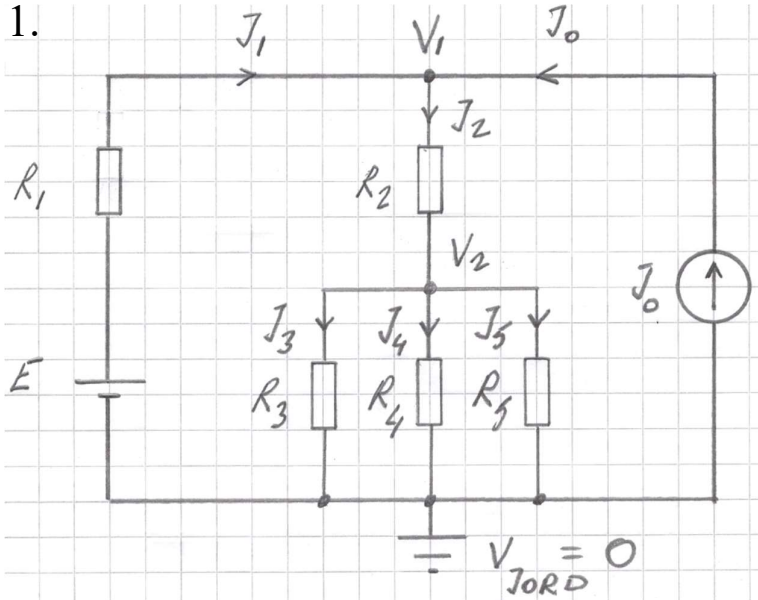
Lösningsförslag till tentamen TMEL08 Eltekniska system 2023-01-13

1.



NOD 1 : $J_0 + J_1 - J_2 = 0$

NOD 2 : $J_2 - J_3 - J_4 - J_5 = 0$

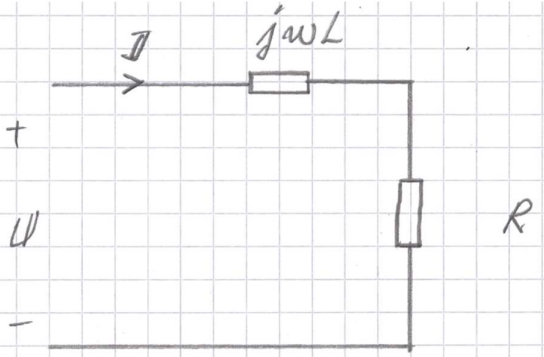
NOD 1 : $J_0 + \frac{E - V_1}{R_1} - \frac{V_1 - V_2}{R_2} = 0$

NOD 2 : $\frac{V_1 - V_2}{R_2} - \frac{V_2 - 0}{R_3} - \frac{V_2 - 0}{R_4} - \frac{V_2 - 0}{R_5} = 0$

$\Rightarrow \quad V_1 = +18\,V \qquad V_2 = +12\,V$

$J_4 = \frac{V_2 - 0}{R_4} \Rightarrow \underline{J_4 = 3{,}0\,mA}$

2a)



$$u(t) = 230\sqrt{2}\sin(100\pi t + 0^\circ)\,V \rightsquigarrow \underline{U} = 230\sqrt{2}\,e^{j0^\circ}\,V$$

$$\underline{I} = \frac{\underline{U}}{R + j\omega L} \Rightarrow$$

$$\underline{I} = \frac{230\sqrt{2}\,e^{j0^\circ}}{24{,}0 + j100\pi \cdot 0{,}0573} =$$

$$= \frac{230\sqrt{2}\,e^{j0^\circ}}{\sqrt{24^2 + 18^2}\cdot e^{j\arctan\frac{18}{24}}} = 7{,}67\sqrt{2}\,e^{-j37^\circ}\,A$$

$$\rightsquigarrow i(t) = 7{,}67\sqrt{2}\sin(100\pi t - 37^\circ)\,A$$

2b)

$$I = \frac{\hat{I}}{\sqrt{2}} = 7{,}67\,A$$

$$P = R I^2 \Rightarrow \underline{P = 1{,}41\,kW}$$

(Q_L)

$$Q = X_L I^2 = |X_L = \omega L| = \underline{1{,}06\,kVAr}$$

$$S = \sqrt{P^2 + Q^2} \Rightarrow \underline{S = 1{,}76\,kVA}$$

ALTERNATIVT SÄTT ATT RÄKNA:

