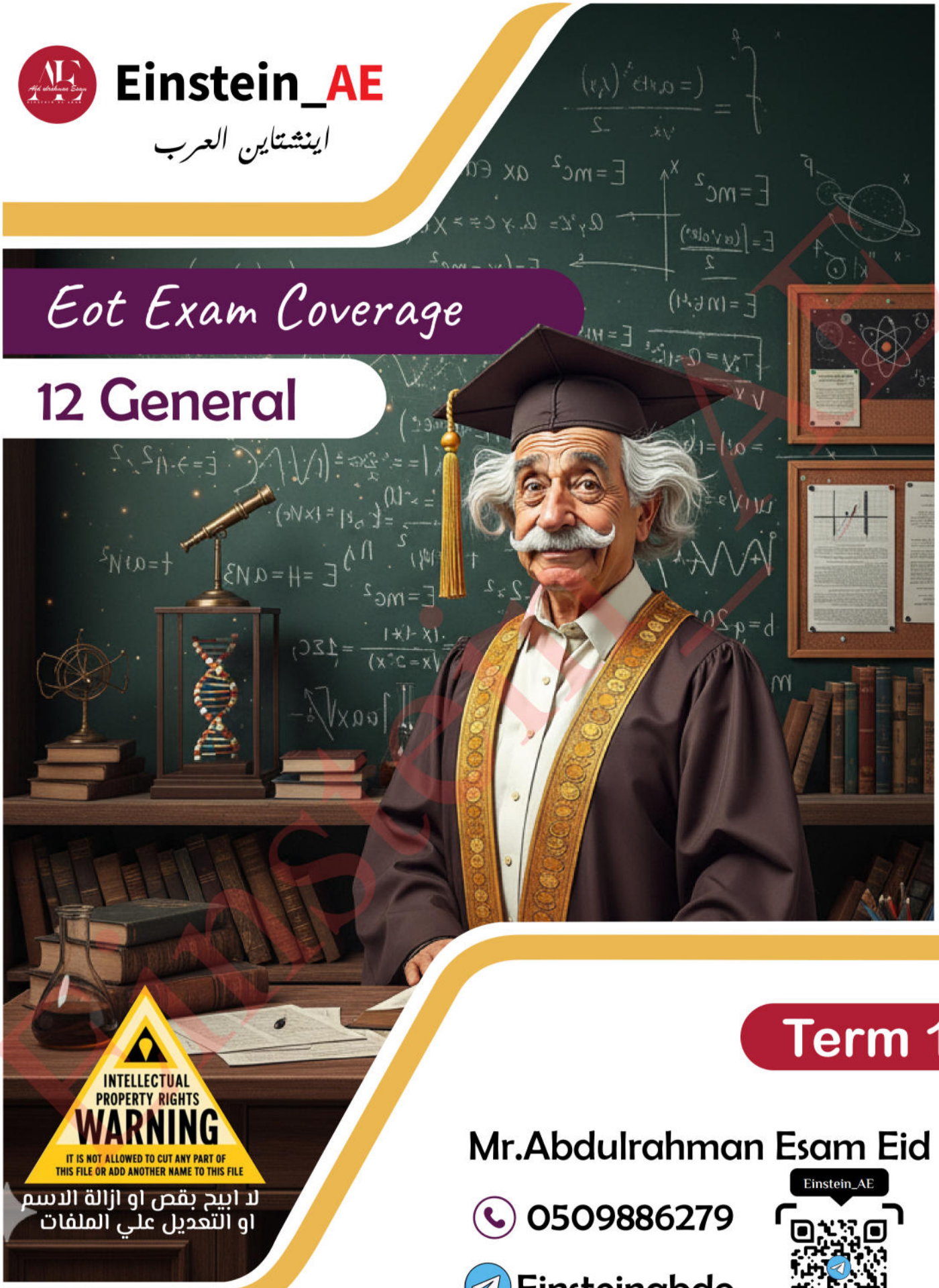
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Eot Exam Coverage

12 General



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Term 1

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Learning Outcomes

1. State the magnitude of the elementary charge in coulombs (C) and that the charges are quantized.
2. Conduct an experiment to demonstrate charging of objects and the electrostatic force between charged objects.
3. Describe how charge is separated on a neutral object due to another charged object.
4. Investigate the electrostatic force between charged objects, and state/demonstrate that unlike charges attract and like charges repel.
5. Understand the mechanism of grounding and how it is used in the process of charging objects.
6. Explain the process of charging by rubbing, conduction, induction.
7. Distinguish between electrical conductors and insulators giving typical examples.
8. Use vector addition to calculate the net force on a charge due to other point charges.
9. State and apply Coulomb's law to charges separated by finite distances.
10. Demonstrate an understanding that the work performed in moving a charged particle in an electric field can result in the particle gaining electric potential energy or kinetic energy or both.
11. Identify the direction of an electric field as the direction of the force on a positive test charge placed in the field. Use vector addition to calculate the net force on a charge due to other point charges.
12. Describe the electrostatic potential energy lost or gained in moving a charge between two points in a known electric field.
13. Derive the electric field strength due to a point charge using Coulomb's law and the definition of electric field strength, to calculate the electric field strength at a point close to a single point charge.
14. Sketch the uniform electric field lines between two parallel plates and explain how the electric potential varies between the plates.
15. Describe how a lightning rod works. State some of the applications of electrostatic forces.
16. Sketch the electric field lines to model the electric field around single point charges (positive or negative) and for a pair of electric charges.
17. Define electric potential difference as the ratio of the work needed to move a charge to the magnitude of that charge, to understand the relationship between work, electric potential and charge.
18. Describe Millikan's oil-drop experiment and explain how it confirms that charge exists in discrete amounts, which are integral multiples of the elementary charge.
19. Explain how electric charges are distributed on a spherical conductor, and the effect of this on both the electric field and the electric potential.
    Explain the meaning of equipotential.
20. Define capacitance as the ratio of the net charge on one plate of a capacitor to the potential difference across the plates, and it is measured in Farads.
    Apply the equation for capacitance to solve numerical problems.

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State the magnitude of the elementary charge in coulombs (C) and that the charges are quantized.

The **magnitude of the elementary charge** is:

$$e = 1.602 \times 10^{-19}\ \text{C}$$

This is the charge of a **single proton** (positive) or **single electron** (negative).

Why Charge Is Quantized

Electric charge is **quantized**, meaning it always exists in **discrete units**—specifically, integer multiples of the elementary charge. You cannot have a charge of, say, half an electron's charge. This is similar to how money works: you can pay in whole cents, but not in fractions of a cent.

So, any observable charge Qmust satisfy:

$$Q = n \cdot e$$

Where:

- $Q$is the total charge,
- $n$is an integer (positive or negative),
- $e$is the elementary charge.

the net charge on an object can be 2e, -5e, 7e, or even -3157e.

The net charge cannot be a fractional charge, such as0.5e, -23.7e, 6.2e, or -31,524.6e.

Which of the following represents the elementary charge?

ⓐ 1.6×10^{-9} C ⓑ Charge of one proton ⓒ 1.6×10^{19} C ⓓ Charge of 1.6 electron

Which of the following can be correct about the charge equals +2 C

ⓐ 2 electrons ⓑ $1.25 \times 10^{+19}$ protons ⓒ $1.25 \times 10^{+19}$ electrons ⓓ 2 protons

How many electrons have been removed from a positively charged electroscope if it has a net charge of 7.5×10^{-11} C?

ⓐ 7.5×10^{-11}**electrons** ⓑ 1.2×10^{8} **electrons** ⓒ 2.1×10^{-9} **electrons** ⓓ 4.7×10^{8} **electrons**

Which of the following is incorrect amount of charge:

ⓐ8.0×10^{-20} C ⓑ1.6×10^{-16} C ⓒ 1.6×10^{-19} C ⓓ 6.4×10^{-19} C

To verify the principle of charge quantization reached by the scientist "Robert Millikan" which states:

"The net charge of an object cannot be a fractional of the basic charge".

A researcher conducted an experiment similar to Millikan's experiment, and the researcher claimed that he obtained the following values for the electric charges carried by charged oil droplets.

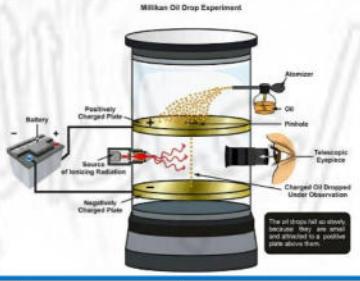
Which of these values can be scientifically accepted?

ⓐ $9.0 \times 10^{-19}\ C$

ⓑ $9.0 \times 10^{-18}\ C$

ⓒ $9.6 \times 10^{-18}\ C$

ⓓ $1.3 \times 10^{-18}\ C$

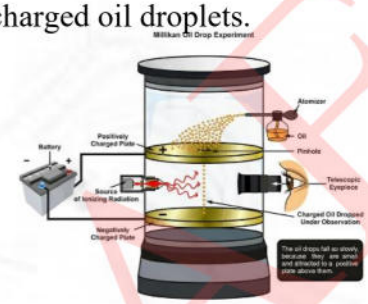


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To verify the principle of charge quantization reached by the scientist "Robert Millikan" which states:
"The net charge of an object cannot be a fractional of the basic charge".
A researcher conducted an experiment similar to Millikan's experiment and claimed that he obtained the following values for the electric charges carried by charged oil droplets.
Which of these values cannot be scientifically accepted?

ⓐ 3.2×10^{-19} C
ⓑ 4.8×10^{-19} C
ⓒ 5.0×10^{-19} C
ⓓ 6.4×10^{-19} C



Suppose that Millikan in his Oil-Drop Experiment observed an oil drop carrying **three elementary units of charge**. What would be the **net charge** on this oil drop?

ⓐ 4.8×10^{-19} C
ⓑ 1.6×10^{-19} C
ⓒ -1.6×10^{-19} C
ⓓ -4.8×10^{-19} C

Conduct an experiment to demonstrate charging of objects and the electrostatic force between charged objects.

the electric field between two plates using the formula

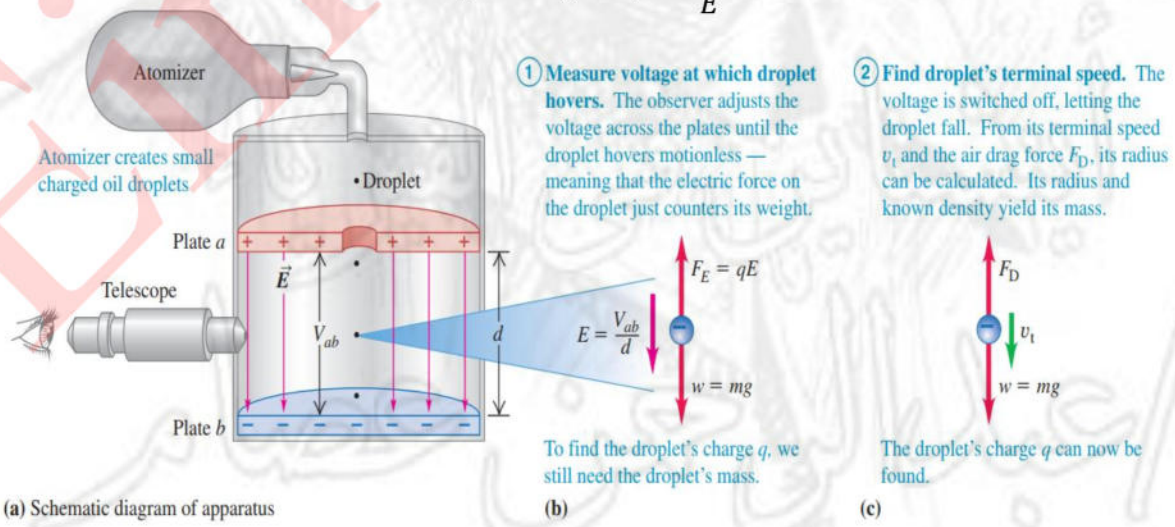
$$E = \frac{\Delta V}{d}$$

where:

- ΔV is the potential difference between the plates
- d is the distance between them

Weight of the Drop (mg): He measured how fast the drop fell when the electric field was off to determine its weight using terminal velocity and air resistance.
Charge (q): When the drop was suspended (balanced between gravity and electric force), he used

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



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An oil drop weighs 1.9×10^{-15} N. You suspend it in an electric field of 6.0×10^{3} N/C. What is the net charge on the drop? How many excess electrons does it carry?

$$F_g = E_q$$

$$q = \frac{F_g}{E} = \frac{1.9\times10^{-15}\,\text{N}}{6.0\times10^{3}\ \text{N/C}}$$

$$= 3.2\times10^{-19}\ \text{C}$$

$$\#\ \text{electrons} = \frac{q}{q_e} = \frac{3.2\times10^{-19}\,\text{C}}{1.602\times10^{-19}\,\text{C}} = 2$$

An oil drop carries one excess electron and weighs 6.4×10^{-15} N. What electric field strength do you need to suspend the drop so it is motionless?

$$E = \frac{F}{q} = \frac{6.4\times10^{-15}\,\text{N}}{1.602\times10^{-19}\,\text{C}} = 4.0\times10^{4}\ \text{N/C}$$

You suspend a positively charged oil drop that weighs 1.2×10^{-14} N between two parallel plates that are 0.64 cm apart. The potential difference between the plates is 240 V. What is the net charge on the drop? How many electrons is the drop missing?

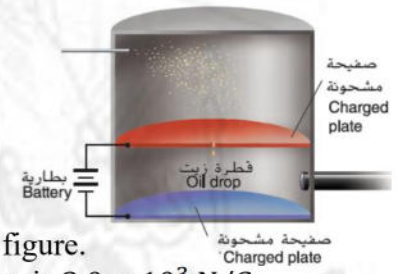
$$E = \frac{\Delta V}{d} = \frac{240\,\text{V}}{6.4\times10^{-3}\,\text{m}} = 3.8\times10^{4}\ \text{N/C}$$

$$E = \frac{F}{q}$$

$$q = \frac{F}{E} = \frac{1.2\times10^{-14}\,\text{N}}{3.8\times10^{4}\,\text{N/C}} = 3.2\times10^{-19}\ \text{C}$$

$$\#\ \text{electrons} = \frac{q}{q_e} = \frac{3.2\times10^{-19}\ \text{C}}{1.602\times10^{-19}\,\text{C}} = 2$$

An oil drop that weighs 5.6×10^{-15} Nand carries a charge of 1.12×10^{-18} C, is suspended between two charged plates as shown in the figure.



What is the strength of the electric field between the two plates?

ⓐ 5.0×10^{3} N/C ⓑ 2.0×10^{-4} N/C

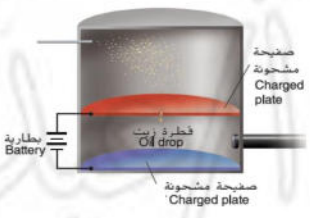
ⓒ 2.5×10^{3} N/C ⓓ 4.5×10^{-4} N/C

An oil drop is suspended between two charged plates as shown in the figure. The drop weighs 4.8×10^{-15} Nand the electric field between the plates is 3.0×10^{3} N/C.

What is the charge carried by the oil drop?

ⓐ 1.6×10^{-18} C ⓑ 2.4×10^{-18} C

ⓒ 3.2×10^{-18} C ⓓ 4.0×10^{-18} C



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Describe how charge is separated on a neutral object due to another charged object.

Initial State – Neutral Object:

- A neutral conductor (like a metal rod) has **equal numbers of positive and negative charges** (protons and electrons), evenly distributed.

Approach of a Charged Object:

- Suppose a **positively charged object** is brought near one end of the neutral rod.
- The **positive charge attracts electrons** in the rod because **electrons are mobile** in conductors.

Redistribution of Charges:

- **Electrons move toward** the end of the rod closest to the charged object.
- This end becomes **negatively charged** due to the excess electrons.
- The far end becomes **positively charged** because it has fewer electrons (they moved away).

Result – Induced Charges:

- The rod remains **overall neutral** but now has **separated charges**: negative near the charged object, positive on the far end.
- This separation creates an **electric dipole**.

