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PHYS-2B, section 34945, Spring 2020

Basic Charge and Coulomb's Law (Homework)

INSTRUCTOR
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Current Score

QUESTION	1	2	3	4	5	6	7	8	9	10	11	12
POINTS	1/1	3/3	3/3	2/2	2/2	2/2	6/6	2/2	1/1	2/2	0/1	3/6

TOTAL SCORE

27/31 87.1%

Due Date Past Due

FRI, JAN 24, 2020

11:59 PM PST

Request Extension

Assignment Submission & Scoring

Assignment Submission

For this assignment, you submit answers by question parts. The number of submissions remaining for each question part only changes if you submit or change the answer.

Assignment Scoring

Your last submission is used for your score.

The due date for this assignment has passed.

Your work can be viewed below, but no changes can be made.

Important! Before you view the answer key, decide whether or not you plan to request an extension. Your Instructor may not grant you an extension if you have viewed the answer key. Automatic extensions are not granted if you have viewed the answer key.

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1. 1/1 points Previous Answers **SERCP11 15.CQ.001.**

My Notes Ask Your Teacher

A glass object receives a positive charge by rubbing it with a silk cloth. In the rubbing process, have protons been added to the object or have electrons been removed from it?

- ○ Protons have been added.
- ● Electrons have been removed. ✓

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2. 3/3 points Previous Answers **SERCP11 15.CQ.003.**

My Notes Ask Your Teacher

Each of the following statements is related to conductors in electrostatic equilibrium. Choose the words that make each statement correct.

HINT

(a) The net charge is always zero inside inside the surface of an isolated conductor.

(b) The electric field is always zero inside inside a perfect conductor.

(c) The charge density on the surface of an isolated, charged conductor is highest where the surface is sharpest sharpest The electric field outside a conductor is highest near sharp points where the charge accumulates. This property explains the effectiveness of lightning rods, invented by Benjamin Franklin in 1749..

Solution or Explanation

(a) Any net charge on an isolated conductor resides entirely on its surface. Inside the conductor, the net charge is always zero.

(b) The electric field is always zero everywhere inside a conductor in electrostatic equilibrium.

(c) On an irregularly shaped conductor, the charge accumulates at sharp points.

Need Help? Read It

3. 3/3 points Previous Answers **SERCP11 15.CQ.004.**

My Notes Ask Your Teacher

Two uncharged, conducting spheres are separated by a distance d. When charge $-Q$ is moved from sphere A to sphere B, the Coulomb force between them has magnitude F_0.

HINT

(a) Is the Coulomb force attractive or repulsive?

- (selected) attractive
- repulsive

The Coulomb force between two charges is proportional to the product of the charges, q_1q_2.

(b) If an additional charge $-Q$ is moved from A to B, what is the ratio of the new Coulomb force to the original Coulomb force, $\frac{F_{\text{new}}}{F_0}$?

4 — 4

(c) If sphere B is neutralized so it has no net charge, what is the ratio of the new to the original Coulomb force, $\frac{F_{\text{new}}}{F_0}$?

0 — 0

Solution or Explanation

(a) Removing charge $-Q$ from object A leaves it with a net positive charge of $+Q$. Object B acquires a net charge $-Q$ so that A and B are oppositely charged and the Coulomb force, proportional to $Q_AQ_B = -Q^2$, is attractive.

(b) After another transfer of $-Q$ from A to B, $Q_A = +2Q$ and $Q_B = -2Q$ so that $Q_AQ_B = -4Q^2$ and $\frac{F_{\text{new}}}{F_0} = 4$.

(c) If B is neutralized so that $Q_B = 0$, the Coulomb force is zero and $\frac{F_{\text{new}}}{F_0} = 0$.

Need Help? Read It

4. 2/2 points Previous Answers **SERCP11 15.2.OP.001.**

My Notes Ask Your Teacher

Two charged particles are a distance of 1.62 m from each other. One of the particles has a charge of 7.10 nC, and the other has a charge of 4.02 nC.

