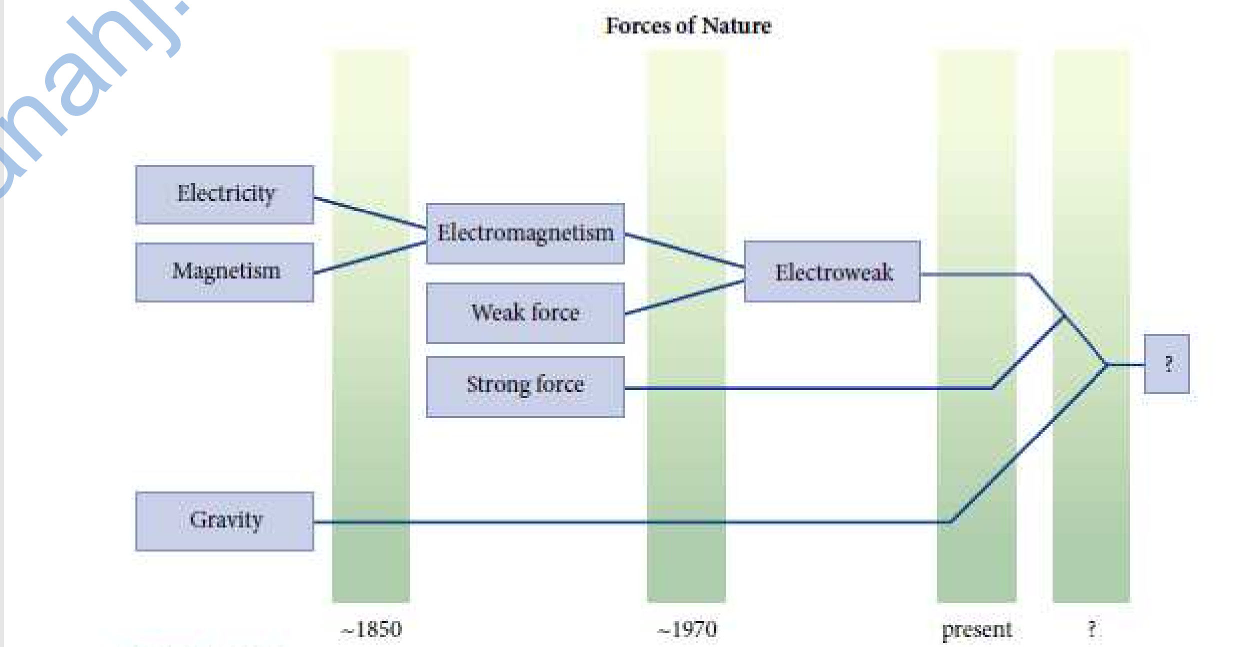
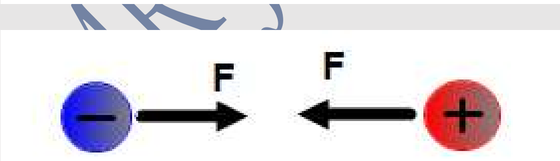


FIGURE 21.3 The history of the unification of fundamental forces.

law of electric charges

Like charges repel and opposite charges attract.



The unit of electric charge is the coulomb (C), 1 C=1 A s.

Elementary charge: ($e = 1.602176487 \cdot 10^{-19}$ C.)

Electric charge occurs only in integral multiples of a minimum size. This is expressed by saying that charge is **quantized**

$q_e = -e$ **$q_p = +e$.**

1.1 in-class exercise

How many electrons does it take to make 1.00 C of charge?

a) $1.60 \cdot 10^{19}$

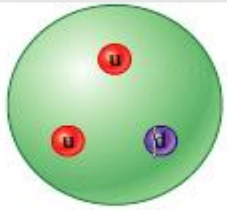
b) $6.60 \cdot 10^{19}$

c) $3.20 \cdot 10^{16}$

d) $6.24 \cdot 10^{18}$

e) $6.66 \cdot 10^{17}$

A proton is composed of two *up quarks* (each with charge + 2/3 *e*) and one *down quark*

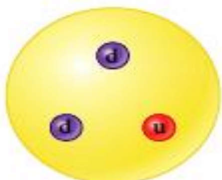


Proton

$q_p = +\frac{2}{3}e + \frac{2}{3}e - \frac{1}{3}e = +e$

(a)

The electrically neutral neutron (hence the name!) is composed of an up quark and two down quarks,



Neutron

$q_n = +\frac{2}{3}e - \frac{1}{3}e - \frac{1}{3}e = 0$

(b)

the charge, q, of any object can be expressed in terms of the sum of the number of protons, Np, minus the sum of the number of electrons, Ne, that make up the object:

$q = e \cdot (N_p - N_e)$.

1.1 Self-test opportunity page:6

Give the charge of the following elementary particles or atoms in terms of the elementary charge

e = 1.602 · 10–19 C.

a) Proton b) neutron

c) Helium atom (two protons, two neutron, and two electrons

d) Hydrogen atom (one proton and one electron):

e) Up quark f) down quark g) electron

h) Alpha particle (two protons and two neutrons)

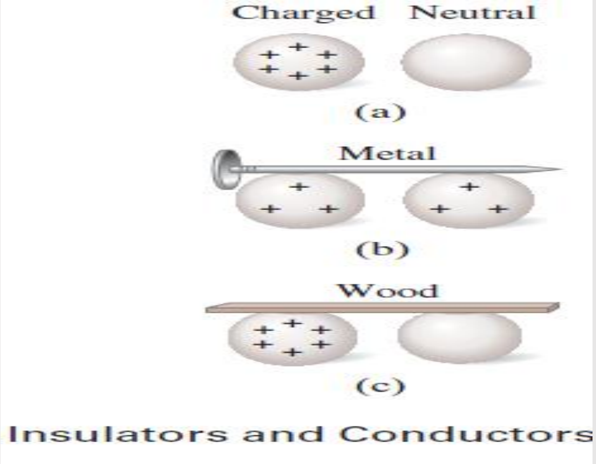
1.3 insulators, conductors, Semiconductors, and Superconductors

Materials that allow charges to move about easily are called __________.

A) Conductors B) Insulators C) Facilitators D) Plastics

Materials through which electrical charges will not move easily are called __________.

