

2022 - 2023

# Electrostatics



**Grade: 12 A**

**2022-2023 Trimester 1**

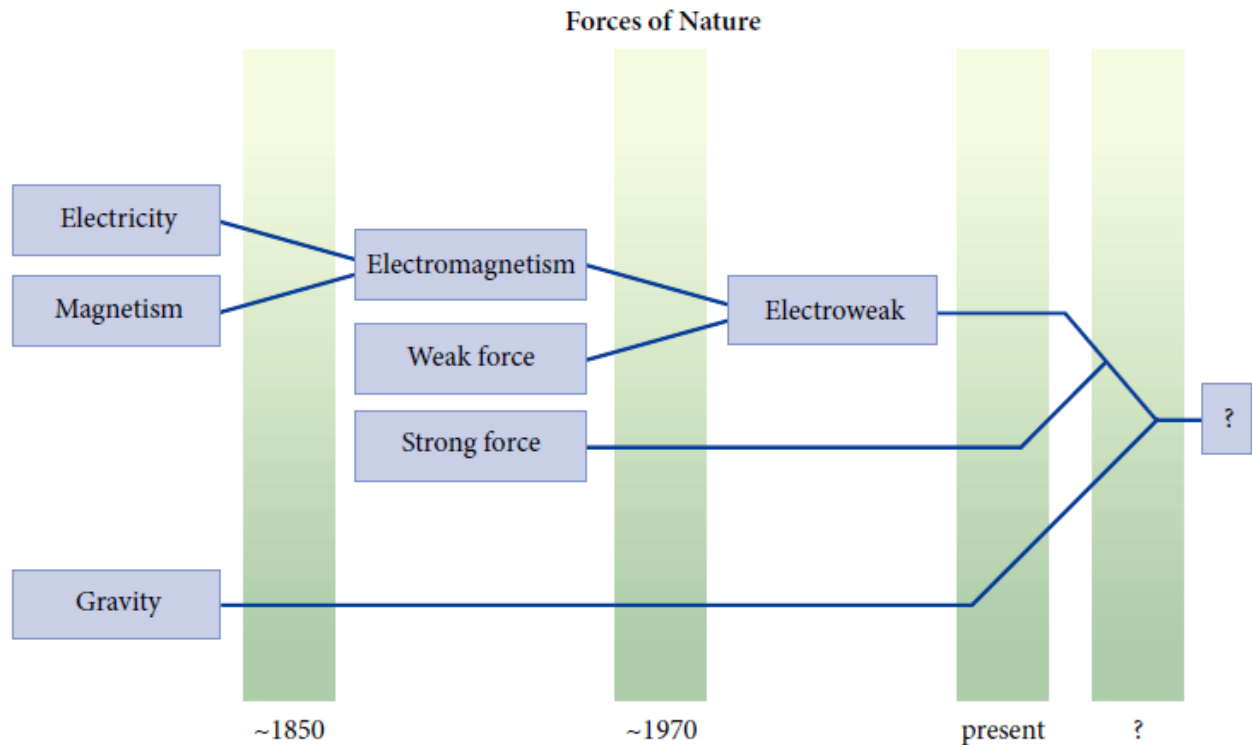
Name: \_\_\_\_\_

Class: \_\_\_\_\_

Dr. Ahmed Alkobrahy

2022 - 2023

## 1.1 Electromagnetism



### Basic forces in nature:

1. **Electric Force** : arises between electric charges, magnetic force (arises between magnetic poles)
2. **Weak force**: works during the decay of a beta in which an electron and a neutrino ( $\beta$ ) are automatically emitted from some nuclei
- 3 - **strong force**: located inside the nucleus of the atom
4. **Gravitational force** : (arises between physical objects)

The effects of static electricity are observed in:

**Electrostatic**: The study of electrical charges that are collected and held somewhere

The effects of static electricity are observed in:

- 1- Lightning
- 2- Attract hair to the comb when combing on a dry day
- 3- Attract the paper scraps to the plastic ruler when kneading the ruler with a piece of wool .
- 4- Attract adhesive tape when the paste and then remove from the surface of the table.
- 5- repulsion of adhesive tape when the paste and then removed from the table surface with another adhesive tape was pasted and then removed from the table surface as well

## 1.2 Electric Charge

**Electric charge:** A physical property of a material that appears only when an electrical equalization occurs.

**The law of electric charges:** similar charges repel each other and different charges attract

### Notes:

- 1- Charging mechanism: transport of negatively charged particles (electrons) from atoms. material and its molecules into atoms of another material.
2. If the material loses electrons, its charge becomes positive.
3. If the material acquires electrons, its charge becomes negative.
4. The susceptibility of materials to loss or gain of electrons varies depending on how electrons are bound to the nucleus.

The unit of electric charge is Coulomb (C) and is equivalent in the International System of Units (A.s),  $1 \text{ s } 1 \text{ C} = 1 \text{ A}$ .

**Conservation Law of charge:** The total amount of electrical charge in a closed system does not change (Electric charge can neither be created nor destroyed. In a closed system).

### Millikan experiment (Oil Drop experiment)

This experiment proved that: charge is **quantized**. The charge of an object  $q$  is equal to a multiple of the basic charge  $e = 1.602 \times 10^{-19} \text{ C}$  (electron charge). The basic charge is constant, indivisible and equal to the amount of the electron charge.

$$e = q_e = 1.6 \times 10^{-19} \text{ C}$$

$$q = N\Delta e \quad e \quad q = (Np - Ne) \quad e \quad N\Delta e = |q|e$$

**Q: We do not notice that charge is quantized. Explain**

because most electrical phenomena involve huge numbers of electrons.

### Atom

- An atom consists of a nucleus containing protons (+) and neutrons ( $\pm$ ) surrounded by electrons (-)
- The mass of an electron is much smaller than of a neutron and a proton (most of the atom's mass is concentrated in the nucleus)

- Electrons can be relatively easily removed from atoms (electrons are carriers of electricity, not protons.)
- The electron is an elementary point particle that has no radius

## The proton

Consists of -:

2 up quarks ( $+\frac{2}{3}e$ )

1 Down quark  $(-\frac{1}{3}e)$

## Neutron

Consists of: -

1 up quark  $(+\frac{2}{3}e)$

2 down quarks  $(-\frac{1}{3}e)$

- In addition to uncharged particles that bind quarks called gluons
- There are also electron-like particles called muon  $\mu$  and tau  $\tau$
- proton has a positive charge with a magnitude and its numbers that is *exactly* equal to the magnitude and numbers of the negative charge of an electron.

## Multiple-Choice Questions

- How many electrons are needed to produce a charge of 1.00 C?  
6.60X10<sup>19</sup>                      1.60X10<sup>19</sup>  
6.24X10<sup>18</sup>                      3.20X10<sup>16</sup>  
6.66X10<sup>17</sup>
- How many electrons are transferred from a positively charged electrode if its net charge is 7.5X10<sup>-11</sup> C?  
2.1X10<sup>-9</sup> electron                      7.5X10<sup>-11</sup> electron  
4.7X10<sup>8</sup> electron                      1.2X10<sup>8</sup> electron
- What is the charge of an electroscope if it has 4.8X10<sup>10</sup> excess electrons?  
4.8X10<sup>-10</sup> C                      3.3X10<sup>-30</sup> C  
4.8X10<sup>10</sup> C                      7.7X10<sup>-9</sup> C
- Which of the following represents the elementary charge?  
Charge of one proton                      Charge of 1.6 electron  
1.6X10<sup>+19</sup> C                      1.0X10<sup>-6</sup> C

5. Which of the following is equivalent to the coulomb ( C )?

A.S <sup>-1</sup>	A.S
S.A <sup>-1</sup>	A.S <sup>-2</sup>
6. A charge (+2 C) equals a charge:

1.25X10 <sup>19</sup> electron	1.25X10 <sup>19</sup> proton
2 electrons	2 protons
7. Which of the following cannot be a quantity of an object's charge in coulombs?

3.2X10 <sup>-19</sup>	3.2X10 <sup>-20</sup>
- 3.2X10 <sup>-19</sup>	3.2X10 <sup>-18</sup>
8. How many electrons have been removed from a positively charged electroscope if it has a net charge of 3x10<sup>-11</sup> C?

3.8x10 <sup>8</sup> electrons	2.1x10 <sup>9</sup> electrons
1.9x10 <sup>8</sup> electrons	4.7x10 <sup>8</sup> electron
9. How many electrons have been removed from a positively charged electroscope if it has a net charge of 6x10<sup>-11</sup> C?

3.8x10 <sup>8</sup> electrons	2.1x10 <sup>9</sup> electrons
1.2x10 <sup>8</sup> electrons	4.7x10 <sup>8</sup> electrons
10. How many electrons does it take to make 3x10<sup>-6</sup> C of charge?

5.3x10 <sup>-14</sup> e	4.8x10 <sup>-25</sup> e
1.9X10 <sup>13</sup> e	1.6x10 <sup>-19</sup> e
11. Which one of these systems has the most negative charge?

2 electrons	3 electrons and 1 neutron
5 electrons and 5 protons	1 electron
12. How many electrons have been removed from a positively charged electroscope if it has a net charge of 7.5X10<sup>-11</sup> C?

7.5X10 <sup>-11</sup> electrons	2.1X10 <sup>-9</sup> electrons
1.2X10 <sup>8</sup> electrons	4.7X10 <sup>8</sup> electrons
13. What is the charge on an electroscope that has an excess of 4.8X10<sup>10</sup> electrons?

3.3X10 <sup>-30</sup>	4.8X10 <sup>-10</sup>
7.7X10 <sup>-9</sup>	4.8X10 <sup>10</sup>
14. If an object is negatively charged, then its charge can be:

3 e	-3 e
1.6 e	-1.6 e
15. To charge a neutral body with a positive charge of (48 μC)

Acquire 3X10 <sup>11</sup> electron	Lose 3X10 <sup>11</sup> electron
Acquire 3X10 <sup>14</sup> electron	Lose 3X10 <sup>14</sup> electron



16. The charge that any of the following charges cannot have is:  
 $1 \times 10^{19} \text{ C}$   $1.6 \times 10^{-19} \text{ C}$   
 $8 \times 10^{-19} \text{ C}$   $1 \times 10^{-19} \text{ C}$
17. The number of electrons that must move from or to an object to be charged with a negative charge of  $(8 \text{ pC})$   
 $5 \times 10^7$  electrons move from the object  $5 \times 10^7$  electrons move to the object  
 $8 \times 10^{19}$  electrons move from the object  $8 \times 10^{19}$  electrons move to the object
18. How many electrons does it take to make up  $5.00 \text{ C}$  of charge?  
 $1.08 \times 10^{19}$   $1.17 \times 10^{19}$   
 $2.11 \times 10^{19}$   $3.12 \times 10^{19}$   
 $3.72 \times 10^{19}$
19. What is the total charge on  $3.72 \times 10^{19}$  electrons?  
 $5.00 \text{ C}$   $6.78 \text{ C}$   
 $5.95 \text{ C}$   $0.430 \text{ C}$   
 $2.33 \text{ C}$
20. What is the net charge of 1 mole ( $6.02 \times 10^{23}$ ) of electrons?  
 $-5.48 \times 10^{-7} \text{ C}$   $5.48 \times 10^{-7} \text{ C}$   
 $-9.63 \times 10^4 \text{ C}$   $9.63 \times 10^4 \text{ C}$   
 $-6.02 \times 10^3 \text{ C}$
21. If you wish to lose weight, you may rub a balloon on your head. If you charge the balloon to a charge of  $q = -1.23 \mu\text{C}$ , how much weight did you lose? The mass of an electron is  $9.11 \times 10^{-31} \text{ kg}$ .  
 $7.27 \times 10^{-24} \text{ N}$   $6.87 \times 10^{-17} \text{ N}$   
 $7.54 \times 10^{-16} \text{ N}$   $1.21 \times 10^{-15} \text{ N}$   
 $1.28 \times 10^{-12} \text{ N}$
22. A glass rod is charged to  $+6.4 \text{ nC}$  by triboelectric charging. The number of electrons that have been removed are  
 $10 \times 10^{10}$   $4 \times 10^{10}$   
 $8 \times 10^{11}$   $13 \times 10^{11}$   
 $19 \times 10^{12}$
23. A glass rod is charged by triboelectric charging and  $13 \times 10^{10}$  electrons removed. What is the charge on the rod?  
 $+6.40 \text{ nC}$   $-6.40 \text{ nC}$   
 $+20.8 \text{ nC}$   $-20.8 \text{ nC}$   
 $+8.12 \text{ nC}$   $-8.12 \text{ nC}$

24. What fraction of the electrons would you have to remove from a 10.0 mg sphere of iron ( $Z=26$ ,  $A=56$ ) in order to make its charge 1.00 C?
- 0.224%                      0.482%
- $2.24 \times 10^{-4}$                        $4.82 \times 10^{-4}$
- $4.00 \times 10^{-7}$
25. 0.482% of the electrons are removed from a sphere of iron ( $Z=26$ ,  $A=56$ ), resulting in a net charge of 1.00 C on the sphere. What is the mass of the iron sphere?
- 4.64 mg                      10.0 mg
- 3.19 mg                      3.99 mg
- 6.20 mg
26. 9. 0.482% of the electrons are removed from a 10.0 mg sphere of iron ( $Z=26$ ,  $A=56$ ), resulting in a net charge on the sphere. What is the net charge on the iron sphere?
- 2.2 C                      1.6 C
- 1.0 C                      1.9 C
- 10.0 C
27. 10. How many alpha particles are needed to produce a total charge of  $2.5 \times 10^{-12}$  C? (Hint: Each alpha particle contains two protons.)
- 7.8 Million                       $1.6 \times 10^{-19}$
- 2                      839
- $4.2 \times 10^{13}$

## Exercises

1. How many electrons are needed to produce a charge of  $1.00\text{ C}$ ?  
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2. A current of  $5.00\text{ mA}$  is enough to make your muscles contract. Calculate how many electrons would flow through your skin if you were exposed to such a current for  $10.0\text{ S}$ ?  
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3. Calculate the number of electrons in 1.00 Kg of water?

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4. Explain the following scientific explanation correctly:  
All materials are electrically neutral?

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5. We do not notice that charge is quantized. Explain

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6. If we wanted a block of iron of mass 3.25 kg to acquire a positive charge of 0.100 C,
- Has the iron lost or acquired electrons?
  - What is the number of electrons the iron block lost or acquired?
  - what fraction of the electrons would it have to remove or gain?

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7. A glass rod formed by charging ( $+ 1.92 \times 10^{-9} \text{ C}$ ) after rubbing it with silk
- 1- Is the glass rod lost electrons or acquired?
  - 2- Calculate the number of electrons transmitted?
  - 3- How much is the charge formed on this silk after rubbing?

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8. Explain the following scientific explanation correctly:  
Although an atom contains positive protons and negative electrons, it is electrically neutral (with a zero quantum charge)

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9. Explain the following scientific explanation correctly:  
An object is charged only when it loses or gains electrons

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10. A balloon has a negative charge of ( $-6 \mu\text{C}$ ) How many extra electrons does it hold?

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11. A neutral body has gained 3000 electrons during the process of charging it, how much will the charge of this body become?

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12. A body with a charge of  $(-3.0 \times 10^{-12} \text{ C})$  How many electrons must the body lose or gain to have a charge of  $(+1.8 \times 10^{-12} \text{ C})$  Then determine whether the body is gaining or losing electrons

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13. Calculate how many electrons an object must gain to be charged with a charge of  $(q = -6.4 \times 10^{-6} \text{ C})$

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14. Can an object be charged with a positive charge of  $(q = 5 \times 10^{-19})$ ? Justify your answer with the calculations

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15. What we mean by "Charge is quantized"?

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16. An apple contains trillions of charged particles. Why do not two apples repel each other when they are brought together?