(a) What is the magnitude (in N) of the electric force that one particle exerts on the other?

9.777190215E-8 9.78e-08 N

(b) Is the force attractive or repulsive?

- attractive
- repulsive

Solution or Explanation

(a) From Coulomb's law, $F = k_e \frac{Q_1 Q_2}{r^2}$, we have

$$F = (8.99 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2)\frac{(7.10 \times 10^{-9}\text{ C})(4.02 \times 10^{-9}\text{ C})}{(1.62\text{ m})^2} = 9.78 \times 10^{-8}\text{ N}.$$

(b) Since these are like charges (both positive), the force is repulsive.

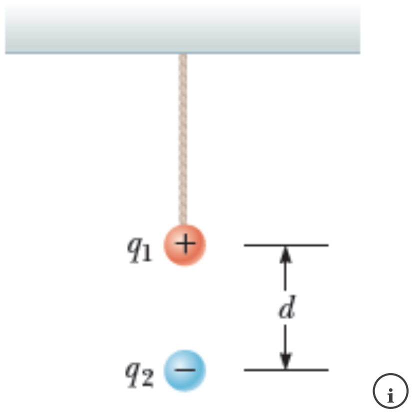
Need Help? Read It

5. 2/2 points Previous Answers **SERCP11 15.2.OP.004.**

My Notes Ask Your Teacher

The figure below shows a small, hollow, plastic sphere hanging vertically from a thin, lightweight string.

The sphere has a mass of 6.80 g and a uniformly distributed charge of q_1 = 28.4 nC. Directly below it is a second sphere with the same mass, but a charge of q_2 = −58.0 nC. (Assume this second sphere is fixed in place.) The centers of the two plastic spheres are a distance *d* = 2.00 cm apart.



(a) What is the tension (in N) in the string?

.104 ✔ 0.104 N

(b) The string will break if the tension in it exceeds 0.180 N. What is the smallest possible value of *d* (in cm) before the string breaks?

1.14 ✔ 1.14 cm

Solution or Explanation

(a) The gravitational force exerted on the upper sphere by the lower one is negligible in comparison to the gravitational force exerted by the Earth and the downward electrical force exerted by the lower sphere. Therefore,

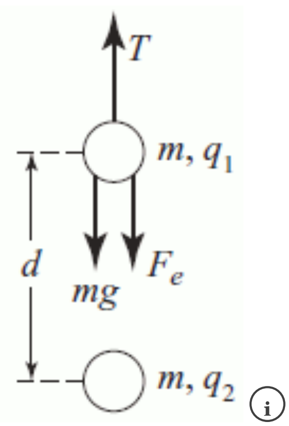
$$\sum F_y = 0 \Rightarrow T - mg - F_e = 0$$

or

$$T = mg + \frac{k_e|q_1||q_2|}{d^2}$$

$$T = (6.80 \times 10^{-3}\text{ kg})(9.80\text{ m/s}^2) + \frac{(8.99 \times 10^9\text{ N}\cdot\text{m}^2/\text{C}^2)(28.4 \times 10^{-9}\text{ C})(58.0 \times 10^{-9}\text{ C})}{(2.00 \times 10^{-2}\text{ m})^2}$$

giving $T = 0.104$ N.



(b) $\sum F_y = 0 \Rightarrow F_e = k_e\frac{q_1q_2}{d^2} = T - mg$, and $d = \sqrt{\frac{k_e|q_1||q_2|}{T - mg}}$

Thus, if $T = 0.180$ N,

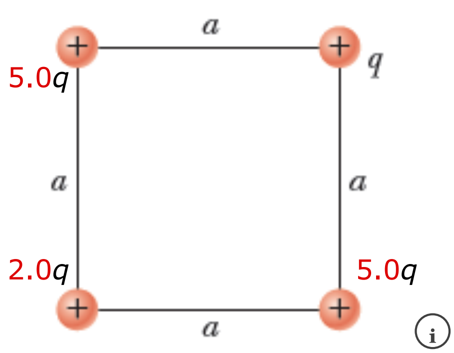
$$d = \sqrt{\frac{(8.99 \times 10^9\text{ N}\cdot\text{m}^2/\text{C}^2)(28.4 \times 10^{-9}\text{ C})(58.0 \times 10^{-9}\text{ C})}{0.180\text{ N} - (6.80 \times 10^{-3}\text{ kg})(9.80\text{ m/s}^2)}} = 1.14 \times 10^{-2}\text{ m} = 1.14\text{ cm}.$$

