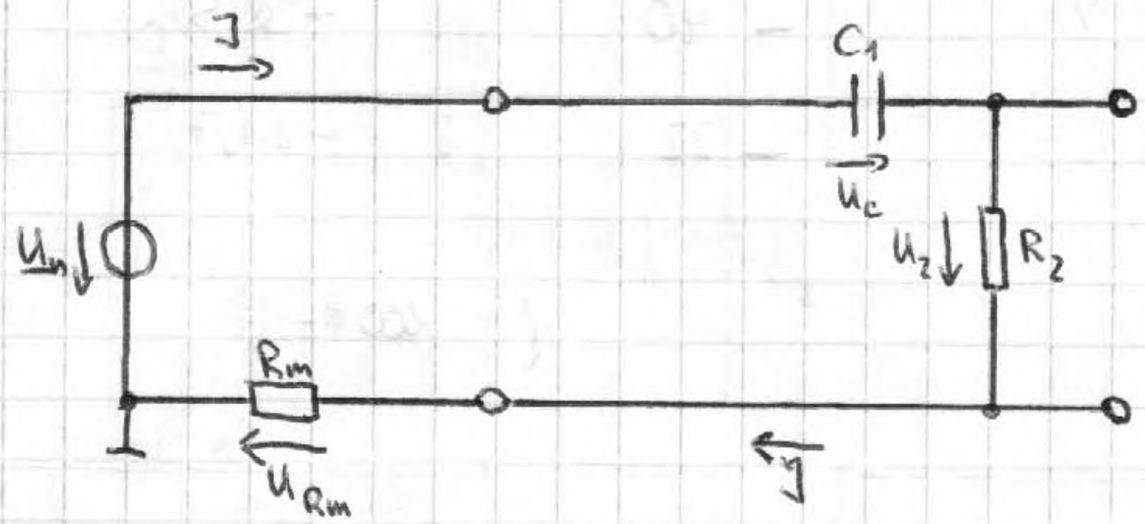
27.04.04

206a

# ET - Praktikum 2

## R, L, C bei Gleich- und Wechselstrom

**1.1.**




$C_1 =$

$U_N = 7,01\ V$

$$\underline{I} = \frac{\underline{U_N}}{Z_{ges}} \qquad Z_{ges} = \sqrt{R_2^2 + \left(\frac{1}{2\pi f C_1}\right)^2} =$$

$$\underline{I} = \frac{\underline{U_N}}{\sqrt{R_2^2 + \left(\frac{1}{2\pi \cdot f \cdot C_1}\right)^2}}$$

$$\underline{U_2} = R_2 \cdot \underline{I} = \frac{R_2 \cdot \underline{U_N}}{\sqrt{R_2^2 + \left(\frac{1}{2\pi \cdot f \cdot C_1}\right)^2}} =$$

Wenn $\underline{U_N}$ Gleichspannung ist: $f = 0$

$$\lim_{f \to 0} \underline{U_2} = \frac{U_N \cdot R_2}{\infty} = 0$$

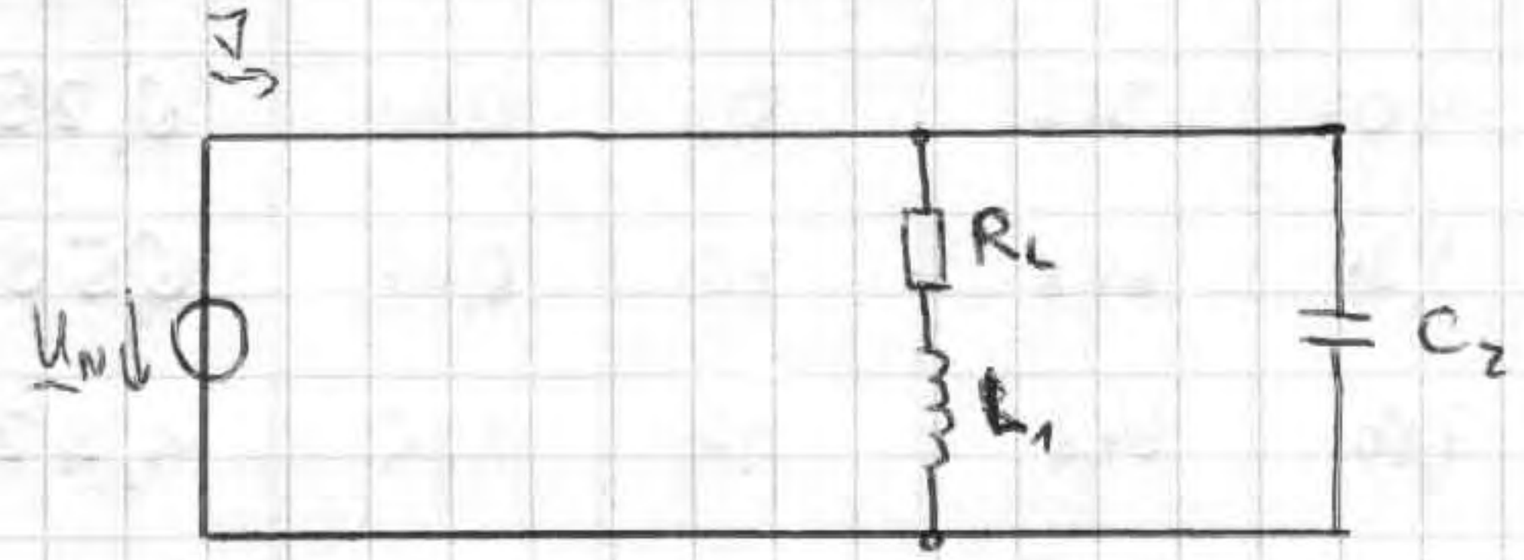
**1.2**

| f[Hz] | gemessen in [V] | | | errechnet in [V] | | | relativer Messfehler [%] | | |
|---|---|---|---|---|---|---|---|---|---|
| | $\underline{U_N}$ | $\underline{U_2}$ | $\underline{U_C}$ | $\underline{U_N}$ | $\underline{U_2}$ | $\underline{U_C}$ | $\underline{U_N}$ | $\underline{U_2}$ | $\underline{U_C}$ |
| — | 7,02 | 0 | 7 | 6,0 | 0 | 6,0 | 17 | — | 14,6 |
| 50 | 7,02 | 3,66 | 5,9 | 6 | 2,3 | 3,7 | 17 | 59 | 59 |
| 100 | 7,02 | 5,26 | 4,46 | 6 | 3,3 | 2,7 | 17 | 59 | 65 |
| 200 | 7,02 | 6,35 | 2,65 | 6 | 4,3 | 1,7 | 17 | 47 | 56 |

| $U_N$ [V] | I [mA] | $I_c$ [mA] | $\varphi$ | f [Hz] | Z [Ω] | $I_c/I$ |
|---|---|---|---|---|---|---|
| 6,52 | 16,12 | 4,07 | 57,6 | 50 | 0,40 | 0,25 |
| 6,76 | 10,02 | 5,96 | 64,8 | 70 | 0,67 | 0,59 |
| 6,89 | 5,51 | 7,80 | 64,8 | 90 | 1,25 | 1,42 |
| 6,95 | 2,45 | 9,78 | 36,5 | 110 | 2,84 | 3,99 |
| 6,97 | 2,38 | 10,61 | 0 | 120 | 2,93 | 4,46 |
| ↓ 7,00 | 4,43 | 12,46 | -50,4 | 140 | 1,56 | 2,78 |
| 7,00 | 7,04 | 14,18 | -72,0 | 160 | 1,00 | 2,01 |
| 7,00 | 10,88 | 16,92 | -79,2 | 190 | 0,64 | 1,56 |
| 7,00 | 13,14 | 18,62 | -82,8 | 210 | 0,53 | 1,42 |

ab 140 Hz → Messgerät für $U_N$ ausgefallen, deshalb wurden weiterhin jeweils 7,00 V angenommen

