Aufgabe 1.

a) $I \cdot t = Q = C \cdot U$

Plattenkondensator in Luft

$I = \frac{C_1 \cdot U_1}{t_1} = \frac{1{,}77\,pF \cdot 200\,V}{0{,}2\,s} =$

$= 1{,}77 \cdot 10^{-9}\,A = 1{,}77\,nA$

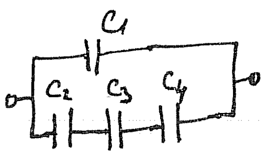
$C_1 = \frac{\varepsilon_0 A}{d} = \frac{8{,}854 \cdot 10^{-12}\,As/Vm \cdot 100\,mm^2}{0{,}5\,mm} =$

$= \frac{8{,}854 \cdot 10^{-15}\,As/Vm \cdot 100\,mm^2}{0{,}5\,mm} =$

$= 1{,}77 \cdot 10^{-12}\,As/V = 1{,}77\,pF$

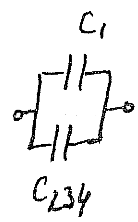
b) $W = \frac{1}{2} C_1 U_1^2 = \frac{1}{2} \cdot 1{,}77\,pF \cdot 200^2\,V^2 =$

$= 35{,}4 \cdot 10^{-9}\,Ws = 35{,}4\,nWs$

c) 

$C_{23} = \frac{8C \cdot 8C}{16C} = 4C$

$C_{234} = \frac{4C \cdot 4C}{8C} = 2C$

$\Rightarrow$ 

$C_{ges} = C_1 + C_{234} =$
$= C + 2C =$
$= 3C \Rightarrow$
$3 \cdot 1{,}77\,pF =$
$= 5{,}31\,pF$

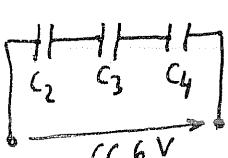
d) Ladung bleibt erhalten: $Q = const.$

$Q = C_1 U_1$ (vor schließen von S_2)

$= 1{,}77\,pF \cdot 200\,V = 354 \cdot 10^{-12}\,As$

$Q = U_1 \cdot C_{ges}$ (nach schließen von S_2)

$U_1 = \frac{Q}{C_{ges}} = \frac{354 \cdot 10^{-12}\,As}{5{,}31 \cdot 10^{-12}\,F} = 66{,}6\,V$



$C_2 = C_3 = 8C$
$C_4 = 4C$

Reihenschaltung:

$U_1 C_{ges} = C_2 U_2 = C_3 U_3 = C_4 U_4$

$U_2 = U_3, \quad U_3 = \frac{C_4 U_4}{C_3} = \frac{4C \cdot U_4}{8C} = \frac{U_4}{2}$

$U_2 + U_3 + U_4 = 66{,}6\,V$

$U_2 + U_2 + 2U_2 = 66{,}6\,V$

$U_2 = U_3 = \frac{66{,}6\,V}{4} = 16{,}65\,V$

$U_4 = 2U_3 = 33{,}3\,V$

e) $W^* = \frac{1}{2} \frac{Q^2}{C_{ges}} = \frac{1 \cdot (354 \cdot 10^{-12})^2 (As)^2}{2 \cdot 5{,}31 \cdot 10^{-12}\,F} =$

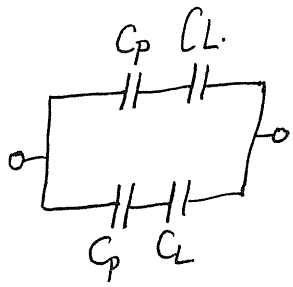
$= 11{,}8 \cdot 10^{-9}\,Ws = 11{,}8\,nWs$

f) $\Delta W = 35{,}4\,nWs - 11{,}8\,nWs =$
$= 23{,}6\,nWs$

Energieverlust durch:
Wärmeverlust in den Zuleitungswiderstände (R),
Umlade Ströme (HF – Abstrahlung
magn. Feld der Leiterstrom)

Aufgabe 2

a)



b) ① $C_{max} = 2\,\dfrac{C_p C_L}{C_p + C_L}$ bei $A_{max} = \dfrac{\pi}{2}(r_1^2 - r_2^2) = \pi \cdot 6\,cm^2$