Need Help? Read It

6. 2/2 points Previous Answers **SERCP11 15.2.OP.008.**

My Notes Ask Your Teacher

The figure below shows four particles, each with a positive charge, at the corners of a square. The length of each side of the square is a. The particle at top-right has a charge of q; the one at lower-left has a charge of $2.0q$; the other two each have a charge of $5.0q$. (Assume that the $+x$-axis is to the right and the $+y$-axis is up along the page.)



(a) What is the magnitude of the force on the particle with charge q? Express your answer in terms of k_e, q, and a in symbolic form.

F =
$$8.07ke q2a2

$8.07k_e\frac{q^2}{a^2}$

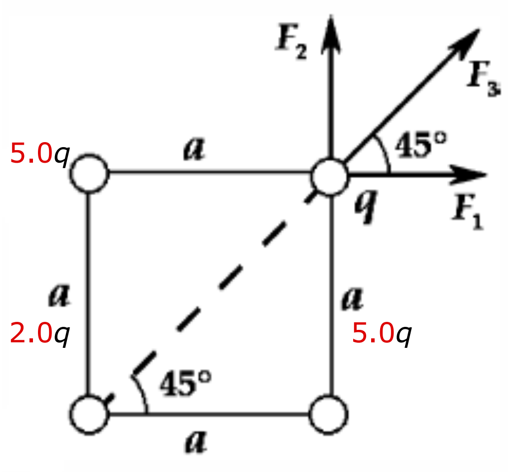
(b) What is the direction of the force on the particle with charge q? (Enter your answer in degrees counterclockwise from the $+x$-axis.)

45 45 ° counterclockwise from the $+x$-axis

Solution or Explanation

Note: We are displaying rounded intermediate values for practical purposes. However, the calculations are made using the unrounded values.

See the sketch below.



The magnitudes of the forces are

$$F_1 = F_2 = k_e\frac{q(5.0q)}{a^2} = 5.0k_e\frac{q^2}{a^2}$$

and

$$F_3 = k_e\frac{q(2.0q)}{(a\sqrt{2})^2} = 1.00k_e\frac{q^2}{a^2}.$$

The components of the resultant force on charge q are

$$F_x = F_1 + F_3\cos(45°) = (5.0 + 1.00\cos(45°))k_e\frac{q^2}{a^2} = 5.71k_e\frac{q^2}{a^2}$$

and

$$F_y = F_1 + F_3\sin(45°) = (5.0 + 1.00\sin(45°))k_e\frac{q^2}{a^2} = 5.71k_e\frac{q^2}{a^2}.$$

The magnitude of the resultant force is

$$F_e = \sqrt{F_x{}^2 + F_y{}^2} = \sqrt{2}\left(5.71k_e\frac{q^2}{a^2}\right) = 8.07k_e\frac{q^2}{a^2}.$$

and it is directed at $\theta = \tan^{-1}\left(\frac{F_y}{F_x}\right) = \tan^{-1}(1.00) = 45°$ above the horizontal.

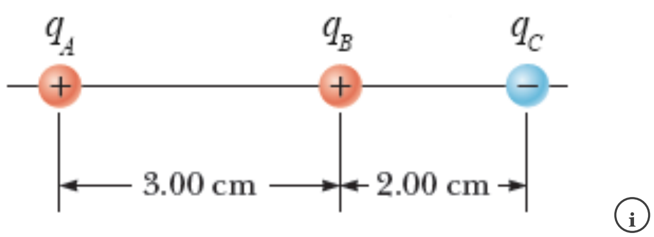
Need Help? Read It

7. 6/6 points Previous Answers **SERCP11 15.2.OP.010.**

My Notes Ask Your Teacher

The figure below shows three small, charged beads, all lying along the horizontal axis. Bead *A*, at left, has a 6.10 nC charge. Bead *B* has a 1.40 nC charge and is 3.00 cm to the right of *A*. Bead *C* has a −2.80 nC charge and is 2.00 cm to the right of *B*.

