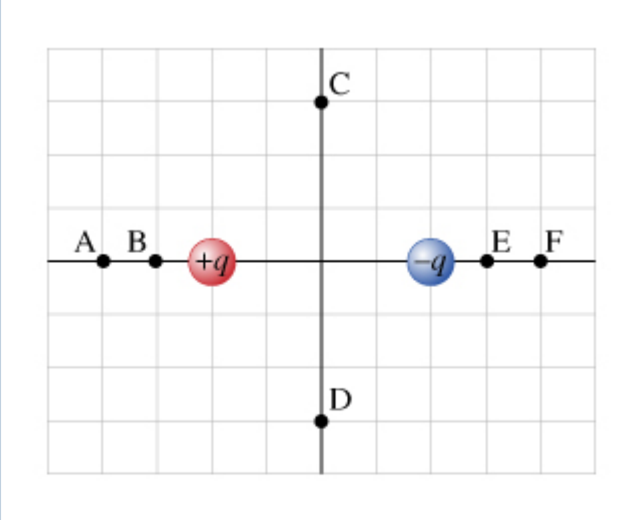
Static Electricity (Part II) In class assignment

Due: 11:59pm on Sunday, August 7, 2022

You will receive no credit for items you complete after the assignment is due. Grading Policy

Electric Potential Ranking Task

In the figurethere are two point charges, $+q$ and $-q$. There are also six positions, labeled A through F, at various distances from the two point charges. You will be asked about the electric potential at the different points (A through F).



Part A

Rank the locations A to F on the basis of the electric potential at each point. Rank positive electric potentials as higher than negative electric potentials.

Rank the locations from highest to lowest potential. To rank items as equivalent, overlap them.

Hint 1. Definition of electric potential

The electric potential surrounding a point charge is defined by

$$V = \frac{kq}{r},$$

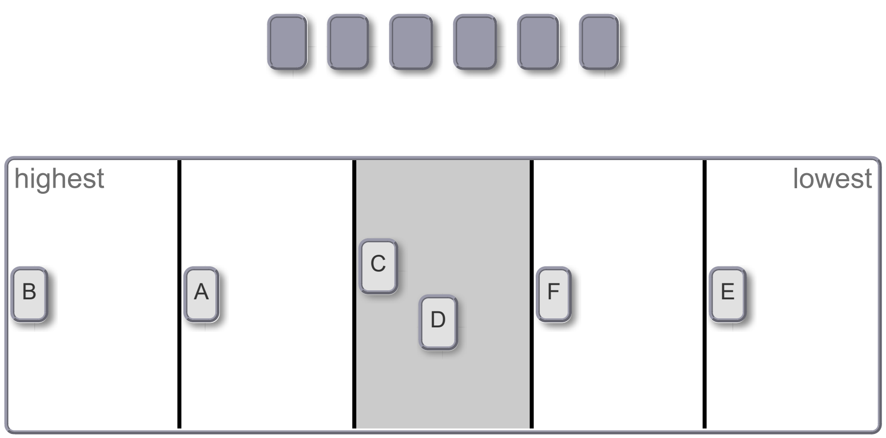
where q is the source charge creating the electric potential and r is the distance between the source charge and the point of interest. If more than one source is present, determine the electric potential from each source and sum the results.

Hint 2. Conceptualizing electric potential

Because positive charges create positive electric potentials in their vicinity and negative charges create negative potentials in their vicinity, electric potential is sometimes visualized as a sort of "elevation." Positive charges represent mountain peaks and negative charges deep valleys. In this picture, when you are close to a positive charge, you are "high up" and have a higher positive potential. Conversely, near a negative charge, you are deep in a "valley" and have a negative potential. The utility of this picture becomes clearer when we begin to think of charges moving through a region of space containing an electric potential. Just as particles naturally roll downhill, converting gravitational potential energy into kinetic energy, positively charged particles naturally "roll downhill" as well, toward regions of lower electric potential, converting electrical potential energy into kinetic energy.

ANSWER:

Reset Help



☐ The correct ranking cannot be determined.