6.1)




$$\underline{I} = \underline{Z} \cdot \underline{U}_N = U_N$$

$$Z_1 = \sqrt{R_L^2 + X_L^2} = \sqrt{R_L^2 + (2\pi f \cdot L)^2}$$

$$Z_2 = X_C = \frac{1}{2\pi \cdot f \cdot C_2}$$

$$\frac{\underline{U}_C}{\underline{I}} = \frac{\underline{I}}{Z_2}$$

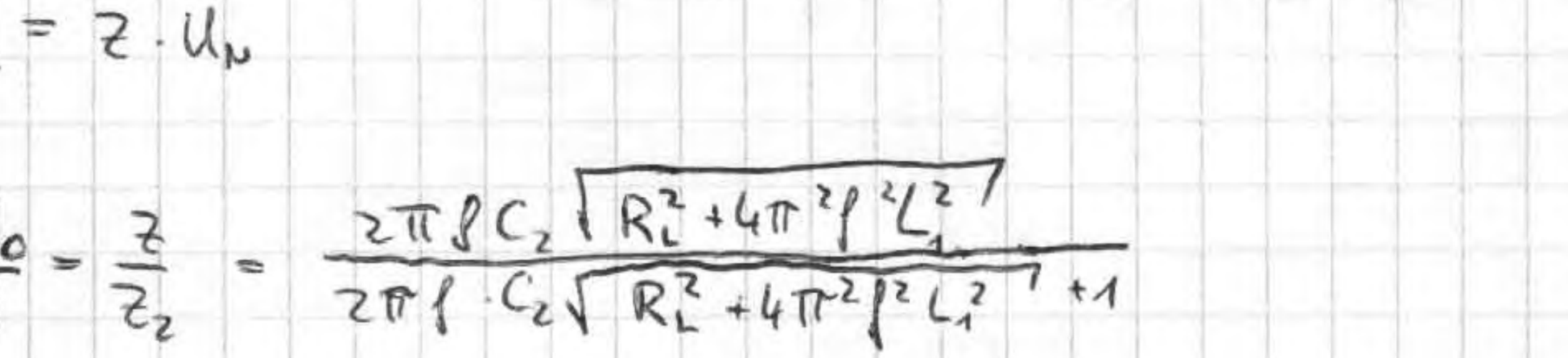
$$f_{res} = \frac{1}{2\pi} \cdot \sqrt{\frac{1}{L_1 C_2} - \frac{R_L^2}{4L_1^2}}$$

$$Z = \frac{Z_1 Z_2}{Z_1 + Z_2} = \frac{\sqrt{R_L^2 + 4\pi^2 f^2 L_1^2}}{2\pi f C_2 \sqrt{R_L^2 + 4\pi^2 f^2 L_1^2} + 1}$$

$$\underline{I} = Z \cdot U_N$$

$$\frac{\underline{U}_C}{\underline{I}} = \frac{Z}{Z_2} = \frac{2\pi f C_2 \sqrt{R_L^2 + 4\pi^2 f^2 L_1^2}}{2\pi f \cdot C_2 \sqrt{R_L^2 + 4\pi^2 f^2 L_1^2} + 1}$$

6.2)

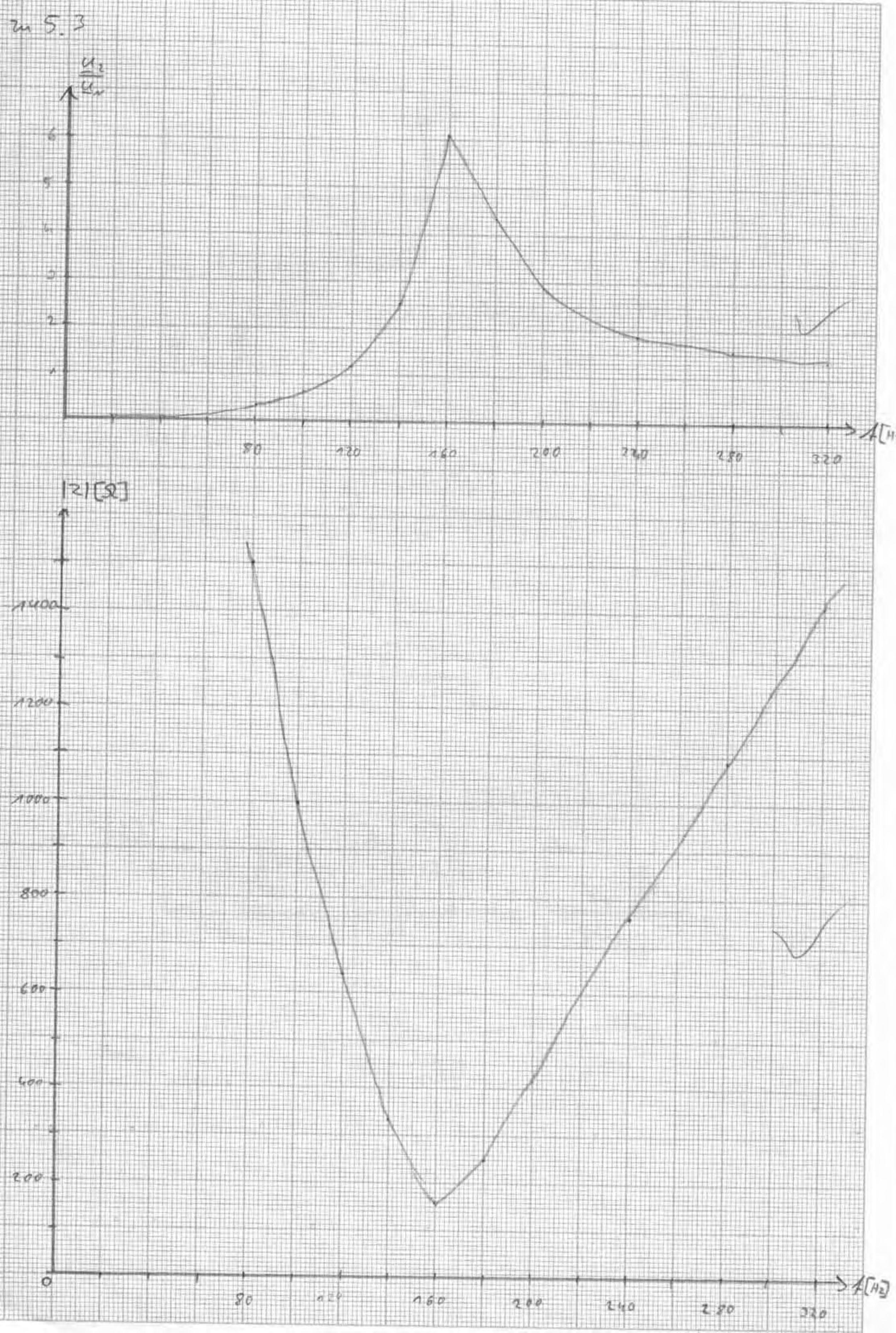



6.3)

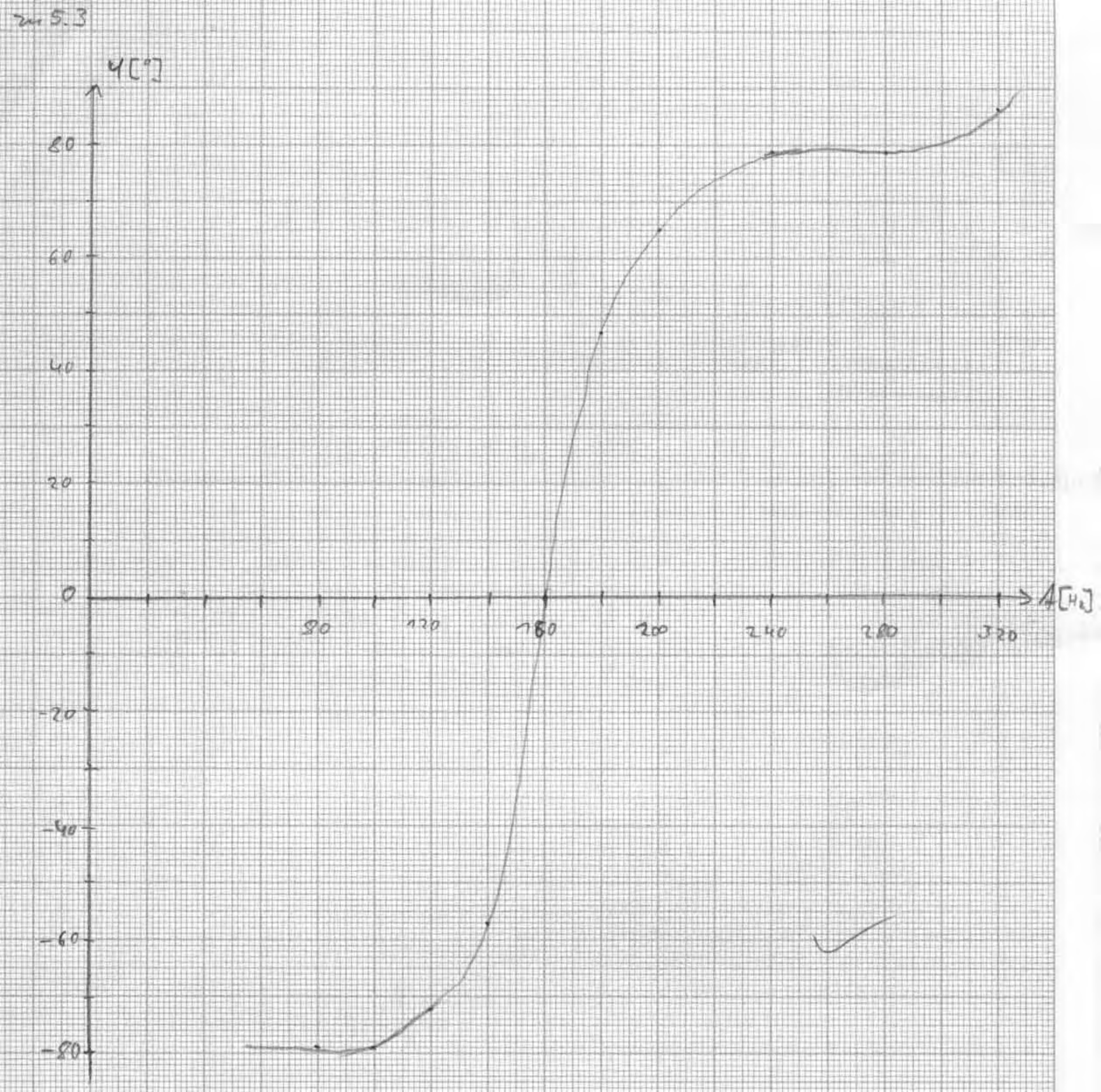
$$f_{res} = \frac{1}{2\pi} \cdot \sqrt{\frac{1}{1\,H \cdot 22 \cdot 10^{-6}\,F} - \frac{(140\,\Omega)^2}{4 \cdot (1\,H)^2}}$$