Find the magnitude (in N) and direction of the net electric force on each of the beads.



Net Force on *A*

magnitude 2.38E-5 2.39e-05 N

direction toward the left toward the left

Net Force on *B*

magnitude 1.73E-4 0.000173 N

direction toward the right toward the right

Net Force on *C*

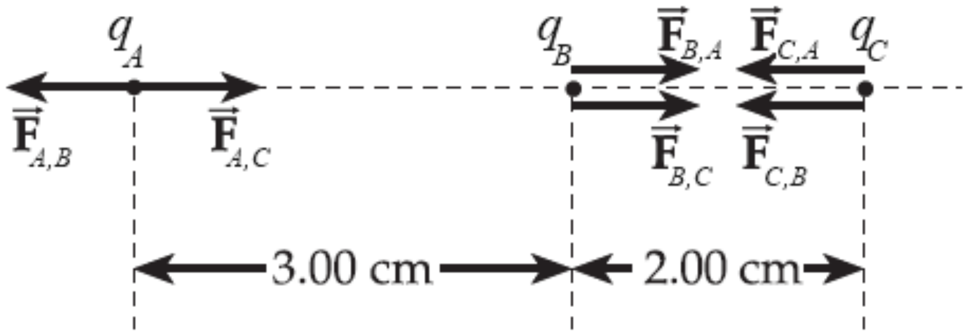
magnitude 1.50E-4 0.00015 N

direction toward the left toward the left

Solution or Explanation

Note: We are displaying rounded intermediate values for practical purposes. However, the calculations are made using the unrounded values.

The figure below shows the forces acting on each charged bead due to the other two. Let's first find the magnitudes of the two forces acting on *A*.



From Coulomb's law we have the following.

$$F_{A,\,B} = \frac{k_e q_A q_B}{r_{AB}^{\;2}} = \left(8.99 \times 10^9\ \frac{\text{N}\cdot\text{m}^2}{\text{C}^2}\right)\frac{(6.10 \times 10^{-9}\text{ C})(1.40 \times 10^{-9}\text{ C})}{(3.00 \times 10^{-2}\text{ m})^2} = 8.53 \times 10^{-5}\text{ N}$$

$$F_{A,\,C} = \frac{k_e q_A |q_C|}{r_{AC}^{\;2}} = \left(8.99 \times 10^9\ \frac{\text{N}\cdot\text{m}^2}{\text{C}^2}\right)\frac{(6.10 \times 10^{-9}\text{ C})(2.80 \times 10^{-9}\text{ C})}{(5.00 \times 10^{-2}\text{ m})^2} = 6.14 \times 10^{-5}\text{ N}$$

Now consider their directions. Note $\vec{\mathbf{F}}_{A,\,B}$ points left because q_A and q_B have the same sign, while $\vec{\mathbf{F}}_{A,\,C}$ points right because q_A and q_C have opposite signs. Because the magnitude $F_{A,\,B}$ is larger than $F_{A,\,C}$, the *net* force points left. The magnitude of the net force on A is then

$$F_{\text{net},\,A} = F_{A,\,B} - F_{A,\,C} = 8.53 \times 10^{-5}\text{ N} - 6.14 \times 10^{-5}\text{ N} = 2.39 \times 10^{-5}\text{ N}$$

with the direction pointing to the left.

