# Exam Summer Semester 2022

## Student Group

| First Name | Surname | Matrikel Nr. |
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## Table of Contents

# Exam Summer Semester 2022

### Additional permitted Aids

- non-programmable calculator,
- formulary (4 one-sided DIN A4 pages)

### Hits

- The duration of the exam is 120 min.
- Attempts to cheat will lead to exclusion and failure of the exam.
- Withdrawal is no longer possible after these exam has been handed out.
- Please write down intermediate calculations and results on the assignment sheet. (when more space is needed also on the reverse side. In this case: Mark it clearly).
- Always use units in the calculation.
- Use a document-proof, non-red pen.

## Only EEE1-relevant Part

# This part is only for about 40 minutes !

### Exercise E2 Electrostatics I
### (written test, approx. 10 % of a 120-minute written test, SS2022)

Given is the arrangement of electric charges in the picture below. The values of the point charges are:

- $q_0=-1 ~\rm nC$
- $q_1=-2 ~\rm nC$

In the beginning, the area charge is $q_4=0 ~\rm nC$.

The permittivity is $\varepsilon_0 = 8.854 \cdot 10^{-12} ~\rm As/Vm$

2. What is the magnitude of the resulting force?

Result

- $\vec{F}_{01} = \left( {\begin{array}{cccc} 19.97 {~\rm \mu N} \\ 0 \\ \end{array} } \right)$
- $\vec{F}_{02} = \left( {\begin{array}{cccc} 28.09 {~\rm \mu N} \\ 0 \\ \end{array} } \right)$
- $\vec{F}_{03} = \left( {\begin{array}{cccc} -10.05 {~\rm \mu N} \\ 20.10 {~\rm \mu N} \\ \end{array} } \right)$

Path

With all the $x$ and $y$ components, we can calculate the resulting magnitude of the force with the Pythagorean Theorem:

\begin{align*} F = |\vec{F}| &= \sqrt{\left( \sum_i F_{i,x} \right)^2 + \left( \sum_i F_{i,y} \right)^2} \\ &= \sqrt{\left( 19.97 {~\rm \mu N} + 28.09 {~\rm \mu N} - 10.05 {~\rm \mu N} \right)^2 + \left( 20.10 {~\rm \mu N} \right)^2} \\ &= 42.99... {~\rm \mu N} \\ \end{align*}

3. Now the charge $q_2=0$ is set to 0. The area charge $q_4$ generates a homogenous field $E_4$. Which value needs $E_4$ to have to get a resulting force of $0 ~\rm N$ on $q_0$?

Path

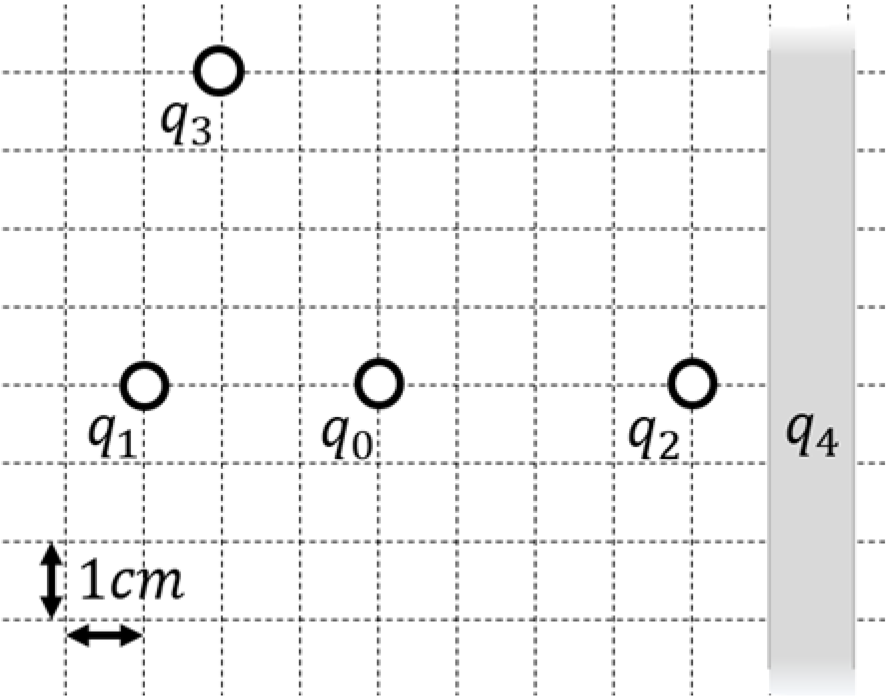
In the homogenous field the force is calculated by $F=E \cdot q$.

