Departement Physik
Universität Basel
Prof. E. Meyer / PD. T. Glatzel
Contact person: Miguel J. Carballido
miguel.carballido@unibas.ch
Office: 1.12
Tel.: +41 (0)61 207 36 91
http://adam.unibas.ch

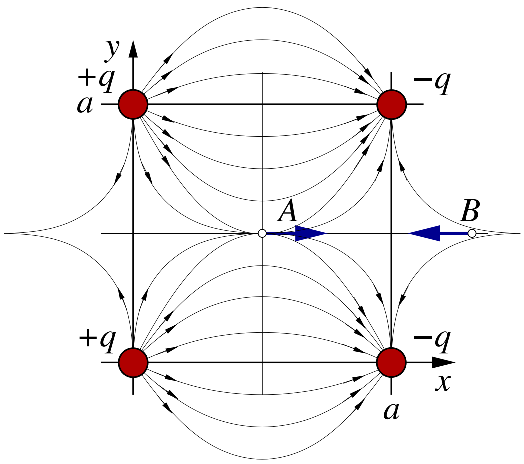
Exercises and Complements for the Introduction to Physics II

for Students

of Biology, Pharmacy and Geoscience

Sheet 1 / 23.02.2022 **Solutions**

Exercise 1.



Exercise 2.

(a) Calculation of the gravitational force:

$$F_G = \gamma \frac{m^2}{R^2} = 1.5 \cdot 10^{-13} \text{ N}$$

with mass m:

$$m = \frac{4\pi r^3 \rho}{3} = 47.501 \text{ g}$$

(b) Calculation of the Coulomb force:

$$F_C = \frac{1}{4\pi\varepsilon_o} \frac{Q^2}{R^2}$$

$Q = Q_1 = Q_2$ is the total charge of the spheres. Q is equal to the number of electrons times the charge of an electron: $Q = n \cdot q$. The number of electrons is given by:

$$n = \frac{m \cdot N_A}{A}$$

with N_A = Avogadro's number, and A = atomic mass. So:

$$F_C = \frac{n^2 q^2}{4\pi\varepsilon_0 R^2} = \frac{m^2 N_A^2 q^2}{4\pi\varepsilon_0 A^2 R^2} = \frac{4\pi r^6 \rho^2 N_A^2 q^2}{9\varepsilon_0 A^2 R^2} = 4.38 \cdot 10^{18} \text{ N}$$

(c) Now $F_G \overset{!}{=} F_C$ must hold:

$$\frac{F_C}{F_G} = \frac{\frac{1}{4\pi\varepsilon_o}\frac{Q^2}{R^2}}{\gamma\frac{m^2}{R^2}} = \frac{1}{4\pi\varepsilon_o\gamma}\left(\frac{Q}{m}\right)^2 \overset{!}{=} 1$$

$$\left(\frac{Q}{m}\right) = \sqrt{4\pi\varepsilon_o\gamma} = 8.614 \cdot 10^{-11}\ \text{C/kg}$$

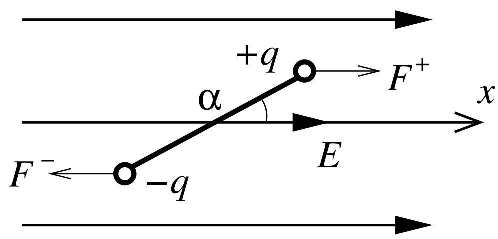
The result is independent of the body types interacting with each other. The result is also valid for the interaction between two protons or two electrons. In latter case, the elementary charge and the electron's mass must be used for Q and m.

Exercise 3.

(a) Dipole moment:

$$\vec{p} = q \cdot \vec{a} = 3.58 \cdot 10^{-30}\ \text{C} \cdot \text{m}$$

(b) The forces $\vec{F}^-$ and $\vec{F}^+$ have the same magnitude but point to opposite directions. This leads to a torque of the dipole around its center and finally a parallel alignment of the dipole to electric field lines.



Forces and charges in the electric field:

$$F^+ = E \cdot q^+ \qquad \text{resp.} \qquad F^- = E \cdot q^-$$

Torques:

$$\vec{M}^{\pm} = \vec{r} \times \vec{F}^{\pm} \qquad \Rightarrow \qquad M^{\pm} = r^{\pm} \cdot F^{\pm} \cdot \sin\alpha$$

with $r = d/2$:

$$M_T = 2 \cdot r \cdot E \cdot ||q|| \cdot \sin\alpha = 4.53 \cdot 10^{-27}\ \text{Nm}$$

(c) In an inhomogeneous electric field, the forces $\vec{F}^-$ and $\vec{F}^+$ are not equal in magnitude. As a result, the dipole will be drawn to the stronger electric field.

Exercise 4.

(a) For the ratio of charge to mass we get:

$$\frac{|e|}{m_e} = \frac{1.602 \cdot 10^{-19}\ \text{C}}{9.109 \cdot 10^{-31}\ \text{kg}} = 1.76 \cdot 10^{11}\frac{\text{C}}{\text{kg}}$$

(b) For the acceleration through the electric field we get:

$$|a| = \frac{|F_{\text{el}}|}{m_e} = \frac{|e| \cdot |E|}{m_e} = \frac{1.602 \cdot 10^{-19}\ \text{C} \cdot 100\ \text{NC}^{-1}}{9.109 \cdot 10^{-31}\ \text{kg}} = 1.76 \cdot 10^{13}\frac{\text{m}}{\text{s}^2}$$

The electron will be accelerated in the opposite direction of the field lines.