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### 1.3 Insulators, Conductors, Semiconductors, and Superconductors

**Materials are divided into:**

#### 1- Conductive materials:

Allows the movement of the charge through it because it contains an abundance of free charges

(ions or electrons)

- Such as metals, electrolytes, the body of the organism, the earth And highly ionized gases (plasma)

- Charges are distributed on the entire surface of the connector

#### 2- Insulating materials:

Materials that do not allow shipments to move through them because they do not contain an

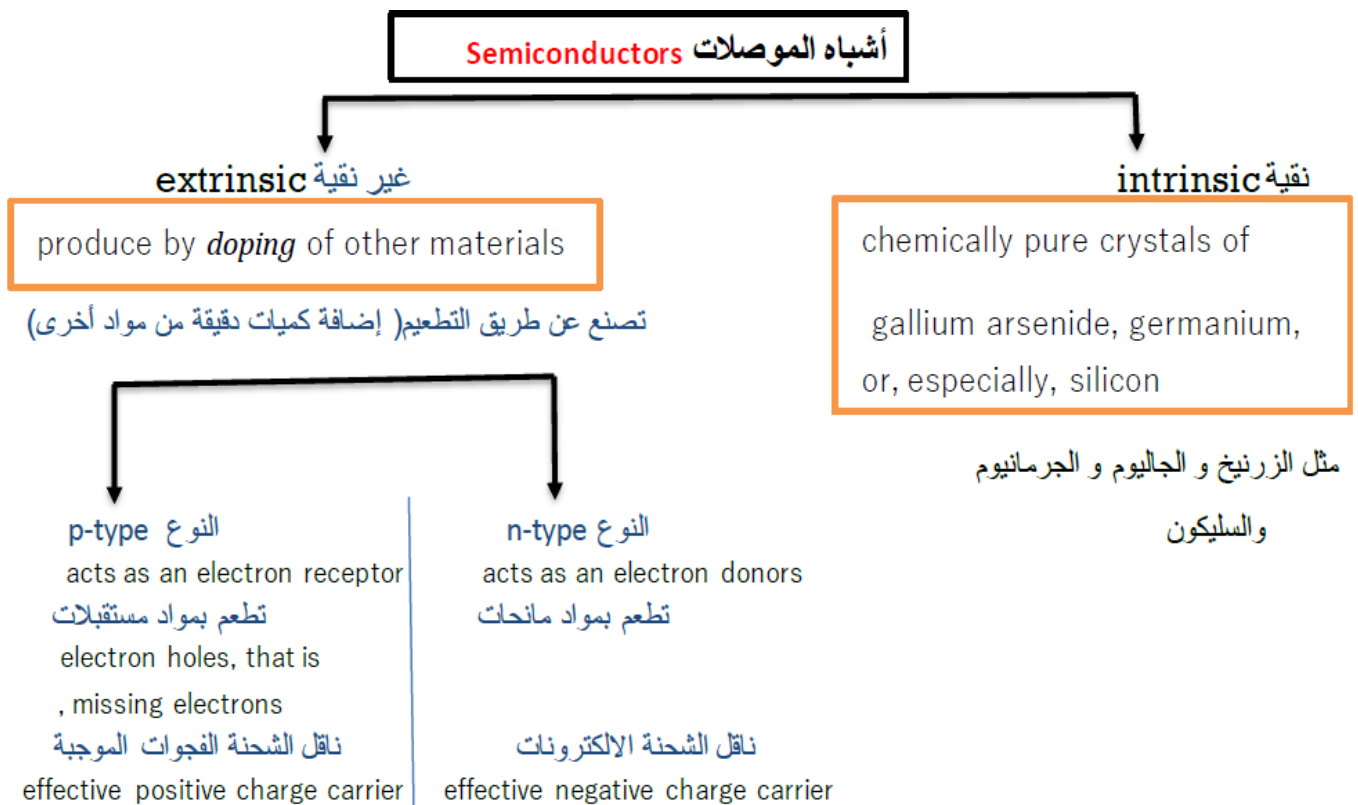
abundance of free shipments

Such as rubber, plastic, glass, silk, air dry

Keep the charge in place on the insulation and does not move

**3- Semiconductors** can change from being an insulator to being a conductor and back to an insulator again It is mainly in all computer and consumer electronics industries.

Used for the first time in transistors, where modern computer chips now function millions of Transistors.



#### 4- Superconductors

- Materials resist to conduct electricity zero, no loss of energy occurs.
- They are effective as superconductors at very low temperatures.
- Such as niobium and titanium alloy, which is kept at 4.2 K.
- Over the past 20 years new materials have been developed that act as superconductors at a relatively high temperature of 77.3 K critical degree.
- So far, superconducting materials at room temperature 300 K have not been detected.

### 1.4 Electrostatic Charging

- Charging the object with a static charge. The car battery is an energy source where chemical energy is used to separate positive and negative charges.
- Many insulating rods can be charged with a positive or negative charge from the power source.

**Grounding:** discharging the charge of the charged object via a connection to the ground.

The Earth is a nearly infinite reservoir of charge.

**An electroscope:** is a device that gives an observable response when it is charged.

**The electroscope consists of:**

1. Two strips of very thin metal foil, in a tie position connect one of them Hinge at the middle so that it stays away from the other fixed connector when charging.
2. A ball attached to the top of the electroscope connected to the conductors and allow the entry of charge or they exit easily.

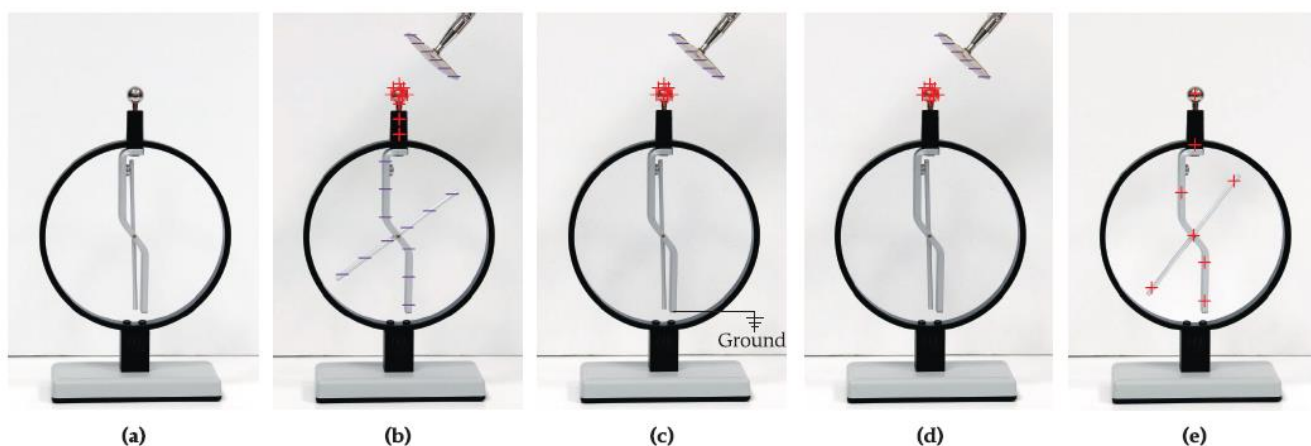


Q: Kitchen aluminum foil is not suitable?

Because it is too thick, but hobby shops sell thinner metal foils.

**Inducing a charge:**

When the charged paddle is brought near the ball of the electroscope, the electrons in the conducting ball of the electroscope are repelled, which produces a net negative charge on the conductors of the electroscope. This negative charge causes the movable conductor to rotate because the stationary conductor also has negative charge and repels it. Because the paddle did not touch the ball, the charge on the movable conductors is induced. If the charged paddle is then taken away, the induced charge reduces to zero, and the movable conductor returns to its original position.

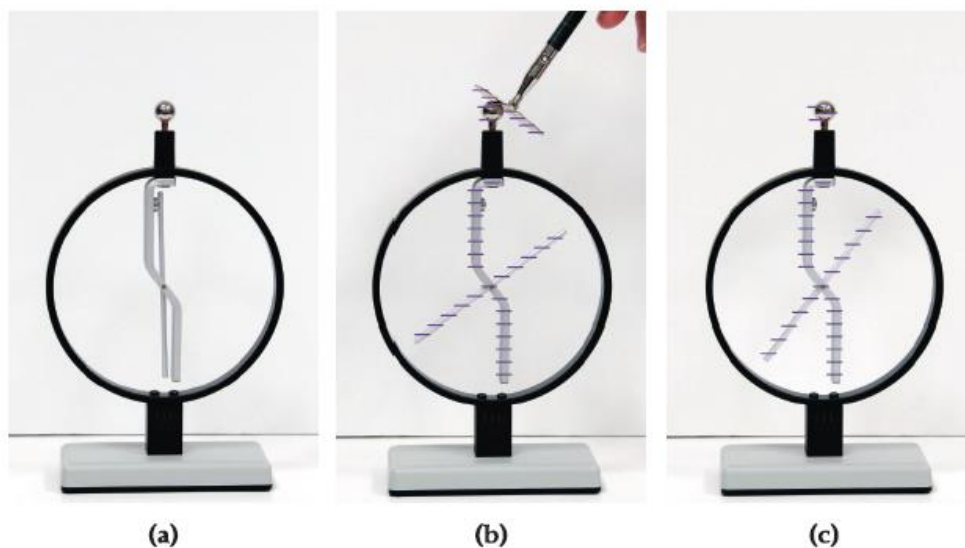


**FIGURE 1.11** Charging by induction: (a) An uncharged electroscope. (b) A negatively charged paddle is brought close to the electroscope. (c) A ground is connected to the electroscope. (d) The connection to the ground is removed. (e) The negatively charged paddle is taken away, leaving the electroscope positively charged.



## Charging by contact:

- (a) An uncharged electroscope.
- (b) A negatively charged paddle touches the electroscope.
- (c) The negatively charged paddle is removed.



### Multiple-Choice Questions

- The hinged conductor moves away from the fixed conductor if a charge is applied to the electroscope, because:
 

Like charges repel each other
Like charges attract each other

Unlike charges attract each other
Unlike charges repel each other
- When a metal plate is given a positive charge, which of the following is taking place?
 

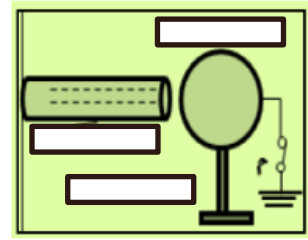
Protons (positive charges) are transferred to the plate from another object.

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

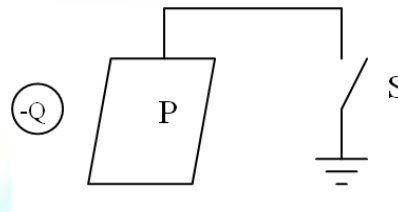
Electrons (negative charges) are transferred from the plate to another object, and protons (positive charges) are also transferred to the plate from another object.

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

3. In the adjacent shape after opening the key (s) and then remove the aponite rod from the ball:  
 The ball is charged with a positive charge.  
 The ball is charged with a negative charge.  
 The ball remains neutral  
 The charge of the ball is unknown
4. Charging a neutral body by touching it with a charged body is called charging by
- |            |             |
|------------|-------------|
| conduction | induction   |
| grounding  | discharging |
5. If the balloon can attract some paper scraps, which of the following cannot be the charge of paper scraps.
- |          |              |
|----------|--------------|
| Neutral  | Positive     |
| Negative | all is right |
6. During rubbing, what have been transferred between the woollen cloth and the balloon?
- |           |         |
|-----------|---------|
| Neutrons  | Protons |
| Electrons | quarks  |
7. Charging a neutral body without touching it with a charged body is called charging by
- |            |             |
|------------|-------------|
| conduction | grounding   |
| induction  | discharging |
8. If the woll can attract some paper scraps, which of the following cannot be the charge of paper scraps.
- |          |              |
|----------|--------------|
| Neutral  | Positive     |
| Negative | all is right |
9. You bring a negatively charged rubber rod close to a grounded conductor without touching it. Then you remove the charged rod. What is the sign of the charge on the conductor after you disconnect the ground?
- |           |   |
|-----------|---|
| negative  | positive  |
| no charge | cannot be determined from the given information |
10. When a positively charged rod is brought near to an isolated neutral conductor without touching it, will the rod experience an attractive force, a repulsive force, or no force at all?
- |                     |                   |
|---------------------|-------------------|
| an attractive force | a repulsive force |
| no force at all     |                   |



11. An uncharged metal plate (P) is connected by a conductor to ground through a switch (S). The switch (S) is initially closed. A negative charge  $-Q$  is brought close to P without touching it and then the switch (S) is opened. After the switch (S) is open, the negative charge  $-Q$  is removed. After the negative charge  $-Q$  is removed, what is the charge on the plate (P)?



It is now positively charged

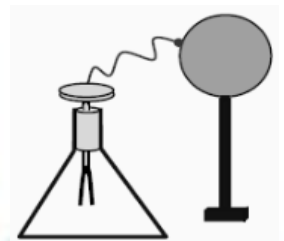
It is now negatively charged

It is still uncharged

It cannot be determined without knowing how much charge was on the metal plate P before switch S was closed

### Exercises

1. The opposite shape is a spherical conductor that rests on a dielectric holder and its surface are connected to electroscope.
- What is the change in the two sheets of electroscope when rounding a negative charged object from the right side of the spherical conductor? Justify your answer.



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2. Negative aponit rod used to charge metal sphere by 3 different methods as in the next drawing:

a) In which methods electrons are transmitted?

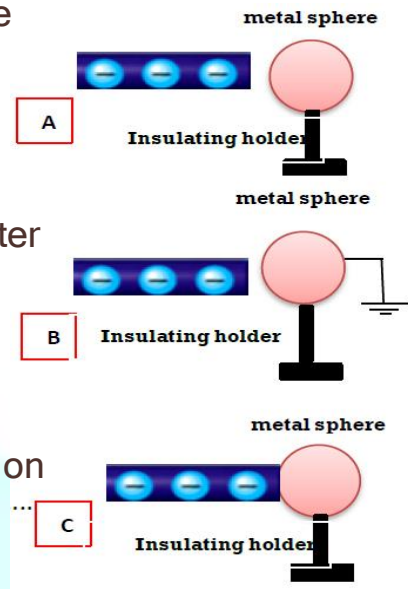
b) Plot the distribution of charges in balls.

c) In which method the ball becomes charged after turning the rod away?

d) In any way the ball charged by induction.

e) Explain what happened to the electric charge on the rod after being removed from the ball in each case

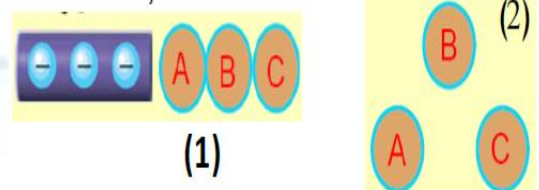
f) In method B, suppose that contact with the ground is cut first and then the rod is removed from the ball. Compare the two types of charge in balls B and c



3. In the next figure after opening the key (S) and then remove the glass rod from the ball  
Draw the distribution of the electric charge on the ball in the next figure 2.  
Type the name of the ball charging method.



4. In Fig. 1, the three balls are conductive and neutral, if the B ball is removed with insulator  
-Determine the charge of each ball as (2)



5. In the figure, the three balls are fully connected and neutral. If the B ball is removed with dielectric, determine the charge of each ball.



6. How to determine whether an object is conductive or not, using a charged rod and an electroscope ?

7. Explain how to charge an electroscope positively using:
- A positive rod
  - A negative rod

8. An electroscope being charged by induction, what happens when the charging rod is moved away before the ground is removed from the knob?

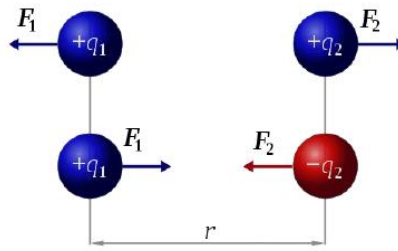
9. If you comb your hair on a dry day, the comb can become positively charged. Can your hair remain neutral? Explain.



