a place of mind

FACULTY OF EDUCATION

Department of
Curriculum and Pedagogy

Physics
Electrostatics Problems

Science and Mathematics
Education Research Group

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Electrostatics Problems

Retrieved from: http://physics.stackexchange.com/questions/130915/what-does-really-attracts-a-water-stream-to-a-charged-object

Electrostatics Problems

The following questions have been compiled from a collection of questions submitted on PeerWise (https://peerwise.cs.auckland.ac.nz/) by teacher candidates as part of the EDCP 357 physics methods courses at UBC.

Electrostatics Problems I

An electric field strength created by charge Q is measured to be 40 N/C at a distance of 0.2 m from the center of the charge. What is the new field strength when the distance from the center of Q is changed to 0.4 m away with twice the charge of Q?

A. 10 N/C
B. 20 N/C
C. 40 N/C
D. 80 N/C

Solution

Answer: B

Justification: Let the electric field strength be denoted by E. The magnitude of the electric field strength (E) is defined as the force (F) per charge (q) on the source charge (Q). In other words, $E = \frac{F}{q}$, where $F = \frac{kqQ}{d^2}$ is the electric force given by Coulomb's law, k is the Coulomb's law constant ($k = 9.0 \times 10^9\ N\ \frac{m^2}{C^2}$), and d is the distance between the centers of q and Q.

So we need to use the expression, $E = \frac{kqQ}{qd^2}$. Simplifying this expression gives, $E = \frac{kQ}{d^2}$.

Solution continued

Answer: B

In our case, since Q and d are doubled, the new field strength is $E_{new} = \frac{k\,(2Q)}{(2d)^2}$, which can be simplified to get $E_{new} = \frac{2}{4} \times \frac{kQ}{d^2} = \frac{1}{2}E$.

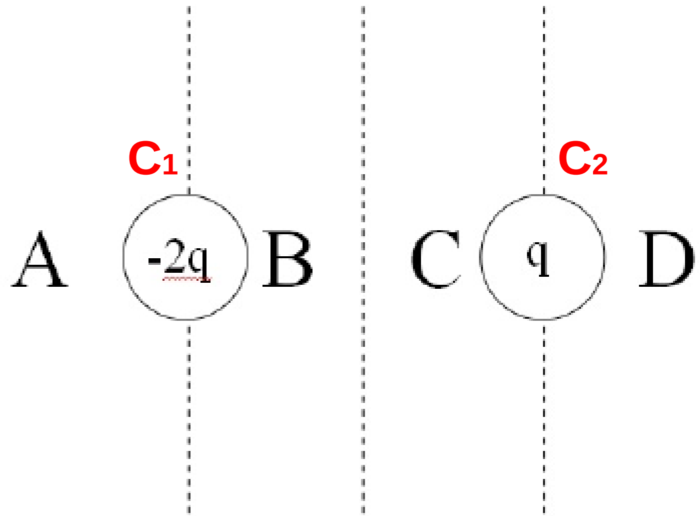
Thus, the new field strength is $E_{new} = \frac{1}{2}E = \frac{1}{2} \times 40\ N/C = 20N/C$.

Despite doubling the charge from Q to $2Q$ and the distance from d to $2d$, our field strength E decreased by half.

Finally, note that the expression for electric field strength illustrates an inverse square relationship between the electric field strength and the distance, $E \propto \frac{1}{d^2}$.

Electrostatics Problems II

Two point charges (C_1 and C_2) are fixed as shown in the setup below. Now consider a third test charge with charge -q that you can place anywhere you want in regions A, B, C, or D. In which region could you place the test charge so that the net force on the test charge is zero?



A. Region A
B. Region B
C. Region C
D. Region D

Solution

Answer: D – Somewhere in region D.

