



Digital version

ENGS123 Electricity and Magnetism - Homework 5

Mher Saribekyan A09210183

October 4, 2024

Problem 1

Under the influence of the electric force of attraction, the electron in a hydrogen atom orbits around the proton on a circle of radius $5.3 \cdot 10^{-11}m$. How much energy do we need to tear off that electron?

$$F = k \frac{e^2}{r^2} \implies A = \int_R^\infty F ds = \int_R^\infty k \frac{e^2}{r^2} dr = -k \frac{e^2}{R} \implies E = 8.99 \cdot 10^9 \frac{(1.602 \cdot 10^{-19})^2}{5.3 \cdot 10^{-11}} \approx 4.35 \cdot 10^{-18} J$$

Problem 2

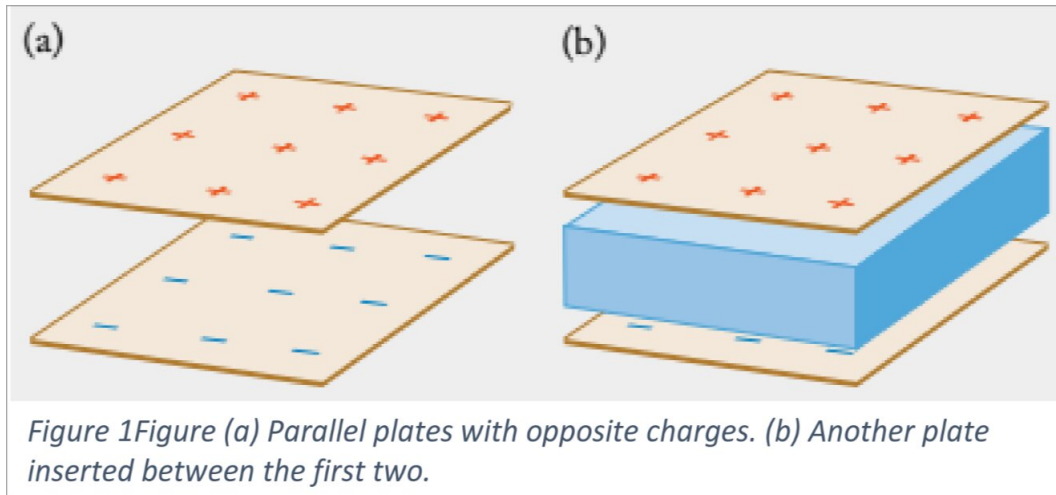
Charge is placed on a small metallic sphere which is surrounded by air. If the radius of the sphere is $0.50cm$, how much charge can be placed on the sphere before the air near the sphere suffers electric breakdown? The critical electric field strength that leads to breakdown in air is $3.0 \cdot 10^6 N/C$.

Image a Gaussian sphere around the charged sphere. Consider the molecules of air at the surface of the sphere.

$$\Phi = ES = E4\pi R^2 = \frac{Q}{\varepsilon_0} \implies Q = 4\pi R^2 E \varepsilon_0 = 4\pi \cdot (0.005)^2 \cdot 3.0 \cdot 10^6 \cdot 8.85 \cdot 10^{-12} \approx 8.34 \cdot 10^{-9} C$$

Problem 3

Consider two large parallel metallic plates with uniform, opposite charge distributions, as in Fig (A). Suppose that the magnitude of the charge density on each plate is $2.0 \cdot 10^{-5} C/m^2$. The upper plate is positive and the lower negative.



- a) What is the magnitude of the net electric field in the region between the plates?

Using the formula derived in Homework 3 Problem 8 (https://docs.cobalt.am/HW/ENGS123_HW3_Mher_Saribekyan.pdf#page=5):

$$E = \frac{\sigma}{\epsilon_0} = \frac{2.0 \cdot 10^{-5}}{8.85 \cdot 10^{-12}} \approx 2.26 \cdot 10^6 N/C$$

- b) You now insert a neutral large parallel metallic plate in the space between the two charged plates, as in Fig. b. Suppose, that this plate is $1.0cm$ thick. What is the magnitude of the electric field inside this thick plate? What is the magnitude of the electric field in the remaining space above and below this thick plate?

The electrons inside the metal plate will flow towards the positively charged plate, leaving the positive metal nuclei at near the negatively charged plate. This process will continue until those separated charges create an opposing magnetic field with the same magnitude as the outside field. This will cause block the electric fields coming from one plate to reach the space between the metal plate and the other plate.

$$\therefore E_{\text{inside}} = 0 \text{ and } E_{\text{outside}} = E \approx 2.26 \cdot 10^6 N/C$$

- c) What is the charge density on the upper surface of the thick plate? The lower surface?

$$\sigma_{\text{top}} = -2.0 \cdot 10^{-5} C/m^2 \text{ and } \sigma_{\text{bottom}} = 2.0 \cdot 10^{-5} C/m^2$$