10. What property makes metal a good conductor and rubber a good insulator?  
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11. Why do socks taken from a clothes dryer sometimes cling to other clothes?  
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12. The combined charge of all electrons in a nickel is hundreds of thousands of coulombs. Does this imply anything about the net charge on the coin? Explain.  
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13. Explain what happens to the leaves of a positively charged electroscope when rods with the following charges are brought close to, but not touching the electroscope:  
a. Positive  
b. negative  
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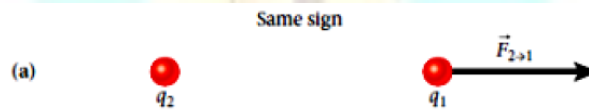
## 1.5 Electrostatic Force - Coulomb's Law

Similar charges repel each other



Different charges attract

a) the force on  $q_1$  points away from  $q_2$  if the charges have like signs



b) the force on  $q_1$  points toward  $q_2$  if the charges have opposite signs



coulomb's law

$$F_{2 \rightarrow 1} = F_{1 \rightarrow 2} = -k \frac{|q_1 q_2|}{r^2}$$

- $F_{1 \rightarrow 2}$  و  $F_{2 \rightarrow 1}$  Is the reciprocal force between the charges in (N) units.
- $q_1$  The value of the first charge in Coulomb.(C)
- $q_2$  The value of the first charge in Coulomb.(C).
- $r^2$  Square the distance between the two charges is in  $m^2$ .  $k=8.99 \times 10^9 \text{ N.m}^2/\text{C}^2$

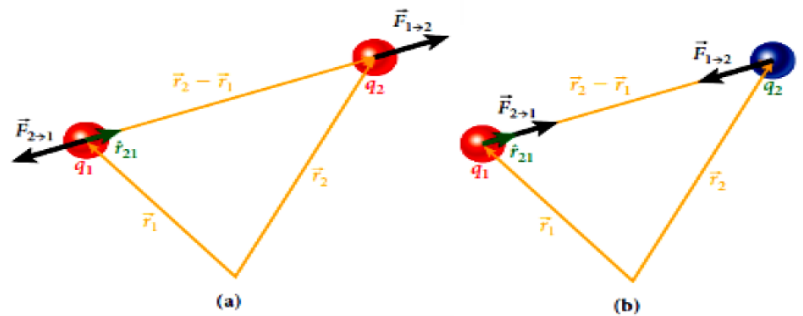
coulomb's constant  $k = \frac{1}{4 \pi \epsilon^0}$

$\epsilon^0 = 8.85 \times 10^{-12} \text{ C}^2/\text{N.m}^2$  electric permittivity of free space

$$\vec{F}_{2 \rightarrow 1} = -K \frac{|q_1 q_2|}{r^3} (\vec{r}_2 - \vec{r}_1)$$

$$\vec{F}_{2 \rightarrow 1} = -K \frac{|q_1 q_2|}{r^3} \hat{r}_{21}$$

$\hat{r}_{21}$  is a unit vector  
pointing from  $q_2$  to  $q_1$



### The sum of the forces acting on a point charge

➤ In the case of multiple charges affecting electrical forces on a certain point charge, we calculate the sum of the forces acting on the point charge as follows:

1- If the forces are on a parallel line of action:

- In the same direction, the sum is equal to the sum of the forces
- The two forces in the opposite direction, the sum is equal to the difference between the two forces and in the larger direction

2 - If one of the forces tend to the other angle  $F_{net} = \sqrt{F_1^2 + F_2^2 - F_1 F_2 \cos \theta}$

### Equilibrium position:

The point at which a third charge is not affected by the sum of the forces acting on it:

➤ If the two charges of the same type: The **Equilibrium** point is located on the line between them and closer to the least value charge.

(The charges are equal the point is halfway between them)

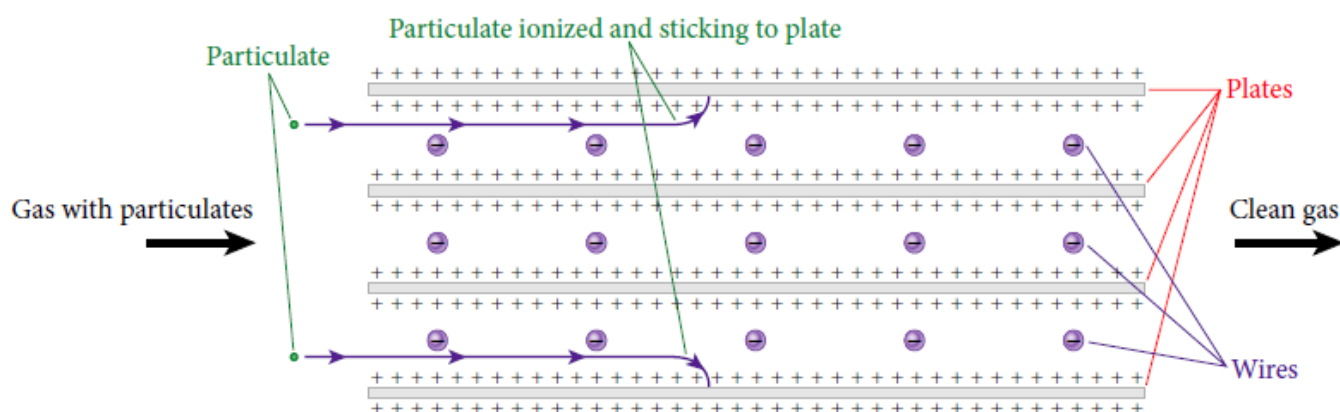
➤ For two different charges: the point is located along the line connecting them (outside) closer to the least amount of charge.

## Some practical applications of electrostatic forces

### electrostatic Precipitator



is used to remove ash and other particulates resulting from the burning of coal to generate electricity. The ESP consists of wires and plates, with the wires held at a high negative voltage relative to a series of plates held at a positive voltage. the exhaust from the coal-burning process enters the ESP from the left. Particulates passing near the wires pick up a negative charge. These particles are then attracted to one of the positive plates and stick there. The gas continues through the ESP, leaving the ash and other particulates behind. The accumulated material is then shaken off the plates to a hamper below. This waste can be used for many purposes, including construction materials and fertilizer.



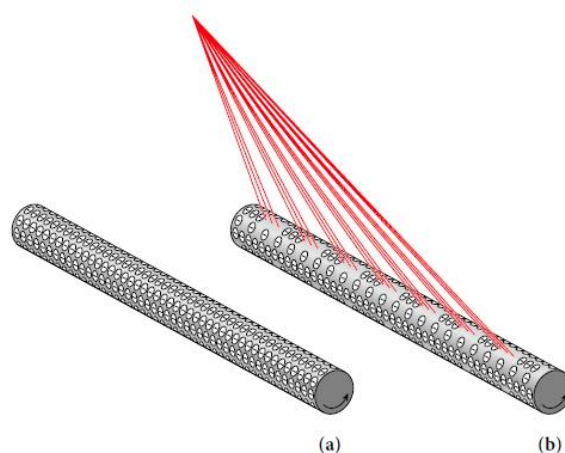
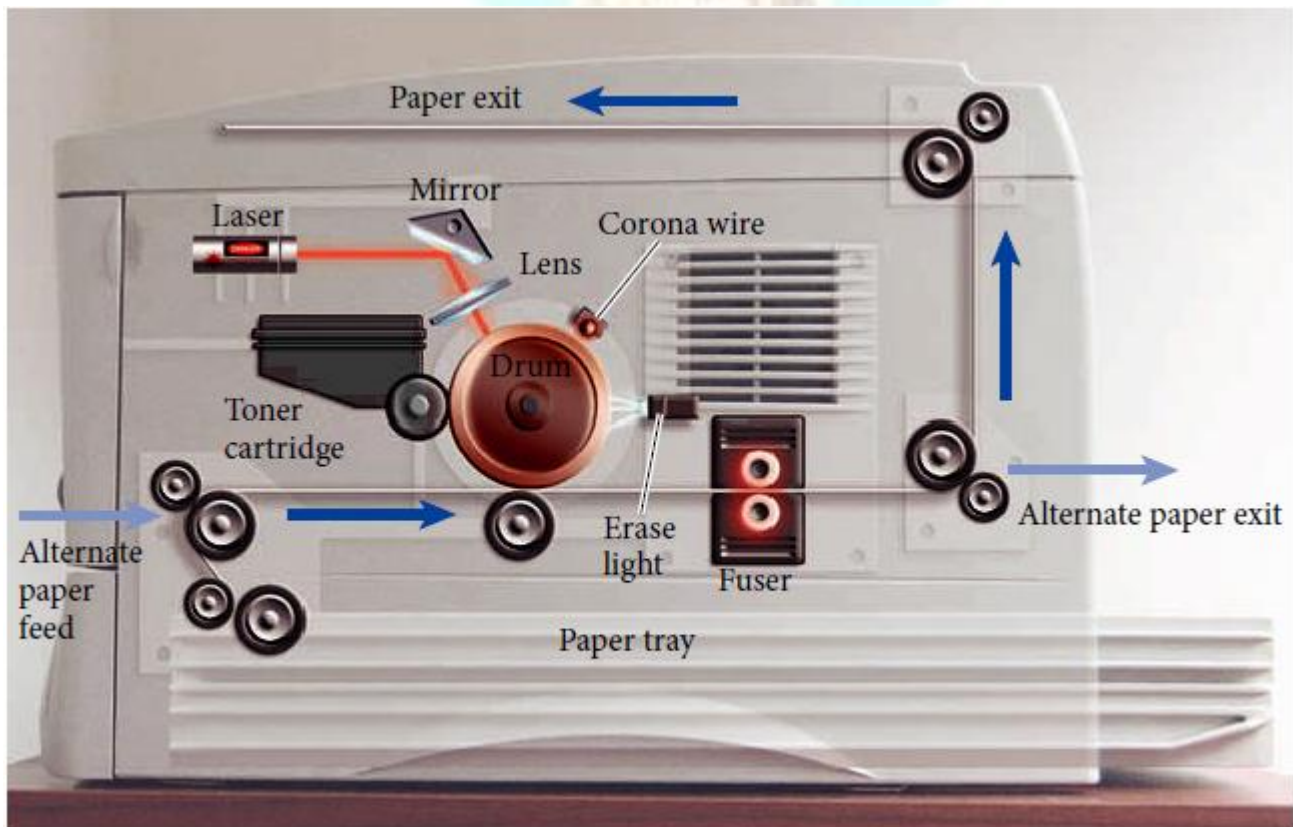
**FIGURE 21.17** Operation of an electrostatic precipitator used to clean the exhaust gas of a coal-fired power plant. The view is from the top of the device.

### laser Printer

The paper path follows the blue arrows. Paper is taken from the paper tray or fed manually through the alternate paper feed. The paper passes over a drum where the toner is placed on the surface of the paper and then passes through a fuser that melts the toner and permanently affixes it to the paper. The drum is negatively charged with electrons using a wire held at high voltage. Then laser light is directed at the surface of the drum. Wherever the laser light strikes the surface of the drum, the surface at that point is discharged. A laser is used because its beam is narrow and remains focused. A line of the image being printed is written one pixel (picture element or dot) at a time using a laser beam directed by a moving mirror and a lens. A typical laser printer can write 300 pixels per inch, with many printers being able to write 600 or 1200 pixels



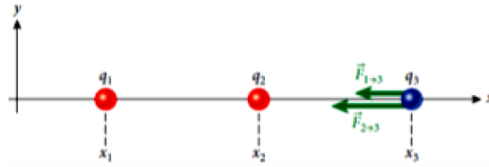
per inch. The surface of the drum then passes by a roller that picks up toner from the toner cartridge. Toner consists of small, black, insulating particles composed of a plastic-like material. The toner roller is charged to the same negative voltage as the drum. Therefore, wherever the surface of the drum has been discharged, electrostatic forces deposit toner on the surface of the drum. Any portion of the drum surface that has not been exposed to the laser will not pick up toner. As the drum rotates, it next comes in contact with the paper. The toner is then transferred from the surface of the drum to the paper. Some printers charge the paper positively to help attract the negatively charged toner. As the drum rotates, any remaining toner is scraped off and the surface is neutralized with an erase light or a rotating erase drum in preparation for printing the next image. The paper then continues on to the fuser, which melts the toner, producing a permanent image on the paper. Finally the paper exits the printer





## Multiple-Choice Questions

1. What do the forces acting on the charge  $q_3$  in Figure indicate about the signs of the three charges?



All three charges must be positive  
All three charges must be negative.

Charge  $q_3$  must be zero.

Charges  $q_1$  and  $q_2$  must have opposite signs.

Charges  $q_1$  and  $q_2$  must have the same sign, and  $q_3$  must have the opposite sign.

2. 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  $q_1$  and  $q_2$ ? (Hint: The distance between  $x_1$  and  $x_2$  is the same as the distance between  $x_2$  and  $x_3$ .)

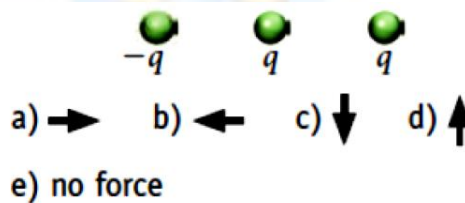
$$|q_1| < |q_2|$$

$$|q_1| = |q_2|$$

$$|q_1| > |q_2|$$

The answer cannot be determined from the information given in the figure.

3. 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?

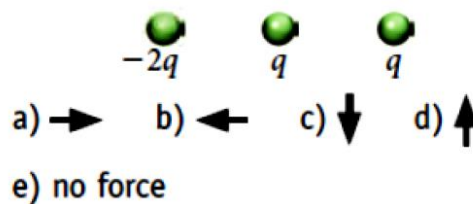


a  
c

b  
d

e

4. 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 the last Exercise.)



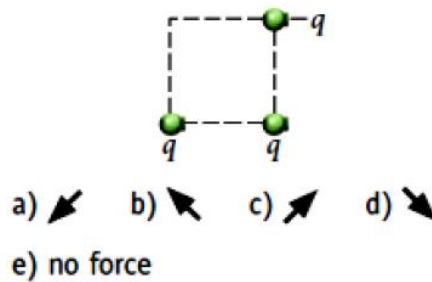
a  
c

b  
d

e

5. Three charges are arranged at the corners of a square as shown in the figure.

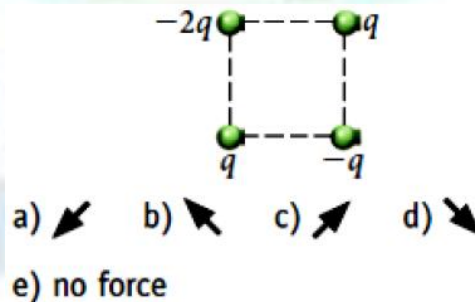
What is the direction of the electrostatic force on the lower right charge?



a b  
c d  
e

6. Four charges are arranged at the corners of a square as shown in the figure.

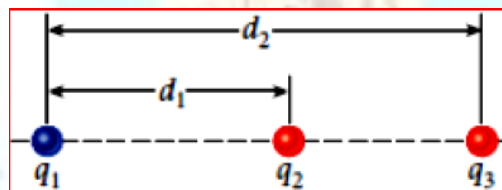
What is the direction of the electrostatic force on the lower right Charge?



a b  
c d  
e

7. Consider three charges placed along the  $x$ -axis, as shown in the figure. The values of the charges are  $q_1 = -8.10 \mu\text{C}$ ,  $q_2 = 2.16 \mu\text{C}$ , and  $q_3 = 2.16 \text{ pC}$ . The distance between  $q_1$  and  $q_2$  is  $d_1 = 1.71 \text{ m}$ . The distance between  $q_1$  and  $q_3$  is  $d_2 = 2.62 \text{ m}$ .

> What is the magnitude of the total electrostatic force exerted on  $q_3$  by  $q_1$  and  $q_2$ ?



$$2.77 \cdot 10^{-8} \text{ N}$$

$$1.44 \cdot 10^{-5} \text{ N}$$

$$6.71 \cdot 10^{-2} \text{ N}$$

$$7.92 \cdot 10^{-6} \text{ N}$$

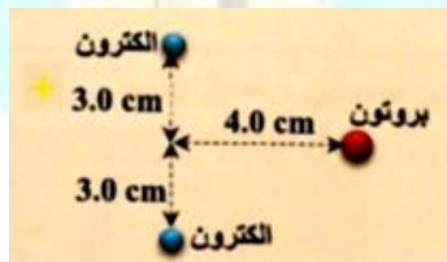
$$2.22 \cdot 10^{-4} \text{ N}$$

8. 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. **which of the following is true?**



Charge the board with a negative charge.  
 The board charges with a positive charge.  
 The board remains uncharged  
 charge type cannot be determined.

9. In the adjacent figure, **how much the electrostatic force affecting in the proton?**



$1.5 \times 10^{-25} \text{ N}$  towards right  
 0 N

$1.5 \times 10^{-25} \text{ N}$  towards left  
 $9.2 \times 10^{-26} \text{ N}$  make angle  $37^\circ$

10. **Which of the following is correct** relationship between coulomb constant (K) and electric permittivity  $\epsilon^\circ$  if the free space is vacuum

$$K \epsilon^\circ = 4\pi$$

$$K \epsilon^\circ = 1/4\pi$$

$$K \epsilon^\circ = 2\pi$$

$$K \epsilon^\circ = 1/2\pi$$

11. 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?

negative  
 positive  
 no charge

cannot be determined from the given information

12. The force between a charge of  $25 \mu\text{C}$  and a charge of  $-10 \mu\text{C}$  is 8.0 N. **What** is the separation between the two charges?