② die Kapazität in Luft:

$$C_L = \frac{\varepsilon_0 A}{d} = C_{L max} = \frac{\varepsilon_0 A_{max}}{d} =$$

$$= \frac{8{,}857 \cdot 10^{-12}\,As/Vm \cdot 6\pi\,cm^2}{1\,mm} = \frac{8{,}857 \cdot 10^{-15}\,As/Vmm \cdot 6 \cdot \pi \cdot 10^2\,mm^2}{1\,mm} =$$

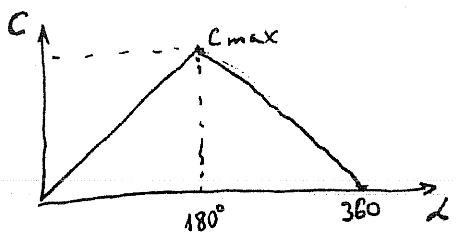
$$= 16{,}68 \cdot 10^{-12}\,As/V = \underline{\underline{16{,}68\,pF}}$$

③ in Papier $C_p = \dfrac{\varepsilon_0 \varepsilon_r A}{d} = 4 C_L$

$$\boxed{C_{max} = 2\left(\frac{4C_L \cdot C_L}{4C_L + C_L}\right) = \frac{8 C_L}{5} = \frac{8}{5} \cdot 16{,}68\,pF = \underline{\underline{26{,}69\,pF}}}$$

c) 1) $C(\alpha) = C_{max} \cdot \dfrac{\alpha}{180°}$ 2) $C(\alpha) = C_{max} \cdot \left(2 - \dfrac{\alpha}{180°}\right)$

d)

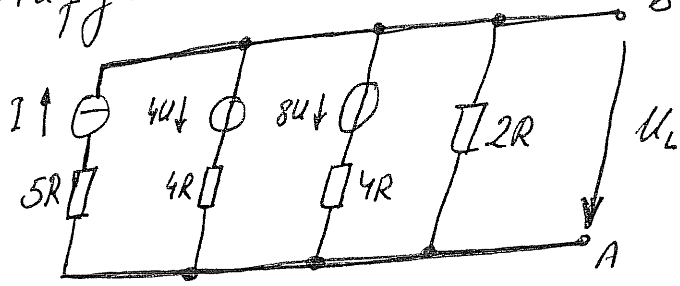


e) $Q_{max} = C_{max} \cdot U_{Q\,max} = 26{,}69\,pF \cdot 500\,V = 13{,}345 \cdot 10^{-9}\,As$

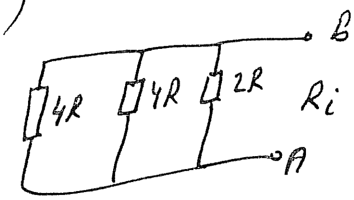
$= 13{,}345\,nAs$

f) $E_D = \dfrac{U_D}{\underbrace{(r - r_1)}_{\text{minimaler Abstand zwischen beiden Elektroden}}} \Rightarrow U_D = E_D \cdot (r - r_1) = 30\,kV/cm \cdot 0{,}1\,cm = 3\,kV$

Aufgabe 3

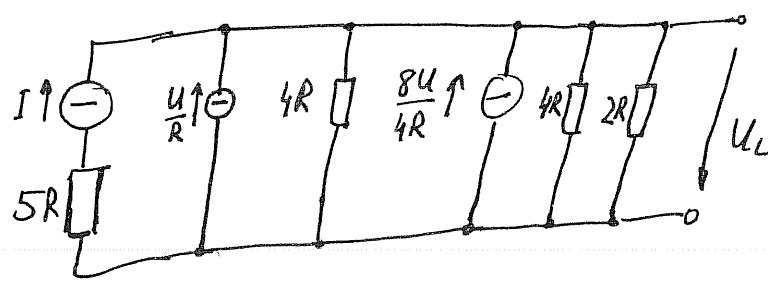


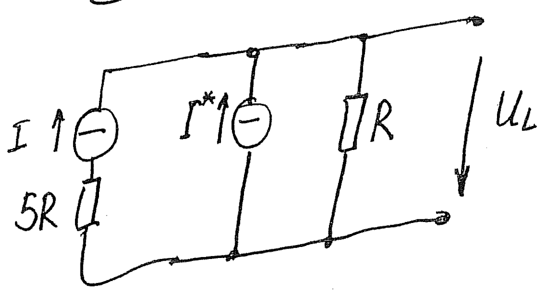
a)



