Two metal spheres that are initially uncharged are mounted on insulating stands, as shown.

A negatively charged rubber rod is brought close to but does not make contact with sphere X. Sphere Y is then brought close to X on the side opposite to the rubber rod. Y is allowed to touch X and then is removed some distance away. The rubber rod is then moved far away from X and Y.

What are the final charges on the spheres?

<table>
<thead>
<tr>
<th>Sphere X</th>
<th>Sphere Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Zero</td>
<td>Zero</td>
</tr>
<tr>
<td>2. Negative</td>
<td>Positive</td>
</tr>
<tr>
<td>3. Negative</td>
<td>Negative</td>
</tr>
<tr>
<td>4. Positive</td>
<td>Positive</td>
</tr>
<tr>
<td>5. Positive</td>
<td>Negative correct</td>
</tr>
</tbody>
</table>

Explanation:
The force between charges of the same sign is repulsive. The force between charges with opposite signs is attractive.
003 (part 2 of 2) 10.0 points
If $F$ is the magnitude of the force on the test charge due to only one of the other charges, what is the magnitude of the net force acting on the test charge due to both of these charges?

1. $F_{net} = \frac{2F}{3}$
2. $F_{net} = \frac{3F}{2}$
3. $F_{net} = \frac{F}{\sqrt{2}}$
4. $F_{net} = \frac{2F}{\sqrt{3}}$
5. $F_{net} = \frac{F}{\sqrt{3}}$
6. $F_{net} = 2F$
7. $F_{net} = F$
8. $F_{net} = 3F$
9. $F_{net} = 0$
10. $F_{net} = \sqrt{2}F$ correct

Explanation:
The two individual forces form a right angle, so the magnitude of the net force is $F_{net} = F\sqrt{1^2 + 1^2} = \sqrt{2}F$.

004 10.0 points
A particle with charge $7\mu C$ is located on the x-axis at the point 10 cm, and a second particle with charge $3\mu C$ is placed on the x-axis at -10 cm.

The Coulomb constant is $8.9875 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2$.

![Diagram of charges](image)

What is the magnitude of the total electrostatic force on a third particle with charge $-9\mu C$ placed on the x-axis at -2 cm?

Correct answer: 1.4043 N.

Explanation:

Let: $q_1 = 7\mu C = 7 \times 10^{-6} \text{ C}$,
$q_2 = 3\mu C = 3 \times 10^{-6} \text{ C}$,
$q_3 = -9\mu C = -9 \times 10^{-6} \text{ C}$,
$x_1 = 10 \text{ cm} = 0.1 \text{ m}$,
$x_2 = -10 \text{ cm} = -0.1 \text{ m}$, and
$x_3 = -2 \text{ cm} = -0.02 \text{ m}$.

Coulomb's law (in vector form) for the electric force exerted by a charge $q_1$ on a second charge $q_3$, written $\vec{F}_{13}$ is

$$\vec{F}_{13} = k_e \frac{q_1 q_3}{r_{13}^2} \hat{r}_{13},$$

where $\hat{r}_{13}$ is a unit vector directed from $q_1$ to $q_3$; i.e., $\hat{r}_{13} = \hat{r}_3 - \hat{r}_1$.

$$x_{13} = x_3 - x_1 = (-2 \text{ cm}) - (10 \text{ cm}) = -0.12 \text{ m}$$
$$x_{23} = x_3 - x_2 = (-2 \text{ cm}) - (-10 \text{ cm}) = 0.08 \text{ m}$$

$$\hat{x}_{13} = \frac{x_3 - x_1}{\sqrt{(x_3 - x_1)^2}} = -\hat{i}$$
$$\hat{x}_{23} = \frac{x_3 - x_2}{\sqrt{(x_3 - x_2)^2}} = +\hat{i}$$

Since the forces are collinear, the force on the third particle is the algebraic sum of the forces between the first and third and the second and third particles.

$$\vec{F} = \vec{F}_{13} + \vec{F}_{23}$$

$$= k_e \left[ \frac{q_1}{r_{13}^2} \hat{r}_{13} + \frac{q_2}{r_{23}^2} \hat{r}_{23} \right] q_3$$

$$= 8.9875 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2 \times \left[ \left(7 \times 10^{-6} \text{ C} \right) \left( -0.12 \text{ m} \right)^2 \right] \left( -\hat{i} \right)$$

$$+ \left(3 \times 10^{-6} \text{ C} \right) \left( 0.08 \text{ m} \right)^2 \left( +\hat{i} \right)$$

$$= (39.3203 \text{ N}) + (-37.916 \text{ N})$$

$$= 1.4043 \text{ N}$$

$$\|\vec{F}\| = 1.4043 \text{ N}.$$
In a thundercloud there may be an electric charge of 48 C near the top of the cloud and \(-48\) C near the bottom of the cloud.

The electric force constant is \(8.98755 \times 10^9\) N \(\cdot\) m\(^2\)/C\(^2\).

If these charges are separated by about 8 km, what is the magnitude of the electric force between these two sets of charges?

Correct answer: \(3.23552 \times 10^5\) N.

