Exercise sheet #2

Problem 1. We want to make a comparison between the gravitational force and the electrostatic (Coulomb) force.

(a) From a *mathematical* point of view, which is the only qualitative difference between the two forces? From the *physical* point of view, is there another important difference?

(b) Let us now consider two electrons in free space placed at distance r: they both feel gravitational attraction because of their mass, and electrostatic repulsion because of their charge. What value the electron mass should have had in order to create the situation where the attraction and the repulsion are balanced and the two electrons do not move?

(c) A charged body with $Q = -1\ \mu C$ is dropped from a height $h = 1\ m$ above the Earth surface. A point charged with 10^{19} electrons is placed exactly below it on the surface. By using the concept of potential energy, evaluate the mass M of the body in order to let it float at height h *(remember that the gravitational potential energy at distance z close to the Earth surface can be approximated as $U = Mgz$, with $g = 9.81\ m/s^2$).*

(d) Describe *qualitatively* what happens if the body with mass M as determined in c) placed at h has an initial velocity v directed towards the Earth *(tip: this is best solved using energy diagrams).*

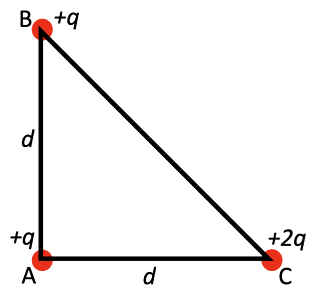
Problem 2. Suppose we loose 1 out of every 10^{12} electrons in our body.

(a) Estimate the charge of a typical human body after this event. Make sure to justify the assumptions you need to make and try not to use a calculator.

(b) Estimate the force between two persons at distance of 1 m? How will this change for 1.5 m?

(c) Estimate the acceleration that each person will experience.

Problem 3. Consider a $45° - 90°$ triangle of side d and three point charges $+q$, $+q$ and $+2q$ fixed at the three corners A, B, C respectively as shown in the figure below. Evaluate the Coulomb force vector acting on a positive charge q_0 fixed in the midpoint of the hypotenuse.



Problem 4. Consider two fixed point charges $+q$ and $+2q$ placed at distance a.

(a) Find the equilibrium position between the two charges for a positive charge q_0.

(b) How does the result change if you consider a negative charge q_0?Would they still be able to be in equilibrium?

Problem 5. What is the total charge on a sheet with the size L_x=60 cm and L_y=50 cm, if the charge distribution in $\frac{\mathrm{C}}{\mathrm{m}^2}$ is given by $\sigma(x, y) = x^2y^3 + ln(x)$?
(assume that one of the corners of the sheet is located at (0/0), and it's expanding in positive x- and y-direction)

Problem 6. A disc shows a radial charge distribution given by $\sigma(r) = e^r$. What is the mean surface charge density as a function of the disc radius R?

Problem 7. In atomic Physics, one of the first attempts to describe the atomic structure is the *Bohr model*. According to this, an atom is depicted as a small positively charged nucleus surrounded by electrons which travel around it in circular orbits. The Hydrogen atom has only one electron and a nucleus made by only one proton (the charge of which has the same magnitude as the electron charge). The radius of the orbit is known as *Bohr radius* and its value is $a_0 = 5.29 \times 10^{-11}\ m$.

(a) Evaluate the potential energy stored in the Hydrogen atom.

(b) Evaluate the kinetic energy of the electron as a function of its charge (Remember the expression for the centripetal force is $F = mv^2/r$).

(c) Evaluate the ionization energy of the Hydrogen atom, that is the energy required to extract the electron from it.