A) Ions B) Conductors C) Grounders D) Insulators



Transferring Charges

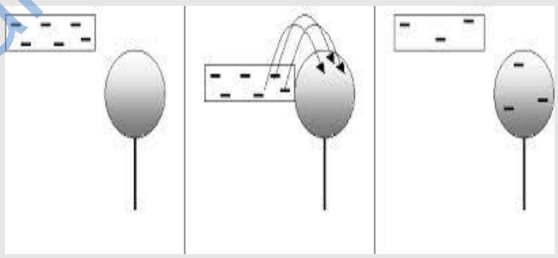
Three ways electric charge can be transferred are by:

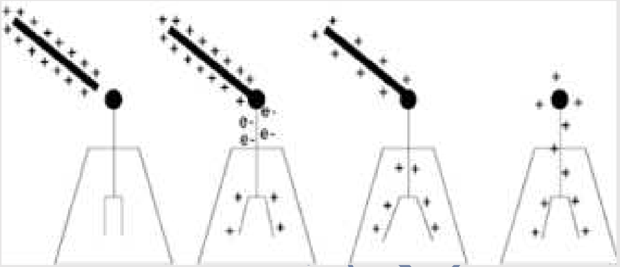
1. Friction (RUBDING)

2. Conduction (Contact)

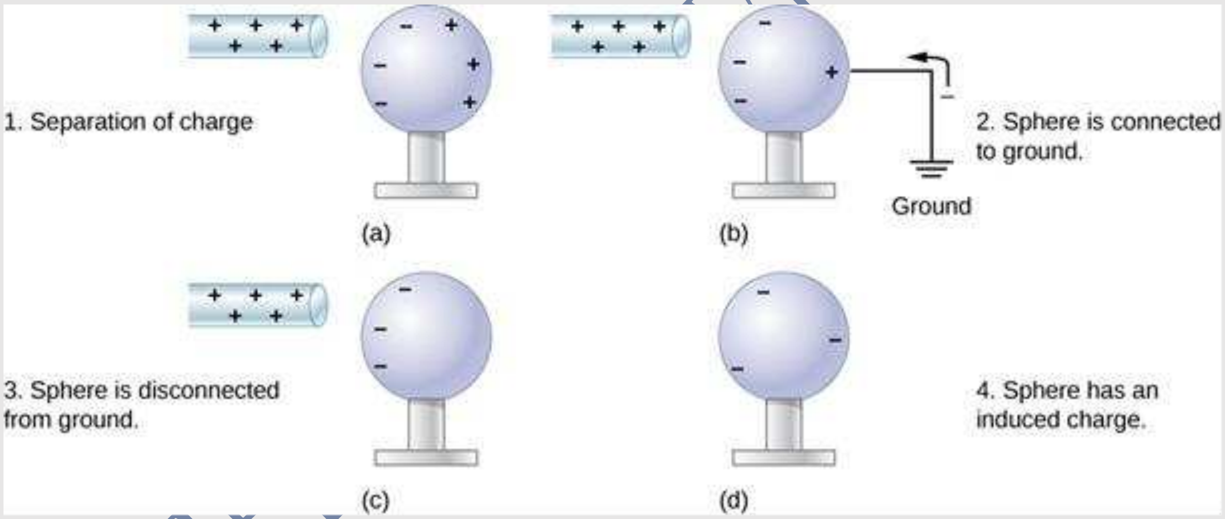
3. Induction

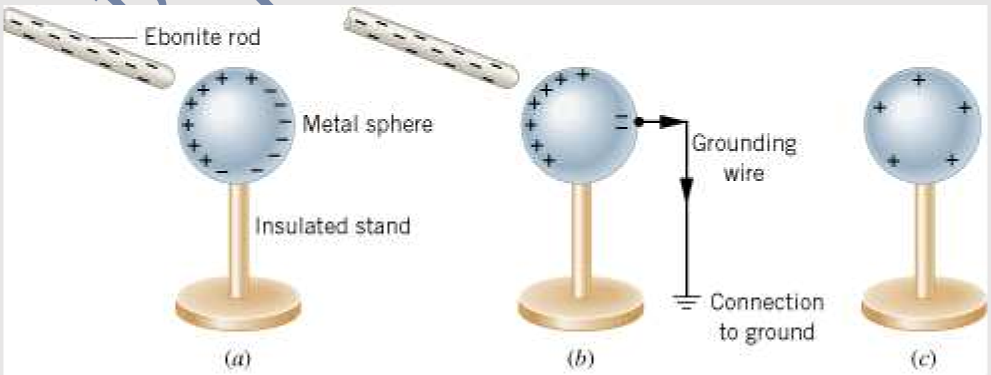
CHARGING BY CONDUCTION(CONTACT)





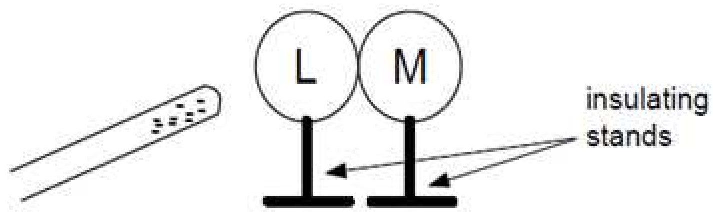
charging by induction.





.Two uncharged metal spheres, L and M, are in contact. A negatively charged rod is brought close to L, but not touching it, as shown. The two spheres are slightly separated and the rod is then withdrawn. As a result:

A) both spheres are neutral.
B) both spheres are positive.
C) both spheres are negative.
D) L is negative and M is positive.
E) L is positive and M is negative.



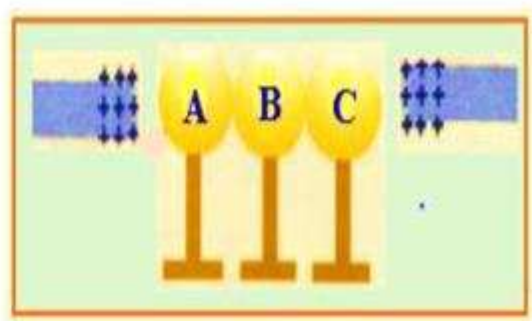
Q6: In the adjacent shape: The two conductors are quite identical. The balls are conductive and electrically neutral.

If ball B is removed, what kind of charge is each ball?

