s = U \cdot \Delta q = U \cdot I \cdot \Delta t = I^2 \cdot R \cdot \Delta t$

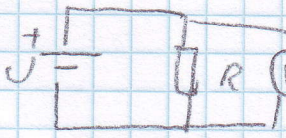
$\Delta q = I \cdot \Delta t$

$P = \frac{\Delta W}{\Delta t} = \frac{U \cdot I \cdot \Delta t}{\Delta t} = U \cdot I = I^2 \cdot R$

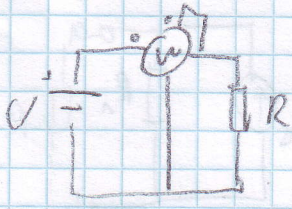
(13)



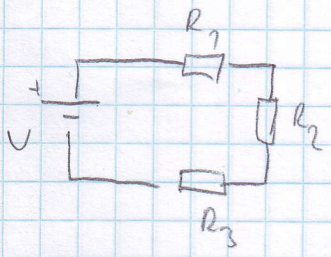
$R_A = 0$



$R_V = \infty$



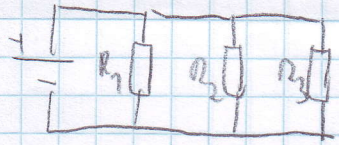
(14)



$U = U_{R_1} + U_{R_2} + U_{R_3} \Rightarrow I \cdot R = I \cdot R_1 + I \cdot R_2 + I \cdot R_3$

$R = R_1 + R_2 + R_3$

(15)



$R_1 = R_2 = R_3$

$U = U_{R_1} = U_{R_2} = U_{R_3}$

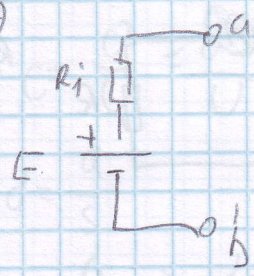
$I \cdot R = I_1 \cdot R_1 = I_2 \cdot R_2 = I_3 \cdot R_3$

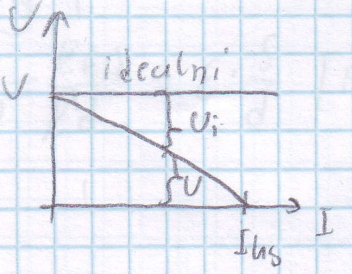
$I = I_1 + I_2 + I_3$

$\frac{U}{R} = \frac{U}{R_1} + \frac{U}{R_2} + \frac{U}{R_3}$

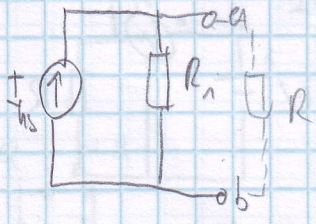
$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$

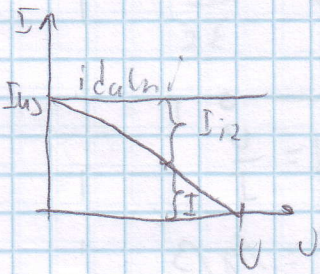
16)





17)

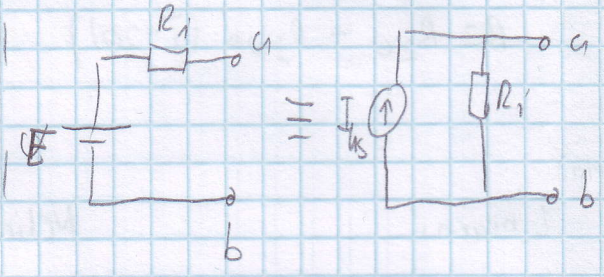




$R_i \gg R$

$R_i = \infty$ ... idealni

18)



$$I_{ks} = \frac{E}{R_i} \Rightarrow E = I_{ks} \cdot R_i$$

20)

$$I = \frac{E}{(R_i + R_T)} \qquad E = I \cdot R_T$$

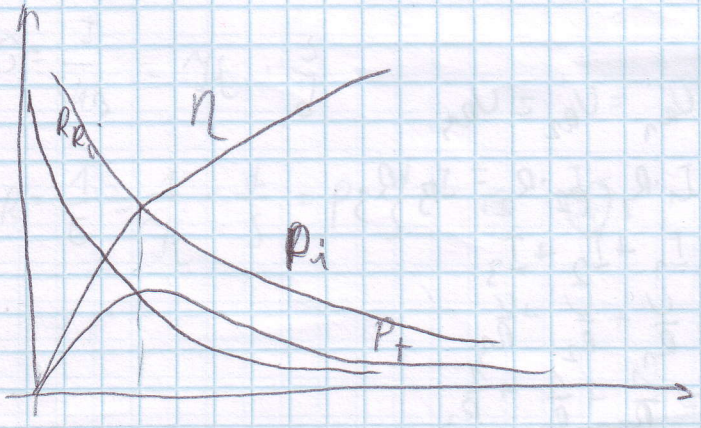
$$P = E \cdot I = E \cdot \left(\frac{E}{(R_i+R_T)}\right)^2 \cdot R_T = \frac{E^2}{(R_i+R_T)^2} \cdot R_T \Big/ \frac{d}{dR_T}$$

$$\frac{dP}{dR_T} = \frac{E^2 (R_i+R_T)^2 - E^2 \cdot 2(R_i+R_T)}{(R_i+R_T)^4} \cdot R_T = 0$$

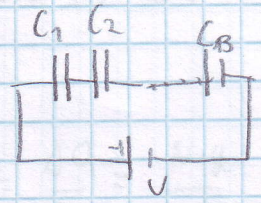
$$(R_i + R_T) - 2R_T = 0$$

$$R_i + R_T = 2R_T$$

$$R_i = R_T$$



22.