$P = U \cdot J \cdot \cos\varphi$

$(Q_L)\quad Q = U \cdot J \cdot \sin\varphi$

$S = U \cdot J$

$\varphi = \arg \underline{U} - \arg \underline{J} = 37°$

$\uparrow \quad \uparrow$

$0° \quad -37°$

$U = \frac{\hat{U}}{\sqrt{2}} = 230\ V$

2c) $Q = Q_L - Q_C$

$Q = 0 \Rightarrow Q_C = Q_L$

$Q_C = \frac{U^2}{X_C} = /X_C = \frac{1}{\omega C}/ = U^2 \omega C$

$1{,}06 \cdot 10^3 = 230^2 \cdot 100\pi \cdot C \Rightarrow \underline{C = 63{,}7\ \mu F}$

2d) $Q = 0 \Rightarrow S = P$ OCH $\cos\varphi = 1 \rightarrow \varphi = 0°$

$S = U \cdot J \rightarrow 1{,}41 \cdot 10^3 = 230 \cdot J$

$\rightarrow J = 6{,}13\ A \quad \hat{J} = 6{,}13\sqrt{2}\ A$

$\Rightarrow \underline{i(t) = 6{,}13\sqrt{2}\sin(100\pi t)\ A}$

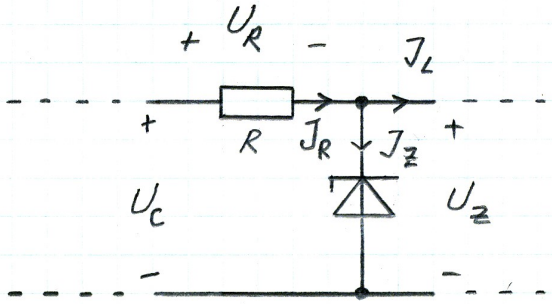
($\varphi = 0°$ INNEBÄR ATT $\arg \underline{J} = \arg \underline{U}$)

3a)

$$\frac{N_1}{N_2} = \frac{\hat{U}_1}{\hat{U}_2} \rightarrow \frac{1500}{N_2} = \frac{230\sqrt{2}}{20}$$

$$\Rightarrow \underline{\underline{N_2 = 92}}$$

3b)



$$R = \frac{U_R}{J_R} = \frac{U_C - U_Z}{J_Z + J_L} \quad \ldots\ldots (1)$$

$$U_C \approx \hat{U}_Z - 2 \cdot 0{,}70 \rightarrow U_C \approx 18{,}6\ V$$

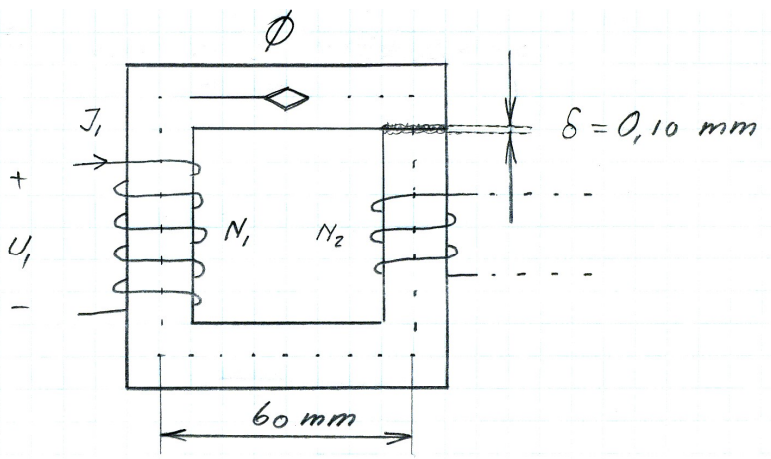
$$(1) \rightarrow R_{MAX} = \frac{18{,}6 - 12}{0{,}100 + 0{,}500} = 11\ \Omega$$

$$P_{Z_{max}} = U_Z \cdot J_{Z_{max}} \rightarrow J_{Z_{max}} = 833\ mA$$

$$(1) \rightarrow R_{MIN} = \frac{18{,}6 - 12}{0{,}833 + 0} \approx 7{,}9\ \Omega$$