0.28  
 0.45 m

0.53 m  
 0.15 m

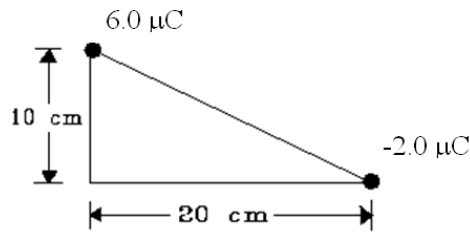
13. A charge  $Q_1$  is positioned on the x-axis at  $x = a$ . Where should a charge  $Q_2 = -4Q_1$  be placed to produce a net electrostatic force of zero on a third charge,  $Q_3 = Q_1$ , located at the origin?

at the origin  
 at  $x = -2a$

at  $x = 2a$   
 at  $x = -a$

14. When two charges are separated by a distance  $d$ , the magnitude of the electrostatic force between them is  $F$ . What would be the magnitude of the electrostatic force between them if the separation distance was  $d/2$ ?
- $F/4$   $F/2$   
 $2F$   $4F$
15. Two ions are placed on the  $x$ -axis. One has a charge of  $+e$  and is located at the origin. The other has a charge of  $-4e$  and is located at  $x = +d$ , where  $d > 0$ . Where on the  $x$ -axis could a third charge be placed such that the net electrostatic force on it caused by the other two charges is zero?
- $x = -2d$   $x = -d$   
 $x = +d$   $x = +2d$
16. In the opposite corners of a square there are two identical ions. Each has a charge of  $-e$ . The length of one side of the square is  $L$ . In one of the other corners there is a third ion which has a charge of  $+e$ . What is the magnitude of the net electrostatic force on the positive ion caused by the two negative ions?
- $ke^2 / 2L^2$   $ke^2 / L^2$   
 $\sqrt{2} ke^2 / L^2$   $2ke^2 / L^2$
17. Three electrons are located at the vertices of an equilateral triangle, one at each vertex. The length of one side of the triangle is 1.00 nm. What is the magnitude of the net electrostatic force on each electron?
- $2.30 \times 10^{-10} \text{ N}$   $3.25 \times 10^{-10} \text{ N}$   
 $3.99 \times 10^{-10} \text{ N}$   $4.60 \times 10^{-10} \text{ N}$
18. Three electrons are located at the vertices of an equilateral triangle, one at each vertex. The length of one side of the triangle is 1.00 nm. What is the magnitude of the initial acceleration of each electron?
- $2.52 \times 10^{20} \text{ m/s}^2$   $3.57 \times 10^{20} \text{ m/s}^2$   
 $4.38 \times 10^{20} \text{ m/s}^2$   $5.05 \times 10^{20} \text{ m/s}^2$
19. A  $3.0 \mu\text{C}$  charge lies 10.0 cm to the right of a  $2.0 \mu\text{C}$  on the  $x$ -axis. What is the magnitude of the force on the  $2.0 \mu\text{C}$  charge?
- $2.4 \text{ N}$   $4.8 \text{ N}$   
 $5.4 \text{ N}$   $6.7 \text{ N}$   
 $7.9 \text{ N}$
20. The force between a  $3.0 \mu\text{C}$  and a  $2.0 \mu\text{C}$  charge is 10 N. What is the separation distance between the two charges?
- $5.2 \text{ cm}$   $7.3 \text{ cm}$   
 $8.6 \text{ cm}$   $9.5 \text{ cm}$

21. Two-point charges are placed on two of the corners of a triangle as shown. What magnitude of force would be felt by a  $6.0 \mu\text{C}$  charge placed at the right angle?

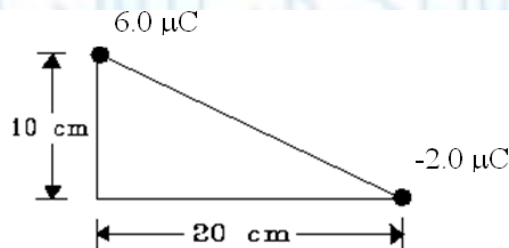


10 N  
32 N

24 N  
44 N

58 N

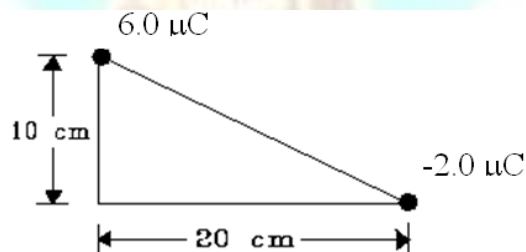
22. Two-point charges are placed on two of the corners of a triangle as shown. What is the direction of the force would be felt by a  $6.0 \mu\text{C}$  charge placed at the right angle relative to the horizontal (positive x-axis to the right)?



$-18^\circ$   
 $-45^\circ$   
 $-85^\circ$

$+18^\circ$   
 $+45^\circ$   
 $+85^\circ$

23. Two-point charges are placed on two of the corners of a triangle as shown. What magnitude of force would be felt by a  $1.0 \mu\text{C}$  charge placed at the right angle?



1.4 N  
3.3 N

2.9 N  
5.4 N

6.8 N



24. A charge  $Q_1 = Q$  is positioned on the  $x$  axis at  $x = a$ . Where should a charge  $Q_2 = 9Q$  be placed to produce a net electric force of zero on a charge placed at the origin?
- at  $x = 2a$  at  $x = -2a$   
at  $x = 3a$  at  $x = -3a$   
at  $x = 4a$
25. A particle (charge =  $-15.0 \mu\text{C}$ ) is located on the  $x$ -axis at the point  $x = -25.0$  cm, and a second particle (charge =  $+45.0 \mu\text{C}$ ) is placed on the  $x$ -axis at  $x = +30.0$  cm. What is the magnitude of the total electrostatic force on a third particle (charge =  $-3.50 \mu\text{C}$ ) placed at the origin ( $x = 0$ )?
- 2.33 mN 23.3 N  
0.818 N 8.18 N  
2.67 N
26. Three-point charges are positioned on the  $x$  axis. If the charges and corresponding positions are  $-25.0 \mu\text{C}$  at  $x = 0.00$  cm,  $-50.0 \mu\text{C}$  at  $x = 30.0$  cm, and  $+100.0 \mu\text{C}$  at  $x = 80.0$  cm, what is the magnitude of the electrostatic force on the  $-25.0 \mu\text{C}$  charge?
- 89.7 N 160 N  
8.97 mN 16.0 mN  
0 N
27. Identical point charges  $Q$  are placed at each of the four corners of a  $1.0 \text{ m} \times 2.0 \text{ m}$  rectangle. If  $Q = 35 \mu\text{C}$ , what is the magnitude of the electrostatic force on any one of the charges?
- 12 N 13 N  
14 N 15 N  
16 N
28. Identical point charges  $Q$  are placed at each of the four corners of a  $1.0 \text{ m} \times 2.0 \text{ m}$  rectangle. If the magnitude of the electrostatic force on one of the charges is  $28.5 \text{ N}$ , what is the charge,  $Q$  of one of the four charges?
- $35 \mu\text{C}$   $68 \mu\text{C}$   
 $79 \mu\text{C}$   $83 \mu\text{C}$   
 $52 \mu\text{C}$
29. Identical point charges  $Q$  are placed at each of the four corners of square  $2.0 \text{ m}$  inside. The magnitude of the electrostatic force on any one of the charges is  $4.41 \text{ N}$ . The absolute value of the charge  $Q$  is
- $32 \mu\text{C}$   $15 \mu\text{C}$   
 $48 \mu\text{C}$   $23 \mu\text{C}$   
 $67 \mu\text{C}$

30. Two-point charges are fixed in space along the x-axis. The first charge of  $3.8 \mu\text{C}$  is located at  $x = -4.5 \text{ cm}$ , while the second charge of  $-5.6 \mu\text{C}$  is located at  $x = 3.5 \text{ cm}$ . Where should a third charge (with charge  $1 \mu\text{C}$ ) be placed on the x-axis so that the total electric force it vanishes?
- $-0.214 \text{ m}$   $0.214 \text{ m}$   
 $-0.312 \text{ m}$   $-0.419 \text{ m}$   
 $0.419 \text{ m}$
31. Two initially uncharged identical metal spheres are connected by an insulating spring (unstretched length  $0.75 \text{ m}$ , spring constant  $k=35.0 \text{ N/m}$ ). Charge  $+2q$  is placed on the first sphere and  $-q$  on the second sphere, causing the spring to contract to a length of  $0.54 \text{ m}$ . Recall that the force exerted by a spring is  $k\Delta x$ , where  $\Delta x$  is the change in the spring's length from its unstretched/uncompressed length. Determine the charge  $q$ .
- $1.19 \times 10^{-10} \text{ C}$   $1.09 \times 10^{-5} \text{ C}$   
 $2.06 \times 10^{-5} \text{ C}$   $1.75 \times 10^{-5} \text{ C}$   
 $3.62 \times 10^{-5} \text{ C}$
32. Two initially uncharged identical metal spheres are connected by an insulating spring (unstretched length  $0.75 \text{ m}$ ). Charge  $+2q$  is placed on the first sphere and  $-q$  on the second sphere, causing the spring to contract to a length of  $0.54 \text{ m}$ . Recall that the force exerted by a spring is  $k\Delta x$ , where  $\Delta x$  is the change in the spring's length from its unstretched/uncompressed length and  $k$  is the spring constant. If the charge  $q = 2.06 \times 10^{-5} \text{ C}$ , what is the spring constant?
- $125 \text{ N/m}$   $187 \text{ N/m}$   
 $35.0 \text{ N/m}$   $58.3 \text{ N/m}$   
 $142 \text{ N/m}$
33. Two initially uncharged identical metal spheres 1 and 2 are connected by an insulating spring (unstretched length of  $0.68 \text{ m}$ ). Charge  $+6.2 \mu\text{C}$  is placed on the first sphere and  $-6.2 \mu\text{C}$  on the second sphere, causing the spring to contract to a length of  $0.43 \text{ m}$ . If someone coats the spring with metal to make it conducting, what is the new length of the spring? Recall that the force exerted by a spring is  $k\Delta x$ , where  $\Delta x$  is the change in the spring's length from its unstretched/uncompressed length.
- $0.25 \text{ m}$   $0.43 \text{ m}$   
 $0.56 \text{ m}$   $0.68 \text{ m}$   
 $0.75 \text{ m}$
34. Two charges are placed at the corners of an equilateral triangle that is  $0.25 \text{ m}$  on each side. The first charge is  $4.5 \mu\text{C}$  and the second is  $3.2 \mu\text{C}$ . If a charge of  $2.5 \mu\text{C}$  is placed at the third corner of the triangle, what is the magnitude of the electric force on the third charge due to the first two charges?
- $0.602 \text{ N}$   $1.96 \text{ N}$   
 $2.41 \text{ N}$   $3.19 \text{ N}$   
 $4.31 \text{ N}$

35. Two small, charged objects,  $Q_1$  and  $Q_2$ , are some distance  $d$  apart from each other and there is a force  $F$  between them. What is the value of the force if  $Q_1$  is increased by a factor of two,  $Q_2$  is increased by a factor of 3, and  $d$  is increased by a factor of 5?
- 0.20 F                      0.24 F  
0.12 F                      1.2 F
36. According to the Bohr model of the atom, an electron orbits the nucleus in a circular orbit. Find the acceleration of an electron in a circular orbit around a proton. Ignore any relativistic or quantum effects.
- Mass of the electron:  $9.11 \times 10^{-31}$  kg  
Mass of the proton:  $1.67 \times 10^{-27}$  kg  
Radius of orbit:  $5.29 \times 10^{-11}$  m
- $2.19 \times 10^6$  m/s<sup>2</sup>                       $1.20 \times 10^8$  m/s<sup>2</sup>  
 $4.78 \times 10^{12}$  m/s<sup>2</sup>                       $4.90 \times 10^{19}$  m/s<sup>2</sup>  
 $9.04 \times 10^{22}$  m/s<sup>2</sup>
37. According to the Bohr model of the atom, an electron orbits the nucleus in a circular orbit. Find the linear speed of an electron in a circular orbit around a proton. Ignore any relativistic or quantum effects.
- Mass of the electron:  $9.11 \times 10^{-31}$  kg  
Mass of the proton:  $1.67 \times 10^{-27}$  kg  
Radius of orbit:  $5.29 \times 10^{-11}$  m
- $2.2 \times 10^6$  m/s                       $5.6 \times 10^5$  m/s  
 $4.3 \times 10^6$  m/s                       $5.9 \times 10^5$  m/s  
 $9.0 \times 10^5$  m/s
38. According to the Bohr model of the atom, an electron orbits the nucleus in a circular orbit. Find the linear speed of an electron in a circular orbit around a proton. Ignore any relativistic or quantum effects.
- Mass of the electron:  $9.11 \times 10^{-31}$  kg  
Mass of the proton:  $1.67 \times 10^{-27}$  kg  
Radius of orbit:  $5.29 \times 10^{-11}$  m
- $5.6 \times 10^{16}$  rad/s                       $3.2 \times 10^{16}$  rad/s  
 $7.9 \times 10^{16}$  rad/s                       $4.1 \times 10^{16}$  rad/s  
 $1.0 \times 10^{16}$  rad/s
39. Find the magnitude of the net force on a 1.20 mC charge at the origin if there is a +2.40 mC charge at (3.0m,0) and a -5.70 mC charge at (0,4.0m).
- 1.8 kN                      2.9 kN  
3.8 kN                      4.8 kN  
16 kN

40. Find the net force between two positively charged objects, each with charge of 1.2 mC, separated by a distance of 2.0m. They are in a material where the electric permittivity is.  $\epsilon = 1.25 \times 10^{-11} \text{ C}^2 / (\text{N} \cdot \text{m}^2)$

2300 N  
4600 N

6400 N 3200 N

$2.6 \times 10^{14} \text{ N}$

41. Which of the following have a largest net force?  
 A 1-C charge a distance of 1 m from a -2-C charge.  
 A 1-C charge a distance of 0.5 m from a -1-C charge.  
 A 1-C charge exactly halfway between a -1-C charge and a 1-C charge separated by 2 m.  
 A 1-C charge exactly halfway between two -2-C charges separated by 2 m.  
 A 1-C charge a distance of 2m from a -4-C charge.
42. Which of the following have a smallest net force?  
 A 1-C charge a distance of 1 m from a -2-C charge.  
 A 1-C charge a distance of 0.5 m from a -1-C charge.  
 A 1-C charge exactly halfway between a -1-C charge and a 1-C charge separated by 2 m.  
 A 1-C charge exactly halfway between two -2-C charges separated by 2 m.  
 A 1-C charge a distance of 2m from a -4-C charge
43. A 1-C charge is placed at the origin with a 2-C charge placed at the coordinates (2,0). Where should a charge of -4 C be placed such that the net force on that charge is zero?  
 at  $x < 0$   
 at  $1 < x < 2$   
 at  $x = 0$   
 at  $0 < x < 1$   
 at  $x > 2$
44. Two equal charges of mass 15 g each are suspended at the end of two 1-m strings of negligible mass. The ropes make an angle of  $5^\circ$  with respect to each other. What is the charge on each?  
 36 nC  
 74 nC  
 64 nC  
 30 nC  
 55 nC
45. Two equal masses of charge 36 nC each are suspended at the end of two 1-m strings of negligible mass. The ropes make an angle of  $5^\circ$  with respect to each other. What is the mass of one of the two equal masses?  
 8.1 g  
 4.1 g  
 6.7 g  
 15 g  
 3.6 g



46. Two equal masses of charge 36 nC each are suspended at the end of two 1-m strings of negligible mass. The ropes make an angle of  $5^\circ$  with respect to each other. What is the tension in one of the strings?

0.060 N

0.044 N

0.019 N

0.023 N

0.035 N

47. Two charges of 0.5 C are placed at (0, 1) and (1, 0). A charge of -0.5 C is placed at (0, 0). What is the direction of the force on a positive charge placed at (1, 1)?

towards the origin

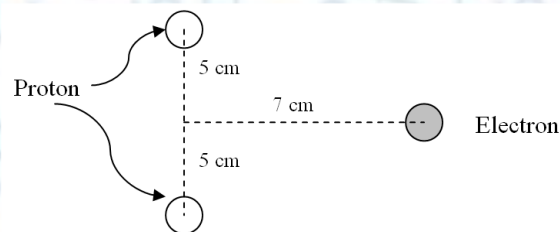
towards (1, 0)

towards (0, 1)

away from the origin

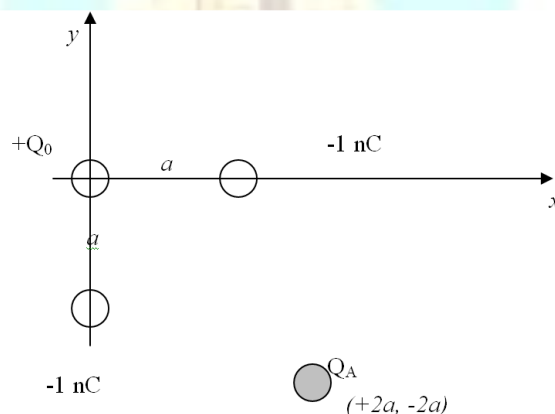
There is not enough information given to tell.