Here, this field has to compensate for the force $\vec{F}_{01}$ from $q_1$ on $q_0$:

\begin{align*} |\vec{F}_{01}| &= |E_4| \cdot |q_0| \\ \rightarrow E_4 &= {{|\vec{F}_{01}|}\over{|q_0|}} \\ &= {{19.97... \cdot 10^{-6} {~\rm N}}\over{1 \cdot 10^{-9} ~\rm C }} \\ &= 19.97... \cdot 10^{3}{{\rm N}\over{\rm C}} \\ &= 19.97... \cdot 10^{3}{{\rm VAs/m}\over{\rm As}} \\ &= 19.97... \cdot 10^{3}{{\rm V}\over{\rm m}} \\ \end{align*}

Result

$E_4 = 19.97 {~\rm k}{{\rm V}\over{\rm m}}$



1. Calculate the single forces $\vec{F}_{01}$, $\vec{F}_{02}$, $\vec{F}_{03}$, on the charge $q_0$!

Path

First, calculate the magnitude of the forces, like $\vec{F}_{01}$.
The force $\vec{F}_{01}$ is purely on the $x$-axis and therefore equal to $F_{01,x}$. \begin{align*} \vec{F}_{01} = F_{01,x} &= {{1}\over{4\pi\varepsilon}}\cdot {{q_1\cdot q_0}\over{r^2_{01}}} \\ &= {{1}\over{4\pi\cdot 8.854 \cdot 10^{-12} ~\rm As/Vm}}\cdot {{1 \cdot 10^{-9} ~\rm C \cdot 2 \cdot 10^{-9} ~\rm C}\over{(3 \cdot 10^{-2} ~\rm m)^2}} \\ &= 19.97... \cdot 10^{-6} {\rm {{(As)^2 \cdot Vm}\over{As \cdot m^2}}} = 19.97... \cdot 10^{-6} {\rm {{VAs}\over{m}}} = 19.97... \cdot 10^{-6} {\rm {{Ws}\over{m}}} \\ &= 19.97... {\rm \mu N} \quad \text{(to the right)} \end{align*}

Similarly, we get for $\vec{F}_{02}$ and $\vec{F}_{03}$ \begin{align*} \vec{F}_{02} = F_{02,x} &= -28.09... {\rm \mu N} \quad \text{(to the right)} \\ \vec{F}_{03} &= -22.47... {\rm \mu N} \quad \text{(to the top left)} \\ \end{align*}

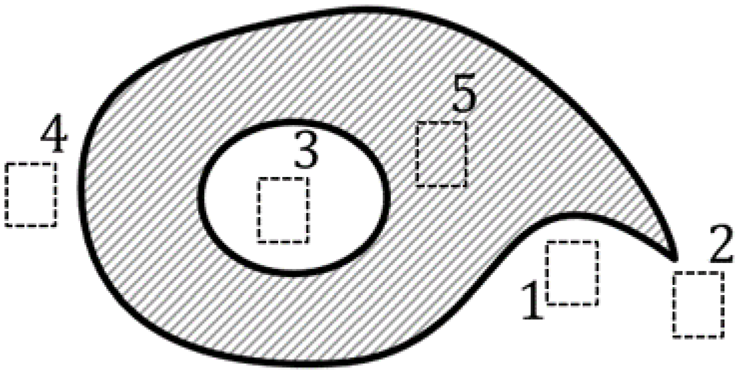
For $\vec{F}_{03}$, we have to calculate the $x$- and $y$-component.
This is possible, by using the angle $\alpha$ between the line through $q_0$ and $q_3$ and the positive $x$-axis (pointing to the right).
So, $\alpha$ has to be between $90°$ and $180°$. It can be calculated by: \begin{align*} \alpha = \arctan(\rm {{-4~cm}\over{+2~cm}}) = \pi - 1.1071... = 180° - 63.4...° = 116.6...° \end{align*}

Based on this, the $x$- and $y$-component is: \begin{align*} F_{03,x} &= |\vec{F}_{03}| \cdot \cos \alpha = 10.05... {~\rm \mu N} \text{(to the left)} \\ F_{03,y} &= |\vec{F}_{03}| \cdot \sin \alpha = 20.10... {~\rm \mu N} \text{(to the top)} \\ \end{align*}

### Exercise E4 Electrostatics II
### (written test, approx. 10 % of a 120-minute written test, SS2022)

The figure below shows an arrangement of ideal metallic conductors (gray hatched) charged up to $q=+1 ~\rm nC$.
In white a dielectric (e.g. vacuum) is shown.
Several designated areas are shown by dashed frames and numbers $x$, which are partly inside the object.

Arrange the designated areas clearly according to ascending field strengths $|\vec{E}_x |$ (absolute magnitude)!
Indicate also, if designated areas have quantitatively the same field strength.



Result

$|E_3|=|E_5|=0 < |E_1| < |E_4| < |E_2|$

### Exercise E8 Capacitor
### (written test, approx. 7 % of a 120-minute written test, SS2022)

Given the product layer position shown below, with the following dimensions:

- Length of layer overlap: $l=1.5 ~\rm mm$

2. Calculate the capacity $C$ [illegible]

Result

3. [illegible] left-side layers are covered with $d_{\rm c}=0.1 ~\rm \mu m$ of air ($\varepsilon_{r, \rm c}=1$), while the thickness of the dielectric material remains the same.

Path

- Distance between single layers: $d=1.0 ~\rm \mu m$
- Depth of component $w=0.7 ~\rm mm$
- Number of layers (as shown in the picture): 3 left-side and 3 right-side layers.

What is the new capacity $C_{\rm c}$?