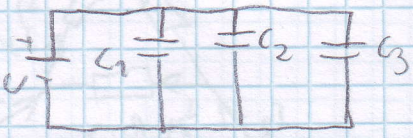
$U = U_1 + U_2 + U_3$

$U = \frac{Q_1}{C_1} + \frac{Q_2}{C_2} + \frac{Q_3}{C_3}$

$\frac{Q}{C} = \frac{Q_1}{C_1} + \frac{Q_2}{C_2} + \frac{Q_3}{C_3}$

$Q = Q_1 = Q_2 = Q_3$

$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$

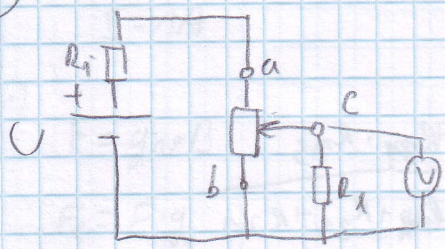


$Q = Q_1 = Q_2 + Q_3$

$UC = UC_1 + UC_2 + UC_3$

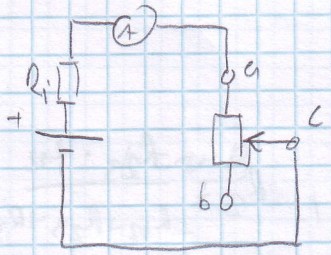
$C = C_1 + C_2 + C_3$

23.



Potenciometarski

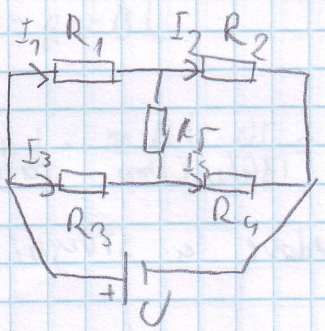
djelitelj napona



Reostatski

djelitelj struje

24.



$I_1 = I_2$

$I_3 = I_4$

$I_1 \cdot R_1 = I_3 \cdot R_3$

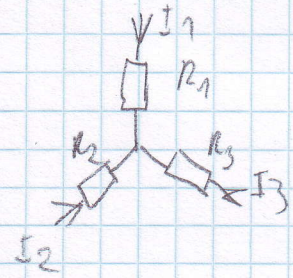
$I_2 \cdot R_2 = I_4 \cdot R_4$

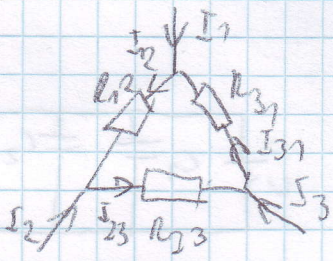
$\frac{I_1}{I_3} = \frac{R_3}{R_1}$ $\quad$ $\frac{I_2}{I_4} = \frac{R_4}{R_2}$

$\frac{R_3}{R_1} = \frac{R_4}{R_2} \Rightarrow R_3 R_2 = R_1 R_4$

$R_3 R_2 - R_1 R_4 = 0$

(26)





$\Delta \rightarrow \curlyvee$

$U_{12} = I_{12} \cdot R_{12} = I_1 \cdot R_1 - I_2 \cdot R_2$

$U_{23} = I_{23} \cdot R_{23} = I_2 \cdot R_2 - I_3 \cdot R_3$

$U_{31} = I_{31} \cdot R_{31} = I_3 \cdot R_3 - I_1 \cdot R_1$

$I_{12} \cdot R_{12} + I_{23} \cdot R_{23} + I_{31} \cdot R_{31} = 0$

$I_1 + I_2 + I_3 = 0$

$I_1 = I_{12} - I_{31}$

$I_2 = I_{23} - I_{12}$

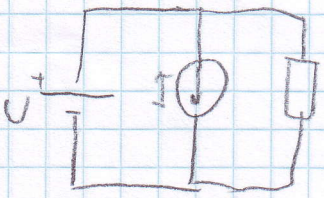
$I_3 = I_{31} - I_{23}$

$$R_1 = \frac{R_{12} \cdot R_{31}}{R_{12} + R_{23} + R_{31}} \quad , \quad R_2 = \frac{R_{23} \cdot R_{12}}{R_{12} + R_{23} + R_{31}} \quad , \quad R_3 = \frac{R_{31} \cdot R_{23}}{R_{12} + R_{23} + R_{31}}$$

$\curlyvee \rightarrow \Delta$

$$R_{12} = R_1 + R_2 + \frac{R_1 \cdot R_2}{R_3} \quad , \quad R_{23} = R_2 + R_3 + \frac{R_2 \cdot R_3}{R_1} \quad , \quad R_{31} = R_3 + R_1 + \frac{R_3 R_1}{R_2}$$

(27)



1) Naponski izvor kada isključimo samo kratko spojimo vodove, a strujni samo otpojimo

2) Na kraju zbrojimo struje s tim da moramo paziti na smjer.

