98 $J = N'Q(v_1 - v_2)$

99 $\oint_S \vec{J}\,d\vec{s} = -\frac{dq}{dt}$ $\quad i = C\frac{du}{dt}$

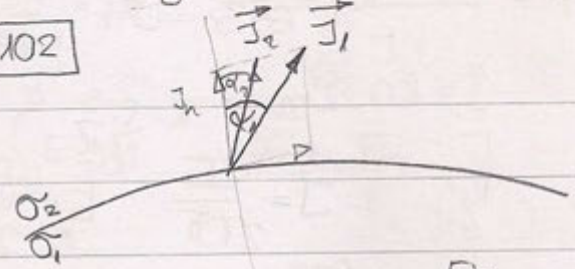
100 a) $\oint_S \vec{J}\,d\vec{s} = 0$

$\oint_C \vec{E}\,d\vec{l} = 0$

$\vec{J} = \vec{J}(\vec{E})$

101 $Q = \oint_S \vec{D}\,d\vec{s} = \oint_S \varepsilon\vec{E}\,d\vec{s} = \frac{\varepsilon}{\sigma}\oint_S \vec{J}\,d\vec{s} = \frac{\varepsilon}{\sigma}\vec{J}\oint_S d\vec{s} = 0$

102



$J_{n1} = J_{n2}$

$E_{t1} = E_{t2}$

$\sigma_1 E_{n1} = \sigma_2 E_{n2}$

$\operatorname{tg}\alpha_1 = \frac{E_1}{E_{n1}} = \frac{E_{t1}}{\frac{1}{\sigma_1}J_{n1}} = k\sigma_1$

$\operatorname{tg}\alpha_2 = k\sigma_2 \Rightarrow \boxed{\frac{\operatorname{tg}\alpha_1}{\operatorname{tg}\alpha_2} = \frac{\sigma_1}{\sigma_2}}$

103

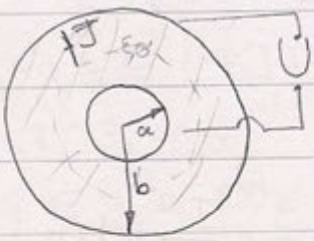
$\rho_s = D_{n1} - D_{n2}$

$D_{n1} = \frac{\varepsilon_1}{\sigma_1}J_{n1}$ $\quad J_{n1} = J_{n2} - J_n$

$D_{n2} = \frac{\varepsilon_2}{\sigma_2}J_{n2}$

$\rho_s = \left(\frac{\varepsilon_1}{\sigma_1} - \frac{\varepsilon_2}{\sigma_2}\right)J_n \neq 0$ у општем случају

104



$P = UI$ $\quad I = \frac{J}{S}$ $\quad \oint_S \vec{J}\,d\vec{s} = I$ $\quad J = \frac{I}{4r^2\pi}$

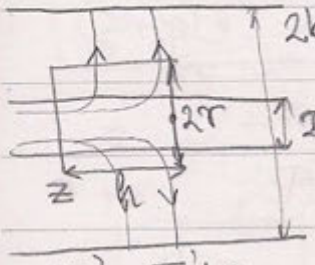
$\vec{J} = \sigma\vec{E}$ $\quad J4r^2\pi = I$

$U = \int_a^b \vec{E}\,d\vec{r}$ $\quad E = \frac{I}{4\sigma\pi r^2}$

$U = \frac{I}{4\sigma\pi}\left(\frac{1}{a} - \frac{1}{b}\right)$ $\quad \boxed{I = \frac{4\sigma\pi abU}{b-a}}$ $\quad P = \frac{4\sigma\pi abU^2}{b-a}$

105

a) G_d? d) P_d?



$J2r\pi h = I_d$ $\quad J2r\pi = -\frac{I(z+h) - I(z)}{h}$

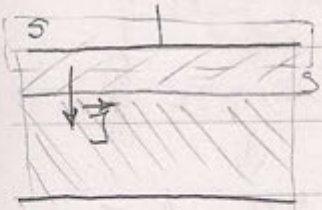
U $\quad I(z) = I_d + I(z+h)$ $\quad h \to 0$ $\quad J = \frac{I'}{2r\pi}$

$I_d = I(z) - (I(z+h))$

$E = \frac{I'}{2r\pi\sigma}$ $\quad U = \frac{I'}{2\pi\sigma}\ln\frac{b}{a}$

$G' = \frac{I'}{U} = \boxed{\frac{2\pi\sigma}{\ln\frac{b}{a}}}$

$P' = I'U = G'U^2 = \boxed{\frac{2\pi\sigma U^2}{\ln\frac{b}{a}}}$



$I = \oint_S \vec{J}\,d\vec{s} = JS$

I? $\quad J = \text{const}$ $\quad E_1 = \frac{J}{\sigma_1}$ $\quad E_2 = \frac{J}{\sigma_2}$

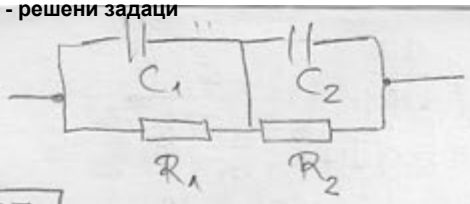
$U = \int_0^{d_1+d_2} \vec{E}\,d\vec{r} = \int_0^{d_1} \frac{J}{\sigma_1}dr + \int_{d_1}^{d_1+d_2} \frac{J}{\sigma_2}dr =$

$= \frac{J}{\sigma_1}d_1 + \frac{J}{\sigma_2}d_2 = J\left(\frac{d_1}{\sigma_1} + \frac{d_2}{\sigma_2}\right)$

$\boxed{I = \frac{U}{\frac{d_1}{\sigma_1} + \frac{d_2}{\sigma_2}}S}$ $\quad D_1 = \frac{\varepsilon_1}{\sigma_1}J$ $\quad \boxed{\rho_{s1} = \frac{\varepsilon_1}{\sigma_1}J}$ $\quad \boxed{\rho_{s2} = -\frac{\varepsilon_2}{\sigma_2}J}$

$\rho = -\left(\frac{\varepsilon_1}{\sigma_1} - \frac{\varepsilon_2}{\sigma_2}\right)J$

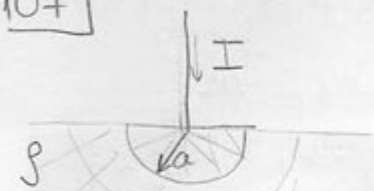
ANALYSIS



$C_1 = \frac{\varepsilon_1 S}{d_1}$ $C_2 = \frac{\varepsilon_2 S}{d_2}$

$R_1 = \frac{d_1}{\sigma_1 S}$ $R_2 = \frac{d_2}{\sigma_2 S}$

107



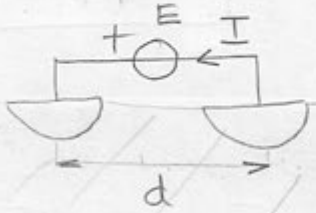
$\rho = 100\ \Omega m$ $R = \rho \frac{S}{\Delta l}$ $\rho = \frac{1}{\sigma}$

R? $J = \frac{I}{2r^2\pi}$ $E = \frac{\rho I}{2r^2\pi}$

$U = \frac{\rho I}{2a\pi}$ $G = \frac{I}{U} = \frac{I}{\frac{\rho I}{2a\pi}} = \frac{2a\pi}{\rho}$

$$R = \frac{\rho}{2a\pi}$$

108

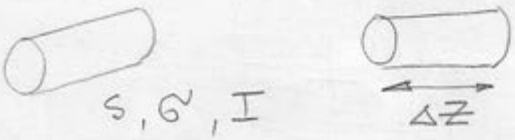


σ

$R_{uk} = \frac{1}{a\pi\sigma}$

$I = \frac{E}{R_{uk}} = a\pi\sigma E$

109



$R = \frac{1}{\sigma}\frac{S}{\Delta z}$

$dP = RI^2 = \frac{1}{\sigma}\frac{\Delta z}{S} I^2 \frac{S}{S} = \frac{I^2}{\sigma S^2} d\sigma$

$\frac{dP}{d\sigma}$?

$$\frac{dP}{d\sigma} = \frac{I^2}{\sigma S^2}$$

110 l, σ_1, σ_2

U $R_1 = \frac{1}{\sigma_1}\frac{l/2}{S} = \frac{l}{2\sigma_1 S}$

$R_2 = \frac{1}{\sigma_2}\frac{l/2}{S} = \frac{l}{2\sigma_2 S}$

$I = \frac{U}{R} = \frac{U}{\frac{l}{2S}\frac{\sigma_1+\sigma_2}{\sigma_1\sigma_2}}$

$$I = \frac{2\sigma_1\sigma_2 S U}{l(\sigma_1+\sigma_2)}$$

$R_{uk} = R_1 + R_2 = \frac{l}{2S}\left(\frac{1}{\sigma_1} + \frac{1}{\sigma_2}\right)$

$J = \frac{I}{S} = \frac{2\sigma_1\sigma_2 U}{l(\sigma_1+\sigma_2)}$

$$E_1 = \frac{J}{\sigma_1} = \frac{2\sigma_2 U}{l(\sigma_1+\sigma_2)}$$

$$E_2 = \frac{J}{\sigma_2} = \frac{2\sigma_1 U}{l(\sigma_1+\sigma_2)}$$

111

I, P?

$E_{t1} = E_{t2}$

$\Downarrow$

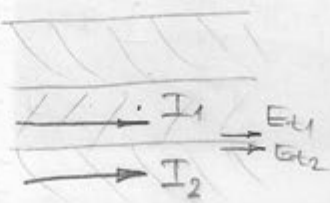
$E_1 = E_2$

$\Downarrow$

$\frac{1}{\sigma_1} J_1 = \frac{1}{\sigma_2} J_2$

$\Downarrow$

$J_1 = \frac{\sigma_1}{\sigma_2} J_2$



$I_1 = J_1 S_1 = \frac{\sigma_1 S_1}{\sigma_2} J_2$

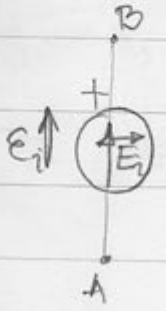
$I_2 = J_2 S_2$

$P = \frac{I^2}{G}$

$U = \int_0^{\ell} \vec{E}\,d\vec{r} = E\ell = \frac{1}{\sigma_2} J_1 \ell$

$G = \frac{I}{U} = \frac{\frac{\sigma_1 S_1}{\sigma_2} J_2 + S_2 J_2}{\frac{1}{\sigma_2} J_2 \ell} = \frac{\sigma_1 S_1 + \sigma_2 S_2}{\ell}$

112. $E_i = \frac{F_i}{Q}$ $\mathcal{E}_i = \int_A^B E_i\,dl$



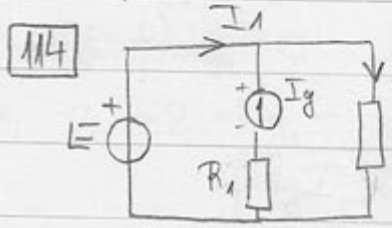
$E_i = E$

113 E_i, J P?

$J = (E_e - E_i)\sigma$

$P = UI$ $\frac{dP}{dV} = E_i J$

114



$E = 100V$

$R_1 = 50\Omega$ $I_g = 1A$

$R_2 = 2R_1$

$E = U_g - R_1 I_g$

$U_g = E + R_1 I_g = 150V$

$P_1 = R_1 I^2 = 50W$

$P_2 = E I_2 = 100W$

$I_2 = \frac{E}{R_2}$

$I_2 = 1A$

$-I_1 - I_g + I_2 = 0$

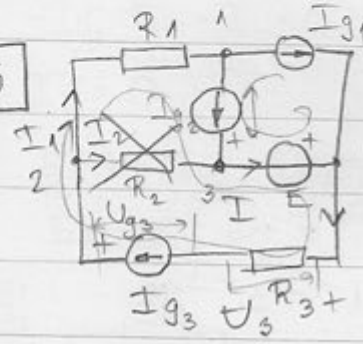
$I_1 = -I_g - I_2$

$I_1 = -2A$

$P_E = E I_2 = -200W$

$P_g = U_g \cdot I_g = 150W$

115



$I_{g_1} = 1mA$ $E = 1V$ $R_3 = 3k\Omega$

$I_{g_2} = 2mA$ $R_1 = 1k\Omega$ P_3?

$I_{g_3} = 3mA$ $R_2 = 2k\Omega$

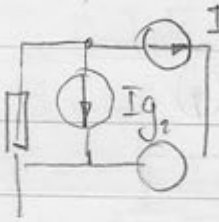
$U_3 = I_{g_3} R_3 = 9V$

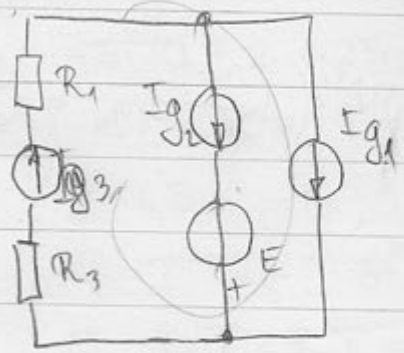
1: $I_1 = I_{g_2} + I_{g_1} = 3mA$

2: $I_1 + I_2 - I_{g_3} = 0$ $I_2 = 0$

(1) $-R_1 I_{g_3} + U_{g_2} + E - R_3 I_{g_3} + U_{g_3} = 0$

$U_{g_2} + E - U_{g_1} = 0$

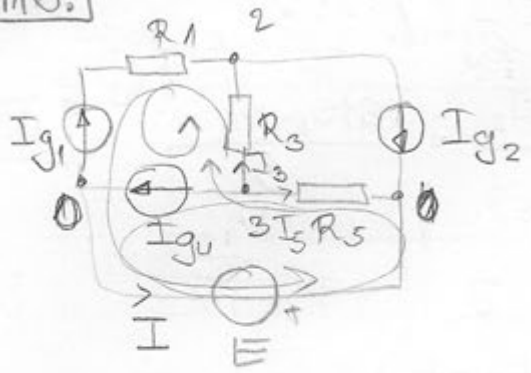




Овде се R мора заменити кратким спојем

ANALYSIS

116.



$I_{g1} = I_{g4} = 1A$

$I_{g2} = 2A$

$E = 10V$

$R_1 = R_5 = 1\,\Omega$

$R_3 = 2\,\Omega$

P_{g1} ?

1: $I + I_{g1} - I_{g4} = 0 \quad I = 0$

2: $I_{g2} - I_{g3} - I_3 = 0$

3: $I_{g4} + I_3 + I_5 = 0$

I $R_1 I_{g1} - U_{g1} + E + I_5 R_5 - R_3 I_3 = 0$

II $R_5 I_5 + U_{g4} + E = 0$

III $R_1 I_{g1} - U_{g1} - U_{g4} - R_3 I_3 = 0 \quad U_{g4} = R_1 I_{g1} - R_3 I_3 - U_{g1}$

$G_{11} V_1 + G_{12} V_2 + \dots + G_{1n} V_n = I_{k1}$

$G_{n1} V_1 + G_{n2} V_2 + \dots + G_{nn} V_n = I_n$

(1): $V_1 = E$

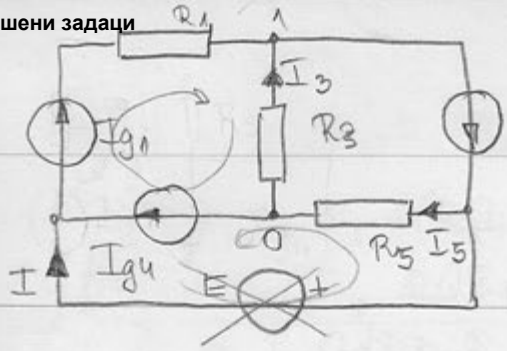
(2) $0 \cdot V_1 + \frac{1}{R_1 \to \infty} + \frac{1}{R_3} V_2 - \frac{1}{R_3} V_3 = I_{g1} + I_3 - I_{g2}$

(3) $-\frac{1}{R_5} V_1 - \frac{1}{R_3} V_2 + \left(\frac{1}{R_3} + \frac{1}{R_5}\right) V_3 = -I_3 - I_5 - I_{g4}$

$\frac{V_2}{R_3} - \frac{V_3}{R_3} = I_{g1} + I_3 - I_{g2}$

$-\frac{E}{R_5} - \frac{V_2}{R_3} + \left(\frac{1}{R_3} + \frac{1}{R_5}\right) V_3 = I_{g4} - I_{g4} = 0$

$-\frac{E}{R_5} + \frac{V_3}{R_5} = I_{g1} + I_3 - I_{g2}$



$-I - I_{g4} + I_{g1} = 0 \qquad I = 0$

$-I_3 - I_{g1} + I_{g2} = 0$

$I_3 = 1A$

$-I_5 + I_3 + I_{g4} = 0 \qquad I_5 = 2A$

$\left(\frac{1}{R_1 \to \infty} + \frac{1}{R_3}\right) V_1 = I_3 + I_{g1} - I_{g2} = 1A + 1A - 2A = 0$

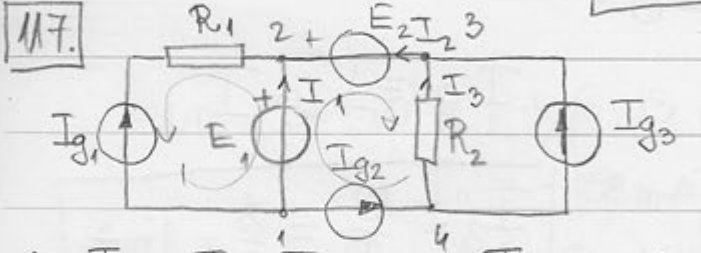
$R_3 I_3 + U_{g4} + U_{g1} - R_1 I_{g1} = 0$

$E - R_5 I_5 + U_{g4} = 0 \qquad U_{g4} = -10V + 1 \cdot 2V = -8V$

$R_3 \quad 2 - 8 + U_{g1} - 1 = 0$

$\boxed{U_{g1} = 7V}$ $\qquad P_g = I_g U_g = 7W$

117.



$P_{E_1}? \; P_{E_2}?$

$P_{g_1} = 20W \qquad P_{g_2} = 0 = P_{g_3}$

1: $I_{g_1} + I_1 + I_{g_2} = 0 \qquad I_1 = -2A \qquad P_{E_1} = -20W$

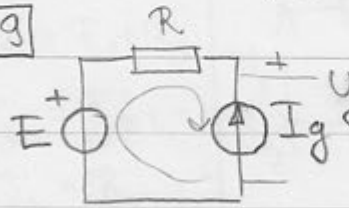
2: $-I_{g_1} - I_1 - I_2 = 0 \qquad I_2 = 1A \qquad P_{E_2} = 10W$

3: $I_3 = 0$

1: $E_1 + R_1 I_{g_1} - U_{g_1} = 0 \qquad U_{g_1} = 10 + 10 \cdot 1 = 20V$

$E_1 - E_2 + \cancel{I_3 R_2}^{0} - U_{g_2} = 0 \qquad U_{g_2} = 0$

119



$E = 10V \quad R = 1\Omega \qquad -U_g + E + RI_g = 0$

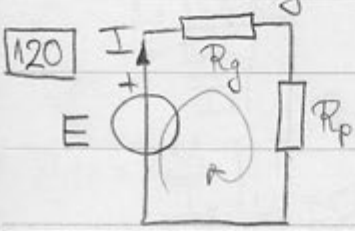
$P_g = I_g \cdot U_g \qquad U_g = E + RI_g$

$P_g = I_g E + R I_g^2 \qquad P_g' = E + 2RI_g \Rightarrow I_{g(max)} = -\frac{E}{2R} = -5A$

$P_{at} = 25W \qquad P_g = -5 \cdot 10 + 2 \cdot 1 \cdot 25 = -25W$

$P = -EI_g = -10(-5) = 50W$

120



$P_p = 4,5W \quad R_p = 0,5\Omega \quad R_p = 2\Omega \qquad R_{p(max)} \; P_{max}?$

$P_p = I^2 R_p = I \cdot U = R_p \frac{E^2}{(R_g + R_p)^2}$

$E - R_g I - R_p I \Rightarrow I = \frac{E}{R_g + R_p} \rightarrow U = E - R_g I$

$P_p = 2 \cdot \frac{E^2}{R_g + 2} = 4,5 \qquad 4,5 R_g^2 + 9 R_g R_p + 4,5 R_p^2 =$

ANALYSIS

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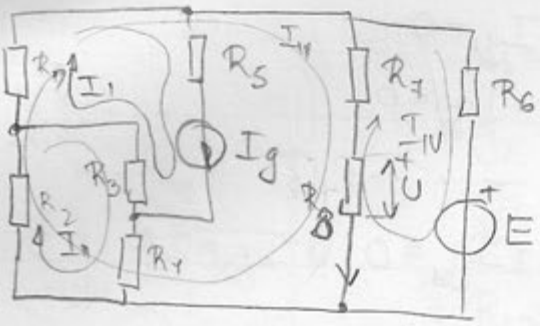


$E = 45V$

$I_g = 9mA$

$R_1 = R_2 = 11k\Omega$

$R_3 = R_5 = R_6 = 1k\Omega$

$R_7 = 25k\Omega \quad R_8 = 8k\Omega$

R_4? $\quad U = 8V$

$I_1 = I_g$

$-R_3 I_1 + (R_3 + R_4 + R_2) I_{II} + R_2 I_{III} = 0$

$R_1 I_1 + R_2 I_{II} + (R_7 + R_8 + R_2 + R_1) I_{III} - (R_7 + R_8) I_{IV} = 0$

$-(R_7 + R_8) I_{III} + (R_7 + R_8 + R_6) I_{IV} = -E$

$-I_g + (1 + R_4 + 11) I_{II} + 11 I_{III} = 0$

$(12 + R_4) I_{II} = I_g - 11 I_{III}$

$I_{II} = \dfrac{I_g - 11 I_{III}}{12 + R_4}$

$I_g = I_{III} - I_{IV}$

$\boxed{I_8 = \dfrac{U}{R_8} = \dfrac{8}{8} = 1mA}$

$I_{III} = 0{,}24mA + I_N$

$11 I_g + 11 \dfrac{I_g - 11 I_{III}}{12 + R_4} + (25 + 8 + 11 + 11) I_{III} - (25 + 8) I_{IV} = 0$

$-(25 + 8) I_{III} + (25 + 8 + 11) I_{IV} = -45$

$-33 \quad -33 I_{III} + 34 I_{IV} = -45$

$I_{IV} = -37mA$

$I_{III} = -36{,}76mA$

$I_{II} = \dfrac{1mA + 121mA}{12 + R_4} = \dfrac{122mA}{12 + R_4}$

$11 \cdot 9mA + 11 \cdot I_{II} - 5 \cdot 36{,}76mA) + 33 \cdot 37mA = 0$

$I_{II} = 137{,}8mA$

$12 + R_4 = \dfrac{9 + 11 \cdot 36{,}76}{137{,}8}$

1 $I_1 = I_g = 9mA$

2 $-R_3 I_1 + (R_2+R_3+R_4) I_{II} + R_2 I_{III} = 0$

3 $R_1 I_1 + R_2 I_{II} + (R_2+R_1+R_7+R_8) I_{III} - (R_7+R_8) I_{IV} = 0$

4 $-(R_7+R_8) I_{III} + (R_7+R_8+R_6) I_{IV} = -E$

$$9 + (12+R_4)\cdot 10^3 I_{II} + 11\cdot 10^3 I_{III} = 0$$

$$9 + \cdot 10^3 I_{II} + 5\,10^3 I_{III} - 3\cdot 10^3 I_{IV} = 0$$

$$-33\cdot 10^3 I_{III} + 34\cdot 10^3 I_{IV} = -45$$

$I_{III} - I_{IV} = 1mA \quad I_{III} = 1mA + I_{IV}$

$$-33 - 33 I_{IV}\cdot 10^3 + 34 I_{IV}\cdot 10^3 = -45$$

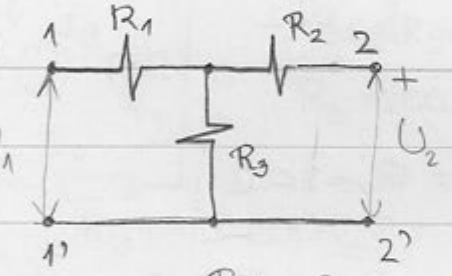
$\boxed{I_{IV} = 12mA}$ $\boxed{I_{III} = 13mA}$

$$9 + 10^3 I_{II} + 5\cdot 13\cdot 10^3 - 3\cdot 12\cdot 10^3 = 0$$

$$I_{II} = -38mA$$

$$9 - (12+R_4)\,38 + 11\cdot 13 = 0$$

Пример

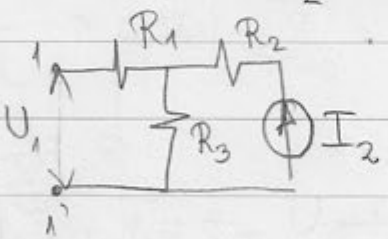


$U_1 = r_{11} I_1 + r_{12} I_2$

$U_2 = r_{21} I_1 + r_{22} I_2$

$r_{11} = \left.\frac{U_1}{I_1}\right|_{I_2=0}$ $r_{12} = \left.\frac{U_1}{I_2}\right|_{I_1=0}$

$r_{21} = \left.\frac{U_2}{I_1}\right|_{I_2=0}$ $r_{22} = \left.\frac{U_2}{I_2}\right|_{I_1=0}$



$r_{11} = R_1 + R_3$

$r_{12} = R_3$

$r_{21} = R_3$

$r_{22} = R_2 + R_3$

$[U] = [R][I]$

$$\begin{bmatrix} U_1 \\ U_2 \end{bmatrix} = \begin{bmatrix} r_{11} & r_{12} \\ r_{21} & r_{22} \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix}$$

$I_1 = g_{11} U_1 + g_{12} U_2$

$I_2 = g_{21} U_1 + g_{22} U_2$

$g_{11} = \left.\frac{U_1}{I_1}\right|_{U_2=0}$

$g_{12} = \left.\frac{U_2}{I_1}\right|_{U_1=0}$

$g_{21} = \left.\frac{U_1}{I_2}\right|_{U_2=0}$

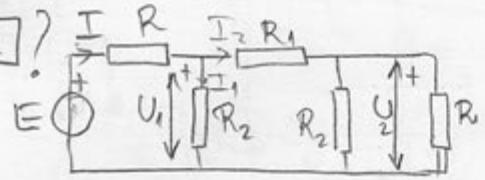
$g_{22} = \left.\frac{U_2}{I_2}\right|_{U_1=0}$

$g_{11} = \frac{1}{R_1+R_3}$

$g_{12} = \frac{R_3 I}{R_3+R_1} = I_1 \quad I = \frac{R_3+R_1}{R_3} I_1$

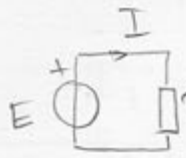
ANALYSIS
LABORATORY EQUIPMENT

122 ?



$E = 2V$
$R = 50\Omega$
$U_1 = 1V$
$U_2 = 0{,}5V$

$I = I_1 + I_2 =$ $\quad Re_1 = R + \left((R_1 + (R_2 \| R)) \| R_2\right)$



$$I = \frac{E}{Re_1} \qquad Re_1 = R + \frac{\left(\frac{R_2 R}{R_2+R} + R_1\right) R_2}{\frac{R_2 R}{R_2+R} + R_1 + R_2}$$

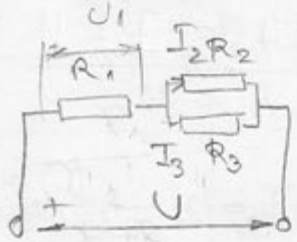
$$I_1 = \frac{U_1}{R_2}$$

$$I_2 = \frac{U_2}{Re_2} = \frac{U_2}{R_1 + \frac{\left(\frac{R_2 R}{R_2+R} + R_1\right) R_2}{\frac{R_2 R}{R_2+R} + R_1 + R_2} + R} = \frac{U_2}{R_2} + \frac{U_2}{R}$$

$$\left(\frac{\left(\frac{R_2 R}{R_2+R} + R_1\right) R_2}{\frac{R_2 R}{R_2+R} + R_1 + R_2} + R\right)\left(\frac{U_2}{R_2} + \frac{U_2}{R} + \frac{U_1}{R_2}\right) = E$$

$$\left(\frac{(R_2 R + R_2 R_1 + R R_1) R_2}{2R_2 R + R_2 R_1 + R_2^2 + R_1 R +} + R\right)\left(\frac{U_2}{R_2} + \frac{U_2}{R} + \frac{U_1}{R_2}\right) = E$$

123.



$P_{1max} = 2W$ $\quad R_1 = 20\Omega$
$P_{2max} = 4W$ $\quad R_2 = 100\Omega$
$P_{3max} = 2W$ $\quad R_3 = 400\Omega$

U $0 \to 50$

$$\frac{R_1}{R} \qquad U_1 = \frac{\frac{R_2 R_3}{R_2+R_3}}{R_1 + \frac{R_2 R_3}{R_2+R_3}} U = \frac{R_2 R_3}{R_1 R_2 + R_1 R_3 + R_2 R_3} U =$$

$$I = \frac{U}{200 + \frac{400}{5}} = \frac{U}{420}$$

$$= \frac{160 \cdot 400}{2000 + 8000 + 40000} = \frac{4}{5} U$$

$$I_2 = \frac{\frac{1}{5}U}{R_2} = \frac{U}{500} \qquad U_3 = U_2 = \frac{1}{5}U$$

$$I_3 = \frac{\frac{1}{5}U}{R_3} = \frac{U}{2000}$$

$$I_2 = \frac{R_3}{R_2+R_3} I = \frac{400}{500} \frac{U}{420} = \frac{4}{5} \frac{U}{420}$$

$$I_3 = \frac{1}{5} \frac{U}{420}$$

$P_1 = IU_1 = \frac{U}{420} \cdot \frac{4}{5}U = \frac{4}{5 \cdot 420}U^2$

$P_2 = I_2 U_2 = \frac{1}{5}U \cdot \frac{4}{5}\frac{U}{420} = \frac{4}{25 \cdot 420}U^2$

$P_3 = I_3 U_3 = \frac{1}{5}\frac{U}{420} \cdot \frac{1}{5}U = \frac{U^2}{25 \cdot 420}$

$U_{1max} = \sqrt{\frac{2 \cdot 5 \cdot 420}{4}} = 32,40$

$U_{2max} = \sqrt{\frac{4 \cdot 25 \cdot 420}{4}} = 102,47$

$U_{3max} = \sqrt{2 \cdot 25 \cdot 420} = 144,91$

Пробоpeће само први отпорник ↯

$I_1 = \frac{U}{20+80} = \frac{U}{100}$

$I_2 = \frac{R_3}{R_2+R_3} \cdot \frac{U}{100} = \frac{400}{500} \cdot \frac{U}{100} = \frac{4}{5}\frac{U}{100}$

$I_3 = \frac{1}{5}\frac{U}{100}$

$P_1 = \frac{4}{5}U \cdot \frac{U}{100} = \frac{4}{5 \cdot 100}U^2$

$P_2 = \frac{1}{5}U \cdot \frac{4}{5}\frac{U}{100} = \frac{4U^2}{25 \cdot 100}$

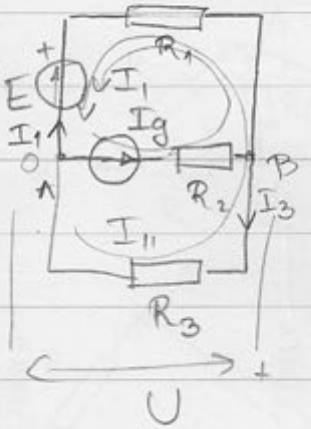
$P_3 = \frac{1}{5}U \cdot \frac{1}{5}\frac{U}{100} = \frac{4U^2}{25 \cdot 100}$

$U_{max}^{(1)} = 15,81$

$U_{max}^{(2)} = 50$

$U_{max}^{(3)} = 100$

124.



$E = 40V$

$R_1 = R_2 = 100\Omega$

$R_3 = 200\Omega$

$P_E = 8W$

P_{Ig} ?

$P_{R_2+I_g}$?

$E + I_1 R_1 = -U_g + I_g R_2 = (I_1 + I_g) R_3$

$I_E = 0,5mA$

$U = 40 + 50 = 90V$

$\frac{90}{200} = I_1 + I_g = I_3$

$I_3 = 0,45mA$

$I_1 = I_g$

$R_1 I_g + (R_3 + R_1) I_{II} = -E$

$I_3 = -I_{II}$

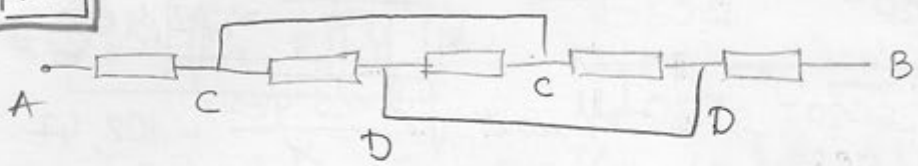
$I_g = \frac{1}{100}(300 \cdot 0,4,5 - 40) = 0,95mA$

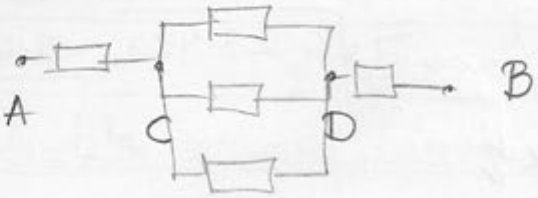
$U_g = 90 - 0,95mA \cdot 100 = 5V$

$P_{Ig} = 4,75W$

ANALYSIS LABORATORY EQUIPMENT

125.

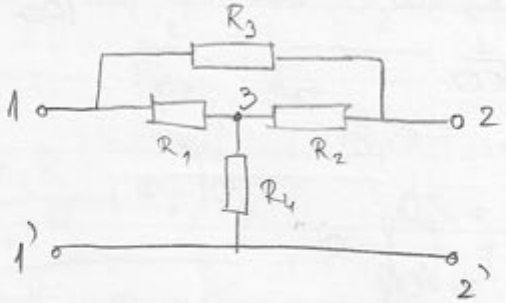




$$R_e = 2R + \frac{R}{3} = \frac{7}{3}R$$

126 $R_{AB} = 0$

127

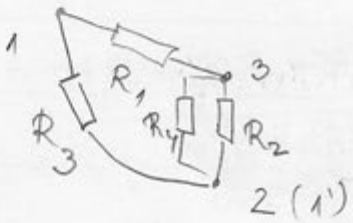


$R_1 = 100\,\Omega = R$

$R_2 = R_4 = 2R$

$R_3 = 8R$

а)



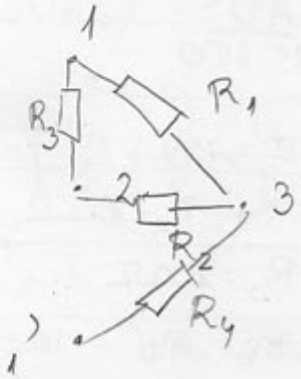
$R_1 + R$

$$\frac{1}{8R} + \frac{1}{2R} = \frac{1}{R_e} \quad | \cdot 4$$

$$\frac{8}{5}R = R_e$$

$R_e = 160\,\Omega$

б)

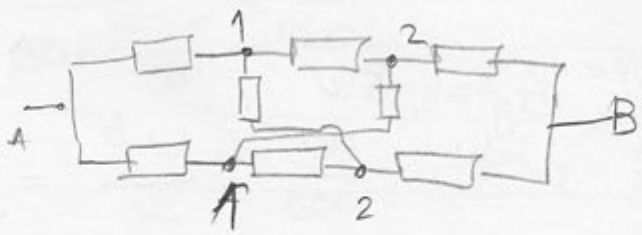


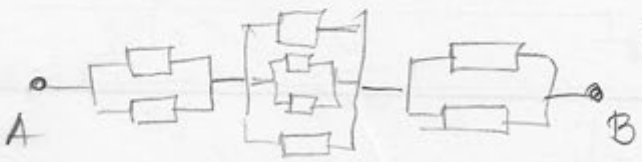
$R_2 + R_3 = 10R$

$$\frac{10R}{\frac{1}{10R} + \frac{1}{R}} = \frac{10}{11}R$$

$$R_e = \frac{10}{11}R + 2R = \frac{32}{11}R = 290{,}91\,\Omega$$

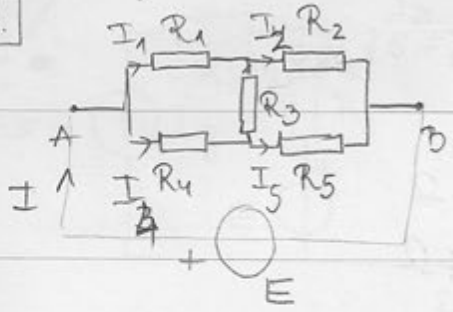
128. $R = 100\,\Omega$





$$R_e = 2 \cdot \frac{R}{2} + \frac{R}{4} = \frac{5}{4}R$$

129.



$R_1 = 2R_2 = 2R$

$R_3 = 3R$

$R_4 = 4R \quad R_5 = 2R$

$E = IR_e$

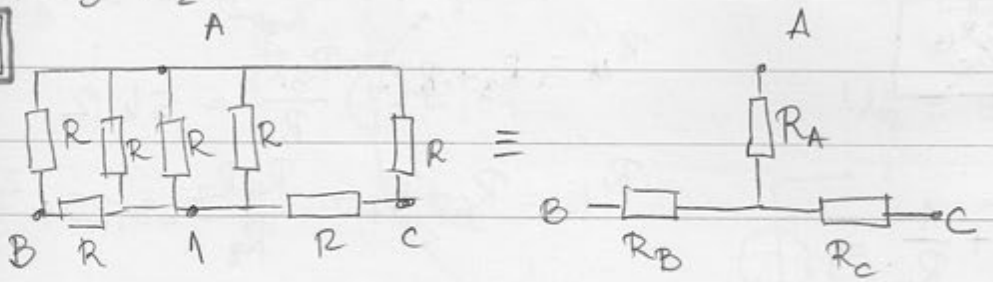
$I_1 + I_4 = I$

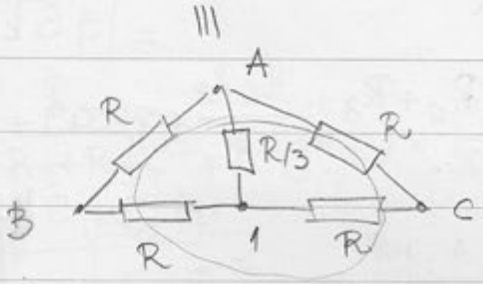
$I_2 + I_5 = I$

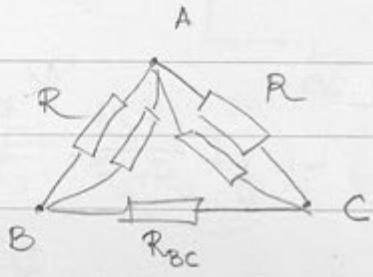
$I_1 + I_3 = I_2$

МОСТ ЈЕ У РАВНОТЕЖИ АКО ЈЕ ИСПУЊЕН УСЛОВ $R_1R_5 = R_2R_4$

130



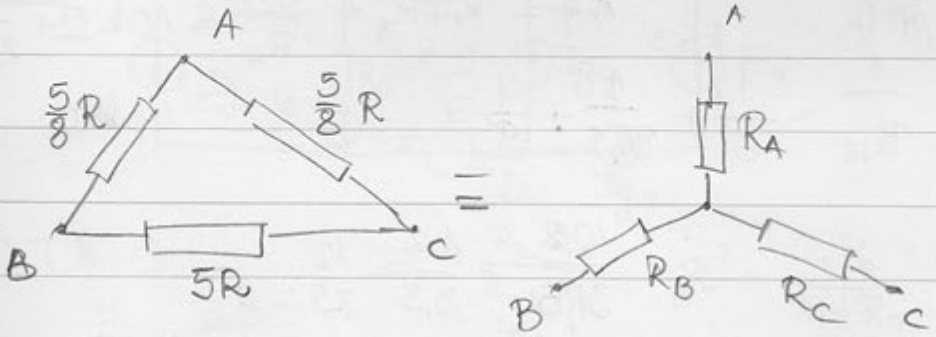




$R_{BC} = R + R + \frac{R^2}{R/3} = 2R + 3R = 5R$

$R_{BA} = R/3 + R + \frac{R^2/3}{R} = \frac{5}{3}R$

$R_{AC} = \frac{5}{3}R$

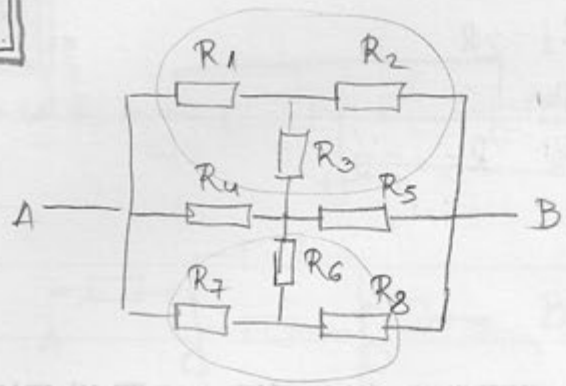


$$R_A = \frac{\frac{5}{8}R \cdot \frac{5}{8}R}{\frac{5}{4}R + \frac{20}{4}R} = \frac{\frac{25}{64}R^2}{\frac{25}{4}R} = \frac{1}{16}R$$

$$R_B = R_C = \frac{\frac{5}{8}R \cdot 5R}{\frac{25}{4}R} = \frac{R}{2}$$

ANALYSIS LABORATORY EQUIPMENT

131.



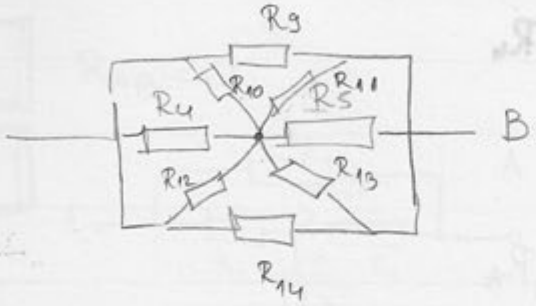
$R_1 = R_3 = R_4 = 3k\Omega$

$R_2 = 1k\Omega$

$R_5 = R_8 = 9k\Omega$

$R_6 = 2{,}25k\Omega$

$R_7 = 1k\Omega$



$$R_9 = R_1 + R_2 + \frac{R_1 R_2}{R_3} = 3 + 1 + \frac{3}{3} = 5k\Omega$$

$$R_{10} = R_1 + R_3 + \frac{R_1 R_3}{R_2} = 3 + 3 + \frac{9}{1} = 15k\Omega$$

$$R_{11} = R_3 + R_2 + \frac{R_3 R_2}{R_1} = 5k\Omega$$

$$R_{12} = R_6 + R_7 + \frac{R_6 R_7}{R_8} = 3{,}25 + \frac{2{,}25}{9} =$$

$$= \boxed{3{,}5k\Omega}$$

$$R_{13} = R_6 + R_8 + \frac{R_6 R_8}{R_7} = 2{,}25 + 9 +$$

$$= \boxed{31{,}5k\Omega}$$

$$R_{14} = R_7 + R_8 + \frac{R_7 R_8}{R_6} = 10k\Omega + \frac{9}{2{,}25}$$

$$= 14k\Omega$$

$$\frac{1}{R_{15}} = \frac{1}{R_{10}} + \frac{1}{R_4} + \frac{1}{R_{12}} =$$

$$= \frac{1}{15} + \frac{1}{3} + \frac{1}{3{,}5} = \frac{7}{105} + \frac{35}{105} + \frac{30}{105}$$

$$= \frac{72}{105}$$

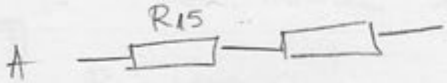
$$R_{15} = \frac{105}{72}k\Omega$$

$$= \frac{35}{24}k\Omega$$

$$\frac{1}{R_{16}} = \frac{1}{5} + \frac{1}{31{,}5} + \frac{1}{9} =$$

$$= \frac{10{,}8}{31{,}5} = \frac{1{,}2}{3{,}5} = \frac{12}{35}$$

$$R_{16} = \frac{35}{12}k\Omega$$

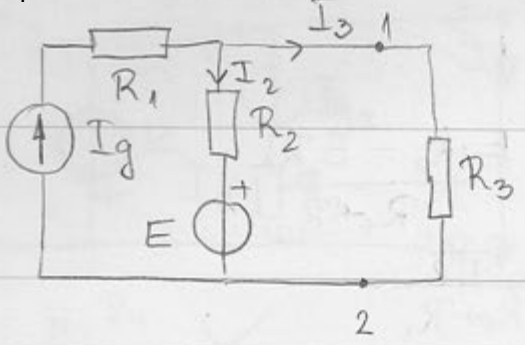


$$R_{17} = \frac{105}{24} = \frac{35}{8}k\Omega$$

$$\frac{1}{R_{AB}} = \frac{1}{5} + \frac{8}{35} + \frac{1}{14} = \frac{35}{70} = 0{,}5$$

$$\boxed{R_{AB} = 2k\Omega}$$

132.



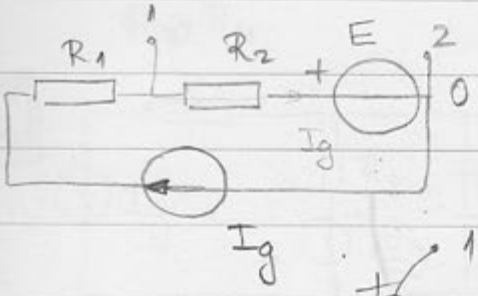
$E = 24\,V$

$I_g = 18\,mA$

$R_1 = R_2 = 1\,k\Omega$

$R_3 = 400\,\Omega$

a)



$E_t = E + I_g R_2$ ✓

$R_t = R_2$ ✓

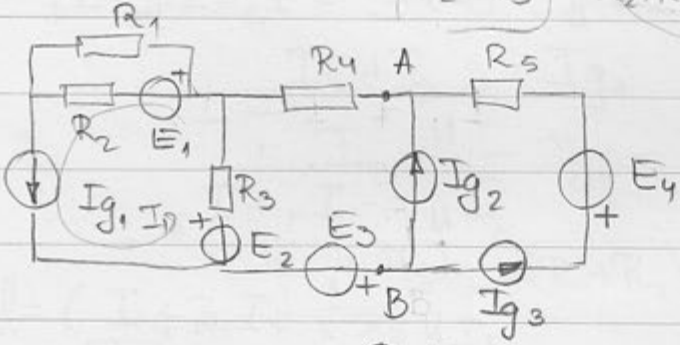
d)

$I_2 = \frac{R_3}{R_2+R_3} I_g$

$U_{12} = E + I_2 R_2 = E + \frac{R_2 R_3}{R_2+R_3} I_g$

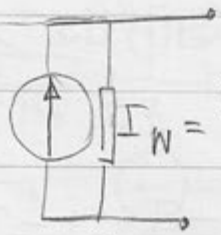
$\frac{R_3}{R_2+R_3}(E + I_g R_2) = \frac{R_3}{R_2+R_3} E + \frac{R_2 R_3}{R_2+R_3} I_g$?

133.



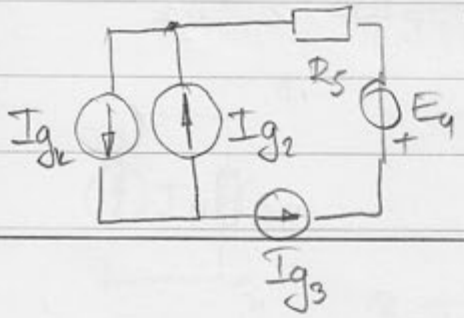
a) T.K.

$E_1' = \frac{R_2 E_1}{R_1+R_2}$ $\quad R' = \frac{R_1 R_2}{R_1+R_2}$



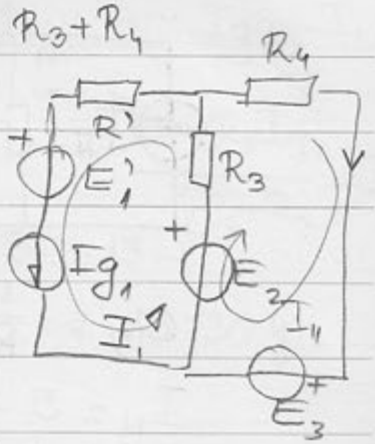
$I_N = \frac{E_3 + R_3 I_{g1} - E_2}{R_3 + R_4}$ ✓

$R_N = R_3 + R_4$ ✓



$I_{gk} = I_{g2} + I_{g3} = 5\,mA$ ✓

d) $R_N = R_3 + R_4$



$I_1 = I_{g1}$

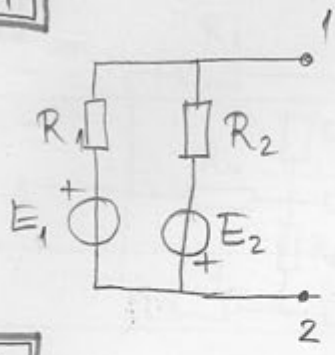
$R_3 I_1 + (R_3+R_4) I_{11} = E_2 - E_3$

$I_{11} = \frac{E_2 - E_3 - R_3 I_{g1}}{R_3+R_4}$

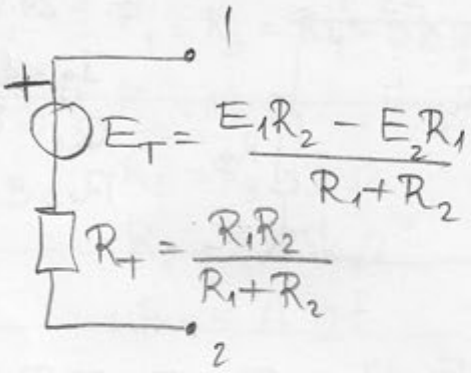
$I_N = -I_{11}$

ANALYSIS LABORATORY EQUIPMENT

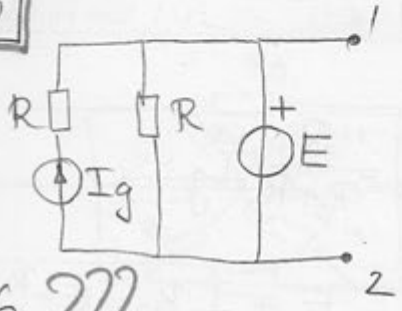
134



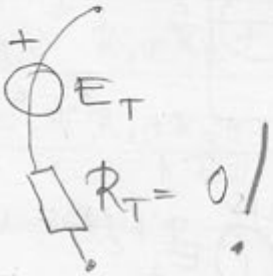
$\Leftrightarrow$



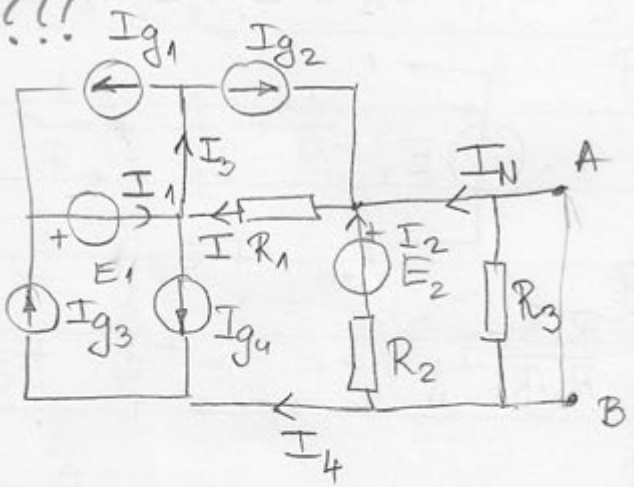
135



$E_T = E$



136. ???



$I_3 = I_{g_1} + I_{g_2}$

$I_4 = I_{g_4} - I_{g_3}$

$I_1 = I_{g_1} + I_{g_3}$

$I = I_3 + I_{g_4} - I_1$

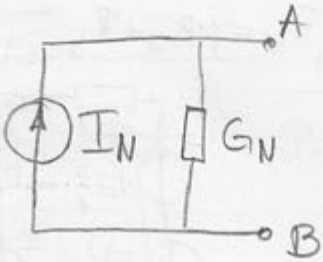
$I_N = I - I_2$

$I_N = I_4 + I_2$

$I_N = \frac{1}{2}(I_4 + I) =$

$= \frac{1}{2}(I_{g_4} - I_{g_3} + \cancel{I_{g_1}} + I_{g_2} + I_{g_4} - \cancel{I_{g_1}} - I_{g_3})$

$= I_{g_4} - I_{g_3} + \frac{1}{2} I_{g_2}$

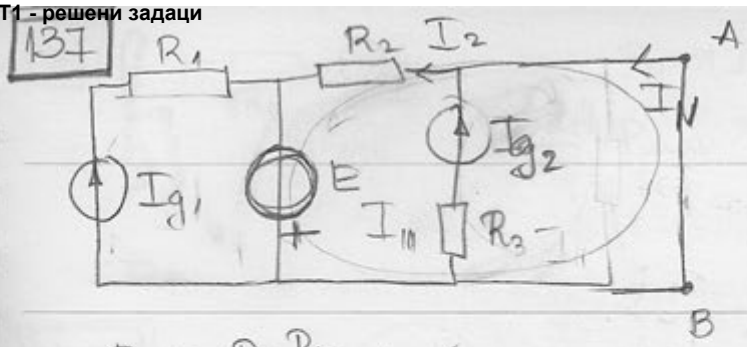


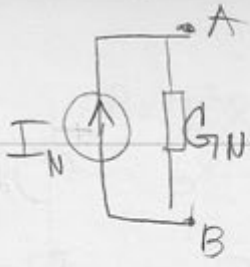
$G_N = \frac{1}{R_2} + \frac{1}{R_3}$

$I_N = 5 - 3 + \frac{1}{2} 2 =$

$= 3\,mA$

137



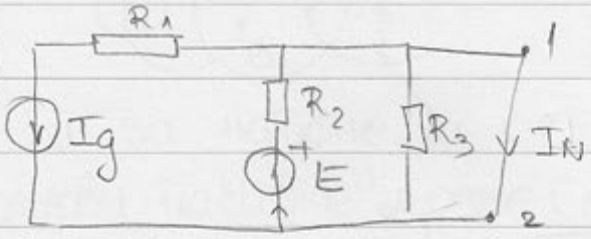


$R_N = \frac{R_2 R_4}{R_2 + R_4}$ ✓

$E - R_2 I_2 = 0 \quad I_2 = \frac{E}{R_2}$

$I_N = -(I_2 - I_{g2}) = -\frac{E}{R_2} + I_{g2}$

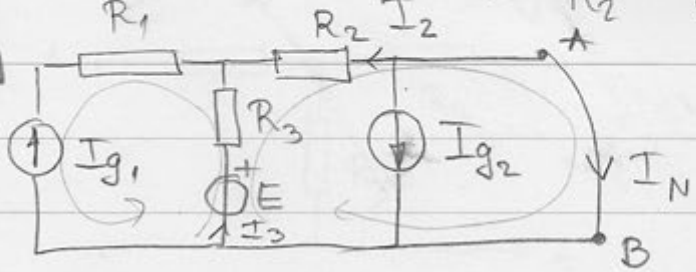
138.



$G_N = \frac{1}{R_3} + \frac{1}{R_2} = 0{,}5 + 2 = 2{,}5\,mS$ ✓

$I_N = \frac{E}{R_2} - I_g = 2 - 1mA = 1mA$ ✓

139



$R_N = R_2 + R_3 \quad G_N = \frac{1}{R_2 + R_3}$

$E - R_3 I_3 + R_2 I_2 = 0 \quad I_2 = -\frac{E + R_3 I_{g1}}{R_3 + R_2}$

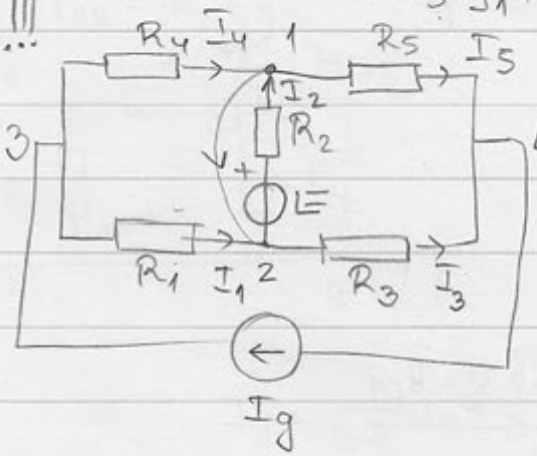
$I_2 + I_3 = -I_{g1}$

$I_3 = -I_{g1} - I_2 \quad I_N = -I_{g2} - I_2 =$

$E + R_3 I_{g1} + (R_3 + R_2) I_2 = 0 \quad = \frac{E + R_3 I_{g1}}{R_3 + R_2} - I_{g2}$

ПОНОВО !!!

140.



$R_4 \cdot R_3 = 5 \cdot 3 = 15$

$R_1 \cdot R_5 = 2 \cdot 15 = 30$ ↓

$R_N = R_2 \,||\, (R_3 + R_5) \,||\, (R_4 + R_1) \Rightarrow$

$\Rightarrow G_N = \frac{1}{R_2} + \frac{1}{R_3 + R_5} + \frac{1}{R_4 + R_1}$

$I_2 = \frac{E}{R_2}$

$I_5 + I_3 = I_g$

$I_1 + I_4 = I_g$

$\frac{2}{5} \cdot 20 - \frac{5}{20} \cdot 20 + 12 = I_N$

$I_4 + I_2 - I_5 = I_N$

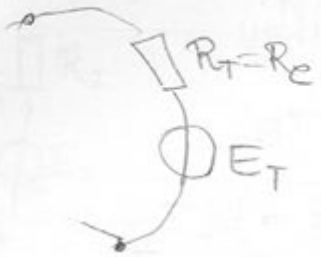
$R_1 I_1 - R_4 I_4 =$

$I_4 = \frac{R_1}{R_4} I_1$

$I_4 = \frac{R_4}{R_4 + R_1} I_g \quad I_5 = \frac{R_3}{R_3 + R_5} I_g$

ANALYSIS LABORATORY EQUIPMENT

141.



142

143

144

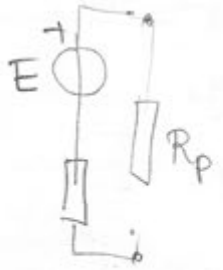
145.

$U_{ph} = 100V$

$I_{ks} = 0{,}4A$

R_p

P_{max} ?



$$I_{ks} = \frac{E}{R}$$

$$E = R \cdot I_{ks}$$

$$U_{ph} = E$$

$$R = \frac{U_{ph}}{I_{ks}}$$

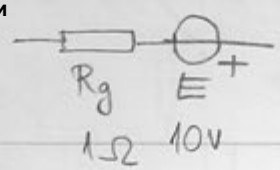
$$P = I^2 R_p = \left(\frac{E}{R+R_p}\right)^2 R_p =$$

$$= \frac{E^2}{(R+R_p)^2} R_p$$

$$P' = E^2 \frac{(R+R_p)^2 - R_p \cdot 2(R+R_p)}{(R+R_p)^4}$$

$$R + R_p = 2R_p \quad R_p = \frac{U_{ph}}{I_{ks}}$$

146



$R_p = 1\,\Omega$

$P = P_{max}$?

$P = I^2 R_p$

$I =$

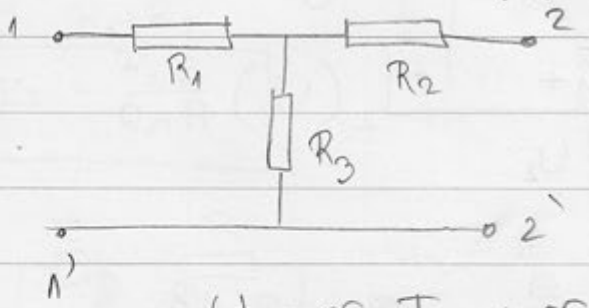
147.

$I_{AB} = I_{MN}$

Исто и за напоне и СГ

- сви делови пасивне мреже (отпорници) су линеарни
- важи за кола само са једним генератором

148



$r_{11} = 1\,k\Omega$

$r_{12} = r_{21} = 600\,\Omega$

$r_{22} = 800\,\Omega$

$U_1 = r_{11} I_1 + r_{12} I_2$

$U_2 = r_{21} I_1 + r_{22} I_2$

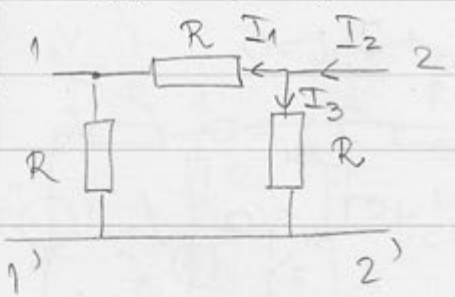
$r_{11} = \frac{U_1}{I_1}\Big|_{I_2=0}$

$r_{11} = R_1 + R_3$

$r_{12} = R_3 = r_{21}$ $\quad R_3 = 600\,\Omega$ ✓ $\quad R_1 = 400\,\Omega$

$r_{22} = R_2 + R_3$ $\quad R_2 = 200\,\Omega$ ✓

149



$R = 12\,k\Omega$

$r_{11} = \frac{2}{3}R = 8\,k\Omega$ ✓

$r_{12} = \frac{1}{3}R = r_{21} = 4\,k\Omega$ ✓

$r_{22} = \frac{2}{3}R = 8\,k\Omega$ ✓

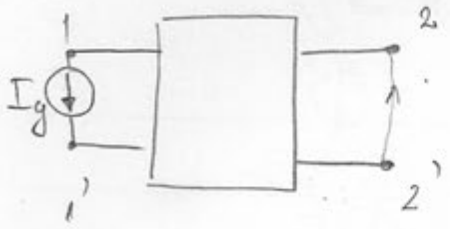
$I_1 = \frac{R}{3R} I_2 = \frac{1}{3} I_2$

$I_3 = \frac{2R}{3R} I_2$

$U_1 = \frac{1}{3} R I_2$

ANALYSIS
LABORATORY EQUIPMENT

150. g_{11}, $g_{12}=g_{21}$ и g_{22}

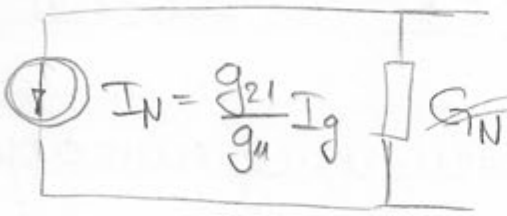


$$I_1 = g_{11}U_1 + g_{12}U_2$$
$$I_2 = g_{21}U_1 + g_{22}U_2$$

$$I_g = g_{11}U_1 + g_{12}U_2 \to 0$$

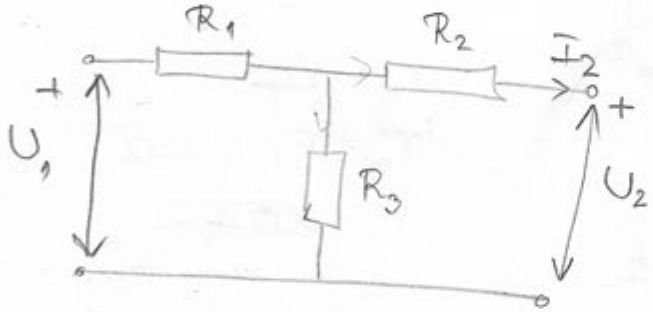
$$\Downarrow$$

$$U_1 = \frac{I_g}{g_{11}} \Rightarrow I_2 = \frac{g_{21}}{g_{11}}I_g$$



$$G_N = \frac{g_{11}g_{22} - g_{12}g_{21}}{g_{11}}$$

151.

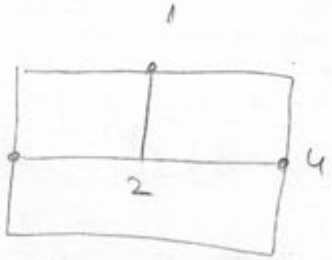


$I_2(U_2)$?

$R_1 + R_3 \| R_2$

$$I_1 = g_{11}U_1 + g_{12}U_2$$
$$I_2 = g_{21}U_1 + g_{22}U_2$$

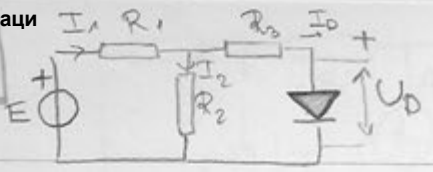
152



$$I_{12} + I_{13} + I_{14} = 0 \quad /\cdot V_1$$
$$-I_{12} + I_{23} + I_{24} = 0 \quad /\cdot V_2$$
$$-I_{13} - I_{23} + I_{34} = 0 \quad /\cdot V_3$$
$$-I_{14} - I_{24} - I_{34} = 0 \quad /\cdot V_4$$

$$(V_1 - V_2)I_{12} + (V_1 - V_3)I_{13} + (V_1 - V_4)I_{14} + (V_2 - V_3)I_{23} +$$
$$+ (V_2 - V_4)I_{24} + (V_3 - V_4)I_{34} = 0$$

153.



$$I_D = (R_2 I_2 - U_D)\frac{1}{R_3}$$

$$E - R_1 I_1 - R_2 I_2 = 0 \qquad I_1 = \frac{1}{R_1}(E - R_2 I_2)$$

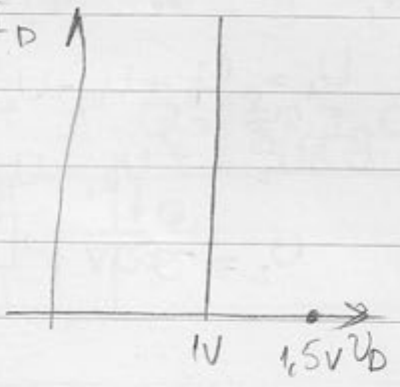
$$I_1 = I_2 + I_D \qquad I_2 = \frac{1}{R_1}(E - R_2 I_2) - I_D$$

$$-R_3 I_D - U_D + R_2 I_2 = 0 \qquad I_2 R_1 = E - R_2 I_2 - I_D R_1$$

$$I_2(R_1 + R_2) = E - I_D R_1$$

$$I_D R_3 = \frac{R_2}{R_1 + R_2} E - \frac{R_1 R_2}{R_1 + R_2} I_D - U_D$$

$$R_T = \frac{R_1 R_2}{R_1 + R_2} + R_3$$

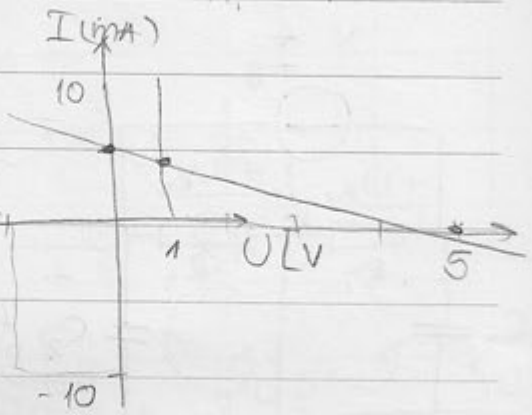


$$E_T = 1{,}5\,V$$

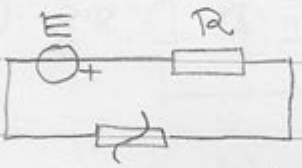
$$I_{ks} = 9{,}75\,mA$$

$$U = \frac{R_2 E}{R_1 + R_2}$$

$$E_T = \frac{R_2 E}{R_1 + R_2}$$



154.



$$U_{p.h} = E$$

$$I_{ks} = \frac{E}{R}$$

$$I = aU + b$$

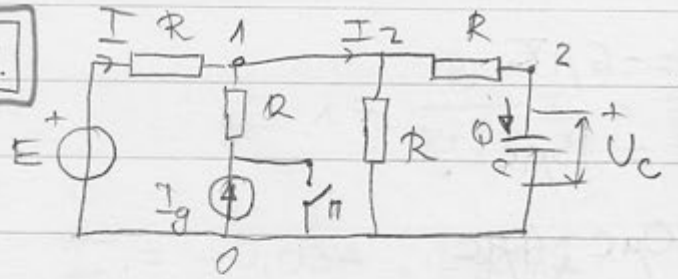
$$b = 5\,mA$$

$$0 = a \cdot 5V + 5\,mA \qquad I = -1\Omega \cdot U + 5\,mA$$

$$a = -1\Omega$$

$$I_T = 4\,mA$$

155.