Electrostatic Attraction:

- The **closer opposite charges** (negative on the rod, positive on the object) experience a **stronger attractive force** than the repulsion from the farther like charges.
- Therefore, the **net force is attractive**, pulling the neutral rod toward the charged object.

Salem is conducting an experiment to charge a neutral electroscope. He brings a negatively charged rod close to the knob while touching it with his hand. If Salem removes the rod while his hand is touching the knob, then he removes his hand,
which of the following figures correctly shows what happens to the electroscope?





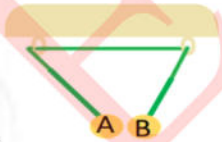
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The **direction of the electrostatic force** depends entirely on the **types of charges** involved:

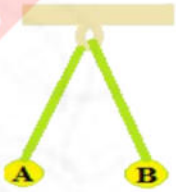
- **Like charges repel**:
  - Two **positive** charges push away from each other.
  - Two **negative** charges also push away from each other.
- **Unlike charges attract**:
  - A **positive** charge and a **negative** charge pull toward each other.

In the figure, two isolated bodies (A and B) are suspended freely.
Which of the following can be correct about the charge type on the two bodies?



ⓐ A: positive, B: positive
ⓑ A: negative, B: negative
ⓒ A: negative, B: positive
ⓓ A: neutral, B: neutral

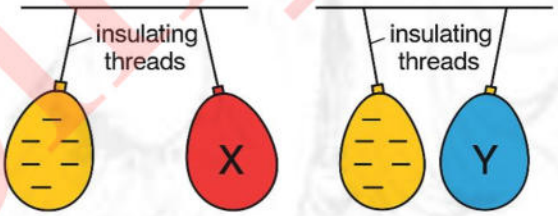
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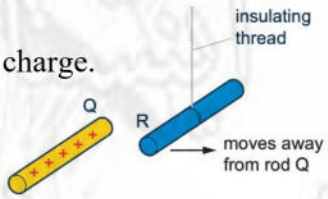
Two balloons, X and Y, are suspended by insulating threads. They are each held near a negatively charged balloon. The balloons hang as shown.
What is the charge on balloon X and what is the charge on balloon Y?

Balloon X	Balloon Y
ⓐ Negative	Negative
ⓑ Negative	Positive
ⓒ Positive	Negative
ⓓ Positive	Positive



Which statement about electric charges is correct?
ⓐ Like charges attract and unlike charges attract
ⓑ Like charges attract and unlike charges repel
ⓒ Like charges repel and unlike charges attract
ⓓ Like charges repel and unlike charges repel

In the diagram, rod **R** hangs from an insulating thread. When the positively charged rod **Q** is brought close to rod **R**, rod **R** moves away from rod **Q**.
Which conclusion can be made from this observation?
ⓐ Rod R is charged, but it is not possible to identify the sign of the charge.
ⓑ Rod R must be positively charged.
ⓒ Rod R must be negatively charged.
ⓓ Rod R is uncharged.



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Grounding is the process of connecting an object to the Earth to allow excess electric charge to flow away safely. The Earth acts as a vast reservoir of charge and can either supply or absorb electrons without becoming significantly charged.

Charging by Induction with Grounding:

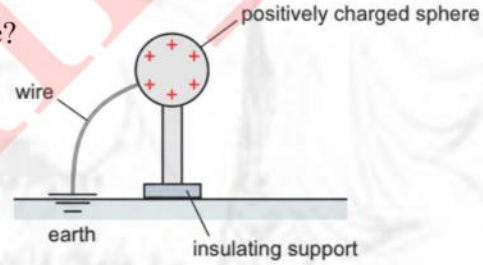
1. **Bring a charged object near a neutral conductor** (e.g., a metal electroscope).
   - If the object is **negatively charged**, it **repels electrons** in the conductor, pushing them away.
   - If the object is **positively charged**, it **attracts electrons** toward it.
2. **Ground the conductor** by touching it with your hand or connecting it to the Earth.
   - If electrons were repelled, they flow into the ground, leaving the conductor **positively charged**.
   - If electrons were attracted, they flow from the ground into the conductor, making it **negatively charged**.
3. **Remove the ground connection**, then remove the charged object.
   - The conductor now retains a **net charge opposite** to that of the nearby object.

Important: The charged object never touches the conductor, so no direct transfer of charge occurs between them.

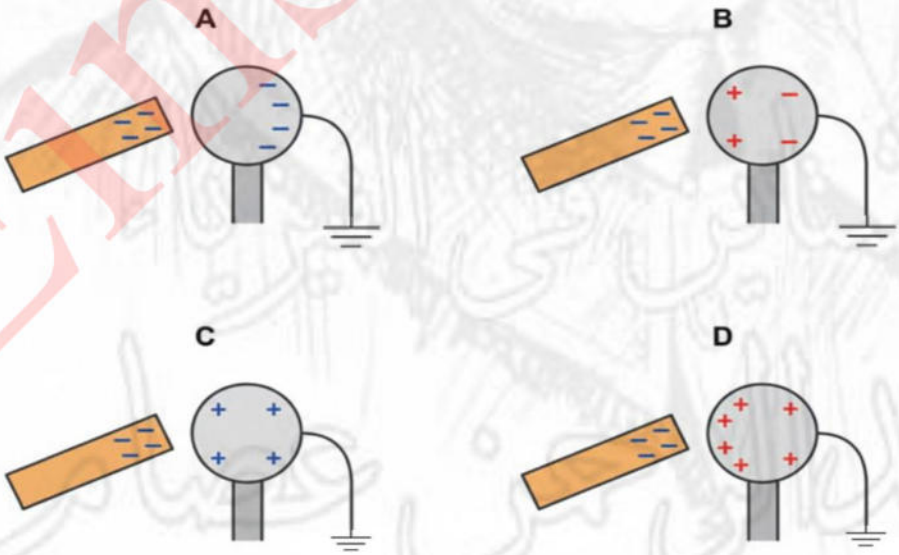
The diagram shows a positively charged conducting sphere and a wire connected to earth.

What happens when the wire is touched onto the sphere?

ⓐ Electrons flow from earth to the sphere
ⓑ Electrons flow from the sphere to earth
ⓒ Positive charges flow from earth to the sphere
ⓓ Positive charges flow from the sphere to earth



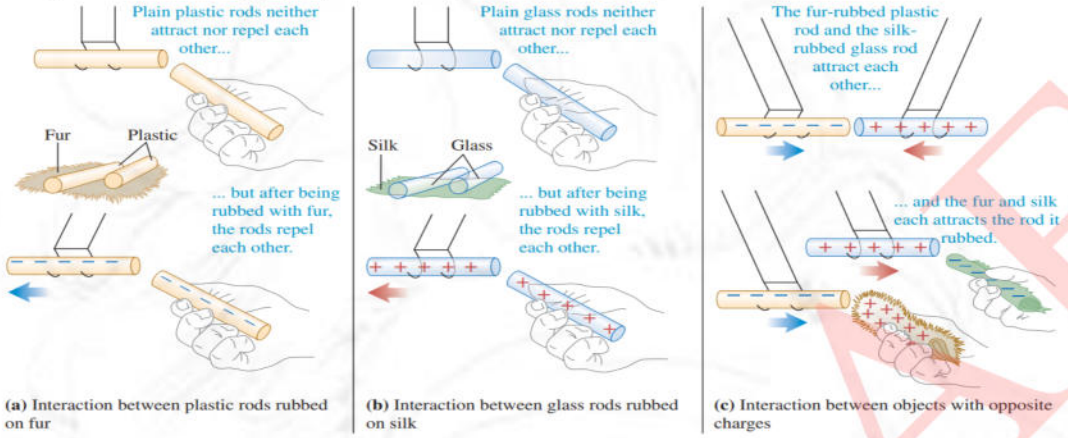
A negatively charged rod is held close to one side of a metal sphere. The other side of the sphere is earthed. Which diagram shows the distribution of charge on the metal sphere?



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Explain the process of charging by Rubbing; Conduction; Induction.



(a) Interaction between plastic rods rubbed on fur

(b) Interaction between glass rods rubbed on silk

(c) Interaction between objects with opposite charges

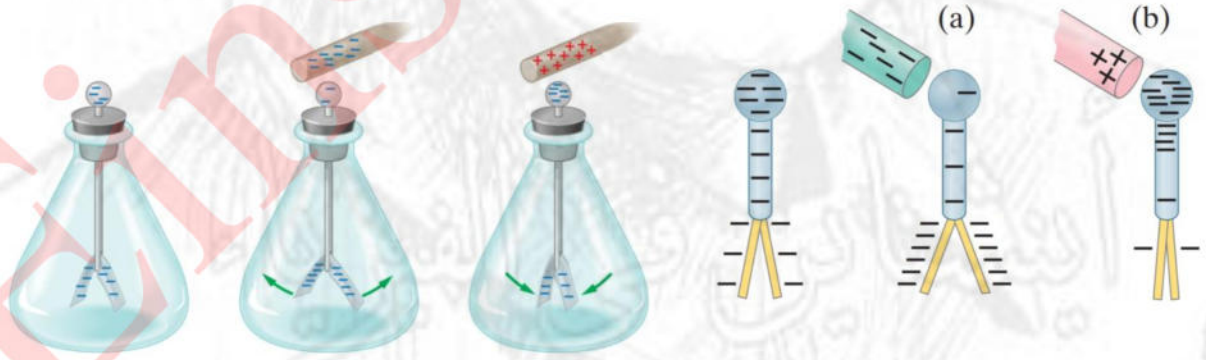
Electroscope Using for Determining charge



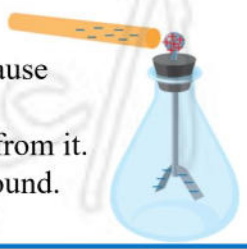
Charging by conduction (contact):
By touching a neutral object with a charged object
can result in a transfer of electrons between them.
As a result, the two objects will have the same kind of charge

NOTES:
To charge an electroscope by conduction, let a charged metal rod touch the electroscope's knob.
How can the type of charge on an electroscope be determined?
Bringing a rod of known charge close to but not touching the electroscope knob.

A. Bringing a negatively charged rod near a negatively charged electroscope causes the leaves to spread apart farther.
B. Bringing a positively charged rod near a negatively charged electroscope causes the leaves to fall closer together



Charging by induction
Without touching a charged object is approaching near to a neutral object it will cause electrons to rearrange their positions on the neutral object.
The neutral object stays neutral because there was no transfer of electrons to it or from it.
To make it charged we need to conduct it with another identical sphere or with ground.



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STEPS

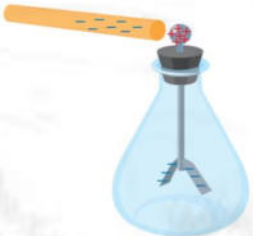
A neutral electroscope has an even charge distribution, and the leaves hang loosely.

A. Separation of charge is induced in the electroscope when a negatively charged rod is brought near it (Without touching) .
B. Touching the electroscope allows the charged rod to push electrons out into the hand instead of down into the leaves (Grounding) .
C. When the ground is removed from the electroscope before the rod is removed, an excess of positive charge is left on the electroscope.

Charging by Induction



A neutral electroscope has an even charge distribution, and the leaves hang loosely.



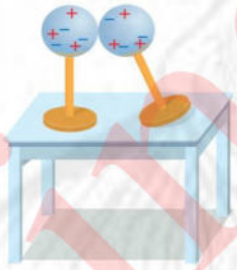
Separation of charge is induced in the electroscope when a negatively charged rod is brought near it.



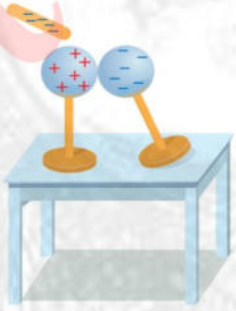
Touching the electroscope allows the charged rod to push electrons out into the hand instead of down into the leaves.



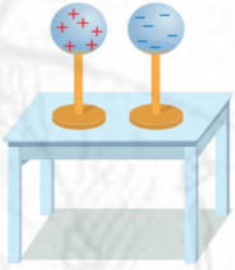
When the ground is removed from the electroscope before the rod is removed, an excess of positive charge is left on the electroscope.



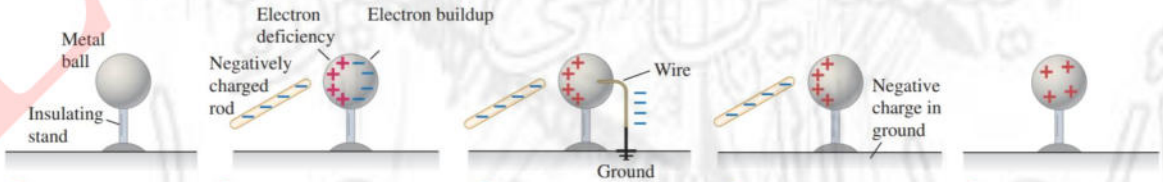
Neutral spheres are touching.



Both spheres are charged by induction.



The separated spheres have opposite charges.



① Uncharged metal ball

② Negative charge on rod repels electrons, creating zones of negative and positive **induced charge**.

③ Wire lets electron build-up (induced negative charge) flow into ground.

④ Wire removed; ball now has only an electron-deficient region of positive charge.

⑤ Rod removed; positive charge spreads over ball.

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How can the type of charge on an electroscope be determined?

A. Blinging a rod of known charge close to but not touching the electroscope knob.
B. Bringing a neutral rod close to but not touching the electroscope knob.
C. Touching the electroscope knob with a neutral rod.
D. Touching the electroscope knob with a rod that has a known charge.

The figure shows charging by



ⓐ Triboelectric ⓑ conduction ⓒ Induction ⓓ Grounding

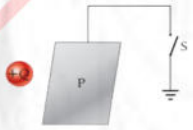
The figure shows charging by



ⓐ Triboelectric ⓑ conduction ⓒ Induction ⓓ Grounding

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

What is the charge on the plate then?
ⓐ The plate could be either positively or negatively charged
ⓑ The plate is positively charged
ⓒ The plate is uncharged.
ⓓ The plate is negatively charged.



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

What is the charge of the conducting sphere if you remove away the ground connection and then remove away the charged rod.



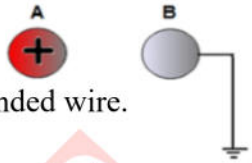
ⓐ Negative ⓑ Positive ⓒ no charge ⓓcannot be determined

When you charge an object by touching it by another charged object.
the process is called charging by
ⓐ Triboelectric ⓑ Conduction ⓒ Induction ⓓ Grounding

When you charge an object by without touching it by another charged object.
the process is called charging by
ⓐ Triboelectric ⓑ Conduction ⓒ Induction ⓓ Grounding

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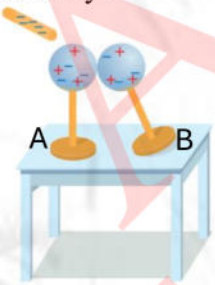


A positively charged sphere A is brought close without touching to a neutral sphere B as shown in the figure. Sphere B is connected with a grounded wire.
What is the type of charge on sphere B?

ⓐ Negative ⓑ Positive ⓒ no charge ⓓcannot be determined

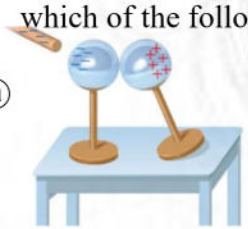
Two conducting isolated neutral spheres (A, B) touching each other as shown in the figure, a negatively charged rod is brought close to sphere A, what is the charge of each sphere if we take sphere B away from A and then take the rod away?

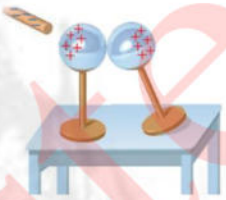
	Sphere A	Sphere B
A	Positive	Positive
B	Negative	Negative
C	Negative	Positive
D	Positive	Negative

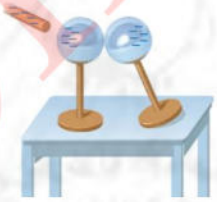


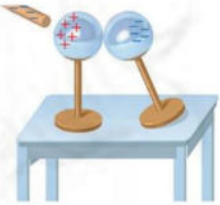
Two identical, neutral, and insulated metal spheres are touching, as show in the figure.
If a negatively charged rod was brought close to one sphere without touching,

which of the following figures correctly shows the charges on the two spheres?