$$\underbrace{\underbrace{4R \parallel 4R}_{2R} \parallel 2R}_{R = R_i}$$

b)





$$I^* = \frac{U}{R} + \frac{2U}{R} = \frac{3U}{R}$$

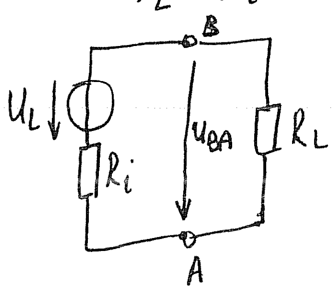
$$U_L = (I + I^*)R =$$

$$= IR + \frac{3U}{\cancel{R}}\cancel{R} = \underline{\underline{IR + 3U}}$$

für $I = \frac{3U}{R} \Rightarrow U_L = 3U + 3U = 6U$

c) für Leistungsanpasung:

$$R_L = R_i = R$$

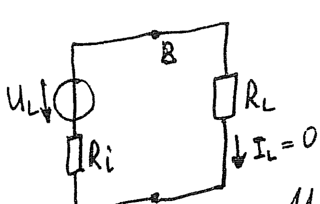


$$U_{AB} = -U_{BA} = -\frac{U_L R_L}{R_L + R_i} = -\frac{U_L \cancel{R}}{2\cancel{R}} = -\frac{U_L}{2}$$

$$U_{AB} = -\frac{6U}{2} = \underline{\underline{-3U}}$$

d) $$P_{RL} = \frac{U_{AB}^2}{R_L} = \frac{(-3U)^2}{R} = \underline{\underline{\frac{9U^2}{R}}}$$

e)

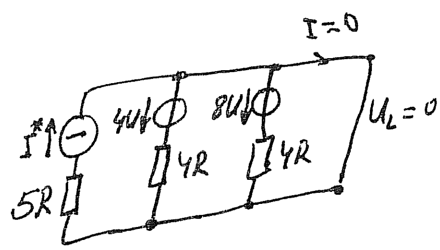


$$I_L = 0 \Rightarrow U_L = 0$$

$$U_L = IR + 3U = 0$$

$$I^* = I = \underline{\underline{-\frac{3U}{R}}}$$

f)



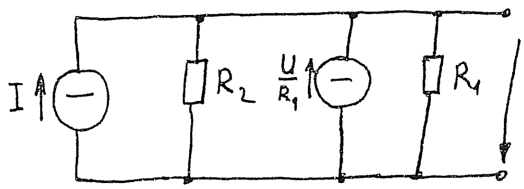
$$P_Q = I^{*2}\,5R + \frac{(4U)^2}{4R} + \frac{(8U)^2}{4R} =$$

$$= \frac{9U^2}{R^2}\cdot 5R + \frac{16U^2}{4R} + \frac{64U^2}{4R} =$$

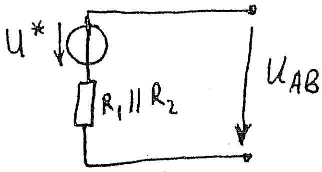
$$= \frac{45U^2}{R} + \frac{4U^2}{R} + \frac{16U^2}{R} = \underline{\underline{\frac{65U^2}{R}}}$$

Aufgabe 4

a)