Charge of ball (A)------------

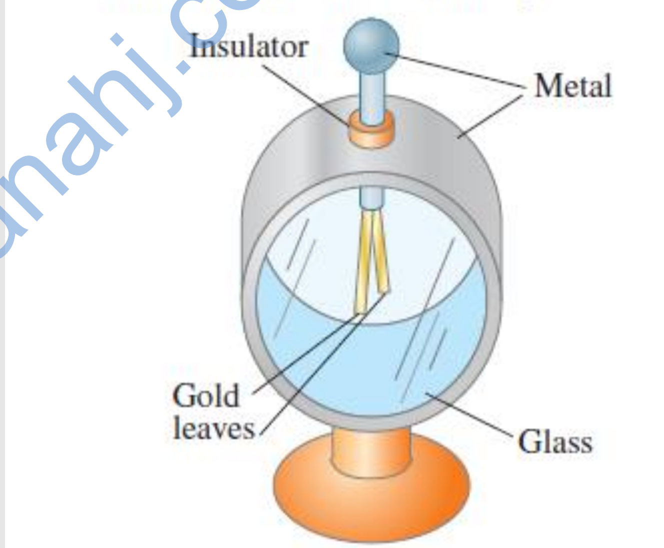
Charge of ball (B)-----------

Charge of ball (C)-------------



An **electroscope** is a device that can be used for detecting charge. As shown in Fig. 16–10, inside a case are two movable metal leaves, often made of gold foil, connected to a metal knob on the outside. (Sometimes only one leaf is movable.)

FIGURE 16–10 Electroscope.

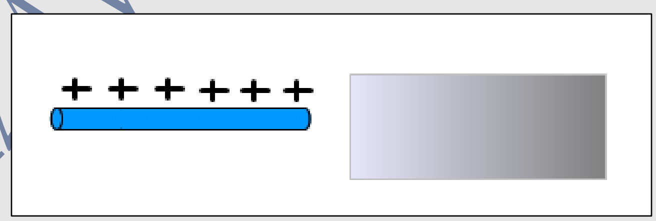


5. A positively charged rod is brought close to one end of a neutral metallic plate. What type of charge is induced on the closest side of the plate?

A. Positive

B. Negative

C. Neutral

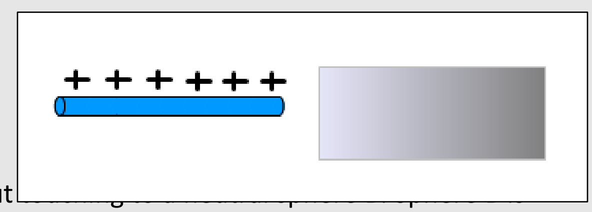


A positively charged rod is brought close to one end of a neutral metallic plate. What type of charge is induced on the farthest side of the plate?

A. Positive

B. Negative

C. Neutral



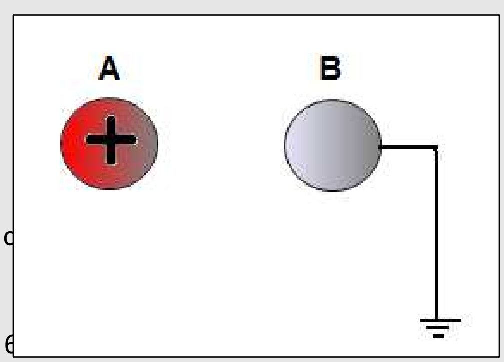
A positively charged sphere A is brought close without

touched with a grounded wire. What is the charge on sphere B after the wire is removed?

A. Positive

B. Negative

C. It stays neutral



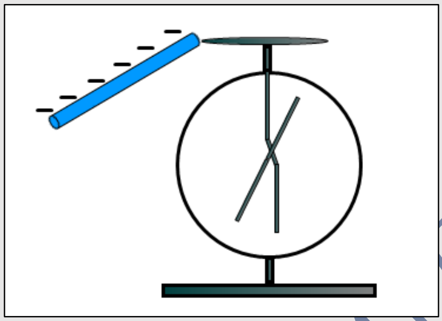
A neutral electroscope is touched with a negatively c

What is the charge on the electroscope after the rod is removed?

A. Positive

B. Negative

C. It stays neutral



A neutral electroscope is touched with a positively carged rod.

After the rod is removed the electroscope is charged positively

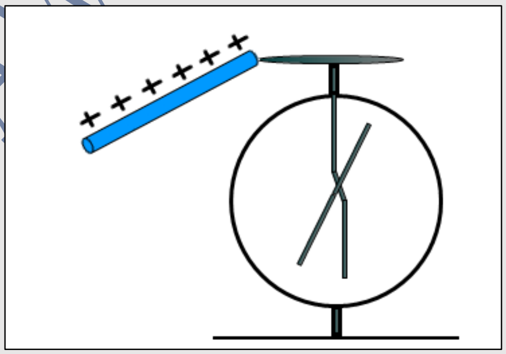
because of:

A. Induction

B. Conduction

C. Thermoemission

D. Photoemission



A negatively charged rod is brought near an uncharged, grounded

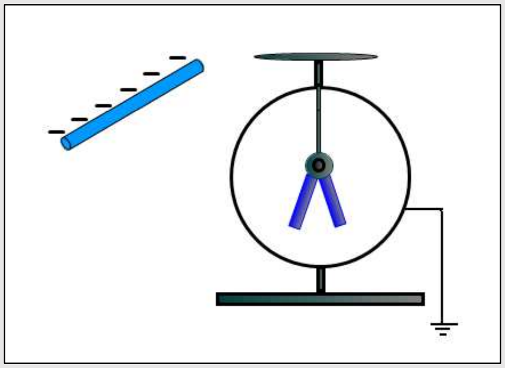
electroscope. Which of the following statements is true?

A. The positive charge flows from the electroscope to the ground

B. The positive charge flows from the ground to the electroscope

C. The negative charge flows from the electroscope to the ground

D. The negative charge flows from the ground to the electroscope



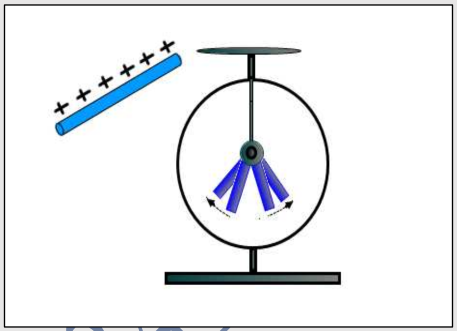
A positively charged rod is brought near a charged electroscope. As a result of doing this, the electroscope leaves move further apart. What is the charge on the electroscope?