ⓐ 

ⓑ 

ⓒ 

ⓓ 

A charged rod was placed near the Knob (disk)of an electroscope, and the two leaves of the electroscope opened, as shown in the figure.
What type of leg charge and what is the method of charging the electroscope?



type of rod charge	method of charging
A Negative	Induction
B Negative	Conduction
C Positive	Conduction
D Positive	induction

Which of the following figures correctly presents charging a neutral electroscope by conduction?



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Which of the following figures correctly presents charging a neutral electroscope by Induction?



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



ⓐ Positive ⓑ Negative ⓒ It is neutral ⓓ Positive or Negative

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

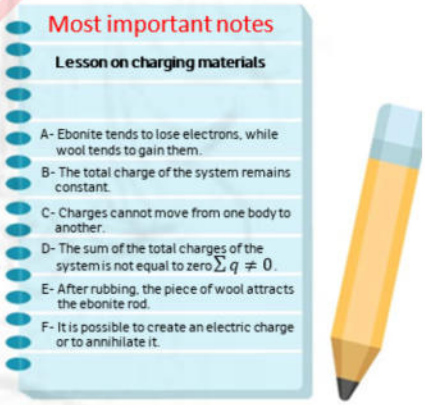


ⓐ Positive ⓑ Negative ⓒ It is neutral ⓓ Positive or Negative

A student rubbed a rod of *ebonite* with a piece of wool. After completing the rubbing process, he brought the ebonite rod closer to the piece of wool. He then wrote the notes in his science notebook:
Look at the notes written, and decide based on your studies which of them is correct?

ⓐ A + B + C + D + E + F
ⓑ B + C + E + F
ⓒ B + E
ⓓ B only





When a polythene rod gains a negative charge when it is rubbed with a cloth,
Which one of the following statements best explains how this happens?



ⓐ Protons transfer to the cloth from the polythene rod
ⓑ Protons transfer from the cloth to the polythene rod
ⓒ Electrons transfer from the cloth to the polythene rod
ⓓ Electrons transfer to the cloth from the polythene rod

When two objects are charged from each other, the total electric charge before charging ..... the total electric charge after touching?

ⓐ Less ⓑ Greater ⓒ Equal ⓓ Not equal

When two objects are charged, the total charge before and after charging remains the same because:

ⓐ Coulomb's law ⓑ Charge quantization
ⓒ Conservation of charge ⓓ Induction law

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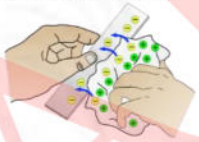
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The figure below shows the distribution of electric charges on the body.
Which of the following is correct?



ⓐ Excess neutrons ⓑ Free protons
ⓒ Excess protons ⓓ Excess electrons

When you rub a polythene rod with a wool cloth, electrons are transferred from one to the other.

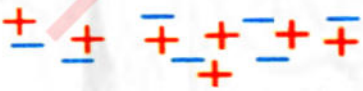


What charge does the polythene rod get?
ⓐ Positive ⓑ Negative ⓒ Neutral ⓓ Can't determine

When two neutral objects, such as rubber and wool, are rubbed together, they gain electric charges.
Which of the following statements correctly describes the total charges on the objects?
ⓐ Is negative ⓑ Is positive
ⓒ Is equal to zero ⓓ It may be positive or negative



The figure shows the distribution of charges on the body.
Which of the following is correct?



ⓐ not charged ⓑ positively charged
ⓒ negatively charged ⓓ We can't know the charge type

A plastic rod and a dry cloth are uncharged. The rod is now rubbed with the cloth and they both become charged. The rod becomes negatively charged because some charged particles move from the cloth to the rod.
What is the charge on the cloth and which particles moved in the charging process?

Charge on cloth	Particles that moved
ⓐ Negative	Electrons
ⓑ Negative	Neutrons
ⓒ Positive	Electrons
ⓓ Positive	Neutrons

A polythene rod is rubbed with a cloth. The rod becomes positively charged because of the movement of charged particles.
Which row gives the name of these charged particles, and the direction in which they move?

Charged particles	Direction of movement
ⓐ Electrons	From cloth to rod
ⓑ Electrons	From rod to cloth
ⓒ Protons	From cloth to rod
ⓓ Protons	From rod to cloth

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A polythene rod becomes negatively charged when it is rubbed with a cloth. Which statement explains this?

ⓐ The rod gains electrons **ⓑ The rod loses electrons**
ⓒ The rod gains protons **ⓓ The rod loses protons**

A plastic rod is rubbed with a dry cloth. The rod becomes positively charged. Why has the rod become positively charged?

ⓐ It has gained electrons **ⓑ It has gained neutrons**
ⓒ It has lost electrons **ⓓ It has lost neutrons**

A plastic rod is rubbed with a cloth. The rod becomes positively charged. What happens to the plastic rod and what is the charge on the cloth?

Plastic rod	Charge on cloth
ⓐ Gains electrons	Negative
ⓑ Gains electrons	Positive
ⓒ Loses electrons	Negative
ⓓ Loses electrons	Positive

When a glass rod is rubbed with silk and the rod becomes **positively charged**, then
ⓐ electrons are removed from the rod
ⓑ protons are removed from the silk
ⓒ the silk remains neutral
ⓓ protons are added to the silk

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Distinguish between electrical conductors and insulators giving typical examples.

Conductors

- **Definition: Materials that allow electric charges (electrons) to move freely.**
- **Behavior: When a charged object touches one end of a conductor, the charge spreads quickly over the entire surface.**

Reason: Metals have free electrons that are not bound to any specific atom, enabling easy movement.

Examples:

- ✓ **Copper**
- ✓ **Aluminum**
- ✓ **Graphite**
- ✓ **Plasma (contains free electrons and ions)**



Insulators

- **Definition: Materials that do not allow electric charges to move easily.**
- **Behavior: When a charged object touches an insulator, the charge stays localized at the point of contact.**

Reason: Electrons in insulators are tightly bound to atoms and cannot move freely.

Examples:

- ✓ **Plastic**
- ✓ **Glass**
- ✓ **Dry wood**
- ✓ **Cloth**
- ✓ **Dry air**



The diagram shows a sphere carrying a charge

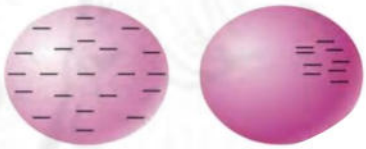
Which of the following is true ?

ⓐThe body is insulator and charged by losing electrons

ⓑ The body is conductor and charged by gaining electrons

ⓒThe body is conductor and charged by losing electrons

ⓓThe body is insulator and charged by gaining electrons



1	2

Which of the following explains why diamond is classified as an insulator?

ⓐ Charges cannot move easily through diamond.

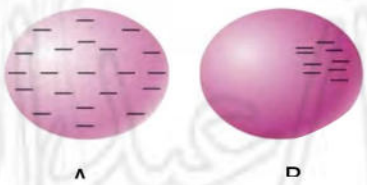
ⓑ The number of electrons in diamond is less than the number of protons.

ⓒ Diamond cannot be charged.

ⓓ Electrons can be easily removed from diamond.



as shown in the figure the negative Charge distribution over the surface of two isolated spheres Which of the following is correct?



	Sphere A	Sphere B
A	Copper	Plastic
B	Plastic	Copper
C	Copper	Copper
D	Plastic	Plastic

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Which of the following explains why copper is classified as a conductor?
ⓐ Charges can move easily through copper.
ⓑ The number of electrons in copper is less than the number of protons.
ⓒ Copper cannot be charged.
ⓓ Electrons can be easily removed from copper.



Which of the following is a characteristic of an electric insulator?
ⓐ Charges cannot move easily through it.
ⓑ Its atoms do not contain electrons.
ⓒ Charge spreads out evenly on its surface.
ⓓ Cannot be electrically charged.

Which of the following is a characteristic of an electric conductor?
ⓐ Charges can move easily through it.
ⓑ Its atoms do not contain electrons.
ⓒ Charge spreads out evenly on its surface.
ⓓ Cannot be electrically charged.

Which one of the following statements is CORRECT?
ⓐ Conductors hold charge where they are placed.
ⓑ An insulator prevents charge from flowing.
ⓒ Charges spread out evenly on an insulator always.
ⓓ Most plastic materials are good conductors.

Materials that are classified as electrical insulators are characterized by their inability to conduct electricity well.
Why are such materials poor conductors of electricity?
ⓐ The strength of bonds between molecules
ⓑ Availability of free outer electrons
ⓒ The absence of free outer electrons
ⓓ Lack of protons in the nucleus



Materials that are classified as electrical conductors are characterized by their ability to conduct electricity well.
Why are such materials good conductors of electricity?
ⓐ The presence of free outer electrons
ⓑ Strong bonds between molecules
ⓒ Lack of protons in the nucleus
ⓓ The absence of free outer electrons

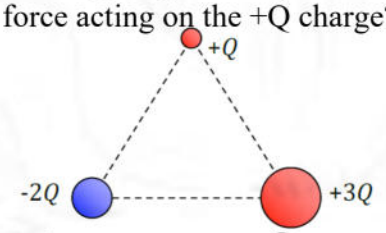


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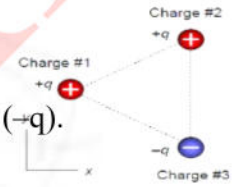
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Use vector addition to calculate the net force on a charge due to other point charges.

Three point-charges of charge +Q, -2Q, and +3Q, are placed equidistant as shown. Which vector best describes the net direction of the electric force acting on the +Q charge?



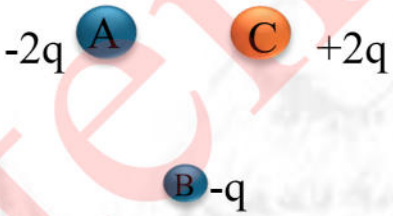
ⓐ ← ⓑ ↑ ⓒ → ⓓ ↓



Three point-charges lie at the vertices of an equilateral triangle as shown. All three charges have the same magnitude, but charges #1 and #2 are positive (+q) and charge #3 is negative (−q). The net electric force that charges #2 and #3 exert on charge #1 is in

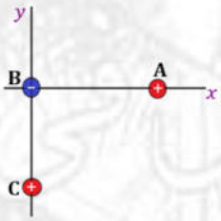
ⓐ the +x-direction. ⓑ the -x-direction. ⓒ the +y-direction. ⓓ the -y-direction.

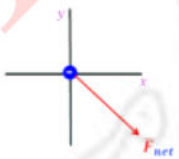
Three charged spheres are at positions shown in figure. Which one of the following diagrams represent the direction of the net force acting on charged sphere B?

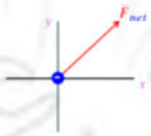


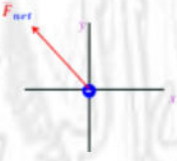
ⓐ ← ⓑ ↑ ⓒ → ⓓ ↓

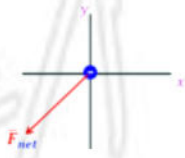
Three charged spheres are at positions shown in figure. Which one of the following diagrams represent the direction of the net force acting on charged sphere B?



ⓐ 

ⓑ 

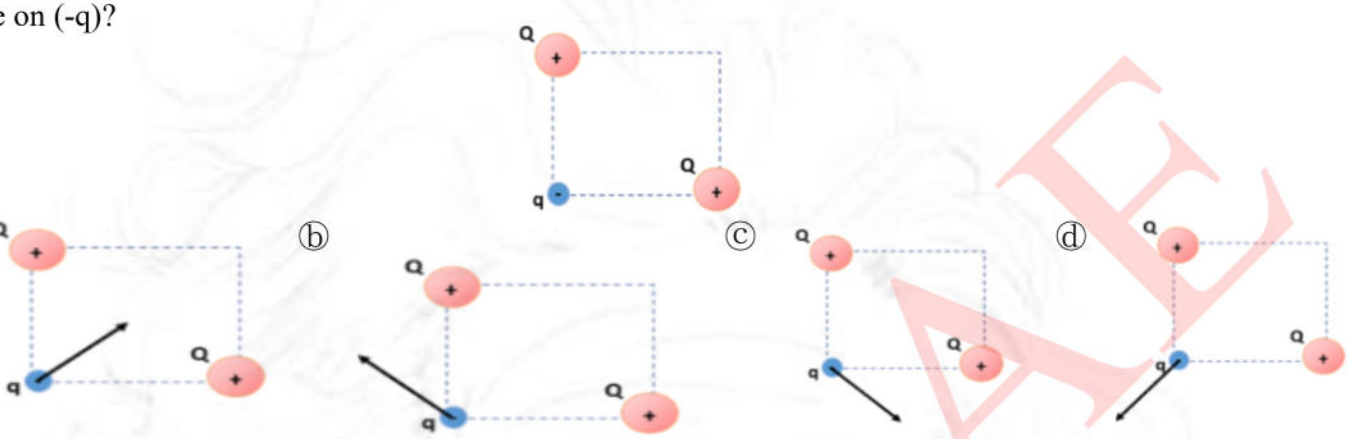
ⓒ 

ⓓ 

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Two-point charges of +Q, are fixed at opposite corners of a square as shown in the figure. A negative charge (-q) is placed at a third corner. Which of the following diagrams represents the correct direction of the net force on (-q)?



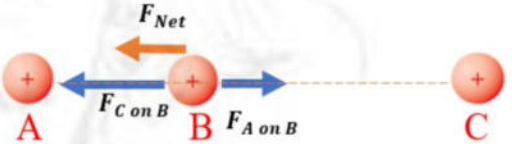
Three equal charges A, B and C are placed as shown in the figure.
Which of the following diagrams correctly represent the electric forces on charge B?



ⓐ



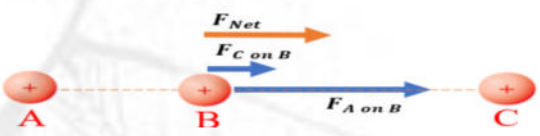
ⓑ



ⓒ



ⓓ

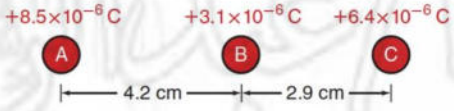


The figure shows three charges $(q_1 = 3.0\ \mu C)$, $(q_2 = -2.0\ \mu C)$, and $(q_3 = -4.0\ \mu C)$.



What is the **net force** exerted on the positive charge (q_1)?
Coulomb's Constant $(K = 9.0 \times 10^9\ N \cdot m^2 \cdot C^{-2})$.
ⓐ 98.4 N ⓑ 141.6 N ⓒ 4.68 N ⓓ 2.52 N

Three charges, A, B, and C, are located in a line, as shown below.
What is the **net force** on charge B?
ⓐ 78 N toward A ⓑ 78 N toward C
ⓒ 130 N toward A ⓓ 210 N toward C



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State and apply Coulomb's law to charges separated by finite distances.

The force is **inversely proportional to the square of the distance**:

$$F \propto \frac{1}{r^2}$$

Ratio of Forces

If two forces F_1 and F_2 correspond to distances r_1 and r_2, then:

$$\frac{F_2}{F_1} = \frac{{r_1}^2}{{r_2}^2}$$

Two electric charges in air repel with a force F. If each charge is doubled but the distance remains constant, the magnitude of the repulsion force will be:

ⓐ $\frac{F}{4}$ ⓑ $\frac{F}{2}$ ⓒ $4F$ ⓓ $2F$

Two electric charges in air, separated by a distance r, attract with a force 40 N. If the distance is increased to $2r$, the magnitude of the attraction force will be:

ⓐ 10 N ⓑ 160 N ⓒ 80 N ⓓ 20 N

Two positive point charges repel each other with force 0.36 Nwhen their separation is 1.5 m. What force do they exert on each other when their separation is 1.0 m?

ⓐ 0.81 N ⓑ 0.16 N ⓒ 0.24 N ⓓ 0.54 N

Two charged spheres are initially a distance $d$apart. The magnitude of the force on each sphere is F. They are moved closer to each other such that the magnitude of the force on each of them is $9F$. By what factor has the distance between the two spheres changed?