ΔW_C?

$$E - RI - U_C = 0$$

$$U_C = E - RI = 10V$$

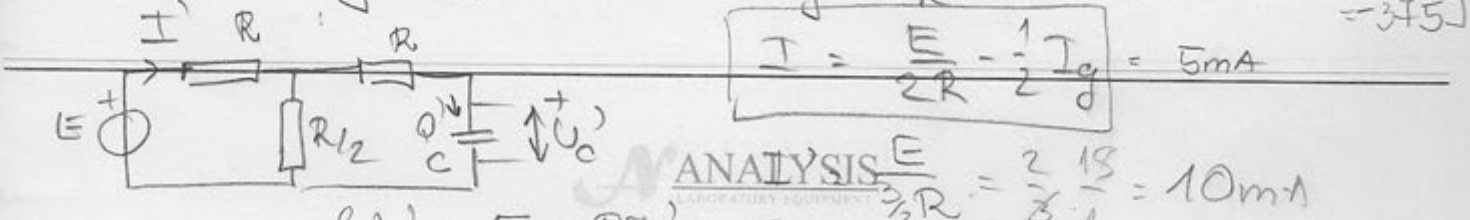
$$W_{C1} = \frac{1}{2} C U^2 \Rightarrow$$

$$\frac{1}{2} 10\,(100 - 25) = 5 \cdot 75 = 375$$

$$E - RI - RI_2 = 0 \qquad I + I_2 = \frac{E}{R}$$

$$I + I_g = I_2 \qquad I + I_g = \frac{E}{R} - I$$

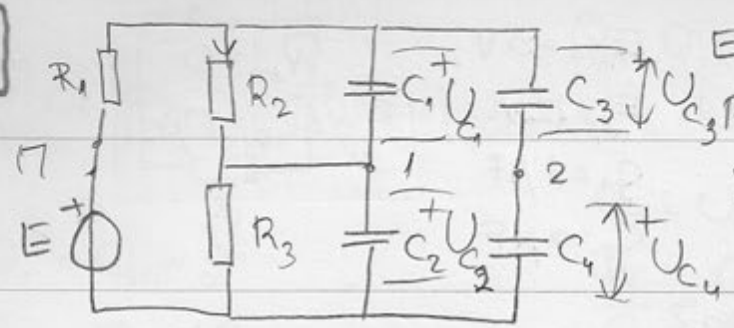
$$I = \frac{E}{2R} - \frac{1}{2} I_g = 5\,mA$$



$$\frac{E}{\frac{3}{2}R} = \frac{2}{3} \cdot \frac{15}{1} = 10\,mA$$

ANALYSIS LABORATORY EQUIPMENT

159



$E = 200V$

$R_1 = 1 M\Omega$

$R_2 = 0{,}4 M\Omega$

$R_3 = 0{,}6 M\Omega$

$C_1 = 6\mu F \quad C_3 = C_4 = 5\mu F$

$C_2 = 4\mu F$

U_{12} ?

$$I = \frac{E}{R_1+R_2+R_3} = \frac{200}{2 \cdot 10^6} = 100\mu A = 0{,}1\,mA$$

$U_{C_1} = U_{R_2} = I R_2 = 40V$

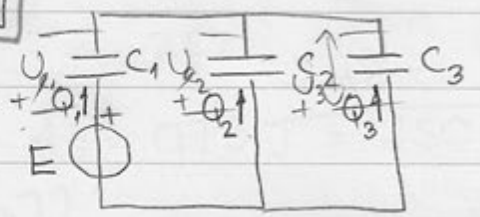
$U_{C_2} = U_{R_3} = I R_3 = 60V$

$U_{C_3} + U_{C_4} = U_{C_1} + U_{C_2} \qquad U_{C_3} = U_{C_4}$

$$U_{C_3} = U_{C_4} = \frac{1}{2}(U_{C_1} + U_{C_2}) = 50V$$

$U_{12} = -U_{C_1} + U_{C_3} = +10V$

160



$E = 2V$

$C_1 = 3\mu F \quad C_2 = 2\mu F \quad C_3 = 1\mu F$

Q_1, Q_2, Q_3 ?

$E - U_1 + U_2 = 0$

$E - U_1 + U_3 = 0$

$U_2 = U_3$

$U_1 = E + U_2$

$-Q_1 - Q_2 - Q_3 = 0 \qquad Q_1 = -(Q_2 + Q_3)$

$U_i = \frac{Q_i}{C_i}$

$$\frac{Q_2}{C_2} = \frac{Q_3}{C_3} \qquad Q_3 = \frac{C_3}{C_2} Q_2 = \frac{1}{2} Q_2$$

$$Q1 = -\frac{3}{2} Q_2$$

$$E = -\frac{\frac{3}{2}Q_2}{C_1} - \frac{Q_2}{C_2}$$

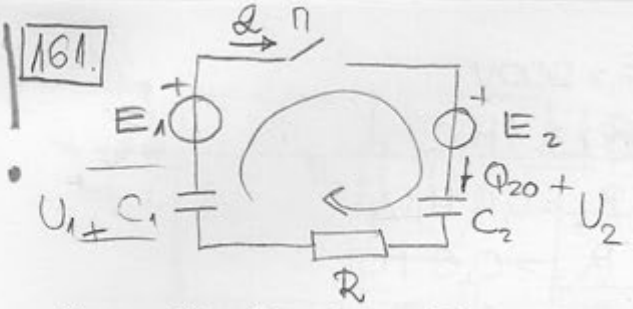
$$E C_1 C_2 = \left(-\frac{3}{2}C_2 + C_1\right) Q_2$$

$$Q_2 = \frac{E C_1 C_2}{-\frac{3}{2}C_2 - C_1} = \frac{3 \cdot 2 \cdot 2}{-3-3} = -2\mu C$$

$Q_3 = -1\mu C \qquad Q_1 = 3\mu C$

ANALYSIS
LABORATORY EQUIPMENT

161.



$E_1 = 5V$ $\quad Q_{10} = 0$

$E_2 = 12V$ $\quad Q_{20} = 10\mu C$

$C_1 = 1\mu F$

$C_2 = 2\mu F$

A → R преласног режима?

$W_{C_{10}} = 0$

$W_{C_{20}} = \frac{1}{2}\frac{Q_{20}^2}{C_2} = \frac{100\,\mu^2}{2 \cdot 1\mu} = 25\mu J$

П:

$E_1 - E_2 - U_2 + U_1 = 0$

$E_1 - E_2 - \frac{Q_2}{C_2} - \frac{Q_1}{C_1} = 0$

$Q_1 = Q$

$Q_2 = Q_{20} + Q$

$E_1 - E_2 = \frac{Q_{20}}{C_2} + Q\frac{C_1 + C_2}{C_1 C_2}$

$\left(E_1 - E_2 - \frac{Q_{20}}{C_2}\right)\frac{C_1 C_2}{C_1 + C_2} = Q \quad \boxed{Q = -8\mu C}$

$Q_1 = -8\mu C$

$Q_2 = 2\mu C$

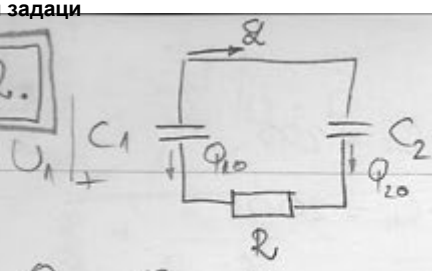
$W_e = \frac{Q_1^2}{2C_1} + \frac{Q_2^2}{2C_2} = 33\mu J$

$A_g = \Delta W_e + A_J$

$A_g = E_1 Q - E_2 Q = 56\mu J$

$A_J = 48\mu J$

162.



$Q_{10} = Q_{20} = 3mC$ $C_1 = 1\mu F$

$R = 1k\Omega$ $C_2 = 2\mu F$

$U_1 = U_2$

$Q_1 = Q_{10} - q$

$Q_2 = Q_{20} + q$

$\frac{Q_1}{C_1} = \frac{Q_2}{C_2}$

$$\frac{Q_{10}}{C_1} - \frac{q}{C_1} = \frac{Q_{20}}{C_2} + \frac{q}{C_2}$$

$$\frac{Q_{10}}{C_1} - \frac{Q_{20}}{C_2} = q\,\frac{C_1 + C_2}{C_1 C_2}$$

$$q = \frac{2}{3} \cdot 0{,}5 = 1\,mC$$

$$We_1 = \frac{Q_{10}^2}{2C_1} + \frac{Q_{20}^2}{2C_2} = 9\,\frac{3}{4} = 6{,}75\,J$$

$$We_2 = \frac{Q_1^2}{2C_1} + \frac{Q_2^2}{2C_2} = \frac{1}{2}\left(\frac{4}{1} + \frac{16}{2}8\right) = 6\,J$$

$A_J = 0{,}75\,J = 750\,mJ$

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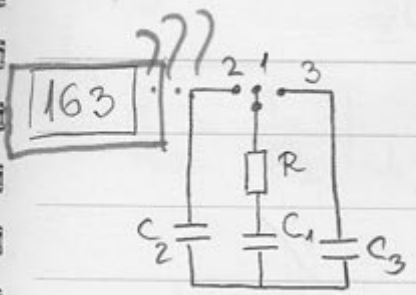


$C_1 = C_2 = C_3 = 10\mu F = C$

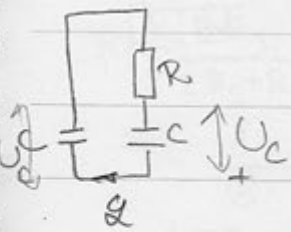
$R = 1k\Omega$

1: $We_1 = 200\,mJ$ $We_{C_2} = 0 = We_{C_3}$

2, 3 A_J?

$200 \cdot 10^{-3} \cdot 2 \cdot 10 \cdot 10^{-6} = 2C$

$We_{C_1} = \frac{Q_{10}^2}{2C}$ $Q_{10} = \pm\sqrt{We_1 \cdot 2C} = \pm 2C$

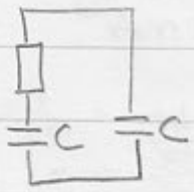


$Q_{10} - q = q$

$q = \frac{1}{2}Q_{10} = 1C$

$We_2 = 7\frac{q^2}{2C} = \frac{1}{10} = 0{,}1\,J = 100\,mJ$

$A_{12} = 100\,mJ$



$q = 0{,}5C$ $We = 2 \cdot \frac{0{,}25}{10} = 0{,}025\,J = 25\,mJ$

$A_{23} = 25\,mJ$ $A = 125\,mJ$

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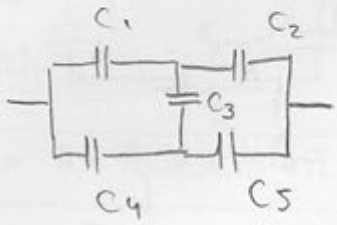


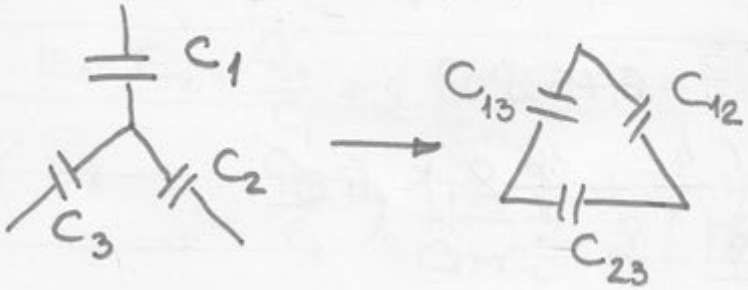
$C_1 = 5nF$
$C_2 = 10nF$
$C_3 = 15nF$
$C_4 = 20nF$
$C_5 = 40nF$

$C_1 \cdot C_5 = 200$
$C_2 \cdot C_4 = 200$

$$\frac{1}{\frac{1}{C_1}+\frac{1}{C_2}} + \frac{1}{\frac{1}{C_4}+\frac{1}{C_5}} = C_e$$

$$C_e = \frac{C_1C_2}{C_2+C_1} + \frac{C_4C_5}{C_4+C_5} = \frac{10}{\frac{5/6}{1/5}} + \frac{40}{\frac{80/3}{3}} = \frac{50}{3}\,nF$$

$C_e = 16{,}67\,nF$



$$C_1 = C_{12} + C_{13} + \frac{C_{12}C_{13}}{C_{23}} \qquad C_{12} = \frac{C_1C_2}{C_1+C_2+C_3}$$

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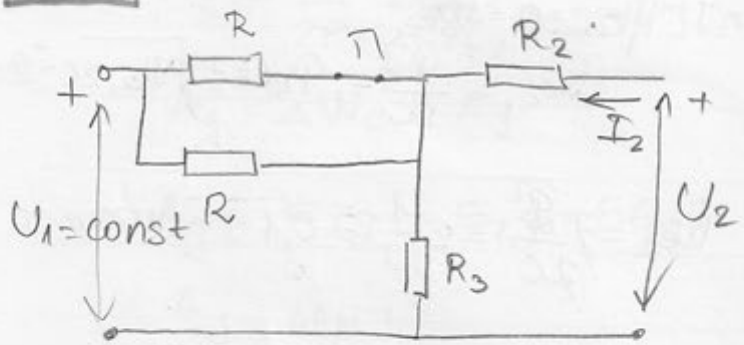
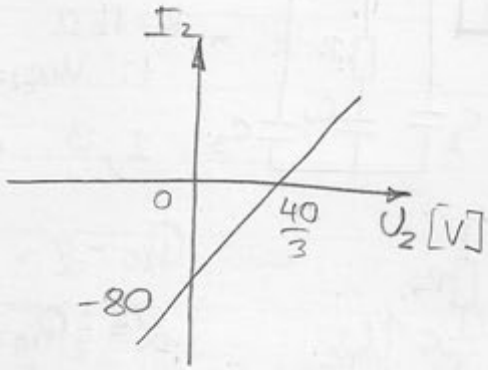




$R_2 = 100\,\Omega$
$R_3 = 200\,\Omega$
$I_2(U_2)$ $\Pi \to \emptyset$

$$I_1 = g_{11}U_1 + g_{12}U_2$$
$$I_2 = g_{21}U_1 + g_{22}U_2$$

$g_{21}U_1 = -80mA \qquad g_{22} = 6mS$

$I_2 = aU_2 + b$

$b = -80\,mA$

$$\frac{80ma}{a} = \frac{40}{3}$$

$a = 6mS$

$$g_{11} = \frac{I_1}{U_1}\Big|_{U_2=0}$$

$$g_{11} = \frac{1}{\frac{R}{2} + \frac{R_2 R_3}{R_2+R_3}}$$

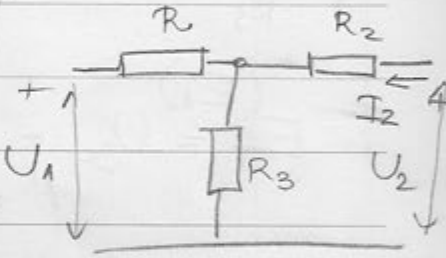
$$g_{12} = \frac{I_1}{U_2}\Big|_{U_1=0} \qquad g_{12} = \frac{1}{R_2 + \frac{R R_3}{2R_3+R}}$$

$$R_2 + \frac{\frac{R}{2}R_3}{\frac{R}{2}+R_3} = R_2 + \frac{RR_3}{2R_3+R}$$

$$g_{21} = \frac{I_2}{U_1}\Big|_{U_2=0} \qquad U_1 = I\left(\frac{R}{2} + \frac{R_2 R_3}{R_2+R_3}\right)$$

$$\frac{I_2}{U_1} = \frac{-I\frac{R_3}{R_2+R_3}}{I\left(\frac{R}{2}+\frac{R_2+R_3}{R_2+R_3}\right)} = \qquad I_2 = -I\cdot\frac{R_3}{R_2+R_3}$$

$$= -\frac{R_3}{\frac{R}{2}(R_2+R_3)+R_2R_3} = -\frac{1}{\frac{R}{2}\left(\frac{R_2+1}{R_3}\right)+R_2}$$



$$g_{21} = -\frac{R_3}{\frac{R}{2}(R_2+R_3)+R_2R_3} = g_{12}$$

$$g_{22} = \frac{I_2}{U_2}\Big|_{U_1=0} \qquad g_{22} = \frac{1}{R_2 + \frac{RR_3}{2R_3+R}}$$

$$I_2 = g_{21}U_1 + g_{22}U_2$$

$$g_{22} = \frac{I_2}{U_2}\Big|_{U_1=0}$$

$$g_{22} = \frac{1}{R_2 + \frac{RR_3}{R+R_3}} =$$

$$\frac{1}{R_2 + \frac{RR_3}{2R_3+R}} = 6\,mS$$

$$= \frac{1}{400 + \frac{200\cdot 200}{2\cdot 200}} =$$

$$\frac{1}{6}\cdot 10^3 = 100 + \frac{200\cdot R}{400+R} \quad / \cdot 400+R$$

$$= \boxed{\frac{1}{200}}$$

$$\frac{400}{6}\cdot 10^3 + \frac{1}{6}\cdot 10^3 R = 40000 + 100R + 200R$$

$$\boxed{R = 200\,\Omega}$$ ✓

$$g_{21} = g_{12} = -\frac{200}{100\cdot 300 + 20000}$$

$$\boxed{U_1 = 20V}$$

$$g_{21} = \frac{I_2}{U_1}\Big|_{U_2=0}$$

$$I = \frac{1}{R + \frac{R_2R_3}{R_2+R_3}}U_1$$

$$g_{12} = g_{21} = -\frac{R_3}{R(R_2+R_3)+R_2R_3}$$

$$I_2 = -\frac{R_3}{R_2+R_3}I$$

$$g_{12} = \frac{200}{100\cdot 300 + 20000} = \boxed{\frac{1}{400}}$$

$$\boxed{I_2 = \frac{1}{200}U_2 - 50mA}$$ ✓

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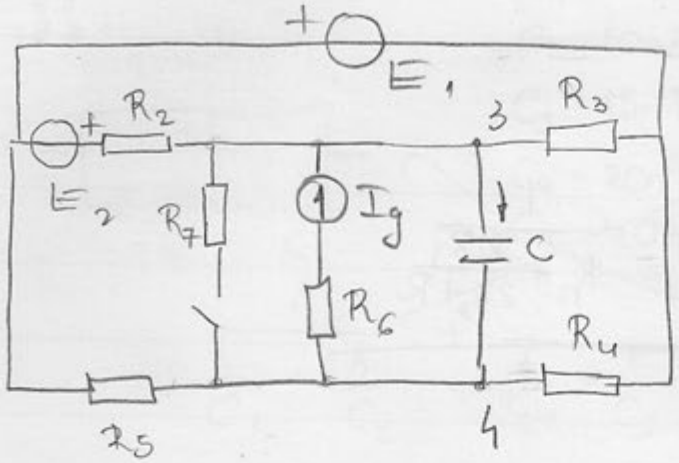


$E_1 = E_2 = 10V$

$I_g = 40mA$

$R_2 = R_3 = 500\Omega$

$R_4 = R_5 = 1k\Omega$

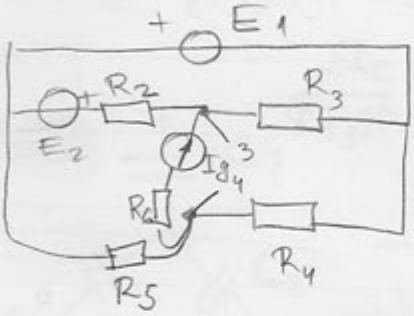
$R_6 = 250\Omega$

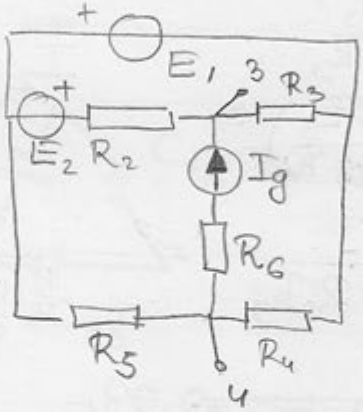
$C = 2\mu F$

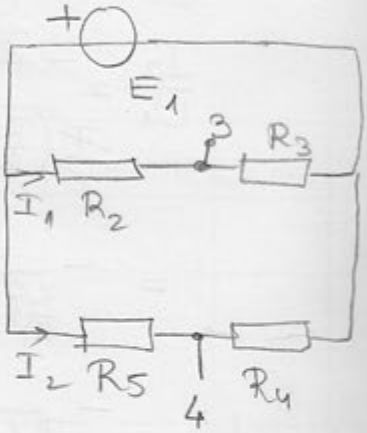
$q_{34} = -35\mu C$

R_T?

$$E_T = U_{34\,ph} = \left(-\frac{R_4}{R_4+R_5} + \frac{R_3}{R_2+R_3}\right)E_1 + R$$







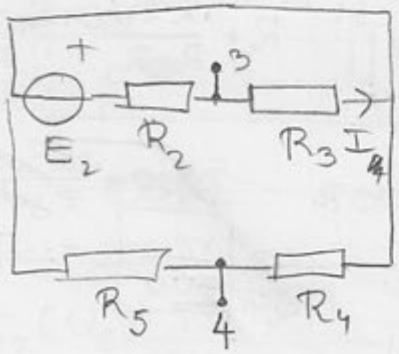
$$E_T = U_{34} = \overset{(E_1)}{}$$

$$= \sum_{4\to 3} E_i - RI =$$

$$= -R_4\frac{E_1}{R_4+R_5} + \frac{R_3 E_1}{R_2+R_3}$$

$$I = \frac{E_1}{\frac{(R_2+R_3)(R_5+R_4)}{R_2+R_3+R_4+R_5}}$$

$$I = \frac{R_2+R_3+R_4+R_5}{(R_2+R_3)(R_4+R_5)}E_1$$

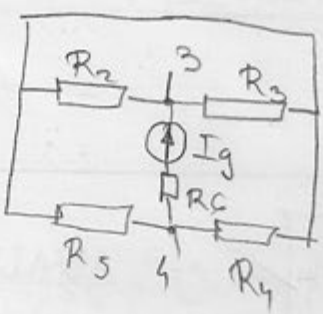


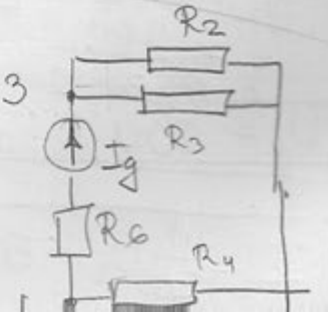
$$I_1 = \frac{R_4+R_5}{\sum R}E_1 = \frac{E_1}{R_2+R_3}$$

$$I_2 = \frac{E_1}{R_4+R_5}$$

$$I = \frac{E_2}{R_2+R_3}$$

$$E_T(E_2) = \frac{R_3}{R_2+R_3}$$

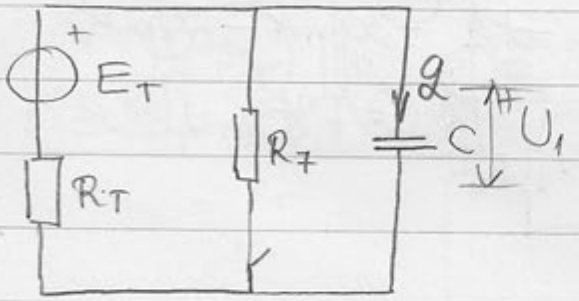




$\frac{R_2R_3}{R_2+R_3} + \frac{R_4R_5}{R_5+R_4}$ $E_T(I_g) = \left(\frac{R_2R_3}{R_2+R_3} + \frac{R_4R_5}{R_4+R_5}\right) I_g$

$E_T = 35\,V$

$R_T = \frac{R_2R_3}{R_2+R_3} + \frac{R_4+R_5}{R_4+R_5}$ 1 2



$U_1 = E_T$ $Q_0 = CU_1 = CE_T$

$\Pi \to 1: I = \frac{E_T}{R_7+R_T}$

$U_2 = U_7 = \frac{R_7}{R_7+R_T} E_T$

$Q_0 = \frac{R_7 E_I C}{R_7 R_T}$

$C E_T + Q = \frac{R_7}{R_7+R_T} E_T C$

$R_7 + R_T + \frac{Q}{E_T C} R_7 + \frac{Q}{E_T C} R_T = R_7$

$R_7 = -\frac{E_T C}{Q} R_T - R_T$

???

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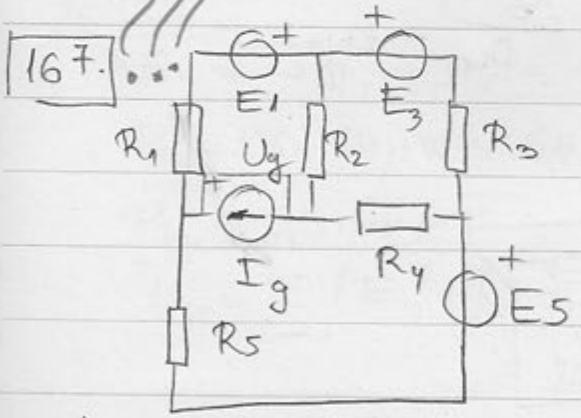


$E_1 = 100mV$ $E_3 = 200mV$

$E_5 = 400mV$ $I_g = 2mA$

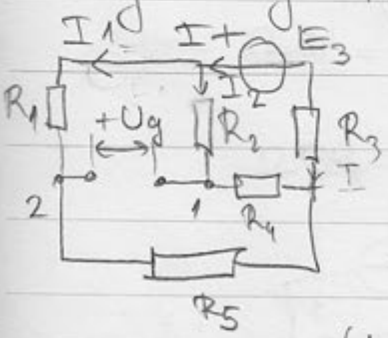
$R_1 = 50\Omega$ $R_2 = 60\Omega$ $R_3 = R_5 = 100\Omega$

$R_4 = 40\Omega$ P_{I_g} ?

$U_{12} = R_1 I_1 - R_2 I_2$

$= -10mV$

$U_g = U_g(E_1) + U_g(E_3) + U_g(E_5) + U_g(I_g) =$



$I = \frac{E_1}{R_1 + R_5 + \frac{R_3(R_2+R_4)}{R_3+R_2+R_4}} = \frac{100\,mV}{50+100+\frac{100\cdot 100}{200}} \cdot \frac{50}{} = 0{,}5\,mA$

$I_2 = \frac{R_3}{R_3+R_2+R_4} I = \frac{100}{200} I = 0{,}25\,mA$

$U_{12} = \sum_{2\to 1} (E_1 - RI) = I R_5 + I_2 R_4 = 50mV + 10mV$

$U_{12} = 60mV$

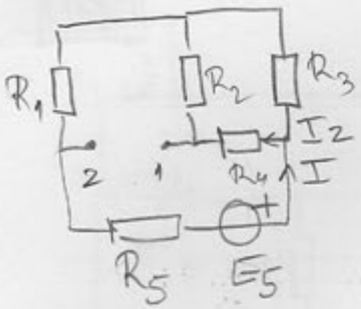
$I = \frac{E_1}{\frac{(R_1+R_5)(R_2+R_4)}{R_1+R_5+R_2+R_4} + R_3} = \frac{100mV}{\frac{150\cdot 100}{250} + 100} = 0{,}625\,mA$

$I_1 = \frac{R_2+R_4}{250} I =$

$= 0{,}25\,mA$

$I_2 = 0.375$

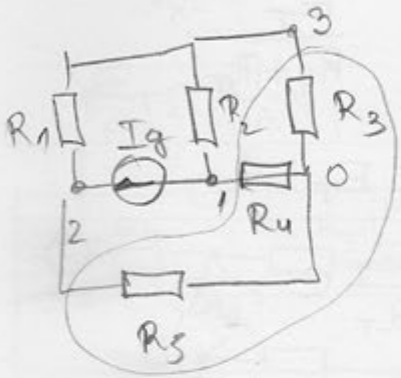
$-U_g = 60mV - 10mV - 80mV - 120mV =$
$= -150mV$

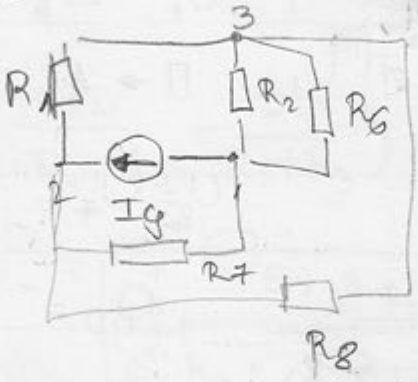


$$I = \frac{E_5}{R_1 + R_5 + \frac{R_3(R_2+R_4)}{R_2+R_4+R_3}} = \frac{E_5}{200} = 1mA$$

$$I_2 = \frac{R_3}{R_2+R_3+R_4} I = 0,5mA$$

$U_{12} = -R_2 I_2 + R_1 I = -30mA - 50mV =$
$= -80mV$



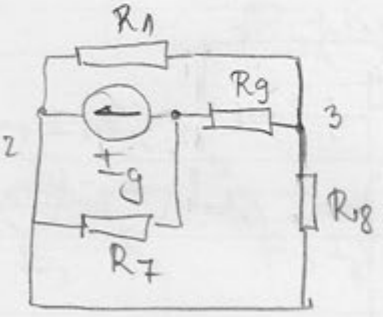


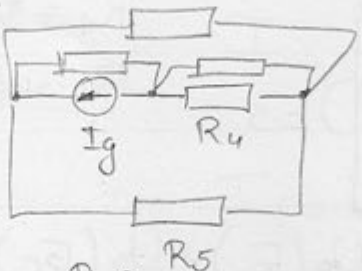
$$R_6 = R_4 + R_3 + \frac{R_4 R_3}{R_5} = 40 + 100 + \frac{40 \cdot 100}{100} = 180$$

$$R_7 = R_4 + R_5 + \frac{R_4 R_5}{R_3} = 100 + 40 + \frac{100 \cdot 40}{100} = 180$$

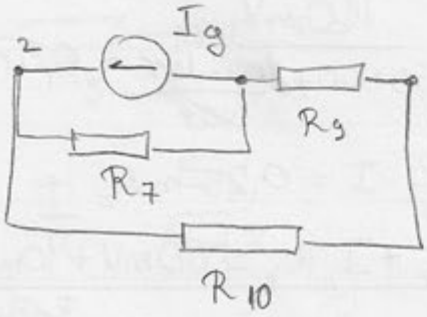
$$R_8 = R_3 + R_5 + \frac{R_5 R_3}{R_4} = 100 + 100 + \frac{10000}{40} = 450$$

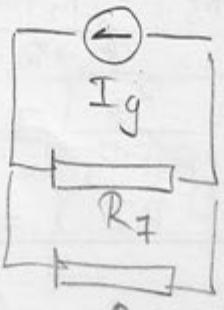
$$R_9 = \frac{R_2 R_6}{R_2 + R_6} = \frac{60 \cdot 180}{240} = 45\Omega$$





$$R_{10} = \frac{R_1 R_8}{R_1 + R_8} = \frac{50 \cdot 450}{500} = 45\Omega$$





$U_{12} = -RI_g$
$= -60 \cdot 2mA$
$= -60mV$

$$R = \frac{90 \cdot 180}{270} = 60\Omega$$

$U_g = 150\,mV$

$P = I_g U_g = 300\,\mu W$

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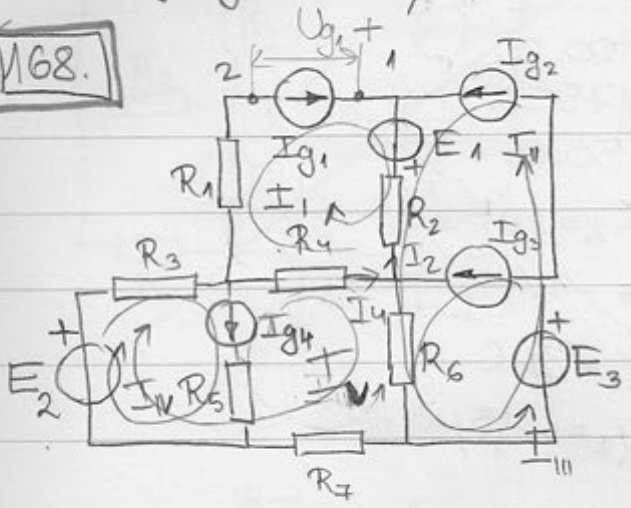

P_{R_4}, $P_{I_{g1}}$

$E_1 = 3V$ $\quad I_{g1} = 10mA$ $\quad R_1 = 200\Omega$

$E_2 = 5V$ $\quad I_{g2} = -5mA$ $\quad R_2 = 250\Omega$

$E_3 = 10V$ $\quad I_{g3} = 5mA$ $\quad R_3 = R_4 = 100\Omega$

$I_{g4} = 6mA$ $\quad R_5 = 25\Omega$

$R_6 = R_7 = 50\Omega$

$I_1 = I_{g1}$

$I_{II} = I_{g2}$

$I_{III} = I_{g3}$

$I_{IV} = I_{g4}$

$-R_4 I_1 + R_6 I_{II} + R_6 I_{III} + R_3 I_{IV} + (R_3 + R_4 + R_6 + R_7) I_V =$

$= E_2$

$-100 \cdot 10mA + 50 \cdot (-5mA) + 50 \cdot 5mA + 100 \cdot 6mA + (200\Omega + 100\Omega) \cdot I_V = 5$

$I_V = \frac{5 + 94}{300} = 18mA$

$I_4 = -I_1 + I_V = -10mA + 18mA = 8mA$

$P_{R_4} = 100 \cdot 64\,\mu W = 6{,}4\,mW$

$P_{I_{g1}} = -5{,}5\,mW$

$U_{12} = \sum_{2 \to 1} (E_i - RI) = R_1 I_{g1} - R_4 I_4 + (I_{g1} + I_{g2}) R_2 - E_1 =$

$= 200 \cdot 10\,mA\Omega - 100 \cdot 8mA + 5 \cdot 250\,mA - 3 =$

$= 2 - 0{,}8 + 0{,}25 - 3 - 1 = -0{,}55V$

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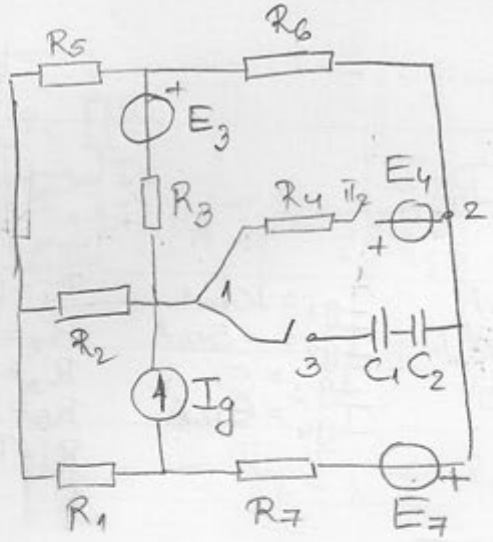
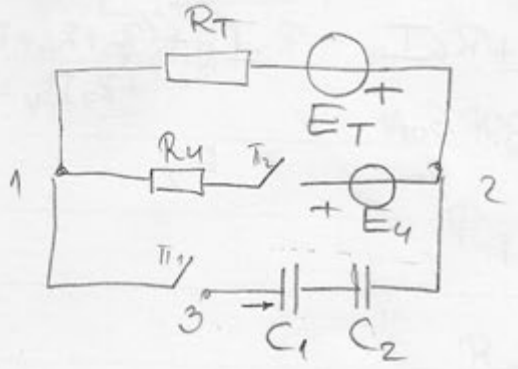


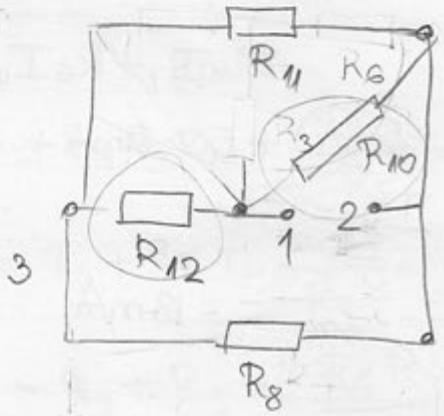
$E_3 = 4V$
$R_1 = R_6 = 100\Omega$
$R_2 = 350\Omega$
$R_3 = 700\Omega$
$R_5 = 175\Omega$
$R_7 = 50\Omega$
$C_1 = C_2 = 1\mu F = C$
$U_{32} = -1V$
$\Pi_1 \; Q_1 = 3\mu C$
$\Pi_2 \; Q_2 = -7{,}5\mu C$

P_4?
$\Pi 2 \to 1$

$U_{32} = U_{35} + U_{52} = 2U_{35} =$

$= 2\frac{Q}{C}$ $\qquad Q_0 = \frac{U_{32}C}{2} = -\frac{1 \cdot 1\mu F}{2} = -0{,}5\mu C$





$R_8 = 150\Omega$

$R_9 = R_3 + R_5 + \frac{R_3 R_5}{R_6}$

$R_9 = 2100\Omega$

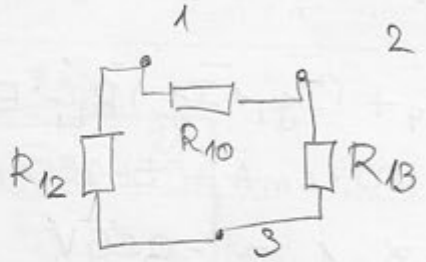
$R_{10} = R_3 + R_6 + \frac{R_3 R_6}{R_5} =$

$= 120\Omega$

$R_{12} = 300\Omega$

$R_{11} = 300\Omega$

$R_{13} = 100\Omega$



$R_T = 92{,}31\Omega$ $\qquad \lightning = 300\Omega$

$Q^{II1} = Q_1^{II1} = Q_2^{II1} = Q_0 + Q_1 = 2{,}5\mu C$

$Q^{II2} = Q_1^{II2} = Q_2^{II2} = Q^{II1} + Q_2 =$

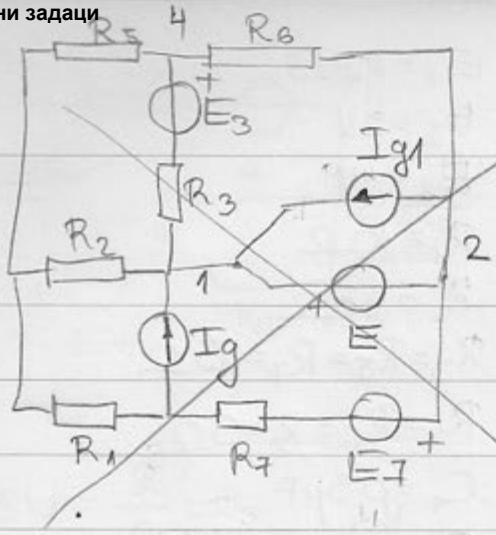
$= -5\mu C$

$U_{32} = 2\frac{Q^{II1}}{C} = 5V = U_{12}$

$U_{12} = -2 \cdot \frac{5\mu C}{1\mu F} = -10V$

$E_T = -5V$

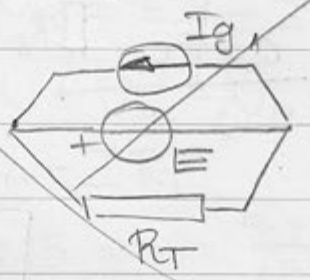
I_{12}

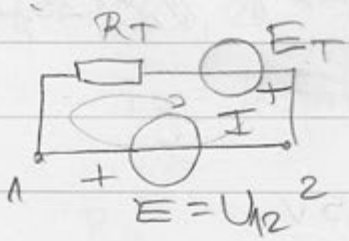


$I_{g1} = I_{g1}(\text{сви}, E)$

$I_{g1} = I_{g1}(\text{сви}) + I_{g1}(E)$

$\Delta I_{g1} = \Delta I_{g1}(E) = a \Delta E$



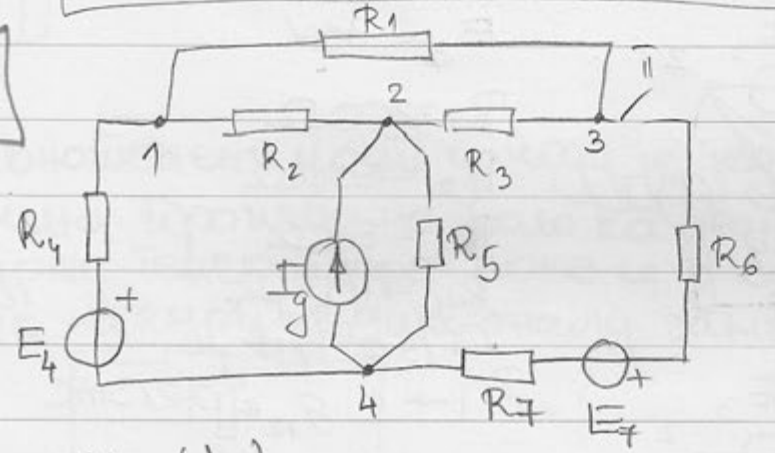


$-R_T I + E_T + E = 0$

$I = \frac{E_T + E}{R_T} = \frac{-5-10}{300} = -50\,mA$

$P = +50\,mA\,(-10\,V) = -0{,}5\,W$

170



$E_7 = 18V$

$I_g = 5mA$

$R_1 = R_6 = 2k\Omega$

$R_2 = 3k\Omega$

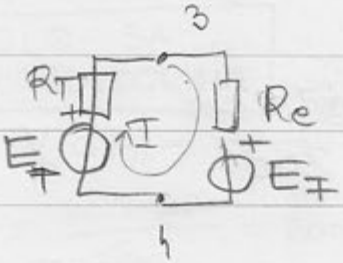
$R_3 = 5k\Omega$

$R_4 = 0{,}4k\Omega$

$R_5 = R_7 = 1{,}5k\Omega$

$U_{34} = 5V \quad U_{34}'$

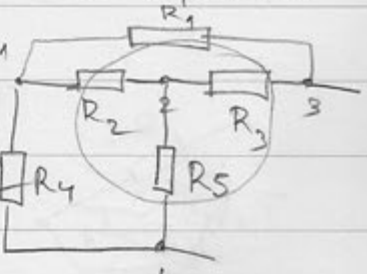
$II \to 1 \qquad II \to 0$



$R_T = 1{,}6\,\Omega$

$R_e = R_6 + R_7 =$

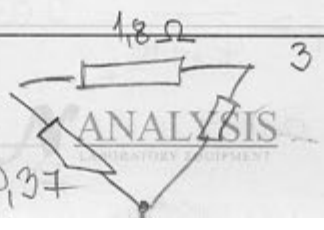
$= 3{,}5k\Omega$

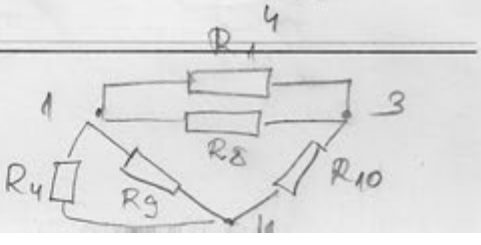


$E_7 = -2V$

$U_{34} = I R_e + E_7 \qquad I = -\frac{14}{3{,}5} = -4mA$

$U_{34} = E_T - I R_T$





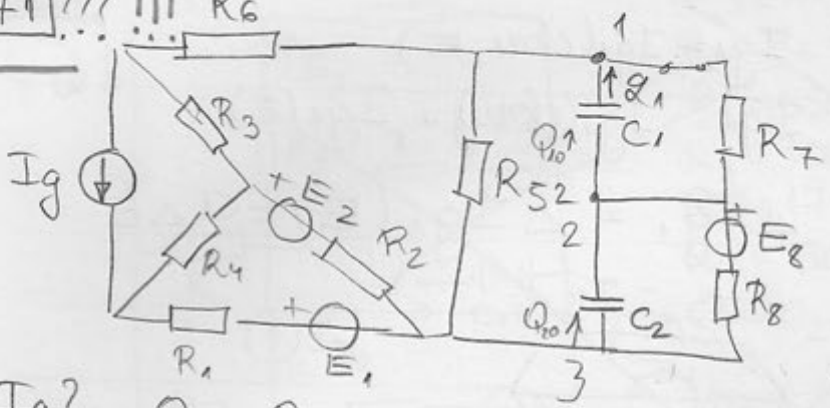
$R_8 = 18\Omega \quad R_{10} = 9\Omega$

$R_9 = 5{,}4\,\Omega$

$R_T = 1{,}75\Omega$ 0,37

ANALYSIS

171 ??? !!! R_6



I_g? Q_{20}, Q_2 ?

$E_1 = 12V$
$E_2 = 2V$
$E_8 = 4V$
$R_1 = 10\Omega$
$R_2 = 30\Omega$
$R_3 = R_5 = R_7 = 15\Omega$
$R_4 = R_6 = R_8 = 5\Omega$
$C_1 = 0{,}5\mu F$
$C_2 = 1{,}2\mu F$
$\Pi \to 1 \quad Q_1 = 1{,}25\mu C$

$Q_1 = Q_{10} + Q_1$

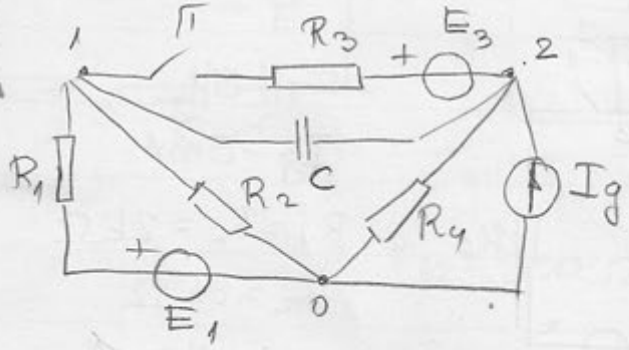
$Q_{10} = U_{21}^{(\sigma)} C_1$

$Q_1 = U_{21}^{(3)} C_1$

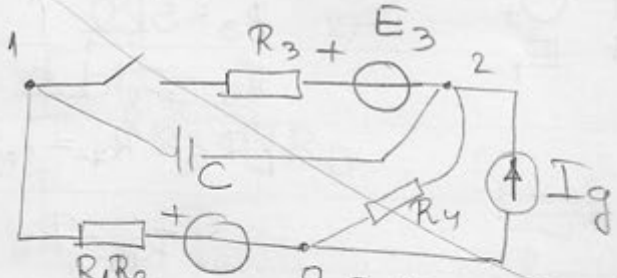
$Q_1 = (U_{21}^{(3)} - U_{21}^{(\sigma)}) C_1 \Rightarrow \Delta U_{21} = \frac{Q_1}{C_1} = 2{,}5\,V$

I_g

172

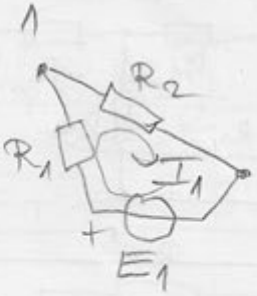


$E_1 = 50\,V$
$E_3 = 30V$
$R_1 = 200\Omega$
$R_2 = 500\Omega$
$R_3 = 3k\Omega$
$R_4 = 10k\Omega$
$C = 0{,}7\mu F$
$\Pi \to 1 \quad Q_{12} = 0{,}213mC$ I_g?



$E = \frac{R_2 E_1}{R_1 + R_2} = \frac{\cancel{50}^{25} \cdot \cancel{700}}{\cancel{200}} = 175\,V$

$R_T = 10{,}143\,k\Omega$ ✓

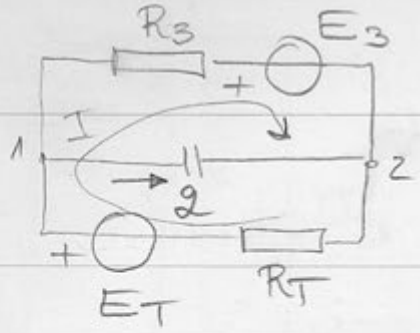


$I_1 = \frac{E_1}{R_1 + R_2} = 9{,}071\,A$

$U_{10} = R_2 I_1 = 35{,}71\,V$

$U_{02} = -I_g R_4$

$E_T = U_{12} = U_{10} + U_{02} =$



$$\frac{E_T - E_3}{R_3 + R_T} = I$$

$R_3 = 13{,}143\,k\Omega$

$$U_{12}' = E_T - I R_T$$

$$\Delta U = U_{12}' - U_{12} = E_T - I R_T - E_T = -I R_T$$

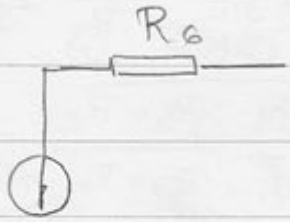
$$\Delta U = \frac{2}{C} =$$

$$304{,}285 = -\frac{E_T - E_3}{13{,}143\,k\Omega} \cdot 10{,}143\,k\Omega$$

$E_T = -364{,}28$

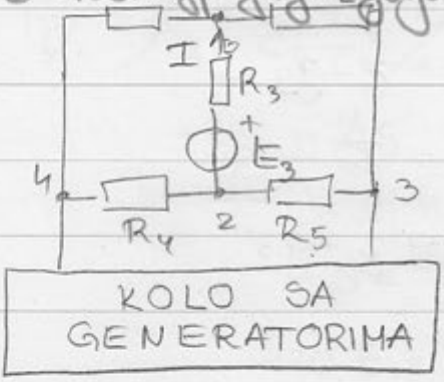
$I_g = 40\,mA$ (39,999 mA)

173.



Уравнотежени мост у чију је једну дијагоналу прикључено произвољно коло са једним паром крајева које садрже генераторе може се у односу на коло прикључено на другу дијагоналу заменити са $E_T = 0$ и R_T

174



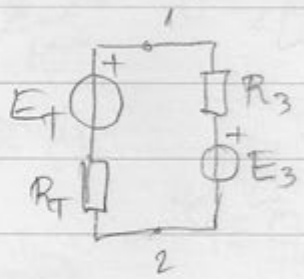
P_{E_3} ?

$E_3 = 10\,V$

$R_1 = R_5 = 200\,\Omega$

$R_2 = 100\,\Omega$ $R_3 = 300\,\Omega$

$R_4 = 400\,\Omega$



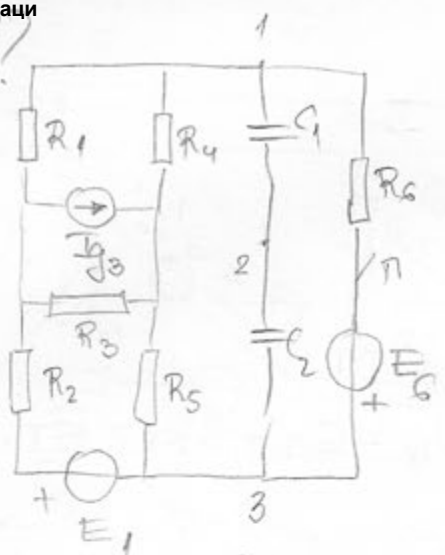
$$R_T = \frac{600 \cdot 200}{{}_3\cancel{900}} = 200\,\Omega$$

$P_{E_3} =$

ANALYSIS

175 !!!

Рачун



$E_6 = -15\,V$

$R_1 = R_2 = 150\,\Omega$

$R_3 = R_4 = R_5 = 50\,\Omega$

$C_1 = 9{,}5\,\mu F$

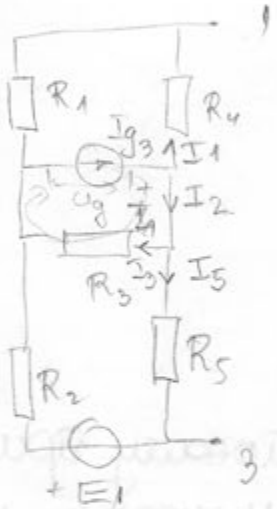
$C_2 = 1\,\mu F$

$\Pi \to 0$

$U_{32} = 15\,V$

$Q = 2{,}5\,\mu C$

Q_{10}? $\Pi \to 0$ E_1?



$U_{13} = U_{13}(I_{g_3}) + U_{13}(E_1)$

$U_{13}(I_{g_3}) = \frac{1}{6}(R_2 - R_1) I_{g_3}$

$-I_5 R_5 - I_5 R_2 + I_3 R_3 = 0$

$I_3 = \frac{R_2 + R_5}{R_3} I_5$

$U_g = I_5 R_3$

$U_g = R_1 I_1 + I_1 R_4$

$I_1 = \frac{R_2 + R_5}{R_1 + R_4} I_5$

$I_{g_3} = I_1 + I_3 + I_5$

$I_{g_3} = \frac{R_2 + R_5}{R_1 + R_4} I_5 + \frac{R_2 + R_5}{R_3} I_5 + I_5$

$U_{13} = -R_1 I_1 + R_2 I_5 =$

$= -\frac{R_1}{6} I_{g_3} + \frac{R_2}{6} I_{g_3} =$

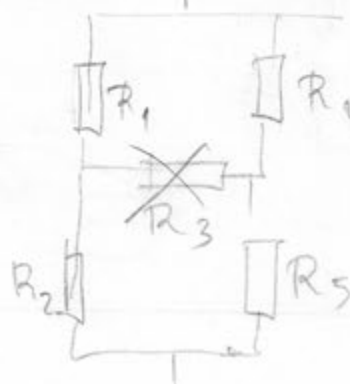
$= \frac{1}{6}(R_2 - R_1) I_{g_3} = 0$

$I_{g_3} = 6 I_5$ $I_5 = \frac{1}{6} I_{g_3}$

$I_1 = \frac{1}{6} I_{g_3}$

$I_3 = \frac{2}{3} I_{g_3}$

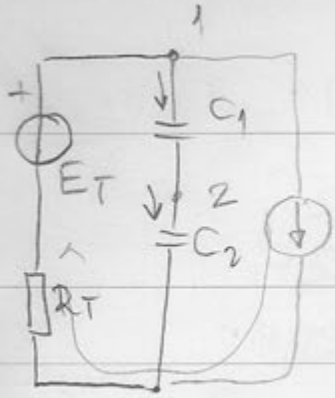
R_T



$R_1 R_5 = R_2 R_4$

$R_T = \frac{R_1 R_4}{R_1 + R_4} + \frac{R_2 R_5}{R_2 + R_5} =$

$= \frac{150 \cdot 50}{200} = 75\,\Omega$



$U_{13} = E_T = U_{12} + U_{23} = \frac{Q_{10}}{C_1} - U_{32}$

$U_{13}' = E_6 - R_6 \frac{E_6 + E_T}{R_T + R_6}$

$Q_{20} = \frac{-U_{32}}{C_2}$

$I_{g2} = \begin{cases} 0 \\ \frac{E_6 + E_T}{R_T + R_6} \end{cases}$

$U_{13}' = E_T - R_T \frac{E_6 + E_T}{R_T + R_6}$

$U_{13}' = \frac{Q_1}{C_1} - U_{32}' = \frac{Q_{10} + Q}{C_1} + \frac{Q_{20} + Q}{C_2}$

$\frac{Q_{10} + Q}{C_1} + \frac{U_{32}}{1} - \frac{Q}{C_2} = E_6 - \frac{R_6 E_6}{R_T + R_6} - \frac{R_6}{R_T + R_6}\left(\frac{Q_{10}}{C_1} - U_{32}\right)$

$\frac{Q_{10} - 2{,}5 \cdot 10^{-6}}{95 \cdot 10^{-6}} + \frac{15\,V}{1} + \frac{2{,}5 \cdot 10^{-6}}{1 \cdot 10^{-6}} = -15 + \frac{25}{70} \cdot 15 - \frac{25}{70}\left(\frac{Q_{10}}{95 \cdot 10^{-6}} + 15\right)$

$\frac{10\,Q_{10}}{9{,}5} 10^6 - 25 + 2{,}5 = 5{,}36 - 5{,}36 - \frac{5}{70} Q_{10} \cdot 10^6$

$2{,}07\, Q_{10} \cdot 10^5 = -22{,}5$

$Q_{10} = -10{,}87\ \mu C$

$\frac{Q_{10}}{C_1} + \frac{Q}{C_1} + \frac{Q}{C_2} + U_{32} = E_T - \frac{R_6 E_6}{R_T + R_6} - \frac{E_T R_6}{R_T + R_6}$

$-\frac{2{,}5}{0{,}5} - \frac{2{,}5}{1} = +\frac{25}{100} \cdot 15 - \frac{25}{100} \frac{Q_{10}}{0{,}5} \cdot 10^6 + \frac{25}{100} \cdot 15$

$-7{,}5 = \frac{50 \cdot 15}{70} - \frac{50}{70} Q_{10} \cdot 10^6 \quad / \frac{7}{5}$

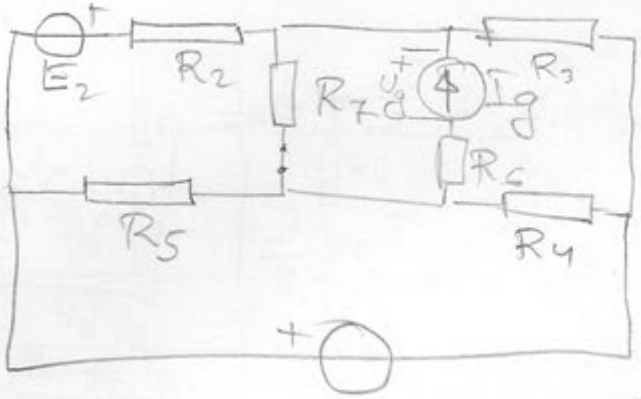
$-10{,}5 = 15 - Q_{10} \cdot 10^6$

$Q_{10} = 25{,}5\ 10^6\ \mu C$

$-7{,}5 = -750 + 750 - 0{,}5\, Q_{10}\, 10^6$

ANALYSIS

176.



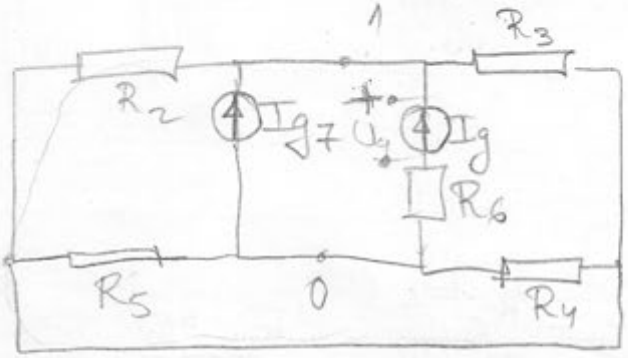
$E_2 = 10V$
$I_g = 40mA$
$R_2 = R_3 = 500\Omega$
$R_4 = R_5 = 1k\Omega$
$R_6 = 250\Omega$

E. $\Delta P_{I_g} = 0,7W$ $R7$?

$$U_g^3 = U_g(E_1) + U_g(I_{k4}^3) + U_g(E_2)$$
$$U_g^\circ = U_g(E_1) + U_g(I_{k0}^\circ) + U_g(E_2)$$
$$U_g^\circ = 0$$

$$\Delta U_g = U_g^\circ - U_g^3 = -U_g(I_{k7}^3)$$

$$\Delta P_{I_g} = P_{I_g}^\circ - P_{I_g}^3 = I_g(U_g^\circ - U_g^3) = I_g \Delta U_g$$



$$\Delta U_g = -U_g(I_{k7}^3) =$$
$$= -U_{10} =$$
$$= U_{01} = V_0 - V_1 =$$
$$= -0,4 I_{g7} + 13 \cdot 10^{-3}$$

1: $\left(\frac{1}{R_2} + \frac{1}{R_3}\right)V_1 - \left(\frac{1}{R_2}\frac{1}{R_3}\right)V_2 = I_{g7} + I_g$

2: $-\left(\frac{1}{R_2} + \frac{1}{R_3}\right)V_1 + \left(\frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_5} + \frac{1}{R_4}\right)V_2 = 0$

$\frac{0,7}{40} \cdot 10^{-3} = -0,4 I_{g7} + 13 \cdot 10^{-3}$

$2 \cdot \left(\frac{4+4+2}{1000\Omega}\right)V_2 = I_{g7} + 40mA$

$V_2 = \frac{I_{g7}}{10 \cdot 10^{-3}} + 4$

$10 \cdot 10^{-3} V_2 - 40 \cdot 10^{-3} = I_{g7}$

$4 \cdot 10^{-3} V_1 - 0,4 \cdot 10^{-3} \cdot \frac{I_{g7}}{10 \cdot 10^{-3}} - 16 \cdot 10^{-3} = I_{g7} + 40 \cdot 10^{-3}$

$4 V_1 = 1,6 \cdot I_{g7} + 52 \cdot 10^{-3}$

$-52 \cdot 10^{-3} = 1,6 I_{g7}$

$V_1 = 0,4 I_{g7} + 13 \cdot 10^{-3}$

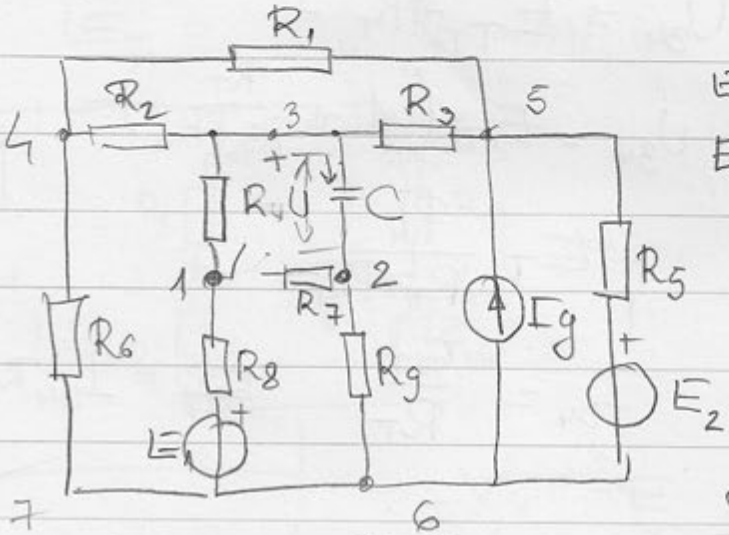
$V_1 = 0{,}4\, I_{g7} + 13 \cdot 10^{-3}$

$17{,}5 = -0{,}4\, I_{g7} + 13 \cdot 10^{-3}$

$-11{,}25\ \text{mA} = I_{g7}$

$V_1 = 8{,}5\ V$

177.



$E_1 = 20V$ $R_8 = 10\Omega$

$E_2 = 16V$ $C = 32\mu F$

$I_g = 1A$

$R_1 = 10\Omega$

$R_2 = 30\Omega$

$R_3 = 60\Omega$

$R_4 = R_6 = R_9 = 7{,}5\Omega$

$R_5 = 4\Omega$

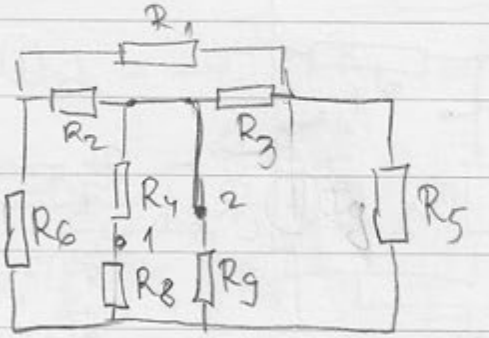
$\Delta W_e = -3{,}825\,mJ$ R_7?