Correct

Moving a Charge

Part A

A point charge with charge q_1 = 2.40 $\mu\mathrm{C}$ is held stationary at the origin. A second point charge with charge q_2 = -4.60 $\mu\mathrm{C}$ moves from the point (0.160 m , 0) to the point (0.245 m , 0.260 m). How much work W is done by the electric force on the moving point charge?

Express your answer in joules. Use k = 8.99×10⁹ $\mathrm{N \cdot m^2/C^2}$ for Coulomb's constant: $k = \frac{1}{4\pi\epsilon_0}$.

Hint 1. How to approach the problem

Use the equation for the electric potential energy between two point charges to calculate the work done by the electric force. Recall that the work done by a *conservative* force is $W = U_\mathrm{i} - U_\mathrm{f} = -\Delta U$, the difference between the initial and final potential energies. A conservative force is one for which the work done on a particle by the force is independent of the path taken and depends only on the initial and final points. The electric force is a conservative force. Gravity is another example of a conservative force.

Hint 2. Calculate the initial electric potential energy

Calculate the initial electric potential energy U_i when the moving point charge is at the point (0.160 m , 0).

Express your answer in joules. Use k = 8.99×10⁹ $\mathrm{N \cdot m^2/C^2}$ for Coulomb's constant: $k = \frac{1}{4\pi\epsilon_0}$.

Hint 1. Derivation of electric potential energy

The force between two point charges q and Q is given by Coulomb's law as $F_r = kqQ/r^2$, where r is the separation between the charges and $k = 1/4\pi\epsilon_0$. The work done by the electric force between the charges as one charge moves from point a to point b and the other is held fixed is calculated using $W_{ab} = \int_a^b \vec{F} \cdot d\vec{l}$. Since the force depends only on the distance between the charges, it follows that

$$W_{ab} = \int_{r_a}^{r_b} \frac{kqQ}{r^2} dr = kqQ \left(\frac{1}{r_a} - \frac{1}{r_b} \right),$$

where r_a and r_b are the distances between the fixed charge and points a and b, respectively. Since the work done is equal to the change in potential energy, this equation is consistent with defining the electric potential energy between two point charges a distance r apart by $U = \frac{kqQ}{r}$.

ANSWER:

U_i = -0.620 J

Hint 3. Calculate the final electric potential energy

Calculate the final electric potential energy U_f when the moving charge is at the point (0.245 m , 0.260 m).

Express your answer in joules. Use k = 8.99×10^9 $\mathrm{N \cdot m^2/C^2}$ for Coulomb's constant: $k = \frac{1}{4\pi\epsilon_0}$.

Hint 1. Derivation of electric potential energy

The force between two point charges q and Q is given by Coulomb's law as $F_r = kqQ/r^2$, where r is the separation between the charges and $k = 1/4\pi\epsilon_0$. The work done by the electric force between the charges as one charge moves from point a to point b and the other is held fixed is calculated using $W_{ab} = \int_a^b \vec{F} \cdot d\vec{l}$. Since the force depends only on the distance between the charges, it follows that

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where r_a and r_b are the distances between the fixed charge and points a and b, respectively. Since the work done is equal to the change in potential energy, this equation is consistent with defining the electric potential energy between two point charges a distance r apart by $U = \frac{kqQ}{r}$.

ANSWER:

U_f = -0.278 J

ANSWER:

W = -0.342 J

Correct

Electric Potential Energy of Three Point Charges

Part A

Three equal point charges, each with charge 1.40 $\mu\mathrm{C}$, are placed at the vertices of an equilateral triangle whose sides are of length 0.400 m . What is the electric potential energy U of the system? (Take as zero the potential energy of the three charges when they are infinitely far apart.)

Use ϵ_0 = 8.85×10^{-12} $\frac{C^2}{N \cdot m^2}$ for the permittivity of free space.

Hint 1. How to approach the problem

Use the equation for the electric potential energy between two point charges to calculate the energy for each interaction between two of the three point charges. The sum of these energies will be the total electric potential energy. Be careful to avoid double counting.

Hint 2. Find the electric potential energy of one pair

Assume that one charge is interacting with a second charge, ignoring any effects from the third charge. What is the electric potential energy U_{12} for this single interaction?

Express your answer in joules to three significant figures.