$U_{AB} = 30\,V$

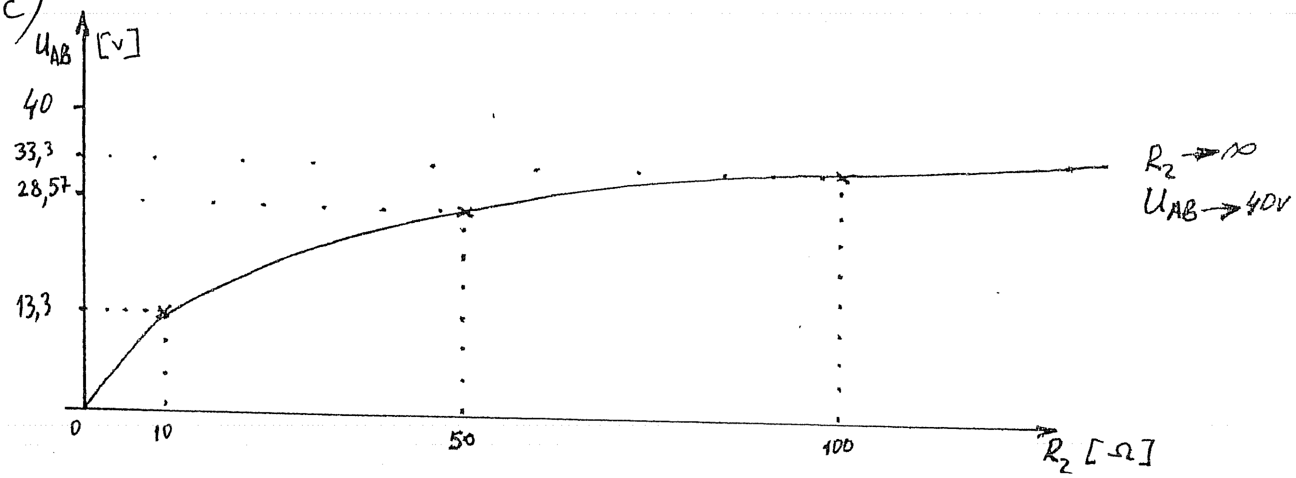


$$U^* = \left(I + \frac{U}{R_1}\right) \cdot \frac{R_1 R_2}{R_1 + R_2} = U_{AB}$$

a) $$R_2 = \frac{U_{AB} \cdot R_1}{I R_1 + U - U_{AB}} = \frac{30\,V \cdot 20\,\Omega}{1A \cdot 20\,\Omega + 20V - 30V} = \frac{600\,\cancel{V}\,\Omega}{10\,\cancel{V}} = \underline{\underline{60\,\Omega}}$$

b) $$U_{AB} = \left(I + \frac{U}{R_1}\right) \cdot \frac{R_1 R_2}{R_1 + R_2} = \left(1A + \frac{20\,V}{20\,\Omega}\right) \cdot \frac{20 R_2}{20 R_2} = \underline{\underline{\frac{40 R_2}{20 + R_2}\,V}}$$

c)

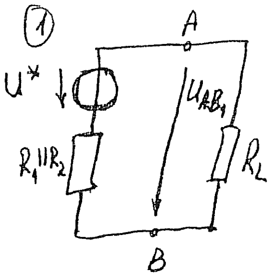


d) $$U_b = 0 \; ; \quad \frac{R_x}{6R_2} = \frac{\cancel{R_2}}{2\cancel{R_2}} \Rightarrow R_x = \frac{6 R_2}{\cancel{2}} = 3 R_2$$

e) für $R_2 = 60\,\Omega$; $R_x = 3 \cdot 60 = 180\,\Omega$ $\Rightarrow$ $\{ R_L = (R_x + 6R_2) \| (R_2 + 2R_2) = \underline{135\,\Omega} \}$

$$R_L = \frac{9R_2 \cdot \cancel{3}R_2}{_4\cancel{12} R_2} = \frac{9}{4} R_2 = 135\,\Omega$$

①



$R_L = 135\,\Omega$

$$U_{AB_1} = \frac{U_1^* \cdot 135\,\Omega}{R_1 \| R_2 + 135\,\Omega} = \frac{30V \cdot 135\,\Omega}{15\,\Omega + 135\,\Omega} = \frac{4050\,V\cancel{\Omega}}{150\,\cancel{\Omega}} = \underline{\underline{27\,V}}$$

für $U^* = \left(I + \frac{U}{R_1}\right) \frac{R_1 R_2}{R_1 + R_2}$

$R_1 \| R_2 = \frac{R_1 R_2}{R_1 + R_2} = 15\,\Omega$

$$P_{L_1} = \frac{U_{AB_1}^2}{R_L} = \frac{27^2\,V^2}{135\,\Omega} = \underline{\underline{5{,}4\,W}}$$