$W_{c1} = \frac{Q_1^2}{2C} = \frac{1}{2} U_1^2 C$

$W_{c2} = \frac{1}{2} U_2^2 C$

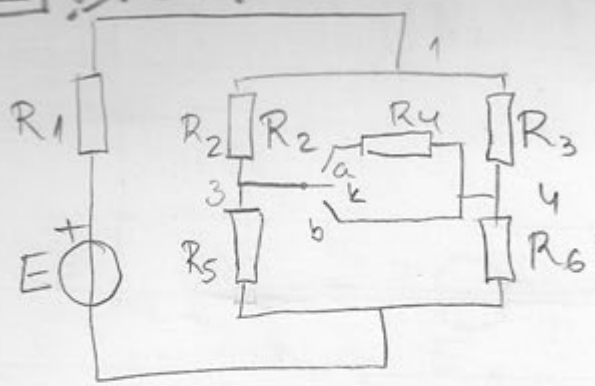
$\Delta W_e = W_{c2} - W_{c1} = \frac{1}{2} C (U_2^2 - U_1^2)$

$\frac{2\Delta W_e}{C} = U_2^2 - U_1^2$



$R_{13} = R_1 + R_3 + \frac{R_1 R_3}{R_5} = 10 + 60 + \frac{10 \cdot 60}{4}$

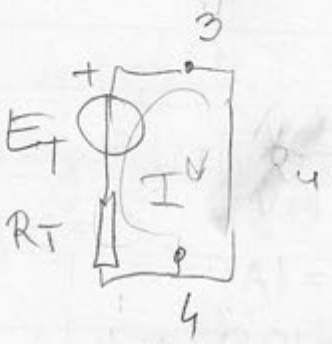
ANALYSIS
LABORATORY EQUIPMENT



$R_1 = 4\,k\Omega$
$R_2 = R_5 = 2\,k\Omega$
$R_3 = 1\,k\Omega$
$R_4 = 6\,k\Omega$

E ?
R_6 ?

a: $U_{34} = 3V$
b: $I_{34} = 2mA$



$$U_{34} = E_T - R_T I$$

$$U_{34} = E_T \left(1 - \frac{R_T}{R_T + R_4}\right) =$$

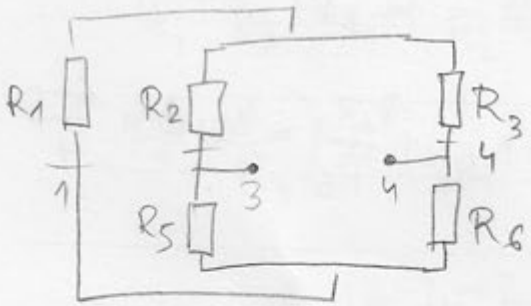
$$= E_T \frac{R_4}{R_T + R_4}$$

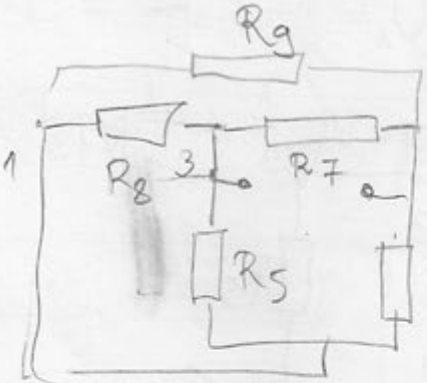
$$I = \frac{E_T}{R_T + R_4} \qquad I_{34} = \frac{E_I}{R_T} \qquad E_T = I_{34} R_T$$

$$U_{34} = I_{34} \frac{R_4 R_T}{R_T + R_4}$$

$$U_{34} R_T + U_{34} R_4 = I_{34} R_4 R_T$$

$$\frac{U_{34} R_4}{R_4 I_{34} - U_{34}} = R_T \qquad R_T = \frac{3 \cdot 6\,10^3}{3} = 2\,k\Omega$$

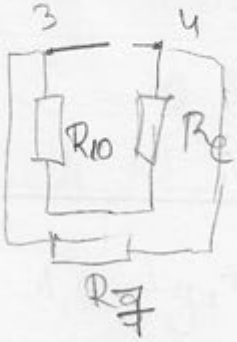




$$R_8 = R_1 + R_2 + \frac{R_1 R_2}{R_3}$$

$$= 6 + 8 = 14\,k\Omega$$

$R_7 = 3{,}5\,k\Omega$
$R_g = 7\,k\Omega$



$$R_{10} = \frac{R_8 R_5}{R_8 + R_5} = 1{,}75\,k\Omega$$

$$R_c = \frac{R_6 R_g}{R_6 + R_g} \qquad \frac{(R_c + R_{10}) R_7}{R_c + R_{10} + R_7} = R_T$$

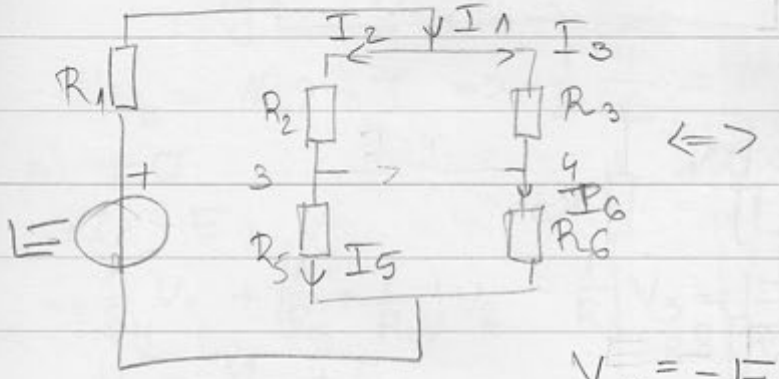
$$3{,}5R_e + 6{,}125 = 2R_e + 3{,}5 + 7$$

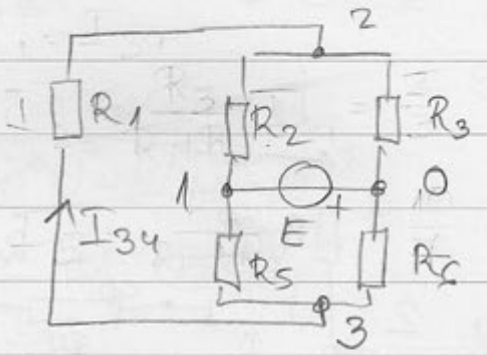
$$1{,}5R_e = 4{,}375$$

$$\frac{4{,}375}{1{,}5}R_6 + \frac{30{,}625}{1{,}5} = 7 \cdot R_6$$

$$\boxed{R_6 = 5\,k\Omega}$$

$$E_T = I_{34} \cdot R_T = 4V$$





$$V_1 = -E$$

$$-\frac{1}{R_2}V_1 + \left(\frac{1}{R_2} + \frac{1}{R_3}\right)V_2 - \left(0 \cdot V_3 = I_{34}\right.$$

$$-\left(\frac{1}{R_5} + \frac{1}{R_6}\right)V_1 + \left(\frac{1}{R_5} + \frac{1}{R_6}\right)V_3 = -I_{34}$$

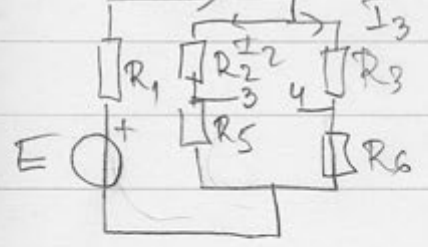
$$V_2 = \frac{R_2R_3}{R_2+R_3}\left(I_{34} - \frac{E}{R_2}\right)$$

$$V_3 = \frac{R_5R_6}{R_5+R_6}\left(\frac{R_3+R_6}{R_5R_6}V_1 - I_{34}\right) = -E - \frac{2.5}{7}I_{34}$$

$$U_{23} = -I_{34}R_1 = V_2 - V_3$$

$$-8 = \frac{4}{3}\quad \frac{2}{3}E \quad + \frac{20}{7}$$

8 V



$$I_2 = \frac{R_3+R_6}{R_2+R_3+R_5+R_6}I_1 = \frac{1+5}{6+4}I_1 = 0{,}6I_1$$

$$E - R_1I_1 - (R_2+R_5)I_2 = 0$$

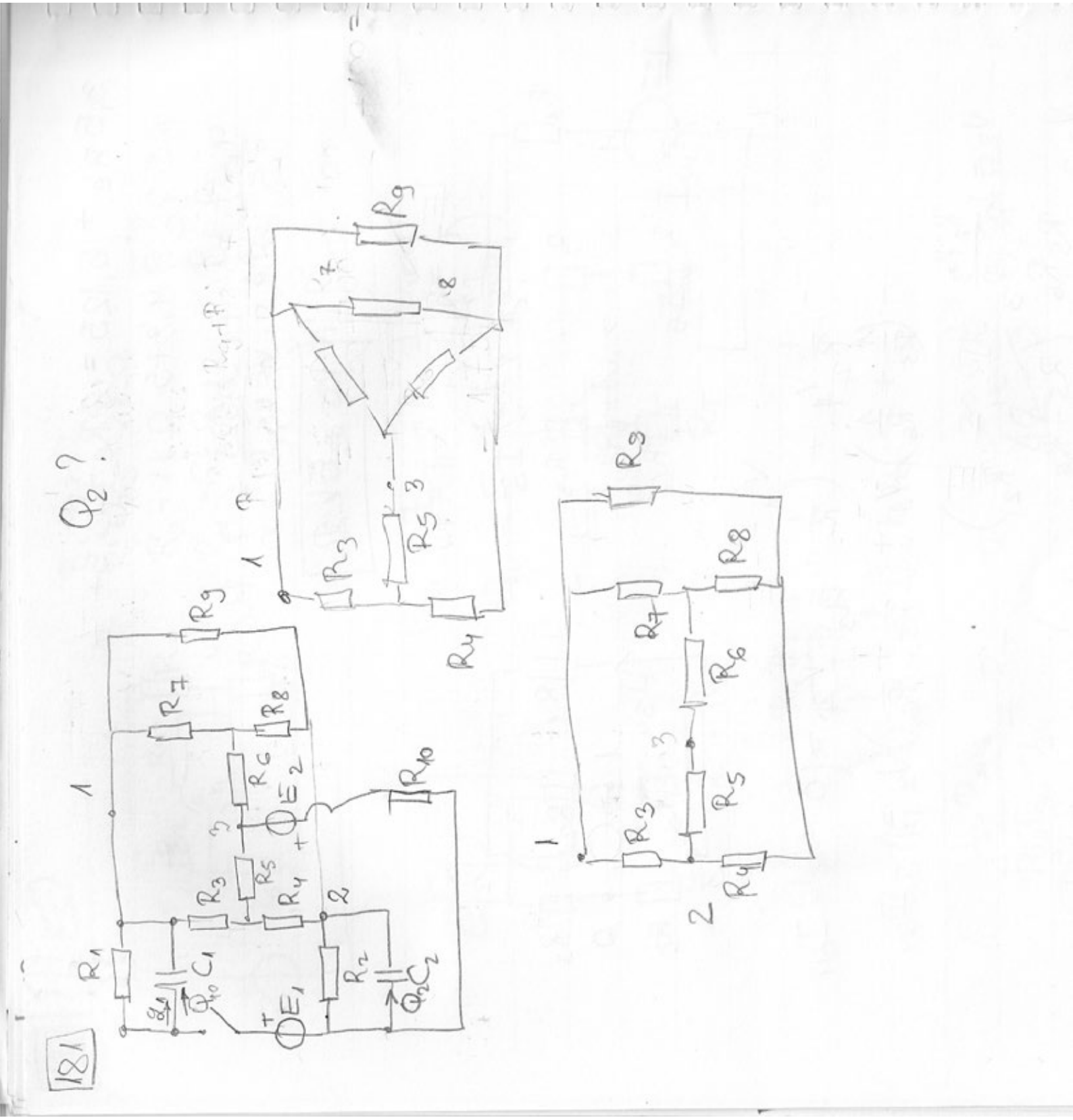
E_T

$$E = 6{,}4I_1 \qquad I_1 = \frac{E}{6{,}4} \qquad I_3 = 0{,}4I_1$$

U''_{34}

$$U_{34} = -R_6I_3 + I_2R_5 = -2I_1 + 1{,}2I_1 = -0{,}8 \cdot \frac{E}{6{,}4} \qquad E = 8 \cdot 4 = 32V$$

ANALYSIS


Q2?
R9
R7
R8
R6
R10
R3
R5
R4
R1
R2
C1
C2
E1
E2
1
2
3

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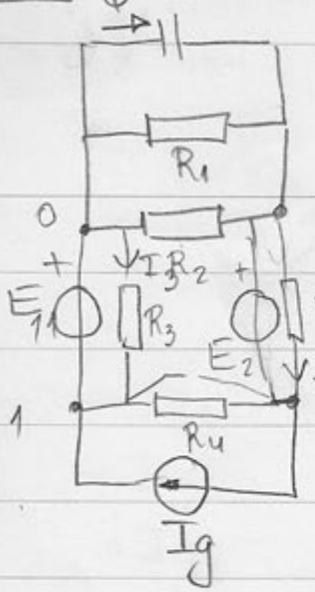

$E_1 = 10V$
$E_2 = 20V$
$I_g = 0,5A$
$R_1 = 200\Omega$
$R_2 = 300\Omega$
$R_3 = 100\Omega$

$\Pi \to 3$ $V_1 = -E_1$

$V_2 = V_1$

$V_3 = V_2 + E_2$

$U_{03} = V_0 - V_3 = E_1 - E_2 =$

$= -10\,V$

$\Delta W_e = 11,2\,mJ$

R_4?

$\Pi \to 13$

$Q_0 = -1\,mC$

$W_{e_1} = \frac{1}{2}\frac{Q_0^2}{C} = \frac{1}{2}\cdot\frac{1\cdot 10^{-6}}{100\cdot 10^{-6}} =$

$= 5\,mJ$

$W_{e_2} = 16,2\,mJ \Rightarrow \frac{1}{2}\frac{Q^2}{C} = 16,2\,mJ$ $Q = \pm 1,8\,mC$

$100\cdot 10^{-6}\,U^2 = 32,4\cdot 10^{-3}$

$U_{03} = \pm 18\,V$

$\Pi \to \sigma$

$V_1 = -E_1$

$-\frac{1}{R_4}V_1 + \left(\frac{1}{R_5} + \frac{1}{R_4}\right)V_2 - \frac{1}{R_5}V_3 = -I_g$

$V_3 = V_2 + E_2$

$\frac{1}{R_4}E_1 + \left(\frac{1}{R_5} + \frac{1}{R_4}\right)(V_3 - E_2) - \frac{1}{R_5}V_3 = -I_g$

1° $\frac{1}{R_4}\cdot 10 + \frac{18}{}$

$U_{13} = V_1 - V_3 = U_{10} - U_{03} = -10V - 18V = -28V$

$\Pi \to 3$

$U_{23} = U_{13}$

$I_{23} = -\frac{E_2}{R_5}$

1° $U_{03} = 18V$

$U_{12} = V_1 - V_2 = V_1 - (V_3 - E_2) = V_1 - V_3 + E_2 = -10 - 18 + 20 = -8\,V$

$U_{12} = -28V$

$I_3 = \frac{E_1}{R_3} = 91A$

$I_5 = \frac{E_2}{R_5}$

ANALYSIS

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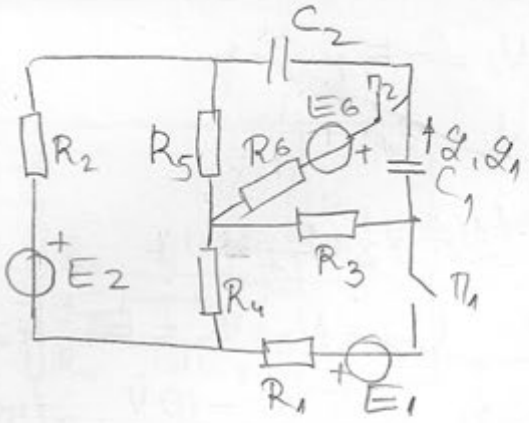
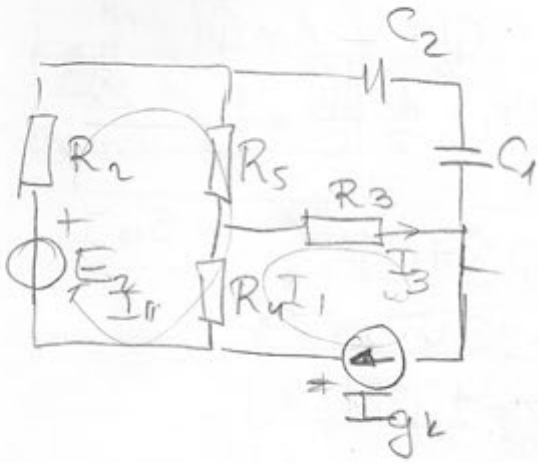


$E_2 = 10V$
$E_G = 20V$
$R_2 = 50\Omega$
$R_3 = 60\Omega$
$R_4 = 150\Omega$
$R_5 = 300\Omega$
$C_1 = 1\mu F$
$C_2 = 0{,}5\mu F$



П1 $Q = 4\mu C$ C_1
П2 $Q_1 = -2{,}2\mu C$ C_1

$I_3 = I_{gk}$

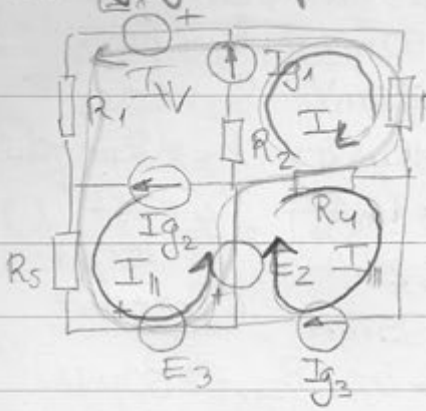
$I_1 = I_{gk}$

$I_{11} =$

$-R_4 I_{gk} + (R_4 + R_5 + R_2) I_{11} = E_2$

$$I_{11} = \frac{E_2 + R_4 I_{gk}}{R_2 + R_4 + R_5}$$

184 Немој да бираш много дугачке отпоре за напон!



$E_1 = 100mV$
$E_2 = 50mV$
$E_3 = 250mV$
$I_{g_1} = 1mA$
$I_{g_2} = 2mA$
$I_{g_3} = 5mA$

$R_1 = 50\Omega$
$R_2 = 100\Omega$
$R_3 = 60\Omega$
$R_4 = 40\Omega$
$P_{I_{g_1}} = 250\mu W$
$R_5 ?$

$$U_{g_1} = \frac{P_{I_{g_1}}}{I_{g_1}} = 250\,mV$$

$I_1 = I_{g_1}$

$I_{11} = I_{g_2}$

$I_{111} = I_{g_3}$

$$-(R_3+R_4)I_1 + R_5 I_{11} + R_4 I_{111} + (R_5+R_1+R_3+R_4)I_{1V} = -E_3 - E_2 - E_1$$

$$-R_5(I_{11}+I_{1V}) - E_3 - E_2 - R_2 I_{g_1} + U_{g_1} - E_1 - R_1 I_{1V} = 0$$

$$-R_5 I_{11} - R_5 I_{1V} - R_1 I_{1V} = E_1 + E_2 + E_3 + R_2 I_{g_1} - U_{g_1}$$

$$-(R_1+R_5)I_{1V} = E_1 + E_2 + E_3 + R_2 I_{g_1} - U_{g_1} + R_5 I_{11}$$

$$-(R_3+R_4)I_{g_1} + R_5 I_{11} + R_4 I_{111} + (R_5+R_1)I_{1V} + (R_3+R_4)\frac{E_1+E_2+E_3+R_2 I_{g_1}-U_{g_1}+R_5 I_{11}}{-(R_1+R_5)} = -E_3 - E_2 - E_1 - R_2 I_{g_1} + U_{g_1} - R_5 I_{11}$$

$$-\frac{R_3+R_4}{R_1+R_5}\left(E_1+E_2+E_3+R_2 I_{g_1} - U_{g_1} + R_5 I_{g_2}\right) = (R_3+R_4)I_{g_1} - R_4 I_{g_3} + R_2 I_{g_1} - U_{g_1}$$

$$-(R_3+R_4)(E_1+E_2+E_3+R_2 I_{g_1} - U_{g_1}) - (R_3+R_4)I_{g_2}R_5 = R_1\left[(R_3+R_4)I_{g_1} - R_4 I_{g_3} + R_2 I_{g_1} - U_{g_1}\right] + R_5 C$$

$100mV \quad -300mV \quad +100mV \quad -250mV$

C

$$C_1 = C + (R_3+R_4)I_{g_2} = 300mV - 200mV + 100mV - 250mV = -50mV$$

$$-100\left[400mV + 100\mu V - 250\mu V\right] = 12.5 - 50mV \cdot R_5$$

$$-25 = 12.5 - 50\cdot 10^{-3} R_5$$

$$R_5 = 750\,\Omega$$

ANALYSIS LABORATORY EQUIPMENT

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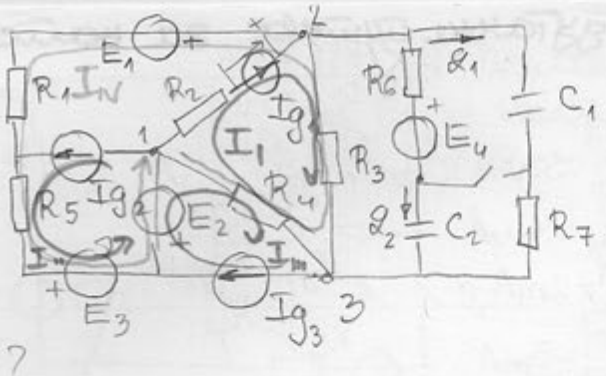


$E_1 = 100mV$ $R_1 = 50\Omega$
$E_2 = 50mV$ $R_2 = 100\Omega$
$E_3 = 250mV$ $R_3 = 60\Omega$
$E_4 = 110mV$ $R_4 = R_7 = 40\Omega$
$I_{g_1} = 1mA$ $R_6 = 9\Omega$
$I_{g_2} = 2mA$ $C_1 = 100nF$
$I_{g_3} = 5mA$ $C_2 = 200nF$
$\Pi \to 0$ $P_{Ig1} = 250\mu W$
$U_{g_1} = 250mV$

Q_1, Q_2?

$I_1 = I_{g_1}$
$I_{II} = I_{g_2}$
$I_{III} = I_{g_3}$

$$-(R_3+R_4)I_1 + R_5 I_{II} + R_4 I_{III} + (R_4+R_3+R_1+R_5)I_{IV} = -E_1 - E_3 - E_2$$

$$U_{12} = -U_{g_1} + R_2 I_{g_1} = -250 + 100 = -150mV$$

$$U_{12} = R_3(I_{IV} - I_1) + R_4(I_{IV} - I_1 + I_{III})$$

$$\frac{-150mV}{100\Omega} = I_{IV} - 1mA$$

$$-1,5mA = I_{IV} - 1mA$$

$$-0,5mA = I_{IV}$$

$$-150mV = 60I_{IV} - 60mV + 40I_{IV} - 40mV + 200mV$$

$$I_{IV} = -2,5mA$$

$$-100mV + R_5 \cdot 2mA + 200mV + 150(-2,5mA) - 2,5mA \cdot R_5 =$$

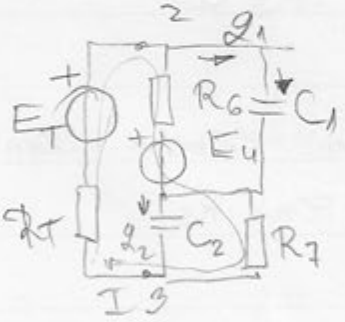
$$= -400mV$$

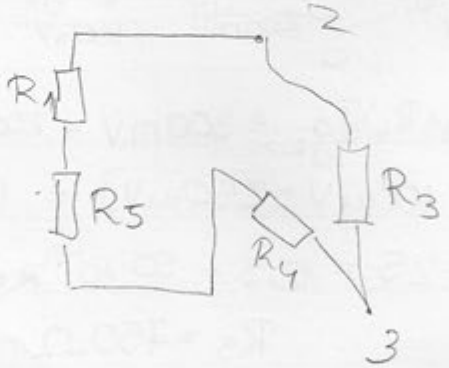
$$-0,5mA \cdot R_5 =$$

$$= -125mV$$

$$R_5 = 250\Omega$$

$$U_{23} = R_3(I_1 - I_{IV}) = 90mV = E_T$$





$$R_T = \frac{(R_1+R_5+R_4)R_3}{R_1+R_3+R_5+R_4} = 51\Omega \qquad U_{10} = U_{20} \neq E_4 = 0$$

$$I = \frac{E_T - E_4}{R_T + R_6 + R_7} = \frac{-10mV}{100} = -0,1mV$$

$$U_{C_2} = U_{R_7} = IR_7 = -4\ mV$$

$$U_{C_1} = E_4 - IR_6 = 100,9\ mV$$

$$\frac{Q_{10} + Q_1}{C_1} = E_4 - IR_6 \qquad -20\mu C + Q_1 = \sim \qquad Q_1 = 20,01\ \mu C$$

$$\frac{Q_{20} + Q_2}{C_2} = IR_7 \qquad -20\mu C\ Q_2 = -0,0008 \qquad Q_2 = 19,9992$$

$$-\frac{Q_{10}}{C_1} + \frac{Q_{20}}{C_2} = E_4 \leftarrow ???$$

$$Q_{10} = Q_{20}$$

$$Q_{10}\left(\frac{1}{200} - \frac{1}{100}\right) = 100 \cdot 10^{-3}$$

$$Q_{10} = -20\mu C$$

ANALYSIS
LABORATORY EQUIPMENT

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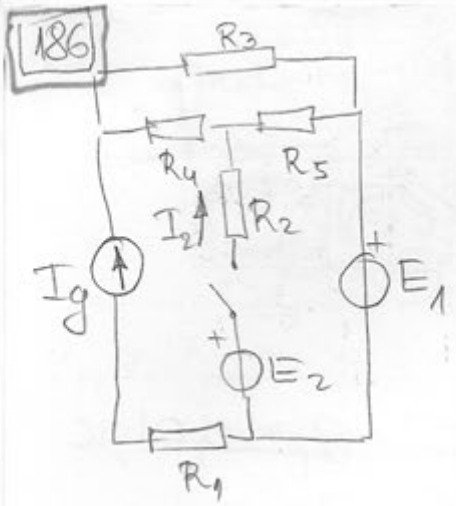


$E_2 = 40\,V$ $I_2 = 0{,}1\,A$

$I_g = 0{,}3\,A$

ΔP_{E_1}, ΔP_{I_g}? ΔP_{E_2}?

$R_1 = 50\,\Omega$

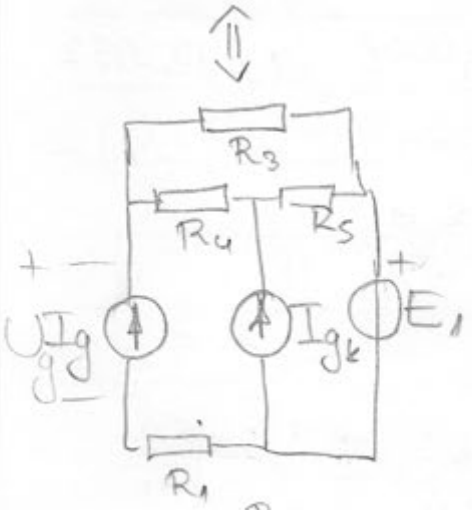
$R_2 = 140\,\Omega$

$R_3 = 210\,\Omega$

$R_4 = 420\,\Omega$

$R_5 = 105\,\Omega$

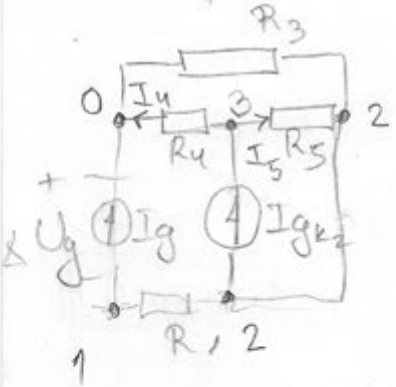
$$I_{gk} = \begin{cases} 0, & n = 0 \\ I_2, & n = 1 \end{cases}$$



$$U_{g_1} = U_g(I_{gk_1}) + U_g(E_1)_1 + U_g(I_g)_1$$

$$U_{g_2} = U_g(I_{gk_2}) + U_g(E_1)_2 + U_g(I_g)_2$$

$$\Delta U_g = U_g(I_{gk_2}) - U_g(I_{gk_1})$$ (→ 0)



$$I_5 = \frac{R_3 + R_4}{R_3 + R_4 + R_5} I_{gk_2} =$$

$$I_4 = \frac{R_5}{R_3 + R_4 + R_5} I_{gk_2}$$

$$\Delta U_g = U_{01} = U_{02} = -I_4 R_4 + R_5 I_5 =$$

$$= -6\,V + 9\,V = 3\,V$$

$$\Delta P_{I_g} = I_g \Delta U_g = 0{,}9\,W$$

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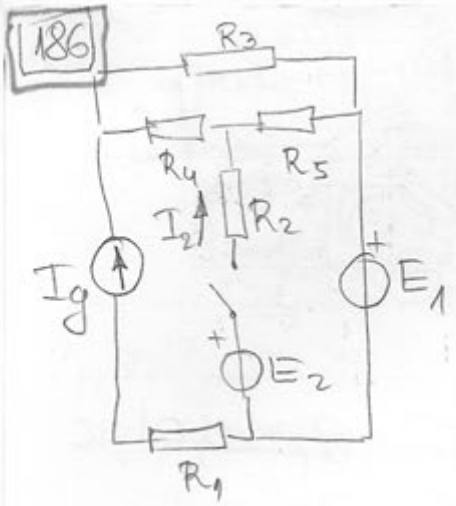

$E_2 = 40\,V$ $I_2 = 0{,}1\,A$

$I_g = 0{,}3\,A$

ΔP_{E_1}, ΔP_{I_g}? ΔP_{E_2}?

$R_1 = 50\,\Omega$

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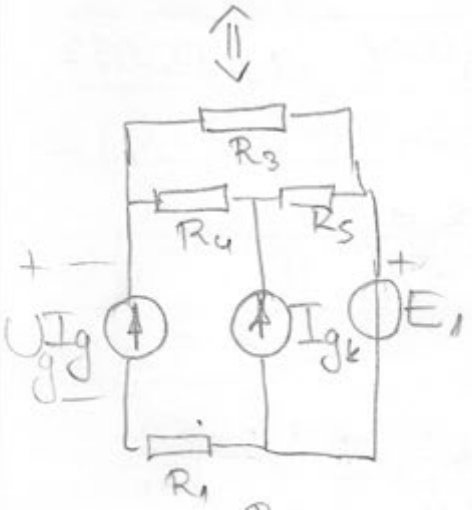
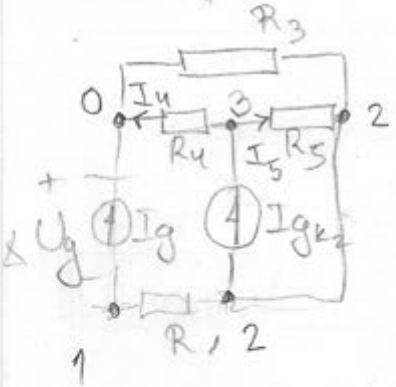
$$I_{gk} = \begin{cases} 0, & n = 0 \\ I_2, & n = 1 \end{cases}$$



$$U_{g_1} = U_g(I_{gk_1}) + U_g(E_1)_1 + U_g(I_g)_1$$

$$U_{g_2} = U_g(I_{gk_2}) + U_g(E_1)_2 + U_g(I_g)_2$$

$$\Delta U_g = U_g(I_{gk_2}) - U_g(I_{gk_1})$$ (→ 0)



$$I_5 = \frac{R_3 + R_4}{R_3 + R_4 + R_5} I_{gk_2} =$$

$$I_4 = \frac{R_5}{R_3 + R_4 + R_5} I_{gk_2}$$

$$\Delta U_g = U_{01} = U_{02} = -I_4 R_4 + R_5 I_5 =$$

$$= -6\,V + 9\,V = 3\,V$$

$$\Delta P_{I_g} = I_g \Delta U_g = 0{,}9\,W$$

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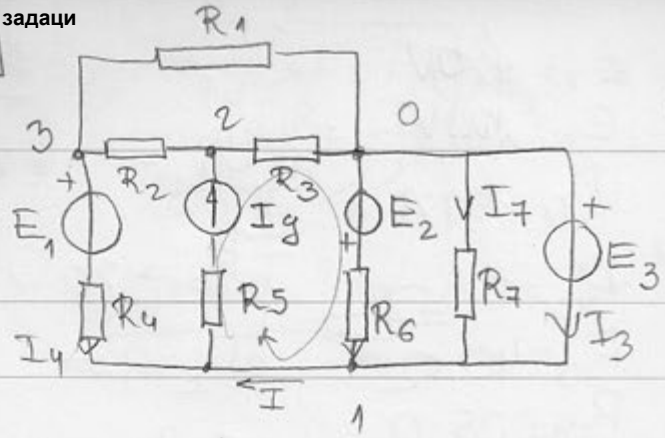

$E_1 = 10V$ $R_2 = 4k\Omega$
$E_2 = 20V$ $R_3 = 5k\Omega$
$E_3 = 30V$ $R_4 = 600\Omega$
$I_g = 5mA$ $R_5 = 1{,}6k\Omega$
$R_1 = R_7 = 1k\Omega$ $R_6 = 2k\Omega$
I?

$$\times \left(\frac{1}{R_6}+\frac{1}{R_7}+\frac{1}{R_4}\right)V_1 - 0\cdot V_2 - \frac{1}{R_4}V_3 = -\frac{E_1}{R_4} - I_g + \frac{E_2}{R_6}$$

$$V_1 = -E_3 = -30V$$

$$0\cdot V_1 + \left(\frac{1}{R_2}+\frac{1}{R_3}\right)V_2 - \frac{1}{R_2}V_3 = -I_g$$

$$-\frac{1}{R_4}V_1 - \frac{1}{R_2}V_2 + \left(\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_4}\right)V_3 = \frac{E_1}{R_4}$$

$$V_3 = +I_g R_2 + \left(1+\frac{R_2}{R_3}\right)V_2$$

$$\frac{20}{600} + \frac{30}{600} - \frac{V_2}{4000} + \left(\frac{1}{1000}+\frac{1}{4\cdot 1000}+\frac{1}{600}\right)\left(4000\cdot 5\cdot 10^{-3} + \frac{9}{5}\cdot V_2\right) = \frac{10}{600}$$

$$-\frac{V_2}{40} + 2 + 0{,}5 + \frac{20}{6} + \frac{39}{8}\left(\frac{35}{40}\right)V_2 = 0$$

$$\frac{20}{40}V_2 = -2{,}5 - 6{,}67$$

$$V_2 = -18{,}33\ V$$

$$V_3 = -5{,}5V \qquad U_{31} = V_3 - V_1 = 83V$$

$$I_7 = \frac{U_{01}}{R_7} = \frac{10}{1000} = 10mA \qquad I_4 = -\frac{E_1 - U_{31}}{R_4} = -33{,}12mA$$

$$I_6 = \frac{E_3 + E_2}{R_6} = 25mA$$

$$I_5 = -I_g = -5mA$$

$$I_4 =$$

$$I_4 + I_5 + I_6 + I_7 + I_3 = 0$$

$$-33{,}12 - 5 + 25 + 10 + I_3 = 0$$

$$I_3 = 3{,}12\ mA$$

$$I = -I_4 - I_5 = 33{,}12 + 5 = 37{,}12mA$$

ANALYSIS
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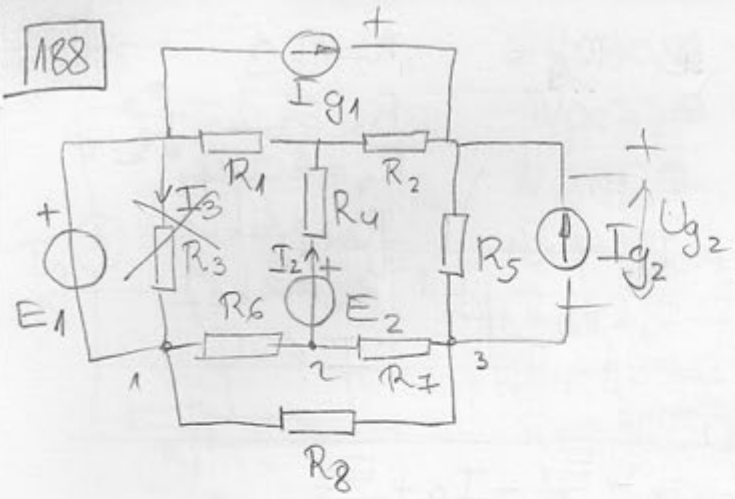


$E_1 = 120V$
$E_2 = 100V$
$I_{g1} = 0,1A$
$R_2 = 30\Omega$
$R_3 = 40\Omega$
$R_4 = 35\Omega$
$R_5 = 100\Omega$
$R_6 = R_7 = 50\Omega$
$R_8 = 25\Omega$

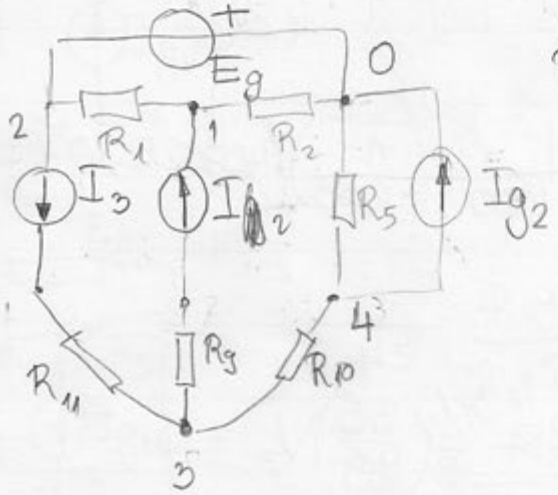
$P_{g1} = -4,6W$
$U_{g1} = -46V$
$P_{E_2} = 20W$
$I_2 = 92A$
R_1?

$$I_3 = \frac{E_1}{R_3} = 3A$$

$U_{g2} = I_{g2} R_5 =$

$$R_g = \frac{R_6 R_7}{R_6 + R_7 + R_8} = 20\Omega$$

$$R_{10} = R_{11} = \frac{R_6 R_8}{125\Omega} = 10\Omega$$



$E_g = U_{g1} = -46V$

$$\left(\frac{1}{R_2} + \frac{1}{R_1}\right)V_1 - \frac{1}{R_1}V_2 - 0V_3 - \frac{1}{R_5}V_4 = I_{g2}$$

$$V_1 = \frac{R_1 R_2}{R_1 + R_2}\left(I_2 - \frac{E_g}{R_1}\right)$$

$V_2 = -E_g$

$$-0 \cdot V_1 = 0 \cdot V_2 + \frac{1}{R_{10}}V_3 - \frac{1}{R_{10}}V_4 = I_3 - I_{g2}$$

$$-0 \cdot V_1 - 0 \cdot V_2 - \frac{1}{R_{10}}V_3 + \left(\frac{1}{R_{10}} + \frac{1}{R_5}\right)V_4 = I_{g2}$$

$V_1 = \frac{30}{30+R_1}(0,2R_1 + 46)$

$$\boxed{V_1 = \frac{R_1 R_2}{R_1 + R_2}\left(I_{g2} - \frac{E_g}{R_1}\right)}$$

$$\frac{1}{R_5}V_4 = I_3$$

$$\boxed{V_4 = I_3 R_5}$$

$$\boxed{V_3 = V_4 + R_{10}(I_3 - I_{g2})}$$

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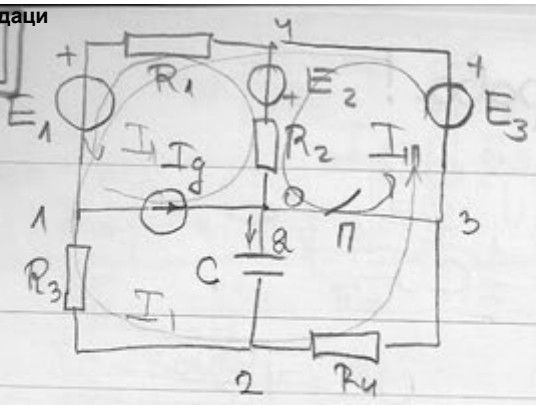

$I_{II} = I_g = 100\,mA$

$(R_3+R_4+R_1)I_1 + R_1 I_g = E_3 + E_1$

$$I_1 = \frac{E_3 + E_1 - R_1 I_g}{R_3+R_4+R_1} = \frac{-25}{375} = -\frac{2}{30}A$$

$U_{03} = E_3 + E_2 + R_2 I_g = 20 + 15 = 35V$

$U_{02} = U_{03} + U_{32} = 35V - I_1 R_4 = 35 + 5 = 40V$

$Q_0 = CU_{02} = 4\,mQ$

П → 3 $\quad -R_2 I_g + R_2 I_{III} = E_2 + E_3$

$$I_{III} = \frac{E_2+E_3}{R_2} - I_g = \cancel{\frac{1}{30}A}$$

$U_{02} = -I_1 R_4 + E_3 + E_2 + R_2(I_g - I_{III}) = 5V$

$Q = 0{,}5\,mQ$

$q = -0{,}5\,mQ$

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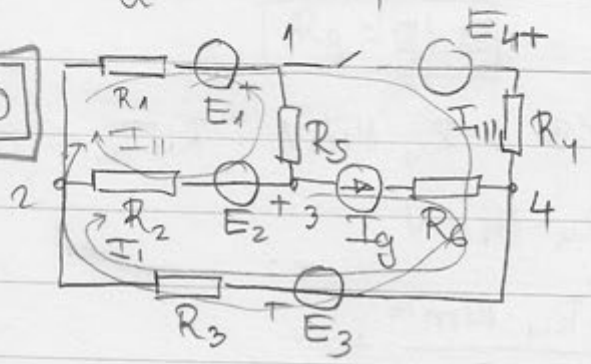


По $U_{23} = 5mV$ $\quad$ П3 $U_{23}' = 6mV$

E_4?

$I_{II} = -9\mu A + I_g$

$U_{23} = -E_2 - R_2(I_{II} - I_1)$ $\quad I_{II}' = -10\mu A - I_g = 5\mu A$

$I_1 = I_g$ $\quad -R_2 I_g + (R_1+R_2+R_5)I_{II} + R_1 I_{III} = E_1 - E_2$

$-R_2 I_g + (R_1+R_2+R_5)I_{II} = E_1 - E_2$ $\quad +15mV + 30mV + 1k\Omega I_{III} = 21mV$

$I_{III} = \cancel{156}\mu A - 24\mu A$

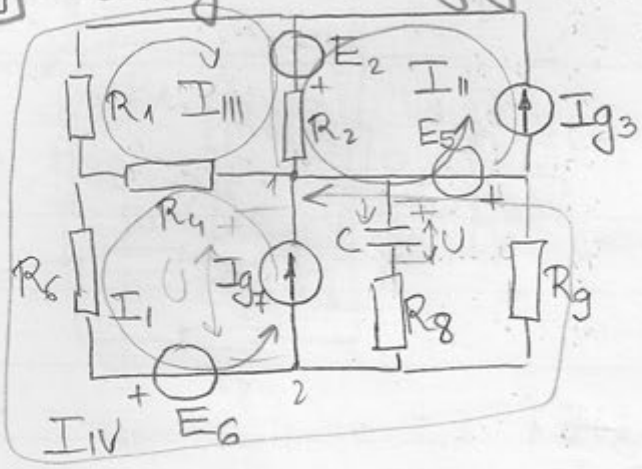
$-1k\Omega \cdot I_g - 6 \cdot 9mV + 6I_g = 21mV$

$5I_g = +75\mu A$ $\quad R_3 I_g + R_1 I_{II} + (R_1+R_4+R_3)I_{III} =$

$\boxed{I_g = 15\mu A}$ $\quad \cancel{+130mV} + 5mV + \cancel{780mV} - 120mV = 80 + E_4$

$= E_3 + E_1 + E_4$

191 Метод потенцијала чворова!



$W_e = 1{,}8\,mJ =$

$= \frac{1}{2}CU^2$

R_4? $U = \pm\sqrt{\frac{2W_e}{C}} = 6$

знак?

$I_1 = I_{g7}$

$I_{II} = I_{g3}$

$R_4 I_1 + R_2 I_{II} + (R_1 + R_2 + R_4) I_{III} + (R_1 + R_2) I_{IV} = E_2$

$R_6 I_1 + 0 \cdot I_{II} + (R_1 + R_2) I_{III} + (R_9 + R_6 + R_1 + R_2) I_{IV} = E_6 + E_2$

$U_{12} = E_6 + R_6(I_1 + I_{IV}) + R_4(I_1 + I_{III})$

$$\frac{U_{12} - E_6 - (R_6 + R_4) I_1 - R_4 I_{III}}{R_6} = I_{IV}$$

2,5V 2kΩ

$R_6 I_{g7} + (R_1 + R_2) I_{III} + 4{,}5\,k\Omega \cdot \frac{U_{12} - 1 - 0{,}5 I_{g7} - R_4 I_{g7} - R_4 I_{III}}{0{,}5\,k\Omega} =$

$= 1 + 5$ 9.6 V

$2\,k\Omega I_{III} + 9U_{12} - 9 - 63 - R_4 \cdot 14\,mV - R_4 I_{III} = 3{,}5$

$I_{III}(2\,k\Omega - R_4) = 21{,}5 + R_4 \cdot 14\,mV$

$-42mA\ R_4 \cdot 14mA + \cancel{8} + (2 + R_4)\frac{21{,}5 + R_4 \cdot 14mA}{2\,k\Omega - R_4} +$

$+ \cancel{8}\left(- \cancel{8} - R_4 56mA - R_4 \frac{86 + R_4 56mA}{2\,k\Omega - R_4} \right) =$

$= \cancel{8} \quad / 2\,k\Omega - R_4$

$-84 + 42mA R_4 + 43 + 18mA R_4 + 21{,}5 R_4 + R_4^2 14mA -$

$- 64\,k\Omega + 8R_4 - 86R_4 + R_4^2 56mA = 0$

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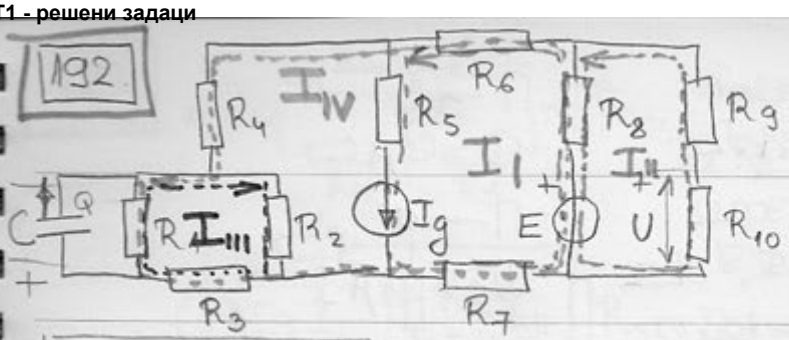

$E = 40V$ $C = 10\mu F$
$I_g = 5mA$ $U = 15V$
$R_1 = 5k\Omega$ $Q = 50\mu C$
$R_2 = 15k\Omega$ R_4? R_8?
$R_3 = 25k\Omega$
$R_5 = 25k\Omega$
$R_6 = 30k\Omega$
$R_7 = 15k\Omega$
$R_9 = R_{10} = 5k\Omega$

$\boxed{I_I = I_g = 5mA}$

$-R_8 I_I + (R_8 + R_9 + R_{10}) I_{II} - R_8 I_{IV} = -E$

$0 \cdot I_I + 0 \cdot I_{II} + (R_1 + R_2 + R_3) I_{III} - (R_1 + R_3) I_{IV} = 0$

$(R_7 + R_8 + R_6) I_I - R_8 I_{II} - (R_1 + R_3) I_{III} + (R_1 + R_3 + R_7 + R_8 + R_6 + R_4) I_{IV} =$

$= E$

$-I_{II} R_{10} = U$ $\boxed{I_{II} = 3mA}$

$R_1 (I_{III} - I_{IV}) = Q/C$

$\boxed{I_{III} = I_{IV} + 1mA}$

$-R_8 \cdot 5 \cdot 10^{-3} - R_8 \cdot 3 \cdot 10^{-3} - 30V - R_8 \cdot I_{IV} = -40$

$R_8 I_{IV} = 10 - 8 \cdot R_8 \cdot 10^{-3}$

$I_{IV} = \frac{10}{R_8} - 8 \cdot 10^{-3}$

$5 \cdot 10^3 I_{IV} + 45 - 30 \cdot 10^3 I_{IV} = 0$

$I_{IV} = -3mA$ $I_{III} = -2mA$

$-3 \cdot 10^{-3} R_8 = 10 - 8 \cdot 10^{-3} R_8$

$\boxed{R_8 = 2k\Omega}$

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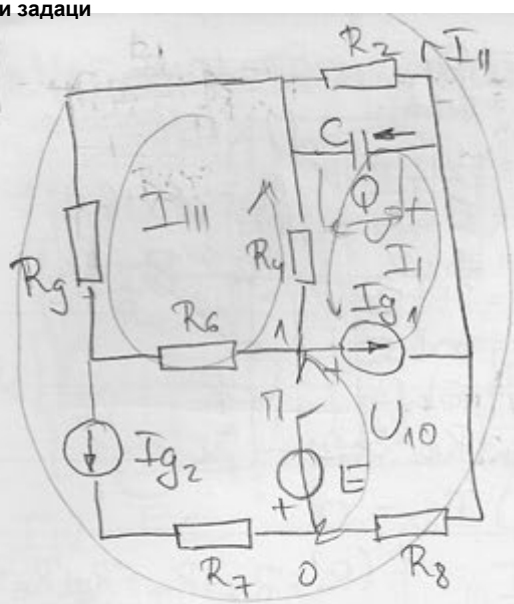
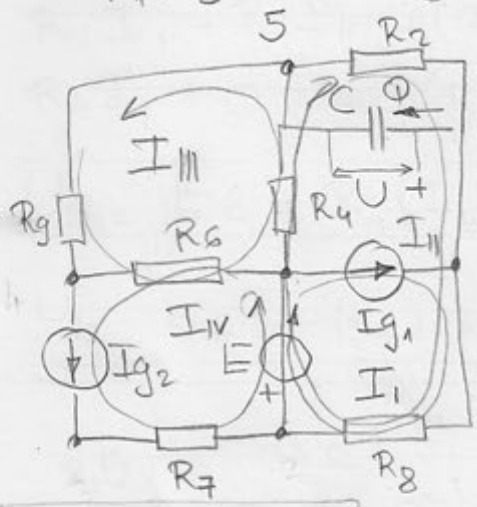


$I_{g1} = 2mA$
$R_1 = 2k\Omega$
$R_2 = 300\Omega$
$R_3 = R_4 = 3k\Omega$
$R_5 = 1{,}8k\Omega$
$R_6 = 4k\Omega$
$R_7 = 1k\Omega$
$R_8 = 600\Omega$
$C = 200\mu F$

$\Pi \to 3$
$Q = 60\mu C$
$\Pi \to \sigma$
$W_e = 81\mu J$
$W_{I_{g1}} < 0$
$E = ?$

$I_1 = I_{g1} = 2mA$
$I_{11} = I_{g2} = -5mA$

$$R_g = \frac{R_1 R_3}{R_1 + R_3} + R_5 = \frac{6}{5}k\Omega + 1{,}8k\Omega = 3k\Omega$$



$I_1 = I_{g1} = 2mA$
$I_{IV} = I_{g2}$

$$R_8 I_1 + (R_2 + R_8 + R_4) I_{11} + R_4 I_{111} = -E$$
$$R_4 I_{11} + (R_4 + R_6 + R_g) I_{111} - R_6 I_{IV} = 0$$

$$-R_4 I_1 + R_g I_{11} + (R_g + R_6 + R_4) I_{111} = 0$$
$$I_{111} = \frac{R_4 I_1 - R_g I_{11}}{R_g + R_6 + R_4}$$

$U = -0{,}9V$
$U = R_2 (I_1 + I_{11})$
$I_{11} = -5mA$

$-6 - 15 + 10k\Omega I_{111} = 0$
$I_{111} = 2{,}1mA$

$$U_{10} = -R_8 I_{11} - R_2 (I_{11} + I_1) + R_4 (I_{111} - I_1) =$$
$$= +3 + 9 + 3 \cdot 2{,}1 - 6 = 4{,}2$$

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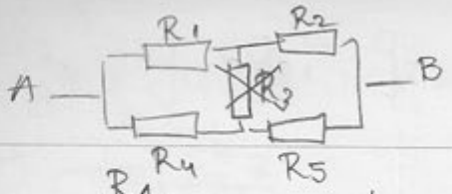
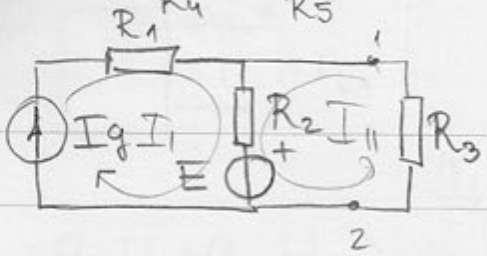


$$R_{AB} = \frac{R_1 R_4}{R_1 + R_4} + \frac{R_2 R_5}{R_2 + R_5} = \frac{200 \cdot 400}{600} + \frac{200 \cdot 200}{600} =$$

$R_1 R_5 = R_2 R_4$

$= 200\,\Omega$

132.



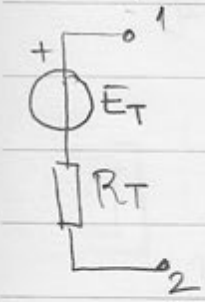
$E = 24V$

$I_g = 18mA$

$R_1 = R_2 = 1k\Omega$

$R_3 = 400\Omega$

а) $E_T = U_{12ph}$



$I_1 = I_g$

$R_2 I_g + (R_2 + R_3) I_{II} = -E$

$I_{II} = \frac{-24 - 18}{1,4} = -30mA$

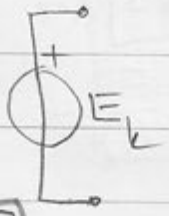
~~$E_T = 12V$~~ $\quad U_{12} = -I_{II} R_3 = 12V$

$R_T = R_2 = 1k\Omega$

$E_T = E + I_g R_2 = 24 + 18$

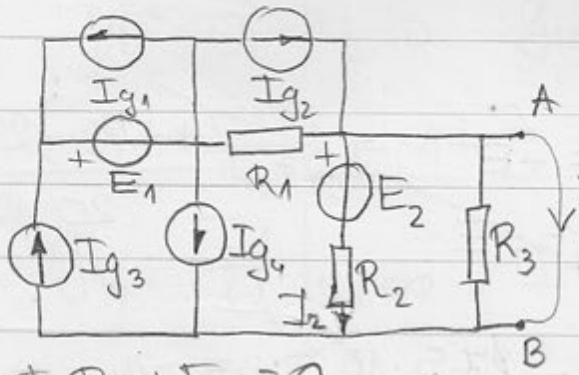
$= 42V$

б)

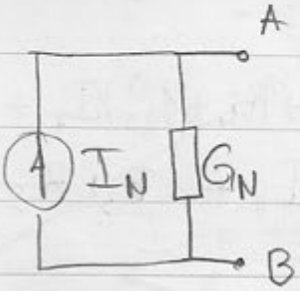


$E_k = 12V$

136



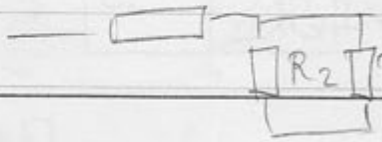
$\equiv$



$I_2 R_2 + E_2 = 0$

$I_2 = -\frac{E_2}{R_2} = -\frac{1V}{2k\Omega} = -0,5mA$

$I_{ks} = -I_2 - I_{g4} + I_{g3} = 3mA + 0,5mA - 5mA = -1,5mA$ ✓



$R_N = \frac{R_2 R_3}{R_2 + R_3} = \frac{2 \cdot 4}{6}$

$G_N = \frac{6}{8} = 0,75\,mS$ ✓

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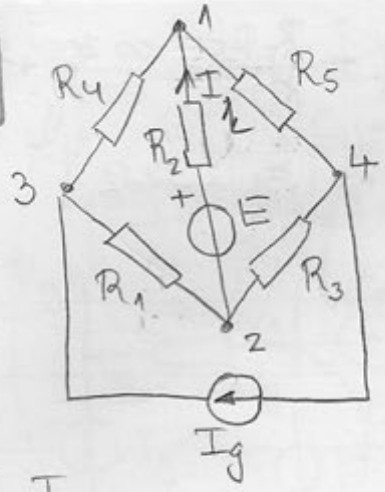


$E = 24V$

$I_g = 20mA$

$R_1 = 2k\Omega$

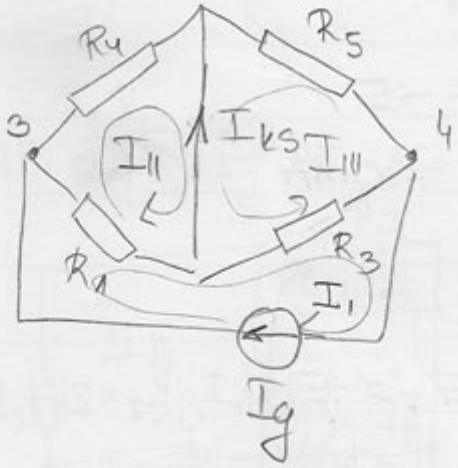
$R_2 = 20k\Omega$

$R_3 = 5k\Omega$

$R_4 = 3k\Omega$

$R_5 = 15k\Omega$

a) I_N



$I_1 = I_g$

$-R_1 I_g + (R_1 + R_4) I_{II} = 0$

$R_3 I_g + (R_3 + R_5) I_{III} = 0$

$I_{II} = 8mA$

$I_{III} = -5mA$

$I_N = -3mA$

$G_N = 0,25mS$

$$R_N = \frac{(R_5 + R_3)(R_1 + R_4)}{R_1 + R_2 + R_3 + R_4} = \frac{20^4 \cdot 8}{25 \, 8} = 4k\Omega$$

d)

$I_1 = I_g$

$-R_1 I_g + (R_1 + R_4 + R_2) I_{II} + R_2 I_{III} = -E$

$R_3 I_g + R_2 I_{II} + (R_3 + R_5 + R_2) I_{III} = -E$

$I_{III} = \frac{-24 + 40 - 25 \cdot 10^3 I_{II}}{20 \cdot 10^3}$

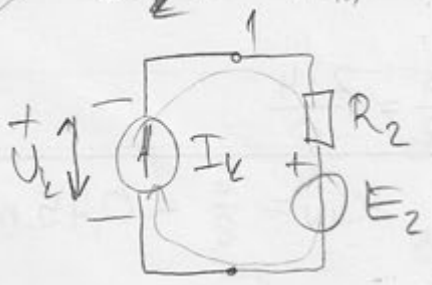
$100 + 20 \cdot 10^3 I_{II} - 26,4 + 44 - 17,5 \cdot 10^3 I_{II} = -24$

$I_{II} = 18,88mA$

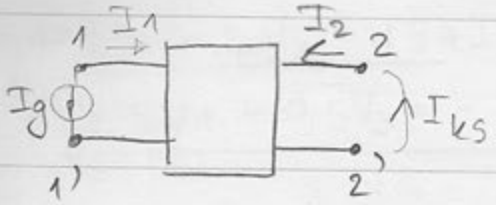
$I_{III} = -22,8mA$

$I_k = -I_{III} - I_{II} = 3,92$

$U_k = E_2 + I_k R_2$



150 $g_{11}, g_{12}=g_{21}, g_{22}$



$I_1 = g_{11}U_1 + g_{12}U_2$

$I_2 = g_{21}U_1 + g_{22}U_2$

$I_1 = -I_g \quad U_1 = -\frac{I_g}{g_{11}}$

$I_{ks} = I_2 = -\frac{g_{21}}{g_{11}} I_g$

$-I_g = g_{11}U_1 + g_{12}U_2$

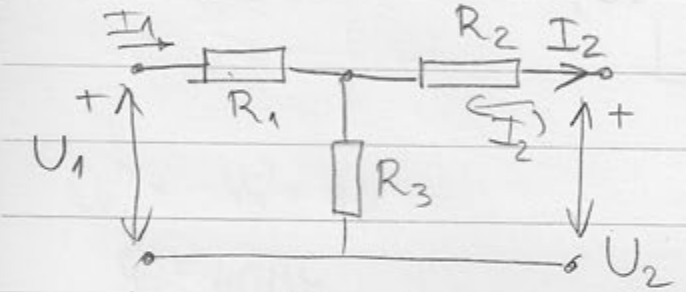
$0 = g_{21}U_1 + g_{22}U_2 \quad U_2 = -\frac{g_{21}}{g_{22}}U_1 \quad U_1 = -\frac{g_{22}}{g_{21}}U_2$

$$G_N = -\frac{I_g}{U_2} = -\frac{g_{11}g_{22}}{g_{21}} + g_{12}$$

151 $U_1 = 10V$

$R_1 = R_2 = 1k\Omega \quad I_2?(U_2)$

$R_3 = 2k\Omega$



$I_1 = g_{11}U_1 + g_{12}U_2$

$I_2 = g_{21}U_1 + g_{22}U_2$

$g_{11} = \frac{I_1}{U_1}\Big|_{U_2=0} \quad g_{11} = 0,6mS \quad g_{12} = -0,4mS = g_{21}$

$R_e = R_1 + \frac{R_2R_3}{R_2+R_3} = 1 + \frac{2}{3} = \frac{5}{3} \quad g_{22} = 0,6mS$

$g_{12} = \frac{I_1}{U_2}\Big|_{U_1=0} \quad -I\frac{R_3}{R_1+R_3} \quad I_2 = +0,4 \cdot 10mA - 0,6 \cdot 10^{-3}U_2 = (4 - 0,6U_2)mA$

$\frac{U_2}{I_2} = \frac{5}{3}k\Omega \quad I_2 = \frac{3}{5}U_2$

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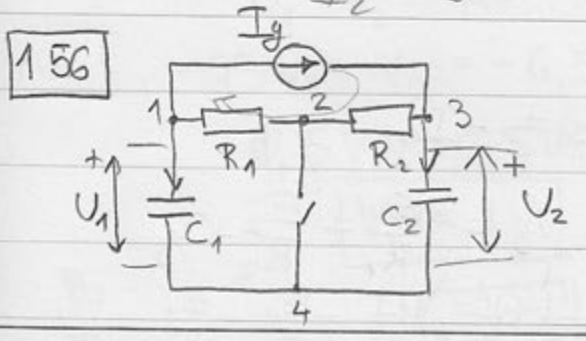

$(R_1+R_2)I_g - U_2 + U_1 = 0$

$\frac{I_g \cdot 400}{0,8} = U_2 \quad U_2 = 50V$

$U_1/U_2 = 0,2 \quad U_2 = \frac{Q_{20}}{C_2} \quad U_1 = 10V$

$U_1 = 0,2U_2 \quad U_1 = \frac{Q_{10}}{C_1} \quad Q_{20} = 10\mu E$

$Q_{10} = 0,2 \cdot \frac{C_1}{C_2}Q_{20} = 0,5Q_{20} \quad Q_{10} = 5\mu E \quad Q_1 = -45\mu C$

$3 \rightarrow \Pi$

$U_1' = -R_1I_g = -100V \quad U_2 = R_2I_g = 300V \quad Q_1 = -50\mu C \quad Q_2 = 50\mu C$

ANALYSIS

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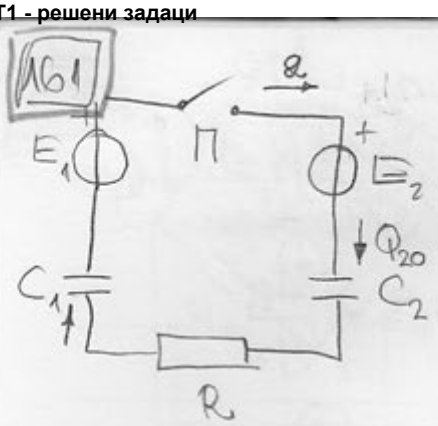

$E_1 = 5V$
$E_2 = 12V$
$C_1 = 1\mu F$
$C_2 = 2\mu F$
$П \to 0$
$Q_{10} = 0$
$Q_{20} = 19\mu C$

$$W_{e_1} = \frac{1}{2}\frac{Q_{20}^2}{C_2} = 25\mu J$$

$Q_1 = -8\mu C$
$Q_2 = 2\mu C$

$$E_1 - E_2 - \frac{Q_2}{C_2} - \frac{Q}{C_1} = 0$$

$$5 - 12 - \frac{10\mu C}{2\mu C} - Q\frac{3}{2} = 0$$

$$Q = -8\mu C$$

$$W_{e_2} = \frac{1}{2}\left(\frac{Q_{20}^2}{C_2} + \frac{Q_{10}^2}{C_1}\right) =$$

$$= \frac{1}{2}\left(\frac{42}{2} + \frac{64}{2}\right) =$$

$$= 33\mu J$$

$$A_E = (E_1 - E_2)Q = 56\mu J$$

$$W_{e_1} + A_E = W_{e_2} + A_R$$

$$A_R = 48\mu J$$

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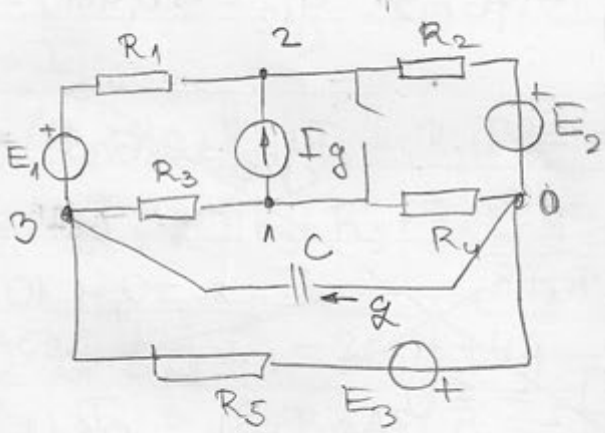


$$E_{1,2} = \begin{cases} 5V \\ 0, П \to 1 \end{cases}$$

$E_1 = 12V$
$E_2 = 6V$
$E_3 = 1V$
$R_1 = R_4 = 1k\Omega$
$R_2 = R_3 = R_5 = 2k\Omega$
$C = 10\mu F$
$Q = 10\mu C$

P_{Ig} $П \to 0$

$$\left(\frac{1}{R_3} + \frac{1}{R_4}\right)V_1 + 0 \cdot V_2 - \frac{1}{R_3}V_3 = -I_g$$

$$0 \cdot V_1 + \left(\frac{1}{R_1} + \frac{1}{R_2}\right)V_2 - \frac{1}{R_1}V_3 = \frac{E_1}{R_1} + \frac{E_2}{R_2} + I_g$$

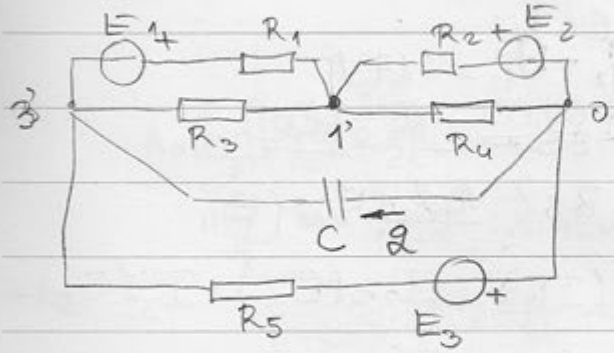
$$-\frac{1}{R_3}V_1 - \frac{1}{R_1}V_2 + \left(\frac{1}{R_1} + \frac{1}{R_3} + \frac{1}{R_5}\right)V_3 = -\frac{E_3}{R_5} - \frac{E_1}{R_1} - \frac{E_2}{R_2}$$

$$-\frac{V_1}{2} \cdot 10^3 - V_2 \cdot 10^3 + \left(\frac{1}{1} + \frac{1}{2} + \frac{1}{2}\right)10^3 V_3 = -0{,}5 \cdot 10^3 - 12 \cdot 10^{-3} - 3 \cdot 10^3$$

$-0,5V_1 - V_2 + 2V_3 = -12,5$

$+ \quad 1,5V_2 - V_3 = 15 + I_g$

$1,5V_1 - 0,5V_3 = -I_g$ ✓



$Q_0 = C \cdot U_{03} = -CV_3$

$\left(\frac{1}{R_1}+\frac{1}{R_3}+\frac{1}{R_2}+\frac{1}{R_4}\right)V_1' - \left(\frac{1}{R_3}+\frac{1}{R_4}\right)V_3' = \frac{E_1}{R_1}+\frac{E_2}{R_2}$

$-\left(\frac{1}{R_1}+\frac{1}{R_3}\right)V_1' + \left(\frac{1}{R_1}+\frac{1}{R_3}+\frac{1}{R_5}\right)V_3' = -\frac{E_1}{R_1}-\frac{E_3}{R_5}$

$\left(1+\frac{1}{2}+\frac{1}{2}+1\right)V_1' - 1,5V_3 = 12+3$

$-1,5V_1' + 2V_3' = -12-0,5$

$3V_1' - 1,5V_3 = 15$

~~$-1,5V_1' + 2V_3' = -12,5 / \cdot 2$~~

$-3V_1' + 4V_3' = -25$

$2,5V_3' = -10 \qquad V_3' = -4V$

$V_1' = 3V$

$U_C' = -V_3' = 4V$

$Q = 40\mu C$

$Q = Q_0 + q$

$Q_0 = 30\mu C$

$\boxed{V_3 = -3V}$

$1,5 + 1,5 = -I_g$

$I_g = -3mA$

$P_{Ig} = (V_2 - V_1) I_g =$

$= -15mW$ ✓

$1,5V_1 + 1,5V_2 - 1,5V_3 = 15$

$V_1 + V_2 - V_3 = 10$

$-0,5V_1 + V_2 = 7V$

$-0,5V_1 - V_2 = -6,5$

$0,5V_1 = 0,5V$

$\boxed{V_1 = 1V}$

$\boxed{V_2 = 6V}$

ANALYSIS
LABORATORY EQUIPMENT

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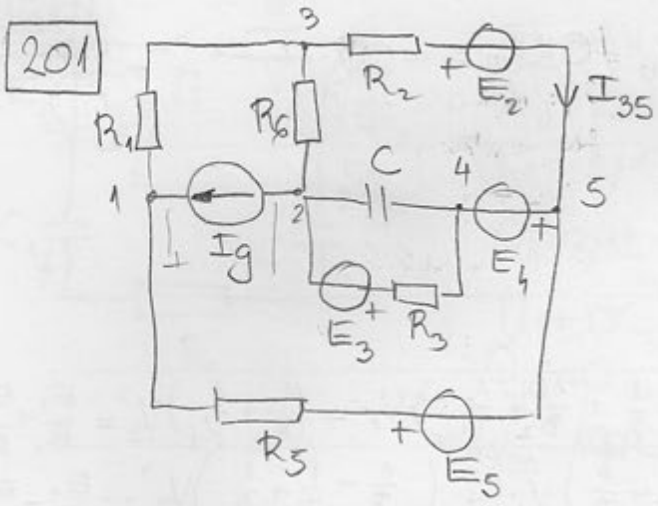


$E_5 = 50V$

$R_1 = R_2 = 100\Omega$

$R_3 = 200\Omega$

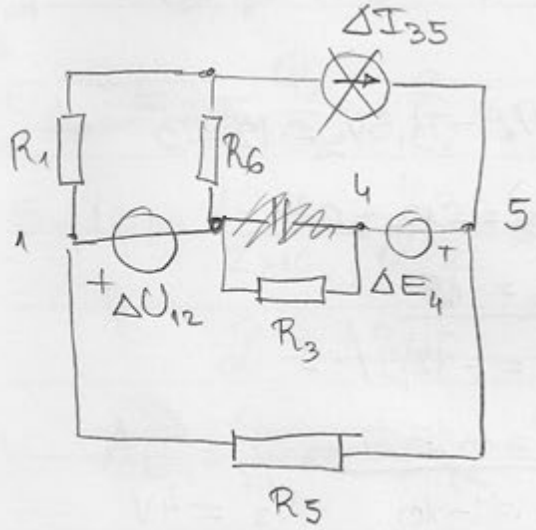
$R_6 = 400\Omega$

E_4 ✗ $\Delta U_{12} = -17V$

$U_{12}^{②} - U_{12}^{①} = -17V$

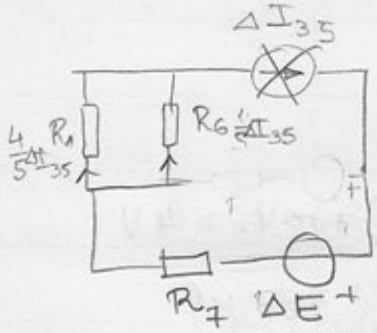
$\Delta I_{35} = I_{35}^{②} - I_{35}^{①} = 30mA$

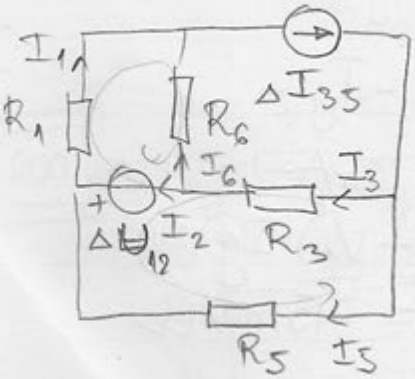
A) R_5? B) ΔE_4, E_4.