$$f_{res} = 106{,}72\ Hz$$

Zu 5.3

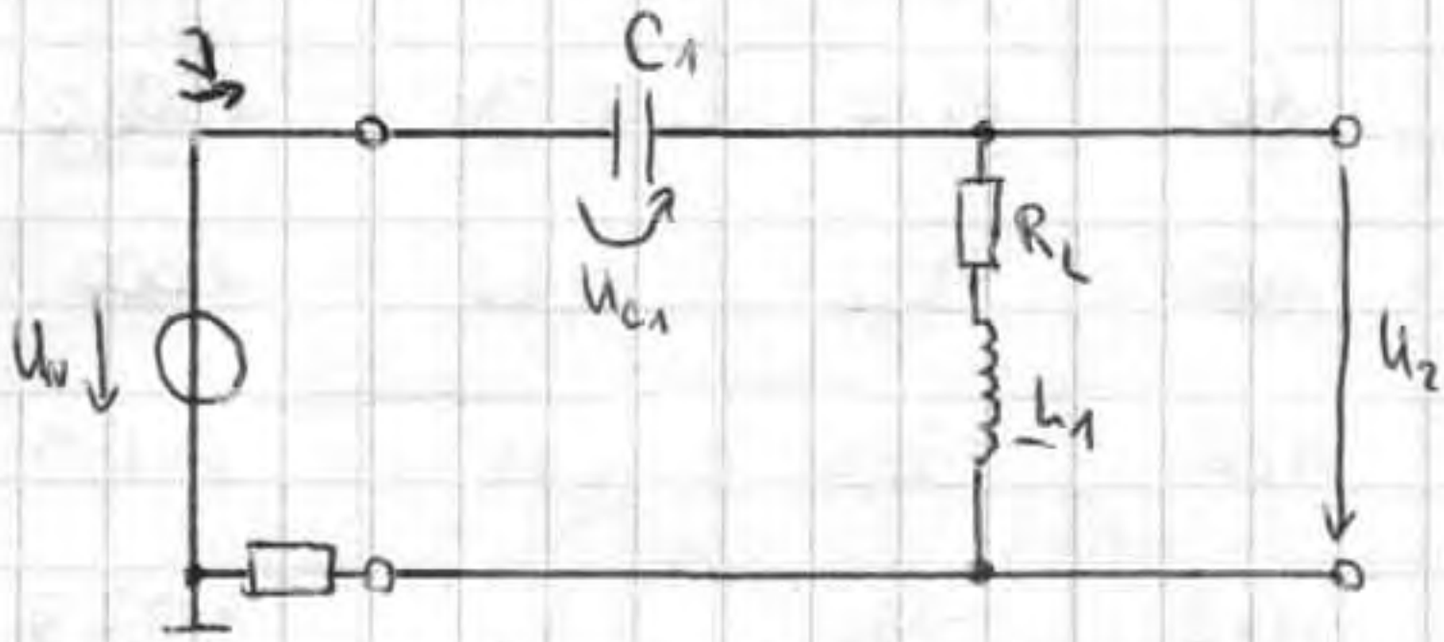

$\frac{U_2}{U_N}$
6
5
4
3
2
1
80
120
160
200
240
280
320
f [Hz]
|Z| [Ω]
1400
1200
1000
800
600
400
200
0
80
120
160
200
240
280
320
f [Hz]

Zu 5.3



| $U_N$ [V] | $U_2$ [V] | $I$ [A] $\cdot 10^{-3}$ | $f_u$ [Hz] | $\varphi_u$ [°] | $\frac{U_2}{U_N}$ | $\lvert Z \rvert$ [Ω] |
|---|---|---|---|---|---|---|
| 7,0 | 2,37 | 4,66 | 80 | -79,2 | 0,34 | 1502,2 |
| 7,0 | 4,31 | 7,0 | 100 | -79,2 | 0,62 | 1000 |
| 6,9 | 7,84 | 10,77 | 120 | -72,0 | 1,14 | 640,7 |
| 6,47 | 16,29 | 19,16 | 140 | -57,6 | 2,52 | 337,7 |
| 5,18 | 31,54 | 31,95 | 160 | 0 | 6,09 | 162,1 |
| 6,08 | 26,78 | 24,20 | 180 | 46,8 | 4,32 | 251,2 |
| 6,67 | 19,18 | 16,05 | 200 | 64,8 | 2,88 | 415,2 |
| 6,98 | 13,05 | 9,14 | 240 | 79,2 | 1,87 | 763,7 |
| 7,06 | 10,78 | 6,48 | 280 | 79,2 | 1,53 | 1089,5 |
| 7,10 | 9,62 | 5,02 | 320 | 86,4 | 1,35 | 1414,3 |

5.1)




$$\underline{Z} = \sqrt{R_L^2 + (X_L - X_C)^2}$$

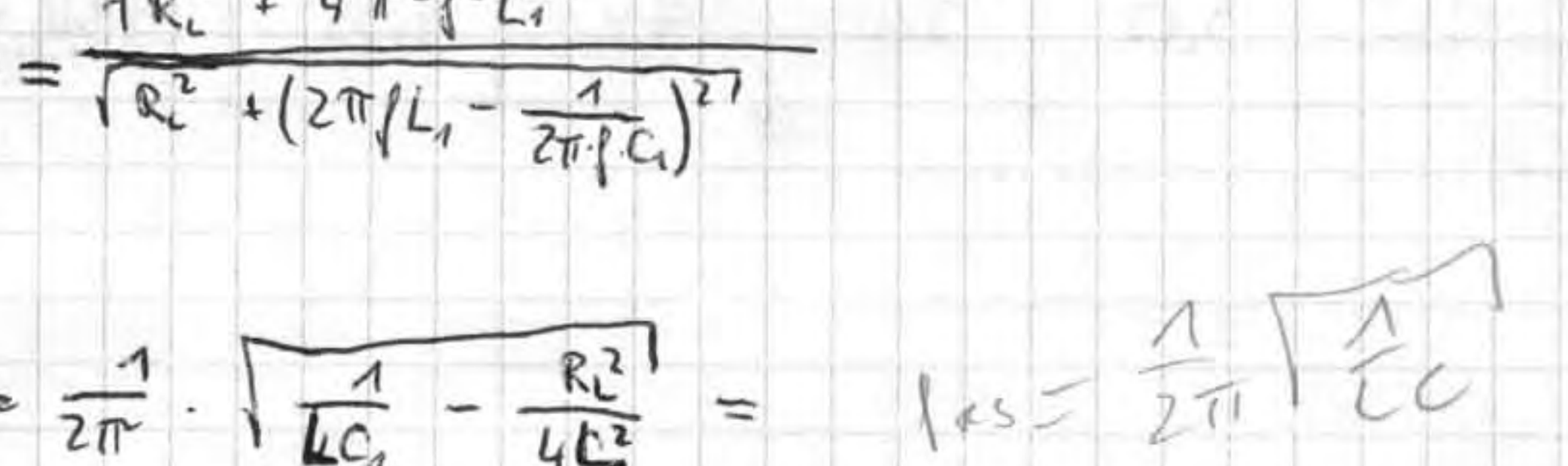
$$\underline{Z} = R_L + j\left(\omega \cdot L_1 - \frac{1}{\omega \cdot C_1}\right) =$$

$$\underline{I} = \frac{U_N}{Z} = \frac{U_N}{\sqrt{R_L^2 + \left(2\pi \cdot f \cdot L_1 - \frac{1}{2\pi f C_1}\right)^2}} =$$

$$\frac{U_2}{U_N} = \frac{\sqrt{R_L^2 + 4\pi^2 f^2 L_1^2}}{\sqrt{R_L^2 + \left(2\pi f L_1 - \frac{1}{2\pi \cdot f \cdot C_1}\right)^2}}$$

$$f_r = \frac{1}{2\pi} \cdot \sqrt{\frac{1}{LC_1} - \frac{R_L^2}{4L^2}} = \quad \text{przy } R_L = 0 \quad = \frac{1}{2\pi}\sqrt{\frac{1}{LC}}$$