(28) $\vec{F} = q(\vec{v} \cdot \vec{B}) = qvB \cdot \sin\alpha$

(29)

(30) $I = \frac{\Delta q}{\Delta t} = \frac{N \cdot q}{\Delta t}$

$\vec{F} = Nq(\vec{v} \times \vec{B}) = \frac{Nq\,lB}{\Delta t} = IlB \cdot \sin\alpha$ ($l = \Delta t$)

$\rightarrow F_{12} = B_{12} \cdot I_2 \cdot l = \mu \cdot \frac{I_1}{2r\pi} \cdot I_2 \cdot l$

$\mu = 4\pi \cdot 10^{-7}$

$r = l = 1m$

$F = 2 \cdot 10^{-7}$

$I = 1A$

(31) $F = qvB$ $\quad F = Fe$ $\quad E = vB$

$Fe = E \cdot q$ $\quad qvB = Eq$

(32)

$E = v \cdot B$

$\mathcal{E} = qvBl$

$U_{ind} = vBl \cdot \frac{\Delta t}{\Delta t} = \frac{SB\Delta S}{\Delta t} = \frac{B \cdot \Delta S}{\Delta t} = \frac{\Delta\Phi}{\Delta t}$

(33)

$U = 2vBl = 2vBl \sin\omega t$

$v = r\omega = \frac{a}{2}\omega$; $\omega t = \omega t \Rightarrow U_{ind} = Bla\omega \sin\omega t$

(34)

$$\psi = N\Phi = N \cdot BS = N\mu \frac{Ni}{l} \cdot S$$

$$e_i = -\frac{d\psi}{dt}$$

$$L = \frac{\psi}{i} = \frac{N\mu \frac{Ni}{l} \cdot S}{i} = N^2 \mu_0 \cdot \frac{S}{l} = \frac{N^2}{\frac{1}{\mu_0} \cdot \frac{l}{S}}$$

$$dW = p(t)\,dt$$

$$= u(t) \cdot i(t) \cdot dt$$

$$dW = i(t) \cdot L \frac{di}{dt} \cdot dt$$

$$= i(t) \cdot L \cdot di$$

$$W = \int_0^I i\, L\, di = L\frac{I^2}{2}$$

(35)

$$M_{12} = \frac{\psi_{12}}{i_1} = \frac{N_2 \cdot \mu_0 \frac{N_1 i_1}{l} \cdot S}{i_1} = \frac{N_1 N_2}{\frac{1}{\mu_0} \cdot \frac{l}{S}}$$

$$M_{12}^2 = L_1 \cdot L_2 \qquad L_1 = \frac{N_1^2}{\frac{1}{\mu_0} \cdot \frac{l}{S}} \qquad L_2 = \frac{N_2^2}{\frac{1}{\mu_0} \cdot \frac{l}{S}}$$

$$M_{12} = \sqrt{L_1 L_2}$$

(38)

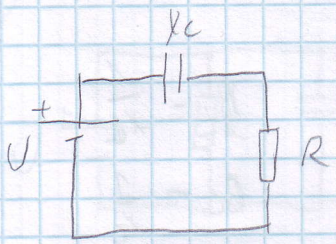
$$Z = \frac{u_m \cdot e^{j\omega t}}{I_m \cdot e^{j\omega t}} = \frac{\frac{u_m}{\sqrt{2}} \cdot e^{j du}}{\frac{I_m}{\sqrt{2}} \cdot e^{j di}} = \frac{U}{I} \cdot e^{j(du - di)}$$

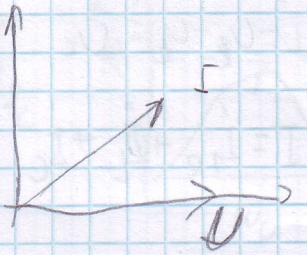
$$\varphi = du - di$$

$$Y = \frac{I_m \cdot e^{j\omega t}}{u_m \cdot e^{j\omega t}} = \frac{I_m \cdot e^{j di}}{\frac{u_m}{\sqrt{2}} \cdot e^{j du}} = \frac{I}{U} \cdot e^{j(di - du)}$$

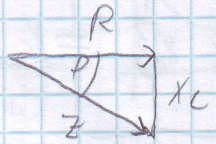
$$\psi = di - du$$

39.



