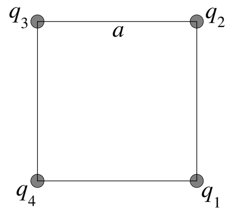
Tutorial series #1 ———— February 2024

!! For numerical calculations, take $k = 9 \times 10^9$ N· m^2·C^{-2} for the Coulomb constant.

Exercise 1 : Four charges q_1, q_2, q_3 and q_4 are placed in this order on the corners of a square of side a (figure opposite). The charges are such that q_1 is negative, $q_2 = -2q_1$, $q_3 = 3q_1$ and $q_4 = -4q_1$. Let's denote $\vec{F}_{2/1}$, $\vec{F}_{3/1}$ and $\vec{F}_{4/1}$ the forces that charges q_2, q_3 et q_4 exert on q_1. a) Express the modulus of each force as a function of F_0, where $F_0 = kq_1^2/a^2$. b) Choose an arbitrary scale for F_0 ((i.e. an arbitrary length, e.g., 0.5 cm) and draw the three forces at this scale.
Ans. : a) $F_{2/1} = 2F_0$; $F_{3/1} = 3F_0/2$; $F_{4/1} = 4F_0$.



Exercise 2 : The charge of an electron is $q_e = -1.6\times10^{-19}$ C and the charge of a proton is $q_p = +1.6\times10^{-19}$ C. If an initially neutral body acquires 10^9 electrons every second, how much time is required to get a net (total) charge of -1 C on it ? (a) 190.19 years ; (b) 150.12 years ; (c) 198.19 years ; (d) 188.21 years.

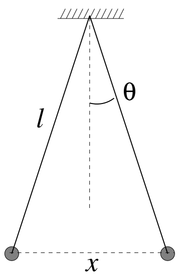
Exercise 3 : What is the acceleration of an electron due to its mutual attraction with the proton when they are 1.6 Å apart ? Take $m_e = 9 \times 10^{-31}$ kg.

Exercise 4 : Which of the following charges cannot exist in nature ? a) 5.2×10^{-19} C, b) 3.2×10^{-19} C, c) 6.7×10^{-19} C, d) 6.4×10^{-19} C, e) 1.6×10^{-10} C, f) 1.6×10^{-20} C.

Exercise 5 : Two objects A and B are rubbed together. If B acquires an excess of 10^9 electrons, object A must have : a) gained 10^9 electrons, b) gained 10^9 protons, c) lost 10^9 electrons, or d) lost 10^9 protons.

Exercise 6 : A metal sphere with a charge $Q_s = -2\,\mu$C sits near a metal cylinder that has a charge $Q_c = +4\,\mu$C. If the sphere comes into contact with the cylinder and then separated, what is a possible final charge on each object ? a) $Q_sf = -2\,\mu\text{C}, Q_cf = -2\,\mu\text{C}$; b) $Q_sf = -2\,\mu\text{C}, Q_cf = +4\,\mu\text{C}$; c) $Q_sf = +1\,\mu\text{C}, Q_cf = +1\,\mu\text{C}$; d) $Q_sf = +4\,\mu\text{C}, Q_cf = +4\,\mu\text{C}$.

Exercise 7 :
The figure opposite shows two identical balls suspended at the same point by insulating wires of length l. Each ball has mass m and charge Q. Because of their mutual electrical repulsion, they move apart and balance at $x = 5$ cm. Find the expression and the value of Q. Take $l = 1.2$ m and $m = 10$ g.
Hint : The Pythagorean theorem implies $l^2 = x^2/4 + l^2\cos^2\theta \implies 1 = x^2/4l^2 + \cos^2\theta \implies \cos^2\theta = 1 - x^2/4l^2$. *Noting that* $x \ll l$, *we deduce that* $x^2 \lll 4l^2$ *and therefore* $x^2/4l^2 \lll 1$. *In other words,* $x^2/4l^2$ *is negligible compared to 1, so we can make the approximation* $\cos^2\theta \approx 1$ *or, equivalently,* $\cos\theta \approx 1$. *Ans. :* $Q = (mgx^3/2kl)^{1/2} = 2.4 \times 10^{-8}$ C.



Exercise 8 : The balls from the previous exercise are conductive. a) What will happen if we completely discharge one of the two balls ? b) Find the new equilibrium position ?

Exercice 9 : A point charge q is placed halfway between two positive point charges q_1, q_2 separated by $2d$ and such that $q_1 = q_2 = Q$.
a_1) Assuming q has the same sign as q_1 and q_2, is the charge q in equilibrium ? If yes, a_2) is equilibrium stable or unstable if q is forced to move along the line q_1q_2 ? a_3) is equilibrium stable or unstable if q is constrained to move in the median plane of segment $[q_1q_2]$ مجبر للتحرك في المستوى العمودي المنصف لقطعة?
Ans. : Hint → Charge q is in stable (instable) equilibrium if, when it moves slightly away from its equilibrium position, it tends to return to it (move away from it). .

— *End of the tutorial serie*