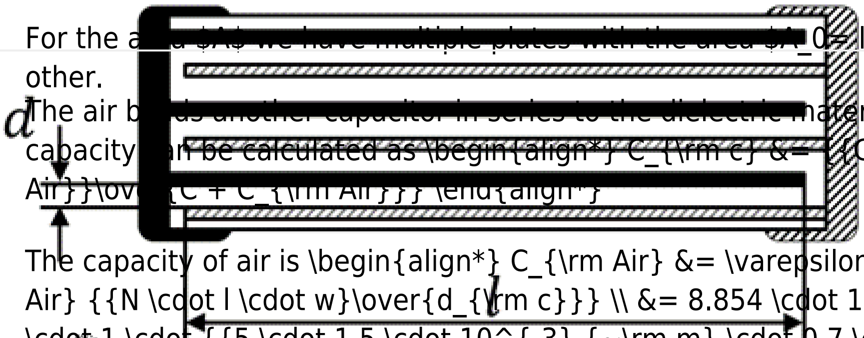
$C_{\rm c}=0.139 ~\rm nF$

$E={6.3}{{\rm MV}\over{\rm m}}$

Path

The capacity can be derived from the geometry by: \begin{align*} C = \varepsilon_0 \varepsilon_r {{A}\over{d}} \end{align*}

For the area $A$ we have multiple plates with the area $A_0= l \cdot w$ facing each other.



The air builds another capacitor in series to the dielectric material. Therefore, the capacity can be calculated as \begin{align*} C_{\rm c} &= {{C \cdot C_{\rm Air}}\over{C + C_{\rm Air}}} \end{align*}

The capacity of air is \begin{align*} C_{\rm Air} &= \varepsilon_0 \varepsilon_{r,\rm Air} {{N \cdot l \cdot w}\over{d_{\rm c}}} \\ &= 8.854 \cdot 10^{-12} ~\rm As/Vm \cdot 1 \cdot {{5 \cdot 1.5 \cdot 10^{-3} {~\rm m} \cdot 0.7 \cdot 10^{-3} {~\rm m} }\over{0.1 \cdot 10^{-6} {~\rm m} }} \\ &= 0.465... ~\rm nF \end{align*}

The material shall have a dielectric permittivity of $\varepsilon_r=3$.

The following calculations shall ignore boundary effects on the end of the layers.

How many "multiple plates" $N$ do we have to consider? –

For this, we have to count facing areas $A_0$. There are $N=5$.

By this the overall capacity is \begin{align*} C_{\rm c} &= {{0.139... ~\rm nF \cdot 0.465... ~\rm nF}\over{0.139... ~\rm nF + 0.465... ~\rm nF}} \end{align*}

$\varepsilon_0 = 8.854 \cdot 10^{-12} ~\rm As/Vm$

1. What is the field strength in the dielectric material between the layer, when a voltage of $U=6.3 ~\rm V$ is applied?

Path

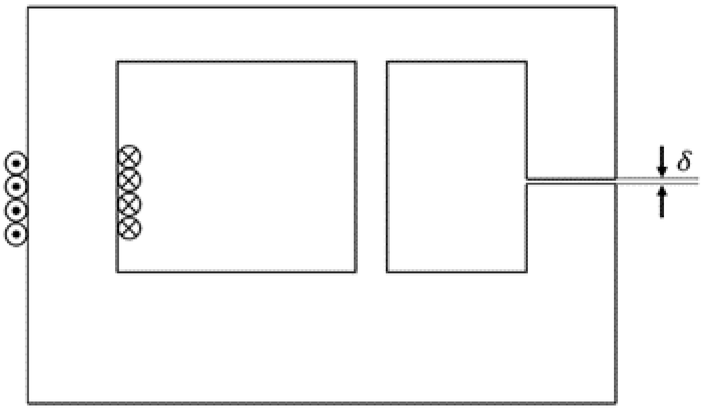
The electric field strength $E$ is given by: \begin{align*} E &= {{U}\over{d}} \\ &= {{6.3 ~\rm V}\over{1 \cdot 10^{-6} ~\rm m}} \\ \end{align*}

Therefore, the formula is \begin{align*} C &= \varepsilon_0 \varepsilon_r {{N \cdot l \cdot w}\over{d}} \\ &= 8.854 \cdot 10^{-12} ~\rm As/Vm \cdot 3 \cdot {{5 \cdot 1.5 \cdot 10^{-3} {~\rm m} \cdot 0.7 \cdot 10^{-3} {~\rm m} }\over{1 \cdot 10^{-6} {~\rm m} }} \end{align*}

## Exercise E10 Magnetic Circuit
## (written test, approx. 7 % of a 120-minute written test, SS2022)

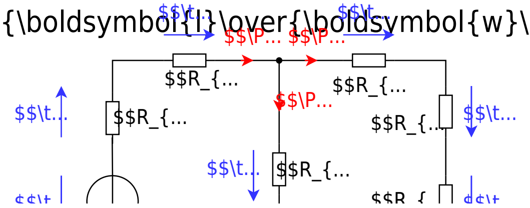
The magnetic setup below shall be given. Draw the equivalent magnetic circuit to represent the setup fully. Name all the necessary magnetic resistances, fluxes, and voltages.
The components shall be designed in such a way, that the magnetic resistance is constant in it.
Formulas are not necessary.