ⓐ $r_2 = \frac{1}{3}r_1$ ⓑ $r_2 = 9r_1$ ⓒ $r_2 = 3r_1$ ⓓ $r_2 = \frac{1}{9}r_1$

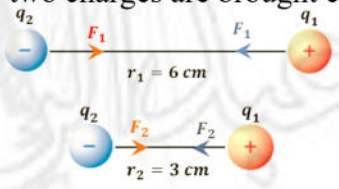
Two charged spheres are 8.00 cm apart. They are moved closer to each other by enough that the force on each of them increases four times. How far apart are they now?

ⓐ $r_2 = 4$ cm ⓑ $r_2 = 2$ cm ⓒ $r_2 = 16$ cm ⓓ $r_2 = 12$ cm

Two point charges, initially 2 cmapart, are moved to a distance of 10 cmapart. By what **factor** does the resulting electric force between them change?

ⓐ $\frac{1}{25}$ ⓑ 25 ⓒ $\frac{1}{5}$ ⓓ 5

The figure shows two-point charges q_1 and q_2, one positive and the other negative. When the distance between them was 6 cm, the force of attraction between them was $F_1 = 22$ N. What will be the **magnitude of the attractive force** F_2 if the two charges are brought closer together until the distance between them is 3 cm?



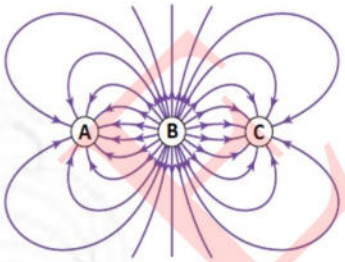
ⓐ 5.5 N ⓑ 11 N
ⓒ 44 N ⓓ 88 N

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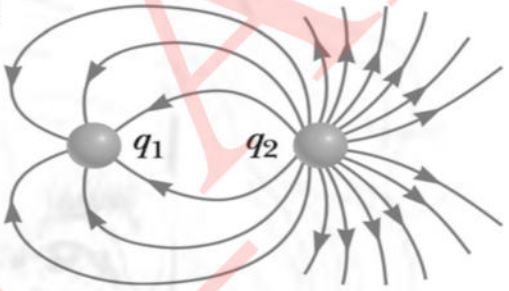
Sketch the electric field lines to model the electric field around single point charges (positive or negative) and for a pair of electric charges.

The spatial distribution of the electric field due to charges (1, 2, 3) is shown in the figure below. Which of the following statements about the charges is correct?



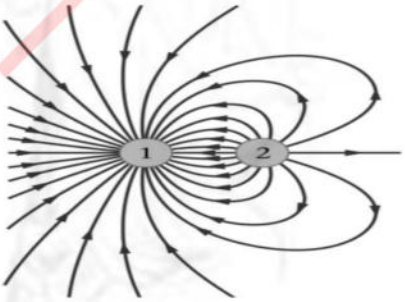
	Positive Charges	Negative Charges	Magnitude of Charges
ⓐ	A, C	B	A > B > C
ⓑ	B	A, C	B > A = C
ⓒ	B	A, C	B > A > C
ⓓ	A, B, C	None	B > A = C

The spatial distribution of the electric field due to charges q_1 and q_2 is shown in the figure below. Which of the following statements is correct?



	Charge q_1	Charge q_2	Magnitude
ⓐ	positive	negative	$q_1 > q_2$
ⓑ	positive	negative	$q_2 > q_1$
ⓒ	negative	positive	$q_1 > q_2$
ⓓ	negative	positive	$q_2 > q_1$

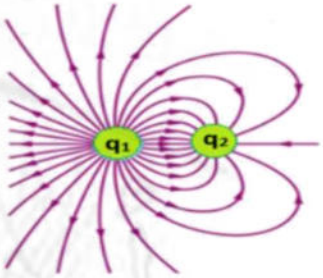
The electric field lines for a system of two charges are shown below. Which of the following could be the correct charges 1 and 2?



	Charge 1	Charge 2
ⓐ	$+32\ \mu C$	$-16\ \mu C$
ⓑ	$-32\ \mu C$	$+16\ \mu C$
ⓒ	$-16\ \mu C$	$+32\ \mu C$
ⓓ	$-32\ \mu C$	$-32\ \mu C$

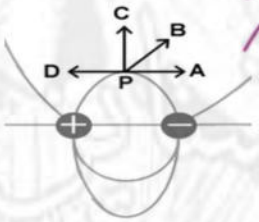
The figure shows the electric field around two-point charges q_1 and q_2. Which of the following statements is true?

ⓐ $q_1 = -2q_2$ ⓑ $q_2 = -2q_1$
ⓒ $q_1 = 2q_2$ ⓓ $q_2 = -2q_1$



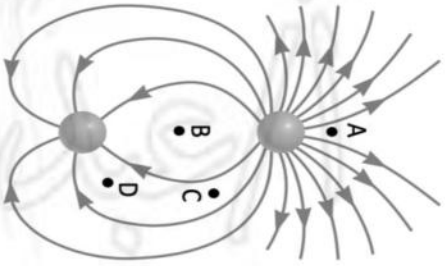
Which of the labelled arrows correctly represents the direction of the electric field vector at point P?

ⓐ A ⓑ B ⓒ C D



The figure below shows the electric field in a region. Rank the magnitudes of the electric field at points A, B, C, and D.

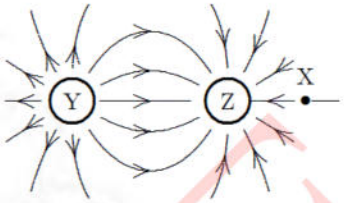
ⓐ A > B > C > D ⓑ B > D > C > A
ⓒ D > C > B > A ⓓ A > C > D > B



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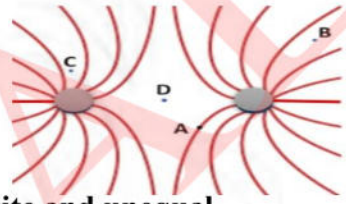
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The figure below shows two equal point charges Y and Z.
What will happen if a negative test charge is placed at point X?



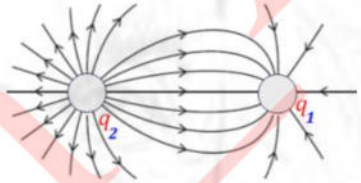
ⓐ It will move towards left
ⓑ It will move towards right
ⓒ It will not move
ⓓ It will move upwards

The figure shows the electric field lines around two charges.
At which of the following positions does the electric field equal zero?



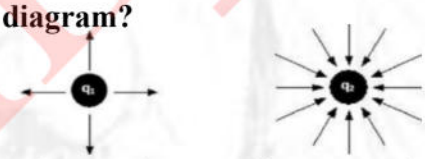
ⓐ A ⓑ B
ⓒ C ⓓ D

The diagram shows the electric field lines pattern between two opposite and unequal point charges q_1 and q_2. Which statement about the charges is correct?



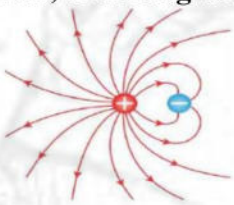
ⓐ q_2 is positive and its magnitude is greater than q_1
ⓑ q_2 is negative and its magnitude is greater than q_1
ⓒ q_2 is positive and its magnitude is smaller than q_1
ⓓ q_2 is negative and its magnitude is smaller than q_1

17. What is the possible value of q_1, q_2 shown in the diagram?



ⓐ $q_1 = -1\,C, q_2 = 3\,C$ ⓑ $q_1 = 3\,C, q_2 = -3\,C$
ⓒ $q_1 = 1\,C, q_2 = -3\,C$ ⓓ $q_1 = 1\,C, q_2 = -1\,C$

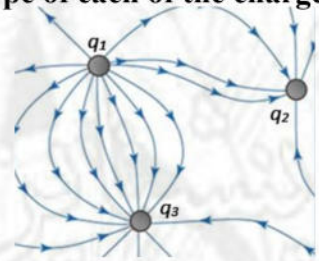
18. According to the electric field line intensity shown in the diagram, if the negative charge is $-12\ \mu C$, what is the magnitude of the positive charge?



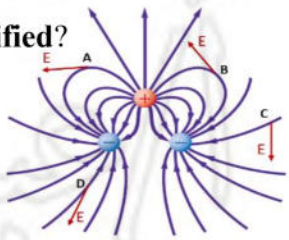
ⓐ $36\ \mu C$ ⓑ $24\ \mu C$
ⓒ $12\ \mu C$ ⓓ $48\ \mu C$

19. The figure shows the electric field of three charges q_1, q_2, q_3.
Which of the following table rows indicates the correct type of each of the charges?

	q1	q2	q3
ⓐ	-	+	+
ⓑ	+	-	-
ⓒ	+	-	+
ⓓ	-	+	-



The diagram shows the electric field lines around three point charges.
At which of the points is the **direction of the electric field (E) correctly identified**?



ⓐ A
ⓑ B
ⓒ C
ⓓ D

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Demonstrate an understanding that the work performed in moving a charged particle in an electric field can result in the particle
gaining electric potential energy or kinetic energy or both.

the **electric potential difference** (also called **voltage**) is the **work done per unit charge** to move a **positive test charge** from one point to another in an electric field.

- **Formula:**

$$\Delta V = \frac{W_{\text{on } q'}}{q'}$$

Where:

- ΔV= electric potential difference (in volts, V)
- $W_{\text{on } q'}$= work done to move the test charge
- q'= magnitude of the test charge

Electric potential difference is measured in joules per coulomb (J/C).
One joule per coulomb is called a **volt** (V).

What work is done on a 3.0-C charge when you move that charge through a 1.5-V electric potential difference?

$W = q\Delta V = (3.0\text{ C})(1.5\text{ V}) = 4.5\text{ J}$

An electron in an old television picture tube passes through a potential difference of 18,000 V. How much work is done on the electron as it passes through that potential difference?

$W = q\Delta V = (1.602\times10^{-19}\text{ C})(1.8\times10^{4}\text{ V}) = 2.9\times10^{-15}\text{ J}$

The electric field in a particle accelerator has a magnitude of 4.5×10^5 N/C. How much work is done to move a proton 25 cm through that field?

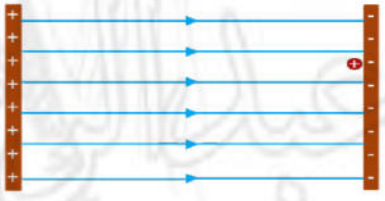
$W = q\Delta V = qEd = (1.602\times10^{-19}\text{ C})(4.5\times10^{5}\text{ N/C}) \times (0.25\text{ m}) = 1.8\times10^{-14}\text{ J}$

A 12-V car battery has 1.44×10^6 C of usable charge on one plate when it is fully energized. How much work can this battery do before it needs to be energized again?

$W = q\Delta V = (1.44\times10^{6}\text{ C})(12\text{ V}) = 1.7\times10^{7}\text{ J}$

Two parallel plates are 1.25×10^{-2} m apart. The magnitude of the electric field between them is 1500 N/C.
How much **work** is required to move a proton from the negative plate to the positive plate?

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



ⓐ 2.0×10^{-19} J
ⓑ 2.4×10^{-16} J
ⓒ 3.0×10^{-18} J
ⓓ 3.0×10^{-16} J

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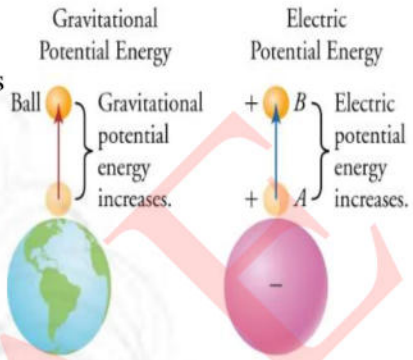
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Electrostatic Potential Energy: Gain or Loss

1. Moving Charges in an Electric Field

When a charge moves in an electric field, **work is done**, and this affects its **electric potential energy (EPE)**:

- **If you move a charge *against* the electric field**, you must do **positive work**, and the **electric potential energy increases**.
- **If you move a charge *with* the electric field**, the field does the work, and the **electric potential energy decreases**.



2. Like Charges (Positive and Positive or Negative and Negative)

- Like charges **repel** each other.
- **Moving them farther apart** means you're moving **with** the electric field.
- The field does the work, so the **electric potential energy decreases**.
- The **electric potential** around a positive charge **decreases** as you move away from it.

3. Unlike Charges (Positive and Negative)

- **When you separate two unlike charges** (e.g., a positive and a negative charge), you are working **against the attractive force**.
- This requires **positive work**, so the **electric potential energy increases**.
- The **electric potential difference (ΔV)** is **positive**.

Charge Movement	Work Done	Change in E PE	Electric Potential Difference (ΔV)
Move positive charge away from positive	Negative (field does work)	Decreases	Negative
Move positive charge toward positive	Positive (you do work)	Increases	Positive
Move positive charge away from negative	Positive (you do work)	Increases	Positive
Move positive charge toward negative	Negative (field does work)	Decreases	Negative





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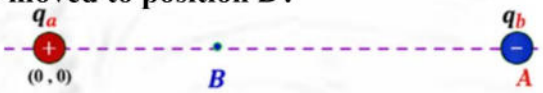
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The figure shows two point charges q_a at position $(0, 0)$ and q_b at position A.
What will happen when q_b is moved to position B?



ⓐ No change in potential energy.
ⓑ Electric potential decreases.
ⓒ Potential energy equal zero.
ⓓ Potential energy increases.

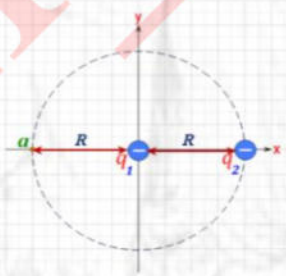
The figure shows two point charges q_a at position $(0, 0)$ and q_b at position A.
What will happen when q_b is moved to position B?



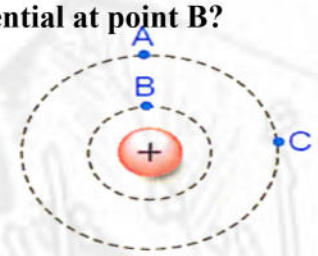
ⓐ No change in potential energy.
ⓑ Electric potential decreases.
ⓒ Potential energy equal zero.
ⓓ Potential energy increases.

The figure shows two point charges q_1 at position $(0, 0)$ and q_2 as in the figure.

What will happen when q_2 is moved to position (a)?
ⓐ Potential energy increases
ⓑ Potential energy equals zero
ⓒ Electric potential decreases
ⓓ No change in potential energy

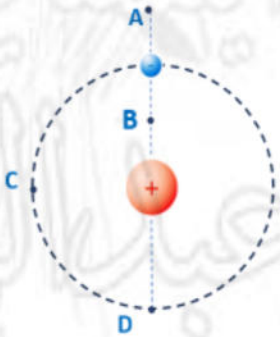


In the diagram below, the broken lines represent two equipotential surfaces around a positive point charge.
Which of the following statements describes the electric potential at point B?
ⓐ The voltage at point B is equal to the voltage at point C
ⓑ Equal to the voltage at point A
ⓒ Less than the voltage at point C
ⓓ Greater than the voltage at point A



The figure shows an electron in an atom.
To which point should the electron be moved to increase its electric potential energy?

ⓐ A ⓑ B ⓒ C ⓓ D



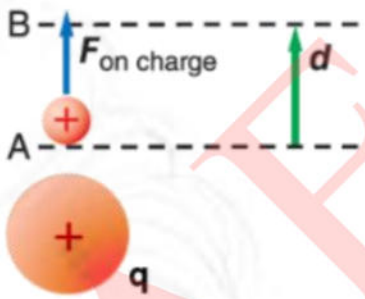
The figure shows an electron in an atom.
To which point should the electron be moved to decrease its electric potential energy?
ⓐ A ⓑ B ⓒ C ⓓ D

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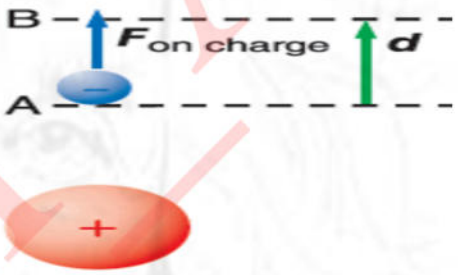
A positive test charge is moved from point A, away from a positive charge q, to point B as shown in the figure.
Which of the following rows is true?