A. Positive

B. Negative

C. It is neutral

D. It depends on the distance between the electroscope and the rod

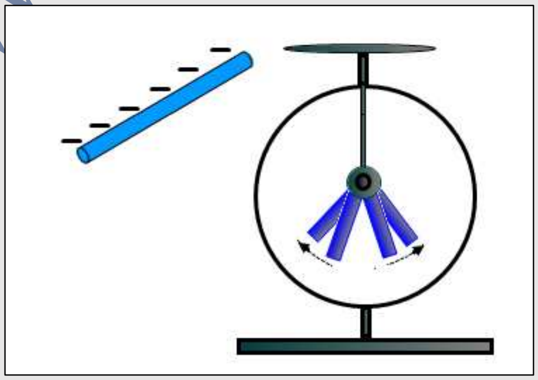


A negatively charged rod is brought near a charged electroscope. As a result of doing this, the electroscope leaves move further apart. What is the charge on the electroscope?

A. Positive

B. Negative

C. It is neutral

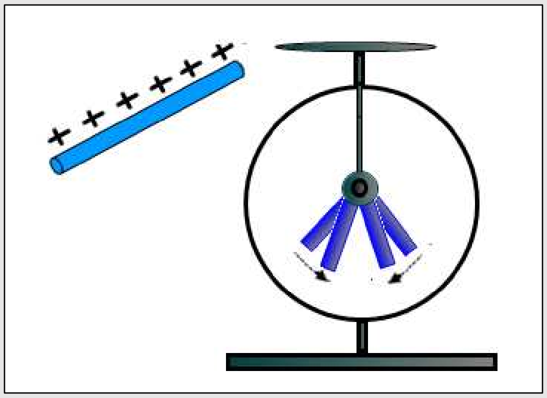


A positively charged rod is brought near a charged electroscope. As a result of doing this, the electroscope leaves move closer to each other. What is the charge on the electroscope?

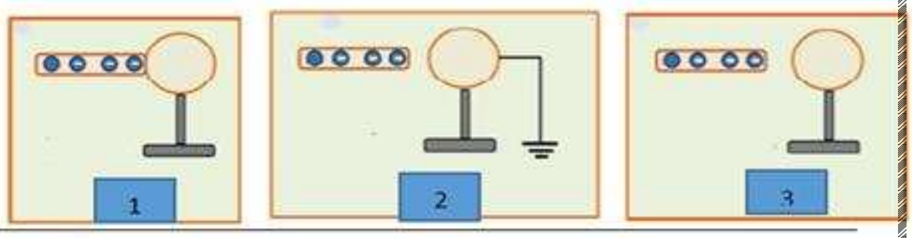
A. Positive

B. Negative

C. It is neutral



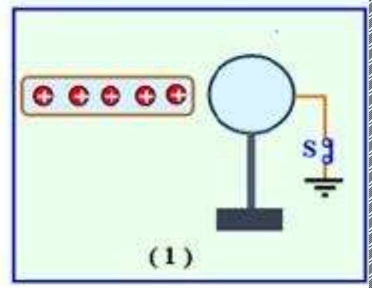
Q1: **The metal ball is insulated not charged and the aponite leg is charged with a negative charge. Identify on the card the distribution of the charge in each form**



Q2: **In the adjacent shape. After opening the key (S)**

And remove the glass leg away from the ball –

what kind of charge on the ball......?



9

is a device used for detecting electrical charges.

A) Electroscope B) conducting sphere C) oscilloscope D) cathode-ray tube

Friction (RUBDING)

A plastic rod is rubbed with a piece of animal fur. The plastic rod acquires a negative charge during this process. Which of the following is true about the charge on the piece of fur?

A. It acquires a positive charge but greater in magnitude than the rod

B. It acquires a positive charge but less in magnitude than the rod

C. It acquires a negative charge but greater in magnitude than the rod

D. It acquires a negative charge but less in magnitude than the rod

E. It acquires a positive charge with the same magnitude as the rod

1.11 when a rubber rod is rubbed with rabbit fur,the rod becomes

a) Negatively charged b) positively charged c) neutral

1. When a glass rod is rubbed with a polyester scarf ,the rod becomes

a) Negatively charged b) positively charged c) neutral

1.5 Electrostatic Force—Coulomb's Law

- The total charge in an isolated system is always conserved.
- Objects can be charged directly by contact or indirectly by induction.
- Coulomb's Law describes the force that two stationary charges exert on each other: $F = k\frac{|q_1 q_2|}{r^2} = \frac{1}{4\pi\epsilon_0}\frac{|q_1 q_2|}{r^2}$.
- The constant in Coulomb's Law is $k = \frac{1}{4\pi\epsilon_0} = 8.99 \cdot 10^9 \frac{\text{N m}^2}{\text{C}^2}$.
- The electric permittivity of free space is $\epsilon_0 = 8.85 \cdot 10^{-12} \frac{\text{C}^2}{\text{N m}^2}$.

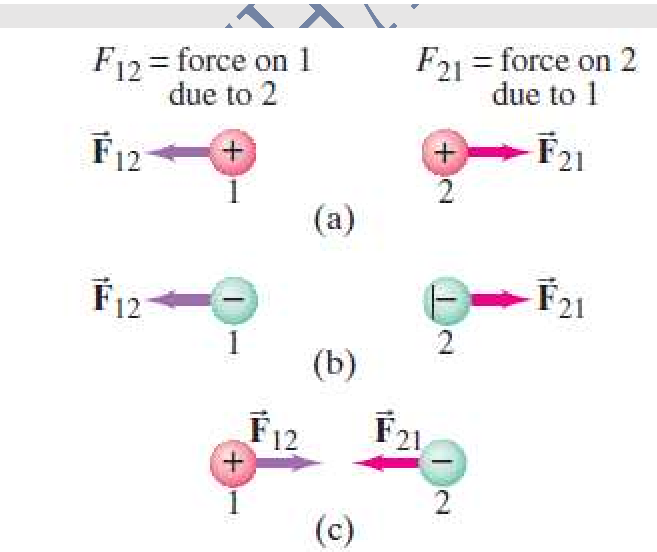
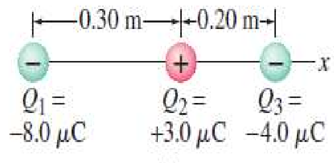


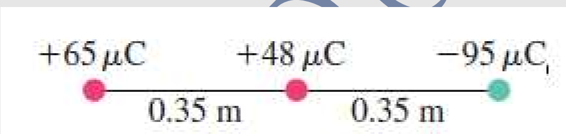
FIGURE 16–15 The direction of the static electric force one point charge exerts on another is always along the line joining the two charges, and depends on whether the charges have the same sign as in (a) and (b), or opposite signs (c).