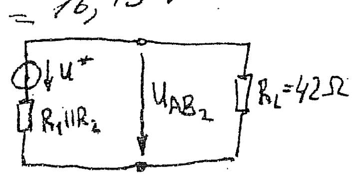
② für $R_2 = R_X = 20\,\Omega$; $R_L = 42\,\Omega$

$U^* = 20V$

$R_1 \| R_2 = 10\,\Omega$

$$U_{AB_2} = \frac{20 \cdot 42\,V\cancel{\Omega}}{52\,\cancel{\Omega}} = 16{,}15\,V$$

$$P_{V_2} = \frac{U_{AB_2}^2}{R_L} = \frac{16{,}15^2\,V^2}{42\,\Omega} = \underline{\underline{6{,}21\,W}}$$



Aufgabe 5

Algemein $i = \frac{U_i}{R}$

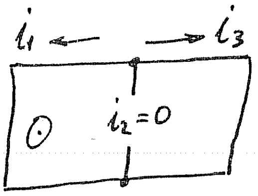
i: Strom in geschlossener Schleife
U_i: induzierte Spannung
R: Schleifenwiderstand
A: Schleifenfläche

$$U_i = -\cancel{N}^{1}\frac{d\Phi}{dt} = -A\frac{dB(t)}{dt} = A\cdot B_0\cdot\omega\cdot\sin\omega t$$

, da $\frac{dB(t)}{dt} = B_0\frac{d(1+\cos\omega t)}{dt} = -B_0\cdot\omega\cdot\sin\omega t$

a) $R = \rho\cdot\frac{b}{\pi r^2}$ πr^2 – Drahtquerschnittsfläche

b)

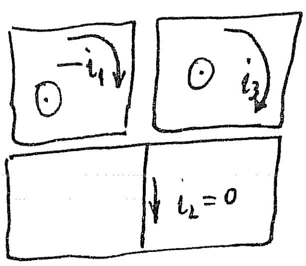


$i_1 = -i_3 = i_b$

mit $R_B = 8R = \frac{\rho 8b}{\pi r^2}$; $A = 2b\cdot 2b = 4b^2$

$$i_b = \frac{4b^{\cancel{2}}\, B_0\cdot\omega\cdot\sin\omega t}{\frac{\cancel{\rho}\cdot 8\cancel{b}}{\pi r^2}} = \frac{\pi r^2 B_0\cdot b\cdot\omega\cdot\sin\omega t}{2\rho}$$

c)



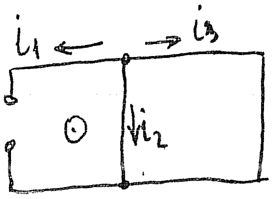
Da die Schleifen sind gleich groß:

$-i_1 = i_3 = i_c$

$i_2 = 0$ (Überlagerung $-i_1, i_3$)

$$i_c = i_b = \frac{\omega\cdot b\cdot\pi r^2 B_0\sin\omega t}{2\rho}$$

d)



$i_1 = 0$; $i_3 = -i_2 = i_c$

$R_d = 6R = \frac{\rho\cdot 6b}{\pi r^2}$; $A = 2b^2$

$$i_c = \frac{\cancel{2}b^{\cancel{2}}\cdot B_0\cdot\omega\cdot\sin\omega t}{\frac{\rho\cdot\cancel{6}\cancel{b}}{\pi r^2}} = \frac{\pi r^2 b\cdot B_0\cdot\omega\cdot\sin\omega t}{3\rho}$$

