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SOLVING SELECTED TASKS PROBLEMS IN ELECTROSTATICS

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Abstract. *Samples of solving problems on Physics from the electrostatics section are given. The solution ways and the received numerical result are explained.*
Keywords: *electric charge, law, interaction, conservation of charge, conservation of energy, work.*

Electrostatics is a branch of electricity that studies electrical phenomena, dealing with the issues about the distribution of electric charges, their interactions, the conditions of equilibrium of electrically charged bodies at rest, as well as the investigating the electrical properties of these bodies. Electric charges can move from one body to another or be redistributed in one body, but cannot be created or destroyed, and “in an isolated system, the algebraic sum of electric charges remains constant.” This statement is called the law of conservation of electric charge.

Electric charges at rest interact with each other according to Coulomb's experimental law, which establishes the dependence of the force of interaction of two-point charges in a vacuum on the size of these charges as well as on the square of the distance between them.

The potential energy of interaction between two charges that are located at some distance from each other also depends on the size of the charges and the distance between them.

A deep understanding of the laws of electrostatics is achieved by solving tasks. Let's consider some tasks in electrostatics:

Task 1

Two identical small charged metal balls are located at a distance of √3 m from each other. They attract each other. The charges of the balls differ by a factor of 3. The balls were brought into contact and separated to some distance. The interaction force turned out to be 75% less than the original one. Find this distance?

Solution

Let's consider the force of interaction between charges before they come into contact:

$$\mathbf{F^1 = K}\frac{|q_1|\bullet|q_2|}{r^2}$$

where - q_1, q_2, - the values of the charges of the balls r= the distance between the centers of the balls in the initial position

$$\mathbf{K} = \frac{1}{4\pi\varepsilon_0}, \varepsilon_0$$

From the conditions of the problem it follows that $F_1 = \mathbf{K}\frac{|3q \quad \bullet q|}{r^2}$

After identical conducting balls come into contact, the charges will be redistributed so that the balls will be equally charged. But according to the law of conservation of charge, the total charge of the system of two balls has not changed [2]. And each charge of the ball will be equal to: $q_0 = \frac{q_1+q_2}{2} = \frac{3q-q}{2} = q$

Here it is important to pay attention to the condition of the problem, which states that charged balls attract, that is, they are charged oppositely.

Let's write Coulomb's law for balls in final position: F_2= **K**$\frac{|q|^2}{r_1^2}$ **(2)**

Dividing equation (1) by equation (2) we determine the distance between the charged balls in the final position - r_2

From the problem conditions it follows that

$F_2=0.25F_1$ Therefore:

$F_1/F=4=3r_2^2/r^2$, hence

$r_2=2r_1/\sqrt{3}=2\sqrt{3}/\sqrt{3}=2$cm

Answer: 2cm

Task 2

Five identical charges of 2 μC each are located on a straight line. The distance between adjacent charges is 20 cm. How much work must be done to place these charges at the vertices of a regular pentagon with an edge of 10 cm?

k = 9 •10m/F. (cos108°= -0.31).

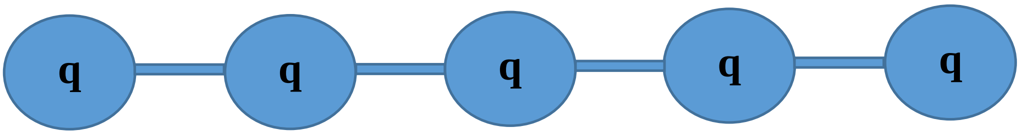
Solution

This problem can be solved by calculating the potential energy of particle interaction and writing the law of conservation of energy [3]. For two-point charges, the potential energy of interaction is equal to:

$$W_1 = \mathbf{K} \cdot \mathbf{q^2 / r}$$

Where q-the magnitude of the charges, r- the distance between adjacent charges

In our problem, the initial potential energy of interaction between five charges, located along a straight line is equal to the sum of the interaction energies between all pairs of charges:



$W_I = 4W_1 + 3W_2 + 2W_3 + W_4$

$W_1 = \mathrm{K}\frac{q^2}{r}$ $\quad W_2 = \mathrm{K}\frac{q^2}{2r}$

$W_3 = \mathrm{K}\frac{q^2}{3r}$ $\quad W_4 = \mathrm{K}\frac{q^2}{4r}$

$W^0 = 4\,\mathrm{K}\frac{q^2}{r} + 3\,\mathrm{K}\,\frac{q^2}{2r} + 2\,\mathrm{K}\,\frac{q^2}{3r} + \mathrm{K}\frac{q^2}{4} = \frac{77}{12}\,\mathrm{K}\frac{q^2}{r}$

$W^0 = \frac{77}{12} \cdot 9 \cdot 10^9 \cdot \frac{4 \cdot 10^{-12}}{2 \cdot 10^{-1}} = \frac{77 \cdot 3 \cdot 10^{-2}}{2} = 115{,}5 \cdot 10^{-2} = 1155$ mJ

The energy of interaction between charges after their location at the vertices of an equilateral pentagon is also equal to the sum of all pair interactions.

From mathematics it is clear that the angle of a regular pentagon is 108°. Therefore, the distance between alternating charges, r- determined by the cosine theorem:

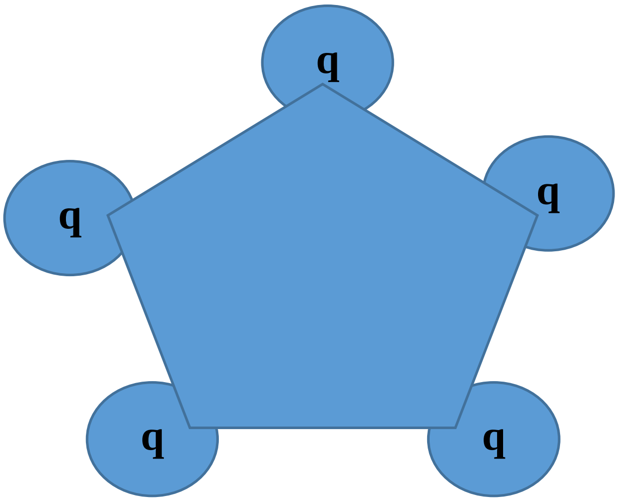
$r^0 = \sqrt{r_1^2 + r_2^2 - 2 \cdot r_1 \cdot r_2 \cdot cos\alpha}$

$W_{II} = 5\,W_1 + 5\,W_2$

$W_1 = \mathrm{k}\,\frac{q^2}{r_2}$ $\quad W_2 = \mathrm{k}\,\frac{q^2}{r}$

$r^0 = \sqrt{100 + 100 - 2 \bullet 100\big(-(0..31)\big)} = 16.18\text{cm}$

$W = 5 \bullet 9 \bullet 10^9 \frac{4\bullet 10^{-12}}{10^{-1}} + 5 \bullet 9 \bullet 10^9 \bullet \frac{4\bullet 10^{-12}}{1{,}618\bullet 10^{-1}} = 2912\text{mJ}$



Now, from the law of conservation of energy, it is possible to calculate the work of changing the arrangement of charges as the difference in energy in the initial and final positions:

A = 2912 – 1155 = 1757 mJ

Answer: A = 1757 mJ

Obviously, solving such problems in electrostatics reinforces students' knowledge of the laws of conservation of charge and energy and allows them to understand the significance of these laws in solving problems in electrostatics.

This use of the reserves of live communication in the system of relationships "Teacher - Student" creates the opportunity to intensify the educational and cognitive activity of students, skills and abilities associated with the use of radiated knowledge are formed. This leads to an increase in the competence of students.

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