$I_{35} = I_{35}(U_g) + I_{35}(E_3) + I_{35}(E_5) + I_{35}(E_4)$

$\Delta I_{35} = I_{35}(\Delta U_g) + I_{35}(\Delta E_4)$





$\Delta I_{35} = I_3 + I_5$

$I_3 = I_2 + I_6$

$I_1 = I_5 + I_2$

$I_1 + I_6 = \Delta I_{35}$

$\Delta E = \frac{R_5 \Delta E_4}{R_3 + R_5}$

$R_7 = \frac{R_3 R_5}{R_3 + R_5}$

$R_8 = \frac{R_1 R_6}{R_1 + R_6} = 80\Omega$

$\Delta U_{12} - R_1 I_1 + R_6 I_6 = 0$

$\Delta U_{12} + R_5 I_5 - R_3 I_3 = 0$

$\Delta U_{12} - 100 \cdot I_1 + 400 \cdot \Delta I_{35} - 400 I_1 = 0$

$\Delta U_{12} + R_5 \cdot \Delta I_{35} - R_5 I_3 - 200 I_3 = 0$

$-\Delta E - (R_7 + 80)\Delta I_{35} +$

$U_{35} = 0$

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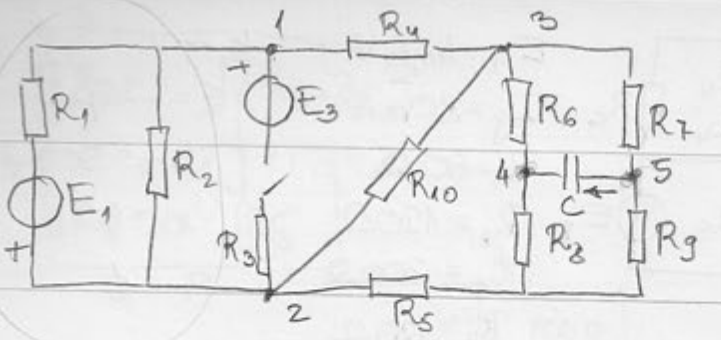
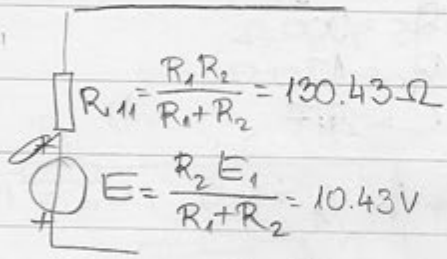
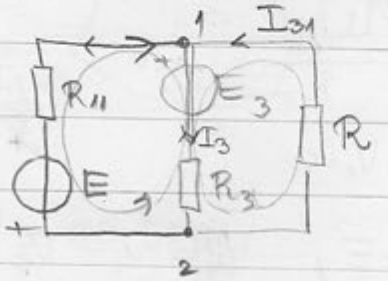


$E_1 = 12V$
$R_1 = 150\Omega$
$R_2 = 1k\Omega$
$C = 0{,}1\mu F$
$U_{21} = 15V$
$U_{54} = 2V$ $\quad Q_0 = 0{,}2\mu F$
$I_{31} = 95mA$



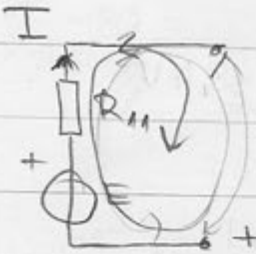
$$R_{11} = \frac{R_1 R_2}{R_1 + R_2} = 130.43\Omega$$

$$E = \frac{R_2 E_1}{R_1 + R_2} = 10.43V$$



$$-I_3 R_3 + E_3 + I_{31} R = 0$$

$$I_3 = \frac{E_3 + I_{31} R}{R_3}$$

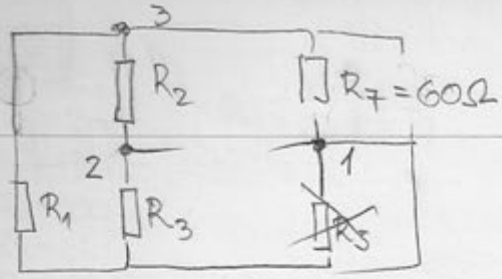


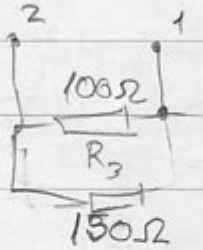
$$\frac{E + U_{21}}{R_{11}} = I_1 \qquad I_3 = 290mA$$

$$I = 195mA$$

$$U_{45} = \alpha I_k + \beta E$$

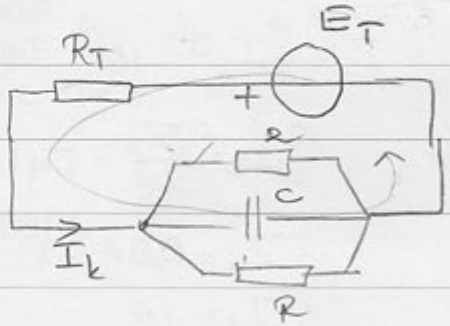
$$U_{45} = \beta E$$





$R_T = 100\Omega$

$R = \frac{4}{3} \cdot 1000\Omega$



$E_T - I_k R_T - \frac{2}{3} \cdot 1000 I_k = 0$

$E_T = -60 \cdot 0{,}1 - \frac{2}{3} \cdot 60 =$

$= -46\,V$

$-46 - I_k' R_T - \frac{4}{3} 1000 I_k' = 0$

$-46 = I_k' \left(1000 \cdot \frac{4}{3}\right)$

$I_k' = -32{,}1\,mA$

$Q = -85{,}58\,\mu C$

$Q_n - 80 = -85{,}58\,\mu C$

$Q_n = -5{,}58\,\mu C$

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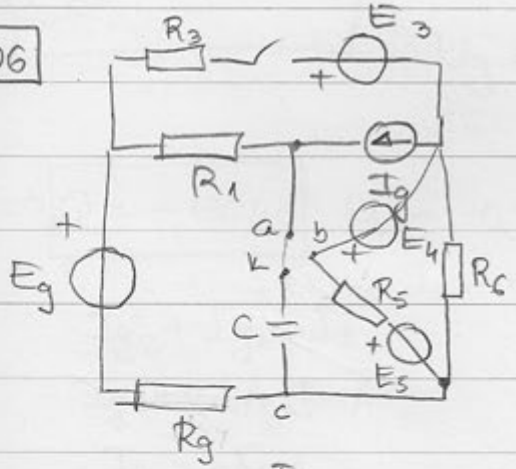


$E_g = \frac{R_8 E_7 - R_7 E_8}{R_7 + R_8}$

$R_g = \frac{R_7 R_8}{R_7 + R_8} = 200\Omega$

$R_7 = R_8 = 400\Omega$

$R_1 = 250\Omega = R_3$

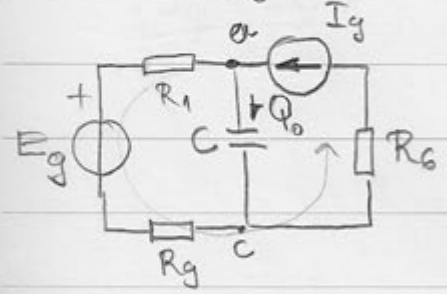
$R_5 = 500\Omega$

$R_6 = 750\Omega$

$C = 0{,}5\,\mu F \quad E_3 = 30\,V \quad E_4 = 20\,V \quad I_g = 20\,mA$

k a→b

$Q_{bc} = -20\,\mu C \qquad I_4 = 77.3\,mA$

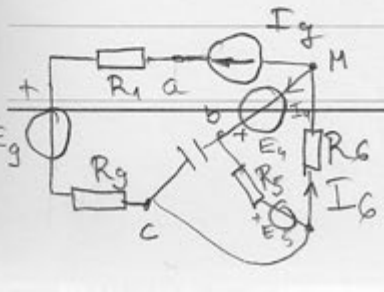


$-(R_1 + R_6 + R_g) I_g - E_g = 0$

$E_g = -1200\Omega \cdot 20\,mA = -24\,V$

$Q_0 = U_{ac} C = \left[(R_g + R_1) I_g + E_g\right] C =$

$= -13 \cdot 0{,}5 = -6{,}5\,\mu C$



$Q_{bc} = -20\,\mu C \qquad Q = Q_0 + Q_{bc} = -26{,}5\,\mu C$

$U_{bc} = -53\,V$

$U_{6M} = V_c - V_M = V_c - V_b + V_b - V_M = -U_{bc} + U_{bM} = 53 + 20 = 73\,V$

$I_6 = 97.3\,mA$

ANALYSIS

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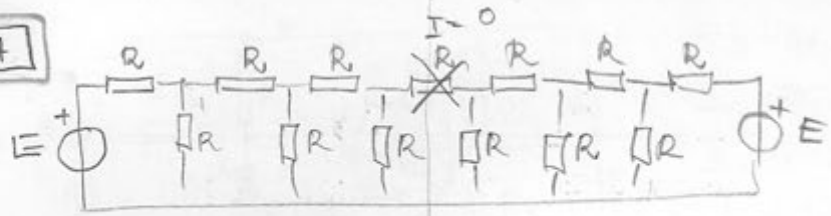
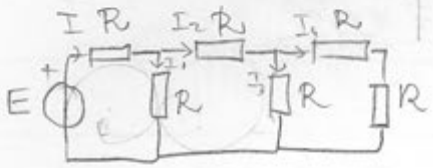


$E = 26V$
$R = 10\Omega$



$E - IR - I_1R = 0$

$I + I_1 = \frac{E}{R}$ $\quad I = I_1 + I_2$

$I_1 = I_2 + I_3 = \frac{5}{3} I_2$

$I_4 = \frac{1}{3} I_2$ $\quad I = \frac{8}{3} I_2$

$I_3 = \frac{2}{3} I_2$

$\frac{13}{3} I_2 = \frac{E}{R}$

$P = RI^2 + RI_1^2 + RI_2^2 + RI_3^2 + 2RI_4^2$

$= 41,6W$

$I_2 = 0,6A$
$I_1 = 1A$
$I_4 = 0,2A$
$I_3 = 0,4A$
$I = 1,6A$

$P_{max} = 83,2W$

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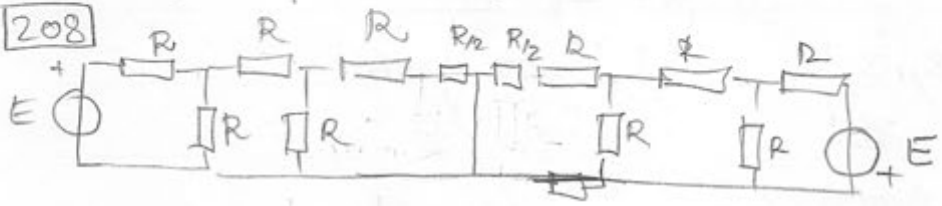
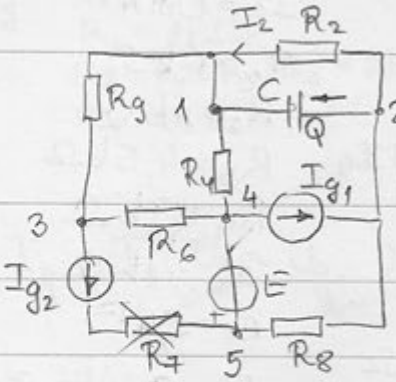


193.

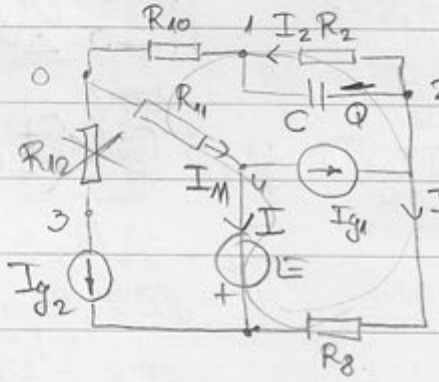
$I_{g_1} = 2mA$ $R_g = 3k\Omega$
$R_1 = 2k\Omega$
$R_2 = 300\Omega$
$R_3 = 3k\Omega$
$R_4 = 3k\Omega$
$R_5 = 1{,}8k\Omega$
$R_6 = 4k\Omega$
$R_7 = 1k\Omega$
$R_8 = 600\Omega$
$C = 200\mu F$
$Q = 60\mu C$
$W_e = 81\mu J = \frac{1}{2}\frac{Q^2}{C}$
$Q = \pm 180\mu C$

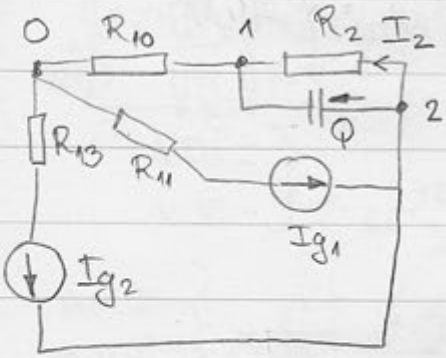
$P_{I_{g1}} < 0$
$\Pi \to 3$



$U_{21} = 0{,}3V$
$I_2 = 1mA$

$R_{10} = 0{,}9k\Omega$
$R_{11} = 1{,}2k\Omega$
$R_{12} = 1{,}2k\Omega$
$R_{13} = 2{,}8k\Omega$





$U_{21} = Q/C$
$I_2 = \frac{U_{21}}{R_2}$

$U_{20} = I_2(R_2 + R_{10})$
$U_{20} = -R_{11}I_{g_1} + U_g$
$U_g = U_{20} + R_{11}I_{g_1}$

$U_g < 0 \Rightarrow U_{20} + 1{,}8 < 0$

$U_{20} = \frac{U_{21}}{0{,}3}(1{,}2) = 4U_{21} = -3{,}6V$

$\Rightarrow \boxed{Q = -180\mu C}$ $U_{21} = -0{,}9V$ $\boxed{U_g = -1{,}8V}$

$I_2 = 3mA$

$I_{g_2} + I_{g_1} = I_2$
$I_{g_2} + 2mA = 3mA$
$I_{g_2} = 1mA$

$I_{11} = I_2 - I_{g_2} = 6mA$
$I = I_{11} - I_{g_1} = 4mA$

$\mathcal{E} + R_8I_8 - I_2R_2 - I_2R_{10} - R_{11}I_{11} = 0$
$\mathcal{E} = 7{,}2 + 0{,}9 + 0{,}3 - 0{,}6 = 7{,}8V$

ANALYSIS LABORATORY EQUIPMENT

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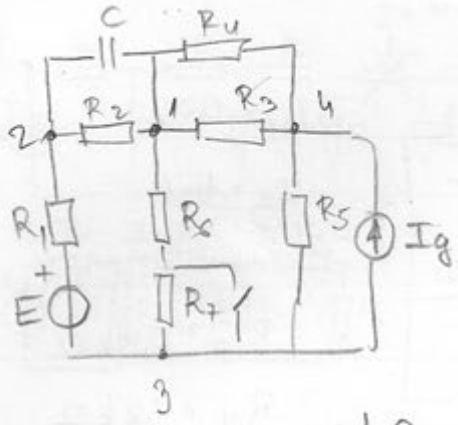


$E = 50V$
$I_g = 10mA$
$R_1 = 6k\Omega$
$R_2 = 4k\Omega$
$R_3 = 4,5k\Omega$
$R_4 = 9k\Omega$
$R_6 = 1k\Omega$
$C = 5\mu F$

$W_{e1} = \frac{1}{2}\frac{Q^2}{C}$

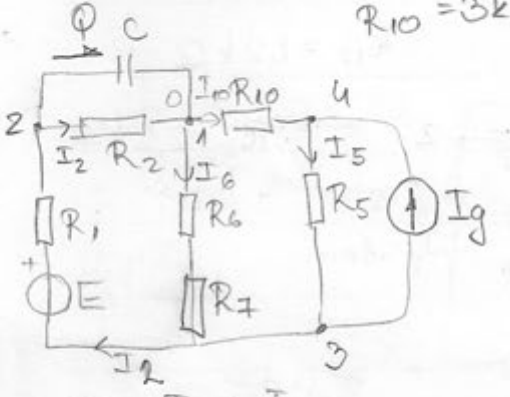
$Q_1 = \pm 80\mu C$

$W_{e2} - W_{e1} = \Delta W_{e1}$

$W_{e2} = 40\mu J$

$Q_2 = \pm 20\mu J$

$R_{10} = 3k\Omega$



$\Pi \to 3 \quad W_{e1} = 640\mu J$

$\Pi \to 0 \quad \Delta W_{e1} = -600\mu J$

R_7 ?

$U_{21} = \frac{Q_1}{C} \begin{cases} + \\ - \end{cases} 16V$

$I_2 = U_{21}/R_2 = \pm 4mA$

$U_{23} = E - R_1 I_2 = \begin{cases} 26V \\ 74V \end{cases}$

$I_{10} + I_6 = I_2$

$I_{10} + I_g = I_5$

$I_6 + I_5 - I_g = I_2$

$I_6 + I_5 = \begin{cases} 14mA & I_2 = +4mA \\ 6mA & I_2 = -4mA \end{cases}$

$V_2 = U_{21}$

$V_3 = U_{21} - U_{23} = \begin{cases} -10V \\ -90V \end{cases}$

$I_6 = \frac{U_{03}}{R_6} = \frac{-V_3}{R_6} = \begin{cases} -10mA \\ -90mA \end{cases}$

$\Pi \to 0$

$U_{21} = \frac{Q_2}{C} = \begin{cases} + \\ - \end{cases} 4V$

$I_2 = \begin{cases} + \\ - \end{cases} 1mA$

$I_6 + I_5 = I_2 + I_g = \begin{cases} 11mA \\ 69mA \end{cases}$

$I_5 = \begin{cases} 24mA \\ 96mA \end{cases} \qquad I_{10} = \begin{cases} 14mA \\ 86mA \end{cases}$

$U_{23} = E - I_2 R_1 = \begin{cases} 44V \\ 56V \end{cases}$

$U_{43} = V_4 - V_3 = \begin{cases} -32V \\ -168V \end{cases}$

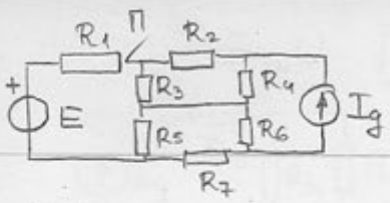
$V_4 = -U_{04} = \begin{cases} -42V \\ +258V \end{cases}$

$U_{13} = V_1 - V_3 + V_2 - V_2 = U_{23} - U_{21} = \begin{cases} 40V \\ 60V \end{cases}$

$R_7 =$

$I_6 = \frac{U_{13}}{R_6 + R_7}$

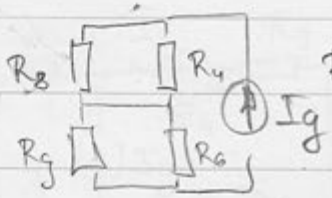
195 ///



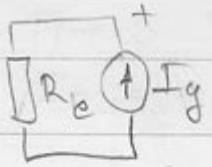
$I_g = 2mA$
$R_1 = 800\Omega$
$R_2 = 1k\Omega$
$R_3 = R_4 = R_5 = R_6 = 2k\Omega$
$R_7 = 1k\Omega$

$\Pi \to 3 \quad \Delta P(I_g) = -2,4mW$
$E = ?$

$$P_2 - P_1 = U_{g_2} I_{g_m} - U_{g_1} I_g = I_g (U_{g_2} - U_{g_1})$$

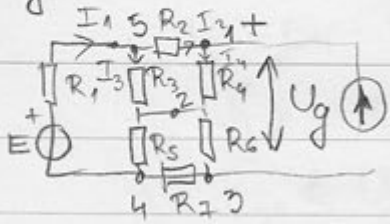


$R_8 = 3k\Omega \quad R_g = 3k\Omega \quad R_e = 2,4k\Omega$



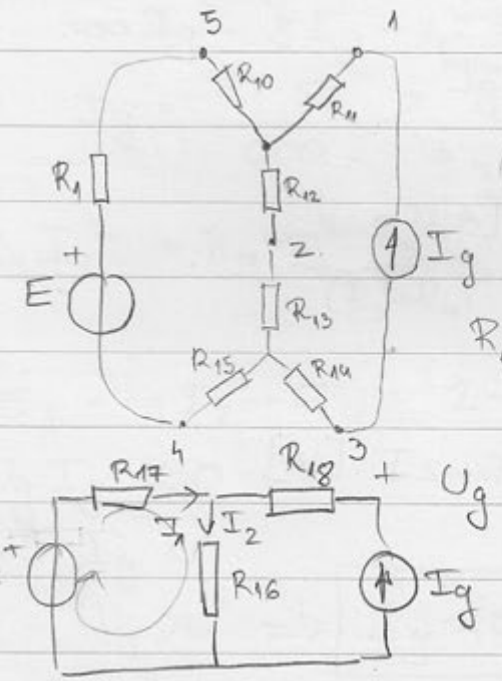
$U_g = I_g R_e = 4,8V$
$P_1 = 9,6mW \quad P_2 = 7,2mW$

$U_g = 3,6\,V$



$I_g + I_2 = I_4$
$I_1 = I_2 + I_3$

$R_{16} = 2k\Omega$



$R_{10} = \frac{2}{3}k\Omega \quad R_{13} = 1k\Omega$
$R_{11} = \frac{2}{3}k\Omega \quad R_{14} = \frac{2}{3}k\Omega$
$R_{12} = 1k\Omega \quad R_{15} = \frac{2}{3}k\Omega$

$R_{15} + R_{10} + R_1 = R_{17} = 2,13\,k\Omega$

$R_{17} = \frac{48}{510}\frac{3}{3} + \frac{2}{3}\frac{5}{5} = \frac{32}{15}k\Omega$

$R_{18} = \frac{4}{3}k\Omega = 1,33k\Omega$

$I_1 + I_g = I_2$

$U_g = I_2 R_{16} + I_g R_8$

$3,6 = 2 \cdot 10^3 \cdot I_2 + 2 \cdot \frac{4}{3}$

$1,8 = 10^3 I_2 + \frac{4}{3}$

$\frac{1,4}{3} \cdot 10^{-3} = I_2$

$I_2 = 0.467$

$I_1 = I_2 - I_g$

$I_1 = -1,53mA$

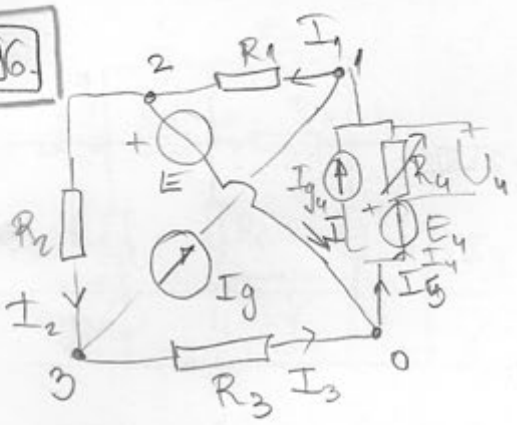
$E - R_{17} I_1 - I_2 R_{16} = 0$

$E = -3,27 + 0,9... =$

$= 2,3$

ANALYSIS LABORATORY EQUIPMENT

196.



$I \in [-3A, -1A]$ $U_4 \in ?$

$E = 5V$

$E_4 = 6V$

$I_g = 1A$

$I_{g4} = 3A$

$R_1 = 2\Omega$

$R_2 = 3\Omega$

$R_3 = 5\Omega$

$V_2 = E$

$V_1 = E_4 + U_4$

3: $-\frac{1}{R_2}V_2 + \left(\frac{1}{R_2} + \frac{1}{R_3}\right)V_3 = -I_g$

$\left(\frac{5}{15} + \frac{3}{15}\right)V_3 = -1 + \frac{5}{3}$

$V_3 = \frac{15}{8} \cdot \frac{5}{3} = 1{,}25V$

$I_3 = \frac{U_{30}}{R_3} = 0{,}25A$

$I_5 = I + I_3 = 0{,}25 + I$

$I_5 = I_{g4} + I_4$

$I_4 = 0{,}5 + I + 3 = 3{,}25 + I$ [A]

$I_2 = I_g + I_3 = 1{,}25A$

$I_1 = I_2 + I = 1{,}25 + I$ [A]

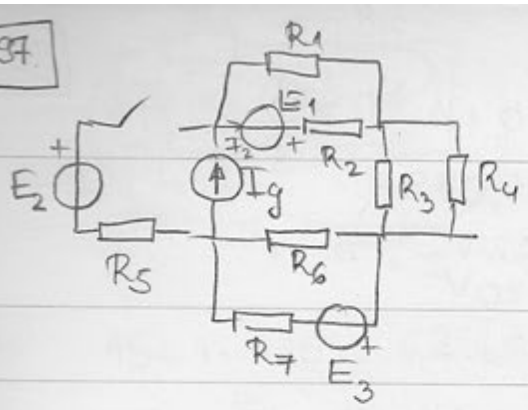
$U_{10} = E + R_1 I_1 = 5 + 2{,}5 + 2I$ [V]

$U_4 = 1{,}5 + 2I$ [V]

$U_4 \in [-4{,}5V, -0{,}5V]$ ✓

$R_4 \in [18\Omega, 0{,}22\Omega]$ ✓

197.



$E_1 = 25V$ $E_4 = 10V$

$E_3 = 4V$ $E_5 = 2V$

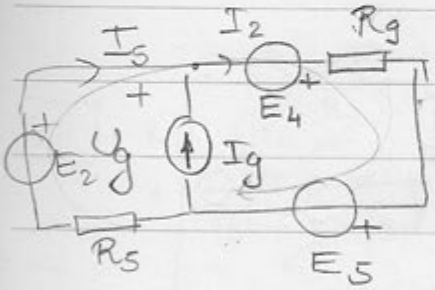
$R_1 = 100\Omega$ $R_8 = 60\Omega$

$R_2 = 150\Omega$ $R_g = 160\Omega + 60\Omega + 80\Omega = 300\Omega$

$R_6 = R_7 = 160\Omega$

$R_3 = 200\Omega$

$R_4 = 800\Omega$ $R_5 = 50\Omega$



$\Pi \to 6 \quad P_{Ig} = 2,2W$

$\Pi \to 3 \quad P_{R_4} = 320mW \quad P_{Ig} < 0$

$E_2 ?$

$$U_g + E_4 - R_g I_g - E_5 = 0$$

$$U_g = -8 + 300 \cdot I_g$$

$$P_{Ig} = U_g I_g = -8 I_g + 300 I_g^2$$

$$300 I_g^2 - 8 I_g - 2,2 = 0$$

$$I_g = \frac{8 \pm 52}{600} \nearrow I_g = 0,1A$$

$$\searrow I_g = -0,073A$$

$$P_{R_4} = R_4 I_4^2 = R_4 \cdot \frac{I_2^2 \cdot R_3^2}{(R_3 + R_4)^2} = I_2^2 \cdot 32$$

$$I_2 = 0,01A$$

$$U_g = E_5 + R_g I_2 - E_4 = 2 - 10 + 3 = -5$$

$$U_g I_g < 0$$

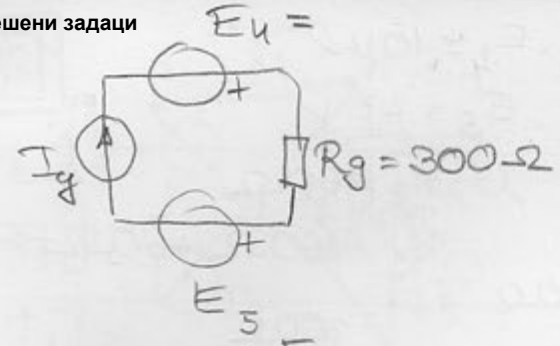
$$-5 \cdot I_g < 0$$

$$I_g > 0 \Rightarrow \boxed{I_g = 0,1A}$$

$$I_5 = -0,09$$

$$-5 = -I_5 R_5 + E_2 = 4,5 + E_2$$

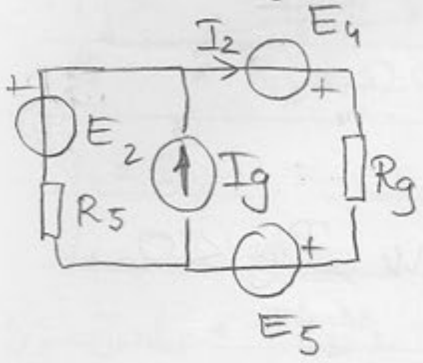
$$E_2 = -9,5V$$



$P_{Ig} = 2{,}2\,W$

$$I_g = \begin{cases} 0{,}1\,A \\ -0{,}073\,A \end{cases}$$

$$U_g = \begin{cases} 22\,V \\ -30\,V \end{cases}$$



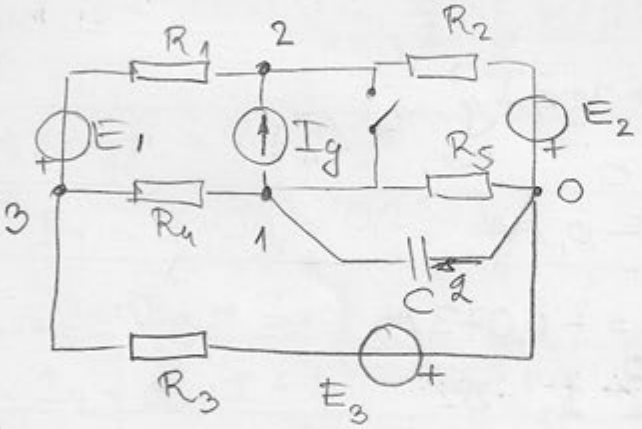
$I_2 = \pm 0{,}01\,A$

$$U_5 = \begin{cases} -5\,V \\ -11\,V \end{cases}$$

$\boxed{I_g = 0{,}1\,A}$

$$I_5 = \begin{cases} 0{,}09\,A \\ 0{,}11\,A \end{cases}$$

198.



$E_1 = 4V$ $C = 1\,\mu F$

$E_2 = 1V$ I_g?

$R_1 = 200\Omega$ $\Pi \to 3$ $q = 4\mu C$

$R_2 = 100\Omega$ P_{Ig} $\Pi \to 0$

$R_3 = 400\Omega$

$R_4 = 400\Omega$

$R_5 = 200\Omega$

$\Pi \to 3$

$$1: \left(\frac{1}{R_4} + \frac{1}{R_5}\right)V_1 + 0\,V_2 - \frac{1}{R_4}V_3 = -I_g$$

$$2: 0 \cdot V_1 + \left(\frac{1}{R_1} + \frac{1}{R_2}\right)V_2 - \frac{1}{R_1}V_3 = -\frac{E_1}{R_1} + I_g - \frac{E_2}{R_2}$$

$$3: -\frac{1}{R_4}V_1 - \frac{1}{R_1}V_2 + \left(\frac{1}{R_1} + \frac{1}{R_4} + \frac{1}{R_3}\right)V_3 = \frac{E_1}{R_1} - \frac{E_3}{R_3}$$

$$1: 7{,}5\,V_1 - 2{,}5V_3 = -I_g \cdot 10^3$$

$$2: 15V_2 - V_3 = -20 + I_g \cdot 10^3 - 10$$

$$3: -2{,}5V_1 - V_2 + 10V_3 = 20 - 2{,}5E_3$$

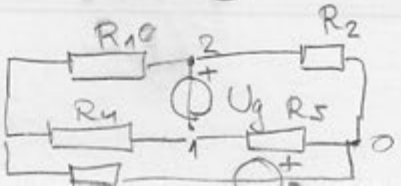
$U_{21}^{\sigma} = U_g$

$U_{21}^{3} = 0$

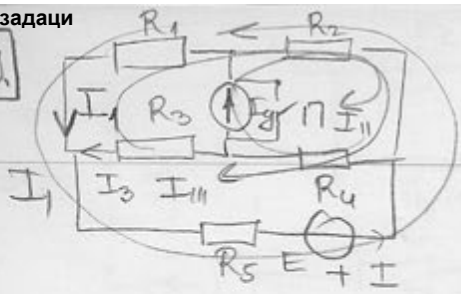
$$U_{01} = a \cdot \Sigma E + b \cdot U_{21}$$

$$\Delta U_{01} = b\,\Delta U_{21} = -bU_g$$

$$\Delta U_{01} = \frac{q}{C} = 4V$$



199.



$E = 75V$
$R_1 = 3k\Omega$
$R_2 = 6k\Omega$
$R_3 = 3k\Omega$
$R_4 = 124\Omega$
$R_5 = 750\Omega$

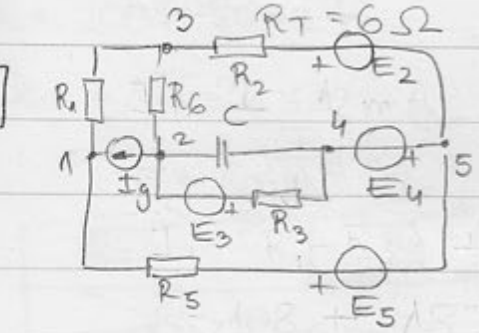
$P_E^{\sigma} = P_E^{3}$

I_g?

b): $1,5 + 4 + 0,75 = 6,25k\Omega$

$I = \frac{E}{6,75} = 12mA$ ✓

201



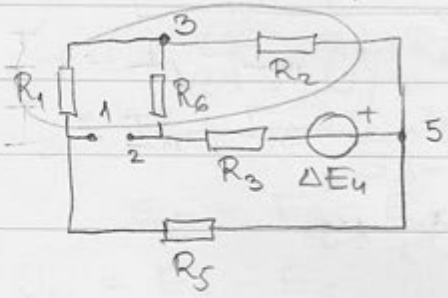
$E_5 = 50V$

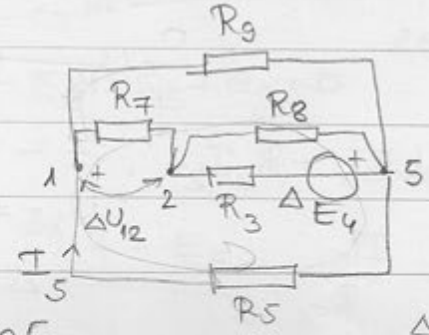
$R_1 = R_2 = 100\Omega$
$R_3 = 200\Omega$
$R_6 = 400\Omega$

R_5? ΔE_4?

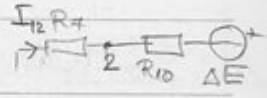
ΔE_4 $\Delta U_{12} = -17V$ $\Delta I_{35} = 30mA$

$\Delta U_{12} = a \Delta E_4$





$R_{10} = 163,64\Omega$



$\Delta E = 0.82 \Delta E_4$

$R_g = R_1 + R_2 + \frac{R_1 R_2}{R_6} = 200 + \frac{100\,000}{400} = 225\Omega$

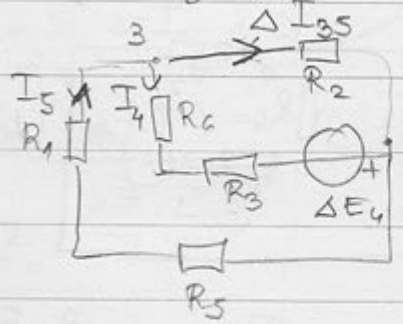
$R_7 = R_1 + R_6 + \frac{R_1 R_6}{R_2} = 400 + 100 + 400 = 900\Omega = R_8$

$I_{12} = -18.89mA$

$I_5 = R_g \cdot \frac{I_{12}}{R_g + R_5}$

$I_{12}(R_7 + R_{10}) - \Delta E + I_5 R_5 = 0$

(1) $-20 - \Delta E + \frac{R_g R_5}{R_g + R_5} \cdot 18.89 = 0$



$I_5 = \Delta I_{35} + I_4$

$-20 - 0.82\Delta E_4 - \frac{R_g R_5}{R_g + R_5} \cdot 18,89 = 0$

$-24.4 - \Delta E_4 - \frac{5183.23 \cdot R_5}{225 + R_5} = 0 \quad / 225 + R_5$

$-5490 - 225\Delta E_4 - 24.4 R_5 - \Delta E_4 R_5 =$

$= 5183.23 R_5$

$U_{35} = R_2 \Delta I_{35} = 3V$

$3V = -\Delta E_4 + 600 \cdot I_4$

$3V = -(R_5 + R_1)(\Delta I_{35} + I_4)$

$I_4 = 0,005 + \frac{\Delta E_4}{600}$

$6,5 = -0.035 R_5 - 5 - R_5 0,005 -$

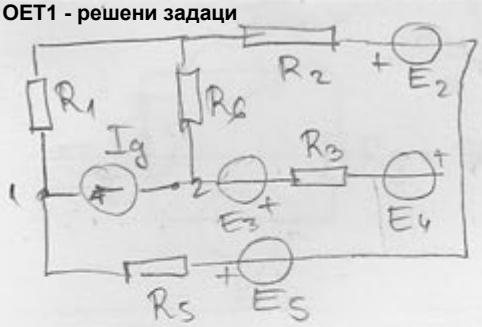
$-R_5 \frac{\Delta E_4}{600} - 1000 \cdot 0,5 + \frac{100 \Delta E_4}{6000}$

$\Delta E_4 = -24.4 - \frac{5183.23}{225 + R_5} R_5$

$(3900 + 21 R_5) = -244 + 24.4 R_5 - \frac{51832.3}{225 + R_5} R_5 + 51$

$\frac{(6,5 + 0,035 R_5) 600}{100 - R_5} = \Delta E_4$

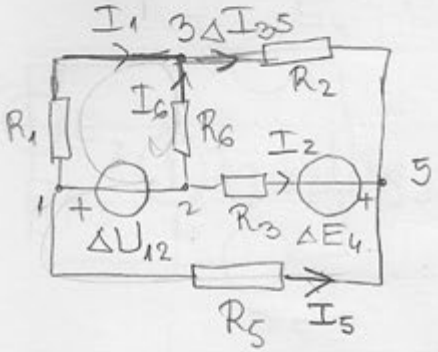
ANALYSIS



ΔE_4

$\Delta U_{12} = -17V$

$\Delta I_{35} = 30mA$



$U_{35} = \Delta I_{35} R_2 = 3V$

$U_{12} = -17\ V$

$I_1 + I_6 = \Delta I_{35}$

$5I_6 - 0.17 = 0.03$

$I_6 = 0.04 = 40mA$

$I_1 = -10mA$

$\Delta U_{12} - R_1 I_1 + R_6 I_6 = 0$

$-17 - 100 I_1 + 400 I_6 = 0 \quad / :100$

$I_1 = 4I_6 - 0.17$

$U_{15} = R_2 \Delta I_{35} + R_1 I_1 =$

$= 100 \cdot 20mA = 2V$

$U_{25} = U_{23} + U_{35} = R_6 I_6 + R_2 \Delta I_{35}$

$U_{15} = U_{12} + U_{25}$

$2 = -17 + U_{25} \quad \boxed{U_{25} = 19V}$

$I_2 + I_5 = -\Delta I_{35}$

$U_{25} = I_2 R_3 - \Delta E_4$

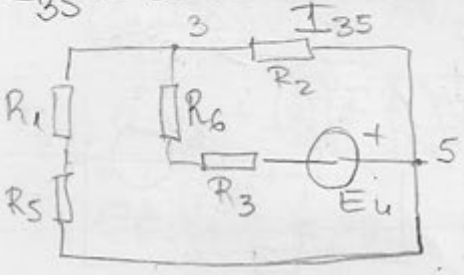
$\Delta E_4 = I_2 R_3 - 19$

$\Delta U_{12} - I_5 R_5 - \Delta E_4 + R_3 I_2 =$

$= 0 \qquad I_5 = \frac{U_{15}}{R_5}$

$I_{35} = aE_4 + b \qquad \Delta U_{12} = c \Delta E_4$

$\Delta I_{35} = a \cdot \Delta E_4$



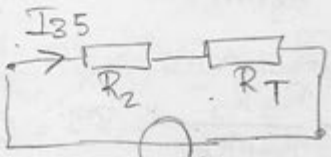
$R_6 + R_3 = 600\Omega = R_8$

$R_1 + R_5 = R_g = 100 + R_5$

$E = \frac{R_g E_4}{R_g + R_8}$

$R_T = \frac{R_8 R_g}{R_g + R_8}$

$R_8' = 400\Omega$



$I_{35} = \frac{-E}{R_2 + R_T} = -\frac{\frac{R_g E_4}{R_g + R_8}}{R_g(R_2 + R_8) + R_2 R_8}$

$\Delta I_{35} = -\frac{R_g \Delta E_4}{R_g R_8' + R_2 R_8}$

$-20 - 0,82E_4 = \frac{225 R_5}{225 + R_5} 18.89$

$-\frac{(21 R_g + 1800)}{R_g} = \Delta E_4$

$-20 + \frac{17,22 R_g + 1476}{R_g} = \frac{4250.25 R_5}{225 + R_5} \quad / (225 + R_5) R_g$

$-20 R_g (225 + R_5)$

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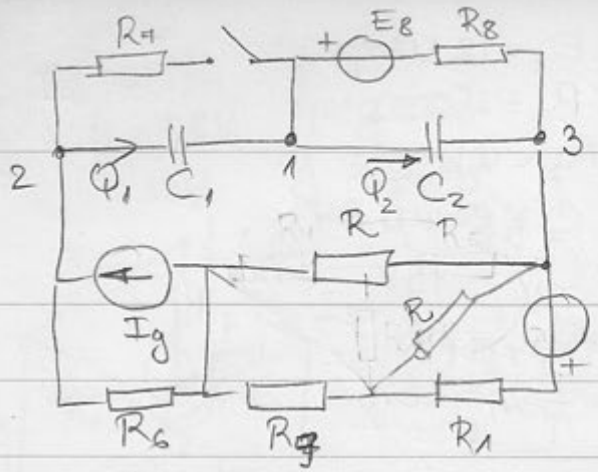


$I_g = 0{,}75\,A$
$R_1 = R_2 = 300\,\Omega$
$R_3 = R_4 = R_5 = 100\,\Omega$
$R_6 = 50\,\Omega \quad R_7 = 200\,\Omega \quad R_8 = 100\,\Omega$
$C_1 = 1\,\mu F \quad C_2 = 0{,}5\,\mu F$
Q_1, Q_2 П → 1 $Q_1 = 2\,\mu C$

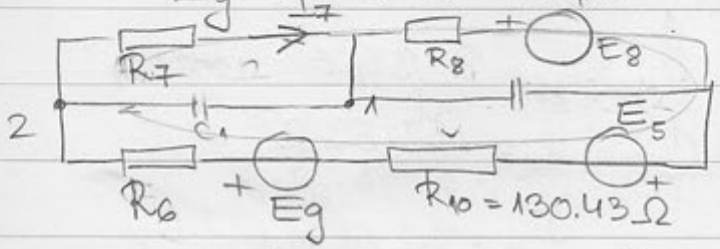
$R = 200 + 50 = 250$

$U_{13} = E_8$ $\quad Q_{20} = U_{13} \cdot C_2 = E_8 C_2$

$R_g = 136{,}36\,\Omega$

$U_{R_6} = U_g \quad I_{R_6} = U_g / R_6$

$E_g = I_g R_6 = 37{,}5\,V$



$U_{21} = \frac{Q_1}{C_1} = 2\,V$

$I_7 = 0{,}01\,A$

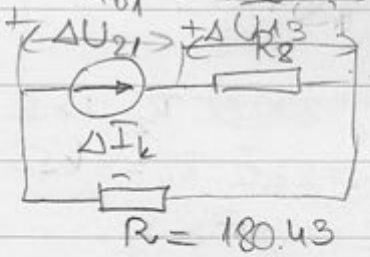
$-I_7 (R_7 + R_8 + R_6 + R_{10}) - E_8 - E_5 + E_g = 0$

$-4.8 - E_8 - E_5 + E_g = 0$ $\quad \Delta U_{21} = a \Delta I_k$

$E_8 = E_g - E_5 - 4{,}8 = 32.7 - E_5$

$U_{21} = E_g - E_5$

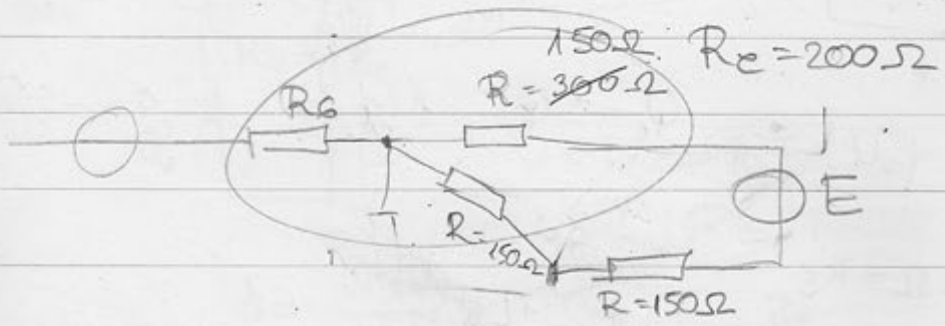
$Q_{01} = (E_g - E_5) C_1$



$\Delta U_{13} = R_8 \Delta I_k = 1\,V$

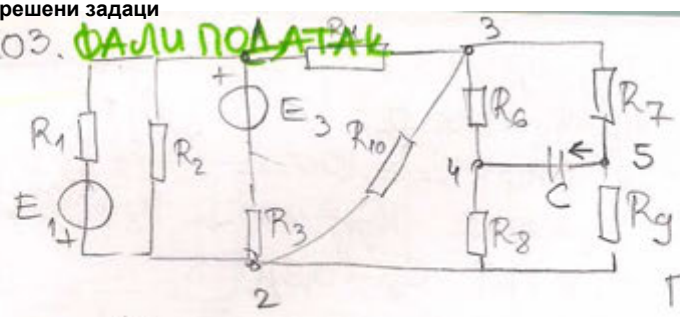
$Q_2 = 95\,\mu C$ $\quad Q_1 = -3\,\mu C$

$\Delta U_{21} = -\Delta I_k (R_8 + R) = -3\,V$



ANALYSIS

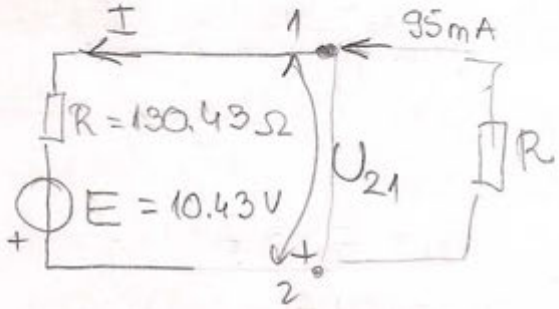
203. ФАЛИ ПОДАТАК



$E_1 = 12\,V$
$R_1 = 150\,\Omega$
$R_2 = 1\,k\Omega$
$C = 0{,}1\,\mu F$
$U_{21} = 13\,V$
$U_{54} = 2\,V$
$I_{31} = 95\,mA$
Q?

$Q_{(1)} = U_{54} \cdot C = 0{,}2\,\mu C$

$I_k = I_{21} = 130\,mA$



$U_{54} = a I_{21} + b$

$\Delta U_{54} = a \Delta I_{21}$

$U_{21} = E - RI$

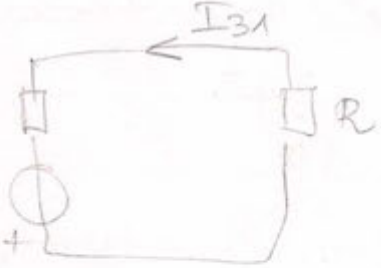
$I = \frac{E - U_{21}}{R} = -35\,mA$

$U_{21} = R \cdot 95\,mA$

$R = 157.89\,\Omega$

$I_{31}' = 36.17\,mA$

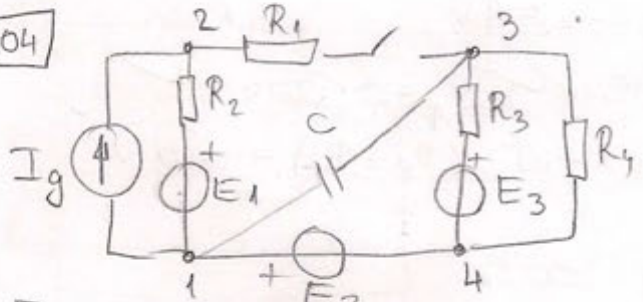
$U_{21} =$



$\frac{q}{C} = a \Delta I_{21}$

$q =$

204

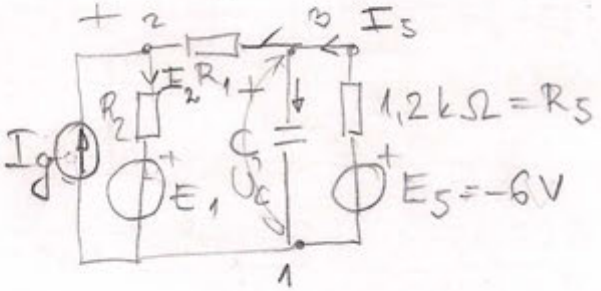


$E_2 = 12\,V \quad R_1 = 800\,\Omega \quad R_2 = 1\,k\Omega$
$E_3 = 10\,V \quad R_3 = 2\,k\Omega \quad R_4 = 3\,k\Omega$
$I_g = 10\,mA \quad C = 10\,\mu F$

$W_{e_1} = W_{e_2}$

$\Pi \to 0 \quad P_{I_g} < 0 \quad E_1$?

$Q_1 = \pm Q_2 \quad 1^\circ\ q = 0 \quad 2^\circ\ q = -2Q_1$



$U_c = -6\,V$

$U_c' = \pm U_c$

$U_c' = E_5 - I_5 R_5 \Rightarrow I_5 = \frac{E_5 - U_c'}{R_5} = 0$

$I_2 = 10\,mA$

$I_2 = I_5 + I_g$

$16.7 U_c' + 40 < 0$

$P_{I_g} = I_g \cdot (U_c' - I_5 R_1) =$

$= I_g \cdot \left(U_c' - \frac{R_1}{R_5} E_5 + \frac{R_1}{R_5} U_c'\right) = I_g (1.67 U_c' + 4)$

$U_c' < -2.39$

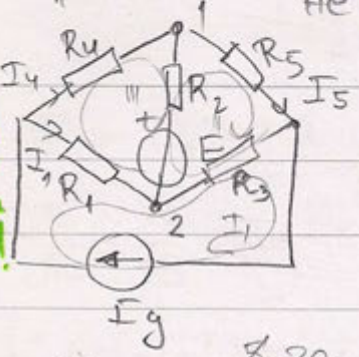
$U_c' = -6\,V$

$U_c' = E_1 + R_2 I_2$ бројне вредности у збирци не важе!

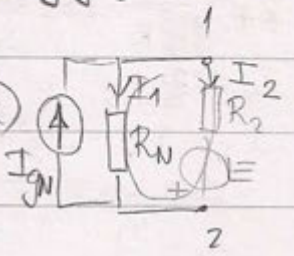
$-6V = E_1 + 8V$

$E_1 = -14V$

140 читати за снер!



a)



$-R_2 I_2 + E + I_1 R_N = 0$

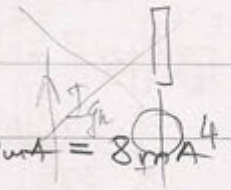
$I_N = I_1 + I_2$

$I_N = 3mA$

I_N

$5 \| 20 = \frac{8 \cdot 20}{25} = 4k\Omega$ $R_N = 4k\Omega$

$I_{gN} = I_{k5} = I_{12}$



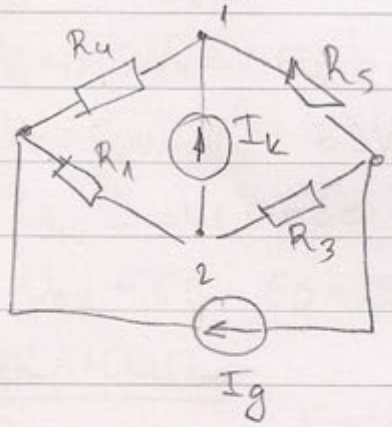
$I_4 = \frac{R_1}{R_1 + R_4} I_g = \frac{2}{5} 20mA = 8mA$

$I_1 = 12mA$

$I_{12} + I_5 = I_4$

$I_5 = \frac{5}{20} \cdot 20 = 5mA$

$I_{12} = 8 - 5 mA = 3mA$



$I_1 = I_g$

$-R_3 I_g + (R_2 + R_3 + R_5) I_{II} - R_2 I_{III} = E$

$-R_1 I_g - R_2 I_{II} + (R_1 + R_4 + R_2) I_{III} = -E$

$-100 + 40 \cdot 10^3 I_{II} - 20 \cdot 10^3 I_{III} = 12$

$2 I_{II} - I_{III} = 6,2 mA$

$-140 - 20 \cdot 10^3 I_{II} + 10 \cdot 10^3 I_{III} = 16$

$-2 I_{II} + \frac{I_{III}}{5} = 1.6mA$

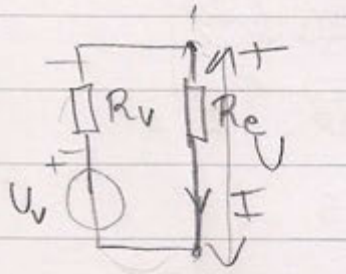
$\frac{4}{5} I_{III} = 5,2mA$

$I_{III} = 6,5mA$

$I_{II} = 5,9mA$

$I_k = I_{II} - I_{III} = 0.6mA$

141.



$I = \frac{U}{R_e}$

$U = U_V + R_V I = U_V - \frac{R_V}{R_e} U$

$\delta = \frac{U - U_V}{U_V} = \frac{-\frac{R_V}{R_e} U}{U} = -\frac{R_V}{R_e}$

$\delta = \frac{U - U_V}{U_V} = \frac{-\frac{R_V}{R_e} U}{\left(1 + \frac{R_V}{R_e}\right) U} =$

$= -\frac{1}{1 + \frac{R_e}{R_V}}$

$U_{AB} = U_V - R_V I =$

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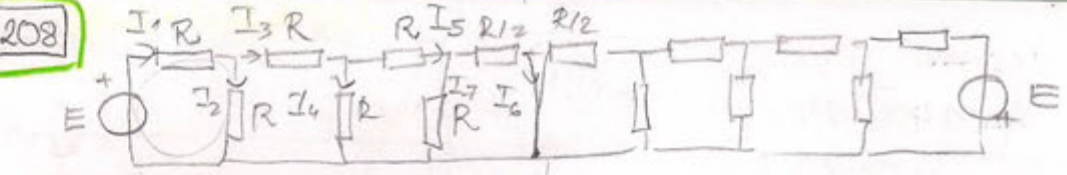
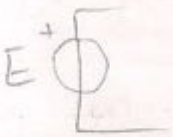




$E - I_1R - \frac{I_1}{2}R = 0$

$E = \frac{3}{2}I_1R \quad I_1 = \frac{2}{3}\frac{E}{R}$

$I_2 = I_3 = \frac{1}{3}\frac{E}{R}$

$I_4 = \frac{1}{30} = \frac{1}{6}\frac{E}{R}$

$I_6 = \frac{1}{9}\frac{E}{R}$

$I_7 = \frac{1}{18}\frac{E}{R}$

$I_7 = \frac{\frac{R}{2}}{\frac{3}{2}R} I_5 = \frac{1}{3}I_5$

$I_6 = \frac{2}{3}I_5$

$I_5 = I_4 \quad I_5 + I_4 = I_3$

$I_3 + I_2 = I_1 \quad I_3 = I_2$

$I_2 = \frac{I_1}{2}$

$P_{uk} = R(I_1^2 + I_2^2 + I_3^2 + I_4^2 + I_5^2 + I_7^2) + \frac{R}{2}I_6^2 =$

$= R\frac{E^2}{R^2}\left(\frac{4}{9} + 2\cdot\frac{1}{9} + \frac{2}{36} + \frac{1}{324}\right) + \frac{R}{2}\cdot\frac{E^2}{R^2}\frac{1}{81} =$

$= \frac{216+1+18}{324} = \frac{235}{324}E^2R + E^2R\frac{4}{324} =$

$= \frac{239}{324}E^2R$

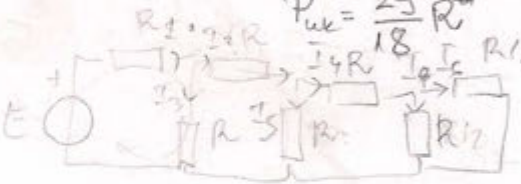
$\frac{\frac{R}{2}R}{\frac{3}{2}R} = \frac{1}{3}R + R = \frac{4}{3}R$

$\frac{\frac{4}{3}RR}{\frac{7}{3}R} = \frac{4}{7}R + R = \frac{11}{7}R$

$\frac{\frac{11}{7}R}{\frac{18}{7}} = \frac{11}{18}R \quad \frac{29}{18}R$

$I = \frac{E}{R_e} = \frac{18E}{29R} = \frac{18}{40} = 0.45A$

$P_{uk} = \frac{29}{18}R\frac{4}{9}$



$E = RI_1 + R\frac{1}{2}I_1$

$\frac{2}{3}\frac{E}{R} = I_1$

$I_6 = \frac{R}{\frac{3}{2}R}I_4 = \frac{2}{3}I_4$

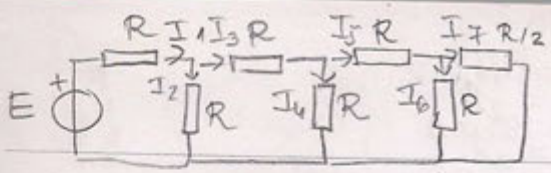
$I_7 = \frac{1}{3}I_4$

$\frac{1}{24}I_A = I_4 = I_5$

$\frac{1}{2}I_1 = I_2 = I_3$

$P = \frac{E^2}{R}\left(\frac{16}{9}\cdot\frac{1}{24}\cdot 2 + \frac{1}{36}\cdot 2 + \frac{1}{144}\right) + \frac{R}{2}\cdot\frac{E^2}{R^2}\frac{R^2}{144}$

$\frac{107}{144}\cdot\frac{E^2}{R}$



$\frac{\frac{4}{3}R^2}{\frac{4}{3}R+R} = \frac{4}{7}R$ $\quad \frac{11}{7}R$

$I_2 = \frac{\frac{11}{7}R}{\frac{18}{7}R} I_1 = \frac{11}{18} I_1 \quad I_3 = \frac{7}{18} I_1$ $\quad I_2 = 0{,}275\,A$ $\quad I_3 = 0{,}175\,A$

$E = I_1 R + R \cdot \frac{11}{18} I_1$ $\quad P = 13{,}05$

$\frac{E}{R} \cdot \frac{18}{29} = I_1 \quad I_1 = 0{,}45\,A$

$I_4 = \frac{\frac{4}{3}R}{\frac{7}{3}R} I_3 = \frac{4}{7} I_3 \quad I_5 = \frac{3}{7} I_3$

$I_4 = 0{,}1 \quad I_5 = 0.075 \quad I_6 = \frac{\frac{1}{2}}{2} = \frac{1}{3} I_5 = 0{,}025$

$I_7 = \frac{2}{3} I_5 = 0{,}05$

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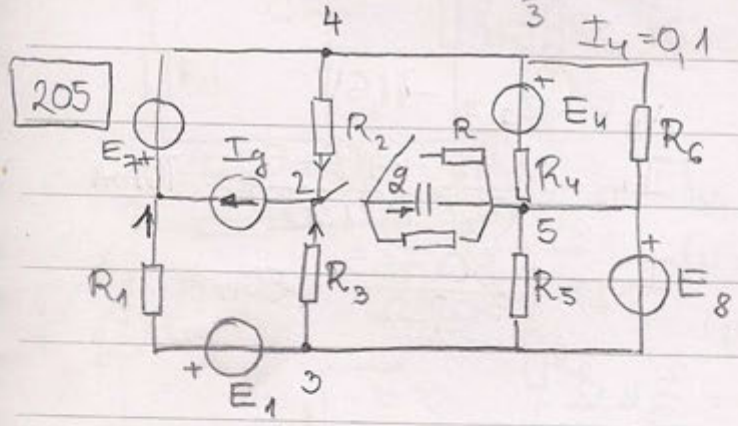


$E_7 = 41{,}6\,V \quad R_2 = R_4 = R_6 = 120\,\Omega$

$I_g = 80\,mA \quad R_3 = R_5 = 300\,\Omega$

$R_1 = 60\,\Omega \quad C = 2\,\mu F$

$k \to 1 \quad q = -80\,\mu C \quad U_{12} = 50\,V$

$\Pi \to 0 \quad q_1 ? \quad U_{13} = 65\,V$

$V_1 = 0 \quad V_4 = -E_7 = -41{,}6$

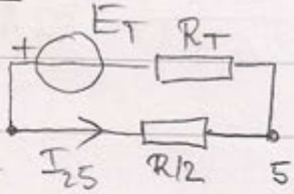
$V_2 = 50V \quad V_3 = 65V$

$U_{42} = -41{,}6 - 50 = -91{,}6\,V \quad I_{42} = 0.763\,A \quad I_{25} = 0.8A$

$U_{32} = 65 - 50 = 15V \quad I_{32} = 0.125A \quad U_{25} = -\frac{q}{C} = -40V$

$R_{12} = -\frac{U_{25}}{I_{25}} = 50\,\Omega$

$R = 100\,\Omega$



$U_{25} = E_T - I_{25} R_T \quad U_{25} = I_{25} \cdot R_{12}$

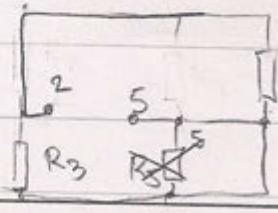
$U_{25}' = E_T - I_{25}' R_T \quad U_{25}' = I_{25}' \cdot R$

$U_{25}' = E_T - U_{25}' \frac{R_T}{R}$

$U_{25}' \left(\frac{R+R_T}{R}\right) = E_T \quad E_T = U_{25} \frac{R+2R_T}{R}$

$U_{25}' = \frac{R}{R+R_T} \cdot \frac{R+2R_T}{R} U_{25}$

$U_{25}' = \frac{300}{200} U_{25} = -60V$



$R_g = 150\,\Omega \quad R_T = 100\,\Omega$

$Q' = -120\,\mu C$

$q + q_1 = Q' \quad q_1 = Q' - q = -120\,\mu C + 80\,\mu C = -40\,\mu C$

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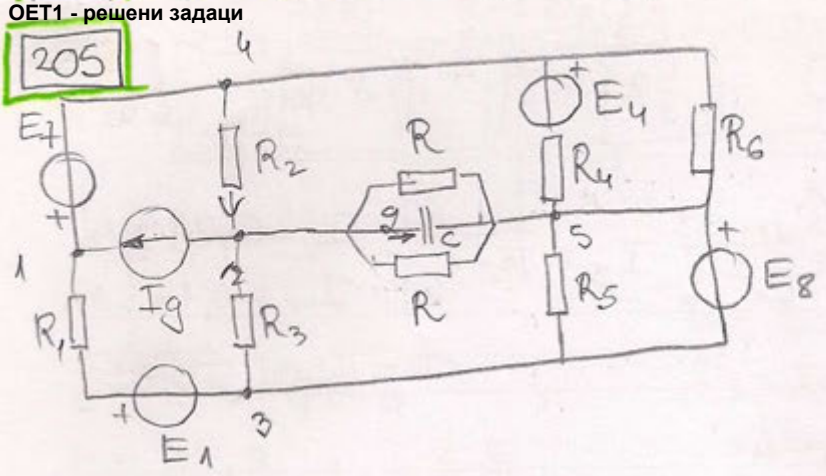
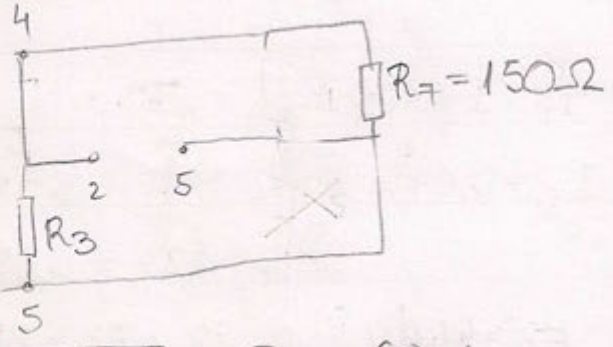


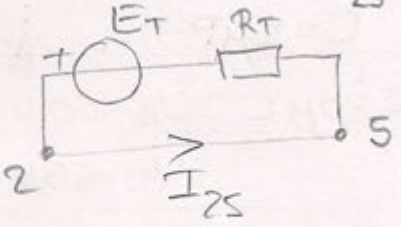
$E_7 = 41,6\,V$
$I_g = 80\,mA$
$R_1 = 60\,\Omega$
$R_2 = R_4 = R_6 = 120\,\Omega$
$R_3 = R_5 = 300\,\Omega$
$C = 2\,\mu F$
$q = -80\,\mu C$ $U_{12} = 50\,V$ $U_{13} = 65\,V$
$\Pi \to 0$ q_1?