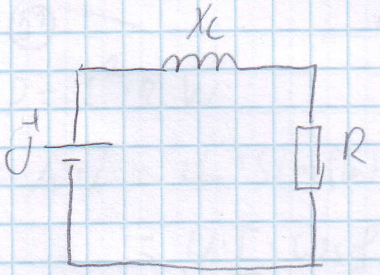


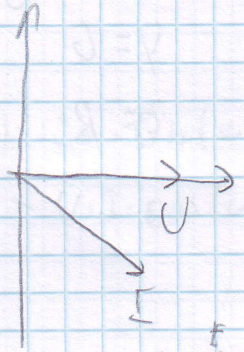
$\underline{Z} = R - jX_C$

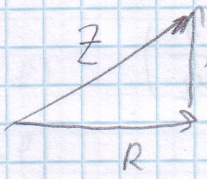


$\varphi < 0$

40.





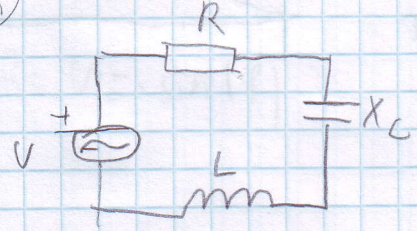


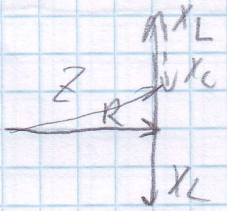
$\varphi > 0 \quad \underline{Z} = R + jX_L$

$u_L = L\frac{di}{dt} \qquad di = \frac{1}{L} u_L\, dt$

$i = \frac{1}{L}\int_0^t U_m \sin\omega t\, dt \qquad i = \frac{1}{\omega L}\int_0^t U_m \sin\omega t\, d(\omega t) = \frac{U_m}{\omega L} \cdot -\cos\omega t \to X_L$

41.





$\underline{Z} = R + j(X_L - X_C)$

$\varphi = \operatorname{arctg}\frac{X_L - X_C}{R}$

$X_L > X_C \qquad X_C > X_L$

$\varphi > 0 \qquad \varphi < 0$

Rezonancija

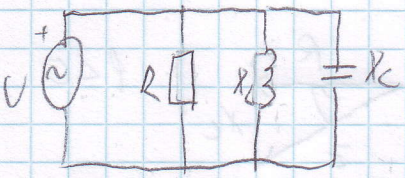
$X_L = X_C$

$\underline{Z} = R + j\overbrace{(X_L - X_C)}^{0}$

$\underline{Z} = R$

$\varphi = 0$

42.



$\dot{U} = \dot{U}_R = \dot{U}_L = \dot{U}_C$

$\dot{I} = \dot{I}_R + \dot{I}_L + \dot{I}_C$

$B_L = \frac{1}{X_L}$

$B_C = \frac{1}{X_C}$

$Y = G + jB_L + jB_C$

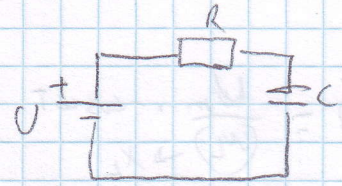
$Y = G + j\left(\omega C - \frac{1}{\omega L}\right)$

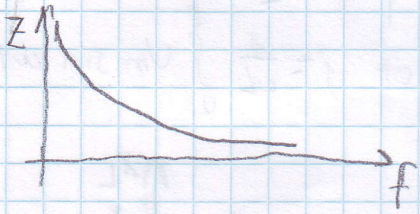
rezonancija

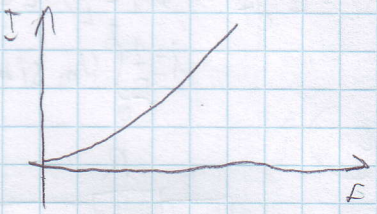
$Y = G$

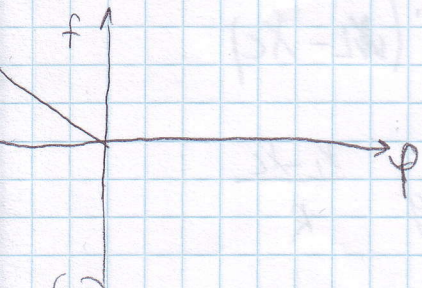
$z = R$

43.

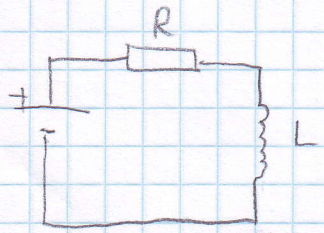


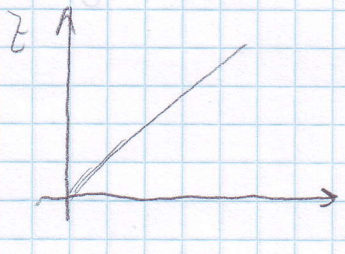


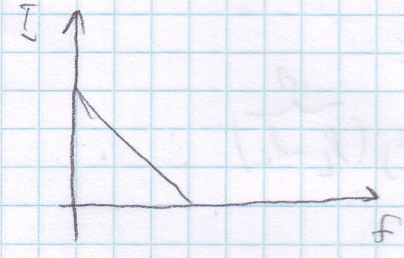




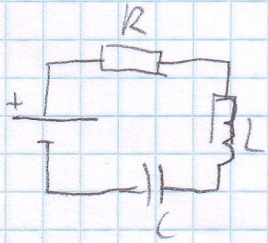
46.