EXAMPLE 16–3 **Three charges in a line.** Three charged particles are arranged in a line, as shown in Fig. 16–19a. Calculate the net electrostatic force on particle 3 (the $-4.0\ \mu C$ on the right) due to the other two charges.

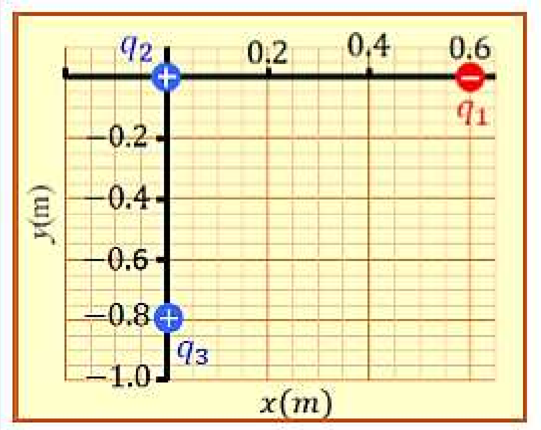


(a)

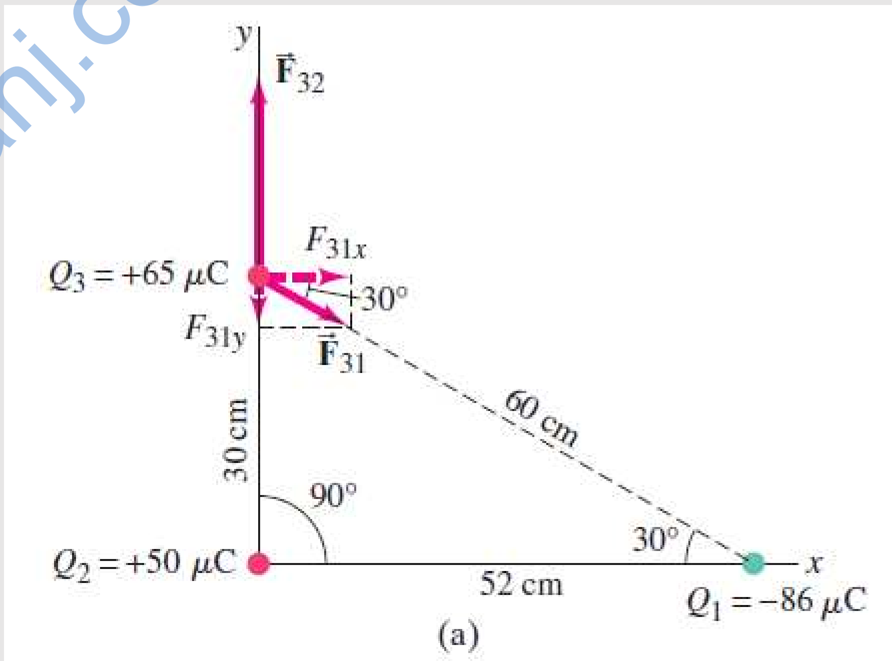
Particles of charge and are placed in a line (Fig. 16–52). The center one is 0.35 m from each of the others. Calculate the net force on the48µc charge due to the other two.

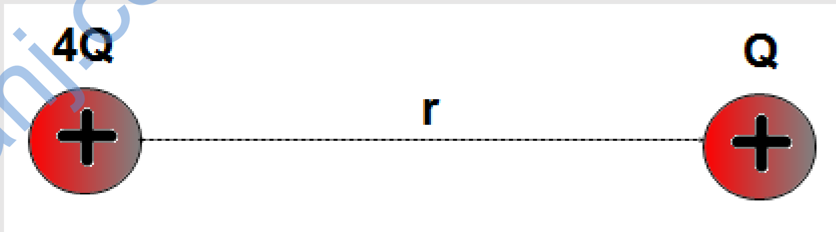


Calculate the amount of electrostatic force acting on the second charge(q2), and determine its direction (q1= -4×10 – 8 C) ,(q2=8×10 - 8 C) ,(q3=6×10 - 8 C) .



Electric force using vector components. Calculate the net electrostatic force on chargeQ3





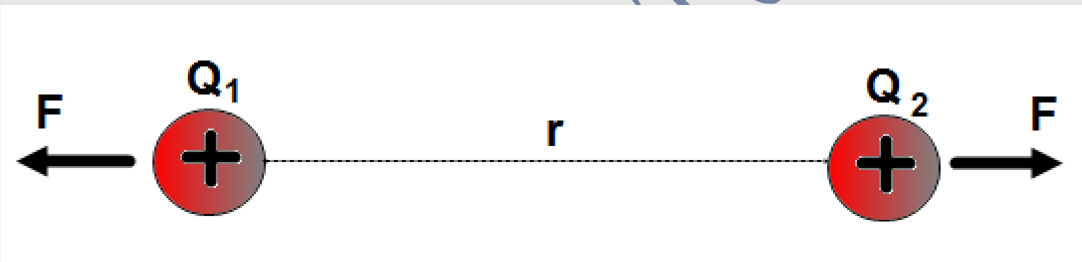
Two positive charges with magnitudes 4Q and Q are separated by a distance r. Which of the following statements is true?

A. The charge with a greater magnitude exerts a larger force on the small charge

B. The charge with a greater magnitude exerts a smaller force on the small charge

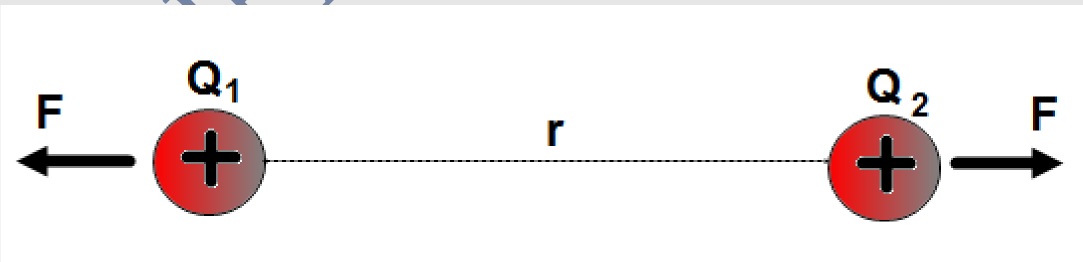
C. The forces on each charge are the same in magnitude and opposite in direction

D. The forces on each charge are the same in magnitude and pointing in the same direction



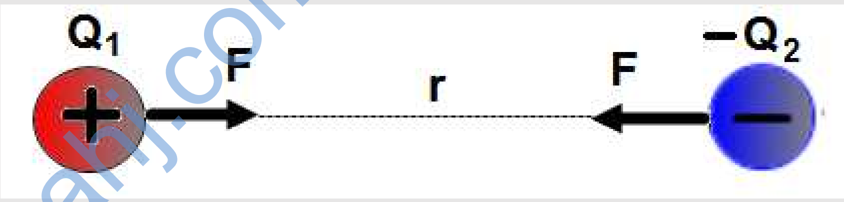
Two positive charges Q1 and Q2 are separated by a distance r. The charges repel each other with a force F. If the magnitude of each charge is doubled and the distance stays unchanged what is the new force between the charges?