Explanation:

Let:

\[ q_1 = 48\ \text{C}, \]
\[ q_2 = -48\ \text{C}, \]
\[ d = 8\ \text{km} = 8000\ \text{m}, \] and
\[ k = 8.98755 \times 10^9\ \text{N} \cdot \text{m}^2/\text{C}^2. \]

Considering the two sets of electric charges as point-charges, separated by a distance of 8 km, we can apply Coulomb’s law:

\[
F = \frac{k q_1 q_2}{r^2} = 8.98755 \times 10^9 \text{N} \cdot \text{m}^2/\text{C}^2 \times \frac{(48 \text{C})(-48 \text{C})}{(8000 \text{m})^2} = -3.23552 \times 10^5\ \text{N},
\]

which has a magnitude of \(3.23552 \times 10^5\) N.

The electrostatic force between the top and the bottom of this thundercloud is

1. zero.
2. repulsive.
3. undetermined.
4. attractive. correct

Explanation:

The negative sign indicates that the force is attractive; i.e., the charges are being pulled towards one another.

Two charges \(q_1\) and \(q_2\) are separated by a distance \(d\) and exert a force \(F\) on each other.

What is the new force \(F'\), if charge 1 is increased to \(q'_1 = 5\ q_1\), charge 2 is decreased to \(q'_2 = q_2/2\), and the distance is decreased to \(d' = d/2\)? Choose one

1. \(F' = 25\ F\)
2. \(F' = 5/4\ F\)
3. \(F' = 10\ F\) correct
4. \(F' = 25/4\ F\)
5. \(F' = 100\ F\)
6. \(F' = 50\ F\)
7. \(F' = 5/2\ F\)
8. \(F' = 5\ F\)
9. \(F' = 25/2\ F\)
10. \(F' = 20\ F\)

Explanation:

\[
F' = \frac{k q'_1 q'_2}{r'^2} = \frac{k (5q_1) (q_2/2)}{(d/2)^2} = 10 \frac{k q_1 q_2}{d^2} = 10\ F
\]

If you double the charge on one of two charged objects, how does the force between them change?

1. Double correct
2. Quadruple
3. Does not change

4. Triple

5. Halve

**Explanation:**
The force doubles because the product of the charge doubles.

\[ F_e = k_e \frac{q_1 q_2}{r^2} \propto q_1 q_2 \]

The factor is \((2 q_1) q_2 = 2 (q_1 q_2)\).

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009 10.0 points

If you double the distance between two charged objects, by what factor is the electric force affected?

Correct answer: 0.25.

**Explanation:**

\[ F_e = k_e \frac{q_1 q_2}{r^2} \propto \frac{1}{r^2} \]

The factor is \(\frac{1}{(2r)^2} = \frac{1}{4r^2} = 0.25\).

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010 10.0 points

Object A and object B are initially uncharged and are separated by a distance of 1 meter. Suppose 10,000 electrons are removed from object A and placed on object B, creating an attractive force between A and B. An additional 10,000 electrons are removed from A and placed on B and the objects are moved so that the distance between them increases to 2 meters.

By what factor does the electric force between them change?

1. Doubles

2. Quadruples

3. Triples

4. No change **correct**

5. Halves

**Explanation:**
The charge on each object doubles.

\[ F \propto \frac{q_1 q_2}{r^2} = \frac{(2q_1)(2q_2)}{(2r)^2} = \frac{q_1 q_2}{r^2} \]

The electrical force between them does not change.

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011 10.0 points

1) Two uncharged metal balls, X and Y, each stand on a glass rod and are touching.

2) A third ball carrying a negative charge, is brought near the first two.

3) While the positions of these balls are fixed, ball X is connected to ground.

4) Then the ground wire is disconnected.

5) While X and Y remain in touch, the ball carrying the negative charge is removed.
6) Then ball X and Y are separated.

After these procedures, the signs of the charge \( q_X \) on X and \( q_Y \) on Y are

1. \( q_X \) is negative and \( q_Y \) is neutral.
2. \( q_X \) is negative and \( q_Y \) is negative.
3. \( q_X \) is positive and \( q_Y \) is positive. correct
4. \( q_X \) is negative and \( q_Y \) is positive.
5. \( q_X \) is neutral and \( q_Y \) is neutral.
6. \( q_X \) is positive and \( q_Y \) is negative.
7. \( q_X \) is neutral and \( q_Y \) is positive.
8. \( q_X \) is neutral and \( q_Y \) is negative.
9. \( q_X \) is positive and \( q_Y \) is neutral.

**Explanation:**

When the ball with negative charge is brought nearby, the free charges inside X and Y rearrange themselves. The positive charges are attracted and go to the right (i.e. move to Y), whereas the negative charges are repelled and collect in the left hand side of the system X Y, i.e., in X.

When we ground X, the negative charges which have collected in X are allowed to escape (they strive to the left), whereas the positive charges in Y are still held enthralled by the negative charge on the third ball. We break the ground.

Now we remove the third ball with negative charge. The charge on Y is redistributed in the system X Y, i.e. they share the positive charge (equally if identical).

Finally we separate X and Y. The signs of the charge on X and that on Y are both positive.