Next, we'll find the forces on B. Note that the magnitudes $F_{B,\,A} = F_{A,\,B} = 8.53 \times 10^{-5}$ N, but the direction of $\vec{\mathbf{F}}_{B,\,A}$ is to the right and $\vec{\mathbf{F}}_{A,\,B}$ is to the left (in agreement with Newton's third law). As for the force due to C,

$$F_{B,\,C} = \frac{k_e q_B |q_C|}{r_{BC}^{\;2}} = \left(8.99 \times 10^9\ \frac{\text{N}\cdot\text{m}^2}{\text{C}^2}\right)\frac{(1.40 \times 10^{-9}\text{ C})(2.80 \times 10^{-9}\text{ C})}{(2.00 \times 10^{-2}\text{ m})^2} = 8.81 \times 10^{-5}\text{ N}.$$

Because the charges are oppositely signed, the force is attractive, and therefore $\vec{\mathbf{F}}_{B,\,C}$, like $\vec{\mathbf{F}}_{B,\,A}$, also points right. The two forces are in the same direction, so the net force magnitude is

$$F_{\text{net},\,B} = F_{B,\,A} + F_{B,\,C} = 8.53 \times 10^{-5}\text{ N} + 8.81 \times 10^{-5}\text{ N} = 1.73 \times 10^{-4}\text{ N}$$

with the direction pointing to the right.

Finally, we can find the forces on C. Note the magnitude $F_{C,\,A} = F_{A,\,C} = 6.14 \times 10^{-5}$ N, but the vector $\vec{\mathbf{F}}_{C,\,A}$ points to the left. Also, the magnitude $F_{C,\,B} = F_{B,\,C} = 8.81 \times 10^{-5}$ N, and the vector $\vec{\mathbf{F}}_{C,\,B}$ also points left. The two forces are in the same direction, so the net force is

$$F_{net,\,C} = F_{C,\,A} + F_{C,\,B} = 6.14 \times 10^{-5}\text{ N} + 8.81 \times 10^{-5}\text{ N} = 1.50 \times 10^{-4}\text{ N}$$

with the direction pointing to the left.

Need Help? Read It

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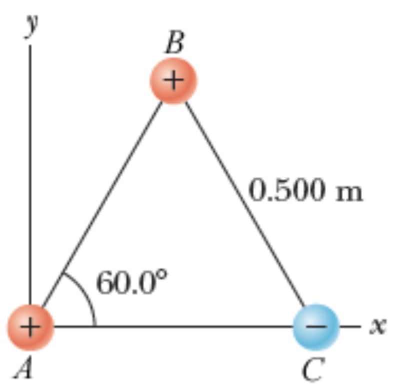
8. 2/2 points Previous Answers **SERCP11 15.2.OP.013.**

My Notes Ask Your Teacher

The figure below shows three charged particles at the corners of an equilateral triangle. Particle *A* has a charge of 1.50 μC; *B* has a charge of 5.60 μC; and *C* has a charge of −5.08 μC. Each side of the triangle is 0.500 m long. What are the magnitude and direction of the net electric force on A? (Enter the magnitude in N and the direction in degrees below the +*x*-axis.)

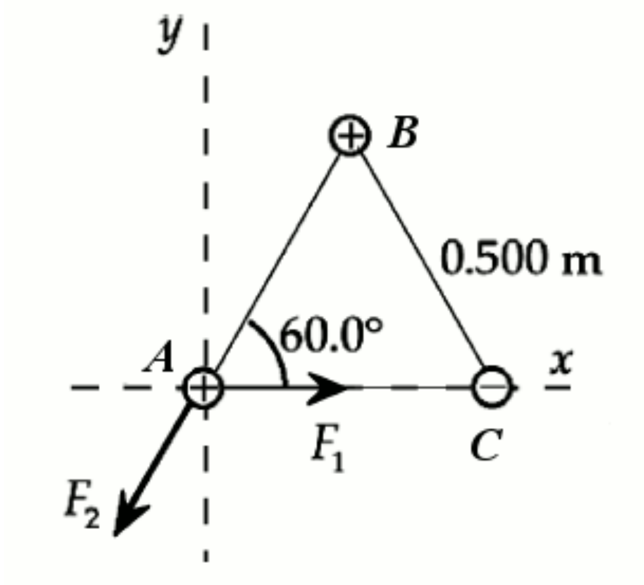


magnitude .29 ✔ 0.289 N

direction 65.22 ✔ 64.8 ° below the +*x*-axis

Solution or Explanation

Please see the sketch below.