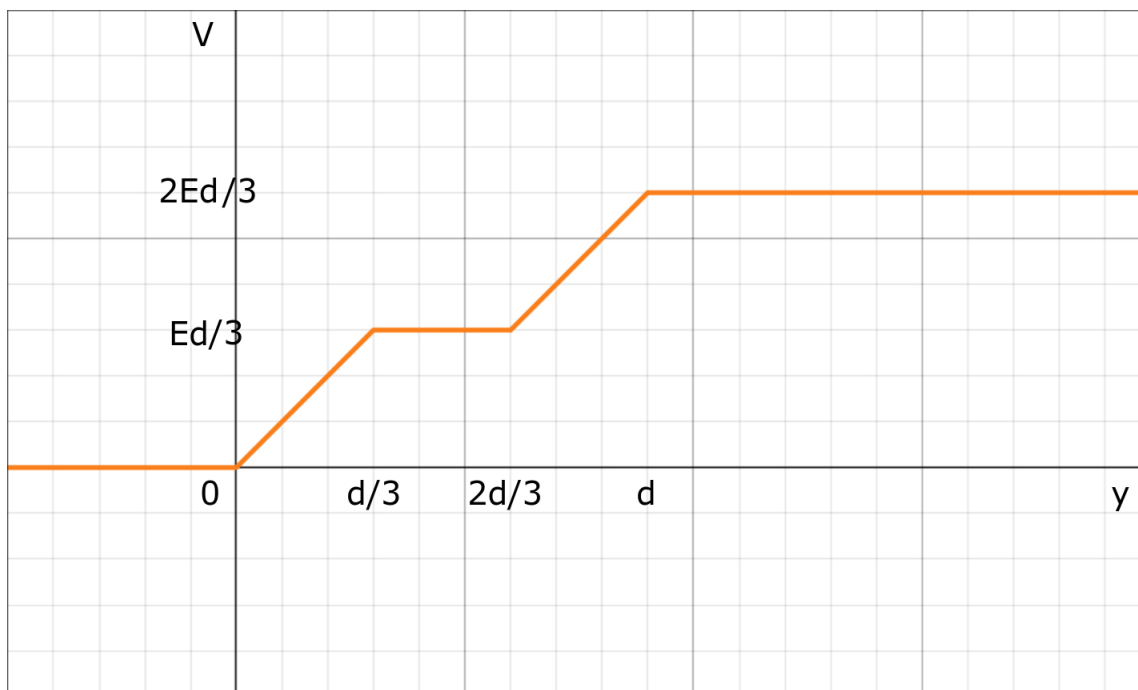
- d) You now insert a neutral large parallel dielectric plate in the space between the two charged plates, as in Fig. b. Suppose, that this plate is $1.0cm$ thick and it's dielectric permittivity is 2. What is the magnitude of the electric field inside this thick plate? What is the magnitude of the electric field in the remaining space above and below this thick plate?

Similar situation as with the metal plate, but instead of the internal electric field being the same as the outside field, it's $\frac{1}{\epsilon} = \frac{1}{2}$ of the outside field.

$$\therefore E_{\text{inside}} = \frac{E}{2} \approx 1.13 \cdot 10^6 N/C \text{ and } E_{\text{outside}} = E \approx 2.26 \cdot 10^6 N/C$$

Problem 4

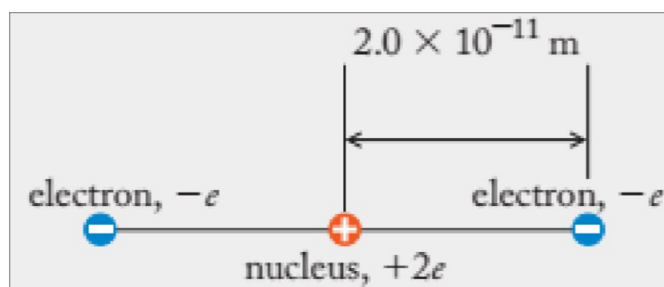
Two large flat parallel sheets have opposite uniform surface charge densities σ and separated by a distance of d . A large, uncharged conducting slab of thickness $d/3$ is parallel to the charged sheets, centered between them. Draw the graph, that represents the dependence of the electrostatic potential vs distance y from the lower sheet. Take the reference potential $V_0 = 0$ and the origin $y = 0$ to be at the negative sheet.



Using the formula derived in Homework 3 Problem 8 (https://docs.cobalt.am/HW/ENGS123_HW3_Mher_Saribekyan.pdf#page=5): $E = \frac{\sigma}{\epsilon_0}$. The field inside the conducting slab is zero.

Problem 5

Suppose that at one instant the electrons and the nucleus of a helium atom occupy the positions shown in Fig. at this instant, the electrons are at a distance of $2.0 \cdot 10^{-11} \text{ m}$ from the nucleus. What is the electric potential energy of this arrangement? Treat the electrons and the nucleus as point charges.



Imagine the lonely nucleus of a helium. Now bring the first electron. Calculate the external work required to do that, that's going to be the same as the potential energy. Now, bring the other electron, and do the same. Take the reference point of potential energy the infinity point.

$$E_{p1} = -k \frac{2e^2}{r} \text{ and } E_{p2} = -k \frac{2e^2}{r} + k \frac{e^2}{2r}$$

$$\therefore E_p = -k \frac{7e^2}{2r} = -8.99 \cdot 10^9 \frac{7(1.602 \cdot 10^{-19})^2}{2 \cdot 2 \cdot 10^{-11}} \approx -4.04 \cdot 10^{-17} J$$

Problem 6

The dipole moment of an HCl molecule is $3.4 \cdot 10^{-30} Cm$. Calculate the magnitude of the torque that an electric field of $2.0 \cdot 10^6 N/C$ exerts on this molecule when the angle between the electric field and the longitudinal axis of the molecule is 45° .

Same exact problem was solved in Homework 2 Problem 9(https://docs.cobalt.am/HW/ENGS123_HW2_Mher_Saribekyan.pdf#page=6):

$$\tau = \mu E \sin \theta = 3.4 \cdot 10^{-30} \cdot 2.0 \cdot 10^6 \cdot \sin \frac{\pi}{4} \approx 4.81 \cdot 10^{-24} Nm$$