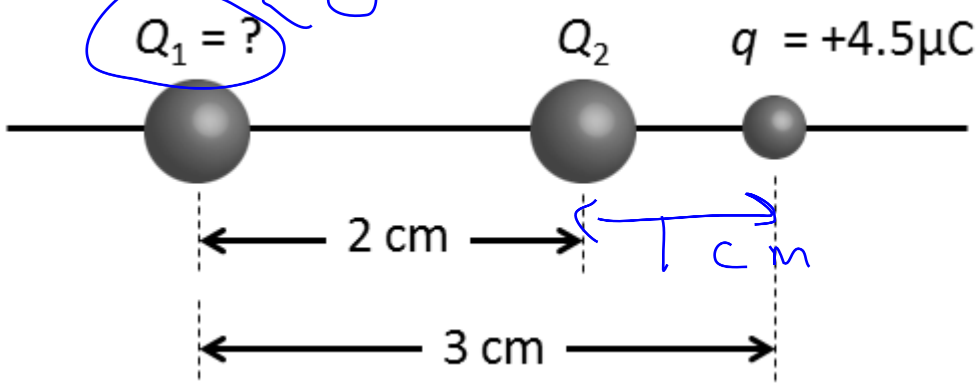
The next two questions pertain to the situation described below.

Two charges Q_1 and Q_2 are placed on the x-axis, at $x = 0$ and $x = 2\ cm$, respectively, as shown in the figure. The charge $Q_2 = 5.5\ \mu C$, whereas Q_1 is not known. A third charge $q = +4.5\ \mu C$ is placed a distance $x = 3\ cm$ from the origin, on the x-axis.



1) What must the value of Q_1 be such that the force on q due to charges 1 and 2 is <u>zero</u>?

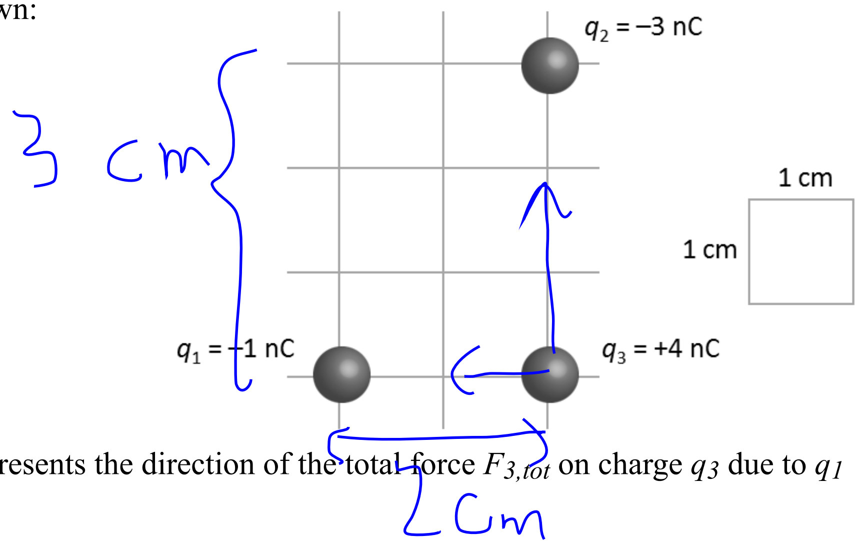
a. $Q_1 = -50\ \mu C$
b. $Q_1 = 17\ \mu C$
c. $Q_1 = 50\ \mu C$
d. $Q_1 = -17\ \mu C$
e. $Q_1 = -5.6\ \mu C$

2) Does your answer change if charge q is now negative?

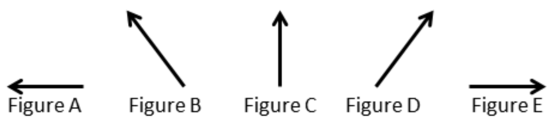
a. *No*
b. *Yes*

The next two questions pertain to the situation described below.

Consider the configuration of charges shown:
$q_1 = -1\ nC$, $q_2 = -3\ nC$, and $q_3 = +4\ nC$.
The grid is $1\ cm$ on a side.



3) Which of the following vectors best represents the direction of the total force $F_{3,tot}$ on charge q_3 due to q_1 and q_2?



a. *Figure C*
b. *Figure D*
c. *Figure E*
d. *Figure B*
e. *Figure A*

4) Calculate the magnitude of the total force $|F_{3,tot}|$ on charge q_3 due to q_1 and q_1.

a. $|F_{3,tot}| = 26\ \mu N$
b. $|F_{3,tot}| = 150\ \mu N$
c. $|F_{3,tot}| = 2200\ \mu N$
d. $|F_{3,tot}| = 630\ \mu N$
e. $|F_{3,tot}| = 93\ \mu N$

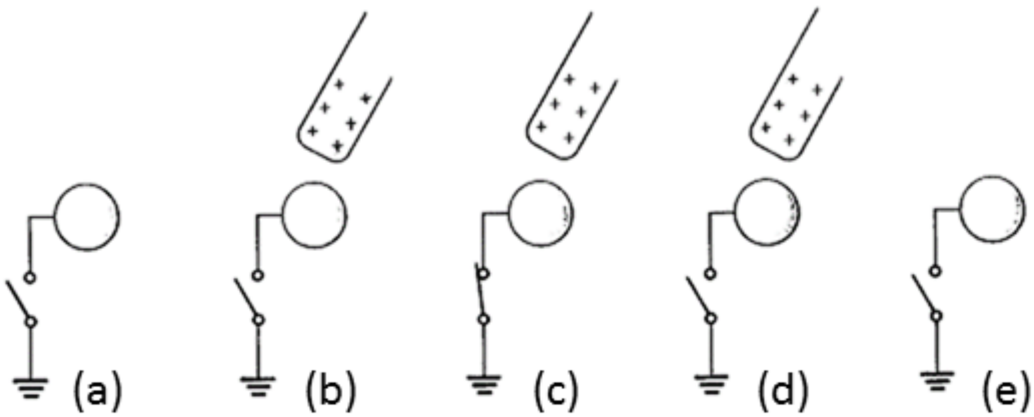
$F_{tot} = \sqrt{F_x^2 + F_y^2} = \sqrt{F_1^2 + F_2^2}$

$|F_1| = \frac{k|q_1||q_3|}{r_{13}^2} = 9 \times 10^{-5}\ N$, $|F_2| = \frac{kq_2 q_3}{r_{23}^2} = 1.2 \times 10^{-4}\ N$

$F_{tot} = 1.5 \times 10^{-4}\ N$

The next two questions pertain to the situation described below.