ALLTSÅ VÄLJ $\underline{\underline{7{,}9\ \Omega < R < 11\ \Omega}}$

3c)



$$N_1 J_1 = R_m \cdot \Phi \quad \ldots . (2)$$

JÄRNKÄRNANS MEDELLÄNGD $l_{Fe} = 4 \cdot 60 = 240\,mm$

TVÄRSNITTSAREAN $A_{Fe} = 15 \cdot 15\,mm^2 = 225\,mm^2$

$$R_{m_{Fe}} = \frac{l_{Fe}}{\mu_r \mu_0 A_{Fe}} \Rightarrow R_{m_{Fe}} \approx 169765\ \frac{A}{Vs}$$

FÖRSUMMA LUFTGAPSSPRIDNINGEN $\Rightarrow A_\delta \approx A_{Fe}$

$$R_{m_\delta} = \frac{\delta}{\mu_0 A_\delta} \Rightarrow R_{m_\delta} \approx 353678\ \frac{A}{Vs}$$

FALL 1: INGET LUFTGAP $\Rightarrow R_m = R_{m_{Fe}}$

FALL 2: LUFTGAP $\Rightarrow R_m = R_{m_{Fe}} + R_{m_\delta}$

OM J_1 ÄR KONSTANT $\Rightarrow$

$$N_1 J_1 = R_{m_{Fe}} \cdot \Phi_1$$

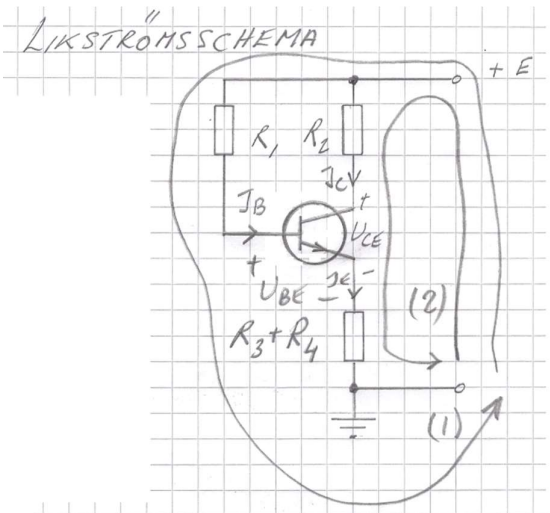
$$N_1 J_1 = \left(R_{m_{Fe}} + R_{m_\delta}\right) \cdot \Phi_2 \quad \Rightarrow$$

$$R_{m_{Fe}} \cdot \Phi_1 = \left(R_{m_{Fe}} + R_{m_S}\right) \cdot \Phi_2 \quad \Rightarrow$$

$$\frac{\Phi_2}{\Phi_1} = \frac{R_{m_{Fe}}}{R_{m_{Fe}} + R_{m_S}} \Rightarrow \frac{\Phi_2}{\Phi_1} \approx 0,32$$

ALLTSÅ, Φ MINSKAR MED 68 %
(32 % AV Φ ÅTERSTÅR)