Justification: With the test charge and C_1 being negative, there is a repulsive force on the test charge to the right. From C_2, there is an attractive force on the test charge to the left. By referring to Coulomb`s law ($F = \frac{kq_1q_2}{r^2}$), we know that the force from C_1 is being divided by a larger r so that the repulsive force between C_1 and the test charge becomes smaller. However, the force from C_2 and the test charge is being caused by a smaller magnitude of charge so that the attractive force between C_2 and the test charge becomes smaller. At some point in region D, these two effects cancel out and there would be no net force on the test charge.

Solution continued (Davor)

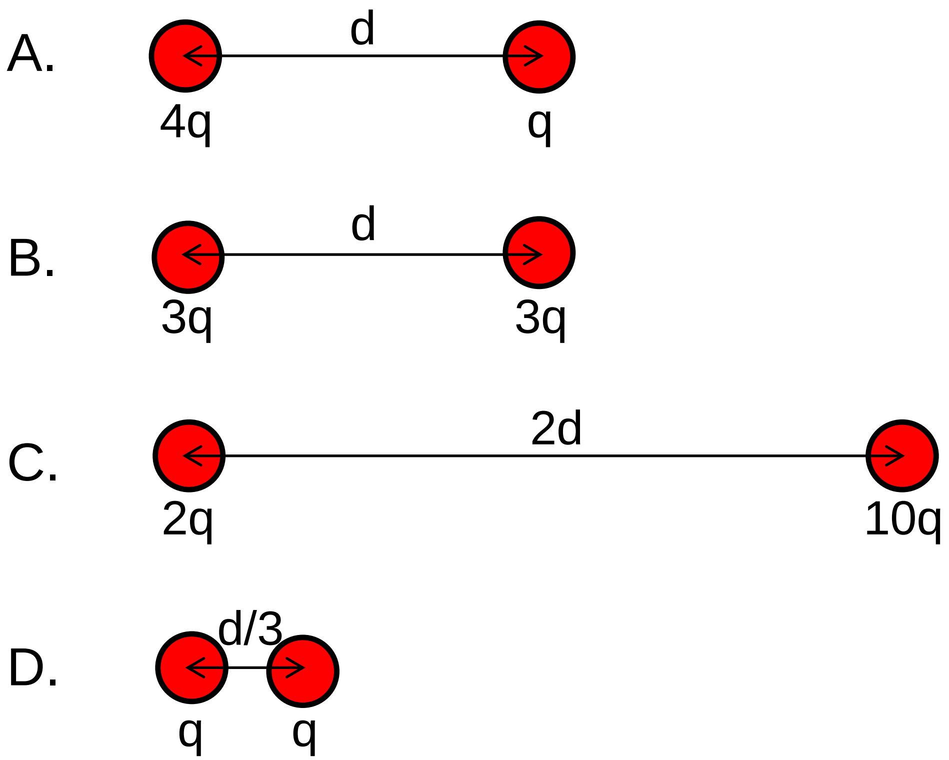
Further explanation:

In region A, the net repulsive force from C_1 would be much greater in strength than the attractive force from C_2. This is because the C_2 charge is greater than the C_1 charge, and the test charge is much closer to C_2. Therefore the net force would always be to the left (the test charge would be repelled away to the left).

In regions B and C, there would be a net repulsive force on the test charge from C_2 to the right, as well as a net attractive force from C_1 to the right as well. No matter where you placed the test charge in this region, it would always be pushed to the right.

Electrostatics Problems III

In each of the four scenarios listed below, the two charges remain fixed in place as shown. Rank the electric potential energies of the four systems from the greatest to the least.



A. B = D > C > A
B. C > B > A > D
C. C > B = D > A
D. D > A = B > C
E. A > C > B = D

Solution

Answer: B

Justification: Recall that electric potential energy depends on two types of quantities: 1) **electric charge** (a property of the object experiencing the electrical field) and 2) the **distance** from the source (the location within the electric field).