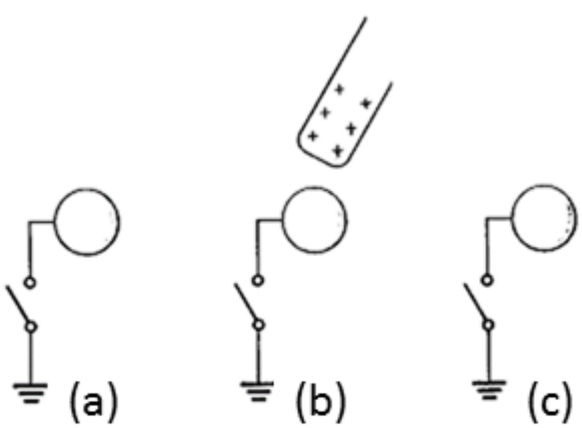
A positively charged rod is brought close but does not touch an uncharged conducting sphere (as shown in steps a-b below). As a rod approaches, the sphere is connected to ground by a conducting wire (c). The grounding wire and rod are then removed (d-e).



5) What is the charge on the conducting sphere after the sequence of steps?

a. *Zero*
b. *Positive*
c. *Negative*

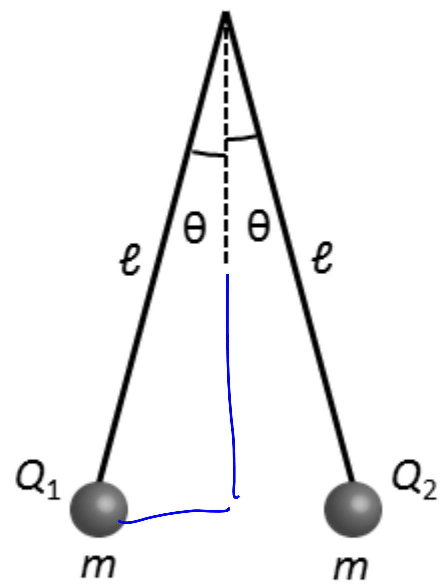
6) Now the sequence of steps is repeated, starting with the same conducting sphere (uncharged), but without grounding the sphere. What is the charge on the sphere after the sequence of steps (a-c)?



a. *Zero*
b. *Negative*
c. *Positive*

The next three questions pertain to the situation described below.

An electroscope is built by suspending two identically sized conducting spheres of mass $m = 0.02\ kg$ from thin wires of length $\ell = 15\ cm$ as shown in the figure. After charging, both spheres make an angle of $\theta = 15°$ relative to vertical and $Q_1 = Q_2$. (Note: in this problem, you may ignore any mass or charge from the thin wires.)



$d = 2\ell\sin\theta$

7) Because the system is in equilibrium:

a. *Gravity does not act on the system.*
b. *The spheres will experience a net acceleration.*
c. *The spheres will not experience a net acceleration.*

8) If the charge of *both* Q_1 and Q_2 is increased, the angle θ will:

a. *decrease.*
b. *increase.*
c. *stay the same.*

9) What is the magnitude of the charge $|Q_1|$?

a. $|Q_1| = 8.4 \times 10^{-8}\ C$
b. $|Q_1| = 1.6 \times 10^{-7}\ C$
c. $|Q_1| = 5 \times 10^{-8}\ C$
d. $|Q_1| = 3.9 \times 10^{-8}\ C$
e. $|Q_1| = 1.9 \times 10^{-7}\ C$

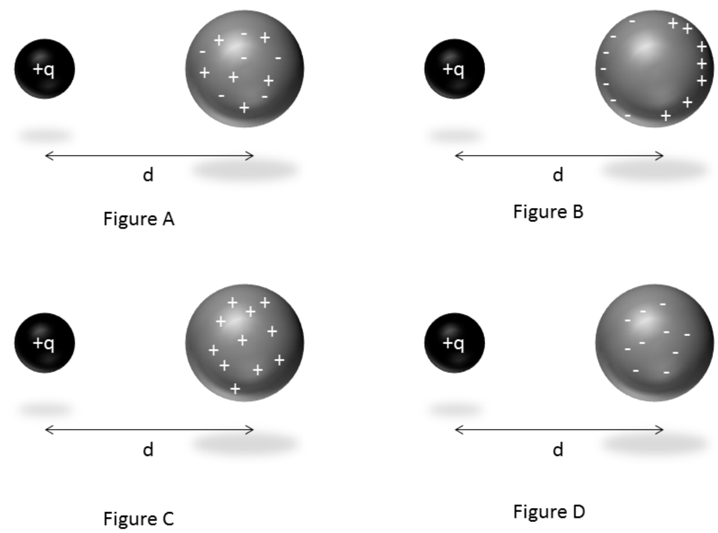
$T\cos\theta = mg$

$T\sin\theta = \frac{kQ^2}{d^2}$

$\tan\theta = \frac{kQ^2}{d^2}\frac{1}{mg} = \frac{kQ^2}{mg \cdot 4\ell^2\sin^2\theta}$

$\sqrt{Q^2} = \sqrt{\frac{mg\,4\ell^2\sin^2\theta\tan\theta}{k}}$

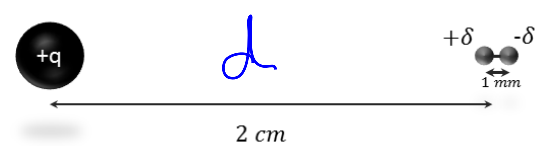
13) A sphere with charge $+q$ is placed a distance d from an uncharged metal sphere. Of the four figures shown, which figure best represents the resulting charge distribution on the metal sphere?



a. *Figure C*
b. *Figure A*
c. *Figure D*
d. *None of these*
e. *Figure B*

The next two questions pertain to the situation described below.

An electric dipole has a separation distance $d = 1\ mm$.
It is placed $2\ cm$ from a fixed, positive charge $q = 9.7\ \mu C$.



14) If $|\delta| = 0.21\ \mu C$ what is the magnitude of the net force on the dipole due to the sphere?

$$F_{net} = F_+ - F_- = \frac{kq\delta}{d^2} - \frac{kq\delta}{(d+1\ mm)^2}$$
$$= kq\delta\left[\frac{1}{(0.02\ m)^2} - \frac{1}{(0.021\ m)^2}\right]$$

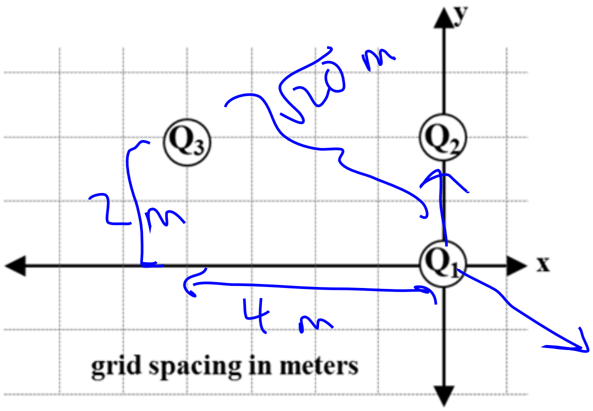
a. $F = 0\ N$
b. $F = 87\ N$
c. $F = 1.8\ N$
d. $F = 0.044\ N$
e. $F = 4.3\ N$

15) The dipole is released. In what direction will it travel?

a. *It will not move.*
b. *It will move away from the charged sphere.*
c. *It will move toward the charged sphere.*

The next three questions pertain to the situation described below.

