University Karlsruhe - International Department

Physics Course - Exercises Summer 2009

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Sheet 6
11.9.2009

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1. Exercise: Competeting forces

Find the ratio of the electric and the gravitational force

(i) between two electrons with mass $m_e = 9.1 \cdot 10^{-31}\,\mathrm{kg}$ which are separated by a distance $r = 1\,\mathrm{m}$.

(ii) for an isotropic ball with mass $m = 1\,\mathrm{kg}$ charged by $q = 1\,\mathrm{C}$ in a thunderstorm generating an homogeneous electric field of $E = 10^6\,\frac{\mathrm{V}}{\mathrm{m}}$ on the earth ($g = 10\,\frac{\mathrm{m}}{\mathrm{s}^2}$).

(iii) between two isotropic planets with masses $M = 6 \cdot 10^{24}\,\mathrm{kg}$ at a distance of $R = 2 \cdot 10^7\,\mathrm{m}$, on each standing one person with mass $m = 80\,\mathrm{kg}$ and a charge excess of 1%. Assume that the neutral persons only consist of neutral carbon atoms with 12 electrons and mass $m_C = 2 \cdot 10^{-26}\,\mathrm{kg}$ and that the persons are separated by a distance of $r = 3\,\mathrm{m}$.

2. Exercise: An airplane in a thunderstorm

Background: When airplanes are flying through clouds, they often get electrostaticly charged. In this way they experience an electrostatic force when they try to land in a thunderstorm. They can cause serious problems for radio, too. For compensation, they carry static dischargers, small antenna like objects, at the back of their wings. Additionally they are grounded when they reach the terminals to prevent injuries after landing.

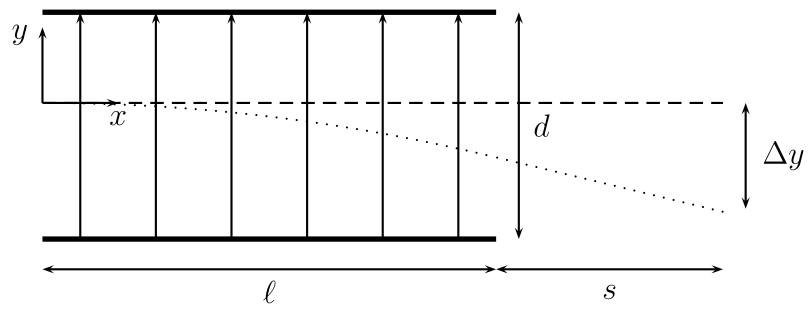
We model the thunderstorm by a square parallel plate capacitor, and the airplane as a point charge where the gravitational force is compensated by the buoyant force. Thus consider a negative point charge with charge $q = -10\,\mu\mathrm{C}$ and mass $m = 500\,\mathrm{kg}$ which moves horizontally with a velocity of $v_0 = 300\,\frac{\mathrm{m}}{\mathrm{s}}$ to the right along the axis of the parallel plate capacitor as shown. The plates of the parallel plate capacitor are separated by a distance $d = 2\,\mathrm{km}$ and have a length of $\ell = 30\,\mathrm{km}$. In the region between the plates an electric field $E = 1 \cdot 10^5\,\frac{\mathrm{V}}{\mathrm{m}}$ is measured which is pointing upwards.

First take a look at the point charge:

(i) What is the absolute value of the electrostatic force on the point charge and in which direction is it pointing?

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

(iii) What is the distance Δy from the original height where the charge will be positioned after the length $s = 20\,\mathrm{km}$ succeeding the end of the capacitor?



Next consider the parallel-plate capacitor:

(iv) What is the capacitance C?

(v) Calculate the potential difference U.

(vi) Determine the amount of charges Q on the plates.

3. Exercise: The coaxial cable

Background: Coaxial cables are the simplest cables which screen their transmitted information from the environment. The characteristics of high frequency communication of these cables are strongly influenced by their capacitance.

Consider two metallic cylinders with the same axis, height ℓ, radius a and $b > a$. They are charged by $Q > 0\,\mathrm{C}$ and $-Q$. Neglect the effects of both bases.

(i) From Gauss' law, what is the electric field inside the small cylinder ($r < a$)?

(ii) What is the electric field outside the small cylinder ($r > b$)?

(iii) Draw the electric field in a plane perpendicular to the central axis.

(iv) From symmetry, state a surface where the electric field E is constant.

(v) Use the first Maxwell equation to determine the electric field as function of r for $a < r < b$.

(vi) Find the voltage U.

(vii) Calculate the capacitance C for a system with $a = 1\,\mathrm{mm}$, $b = 5\,\mathrm{mm}$ and $\ell = 1\,\mathrm{m}$.

Note:

- Permitivity of free space: $\epsilon_0 = 8.85 \cdot 10^{-12}\,\frac{\mathrm{C}}{\mathrm{Vm}}$
- Gravitation constant: $\gamma = 6.67 \cdot 10^{-11}\,\frac{\mathrm{Nm}^2}{\mathrm{kg}^2}$
- Elemetary charge: $e = 1.6 \cdot 10^{-19}\,\mathrm{C}$
- The antiderivative $\int \frac{1}{r}\mathrm{d}r = \ln r$