$$F_1 = \frac{(8.99 \times 10^9\ \text{N} \cdot \text{m}^2/\text{C}^2)(1.50 \times 10^{-6}\ \text{C})(5.08 \times 10^{-6}\ \text{C})}{(0.500\ \text{m})^2}$$

or

$$F_1 = 0.274\ \text{N}$$

$$F_2 = \frac{(8.99 \times 10^9\ \text{N} \cdot \text{m}^2/\text{C}^2)(1.50 \times 10^{-6}\ \text{C})(5.60 \times 10^{-6}\ \text{C})}{(0.500\ \text{m})^2}$$

or

$$F_2 = 0.302\ \text{N}.$$

The components of the resultant force acting on the 1.50 μC charge are

$$F_x = F_1 - F_2 \cos(60.0°) = 0.274\ \text{N} - (0.302\ \text{N}) \cos(60.0°) = 0.123\ \text{N}$$

and

$$F_y = -F_2 \sin(60.0°) = -(0.302\ \text{N}) \sin(60.0°) = -0.262\ \text{N}.$$

The magnitude and direction of this resultant force are

$$F = \sqrt{F_x{}^2 + F_y{}^2} = \sqrt{(0.123\ \text{N})^2 + (-0.262\ \text{N})^2} = 0.289\ \text{N}$$

at

$$\theta = \tan^{-1}\left(\frac{F_y}{F_x}\right) = \tan^{-1}\left(\frac{-0.262\ \text{N}}{0.123\ \text{N}}\right) = -64.8°$$

or 64.8° below the +x-axis.

Need Help? Read It

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9. 1/1 points Previous Answers **SERCP11 15.2.P.002.**

My Notes Ask Your Teacher

A charged particle *A* exerts a force of 2.5 N to the right on charged particle *B* when the particles are 13.8 mm apart. Particle *B* moves straight away from *A* to make the distance between them 17.5 mm. What vector force does particle B then exert on A?

1.55 ✔ 1.55 N to the left

Solution or Explanation

Particle *A* exerts a force toward the right on particle *B*. By Newton's third law, particle *B* will then exert a force of equal magnitude toward the left on particle *A*. The ratio of the final magnitude of the force to the original magnitude of the force is

$$\frac{F_f}{F_i} = \frac{k_e q_1 q_2 / r_f^2}{k_e q_1 q_2 / r_i^2} = \left(\frac{r_i^2}{r_f^2}\right)$$

so

$$F_f = F_i\left(\frac{r_i}{r_f}\right)^2 = (2.5\text{ N})\left(\frac{13.8\text{ mm}}{17.5\text{ mm}}\right)^2 = 1.55\text{ N}$$

the final vector force that *B* exerts on *A* is 1.55 N directed to the left.

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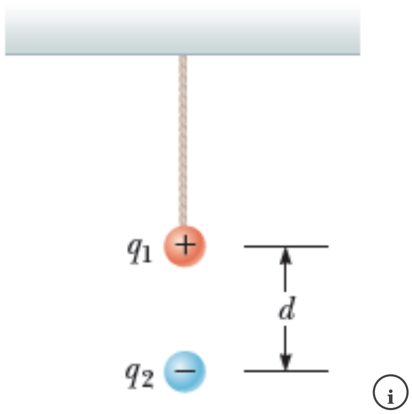
10. 2/2 points Previous Answers **SERCP11 15.2.P.004.**

My Notes Ask Your Teacher

A small sphere of mass m = 7.00 g and charge q_1 = 30.1 nC is attached to the end of a string and hangs vertically as in the figure. A second charge of equal mass and charge q_2 = −58.0 nC is located below the first charge a distance d = 2.00 cm below the first charge as in the figure.



