UNIVERSITY OF KWAZULU-NATAL

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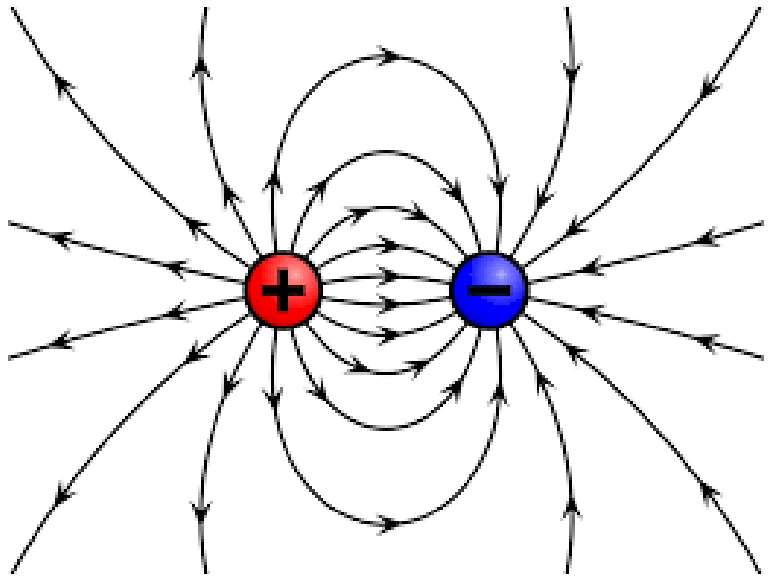
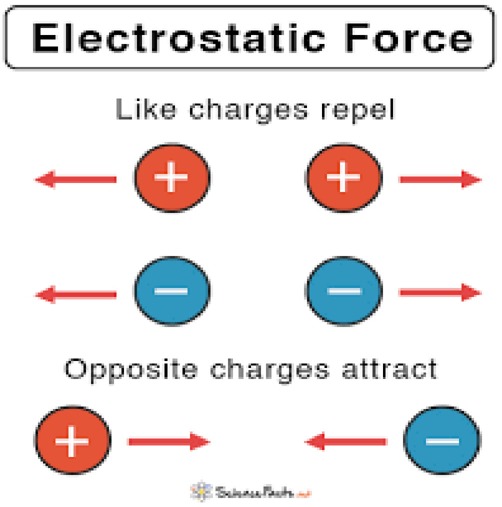
Grade 11 & 12
Physical Science
IsiZulu

Electrostatics

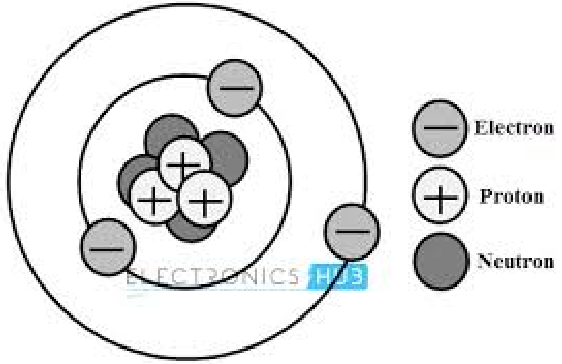
Electrostatics

- Definition: Electrical charge & electric force
- The Law of Conservation of Charge
- Coulomb's Law
- Electric fields around charged objects
- Electric field strength