Three charges are fixed in position as shown in below. Note, charges Q1 and Q3 are positive, charge Q2 is negative.



Q1=2.4 × 10^{-6} Coulombs
Q2=-4.8 × 10^{-6} Coulombs
Q3=2.4 × 10^{-6}Coulombs

4) What is the x component of the force on charge Q1 due to the other two charges?

$$F_{tot,x} = F_{31,x} = |F_{31}| \cdot \left(\frac{4}{\sqrt{20}}\right) = \frac{kQ_3Q_1}{20\ m^2} \cdot \frac{4}{\sqrt{20}}$$

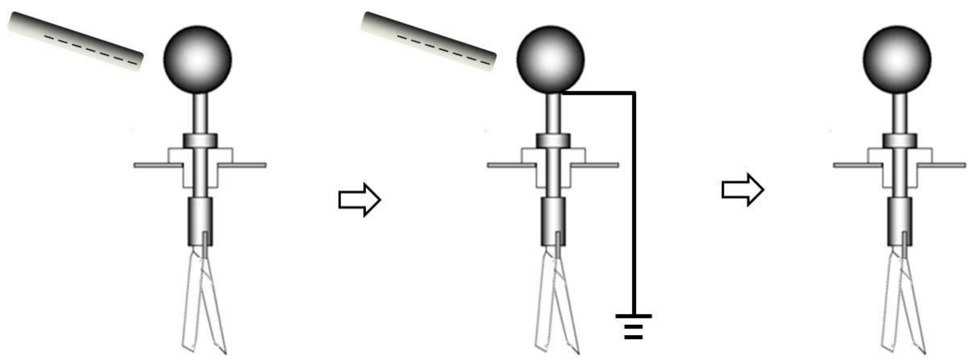
a. F_{1x} = -0.0236 N
b. F_{1x} = 0.00116 N
c. F_{1x} = 0.00232 N
d. F_{1x} = 0.00259 N
e. F_{1x} = -0.0259 N

5) What is the y component of the force on charge Q1 due to the other two charges?

$$F_{tot,y} = +|F_{21}| - |F_{31,y}| = \frac{k|Q_2|Q_1}{4\ m^2} - \frac{kQ_3Q_1}{20\ m^2}\left(\frac{2}{\sqrt{20}}\right)$$

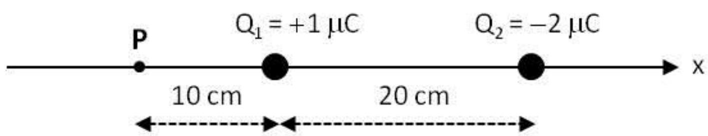
a. F_{1y} = 0.0233 N
b. F_{1y} = -0.0233 N
c. F_{1y} = 0.0224 N
d. F_{1y} = -0.0282 N
e. F_{1y} = 0.0248 N

1. A negatively charged rod is brought near (but does not touch) an electroscope as shown. Then, the scope is briefly grounded. Finally, the electroscope is disconnected from ground and the charged rod is removed. Regarding the whole sequence of three steps, which statement is **FALSE**?



a. Negative charges will flow from the scope to the ground. ✓
(b.) Negative charges will be induced on the scope when the rod is moved away.
c. The leaves will repel each other when the rod is moved away. ✓

2. Two point charges are placed on the *x*-axis as shown. If a positive charge is brought to the point **P**, what is the direction of the net electric force felt by this charge?

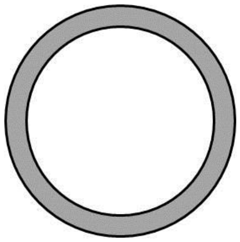


← 30 cm →

(a.) Along the negative *x*-axis.
b. Along the positive *x*-axis.
c. It depends on the magnitude of the positive charge at point **P**.

$$\frac{|F_1|}{|F_2|} = \frac{kqQ_1/(10\text{ cm})^2}{kqQ_2/(30\text{ cm})^2} = \left|\frac{Q_1}{Q_2}\right| \cdot 9 = \frac{9}{2}$$

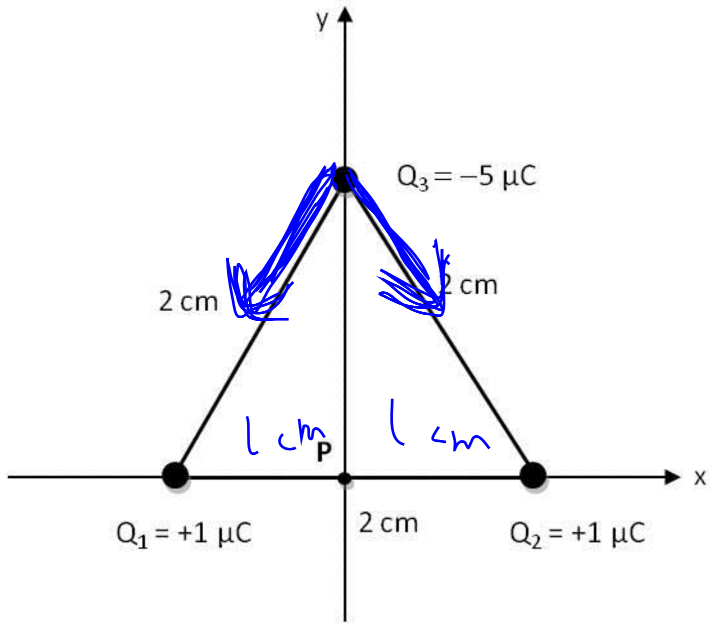
6. Consider an uncharged spherical conducting shell as shown. If charges are transferred to it, which statement is TRUE regarding their behavior?



a. They will be distributed uniformly throughout the conductor.
b. They will spread on the inner surface.
c. They will spread on the outer surface.

The next five questions pertain to the following situation.

Three point charges are positioned on the vertices of an equilateral triangle as shown.

