# Tentamen

# **EEM076 Elektriska Kretsar och Fält, D2**

Examinator: Max Ortiz Catalan

20 Aug 2018 kl. 14.00-18.00, sal: SB Multisal

Förfrågningar: Max Ortiz Catalan, tel: 0708461065

Lösningar: Anslås onsdagen den 22 agusti på institutionens anslagstavla, plan 5.

Resultat: Rapporteras in i Ladok

Granskning: Torsdag 30 agusti kl. 09.30 - 10.00, rum 3311.

Plan 3 i ED-huset (Lunnerummet),

korridor parallell med Hörsalsvägen.

Bedömning: En korrekt och välmotiverad lösning med ett tydligt angivet svar ger full poäng.

Hjälpmedel

- Typgodkänd miniräknare
- Beta Mathematics Handbook
- Physics Handbook

Betygsgränser (6 uppgifter om vardera 3 poäng).

| Poäng | 0-7.5 | 8-11 | 11.5-14.5 | 15-18 |
|---|---|---|---|---|
| Betyg | U | 3 | 4 | 5 |

*Lycka till!*

1)

I) We are calculating the impedances related to an inductor and a capacitor. Which of the following is the correct?

A) Inductive reactance translates into a positive imaginary impedance while capacitive reactance translates into a negative imaginary impedance.
B) Both inductive and capacitive reactance translate into a positive imaginary impedance.
C) It depends on the values of the inductor and the capacitor.
D) Inductive reactance translates into a negative imaginary impedance while capacitive reactance translates into a positive imaginary impedance

II) Represent the following voltage sources in their phasor form.

A) $u_{DC}(t) = 150\text{ V}$
B) $u_{s1}(t) = 120\cos(100t + 45°)\ V$
C) $u_{s2}(t) = 130\sin(100t)\ V$
D) $u_{s3}(t) = 220\sin(100 * 2\pi * t + 75°)\ V$

TIP: $\sin(\omega t) = \cos(\omega t - 90°)$

III) What is the configuration of an instrumentational amplifier?

A) Two inverting amplifiers follow by a differential amplifier
B) Two buffer amplifiers follow by a non-inverting amplifier
C) Two differential amplifiers follow by a buffer
D) Two non-inverting amplifiers follow by a differential amplifier

2)

[EN] Consider the DC network in Figure 1 and calculate current Ix and voltage U4 over resistor R4.

[SV] Betrakta likströmsnätet i Figur 1 nedan och beräkna strömmen Ix samt spänningen U4 över resistansen R4.

R1 = 70.0 Ω      R2 = 20.0 Ω      R3 = 30.0 Ω

R4 = 5.0 Ω      U0 = 5.0 V

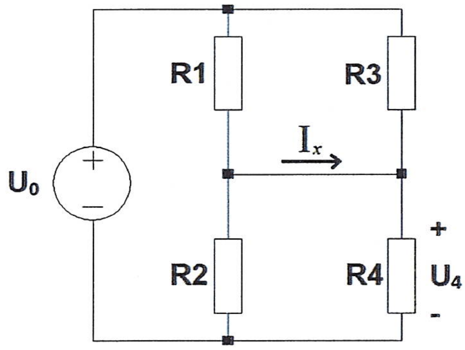


Figure 1

3)

[EN] The AC power circuit in Figure 2 consists of a voltage source and an impedance Z made up of two resistors and a capacitor. Calculate the average power across the impedance Z. Assume sinusoidal steady state.

[SV] Växelströmskretsen i Figur 2 består av en spänningskälla samt en impedans Z uppbyggd av två resistanser och en kondensator. Beräkna den medeleffekt som upptas av impedansen Z. Antag sinusformat stationärtillstånd.

$$u_s(t) = 12\cos(4000t + 45°)\,V$$

R = 2.0 Ω   C = 250 µF

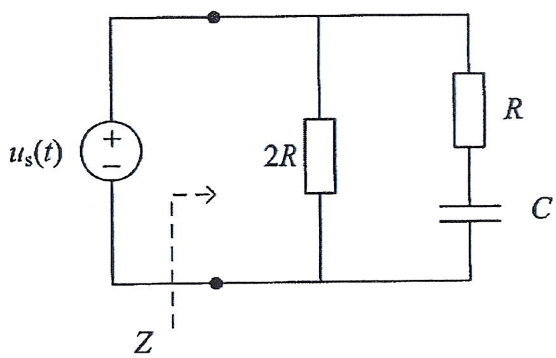


Figure 2

# 4)

[EN] A DC circuit in the form of a two-terminal network is shown in Figure 3.

a) Find Thevenin's equivalent circuit respect to the terminals A and B
b) If resistance R5 is placed between terminals A and B, calculate the voltage across resistance R5 (consider polarity positive (+) at terminal A.)