Hint 1. Electric potential energy of a pair of charges

Recall that the electric potential energy U between two charges q_1 and q_2 separated by a distance r is given by the formula

$$U = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{r}.$$

ANSWER:

U_{12} = 4.40×10^{-2} J

Hint 3. How many interactions are there?

How many pair interactions are there for the three charges?

Hint 1. Double counting

It is important to keep in mind that a pair of charges can interact only once, so if the first charge is interacting with the second charge for one pair, the interaction of the second charge with the first charge cannot also be used, since the pair has already been counted.

ANSWER:

3

ANSWER:

U = 0.132 J

Correct

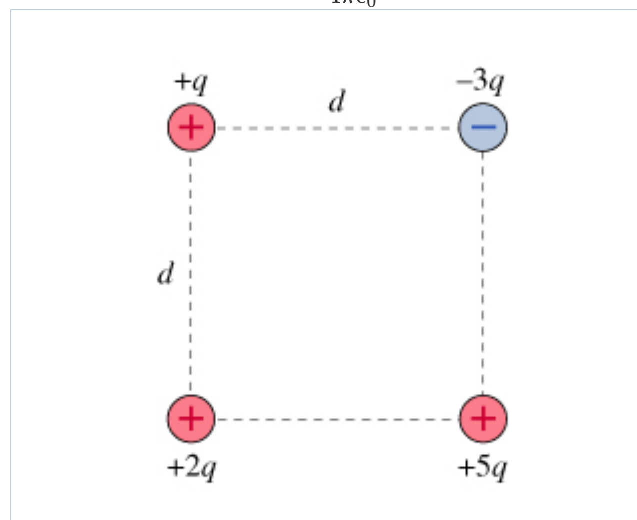
The potential energy is usually written

$$U = \sum_{i<j} \frac{q_i q_j}{4\pi\epsilon_0 r_{ij}}.$$

This means that all pairs of charges (1-2, 1-3, and 2-3) will interact, but no charge can interact with itself ($i = j$), nor can any pair be counted twice as a result of the condition $i < j$ for all possible pairs. For example, $i = 1, j = 2$ will be counted, while $i = 2, j = 1$ will not.

Back to Square One

Four point charges form a square with sides of length d, as shown in the figure. In the questions that follow, use the constant k in place of $\frac{1}{4\pi\epsilon_0}$.



Part A

What is the electric potential V_{tot} at the center of the square?

Make the usual assumption that the potential tends to zero far away from a charge.

Express your answer in terms of q, d, and appropriate constants.

Hint 1. How to approach the problem

Find the potential at the center due to each of the four charges and then use the principle of superposition to determine the potential due to all of the charges together.

Hint 2. Find the distance to the center

How far is the center of the square from each of the charges?

ANSWER:

- ○ $2\sqrt{2}d$
- ○ $\sqrt{2}d$
- ◉ $d\frac{\sqrt{2}}{2}$
- ○ $d\frac{\sqrt{2}}{4}$

Correct

ANSWER:

$V_{\rm tot}$ = $\left(5\sqrt{2}\right) k\frac{q}{d}$

Correct

Part B

What is the contribution $U_{\rm 2q}$ to the electric potential *energy* of the system, due to interactions involving the charge $2q$?

Express your answer in terms of q, d, and appropriate constants.

Hint 1. Find the electric potential at the point with charge $2q$

What is the electric potential V_{2q} at the location of the point with charge $2q$ due to the other three charges?

Express your answer in terms of q, d, and appropriate constants.

ANSWER:

$$V_{2q} = \frac{(12-3\sqrt{2})kq}{2d}$$

ANSWER:

$$U_{2q} = 7.76\left(k\frac{q^2}{d}\right)$$

Correct

Part C

What is the total electric potential energy U_{tot} of this system of charges?

Express your answer in terms of q, d, and appropriate constants.

Hint 1. How to approach the problem

Find the potential due to each *pair* of charges and then use the principle of superposition. Be sure not to count a pair twice!

Hint 2. How many pairs?

How many pairs of charges do you need to consider? (In other words, how many terms do you have to add in order to obtain the value of U_{tot}?)