4a)



$$h_{FE} = \frac{J_C}{J_B} \Rightarrow J_B = 20\,\mu A$$

$$J_E = J_B + J_C \rightarrow J_E = 4020\,\mu A$$

$$+E - R_1 J_B - U_{BE} - (R_3 + R_4) J_E = 0 \ldots (1)$$

$$(1) \rightarrow R_1 \approx 0{,}49\,M\Omega$$

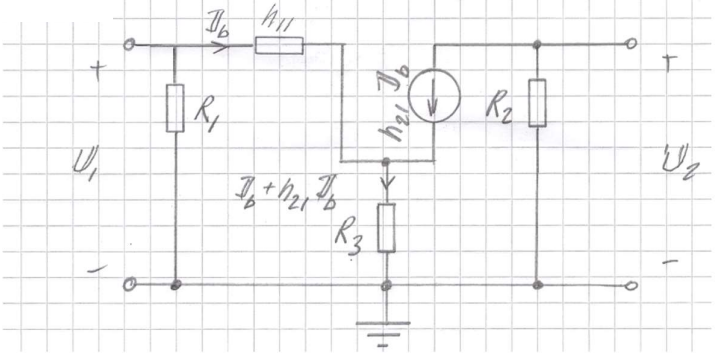
4b)

$$+E - R_2 J_C - U_{CE} - (R_3 + R_4) J_E = 0 \ldots (2)$$

$$(2) \rightarrow U_{CE} = 6{,}4\,V$$

4c)

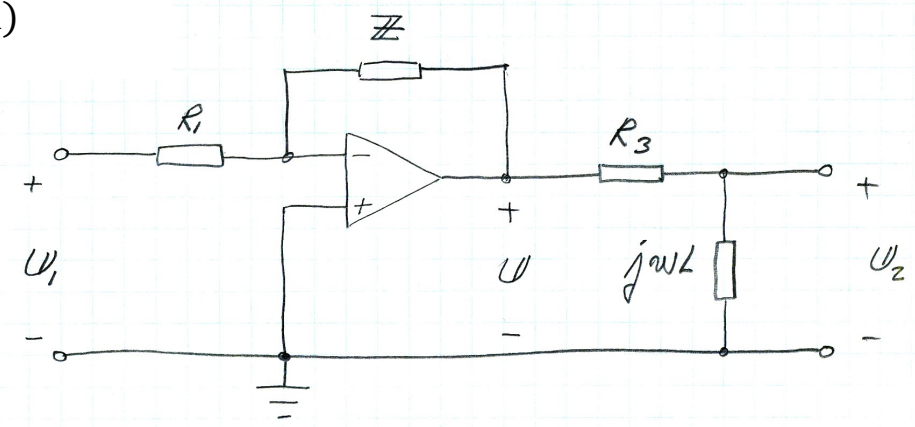
EKVIVALENT SIGNALSCHEMA



$$A = \frac{U_2}{U_1} = \frac{-h_{21} J_b R_2}{R_3 (J_b + h_{21} J_b) + h_{11} J_b}$$

$$|A| = 50 \Rightarrow R_3 = 10\,\Omega \rightarrow R_4 = 380\,\Omega$$

5a)



$$\frac{U_2}{U_1} = \frac{U_2}{U} \cdot \frac{U}{U_1} \quad \ldots (1)$$

$$U_2 = U \cdot \frac{j\omega L}{R_3 + j\omega L} \rightarrow \frac{U_2}{U} = \frac{j\omega \cdot \frac{L}{R_3}}{1 + j\omega \cdot \frac{L}{R_3}}$$

$$\Rightarrow \frac{U_2}{U} = \frac{j\frac{\omega}{1587}}{1 + j\frac{\omega}{1587}}$$

$$\frac{U}{U_1} = -\frac{Z}{R_1} \quad \text{där} \quad Z = \frac{\frac{1}{j\omega C} \cdot R_2}{\frac{1}{j\omega C} + R_2} =$$

$$= \frac{R_2}{1 + j\omega C R_2} \Rightarrow \frac{U}{U_1} = -\frac{R_2}{R_1} \cdot \frac{1}{1 + j\omega C R_2}$$

$$\Rightarrow \frac{U}{U_1} = -10 \cdot \frac{1}{1 + j\frac{\omega}{62500}}$$

$$(1) \Rightarrow \frac{U_2}{U_1} = -10 \cdot \frac{1}{1 + j\frac{\omega}{62500}} \cdot \frac{j\frac{\omega}{1587}}{1 + j\frac{\omega}{1587}}$$