e) Über S_1 liegt die induzierte Spannung der linken Schleife

$$U_{iL} = 2b^2\cdot\omega\cdot B_0\sin\omega t$$

zusätzlich überlagert sich der Spannungsabfall am mittleren Leiter

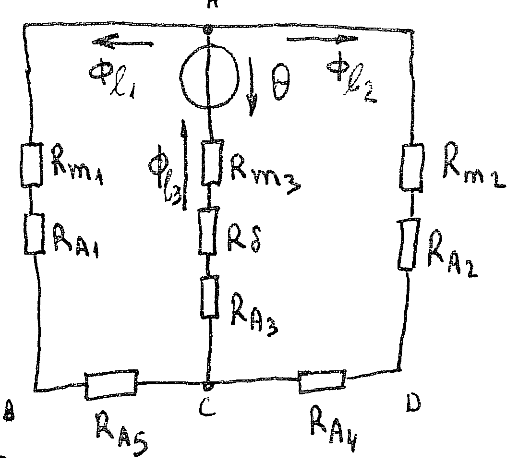
$U_{iM} = R_M i$ da $R_M = \frac{\rho\cdot 2b}{\pi r^2}$ $i = \frac{\pi r^2\cdot b\cdot B_0\cdot\omega\cdot\sin\omega t}{3\rho}$

$U_{iM} = \frac{2}{3}\cdot b^2\cdot B_0\cdot\omega\cdot\sin\omega t$

$$U_{iS1} = U_{iL} + U_{iM} = \left(2+\frac{2}{3}\right)\cdot\omega\cdot b^2\cdot B_0\cdot\sin\omega t = \frac{8}{3}\,\omega\cdot b^2\cdot B_0\cdot\sin\omega t$$

Aufgabe 6

a)



b) Kreis symetrisch

$\Phi_{l_1} = \frac{\Phi_{l_3}}{2} = \Phi_{l_2}$, da $\Phi_{l_3} = \Phi_\delta$ (keine Streuung) $A_\delta = h^2 = 100\,mm^2 = 100 \cdot 10^{-6}\,m^2$

$$\Phi_\delta = \sqrt{F_L \cdot 2\mu_0 \cdot A_\delta} = \sqrt{102\,N \cdot 2 \cdot 1{,}257 \cdot 10^{-6}\,H/m \cdot 100 \cdot 10^{-6}\,m^2} =$$
$$= 1{,}6 \cdot 10^{-4}\,Vs$$

$$\Phi_{l_1} = \frac{1{,}6 \cdot 10^{-4}\,Vs}{2} = \underline{\underline{0{,}8 \cdot 10^{-4}\,Wb}}$$

c) $V_\delta = \Phi_\delta \cdot R_\delta$ $\qquad R_\delta = \frac{\delta}{\mu_0 A_\delta} = \frac{15 \cdot 10^{-3}\,m}{1{,}257 \cdot 10^{-6}\,H/m \cdot 100 \cdot 10^{-6}\,m^2} = 119{,}3 \cdot 10^{6}\,\frac{1}{H}$

$$V_\delta = 1{,}6 \cdot 10^{-4}\,Vs \cdot 119{,}3 \cdot 10^{6}\,\frac{A}{Vs} = 190{,}88 \cdot 10^{2}\,A$$

d) $\Theta = NI = \sum_{i=1}^{n} H \cdot l$; Umlauf rechts oder links, ADC oder ABC

$$\sum H \cdot l_{(ABC)\,\text{links}} = H_1 \cdot l_1 + H_{A1} \cdot \frac{h}{2} + H_{A5} \cdot l_5 + H_{A3} \cdot \frac{h}{2} + H_\delta \cdot \delta + H_3 \cdot l_3$$

(keine Streuung)

$B_3 = B_\delta = \frac{\Phi_\delta}{A_\delta} = \frac{1{,}6 \cdot 10^{-4}\,Vs}{100 \cdot 10^{-6}\,m^2} = 1{,}6\,T$ oder auch $B_\delta = \sqrt{\frac{2\mu_0 F_L}{A_\delta}} = 1{,}6\,T \Rightarrow$ für Dynamoblech $\boxed{H_3 = 37\,A/cm}$