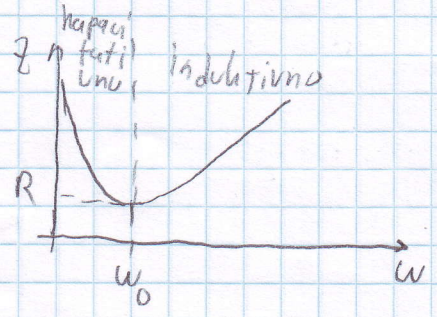


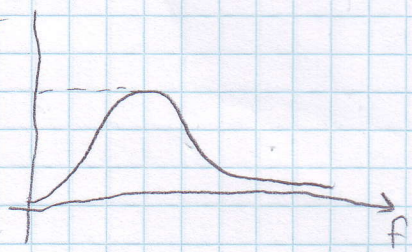




47.

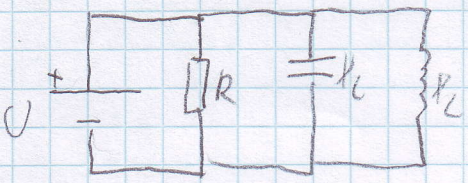


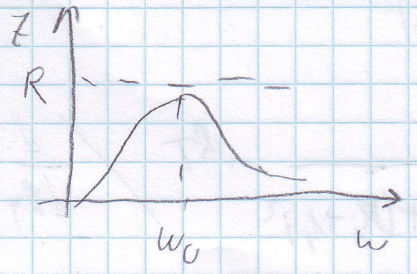


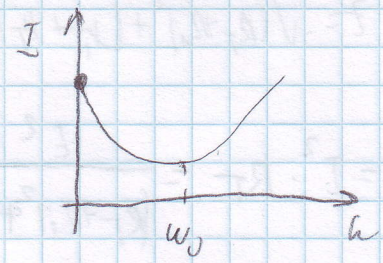


$\omega_0 \Rightarrow$ rezonancija

(48)







(50) (51)

$P = I^2 \cdot R \; W$

$p = u \cdot i = U_m \cdot \sin(\omega t) \cdot I_m \cdot \sin(\omega t - \varphi)$

$= \underbrace{U \cdot I \cdot \cos\varphi}_{P} - U \cdot I \cdot \cos(\omega t - \varphi)$

$Q = I^2 \cdot X_L - I^2 \cdot X_L \; VA$

(52) $Q = U \cdot I \cdot \sin(\varphi)$

(53)

$P = I^2 \cdot Re\{Z\}$ $\quad P = U \cdot I \cdot \cos\varphi$

$Q = I^2 \cdot Im\{Z\}$ $\quad Q = U \cdot I \cdot \sin\varphi$

(54)

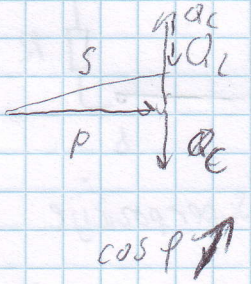
$\dot{U} = a + jb = \sqrt{a^2+b^2} \cdot e^{j\alpha_u}$

$\dot{I} = c + jd = \sqrt{c^2+d^2} \cdot e^{j\alpha_i}$

$\dot{I}^* = c - jd = \sqrt{c^2+d^2} \cdot e^{-j\alpha_i}$

$\dot{U}\dot{I}^* = U \cdot I \cdot e^{j(\alpha_u - \alpha_i)} = U \cdot I \cdot e^{j\varphi} = U \cdot I \; \underset{P}{\cdot}$

$U \cdot I \cdot e^{j\varphi} = \underbrace{U \cdot I \cdot \cos\varphi}_{P} + U \cdot I \cdot \sin\varphi$



55.

$$Z = \sqrt{(R_T + R_i)^2 + (X_i + X_T)^2}$$

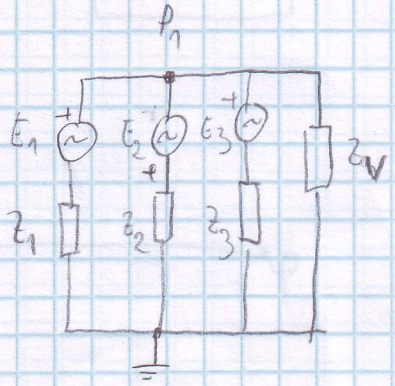
$$P = I^2 \cdot R_T = \frac{E^2}{(R_T + R_i)^2 + (X_i + X_T)^2} \cdot R_T \quad / \frac{d}{dR_T}$$

$$\frac{dP}{dR_T} = \frac{E^2\left[(R_T + R_i)^2 + (X_i + X_T)^2\right] - E^2 \cdot 2(R_T + R_i)}{\left[(R_T + R_i)^2 + (X_i + X_T)^2\right]^2} \cdot R_T$$