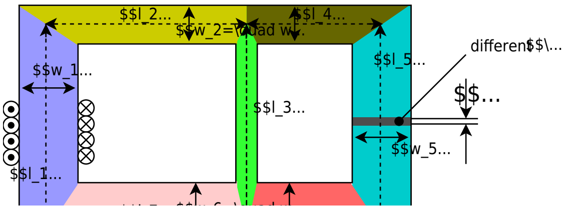
Result



Path

Watch for parts of the magnetic circuit, where the width and material are constant. These parts represent the magnetic resistors which have to be calculated individually. Be aware, that every junction creates a branch with a new resistor, like for an electrical circuit - there must be a node on each “diversion”. \begin{align*} R_{\rm m} = {{1}\over{\mu_0 \boldsymbol{\mu_{\rm r}}} }{\boldsymbol{l}}\over{\boldsymbol{w}\cdot h}} \end{align*}





## Full Exam

Here is only a part of the exam in more details given.
The full results can be found in ILIAS

Full exam

### Exercise E2 Electrostatics I
### (written test, approx. 10 % of a 120-minute written test, SS2022)

Given is the arrangement of electric charges in the picture below. The charge $q_4$ generates a homogeneous field of $E_4$. Which value needs $E_4$ to have to get a resulting force of $0 ~\rm N$ on $q_0$?

- $q_0=-1 ~\rm nC$
- $q_1=-2 ~\rm nC$
- $q_2=...

Result

Path

$E_4 = 19.97 {\rm kV}\over{\rm m}}$

Path

- $\vec{F}_{01} = \left( {\begin{array}{cccc} 19.97 {~\rm \mu N} \\ 0 \\ \end{array} } \right)$
- $\vec{F}_{02} = \left( {\begin{array}{cccc} 28.09 {~\rm \mu N} \\ 0 \\ \end{array} } \right)$
- $\vec{F}_{03} = \left( {\begin{array}{cccc} 10.05 {~\rm \mu N} \\ 20.10 {~\rm \mu N} \\ \end{array} } \right)$

In the beginning, the area charge is $q_4=0 ~\rm nC$.

With all the x and y components, we can calculate the resulting magnitude of the force with the Pythagorean Theorem:

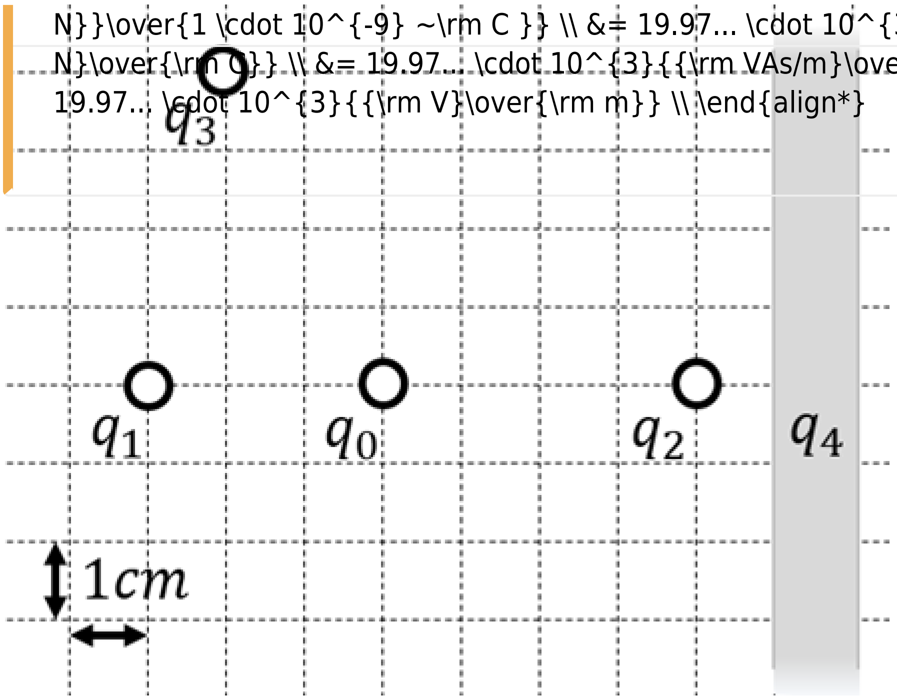
The permittivity is $\varepsilon_0 = 8.854 \cdot 10^{-12} ~\rm As/Vm$

\begin{align*} F = |\vec{F}| &= \sqrt{\left( \sum_i F_{i,x} \right)^2 + \left( \sum_i F_{i,y} \right)^2} \\ &= \sqrt{\left( 19.97 {~\rm \mu N} + 28.09 {~\rm \mu N} - 10.05 {~\rm \mu N} \right)^2 + \left( 20.10 {~\rm \mu N} \right)^2} \\ &= 42.99... {~\rm \mu N} \\ \end{align*}

In the homogeneous field the force is calculated by $F=E \cdot q$.