48. Find the magnitude and direction of the electrostatic force on the electron in the figure shown.

 $5.07 \times 10^{-26}$  N to the left $5.07 \times 10^{-26}$  N to the right $6.23 \times 10^{-26}$  N to the left $6.23 \times 10^{-26}$  N to the right

0 N

49. In the figure the net electrostatic force on charge  $Q_A$  is zero. If  $Q_A = +1$  nC, determine the magnitude of  $Q_0$  if position of  $Q_A$  is  $(+2a, -2a)$ .



4.24 nC

3.04 nC

6.80 nC

9.61 nC

2.15 nC



50. Two charges,  $q_1 = +10 \text{ nC}$  and  $q_2 = -30 \text{ nC}$  are 20 cm apart. Where (other than infinity) can a proton be placed so as to experience no net force?

$$\frac{q_1 (+10 \text{ nC})}{q_2 (-30 \text{ nC})}$$

left of charge  $q_1$   
on the line joining  $q_1$  and  $q_2$   
right of charge  $q_2$

at a point P on the right bisector of the line joining the two charges

51. In Bohr's model of the hydrogen atom an electron revolves in a circular orbit of radius 0.053 nm around a proton. The number of revolutions made by the electron in one second is

$$12.8 \times 10^{39}$$

$$9.8 \times 10^{35}$$

$$4.3 \times 10^{31}$$

$$6.6 \times 10^{15}$$

$$6.2 \times 10^{12}$$

52. The diameter of  $\text{C}^{12}$  nucleus is  $2.75 \times 10^{-15} \text{ m}$ . It has a charge of  $+6e$ . The magnitude of the force on a proton placed  $2 \times 10^{-15} \text{ m}$  from its surface is

$$121.4 \text{ N}$$

$$345.6 \text{ N}$$

$$542.1 \text{ N}$$

$$632.5 \text{ N}$$

$$980.1 \text{ N}$$

53. Two spheres carry electric charge, and a third charged sphere is now placed between the two charged spheres on a line connecting the two spheres' centers. If the result of the placement of the third charge is that there is no net electrostatic force on each of the two original spheres, what can be said?

The original spheres carried charges of opposite sign.

The original spheres carried charges of the same sign.

The original spheres carried charges of equal magnitude.

The new charge is placed equidistant from each of the two original charges.

None of the choices may be said with certainty.

54. Two spheres carry electric charge, and a third charged sphere is now placed somewhere on the line that runs through the two spheres' centers. If the result of the placement of the third charge is that there is no net electrostatic force on each of the two original spheres, what can be said?

The original spheres carried charges of opposite sign.

The original spheres carried charges of the same sign.

The original spheres carried charges of equal magnitude.

The new charge is placed equidistant from each of the two original charges.

None of the choices may be said with certainty.

55. In a region of space there are 3 fixed charges:  $+1.0 \text{ mC}$  at  $(-1.0 \text{ mm}, 0.0 \text{ mm})$ ,  $-2.0 \text{ mC}$  at  $(8.0 \text{ mm}, 5.0 \text{ mm})$ , and  $+3.0 \text{ mC}$  at  $(0.0 \text{ mm}, 9.0 \text{ mm})$ . What is the magnitude of the net force on the  $-2.0 \text{ mC}$  charge?
- $5.3 \times 10^8 \text{ N}$   $7.8 \times 10^8 \text{ N}$   
 $8.4 \times 10^8 \text{ N}$   $9.7 \times 10^8 \text{ N}$   
 $7.5 \times 10^9 \text{ N}$
56. A small ball with a mass of  $40 \text{ g}$  and a charge of  $-0.3 \text{ } \mu\text{C}$  is suspended from the ceiling on a string. The ball is suspended a distance of  $7.0 \text{ cm}$  above an insulating floor. If a second small ball with a mass of  $50 \text{ g}$  and a charge of  $0.6 \text{ } \mu\text{C}$  is placed on the floor directly beneath the first ball, what is the tension in the string?
- $0.04 \text{ N}$   $0.06 \text{ N}$   
 $0.33 \text{ N}$   $0.39 \text{ N}$   
 $0.72 \text{ N}$
57. A small ball with a mass of  $40 \text{ g}$  and a charge of  $-0.3 \text{ } \mu\text{C}$  is suspended from the ceiling on a string. The ball is suspended above an insulating floor. If a second small ball with a mass of  $50 \text{ g}$  and a charge of  $0.6 \text{ } \mu\text{C}$  is placed on the floor directly beneath the first ball and the tension in the string is  $1.0 \text{ N}$ , what is the distance between the first ball and the insulating floor?
- $8.3 \text{ cm}$   $7.0 \text{ cm}$   
 $5.2 \text{ cm}$   $5.7 \text{ cm}$   
 $6.4 \text{ cm}$
58. A small ball with a mass of  $40 \text{ g}$  and a charge of  $0.3 \text{ } \mu\text{C}$  is suspended from the ceiling on a string. The ball is suspended a distance of  $7.0 \text{ cm}$  above an insulating floor. If a second small ball with a mass of  $50 \text{ g}$  and a charge of  $0.6 \text{ } \mu\text{C}$  is placed on the floor directly beneath the first ball, what is the tension in the string?
- $0.04 \text{ N}$   $0.06 \text{ N}$   
 $0.33 \text{ N}$   $0.39 \text{ N}$   
 $0.72 \text{ N}$
59. A small charged ball with a mass of  $40 \text{ g}$  is suspended from the ceiling on a string. The ball is suspended a distance of  $7.0 \text{ cm}$  above an insulating floor. If a second small ball with a mass of  $50 \text{ g}$  and a charge of  $-0.60 \text{ } \mu\text{C}$  is placed on the floor directly beneath the first ball and the tension in the string is  $1.00 \text{ N}$ , what is the charge on the ball attached to the string?
- $0.96 \text{ } \mu\text{C}$   $0.55 \text{ } \mu\text{C}$   
 $0.72 \text{ } \mu\text{C}$   $1.3 \text{ } \mu\text{C}$   
 $0.30 \text{ } \mu\text{C}$

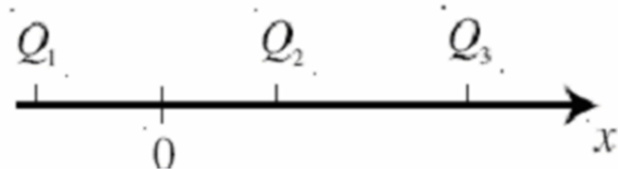
60. A fixed  $+2.0 \text{ mC}$  charge is located at the origin, and a fixed  $-5.0 \text{ mC}$  charge is located at  $x = 1.0 \text{ m}$ . Where could a  $+7.0 \text{ mC}$  charge be placed so that the net force on it is zero?

-1.7 m  
-0.39 m

-0.67 m  
+0.39 m

+0.67 m

61. Three-point charges are placed on the x-axis as shown. Assume that  $Q_1 = 2.40 \mu\text{C}$ ,  $Q_2 = -Q_1$ , and  $Q_3 = Q_1$ . The coordinates of the point charges are  $x_1 = -0.100 \text{ m}$ ,  $x_2 = 0.120 \text{ m}$ ,  $x_3 = 0.300 \text{ m}$ . What is the force (in N) on  $Q_2$ ?



0.324  
0.414  
0.528  
0.675

0.366  
0.468  
0.597  
0.762

62. Two charged objects are a distance  $2.0 \text{ m}$  apart. Object X has a charge  $33.0 \text{ C}$  and Object Y has  $3.0 \text{ C}$ .

The magnitude of electrostatic force on X is 11 times that on Y.

The magnitude of electrostatic force on Y is 11 times that on X.

The electrostatic force on X is the negative of that on Y.

The electrostatic force on X is the same as that on Y.

The electrostatic force on X is 99 times that on Y.

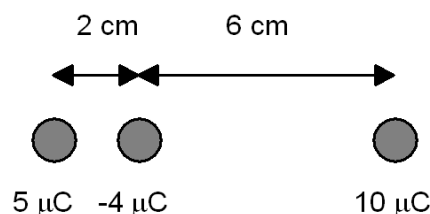
63. Two charged particles attract each other with a force  $F$ . If the charges on both are doubled, and the distance between the charges is halved then the force

is 16 times stronger  
is twice as strong

is 4 time stronger  
remains the same

is  $1/2$  as strong

64. What is the force on the  $-4 \mu\text{C}$  sphere?



550 N, to the left  
350 N, to the left

550 N to the right  
350 N, to the right

0

65. An electron in a hydrogen atom experiences a Coulomb force,  $F = 85.2 \times 10^{-9} \text{ N}$ , as it goes in a circular orbit around the central proton. How far away is the electron from the proton?

0.052 nm

52  $\mu\text{m}$ 

0.35 nm

35  $\mu\text{m}$ 

27 mm

66. Two charges of  $1.6 \times 10^{-3} \text{ C}$  and  $6.4 \times 10^{-4} \text{ C}$  are a distance of 5.1 m apart. What is the magnitude of the force (in N) acting between them?

354 N

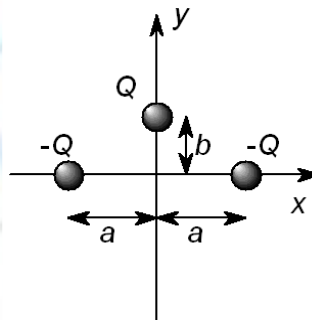
290 N

120 N

456 N

35 N

67. Three charges of equal magnitude  $Q$  are held in the configuration shown. If a small positive charge,  $q$ , is placed at the origin what will be the magnitude and direction of the force it experiences? (Note: Pay attention to the sign on each of the three charges.)



$$\frac{qQ}{4\pi\epsilon_0 b^2} \text{ in positive y-direction}$$

$$\frac{qQ}{2\pi\epsilon_0 a^2} \text{ in positive x-direction}$$

$$\frac{qQ}{4\pi\epsilon_0 b^2} \text{ in negative y-direction}$$

$$\frac{qQ}{2\pi\epsilon_0 a^2} \text{ in negative x-direction}$$

0

68. What acceleration, will an electron experience when it is a distance of 30 nm away from a charge of  $Q = -30e$ ? (Use the sign convention here: + for acceleration away from the charge  $Q$ , and - for acceleration towards it.)

 $-7.68 \times 10^{-12} \text{ m/s}^2$  $8.43 \times 10^{18} \text{ m/s}^2$  $3.26 \times 10^{-7} \text{ m/s}^2$  $-8.99 \times 10^9 \text{ m/s}^2$  $+8.99 \times 10^9 \text{ m/s}^2$ 

69. In a hydrogen atom, the average separation between the orbiting electron and the proton is  $0.53 \times 10^{-10} \text{ m}$ . What is the force of the electron? Use a negative sign for attractive, positive sign for repulsive force.

 $-8.2 \times 10^{-8} \text{ N}$  $+8.2 \times 10^{-8} \text{ N}$  $-4.4 \times 10^{-3} \text{ N}$  $+4.4 \times 10^{-3} \text{ N}$ 

0

## Exercises

1. **What** is the magnitude of the electrostatic force that the two protons inside the nucleus of a helium atom exert on each other?  $k=8.99 \times 10^9 \text{ Nm}^2/\text{C}^2$   
 $q_p = +e = 1.602 \times 10^{-19} \text{ C}$  و  $r = 2.00 \times 10^{-15} \text{ m}$

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2. **What** is the magnitude of the electrostatic force between a gold nucleus and an electron of the gold atom in an orbit with radius  $4.88 \times 10^{-12} \text{ m}$  ?  
 $Z=79$

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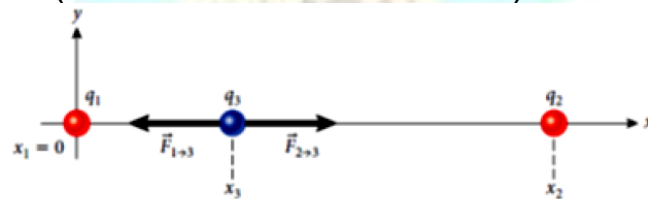
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3. Two charged particles are placed as shown in Figure :  $q_1 = 0.15 \mu\text{C}$  is located at the origin, and  $q_2 = 0.35 \mu\text{C}$  is located on the positive  $x$ -axis at  $x_2 = 0.40 \text{ m}$ . **Where** should a third charged particle,  $q_3$ , be placed to be at an equilibrium point (the forces on it sum to zero)?



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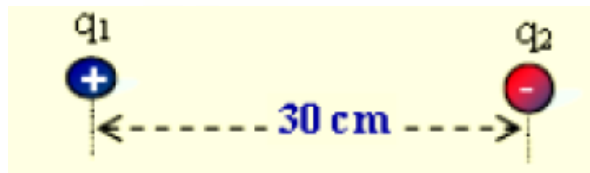
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4. Two point charges  $q_2 = -20 \mu\text{C}$ ,  $q_1 = 40 \mu\text{C}$  the distance between them is equal to 30 cm as adjacent.
- a) **Determine on the drawing** the direction of the electric force that the first charge affects On the second charge.
  - b) **Calculate** the amount of electric force that the first charge affects On the second charge.



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5. Two small balls of the bilsan marrow were attached to two light strands adjacent to the air so that the distance between them was 0.06 cm when charged with identical charges repulsed at 40 N.
- **Calculate the amount of charge on each ball.**

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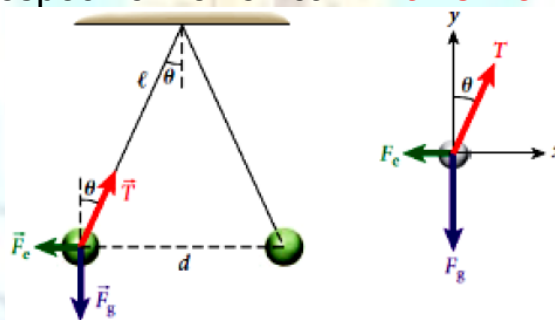
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6. Two identical charged balls hang from the ceiling by insulated ropes of equal length,  $L = 1.50 \text{ m}$  (Figure 1.16). A charge  $q = 25.0 \mu\text{C}$  is applied to each ball. Then the two balls hang at rest, and each supporting rope has an angle of  $25.0^\circ$  with respect to the vertical **What is the mass of each ball?**



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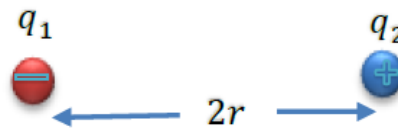
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7. The point charge ( $q_1$ ) in the adjacent figure affects electric force (  $F$  )  
 ➤ How much the force will become if the distance between the two charges becomes (  $r$  ) ?



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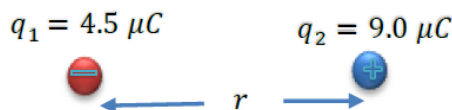
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8. The point charge ( $q_1$ ) in the adjacent figure affected by electric force ( 0.64 N )  
 ➤ How much the force in the charge ( $q_2$ ) ?



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9. The point charge ( $q_1$ ) in the adjacent figure affects electric force (  $F$  )  
 How much force becomes if the distance between the two charges becomes twice ?



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10. The point charge ( $q_2$ ) in the adjacent figure affected by electric force ( 0.4 N )  
How much force becomes if the distance between the two charges becomes (  $3x$  ) ?



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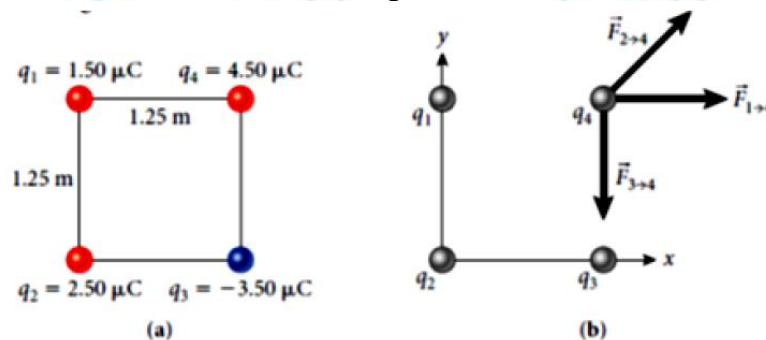
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11. Consider four charges placed at the corners of a square with side length 1.25 m, as shown in Figure .  
Problem :What are the magnitude and direction of the electrostatic force on  $q_4$  resulting from the other three charges?