1) $X_i = -X_T$

2) $R_i = R_T$

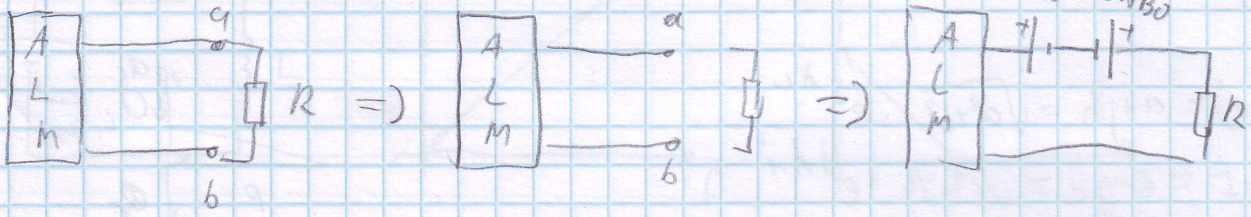
58.



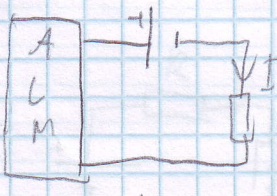
$$P_1(Y_1 + Y_2 + Y_3) = E_1 Y_1 - E_2 Y_2 + E_3 Y_3$$

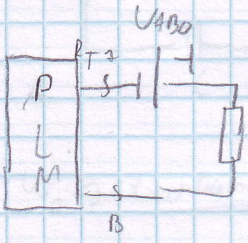
$$P_1 = \frac{E_1 Y_1 - E_2 Y_2 + E_3 Y_3}{Y_1 + Y_2 + Y_3 + Y_V} = \frac{\sum_{i=1}^{n} E_i \cdot Y_i}{\sum_{i=1}^{n} Y_i + Y_V}$$

59.

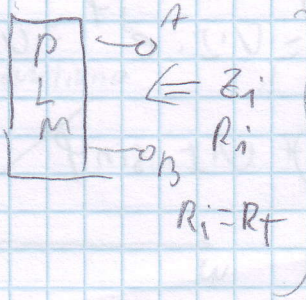


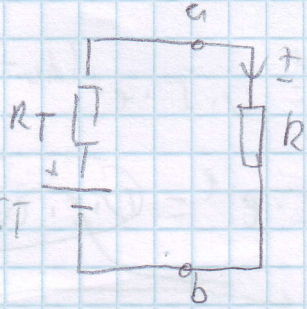
Metoda superpozicije



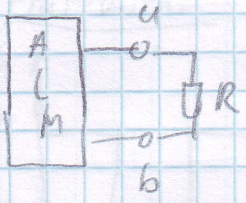


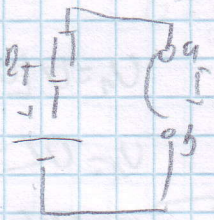
$$I' = \frac{U_{ABO}}{R_T + R}$$





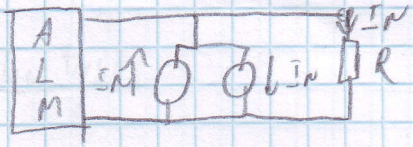
60.



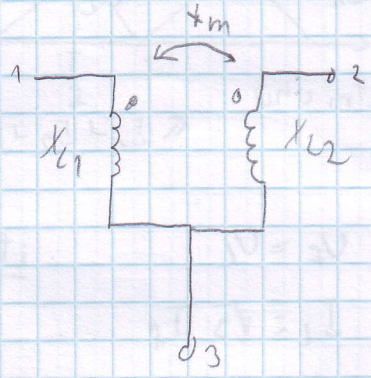


$$I_N = \frac{E_T}{R_T} \qquad R_N = R_T$$

Dobro 2



61.



$$\dot{U}_{13} = \dot{I}_1 \cdot x_{L_1} + \dot{I}_2 \cdot x_m$$

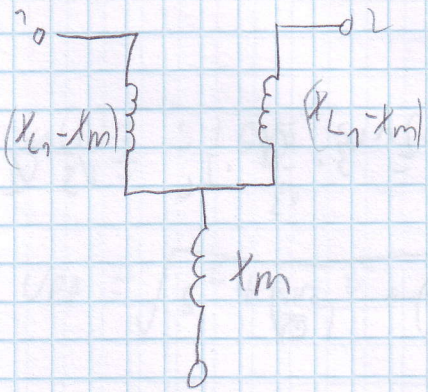
$$\dot{U}_{23} = \dot{I}_2 \cdot x_{L_2} + \dot{I}_1 \cdot x_m$$