Potential difference between A and B $(V_B - V_A)$	Change in potential energy of the test charge
ⓐ Negative	Negative
ⓑ Positive	Positive
ⓒ Positive	Negative
ⓓ Negative	Positive



A negative test charge is moved from point A to point B, away from a positive charge, as shown in the figure.
Which of the following table rows is true?

Potential difference between A and B $(V_B - V_A)$	Change in the test charge potential energy ΔPE
ⓐ Negative	Negative
ⓑ Positive	Positive
ⓒ Positive	Negative
ⓓ Negative	Positive



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Derive the electric field strength due to a point charge using Coulomb's law and the definition of electric field strength, to calculate the electric field strength at a point close to a single point charge.

$$\boxed{E = k\frac{q}{r^2}}$$

Where:

- E= electric field strength (N/C)
- q= source charge (C)
- r= distance from the charge (m)
- $k = 9.0 \times 10^9\ \text{N m}^2/\text{C}^2$

Unit Conversions

$$1\ \text{nC} = 10^{-9}\ \text{C} \qquad 1\ \mu\text{C} = 10^{-6}\ \text{C}$$

$$1\ \text{cm} = 10^{-2}\ \text{m}$$

What is the magnitude of the electric field at a position that is 1.2 m from a 4.2×10^{-6}-C point charge?

$$E = K\frac{q}{d^2}$$

$$= (9.0\times10^9\ \text{N·m}^2/\text{C}^2)\frac{(4.2\times10^{-6}\ \text{C})}{(1.2\ \text{m})^2} = 2.6\times10^4\ \text{N/C}$$

What is the electric field at a position that is 1.6 m east of a point charge of $+7.2\times10^{-6}$ C?

$$E = K\frac{q}{d^2}$$

$$= (9.0\times10^9\ \text{N·m}^2/\text{C}^2)\frac{(7.2\times10^{-6}\ \text{C})}{(1.6\ \text{m})^2} = 2.5\times10^4\ \text{N/C}$$

The electric field that is 0.25 m from a small sphere is 450 N/C toward the sphere. What is the net charge on the sphere?

$$E = K\frac{q}{d^2}$$

$$q = \frac{Ed^2}{K} = \frac{(450\ \text{N/C})(0.25\ \text{m})^2}{(9.0\times10^9\ \text{N·m}^2/\text{C}^2)} = -3.1\times10^{-9}\ \text{C}$$

How far from a point charge of $+2.4\times10^{-6}$ C must you place a test charge in order to measure a field magnitude of 360 N/C?

$$E = K\frac{q}{d^2}$$

$$d = \sqrt{\frac{Kq}{E}} = \sqrt{\frac{(9.0\times10^9\ \text{N·m}^2/\text{C}^2)(2.4\times10^{-6}\ \text{C})}{360\ \text{N/C}}} = 7.7\ \text{m}$$

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What is the magnitude of the electric field from 20 cmaway from a point charge of $q = 33$ nC?

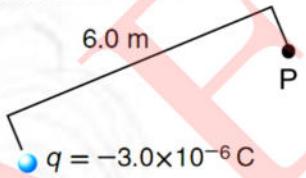
ⓐ 1.48×10^{-3} N/C ⓑ 7.43×10^{-3} N/C

ⓒ 7.43×10^{3} N/C ⓓ 1.48×10^{3} N/C

The figure shows a point Pat 6.0 mfrom a point charge q. What is the electric field at P?

ⓐ 750 N/C,towards the charge ⓑ 750 N/C,away from the charge

ⓒ 4500 N/C,towards the charge ⓓ 4550 N/C,away from the charge



What is the electric field 0.25 maway from a $-6.5\ \mu$Cpoint charge?

ⓐ 2.3×10^{5} N/C ⓑ 9.3×10^{5} N/C

ⓒ 9.3×10^{11} N/C ⓓ 1.5×10^{12} N/C

The electric field 0.25 maway from a point charge is 9.4×10^{5} N/C.
What is the magnitude of the charge?

ⓐ 1.6 μC ⓑ 5.0 μC

ⓒ 6.5 μC ⓓ 1.6 C

A (+1.6 μC) test charge is located at point (a) near a point charge (q), as shown in the figure.
The electric force exerted by (q) on the test charge is (0.68 N).
What is the magnitude of the electric field at point (a)?

ⓐ 4.3×10^{5} N/C ⓑ 1.09×10^{-6} N/C

ⓒ 4.3×10^{2} N/C ⓓ 2.4×10^{-6} N/C



A point **a** is located **6.0 m** away from a point charge **q = 3.6 μC**. What is the magnitude and direction of the electric field at point **P**?

ⓐ 899 N/C, towards the charge

ⓑ 899 N/C, away from the charge

ⓒ 4500 N/C, towards the charge

ⓓ 4550 N/C, away from the charge



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How a Lightning Rod Works

When the **electric field** in the atmosphere becomes strong enough—such as during a thunderstorm—it can cause particles in the air to collide with other molecules, creating a **plasma** (a stream of ions and electrons). Plasma is a **conductor**, and this can lead to a **spark** or even **lightning**.

To protect buildings from lightning:

- A **lightning rod** is installed at the highest point of the structure.
- The **electric field is strongest near the pointed tip** of the rod.
- This strong field causes charges in the clouds to **discharge to the rod** instead of striking other parts of the building.
- A **conductor** connected to the rod safely carries the charge **into the ground**, preventing damage.

Thus, the lightning rod **diverts the lightning safely away** from the building.

Applications of Electrostatic Forces

Electrostatic forces have many practical uses in **commercial and industrial** settings:

1. Electrostatic Painting

- **Paint droplets** are charged by **induction**.
- When sprayed, the droplets **repel each other**, helping the paint to **spread evenly** on surfaces like car bodies.

2. Photocopiers and Laser Printers

- These devices use **static electricity** to attract **toner particles** to specific areas.
- In **photocopiers**, static charges help form a precise image of the original document.
- **Laser printers** use a similar method, where toner sticks to **charged characters** on a drum before being transferred to paper.

3. Pollution Control – Electrostatic Precipitators

- In **smokestacks**, emissions from combustion are **electrically charged**.
- These charged particles are attracted to **oppositely charged collectors**.
- A **liquid spray** then removes the collected particles safely.
- This significantly **reduces air pollution**.

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Electric Fields Near Conductors

Charge Distribution on Conductors:

- In a **conducting sphere**, many electrons are **free to move**.
- Since **like charges repel**, these electrons spread out as far as possible to **minimize potential energy**.
- As a result, **excess charges move to the outer surface** of the conductor—this is true whether the sphere is **solid or hollow**.

Electric Field Inside a Closed Metal Container:

- In a **closed metal container** (like a metal box or a car), if the container is charged:
- ✓ A **voltmeter** will show that the **electric potential difference is zero** between any two points **inside** the container.

$$\Delta V = E \cdot d$$

and $\Delta V = 0$, it follows that the **electric field (E) inside is also zero**.

- This means the **interior of a closed conductor is shielded** from external electric fields.

Which of the following statements is true about equipotential positions?

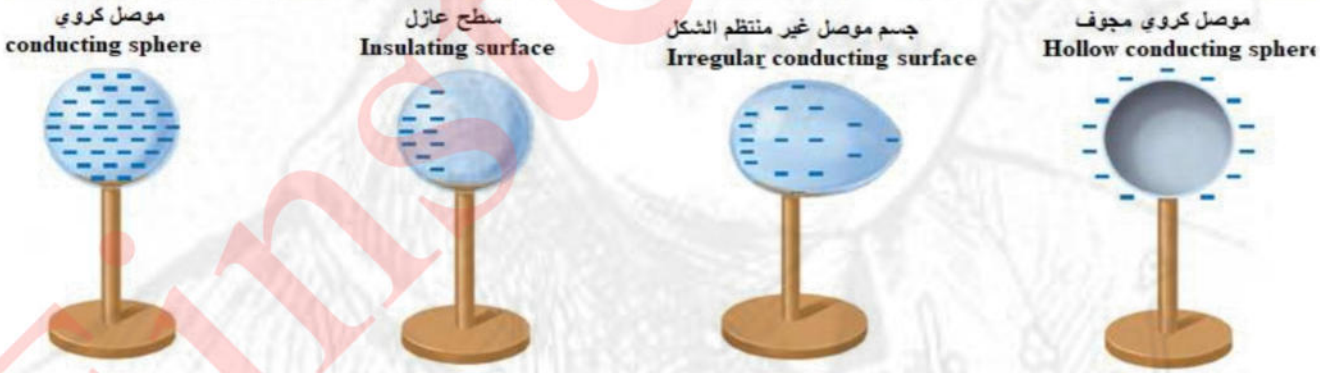
ⓐ **The work done to move a charge between any two of these positions must equal zero**

ⓑ **The electric potential at any of these positions must be zero**

ⓒ **The electric force acting on a charge placed at any of these positions must equal zero**

ⓓ **The electric field at any of these positions must be zero**

:Which of the following charge distributions is NOT correct?



ⓐ A ⓑ B ⓒ C ⓓ D

The figure shows a charged conducting irregular surface.
At which of the points shown in the figure ,the electric field is strongest?



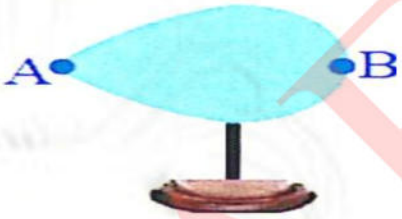
ⓐ A ⓑ B ⓒ C ⓓ D

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Points A and B are located on the surface of the charged conductor shown in the adjacent diagram.
Which rows of the following table show the electric field strength and the electric potential at the two points?

	the electric potential	the electric field
ⓐ	$V_B = V_A$	$E_B = E_A$
ⓑ	$V_B > V_A$	$E_B > E_A$
ⓒ	$V_B = V_A$	$E_B < E_A$
ⓓ	$V_B < V_A$	$E_B = E_A$



The figure shows a charged spherical conductor. Which of the following statements is **true** and expresses the magnitude of the electric potential at the surface of a charged conductor?

ⓐ Be constant
ⓑ Depends on the type of electric charge
ⓒ Depends on the charge distribution inside the conductor
ⓓ Always equal to zero


Conducting Sphere
جسم كروي موصل

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Definition

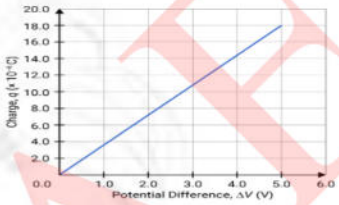
Capacitance is the ratio of the magnitude of the net charge on one plate of a capacitor to the potential difference across the plates:

$$C = \frac{q}{\Delta V}$$



It is measured in **Farads (F)**, where

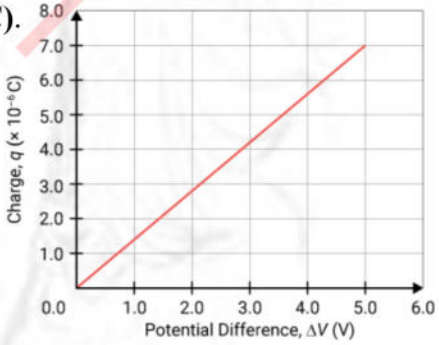
$$1\,\text{F} = 1\,\frac{\text{Coulomb}}{\text{Volt}}.$$



Concept

- A capacitor stores **electric energy** in an electric field, similar to how gravitational potential energy is stored when lifting an object.
- It consists of **two conducting plates** separated by an **insulator**.
- When connected to a voltage source, one plate becomes positively charged (+q) and the other negatively charged (–q).
- Increasing the voltage increases the charge proportionally, as shown by a straight-line graph of $q$vs. ΔV.The slope of this graph is the **capacitance (C)**.

Use the following graph to calculate the capacitance (C).

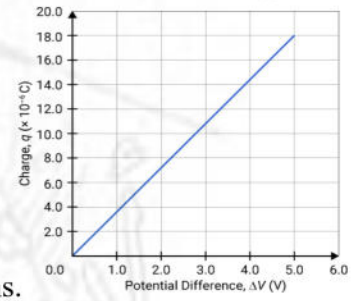


Use the following formula.

$$C = \frac{q}{\Delta V}$$

$$C = \frac{q}{\Delta V} = \frac{7.0 \times 10^{-6}}{5.0} = 1.4 \times 10^{-6}\,F$$

The capacitance from the data in the following graph is



Use the following formula.

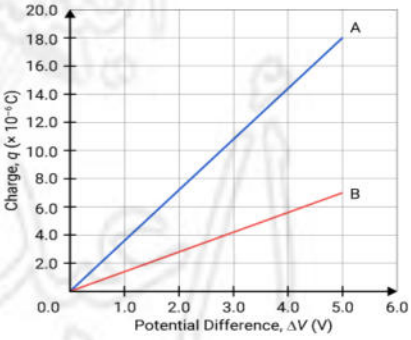
$$C = \frac{q}{\Delta V}$$

$$C = \frac{q}{\Delta V}\ \frac{18 \times 10^{-6}}{5.0} = 3.6 \times 10^{-6}\,F\,.$$

Study the following graph for two capacitors A &B and answer the questions.

The capacitance of A is ..... F.

The capacitance of B is .....F.



$$Capacitance, C = \frac{Charge\,, q}{Potentail\ difference}$$

$$C = \frac{q}{\Delta V}$$

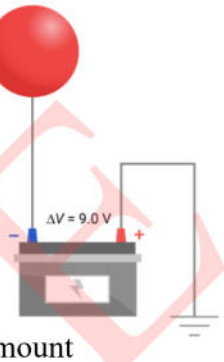
$$C_A = \frac{18 \times 10^{-6}}{5.0} = 3.6 \times 10^{-6}\,F\,.$$

$$C_B = \frac{q}{\Delta V} = \frac{7.0 \times 10^{-6}}{5.0} = 1.4 \times 10^{-6}\,F$$

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A sphere is attached to the negative terminal of a 9.0 V battery. The other terminal is connected to Earth, so it is grounded. The sphere -Earth system has a capacitance of $3.0 \times 10^{-9} F$. What is the net charge on the sphere?



$$C = \frac{q}{\Delta V}$$

$$q = C\,\Delta V$$

$$q = C\,\Delta V = 3.0 \times 10^{-9} \times 9.0 = 27 \times 10^{-9} = 2.7 \times 10^{-8}\ C$$

A 27-μF capacitor has an electric potential difference of 45 V across it. What is the amount the net charge on the positively charged plate of the capacitor?

$$q = C\Delta V = (27\times10^{-6}\ \text{F})(45\ \text{V}) = 1.2\times10^{-3}\ \text{C}$$

Suppose you connect both a 3.3-μF and a 6.8-μF capacitor across a 24-V electric potential difference. Which capacitor has the greater net charge on its positively charged plate and what is its magnitude?

$q = C\Delta V$, so the larger capacitor (6.8μF) has a greater charge.

$$q = (6.8\times10^{-6}\ \text{F})(24\ \text{V}) = 1.6\times10^{-4}\ \text{C}$$

You later find that the magnitude of net charge on each of the plates for each of the capacitors in the previous problem is 3.5×10^{-4} C. Which capacitor has the larger potential difference across it? What is that potential difference?