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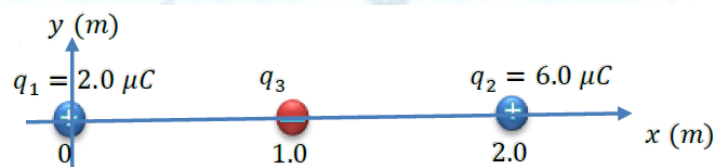
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12. As shown in the figure: Calculate the amount of electric force affecting on the charge  $q_3$ . and determine the direction of the force.



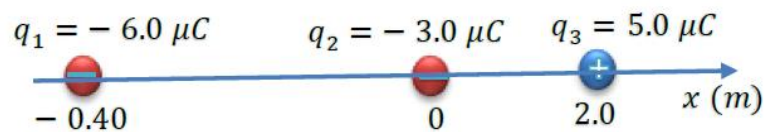
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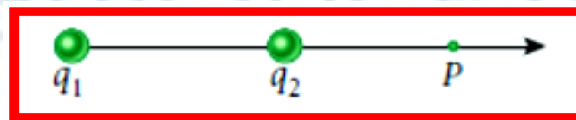
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13. As shown in the figure
- Calculate the amount of electric force affecting on the charge  $q_2$ .
  - and determine the direction of the force.



14. 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.
15. two point charges  $5.0 \mu C$ ,  $6.0 \mu C$ , if the reciprocal force between them (3N),
- What is the distance between the two charges?

16. Two identical charges(  $-6.0 \text{ nC}$  ), placed at the two positions (  $0.0 \text{ cm}$  ,  $0.0 \text{ cm}$  ) , . (  $+3.0 \text{ cm}$  ,  $+3.0 \text{ cm}$  )
- Calculate the net electrostatic force affect on a third charge  $2.5 \text{ nC}$  at the position (  $0.0 \text{ cm}$  ,  $+3.0 \text{ cm}$  )?
- Calculate the angle that the net force makes with an  $x$ -axis

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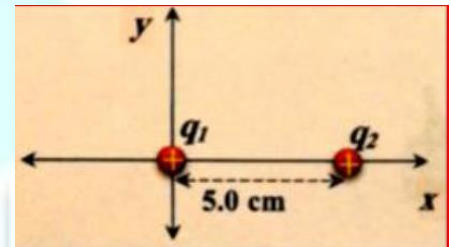
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17. Two point charges  $q_1$  and  $q_2$  were placed on the  $x$ -axis as in the adjacent figure, and when you put a point charge  $q_3$  on the  $x$ -axis The electrostatic force effect on charge  $q_1$  is zero. If  $q_1 = q_2 = Q$  and  $q_3 = -9Q$



- Find the distance between ( $q_3$ ) and the charge ( $q_1$ ).

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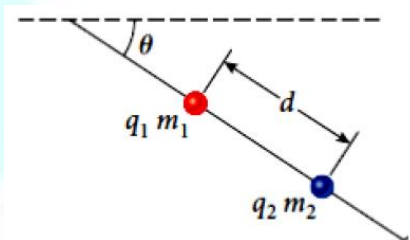
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18. A bead with charge  $q_1 = +1.28 \mu\text{C}$  is fixed in place on an insulating wire that makes an angle of  $\theta = 42.3^\circ$  with respect to the horizontal (Figure). A second bead with charge  $q_2 = -5.06 \mu\text{C}$  slides without friction on the wire. At a distance  $d = 0.380 \text{ m}$  between the beads, the net force on the second bead is zero. What is the mass,  $m_1$ , of the second bead?



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19. 2 balls with equal mass  $m$  and equal positive charge  $q$  at a distance  $r$  from each other as shown in the figure
1. **Derive an expression for charge  $q$ ,** which must be on each ball so that they are in a state of balance between the forces of electrical repulsion and gravitation attraction.
  2. How can double the distance between the two balls affect the value of  $q$ ? Explain your answer
  3. Assume that the mass of each ball is equal to 1.50 kg Determine the charge that each ball needs to remain in equilibrium?
  4. How does the electric force change between two charges if the distance between them is three times greater than they were?

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20. Charles Coulomb measured the deviation of the ball A when the charges of balls A and B were equal and located R from each other. If Ball B makes one third of Ball A's charge, how far should the distance be between the two balls for Ball A to take the previous deviation itself ?

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21. Static electric forces between charges are enormous compared to gravitational forces, but we usually do not feel the static electric forces between us and our surroundings, while we feel the interactions resulting from gravity. Explain .

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22. Calculate the ratio of electric force to gravitational force between the electron and the proton in the hydrogen atom.

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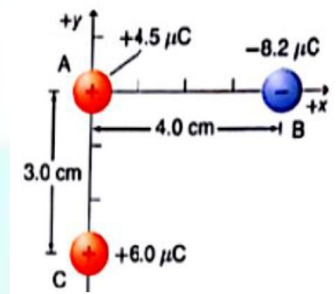
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23. three charged balls placed, as shown in Figure.  
Calculate the net forces acting on the ball B



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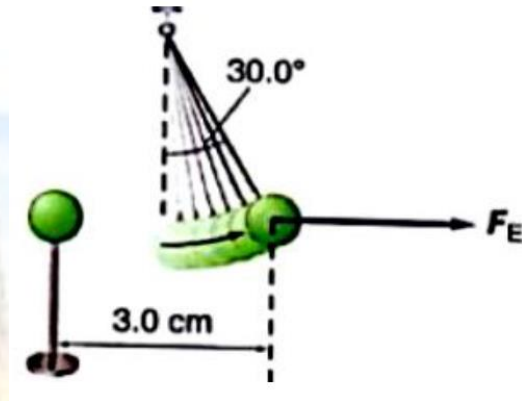
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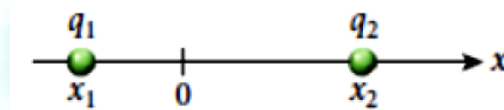
24. The balls in Fig. have masses of 1 g each and their charges are equal. One was suspended with an insulator thread and the other ball was rounded to 3.0 cm from the suspended ball. The hanging ball now hangs, and the thread forms an angle of  $30^\circ$  with the vertical axis. Balanced

Calculate both:

- a) Tensile force in thread  
b) electric force



25. As shown in the figure, charge 1 is  $3.94 \mu\text{C}$  and is located at  $x_1 = -4.7 \text{ m}$ , and charge 2 is  $6.14 \mu\text{C}$  and is at  $x_2 = 12.2 \text{ m}$ . What is the x-coordinate of the point at which the net force on a point charge of  $0.300 \mu\text{C}$  is zero?



## 1.6 Coulomb's Law and Newton's Law of Gravitation

<b>newton's law of gravitation</b>	<b>coulomb's law</b>
$F_g = G \frac{m_1 m_2}{r^2}$	$F_e = k \frac{q_1 q_2}{r^2}$
The inverse square law applies	
The force is inversely proportional to the square of the distance between the two objects	The force is inversely proportional to the square of the distance between the two charges
The gravitational force is directly proportional to the multiplication product of the two masses	The electric force is directly proportional to the multiplication product of the two charges
Only Attraction force Because there is one kind of mass	Attraction or repulsion force Because there are two kind of charges
Too small from electric force	Much greater than the force of gravity

### Multiple-Choice Questions

- For a hydrogen atom of radius  $10^{-10}$  m how does the ratio of the gravitational force between the electron and the proton to the electrostatic force  $F_g/F_e$  change if the atomic radius is doubled?
  - The ratio decreases by a factor of four
  - The ratio decreases by a factor of two
  - The ratio remains unchanged
  - The ratio doubles
  - The ratio increases by a factor of four
- Consider two protons placed near one another with no other objects close by. They would
  - accelerate away from each other
  - remain motionless
  - accelerate toward each other
  - be pulled together at constant speed
  - move away from each other at constant speed

3. A plastic ball of charge  $-5 \text{ nC}$  is held  $2 \text{ cm}$  above a glass bead of charge  $+5 \text{ nC}$  at rest on a table. For the glass bead to leap up to the plastic ball its mass must be

 $57 \mu\text{g}$  $81 \mu\text{g}$  $65 \mu\text{g}$  $98 \mu\text{g}$  $112 \mu\text{g}$ 

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## Additional Exercises

### Multiple-Choice Questions

1. Which one of the following statements *best* explains why tiny bits of paper are attracted to a charged rubber rod?
  - Paper is naturally a positive material.
  - Paper is naturally a negative material.
  - The paper becomes electrically polarized by induction.
  - Rubber and paper always attract each other.
  - The paper acquires a net positive charge by induction.
2. Five styrofoam balls are suspended from insulating threads. Several experiments are performed on the balls; and the following observations are made:

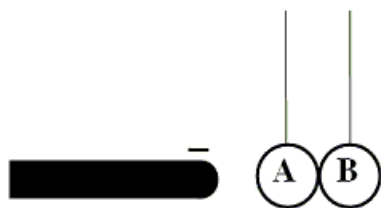


- I. Ball A attracts B and A repels C.
- II. Ball D attracts B and D has no effect on E.
- III. A negatively charged rod attracts both A and E.

What are the charges, *if any*, on *each* ball?

A	B	C	D	E
+	-	+	0	+
+	-	+	0	0
+	0	-	+	0
+	-	+	+	0
-	+	-	0	0

3. Two uncharged conducting spheres, **A** and **B**, are suspended from insulating threads so that they touch each other. While a negatively charged rod is held *near, but not touching* sphere **A**, someone moves ball **B** away from **A**. How will the spheres be charged, *if at all*?



Sphere A	Sphere B
0	+
0	0
+	-
-	+
-	0

4. Each of three objects has a net charge. Objects **A** and **B** attract one another. Objects **B** and **C** also attract one another, but objects **A** and **C** repel one another. Which one of the following table entries is a possible combination of the signs of the net charges on these three objects?

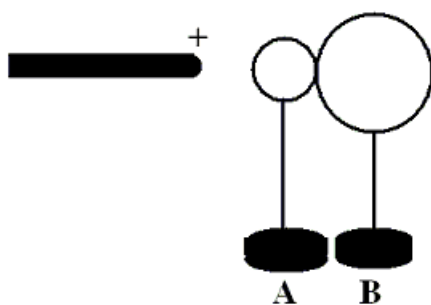
A	B	C
+	+	-
+	-	-
-	-	+
-	+	+
-	+	-

5. A conducting sphere has a net charge of  $-6.4 \times 10^{-17}$  C. What is the approximate number of excess electrons on the sphere?

100	200
300	400
500	

6. Complete the following statement: When an ebonite rod is rubbed with animal fur, the rod becomes negatively charged as
- positive charges are transferred from the fur to the rod.
  - negative charges are transferred from the rod to the fur.
  - negative charges are created on the surface of the rod.
  - negative charges are transferred from the fur to the rod.
  - positive charges are transferred from the rod to the fur.

7. Complete the following statement: When a glass rod is rubbed with silk cloth, the rod becomes positively charged as
- positive charges are transferred from the silk to the rod.
  - negative charges are transferred from the rod to the silk.
  - positive charges are created on the surface of the rod.
  - negative charges are transferred from the silk to the rod.
  - positive charges are transferred from the rod to the silk.
8. A charged conductor is brought near an uncharged insulator. Which one of the following statements is true?
- Both objects will repel each other.
  - Both objects will attract each other.
  - Neither object exerts an electrical force on the other.
  - The objects will repel each other only if the conductor has a negative charge.
  - The objects will attract each other only if the conductor has a positive charge.
9. An aluminum nail has an excess charge of  $+3.2 \mu\text{C}$ . How many electrons must be added to the nail to make it electrically neutral?
- |                       |                      |
|-----------------------|----------------------|
| $2.0 \times 10^{13}$  | $2.0 \times 10^{19}$ |
| $3.2 \times 10^{16}$  | $3.2 \times 10^6$    |
| $5.0 \times 10^{-14}$ |                      |
10. Two uncharged, conducting spheres, **A** and **B**, are held at rest on insulating stands and are in contact. A positively charged rod is brought near sphere **A** as suggested in the figure. While the rod is in place, someone moves sphere **B** away from **A**. How will the spheres be charged, *if at all*?



Sphere A

positive  
negative  
zero  
positive  
negative

Sphere B

positive  
positive  
Zero  
negative  
negative

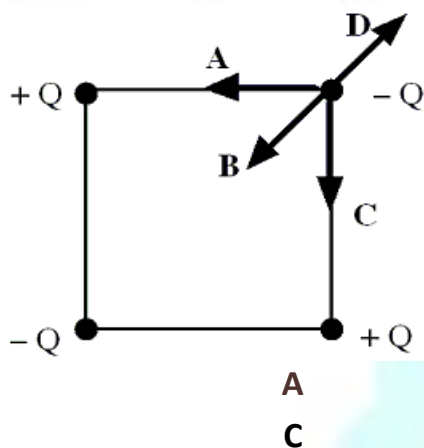
11. Consider three identical metal spheres, **A**, **B**, and **C**. Sphere **A** carries a charge of  $-2.0 \mu\text{C}$ ; sphere **B** carries a charge of  $-6.0 \mu\text{C}$ ; and sphere **C** carries a charge of  $+4.0 \mu\text{C}$ . Spheres **A** and **B** are touched together and then separated. Spheres **B** and **C** are then touched and separated. Does sphere **C** end up with an excess or a deficiency of electrons and how many electrons is it?

deficiency,  $6 \times 10^{13}$ excess,  $3 \times 10^{13}$ excess,  $2 \times 10^{13}$ deficiency,  $3 \times 10^{12}$ 

There is no excess or deficiency of electrons.

12. Two charged particles **A** and **B** are located near one another. Both the *magnitude* and *direction* of the force that particle **A** exerts on particle **B** is *independent* of
- the sign of charge **B**.                      the sign of charge **A**.
- the distance between **A** and **B**.                      the magnitude of the charge on **B**.
- The magnitude and direction of the force are dependent on all of the above choices.

13. Four point charges, each of the same magnitude, with varying signs are arranged at the corners of a square as shown. Which of the arrows labeled **A**, **B**, **C**, and **D** gives the correct direction of the net force that acts on the charge at the upper right corner?



The net force on that charge is zero.

14. Two positive point charges  $Q$  and  $2Q$  are separated by a distance  $R$ . If the charge  $Q$  experiences a force of magnitude  $F$  when the separation is  $R$ , what is the magnitude of the force on the charge  $2Q$  when the separation is  $2R$ ?

 $F/4$  $F/2$  $F$  $2F$  $4F$ 

15. A charge  $Q$  exerts a  $1.2 \text{ N}$  force on another charge  $q$ . If the distance between the charges is doubled, what is the magnitude of the force exerted on  $Q$  by  $q$ ?