A. F B. 2 F C. 4 F D. 1/4 F E. 1/2 F



Two positive charges Q1 and Q2 are separated by a distance r. The charges repel each other with a force F. If the distance between the charges is cut to one-fourth what is the new force acting on each charge?

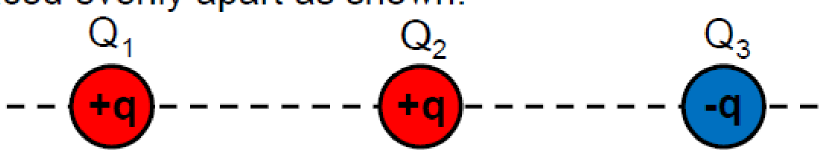
A. 16 F B. 2 F C. 4 F D. 1/4 F E. 1/2 F



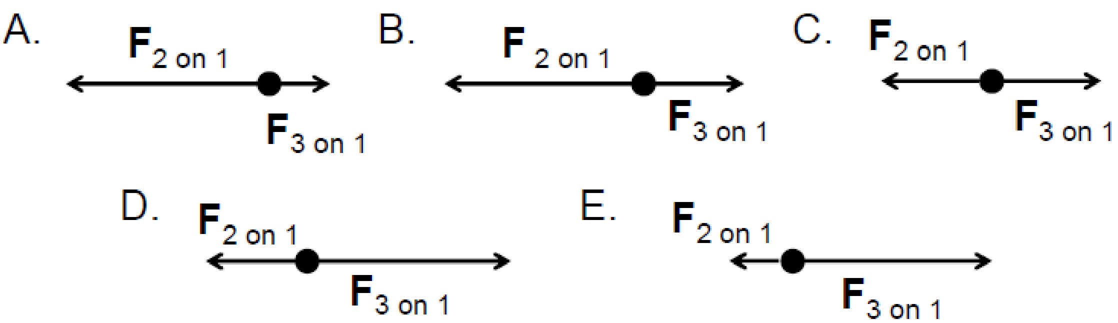
Two charges Q1 and –Q2 are separated by a distance r. The charges attract each other with a force F. What is the new force between the charges if the distance is tripled?

A. 16 F B. 2 F C. 4 F D. 1/4 F E. 1/9 F

Three charges with equal magnitudes are arranged horizontally and spaced evenly apart as shown:

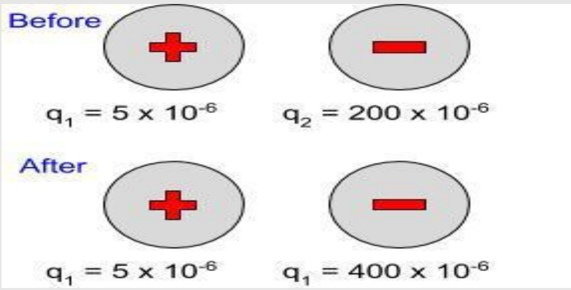


Which of the following free-body diagrams best represents the electric forces acting on Q_1?

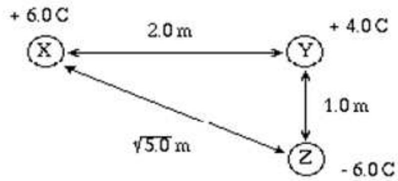


The image shows two charged particles with a force of 2.4 N. What would you predict the force of interaction would be when the magnitude of charge on q2 doubles?

9.6 N 4.8 N 1.2 N 6 N



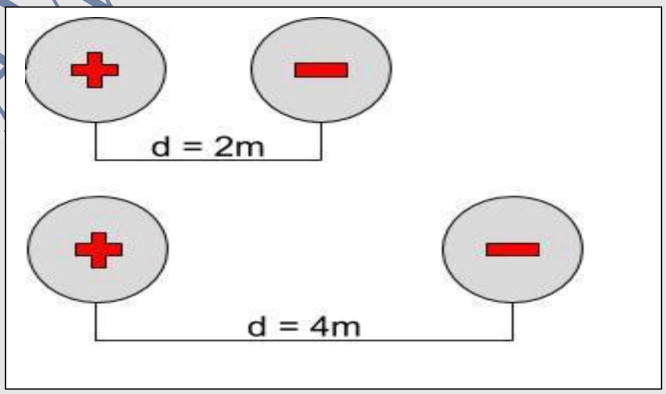
21. The magnitude of the force acting on Y due to X and Z is:



a. 7.6×10^{11} N b. 2.2×10^{11} N c. 3.2×10^{10} N d. 2.7×10^{10} N

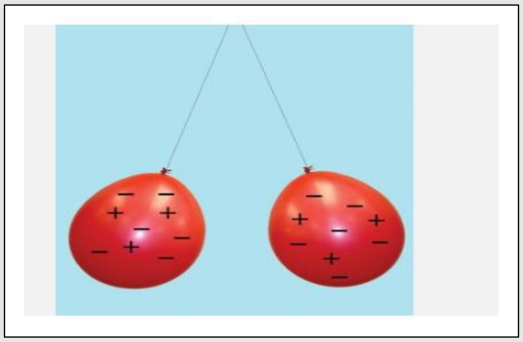
The image shows two charged particles with a force of 2.4 N. What would you predict the force of interaction would be when the distance doubles?