Here, this field has to compensate for the force $\vec{F}_{01}$ from $q_1$ on $q_0$: \begin{align*} |\vec{F}_{01}| &= |E_4| \cdot |q_0| \\ \rightarrow E_4 &= {{|\vec{F}_{01}|}\over{|q_0|}} \\ &= {{19.97... \cdot 10^{-6} {~\rm

N}}\over{1 \cdot 10^{-9} ~\rm C }} \\ &= 19.97... \cdot 10^{3}{{\rm N}\over{\rm C}} \\ &= 19.97... \cdot 10^{3}{{\rm VAs/m}\over{\rm As}} \\ &= 19.97... \cdot 10^{3}{{\rm V}\over{\rm m}} \\ \end{align*}



1. Calculate the single forces $\vec{F}_{01}$, $\vec{F}_{02}$, $\vec{F}_{03}$, on the charge $q_0$!

Path

First, calculate the magnitude of the forces, like $\vec{F}_{01}$.
The force $\vec{F}_{01}$ is purely on the $x$-axis and therefore equal to $F_{01,x}$. \begin{align*} \vec{F}_{01} = F_{01,x} &= {{1}\over{4\pi\varepsilon}}\cdot {{q_1\cdot q_0}\over{r^2_{01}}} \\ &= {{1}\over{4\pi\cdot 8.854 \cdot 10^{-12} ~\rm As/Vm}}\cdot {{1 \cdot 10^{-9} ~\rm C \cdot 2 \cdot 10^{-9} ~\rm C}\over{(3 \cdot 10^{-2} ~\rm m)^2}} \\ &= 19.97... \cdot 10^{-6} {\rm {{(As)^2 \cdot Vm}\over{As \cdot m^2}}} = 19.97... \cdot 10^{-6} {\rm {{VAs}\over{m}}} = 19.97... \cdot 10^{-6} {\rm {{Ws}\over{m}}} \\ &= 19.97... {\rm \mu N} \quad \text{(to the right)} \end{align*}

Similarly, we get for $\vec{F}_{02}$ and $\vec{F}_{03}$ \begin{align*} \vec{F}_{02} = F_{02,x} &= -28.09... {\rm \mu N} \quad \text{(to the right)} \\ \vec{F}_{03} &= -22.47... {\rm \mu N} \quad \text{(to the top left)} \\ \end{align*}

For $\vec{F}_{03}$, we have to calculate the $x$- and $y$-component.
This is possible, by using the angle $\alpha$ between the line through $q_0$ and $q_3$ and the positive $x$-axis (pointing to the right).
So, $\alpha$ has to be between $90°$ and $180°$. It can be calculated by: \begin{align*} \alpha = \arctan(\rm {{-4~cm}\over{+2~cm}}) = \pi - 1.1071... = 180° - 63.4...° = 116.6...° \end{align*}

Based on this, the $x$- and $y$-component is: \begin{align*} F_{03,x} &=

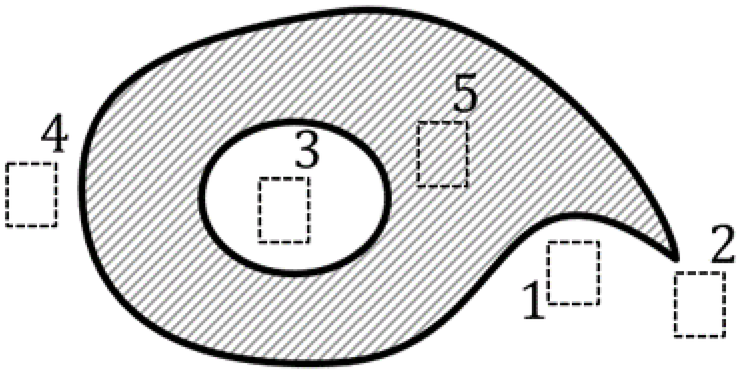
> |\vec{F}_{03}| \cdot \cos \alpha = 10.05... {~\rm \mu N} \text{(to the left)} \\ F_{03,y} &= |\vec{F}_{03}| \cdot \sin \alpha = 20.10... {~\rm \mu N} \text{(to the top)} \\ \end{align*}

electrical_engineering_and_electronics:task_dtoqvpvrbdtcozfk_with_calculation
electrostatic, field lines, exam ee2 ss2022

### Exercise E4 Electrostatics II
### (written test, approx. 10 % of a 120-minute written test, SS2022)

The figure below shows an arrangement of ideal metallic conductors (gray hatched) charged up to $q=+1 ~\rm nC$.
In white a dielectric (e.g. vacuum) is shown.
Several designated areas are shown by dashed frames and numbers $x$, which are partly inside the object.

Arrange the designated areas clearly according to ascending field strengths $|\vec{E}_x |$ (absolute magnitude)!
Indicate also, if designated areas have quantitatively the same field strength.