$\Delta V = \frac{q}{C}$, so the smaller capacitor (3.3μF) has the larger potential difference.

$$\Delta V = \frac{3.5\times10^{-4}\ \text{C}}{3.5\times10^{-6}\ \text{F}} = 1.1\times10^{2}\ \text{V}$$

Suppose that you apply an electric potential difference of 6.0 V across a 2.2-μF capacitor. What does the magnitude of the net charge on one plate need to be to increase the electric potential difference to 15.0 V?

$$q = C\Delta V = (2.2\times10^{-6}\ \text{F})(15.0\ \text{V}) = 3.3\times10^{-5}\ \text{C}$$

Additional charge required: than was on the plate when $\Delta V = 6.0$ V

$$3.3 \times 10^{-5} - 1.32 \times 10^{-5} = 1.98 \times 10^{-5}\ \text{C}$$

A sphere is charged by a 12 V battery and suspended above Earth as shown in
What is the net charge on the sphere?

$$q = C\Delta V = (5.3 \times 10^{-11} F)(12\ V) = 6.4 \times 10^{-10}\ C$$

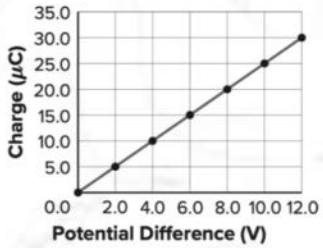
You increase the potential difference across a capacitor from 12.0 V to 14.5 V. As a result, the magnitude of the net charge on each plate increases by 2.5×10^{-5} C.
What is the capacitance of the capacitor?

$$C = \frac{q}{\Delta V_2 - \Delta V_1} = \frac{2.5\times10^{-5}\ \text{C}}{14.5\ \text{V} - 12.0\ \text{V}}$$

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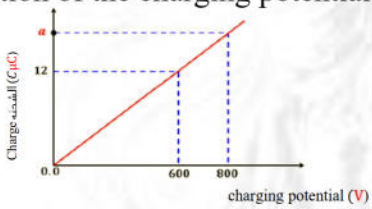
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The graph in the figure below represents the amount of charge stored on one plate of a capacitor as a function of the charging potential. Calculate the capacitance of the capacitor.



ⓐ 0.4 μF ⓑ 2.5 μF ⓒ 0.4 F ⓓ 2.5 F

The figure represents the relationship between the amount of charge stored on one plate of capacitor as a function of the charging potential. What is the amount of charge (a) on the graph?



ⓐ 18 µC ⓒ 16 µC
ⓑ 24 µC ⓓ 6 µC

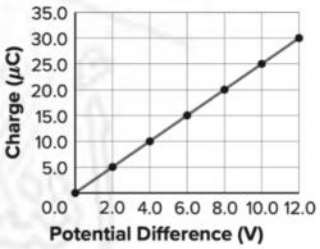
When a 20µF capacitor is connected to a battery, the net charge on the positive charged plate is 40 µC. is the potential difference between the two plates of the capacitor?



ⓐ 60.0 v ⓒ 2.00 v
ⓑ 800.0 v ⓓ 0.50 v

What does the slope of the graph of q versus ΔV represent?

ⓐ Capacitors in volts ⓑ Capacitance in volts per coulomb
ⓒ Capacitance in farads ⓓ Electric field in coulombs per volt



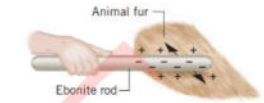
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1. Describe how an object becomes charged by the gain or loss of electrons and describe charging by friction.

The frictional charging process involves the transfer of electrons between two rubbing objects. Rubber attracts electrons far more strongly than animal fur. As a result, the atoms of rubber pull electrons from the atoms of animal fur, resulting in a charge imbalance in both objects.



Einstein_AE When an ebonite rod is rubbed against animal fur, electrons from atoms of the fur are transferred to the rod. This transfer gives the rod a negative charge (−) and leaves a positive charge (+) on the fur.

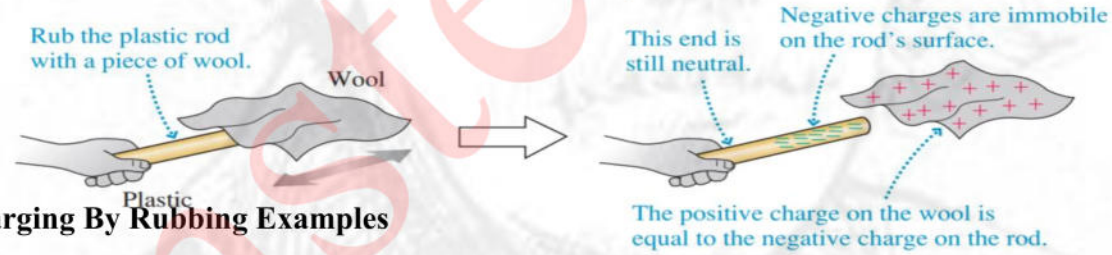
It results in two bodies with the same amount of charge but different in type, in application of the principle of conservation of charge.

The amount of charge on both bodies increases with the number of times the kneading increases.

This is a well-known electric phenomenon in which charged particles are transferred from one body to another. When two objects are rubbed together, an attractive force develops between them, especially if the objects are insulators and the surrounding air is dry.

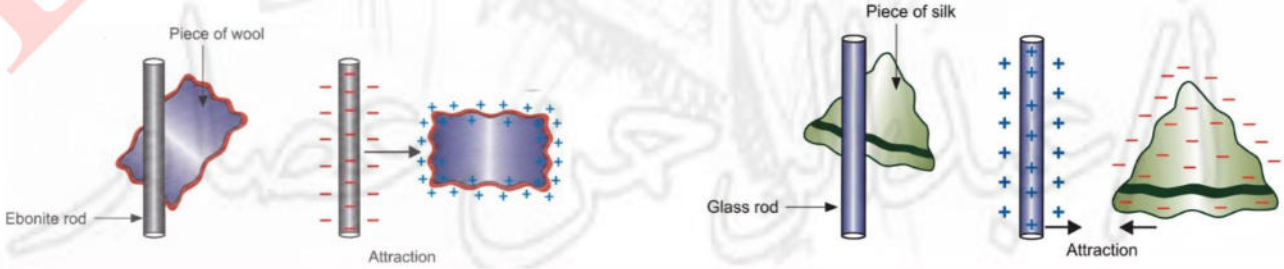
- When an object loses electrons, it becomes positively charged.
- The other object that gains electrons will become negatively charged.
- The force is simply the attraction of opposite-sign charges.

Uncharged Cloth Got Charged By Rubbing With A Charged Plastic Rod



Charging By Rubbing Examples

- Electrons are transferred from fur to the other material when a piece of amber, plastic, polythene, or hard rubber is rubbed with fur. Fur gains a net positive charge because it contains fewer electrons than protons. Similarly, because of excess electrons, amber, plastic, and hard rubber acquire a net negative charge.
- Hair combing charges the comb in the same way.
- Glass (perspex) gains a net positive charge after being rubbed with silk.



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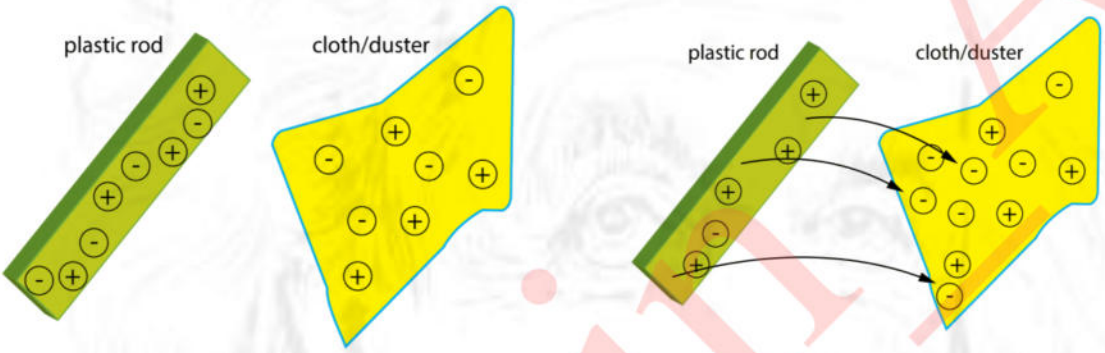
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Identify the two type of charges, positive and negative, and that the net charge of an isolated system is always conserved

atoms are neutral, because numberof electrons equal to number of protons
neutral *object, the amount of negative charge exactly balances the amount of positive charge*

positive charge (+)	negative charge (–)
Lost or remove some electron $N_P > N_e$	Gain or add some electron $N_e > N_p$

Example



Before the experiment **After rubbing with the cloth**

This diagram simplifies the picture by only showing a few of the charges present - four of each type instead of billions! As can be seen in the first image, the cloth and rod have equal positive and negative charges, so both of them are **neutral.** (No net charge present).
However friction dislodges some of the charges. In this example, the **negative electrons move from the rod to the cloth**. This makes the **rod** have an overall **positive charge** and the cloth has a negative charge.
Some substances hold on to their electrons tighter than others, and so the direction of travel of the electrons depends on the substance used. In figure 2, a different plastic is used, resulting in the electrons moving in the opposite direction:

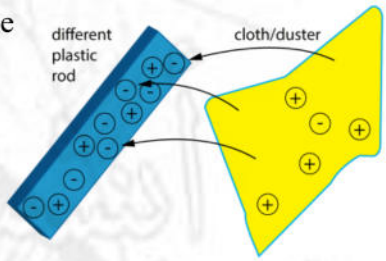


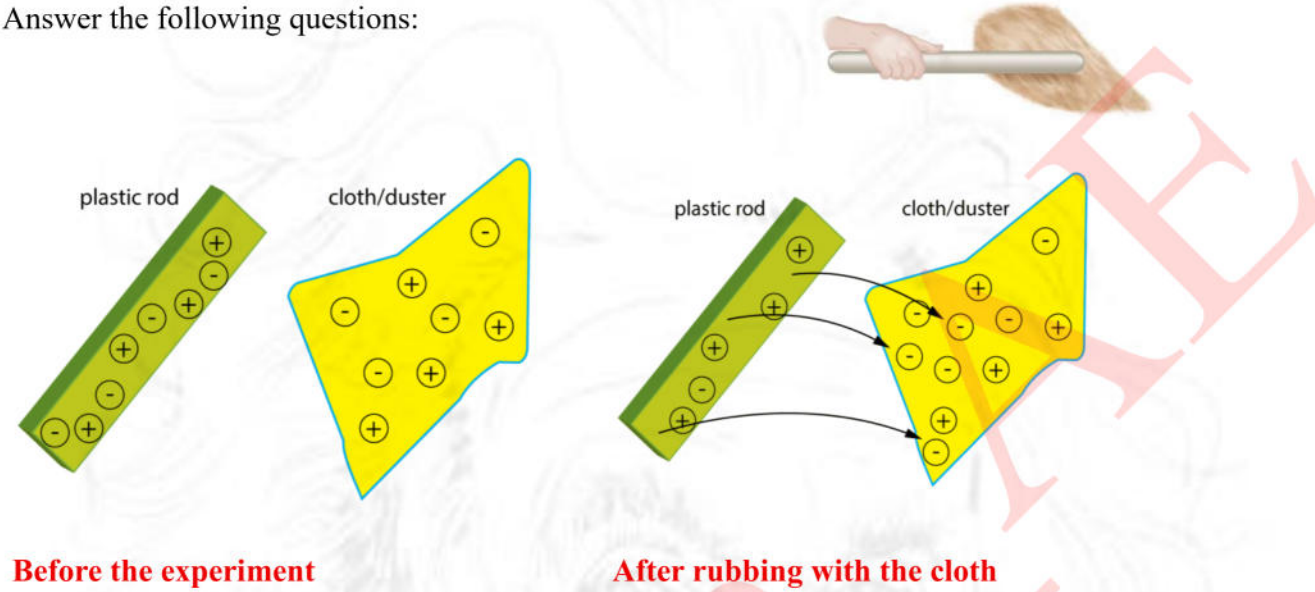
Figure 2 - Producing a negative static charge on the rod

electrostatics study of electric charges that can be collected and held in one place

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When you rub two neutral objects such as rubber and wool together, they become charged due to the transfer of electrons.
Answer the following questions:



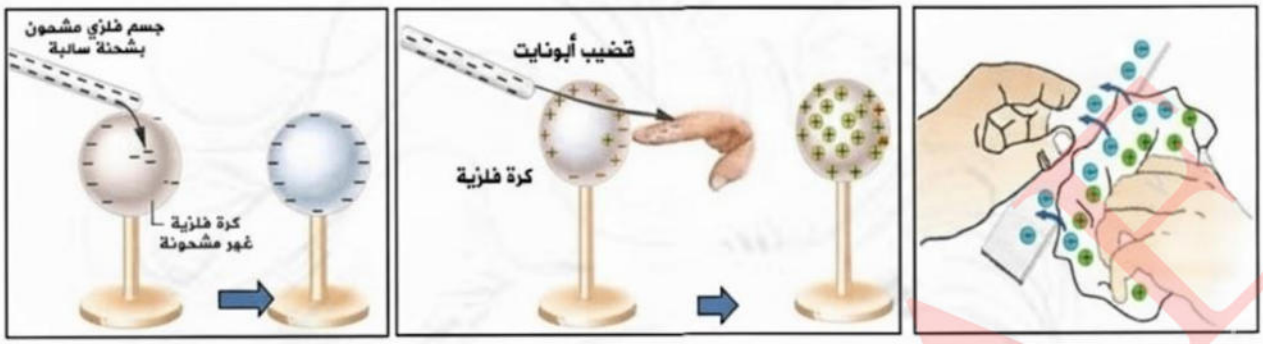
Before the experiment **After rubbing with the cloth**

1. **What is the name of the charging method used in this process?**
2. **What type of charge did the plastic rod acquire?**
3. **What type of charge did the wool acquire?**
4. **If the wool lost 3000 electrons during the rubbing process, how many electrons did the plastic rod gain?**
5. **Explain how rubbing two neutral objects like a plastic rod and wool can cause them to become charged.**

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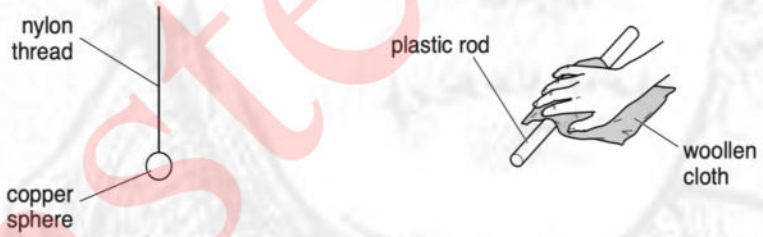
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Examine the figures above that represent the **methods of charging**, then look at the following table and fill in the blanks according to each method.



Comparison Aspect	Method (1)	Method (2)	Method (3)
Name of the charging method			
Type of the charging object (the influencer) Opposite to it – Similar to it			
Type of the material being charged in terms of electrical conductivity (Conductor – Insulator)			

Fig. shows a small, uncharged copper sphere suspended from a nylon thread, and a plastic rod being rubbed with a woollen cloth. The rod becomes negatively charged as it is rubbed.



ⓐ Explain, in terms of electrons, why copper is a conductor but nylon is an insulator.

ⓑ Describe how the negatively charged rod may be used to induce a positive charge on the copper sphere.

ⓒ The copper sphere is given a positive charge, as shown in Fig draw arrows to indicate the direction and pattern of the electric field that surrounds the positively charged sphere.

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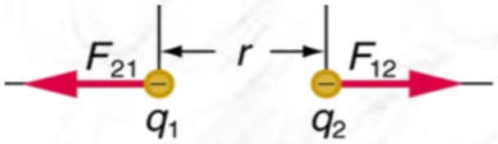
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Solve problems involving the electrostatic force acting on charged particles by making use of Coulomb's Law.

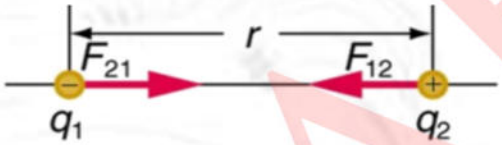
Electrostatic Force

"Alike charges repel each other while unlike charges attract each other "

Repulsive



Attractive



The forces between the two electrical charges depend on

1. Type of insulating medium between the two charges
2. The distance between the two charges (r)
   the force is inversely proportional to the square of the distance between charges
3. The Amount of both charges

the force is directly proportional between two charges

the magnitude of electric force between two charges is calculated by Coulomb's law

$$F = \frac{kq_1q_2}{r^2}$$

F: electric force between charges (N)
q: first and second charge (C)
r: distance between charges (m)
ε: electric permittivity of medium (C^2/Nm^2)
k: Coulomb's constant (Nm^2/C^2)

We do not use the negative charge sin in law

Notes:

1. Electrical force is a vector quantity.
2. Equal in magnitude and opposite in direction
3. Newton's third law. The force on q1 is equal in magnitude and opposite in direction to the force on q2. $F_{12} = -F_{21}$

1. A negative charge of -2.0×10^{-4} C and a positive charge of 8.0×10^{-4} C are separated by 0.30 m. What is the force between the two charges?