Somewhat similar to the gravitational potential energy, the electric potential energy is inversely proportional to r. The electric potential energy, E_P, is given by $E_P = k\,\frac{q_1\,q_2}{r}$, where k is the Coulomb's law constant, q_1 and q_2 are point charges, and r is the distance between the two point charges. Note that E_P is related to the electric force, F, given by Coulomb's law. That is, $E_P = F\ \times r$, where $F = k\frac{q_1 q_2}{r^2}$.

Solution continued

Answer: B

For system A: $E_P = k\ \dfrac{4q \times q}{d} = 4k\dfrac{q^2}{d}$

For system B: $E_P = k\ \dfrac{3q \times 3q}{d} = 9k\dfrac{q^2}{d}$

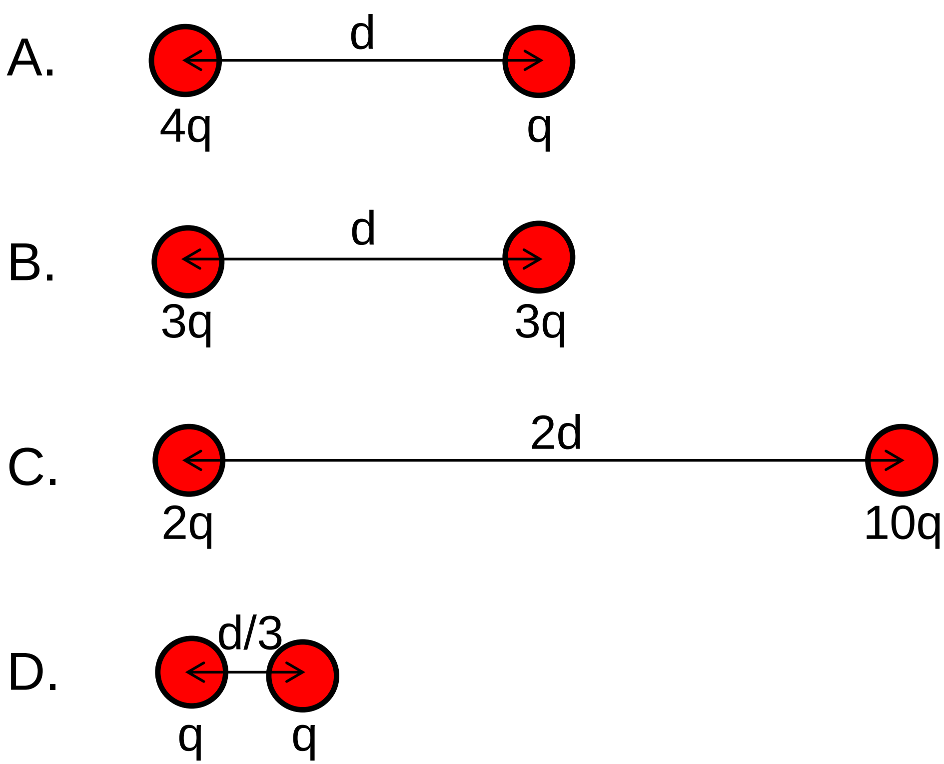
For system C: $E_P = k\ \dfrac{2q \times 10q}{2d} = 10k\dfrac{q^2}{d}$

For system D: $E_P = k\ \dfrac{q \times q}{d/3} = 3k\dfrac{q^2}{d}$

Since $k\dfrac{q^2}{d}$ is common to all of the above expressions, we note that the numerical coefficients determine the rank of the electric potential energies (i.e. $10 > 9 > 4 > 3$). Thus B is the correct answer.

Electrostatics Problems IV

In each of the four scenarios listed below, the two charges remain fixed in place as shown. Rank the forces acting between the two charges from the greatest to the least.



A. C > B > A > D
B. C > B = D > A
C. B = D > C > A
D. B = D > A > C
E. A > C > B = D

Solution

Answer: C

Justification: Recall that the electric force is a fundamental force of the universe that exists between all charged particles. For example, the electric force is responsible for chemical bonds. The strength of the electric force between any two charged objects depends on the amount of charge that each object contains and also on the distance between the two charges. From Coulomb's law, we know that the electric force is given by $F = k\frac{q_1 q_2}{r^2}$, where k is the Coulomb's law constant, q_1 and q_2 are point charges, and r is the distance between the two point charges.