Result

> $|E_3|=|E_5|=0 < |E_1| < |E_4| < |E_2|$

electrical_engineering_and_electronics:task_ic9pioiu0notvwfp_with_calculation
electrostatic, electric field strength, exam ee2 ss2022

### Exercise E6 Electron Velocity in Semiconductors
### (written test, approx. 6 % of a 120-minute written test, SS2022)

A current of $I=1~\rm mA$ flows through a cross-sectional area $A=10~\rm \mu m^2$ in a semiconductor.
The electron density in the semiconductor is given by the number of dopant atoms per volume.
The doping shall provide 1 donator atom (= one electron) per $10^{10}$ silicon atoms.
The molar volume of silicon is $V_{\rm mol,Si} = 12\cdot 10^{-6} ~\rm m^3/mol$ , with $N_{\rm A} = 6.022 \cdot 10^{23}$ silicon atoms per $1 ~\rm mol$.

Result

$v_e = 123 \cdot 10^6~\rm m/s$ (about $41~\%$ of the speed of light)

The elementary charge is given as: $e_0 = 1.602 \cdot 10^{-19} ~\rm As$

What is the average electron velocity $v_e$ in this semiconductor?

Path

The following formula gives the speed, where $n_e$ is the number of electrons per volume. \begin{align*} v_e &= {{I}\over{n_e \cdot e_0 \cdot A}} \\ \end{align*}

$n_e$ can be derived from the overall number of Si-atoms per volume (${{N_{\rm A}}\over{V_{\rm mol,Si}}}$) and the fraction $k_{\rm Donators}$ of these atoms, which got substituted by donators. \begin{align*} v_e &= {{I}\over{{{N_{\rm A}}\over{V_{\rm mol,Si}}} \cdot k_{\rm Donators} \cdot e_0 \cdot A}} \\ \end{align*}

Putting in the numbers: \begin{align*} v_e &= {{1 \cdot 10^{-3}~\rm A}\over{{{6.022 \cdot 10^{23} 1/ \rm mol}\over{12\cdot 10^{-6} ~\rm m^3/mol}} \cdot 10^{-10} \cdot 1.602 \cdot 10^{-19} ~\rm As \cdot 10 \cdot (10^{-6} ~\rm m)^2}} \\ \end{align*}

electrical_engineering_and_electronics:task_tx86fewvysrcy8fc_with_calculation
electrostatic, electric field strength, exam ee2 ss2022

### Exercise E8 Capacitor
### (written test, approx. 7 % of a 120-minute written test, SS2022)

Given the multilayer capacitor shown below, with the following dimensions: [illegible] $d_{\rm c}=0.1$ ~\rm \mu m$ of air ($\varepsilon_{r, \rm c}=1$), while the thickness of the dielectric material remains the same.
What is the new capacity $C_{\rm c}$?

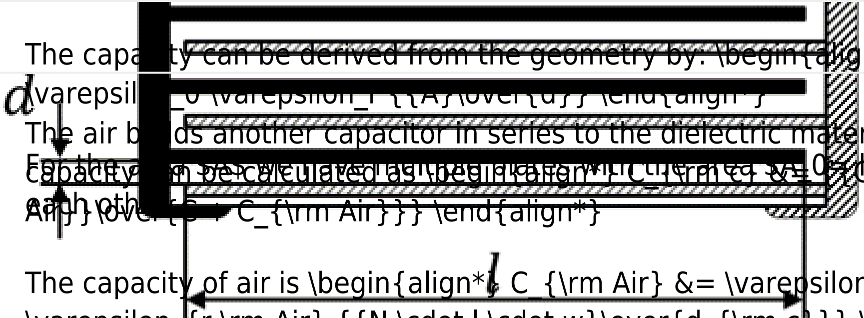
Result

Path

- Length of layer overlap: $l=1.5 ~\rm mm$
- Distance between single layers: $d=1.0 ~\rm \mu m$
- Depth of component: $w=0.7 ~\rm mm$
- Number of layers (as shown in the picture): 3 left-side and 3 right-side layers.

[illegible]

Path



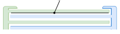
The capa ty can be derived from the geometry by: \begin{align*} C = \varepsil _0 \varepsilon_r {{A}\over{d}} \end{align*}

The air b ds another capacitor in series to the dielectric material. Therefore, the capacity can be calculated as \begin{align*} C_{\rm c} &= {{C \cdot C_{\rm Air}}\over{C + C_{\rm Air}}} \end{align*}

For the a we have multiple plates with the area $A_0 = l \cdot w$ facing each oth

The capacity of air is \begin{align*} C_{\rm Air} &= \varepsilon_0 \varepsilon_{r,\rm Air} {{N \cdot l \cdot w}\over{d_{\rm c}}} \\ &= 8.854 \cdot 10^{-12} ~\rm As/Vm \cdot 1 \cdot {{5 \cdot 1.5 \cdot 10^{-3} {~\rm m} \cdot 0.7 \cdot 10^{-3} {~\rm m} }\over{0.1 \cdot 10^{-6} {~\rm m} }} \\ &= 0.465... ~\rm nF \end{align*}

The material shall have a dielectric permittivity of $\varepsilon_r=3$.
The following calculations shall ignore boundary effects on the end of the layers.



$\varepsilon_0 = 8.854 \cdot 10^{-12} ~\rm As/Vm$

By this the overall capacity is \begin{align*} C_{\rm c} &= {{0.139... ~\rm nF \cdot 0.465... ~\rm nF}\over{0.139... ~\rm nF + 0.465... ~\rm nF}} \end{align*}

How many “multiple plates” $N$ do we have to consider?