Electric charge

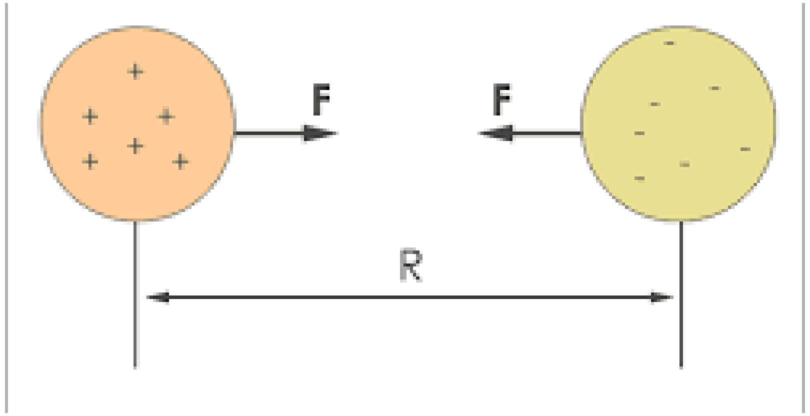


- At the atomic level, charge is associated with protons and electrons. They have the same magnitude of charge, but their charge is opposite in sign.
- Protons have Positive charge(+) and Electrons have Negative charge(-).
- A coulomb C, the units for charge, is defined technically as one ampere-second (1 As), in other words, the amount of charge carried by one ampere in one second.
- Electrical charges will exert forces on each other. Two positive charges will repel each other and two negative charges will repel each other.

“Like charges, or charges of the same sign, repel each other”

“Unlike charges attract each other”

Electric Force



- Electrical charges will exert forces on each other.
- Coulomb's Law is a measure of how strong the force is between two charged objects.

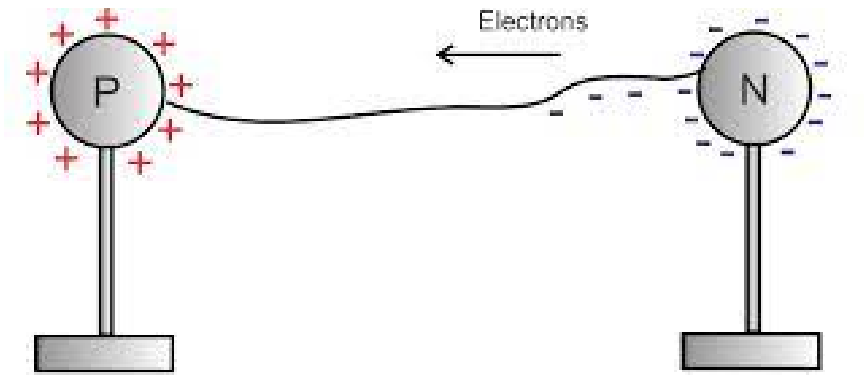
$$\vec{F} = k\frac{Q_1 Q_2}{r^2} \quad \text{.........(2)}$$

where Q_1 and Q_2 are the magnitudes of charge on charge 1 and charge 2 respectively. The distance between their centres is *r*.

- The force is proportional to the product of the charges and inversely proportional to the square of the distance between them.