5b)

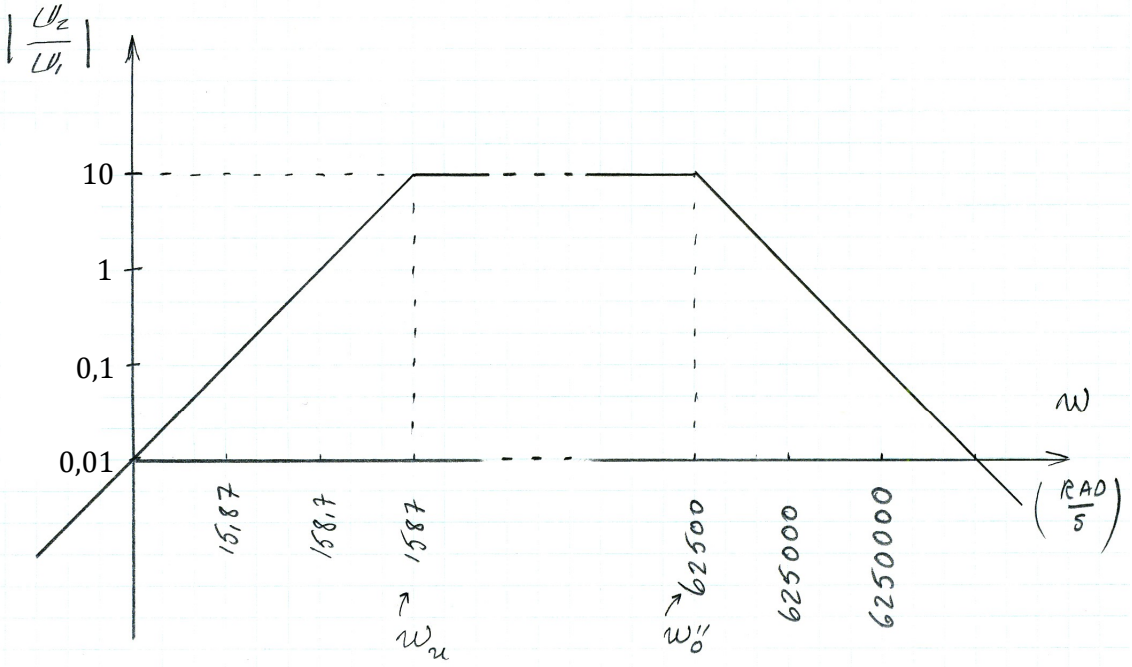
$$\left|\frac{U_2}{U_1}\right| = 10 \cdot \frac{1}{\sqrt{1^2 + \left(\frac{\omega}{62500}\right)^2}} \cdot \frac{\frac{\omega}{1587}}{\sqrt{1^2 + \left(\frac{\omega}{1587}\right)^2}}$$

OM $\omega << 1587 \frac{RAD}{S} \Rightarrow \left|\frac{U_2}{U_1}\right| \approx \frac{10}{1587} \cdot \omega$

OM $1587 \frac{RAD}{S} << \omega << 62500 \frac{RAD}{S} \Rightarrow \left|\frac{U_2}{U_1}\right| = 10$

OM $\omega >> 62500 \frac{RAD}{S} \Rightarrow \left|\frac{U_2}{U_1}\right| = \frac{625000}{\omega}$

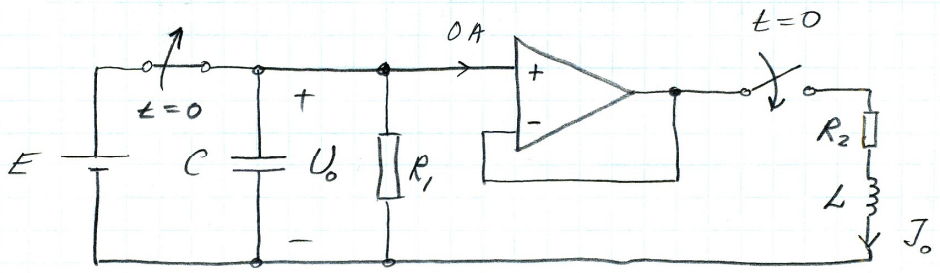
BODEDIAGRAM (AMPLITUDKURVA)