 $0.30 \text{ N}$  $0.60 \text{ N}$  $2.4 \text{ N}$  $3.6 \text{ N}$  $4.8 \text{ N}$

16. At what separation will two charges, each of magnitude  $6.0 \mu\text{C}$ , exert a force of  $0.70 \text{ N}$  on each other?

$$1.1 \times 10^{-5} \text{ m}$$

$$0.23 \text{ m}$$

$$0.48 \text{ m}$$

$$0.68 \text{ m}$$

$$1.4 \text{ m}$$

17. One mole of a substance contains  $6.02 \times 10^{23}$  protons and an equal number of electrons. If the protons could somehow be separated from the electrons and placed in very small, individual containers separated by a million meters, what would be the magnitude of the electrostatic force exerted by one box on the other?

$$8.7 \times 10^3 \text{ N}$$

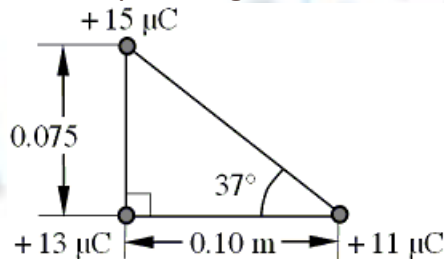
$$9.5 \times 10^4 \text{ N}$$

$$2.2 \times 10^5 \text{ N}$$

$$8.4 \times 10^7 \text{ N}$$

$$1.6 \times 10^8 \text{ N}$$

18. Three charges are positioned as indicated in the figure. What are the horizontal and vertical components of the net force exerted on the  $+15 \mu\text{C}$  charge by the  $+11 \mu\text{C}$  and  $+13 \mu\text{C}$  charges?



horizontal

vertical

$$95 \text{ N}$$

$$310 \text{ N}$$

$$250 \text{ N}$$

$$130 \text{ N}$$

$$76 \text{ N}$$

$$370 \text{ N}$$

$$76 \text{ N}$$

$$310 \text{ N}$$

$$95 \text{ N}$$

$$130 \text{ N}$$

19. A  $-4.0\text{-}\mu\text{C}$  charge is located  $0.45 \text{ m}$  to the left of a  $+6.0\text{-}\mu\text{C}$  charge. What is the magnitude and direction of the electrostatic force on the positive charge?

$$2.2 \text{ N, to the right}$$

$$2.2 \text{ N, to the left}$$

$$1.1 \text{ N, to the right}$$

$$1.1 \text{ N, to the left}$$

$$4.4 \text{ N, to the right}$$

20. Determine the ratio of the electrostatic force to the gravitational force between a proton and an electron,  $F_E/F_G$ . **Note:**  $k = 8.99 \times 10^9 \text{ N}\cdot\text{m}^2/\text{C}^2$ ;  $G = 6.672 \times 10^{-11} \text{ N}\cdot\text{m}^2/\text{kg}^2$ ;  $m_e = 9.109 \times 10^{-31} \text{ kg}$ ; and  $m_p = 1.672 \times 10^{-27} \text{ kg}$ .

$$1.24 \times 10^{23}$$

$$2.52 \times 10^{29}$$

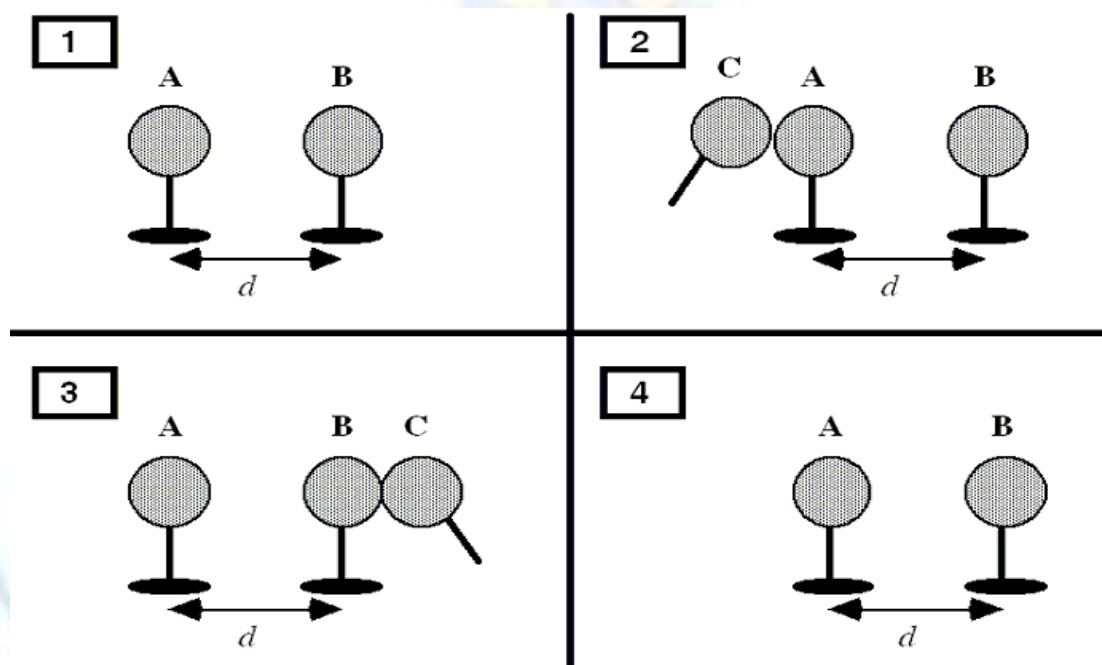
$$1.15 \times 10^{31}$$

$$2.26 \times 10^{39}$$

$$1.42 \times 10^{58}$$



21. In Frame 1, two identical conducting spheres, **A** and **B**, carry equal amounts of excess charge that have the same sign. The spheres are separated by a distance  $d$ ; and sphere **A** exerts an electrostatic force on sphere **B** that has a magnitude  $F$ . A third sphere, **C**, which is handled only by an insulating rod, is introduced in Frame 2. Sphere **C** is identical to **A** and **B** except that it is *initially uncharged*. Sphere **C** is touched first to sphere **A**, in Frame 2, and then to sphere **B**, in Frame 3, and is finally removed in Frame 4.



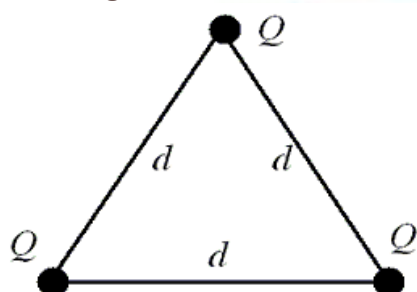
Determine the magnitude of the electrostatic force that sphere **A** exerts on sphere **B** in Frame 4.

$$\begin{array}{l} F/2 \\ 3F/4 \end{array}$$

$$\begin{array}{l} F/3 \\ 3F/8 \end{array}$$

zero

22. Three identical point charges,  $Q$ , are placed at the vertices of an equilateral triangle as shown in the figure. The length of each side of the triangle is  $d$ . Determine the magnitude and direction of the total electrostatic force on the charge at the top of the triangle.

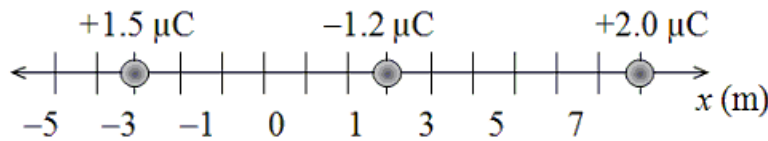


directed upward  
directed upward

directed downward  
directed downward

zero

23. Three charges are located along the x axis as shown in the drawing. The mass of the  $-1.2 \mu\text{C}$  is  $4.0 \times 10^{-9} \text{ kg}$ . Determine the magnitude and direction of the acceleration of the  $-1.2 \mu\text{C}$  charge when it is allowed to move if the other two charges remain fixed.



$$2 \times 10^5 \text{ m/s}^2, \text{ to the right}$$

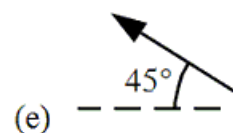
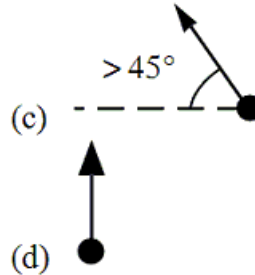
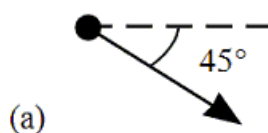
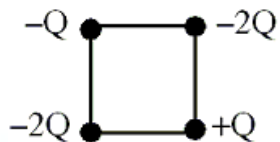
$$1 \times 10^5 \text{ m/s}^2, \text{ to the left}$$

$$7 \times 10^4 \text{ m/s}^2, \text{ to the right}$$

$$3 \times 10^5 \text{ m/s}^2, \text{ to the left}$$

$$4 \times 10^6 \text{ m/s}^2, \text{ to the right}$$

24. Four point charges are held fixed at the corners of a square as shown in the figure. Which of the five arrows shown below most accurately shows the direction of the net force on the charge  $-Q$  due to the presence of the three other charges?



a

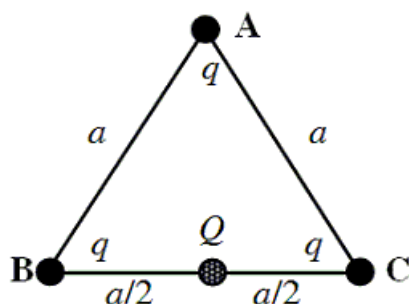
b

c

d

e

25. The figure shows an equilateral triangle **ABC**. A positive point charge  $+q$  is located at each of the three vertices **A**, **B**, and **C**. Each side of the triangle is of length  $a$ . A point charge  $Q$  (that may be positive or negative) is placed at the mid-point between **B** and **C**.



Is it possible to choose the value of  $Q$  (that is non-zero) such that the force on  $Q$  is zero? Explain why or why not.

Yes, because the forces on  $Q$  are vectors and three vectors can add to zero.

No, because the forces on  $Q$  are vectors and three vectors can never add to zero.

Yes, because the electric force at the mid-point between **B** and **C** is zero whether a charge is placed there or not.

No, because the forces on  $Q$  due to the charges at **B** and **C** point in the same direction.

No, because a fourth charge would be needed to cancel the force on  $Q$  due to the charge at **A**.

26. Is it possible for two negative charges to attract each other?

Yes, they always attract.

Yes, they will attract if they are close enough.

Yes, they will attract if one carries a larger charge than the other.

No, they will never attract.

27. Is it possible for a positive and a negative charge to attract each other?

Yes, they always attract.

Yes, they will attract if they are close enough.

Yes, they will attract if one carries a larger charge than the other.

No, they will never attract.

28. A glass rod is rubbed with a piece of silk. During the process the glass rod acquires a positive charge and the silk

acquires a positive charge also.

acquires a negative charge.

remains neutral.

could either be positively charged or negatively charged. It depends on how hard the rod was rubbed.

29. A proton carries a

positive charge

negative charge

neutral charge

variable charge

30. An atom has more electrons than protons. The atom is

a positive ion

a superconductor

a negative ion

impossible

31. Materials in which the electrons are bound very tightly to the nuclei are referred to as

insulators.

semiconductors.

conductors.

superconductors.

32. Materials in which the electrons are bound very loosely to the nuclei and can move about freely within the material are referred to as  
insulators. conductors.  
semiconductors. superconductors.
33. A negatively charged rod is brought near one end of an uncharged metal bar. The end of the metal bar farthest from the charged rod will be charged  
positive negative  
neutral none of the given answers
34. Sphere A carries a net positive charge, and sphere B is neutral. They are placed near each other on an insulated table. Sphere B is briefly touched with a wire that is grounded. Which statement is correct?  
Sphere B remains neutral  
Sphere B is now positively charged  
Sphere B is now negatively charged  
The charge on sphere B cannot be determined without additional information
35. How can a negatively charged rod charge an electroscope positively?  
by conduction by induction  
by deduction It cannot
36. An originally neutral electroscope is briefly touched with a positively charged glass rod. The electroscope  
remains neutral  
becomes negatively charged  
becomes positively charged  
could become either positively or negatively charged, depending on the time of contact
37. An originally neutral electroscope is grounded briefly while a positively charged glass rod is held near it. After the glass rod is removed, the electroscope  
remains neutral  
is negatively charged  
is positively charged  
could be either positively or negatively charged, depending on how long the contact with ground lasted

38. A positive object touches a neutral electroscope, and the leaves separate. Then a negative object is brought near the electroscope, but does not touch it. What happens to the leaves?
- They separate further  
They move closer together  
They are unaffected  
cannot be determined without further information
39. A large negatively charged object is placed on an insulated table. A neutral metallic ball rolls straight toward the object, but stops before it touches it. A second neutral metallic ball rolls along the path followed by the first ball, strikes the first ball, and stops. The first ball rolls forward, but does not touch the negative object. At no time does either ball touch the negative object. What is the final charge on each ball?
- The first ball is positive, and the second ball is negative  
The first ball is negative, and the second ball is positive  
Both balls remain neutral  
Both balls are positive
40. Charge is
- quantized  
invariant  
conserved  
all of the given answers
41. What are the units of the Coulomb constant  $k$ , which appears in Coulomb's law?
- $\text{N.m/C}$   
 $\text{N}^2.\text{m/C}^2$   
 $\text{N/C}$   
 $\text{N.m}^2/\text{C}^2$
42. Two charged objects are separated by a distance  $d$ . The first charge is larger in magnitude than the second charge
- The first charge exerts a larger force on the second charge  
The second charge exerts a larger force on the first charge  
The charges exert forces on each other equal in magnitude and opposite in direction  
The charges exert forces on each other equal in magnitude and pointing in the same direction
43. Sphere A carries a net charge and sphere B is neutral. They are placed near each other on an insulated table. Which statement best describes the electrostatic force between them?
- There is no force between them since one is neutral  
There is a force of repulsion between them  
There is a force of attraction between them  
The force is attractive if A is charged positively and repulsive if A is charged negatively

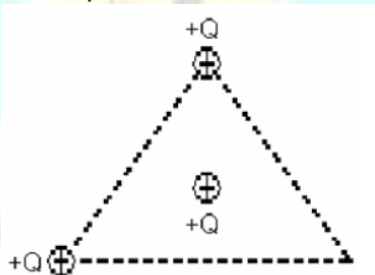


44. Two charged objects attract each other with a certain force. If the charges on both objects are doubled with no change in separation, the force between them  
 quadruples  
 doubles  
 halves  
 increases, but we can't say how much without knowing the distance between them
45. Two charges are separated by a distance  $d$  and exert mutual attractive forces of  $F$  on each other. If the charges are separated by a distance of  $d/3$ , what are the new mutual forces?
- |       |       |
|-------|-------|
| $F/9$ | $F/3$ |
| $3F$  | $9F$  |
46. Two charged objects attract each other with a force  $F$ . What happens to the force between them if one charge is doubled, the other charge is tripled, and the separation distance between their centers is reduced to one-fourth its original value? The force is now equal to
- |          |       |
|----------|-------|
| $16F$    | $24F$ |
| $(3/8)F$ | $96F$ |
47. An electron and a proton are separated by a distance of 1.0 m. What happens to the magnitude of the force on the proton if a second electron is placed next to the first electron?
- |                    |                 |
|--------------------|-----------------|
| It quadruples      | It doubles      |
| It will not change | It goes to zero |
48. An electron and a proton are separated by a distance of 1.0 m. What happens to the magnitude of the force on the first electron if a second electron is placed next to the proton?
- |                       |                    |
|-----------------------|--------------------|
| It doubles            | It does not change |
| It is reduced to half | It becomes zero    |
49. An electron and a proton are separated by a distance of 1.0 m. What happens to the size of the force on the proton if the electron is moved 0.50 m closer to the proton?
- It increases to 4 times its original value  
 It increases to 2 times its original value  
 It decreases to one-half its original value  
 It decreases to one-fourth its original value

50. A point charge of  $+Q$  is placed at the center of a square. When a second point charge of  $-Q$  is placed at one of the square's corners, it is observed that an electrostatic force of  $2.0 \text{ N}$  acts on the positive charge at the square's center. Now, identical charges of  $-Q$  are placed at the other three corners of the square. What is the magnitude of the net electrostatic force acting on the positive charge at the center of the square?

zero  
 $4.0 \text{ N}$   
 $2.8 \text{ N}$   
 $8.0 \text{ N}$

51. A point charge of  $+Q$  is placed at the centroid of an equilateral triangle. When a second charge of  $+Q$  is placed at one of the triangle's vertices, an electrostatic force of  $4.0 \text{ N}$  acts on it. What is the magnitude of the force that acts on the center charge due to a third charge of  $+Q$  placed at one of the other vertices?



zero  
 $8.0 \text{ N}$   
 $4.0 \text{ N}$   
 $16 \text{ N}$

52. A coulomb is the same as:

an ampere/second  
 an ampere/meter<sup>2</sup>  
 half an ampere·second<sup>2</sup>  
 an ampere second  
 a newton·meter<sup>2</sup>

53. A kiloampere·hour is a unit of:

current  
 power  
 energy  
 charge per time  
 charge

54. The magnitude of the charge on an electron is approximately:

$10^{23} \text{ C}$   
 $10^{19} \text{ C}$   
 $10^{-23} \text{ C}$   
 $10^{-19} \text{ C}$   
 $10^9 \text{ C}$

55. The total negative charge on the electrons in 1 mol of helium (atomic number 2, molar mass 4) is:
- $4.8 \times 10^4 \text{ C}$   $9.6 \times 10^4 \text{ C}$   
 $1.9 \times 10^5 \text{ C}$   $3.8 \times 10^5 \text{ C}$   
 $7.7 \times 10^5 \text{ C}$
56. The total negative charge on the electrons in 1 kg of helium (atomic number 2, molar mass 4) is:
- $48 \text{ C}$   $2.4 \times 10^7 \text{ C}$   
 $4.8 \times 10^7 \text{ C}$   $9.6 \times 10^8 \text{ C}$   
 $1.9 \times 10^8 \text{ C}$
57. A wire carries a steady current of 2 A. The charge that passes a cross section in 2 s is:
- $3.2 \times 10^{-19} \text{ C}$   $6.4 \times 10^{-19} \text{ C}$   
 $1 \text{ C}$   $2 \text{ C}$   
 $4 \text{ C}$
58. A wire contains a steady current of 2 A. The number of electrons that pass a cross section in 2 s is:
- $2$   $4$   
 $6.3 \times 10^{18}$   $1.3 \times 10^{19}$   
 $2.5 \times 10^{19}$
59. The charge on a glass rod that has been rubbed with silk is called positive:
- by arbitrary convention  
 so that the proton charge will be positive  
 to conform to the conventions adopted for G and m in Newton's law of gravitation  
 because like charges repel  
 because glass is an insulator
60. To make an uncharged object have a negative charge we must:
- add some atoms remove some atoms  
 add some electrons remove some electrons  
 write down a negative sign
61. To make an uncharged object have a positive charge:
- remove some neutrons add some neutrons  
 add some electrons remove some electrons  
 heat it to cause a change of phase

62. When a hard rubber rod is given a negative charge by rubbing it with wool:

positive charges are transferred from rod to wool  
 negative charges are transferred from rod to wool  
 positive charges are transferred from wool to rod  
 negative charges are transferred from wool to rod  
 negative charges are created and stored on the rod

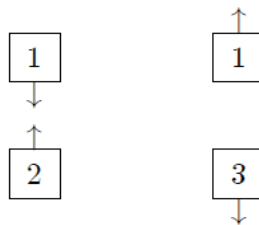
63. An electrical insulator is a material:

containing no electrons  
 through which electrons do not flow easily  
 that has more electrons than protons on its surface  
 cannot be a pure chemical element  
 must be a crystal

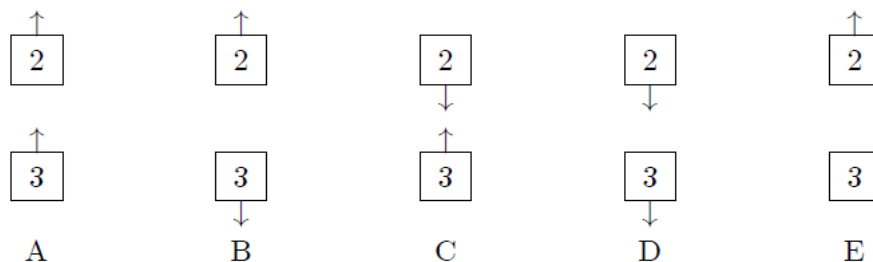
64. A conductor is distinguished from an insulator with the same number of atoms by the number of:

nearly free atoms      electrons  
 nearly free electrons      protons  
 molecules

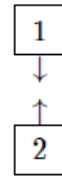
65. The diagram shows two pairs of heavily charged plastic cubes. Cubes 1 and 2 attract each other and cubes 1 and 3 repel each other.



