University Karlsruhe - International Department

Physics Course - Exercises Summer 2009

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Extra Tutorial
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1. Exercise

(i) Give two different possible SI-units of the electric field.

(ii) What is the electric field of a point charge q?

(iii) What is the electric force $\vec{F}$ on a charge q if the electric field $\vec{E}$ is given?

(iv) What is the relation between the electric field E, the voltage U and the distance d of the plates of a parallel plate capacitor?

(v) What kind of motion does a charge q if it enters a parallel plate capacitor parallel to the electric field?

(vi) What kind of motion does a charge q if it enters a parallel plate capacitor perpendicular to the electric field?

(vii) How is the capacitance C defined?

(viii) What is the capacitance of parallel plate capacitor.
Distance between the plates: d. Area of the plates: A.

(ix) What energy does a charge q gain in a parallel plate capacitor with an applied voltage of U (i.e. if the capacitor is used as an electron source)?

(x) What is the physical effect of a dielectric? How does it affect the capacitance?

(xi) What is the content of the Kirchhoff rules?

(xii) What states Ohm's law? What is the (microscopic) starting point to derive this law?

(xiii) A metallic wire ($\rho_s = 10^{-5}\,\Omega\,\mathrm{m}$) has cross section $A = 0.5\,\mathrm{mm}$ and length $\ell = 2\,\mathrm{m}$. How are the current I and voltage U related in this wire?

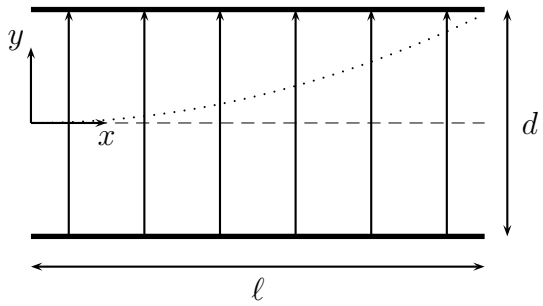
(xiv) What is the power dissipated in a resistor if a voltage U is applied?

2. Exercise

Consider a simplified version of Millikan's oildrop experiment. (The experiment with which the electric charge was measured for the first time.) A uniform electric field is provided by a pair of horizontal parallel plates of area A with distance d and a high potential difference U between them. A charged drop of oil with mass m is allowed to drift in between them (i.e. it is exposed to the gravitational force). By varying the potential, the drop can be made to stay steady. Determine the charge Q of the oil drop.

3. Exercise

Consider a point charge $q = e$ with mass $m = 10^{-16}\,\text{kg}$ which is accelerated by crossing a potential difference $\Delta U = 1250\,\text{V}$. Then it moves to the right along the axis of the square parallel plate capacitor as shown. The plates of the parallel plate capacitor are separated by a distance $d = 1\,\text{cm}$, have length $\ell = 3\,\text{cm}$. There is an electric field $E = 2 \cdot 10^4\,\frac{\text{V}}{\text{m}}$ in the region between the plates.



(i) What is the velocity v_0 of the charge before it reaches the deflection plates?

(ii) Write down the position of the particle in the parallel plate capacitor either as vector $\vec{r}(t)$ or in component form (i.e. $x(t)$ and $y(t)$).

(iii) How long does the charge need to pass the parallel plate capacitor?

(iv) Find the angle with respect to the horizontal when the point charge leaves the parallel plate capacitor.

(v) What potential difference U have to be applied when the point charge should leave the capacitor at the upper right corner.

There is a screen separated at a distance $s = 12\,\text{cm}$ from the end of the plates.

(vi) At what distance Δy from the axis will the charge strike the screen?

4. Exercise

The plates of a parallel-plate capacitor are $d = 3.3\,\text{mm}$ apart, each has an area of $A = 12\,\text{cm}^2$. Each plate carries a charge of magnitude $Q = 4.4 \cdot 10^{-8}\,\text{C}$. The plates are in vacuum.

(i) What is the capacitance C?

(ii) What is the potential difference U between the plates?

The capacitor is not connected to any battery. A dielectric with a dielectric constant of $\epsilon_r = 2$ is inserted into the capacitor, filling the total gap.

(iii) How does this influence the charge on the plates?

(iv) How does this influence the potential difference between the plates?

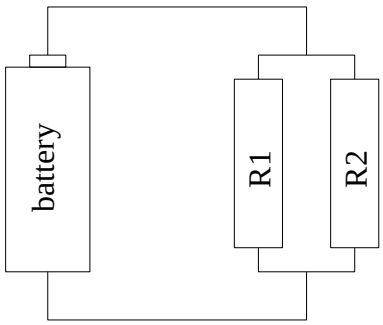
The capacitor is connected to a battery. Again a dielectric with a dielectric constant of $\epsilon_r = 2$ is inserted into the capacitor, filling the total gap.

(v) How does this influence the charge on the plates?

(vi) How does this influence the potential difference between the plates?

5. Exercise

Consider a battery with a voltage $U = 5\,\mathrm{V}$ and an inner resistance of $R_b = 1\,\Omega$. It is connected to two parallel connected resistors with resistances $R_1 = 40\,\Omega$ and $R_2 = 60\,\Omega$.



(i) Calculate the equivalent resistance R_R of the two resistors.

(ii) Calculate the resistance R_{eq} of the whole circuit.

(iii) Calculate the current I in the circuit and the power P provided by the battery.

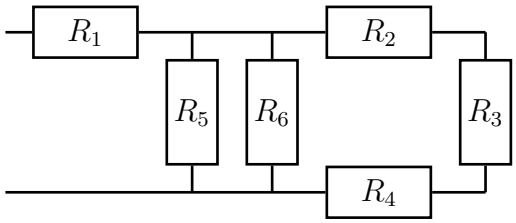
(iv) Calculate the voltage U_R that falls at the two resistors and the voltage U_b that falls at the battery.

(v) Calculate the currents I_1 and I_2 through the resistors R_1 and R_2.

(vi) Which resistor gets hotter and why?

6. Exercise

Calculate the equivalent resistance of the following resistor network with $R_1 = 1\Omega$, $R_2 = 2\Omega$, $R_3 = 3\,\Omega$, $R_4 = 5\,\Omega$, $R_5 = 4\,\Omega$, $R_6 = 6\,\Omega$:



7. Exercise*

Calculate the equivalent resistance of a cube consisting of resistors of $R = 1\Omega$ at the edges which is contacted at two opposite corners.

8. Exercise*

A metal cube with dimension $\ell \times \ell \times \Delta$ is fully inserted at position x into a capacitor with plates of size $A = \ell^2$ at a distance d which is charged by a voltage U. What is the equivalent capacitance and how much energy is needed for in this process?

Note:

- Permittivity of free space: $\epsilon_0 = 8.85 \cdot 10^{-12} \, \frac{\mathrm{C}}{\mathrm{Vm}}$
- Elementary charge: $e = 1.6 \cdot 10^{-19} \, \mathrm{C}$
- General definition of voltage

$$U = \int_{x_1}^{x_2} E \, \mathrm{d}x$$

- Ohm's law

$$j = \sigma E$$

- Current and voltage in a wire of length ℓ and cross section A

$$I = jA, \quad U = E\ell$$

- Resistance

$$R = \rho_s \frac{\ell}{A}$$

- Electric power

$$P = UI$$