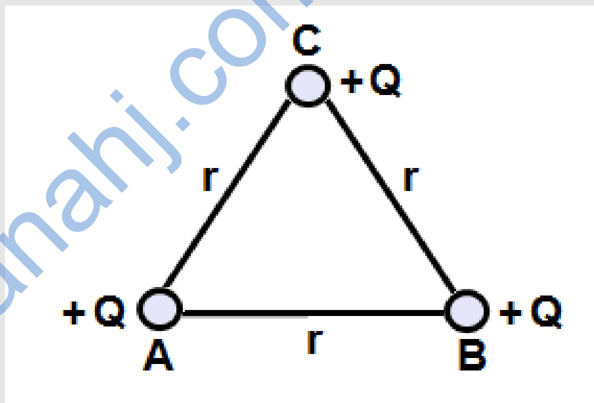
4.8 N 1.2 N 6 N .3 N



What is the overall charge on this balloon? (They are the same so look at either one!)

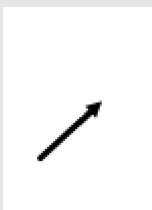
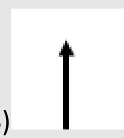
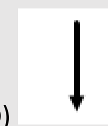
+3e -6e +6e -3e





Three positive charges with an equal charge of Q are located at the corners of an equilateral triangle of side r.

1. What is the direction of the net force on charge C due to charges A and B?

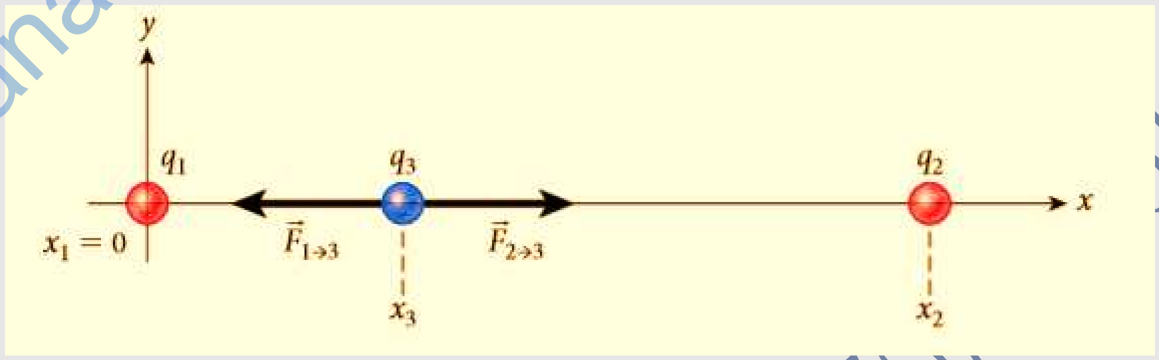
(A)  (B)  (C)  (D) 

1. Two isolated charges, + 2q and -5q, are 2 centimeters apart. If F is the magnitude of the force acting on charge -5Q, what are the magnitude and direction of the force acting on charge + 2q ?

	Magnitude	Direction
(A)	(1/2) F	Toward charge -5q
(B)	2 F	Away from charge -5q
(C)	F	Toward charge -5q
(D)	F	Away from charge -5q

Equilibrium Position

Two charged particles are placed as shown in Figure (q_1 = 4.0 μC) is located at the origin, and (q_2 = 9.0 μC) is located on the positive x-axis at (x_2 = 0.40 m). Where should a third charged particle, (q_3), be placed to be at an equilibrium point (the forces on it sum to zero)?



A positive charge $q1$ = 1.00 μC is fixed at the origin, and a second charge $q2$ = –2.00 μC is fixed at x = 10.0 cm. Where along the x-axis should a third charge be positioned so that it experiences no force?

MULTIPLE-CHOICE QUESTIONS

21.1 When a metal plate is given a positive charge, which of the following is taking place?

a) Protons (positive charges) are transferred to the plate from another object.

b) Electrons (negative charges) are transferred from the plate to another object.

c) Electrons (negative charges) are transferred from the plate to another object, and protons (positive charges) are also transferred to the plate from another object.

d) It depends on whether the object conveying the charge is a conductor or an insulator.

21.2 The force between a charge of 25 μC and a charge of -10 μC is 8.0 N. What is the separation between the two charges?

a) 0.28 m
b) 0.53 m
c) 0.45 m
d) 0.15 m

21.3 A charge Q_1 is positioned on the x-axis at $x = a$. Where should a charge $Q_2 = -4Q_1$ be placed to produce a net electrostatic force of zero on a third charge, $Q_3 = Q_1$, located at the origin?

a) at the origin
b) at $x = 2a$
c) at $x = -2a$
d) at $x = -a$

21.4 Which one of these systems has the most negative charge?

a) 2 electrons
b) 3 electrons and 1 proton
c) 5 electrons and 5 protons
d) N electrons and $N - 3$ protons
e) 1 electron

21.5 Two point charges are fixed on the x-axis: $q_1 = 6.0$ μC is located at the origin, O, with $x_1 = 0.0$ cm, and $q_2 = -3.0$ μC is located at point A, with $x_2 = 8.0$ cm. Where should a third charge, q_3, be placed on the x-axis so that the total electrostatic force acting on it is zero?

a) 19 cm
b) 27 cm
c) 0.0 cm
d) 8.0 cm
e) -19 cm

21.6 Which of the following situations produces the largest net force on the charge Q?

a) Charge $Q = 1$ C is 1 m from a charge of -2 C.

b) Charge $Q = 1$ C is 0.5 m from a charge of -1 C.

c) Charge $Q = 1$ C is halfway between a charge of -1 C and a charge of 1 C that are 2 m apart.

d) Charge $Q = 1$ C is halfway between two charges of -2 C that are 2 m apart.

e) Charge $Q = 1$ C is a distance of 2 m from a charge of -4 C.

21.7 Two protons placed near one another with no other objects close by would

a) accelerate away from each other.

b) remain motionless.

c) accelerate toward each other.

d) be pulled together at constant speed.

e) move away from each other at constant speed.

21.8 Two lightweight metal spheres are suspended near each other from insulating threads. One sphere has a net charge; the other sphere has no net charge. The spheres will

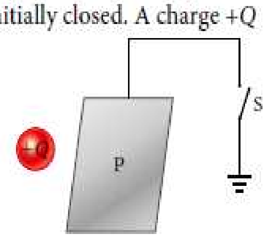
a) attract each other.

b) exert no net electrostatic force on each other.

c) repel each other.

d) do any of these things depending on the sign of the charge on the one sphere.

21.9 A metal plate is connected by a conductor to a ground through a switch. The switch is initially closed. A charge $+Q$ is brought close to the plate without touching it, and then the switch is opened. After the switch is opened, the charge $+Q$ is removed. What is the charge on the plate then?



a) The plate is uncharged.

b) The plate is positively charged.

c) The plate is negatively charged.