$\boxed{H_\delta = \frac{B_\delta}{\mu_0} = \frac{1{,}6\,T}{1{,}257 \cdot 10^{-6}\,H/m} = 1{,}27 \cdot 10^{6}\,A/m = \boxed{1{,}27 \cdot 10^{4}\,A/cm}}$; Magn. Kreis ist symetrisch $B_1 = B_2 = \frac{B_3}{2}$,

da $\Phi_\delta = \Phi_3 = 2\Phi_1 = 2\Phi_2 = 2\Phi_5 = 2\Phi_4$

$B_1 = \frac{\Phi_{l_1}}{A_1} = \frac{0{,}8 \cdot 10^{-4}\,Vs}{100 \cdot 10^{-6}\,m^2} = 0{,}8\,T$; $B_5 = B_1$, weil $\Phi_5 = \Phi_1$

$B_{A3} = B_\delta$

aus magn. Kennlinie für Dynamoblech

$\boxed{H_1 = H_2 = 2\,A/cm}$

für Walzstahl

$\boxed{H_{A1} = H_{A5} = H_{A4} = H_{A2} = 7{,}5\,A/cm}$

für Walzstahl

$\boxed{H_{A3} = 50\,A/cm}$

$$\sum H \cdot l_{(ABC)} = 2\,A/cm \cdot 16\,cm + 7{,}5\,A/cm \cdot 0{,}5\,cm + 7{,}5\,A/cm \cdot 8\,cm + 50\,A/cm \cdot 0{,}5\,cm + 1{,}27 \cdot 10^{4}\,A/cm \cdot 1{,}5\,cm + 37\,A/cm \cdot 4\,cm =$$
$$= 32\,A + 3{,}75\,A + 60\,A + 25\,A + 19050\,A + 148\,A = 19318{,}75\,A = \Theta$$

e) $NI = \Theta = N \cdot \frac{U}{R} \Rightarrow N = \frac{\Theta \cdot R}{U}$ $\qquad N = \frac{19318{,}75\,A \cdot 100\,\Omega}{220\,V} = 8782$ Windungen

Aufgabe 7

a) $\underline{U}_{R2} = \dfrac{\underline{U}_0 \cdot R_2}{2R_2} = \dfrac{\underline{U}_0}{2} = 5\,V \cdot e^{j0°}$

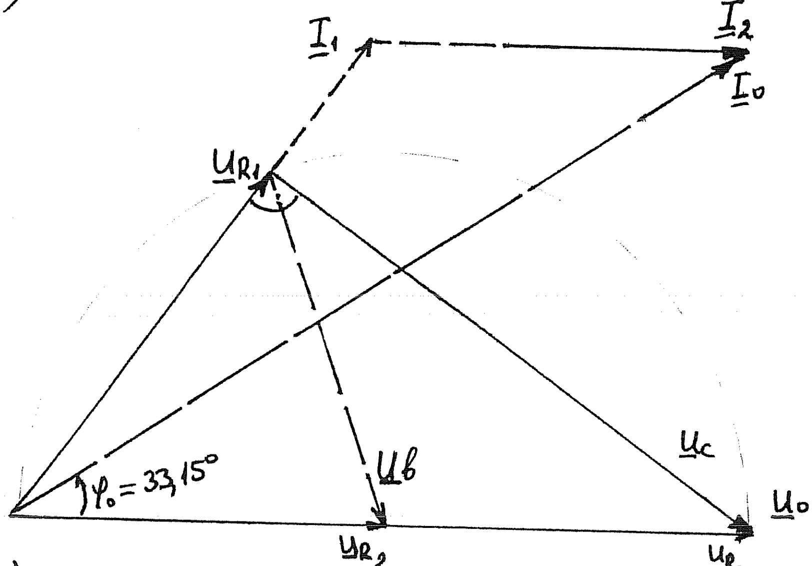
$\underline{U}_C = \dfrac{\underline{U}_0 \cdot \frac{1}{j\omega C}}{R_1 + \frac{1}{j\omega C}} = \dfrac{\underline{U}_0}{1 + j\omega R_1 C} = \dfrac{10 \cdot e^{j0°}}{1 + j\,750 \cdot 10^{-3}} = \dfrac{10 \cdot e^{j0°}}{1 + j\,0{,}75} =$