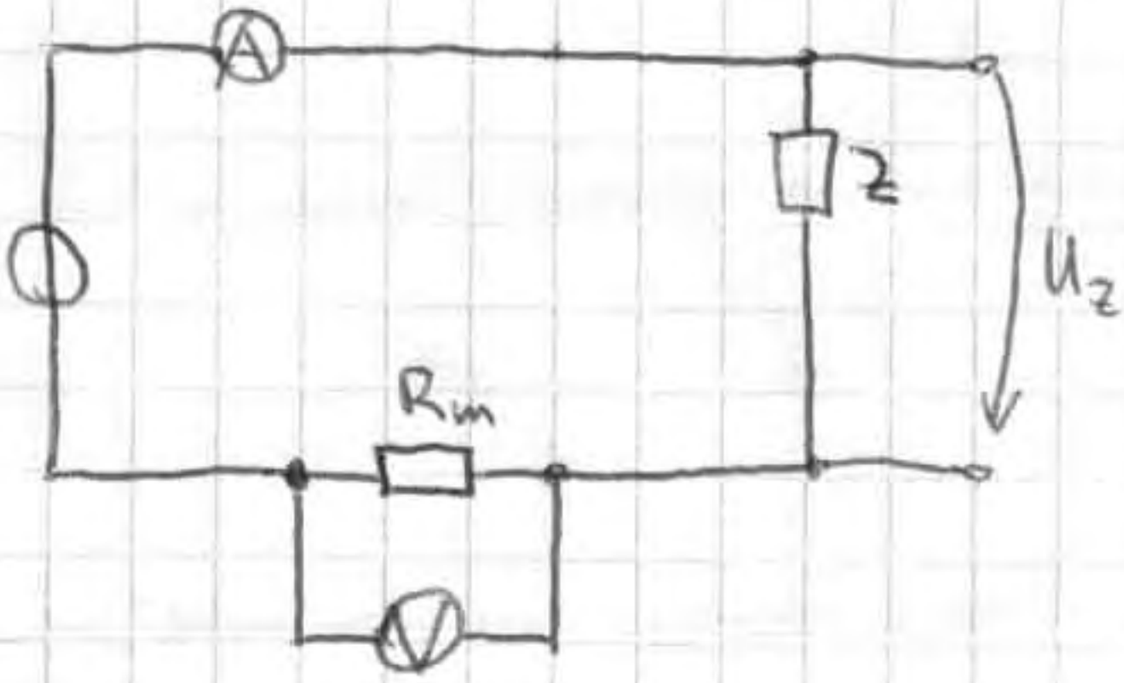
5.2)

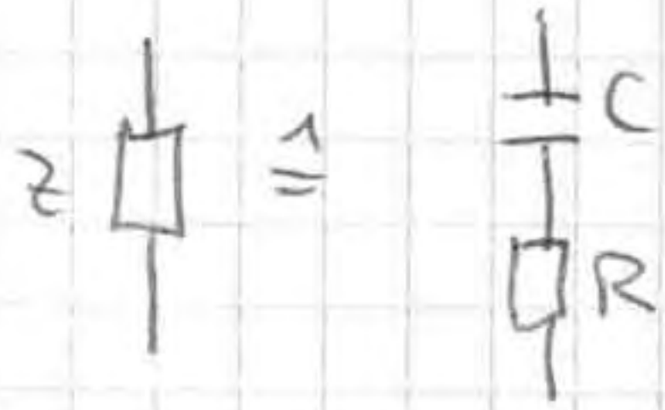



5.3)

| f [Hz] | $U_N$ [V] | $U_2$ [V] | I [A] | $\varphi_n$ [°] |
|---|---|---|---|---|
| 50 | 7,02 | 0,88 | ? | 84° |
| 100 | 7,02 | 4,12 | $< 1 \cdot 10^{-6}$ | 78° |
| 200 | 7,02 | 19,41 | $53 \cdot 10^{-6}$ | 49,1° |

4.1)




4.2) $U_z = 6,12\ V$ $\quad f = 50\ Hz$

$I_z = 0,41\ mA = 4,1 \cdot 10^{-4}\ A$ zu klein

$\varphi = -24°$

Die Stromstärke eilt der Spannung um 24° voraus. Daraus lässt sich schließen, dass der passive Zweipol ein Kondensator sein muss, gekoppelt mit einem ohmschen Widerstand.

$$\underline{Z}_z = R + \frac{1}{j\omega C}$$

$$Z_z = \frac{U}{I} = 15\,k\Omega$$

4.3)

Kondensator ohm. Widerstand

C ?

R ?

| | gerechnet | | gemessen | | Fehler [%] | | |
|---|---|---|---|---|---|---|---|
| f [Hz] | $U_2$ | $\underline{U_2}$ | $U_2$ | $\underline{U_2}$ | $U_2$ | $\underline{U_2}$ | φ [°] |
| 50 | 4,67 | 2,17 | 4,65 | 3,98 | +0,428 | 83,41 | 16,5 |
| 100 | / | 2,26 | / | 3,26 | / | 44,24 | 21,6 |
| 200 | / | 2,17 | / | 2,02 | / | 6,91 | 21,1 |

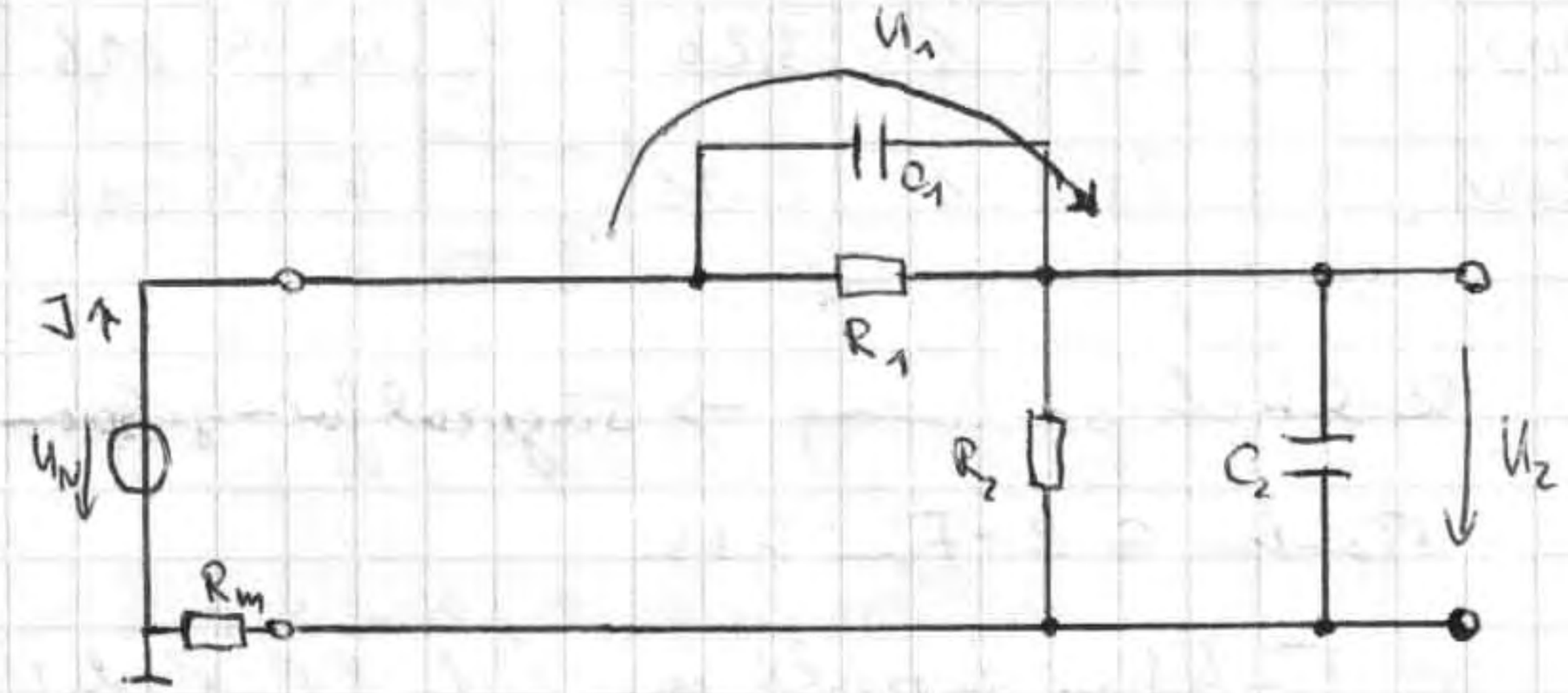
Sägezahnspannung ?