[SV] En likströmskrets i form av en tvåpol visas i Figur 3.

a) Ta fram Thevenins ekvivalenta tvåpol för kretsen med avseende på polerna A och B
b) En resistans $R_5$ kopplas till tvåoplen mellan A och B. Beräkna spänningen $U_{AB}$ mellan pollerna A och B. (Ansätt polaritet med plus (+) vid polen A.)

| | | |
|---|---|---|
| R1 = 200 Ω | R2 = 300 Ω | R3 = 60 Ω |
| R4 = 220 Ω | R5 = 100 Ω | U = 120 V |

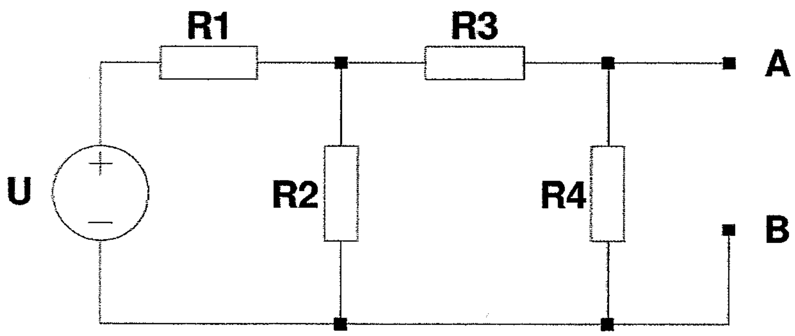


Figure 1

5)

[EN] Analyze the operational amplifier circuit in Figure 4. Calculate the output voltage U0 as a function of the two voltages U1 and U2. Fill in the results for the given voltages according to the table below. Assume ideal operational amplifiers. Copy the table into your solutions paper and fill it with the proper values for U0.

[SV] Studera operationsförstärkarkretsen i Figur 4. Beräkna utspänningen U0 som funktion av de båda inspänningarna U1 och U2. Fyll i några delresultat för givna inspänningar enligt tabellen nedan. Antag ideal operationsförstärkare. Kopiera tabellen i din lösning och fyll i dina framräknande värden på utspänningen U0.

R1 = 10 kΩ  R2 = 20 kΩ
Rf = 30 kΩ  R0 = 1.0 kΩ

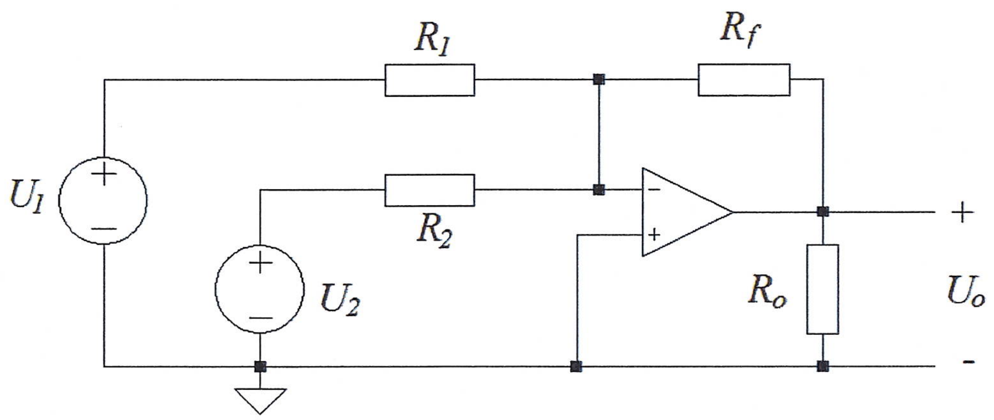


**Figure 2**

| In [V] | | Out [V] |
|---|---|---|
| $U_1$ | $U_2$ | $U_0$ |
| 1 | 1 | |
| 1 | -1 | |
| 0 | -2 | |
| -2 | 4 | |

6)

