Karlsruhe Institute of Technology - International Department GmbH

Pre-Semester 2010 - Physics Course - Extra Tutorial

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1. Electrostatics - Things to *learn by heart*

(a) **Coulomb's law**: What force F_{12} does a point with charge q_1 exert on a point with charge q_2 which is located in a distance r_{12}? In which direction does it point?

(b) An **electric field** $\vec{E}$ is *defined* (it's best not to ask for a deeper meaning) by the force $\vec{F}$ which it exerts on a charge q. How are the 3 quantities related? For given $\vec{E}$ and q, in which direction does the force $\vec{F}$ point?

(c) Imagine two large **parallel plates** with distance d, each of them having an area A. One of them is charged with (constant) *charge density* $\boxed{\sigma = Q/A}$, the other one is charged oppositely with $-\sigma$. What is the electric field between the two plates? In which direction does it point? What is the **voltage** U between the two plates?

2. Potential energy and electric voltage

(a) A point with mass m moves under the influence of gravity g. Initially (at $t = 0$) it is at rest and located at an height h above the ground.

(i) What force F_g acts on the point? In which direction does it point?

(ii) What is the potential energy of the point if it is at an height z above the ground?

(iii) What is its velocity v_g when it hits the ground?

(b) A point with mass m and charge $q < 0$ moves through an homogeneous electric field $E > 0$ which points upwards. Gravity is neglected. Initially (at $t = 0$) the point is at rest and located at an height $z(t = 0) = h$ above the ground.

(i) What force F acts on the point? In which direction does it point?

(ii) What is the point's position $z(t)$ at time t?

(iii) What is the point's velocity $v(t)$ at time t?

(iv) At what time t_g does the point hit the ground?

(v) What is its velocity v_g when it hits the ground?

(vi) Let's assume the **potential energy** of the point is $\boxed{E_{\text{pot}} = -qEz}$, if it is at an height z above the ground. Assume further that the total energy $E_{\text{pot}} + E_{\text{kin}}$ is conserved.
Again, calculate the velocity v_g with which the point hits the ground!

(vii) The **electric voltage** *between two points* z_1 and z_2 is
$\boxed{U_{12} = (E_{\text{pot}}(z_1) - E_{\text{pot}}(z_2))/q}$.
Calculate the voltage U_h between $z = h$ and the ground. Does it depend on q?

3. Two parallel plates

Consider two large parallel square plates with edge length $l = 10\,\text{cm}$ with a distance $d = 1\,\text{cm}$. One of them is uniformly charged with $Q = 10^{-3}\,\text{C}$, the other one with $-Q$.

(a) Calculate the area A of each of the plates.

(b) What is the charge density σ?

(c) What is the electric field E between the plates?

(d) What is the voltage U between the plates?

(e) Imagine a point of charge $q = +10^{-8}\,\text{C}$ and mass $m = 0.05\,\text{kg}$ is put on the positively charged plate. It is repelled and moves towards the oppositely charged plate. With which velocity v does it reach the other plate?

4. Motion in homogeneous field

A point with charge q and mass m enters a region where an constant electric field E is present, which points "upward" in y-direction. Initially, the point moves in x-direction with velocity v_{x0}.

(a) Consider the force which acts on the point charge: What are its components F_x, F_y in x- and y-direction?

(b) Deduce the acceleration a_x, a_y (in both directions) which the point undergoes.

(c) What are the point's coordinates $x(t)$, $y(t)$ at time t, if initially (at $t = 0$) the particle is at $x(0) = y(0) = 0$?

(d) If the point has travelled a given distance l in y-direction, $y(t') = l$, what is its velocity $v_x(t')$, $v_y(t')$? How much kinetic energy has the point gained (as compared to the initial situation?).

5. Coulomb's Law

Consider a point with *positive* charge $q_1 = 10^{-6}\,\text{C}$. A second point with (unknown) charge q_2, located in a distance $d = 1\,\text{m}$, is *attracted* by the first one with a force $F_{12} = 20\,\text{N}$.

(a) Is the charge q_2 negative or positive?

(b) Calculate q_2.

(c) What would be the force F'_{12} if the distance were $d' = 2\,\text{m}$?

Notes: You may need $\epsilon_0 = 8.85 \cdot 10^{-12} \frac{\text{C}^2}{\text{Jm}}$.