The Law of Conservation of Charge

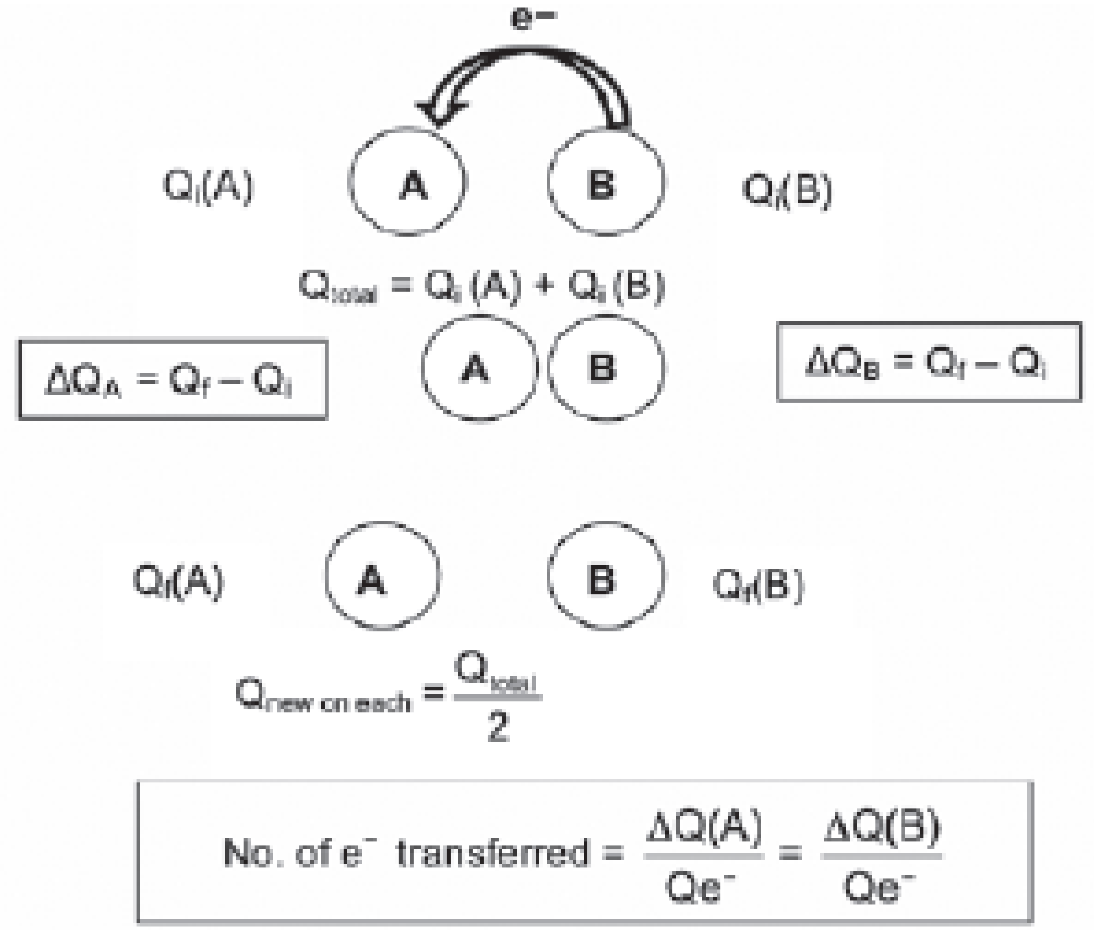
- The Law of Conservation of Charge states that: **“the net charge of an isolated system will always remain constant”**.
- When two charged spheres are brought into contact with each other, electrons flow from the sphere with more electrons to the sphere with fewer electrons.



The charge on an electron (Q e^-) is 1.622×10^{-19} C

Only Electrons are free to move because they are loosely held in an atom.

The Law of Conservation of Charge



Question

- Two spheres A and B carry charges of +5 C and −7 C respectively. They are brought into contact and are then separated.

1. What is the nature of the force between the charges before they are allowed to touch? Explain.
2. In which direction are electrons transferred during the contact? Explain.
3. Calculate the total charge in the system.
4. Calculate the charge on each sphere when they are separated.
5. Calculate the change in the charge on A and on B.
6. Calculate the number of electrons transferred from one sphere to the other.

Solutions

1. Attraction. Opposite charges (+ and −) attract.
2. From sphere B to sphere A. Electrons are transferred from the sphere with the most electrons (B in this case) to the sphere with the least electrons (A).
3. $Q_{total} = Q_i\,(A) + Q_i\,(B) = +5 + (-7) = -2$ C.
4. $\Delta Q_A = Q_f - Q_i = -1 - (+5) = -6$ C ∴ 6 C charge was transferred from B to A.
5. $\Delta Q_B = Q_f - Q_i = -1 - (-7) = +6$ C ∴ 6 C charge was transferred from B to A.
6. No. of e– transferred = $\frac{\Delta Q(A)}{Q\_e^-} = \frac{\Delta Q(B)}{Q\_e^-} = \frac{6}{1.622x10-19} =$ 3.75 x10−1^9 electrons

Coulomb's Law

- Coloumb's Law is the electrostatic force of attraction or repulsion between two charged objects is directly proportional to the product of the charges and inversely proportional to the square of the distance between their centres.

$$\vec{F} = k\,\frac{Q_1 Q_2}{r^2}$$

where Q_1 and Q_2 are the magnitudes of charge on charge 1 and charge 2 respectively. The distance between their centres is *r.*

- For any two charges, where F is electrostatic force (N), Q is charge (C), r is the distance between the centres of the objects (m), and k is Coulomb's constant is (9×10^9 Nm^2C^{-2}).