[EN] a) A spherical vacuum capacitor consists of an inner and outer spherical conductive shell with vacuum between the conductors; see Figure 5. The inner conductor with charge +Q has a radius a and the outer conductor with -Q has a radius b. You can neglect the thickness on each shell. Calculate the E-field everywhere. (2p)
b) Sketch the **electric field lines** from the following charges in Figure 6. Draw the field direction with arrows. All images show different configurations of positively and negatively charged point charges, except at the bottom right, where there are line charges perpendicular to the plane of the paper. For points, the basic appearance of the field lines should be correct throughout the selected square area for each configuration. (1p)

[SV] a) En sfärisk vacuum-kondensator består av ett inre och yttre sfärisk ledande skal, med vakuum medan ledarna; se Figur 5. Den inre ledaren med laddning +Q har en radie a och den yttre ledaren med –Q har en radie b. Du kan försumma tjockleken på varje skal. Beräkna E-fältet överallt. (2p)
b) Skissa de **elektriska fältlinjerna** från följande laddningar i Figur 6. Markera även fältets riktning med pilar. Alla bilder visar olika konfigurationer av positivt och negativt laddade punktladdningar, förutom längst ner till höger då det är linjeladdningar som ligger vinkelrätt mot pappeters plan. För poäng ska det principiella utseendet på fältlinjerna vara korrekt i hela det markerade kvadratiska området för respektive konfiguration. (1p)

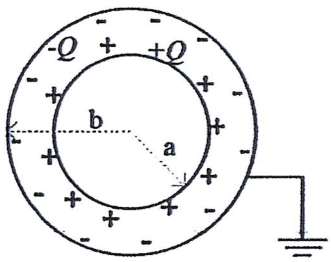


Figure 5

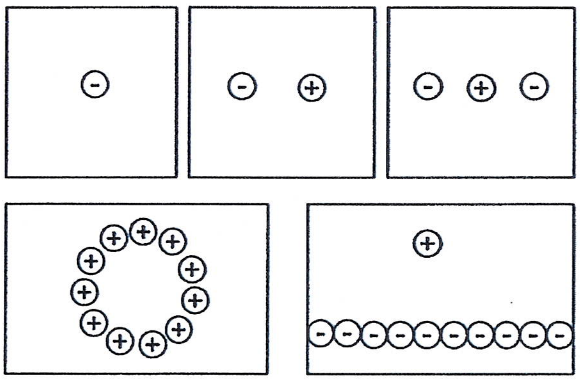

Figure 6

**I)** We are calculating the impedances related to an inductor and a capacitor. Which of the following is the correct?

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B) Both inductive and capacitive reactance translate into a positive imaginary impedance.
C) It depends on the values of the inductor and the capacitor.
D) Inductive reactance translates into a negative imaginary impedance while capacitive reactance translates into a positive imaginary impedance

**II)** Rapresent the following voltage sources in the phasor form.

A) $u_{DC}(t) = 150\text{ V} \rightarrow 150\angle 0°\text{ V}$
B) $u_{s1}(t) = 120\cos(100t + 45°)\ V \rightarrow 120\angle 45°\text{ V}$
C) $u_{s2}(t) = 130\sin(100t)\ V \rightarrow 130\angle -90°\text{ V}$
D) $u_{s3}(t) = 220\sin(100 * 2\pi * t + 75°)\ V \rightarrow 220\angle -15°\text{ V}$

TIP: $\sin(\omega t) = \cos(\omega t - 90°)$

**III)** What is the configuration of an instrumentational amplifier?

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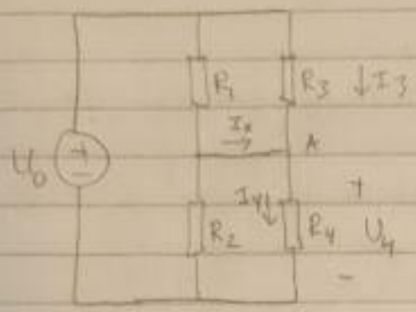
①




$R_1 = 70\,\Omega$

$R_2 = 20\,\Omega$

$R_3 = 30\,\Omega$

$R_4 = 5\,\Omega$

$U_0 = 5\text{ V}$

Parallellkoppla $\quad R_{13} = R_1 /\!/ R_3 = \frac{70 \cdot 30}{70+30} = 21\,\Omega$

$$R_{24} = R_2 /\!/ R_4 = \frac{20 \cdot 5}{20+5} = 4\,\Omega$$

Sp. delning

$$U_4 = U_0 \frac{R_{24}}{R_{24} + R_{13}} = 5 \cdot \frac{4}{4+21} = \frac{4}{5}\text{ V}$$