$$\dot{U}_{13} = \dot{I}_1 \cdot x_{L_1} + (\dot{I}_3 - \dot{I}_1) x_m$$

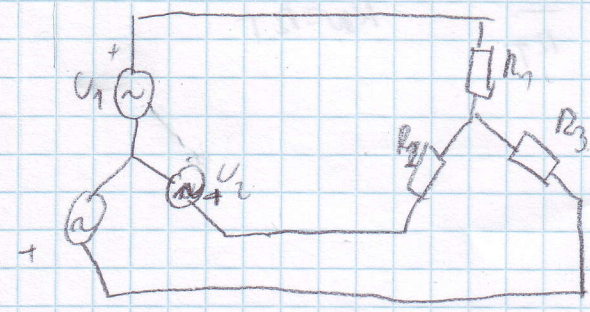
$$\dot{U}_{23} = \dot{I}_2 \cdot x_{L_2} + (\dot{I}_3 - \dot{I}_2) x_m$$

$$\dot{U}_{13} = \dot{I}_1 (x_{L_1} - x_m) + \dot{I}_3 \cdot x_m$$

$$\dot{U}_{23} = \dot{I}_2 (x_{L_2} - x_m) + \dot{I}_3 \cdot x_m$$



(63.)



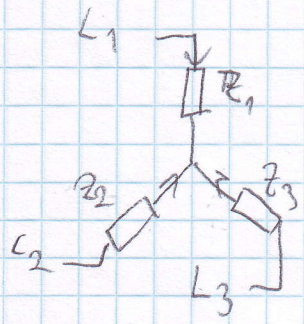
$U_1 = U \angle 0^\circ$

$U_1 = U \angle -120^\circ$

$U_2 = U \angle -240^\circ$

$R_1 = R_2 = R_3$

(64.) (65.)

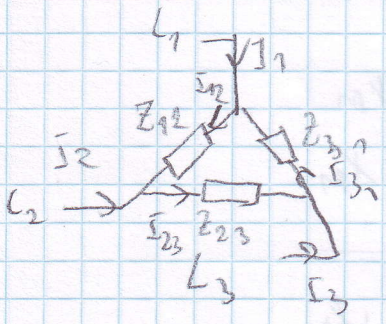


$I_L = I_f \qquad U_p = \frac{U_L}{\sqrt{3}}$

$I_{f_1} = \frac{U_{f_1}}{Z_1} = \frac{\frac{U_L}{\sqrt{3}}}{Z_1} = \frac{U_L}{\sqrt{3} Z_1}$ $\qquad I_{f_2} = \frac{U_{f_2}}{Z_2}$ $\qquad I_{f_3} = \frac{U_{f_3}}{Z_3}$

$|I_{f_1}| = |I_{f_2}| = |I_{f_3}|$ ∈ simétrico

$\ll I_1 + I_2 + I_3 = 0$



$I_{12} = I_1 + I_{31}$

$I_{23} = I_2 + I_{12}$

$I_{31} = I_3 + I_{23}$

$U_f = U_L$

$I_L = \sqrt{3}\, I_f$

$I_{f_{12}} = \frac{U_{12}}{Z_{12}} \qquad I_{f_{23}} = \frac{U_{23}}{Z_{23}}$

$I_{f_{31}} = \frac{U_{31}}{Z_{31}}$

$I_{12} = I_{23} = I_{31}$ ∈ simétrico

(67.)

Y $P = P_{1f} + P_{2f} + P_{3f} = 3 \cdot P_f = 3 \cdot U_f \cdot I_f = 3 \cdot \frac{U_L}{\sqrt{3}} \cdot I_L = \sqrt{3}\, U_L \cdot I_L \cos\varphi$

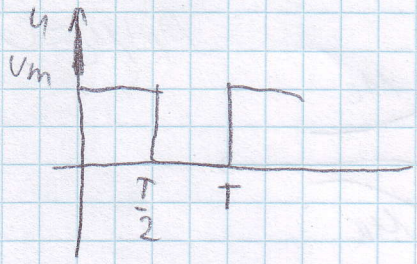
$P_{1f} = P_{2f} = P_{3f} = P_f$

Δ $P = P_{f_1} + P_{f_2} + P_{f_3} = 3 \cdot P_f = 3 \cdot U_f \cdot I_f = 3 \cdot U_L \cdot \frac{I_L}{\sqrt{3}} = \sqrt{3}\, U_L \cdot I_L \cos\varphi$

(69.)

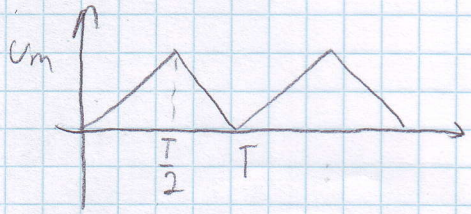
$$\sigma = \frac{U_m}{U_{ef}}$$

Pravokutni



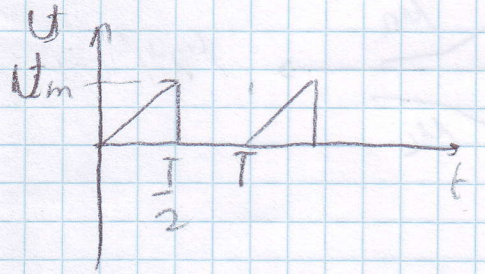
$$U_{ef} = \sqrt{U_m^2 \cdot \frac{t}{\tau}} = \sqrt{U_m^2 \cdot \frac{1}{2}}$$

