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Exercises and Complements for the Introduction to Physics II

for Students

of Biology, Pharmacy and Geoscience

Sheet 5 / 30.03.2022 **Solutions**

Exercise 17.

From the Lorentz force on a wire/conductor **(Script: 307-3)**

$$F_L = IlB$$

and the force of gravity

$$F_G = mg = \rho A l g$$

follows:

$$\tan\varphi = \frac{F_L}{F_G} = \frac{IB}{\rho A g} = \frac{jB}{\rho g} = 0.302 \qquad \Rightarrow \qquad \varphi = 16.8^\circ$$

where $j = I/A$ is the current density.

Exercise 18.

From the energy equation/balance it follows that the energy from the acceleration due to magnetic field = kinetic energy:

$$\begin{aligned} E_b &= E_{kin} \\ eU &= \frac{1}{2} m_1 v^2 \end{aligned}$$

follows:

$$v = \sqrt{\frac{2eU}{m_1}} = 8.755 \cdot 10^4 \ \frac{\mathrm{m}}{\mathrm{s}}$$

and thus, from the force balance in the circular path:

$$\begin{aligned} \text{Lorentz-force} &= \text{Centrifugal-force} \\ F_L &= F_Z \\ evB &= \frac{m_1 v^2}{r_1} \end{aligned}$$

(a) For the magnetic field, this results in:

$$B = \frac{\sqrt{2(m_1/e)U}}{r_1} = 0.18 \ \mathrm{T}$$

(b) The slightly heavier ^{65}Cu-ion describes a circular path with the radius:

$$r_2 = r_1 \sqrt{\frac{m_2}{m_1}} = 322.2 \text{ mm}$$

In the case of a semi-circular orbit, the detection points of the two types of ions are thus separated by the distance $\Delta x = 2(r_2 - r_1) \approx 10$ mm.

Exercise 19.

(a) See Script 307-11.

$$B = \frac{\mu_0 N I}{l} \qquad \Rightarrow \qquad I = \frac{B_h l}{\mu_0 N} = 0.33 \text{ A}$$

(b) So that the field B_H from Earth can be compensated, the field B_S from the coil must point to the right. With the "right-Hand rule" one realizes the current must be I_+.

Exercise 20.

As a result of the temporal change of the magnetic flux Φ inside the coil when switching it off, a short-circuit happens in the coil itself

$$I = \frac{U_{ind}}{R} = -\frac{N}{R}\frac{d\Phi}{dt} = -\frac{L}{R}\frac{dI}{dt}$$

inducing therefore the ohmic resistance of the winding $R = U_0/I_0$ and inductance of the coil $L = \mu_r \mu_0 N^2 A/l$, where $A = \pi d_E^2/4$ is the cross-section and $l = 2\pi r = \pi d_S$ the length. We apply the numerical values $R = 38\ \Omega$ and $L = 67.9$ mH. Writing in terms of I:

$$\frac{dI}{I} = -\frac{R}{L}dt$$

After integration, with initial condition $I(t = 0) = I_0$:

$$\ln I - \ln I_0 = \ln \frac{I}{I_0} = -\frac{R}{L}t \qquad \text{bzw.} \qquad I(t) = I_0 \exp^{-(R/L)t}$$

For $t = 1 \cdot 10^{-3}$ s follows $I(t = 1 \cdot 10^{-3}) = 2.0$ A.