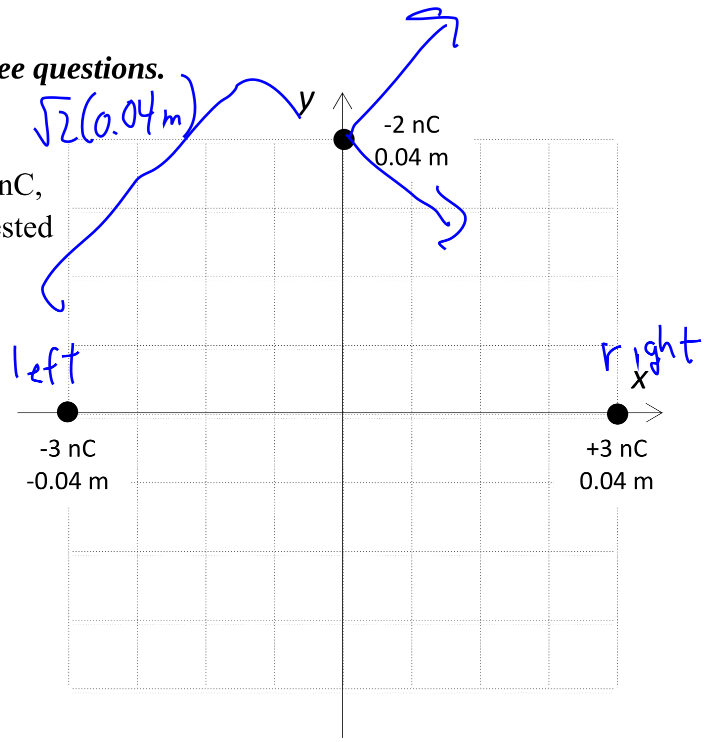


8. What is the magnitude of the net electric force F on the charge Q_3?

a. $F = 3.89$ N
b. $F = 112$ N
c. $F = 195$ N

The following situation pertains to the next three questions.

A positive charge, +3nC is placed at +0.04 m on the *x*-axis. A negative charge, -3 nC, is placed at -0.04 m on the x-axis. We are interested in the electric force on a -2 nC charge placed at +0.04 m on the *y*-axis.



13. What is the direction of the electric force on the -2 nC particle?

a. In the +*x* direction.
b. In the -*x* direction.
c. In the +*y* direction.
d. In the -*y* direction.
e. The force is zero.

14. What is the magnitude of the electric force on the -2 nC particle?

a. 0 N
b. 2.4 N
c. 3.6×10^{-5} N
d. 2.4×10^{-5} N
e. 4.8×10^{-5} N

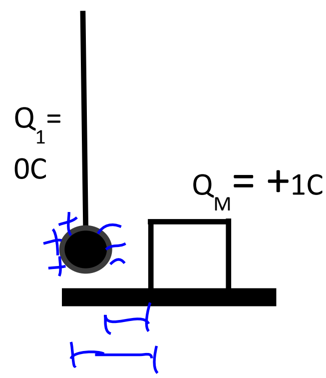
$\vec{F}_{tot} = \vec{F}_{left} + \vec{F}_{right} = F_{L,x} + F_{R,x} = 2F_{L,x}$

$= 2F_L \cdot \left(\frac{1}{\sqrt{2}}\right)$

$= \frac{2kQ_L q}{2(0.04\,m)^2} \cdot \frac{1}{\sqrt{2}}$

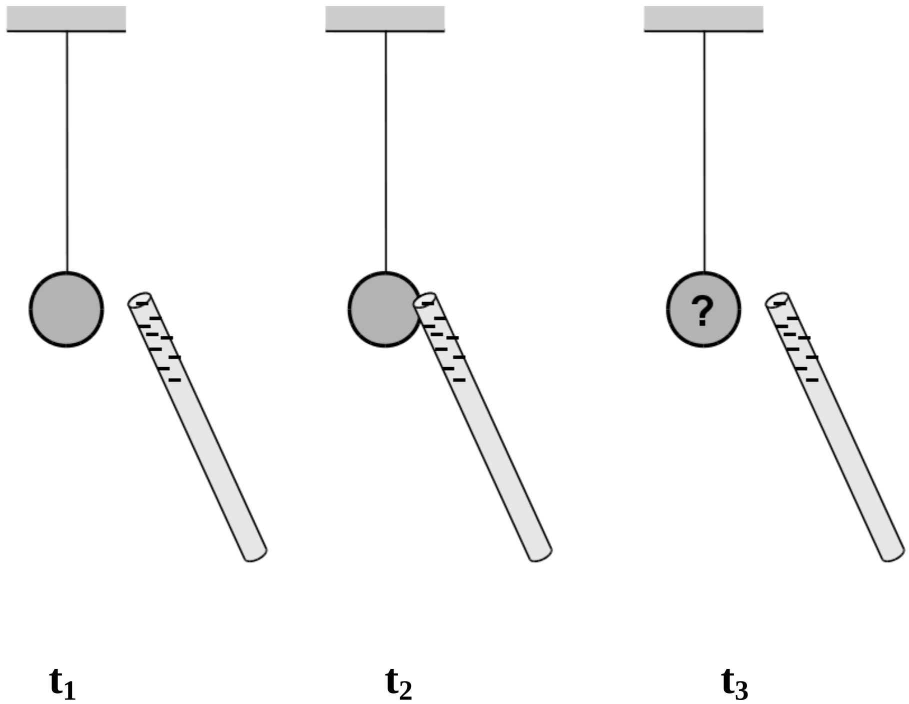
27. A metal box carries a charge $Q_M = +1C$. A polarizable ball that carries no net electric charge, $Q_1 = 0C$, is held in place with a rod so that it is located near the box. Which statement with regards to the force between the rubber ball and the metal box is correct?

a. There will be no force since $Q_1 = 0C$.
b. There will a repulsive force.
c. There will be an attractive force.



Check to make sure you bubbled in all your answers.
Did you bubble in your name, exam version and network-ID?

18. A sphere is hung from a light cotton string attached to a fixed support (**t_1**). A conducting rod with a net negative charge is made to touch the sphere (**t_2**) and then moved away.

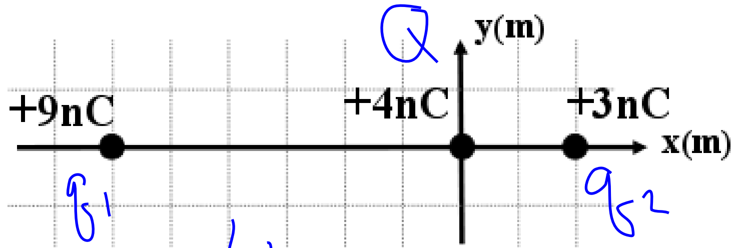


Which direction does the sphere move at time **t_3**, when the rod is held nearby?

a. toward the rod
b. away from the rod
c. does not move

The next two questions continue from the previous page:

Another charge with mass m = 4.3 x 10^{-17} kg is added to the configuration at the origin. The +9nC and +3nC charges are held stationary, while the 4nC charge is free to move.

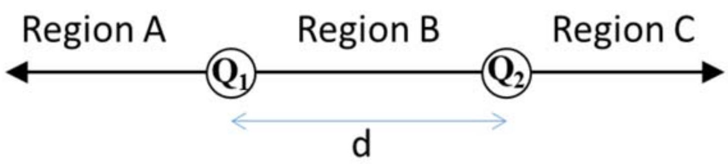


24. What is the magnitude of the force on the 4 nC charge?

a. 8 x 10^{-9} N
b. 1.8 x 10^{-8} N
c. 3.9 x 10^{-8} N

The next three questions pertain to the situation described below.