KCL i nod A $\quad I_x + I_3 - I_4 = 0$

$$I_4 = \frac{U_4}{R_4} \;;\; I_3 = \frac{U_0 - U_4}{R_3}$$

$$I_x = I_4 - I_3 = \frac{U_4}{R_4} - \frac{U_0 - U_4}{R_3} =$$

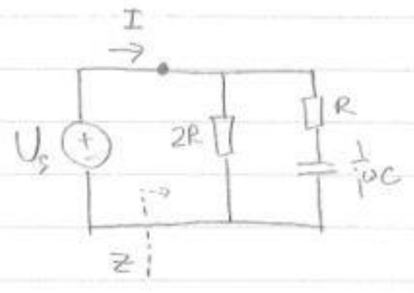
$$= \frac{4}{5 \cdot 5} - \frac{\left(5 - \frac{4}{5}\right)}{30} = \frac{4}{25} - \frac{21}{5 \cdot 30} =$$

$$= \frac{1}{5}\left(\frac{4}{5} - \frac{7}{10}\right) = \frac{1}{5}\left(\frac{1}{10}\right) = \frac{1}{50}\text{ A}$$

Svar: $U_4 = \frac{4}{5} = 0{,}8\text{ V}$

$I_x = \frac{1}{50} = 0.02\text{ A}$

4. $j\omega$-transformera kretsen




$u_s(t) = 12\cos(\omega t + 45°)$ V

$\omega = 4000$ rad/s

$R = 2{,}0\ \Omega$

$$\frac{1}{j\omega C} = -j\frac{1}{4\cdot 10^{3}\cdot 250\cdot 10^{-6}} = -j$$

$$Z = 2R // \left(R + \frac{1}{j\omega C}\right) = \frac{2R\left(R+\frac{1}{j\omega C}\right)}{2R+R+\frac{1}{j\omega C}} = \frac{4(2-j)}{6-j} =$$

$$= \frac{4(2-j)(6+j)}{(6-j)(6+j)} = \frac{4(12+1-j6+j2)}{37} = \frac{4(13-j4)}{37}$$

Z mottager komplex effekt $S = P + jQ$

$$S = \frac{1}{2}U_s I^* = \frac{1}{2}U_s\left(\frac{U_s}{Z}\right)^* = \frac{1}{2}\frac{|U_s|^2}{Z^*}\cdot\frac{Z}{Z} =$$

$$= \frac{1}{2}\frac{|U_s|^2}{|Z|^2}Z$$

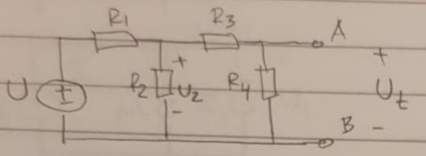
$$|Z| = \frac{4}{37}\sqrt{13^2+4^2} \approx 1{,}47$$

Medeleffekt $P = \mathrm{Re}\{S\} = \frac{1}{2}\frac{|U_s|^2}{|Z|^2}\cdot \mathrm{Re}\{Z\} =$

$$= \frac{1}{2}\frac{12^2}{1{,}47^2}\cdot\frac{4}{37}\cdot 13 = 46{,}8\ \text{W}$$

Svar: $P = 46{,}8$ W

2.




$R_1 = 200\ \Omega$
$R_2 = 300\ \Omega$
$R_3 = 60\ \Omega$
$R_4 = 220\ \Omega$
$R_5 = 100\ \Omega$
$U = 120\ V$

a) Tomgångsspänning $U_t$.