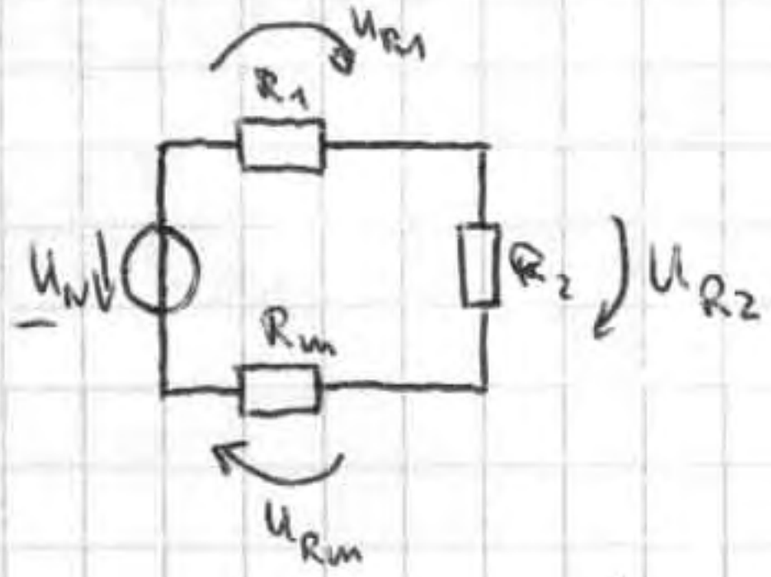
3.3 Rechteckspannung → sägezahnförmige Spannung

Flanken ≙ e-Funktion

e-Funktion entsteht aus Lade- & Entladekurve des Kondensators

3.1)




Wechselstrom:

$$\frac{U_1}{U_2} = \frac{Z_1}{Z_2}$$

$$Z_1 = \frac{1}{\sqrt{R_1^2 + \frac{1}{4\pi^2 f^2 C_1^2}}}$$

$$Z_2 = \frac{1}{\sqrt{\frac{1}{R_2^2} + \frac{1}{4\pi^2 f^2 C_2^2}}}$$

$$U_2 = \frac{U_{N1} \quad Z_2}{Z_1 + Z_2 + R_m}$$

$$\hat{U} = U_2 \cdot \sqrt{2}$$

$$\underline{U_2} = \frac{\hat{U}_n \cdot R_2 + 2\pi f \cdot C_2}{\sqrt{R_2^2 + 4\pi^2 f^2 \cdot C_2^2}}$$

Gleichstrom

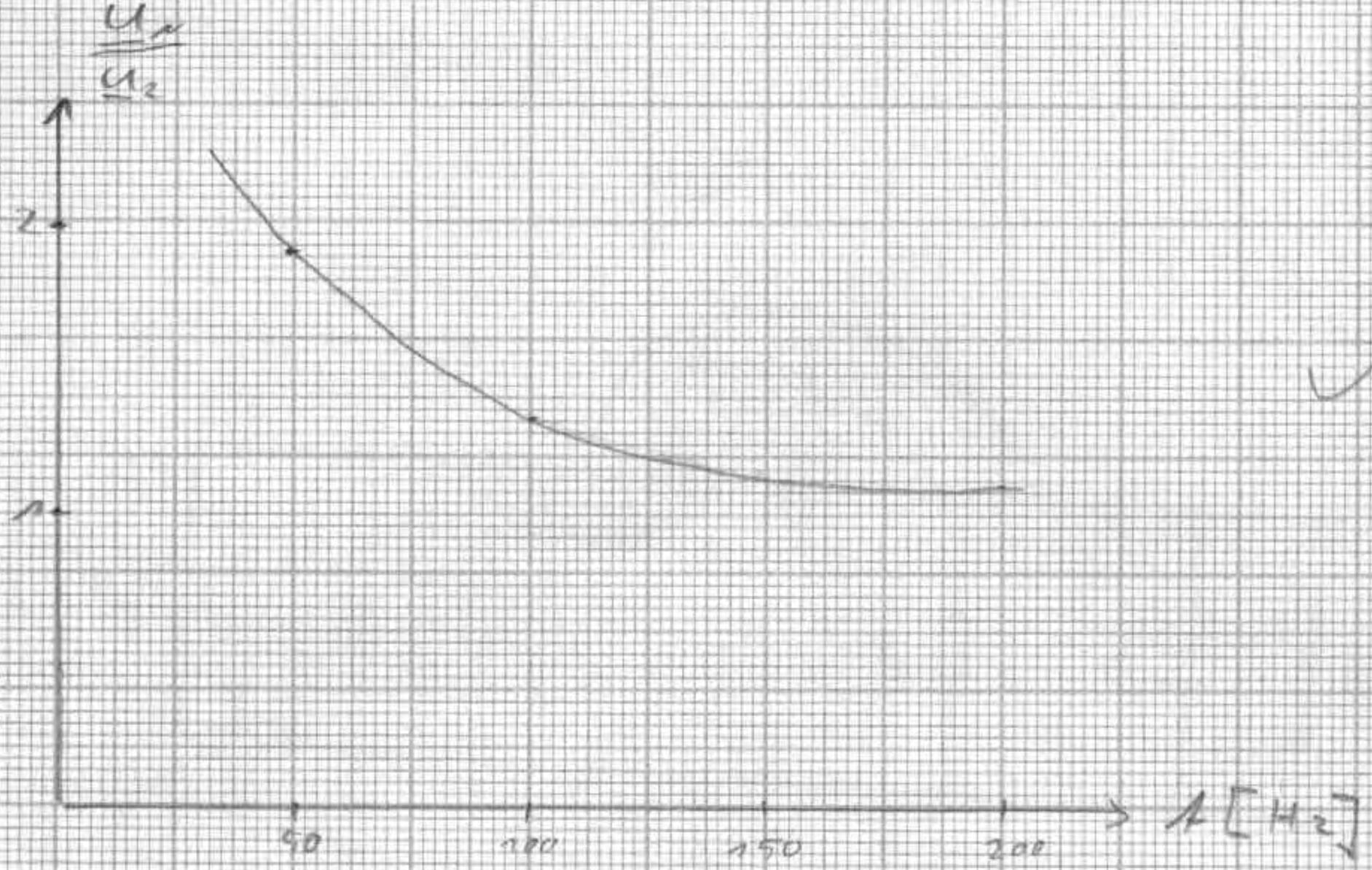
$$J_1 = J_2$$

$$\frac{U_{R1}}{U_{R2}} = \frac{R_1}{R_2} \qquad \frac{U_{Rm}}{U_{R2}} = \frac{R_m}{R_2}$$

$$U_{NO} = U_{R1} + U_{R2}$$

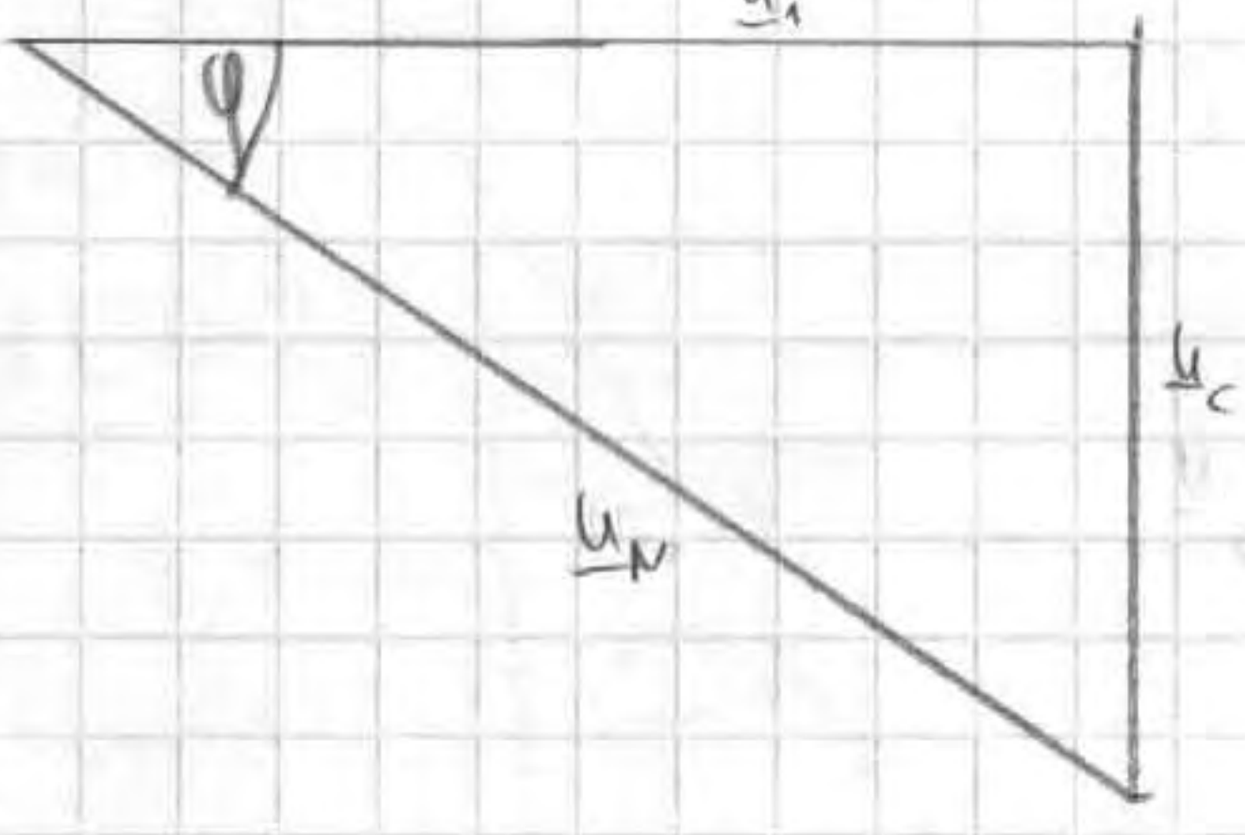
$$U_2 = \frac{U_{NO}}{\frac{R_1}{R_2} - 1 + \frac{R_m}{R_2}}$$