A positive and a negative charge have mass 0.4 kg and are fixed in position along the x-axis separated by a distance d=0.2 m as shown in below.



Q1=8.2×10^{-6} Coulombs =8.2 uC
Q2=-1.64×10^{-5} Coulombs =16.4 uC
d =0.2 m
m =0.4 kg

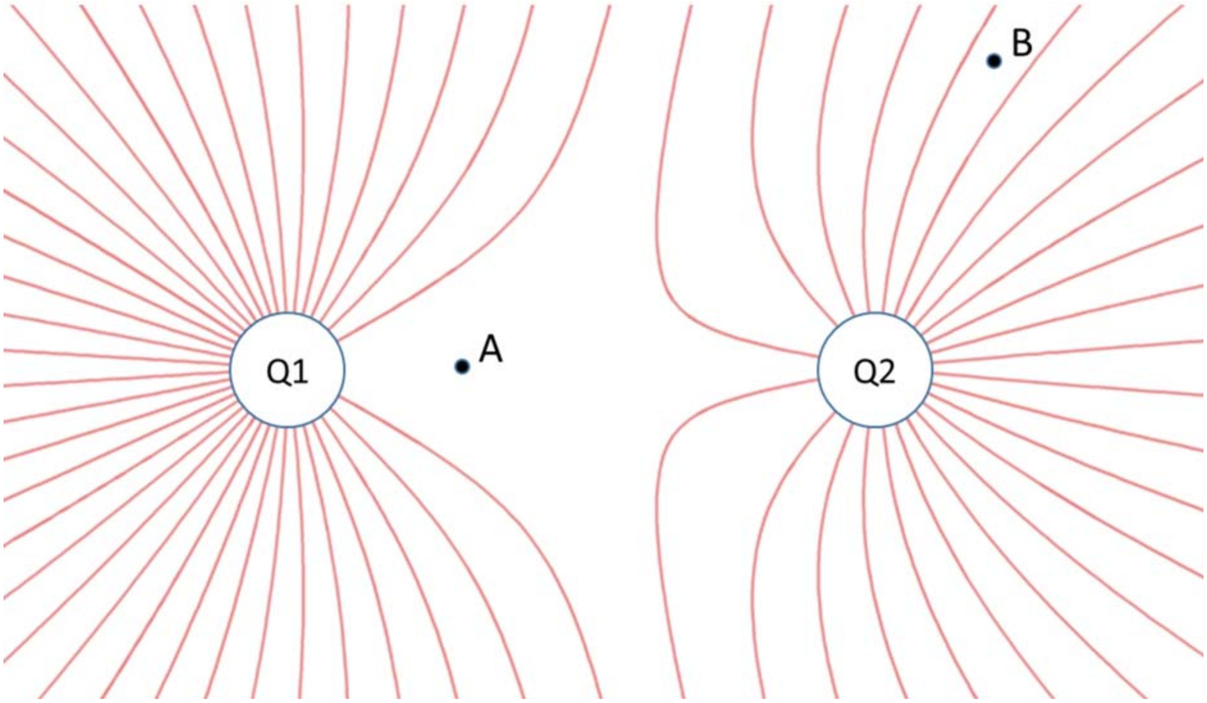
2) In which region(s) is there a point on the x-axis where the electric field due to the two charges is zero?

a. Region A only ✓
b. Region A and B.
c. Region B only.

$|Q_2| > |Q_1| \Rightarrow$ far to the left $\vec{E}$ is $\rightarrow$
just left of Q_1 $\vec{E}$ is $\leftarrow$

The next two questions pertain to the situation described below.

The figure below shows the field lines due to two unknown point charges.



7) Compare the magnitude of the two charges.

a. |Q1| < |Q2|
b. |Q1| > |Q2|
c. |Q1| = |Q2|

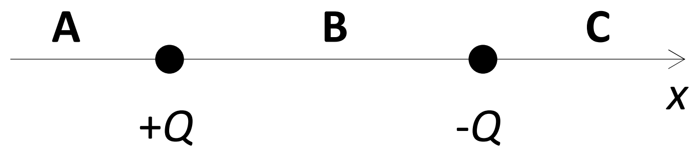
more field lines coming out of Q_1

8) Compare the magnitude of the electric field at points **A** and **B**.

a. $|E_A| > |E_B|$
b. $|E_A| = |E_B|$
c. $|E_A| < |E_B|$

Higher density of lines near B

9. Two charges, $+Q$ and $-Q$, are placed on the x-axis as shown. In which of the three regions, **A**, **B**, and **C**, on the x-axis can the electric field be zero?



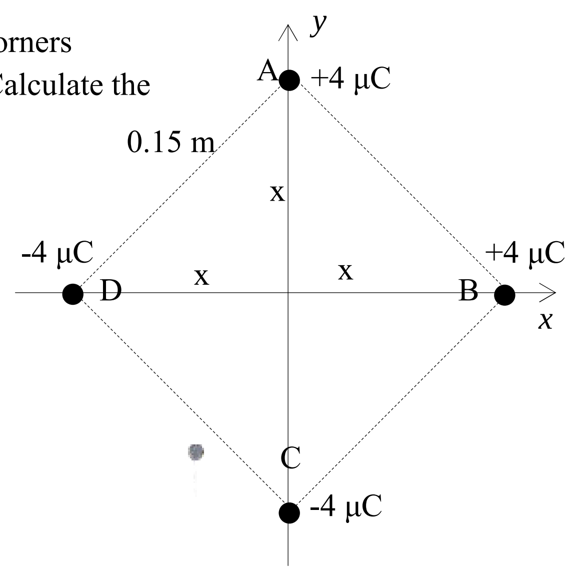
a. Region **A**
b. Region **B**
c. Region **C**
d. Regions **A** and **C**
e. No regions.

Wow, what a nasty question!