Sp. delning $U_2 = U \dfrac{R_2 // (R_3+R_4)}{R_1 + R_2 // (R_3+R_4)} =$

$$= U \frac{\frac{R_2(R_3+R_4)}{R_2+R_3+R_4}}{R_1 + \frac{R_2(R_3+R_4)}{R_2+R_3+R_4}} = U \frac{1}{1+\frac{R_1(R_2+R_3+R_4)}{R_2(R_3+R_4)}} =$$

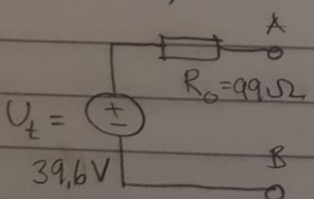
$$= U \cdot \frac{1}{1+\frac{200(300+60+220)}{300(60+220)}} = \frac{U}{1+\frac{29}{21}} = 0{,}42\,U = U_2$$

$$U_t = U_2 \frac{R_4}{R_3+R_4} = \dots = 39{,}6\,V$$

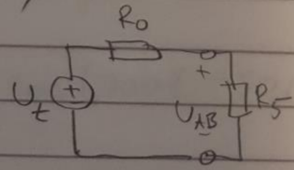
Ekv. Resistans. (nollställ U)

$$R_0 = R_4 // (R_3 + R_1 // R_2) = \frac{R_4 \cdot \left(R_3 + \frac{R_1 R_2}{R_1+R_2}\right)}{R_4 + R_3 + \frac{R_1 R_2}{R_1+R_2}} = \dots = 99\ \Omega$$

Svar a)




b)

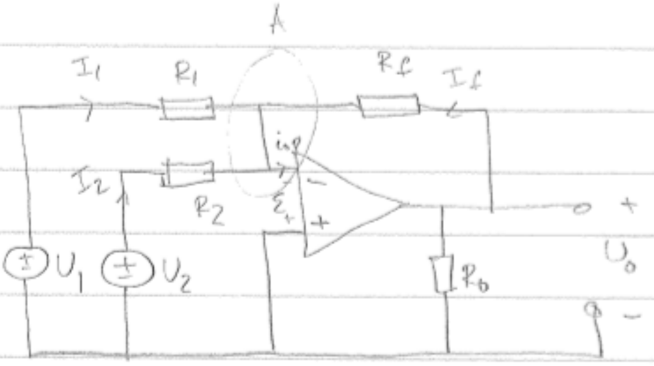



Sp. delning ger

$$U_{AB} = U_t \cdot \frac{R_5}{R_0 + R_5}$$

$$U_{AB} = 39.6 \cdot \frac{100}{99+100} = \underline{\underline{19{,}9\ V}}$$

5.




$R_1 = 10\,k\Omega$

$R_2 = 20\,k\Omega$

$R_f = 30\,k\Omega$

$R_0 = 1{,}0\,k\Omega$

$$\left.\begin{array}{l}\text{Ideal op. förstk.}\\ \text{Neg. återkoppl.}\end{array}\right\} \Rightarrow \left\{\begin{array}{l}\varepsilon = 0\\ i_{op} = 0\end{array}\right.$$

Summera strömmar i nod A (KCL)

$$I_1 + I_2 + I_f = 0$$

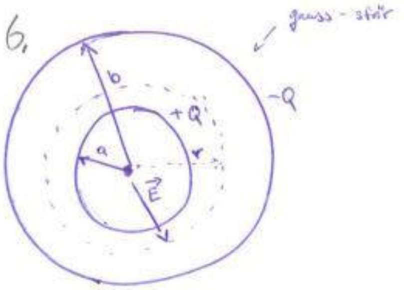
$$\frac{U_1}{R_1} + \frac{U_2}{R_2} + \frac{U_0}{R_f} = 0$$

$$U_0 = -U_1 \frac{R_f}{R_1} - U_2 \frac{R_f}{R_2} =$$

$$= -U_1 \frac{30}{10} - U_2 \frac{30}{20} = -3\left(U_1 + \frac{1}{2}U_2\right) \text{ V}$$

| $U_1$ [V] | $U_2$ [V] | $U_0 = -3\left(U_1 + \frac{1}{2}U_2\right)$ [V] |
|---|---|---|
| 1 | 1 | −4,5 |
| 1 | −1 | −1,5 |
| 0 | −2 | 3 |
| −2 | 4 | 0 |

6.




a) $r < a$ $\qquad \vec{E} = 0 \qquad$ Laddningen innesluten i en Gauss-sfär med radien r är 0

$a < r < b$ $\qquad \oiint \vec{E}\, \vec{dA} = \frac{Q}{\varepsilon_0}$

$$E\, 4\pi r^2 = \frac{Q}{\varepsilon_0}$$

$$E = 4\pi\varepsilon_0 r^2$$

riktningen : radiellt utåt $\qquad \vec{E} = \frac{Q}{4\pi\varepsilon_0 r^2}\,\hat{r}$

$r > b$ $\qquad \vec{E} = 0$

b)