Note that F is proportional to the amount of charge and also inversely proportional to the square of the distance between the charges.

Solution continued

Answer: C

For system A: $F = k\ \frac{4q \times q}{d^2} = 4k\frac{q^2}{d^2}$

For system B: $F = k\ \frac{3q \times 3q}{d} = 9k\frac{q^2}{d^2}$

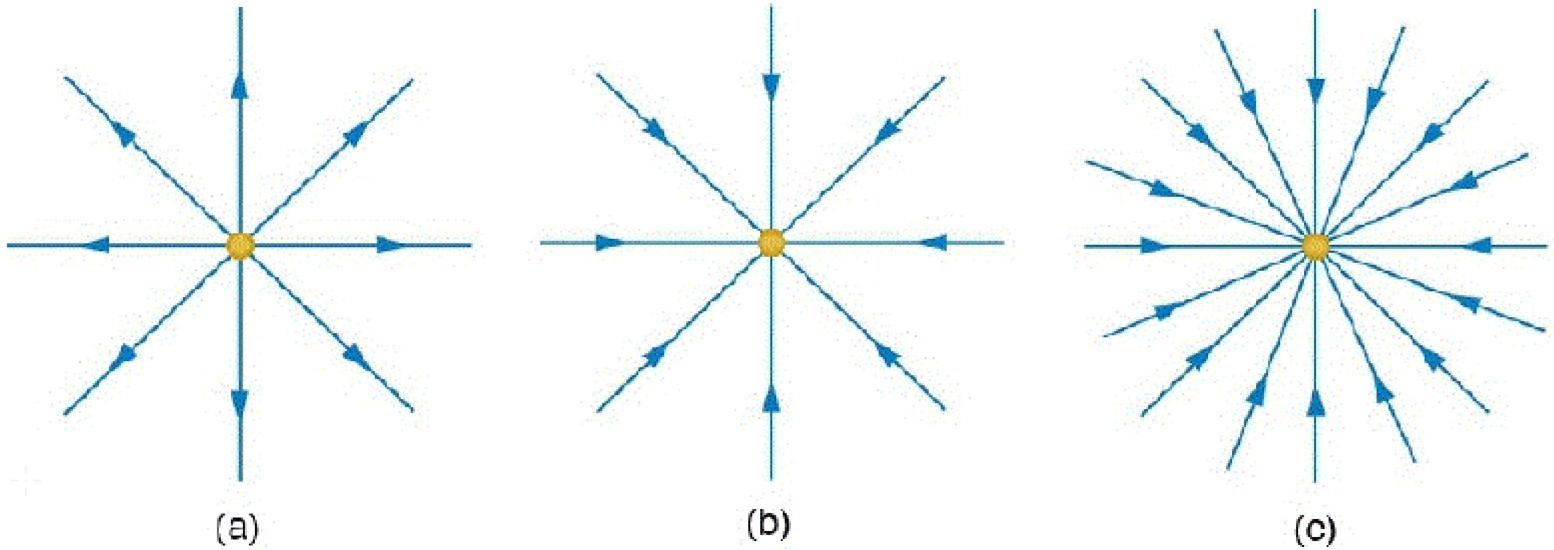
For system C: $F = k\ \frac{2q \times 10q}{(2d)^2} = 5k\frac{q^2}{d^2}$

For system D: $F = k\ \frac{q \times q}{(d/3)^2} = 9k\frac{q^2}{d^2}$

Since $k\frac{q^2}{d^2}$ is common to all of the above expressions, we note that the numerical coefficients determine the rank of the electric forces (i.e. $9 = 9 > 5 > 4$). Thus C is the correct answer.