Because the two questions have exactly the same magnitude, it isn't until you get infinitely far away that $\vec{E} \to 0$

Strictly speaking, the answer is (e), but answer (d) is ~~not~~ tempting

10. Four charges, all ±4 μC, are placed at the corners of a square with 0.15 m long sides, as shown. Calculate the x-component, E_x, of the electric field at the center of the square.



a. $E_x = -6.4\times10^6$ N/C
b. $E_x = -3.2\times10^6$ N/C
c. $E_x = 0$ N/C
d. $E_x = +3.2\times10^6$ N/C
e. $E_x = +6.4\times10^6$ N/C

If 0.15 m on a side

$\Rightarrow x^2 + x^2 = 0.15^2\ m^2$

$\Rightarrow x = 0.1061$ m

A & C don't contribute ~~the~~ to E_x

D & B both gives a negative E_x

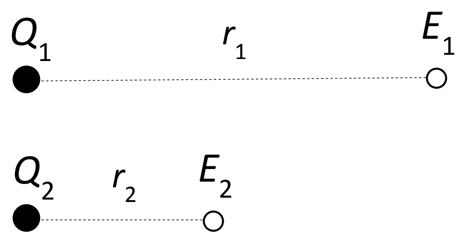
$$\vec{E}_x = \vec{E}_B + \vec{E}_D = -2 \cdot \frac{k(4\mu C)}{x^2}$$

$$= -8 \cdot \frac{9\times10^9 \times 10^{-6}}{(0.1061)^2}$$

$$= -6.4\times10^6\ N/C$$

11. Compare the magnitudes of the electric fields, E_1 and E_2, produced by two charges, $Q_1 = 3.2$ μC and $Q_2 = 0.75$ μC. We measure E_1 a distance $r_1 = 0.2$ m from Q_1, and E_2 a distance $r_2 = 0.1$ m from Q_2. Which is larger, E_1 or E_2?

a. E_1 is larger.
b. E_1 and E_2 are equal.
c. E_2 is larger.



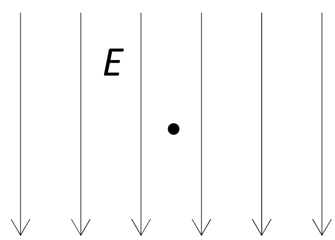
$E \propto \frac{q}{r^2}$

$r \to 2r \Rightarrow$ 4x smaller E

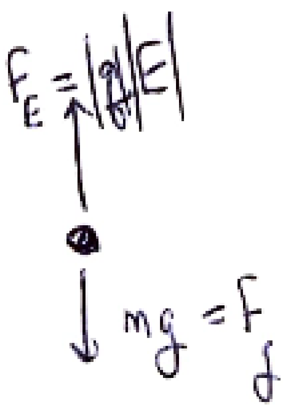
$q \to \frac{3.2}{0.75} \Rightarrow$ 4.3x larger E

18. A small particle of mass $m = 4\times10^{-18}$ kg has a charge of $q = -1.6\times10^{-19}$ C. It is placed in a vertical electric field, E, as shown. What must the magnitude of E be to suspend the particle against the force of gravity?

a. 0.04 N/C
b. 25 N/C
c. 245 N/C



$m = 4\times10^{-18}$ kg
$q = -1.6\times10^{-19}$ C



$\therefore |qE| = mg$

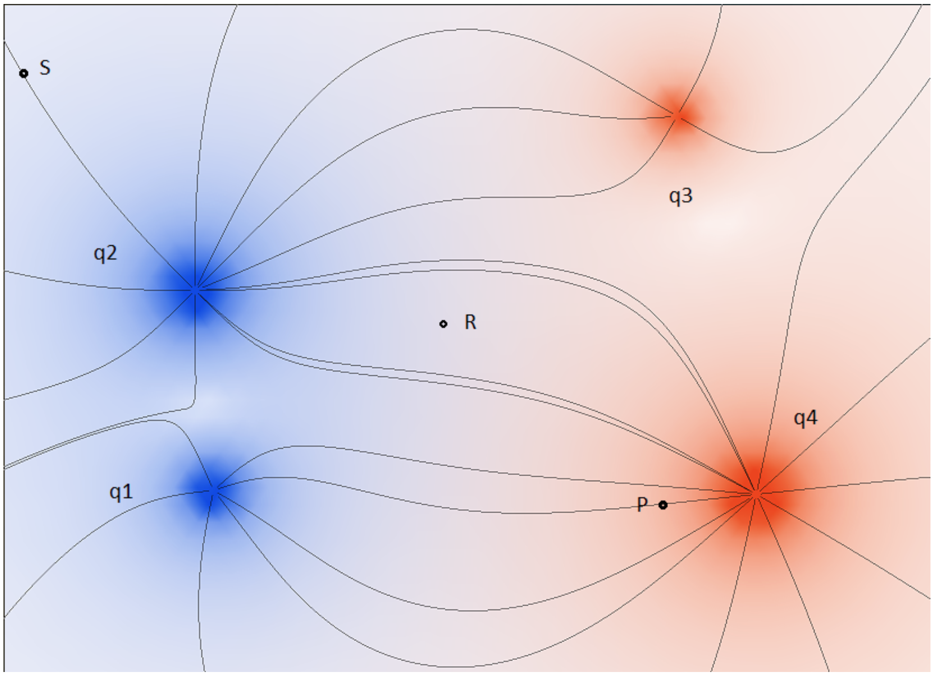
$\Rightarrow E = \frac{mg}{|q|}$

$= \frac{4\times10^{-18} \cdot 9.8 \ \text{kg m/s}^2}{1.6\times10^{-19} \ \text{C}}$

$= 245$ N/C

The next three questions pertain to the situation described below.

Consider the collection of 4 charges below:



10) Using the field lines determine the correct ordering for the magnitudes of the charges

a. $|q3| < |q1| < |q2| < |q4|$
b. $|q2| < |q1| < |q4| < |q3|$
c. $|q3| < |q2| < |q1| < |q4|$
d. $|q1| < |q2| < |q3| < |q4|$
e. $|q1| < |q3| < |q2| < |q4|$

count field lines

11) Based on the nature of the field lines which of the following is true:

a. *The signs of q1 and q2 are opposite of q3 and q4.*
b. *All of the charges have the same sign.*
c. *The charges q1 and q4 have the same sign.*

q2 connects to q3, so are opposite q
q1/q2 don't connect, so must be same
q3/q4 don't connect, so must be same

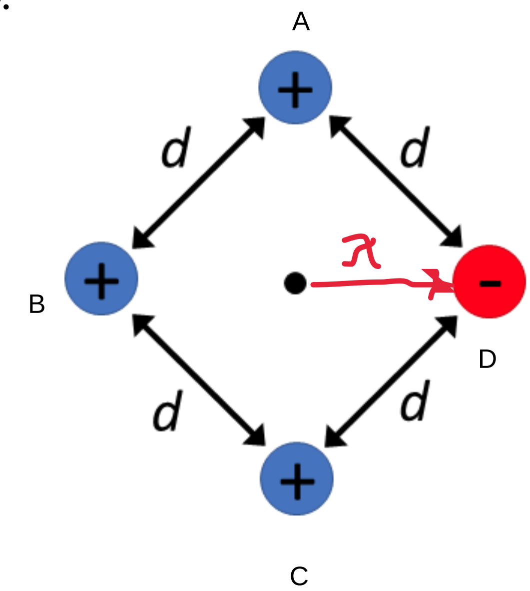
12) When placed at which point will a test charge experience the largest force?

a. *P*
b. *R*
c. *S*

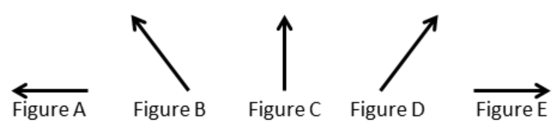
density of lines is highest

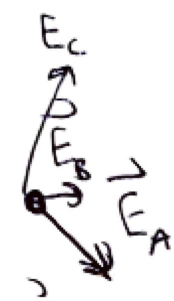
The next three questions pertain to the situation described below.