$= \dfrac{10 \cdot e^{j0°}}{1{,}25 \cdot e^{j36{,}87°}} = 8 \cdot e^{-j36{,}87}$

$\underline{I}_2 = \dfrac{\underline{U}_{R2}}{R_2} = \dfrac{5 \cdot e^{j0°}}{1\,k\Omega} = 5\,mA \cdot e^{j0°}$

$\underline{I}_1 = \underline{U}_C \cdot j\omega C = 8 \cdot e^{-j36{,}87} \cdot 10^{-3}\, e^{j90°} = 8\,mA \cdot e^{j53{,}13°}$

b)



Aus Zeigerdiagramm

$\underline{U}_0 = \underline{U}_{R2} + \underline{U}_{R2} = \underline{U}_{R1} + \underline{U}_C \Rightarrow$

$\underline{U}_{R1} = \underline{U}_0 - \underline{U}_C = 10 + j0 - 6{,}4 + j4{,}8 =$
$= 3{,}6 + j4{,}8 = 6\,e^{j53{,}13°}$

$\underline{U}_b = \underline{U}_C - \underline{U}_{R2} = \underline{U}_{R2} - \underline{U}_{R1} \Rightarrow$
$= 8 \cdot e^{-j36{,}87°} - 5\,e^{j0°} = 6{,}4 - j4{,}8 - 5 + j0 =$
$= 1{,}4 - j4{,}8 = 5\,e^{-j73{,}74°}$

$\underline{I}_0 = \underline{I}_1 + \underline{I}_2 = 11{,}7\,mA\,e^{j33{,}15°}$

c) Scheinleistung: $S = \underline{I}_0\,\underline{U}_0 = 10\,V \cdot 11{,}7\,mA = 117\,mW$

Blindleistung: $Q = \underline{U}_0 \cdot \underline{I}_0 \sin\varphi_0 = 64\,mW$

Wirkleistung: $P = \underline{U}_0 \cdot \underline{I}_0 \cos\varphi_0 = 97{,}96\,mW$

d) Thaleskreis;

Kreis mit $d = \underline{U}_0$; $r = \dfrac{\underline{U}_0}{2}$

e) $R_1 = 0\,\Omega$: $\underline{U}_{R1} = 0\,V$, $\underline{U} = \underline{U}_{R2} \rightarrow \varphi = 0°$

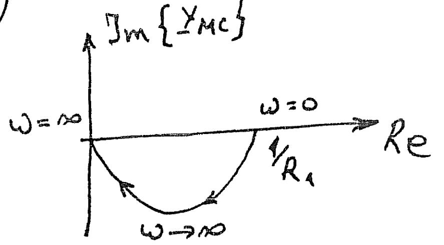
$R_1 = \infty\,\Omega$: $\underline{U}_C \rightarrow 0\,V$, $\underline{U}_b = -\underline{U}_{R2} \rightarrow \varphi = -180°$

Aufgabe 8

a) $\underline{Y}_{MC} = \frac{1}{\underline{Z}_{MC}} = \frac{1}{R_1 + j\omega L}$;

$\omega = 0$	$\omega = \infty$
$\underline{Y}_{MC} = \frac{1}{R_1}$	$\underline{Y}_{MC} = 0$

b)



c) $\frac{1}{\underline{Z}_{NC}} = \frac{1}{R_2} + \frac{1}{j\omega L} + \frac{1}{1/j\omega C} = \frac{1}{R_2} + j\left(\omega C - \frac{1}{\omega L}\right)$

$\underline{Z}_{NC} = \frac{R_2}{1 + jR_2\left(\omega C - \frac{1}{\omega L}\right)} \Rightarrow \underline{Z}_{NC} = \frac{R_2 - jR_2^2\left(\omega C - \frac{1}{\omega L}\right)}{1 + R_2^2\left(\omega C - \frac{1}{\omega L}\right)^2}$

d) Parallelschwingkreis, $\omega_0 = \frac{1}{\sqrt{LC}}$

$\mathrm{Im}\{\underline{Z}_{NC}\} = 0$

$\underline{Z}_{NC} = R_2$

e)

ω	0	$\omega = \omega_0$	∞
$\underline{Z}_{NC}$	0	R_2	0

f)