Electrostatics Problems V

Given the following electric field diagrams:



What are the respective charges of the yellow particles shown in diagrams (a), (b), and (c)?

A. (a,b,c) = (-q, +q, +q)

B. (a,b,c) = (+q, q, -q)

C. (a,b,c) = (+q, -q, -2q)

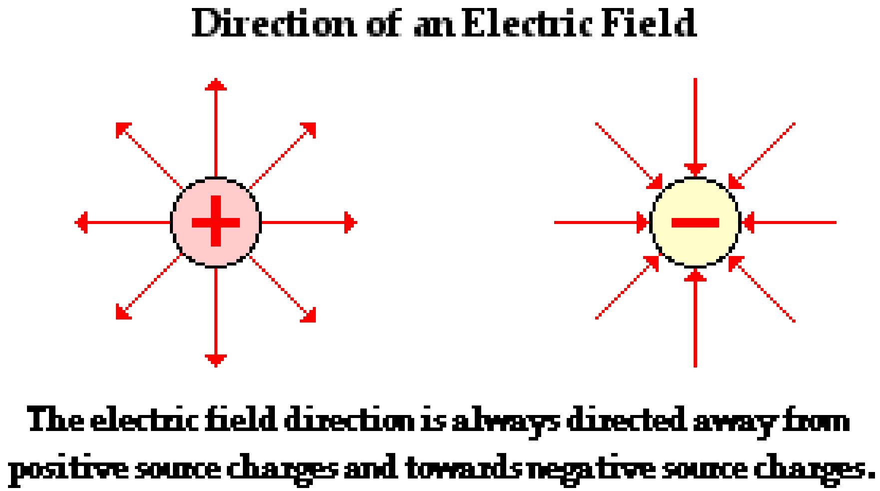
D. (a,b,c) = (-q, +q, +2q)

E. (a,b,c) = (+2q, -2q, -q)

Solution

Answer: C

Justification: Recall that the direction of an electric field is defined as the direction that a positive test charge would be pushed when placed in the electric field. The electric field direction of a positively charged object is always directed away from the object. And also, the electric field direction of a negatively charged object is directed towards the object.



Solution continued

Answer: C

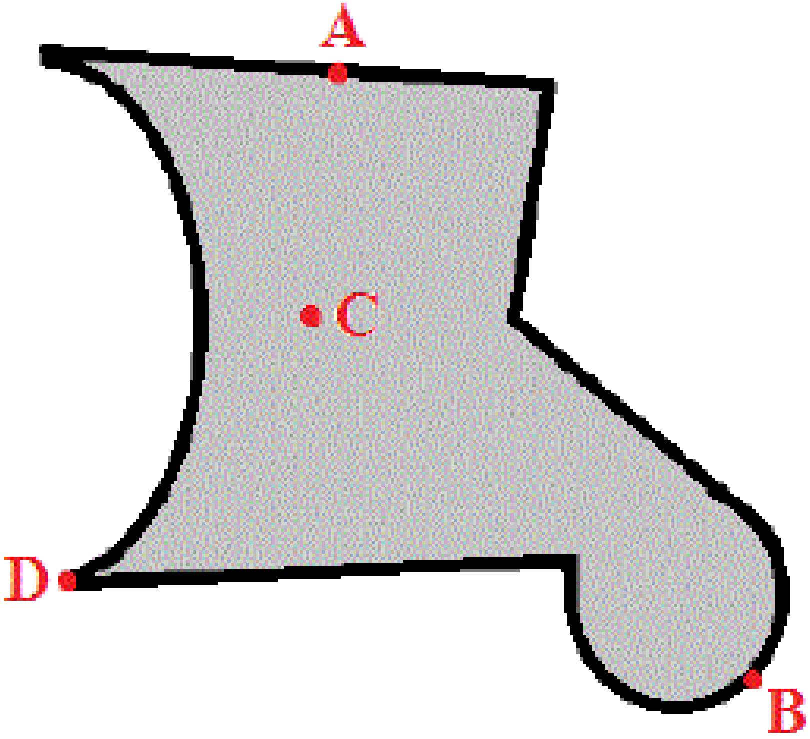
Since the field direction is directed away from (a) but towards (b) and (c), we know that the relative charges of (a,b,c) = (+,-,-)