Four point charges are equally spaced by a distance $d = 4.69\ mm$ at the corners of a square, as shown in the figure. Three of the charges are positive, with $q = 2.9\ \mu C$, while one is negative with charge $q = -2.9\ \mu C$.



24) Considering only the three positive charges, which vector arrow shown below best represents the direction of the electric field at the position of the negative charge?





a. *Figure A*
b. *Figure B*
c. *Figure C*
d. *Figure E*
e. *Figure D*

$\vec{E}_A$ points away from A
$\vec{E}_B$ " " " B
E_C " " " C

$\vec{E}_A + \vec{E}_C$ cancel in vertical direction

25) Considering only the three positive charges, what is the magnitude of the electric field at the position of the negative charge?

a. $E = 1.19 \times 10^9\ N/C$
b. $E = 2.27 \times 10^9\ N/C$
c. $E = 0\ N/C$
d. $E = 1.78 \times 10^9\ N/C$
e. $E = 1.08 \times 10^9\ N/C$

$$E_{D,x} = |\vec{E}_B| + E_{Ax} + E_{Cx}$$

$$= \frac{kq}{(2x)^2} + 2\frac{kq}{d^2}\cdot\frac{x}{d}$$

$$= kq\left[\frac{1}{4x^2} + \frac{2x}{d^3}\right]$$

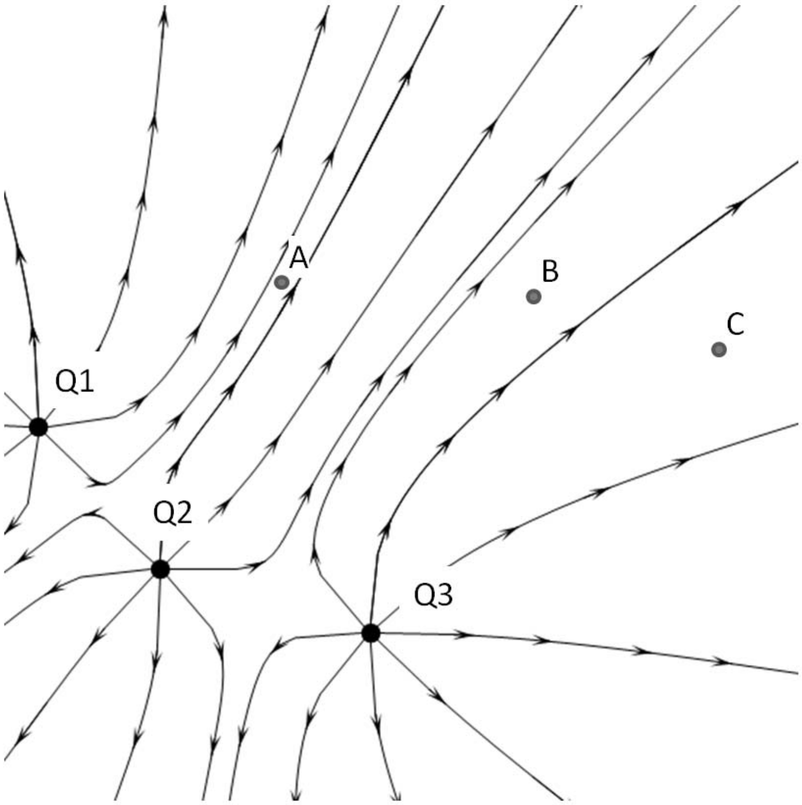
$$= \frac{kq}{d^2}\left[\frac{1}{2} + \sqrt{2}\right] = \frac{9\times10^9 \cdot 2.9\times10^{-6}}{(4.69\times10^{-3})^2}(0.5+\sqrt{2}) = 2.3\times10^9\ N/C$$

$x^2 + x^2 = d^2$

$\Rightarrow x = \frac{d}{\sqrt{2}}$

The next two questions pertain to the following diagram.

The following diagram has three charges, Q_1, Q_2 , Q_3, and three points in space, A, B, C.



12. Where is the magnitude of the electric field strongest?

a. A
b. B
c. C

density of field lines

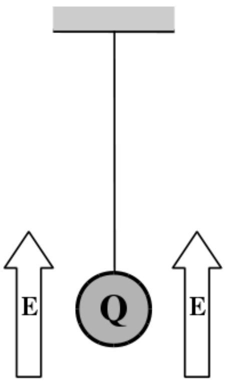
13. What is true about the magnitude of the charges?

a. $Q_1>Q_2>Q_3$
b. $Q_1=Q_2=Q_3$
c. $Q_3>Q_2>Q_1$

count lines coming out of each

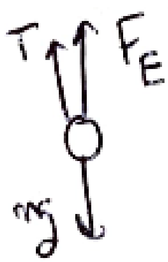
The next two questions pertain to the following situation:

An insulating sphere of mass m = 9.3 kg and charge Q = +4.6 mC is hung on a light cotton string and then placed in an external electric field. The electric field is unknown in magnitude and points upward. The tension in the string is measured to be 76 N.



19. What is the magnitude of the external electric field?

a. E = 480 N/C
b. E = 630 N/C
c. E = 1900 N/C
d. E = 3300 N/C
e. E = 5400 N/C



$T + qE = mg$

$E = \frac{mg - T}{q} = \frac{(9.3 \times 9.8)N - 76\ N}{4.6 \times 10^{-3}\ C}$

$= 3291.\ N/C$

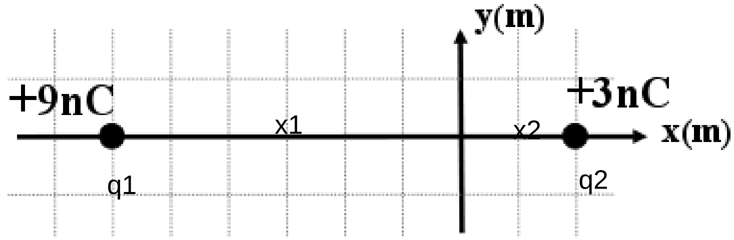
20. Let the original tension in the string be T_0. The charge Q is changed from +4.6 mC to -4.6 mC. What is the relationship between the new tension T_{new} and the original tension T_0?

a. $T_{new} < T_0$
b. $T_{new} = T_0$
c. $T_{new} > T_0$

$T_{new} > T_{old}$

The next two questions pertain to the following situation:

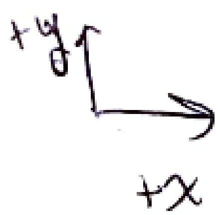
Two charges are located on the x-axis at positions –6 m and +2 m respectively. Each grid spacing is 1 meter.