zn 1.2

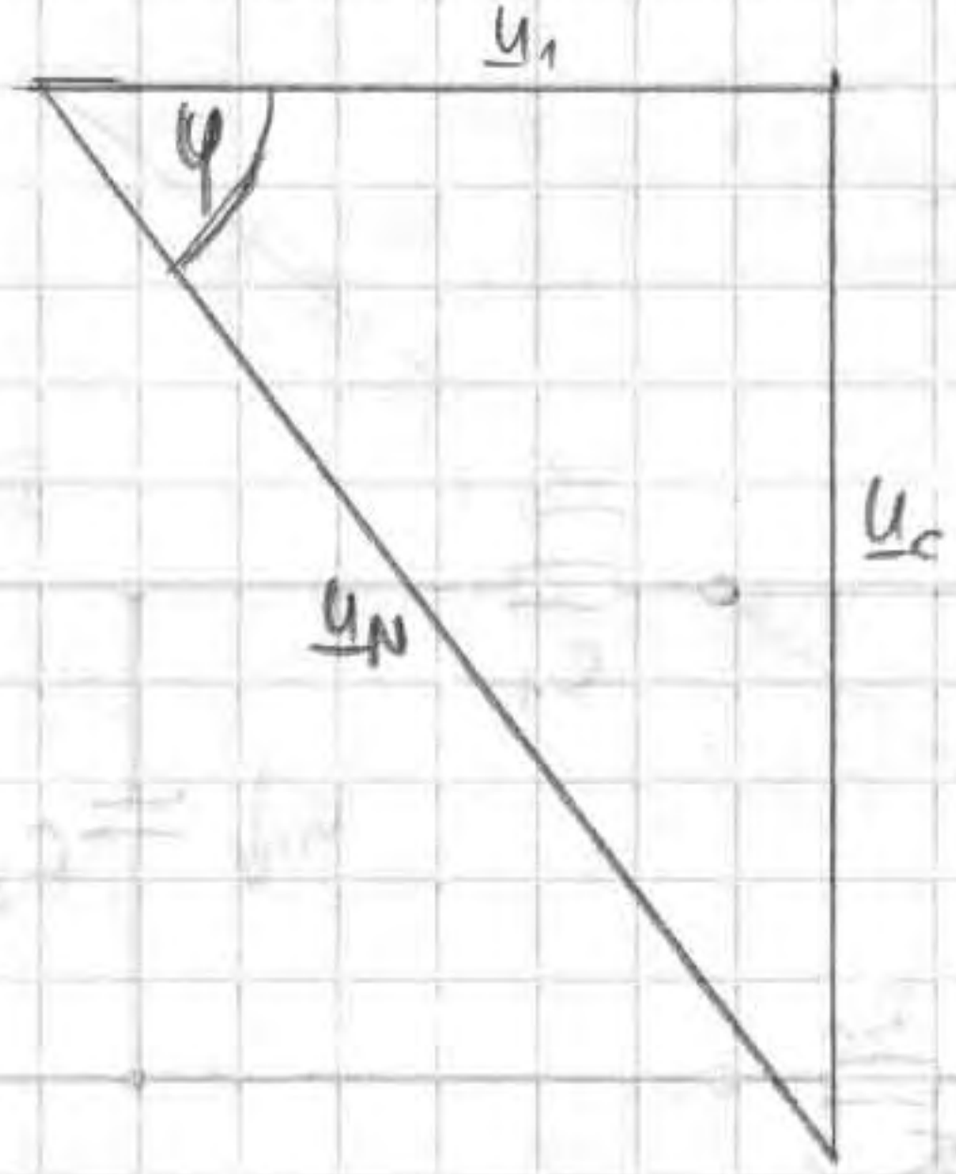



zn 2.2.