Solution.

Given.

$q_1 = -2.0\times10^{4}$ C

$q_2 = 8.0\times10^{-4}$ C

r = 0.30 m

K = 9.0×10^{9} $N.m^2/C^2$.

Unknown.

f_e=?

We must apply coulomb's law.

$$f_e = \frac{K\,q_1\,q_2}{r^2} = \frac{9.0\times10^{9}\times2.0\times10^{-4}\times8.0\times10^{-4}}{0.30^2} = 16000\ N.$$

$$f_e = 16000 = 1.6\times10^{4}\ N.$$

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2. A positive and a negative charge, each of magnitude 2.5×10^{-5} C, are separated by a distance of 15 cm. Find the force on each the particles.

Known(Given).
$q_1 = +2.5\times10^{-5}$ C.
$q_2 = -2.5\times10^{-5}$ C.
r= 15 cm = 0.15 m
K= 9.0×10^{9} N.m^2/C^2.

Unknown.
f_e=? N

$$f_e = \frac{K\,q_1\,q_2}{r^2} = \frac{9.0\times10^{9}\times2.5\times10^{-5}\times2.5\times10^{-5}}{0.15^2} = \mathbf{250N}\ .$$

3. A negative charge of -6.0×10^{-6} C exerts an attractive force of 65 N on a second charge that is 0.050 m away. What is the magnitude of the second charge?

Known (Given).
$q_1 = -6.0\times10^{-6}$.
F=65 N
r = 0.050 m

Unknown.
q_2 =?

$$f_e = \frac{K\,q_1\,q_2}{r^2} \qquad q_2 = \frac{f_e\times r^2}{K\,q_1}$$

$$q_2 = \frac{65\times0.050^2}{9.0\times10^{9}\times6.0\times10^{-6}} = \mathbf{3.0\times10^{-6}\ C}\ .$$

4. Two identical positive charges exert a repulsive force of 6.4×10^{-9} N when separated by a distance of 3.8×10^{-10} m. Calculate the charge of each.

Solution,
Known (Given).
$F_e = +6.4\times10^{-9}$ C.
r= 3.8×10^{-10} m.
K= 9.0×10^{9} N.m^2/C^2

Unknown.
q= q_1 =q_2 =? N.

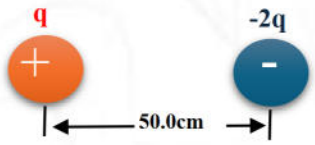
$$f_e = \frac{K\,q^2}{r^2} \qquad q^2 = \frac{f_e\times r^2}{K} \qquad q = \sqrt{\frac{f_e\times r^2}{K}}$$

$$q = \sqrt{\frac{6.4\times10^{-9}\times(3.8\times10^{-10})^2}{9.0\times10^{10}}} = 3.2\times10^{-19}\ C\ .$$

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Two spheres are charged with different types of charge. The spheres are 50 cm apart as shown in the figure, and the electric force between them is 2.6 N.



a. Calculate the charge on each of the two spheres.

.....

.....

.....

b. If the distance between the two spheres is reduced to 25cm, What happens to the magnitude of the electric force between the two spheres? Explain your answer.

.....

.....

.....

two positively charged spheres, one with three times the charge of the other. The spheres are 16 cm apart, and the force between them is 0.28 N.
What are the charges on the two spheres?



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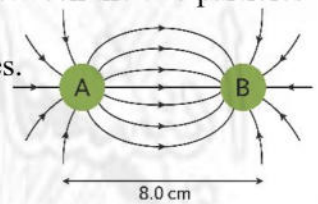
If the distance between the two spheres is reduced to 4cm, What happens to the magnitude of the electric force between the two spheres? Explain your answer.

.....

.....

.....

The figure shows the electric field lines around two particles (A and B) with equal charges, placed at a distance of 8.0 cm. The magnitude of the electric force between the two particles is 50.0 N.



a. Find the **magnitude of the electric charge** on each of the particles.

b. Identify the **type of electric charge** on each particle:

- Particle A:
- Particle B:

c. Draw an arrow on the above figure to show the **direction of the electric force on particle A**.

d. If the distance between the two particles is reduced to 4.0 cm, what happens to the **magnitude of the electric force between them**? Explain your answer.

.....

.....

.....

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The two forces on one straightness and in the same direction
(The result is the sum of their amounts in the same direction)

$$Fnet = F_1 + F_2$$

1. The two forces on one straightness and in the opposite direction
(The result is the minus of their amounts and in the direction of the great force)

$$Fnet = F_1 - F_2$$

2. The two forces are perpendicular We apply the Pythagorean law

$$Fnet = \sqrt{{F_x}^2 + {F_y}^2} \quad \theta = tan^{-1}(\frac{F_y}{F_x})$$

Coulomb's Law in two Dimensions.

Sphere A is located at the origin and has a charge of $+2.0\times10^{-6}$ C. Sphere B is located at +0.60 m on the *x*-axis and has a charge of -3.6×10^{-6} C. Sphere C is located at +0.80 m on the *x*-axis and has a charge of $+4.0\times10^{-6}$ C. Determine the net force on sphere A.

$$\mathbf{F_{B\ on\ A} = \frac{Kq_Aq_B}{r_{AB}^2}}$$

$$\mathbf{= \frac{(9.0\times10^9\ N\cdot m^2/C^2)(2.0\times10^{-6}\ C)(8.0\times10^{-6}\ C)}{(0.60\ m)^2}}$$

$$\mathbf{= 0.18\ N}$$

direction: toward the right

$$\mathbf{F_{C\ on\ A} = \frac{Kq_Aq_C}{r_{AC}^2}}$$

$$\mathbf{= \frac{(9.0\times10^9\ N\cdot m^2/C^2)(2.0\times10^{-6}\ C)(4.0\times10^{-6}\ C)}{(0.80\ m)^2}}$$

$$\mathbf{= 0.1125\ N}$$

direction: toward the left

$$\mathbf{F_{net} = F_{B\ on\ A} - F_{C\ on\ A} = (0.18\ N) - (0.1125\ N) = 0.068\ N\ toward\ the\ right}$$

Sphere A is located at the origin and has a charge of $+2.0\times10^{-6}$ C. Sphere B is located at +0.60 m on the *x*-axis and has a charge of -3.6×10^{-6} C. Sphere C is located at +0.80 m on the *x*-axis and has a charge of $+4.0\times10^{-6}$ C. Determine the net force on sphere B.

$$\mathbf{F_{net} = F_{net} - F_{net} = \frac{Kq_Bq_C}{r_{BC}^2} - \frac{Kq_Aq_B}{r_{AB}^2}}$$

$$F_{A\ on\ B} = K\frac{q_Aq_B}{r_{AB}^2} \text{ and } F_{C\ on\ B} = K\frac{q_Cq_B}{r_{CB}^2}$$

$$\mathbf{= \frac{(9.0\times10^9\ N\cdot m^2/C^2)(3.6\times10^{-6}\ C)(4.0\times10^{-6}\ C)}{(0.20\ m)^2}}$$

$$\mathbf{- \frac{(9.0\times10^9\ N\cdot m^2/C^2)(2.0\times10^{-6}\ C)(3.6\times10^{-6}\ C)}{(0.60\ m)^2}}$$

$$\mathbf{= 3.1\ N\ toward\ the\ right}$$

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1. Sphere A, with a charge of +6.0 μC, is located near another charged sphere, B. Sphere B has a charge of -3.0 μC and is located 4.0 cm to the right of A.
   a. What is the force of sphere B on sphere A?
   b. A third sphere, C with a +1.5 μC charge, is added. If it is located 3.0 cm directly beneath A, what is the new net force on sphere A?

Known (Given).

$q_A = q_1 = +6.0\ \mu C = +6.0\times10^{-6} C$

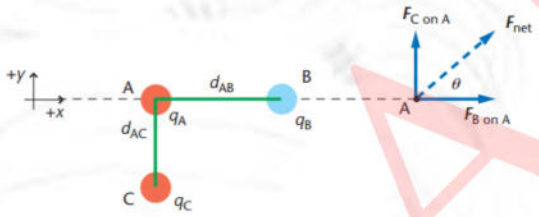
$q_B = q_2 = -3.0\ \mu C = -3.0\times10^{-6} C$

$q_c = q_3 = +1.5\ \mu C = +1.5\times10^{-6} C$

$r_{AB} = r_1 = 4.0\ cm = 4.0\times10^{-2} m$

$r_{AC} = 3.0\ cm = 3.0\times10^{-2} m$

$K = 9.0\times10^{9}\ N.m^2/C^2$.



Unknown (Not Given).

$F_{BA} = ?$ - $F_{CA} = ?$ - $F_{net} = ?$

$$F_{BA} = \frac{K\, q_1\, q_2}{r_1^2} = \frac{9.0\times10^{9} \times 6.0\times10^{-6} \times 3.0\times10^{-6}}{(4.0\times10^{-2})^2} = 1.0\times10^{2}\ N\ .$$

Because spheres A and B have unlike charges, the force of B on A is to the right.

$$F_{CA} = \frac{K\, q_3 \times q_1}{{r_{AC}}^2} = \frac{9.0\times10^{9} \times 1.5\times10^{-6} \times 6.0\times10^{-6}}{(3.0\times10^{-2})^2} = 9.0\times10^{1}\ N$$

Spheres A and C have like charges, which repel. The force of C on A is upward.

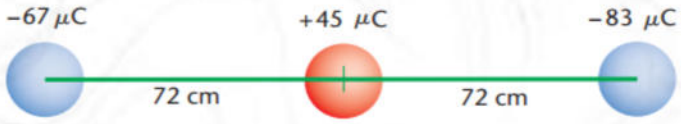
Find the vector sum of $F_{B\ on\ A}$ and $F_{C\ on\ A}$ to find F_{net} on sphere A.

$$F_{net} = \sqrt{(F_{(B\ on\ A)})^2 + (F_{C\ on\ A})^2} = \sqrt{(1.0\times10^{2})^2 + (9.0\times10^{1})^2} = 130\ N.$$

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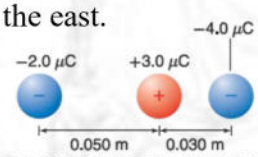
Three particles are placed in a line. The left particle has a charge of -67 μC, the middle,45 μC, and the right, -83 μC. The middle particle is 72 cm from each of the others, as shown in the Figure



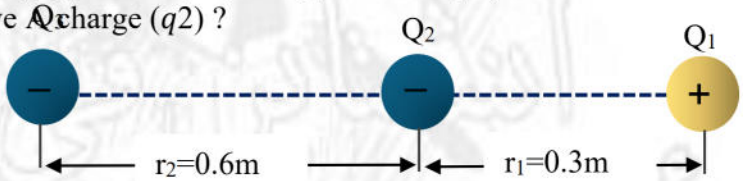
a. Find the net force on the middle particle.
b. Find the net force on the right particle

A positive charge of 3.0 μC is pulled on by two negative charges.one negative charge, -2.0 μC is 0.050 m to the west, and the other, -4.0 μC, is 0.030 m to the east.

What net force is exerted on the positive charge?



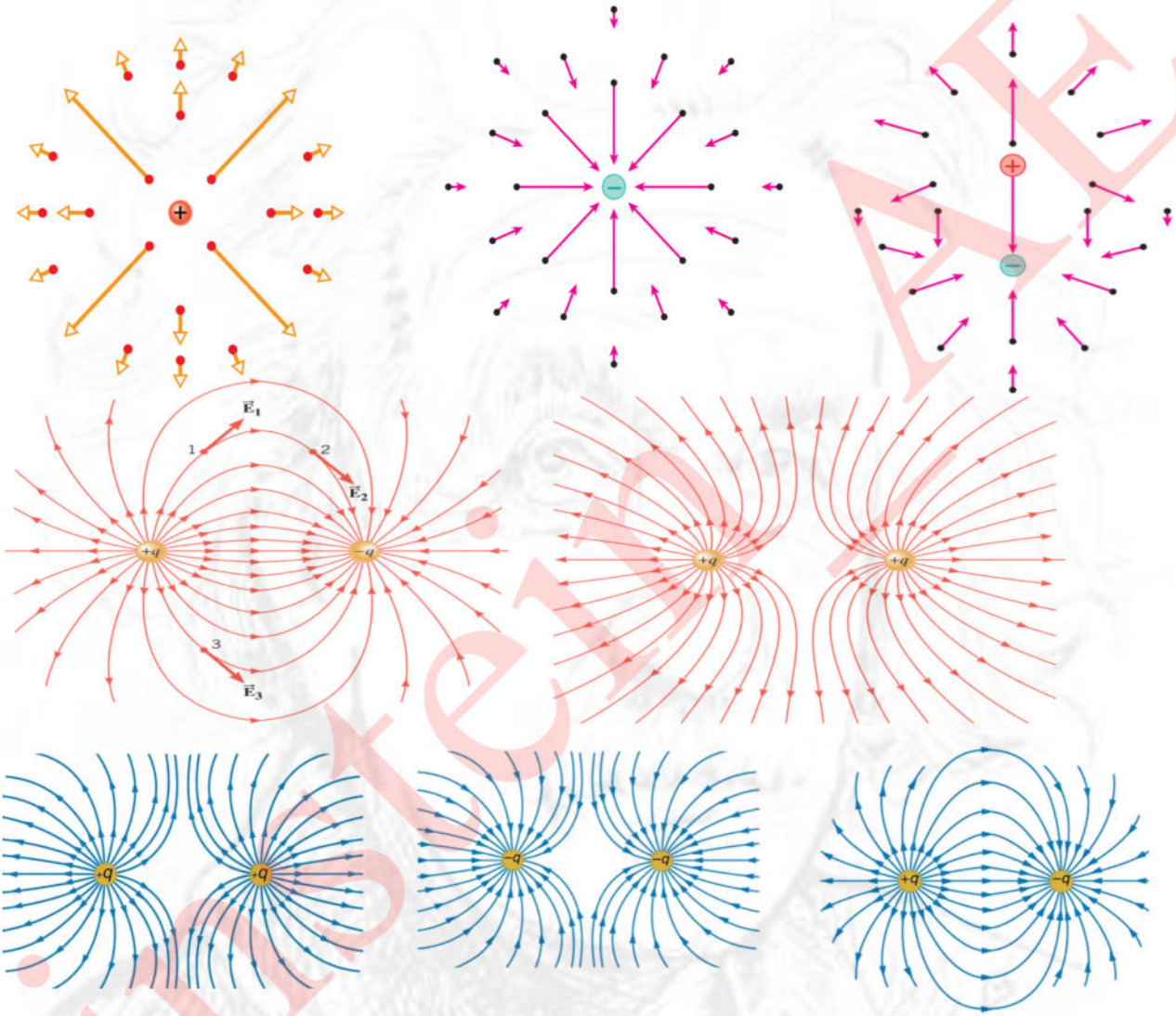
The figure shows three charges ($q1 = 3.0\ \mu C$), ($q2 = -1.0\ \mu C$) and ($q3 = -1.5.0\ \mu C$) what is the net force exerted on the negative charge ($q2$) ?
Coulomb's constant $k = 9 \times 10^9$



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Develop a tool, sketches, descriptive text or presentation to show the morphology of electric field lines of a single or multiple charge system with positive and/or negative charges.



Draw the Electric Field Lines (Diagrams):

Case 1: Single Point Charge

1. Draw the electric field lines for:
   - ✓ A **positive charge**
   - ✓ A **negative charge**



Case 2: Like Charges

2. Draw the electric field lines for:
   - ✓ **Two positive charges** of the same magnitude.
   - ✓ **Two negative charges** of the same magnitude.