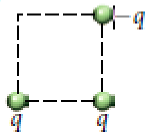
d) The plate could be either positively or negatively charged, depending on the charge it had before $+Q$ was brought near.

21.10 You bring a negatively charged rubber rod close to a grounded conductor without touching it. Then you disconnect the ground. What is the sign of the charge on the conductor after you remove the charged rod?

a) negative
b) positive
c) no charge
d) cannot be determined from the given information

21.9 In-Class Exercise

Three charges are arranged at the corners of a square as shown in the figure. What is the direction of the electrostatic force on the *lower-right* charge?

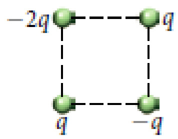


a) ↙ b) ↖ c) ↗ d) ↘

e) no force

21.10 In-Class Exercise

Four charges are arranged at the corners of a square as shown in the figure. What is the direction of the electrostatic force on the *lower-right* charge?



a) ↙ b) ↖ c) ↗ d) ↘

e) no force

21.2 Self-Test Opportunity

A positive point charge $+q$ is placed at point P, to the right of two charges q_1 and q_2, as shown in the figure. The net electrostatic force on the positive charge $+q$ is found to be zero. Identify each of the following statements as true or false.

a) Charge q_2 must have the opposite sign from q_1 and be smaller in magnitude.

b) The magnitude of charge q_1 must be smaller than the magnitude of charge q_2.

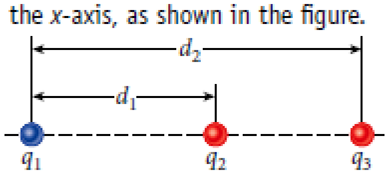
c) Charges q_1 and q_2 must have the same sign.

d) If q_1 is negative, then q_2 must be positive.

e) Either q_1 or q_2 must be positive.

21.8 In-Class Exercise

Consider three charges placed along the x-axis, as shown in the figure.



The values of the charges are $q_1 = -8.10\ \mu C$, $q_2 = 2.16\ \mu C$, and $q_3 = 2.16$ pC. The distance between q_1 and q_2 is $d_1 = 1.71$ m. The distance between q_1 and q_3 is $d_2 = 2.62$ m. What is the magnitude of the total electrostatic force exerted on q_3 by q_1 and q_2?

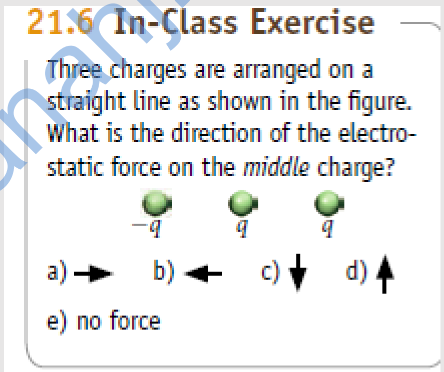
a) $2.77 \cdot 10^{-8}$ N

b) $7.92 \cdot 10^{-6}$ N

c) $1.44 \cdot 10^{-5}$ N

d) $2.22 \cdot 10^{-4}$ N

e) $6.71 \cdot 10^{-2}$ N

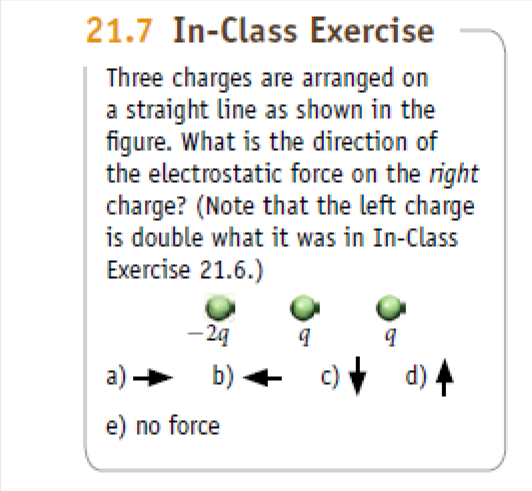


21.6 In-Class Exercise

Three charges are arranged on a straight line as shown in the figure. What is the direction of the electrostatic force on the *middle* charge?

a) → b) ← c) ↓ d) ↑

e) no force



21.7 In-Class Exercise

Three charges are arranged on a straight line as shown in the figure. What is the direction of the electrostatic force on the *right* charge? (Note that the left charge is double what it was in In-Class Exercise 21.6.)

a) → b) ← c) ↓ d) ↑

e) no force

What do the forces acting on the charge q3 in Figure indicate about the signs of the three charges?

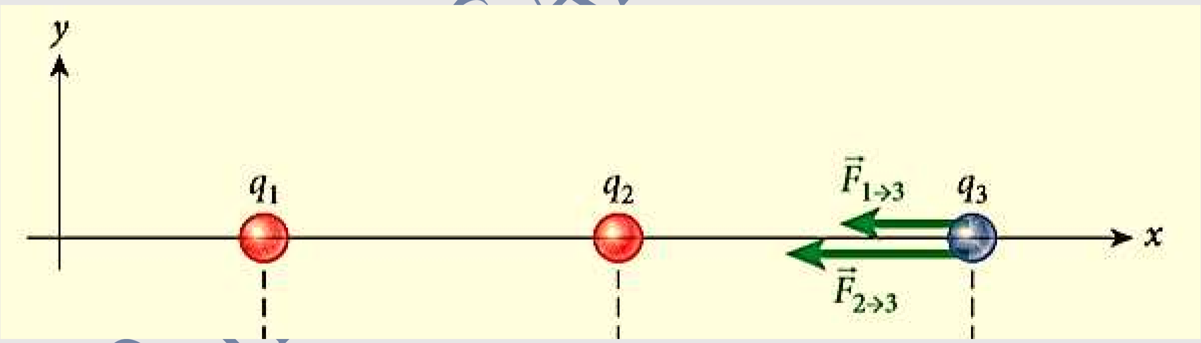
a) All three charges must be positive.

b) All three charges must be negative.

c) Charge q3 must be zero.

d) Charges q1 and q2 must have opposite signs.

e) Charges q1 and q2 must have the same sign, and q3 must have the opposite sign.



Assuming that the lengths of the vectors in Figure are proportional to the magnitudes of the forces they represent, what do they indicate about the magnitudes of the charges q1 and q2? (Hint: The distance between x1 and x2 is the same as the distance between x2 and x3.)

a) q 1 < q2

b) q1=q2

c) q 1 >q2

d) The answer cannot be determined from the information given in the figure