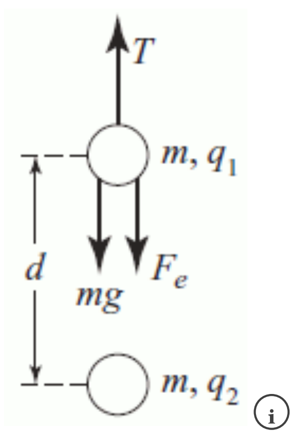
(a) Find the tension in the string.

.108 ✔ 0.108 N

(b) If the string can withstand a maximum tension of 0.180 N, what is the smallest value *d* can have before the string breaks?

1.2 ✔ 1.19 cm

Solution or Explanation



(a) The gravitational force exerted on the upper sphere by the lower one is negligible in comparison to the gravitational force exerted by the Earth and the downward electrical force exerted by the lower sphere. Therefore,

$$\sum F_y = 0 \Rightarrow T - mg - F_e = 0$$

or

$$T = mg + \frac{k_e|q_1||q_2|}{d^2}$$

$$T = (7.00 \times 10^{-3}\text{ kg})(9.80\text{ m/s}^2) + \frac{(8.99 \times 10^9\text{ N}\cdot\text{m}^2/\text{C}^2)(30.1 \times 10^{-9}\text{ C})(58.0 \times 10^{-9}\text{ C})}{(2.00 \times 10^{-2}\text{ m})^2}$$

giving $T = 0.108$ N

(b) $\sum F_y = 0 \Rightarrow F_e = k_e \dfrac{q_1 q_2}{d^2} = T - mg$, and $d = \sqrt{\dfrac{k_e |q_1||q_2|}{T - mg}}$

Thus, if $T = 0.180$ N,

$$d = \sqrt{\frac{(8.99 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2)(30.1 \times 10^{-9} \text{ C})(58.0 \times 10^{-9} \text{ C})}{0.180 \text{ N} - (7.00 \times 10^{-3} \text{ kg})(9.80 \text{ m/s}^2)}} = 1.19 \times 10^{-2} \text{ m} = 1.19 \text{ cm}.$$

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11. 0/1 points Previous Answers **SERCP11 15.2.P.006.**

My Notes Ask Your Teacher

A molecule of DNA (deoxyribonucleic acid) is 2.28 μm long. The ends of the molecule become singly ionized: negative on one end, positive on the other. The helical molecule acts like a spring and compresses 1.30% upon becoming charged. Determine the effective spring constant of the molecule.

1.38E-9 ✗ 1.53e-09

Your response is within 10% of the correct value. This may be due to roundoff error, or you could have a mistake in your calculation. Carry out all intermediate results to at least four-digit accuracy to minimize roundoff error. N/m

Solution or Explanation

Note: We are displaying rounded intermediate values for practical purposes. However, the calculations are made using the unrounded values.

The compression of the "spring" is

$$x = (0.0130)r = (0.0130)(2.28 \times 10^{-6}\text{ m}) = 2.96 \times 10^{-8}\text{ m}.$$

The attractive force between the charged ends tends to compress the molecule. Its magnitude is

$$F = \frac{k_e(1e)^2}{d^2} = \frac{(8.99 \times 10^9\text{ N}\cdot\text{m}^2/\text{C}^2)(1.60 \times 10^{-19}\text{ C})^2}{(2.28 \times 10^{-6}\text{ m} - 2.96 \times 10^{-8}\text{ m})^2} = 4.54 \times 10^{-17}\text{ N},$$

so the spring constant is

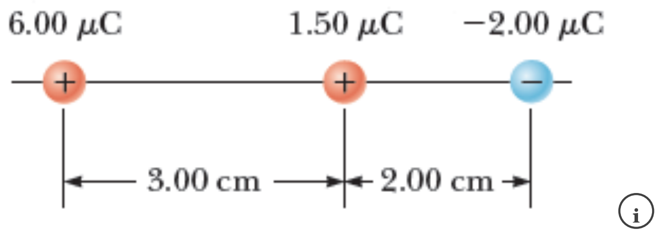
$$k = \frac{F}{x} = \frac{4.54 \times 10^{-17}\text{ N}}{2.96 \times 10^{-8}\text{ m}} = 1.53 \times 10^{-9}\text{ N/m}.$$