Trokut testi



$$U_{ef} = \sqrt{\left(\frac{U_m}{\sqrt{3}}\right)^2 \cdot \frac{t}{\tau} + \left(\frac{U_m}{\sqrt{3}}\right)^2 \cdot \frac{t}{\tau}} = \sqrt{\frac{U_m^2}{3} \cdot \frac{1}{2} + \frac{U_m^2}{3} \cdot \frac{1}{2}}$$

Pilasti



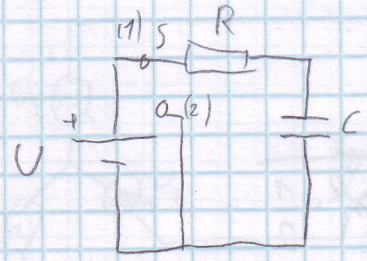
$$U_{ef} = \sqrt{\frac{U_m \cdot t}{2}} = \frac{U_m \cdot \frac{T}{2}}{2} = \frac{U_m \cdot T}{4}$$

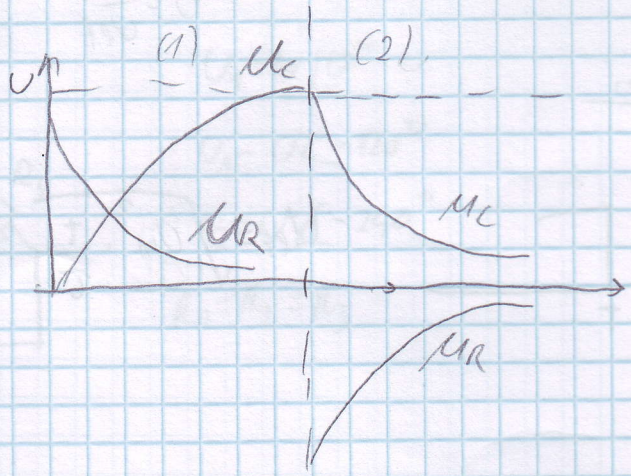
(71.)

$$u(t) = 5 + 6\sqrt{2}\sin(\omega t) + 15\sqrt{2}\sin(\omega t)$$

$$U_{ef} = \sqrt{5^2 + \left(\frac{6\sqrt{2}}{\sqrt{2}}\right)^2 + \left(\frac{15\sqrt{2}}{\sqrt{2}}\right)^2}$$

72.





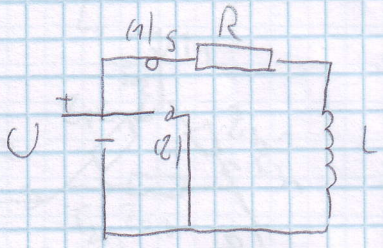
$u_R + u_C = 0$

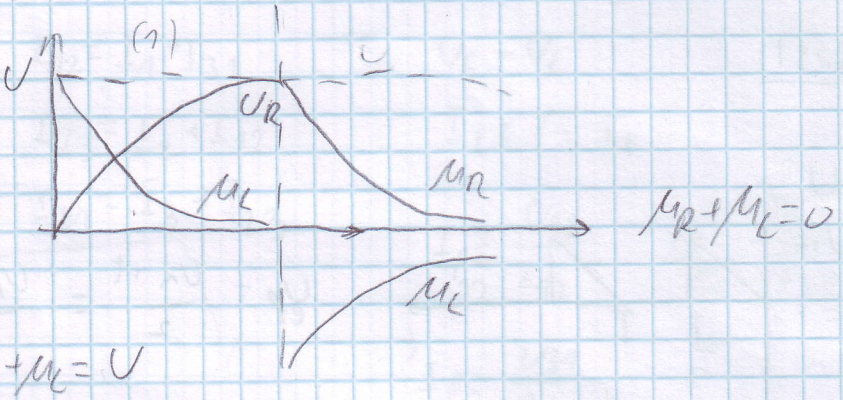
$u_R + u_C = U$

$u_C = U(1 - e^{-\frac{t}{\tau}})$

$\tau = R \cdot C$

73.





$u_R + u_L = 0$

$u_R + u_L = U$

$u_L = U e^{-\frac{t}{\tau}}$

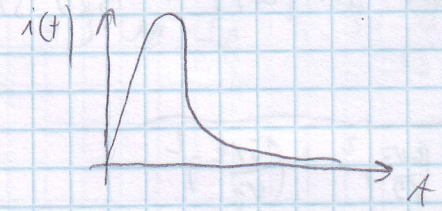
$\tau = \frac{L}{R}$

74.

- aperiodski $R > \sqrt{2\frac{L}{C}}$
- granični $R = \sqrt{2\frac{L}{C}}$
- prigušeno $R < \sqrt{2\frac{L}{C}}$
- oscilirnje $R = 0$ → sinusoida

$\tau = \frac{L}{RC}$

aperiodski i granični



prigušeno