$V_1 = 0$
$V_2 = -50\,V$
$V_3 = -65\,V$
$V_4 = -E_7 = -41,6\,V$
$I_{42} = \frac{U_{42}}{R_2} = \frac{-41,6+50}{120} = 70\,mA$
$I_{32} = -\frac{50+65}{300\,\Omega} = -50\,mA$

$R_T = 100\,\Omega$

$I_{25} = -60\,mA$
$U_{25} = -40\,V$



$\Downarrow$

$R_{12} = \frac{U_{25}}{I_{25}} = \frac{2}{3}\,k\Omega$

$R = \frac{4}{3}\,k\Omega$

$U_{25} = -I_{25} R_T + E_T$

$-40 + \left(\frac{-60 \cdot 100}{1000}\right) = E_T$

$E_T = -46\,V$

$I_{25}' = \frac{E_T}{R_T + R} = \frac{-46 \cdot 3}{4,9} = 32,1\,mA$

$U_{25}' = E_T - I_{25}' R_T$

$Q' = -85,58$

$Q' = q + q_1 \Rightarrow q_1 = -5,58\,\mu C$

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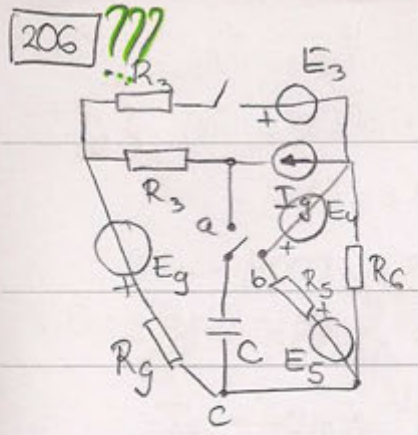
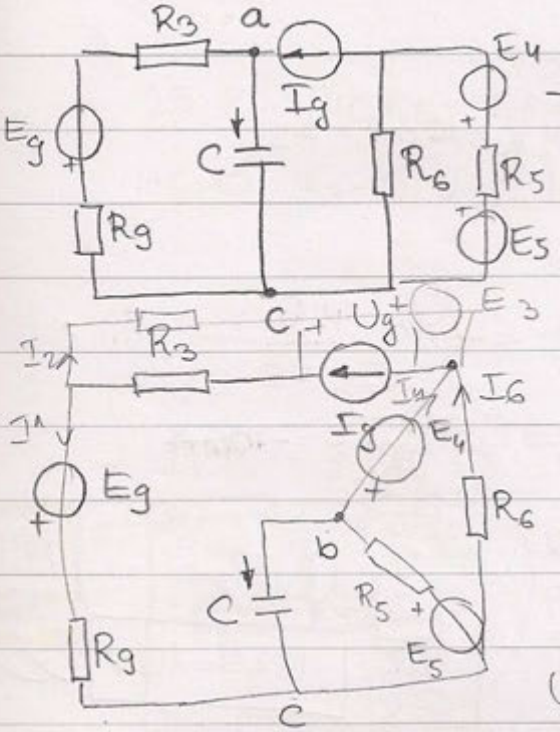


$R_1 = R_3 = 250\Omega$
$R_5 = 500\Omega$
$R_6 = 750\Omega$
$R_7 = R_8 = 400\Omega$ $R_g = 200\Omega$
$C = 0{,}5\mu F$
$E_3 = 30V$
$E_4 = 20V$
$I_g = 20mA$

$K \to a \to b$ $Q_{bc} = -20\mu C$
$\Pi \to 1$ Q?



$-U_{ac} = E_g - 450 \cdot 20 \cdot 10^{-3} = E_g - 9V$

$Q_0 = -CE_g + 4{,}5\mu C$ $\quad Q_0 = 4{,}5\mu C - CE_g$

$U_{bc} = (R_g + R_3) I_g - E_g + E_4 - U_g$ (9V, 30V)

$Q = 19{,}5\mu C - CE_g - U_g$

$Q = Q_0 + q_{bc}$ $\quad 19{,}5 - CE_g - U_g = 4{,}5 - CE_g$ -20

$U_g = 70V$

$U_{bc} = R_g I_1 - E_g$

$I_6 R_6 = E_4 + R_5 I_4 - E_5$

$I_6 R_6 = E_4 + R_5 I_g - R_5 I_6 - E_5$

$(R_5 + R_6) I_6 = E_4 + R_5 I_g - E_5$

$U_{bc} = E_5 - I_g R_5 + R_5 I_6$

ANALYSIS LABORATORY EQUIPMENT

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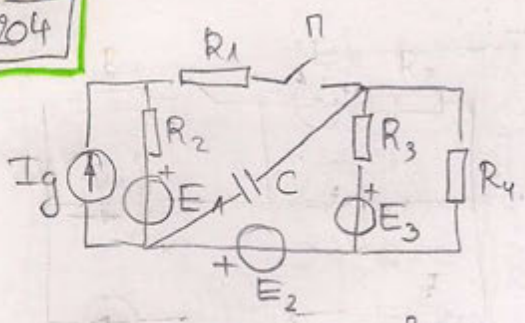
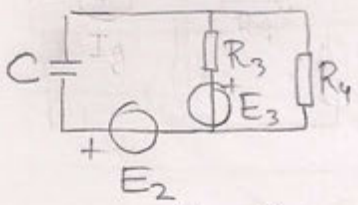


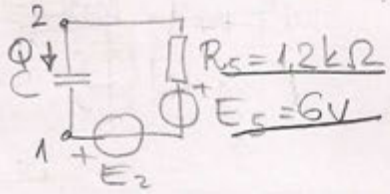
$E_2 = 12V$ $R_2 = 1k\Omega$ $We_1 = We_2$

$E_3 = 10V$ $R_3 = 2k\Omega$ $П \to 3$ $P_{I_g} < 0$

$I_g = 10mA$ $R_4 = 3k\Omega$

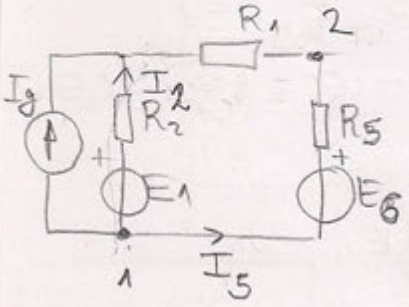
$R_1 = 800\Omega$ $C = 10\mu F$





$U_{21} = -E_2 + E_5 = -12 + 6 = -6V$

$U_{21}' = \pm 6V$



$I_g + I_2 + I_5 = 0$ $I_2 = -10mA - I_5$

$U_{21}' = E_6 - R_5 I_5$

$1^\circ\ U_{21}' = 6V$ $2^\circ\ U_{21}' = -6$

$6 = -6V - R_5 I_5$ $I_5 = 0$

$I_5 = -10mA$ $I_2 = -10mA$

$I_2 = 0$ $U_{21}' = E_1 - R_2 I_2$

$-6 = E_1 + 10$

$\boxed{E_1 = -16V}$

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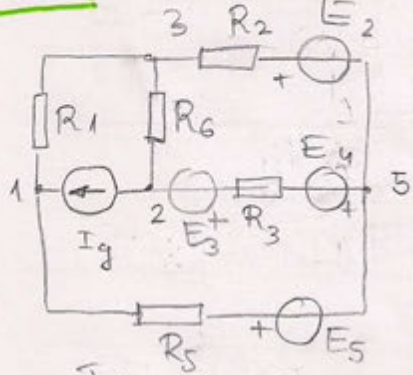


$E_5 = 50V$

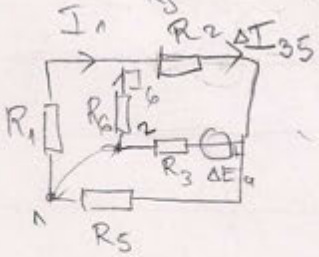
$R_1 = R_2 = 100\Omega$

$R_3 = 200\Omega$

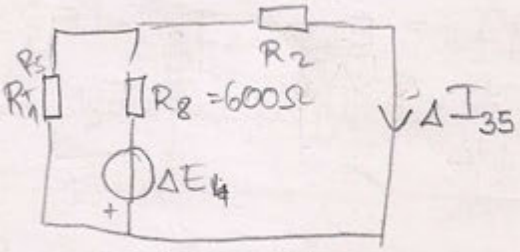
$R_6 = 400\Omega$

$\Delta E_4 \to \Delta U_{12} = -17V$ $R_5?$ $\Delta E_4?$

$\to \Delta I_{35} = 30mA$

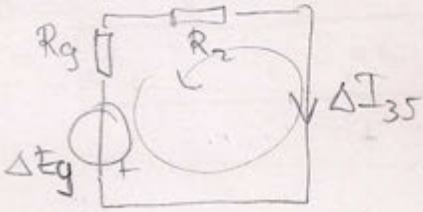


ΔI_{35}



$R_g = \dfrac{(R_1 + R_5)R_8}{R_1 + R_8 + R_5}$

$\Delta E_g = \dfrac{(R_1 + R_5)\Delta E_4}{R_1 + R_8 + R_5}$



$\Delta E_g = -\Delta I_{35}(R_2 + R_g)$

$$\frac{(R_1+R_5)\Delta E_4}{R_1+R_8+R_5} \cdot \frac{1}{\dfrac{(R_1+R_5)R_8 + R_2(R_1+R_5) + R_2R_8}{R_1+R_5}} = -\Delta I_{35}$$

$$\boxed{\Delta E_4 = -\Delta I_{35}\left(R_8 + R_2 + \frac{R_2 R_8}{R_1 + R_5}\right)}$$

$I_1 + I_6 = \Delta I_{35}$

$\Delta U_{12} = -R_6 I_6 + R_1 I_1$

$-17 = -400 I_6 + 100 I_1$

$-17 = -500 I_6 + 3$

$-20 = -500 I_6$

$I_6 = 40mA \quad I_1 = -10mA$

$\Delta U_{12} = R_3 I_6 + \Delta E_4 - R_5 I_1$

$-17 = 8 + \Delta E_4 + R_5 \cdot 10^{-2}$

$\Delta E_4 = -25 - R_5 \cdot 10^{-2}$

$+25 \cdot 10^3 + R_5 10^{-3} = 30 \cdot 10^{-3} \cdot (700 + \frac{60000}{100 + R_5})$

$25 \cdot 10^3 + 10 R_5 = 21 \cdot 10^3 + \frac{18 \cdot 10^5}{100 + R_5} \quad / \cdot (100 + R_5)$

$25 \cdot 10^5 + R_5 10^3 + 25 \cdot 10^3 R_5 + 10 R_5^2 = 21 \cdot 10^5 + 18 \cdot 10^5 + 21 \cdot 10^3 R_5$

$R_5^2 + 500 R_5 - 140000 = 0$

$R_5 = \frac{-500 + 900}{2} = 200\Omega$ ✓

$\Delta E_4 = -25 - 2 = -27V$ ✓

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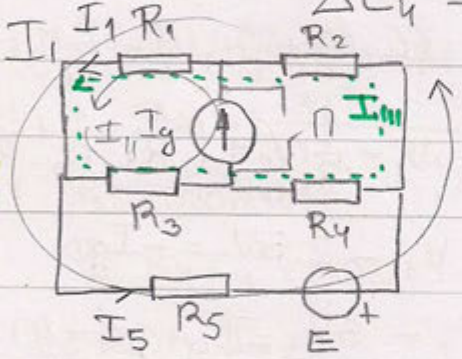
ЗНАК СТРУЈЕ?



$E = 75V$

$R_1 = R_3 = 3k\Omega$

$R_2 = 6k\Omega$

$R_4 = 12k\Omega$

$R_5 = 750\Omega$

$P_{Ig_1} = P_{Ig_2}$

$U_{g_1} I_g = U_{g_2} I_g$

$U_{g_1} = U_{g_2} = 0 \quad P_g = 0$

I_5?

$P_E \; II \to 0$

$1,5k\Omega + 4k\Omega = 5,5k\Omega$

$R_e = 6,25 \qquad I_5 = 12mA$

$E = I_5 \cdot R_e$

$I_1 = \frac{R_3}{R_1 + R_3} I_5 = \frac{3}{4} 12mA = 9mA$

$I_{11} = I_g$

$I_1 = 12mA$

$I_1 = I_1 + I_{11} + I_{111} \quad I_{111} = 9mA - I_g - 12mA = -3mA - I_g$

$(R_1 + R_2) I_1 + (R_1 + R_3) I_{11} + (R_1 + R_2 + R_3 + R_4) I_{111} = 0$

$108 + 6k\Omega \, I_g + 24k\Omega \, I_{111} = 0 \quad / : 6$

$18mA + I_g - 12mA - 4I_g = 0 \quad I_g = 2mA$

ANALYSIS LABORATORY EQUIPMENT

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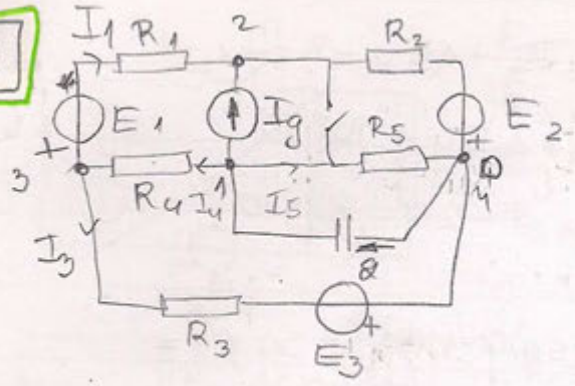


$E_1 = 4V$

$E_2 = 1V$

$R_1 = R_5 = 200\Omega$

$R_2 = 100\Omega$

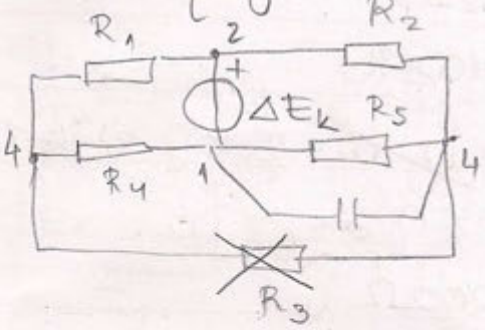
$R_3 = R_4 = 400\Omega$

$C = 1\mu F$

I_g? $\Pi \to 1$ $q = 4\mu C$

P_{I_g}? $\Pi \to 0$

$$E_k = \begin{cases} U_g \\ 0 \end{cases}$$

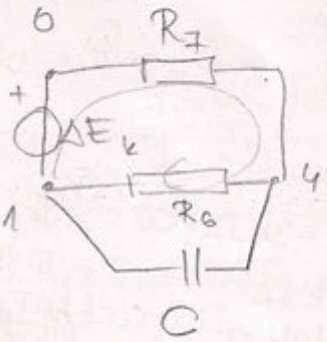


$$\Delta U_{41} = \frac{q}{C} = 4V$$

$$U_{g1} = -6V$$

$R_6 = \frac{800}{6}$

$R_7 = \frac{200}{3}$ $\angle 2$



$$1: \left(\frac{1}{R_4} + \frac{1}{R_5}\right) \cdot V_1 - 0\, V_2 - \frac{1}{R_4} V_3 = -I_g$$

$$-0 \cdot V_1 + \left(\frac{1}{R_1} + \frac{1}{R_2}\right) V_2 - \frac{1}{R_1} V_3 = \frac{E_1}{R_1} + I_g - \frac{E_2}{R_2}$$

$$-\frac{1}{R_4} V_1 - \frac{1}{R_1} V_2 + \left(\frac{1}{R_1} + \frac{1}{R_3} + \frac{1}{R_4}\right) = -\frac{E_1}{R_1} - \frac{E_3}{R_3}$$

$$I = \frac{\Delta E_k}{200}$$

$$\Delta U_{41} = \frac{\cancel{800}^{4}}{6} \cdot \frac{\Delta E_k}{\cancel{200}}$$

$$\Delta E_k = 6V$$

$$7.5 V_1 - 2.5 V_3 = -I_g$$

$$15 V_2 - 5 V_3 = I_g + \cancel{20} + 10$$

$$-2.5 V_1 - 5 V_2 + 10 V_3 = -30 - 2.5 E_3$$

$$U_{g1} = V_2 - V_1 \Rightarrow V_2 = V_1 - 6$$

$$\cancel{7.5 V_1 - 2.5 V_3 = -I_g}$$

$$\cancel{15 V_1 - 90 - 5 V_3 = I_g + 30}$$

$$\Delta E_k = \Delta U_{21} =$$

$$= U_{g2} - U_{g1} \Rightarrow$$

$$\Rightarrow U_{g1} = -6V$$

$$15 V_1 - 5 V_3 = -2 I_g$$

$$15 V_1 - 5 V_3 = \cancel{100} + I_g + 60$$

$$I_g = -20\,mA$$

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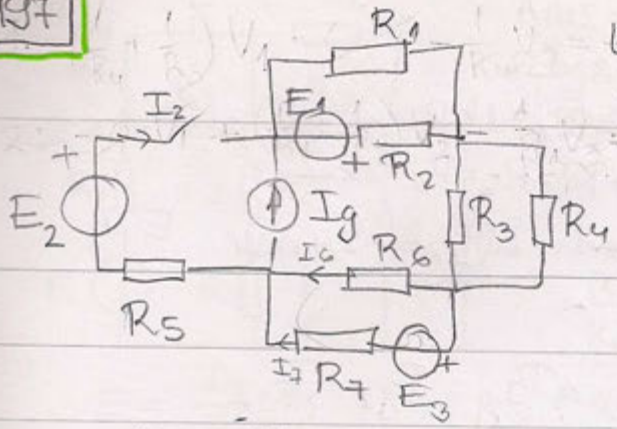


$E_1 = 25V \quad E_3 = 4V$

$R_1 = 100\Omega \quad R_2 = 150\Omega$

$R_3 = 200\Omega \quad R_4 = 800\Omega$

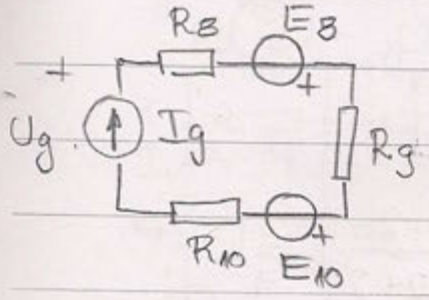
$R_5 = 50\Omega$

$R_6 = R_7 = 160\Omega \quad P_{I_g} = 2{,}2W \quad \Pi \to 0$

$PE_3 < 0$

$\Pi \to 1 \quad P_{R_4} = 320mW$

$P_{I_g} < 0 \quad E_2 ?$



$R_8 = 60\Omega$

$E_8 = 10V$

$R_g = 160\Omega$

$R_{10} = 80\Omega \quad E_{10} = 2V$

$U_g = +R_{10}I_g + E_{10} + I_g R_g - E_8 + R_8 I_g$

$U_g = 300 I_g - 8$

$2{,}2 = 300 I_g^2 - 8 I_g$

$I_{g_{12}} = \frac{+8 \pm 52}{600}$

$I_{g_1} = 0{,}1A \quad I_{g_2} = -0{,}7$

$I_6 + I_7 = I_{g_1}$

$-I_6 R_6 + I_7 R_7 + E_3 = 0$

$-I_{g_1} R_6 + (R_6 + R_7) I_7 + E_3 = 0$

$I_7 = \frac{I_{g_1} R_6 - E_3}{R_6 + R_7} > 0 \quad I_{g_1} R_6 > E_3 \quad I_{g_1} > 0.025A \Rightarrow \boxed{I_g = 0.1A}$

$\Pi \to 1 \quad P_{R_4} = 320mW$

$P = R_4 I_4^2 = 800 \cdot I_4^2 \quad I_4 = \pm 0.02A$

$I_4 + I_3 = I_g + I_2 \quad I_3 = \pm 0.08A$

$I_4 = \frac{R_3}{R_4 + R_3}(I_g + I_2) \quad I_g + I_2 = \pm 0.1A \Rightarrow I_2 = \begin{cases} -0{,}2A \\ 0 \end{cases}$

$I_3 = \frac{R_4}{R_3} I_4 \quad P_{I_g} < 0 \Rightarrow I_2 = -0{,}2A$

$-R_5 I_2 + E_2 + 0.1(R_8 + R_g + R_{10}) + E_8 - E_{10} = 0$

$+10 + E_2 + 30 + 10 - 2 = 0 \quad E_2 = -48V$ ✓

ANALYSIS LABORATORY EQUIPMENT

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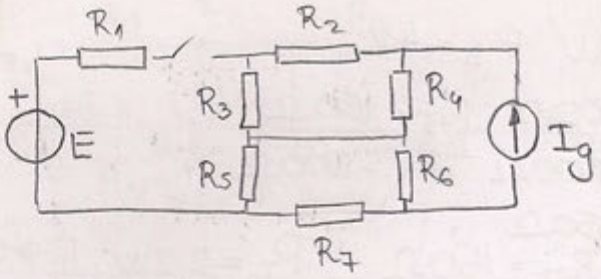
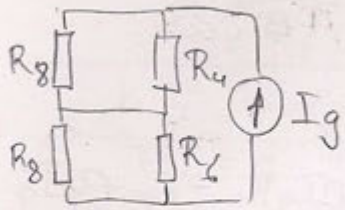
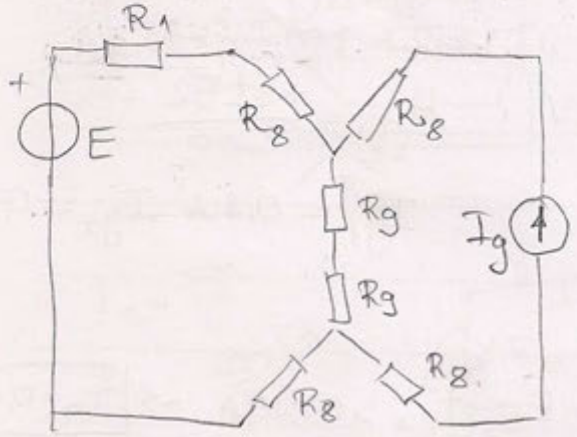


$I_g = 2mA$
$R_1 = 800\Omega$
$R_2 = R_7 = 1k\Omega$
$R_3 = R_4 = R_5 = R_6 = 2k\Omega$
$\Pi \to 1 \quad \Delta P_{I_g} = -2,4mW \quad E = ?$



$R_8 = 3k\Omega$
$R_e = 2 \cdot \frac{3 \cdot 2}{5} = 2,4k\Omega$
$U_g = I_g R_e = 4,8V$
$-1,2 = U_{g_2} - 4,8 \quad \boxed{U_{g_2} = 3,6V}$

$\Delta P_{I_g} = P_{g_2} - P_{I_{g_1}} = I_g(U_{g_2} - U_{g_1})$

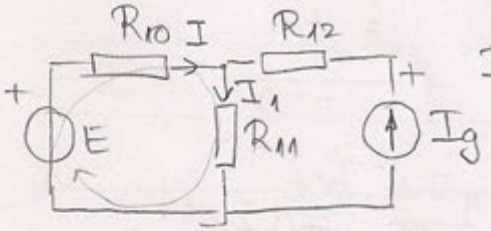


$R_8 = \frac{R_2 R_3}{R_2 + R_3 + R_4} = \frac{1 \cdot 2}{1+2+2} = \frac{2}{5}k\Omega$

$R_g = \frac{R_3 \cdot R_4}{R_2 + R_3 + R_4} = \frac{4}{5}k\Omega$

$2 \cdot R_g = \frac{8}{5}k\Omega$

$R_{10} = 1,6k\Omega \quad R_{11} = 1,6k\Omega \quad R_{12} = 0,8k\Omega$



$I_g + I = I_1$

$E - R_{10}I - R_{11}I_1 = 0$

$E = (R_{10} + R_{11})I + R_{11}I_g = 3,2 + 3,2I$

$U_g = R_{11}I_1 + R_{12}I_g$

$3,6 = 1,6I_1 + 0,8 \quad I_1 = 1,25mA \quad I = -0,75mA$

$\boxed{E = 0,8V}$ ✓

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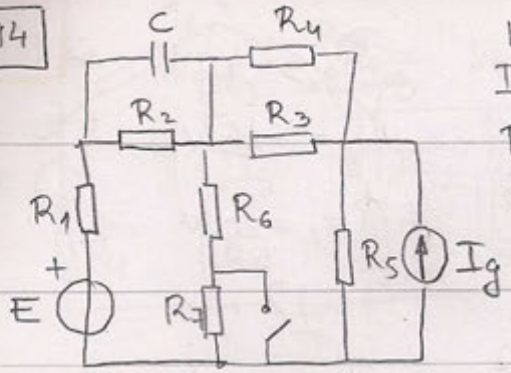


$E = 50V$ $C = 5\mu F$

$I_g = 10mA$

$R_1 = 6k\Omega$

$R_2 = 4k\Omega$

$R_3 = 4{,}5k\Omega$

$R_4 = 9k\Omega$

$R_6 = 1k\Omega$

$R_8 = 3k\Omega$

$\Pi \to 1$ $W_{e_1} = 640\mu J$

$W_{e_1} = \frac{1}{2}CU^2 \Rightarrow U_1 = \pm 16V$

$\Pi \to 0$ $\Delta W_{e_1} = -600\mu J$

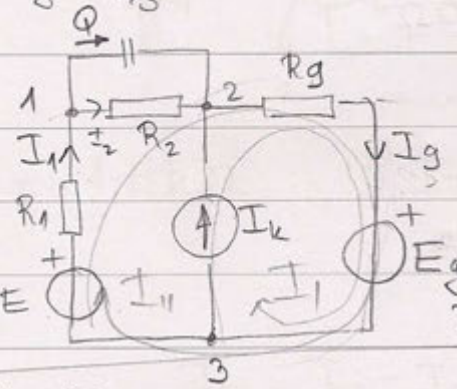
$W_{e_2} = 40\mu J$ $U_2 = \pm 4V$

R_7 ?

$E_g = \frac{I_g}{\cancel{R_5}} \cdot R_5$

$I_2 = \frac{U_{12}}{R_2} = \begin{cases} + \\ \cancel{-4mA} \end{cases}$

$U_{23} = \begin{cases} 40V \\ \cancel{60V} \end{cases}$



$R_9 = R_8 + R_5$

$\frac{40}{4mA} = 1 + R_7$

$R_7 =$

$I_k = \begin{cases} \frac{U_{23}}{R_6}, & \Pi \to 1 \\ \frac{U_{23}}{R_6 + R_7}, & \Pi \to 0 \end{cases}$

$I_k = \frac{U_{23}}{R_6 + R_7}$

$I_4 = I_g - I_2$

$U_{23} = E_g + IR_g$

$I_k = \begin{cases} -4mA \\ \cancel{0} \end{cases}$

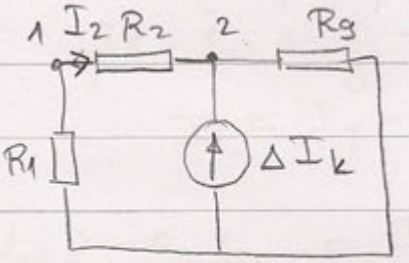
$U_{23} = \frac{70}{10} = I$

$I_g = \begin{cases} -3mA \\ \cancel{-1mA} \end{cases}$

$\boxed{I_2 = \frac{\Delta U_{12}}{R_2}}$

$I_1 = I_k$

Δ коло



$I_2 = -\frac{R_g}{R_1 + R_2 + R_g} \Delta I_k$

$R_g I_1 + (R_1 + R_2 + R_g) I_{11} = E - E_g$

$R_g I_k + (R_1 + R_2 + R_g) I_{11} = E - E_g$

$I_{11} = \frac{E - E_g - R_g I_k}{}$

$I_1 = -I_k + I_g = -\cancel{I_k} + \cancel{I_k} + I_2$

$U_{23} = E - R_1 I_1 - U_{12} = E - U_{12} - R_1 \frac{U_{12}}{R_2} = E - 2{,}5U_{12} = \begin{cases} 10V \\ 90V \end{cases}$

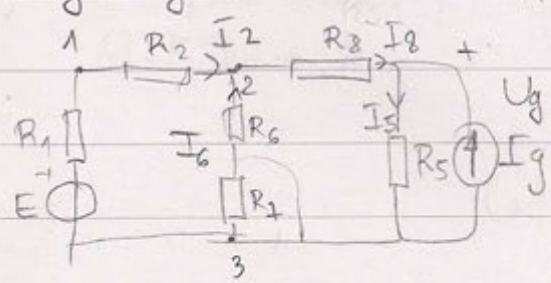
$I_k = \begin{cases} \frac{E - 2{,}5U_{12}^{(1)}}{R_6}, & \Pi \to 1 \\ \frac{E - 2{,}5U_{12}^{(0)}}{R_6 + R_7}, & \Pi \to 0 \end{cases}$

$\Delta I_k = \frac{(E - 2{,}5U_{12}^{(1)})(R_6 + R_7) - R_6 E - 2{,}5R_6 U_{12}^{(0)}}{(R_6 + R_7) R_6}$

$\Delta I_k = \frac{\cancel{E R_6} - 2{,}5 \cdot 10^3 U_{12}^{(1)} + E R_7 - 2{,}5 R_7 U_{12}^{(1)} - \cancel{E R_6} - 2{,}5 \cdot 10^3 U_{12}^{(0)}}{10^3 \cdot (10^3 + R_7)}$

$U_{23} = E_g + I_g R_g$

$\Pi \to 3$



$U_{23} = R_5 I_5 + R_8 I_8 = R_5 I_8 + R_5 I_g + R_8 I_8$

$I_8 + I_g = I_5$ $I_8 = I_2 + I_6$

$I_6 = U_{32}/R_6 = -\frac{U_{23}}{R_6} = \begin{cases} -10mA \\ -90mA \end{cases}$

$R_5 = \frac{U_{23} - R_8 I_8}{I_8 + I_g} = \frac{\cancel{10} + 24}{\cancel{2}\ 4} = \boxed{7k\Omega}$

1° $U_{12} = +16V$ $U_{23} = 50 - 40 = 10V$

$I_2 = \frac{U_{12}}{R_2} = \begin{cases} + \\ -4mA \end{cases}$ $I_8 = \begin{cases} -6mA \\ -94mA \end{cases}$

$R_5 = 7k\Omega$ $R_9 = 10k\Omega$

$E_g = 70V$

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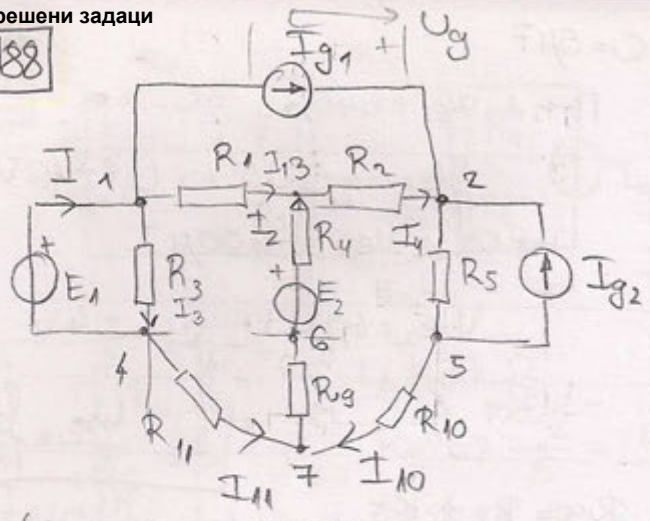

$E_1 = 120V$
$E_2 = 100V$
$I_{g1} = 0,1\,A$
$R_2 = 30\Omega$
$R_3 = 40\Omega$
$R_4 = 35\Omega$
$R_5 = 100\Omega$
$R_6 = R_7 = 50\Omega$
$R_8 = 25\Omega$

$P_{I_{g1}} = -4,6W$
$U_g = -46V$
$P_{E_2} = 20W$
$R1?$
$I_2 = 0,2A$

$U_{14} = E_1 = 120V$

$U_{12} = 46V$

$U_{36} = 93V$

$R_{11} = \frac{R_8 R_6}{125} = 10\Omega = R_{10}$

$R_g = 20\Omega$ $I_3 = 3A$

$U_{37} = 89V$

$U_{13} = V_1 - V_3 - V_4 + V_4 = V_1 - V_4 + U_4 - V_7 + V_7 - V_3 =$
$= U_{14} + U_{47} - U_{37} = 31V + U_{47}$

$R_1 I_1 = 31 + I_{11} R_1$

$I_1 = I - I_3$
$I_{11} = I_3 - I$
$I_{11} = -I_1$

$I_1 (R_1 + R_{11}) = 31$

$U_{32} = I_4 R_2$ $U_{13} + U_{32} = U_{12}$ $U_{32} = U_{12} - U_{13}$

~~$U_{32} = V_3 - V_2 + V_7 - V_7 + V_5 - V_5 = U_{37} + U$~~

$I_4 R_2 = U_{12} - U_{13}$ $I_4 = I_2 + I_1$

$(I_2 + I_1) R_2 = 46V - I_1 R_1$ $930 + 31R_1 = 400 + 40R_1$

$6 + (30 + R_1) I_1 = 46$ $530 = 9R_1$

$(30 + R_1) I_1 = 40$ $R_1 = 58.89\Omega$

$(10 + R_1) I_1 = 31$

$31(30 + R_1) = 40(10 + R_1)$

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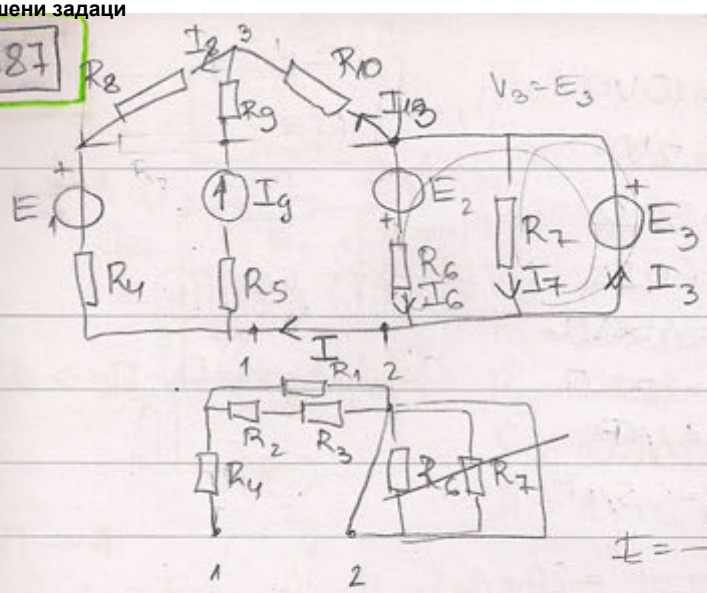


$E_1 = 10V$
$E_2 = 20V$
$E_3 = 30V$
$I_g = 5mA$
$R_1 = R_7 = 1k\Omega$
$R_2 = 4k\Omega$
$R_3 = 5k\Omega$
$R_4 = 600\Omega$

$R_5 = 1,6k\Omega$
$R_6 = 2k\Omega$
I ?

$R_8 = 0,4k\Omega$
$R_9 = 2k\Omega$ $R_{10} = 0,5k\Omega$

$I = \frac{E_2 \cdot R_T}{2+1} = \frac{20}{3}$

$R_e = \frac{2}{3}k\Omega$

$R_T = 1,5k\Omega$ $I_7 = \frac{E_3}{R_7} = 30mA$ $\frac{\frac{2}{3}E_3}{\frac{2}{3}}$

$\frac{E_3 + E_2}{R_6} = I_6$ $I_6 = 25mA$

$I_{10} = I_3 - I_6 - I_7$

$I_8 = I_{10} + I_g = I_3 + I_g - I_6 - I_7$

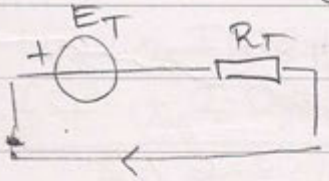
$I = I_g - I_8 = I_g - I_3 - I_g + I_6 + I_7$

$U_{13} = -R_8 I_g - E_1 - R_4 I_g = -2 - 10 - 3 = -15V$

$V_1 = V_3 - 15V$ $V_1 - V_2 = 15V$

$U_{23} = V_2 - V_3 = -E_3$ $U_{12} = 15V$

$V_3 = V_2 + E_3$



$I = -\frac{E_T}{R_T} = -10mA$

ANALYSIS LABORATORY EQUIPMENT

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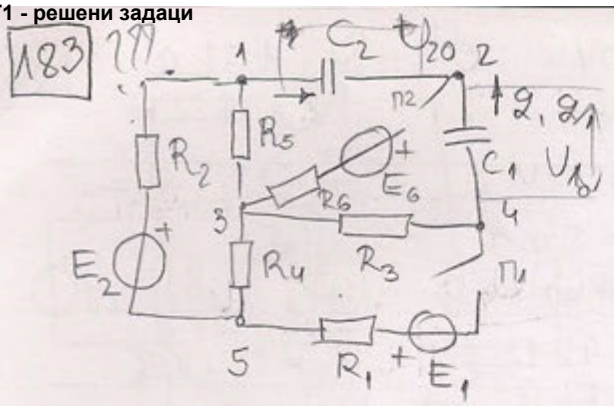
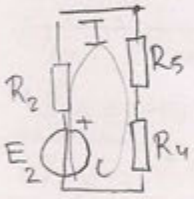


$E_2 = 10V$
$E_6 = 2V$
$R_2 = 50\Omega$
$R_3 = 60\Omega$
$R_4 = 150\Omega$
$R_5 = 300\Omega$
$C_1 = 1\mu F$
$C_2 = 0{,}5\mu F$

$\Pi_1 \to 1$
$Q = 4\mu C$ C_1
$\Pi \to 1$
$Q_1 = -2{,}2\mu C$ C_1
Q_{10}, Q_{20} ? $\Pi_1, \Pi_2 \Rightarrow \emptyset$



$$I = \frac{E_2}{R_2 + R_4 + R_5} = \frac{10}{50+150+300} = 20mA$$

$U_{13} = 6V$

$U_{20} + U_{10} = -U_{13}$

$$\frac{Q_{20}}{C_2} + \frac{Q_{10}}{C_1} = -U_{13}$$

$Q_2 = Q_{20} + Q$

$Q_1 = Q_{10} + Q$

$$-U_{13}' = -U_{13} + Q\frac{C_1 + C_2}{C_1 C_2}$$

$$-U_{14}' = -U_{13} + \left(4 \cdot \frac{1{,}5}{0{,}5}\right)12 = 6$$

$U_{14}' = 6V$

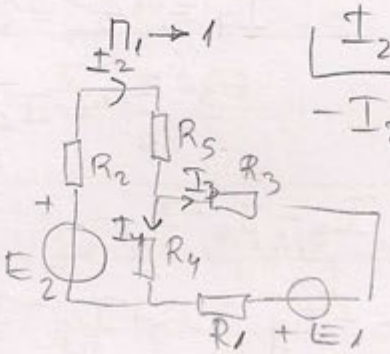
U_{45}

$\Pi 2 \to$

$U_{42} = R_3 I_3 + E_6 =$
$= -4.8 + 2 = -2{,}8$

$U_{21} = -I_2 R_5 + E_6 =$
$= +1{,}2 + 2 = 3{,}2$

$Q_2' = U_{21} \cdot C_2 = 1{,}6\mu C$ $Q_1' = -2{,}8\mu C$
$Q_2 = Q_2' - Q = 3{,}8\mu C$ $Q_1 = -0{,}6\mu C$
$Q_{20} = -0{,}2\mu C$ $Q_{10} = -4{,}6\mu C$



$I_2 = I_3 + I_4$

$-I_3 R_3 + E_1 - I_3 R_1 + I_4 R_4 = 0$

$I_4 R_4 = I_3(R_1 + R_3) - E_1$

$I_4 =$

$U_{14}' = I_3 R_3 + R_5 I_2$

$E_2 + I_2 R_2 - I_2 R_5 - I_4 R_4 = 0$

$-6 = 60 I_3 + 300 I_2$
$10 = 350 I_2 + 150 \cdot I_2 - 150 I_3$

$300 I_2 + 60 I_3 = -6 \;/\cdot \frac{5}{3}$
$500 I_2 - 150 I_3 = 10$

$500 I_2 + 100 I_3 = -10$
$500 I_2 - 150 I_3 = 10$

$-250 I_3 = +20$

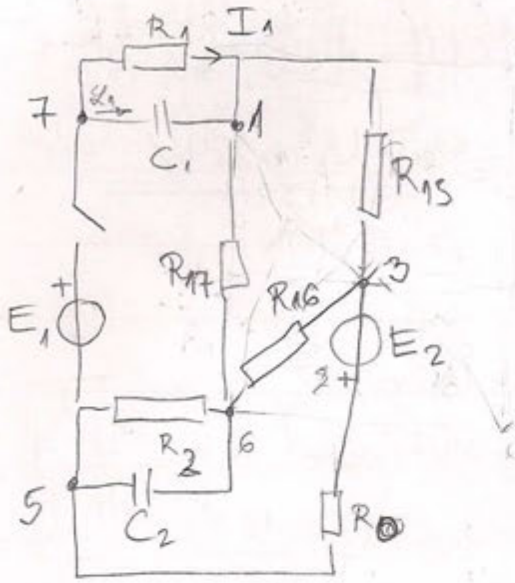
$I_3 = -0{,}08A = -80mA$
$I_2 = -0{,}004A = -4mA$
$I_4 = 76mA$

181. $E_1 = 10V$ $R_1 = 180\Omega$ $R_2 = 60\Omega$ $R_3 = R_4 = R_5 = 200\Omega$

$R_6 = R_7 = R_8 = 100\Omega$

$R_9 = 200\Omega$ $C_1 = 100nF$

$C_2 = 200nF$



$\Pi \to 1$ $Q_1 = 1,8\mu C$

Q_2 ?

$R_{10} = R_{11} = R_9 = R_3 + R_4 + \frac{R_3 R_4}{R_5} = 600\Omega$

$R_{12} = R_{13} = R_{14} = 300\Omega$

$R_9 \| R_{12} = 200\Omega = R_{15} = R_{16}$

$R_{10} \| R_{14} = 200\Omega$

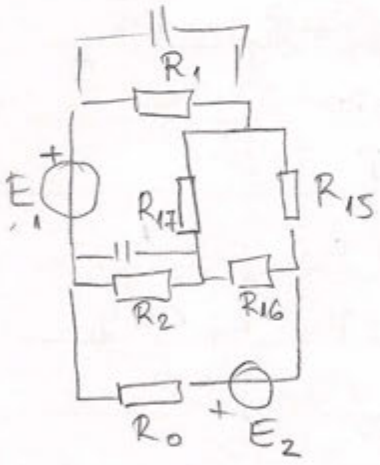
$R_{17} = \frac{200 \cdot 600}{800} = 150\Omega$

$U_{71} = \frac{Q_1}{C_1} = 18V$

$Q_{10} = Q_{20} = 0$

$I_1 = 0,1A$ ✓

$U_{75} = E_1$



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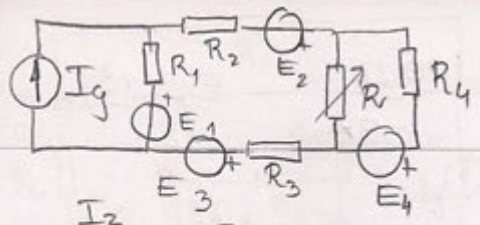
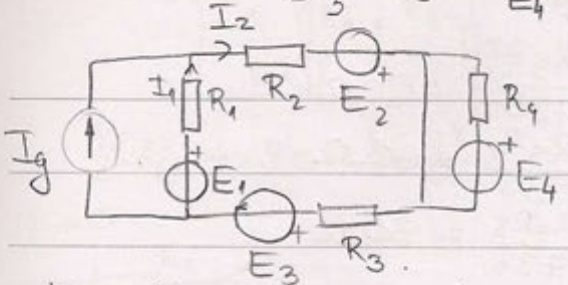


$E_1 = 1V$ $R_2 = 2k\Omega$ $R = 0$ $P_{E_1} = -5mW$

$I_g = 6mA$ $R_3 = 3k\Omega$ $R = 1,2k\Omega$ $P_{I_g} = 37,6mW$

$R_1 = 1k\Omega$ $R_4 = 4k\Omega$ P_{E_4} $R = 2,4k\Omega$?



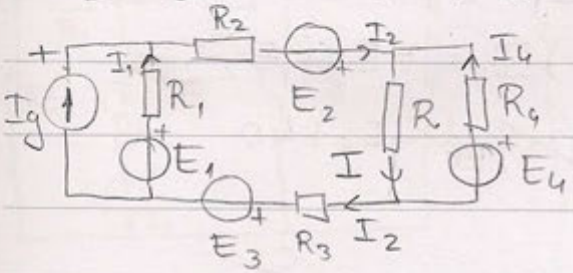
$P_{E_1} = I_1 E_1 \Rightarrow I_1 = -5mA$

$I_2 = 1mA$

$E_1 - R_1 I_1 - I_2 R_2 + E_2 - R_3 I_2 - E_3 = 0$

$E_2 - E_3 = -5 + 5 - 1 = -1$

$\boxed{E_2 - E_3 = -1}$ ✓



$U_g = 6,27V$

$U_g = E_1 - R_1 I_1$

$I_1 = \frac{E_1 - U_g}{R_1} = -5,27mA$ ✓

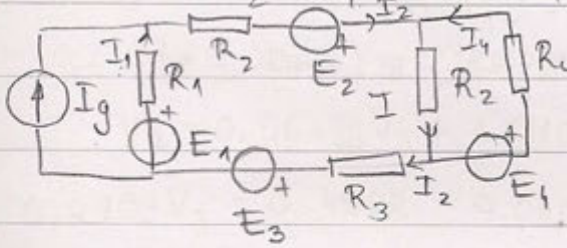
$I_2 = 0,73mA$

$E_4 - R_4 I_4 - IR = 0$ $U_g = E_3 + I_2 R_3 + IR - E_2 + I_2 R_2$

$6,27 = 1 + 3,67 + IR$

$I = 1,33mA$ ✓ $E_4 = 2,4 + 1,6 = 4V$ $\boxed{E_4 = 4V}$

$I_2 + I_4 = I$ $I_4 = 0,6$ ✓



$E_4 - R_4 I_4 - IR = 0$

$4 - 4I_4 - 2,4I = 0$

$\boxed{I_4 = 1 - 0,6I}$ $I_2 + 1 = 1,6I$

$I_2 = 1,6I - 1$

$I_1 = I_2 - I_g = I_2 - 6$

$E_1 - R_1(I_2 - 6) - (R_2 + R_3)I_2 + E_2 - IR - E_3 = 0$

$-1 + 1 - I_2 + 6 - 5I_2 - IR = 0$

$-9,6I + 6 + 6 - 2,4I = 0$ $I_4 = 0,4mA$

$I = \frac{12}{12} = 1mA$ $P_{E_4} = 4 \cdot 0,4mA = 1,6mW$

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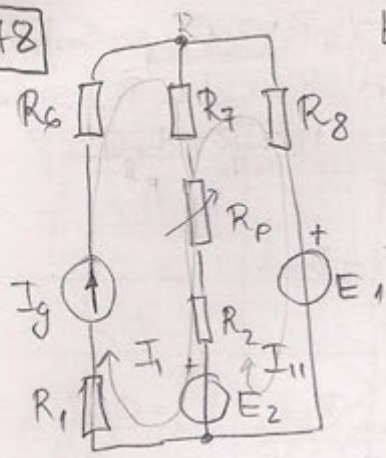


$E_2 = 40V$ $0 \le R_p \le 100\Omega$ E_1? $I_p = 0$ za svako R_p

$I_g = 0{,}3A$ $I_{p\,max} = 92A$

$R_1 = 50\Omega$

$R_2 = 40\Omega$

$R_3 = 210\Omega$ $R_6 = \frac{R_3 R_4}{735} = 120\Omega$

$R_4 = 420\Omega$ $R_7 = \frac{R_5 R_4}{735} = 60\Omega$

$R_5 = 105\Omega$ $R_8 = \frac{R_3 R_5}{735} = 30\Omega$

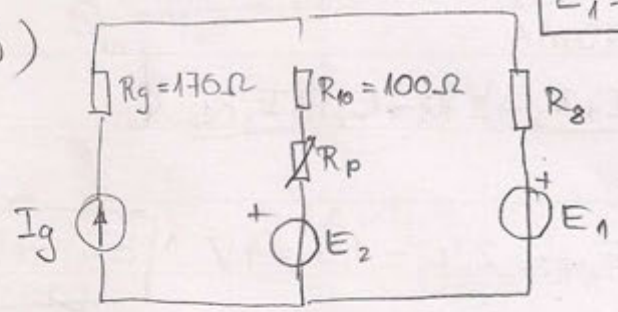
a) $I_1 = I_g$ $0 = I_1 - I_{11}$ $I_1 = I_{11}$

2: $-(R_2 + R_7 + R_p) I_1 + (R_7 + R_p + R_2 + R_8) I_{11} = -E_1 + E_2$

$-100 \cdot 0{,}3 - R_p \cdot 0{,}3 + 30 \cdot 0{,}3 + 0{,}3 R_p = -E_1 + 40$

$E_1 = 31V$

б)



$I_1 = I_g$ $10 - 2 = 8A = I_1 - I_{11}$ $I_{11} = 0{,}1A$

$-17 - 100 \cdot 0{,}3 - R_p \cdot 0{,}3 + 130 \cdot 0{,}1 + 0{,}1 \cdot R_p = -E_1 + 40$

-30

$-92 R_p = 57 - E_1$

$R_p = 5E_1 - 285$

$0 \le 5E_1 - 285 \le 100$

$77V \ge E_1 \ge 57V$

$-92 = 0{,}3 - I_{11}$ $I_{11} = 0{,}5$

$-100 \cdot 0{,}3 - R_p \cdot 0{,}3 + 130 \cdot 0{,}5 + R_p \cdot 0{,}5 = -E_1 + 46\,5$

-30 $65\ 35$

$0{,}2 R_p = -E_1 + 5$ $E_1 \in [-15, 5] \cup [57, 77V]$

$R_p = -5E_1 + 25$

$0 \le -5E_1 + 25 \le 100$

$5E_1 \le 5V$ $E_1 \ge -15V$

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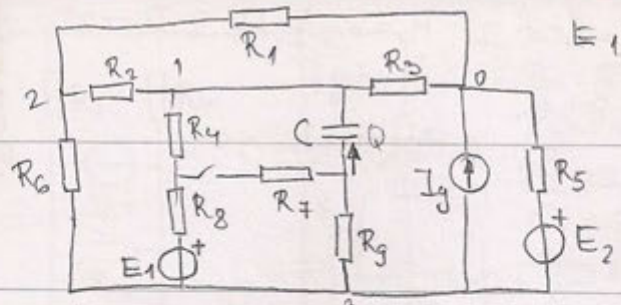


$E_1 = 20V \quad E_2 = 16V \quad I_g = 1A$

$R_1 = 10\Omega \quad R_3 = 60\Omega$

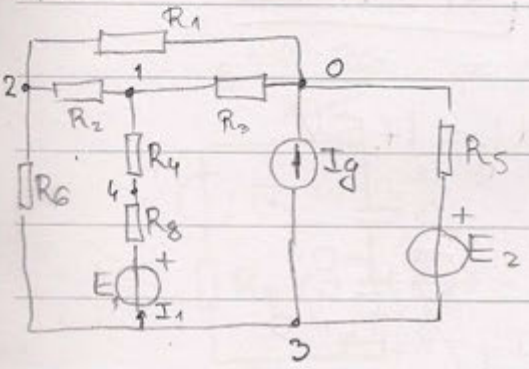
$R_2 = 30\Omega \quad R_4 = R_6 = R_9 = 7\Omega$

$R_5 = 4\Omega \quad R_8 = 10\Omega \quad R_7 ?$

$C = 32\mu F \quad \Pi \to 1 \quad \Delta W_e = -3825mJ$

$\frac{1}{2}CU_{C1}^2 + \Delta W_e = \frac{1}{2}CU_{C2}^2 \qquad U_2^2 = 239,0625 + U_1^2$

$\Pi \to 0$



1: $\left(\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}+\frac{1}{R_4+R_8}\right)V_1 - \frac{1}{R_2}V_2 - \frac{1}{R_4+R_8}V_3 = \frac{E_1}{R_4+R_8}$

2: $\left(\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_6}\right)V_2 - \frac{1}{R_2}V_1 - \frac{1}{R_6}V_3 = 0$

3: $-\frac{1}{R_4+R_8}V_1 - \frac{1}{R_6}V_2 + \left(\frac{1}{R_4+R_8}+\frac{1}{R_6}+\frac{1}{R_5}\right)V_3 = -I_g - \frac{E_2}{R_5} - \frac{E_1}{R_4+R_8}$

-1-4

$0.2088V_1 - 0.0333V_2 - 0.0588V_3 = 1,17647 \qquad U_{C_2} = \pm 15.48\ V$

$-0.0333V_1 + 0.2762V_2 - 0.14286V_3 = 0$

$-0.0588V_1 - 0.14286V_2 + 0.4517V_3 = -6.1765$

$V_1 = 0.1595V_2 + 0.2816V_3 + 8.2206 = 8.3817 + 0.3712V_3$

$-(0,2737 + 0.00938V_3 + 0.0053V_2) + 0.2709V_2 = 0.15224V_3$

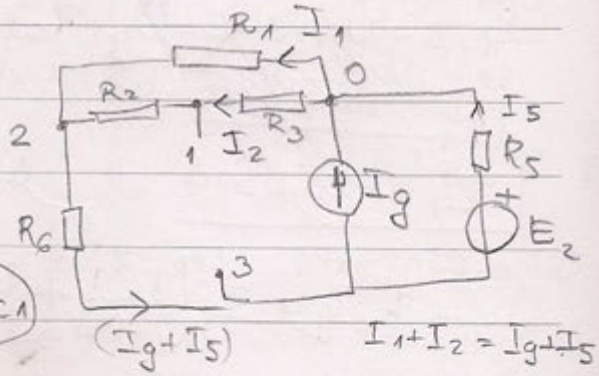
$V_2 = 0.56198V_3 + 1.0103$

$0.4299V_3 - 0.4928 - 0.0803V_3 - 0.14433 = -6.1765$

$V_3 = -15.84 \approx -15.8\ V$

$V_2 = -7.89 \approx -7.9\ V$

$V_1 = 2.5\ V$



$U_{13} = E_1 - I_1(R_8+R_4)$

$\frac{E_1 - V_1 + V_3}{R_8+R_4} = I_1$

$U_{41} = R_4 I_1 = 0.7V = U_{C1}$

$(I_g + I_5) \qquad I_1 + I_2 = I_g + I_5$

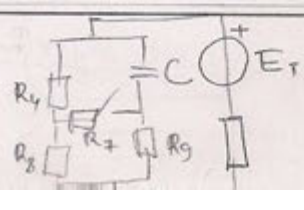
$20 - 4 \cdot I_5 - \frac{10}{100}(1 - \frac{10}{100}I_5) - 7 - 7I_5 = 0$

$E_2 - R_5 I_5 - I_2(R_2+R_3) - R_9(I_g+I_5)$

$-11I_5 + 13 \qquad -11.1\ I_5 = -12.9 \qquad I_5 = \qquad I_2 = \frac{R_1}{R_1+R_2+R_3}(I_g+I_5)$

$\frac{494}{44}I_5 = \frac{562}{44} \qquad I_5 = 1,1377\ A \qquad I_2 = 0.25856\ A$

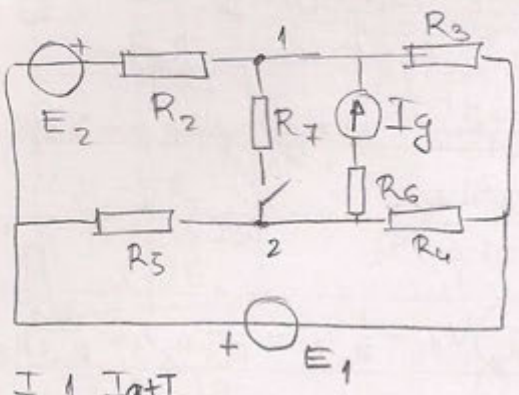
$U_{pn} = U_{13} = (I_g + I_5)R_6 + I_2 R_2 = 8.772V$

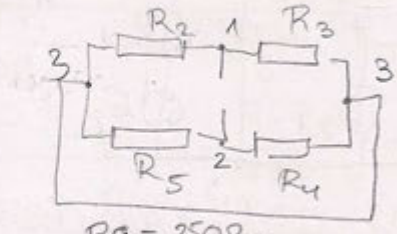


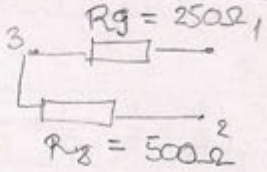
ANALYSIS LABORATORY EQUIPMENT

176. $E_2 = 10V$ $I_g = 40mA$ $R_2 = R_3 = 500\Omega$ $R_4 = R_5 = 1k\Omega$ $R_6 = 250\Omega$

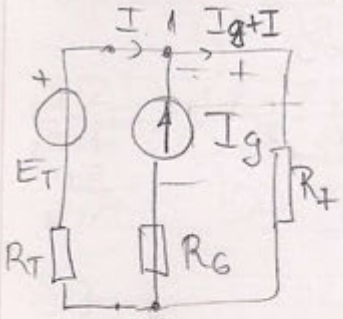
$n \to 1$, $n \to 0$ $\Delta P_{Ig} = 0{,}7W$ R_7?







$R_T = 750\Omega$



$E_T - U_g + R_6 I_g + R_7 I_g = 0$ $\Delta U_g = 17{,}5V$

$E_T = U_g - 40$

$E_T - R_T I - R_7 I_7 = 0$ $(I_7 = I + I_g)$

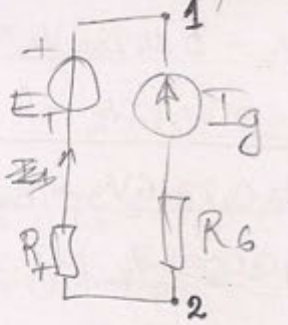
$U_{g_2} - R_6 I_g - R_7 I_7 = 0$

$U_{g_1} - 40 - R_7 I - R_7 (I + I_g) = 0$

$E_T - I R_T - U_{g_2} + R_6 I_g = 0$

$U_{g_1} - 40 - U_{g_2} = I R_T - R_6 I_g$

$-\Delta U_g = I R_T - R_6 I_g + 40$



$-R_T I + E_T - R_7 (I_g + I) = 0$

$-R_T I + E_T - U_{g_1} + R_6 I_g = 0$

$U_{g_2} - U_{g_1} = 17{,}5$

$U_{g_2} = 17{,}5 + U_{g_1}$

$U_{g_1} - R_7 (I_g + I) + R_6 I_g = 0$

$-I_g R_T + E_T - U_{g_2} + R_6 I_g = 0$

$-R_T I + U_{g_1} + 37{,}5 - U_g + R_6 I_g = 0$ (10)

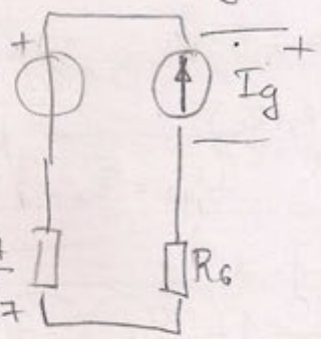
$17{,}5 + U_{g_1} = E_T - 20$

$U_{g_1} = E_T - 37{,}5$

$I = -0.063A$

$I_7 = -23.33mA$

$\frac{R_7 E_T}{R_T + R_7}$



$U_{g_1} = R_6 I_g + I_g \frac{R_T R_1}{R_7 + R_T} + \frac{R_7 E_T}{R_T + R_7}$

$\frac{R_T R_7}{R_T + R_7}$

$U_{g_1} = 10 + \frac{R_7}{R_7 + R_T}(30 + E_T)$

$-47.5 + 47{,}5 + 47{,}5 \frac{R_7}{R_T} + 23.33 \cdot 10^{-3} R_7 = 0$

$\frac{R_T E_T}{R_7 + R_T} = 47{,}5 + \frac{30 R_1}{R_7 + R_T}$

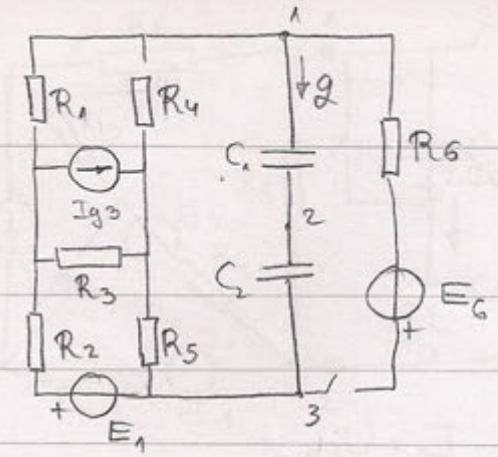
$R_7 \geq 2$

$E_T = 47{,}5 \frac{R_7 + R_T}{R_T} + 30 \frac{R_7}{R_T}$

$+47{,}5$ 95 $R_7 = 750$

ЗНАЧИ!!!

175

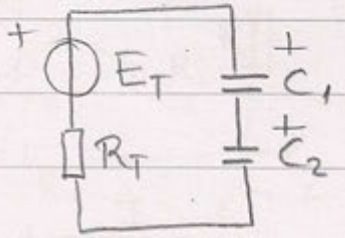


$E_6 = -15V$
$R_1 = R_2 = 150\Omega$
$R_3 = R_4 = R_5 = 50\Omega$
$R_6 = 25\Omega$
$C_1 = 95\mu F$
$C_2 = 1\mu F$

$\Pi \to \emptyset \quad U_{32} = 15V \qquad Q_{10}?\ E_1?$

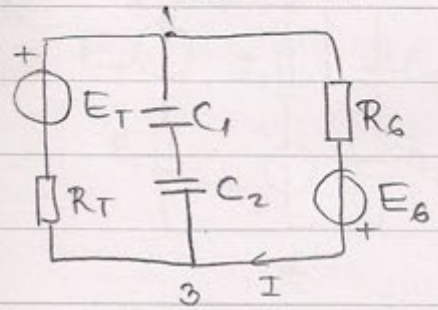
$\Pi \to 1 \quad q = -2{,}5\mu C$

$2 \cdot \frac{150 \cdot 50}{200} = 75\Omega = R_T$ ✓



$E_T - U_{C_{10}} - U_{C_{20}} = 0$

$E_T = -U_{32} + U_{C10}$



$\frac{E_6 + E_T}{R_T + R_6} = I$

$-\frac{15 + E_T}{100} = I$

$U_{C_1} = \frac{Q_{10} + q}{C_1} = U_{C_{10}} - 5$

$U_{C_2} = -U_{32} - 2{,}5$

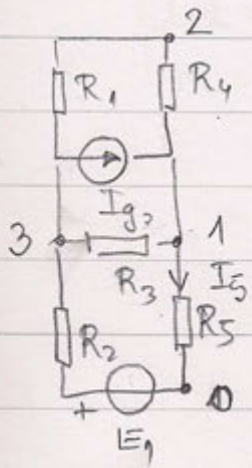
$U_{13} = -E_6 + R_6 \cdot \frac{-15 + E_T}{100} = U_{32} + U_{C10} - 7{,}5$

$15 - 3{,}75 + 0.25 - U_{32} + 0.25 U_{C10} = -U_{32} + U_{C10} - 7{,}5$

$-U_{32} + U_{C10} = 25 \Rightarrow U_{C10} = 40 \quad Q_{10} = 20\mu C$

$E_T = -15 + 40 = 25\ V$

$V_2 = 25V$



$U_{13} = R_3 I_{g3}$

$1: \left(\frac{1}{R_3} + \frac{1}{R_4} + \frac{1}{R_5}\right) V_1 - \frac{1}{R_4} V_2 - \frac{1}{R_3} V_3 = I_{g3}$

$2: -\frac{1}{R_4} V_1 + \left(\frac{1}{R_1} + \frac{1}{R_4}\right) V_2 - \frac{1}{R_1} V_3 = 0$

$-\frac{1}{R_3} V_1 - \frac{1}{R_1} V_2 + \left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right) V_3 = \frac{E_1}{R_2}$

$\frac{3}{50} V_1 - \frac{1}{50} \cdot 25 - \frac{1}{50} V_3 = I_{g3} \qquad 3V_1 - V_3 = 50 I_{g3} + 25$

$-\frac{1}{50} V_1 + \frac{4}{150} V_2 - \frac{1}{150} V_3 = 0$

$-3V_1 + 100 - V_3 = 0 \qquad V_3 = 100 - 3V_1$

$V_1 - V_3 = R_3 I_{g3} = 50 I_{g3} \qquad 3V_1 - V_3 = V_1 - V_3 + 25$

$I_{g3} = -1A \qquad V_1 = 12.5\Omega$

$U_{13} = -50V \qquad V_3 = 62.5$

$I_5 = \frac{V_1 - 0}{R_5} = 0.25\ A$

$U_{13} = E_1 + I_5 (R_5 + R_2)$

$-100 = -E_1 \qquad E_1 = 100V$

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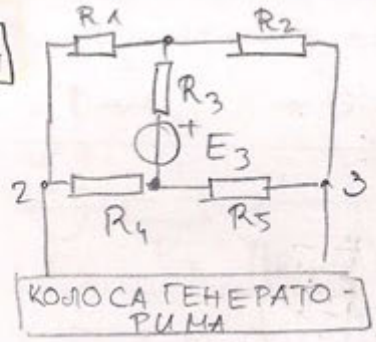


КОЛОСА ГЕНЕРАТОРИМА

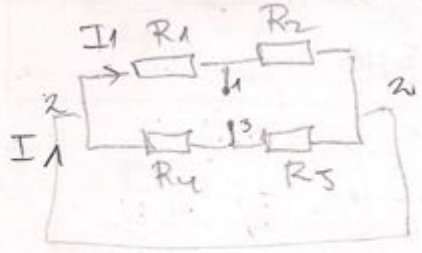
$E_3 = 10\,V$

$R_1 = R_5 = 200\,\Omega$

$R_2 = 100\,\Omega \quad R_3 = 300\,\Omega$

$R_4 = 400\,\Omega$

P_{E_3} ?



$\frac{200}{3}$

$\frac{800}{6} = \frac{400}{3}$

$E_T = U_{p4} =$

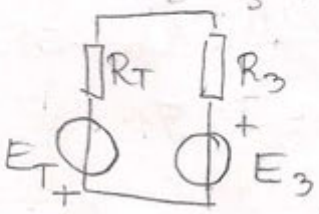
$\frac{600}{3} = 200\,\Omega$

$R_T = 200\,\Omega$

$R_1 + R_4 = 600\,\Omega$

$R_2 + R_5 = 300\,\Omega$

$\frac{600 \cdot 300}{900} = 200\,\Omega$



$I = \frac{E_3 + E_T}{R_T + R_3} = \frac{10 + E_T}{500}$

$I_1 = \frac{R_4 + R_5}{R_1 + R_2 + R_4 + R_5} I = \frac{2600}{3900} I = \frac{2}{3}$

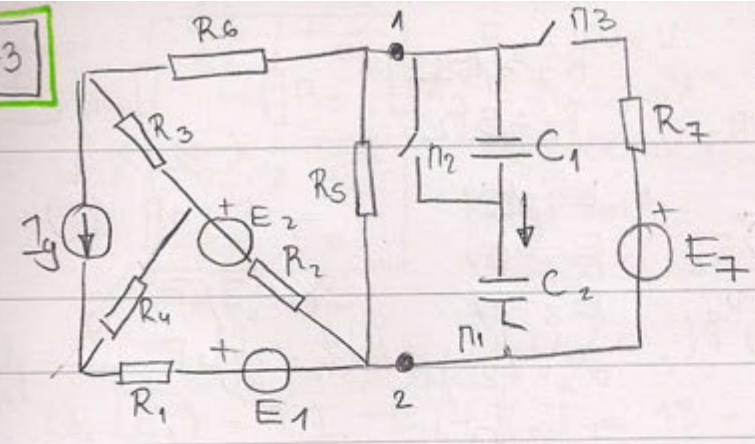
$I_2 = \frac{1}{3} I$

$U_{31} = R_1 I_1 - R_4 I_2 = \frac{2}{3} I \cdot 200 - 400 \cdot \frac{1}{3} I = 0$

$P = 0.2\,W$

$E_T = 0 \Rightarrow I = 0.02\,A$

173

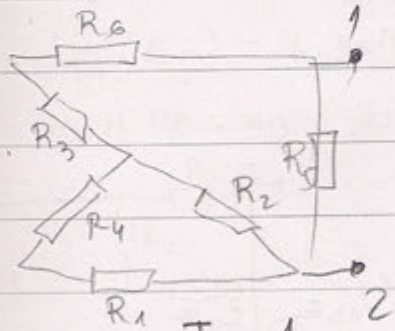


$E_1 = 8V$
$E_7 = 12V$
$R_1 = R_7 = 10\Omega$
$R_2 = 30\Omega$
$R_3 = R_5 = 15\Omega$
$R_4 = R_6 = 5\Omega$
$C_1 = 0{,}5\mu F \quad C_2 = 1\mu F$

П1 → 1 $Q_1 = 2\mu C$ C_2 Q_{10}, Q_{20}?