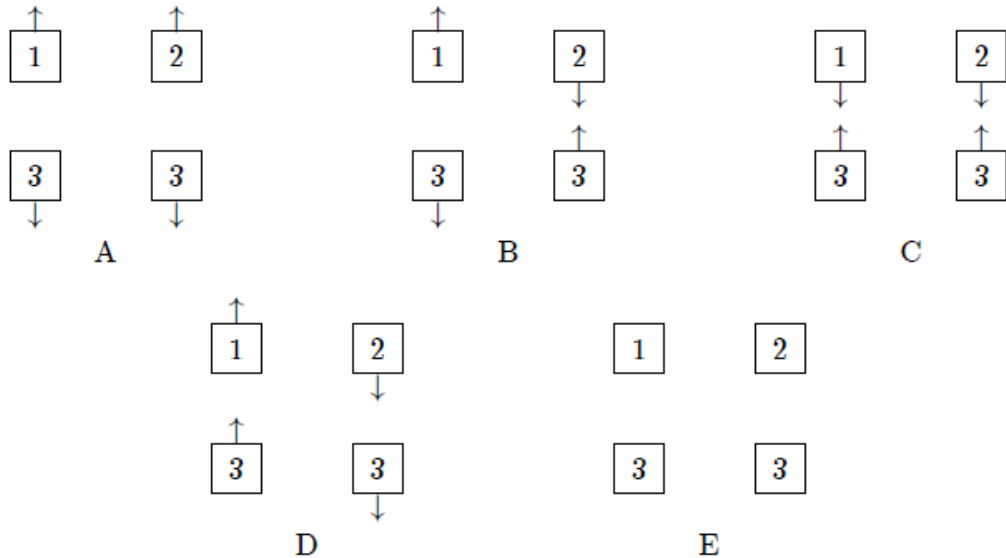
Which of the following illustrates the forces of cube 2 on cube 3 and cube 3 on cube 2?



66. The diagram shows a pair of heavily charged plastic cubes that attract each other.



Cube 3 is a conductor and is uncharged. Which of the following illustrates the forces between cubes 1 and 3 and between cubes 2 and 3?

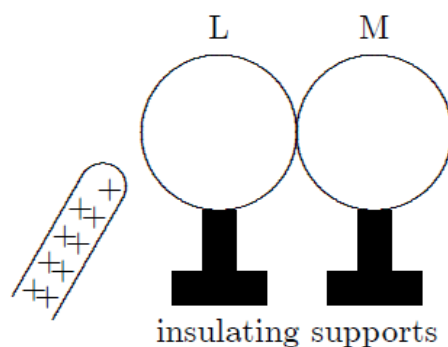


67. A neutral metal ball is suspended by a string. A positively charged insulating rod is placed near the ball, which is observed to be attracted to the rod. This is because:
- the ball becomes positively charged by induction
  - the ball becomes negatively charged by induction
  - the number of electrons in the ball is more than the number in the rod
  - the string is not a perfect insulator
  - there is a rearrangement of the electrons in the ball
68. A positively charged insulating rod is brought close to an object that is suspended by a string. If the object is attracted toward the rod we can conclude:
- the object is positively charged
  - the object is negatively charged
  - the object is an insulator
  - the object is a conductor
  - none of the above



69. A positively charged insulating rod is brought close to an object that is suspended by a string. If the object is repelled away from the rod we can conclude:
- the object is positively charged
  - the object is negatively charged
  - the object is an insulator
  - the object is a conductor
  - none of the above

70. 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:



- both spheres are neutral
  - both spheres are positive
  - both spheres are negative
  - L is negative and M is positive
  - L is positive and M is negative
71. A positively charged metal sphere A is brought into contact with an uncharged metal sphere B. As a result:
- both spheres are positively charged
  - A is positively charged and B is neutral
  - A is positively charged and B is negatively charged
  - A is neutral and B is positively charged
  - A is neutral and B is negatively charged
72. The leaves of a positively charged electroscope diverge more when an object is brought near the knob of the electroscope. The object must be:
- a conductor
  - an insulator
  - positively charged
  - negatively charged
  - uncharged
73. A negatively charged rubber rod is brought near the knob of a positively charged electroscope. The result is that:
- the electroscope leaves will move farther apart
  - the rod will lose its charge
  - the electroscope leaves will tend to collapse
  - the electroscope will become discharged
  - nothing noticeable will happen

74. An electroscope is charged by induction using a glass rod that has been made positive by rubbing it with silk. The electroscope leaves:

gain electrons	gain protons
lose electrons	lose protons
gain an equal number of protons and electrons	

75. Consider the following procedural steps:

1. ground an electroscope
2. remove the ground from the electroscope
3. touch a charged rod to the electroscope
4. bring a charged rod near, but not touching, the electroscope
5. remove the charged rod

To charge an electroscope by induction, use the sequence:

1, 4, 5, 2	4, 1, 2, 5
3, 1, 2, 5	4, 1, 5, 2
3, 5	

76. A small object has charge  $Q$ . Charge  $q$  is removed from it and placed on a second small object. The two objects are placed 1m apart. For the force that each object exerts on the other to be a maximum.  $q$  should be:

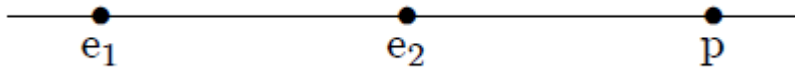
$2Q$	$Q$
$Q/2$	$Q/4$
0	

77. Two small charged objects attract each other with a force  $F$  when separated by a distance  $d$ . If the charge on each object is reduced to one-fourth of its original value and the distance between them is reduced to  $d/2$  the force becomes:

$F/16$	$F/8$
$F/4$	$F/2$
$F$	

78. Two identical conducting spheres A and B carry equal charge. They are separated by a distance much larger than their diameters. A third identical conducting sphere C is uncharged. Sphere C is first touched to A, then to B, and finally removed. As a result, the electrostatic force between A and B, which was originally  $F$ , becomes:

$F/2$	$F/4$
$3F/8$	$F/16$
0	

79. Two particles, X and Y, are 4m apart. X has a charge of  $2Q$  and Y has a charge of  $Q$ . The force of X on Y:
- has twice the magnitude of the force of Y on X
  - has half the magnitude of the force of Y on X
  - has four times the magnitude of the force of Y on X
  - has one-fourth the magnitude of the force of Y on X
  - has the same magnitude as the force of Y on X
80. The units of  $1/4\pi\epsilon_0$  are:
- $N^2C^2$
  - $N^2 \cdot m^2/C^2$
  - $m^2/C^2$
  - $N \cdot m/C$
  - $N \cdot m^2/C^2$
81. A 5.0-C charge is 10m from a  $-2.0$ -C charge. The electrostatic force on the positive charge is:
- $9.0 \times 10^8$  N toward the negative charge
  - $9.0 \times 10^8$  N away from the negative charge
  - $9.0 \times 10^9$  N toward the negative charge
  - $9.0 \times 10^9$  N away from the negative charge
  - none of these
82. Two identical charges, 2.0m apart, exert forces of magnitude 4.0N on each other. The value of either charge is:
- $1.8 \times 10^{-9}$  C
  - $4.2 \times 10^{-5}$  C
  - $2.1 \times 10^{-5}$  C
  - $1.9 \times 10^5$  C
  - $3.8 \times 10^5$  C
83. Two electrons ( $e_1$  and  $e_2$ ) and a proton ( $p$ ) lie on a straight line, as shown. The directions of the force of  $e_2$  on  $e_1$ , the force of  $p$  on  $e_1$ , and the total force on  $e_1$ , respectively, are:
- 
- $e_1$                        $e_2$                        $p$
- $\rightarrow, \leftarrow, \rightarrow$                        $\leftarrow, \rightarrow, \rightarrow$   
 $\rightarrow, \leftarrow, \leftarrow$                        $\leftarrow, \rightarrow, \leftarrow$   
 $\leftarrow, \leftarrow, \leftarrow$

84. Two protons ( $p_1$  and  $p_2$ ) and an electron ( $e$ ) lie on a straight line, as shown. The directions of the force of  $p_1$  on  $e$ , the force of  $p_2$  on  $e$ , and the total force on  $e$ , respectively, are:



85. Two particles have charges  $Q$  and  $-Q$  (equal magnitude and opposite sign). For a net force of zero to be exerted on a third charge it must be placed:  
midway between  $Q$  and  $-Q$

on the perpendicular bisector of the line joining  $Q$  and  $-Q$ , but not on that line itself  
on the line joining  $Q$  and  $-Q$ , to the side of  $Q$  opposite  $-Q$   
on the line joining  $Q$  and  $-Q$ , to the side of  $-Q$  opposite  $Q$   
at none of these places (there is no place)

86. Particles 1, with charge  $q_1$ , and 2, with charge  $q_2$ , are on the  $x$  axis, with particle 1 at  $x = a$ , and particle 2 at  $x = -2a$ . For the net force on a third charged particle, at the origin, to be zero,  $q_1$  and  $q_2$  must be related by  $q_2 =$ :

$2q_1$	$4q_1$
$-2q_1$	$-4q_1$
$-q_1/4$	

87. Two particles A and B have identical charge  $Q$ . For a net force of zero to be exerted on a third charged particle it must be placed:

midway between A and B  
on the perpendicular bisector of the line joining A and B but away from the line  
on the line joining A and B, not between the particles  
on the line joining A and B, closer to one of them than the other  
at none of these places (there is no place)

88. A particle with charge  $2\text{-}\mu\text{C}$  is placed at the origin, an identical particle, with the same charge, is placed  $2\text{m}$  from the origin on the  $x$  axis, and a third identical particle, with the same charge, is placed  $2\text{m}$  from the origin on the  $y$  axis. The magnitude of the force on the particle at the origin is:

$9.0 \times 10^{-3} \text{ N}$	$6.4 \times 10^{-3} \text{ N}$
$1.3 \times 10^{-2} \text{ N}$	$1.8 \times 10^{-2} \text{ N}$
$3.6 \times 10^{-2} \text{ N}$	

89. Charge  $Q$  is spread uniformly along the circumference of a circle of radius  $R$ . A point particle with charge  $q$  is placed at the center of this circle. The total force exerted on the particle can be calculated by Coulomb's law:

just use  $R$  for the distance

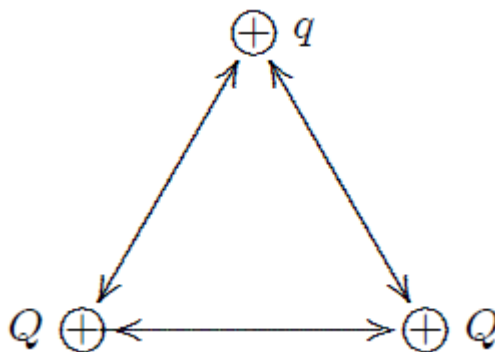
just use  $2R$  for the distance

just use  $2\pi R$  for the distance

the result of the calculation is zero

none of the above

90. Two particles, each with charge  $Q$ , and a third particle, with charge  $q$ , are placed at the vertices of an equilateral triangle as shown. The total force on the particle with charge  $q$  is:



parallel to the left side of the triangle

parallel to the right side of the triangle

parallel to the bottom side of the triangle

perpendicular to the bottom side of the triangle

perpendicular to the left side of the triangle

91. A particle with charge  $Q$  is on the  $y$  axis a distance  $a$  from the origin and a particle with charge  $q$  is on the  $x$  axis a distance  $d$  from the origin. The value of  $d$  for which the  $x$  component of the force on the second particle is the greatest is:

0

$a$

$\sqrt{2}a$

$a/2$

$a/\sqrt{2}$

92. In the Rutherford model of the hydrogen atom, a proton (mass  $M$ , charge  $Q$ ) is the nucleus and an electron (mass  $m$ , charge  $q$ ) moves around the proton in a circle of radius  $r$ . Let  $k$  denote the Coulomb force constant ( $1/4\pi\epsilon_0$ ) and  $G$  the universal gravitational constant. The ratio of the electrostatic force to the gravitational force between electron and proton is:

$kQq/GMmr^2$

$GQq/kMm$

$kMm/GQq$

$GMm/kQq$

$kQq/GMm$



93. A particle with a charge of  $5 \times 10^{-6}$  C and a mass of 20 g moves uniformly with a speed of 7m/s in a circular orbit around a stationary particle with a charge of  $-5 \times 10^{-6}$  C. The radius of the orbit is:
- 0 0.23m  
0.62m 1.6  
4.4m
94. Charge is distributed uniformly on the surface of a spherical balloon (an insulator). A point particle with charge q is inside. The electrical force on the particle is greatest when:
- it is near the inside surface of the balloon  
it is at the center of the balloon  
it is halfway between the balloon center and the inside surface  
it is anywhere inside (the force is same everywhere and is not zero)  
it is anywhere inside (the force is zero everywhere)
95. Charge is distributed on the surface of a spherical conducting shell. A point particle with charge q is inside. If polarization effects are negligible the electrical force on the particle is greatest when:
- it is near the inside surface of the balloon  
it is at the center of the balloon  
it is halfway between the balloon center and the inside surface  
it is anywhere inside (the force is same everywhere and is not zero)  
it is anywhere inside (the force is zero everywhere)
96. Which one of these systems has the most negative charge?
- 2 electrons 3 electrons and 1 proton  
5 electrons and 5 protons N electrons and N-3 protons  
1 electron
97. 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:
- Attract each other  
Exert no net electrostatic force on each other  
Repel each other  
Doing any of these things depending on the sign of the charge on the one sphere
98. If an object is charged with a negative electrical charge, its charge can be equivalent to a charge:
- + 3 e - 3 e  
+ 1.6 e - 1.6 e

99. The electric charge (+ 2 C) is equivalent to a charge:

1.25x 10<sup>19</sup> protons  
2 electrons

1.25x 10<sup>19</sup> electrons  
2 protons

### Exercises

1. State the law of conservation of electric charge.

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2. An object with ( − 1.28 n C ) net charge . What is The number of electrons it loses or acquires to become its charge ( + 2.00 n C )  
Is the object lose or gain electrons ?

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3. Two conductive and identical balls . one of them has ( + 7.90 n C ) net charge and the other has ( + 1.50 n C ) The two balls touched and then separated

- What charge both of them after touching ?
- Calculate the number of electrons that moved ?

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4. Whichever is considered to be evidence that one object is charged . attracted to another object or repulsion ? Explain your answer

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5. The rounded rod is charged to a small plastic balls drawn some balls for the rod then rushed away in different directions after touching the rod. Explain why?

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