For this, we have to count facing areas $A_0$. There are $N=5$

. What is the field strength in the dielectric material between the layer, when a voltage of $U=6.3 ~\rm V$ is applied?

Path

The electric field strength $E$ is given by: \begin{align*} E &= {{U}\over{d}} \\ &= {{6.3 ~\rm V}\over{1 \cdot 10^{-6} ~\rm m}} \\ \end{align*}

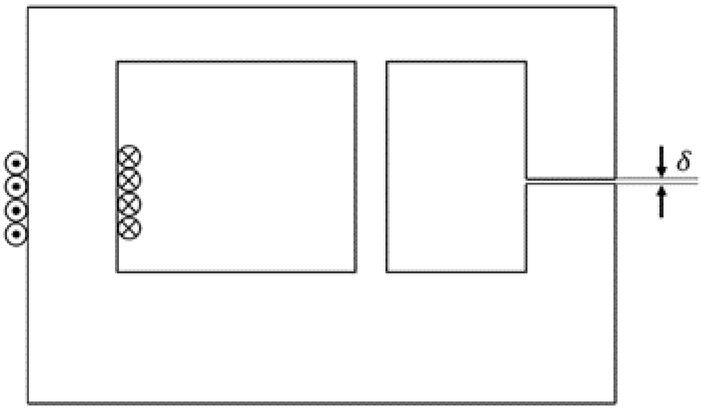
Therefore, the formula is \begin{align*} C &= \varepsilon_0 \varepsilon_r {{N \cdot l \cdot w}\over{d}} \\ &= 8.854 \cdot 10^{-12} ~\rm As/Vm \cdot 3 \cdot {{5 \cdot 1.5 \cdot 10^{-3} {~\rm m} \cdot 0.7 \cdot 10^{-3} {~\rm m} }\over{1 \cdot 10^{-6} {~\rm m} }} \end{align*}

electrical_engineering_and_electronics:task_y7dozgdsljqvnqge_with_calculation electrostatic, capacitor, plate capacitor, capacity, exam ee2 ss2022

### Exercise E10 Magnetic Circuit
### (written test, approx. 7 % of a 120-minute written test, SS2022)

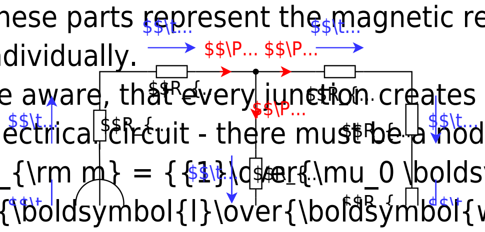
The magnetic setup below shall be given. Draw the equivalent magnetic circuit to represent the setup fully. Name all the necessary magnetic resistances, fluxes, and voltages.
The components shall be designed in such a way, that the magnetic resistance is constant in it.
Formulas are not necessary.

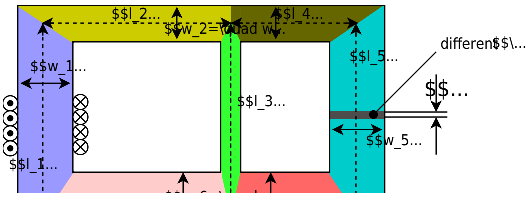
Result



Path

Watch for parts of the magnetic circuit, where the width and material are constant.
These parts represent the magnetic resistors which have to be calculated individually.
Be aware, that every junction creates a branch with a new resistor, like for an electrical circuit - there must be a node on each “diversion”. \begin{align*} R_{\rm m} = {{1}\over{\mu_0 \boldsymbol{\mu_{\rm r}}} }{\boldsymbol{l}\over{\boldsymbol{w}\cdot h}} \end{align*}





electrical_engineering_and_electronics:task_yp4rbdlj8kktyrhp_with_calculation
magnetic circuit, exam ee2 ss2022

### Exercise E12 Self Induction
### (written test, approx. 8 % of a 120-minute written test, SS2022)

Accidentally, a motor with an inductance of $L=50 ~\rm H$ is connected to a DC voltage source, which is fused with a circuit breaker.
The circuit breaker opens the circuit at $t_0=0$ with a current of $I=63 ~\rm A$. The current is reduced linearly down to $0 ~\rm A$ within $1 ~\rm \mu s$.
(The inner resistance of the motor shall be neglected.)

2. What is the maximum magnitude of the voltage, which the circuit breaker has to withstand?

Result

Sketch the diagrams $i(t)$ and $u_{\rm ind}(t)$ with the calculated value in the induced voltage.

$u_{\rm ind} (t) = 3150 ~\rm V$

Path

1. Draw the circuit (the circuit breaker can be drawn as a switch), with all voltage and current arrows.

Result

For the maximum voltage on the circuit breaker one has to consider the following:

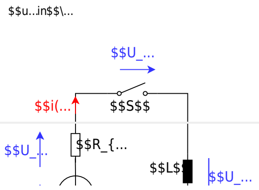
- external voltage of the voltage source $U_\rm s$
- voltage $u_{\rm ind} (t)$ induced by the change of the current

The first one is not given in the exercise, and therefore not considered here.