Need Help? Read It

12. 3/6 points Previous Answers **SERCP11 15.2.P.010.**

My Notes Ask Your Teacher

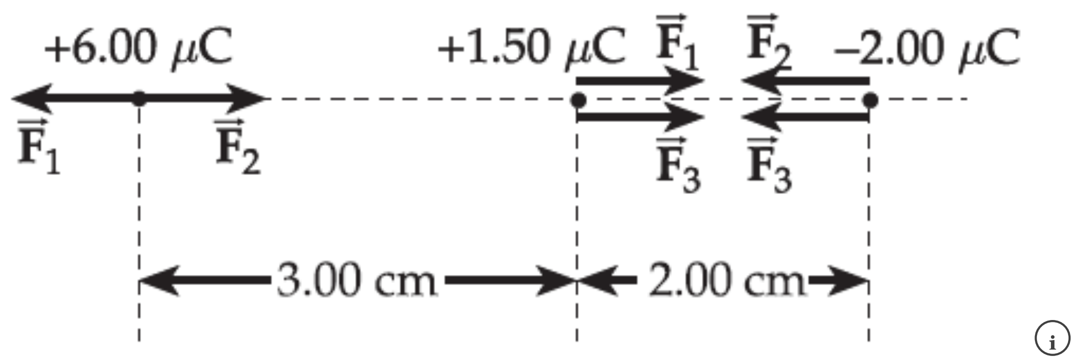
Calculate the magnitude and direction of the Coulomb force on each of the three charges shown in the figure below.



6.00 μC charge	magnitude	4.68E-3 ✗ 46.7 Your response differs significantly from the correct answer. Rework your solution from the beginning and check each step carefully. N
6.00 μC charge	direction	toward the left ✓ toward the left
1.50 μC charge	magnitude	(No Response) 157 N
1.50 μC charge	direction	toward the right ✓ toward the right
−2.00 μC charge	magnitude	(No Response) 111 N
−2.00 μC charge	direction	toward the left ✓ toward the left

Solution or Explanation

The forces are as shown in the sketch below.



$$F_1 = \frac{k_e q_1 q_2}{{r_{12}}^2} = \left(8.99 \times 10^9 \ \frac{\mathrm{N \cdot m^2}}{\mathrm{C^2}}\right)\frac{(6.00 \times 10^{-6}\ \mathrm{C})(1.50 \times 10^{-6}\ \mathrm{C})}{(3.00 \times 10^{-2}\ \mathrm{m})^2} = 89.9\ \mathrm{N}$$

$$F_2 = \frac{k_e q_1 |q_3|}{{r_{13}}^2} = \left(8.99 \times 10^9 \ \frac{\mathrm{N \cdot m^2}}{\mathrm{C^2}}\right)\frac{(6.00 \times 10^{-6}\ \mathrm{C})(2.00 \times 10^{-6}\ \mathrm{C})}{(5.00 \times 10^{-2}\ \mathrm{m})^2} = 43.2\ \mathrm{N}$$

$$F_3 = \frac{k_e q_2 |q_3|}{{r_{23}}^2} = \left(8.99 \times 10^9 \ \frac{\mathrm{N \cdot m^2}}{\mathrm{C^2}}\right)\frac{(1.50 \times 10^{-6}\ \mathrm{C})(2.00 \times 10^{-6}\ \mathrm{C})}{(2.00 \times 10^{-2}\ \mathrm{m})^2} = 67.4\ \mathrm{N}$$

The net force on the 6 μC charge is $F_{6\ \mu\mathrm{C}} = F_1 - F_2 = 46.7$ N (to the left).

The net force on the 1.5 μC charge is $F_{1.5\ \mu C} = F_1 + F_3 = 157$ N (to the right).

The net force on the −2 μC charge is $F_{-2\ \mu C} = F_2 + F_3 = 111$ N (to the left).

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