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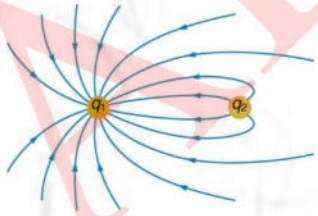
Case 3: Unlike Charges

3. Draw the electric field lines for:
   - ✓ **Two opposite charges** (one positive and one negative) of the same magnitude.

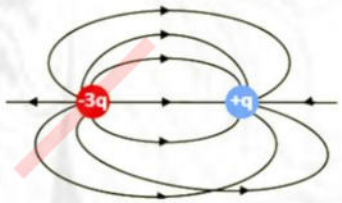


Depending on the adjacent diagram, complete the following table as appropriate:

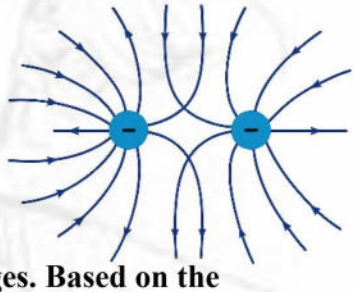
Charge	q_1	q_2
Type of charge		
Amount of charge	36μc	



A student drew the electric field lines around two charges, as shown in the figure. Write the three mistakes the student made.



A student drew the electric field lines around two equal and adjacent negative charges, as shown in the figure. Write the three mistakes the student made.



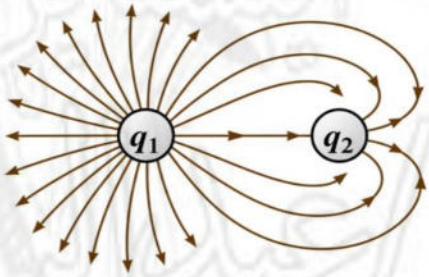
The diagram shows the electric field lines around two electric charges. Based on the diagram, answer the following:

a) What is the type of each of the two charges?

b) Which of the following inequalities expresses the relationship between the magnitude of the two charges q_1 and q_2? Justify the reason for your choice.

- $q_1 = q_2$
- $q_1 > q_2$
- $q_1 < q_2$

Justification:

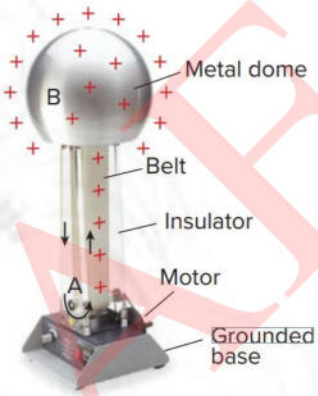


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Study of the Van de Graaff apparatus, a device that works on static electricity, including its components and working mechanism.

A **Van de Graaff generator** is a device that works on **static electricity** to build up a large amount of charge on a metal dome.



Main Components

- **Metal Dome**: Stores the accumulated charge.
- **Belt**: Moves charges from the bottom to the top.
- **Rollers (Pulleys)**: Drive the belt and help in charge separation.
- **Brush Assemblies**: Transfer charges to and from the belt.

Working Mechanism

1. The **bottom roller** becomes strongly **negatively charged**.
2. The **belt** acquires a weaker **positive charge**.
3. The negative roller repels electrons from the **brush tips** near point A, making them **positively charged**.
4. Electrons from the air are attracted to the brush tips, while **positive ions stick to the belt**.
5. The belt carries these positive charges to the **metal dome**.
6. Charges on the dome move to the **outer surface**, so they do not repel new charges arriving at point B.
7. When a person touches the dome, electrons from the body move toward the dome, causing **hair to stand up** due to repulsion between positively charged hairs.

Why isn't charge repelled back onto the belt at point B?

Because the charges on the dome produce **no electric field inside the dome** (Faraday cage effect). New charges are transferred to the outside immediately.

Why does hair stand up?

The person becomes positively charged, and individual hairs repel each other, aligning with the electric field



Why does your hair stand on end when you touch a Van de Graaff generator?

This is all down to static electricity.

- Inside the Van de Graaff generator, there is a rubber band and rollers. As they are electrically insulated, when the motor turns they rub together and electrons are 'knocked' off causing a positive charge.
- In order to try and reach an equilibrium, electrons from the dome (and anything touching it) move to the positively charged rubber band causing it to slowly gain a positive charge.
- If you are also touching the dome, you will slowly become positively charged including each of your hairs. As like charges repel, and hair is very light, they will try and get as far away from each other as possible, causing them to stand up.

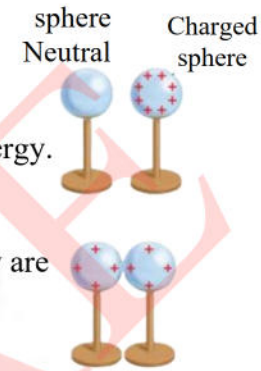
Why does a person's hair stand up when they touch a Van de Graaff generator?

- Because electric charges transfer from the generator to the person's body, causing the hair to become negatively charged and the strands repel each other.

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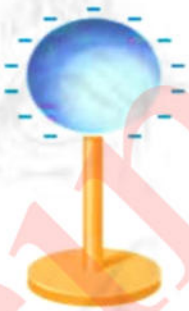
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1. Describe the charge distribution on a solid conducting sphere, a hollow conducting sphere and an irregular conducting surface.



➢ Sharing of Charge:

when a conductor is charged with a positive charge, due to the repulsive force.
These charges are separated from each other in a way that reduces their potential energy.
These charges are on the surface of the conductor.
(The conductor might be hollow or solid).
A charged sphere shares charge equally with a neutral sphere of equal size when they are placed in contact with each other.

Conducting Sphere	Hollow Sphere	Irregular Surface
On a conducting sphere, the charge is evenly distributed around the surface.	The charges on the hollow sphere are entirely on the outer surface.	On an irregular conducting surface, the charges are closest together at sharp points
		

1. Solid Conducting Sphere

- **Charge Distribution**: All excess charges reside **on the outer surface**.
- **Reason**: Charges repel each other and move as far apart as possible to minimize the system's energy.
- **Electric Field Inside**: **Zero** (due to electrostatic equilibrium).
- **Electric Field Outside**: Depends on the total charge and distance from the sphere; behaves like a point charge.

2. Hollow Conducting Sphere (or Shell)

- **Charge Distribution**: Excess charges also reside **only on the outer surface**.
- **Inside Surface**: No excess charge unless influenced by a charge placed inside the cavity.
- **Shielding Effect**: The hollow conductor **shields** its interior from external electric fields (Faraday cage effect).
- **Electric Field Inside the Cavity**: **Zero**, unless a charge is placed inside.

3. Irregular Conducting Surface

- **Charge Distribution**: Charges accumulate more densely at **sharp points or edges**.
- **Reason**: The curvature affects the local electric field; sharper regions have stronger fields and attract more charge.
- **Electric Field**: Stronger near sharp points due to closer field lines.
- **Consequences**:
  - ✓ Can lead to **ionization** of nearby air molecules.
  - ✓ May cause **sparks or discharge** (lightning or plasma formation).
  - ✓ To prevent this, high-voltage conductors are made **smooth**.

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Calculate the electric field strength at a point close to a single point charge / a conducting charged sphere.

A positive test charge of 5.0×10^{-6} C is in an electric field that exerts a force of 2.0×10^{-4} N on it. What is the magnitude of the electric field at the location of the test charge?

$$E = \frac{F}{q} = \frac{2.0\times10^{-4}\,\text{N}}{5.0\times10^{-6}\,\text{C}} = 4.0\times10^{1}\ \text{N/C}$$

A negative charge of 2.0×10^{-8} C experiences a force of 0.060 N to the right in an electric field. What are the field's magnitude and direction at that location?

$$E = \frac{F}{q} = \frac{0.060\ \text{N}}{2.0\times10^{-8}\,\text{C}} = 3.0\times10^{6}\ \text{N/C}$$

directed to the left

A positive charge of 3.0×10^{-7} C is located in a field of 27 N/C directed toward the south. What is the force acting on the charge?

$$E = \frac{F}{q}$$

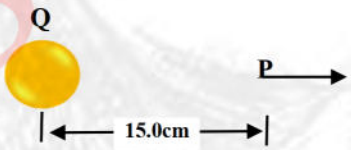
$$F = Eq = (27\ \text{N/C})(3.0\times10^{-7}\ \text{C})$$
$$= 8.1\times10^{-6}\ \text{N south}$$

A negative test charge is placed in an electric field as shown in. It experiences the force shown. What is the magnitude of the electric field at the location of the charge?

$$E = \frac{F}{q'} = \frac{0.080\ \text{N}}{-5.0\times10^{-6}\,\text{C}} = -1.6\times10^{-4}\ \text{N/C}$$

1.6×10^{-4} N/C, toward q

The magnitude of the electric field at point p is $6\times 10^{6} N/C$ p is 15.0cm away from a charge Q as shown in the figure.



a. Calculate the charge Q.

If a test charge with $-0.25\ \mu C$ was placed at point p,

b. find the magnitude. And determine the direction of the electric force acting on it.

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The figure shows a positive charge of 15.0 μC and a point A at a distance of 3.0 m from it.
Calculate the magnitude of the electric field at point A.
Draw an arrow to show the direction of the electric field at point A.
When a charge q is placed at point A, it experiences a force of 6.0 N opposite to the electric field.
What is the magnitude of the charge q?
What type is it?



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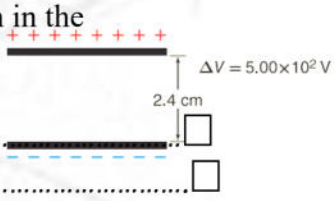
The electric field intensity between two large, charged parallel metal plates is 6000 N/C.
The plates are 0.05 m apart. What is the electric potential difference between them?

$$\Delta V = Ed = (6000\ \text{N/C})(0.05\ \text{m})$$
$$= 300\ \text{J/C} = 3\times10^{2}\ \text{V}$$

You apply a potential difference of 275 V between two parallel plates that are 0.35 cm apart.
How large is the electric field between the plates?

$$E = \frac{\Delta V}{d} = \frac{275\ \text{V}}{3.5\times10^{-3}\ \text{m}} = 7.9\times10^{4}\ \text{N/C}$$

What is the magnitude of the electric field between the two metal plates shown in the following figure?



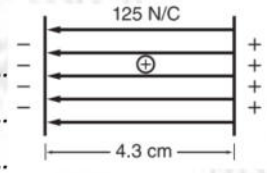
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How much work is done on a proton to move it from the negative plate to a positive plate 4.3 cm away if the field is 125 N/C?



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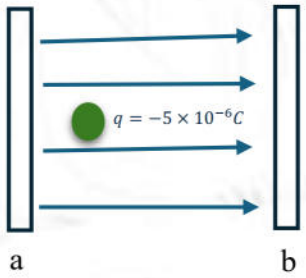
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The figure shows a negative charge of $q = -5 \times 10^{-6} C$ moving between two charged plates A and B. The electric field between the plates is $120 N/C$, the distance between them is $2.5\ cm$.



a. Find the magnitude of the electric force exerted on the charge.

b. Use the information on the figure to determine the direction in which the charge will move.
Draw a vector on the figure to show the direction of motion.

c. Calculate the magnitude of the work done to move the charge between the Two plates.

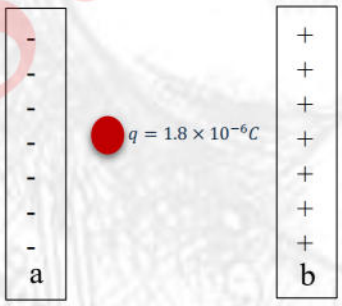
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The figure shows two charged plates (A and B) separated by a distance of 0.15 m. The work done to move a 1.8×10^{-6} Ccharge from A to B is 2.7×10^{-4} J.
a) Find the potential difference between the two plates.
b) Calculate the magnitude of the electric force acting on the charge.
c) Draw on the figure the electric field lines between the two plates showing its direction.



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Concepts in Electrostatics

Electrostatics
The study of electric charges at rest. It deals with forces, fields, and potentials created by static electric charges.

Neutral
An object is neutral when it has an equal number of positive and negative charges (protons and electrons).

Insulator
A material in which electric charge does **not move easily**. Examples: plastic, glass, dry wood.

Conductor
A material that allows electric charges to **move freely**. Examples: metals like copper and aluminum.

Electroscope
A device used to detect the presence of electric charge. It typically consists of metal leaves that spread apart when charged.

Charging by Conduction
Transferring charge by **direct contact** between a charged object and a neutral one.

Charging by Induction
Charging an object **without direct contact**, by bringing a charged object near and then grounding the neutral object.

Grounding
Connecting an object to the Earth to allow excess charge to flow away safely.

Coulomb's Law
Describes the force between two point charges:

$$F = k\frac{|\, q_1 q_2 \,|}{r^2}$$

where F is the force, q_1 and q_2 are the charges, r is the distance between them, and k is Coulomb's constant.

Coulomb (C)
The SI unit of electric charge. One coulomb is the amount of charge transferred by a current of one ampere in one second.

Elementary Charge (e)
The smallest unit of electric charge:

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

It's the charge of a single proton (positive) or electron (negative).

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Electric Field (E)
A region around a charged object where other charges experience a force.

$$E = \frac{F}{q}$$

where F is the force and q is the test charge.

Electric Field Line
Imaginary lines that represent the direction and strength of an electric field. They point away from positive charges and toward negative charges.

Electric Potential Difference (Voltage)
The work done to move a unit charge between two points in an electric field.

$$V = \frac{W}{q}$$

where V is voltage, W is work, and q is charge.

Volt (V)
The SI unit of electric potential difference. One volt equals one joule per coulomb.

Equipotential
A region where every point has the same electric potential. No work is needed to move a charge within this region.

Capacitor
A device that stores electric charge and energy in an electric field. It consists of two conductive plates separated by an insulator.

Capacitance (C)
The ability of a capacitor to store charge per unit voltage:

$$C = \frac{Q}{V}$$

where Q is charge and V is voltage. Measured in farads (F).

Match the Terms with Their Correct Definitions

Column A (Terms)	Column B (Definitions)
1. Electrostatics	A. A device that stores electric charge and energy.
2. Conductor	B. Connecting an object to the Earth to remove excess charge.
3. Grounding	C. The study of electric charges at rest.
4. Coulomb's Law	D. A material that allows electric charges to move freely.
5. Capacitor	E. Describes the force between two point charges.
6. Electric Field	F. Region around a charged object where other charges experience a force.

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The study of electric charges that can be collected and held in one place is called __. electrostatics

Fill in the blanks using the vocabulary terms from the table. Each term will be used once.

capacitor	electric field lines	grounding
conductor	electroscope	insulator
electric field	elementary charge	neutral

[1] An atom is said to be __ if the positive charge of the nucleus exactly balances the negative charge of the surrounding electrons. neutral

[2] The process of connecting a body to Earth to eliminate excess charge is called __. grounding

[3] An electric __ is a material through which charges move about easily. conductor

[4] A material through which electrical charges does not move easily is an electrical __. insulator

[5] A device that helps determine charge using pieces of metal foil is a(n) __. electroscope

[6] The magnitude of the charge of an electron is the __. elementary charge

[7] A device with a specific capacitance that is used in electric circuits to store electrical energy is a(n) __. capacitor

[8] The property of the space around a charged object that exerts a force on other charged objects is the __. electric field

[9] The lines providing a picture of the size and strength of the field around a charged object are called the __. electric field lines

Match each vocabulary term to its definition.

the SI standard unit of charge.	coulomb
1 J/C	volt

Match each vocabulary term to its definition.

giving a neutral object a charge by touching it with a charged object	charging by conduction
separating the charges in an object without touching it	charging by induction

Fill in the blanks using the vocabulary terms from the table. Each term will be used once.

capacitance	equipotential	potential difference

[1] The ratio of the net charge on one plate to the potential difference, measured in farads, between two plates of a capacitor is the __. capacitance

[2] The work done moving a positive test charge between two points in an electric field divided by the magnitude of the test charge is the electric __. potential difference

[3] The potential difference of zero between two or more positions in an electric field is the __. Equipotential

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