П2 → 1 $Q_2 = 3\mu C$ C_2

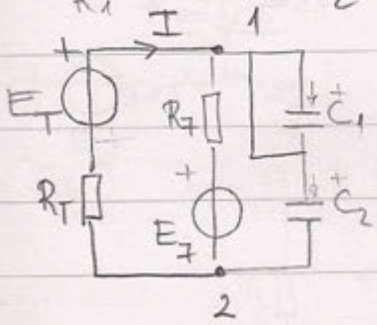
П3 → 1 $Q_3 = 5\mu C$ C_2



$R_6 + R_3 = 20\Omega$
$R_4 + R_1 = 15\Omega$

$30 \parallel 15 = 10\Omega$

$15 \parallel 30 = 10\Omega$ $\boxed{R_T = 10\Omega}$



П1 $E_T = \frac{Q_1 + Q_{10}}{C_1} + \frac{Q_1 + Q_{20}}{C_2} = 6V + \frac{Q_{10}}{C_1} + \frac{Q_{20}}{C_2}$ ✓

П2 $E_T = \frac{Q_1 + Q_2 + Q_{20}}{C_2} = 5V + \frac{Q_{20}}{C_2}$ → $\boxed{Q_{10} = 0{,}5\mu F}$ ✓

$Q_1 = 0$

П3:

$\frac{Q_3}{C_1} + \frac{Q_1 + Q_2 + Q_3}{C_2} + \frac{Q_{20}}{C_2} = -R_T I + E_T$

$10 + 10 + E_T - 5 = -R_T I + E_T$

$I = \frac{E_T - E_7}{R_T + R_7}$

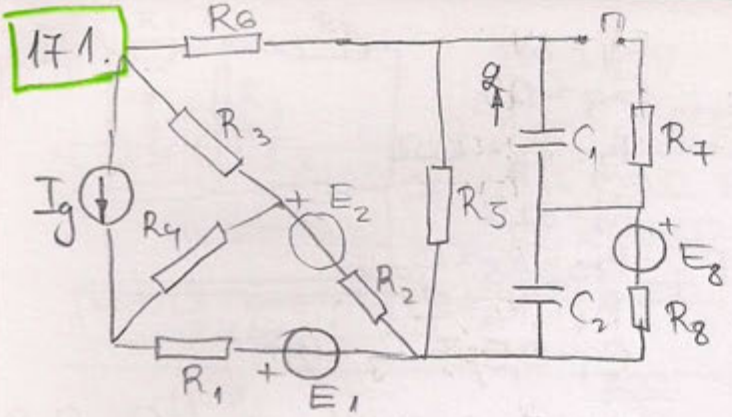
$I = -0{,}5A$

$U_{12} = E_7 + R_7 I = 12 - 5 = 7V$

$\frac{Q_1 + Q_2 + Q_3}{C_2} + \frac{Q_{20}}{C_2} = 7V$ $\boxed{Q_{20} = -3\mu F}$ ✓

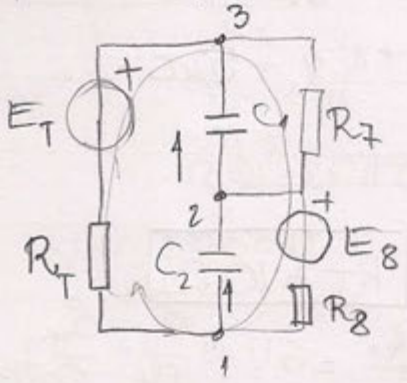
ANALYSIS LABORATORY EQUIPMENT

17 1.



$R_7 = 15\Omega$
$R_8 = 5\Omega$
$E_1 = 12V$
$E_2 = 2V$
$E_8 = 4V$
$C_1 = 0{,}5\mu F$
$C_2 = 1{,}2\mu F$
$Q_1 = 1{,}25\mu C$
I_g? Q_{C_2} $_{n\to\infty,\ n\to 1}$

$R_T = 10\Omega$



$U_{12} = -E_8$

$Q_{2_2} = -4{,}8\mu C$ ✓

$U_{13} = -E_T$

$U_{13} = -E_T$

$U_{12} + U_{23} = -E_T$

$\frac{Q_{10}}{C_1} - E_8 = -E_T$

$I = \frac{E_T - E_8}{R_T + R_8 + R_7}$

$\frac{Q_{10}}{C_1} + \frac{Q_1}{C_1} = -IR_7$

~~$I = -0.35A = 1.67$~~

$-\frac{1}{2}E_T + E_8 + 2{,}5 = -\frac{1}{2}E_T + \frac{1}{2}E_8$

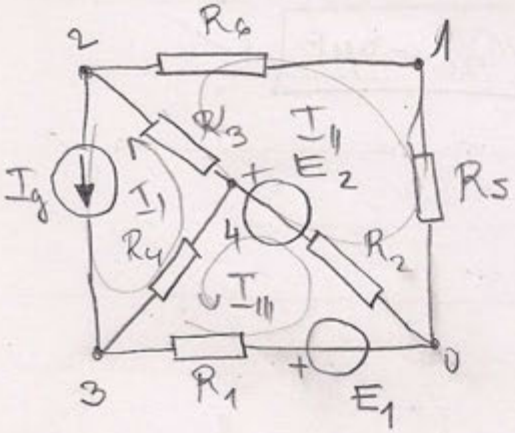
~~$E_T = -1{,}25V$~~ $E_T = 9V$ ✓

$\frac{Q_{10}}{C_1} + 2{,}5 = 5{,}25$

$Q_{10} = 1{,}375\mu C$

$U_{12} = -E_8 - R_8 I = -4{,}83$

$Q_2 = -5{,}8\mu C$ ✓



$I_1 = I_g$

$-R_3 I_1 + (R_6 + R_2 + R_5 + R_3) I_{II} - R_2 I_{III} = -E_2$

$-R_4 I_1 - R_2 I_{II} + (R_1 + R_4 + R_2) I_{III} = -E_1 + E_2$

$-15 I_g + 65 I_{II} - 30 I_{III} = -2$

$-5 I_g - 30 I_{II} + 45 I_{III} = -10$

$-27{,}5 I_g + 17{,}5 I_{II} = -13$

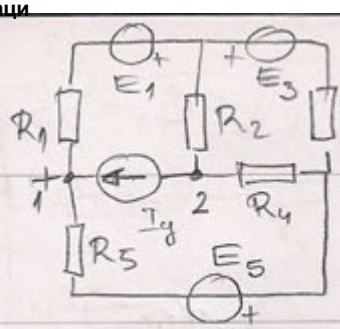
$I_{II} = -\frac{E_T}{R_5} = -0{,}6A$

$I_{III} = 0.49A$

$I_g = -1A$

$15 I_g = 30.25 -$

167.



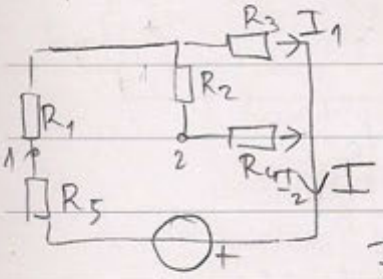
$E_1 = 100mV$ $R_2 = 60\Omega$
$E_3 = 200mV$ $R_3 = 100\Omega$
$E_5 = 400mV$ $R_4 = 40\Omega$
$I_g = 2mA$ $R_5 = 100\Omega$
$R_1 = 50\Omega$ P_{Ig} ?

$U_g = U_{12}$ $U_g = U_g(E_1) + U_g(E_3) + U_g(E_5) + U_g(I_g)$

$U_g(E_1) = R_2 I_2 - E_1 + R_1 I = 15 - 100 + 25 = -60mV$

$U_g(E_5) = R_2 I_2 + R_1 I = -60 - 100 = -160mV$

$100 \parallel 100 = 50$ 200Ω $I = \frac{E_1}{200} = 0,5mA$

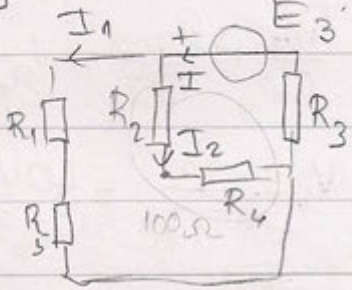


$I_2 = \frac{100}{200} I = 0,25mA$

$I = -2mA$

$I_2 = -1mA$

$U_g(E_3)$:



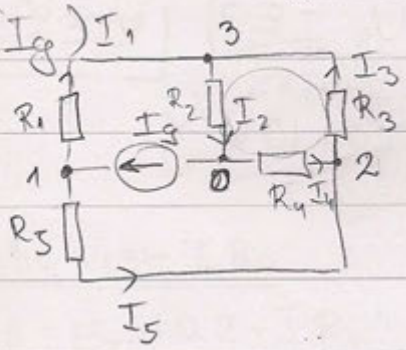
$I = 1,25mA$

$I_2 = \frac{150}{250} 1,25 = 0.75mA$

$I_1 = 0.5mA$

$U_g(E_3) = R_2 I_2 - R_1 I_1 = 45 - 25 = 20mV$

$U_g(I_g)$



I: $\left(\frac{1}{R_1} + \frac{1}{R_5}\right) V_1 - \frac{1}{R_5} V_2 - \frac{1}{R_1} V_3 = I_g$

II: $-\frac{1}{R_5} V_1 + \left(\frac{1}{R_3} + \frac{1}{R_4} + \frac{1}{R_5}\right) V_2 - \frac{1}{R_3} V_3 = 0$

III: $\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right) \cdot V_3 - \frac{1}{R_1} V_1 - \frac{1}{R_3} V_2 = 0$

$3V_1 - 1V_2 - 2V_3 = 200$

$V_2 = 3V_1 - 2V_3 - 200 \;/\cdot 9$

$-V_1 + 4V_2 - V_3 = 0$

$\left(3 + \frac{5}{3}\right) V_3 - 2V_1 - \frac{5}{3} V_2 = 0$

$V_3 = 12V_1 - 8V_3 - 800 - V_1$

$14V_3 - 6V_1 - 5V_2 = 0 \;/\cdot 9$

$V_3 = \frac{11V_1 - 800}{9}$

$154V_1 - 11200 - 54V_1 - 45 \cdot V_2 = 0$

$100V_1 - 11200 - 45V_2 = 0$

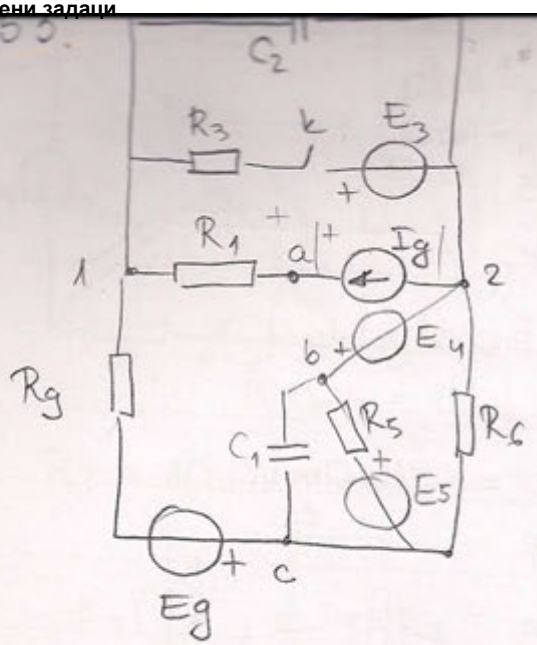
$9V_2 = 18V_1 - 22V_1 + 1600 - 1800$

$100V_1 - 11200 + 20V_1 + 1000 = 0$

$9V_2 = -4V_1 - 200$

$V_1 = 85mV$

ANALYSIS
LABORATORY EQUIPMENT



$R_g = 200\Omega$
$E_3 = 30V$
$E_4 = 20V$
$E_5 = 30V$
$I_g = 20mA$
$R_1 = 250\Omega$
$R_3 = 300\Omega$
$R_5 = 500\Omega$
$R_6 = 750\Omega$
$R_7 = R_8 = 400\Omega$

$C_1 = 0,5\mu F$
$C_2 = 0,2\mu F$
$Q_{ac} = 20\mu C$
Q_{12} C_2 k → 1

$U_{a1} = 50V$

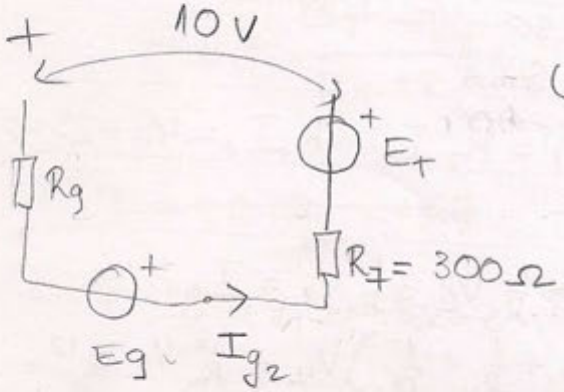
$U_{bc} = \frac{Q_{01}}{C_1} = V_b - V_c$

$Q_{ac} = \frac{Q_{01}}{C_1} + \frac{Q_{ac}}{C_1} = V_a - V_c$

$U_{ab} = V_a - V_b = \frac{Q_{ac}}{C_1} = 40V$

$U_{ab} = +U_g - E_4$ $U_g = 60V$

$U_{12} = 60 - 50 = 10V$

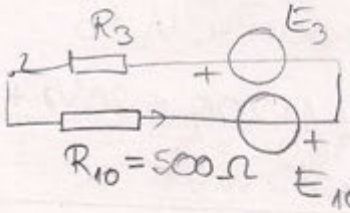


$\frac{R_6(E_5 - E_4)}{1250} = 6V = E_T$

$10 = -E_T + R_7 I_{g_2} - E_g + R_g I_{g_2}$

$10 = -6 + 500 \cdot 20 \cdot 10^{-3} - E_g$

$E_g = 6V$

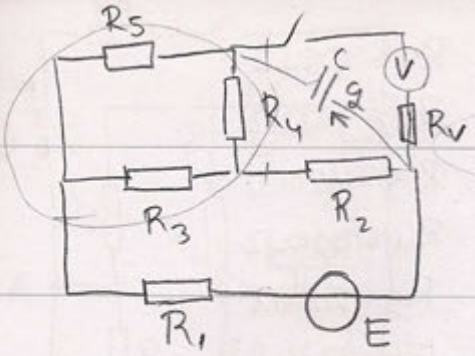


$Q_{02} = 10V \cdot 0,2\mu F = 2\mu C$

$I = \frac{E_{10} + E_3}{R_3 + R_{10}} =$

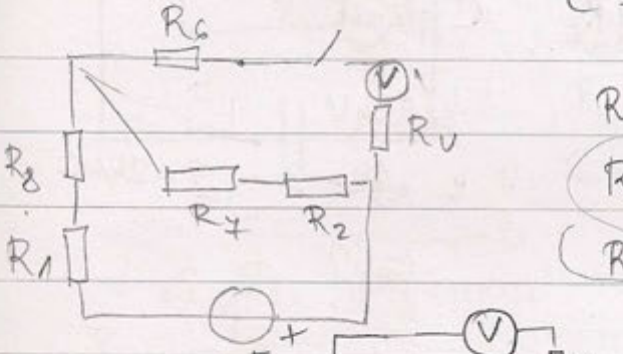
$E_3 - 15.75 = Q_2 C_2$

54.



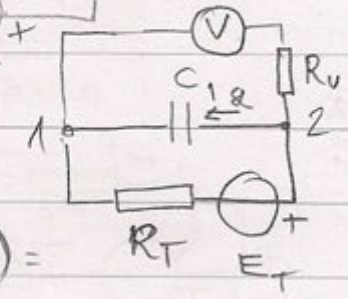
$R_1 = 600\Omega$
$R_2 = 150\Omega$
$R_3 = 500\Omega$
$R_4 = 100\Omega$
$R_5 = 400\Omega$
$C = 8\mu F$

$k \to 1 \quad Q = 1{,}6\mu C$
$U_{12} = 5{,}8\,V$



$R_6 = 40\ \Omega$
$R_7 = 50\ \Omega$
$R_8 = 200\Omega$

$R_T = \frac{800 \cdot 200}{1000} + 40 = 200\Omega$



$\frac{Q_0}{C} = E_T$

$U_{31} = E_T + \frac{Q}{C}$

$E_T = \frac{200}{800+200}(E_6) =$

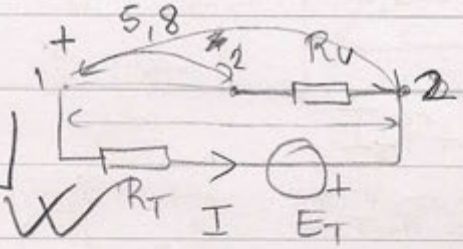
$= -6V$

$I = \frac{E_T + 5{,}8}{R_T}$

$U_{31} = E_T + R_T I'$

$U_{31} = +I R_T + 5{,}8 \quad E_T + \frac{Q}{C}$

$E = -30V$



$E_T + \frac{Q}{C} = \frac{R_V}{R_T + R_V}(E_T + 5{,}8)$

$-0.2 = E_T + 5{,}8$

$\Downarrow$

$-R_T I = \frac{Q}{C}$

$I = -\frac{0.2}{R_T}$

① $5{,}8 = U_{13} - I R_V$

$5{,}8 = E_T + 0.2 - I R_V$

$5{,}6 + I R_V = E_T$

$5{,}8 + -I R_T + E_T - I R_V = 0$

$I = \frac{E_T}{\quad}$

$U_{21} = \frac{Q}{C}$

$I = \frac{-6V}{R_T + R_V}$

$\frac{120 \cdot (+6)}{+0{,}2} = 300 + R_V$

$U_{21} = \frac{Q_0}{C} + \frac{Q}{C}$

$\frac{U_{12} + E_T}{V_{12}} = I$

$R_V = 3.3k\Omega$

$-5{,}8 = E_T + 0.2$

$V_{12} = R_T E_T + R_T$

$6000 = 200 + R_V$

$E_T = -6V$

$\frac{5{,}8 - 6}{420} = I$

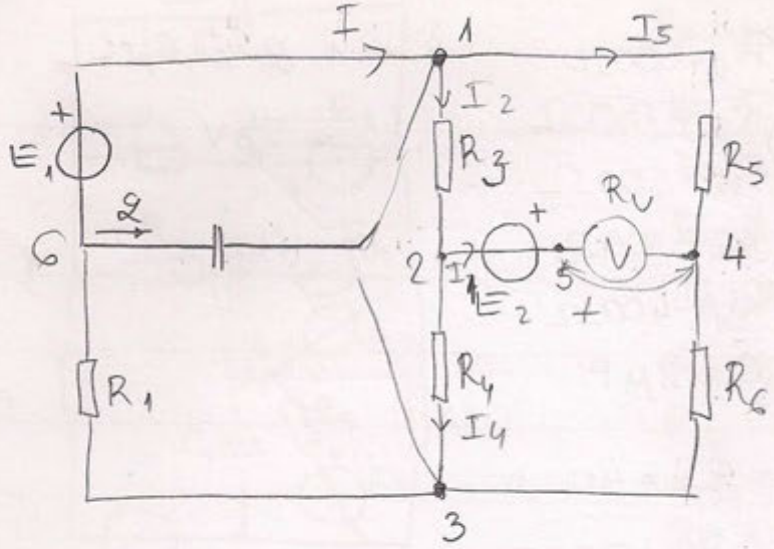
$R_V = 5800\ \Omega$

$I = -0{,}001$

$-\frac{0{,}2}{200} = I$

ANALYSIS

55.



$R_1 = 300\Omega$
$R_6 = 700\Omega$
$R_3 = 120\Omega$
$R_4 = 300\Omega$
$R_5 = 200\Omega$
$E_2 = 32V$
$C = 2\mu F$

$U_{54} = 24V$

k $1 \to 3$ $Q = 24\mu C$

E_1? R_V?

$\frac{Q_0}{C} = U_{61}$

$\frac{Q_0 + Q}{C} = U_{63}$

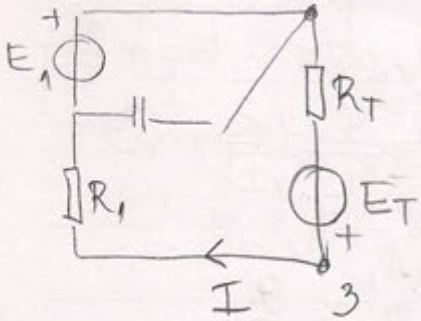
$U_{13} = \frac{Q}{C}$ | $U_{13} = 12V$

$V_6 - V_1 = \frac{Q_0}{C}$

$V_6 - V_3 = \frac{Q_0}{C} + \frac{Q}{C}$

$I_2 = \frac{U_{24}}{R_V}$

$U_{24} = U_{54} - E_2 = 24 - 32 = -8V$



$U_{13} = -E_T + R_T I$

$E_T + 12 = R_T I$

$E_1 - R_1 I = 12$

$E_1 - \frac{300}{R_T}(E_T + 12) = 12$

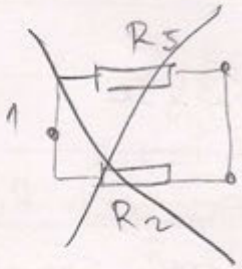
$U_{13} = I_4 R_4 + I_2 R_2$

II

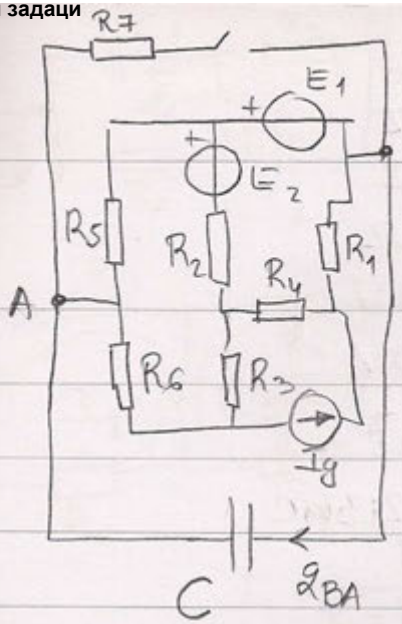
$I_5 R_5 = U_{24} + R_2 I_2$

$I R_5 = (R_2 + R_5) I_2 + U_{24}$

I IR_2



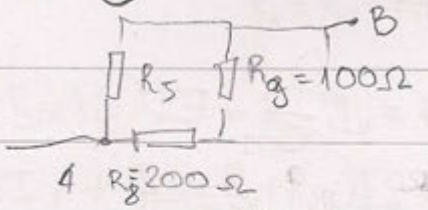
56.



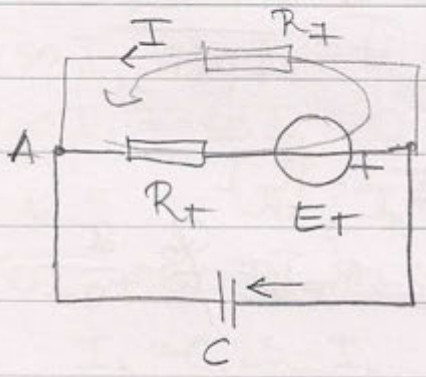
$E = 12V$
$E_2 = 2V$
$R_1 = 100\Omega$
$R_2 = 300\Omega$
$R_3 = 150\Omega$
$R_4 = 50\Omega$
$R_5 = 150\Omega$
$R_6 = 50\Omega$
$R_7 = 500\Omega$
$C = 1{,}6\mu F$

$k \to 1$ $q_{BA} = 0{,}8\mu C$ I_g?

$R_T = 100\Omega$



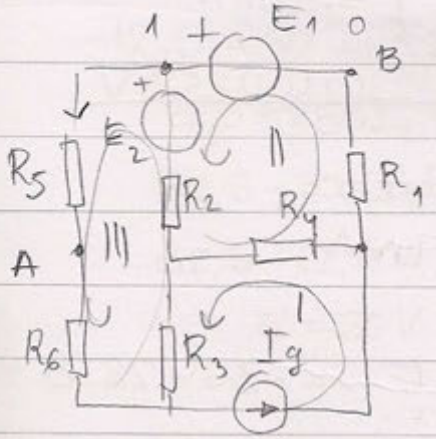
$$\frac{Q_0}{C} = E_T$$



$$I = \frac{E_T}{R_T + R_7}$$

$$\frac{Q_0}{C} + q = U_{BA} = E_T - R_T I$$

$I = -5mA$ $E_T = -3V = U_{BA}$



$I_1 = I_g$

$-R_4 I_g + (R_1 + R_2 + R_4) I_{II} - R_2 I_{III} = E_1 - E_2$

$-R_3 I_g - R_2 I_{II} + (R_2 + R_3 + R_5 + R_6) I_{III} = E_2$

$-50 I_g + 450 I_{II} - 18 = 10$

$-150 I_g - 300 I_{II} + 650 \frac{q}{150} = 2 \quad / 1.5$

$-225 I_g - 450 I_{II} + 58.5 = 3$

$-275 I_g + 40.5 = 13$

$$I_g = 0.1A$$

$V_1 = E_1 = 12V$

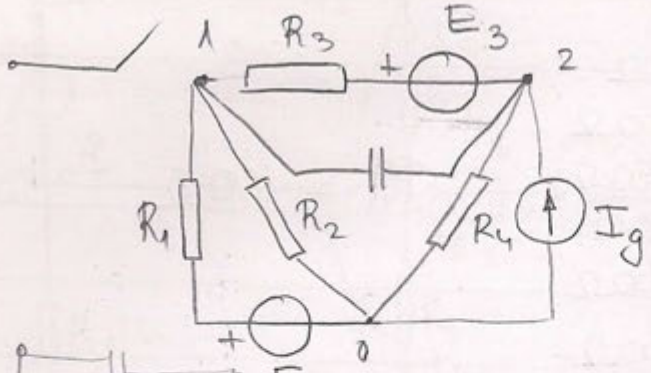
$V_B - V_A = -9$

$V_A = V_B + 9V = 9V$

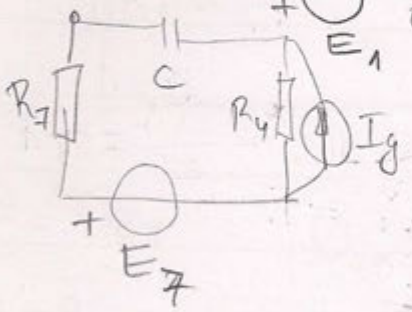
$$I_{III} = \frac{V_1 - V_A}{R_5} = \frac{12 - 9}{150} = \frac{9}{150} = 0.06$$

ANALYSIS LABORATORY EQUIPMENT

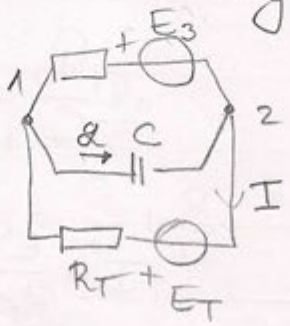
57.



$R_1 = 200\Omega$
$R_2 = 500\Omega$
$R_3 = 3k\Omega$
$R_4 = 10k\Omega$
$E_1 = 50V$
$E_3 = 30V$
$C = 0,7\mu F$
$Q_{12} = 0,213mC$
I_g ?



$E_7 = 35.71V$
$R_7 = 142.86\Omega$
$R_T = 10142.86\Omega$



$\frac{Q_0}{C} = E_T = U_{12}$

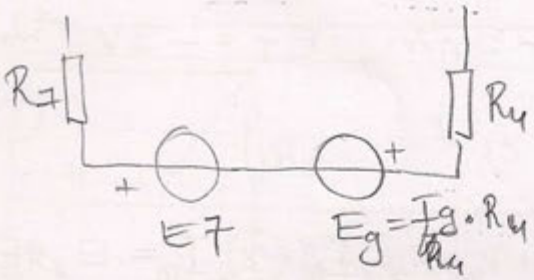
$I = \frac{E_T - E_3}{R_T + R_3}$

$U_{12} = E_T - R_T I$

$E_T - R_T I = \frac{Q_0}{C} + \frac{Q}{C}$

$I = -30mA$

~~$E_T = -424.2858V$~~



$E_T = E_7 - E_g$

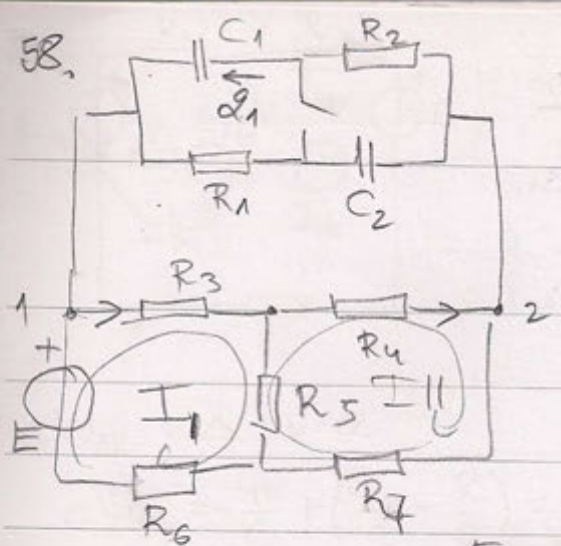
~~$I_g = 0.057A$~~
~~$0.56,7mA$~~

$I_g = 40mA$

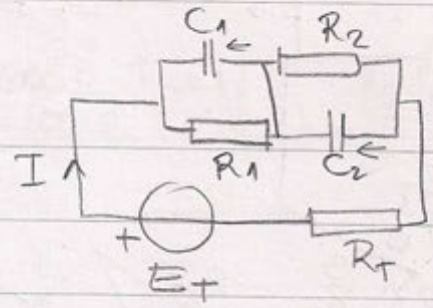
-424.2858

$E_T = -364.2858$
-30

58.



$R_T = 75\Omega$



$U_0 = U_{C1} = U_{C2} = -E_T$

$\frac{Q_{01}}{C_1} = \frac{Q_{02}}{C_2}$

$Q_1 = 30\mu C$ E ?

$$I = \frac{E_T}{R_1 + R_2 + R_T} = \frac{E_T}{250\Omega}$$

$$U_{C_1} = \frac{Q}{C_1} = -IR_1$$

$$\frac{Q_{01}}{C_1} + \frac{Q_1}{C_1} = -IR_1$$

$$(R_3 + R_5 + R_6)I_1 - R_5 I_{11} = E$$

$$-R_5 I_1 + (R_5 + R_4 + R_7)I_{11} = 0$$

$$250 I_1 - 50 I_{11} = E$$

$$-50 I_1 + 250 I_{11} = 0$$

$$-E_T + 7{,}5 = -100\frac{E_T}{250}$$

$$-0{,}6 E_T + 7{,}5 = 0$$

$$E_T = 12.5V$$

$U_{12} = 12.5$ $\quad U_{12} = I_{II} R_4 + I_1 R_3 =$

$$50 I_1 + 50 I_{II} = 12{,}5 \quad / 50$$

$$I_1 = 0.25 - I_{II}$$

$$-12{,}5 + 50 I_{II} + 250 I_{II} = 0 \qquad I_{II} = \frac{12.5}{300}$$

$$62{,}5 - 250 I_{II} = 250 I_1$$

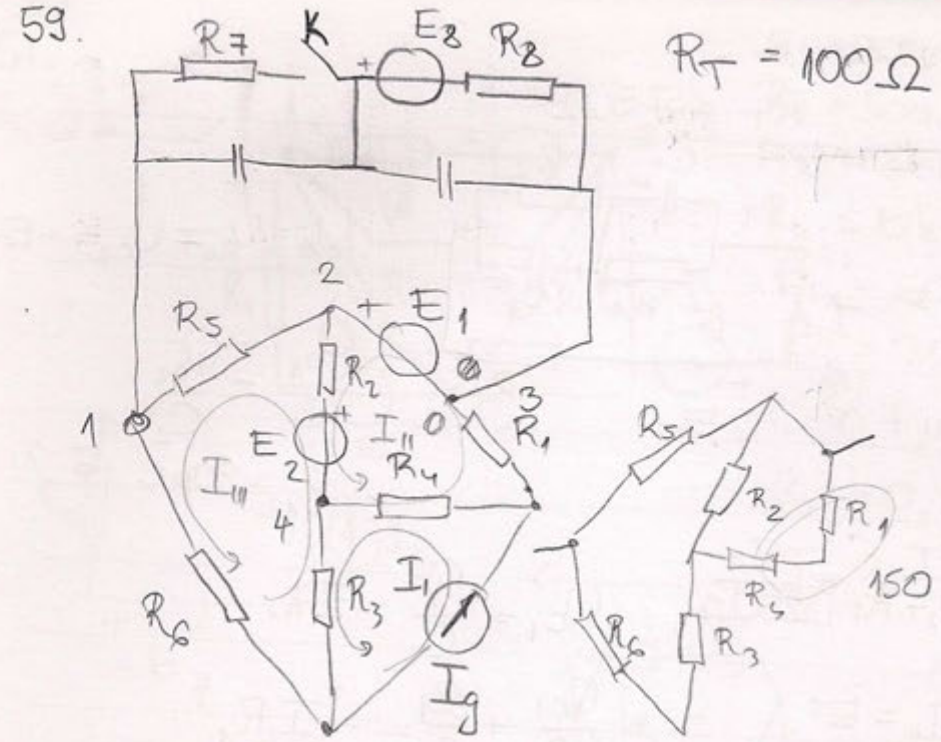
$$62{,}5 - 300 I_{II} = E$$

$$62{,}5 - 12{,}5 = E$$

$$E = 50V$$

ANALYSIS
LABORATORY EQUIPMENT

59.



$R_T = 100\,\Omega$

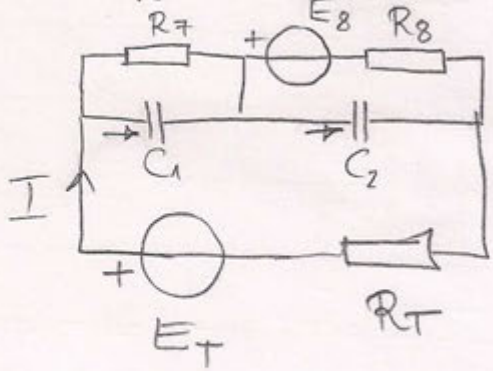
V. $I_1 = I_g$

$$-R_4 I_g + (R_1 + R_2 + R_4) I_{II} - R_2 I_{III} = E_1 - E_2$$
$$-R_3 I_g - R_2 I_{II} + (R_3 + R_2 + R_5 + R_6) I_{III} = E_2$$

$$-5 + 450 I_{II} - 300 I_{III} = 10\,V$$
$$-15 - 300 I_{II} + 650 I_{III} = 2$$

$$300 I_{II} - 200 I_{III} = 10 \qquad 300 I_{II} = 10 + 200 I_{III}$$
$$-10 - 200 I_{III} + 650 I_{III} = 17$$
$$450 I_{III} = 27$$
$$I_{III} = 0.06\,A$$

$$U_{13} = E_1 - R_5 I_{III} = 12 - 9 = \boxed{3V = E_T}$$



$$I = \frac{E_T - E_8}{R_T + R_T + R_8} = -5\,mA$$

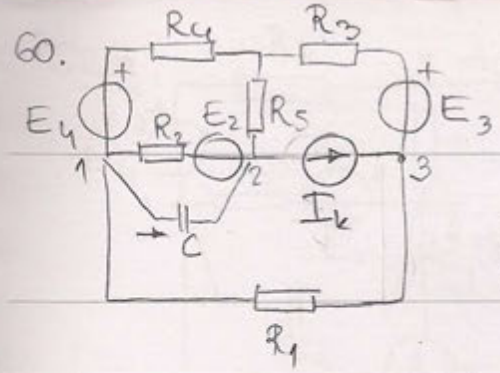
$$Q_1 = I R_7 C_1 = -1{,}5\,\mu C$$

$$Q_2 = I R_8 C_2 + E_8 C_2 = 2{,}5\,\mu C$$

$$Q_{20} = E_8 C_2 = 3\,\mu C \qquad \boxed{Q_2 = -0{,}5\,\mu C}$$

$E_T - U_{C_1 0} - E_8 = 0 \qquad U_{C_1} = -3 \qquad Q_1 = -3\,\mu C \;/\; Q_1 = 1{,}5\,\mu C$

60.



$I_k = \begin{cases} I_g \\ 0 \end{cases}$

$Q_{12} = 6\mu C$ I_g?

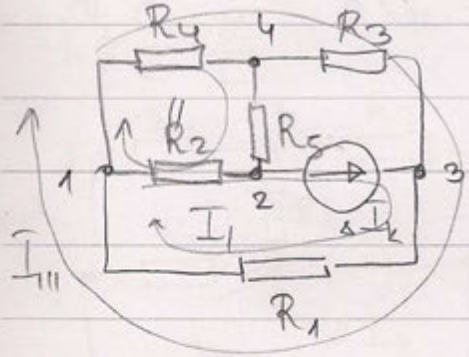
$R_2 = 600\Omega$ $R_3 = 1k\Omega$ $R_5 = 1{,}2k\Omega$
$R_1 = 500\Omega$ $R_4 = 1{,}8k\Omega$

$C = 0{,}5\mu F$
$E_3 = 12V$ $E_4 = 20V$

$\Delta U_{12} = \Delta I_k \cdot a$

$\Delta U_{12} = -\frac{Q_0}{C} + \left(\frac{Q_0}{C} + \frac{Q}{C}\right) = +\frac{Q}{C} = +12V$

$+12V = (0 - I_g)a$ $\quad a I_g = -12V$



$I_1 = \Delta I_k$

$-R_2 I_1 + (R_2 + R_4 + R_5) I_{II} + R_4 I_{III} = 0$

$R_1 I_1 + R_4 I_{II} + (R_1 + R_4 + R_3) I_{III} = 0$

$-600 I_1 + 3600 I_{II} + 1800 I_{III} = 0$

$(500 I_1 + 1800 I_{II} + 3300 I_{III} = 0) / \cdot 2$

$1000 I_1 + 3600 I_{II} + 6600 I_{III} = 0$

$1600 I_1 + 4800 I_{III} = 0$

$I_{III} = -\frac{1}{3} I_1$

$1000 I_1 + 3600 I_{II} - 2200 I_1 = 0$

$3600 I_{II} = 1200 I_1$

$I_{II} = \frac{1}{3} I_1$

$I_{12} = I_1 - I_{II} = -\frac{2}{3} I_1$

$\Delta U_{12} = 12$

$\Delta U_{12} = -\frac{2}{3} R_1 \Delta I_k =$

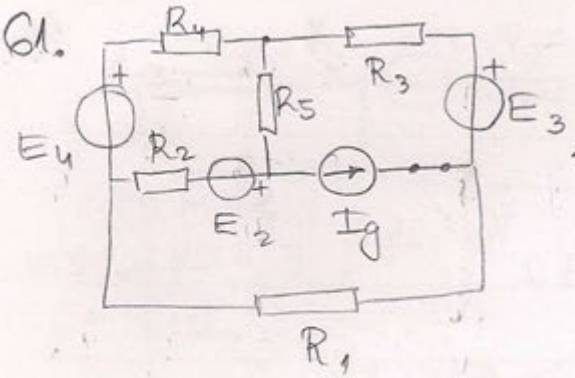
$12 = -\frac{2}{3} R_1 \Delta I_k$

$\Delta I_k = -0.036A$

$I_g = 36mA$

ANALYSIS LABORATORY EQUIPMENT

61.



$I_{12}(k \to 1) = -30mA$

$P_2 = -0,48W$

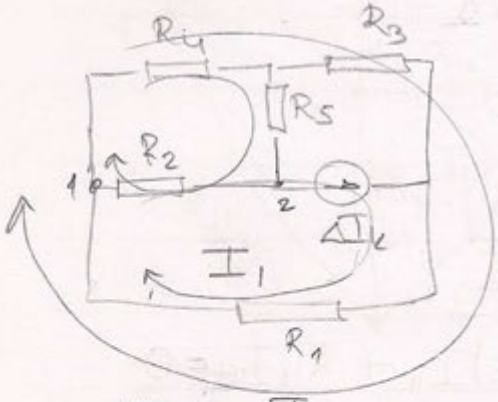
$P_1 = R_2 I_{12}^2 = 0,54$

$P_2 - P_1 = -0,48$

$P_2 = 0.06$

$I_{12}(k \to 0) = \pm 10mA$

$\Delta I_k = a \Delta I_{12}$



$I_1 = \Delta I_k$

$$-R_2 I_1 + (R_2 + R_4 + R_5) I_{II} + R_4 I_{III} = 0$$
$$R_1 I_1 + (R_1 + R_3 + R_4) I_{III} + R_4 I_{II} = 0$$

$$-600 I_1 + (600 + 1800 + 1200) I_{II} + 1800 I_{III} = 0$$
$$500 I_1 + 1800 I_{II} + (500 + 1000 + 1800) I_{III} = 0$$

$$5I_1 + 18 I_{II} + 33 I_{III} = 0 \quad /.2$$
$$-6I_1 + 36 I_{II} + 18 I_{III} = 0$$
$$10 I_1 + 36 I_{II} + 66 I_{III} = 0$$

$$16 I_1 + 48 I_{III} = 0$$

$$I_{III} = -\frac{1}{3} I_1$$

$$5 I_1 + 18 I_{II} - 11 I_1 = 0$$

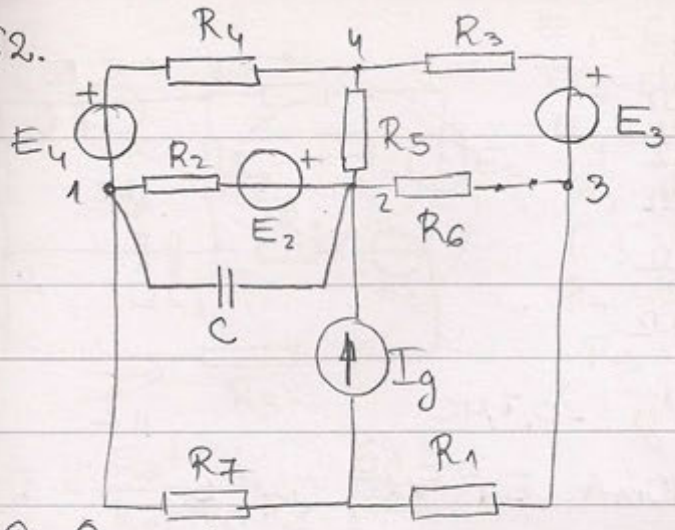
$$I_{II} = \frac{1}{3} I_1$$

$$\Delta I_{12} = I_1 - I_{II} = -\frac{2}{3} \Delta I_k = -\frac{2}{3}(0 - I_g) = \frac{2}{3} I_g$$

1° $I_{12}^{(1)} = 10\,mA$ $\quad \frac{3}{2}(10 + 30) = I_g \quad I_g = 60mA$

2° $I_{12}^{(1)} = -10mA$ $\quad \frac{3}{2}(-10 + 30) = I_g \quad I_g = 30mA$

62.



$R_1 = 200\,\Omega$
$R_2 = 600\,\Omega$
$R_3 = 1\,k\Omega$
$R_4 = 1{,}8\,k\Omega$
$R_5 = 1{,}2\,k\Omega$
$R_7 = 300\,\Omega$
$E_3 = 12\,V$
$I_g = 20\,mA$
$C = 0{,}5\,\mu F$

$k \to 1 \quad U_{23} = -6\,V$

$I_{23}^{①} = \frac{U_{23}}{R_6} = -\frac{6}{R_6}$

$I_{23}^{②} = 0$

$k \to 0 \quad Q_{12} = 2\,\mu C$

R_6 ?

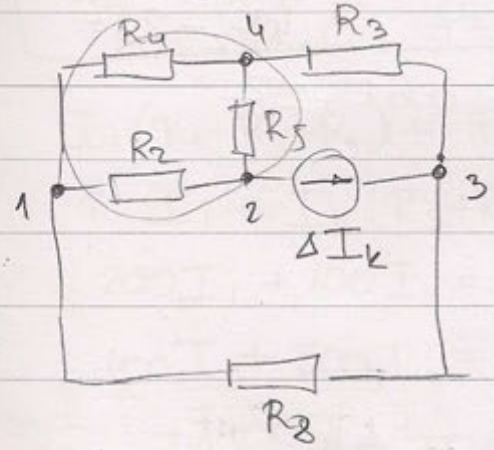
$R_8 = 500\,\Omega$

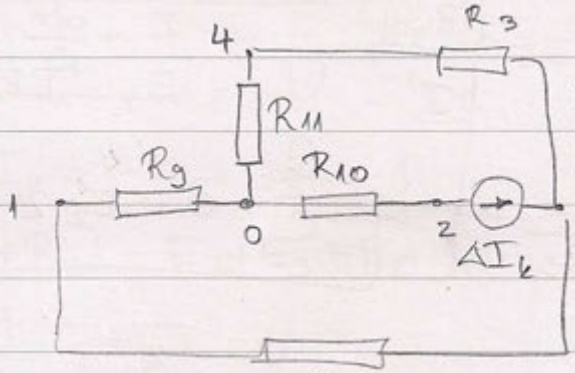
$U_{12}^{①} = \frac{Q_0}{C}$

$U_{12}^{②} = \frac{Q_0}{C} + \frac{Q}{C}$

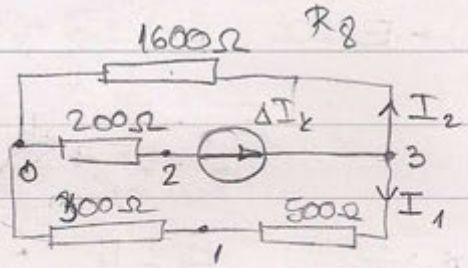
$\Delta U_{12} = \frac{Q}{C} = 4\,V$

$\Delta U_{12} = a \cdot \Delta I_{23} = a \cdot \frac{6}{R_6}$





$R_9 = 200\,\Omega$
$R_{10} = 200\,\Omega$
$R_{11} = 600\,\Omega$



$I_1 = \frac{1600}{2400}\Delta I_k$

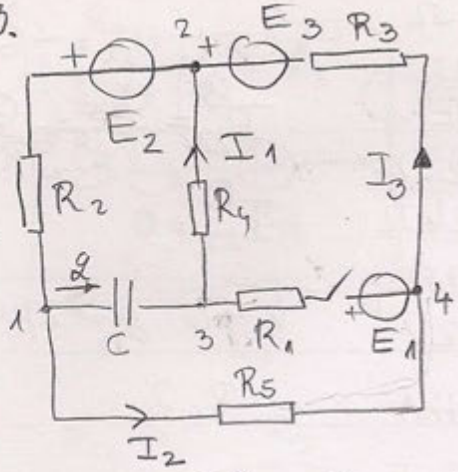
$\Delta U_{12} = \Delta I_k \cdot 200 + \frac{1600}{2400}\Delta I_k \cdot 300 = 400\,\Delta I_k$

$4 = 400 \cdot \frac{6}{R_6}$

$\boxed{R_6 = 600\,\Omega}$

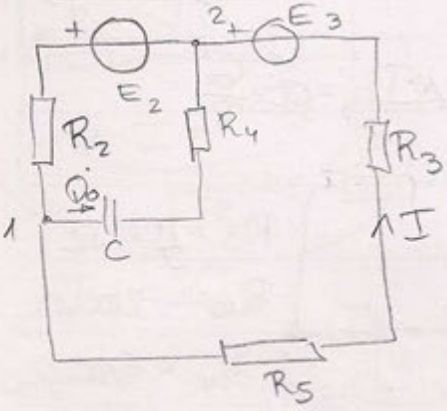
ANALYSIS LABORATORY EQUIPMENT

63.



$E_3 = 5V$
$R_1 = 150\Omega$
$R_2 = 100\Omega$
$R_3 = 100\Omega$
$R_4 = 50\Omega$
$R_5 = 300\Omega$
$C = 1\mu F$
$k \to 1 \quad Q = -0.7\mu C$

$U_{42} = -E_3 + I_3 R_3 = -5 + 1 = -4V$ $I_{42} = 10mA$ $E_1 ? E_2 ?$



$$I = \frac{E_2 + E_3}{R_2 + R_3 + R_5} = \frac{E_2 + 5}{250}$$

$$U_{12} = E_2 - IR_2 = E_2 - 0.4E_2 - 2 = 0.6E_2 - 2$$

$$\frac{Q_0}{C} = 0.75E_2 - 2$$

$U_{42} = -4V$

$U_{42} = I_1(R_4 + R_1) - E_1$

$$\frac{E_1 - 4}{R_4 + R_1} = I_1$$

$$\frac{E_1 - 4}{R_4 + R_1} + I_3 = \frac{E_2 + 4}{R_2 + R_5}$$

$U_{42} = E_2 - (R_2 + R_5) I_2$

$$\frac{E_1 - 4}{200} + 10mA = \frac{E_2 + 4}{400} \quad / \cdot 400$$

$$\frac{E_2 + 4}{R_2 + R_5} = I_2$$

$2E_1 - 8 + 4 = E_2 + 4$

$E_2 = 2E_1 - 8$

$30E_1 - 120 = -2.5E_1 - 33$

$32.5E_1 = 87$

$U_{13} = \frac{Q_0}{C} + \frac{Q}{C}$

$5E_1 - 3E_2 = 54$

$U_{13} = I_1 R_1 - E_1 + I_2 R_5$

$5E_1 - 6E_1 + 24 = 54$

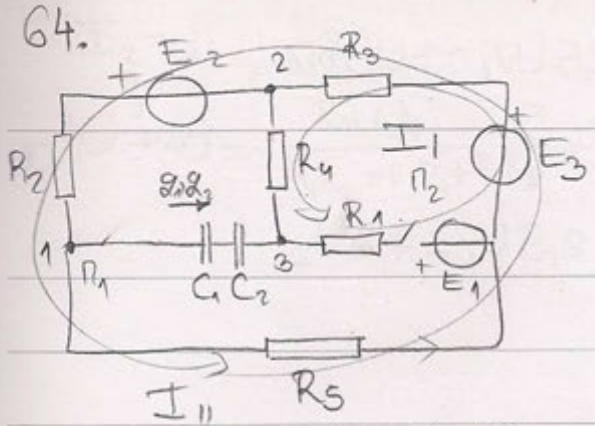
$E_1 = -30V$

$0.75E_2 - 2 - 0.7 = 150 \frac{E_1 - 4}{200} - E_1 + \frac{E_2 + 4}{400} \cdot 300$

$0.6E_2 - 2.7 = 0.75E_1 - 3 - E_1 + 0.75E_2 + 3 \quad E_2 = -68V$

$-2.25E_1 - 2.70 = -2.15E_2$

64.



$E_1 = 6V$
$E_3 = 5V$
$R_1 = 150\Omega$
$R_2 = 100\Omega$
$R_3 = 100\Omega$
$R_4 = 50\Omega$
$R_5 = 300\Omega$
$C_1 = 1\mu F, C_2 = 2{,}5\mu F$

$Q_{10} \neq 0, \; Q_{20} = 0$

$\Pi_1 \to 1 \quad Q_1 = 5\mu C$

$\Pi_2 \to 1 \quad Q_2 = -0{,}5\mu C$

U_{13}?

$$I = \frac{E_3 + E_2}{R_2 + R_3 + R_5} = \frac{5 + E_2}{500}$$

$$U_{12} = E_2 - R_2 I = E_2 - 1.2 - 0.2E_2 = 0.8E_2 - 1$$

$$U_{12} = \frac{Q_{10}}{C_1} + \frac{Q_1}{C_1} + \frac{Q_1}{C_2} = \frac{Q_{10}}{C_1} + 7 \qquad \frac{Q_{10}}{C_1} = 0.8E_2 - 8$$

$$I_1(R_1 + R_3 + R_4) + R_3 I_{11} = -E_1 + E_3 = -1$$

$$R_3 I_1 + I_{11}(R_3 + R_5 + R_2) = E_2 + E_3 = E_2 + 5$$

$$300 I_1 + 100 I_{11} = -1$$

$$100 I_1 + 500 I_{11} = E_2 + 5 \quad / \cdot 3 \quad -300 I_1 - 1500 I_{11} = -3E_2 - 15$$

$$-1400 I_{11} = -3E_2 - 16$$

$$I_{11} = \frac{3E_2 + 16}{1400}$$

$$300 I_1 = -\frac{14}{14} \cdot \frac{-3E_2 - 16}{14} = \frac{-10 - 3E_2}{14}$$

$$I_1 = -\frac{E_2 + 10}{1400} =$$

$$U_{13} = R_4 I_1 + E_2 - R_2 I_{11} = -50\frac{E_2 + 10}{1400} + E_2 - 100 \cdot \frac{3E_2 + 16}{1400}$$

$$U_{13} = \frac{Q_{10}}{C_1} + 7 + Q_2 \cdot 1.4 = 0.8E_2 - 8 + 6.3 = 0.8E_2 - 1.7$$

$$1120E_2 - 2380 = -50E_2 - 500 + 1400E_2 - 300E_2 - 1600$$

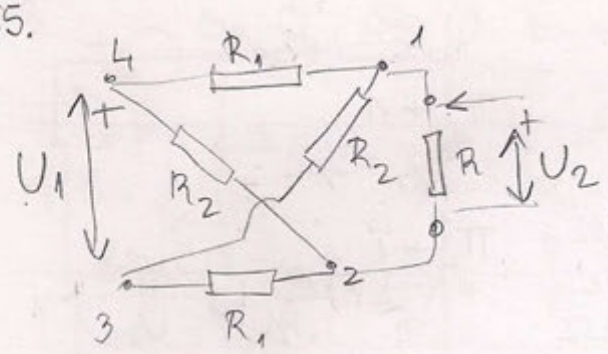
$$70E_2 = 280 \qquad E_2 = 4V$$

$$U_{13} = 1.5V$$

$Q_{10} =$

ANALYSIS LABORATORY EQUIPMENT

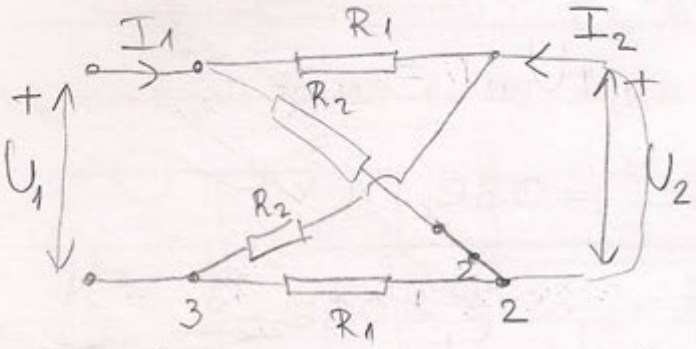
65.



$I_{12} = 2{,}5(U_1 - 3U_2)\,mA$

R_1, R_2 ?

$I_{12} = 2{,}5U_1 - 7{,}5U_2$



$I_1 = g_{11}U_1 + g_{12}U_2$

$I_2 = g_{21}U_1 + g_{22}U_2$

$g_{12} = g_{21}$

$\frac{1}{g_{11}} = \frac{U_1}{I_1}\Big|_{U_2=0}$

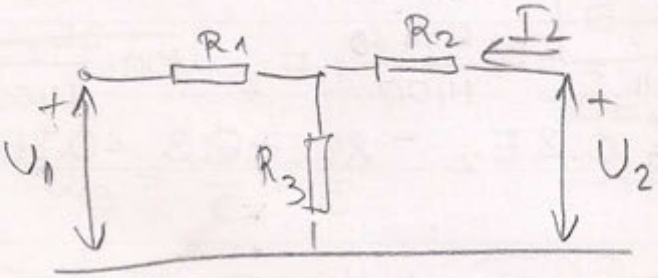
$I_{12} = -I_2$

$\frac{1}{g_{11}} = R_e = 2\frac{R_1R_2}{R_1+R_2}$ $\quad g_{11} = \frac{R_1+R_2}{2R_1R_2}$

$\frac{1}{g_{12}} = \frac{U_2}{I_1}\Big|_{U_1=0}$

$\frac{1}{g_{12}} = \frac{1}{g_{21}} = \frac{U_1}{I_2}\Big|_{U_2=0}$ $\quad g_{12} = -\frac{R_1+R_2}{2R_1R_2}$

66. $g_{22} = \frac{R_1+R_2}{2R_1R_2}$



$I_2 = g_{21}U_1 + g_{22}U_2$

$\frac{1}{g_{21}} = \frac{U_1}{I_2}\Big|_{U_2=0}$

$g_{22} = \frac{R_1+R_3}{R_1R_2+R_2R_3+R_1R_3}$ ✓

$I = \frac{U_1}{R_1 + \frac{R_2R_3}{R_2+R_3}}$ $\quad I_2 = \frac{R_3}{R_3+R_2}\cdot\frac{U_1}{R_1+\frac{R_2R_3}{R_2+R_3}} = \frac{R_3U_1}{R_1(R_2+R_3)+R_2R_3}$ ✓

$g_{21} = -\frac{R_3}{R_1R_2+R_2R_3+R_1R_3}$ $\quad \frac{1}{g_{22}} = \frac{U_2}{I_2}\Big|_{U_1=0}$ $\quad I_2 = \frac{U_2}{\left(R_2+\frac{R_1R_3}{R_1+R_3}\right)}$

$I_2 = \frac{U_2}{-80}$

$10^{-3}(-80) = -\frac{R_3 U_1}{R_1R_2 + R_2R_3 + R_1R_3}$

$+10^{-3} \cdot 80 = +\frac{200\,U_1}{300 \cdot 100 + 500 \cdot 00}$

$U_1 = 20V$

$\operatorname{tg}\alpha = \frac{80}{\frac{40}{3}} = 16 = k$

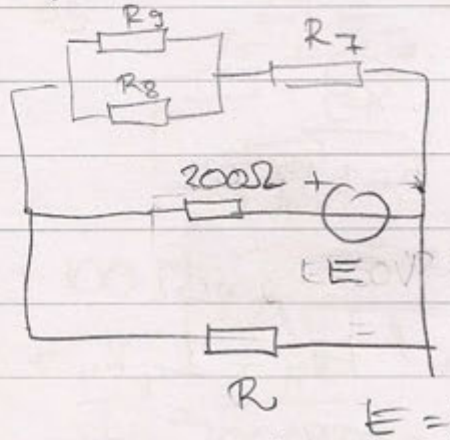
$\frac{R_1 + 200}{R_1 \cdot 300 + 200 \cdot 00} = 6 \cdot 10^{-3}$

$R_1 + 200 = 1.8R_1 + 120$

$80 = 0.8R_1 \quad R_1 = 100\Omega$

$\frac{\frac{R_1}{200} + 1}{1.5R_1 + 100} U_2 - \frac{U_1}{1.5R + 100}$

67.



$R_1 = R_2 = 300\Omega \quad R_3 = R_4 = R_5 = 100\Omega$

$R_6 = 50\Omega \quad E_1 = 50V \quad E_6 = 37,5V$

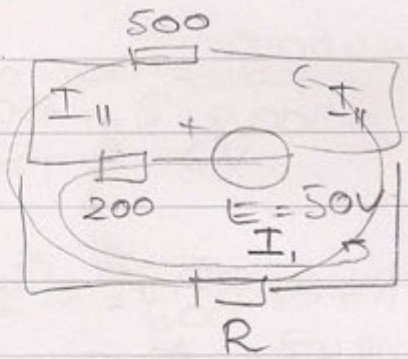
$R_7 = 200\Omega \quad R_8 = 500\Omega \quad R_g = 750\Omega$

$P_{7max} = 2W \quad P_{8max} = 0,8 \quad P_{gmax} = 0.6\,W$

$|I_{7max}| = 0.1A \quad |I_{gmax}| = 0.04A$

$E = 50V \quad R_{max}?$

$|I_{gmax}| = \frac{0.04}{\sqrt{2}}A$



1: $(200+R)I_1 + RI_{11} = E$

2: $RI_1 + (500+R)I_{11} = 0$

$I_1 = \frac{E - RI_{11}}{200+R}$

$\frac{RE - R^2 I_{11}}{200+R} + 500I_{11} + RI_{11} = 0 \quad / \cdot 200+R$

$50R - R^2 I_{11} + 100000\,I_{11} + 500RI_{11} + 200RI_{11} + R^2 I_{11} = 0$

$(50 + 700I_{11})R = -100\,000\,I_{11}$

$R = -\frac{10\,0000\,I_{11}}{50 + 700\,I_{11}}$

$I_{11} = I_7$

$I_8 = \frac{R_g}{R_8 + R_g} I_{11} = 0.4I_{11}$

$I_g = 0.6I_{11}$

4714.045208

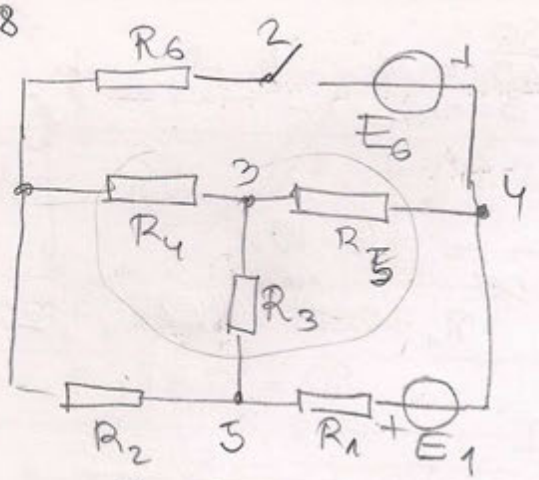
$R = 277.26\Omega$

$|I_{11}| < 0.1A$

$|I_{11}| < 0.04714 = \frac{4}{60\sqrt{2}}$

ANALYSIS LABORATORY EQUIPMENT

68



$R_1 = R_2 = 150\Omega$

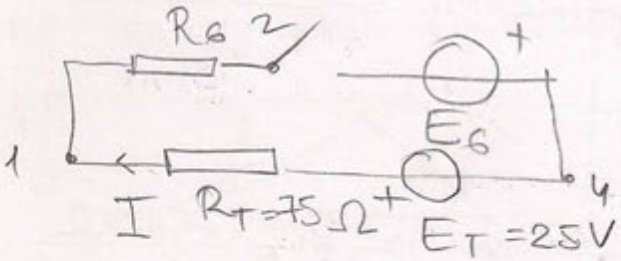
$R_3 = R_4 = R_5 = 50\Omega$

$E_6 = -15V$

$U_{14}' = 25V$ $\quad k \to 0$

$U_{12} = 2{,}5V$ $\quad k \to 1$

R_6 ?



$$I = \frac{E_T + E_6}{R_6 + R_T}$$

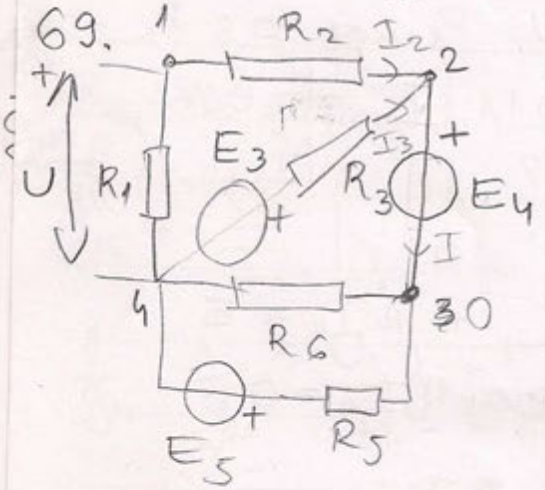
$$U_{12} = I R_6$$

$$\frac{2{,}5}{R_6} = \frac{10}{R_6 + 75}$$

$2{,}5 R_6 + 187{,}5 = 10 R_6$

$R_6 = 25\Omega$

69.



R_4

$I_{23} = 40mA$ $\quad E_4 = I_4 R_4 = 12V$

$E_3 = 12V$ $\quad E_5 = 32V$

$R_1 = 5k\Omega$ $\quad R_2 = 400\Omega$

$R_3 = 1k\Omega$ $\quad R_4 = 300\Omega$ $\quad R_5 = 100\Omega$

$R_6 = 500\Omega$

$V_3 = 0$

$V_2 = E_4$

$I_2 + I_3 = I_{23}$ $\quad -(R_1 + R_2) I_2 + I_3 R_3 - E_3 = 0$

$I_2 = 1.25$ $\quad -5{,}4 I_2 + 40 - I_2 - 32 = 0$

$8 = 6{,}4 I_2$

$$4: \left(\frac{1}{R_1} + \frac{1}{R_3} + \frac{1}{R_5} + \frac{1}{R_6}\right) V_4 - \frac{1}{R_1} V_1 - \frac{1}{R_3} V_2 = -\frac{E_3}{R_3} - \frac{E_5}{R_5}$$

$$1: \left(\frac{1}{R_2} + \frac{1}{R_1}\right) V_1 - \frac{1}{R_1} V_4 - \frac{1}{R_2} V_2 = 0$$

$\left(\frac{1}{5} \cdot 10^{-3} + 1 \cdot 10^{-3} + 10 \cdot 10^{-3} + 2 \cdot 10^{-3}\right) V_4 - 0.2 \cdot 10^{-3} V_1 - 12 \cdot 10^{-3} = -320$

$13.2\, V_4 = 320 + 0.2 V_1 \quad / : 0.2$

$66 V_4 = 1600 + V_1$

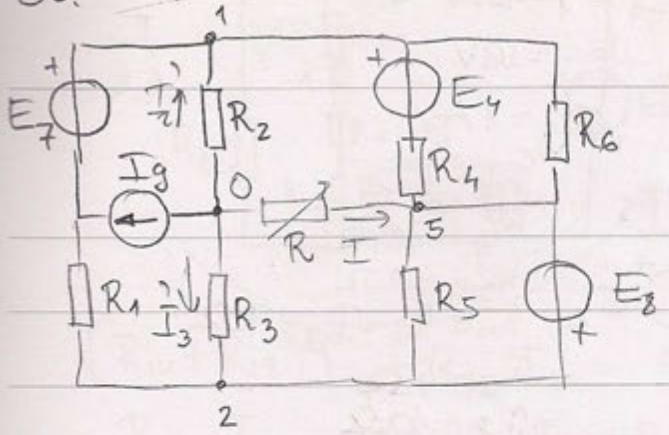
$0{,}25 V_1 - 0{,}2 V_4 = 30$

$-720 + 29.7 V_4 - 0.2 V_4 = 30$

$V_1 = \frac{750}{}$

85. $R_1 = 60\Omega$ $R_2 = 120\Omega$ $R_3 = 300\Omega$ $R_4 = 120\Omega$

$R_5 = 300\Omega$ $R_6 = 120\Omega$ $E_4 = 8V$



$I_g = 8mA$

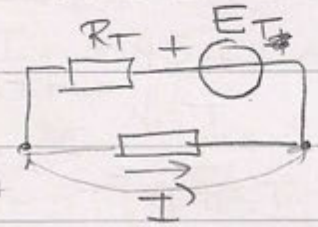
$R' = 200\Omega$ $I_2' = 7mA$

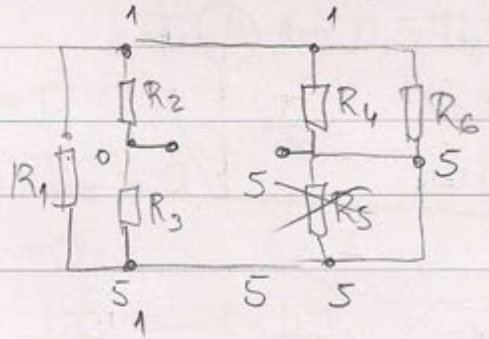
$I_3' = 5mA$

$I?$ $R' = 500\Omega$

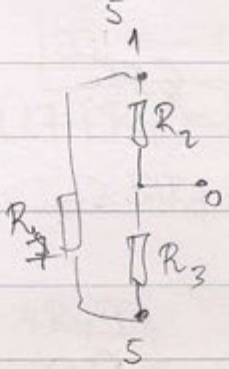
$V_1 = -R_2 I_2' = -0.84$ $I' = -(I_2' + I_3' + I_g) = -20mA$

$U_{05} = R \cdot I' = -4V$





$R_T = 100\Omega$



$R_7 = 30\Omega$

150

$$I' = \frac{E_T}{100+200}$$

$-20 \cdot 300 = E_T$

$E_T = -6V$

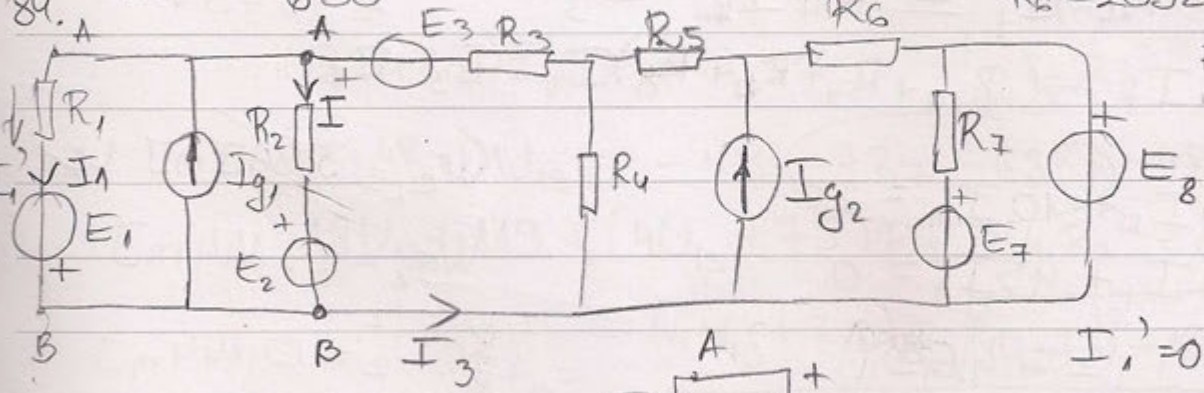
$R_1 = 200\Omega$ $R_2 = 300\Omega$

$R_3 = 150\Omega$ $R_4 = 100\Omega$ $R_5 = 80\Omega$

$R_6 = 20\Omega$ $R_7 = 250\Omega$

$$I' = \frac{-6}{600} = -10mA$$

84.