$\omega_u = 2\pi f_u \Rightarrow \underline{f_u \approx 0{,}25 \text{ kHz}}$

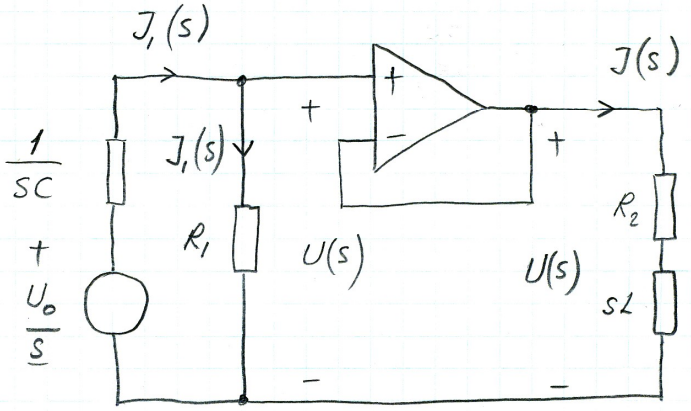
$\omega_o'' = 2\pi f_o'' \Rightarrow \underline{f_o'' \approx 9{,}9 \text{ kHz}}$

6. BEGYNNELSEVILLKOR OM $t < 0$



$$J_0 = 0 \quad \text{OCH} \quad U_0 = E = 9{,}0\ \text{V}$$

OPERATORSCHEMA $(t \geq 0)$



$$\frac{U_0}{s} - \frac{1}{sC} \cdot J_1(s) - R_1 J_1(s) = 0$$

$$J_1(s) = \frac{\frac{U_0}{s}}{\frac{1}{sC} + R_1} = \frac{U_0}{R_1} \cdot \frac{1}{s + \frac{1}{CR_1}}$$

$$U(s) = R_1 \cdot J_1(s) \Rightarrow \quad U(s) = U_0 \cdot \frac{1}{s + \frac{1}{CR_1}}$$

$$\Rightarrow U(s) = 9{,}0 \cdot \frac{1}{s + 100} \rightsquigarrow u(t) = 9{,}0 \cdot e^{-100t}\ \text{V}$$

$$I(s) = \frac{U(s)}{R_2 + sL} \Rightarrow$$

$$I(s) = \frac{9{,}0 \cdot \frac{1}{s+100}}{10 + s \cdot 0{,}200} = 45 \cdot \frac{1}{s+100} \cdot \frac{1}{s+50}$$

PARTIALBRÅKSUPPDELNING

$$\frac{45}{(s+100)(s+50)} = \frac{A}{s+100} + \frac{B}{s+50} =$$

$$= \frac{A(s+50) + B(s+100)}{(s+100)(s+50)}$$

$$\begin{aligned} A + B &= 0 \\ 50A + 100B &= 45 \end{aligned} \Rightarrow \begin{aligned} A &= -0{,}90 \\ B &= 0{,}90 \end{aligned}$$

$$\Rightarrow I(s) = -0{,}90 \cdot \frac{1}{s+100} + 0{,}90 \cdot \frac{1}{s+50}$$

$$\rightsquigarrow \underline{\underline{i(t) = 0{,}90\, e^{-50t} - 0{,}90\, e^{-100t} \quad A}}$$

ELLER ALTERNATIVT

$$I(s) = -0{,}90 \cdot \frac{1}{(s+75)+25} + 0{,}90 \cdot \frac{1}{(s+75)-25} =$$

$$= 1{,}8 \cdot \frac{25}{(s+75)^2 - 25^2} \rightsquigarrow$$

$$\underline{\underline{i(t) = 1{,}8 \cdot e^{-75t} \cdot \sinh(25t) \quad A}}$$