The induced voltage can be calculated by linearizing the following:
\begin{align*} u_{\rm ind} (t) &= - L {{ {\rm d} i}\over{ {\rm d} t }}\\

\rightarrow u_{\rm ind} (t) &= - L {{ \Delta i}\over{ \Delta t }}\\ \end{align*}

With the given details: \begin{align*} u_{\rm ind} (t) &= - L {{ 0 - I}\over{ t_1 - t_0 }}\\ &= 50 \cdot 10^{-6} {~\rm H} {{ 63 ~\rm A}\over{ 1 \cdot 10^{-6} ~\rm s}}\\ &= 3150 {{ ~\rm Vs}\over{ ~\rm A}} \; {{ ~\rm A}\over{ ~\rm s}}\\ \end{align*}



electrical_engineering_and_electronics:task_unkkahm3u0v9azny_with_calculation
self induction, induction, exam ee2 ss2022

## Exercise E14 Series Resonant Circuit
(written test, approx. 10 % of a 120-minute written test, SS2022)

[illegible] series inductance $L$.

[illegible] would be $X_{C0}=Z_{RLC}$.
Which value would $C_0$ have for the given $f_0$?

Path
- $C=10 ~\rm nF$

[illegible]

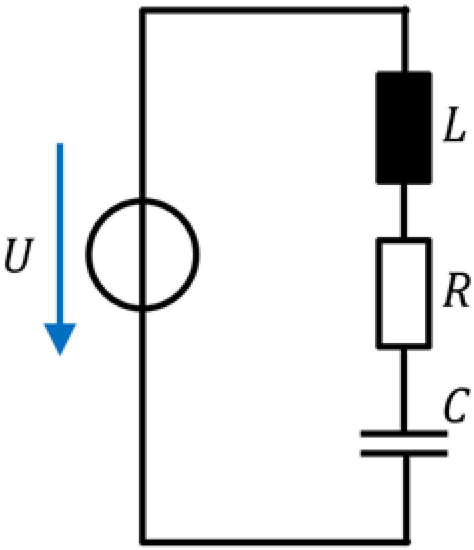
Path
- $L=60 ~\rm pH$
  - [illegible]
  - [illegible]

The resonance frequency is given as \begin{align*} f_{\rm r} &= {{1}\over{2\pi\sqrt{LC}}} \\ &= {{1}\over{2\pi\sqrt{60 \cdot 10^{-12}{~\rm [illegible]

\begin{align*} Z_{RLC} &= X_{C0} \\ &= {{1}\over{2\pi f \cdot C}} \\ \rightarrow C &= {{1}\over{2\pi f \cdot Z_{RLC}}} \end{align*}

At resonance, the impedance is given purely by the resistor.

With values: \begin{align*} C &= {{1}\over{2\pi 100 \cdot 10^{6} {~\rm MHz}\cdot 0.1500... {~\rm \Omega} }} \\ &= 10.6... ~\rm nF \end{align*}



1. What is the impedance $\underline{Z}_{RLC}$ of this real capacitor for $f_0=100 ~\rm MHz$? (Phase and magnitude)

Path

> The impedance $\underline{Z}_{RLC}$ is given by: \begin{align*} \underline{Z}_{RLC} &= R + \underline{X}_{L} + \underline{X}_{C} \\ &= R + {\rm j}\omega L - {{\rm j}\over{\omega C}} \\ &= R + {\rm j}\cdot \left(\omega L - {{1}\over{\omega C}} \right)\\ &= R + {\rm j}\cdot {X}_{LC} \\ \end{align*}
>
> Putting in the numbers, only for the reactive part ${X}_{LC}$: \begin{align*} {X}_{LC} &= 2\pi\cdot \quad \quad f_0 \quad \quad \cdot \quad L \quad \quad \quad \; - {{1}\over{2\pi \cdot \quad \quad f_0 \quad \quad \cdot \quad \quad C \quad\quad}} \\ &= 2\pi \cdot 100 \cdot 10^{6}{~\rm Hz} \cdot 60 \cdot 10^{-12}{~\rm H} - {{1}\over{2\pi \cdot 100 \cdot 10^{6}{~\rm Hz} \cdot 10 \cdot 10^{-9}{~\rm F}}} \\ &= -121.45... ~\rm m\Omega \\ \end{align*}
>
> With the real and imaginary parts, we can derive the magnitude and phase: \begin{align*} Z_{RLC} &=\sqrt{R^2 + {X}_{LC}^2} \\ &=\sqrt{(88 ~\rm m\Omega)^2 + (-121.45 ~\rm m\Omega)^2} \\ &= 150.0... ~\rm m\Omega \\ \end{align*}
>
> \begin{align*} \varphi &=\arctan \left( { {{{X}_{LC}}\over{R}}} \right)\\ &=\arctan \left( { {{-121.45 ~\rm m\Omega}\over{88 ~\rm m\Omega}}} \right)\\ &= -0.9437... = -54.07...° \\ \end{align*}

electrical_engineering_and_electronics:task_7el8zlzjglaazxtw_with_calculation
resonant circuit, exam ee2 ss2022