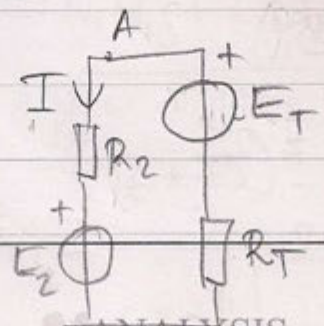
$E_1 = 12V$

$I_{g_1} = 25mA$

$E_2 = 4V$

$E_7 = 20V$

$I_1' = 0.1A$



$U_{AB} = +20 - 12 = 8V$

$R_T = 100\Omega$ ✓

$E_T = U_{ph\,AB} = 8V$ ✓

$I = \frac{E_T - E_2}{R_T + R_2} = \frac{+4}{400} = +10mA$

$\boxed{I_3 = 80mA}$

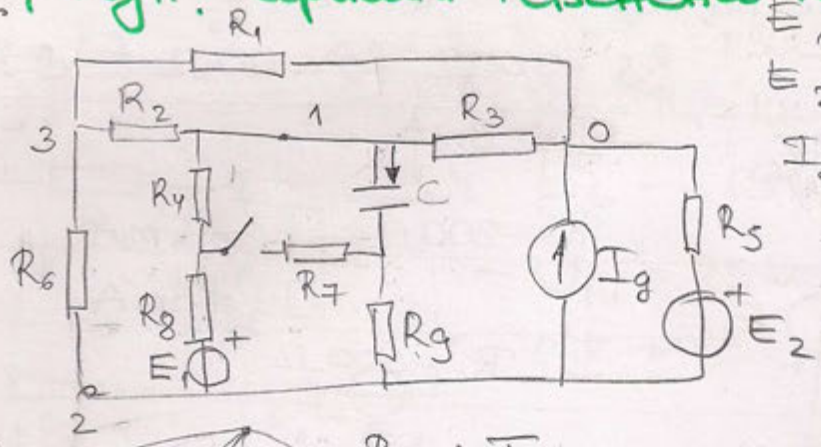
$E_2 + R_2 I - R_1 I_1 + E_1 = 0$

$I_0 =$

$I_1 = 95$ A

ANALYSIS LABORATORY EQUIPMENT

177. Рачун! користи Тевенена, кад Тад можеш



$E_1 = 20V$

$E_2 = 16V$

$I_g = 1A$

$R_1 = 10\Omega$

$R_2 = 30\Omega$

$R_3 = 60\Omega$

$R_4 = R_6 = R_g = 7\Omega$

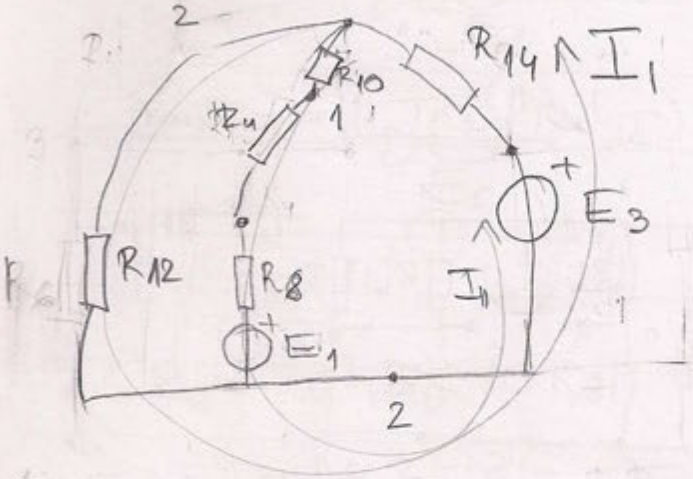
$R_5 = 4\Omega$

$R_8 = 10\Omega$

$C = 32\mu F$

$\Pi \to 1 \quad \Delta W_e = -3{,}825 mJ$

R_7?



$I_{g_1} = 4 + 1 = 5A$

$E_3 = I_{g1} \cdot R_5 =$

$= 20V$

$R_{14} = R_{10} + R_5 = 10$

$U_{C_1} = U_{12}$

$R_{10} = \frac{600}{1000} = 6\Omega$

$R_{10} = \frac{1800}{100} = 18\Omega$

$R_{11} = 3\Omega$

$R_{11} + R_6 = R_{12} = 10\Omega$

$R_{13} = R_4 + R_{10} = 25\Omega$

$U_{12} = E_1 + I_{11}(R_8 + R_4) =$

$= 20 - 0.25 \cdot 17 =$

$= 15.75V$

$(R_{12} + R_{14}) I_1 + R_{14} I_{11} = E_3$

$R_{14} I_1 + (R_{14} + R_4 + R_{10} + R_8) I_{11} = E_3 - E_1$

$20 I_1 + 10 I_{11} = 20$

$10 I_1 + 45 I_{11} = 0$

$I_1 = -4.5 I_{11}$

$-9 I_{11} + I_{11} = 2$

$-8 I_{11} = 2$

$I_{11} = -0{,}25A$

$I_1 = 1.125A$

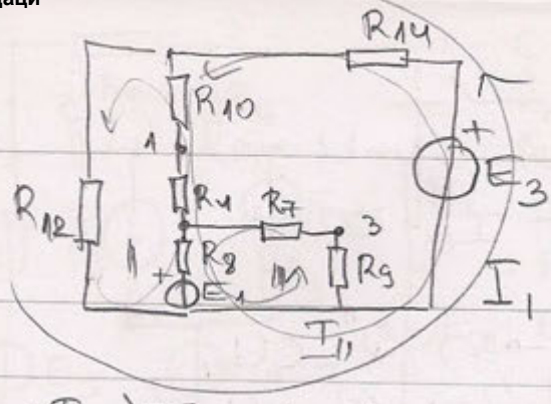
$W_{e_1} = 3.969 mJ$

$W_{e_2} = 0.144 mJ$

$\frac{1}{2} C U_2^2 = 0.144 mJ$

$U_2^2 = 0.009$

$U_2 = \pm 3V$



$U_2 = U_{13}$

$U_{13} = -I_{III} R_7 + I_{II} R_4$

$$\boxed{\frac{I_{II} R_4 - U_{13}}{R_7} = I_{III}}$$

$(R_{14}+R_{12}) I_I + R_{12} I_{II} = E_3$

$R_{12} I_I + (R_4+R_{10}+R_{14}+R_8) I_{II} + R_8 I_{III} = E_3 - E_1$

$R_8 I_{II} + (R_9+R_8+R_7) I_{III} = -E_1$

$20 I_I + 10 I_{II} = 20$ $\qquad I_I = 1 - 0{,}5 I_{II}$

$10 I_I + 45 I_{II} + 10 I_{III} = 0$

$10 I_{II} + (17+R_7) I_{III} = 0$

$10 - 5 I_{II} + 45 I_{II} + 10 I_{III} = 0$

$10 + 40 I_{II} + 10 I_{III} = 0$ $\qquad \boxed{I_{III} = -1 - 4 I_{II}}$

$10 I_{II} - (1+4 I_{II})(17+R_7) = 0$

$10 I_{II} - 17 - R_7 - 28 I_{II} - 4 R_7 I_{II} = 0$

$7 I_{II} - U_{13} = -R_7 - 4 R_7 I_{II}$

$(7+4R_7) I_{II} = U_{13} - R_7$

$$I_{II} = \frac{U_{13} - R_7}{7+4R_7}$$

$(18+4R_7) I_{II} = -17 - R_7$ $\qquad -75 R_7$

$(18+4R_7) U_{13} = -119 - 7R_7 - 68R_7 - 4R_7^2$

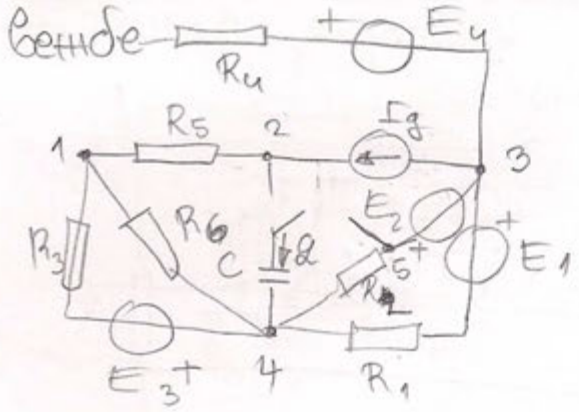
$18 U_{13} + 119 + (4U_{13}+75) R_7 + 4 R_7^2 = 0$

$$R_{7_{12}} = \frac{-(4U_{13}+75) \pm \sqrt{(4U_{13}+75)^2 - 16(18U_{13}+119)}}{8}$$

$U_{13} = 3$ $\qquad R_{7_{12}} = -(12+75) \pm$ $\qquad < 0$ ↯

$U_{13} = -3V$ $\qquad R_{7_{12}} = -63 \pm$ $\qquad$ ↯

ANALYSIS LABORATORY EQUIPMENT



E_4? k_2 /

$Q = 180\mu C$ (5) → k1 → (2)

k_2

$I_{13} = 100\,mA$

$R_T = R_3 \| R_6 + R_2 \| R_6$

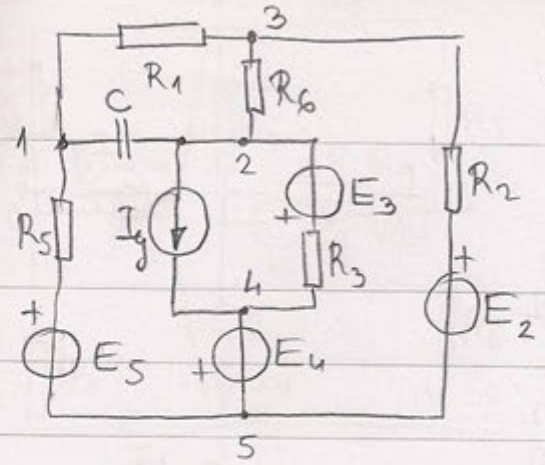
k → (2) $Q'' = C U_{24}$

k → (5) $Q' = C U_{54}$

$Q'' - Q' = Q$

$Q'' - Q' = C(U_{24} - U_{54}) = C U_{25}$

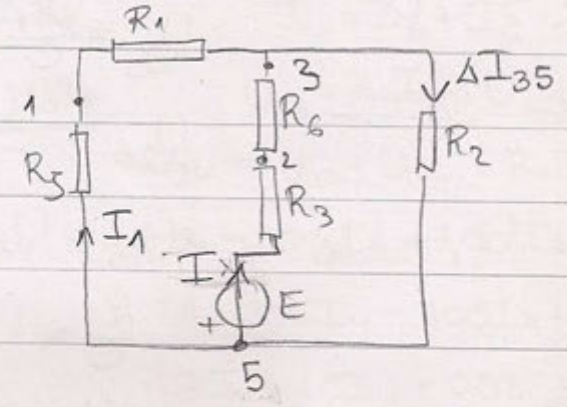
50.



$C = 2\mu F$
$R_1 = 100\Omega$
$R_2 = 100\Omega$
$R_3 = 200\Omega$
$R_6 = 400\Omega$
$E_5 = 50V$
$I_g = 40mA$
$I_{35} = -30mA$

$E_4' = E_4 + E$
$Q_{12} = -34\mu C$
R_2 $I_{35}' = 0$
R_5? $E_{4'}$?

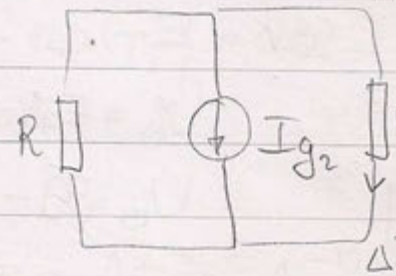
$$I_{35} = I_{35}(E_5, E_3, E_2, I_g) + I_{35}(E_4) = A + B \cdot E_4$$
$$I_{35}' = A + BE_4 + BE$$
$$-30mA = A + BE_4$$
$$\Delta I_{35} = 30mA$$
$$0 = A + BE_4 + BE$$
$$30mA = B \cdot E$$



$$U_{12} = \frac{Q_0}{C}$$
$$U_{12}' = \frac{Q_1}{C} = \frac{Q_0 + Q}{C} = U_{12} + \frac{Q}{C}$$
$$U_{12}' - U_{12} = \frac{Q}{C} = -17V$$

$$\Delta I_{35} R_2 + I_1 (R_5 + R_1) = 0$$
$$I_1 = -\frac{R_2}{R_5 + R_1} \Delta I_{35}$$

$$U_{35} = \Delta I_{35} R_2 = 3V$$
$$I_1 = \frac{U_{35}}{R_1 + R_5} =$$



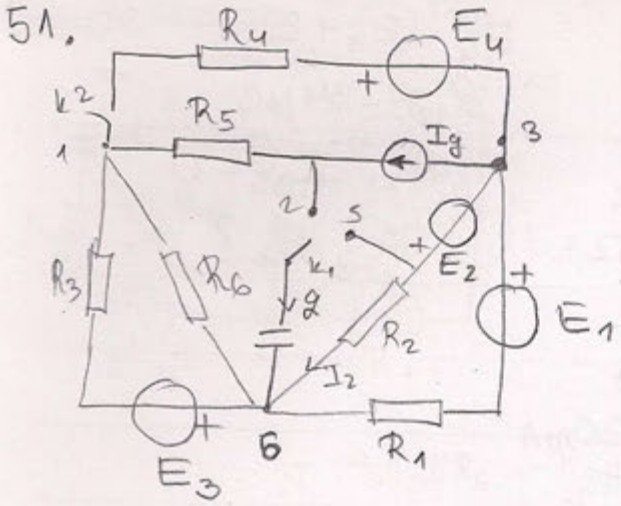
$$I_{g2} = \frac{E}{R_6 + R_3} = \frac{E}{600}$$

$$U_{35} + (R_3 + R_6) I + E = 0$$
$$I = -\frac{3 + E}{600}$$
$$\Delta I_{35} = \frac{R}{R_2 + R} \frac{E}{600}$$
$$I_1 = \Delta I_{35} + I = 30mA - \frac{3+E}{600}$$
$$R = \frac{600 \cdot (R_5 + 100)}{R_5 + 700}$$
$$\Delta U_{12} = -R_6 I + I_1 R_1 = -400 \frac{3+E}{600} + 3 - \frac{3+E}{6}$$
$$-102 = -12 - 4E + 18 - 3 - E$$
$$-105 = -5E \quad E = 21V$$

$$I_1 = 30mA - \frac{24}{600} = 10mA \qquad I = -40mA \qquad U_{51} = -2V$$
$$R_5 = \frac{U_{51}}{I_1} = 200\Omega$$
$$U_{51} = -R_1 I_1 + I \cdot 600 + 21 = 1 - 24 + 21$$

ANALYSIS

51.



$E_2 = 23V$

$I_g = 40mA$

$R_1 = 200\Omega$

$R_2 = 300\Omega$

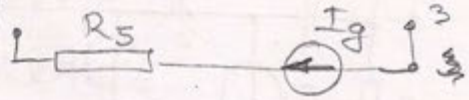
$R_3 = 600\Omega$

$R_4 = 380\Omega$

$R_5 = 200\Omega$

$R_6 = 300\Omega$

$C = 4{,}7\mu F$



$k1: 5 \to 2 \quad k_2 \to 0$

$Q = 188\mu C$

$k2 \to 1 \quad R_4, E_4 \quad I_{13} = 100mA$

P_4 коју трпи

$P_{E_4} < > = 0$?

$R_T = 320\Omega$

$U_{26} = U_{21} + U_{16}$

$U_{56} = \frac{Q_0}{C} = R_2 I_2$

$U_{26} = \frac{Q_0 + Q}{C}$

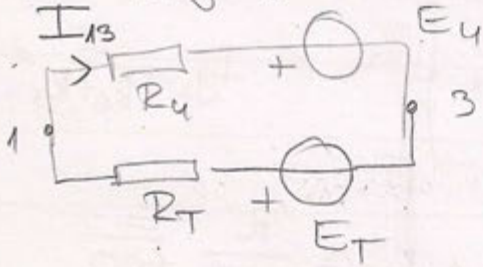
$U_{26} = U_{23} - E_2 + U_{56}$

$\frac{Q}{C} = U_{23} - E_2$

$U_{23} = 63V$

$U_{13_{p4}} = U_{12} + U_{23} =$

$= -I_g R_5 + 63 = 55V = E_T$



$U_{13} = E_T - I_{13} R_T$

$U_{13} = 55 - 32 = +23V$

$P_4 = +2{,}3W$

$P_{R_T} = 3{,}2W$

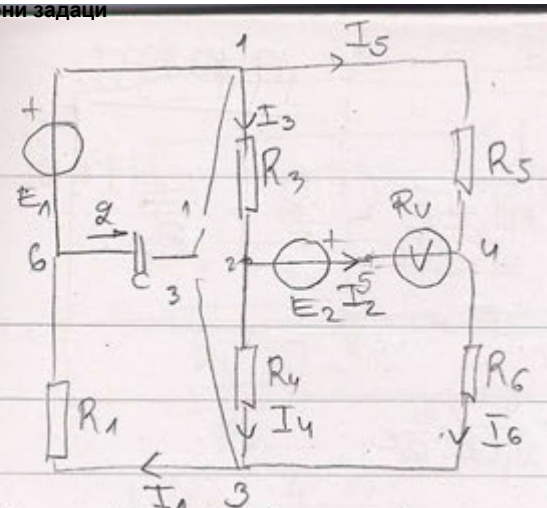
$P_{R_4} = 3.8W$

$P_{E_T} = 8{,}5W$

$3{,}2 + 3{,}8 = 8.5 + P_{E_4}$

$4{,}5 = P_{E_4}$

55



$R_1 = 300\Omega$ E?
$R_3 = 120\Omega$ R_V?
$R_4 = 300\Omega$
$R_5 = 200\Omega$
$R_6 = 700\Omega$
$E_2 = 32V$
$C = 2\mu F$
$U_{54} = 24V$

$k: 1 \to 3$
$Q = 24\mu C$

$U_{24} = -E_2 + U_{54} = -8$

$\frac{Q_0}{C} = U_{61} = -E_1$

$\frac{Q_0 + Q}{C} = U_{63} = -I_1 R_1$

$U_{13} = U_{16} + U_{63} = -U_{61} + U_{63} = -\frac{Q_0}{C} + \frac{Q_0}{C} + \frac{Q}{C}$

$\boxed{U_{13} = 12V}$ $U_{13} = E_1 - I_1 R_1$

$I_1 = I_4 + I_6$ $I_6 = I_1 - I_4$

$I_1 = I_3 + I_5$ $\boxed{I_1 = 1.6 I_3 - 0.04}$

$U_{23} = R_4 I_4$ $U_{43} = R_6 I_6$

$U_{12} = I_3 R_3$

$U_{24} = U_{23} + U_{34} = R_4 I_4 - R_6 I_6$

$I_5 R_5 = U_{14} = U_{12} + U_{24} = I_3 R_3 - E_2 + U_{54}$

$-8 = 300 I_4 - 700 I_6$

$I_5 = 0.6 I_3 - 0.16 + 0.02$

$-8 = 300 I_4 - 700 I_1 + 700 I_4$

$\boxed{7 I_1 = 10 I_4 + 0.08}$

$U_{13} = R_4 I_4 + R_3 I_3$

$12V = 30(7 I_1 - 0.08) + 120\left(\frac{I_1}{1.6} + 0.025\right)$

$9.12 = 210 I_1 - 2.4 + 75 I_1 + 3$

$11.48 = 285 I_1 - 2.4$

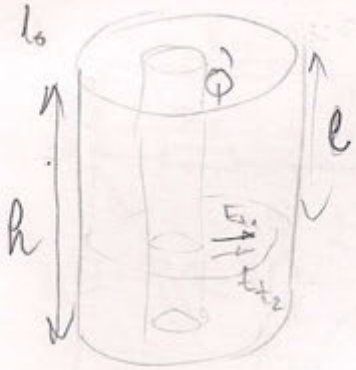
$I_1 = 0.04A$ $12 = E_1 - 0.04 \cdot 300 \Rightarrow \boxed{E_1 = 24V}$

$0.08 = 1.6 I_3$ $I_3 = 0.05A$ $I_4 = 0.02$

$I_2 + I_4 = I_3$ $\boxed{I_2 = 0.03A}$

$R_V = \frac{U_{54}}{I_2} = 800\Omega$

ANALYSIS LABORATORY EQUIPMENT



10.10.1997.

$$\oint 2r\pi z E = \frac{Q}{\varepsilon_0} = \frac{zQ'}{\varepsilon_0}$$

$$Q = zQ' \qquad E = \frac{Q'}{2\pi\varepsilon_0 r}$$

$$E_{l_1} = E_{l_2} = E \qquad U = \int_a^b \frac{Q'}{2\pi\varepsilon_0 r}\,dr = \frac{Q'}{2\pi\varepsilon_0\varepsilon_r}\ln\frac{b}{a}$$

$$D\,2r\pi z = zQ' \qquad \boxed{D = \frac{Q'}{2r\pi}}$$

$$D = \varepsilon E = \varepsilon_0\varepsilon_r E$$

$$l\cdot 2r\pi\cdot D_1 + (h-l)2r\pi D_2 = Q'h$$

$$l\,2r\pi\cdot\varepsilon_0 E + (h-l)2r\pi\varepsilon_0\varepsilon_r E = Q'h$$

$$E = \frac{Q'h}{2r\pi\varepsilon_0(l+\varepsilon_r(h-l))}$$

$$U = \frac{Q'h}{2\pi\varepsilon_0(l+\varepsilon_r(h-l))}\cdot\ln\frac{b}{a}$$

$$\frac{3}{2}\frac{Q'}{2\pi\varepsilon_0\varepsilon_r}\ln\frac{b}{a} = \frac{Q'h\ln\frac{b}{a}}{2\pi\varepsilon_0(l+\varepsilon_r(h-l))}$$

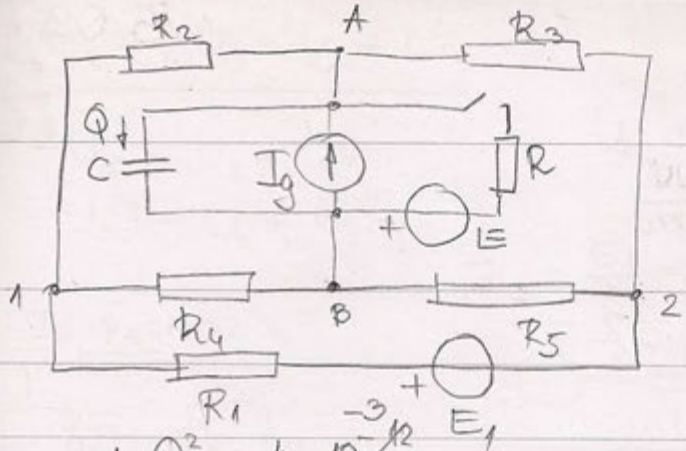
$$\frac{3}{2}(l+6h-6l) = 4h$$

$$-5l+6h = 4h$$

$$l = \frac{2}{5}h$$

$$l =$$

2.



$C = 20nF$ $Q_0 = 2\mu C$

$R_1 = 100\Omega$ R?

$R_2 = 50\Omega$ $P > 0$

$R_3 = 100\Omega$ $\Delta W = -75 \cdot 10^{-6} J$

$R_4 = 540\Omega$

$R_5 = 520\Omega$

$E = 60V$

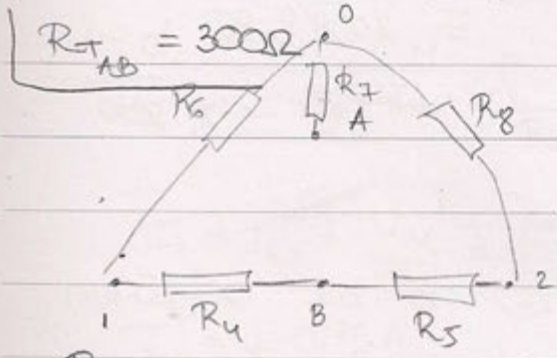
$$W_{e_1} = \frac{1}{2}\frac{Q_0^2}{C} = \frac{4 \cdot 10^{-12}}{2 \cdot 20 \cdot 10^{-9}} = 0.1\,mJ = 100\,\mu J$$

$W_{e_2} - W_{e_1} = -75\mu J$ $W_{e_2} = 25\mu J$

$\frac{1}{2} 20 \cdot 10^{-9} \cdot U^2 = 25 \cdot 10^{-6}$ $U^2 = 2500$

$U_1 = 100V$

$U_2 = \pm 50V$

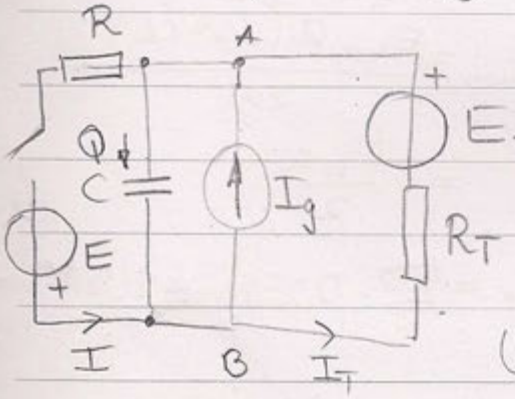


$$R_6 = \frac{R_2 R_1}{\Sigma} = 20\Omega \quad 560$$

$$R_7 = \frac{R_2 R_3}{\Sigma} = 20\Omega \quad 560$$

$$R_8 = \frac{R_1 R_3}{\Sigma} = 40\Omega$$

$280 + 20 = 30$



$U_1 = U_{AB} = E_T + I_g R_T$ $E_T = 100 - I_g R_T$

$P > 0 \Rightarrow P_E > P_R$ (

$EI > RI^2$ ($I > 0$ због рс)

$E > RI$

$U_2 = U_{AB} = -E + RI \Rightarrow U_2 < 0 \Rightarrow U_2 = -50V$

$I = I_g + I_T$ $-50 = -E + RI$

$-50 = E_T - R_T I_T = 100 - (I_T + I_g) R_T =$

$= 100 - I R_T$

$-50 + 60 = 0.5R$

$\boxed{R = 20\Omega}$ ✓

$I R_T = 150$

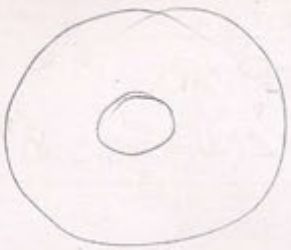
$I = 0.5\,A$

ANALYSIS
LABORATORY EQUIPMENT

15.09.1992

1. a, $b = 500mm$, $\varepsilon_r = 3$

сфера $4r^2\pi$



$E_{kr} = 20 \frac{kV}{m}$

$a?$

$U_{max}?$

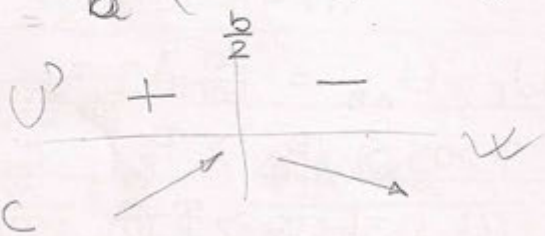
$$E = \frac{Q}{4r^2\pi\varepsilon_0\varepsilon_r}$$

$$Q_{max} = E_{kr} \cdot 4a^2\pi\varepsilon_0\varepsilon_r$$

$$U = \frac{Q}{4\pi\varepsilon_0\varepsilon_r}\left(\frac{1}{a} - \frac{1}{b}\right) = \frac{Q}{4\pi\varepsilon_0\varepsilon_r}\frac{b-a}{ab} = \frac{E_{kr}\cancel{4}a^{\cancel{2}}\cancel{\pi}\cancel{\varepsilon_0\varepsilon_r}}{\cancel{4\pi\varepsilon_0\varepsilon_r}} \cdot \frac{b-a}{\cancel{a}b}$$

$$U = \frac{E_{kr}\,a(b-a)}{b}$$

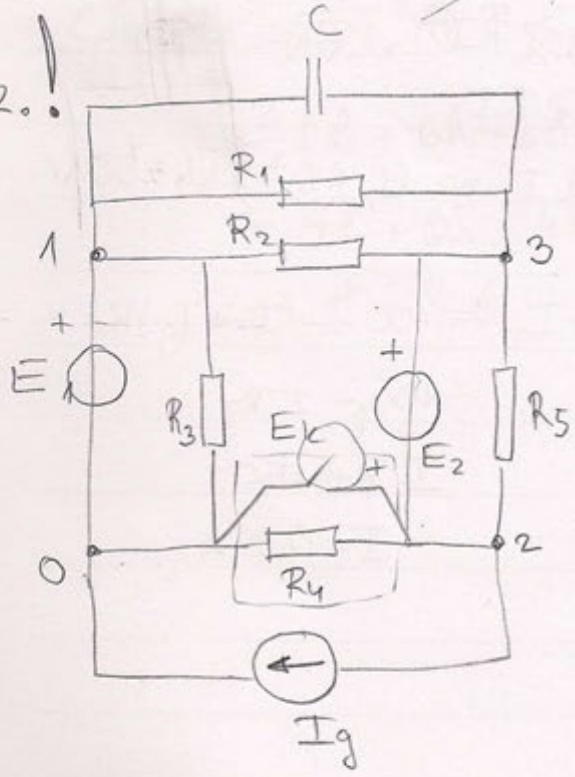
$$U'_a = \frac{E_{kr}}{b}(b-2a) \qquad U'_a = 0 \Leftrightarrow b = 2a \quad a = 250mm$$



$$U_{max} = \frac{E_{kr}\,\cancel{a}(\cancel{2}a - \cancel{a})}{2\cancel{a}} = \frac{E_{kr}a}{2}$$

$$U_{max} = \frac{20}{2} \cdot 0.25m = 2.5V$$

2.!



$E_1 = 10V$

$E_2 = 20V$

$I_{g1} = 0{,}5A$

$R_1 = 200\Omega$

$R_2 = 300\Omega$

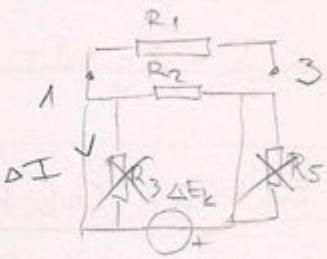
$R_3 = 100\Omega$

$C = 100\mu F$

$\Pi \to \emptyset$

$\Pi \to \emptyset \quad \Delta W_c = 11{,}2mJ$

$R_4?$



$$\Delta U_{13} = \cancel{C_4} \cdot \Delta E_k$$

$$E_k = \begin{cases} 0, & \Pi \to 1 \\ U_{20}, & \Pi \to 0 \end{cases}$$

$$U_1 = U_{13} = -E_2 + E_1 = -10V$$

$$U'_{13} = \frac{Q_0}{C}$$

$$\Delta W_{e_2} = W_{e_2} - W_{e_1} = \frac{1}{2}CU_2^2 - \frac{1}{2}CU_1^2$$

$$\boxed{U_2^2 = U_1^2 + 224}$$

$$U_2 = \pm 18V$$

$\Delta E_k = \Delta U_{13} = U_2 + 10V$

$U_{13}' = -10V$

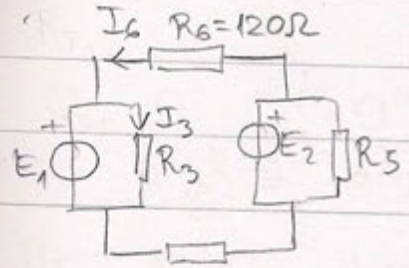
$-U_{20} = U_2 + 10V$

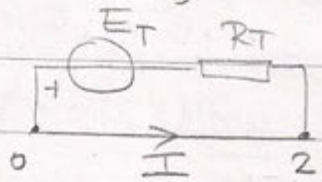
$U_{13}'' = U_2$

$U_{02} = U_2 + 10V$

$I_6 = -\frac{U_{13}}{R_6} = -\frac{\pm 18}{120} = \mp 0.15A$

$I_3 = \frac{E_1}{R_3} = 0.1A$





$E_T - R_T I = 0$

$I' = \frac{U_{02}}{R_4}$

$U_{02} =$

$\Delta I_{\pm} = \frac{\Delta E_k}{R_6} = \frac{U_2 + 10}{R_6}$

$I_1 = I_{k5} = \frac{U_{31}'}{R_6} = \frac{10}{120} = \frac{1}{12}A$

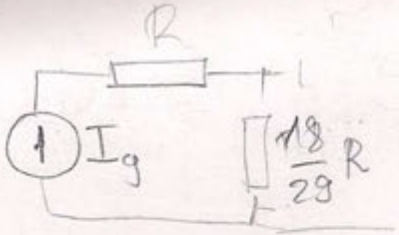
$I_2 = \mp 0.15A$

ANALYSIS
LABORATORY EQUIPMENT

Милана Милошевић

13. 10. 2007.

1.



$\frac{7}{11}R$

P_{uk} $R = 1k\Omega$

$I_g = 20mA$

$\frac{3}{4R} + \frac{4}{4R}$ $\frac{1}{R_e}$

$\frac{1}{3R} + \frac{3}{3R} \Rightarrow R_e = \frac{3R}{4}$

$R_e = \frac{4}{7}R$

$+\frac{7R}{4}$

$\frac{11}{7}R$

$\frac{4}{7R} + \frac{7}{7R} \Rightarrow R_e = \frac{7}{11}R$

$\frac{7}{11R} + \frac{11}{11R}$ $R_e = \frac{11}{18}R$

$\frac{18}{11}R$

$\frac{29}{18}R = R_e$

$\frac{11}{18R} + \frac{18}{18R}$ $R_e = \frac{18}{29}R$

$P_{uk} = 2 \cdot \frac{47}{29} 0.4 = 1.29$

$\frac{47R}{29}$

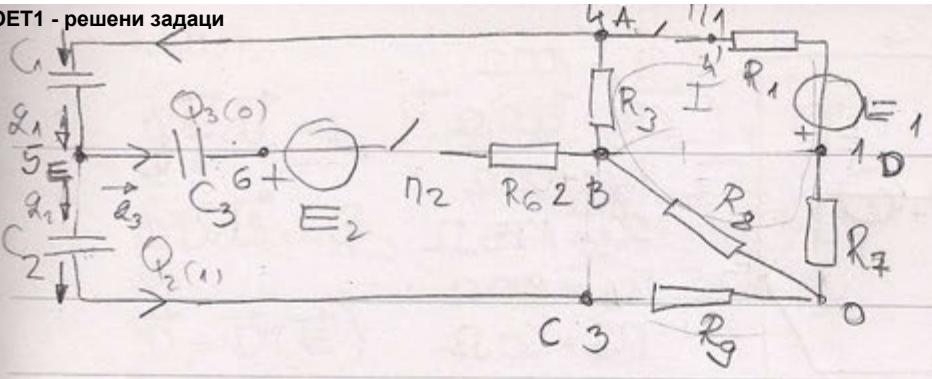
$P_{uk} = 2 \cdot \frac{21}{13} \cdot 0.4 = 1{,}292W$

$\frac{3}{2}(R \parallel R) + R) \parallel R + R$

$\frac{2}{3R} + \frac{3}{3R} \Rightarrow \frac{5}{5}R$

$\frac{8}{13}R + \frac{13}{13}R =$

$\frac{8}{5}R$ $= \frac{21}{13}R$



$C_1 = 1\,\mu F \quad C_2 = 0{,}5\,\mu F \quad C_3 = 2\,\mu F$

$R_2 = 50\,\Omega$

$R_3 = 60\,\Omega \quad R_6 = 200\,\Omega$

$R_4 = 150\,\Omega \quad E_2 = 2\,V$

$R_5 = 300\,\Omega$

$R_7 = 15\,\Omega$

$R_8 = 90\,\Omega$

$R_g = 30\,\Omega$

$Q_{01} = 0 \quad Q_{02} = 0 \quad Q_{03} = -0{,}4\,\mu C$

$U_{56} = -0.2\,V \quad V_0 = 0$

$\Pi_1 \to 1 \quad \Pi_1 \to 0 \quad \Pi_2 \to 0 \quad U_{AC} = \frac{Q_2}{C_4} + \frac{Q_2}{C_2} = 12\,V$

$I_{AC} = 80\,mA \quad \Pi_2 \to 0 \quad V_3 = 0$

$Q_1 = Q_2 + Q_3 \qquad Q_1 = Q_2$

$Q_2 = 4\,\mu C \qquad Q_2' = Q_2$

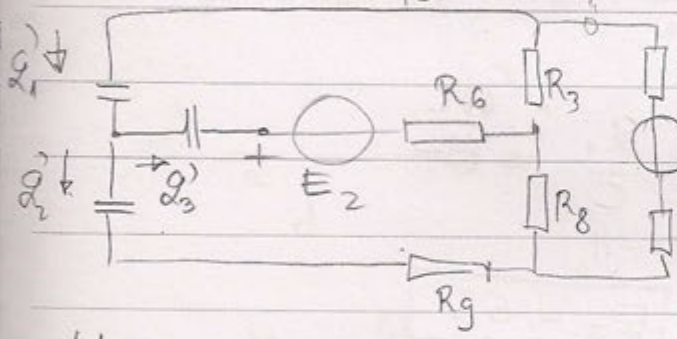
$U_{AE} + U_{EB} + U_{BA} = 0$

$\frac{Q_2 + Q_2'}{C_1} + \frac{Q_{30} + Q_3'}{C_3} + 2 - 4{,}8 = 0 \quad -1$

$U_{AE} + U_{EC} + U_0^0 + U_{0A} = 0$ ($U_{0A} = 12\,V$)

$U_{45} = \frac{Q_1}{C_1} = Q \qquad I = \frac{E_1}{\Sigma R}$

$U_{45} + U_{53} + I(R_7 + R_1) - E_1 = 0$



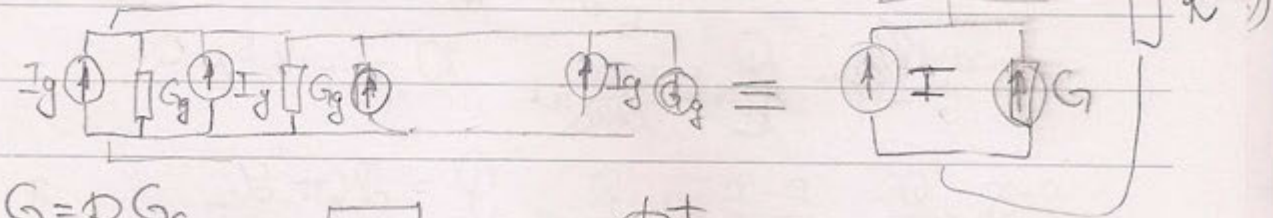
$\frac{Q_1}{C_1} + \frac{Q_2}{C_2} = E - (R_7 + R_1)\,I$

$\frac{Q_3}{C_1} + Q_2 \frac{C_1 + C_2}{C_1 C_2} = E - (R_7 + R_1)\frac{E}{\Sigma}$

$U_{56} = a \cdot E_1$

$\frac{Rn I_g}{Rp^2 G_g + n} \qquad \frac{Rn I_g p}{Rp^2 G_g + n} \qquad \frac{Rn I_g p^2 - Rn I_g p^2}{(Rp^2 G_g + n)^2}$

$n = p^2 \cdot 0.1 \cdot 9 \qquad p = \frac{10}{\sqrt{3}}$



$I = pI_g \quad G = pG_g$

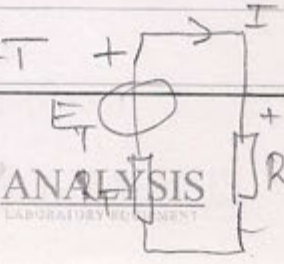
$I \quad G \equiv E \quad R = \frac{1}{G}$

$E = \frac{I_g}{G} = \frac{I_g}{G_g}$

$R = \frac{1}{pG_p}$

$E_T =$

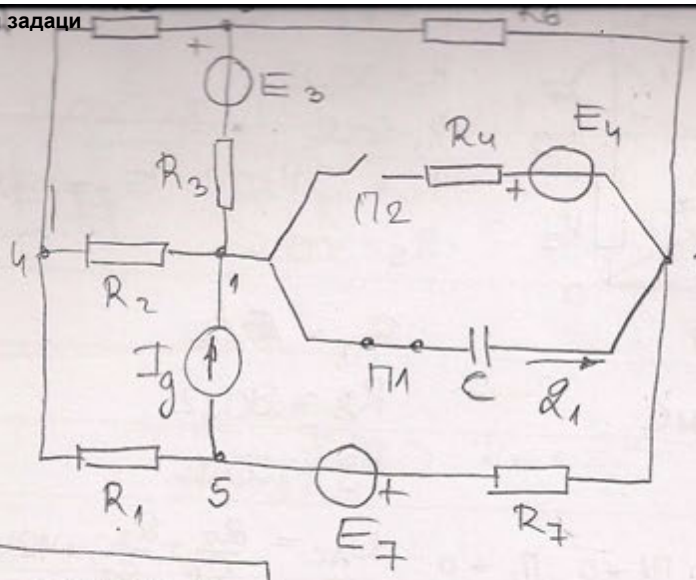
$E_T = \frac{n}{p} E \frac{n}{p^2} \frac{1}{G_p} = R_T +$



$I = \frac{E_T}{R_T + R} \qquad U = IR = \frac{R E_T}{R_T + R} =$

$= \frac{R \frac{n}{p} \frac{I_g}{G_g}}{R + \frac{n}{p} \frac{1}{G_p}}$

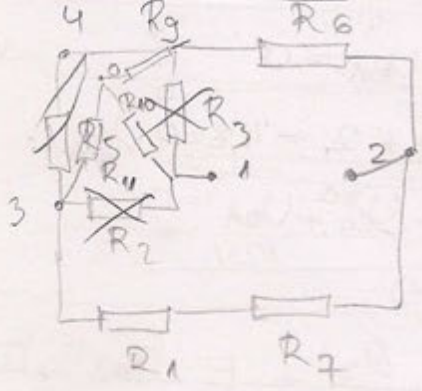
ANALYSIS LABORATORY ENGINEERING



$R_1 = 100\Omega$
$R_2 = 350\Omega$
$R_3 = 700\Omega$
$R_5 = 175\Omega$
$R_6 = 100\Omega$
$R_7 = 50\Omega$
$E_3 = 4\,V$
$C = 0{,}5\mu F$

$П1 \to 1 \quad Q_1 = 3\mu C$

$\boxed{R_T = 300\Omega}$

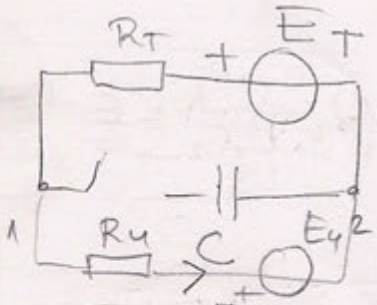


$R_8 = R_1 + R_7 = 150\Omega \quad 50 = 200\Omega$

$R_g = \frac{R_3 R_5}{\Sigma} = 100\Omega \qquad R_g + R_6 = 200\Omega$

$R_{10} = \frac{R_3 R_2}{\Sigma} = 200\Omega$

$R_{11} = 50\Omega$



$U_{12} = \frac{Q_0}{C} + \frac{Q_1}{C} = E_T$

$Q_0 = 0 \Rightarrow \boxed{E_T = 6\,V}$

$I_4 = I_{12} = 50\,mA \qquad I_4 = \frac{E_T - E_4}{R_T + R_4}$

Q_2 ? $\qquad U_{12}' = E_T - R_T I = 6 - 15 = -9\,V$

$\frac{Q}{C} = U_{12}' \qquad Q = -4{,}5\mu C$

$Q = Q_1 + Q_2$

$-4{,}5\mu C = 3\mu C + Q_2$

$\boxed{Q_2 = -7{,}5\mu C}$

03.03.2007.

1. $\oint_C \vec{E}\,d\vec{l} = 0$ $\quad \vec{n}\times(\vec{D}_1 - \vec{D}_2) = \sigma'$

$\oint_S \vec{D}\,d\vec{S} = Q_{uS}$ $\quad E_{t1} = E_{t2} = 0$ $\quad D_2 = \varepsilon_0 E_{n2} = 0$

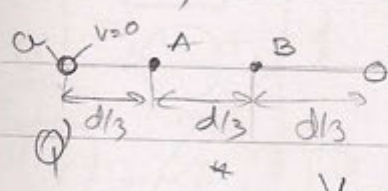
$\Phi_n = \rho_S$

$\vec{D} = \vec{D}(\vec{E})$

$\vec{D} = \varepsilon_0\vec{E} + \vec{P}$

$U = V_2 - V_1 = V_2 = \frac{Q'}{2\pi\varepsilon_0}\ln\frac{d-a}{a}$

2. U, $d/a = 100$

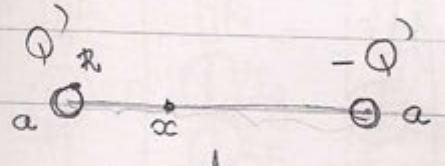


$V = \frac{Q'}{2\pi\varepsilon_0}\ln\frac{r_R}{r_P}$ $\quad \frac{Q'}{2\pi\varepsilon_0} = \frac{U}{\ln\frac{d}{a}}$

$V_A = \frac{Q'}{2\pi\varepsilon_0}\ln\frac{d/3-a}{d/3} + \frac{Q'}{2\pi\varepsilon_0}\ln\frac{d/3-a}{2d/3} = -\frac{Q'}{2\pi\varepsilon_0}\ln\frac{1}{2} = +\frac{U}{\ln\frac{d}{a}}\ln 2$

$V_B = \frac{Q'}{2\pi\varepsilon_0}\ln\frac{2d/3-a}{2d/3} + \frac{Q'}{2\pi\varepsilon_0}\ln\frac{2d/3-a}{d/3} = \frac{Q'}{2\pi\varepsilon_0}\ln 2 = \frac{U}{\ln\frac{d}{a}}\ln 2$

$U_{AB} = V_A - V_B = -\frac{2U}{\ln\frac{d}{a}}\ln 2$



$V_x = V_x^{Q'} + V_x^{-Q'}$

$V_x^{Q'} = \frac{Q'}{2\pi\varepsilon_0}\ln\frac{a}{x}$ $\quad V_x^{-Q'} = \frac{Q'}{2\pi\varepsilon_0}\ln\frac{d}{d-x}$

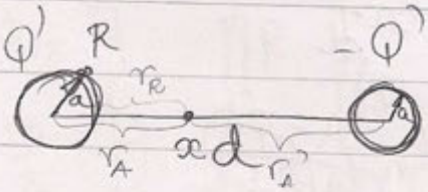
$V_x = \frac{Q'}{2\pi\varepsilon_0}(\ln a - \ln x - \ln a - \ln d + \ln d - x + a)$

$x = d$ $\quad V_x = \frac{Q'}{2\pi\varepsilon_0}(\ln a - \ln d - \ln d + \ln a) = \frac{Q'}{2\pi\varepsilon_0}\cdot 2\cdot\ln\frac{a}{d}$

$\frac{U}{\ln\frac{a}{d}} = \frac{Q'}{\pi\varepsilon_0}$ $\quad V_A = \frac{1}{2}\frac{U}{\ln\frac{a}{d}}(\ln a - \ln(d/3 - a) - \ln d - \ln(2d/3 - a))$

$\ln\frac{a}{d/3-a}\ln\frac{a}{d} + \ln\frac{d-x+a}{}$

$R_T = R/2$



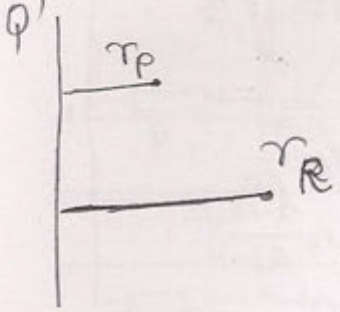
$V_x = \frac{Q'}{2\pi\varepsilon_0}\ln\frac{x-a}{x} - \frac{Q'}{2\pi\varepsilon_0}\frac{x-a}{d-x}$

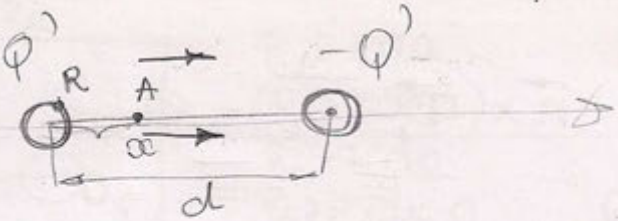
$U = V_{x=d-a} = \frac{Q'}{2\pi\varepsilon_0}\ln\frac{d-a}{d-a} - \frac{Q'}{2\pi\varepsilon_0}\frac{d-a}{a}$

=

ANALYSIS
LABORATORY EQUIPMENT

$$V_P = \frac{Q'}{2\pi\varepsilon_0} \ln \frac{r_R}{r_P}$$

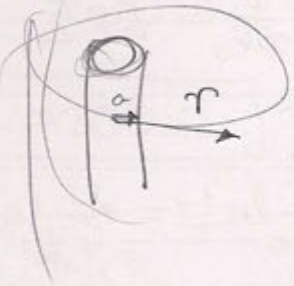




$$V_A = V_A^{Q'} + V_A^{-Q'} =$$

$$= \frac{Q'}{2\pi\varepsilon_0} \cdot \ln \frac{x-a}{x-a} - \frac{Q'}{2\pi\varepsilon_0} \ln \frac{d-a}{d-x+a}$$

$$U = V_{A-d}$$



$$E \cdot 2r\pi l = \frac{Q'l}{\varepsilon_0}$$

$$E_1 = \frac{Q'}{2r\pi\varepsilon_0} = \frac{Q'}{2r\pi\varepsilon_0}\vec{i}_x$$

$$E_2 = \frac{-Q'}{2r\pi\varepsilon_0} = \frac{Q'}{2r\pi\varepsilon_0(d-r)}\vec{i}_x$$

$$V = \int_a^x (\vec{E_1} + \vec{E_2})\vec{dr} = \int_a^x \left(\frac{Q'}{2\pi\varepsilon_0 r} + \frac{Q'}{2\pi\varepsilon_0(r-d)}\right)dr =$$

$$= \frac{Q'}{2\pi\varepsilon_0} \ln r \Big|_a^x + \frac{Q'}{2\pi\varepsilon_0} \ln(r-d)\Big|_a^x =$$

$$= \frac{Q'}{2\pi\varepsilon_0} \ln \frac{a}{x} + \frac{Q'}{2\pi\varepsilon_0} \cdot \ln \frac{a-d}{x-d}$$

$$U = V_{x=d-a} = \frac{Q'}{2\pi\varepsilon_0}\left(\ln \frac{a}{d-a} + \ln \frac{d-a}{d-d+a}\right) =$$

$$= \frac{Q'}{\pi\varepsilon_0} \ln \frac{a}{d} \qquad \frac{Q'}{\pi\varepsilon_0} = \frac{U}{\ln \frac{a}{d}}$$

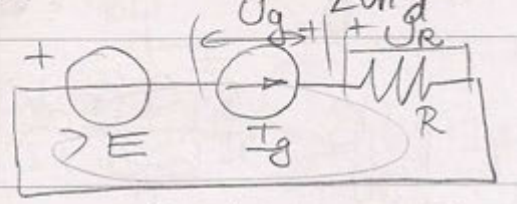
$$V_A = \frac{Q'}{2\pi\varepsilon_0} \ln \frac{d/3}{a} - \frac{Q'}{2\pi\varepsilon_0} \ln \frac{a-d}{d/3-d} =$$

$$= \frac{Q'}{2\pi\varepsilon_0}\left(\ln \frac{d/3}{3a/2} + \ln \frac{d-d}{2d/3}\right) = \frac{U}{2\ln \frac{a}{d}}\left(\ln \frac{3a}{2d} + \ln \frac{2}{3}\right)$$

$$V_B = \frac{Q'}{2\pi\varepsilon_0}\left(\ln \frac{3a}{2d} + \ln \frac{d-2d/3}{d-a}\right) = \frac{U}{2\ln \frac{a}{d}}\left(\ln \frac{3a}{2d} + \ln \frac{1}{3}\right)$$

$$U_{AB} = V_A - V_B = \frac{U}{2\ln\frac{a}{d}}\left(\ln\frac{\frac{3a}{d}}{\frac{3a}{2d}} + \ln\frac{\frac{2}{3}}{\frac{1}{3}}\right) = -\frac{U}{\ln\frac{d}{a}}\ln 2$$

3.

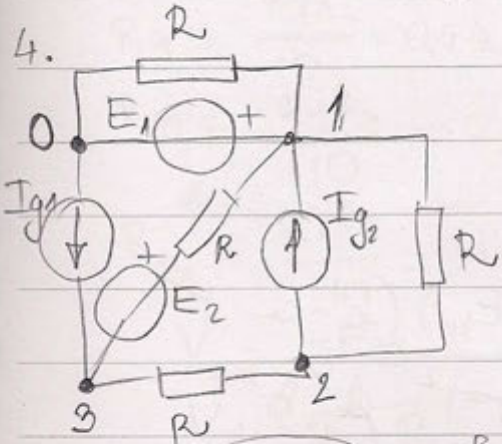


$P_R = 20W = U_R I_g$

$-E + U_g - U_R = 0$ $\quad P_{I_g} = 0 \Rightarrow U_g = 0$

$U_R = -E = -10V$ $\quad \Rightarrow I_g = -2A$

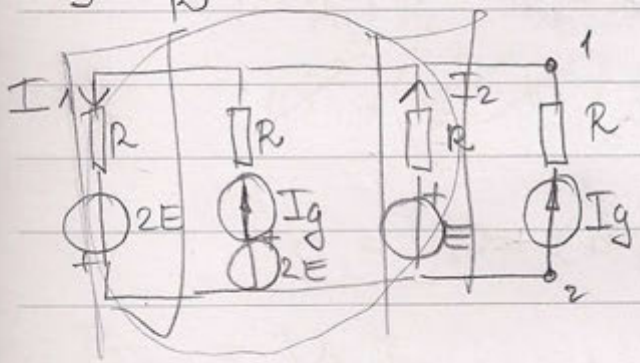
4.



$V_1 = E_1$

$2: -\frac{1}{R}V_1 + \frac{2}{R}V_2 - \frac{1}{R}V_3 = -I_{g2}$

$3: \frac{2}{R}V_3 - \frac{1}{R}V_1 - \frac{1}{R}V_2 = -\frac{E_2}{R} + I_{g1}$



$I_g + I_2 = I_1$

$-I_1 R + 2E + E - RI_2 = 0$

$\frac{3E}{R} = 2I_2 + I_g$

$I_2 = \frac{3E}{2R} - \frac{I_g}{2}$

$I_1 = \frac{3E}{2R} + \frac{I_g}{2}$

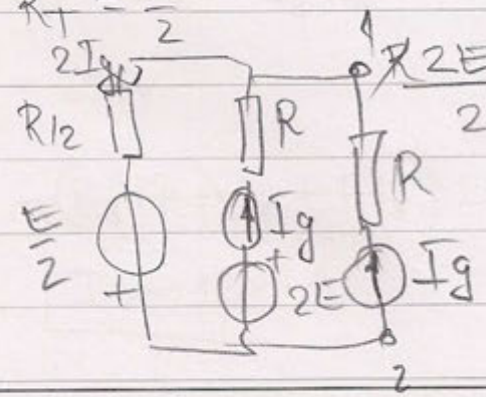
$U_{12} = E - I_2 R =$

$= E - \frac{3}{2}E + \frac{1}{2}I_g R =$

$= \frac{1}{2}(I_g R - E)$

$E_T = \frac{1}{2}(I_g R - E)$

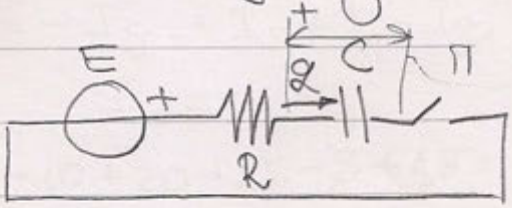
$R_T = \frac{R}{2}$



$\frac{\cancel{R}2E - E}{2\cancel{R}} = \frac{E}{2}$

$U_{12} = -\frac{E}{2} + 2I_g\frac{R}{2} =$

$= I_g R - \frac{E}{2}$



$q = 2CU =$ $\quad E = 10V \quad C = 20\mu F$

$Q_2 = Q_1 + q$ $\quad E - U = 0$ $\quad 2CE = 400\mu C$ $\quad We_1 = We_2$ $\quad q?$

$U = E$ $\quad U_1 = \pm U_2$ $\quad \Downarrow$

$Q = CU$ $\quad Q = \pm Q$

ANALYSIS LABORATORY EQUIPMENT

$\varepsilon_r = 5 \quad E_{kr} = 100\ kV/cm$

$b = 40\ mm$

a

$$C = \frac{4\pi\varepsilon_0\varepsilon_r}{b-a}ab$$

$$E_{kr} = \frac{Q}{4a^2\pi\varepsilon_0\varepsilon_r}$$

$$W_e = \frac{1}{2}CU^2$$

$$U = \int_a^b \frac{Q}{4\pi\varepsilon_0\varepsilon_r r^2}dr = \frac{Q}{4\pi\varepsilon_0\varepsilon_r}\frac{b-a}{ab}$$

$$W_e = \frac{1}{\cancel{2}}\frac{2\cancel{4}\pi\varepsilon_0\varepsilon_r \cancel{ab}}{\cancel{b-a}}\frac{(\cancel{4}a^2\cancel{\pi}\cancel{\varepsilon_0}\cancel{\varepsilon_r}E_{kr})^2(b-a)^{\cancel{2}}}{\cancel{(4\pi\varepsilon_0\varepsilon_r)^2}\ \cancel{a^2}b^{\cancel{2}}}$$

$$W_e = \frac{2\pi\varepsilon_0\varepsilon_r a^3 E_{kr}^2}{b}(b-a)$$

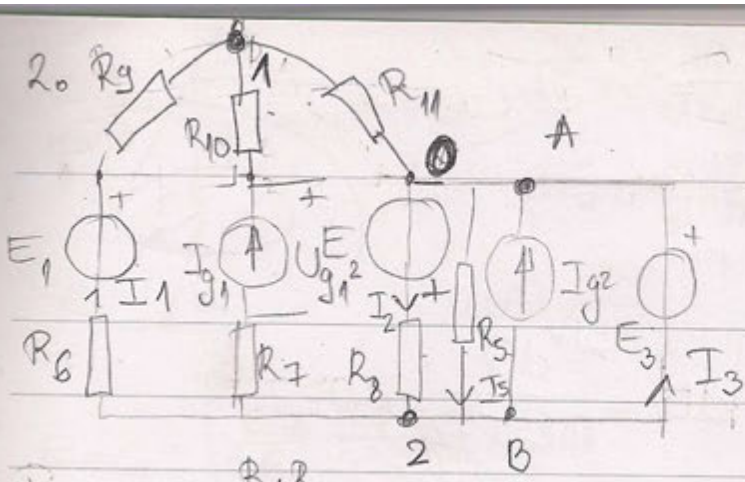
$$W_e' = \frac{2\pi\varepsilon_0\varepsilon_r E_{kr}^2}{b}\left[3a^2(b-a) - a^3\right] = 0$$

$$\Leftrightarrow \quad 3\cancel{a^2}b = 4a^{\cancel{3}}$$

$$a = \frac{3}{4}b = 30\ mm$$

$$W_{e\,max} = \frac{\cancel{2}\cdot 3{,}14\cdot 8{,}85\cdot \cancel{10^{-12}}\cdot 5\cdot 27\cdot \cancel{10^{3}}\cdot \cancel{10^{-9}}}{2\cdot \cancel{40\cdot 10^{-3}}\cdot \cancel{10^{14}}\cdot 10^{-4}\cdot \cancel{10\cdot 10^{-3}}}$$

$$W_{e\,max} = 0{,}18757575 \approx 18.76\ mJ$$

2. 

$E_1 = 10V$ $E_3 = 30V$ $E_2 = 20V$ $I_{g_1} = 5mA$ $I_{g_2} = 10mA$

$R_1 = 1k\Omega$ $R_2 = 2k\Omega$ $R_3 = 4k\Omega$ $R_4 = 5k\Omega$ $R_5 = 1,5k\Omega$ $R_6 = 0,6k\Omega$ $R_7 = 1,6k\Omega$ $R_8 = 2k\Omega$

$P_{Ig_1}?$ $P_{E_3}?$

$$R_{g_1} = \frac{R_1 R_3}{10} = 0,4\,k\Omega$$

$$R_{10_2} = \frac{R_3 R_4}{10} = 2\,k\Omega \qquad R_T = \frac{1,5}{2,75}\,k\Omega$$

$$R_{11_3} = \frac{R_1 R_4}{10} = 0,5\,k\Omega$$

$$V_2 = -E_3$$

$$V_1\left(\frac{1}{R_g+R_6} + \frac{1}{R_{10}+R_7} + \frac{1}{R_{11}}\right) - \left(\frac{1}{R_g+R_6}\right)V_2 = I_g + \frac{E_1}{R_g+R_6}$$

$$10^{-3} + \left(\frac{1}{3,6}\cdot 10^{-3} + 3\cdot 10^{-3}\right)V_1 + 10^{-3}\cdot 30 = 5\cdot 10^{-3} + \frac{10\cdot 10^{-3}}{-15}$$

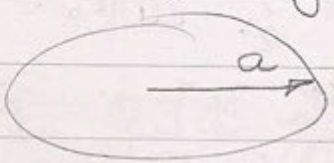
$$V_1 = -5V$$

$$P_{Ig_1} = U_{g_1} I_{g_1} \qquad U_{12} = -5 + 30V = 25V$$

$$U_{12} = -I_g(R_7 + R_{10}) + U_{g_1}$$

$$20 + 36 = U_{g_1} \qquad U_{g_1} = 56V$$

$$\boxed{P_{Ig} = 280mW}$$



$$\sigma = \frac{Q}{a^2\pi}$$

$$U_{20} = E_2 - I_2 R_8 \qquad I_2 R_8 = 20 + 30 \qquad \boxed{I_2 = 25mA}$$

$$U_{12} = 25V \qquad I_5 = 20mA$$

$$I_3 = -I_{g_2} + I_5 + I_2 - I_{g_1} - I_1 =$$

$$-(R_6 + R_g)I_1 + E_1 = 25V$$

$$\boxed{I_1 = -15mA}$$

$$= -10 + 20 + 25 - 5 + 15 =$$

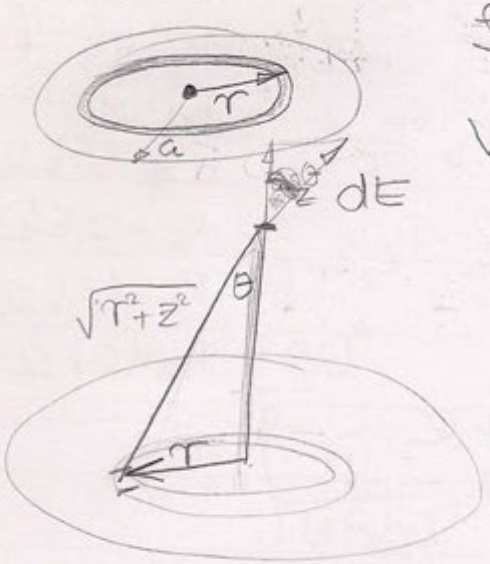
$$= 55mA$$

$$P_{E_3} = 1650mW$$

ANALYSIS

10.02.2007.

1.