Note that the field lines allow us to not only visualize the direction of the electric field, but also to qualitatively get the magnitude of the field through the density of the field lines. From (a), (b), and (c), we can see that the density of the electric field lines in (c) is twice that of (a) or (b). We would expect the magnitude of the charge in (c) to also be twice as strong as (a) or (b). Thus, the answer choice C is correct.

Electrostatics Problems VI

Below is a diagram of a charged object (conductor) at electrostatic equilibrium. Points A, B, and D are on the surface of the object, whereas point C is located inside the object.

Rank the strength of the electric field at points A, B, C, and D from strongest to weakest.



A. B > D > A > C
B. B > D > C > A
C. D > B > C > A
D. D > B > A > C
E. A > B > D > C

Solution

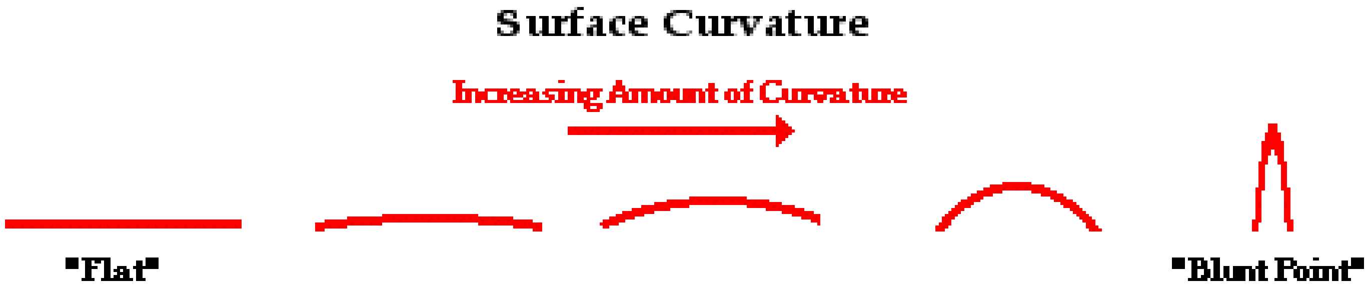
Answer: D

Justification: We need to understand the concept of the electric field being zero inside of a closed conducting surface of an object, which was demonstrated by Michael Faraday in the 19th century. Suppose to the contrary, if an electric field were to exist below the surface of the conductor, then the electric field would exert a force on electrons present there. This implies that electrons would be in motion. However, the assumption that we made was that for objects at electrostatic equilibrium, charged particles are not in motion. So if charged particles are in motion, then the object is not in electrostatic equilibrium. Thus, if we assume that the conductor is at electrostatic equilibrium, then the net force on the electrons within the conductor is zero. So at point C, the electric field is zero.

Solution continued

Answer: D

For conductors at electrostatic equilibrium, the electric fields are strongest at regions along the surface where the object is most curved. The curvature of the surface can range from flat regions to that of being a blunt point, as shown below.



http://www.physicsclassroom.com/class/estatics/Lesson-4/Electric-Fields-and-Conductors

We can notice that the curvature at D is greater than the curvature at B, which, in turn, is greater than the curvature at A. Thus, from the above discussion, we can say that D is the correct answer.

Solution continued (MV)

Further explanations regarding electric field strength and curvature of an object can be found in the following links:

https://www.youtube.com/watch?v=dUNoxVY0p3Q

http://physics.stackexchange.com/questions/43068/why-is-electric-field-strong-at-sharp-edges

http://www.physicsclassroom.com/class/estatics/Lesson-4/Electric-Fields-and-Conductors