ANSWER:

- 3
- 6
- 9
- 12

ANSWER:

U_{tot} = $-6.71\left(k\frac{q^2}{d}\right)$

Correct

Imagine now that charge $2q$ is released, and it drifts away from the rest of the charges, which remain fixed in place.

Part D

What would be the kinetic energy $K_{2\mathrm{q}}$ of charge $2q$ at a very large distance from the other charges?

Express your answer in terms of q, d, and appropriate constants.

Hint 1. What happens to energy?

As charge $2q$ moves away from the other charges, the potential energy of the system decreases, while the kinetic energy of the charge $2q$ increases. What is the contribution to the potential energy of the system due to the presence of charge $2q$ when it is very far away from the rest of the charges?

ANSWER:

$K_{2\mathrm{q}}$ = $7.76\left(k\frac{q^2}{d}\right)$

Correct

It should not come as a surprise that the answer to Part D is equal to the intial contribution to the potential energy of the system due to the presence of charge $2q$. Initially, the *kinetic energy* of charge $2q$ is zero. Because the electric potential between two charges is inversely proportional to the distance between them, after charge $2q$ has drifted far away from the others, $U_{\rm 2q}$ (see B) is (very close to) zero. Since total energy is conserved, the change in potential energy must have been converted into kinetic energy.

Part E

What will be the potential energy $U_{\rm tot}$ of the system of charges when charge $2q$ is at a very large distance from the other charges?

Express your answer in terms of q, d, and appropriate constants.

Hint 1. What happens to energy?

As charge $2q$ moves far away, the electric potential difference between this charge and each of the other three charges decreases to zero. Thus, $U_{\rm 2q}$ is negligible; only the interactions between the other three charges contribute to the total potential energy of the system.

ANSWER:

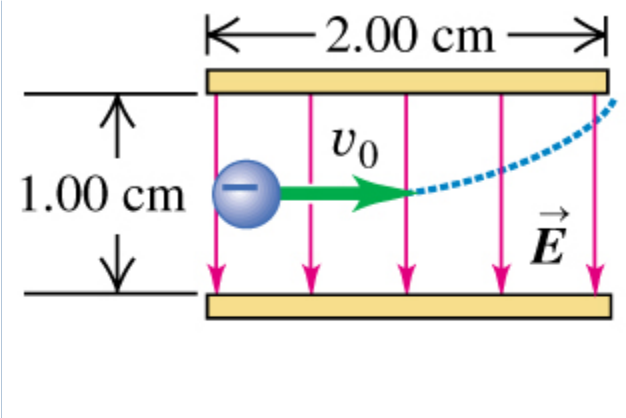
$U_{\rm tot}$ = $-14.5\left(k\frac{q^2}{d}\right)$

Correct

There are two ways you could have approached this question. You could have found the sum of the three terms corresponding to the three remaining pairs of charges, or you could have subtracted the initial $U_{\rm 2q}$ from the total energy of the system before charge $2q$ was removed.

Exercise 21.31

An electron is projected with an initial speed 2.00×10^6 $\rm m/s$ into the uniform field between the parallel plates in the figure. Assume that the field between the plates is uniform and directed vertically downward, and that the field outside the plates is zero. The electron enters the field at a point midway between the plates.



Part A

If the electron just misses the upper plate as it emerges from the field, find the speed of the electron as it emerges from the field?

ANSWER:

v = 2.24×10^6 $\mathrm{m/s}$

Correct

Exercise 21.32

A uniform electric field exists in the region between two oppositely charged plane parallel plates. A proton is released from rest at the surface of the positively charged plate and strikes the surface of the opposite plate, 1.80 cm distant from the first, in a time interval of 2.30×10^{-6} s .

Part A

Find the magnitude of the electric field.

Express your answer with the appropriate units.

ANSWER:

$E = 71.0 \ \frac{\mathrm{N}}{\mathrm{C}}$

Correct

Part B

Find the speed of the proton when it strikes the negatively charged plate.

Express your answer with the appropriate units.

ANSWER:

$v = 1.57\times10^{4} \ \frac{\mathrm{m}}{\mathrm{s}}$

Correct

Score Summary:

Your score on this assignment is 96.2%.
You received 96.22 out of a possible total of 100 points.