$\rho_s = \frac{Q}{a^2\pi}$

V_0 ?

$$dE = \frac{dQ}{4\pi\varepsilon_0(r^2+z^2)}\cos\theta = \frac{dl\,dr\,\frac{Q}{a^2\pi}\,z}{4\pi\varepsilon_0(r^2+z^2)^{3/2}}$$

$$E = \int_{l=0}^{l=2r\pi}\frac{Q z\,dr}{4a^2\pi^2\varepsilon_0(r^2+z^2)^{3/2}}dl = \frac{2r\pi Q z\,dr}{2\cancel{4}a^2\pi^2\varepsilon_0(r^2+z^2)^{3/2}}$$

$$E_{uk} = \int_0^a \frac{Qz}{2a^2\pi\varepsilon_0}\frac{r\,dr}{(r^2+z^2)^{3/2}}$$

$t = r^2+z^2$ $\quad a \to a^2+z^2$

$a \to \cancel{z^2}$

$\frac{dt}{2} = r\,dr$

$$E_{uk} = \int_{z^2}^{a^2+z^2}\frac{Q z\,dt/2}{2a^2\pi\varepsilon_0 t^{3/2}} = \frac{\cancel{2}Qz}{2\cancel{4}a^2\pi\varepsilon_0}\left(\frac{1}{\sqrt{a^2+z^2}} + \frac{1}{\sqrt{z^2}}\right) \text{ V}$$

$$V = \int_0^\infty \vec{E}\,d\vec{z} = \int_0^\infty \frac{Qz\,dz}{2a^2\pi\varepsilon_0}\left(\frac{1}{\sqrt{a^2+z^2}} + \frac{1}{\sqrt{z^2}}\right) =$$

$$= -\int_0^\infty \frac{Q}{4a^2\pi\varepsilon_0}\frac{dt}{t^{1/2}} + \int_0^\infty \frac{Q}{2a^2\pi\varepsilon_0}dz = -\frac{Q}{4a^2\pi\varepsilon_0}\sqrt{a^2+z^2}\Big|_0^\infty + \frac{Q}{2a^2\pi\varepsilon_0}z\Big|_0^\infty$$

$z>0$ $\quad t = a^2+z^2$

$\frac{dt}{2} = z\,dz$

$$= \frac{Q}{2a^2\pi\varepsilon_0}\left(2z - \frac{\sqrt{a^2+z^2}}{2}\right) = \frac{Q}{4a^2\pi\varepsilon_0}\frac{4z^2 - a^2 - z^2}{2z+\sqrt{a^2+z^2}}$$

$$\vec{E} = \frac{\sigma}{2\varepsilon_0}\left(\frac{1}{z} - \frac{1}{\sqrt{a^2+z^2}}\right)$$

$$d\vec{E} = \frac{dQ}{4\pi\varepsilon_0}\frac{1}{r^2+z^2} \qquad dQ = dl\cdot dr\cdot\sigma \qquad \sigma = \frac{Q}{a^2\pi}$$

$$d\vec{E}_z = \frac{\sigma dr\, dl}{4\pi\varepsilon_0(r^2+z^2)} = \frac{\sigma dr\, z}{4\pi\varepsilon_0(r^2+z^2)^{3/2}}dl$$

$$\cos\theta = \frac{z}{\sqrt{r^2+z^2}} \qquad d\vec{E}_{z\,uk} = \int_0^{2r\pi}\frac{\sigma dr z}{4\pi\varepsilon_0(r^2+z^2)^{3/2}}dl = \frac{\sigma r z dr}{2\varepsilon_0(r^2+z^2)^{3/2}}$$

$$E_{z\,uk} = \int_0^a \frac{\sigma z}{2\varepsilon_0}\frac{r dr}{(r^2+z^2)^{3/2}} =$$

$$= \frac{\sigma z}{4\varepsilon_0}\int_{t_1}^{t_2}\frac{dt}{2}t^{-\frac{3}{2}} = \frac{\sigma z}{4\varepsilon_0}(-2)\cdot t^{-\frac{1}{2}}\Big|_{t_1}^{t_2} = -\frac{\sigma z}{2\varepsilon_0}\frac{1}{\sqrt{r^2+z^2}}\Big|_0^a =$$

$$t = r^2+z^2 \qquad \frac{dt}{2} = r dr \qquad = -\frac{\sigma z}{2\varepsilon_0}\left(\frac{1}{\sqrt{a^2+z^2}} - \frac{1}{\sqrt{z^2}}\right)$$

$$z>0 \qquad E_z = \frac{\sigma z}{2\varepsilon_0}\left(-\frac{1}{\sqrt{a^2+z^2}} + \frac{1}{z}\right)$$

$$V_0 = \int_0^\infty E_z dz = \frac{\sigma}{2\varepsilon_0}\left(\int_0^\infty\left(1 - \frac{z}{\sqrt{a^2+z^2}}\right)dz\right) = \frac{\sigma}{2\varepsilon_0}\left(z - \sqrt{z^2+a^2}\right)\Big|_0^\infty =$$

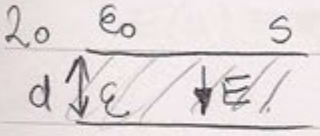
$$\int\frac{z dz}{\sqrt{a^2+z^2}} = \int\frac{dt}{2}t^{-\frac{1}{2}} = t^{1/2} \qquad = \frac{\sigma}{2\varepsilon_0}\frac{\cancel{z^2}-\cancel{z^2}-a^2}{z+\sqrt{z^2+a^2}}\Big|_0^\infty =$$

$$t = a^2+z^2 \qquad = -\frac{\sigma a^2}{2\varepsilon_0}\frac{1}{\infty}$$

$$\frac{dt}{2} = z dz \qquad + \frac{\sigma a^2}{2\varepsilon_0 a} = \frac{\sigma a}{2\varepsilon_0}$$

$$V_0 = \frac{Q}{2\pi a\varepsilon_0}$$

2.



$$2E\cdot S = \frac{Q}{\varepsilon_0}$$

$$E = \frac{\sigma}{2\varepsilon_0}$$

и кондензатору

$$E = \frac{\sigma}{\varepsilon_0\varepsilon_r} = \frac{Q}{S\varepsilon_0\varepsilon_r} = \frac{Q}{S\varepsilon}$$

$$\vec{D} = \varepsilon\vec{E}$$

$$\boxed{\vec{P} = (\varepsilon-\varepsilon_0)\vec{E}}$$

$$\sigma = \varepsilon E$$

$$\sigma_p = -(\varepsilon-\varepsilon_0)E$$

$$P_{R_1} = RI^2 = \frac{U^2}{R} = \frac{E_1^2}{R} = 100\ mW$$

$$P_{I_{g1}} = -E_1 I_{g1} = -200\ mW$$

$$\sum_C \pm U = 0$$

$$P_{E_1} = 500\ mW$$

$$I_{R_1} = 10\ mW$$

$$\sum_C \pm I = 0$$

3.

$$\oint_S \vec{J}d\vec{S} = 0$$

$$\oint_C \vec{E}d\vec{l} = 0$$

$$J_{1n} = J_{2n}$$

$$E_{1t} = E_{2t}$$

$$P_{R_2} = 400\ mW$$

$$I_{R_2} = -20\ mW$$

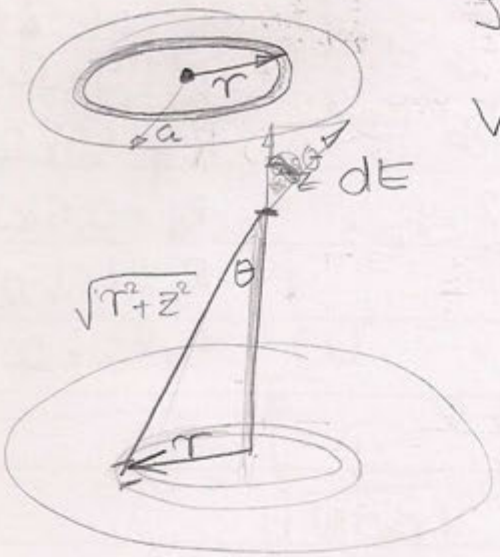
$$U_{R_2} + E_2 + E_1 = 0$$

$$U_{R_2} = -(E_2+E_1)$$

ANALYSIS

10.02.2007.

1.



$\rho_s = \frac{Q}{a^2\pi}$

V_0 ?

$$dE = \frac{dQ}{4\pi\varepsilon_0(r^2+z^2)}\cos\theta = \frac{dl\,dr\,\frac{Q}{a^2\pi}\,z}{4\pi\varepsilon_0(r^2+z^2)^{3/2}}$$

$$E = \int_{l=0}^{l=2r\pi}\frac{Q\,z\,dr}{4a^2\pi^2\varepsilon_0(r^2+z^2)^{3/2}}dl = \frac{2r\pi\,Q\,z\,dr}{2\cancel{4}a^2\pi^2\varepsilon_0(r^2+z^2)^{3/2}}$$

$$E_{uk} = \int_0^a \frac{Qz}{2a^2\pi\varepsilon_0}\frac{r\,dr}{(r^2+z^2)^{3/2}}$$

$t = r^2+z^2$ $\quad a \to a^2+z^2$

$\frac{dt}{2} = r\,dr$ $\quad a \to \cancel{z^2}$

$$E_{uk} = \int_{z^2}^{a^2+z^2}\frac{Qz\,dt/2}{2a^2\pi\varepsilon_0 t^{3/2}} = \frac{\cancel{2}Qz}{2\cancel{4}a^2\pi\varepsilon_0}\left(\frac{1}{\sqrt{a^2+z^2}} + \frac{1}{\sqrt{z^2}}\right)W$$

$$V = \int_0^\infty \vec{E}\,d\vec{z} = \int_0^\infty \frac{Qz\,dz}{2a^2\pi\varepsilon_0}\left(\frac{1}{\sqrt{a^2+z^2}} + \frac{1}{\sqrt{z^2}}\right) =$$

$$= -\int_0^\infty \frac{Q}{4a^2\pi\varepsilon_0}\frac{dt}{\cancel{t}^{1/2}} + \int_0^\infty \frac{Q}{2a^2\pi\varepsilon_0}dz = \frac{-Q}{4a^2\pi\varepsilon_0}\sqrt{a^2+z^2}\Big|_0^\infty + \frac{Q}{2a^2\pi\varepsilon_0}z\Big|_0^\infty$$

$z>0$ $\quad t = a^2+z^2$

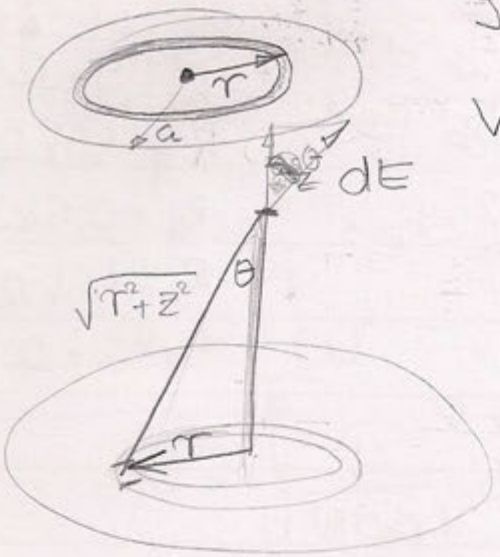
$\frac{dt}{2} = z\,dz$

$$= \frac{Q}{2a^2\pi\varepsilon_0}\left(2z - \frac{\sqrt{a^2+z^2}}{2}\right) =$$

$$\vec{E} = \frac{\sigma}{2\varepsilon_0}\left(\frac{1}{z} - \frac{1}{\sqrt{a^2+z^2}}\right) = \frac{Q}{4a^2\pi\varepsilon_0}\frac{2z^2-a^2-z^2}{2z+\sqrt{a^2+z^2}}$$

10.02.2007.

1.



$\rho_s = \frac{Q}{a^2\pi}$

V_0 ?

$$dE = \frac{dQ}{4\pi\varepsilon_0(r^2+z^2)}\cos\theta = \frac{dl\,dr\,\frac{Q}{a^2\pi}\,z}{4\pi\varepsilon_0(r^2+z^2)^{3/2}}$$

$$E = \int_{l=0}^{l=2r\pi}\frac{Q\,z\,dr}{4a^2\pi^2\varepsilon_0(r^2+z^2)^{3/2}}dl = \frac{2r\pi\,Q\,z\,dr}{2\cancel{4}a^2\pi^2\varepsilon_0(r^2+z^2)^{3/2}}$$

$$E_{uk} = \int_0^a \frac{Qz}{2a^2\pi\varepsilon_0}\frac{r\,dr}{(r^2+z^2)^{3/2}}$$

$t = r^2+z^2$ $\quad a \to a^2+z^2$

$\frac{dt}{2} = r\,dr$ $\quad a \to \cancel{z^2}$

$$E_{uk} = \int_{z^2}^{a^2+z^2}\frac{Qz\,dt/2}{2a^2\pi\varepsilon_0 t^{3/2}} = \frac{\cancel{2}Qz}{2\cancel{4}a^2\pi\varepsilon_0}\left(\frac{1}{\sqrt{a^2+z^2}} + \frac{1}{\sqrt{z^2}}\right)W$$

$$V = \int_0^\infty \vec{E}\,d\vec{z} = \int_0^\infty \frac{Qz\,dz}{2a^2\pi\varepsilon_0}\left(\frac{1}{\sqrt{a^2+z^2}} + \frac{1}{\sqrt{z^2}}\right) =$$

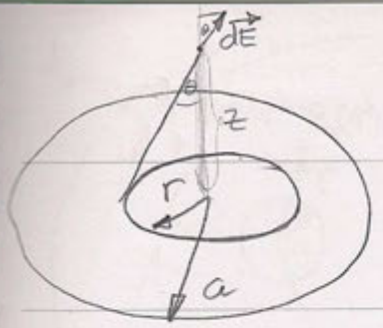
$$= -\int_0^\infty \frac{Q}{4a^2\pi\varepsilon_0}\frac{dt}{\cancel{t}^{1/2}} + \int_0^\infty \frac{Q}{2a^2\pi\varepsilon_0}dz = \frac{-Q}{4a^2\pi\varepsilon_0}\sqrt{a^2+z^2}\Big|_0^\infty + \frac{Q}{2a^2\pi\varepsilon_0}z\Big|_0^\infty$$

$z>0$ $\quad t = a^2+z^2$

$\frac{dt}{2} = z\,dz$

$$= \frac{Q}{2a^2\pi\varepsilon_0}\left(2z - \frac{\sqrt{a^2+z^2}}{2}\right) =$$

$$\vec{E} = \frac{\sigma}{2\varepsilon_0}\left(\frac{1}{z} - \frac{1}{\sqrt{a^2+z^2}}\right) = \frac{Q}{4a^2\pi\varepsilon_0}\frac{2z^2-a^2-z^2}{2z+\sqrt{a^2+z^2}}$$



$$d\vec{E} = \frac{dQ}{4\pi\varepsilon_0}\frac{1}{r^2+z^2} \qquad dQ = dl\cdot dr\cdot\sigma \qquad \sigma = \frac{Q}{a^2\pi}$$

$$d\vec{E}_z = \frac{\sigma dr\, dl}{4\pi\varepsilon_0(r^2+z^2)} = \frac{\sigma dr\, z}{4\pi\varepsilon_0(r^2+z^2)^{3/2}}dl$$

$$\cos\theta = \frac{z}{\sqrt{r^2+z^2}} \qquad d\vec{E}_{z\,uk} = \int_0^{2r\pi}\frac{\sigma dr z}{4\pi\varepsilon_0(r^2+z^2)^{3/2}}dl =$$

$$= \frac{\sigma r z dr}{2\varepsilon_0(r^2+z^2)^{3/2}}$$

$$E_{z\,uk} = \int_0^a \frac{\sigma z}{2\varepsilon_0}\frac{r dr}{(r^2+z^2)^{3/2}} =$$

$$= \frac{\sigma z}{4\varepsilon_0}\int_{t_1}^{t_2}\frac{dt}{2}t^{-\frac{3}{2}} = \frac{\sigma z}{4\varepsilon_0}(-2)\cdot t^{-\frac{1}{2}}\Big|_{t_1}^{t_2} = -\frac{\sigma z}{2\varepsilon_0}\frac{1}{\sqrt{r^2+z^2}}\Big|_0^a =$$

$$= -\frac{\sigma z}{2\varepsilon_0}\left(\frac{1}{\sqrt{a^2+z^2}} - \frac{1}{\sqrt{z^2}}\right)$$

$$t = r^2+z^2 \qquad \frac{dt}{2} = r dr$$

$$z>0 \qquad E_z = \frac{\sigma z}{2\varepsilon_0}\left(-\frac{1}{\sqrt{a^2+z^2}} + \frac{1}{z}\right)$$

$$V_0 = \int_0^\infty E_z dz = \frac{\sigma}{2\varepsilon_0}\left(\int_0^\infty\left(1 - \frac{z}{\sqrt{a^2+z^2}}\right)dz\right) = \frac{\sigma}{2\varepsilon_0}\left(z - \sqrt{z^2+a^2}\right)\Big|_0^\infty =$$

$$= \frac{\sigma}{2\varepsilon_0}\frac{\cancel{z^2}-\cancel{z^2}-a^2}{z+\sqrt{z^2+a^2}}\Big|_0^\infty =$$

$$\int\frac{z dz}{\sqrt{a^2+z^2}} = \int\frac{dt}{2}t^{-\frac{1}{2}} = t^{1/2}$$

$$= -\frac{\sigma a^2}{2\varepsilon_0}\frac{1}{\infty}$$

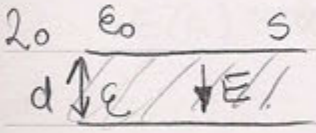
$$t = a^2+z^2$$

$$\frac{dt}{2} = z dz$$

$$+\frac{\sigma a^2}{2\varepsilon_0 a} = \frac{\sigma a}{2\varepsilon_0}$$

$$V_0 = \frac{Q}{2\pi a\varepsilon_0}$$

2.



$$2E\cdot S = \frac{Q}{\varepsilon_0}$$

$$E = \frac{\sigma}{2\varepsilon_0}$$

и кондензатору

$$E = \frac{\sigma}{2\varepsilon_0\varepsilon_r} = \frac{Q}{S\varepsilon_0\varepsilon_r} = \frac{Q}{S\varepsilon}$$

$$\vec{D} = \varepsilon\vec{E}$$

$$\boxed{\vec{P} = (\varepsilon-\varepsilon_0)\vec{E}}$$

$$\sigma = \varepsilon E$$

$$\sigma_p = -(\varepsilon-\varepsilon_0)E$$

$$P_{R_1} = RI^2 = \frac{U^2}{R} = \frac{E_1^2}{R} = 100\ mW$$

$$P_{I_{g_1}} = -E_1 I_{g_1} = -200\ mW$$

$$\sum_C \pm U = 0$$

$$P_{E_1} = 500\ mW$$

$$I_{R_1} = 10\ mW$$

$$\sum_C \pm I = 0$$

$$U_{R_2} + E_2 + E_1 = 0$$

$$U_{R_2} = -(E_2+E_1)$$

$$P_{E} = \ldots 100\ mW$$

3. $\oint_S \vec{J}d\vec{S} = 0$

$$\oint_C \vec{E}d\vec{l} = 0$$

$$J_{1n} = J_{2n}$$

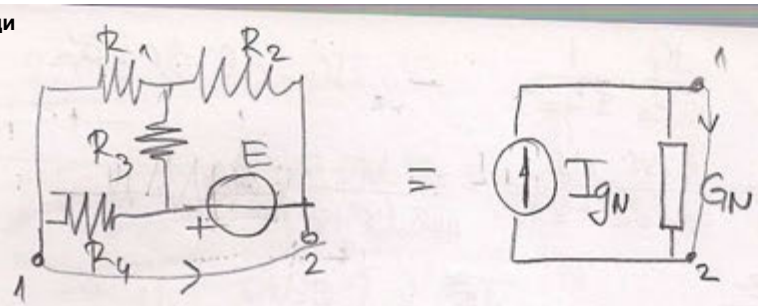
$$E_{1t} = E_{2t}$$

$$P_{R_2} = 400\ mW$$

$$I_{R_2} = -20\ mW$$

ANALYSIS

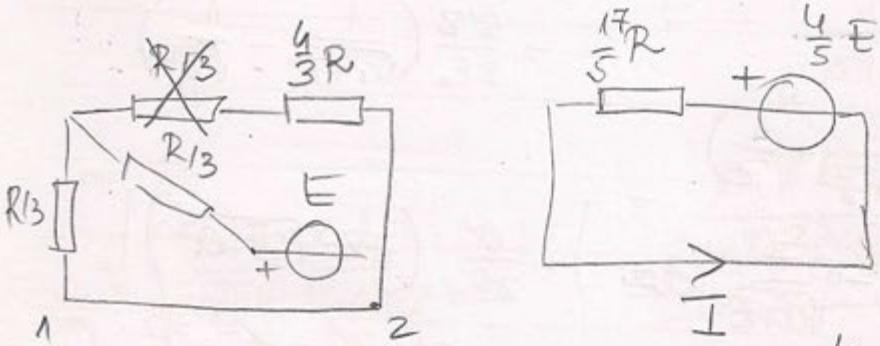
5.



$R_{12} + \frac{\frac{3}{2}R \cdot R}{\frac{5}{2}R} = \frac{3}{5}R$

$R_T = 600\Omega$

$G_N = \frac{10}{6} \cdot 10^{-3} S = \frac{5}{3} mS$ ✓

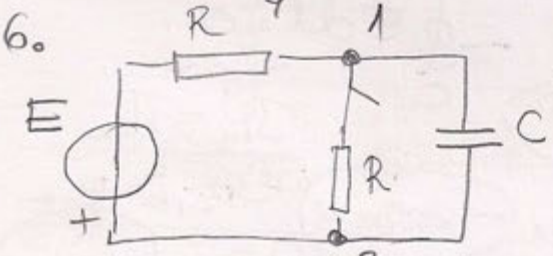


$\frac{\frac{4}{3}R \cdot \frac{R}{3}}{\frac{5}{3}R} = \frac{4}{15}R$

$I = \frac{\frac{4}{5}E}{\frac{3}{8}R} = \frac{4}{3} \cdot \frac{E}{R} = 40mA$

$\frac{\frac{4}{5}E}{\frac{5}{3}E} = \frac{4}{5}E$ $\frac{\frac{4}{5}ER}{\frac{5}{3}R} = \frac{4}{5}E$

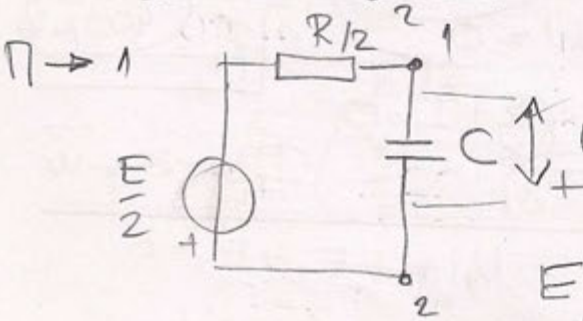
6.



$E = 12V$
$R = 1k\Omega$
$C = 100\mu F$

$\Delta W_e = 5,4 mJ$

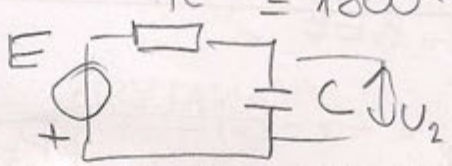
П → 1



$U = \frac{E}{2}$

$W_{e1} = \frac{1}{2}CU_1^2 = \frac{1}{2} \cdot 100 \cdot 10^{-6} \cdot 36 =$

$= 1800 \cdot 10^{-6} J = 1,8 mJ$



$U_2 = E$ $W_{e2} = \frac{1}{2}CU_2^2 =$

1.

$\varepsilon_r(r) = R\,\frac{m+|n-r|}{r^2}$ $m=6mm$ $n=5mm$ $R=6mm$

$E_{kr} = 100 kV/cm = 100 \cdot 10^2 \cdot 10^3 \frac{V}{m} = 10^7 \frac{V}{m}$

$U_{proboja}$?

$a = 3mm$ $b = 6mm$

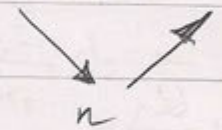
$$E(r)\,2r\Pi = \frac{Q'}{\varepsilon_0 \varepsilon_r(r)}$$

$$E(r) = \frac{Q'}{2\varepsilon_0 r\Pi}\,\frac{r}{R(m+|n-r|)} = \frac{Q'}{2\varepsilon_0 R\Pi}\,\frac{1}{m+|n-r|}$$

$$E = \begin{cases} \frac{Q'}{2\varepsilon_0 R\Pi}\,\frac{1}{m+n-r} & r \le 5mm \\ \frac{Q'}{2\varepsilon_0 R\Pi}\,\frac{1}{m-n+r} & 5mm \le r \le 6mm \end{cases}$$

$$E(a) = \frac{Q'}{2\varepsilon_0 R\Pi}\,\frac{1}{m+n-a}$$

$$E' = \begin{cases} \frac{Q'}{2\varepsilon_0 R\Pi}\,\frac{m+n-r+1}{(m+n-r)^2} & < 0 \\ \frac{Q'}{2\varepsilon_0 R\Pi}\,\frac{m-n+r+1}{(m-n+r)^2} & > 0 \end{cases}$$



$$E(b) = \frac{Q'}{2\varepsilon_0 R\Pi}\,\frac{1}{m+b-n}$$

$$Q' = \frac{m+b-n}{b}\,2\varepsilon_0 R\Pi\, E_{kr}$$

$$U = \int_a^n \frac{Q'}{2\varepsilon_0 R\Pi}\,\frac{dr}{m+n-r} + \int_n^b \frac{Q'}{2\varepsilon_0 R\Pi}\,\frac{dr}{m-n+r}$$

$$E(b) = \frac{Q'}{2\varepsilon_0 R\Pi}\,\frac{1}{6-5+6} = \frac{1}{7}k = E_{max}$$

$$E(a) = k\,\frac{1}{6+5-3} = \frac{1}{8}k$$

$6+6-5$ 10^{-11}

$2 \cdot 8{,}85 \cdot 10^{-12}$

$6 \cdot 10^{-3} \cdot 3{,}14 \cdot 10^{-3}$

23.34

$$U = -(m+b-n)E_{kr}\left[\ln(m+n-r)\Big|_a^n - \ln(m-n+r)\Big|_n^b\right] =$$

$$= -(m+b-n)E_{kr}\left[\ln(m) - \ln(m+n-a) - \ln(m-n+b) + \ln(m)\right]$$

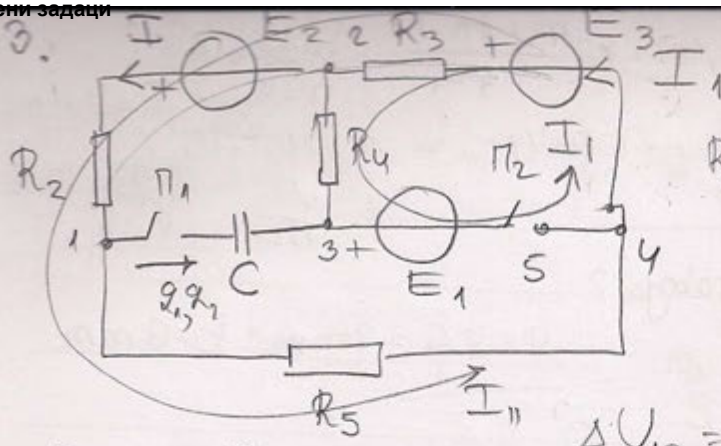
$$= -(m+b-n)E_{kr}\left[2\ln\left(\frac{m}{(m+n-a)(m+b-n)}\right)\right]$$

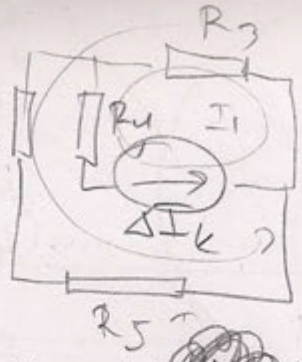
$$\int \frac{t\,dt}{c-t} = \int \frac{t-c}{c-t}\,dt + \int \frac{c\,dt}{c-t} =$$

$$\int dt + c\int \frac{d(c-t)}{c-t} \ldots$$

ANALYSIS LABORATORY EQUIPMENT

3.





$I_1 = \Delta I_k$

$I_{11}(R_3+R_2+R_5) + R_3 I_1 = 0$

$I_{11} = -\frac{100}{500} I_1 = -0.2\Delta I_k$

$\Delta U_{13} = U_{c2} - U_{c1}$ $\Pi 2 \to 1$

$\Pi 1 \to 1 \quad \Pi 2 \to 0$

$$I = \frac{E_2+E_3}{R_3+R_2+R_5}$$

$U_{c1} = U_{12} = E_2 - R_2 I$

$= -E_3 + I(R_3+R_5)$

$$U_{c1} = \frac{Q_0}{C} + \frac{Q_1}{C}$$

$$U_{c2} = \frac{Q_0}{C} + \frac{Q_1}{C} + \frac{Q_2}{C}$$

$$U_{c2} = U_{c1} + \frac{Q_2}{C}$$

$I_{24} = I_1 + I_{11}$

$I_{23} = I_1$

$U_{c2} = U_{13} =$

$= I_{21} R_2 - E_2 - I_{23} R_4$

$= I_1 R_2 - E_2 - I_1 R_4$

$= -E_1 + I_{11} R_5$

$$(R_3+R_4) I_1 + R_3 I_{11} = E_3 - E_1$$

$$R_3 I_1 + (R_3+R_2+R_5) I_{11} = E_3 + E$$

$R_4 I_1 - R_2 I_{11} = \frac{Q_2}{C}$

$50\Delta I_k + 20\Delta I_k = -0.7$

$\Delta I_k = 10\,mA$

$$-E_1 + I_{11} R_5 = -E_3 + \frac{E_2+E_3}{R_2+R_3+R_5}(R_3+R_5) + \frac{Q_2}{C}$$

$-6 + 300 I_{11} = -5 + \frac{E_2+5}{500} \cdot 400$

$-5 + 300 I_{11} = 0.8 E_2 - 0.7 \;/:0.8$

$E_2 = -3.125 + 240 I_{11}$

260

$100 I_1 + 500 I_{11} = 5 + 240 I_{11} - 3.125 + 1.875$

$150 I_1 + 100 I_{11} = -1 \;/2.6$

$390 I_1 + 260 I_{11} = -2.6$

$290 I_1 = -4.475$

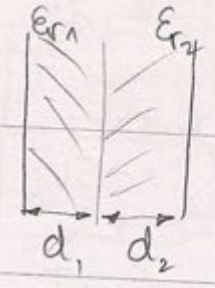
$I_1 = -0.0154$

$I_{11} = 0.01314$

$I_{54} = 10\,mA$

$R_V = 150\,\Omega$

1.



$\varepsilon_{r_1} = 2$ $\quad d_1 = d_2 = 1mm$

$\varepsilon_{r_2} = 4$

$E_{kr_1} = 300 \frac{kV}{cm} = 3 \cdot 10^2 \cdot 10^2 \cdot 10^3 \frac{V}{m} = 3 \cdot 10^7 \frac{V}{m}$

$E_{kr_2} = 2 \cdot 10^7 \frac{V}{m}$

U_{max} ?

$D \cdot S = Q \quad D = \frac{Q}{S}$

$E_1 = \frac{Q}{\varepsilon_0 \varepsilon_{r_1} S}$ $\quad Q^{(1)}_{max} = E_{kr_1} \varepsilon_0 \varepsilon_{r_1} S = \varepsilon_0 S \cdot 3 \cdot 10^7 \cdot 2 = 6 k$

$E_2 = \frac{Q}{\varepsilon_0 \varepsilon_{r_2} S}$ $\quad Q^{(2)}_{max} = E_{kr_2} \varepsilon_0 \varepsilon_{r_2} S = 2 \cdot 10^7 \cdot S \cdot \varepsilon_0 \cdot 4 = 8 k$

$\Downarrow$

$\frac{Q_{max}}{S} = 6 \cdot \cancel{10^7} \cdot 8{,}85 \cdot \cancel{10^{-12}}^{10^{-5}} = 531 \frac{\mu C}{m^2}$

$\sigma_{max} = E_{kr_1} \varepsilon_0 \varepsilon_{r_1}$

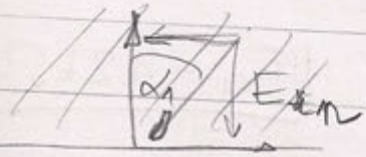
$U = \frac{\sigma_{max}}{\varepsilon_0 \varepsilon_{r_1}} d_1 + \frac{\sigma_{max}}{\varepsilon_0 \varepsilon_{r_2}} d_2 = E_{kr_1} d_1 + \frac{E_{kr_1} \varepsilon_{r_1}}{\varepsilon_{r_2}} d_2 =$

$= E_{kr_1} d \left(1 + \frac{1}{2}\right) = \frac{3}{2} E_{kr_1} d = \frac{3}{2} \cdot \cancel{10^{-3}} \cdot 3 \cdot \cancel{10^{-4}} = 45 \text{ kV}$

2. $\varepsilon_{r_1} = 2$, $\varepsilon_{r_2} = 3$ $\quad \vec{E}_2 = (2\vec{i}_x - 3\vec{i}_y)$ V/m

$\frac{tg\,\alpha_1}{tg\,\alpha_2} = \frac{\varepsilon_{r_1}}{\varepsilon_{r_2}} = \frac{2}{3}$ $\quad \vec{E}_1 = (2\vec{i}_x - 4.5\vec{i}_y)$ V/m

$E_{t_1} = E_{t_2} = 2$



$tg\,\alpha_1 = \frac{E_{t_1}}{E_{n_1}}$ $\quad \frac{tg\,\alpha_1}{tg\,\alpha_2} = \frac{E_{n_2}}{E_{n_1}}$

$tg\,\alpha_2 = \frac{E_{t_2}}{E_{n_2}}$ $\quad \frac{2}{3} E_{n_1} = E_{n_2}$

$E_{n_1} = -\frac{3}{2} 3 =$

$= -4.5$

3.

S, σ, I

P' Уулових губитака

$JS = I$

$J = \frac{I}{S}$ $\quad \sigma = \frac{1}{\rho}$ $\quad R = \rho \frac{l}{S}$ $\quad P = I^2 \rho \frac{l}{S}$

$\boxed{P' = \frac{I^2}{\sigma S}}$

ANALYSIS LABORATORY EQUIPMENT

$E = 30V$

R

R_1 $U_{11'} = 12V$ $U_{22'} = -5V$

$I_1 = 10mA$

$R = 300\Omega$ $U_{22'}$?

$U_{11'} = U_{11'}(E)$

$U_{11'} = E - R_1 I_1$

$12 = 30 - R_1 10 \cdot 10^{-3}$

$R_1 \cdot 10^{-2} = 18$

$R_1 = 180\Omega$

$U_{11'} = E - R \cdot I$

$U_{22'} = A \cdot U_{11'} + B$

$-5 = A \cdot 12 + B$

$A(E - RI) + B = U_{22}$

$\Delta U_{22'} = A \Delta U_{11'}$

$U_{11'} = r_{11} I_1 + r_{12} I_2$ (0)

$U_{12'} = r_{21} I_1 + r_{22} I_2$ (0)

$U_{22'} = r_{21} I_1$

$\frac{U_{11'}}{I_1} = r_{11}$

$\frac{12}{10} 10^3 = r_{11}$

$r_{11} = 1.2k\Omega$

$r_{21} = -\frac{5}{10} \cdot 10^3 = -0.5k\Omega$

$U_{22'} = -0.5 I_1 = -0.5 \frac{U_{11'}}{1.2} = -\frac{5}{12} U_{11'} =$

$= -\frac{5}{12} E + \frac{5}{12} R_1 I_1$

$-\frac{0.5 \cdot 12}{5} 10 I_1 = -E + R_1 I_1$

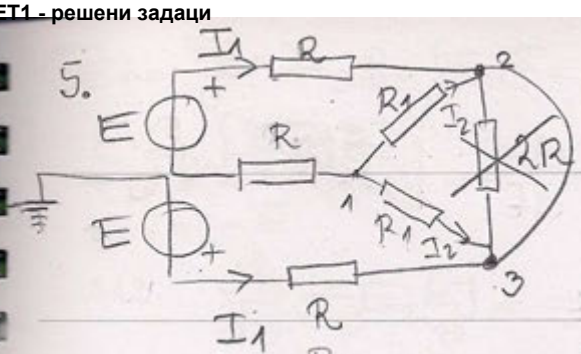
$E = (R_1 + 1200) I_1$

$I_1 = \frac{30}{R + 1200}$

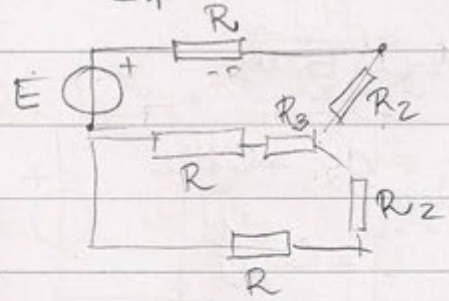
$U_{22'} = -0.5 \cdot 10^3 \frac{30}{R + 1200}$

$U_{22'} = -0.5 \cdot 10^3 \frac{30}{1500} = -10V$

5.



$E = 24\,V \quad R = 80\,\Omega \quad R_1 = 90\,\Omega$



$$R_2 = \frac{2R_1R}{280} = \frac{9000}{280} = \frac{900}{28} = \frac{225}{7}\,\Omega$$

$$R_3 = \frac{8100}{280} = \frac{202.5}{7}\,\Omega$$

$$I = \frac{E}{R+R_2} = \frac{24}{50+\frac{225}{7}} =$$

$$V_2 = E - IR = 9.99\,V$$

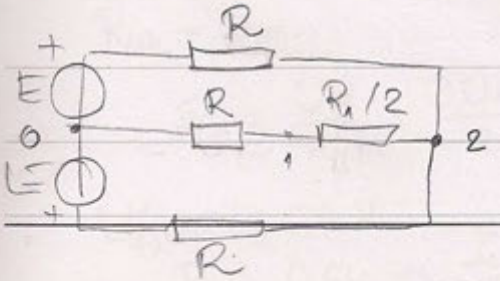
$$I = E\,\frac{1}{\quad}$$

$$E - E\frac{R}{R+R_2} = E\frac{R_2}{R+R_2} = E\frac{\frac{2R_1R}{2R+2R_1}}{R+\frac{2R_1R}{2R+2R_1}} =$$

$$= E\frac{2R_1R}{2R^2+2RR_1} = E\frac{R_1R}{R^2+RR_1}$$

$$\frac{E}{\frac{R_1R}{R_1+R}+R} = I \qquad \frac{\frac{2R_1R}{R_1+2R}}{\frac{2R_1R}{R_1+2R}+R} = \frac{2R_1R}{2R_1R+R_1R+2R^2} = \frac{R_1R}{3R_1R+R^2}$$

$$V_2 = V_{20} = E - \frac{E}{\frac{R_1R}{R_1+R}+R}R = E\left(\frac{\frac{R_1R}{R_1+R}+R-R}{\frac{3R_1R+2R^2}{R_1+R}}\right) =$$



$$= \frac{R_1R}{2R_1R+R^2}$$

ANALYSIS
LABORATORY EQUIPMENT

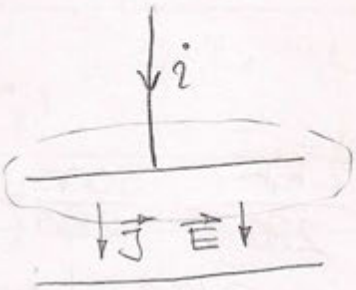
98. $Q_1, -Q$
N'
v_1, v_2

$\vec{J} = NQ(\vec{v}_1 - \vec{v}_2)$

$q_s = Cu$

$i = \frac{dq_s}{dt} = \oint \vec{J} d\vec{S} = J \cdot S$

99. $\oint_S \vec{J} d\vec{S} = -\frac{dq_s}{dt}$



$E = \frac{J}{\sigma} = \frac{i}{S\sigma}$

$U = \int \vec{E} d\vec{l} =$

100.

$dq_s = C du$

$i = C \frac{du}{dt}$

$\oint_S \vec{J} d\vec{S} = 0$ $\quad \sum_c \pm I = 0$

$\oint_c \vec{E} d\vec{l} = 0$ $\quad \sum_c \pm U = 0$

$\vec{J} = \sigma \vec{E}$

$\vec{J} = \vec{J}(\vec{E})$

$\oint \vec{J} d\vec{S}$

101. $Q_{us} = \oint_S \vec{D} d\vec{S} = \oint_S \varepsilon \vec{E} d\vec{S} = \oint_S \frac{\varepsilon}{\sigma} \vec{J} d\vec{S} = \frac{\varepsilon}{\sigma} \underbrace{\oint_S \vec{J} d\vec{S}}_{=0} = 0$

102. $E_{t1} = E_{t2}$ $\quad \rho_S = 0$ $\quad D_{1n} = D_{2n}$

105.

$2r\pi l \cdot J = I(z) - I(z+l)$

$2r\pi J = I'$

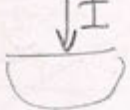
$J = \frac{I'}{2r\pi}$

$E = \frac{I'}{\sigma 2r\pi}$

$U = \frac{I'}{2\sigma\pi} \ln \frac{b}{a}$

$G' = \frac{I'}{U} = \frac{2\sigma\pi}{\ln \frac{b}{a}}$

107. $a = 10m$
$\rho = 100 \Omega m$



$I = 2r^2\pi J$

$J = \frac{I}{2r^2\pi}$

$V = \frac{I}{2\sigma\pi a}$

$E = \frac{I}{2\sigma\pi r^2}$

$P_J = GU^2 = GV^2$

$G = \frac{I}{V} = 2\sigma\pi a$ $\quad R = \frac{1}{2\sigma\pi a} = \frac{\rho}{2\pi a}$

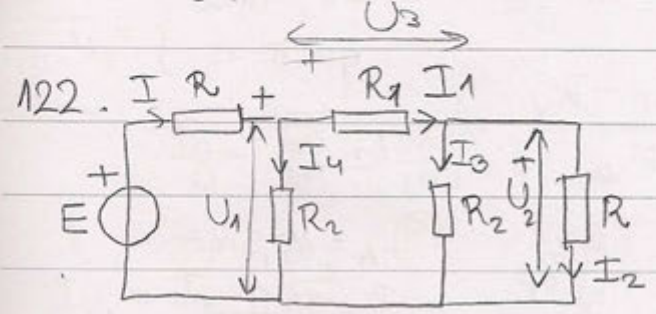
$E_i = \frac{F_i}{Q}$ $\quad E = \cancel{\int \vec{E}\,d\vec{l}} = \int (\vec{E}_i + \cancel{\vec{E}})\,d\vec{l}$

$\mathcal{E} = \int \vec{E}_i\,d\vec{l}$

$\vec{E}_i = -\vec{E}$

113. $\frac{dP_E}{dv} = E_i \cdot J$

122.



$E = 2V \quad R = 50\Omega \quad U_1 = 1V \quad U_2 = 0{,}5V$

R_1, R_2 ?

$I_2 = 10mA$

$I_3 = \frac{U_2}{R_2}$ $\quad I = \frac{U_3}{R_1} + \frac{U_1}{R_2}$

$I_4 = \frac{U_1}{R_2}$ $\quad \frac{U_3}{R_1} = \frac{U_2}{R_2} + I_2$

$I_1 = I - I_4$

$I_1 = \frac{U_3}{R_1}$

$E - RI - U_1 = 0$

$I = \frac{E - U_1}{R} = 20mA$

$U_1 - U_3 - U_2 = 0$

$U_3 = 0{,}5V$

$20mA = \frac{0{,}5}{R_1} + \frac{1}{R_2}$

$\frac{0{,}5}{R_1} = \frac{0{,}5}{R_2} + 10mA$

$10mA - \frac{0{,}5}{R_2} = \frac{1}{R_2}$

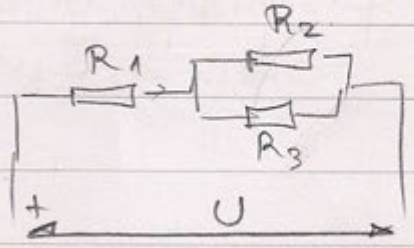
$R_2 = \frac{1{,}5}{10mA} = 150\Omega$

$\frac{0{,}5}{R_1} + \frac{1}{150} = 20mA \quad / 150$

$\frac{75}{R_1} + 1 = 3$

$R_1 = 37{,}5$

123.



$R_1 = 20\Omega \quad R_2 = 100\Omega$

$R_3 = 400\Omega$

$P_{1max} = 2W$

$P_{2max} = 4W$

$P_{3max} = 2W$

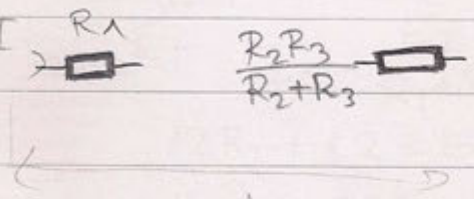
$U \nearrow 0{,}50$

$U_1 = \frac{20}{420}U = \frac{1}{21}U$

$U_3 = \frac{40}{42}U = \frac{20}{21}U$

$U_{R_1} = \frac{R_1}{R_{uk}}U = 0{,}2U$

$U_{R_{2,3}} = 0{,}8U \quad P_1 =$



$R_{uk} = 100\Omega$

$P_1 = \frac{U_1^2}{R_1} = \frac{0{,}04U^2}{20} = 2 \cdot 10^{-3}U^2$

$IR_1 + IR = U = IR_{uk}$

$U_1 = \frac{R_1}{R_{uk}}$

$U_{(1)} = 31.62V$

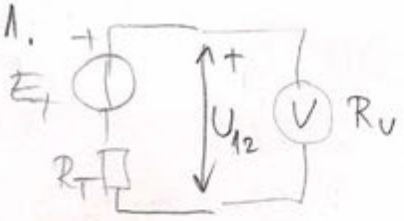
$P_2 = \frac{0{,}64}{100}U^2 = 6{,}4 \cdot 10^{-3}U^2$ $\quad P_3 = \frac{0{,}64}{400}U^2 = 1{,}6 \cdot 10^{-3}U^2$

R_2

$U_{(2)} = 25V$ $\quad U_{(3)} = 35.355$

ANALYSIS

14.1.



$$U_{12} = \frac{R_V E_T}{R_T + R_V}$$

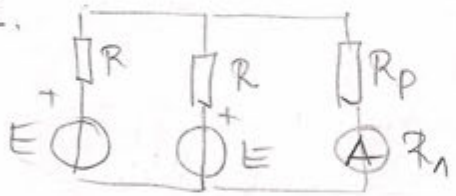
$$U_{12}' = E_T$$

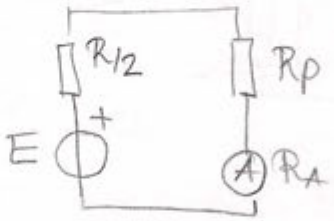
$R_T = R_e$

$$\frac{U_{12} - U_{12}'}{U_{12}'} = -\frac{1 - \frac{R_V}{R_T + R_V}}{}$$

$$\frac{R_V}{R_T + R_V} - 1 = \frac{\cancel{R_V} - R_T - \cancel{R_V}}{R_T + R_V} = -\frac{1}{1 + \frac{R_V}{R_e}}$$

14.2.





$I_A = 10{,}5\,mA$

$R_A = 1\,\Omega$

$R = 30\,\Omega$ $R_p = 6\,\Omega$

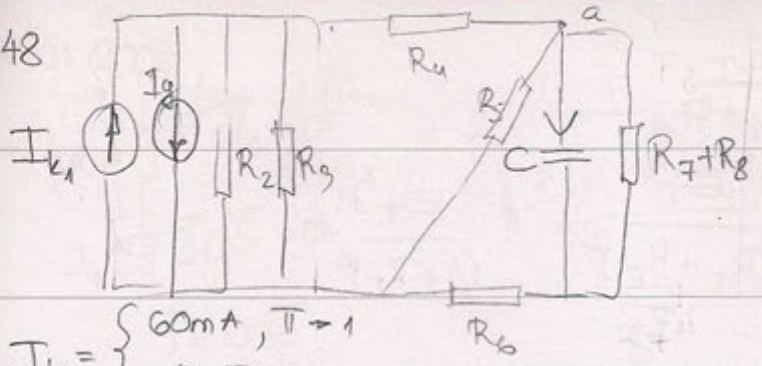
$$I = \frac{E}{R_{12} + R_p}$$

$I_A =$

I_{ks} -

$$I_N = \frac{2E}{R}$$

T48



Q_{ab}? T/A

$E_1 = 4V$ $R_2 = 1k\Omega$

$E_3 = 12V$ $R_3 = 150\Omega$

$R_6 = 200\Omega$

$I_1 = 60mA$ $Q_{ab} = -Q_{4C}$

$$I_{k_1} = \begin{cases} 60mA, T \to 1 \\ 0, T \to 0 \end{cases}$$

$$I_g = \frac{E_3}{R_3} = \frac{12}{150} = 80\,mA$$

$$I_{k_2} = I_{k_1} - \frac{E_3}{R_3}$$

Линеарност

$$Q_{ab} = a I_{k_2}$$

1) $Q_{ab} = a\left(I_1 - \frac{E_3}{R_3}\right)$

$+0,2 \cdot 10^{-6} = a \cdot 10^{-3}(60-80) =$

$= a \cdot (-20)$

$a = 10^{-5}\,\frac{C}{A}$

2) $Q_{ab}' = a \cdot \left(-\frac{E_3}{R_3}\right) = -10^{-5} \cdot 80 \cdot 10^{-3} =$

$= -8 \cdot 10^{-7} = -0,8\mu C$

$Q_{ab} = -0,1C$

143 $R_{V_1} = 10k\Omega$

$U_{12} = 12V$

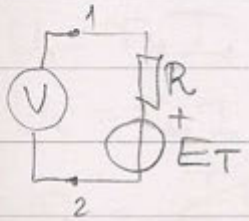
$R_{V_2} = 20k\Omega$

$U_{12}' = 16V$

$R_{V_3} = 30k\Omega$? U_{12}''

$I = 1,2mA$

$I' = 0,8mA$



$$U_{12} = \frac{R_V}{R_T + R_V} E_T$$

$$12 = \frac{10}{10 + R_T} E_T$$

$10E_T = 120 + 12R_T$

$20E_T = 320 + 16R_T$

$20E_T = 240 + 24R_T$

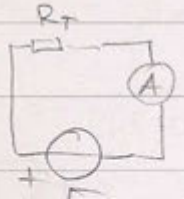
$0 = 80 + 8R_T$

$R_T = 10k\Omega$

$E_T = 24V$

$$U_{12}'' = \frac{30}{30+10} 24 = \frac{3}{4} 24 = 18V$$

144. $R_{A_1} = 100m\Omega$ $I_1 = 12A$



$R_{A_2} = 50m\Omega$ $I_2 = 15A$

I_0 ?

$$I_1 = \frac{E_T}{R_T + R_{A_1}}$$

$12R_T + 1,2 = E_T$

$15R_T + 0,75 = E_T$

$3R_T = 0,45$

$R_T = 150m\Omega$

$225 + 0,75 = E_T$

$$\frac{E_T}{R_T + R_A} = \frac{E}{R_T + R_A}$$

$I_A = 10,5mA$

$10,5 \cdot (21 + 1) = E$

$231V = E$

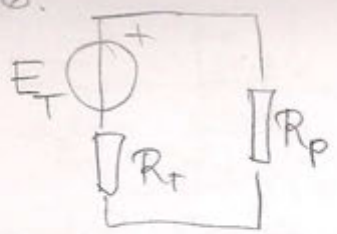
$$I = \frac{2,31}{R_T + R_p} = 11mA$$

$$I_0 = \frac{E_T}{R_T} =$$

$$= \frac{3}{0,15} = \frac{30}{1,5} = \frac{300}{0,5} = \frac{300}{5} = 20A$$

ANALYSIS LABORATORY EQUIPMENT

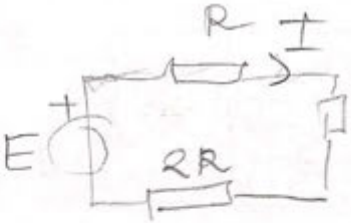
146.



$$I = \frac{E_T}{R_T + R_p}$$

$$P = R_p \cdot \frac{E_T^2}{(R_T + R_p)^2} = \cancel{1} \cdot \frac{E_T^2}{(1 + R_T)^2}$$

$$E_T = \begin{cases} 4E & 4R_g \\ 3E & \frac{5}{2}R_g \\ 2E & R_g \\ E & R_g/4 \end{cases}$$



$$I = \frac{\cancel{E}\ E}{3R + \frac{R_1 R}{R_1 + R}} = \frac{24 \cdot 140}{150 \cdot 140 + 50 \cdot 90}$$

$$50(132$$

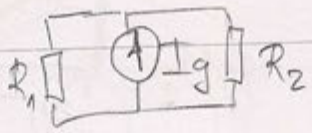
26.01.2007. 04.

1. $\oint_C \vec{E}\,d\vec{l} = 0$

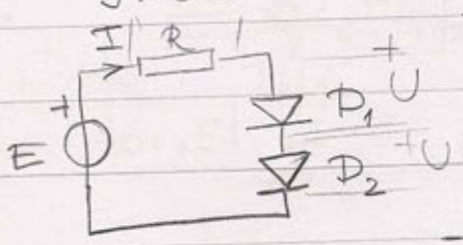
$\oint \vec{J}\,d\vec{S} = 0$

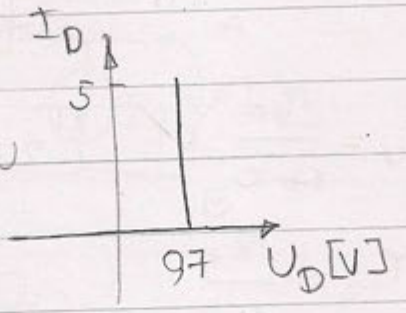
$\vec{J} = \sigma \vec{E}$

2.



1.





$P = I^2 R =$

$= 129{,}6\,mW \approx$

$\approx 130\,mW$

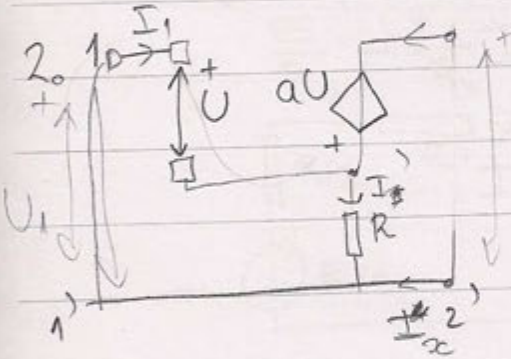
$E - IR - 2U = 0$ $\qquad I = 36mA$

$\frac{E - 2U}{R} = I \qquad \frac{5 - 1{,}4}{100} = I$

$U_2 = \cancel{I_2 R} +$

$= -U(a+1)$

2.



$a = 9 \quad R = 10k\Omega \quad g?$

$I_1 = g_{11} U_1 + g_{12} U_2$

$I_2 = g_{21} U_1 + g_{22} U_2$

$g_{11} = \frac{I_1}{U_1}\Big|_{U_2=0} = 0$

$\cancel{g_{11} = \frac{\frac{a}{R}}{a+1} = \frac{a}{(a+1)}\frac{1}{R}}$

$U_1 = r_{11} I_1 + r_{12} I_2$

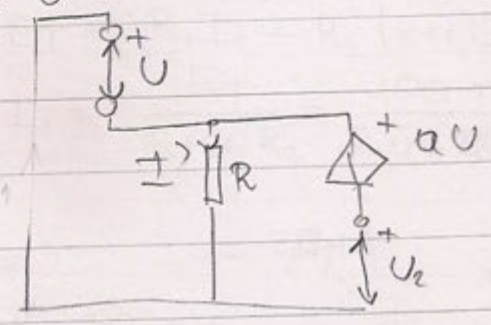
$U_2 = r_{21} I_1 + r_{22} I_2$

$\cancel{r_{11} = \frac{I_1}{U_1}\Big|_{I_2=0} = \frac{I_1}{U + I_1 R}}$

$\cancel{r_{11}}$ - $g_{12} = \frac{U_1}{I_1}\Big|_{U_2} = \frac{I_1}{U_2}\Big|_{U_1=0}$

$g_{12} = \frac{\frac{U_1 - U}{R}}{-aU - U} = \frac{1}{R(1+a)} = 0$

$g_{21} = \frac{I_2}{U_1}\Big|_{U_2=0} \qquad g_{22} =$

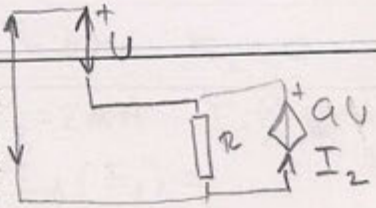


$\frac{U_1 - U}{R} = I'$ $\qquad I' = \frac{aU}{R}$

$g_{21} = \frac{a}{(1+a)R}$

$U_1 - U = aU$

$\frac{aU + U_2}{R} = I_2$ $\qquad U_1 = U(1+a) \qquad g_{22} = \frac{I_2}{U_2}\Big|_{U_1=0}$



$g_{22} = \frac{1}{R}\frac{(a - a - 1)}{-a+1} = \frac{1}{R(a+1)}$

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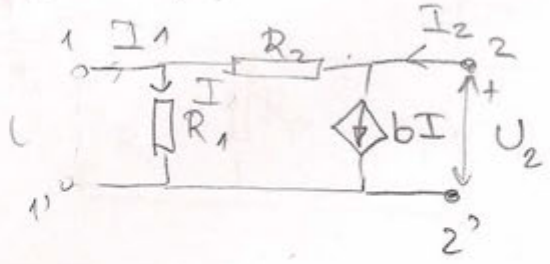
Примери



$$U_1 = r_{11} I_1 + r_{12} I_2$$

$$U_2 = r_{21} I_1 + r_{22} I_2$$

$$r_{11} = \frac{U_1}{I_1}\Big|_{I_2=0}$$

$$I_1 = I + bI$$

$$U_1 = R_1 I$$

$$r_{11} = \frac{R_1}{1+b} \checkmark$$

$$r_{22} = \frac{U_2}{I_2}\Big|_{I_1=0}$$

$$r_{12} = \frac{U_1}{I_2}\Big|_{I_1=0}$$

$$r_{12} = \frac{R_1}{1+b} \checkmark$$

$$I_2 = I + bI$$

$$U_2 = I(R_1 + R$$

$$U_1 = R_1 I$$

$$I_2 = I + bI$$

$$r_{22} = \frac{R_1 + R_2}{1+b} \checkmark$$

$$r_{21} = \frac{U_2}{I_1}\Big|_{I_2=0}$$

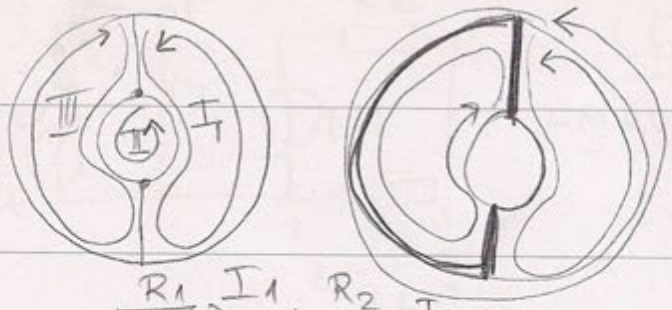
$$r_{21} = \frac{R_1 - bR_2}{1+b}$$

$$I_1 = I + bI$$

$$U_2 = I(R_1 - bR_2)$$

17.01.2004.

1.



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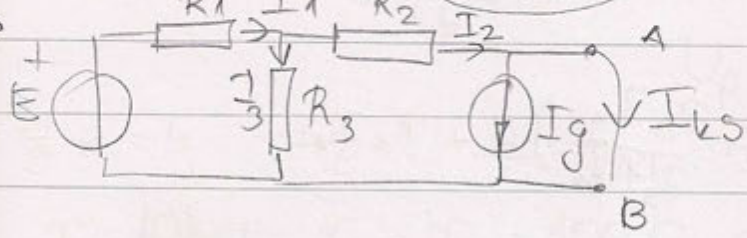
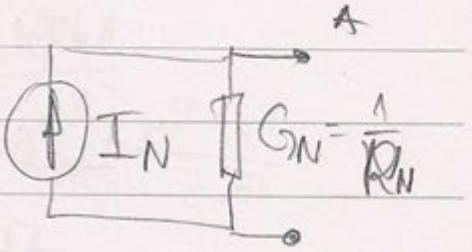


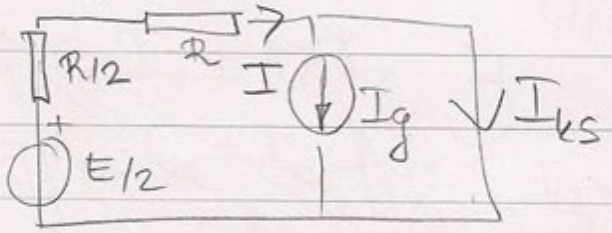


$R_N = 1{,}8k\Omega$

$I_1 = I_2 + I_3$ $\quad I_2 = I_1 + \frac{R_1}{R_3} I_1 - \frac{E}{R_3}$

$E - R_1 I_1 - R_3 I_3 = 0$ $\quad I_{ks} = I_1 + \frac{R_1}{R_3} I_1 - \frac{E}{R_3} - I_g$

$\frac{E}{R_3} - \frac{R_1}{R_3} I_1 = I_3$



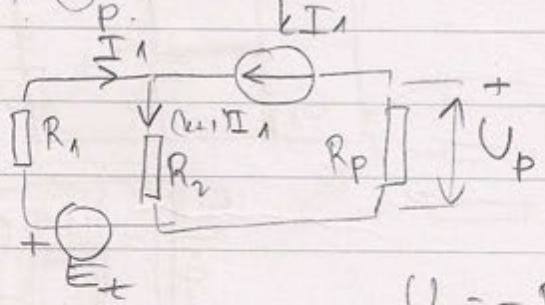
$\frac{E}{2} - \frac{3R}{2} I = 0$

$\frac{E}{3R} = I$

$I_{ks} = \frac{E}{3R} - I_g = \frac{3}{3} - 3 = \boxed{-2\mu A}$

3. $E_t = 100mV$ $R_1 = 2{,}4\,k\Omega$ $R_2 = 100\Omega$ $R_p = 1\,k\Omega$ $k = 25$

I_1? U_p?



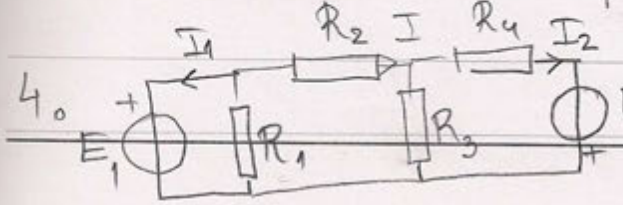
$E_T = R_1 I_1 + R_2 (k+1) I_1$

$I_1 = \frac{E_T}{R_1 + 26 R_2} = \frac{100\,mV}{2{,}4 + 2{,}6} =$

$U_p = -R_p k I_p =$ $\quad = 2{,}0\mu A$

$= -62{,}5mV$ $\quad 500mV$

4.



$E_1 = 10V$ $\quad E_2 = 0$

$I_2 = 2mA$ $\quad I_1$?

$I_2 = \frac{R_3}{R_3 + R_4} I$ $\quad I = \frac{R_3 + R_4}{R_3} I_2$

$I_1 = I_1(E_1) + I_1(E_2) = I_1(E_1) =$

$\frac{R_1 \left(R_2 + \frac{R_3 R_4}{R_3 + R_4}\right)}{R_1 +}$

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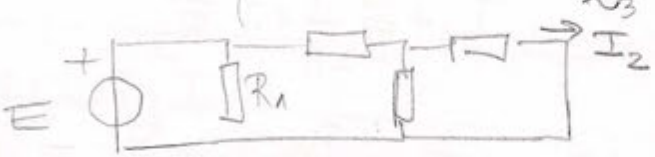
4о $I_1 = AE_1 + BE_2$

$I_2 = CE_1 + DE_2$ $C = 0{,}2\,mS$,

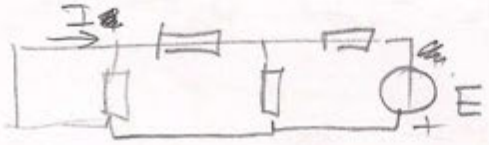
$$I = -\frac{R_1}{R_1 + R_2 + \frac{R_3 R_4}{R_3 + R_4}} I_1$$

$$\frac{R_3 + R_4}{R_3} I_2 \left(R_1 + R_2 + \frac{R_3 R_4}{R_3 + R_4} \right) = -R_1 I_1$$

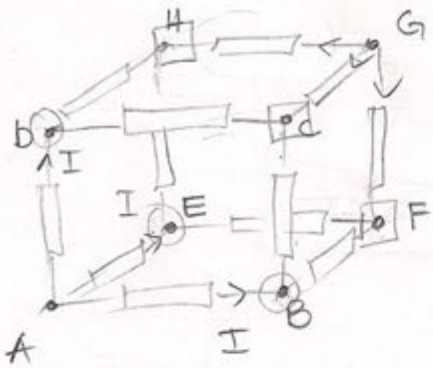
$$I_2 \left(\frac{(R_1 + R_2)(R_3 + R_4)}{R_3} + R_4 \right) = -R_1 I_1$$

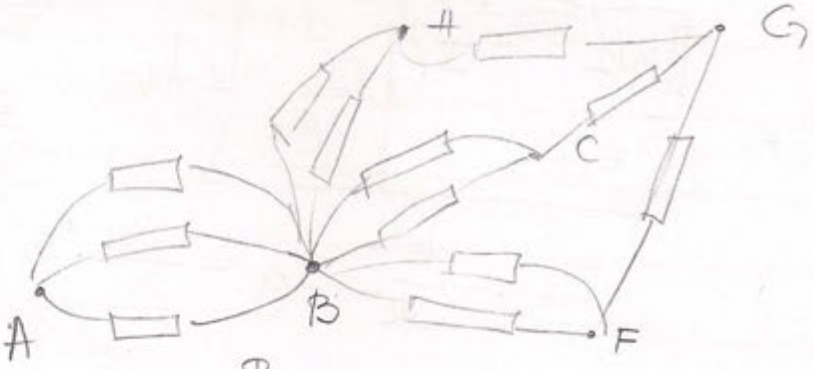


$I_2 = aE$ $a = 0{,}2\,mS$

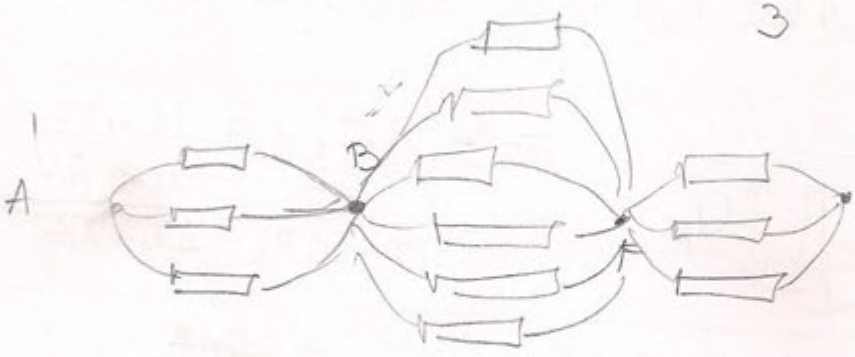


$I_1 = -aE = -0{,}2 \cdot 5 = -1\,mA$





$\frac{R}{3}$ $R_{AB} = 4\,\Omega$



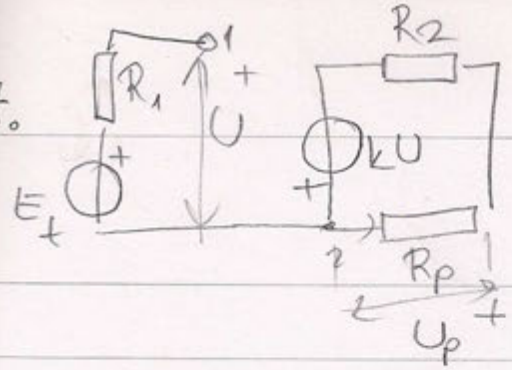
$\frac{2R}{3} + \frac{R}{6} =$

$\frac{5R}{6} = 10\,\Omega$

$\sum R_i \,||\, (2R + R) =$

$= \frac{3R^2}{4R} = 9\,\Omega$

7.



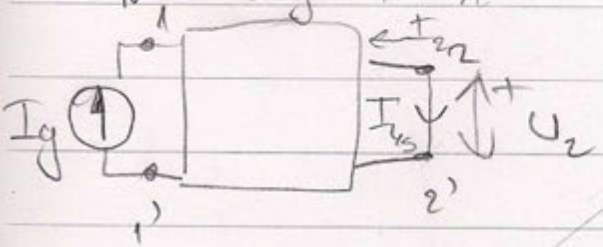
$$\frac{U_p}{E_t} = \frac{20 \cdot 30}{40} = 15\,k\Omega$$

$$I = -\frac{kU}{R_p + R_2}$$

$$U_p = -\frac{kR_pU}{R_p + R_2}$$

$\frac{R_2}{3} \cdot 2 = 4 \rightarrow 2 \rightarrow 1\,\Omega = R_{AB}$

2. $r_{11} = 10\,k\Omega \quad r_{12} = r_{21} = 100\,\Omega \quad r_{22} = 1\,\Omega$



$$I_1 = g_{11}U_1 + r_{12}U_2$$

$$I_2 = g_{21}U_1 + r_{22}U_2$$

$$I_{ks} = -I_2$$

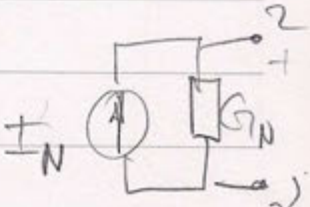
$$I_1 = I_g$$

$$U_1 = \frac{I_g}{r_{11}} =$$

$$U_1 =$$

$$U_1 = r_{11}I_1 + r_{12}I_2$$

$$U_2 = r_{21}I_1 + r_{22}I_2$$

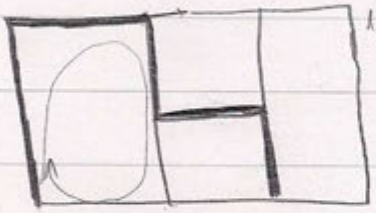


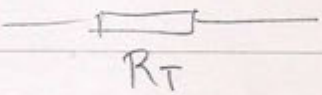
$$I_2 = -\frac{r_{21}}{r_{22}}I_1 = -1A \quad I_N = +1A$$

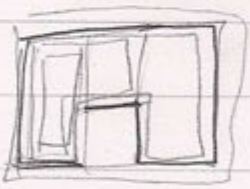
$$I_N = G_N U_2$$

$$G_N = \frac{1}{100 \cdot 10m} = 1\,\Omega$$

4.







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