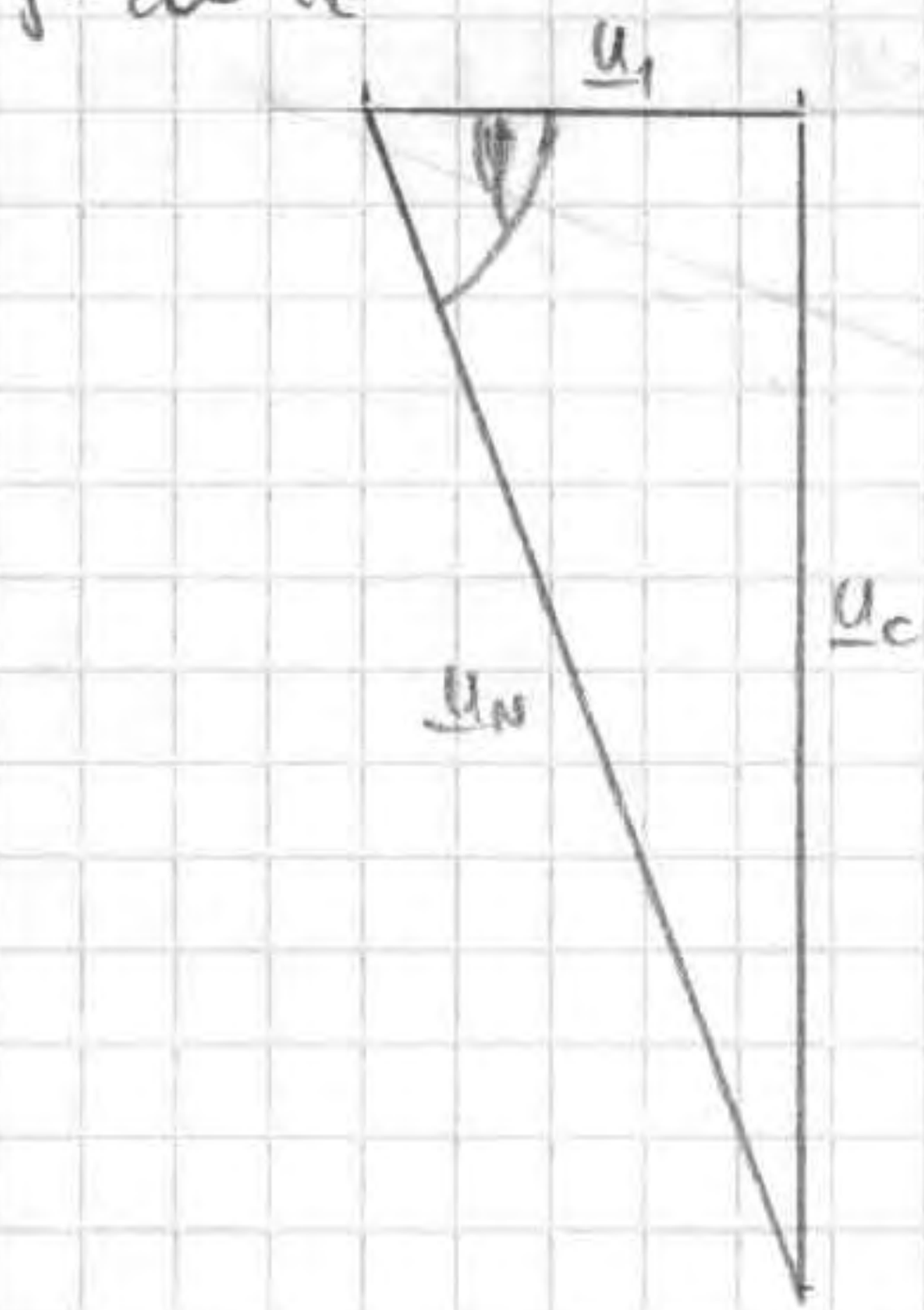
$f = 50\,Hz$



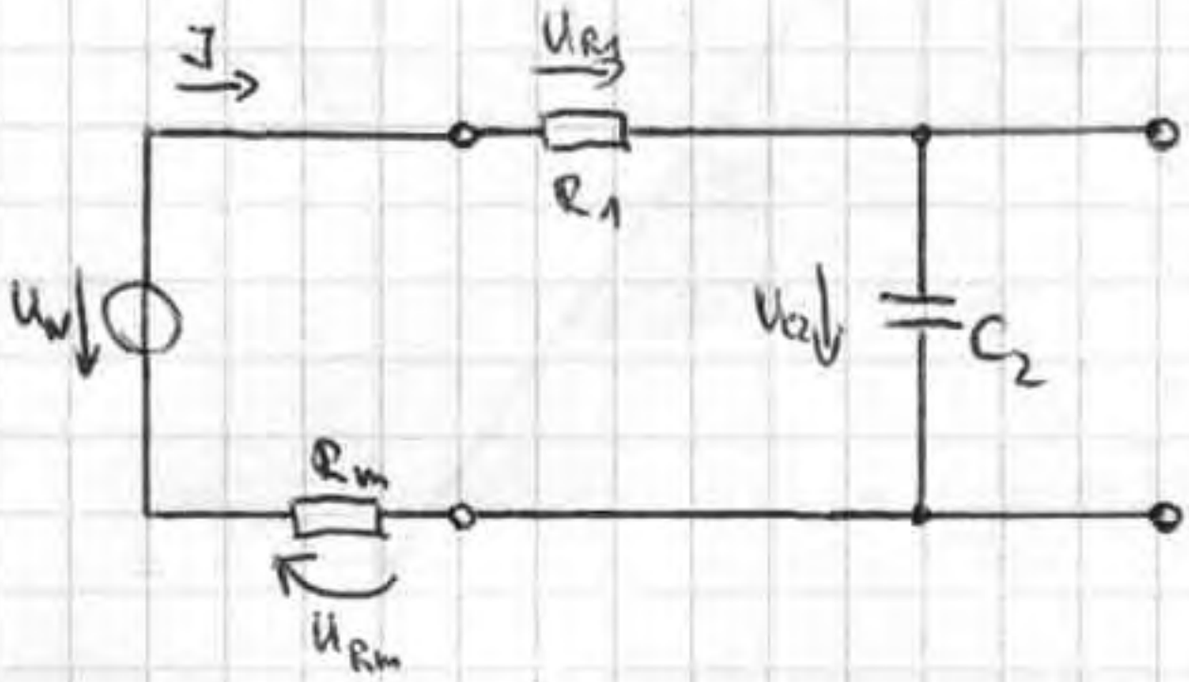

$f = 100\,Hz$




$f = 200\,Hz$



2.1)




$$\underline{I} = \frac{U_N}{Z_{ges}} \qquad Z_{ges} = \sqrt{R_1^2 + \left(\frac{1}{2\pi f C_2}\right)^2}$$

$$\underline{I} = \frac{U_N}{\sqrt{R_1^2 + \left(\frac{1}{2\pi f C_2}\right)^2}}$$

$$\underline{U_2} = \frac{1}{\omega C_2} \cdot \underline{I} = \frac{R_m \cdot U_N \cdot C_2 \cdot 2\pi f}{\sqrt{R_1^2 + \left(\frac{1}{2\pi \cdot f \cdot C_2}\right)^2}} =$$

Wenn $U_N$ Gleichspannung ist : $f = 0$

$$\lim_{f \to 0} U_2 = U_N \cdot \infty$$

2.2)

| f [Hz] | gemessen [V] $U_N$ | $U_{R_1}$ | $U_{C_2}$ | errechnet [V] $U_N$ | $U_{R_1}$ | $U_{C_2}$ | Meßfehler [%] $U_N$ | $U_{R_1}$ | $U_{C_2}$ |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 7,02 | 0 | 7 | 7 | 0 | 6 | | | |
| 50 | 7,02 | 3,77 | 5,73 | 7 | 2,9 | 4,8 | 0,3 | 30 | 19 |
| 100 | 7,02 | 5,43 | 4,03 | 7 | 3,48 | 7,52 | 0,3 | 56 | 60 |
| 200 | 7,02 | 6,28 | 2,38 | 7 | 4,41 | 1,59 | 0,3 | 42 | 49,6 |

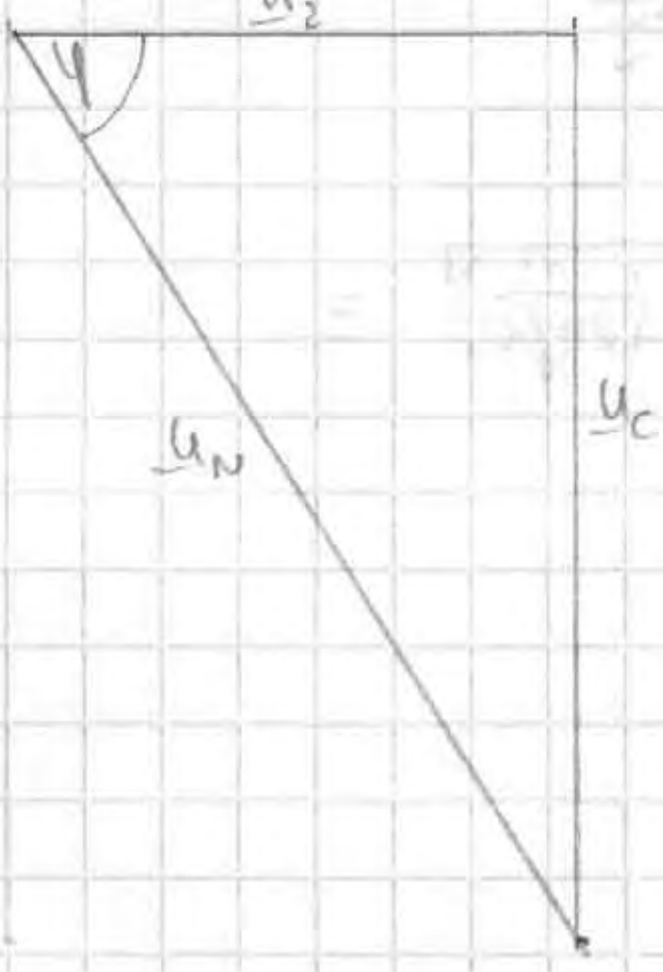
Phasenverschiebung

| f [Hz] | φ [°] exp. | φ [°] graph. | φ [°] errech. | $\frac{U_{R_1}}{U_1}$ |
|---|---|---|---|---|
| 50 | -40 | -34 | -34,65 | 1,86 |
| 100 | -60 | -54 | -54,12 | 1,29 |
| 200 | -67, | -70 | -70,12 | 1,11 |

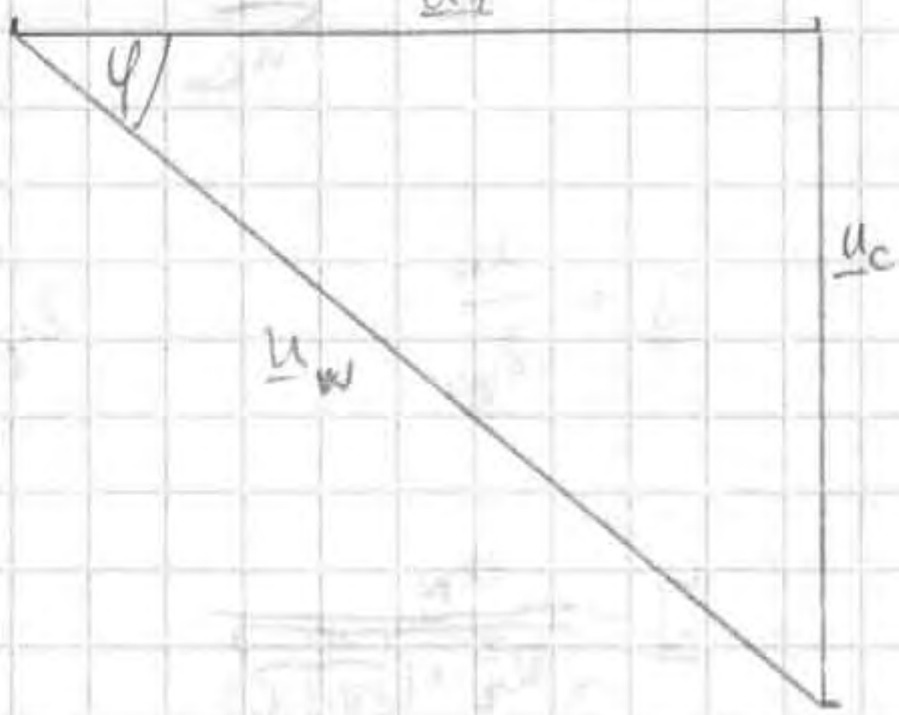
Phasenverschiebung

| f [Hz] | φ [°] Oszilloskop | φ [°] gerechnet | φ [°] gemessen | $\frac{U_W}{U_{12}}$ |
|---|---|---|---|---|
| 50 | −62 | −58 | −57,9 | 1,92 |
| 100 | −39 | −40 | −38,5 | 1,33 |
| 200 | −22 | −22 | −21,7 | 1,11 |