22. What is the net electric field at the origin due to the two charges?

a. –4.50 V/m
b. –2.25 V/m
c. +9.00 V/m

Assume right to be +'ve



$\vec{E}_1 + \vec{E}_2 = \frac{kq_1}{x_1^2} - \frac{kq_2}{x_2^2}$

$= k\left(\frac{9\times10^{-9}\,C}{6^2\,m^2} - \frac{3\times10^{-9}\,C}{2^2\,m^2}\right)$

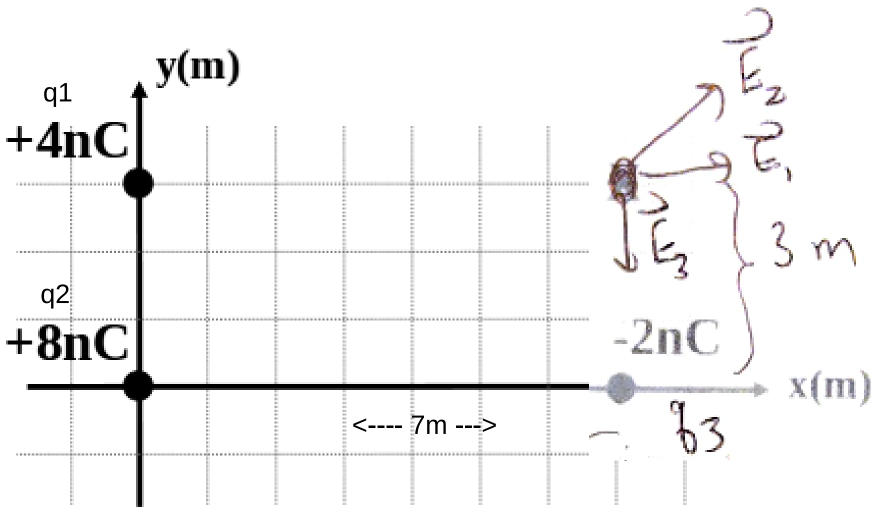
$= 9\times10^{9}\left(\frac{9\times10^{-9}}{36} - \frac{3\times10^{-9}}{4}\right)$

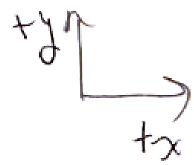
$= \left(\frac{81}{36} - \frac{27}{4}\right)$ N/C

$= -4.5$ N/C

The next question pertains to the following situation:

Three charges are located at (0,0), (7 m,0), and (0, 3m), as shown below. Each grid spacing is 1 meter.





26. What is the net electric field at the point indicated at (7 m, 3 m)?

a. 0.76 V/m
b. 2.4 V/m
c. 5.9 V/m
d. 12 V/m
e. 39 V/m

$\vec{E}_1 = \frac{kq_1}{x_1^2}$ [right]

$\Rightarrow |\vec{E}_1| = \frac{9\times10^9 \cdot 4\times10^{-9}}{49} = +\frac{36}{49}$ N/C

$\vec{E}_1 = 0.7347$ N/C $+\hat{x}$

$\vec{E}_3 = \frac{kq_3}{r_3^2} = \frac{9\times10^9\cdot(2\times10^{-9})}{9\,m^2}$ [down]

$= 2$ N/C $(-\hat{y})$

$|\vec{E}_2| = \frac{kq_2}{r_2^2} = \frac{9\times10^9\cdot 8\times10^{-9}}{(49+9)\,m^2} = \left(\frac{72}{58}\right)$ N/C $= 1.24$ N/C

$E_{2x} = |\vec{E}_2|\left(\frac{7}{\sqrt{58}}\right)$; $E_{2y} = +|\vec{E}_2|\cdot\frac{3}{\sqrt{58}}$

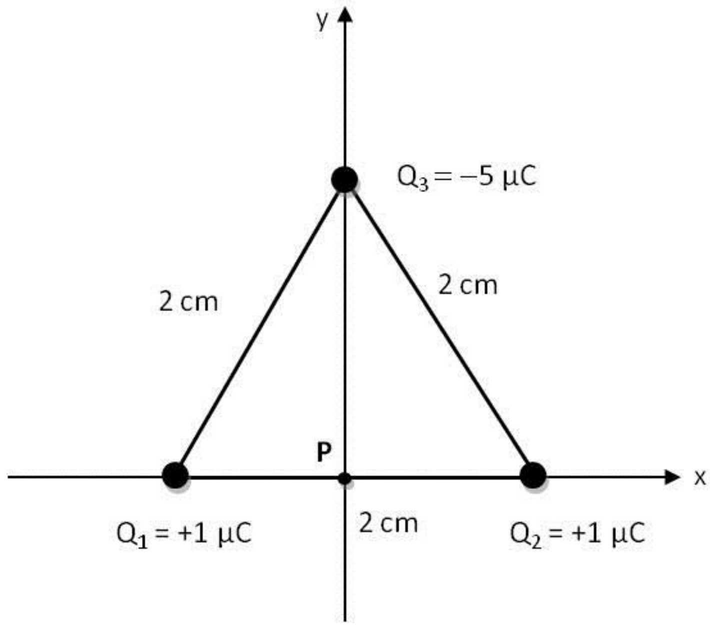
$= +1.14$ N/C $\qquad = +0.489$ N/C

$\Rightarrow \vec{E}_{tot} = 1.87\,\hat{x} + (-1.51)\,\hat{y}$ N/C $\Rightarrow |E_{tot}| = \sqrt{1.87^2 + 1.51^2}$

$= 2.4$ N/C

The next five questions pertain to the following situation.

Three point charges are positioned on the vertices of an equilateral triangle as shown.



9. What is the direction of the electric field at the origin, **P**?

a. Along the positive *y*-axis.
b. Along the negative *y*-axis.

$\vec{E}_1$ & $\vec{E}_2$ cancel
$\vec{E}_3$ points toward − charge

10. What is the magnitude of the electric field E at the origin, **P**?

a. $E = 1.35\times10^{7}$ N/C
b. $E = 5.39\times10^{8}$ N/C
c. $E = 1.50\times10^{8}$ N/C
d. $E = 1.12\times10^{8}$ N/C
e. $E = 7.01\times10^{8}$ N/C

$\vec{E}_{tot} = \vec{E}_3$

$\Rightarrow |\vec{E}_{tot}| = \frac{k|q_3|}{r_3^2} = \frac{9\times10^9 \cdot (+5\times10^{-6})}{((\sqrt{3})\times10^{-2}\,m)^2}$

$r_3 = \sqrt{3}$ cm

$= \frac{9(5)\times10^{+3}}{3\cdot10^{-4}}$
$= 15\times10^{7}$ N/C
$= 1.5\times10^{8}$ N/C