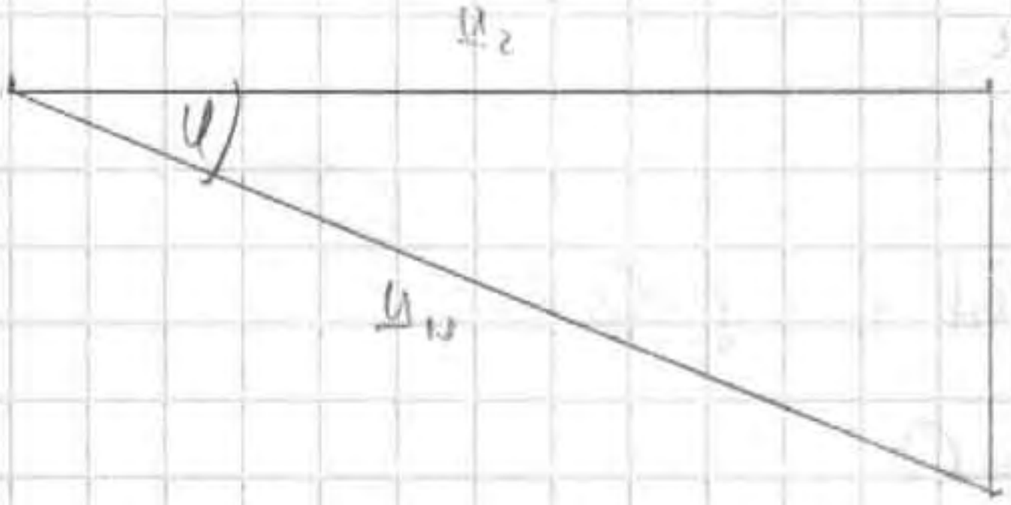
f = 50 Hz



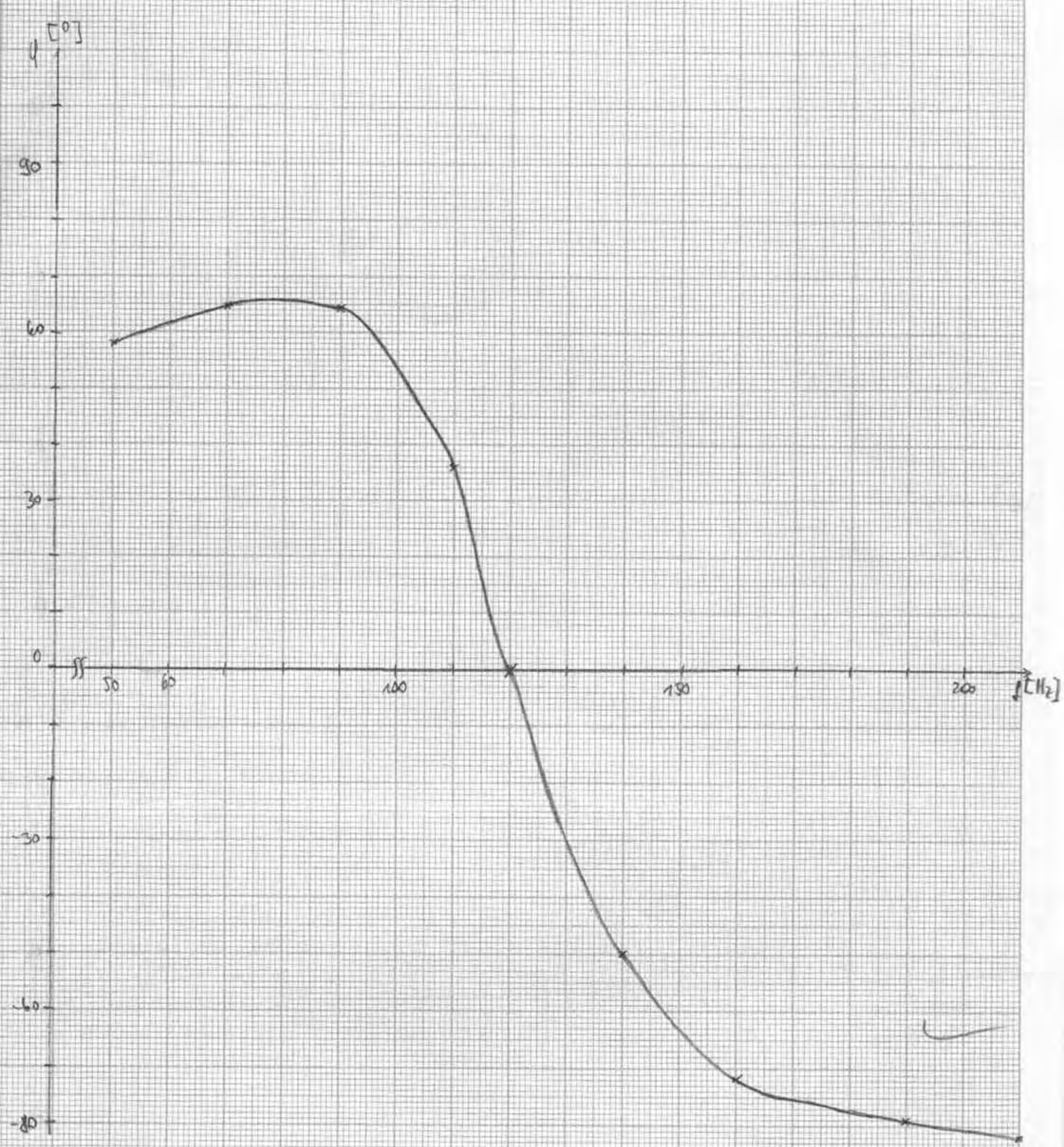

f = 100 Hz

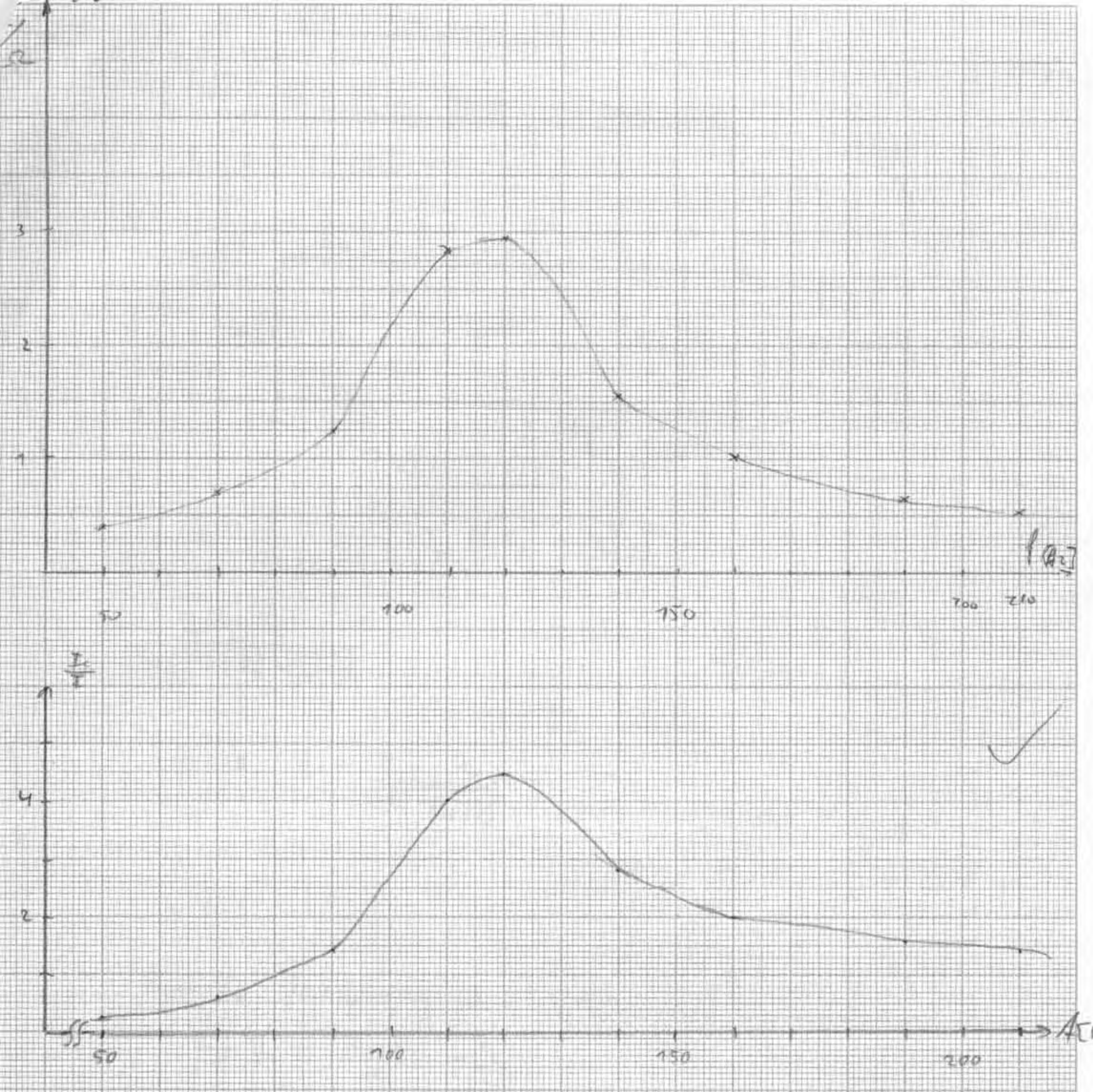



f = 200 Hz




1.3 Unterdrückung tiefer Frequenzen – Kompensation von Blindleistungen ✓


φ [°]
90
60
30
0
-30
-60
-90
50
60
100
150
200
f [Hz]


I/I
2
3
2
1
f [Hz]


50
100
150
200
I/I
4
2
f [Hz]