Question

Two small identical metal spheres, A and B carrying charge of -4×10^{-12}C and -3×10^{-12}C respectively, are mounted on insulated stands. The distance between the centres of the spheres is 5 cm.

1. Calculate the magnitude and direction of the force that A exerts on B. Sphere A is moved and makes contact with sphere B. It is then moved back to its original position.

2. Calculate the new charge on each of the spheres. (3)

3. How does the magnitude of the force that the sphere A exerts on sphere B change? Answer by writing ONLY increases, decreases or remains the same.

Solution

1. $\vec{F} = k\,\frac{Q_1 Q_2}{r^2} = \frac{9\times10^9\,(3\times10^{-12})(-4\times10^{-12})}{(0.05)^2} = -4.3\times10^{-11}$ N , Force of attraction.

2. $Q = Q_1 + Q_2 = \frac{3\times10^{-12} + (-4\times10^{-12})}{2} = 5\times10^{-13}$ C

3. Increases

Electric fields around charged objects

- **Definition**:

An electric field is a region or space in which an electric charge experiences an electric force. Electric field is a **vector quantity**.

- An electric field line indicates the direction in which a positive test charge would move if placed at a point in the electric field.

Properties of Electric Field Lines

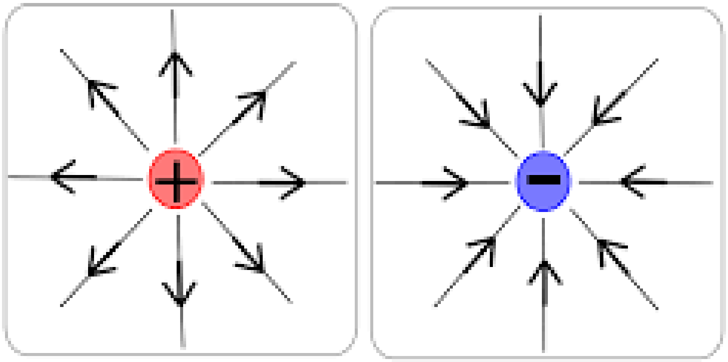
Electric field lines:

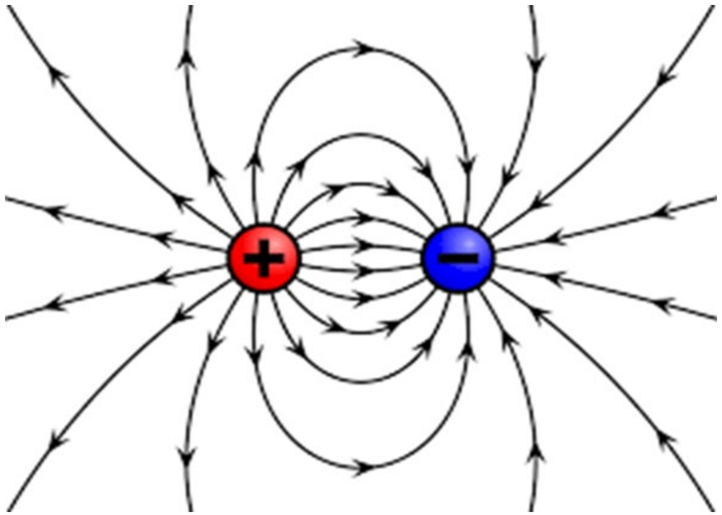
• start and end perpendicular to the surface of a charged object.

• never cross each other

• are closer where the electric field is stronger

• are directed from positive to negative





Electric field strength

- The electric field strength at a point is the electric force per unit positive charge experienced at a point in an electric field.

$$\vec{E} = k\,\frac{Q}{r^2}$$ **SI unit: (NC^{-1})**

The electric field $\vec{E}$ produced by a charge Q at the location of a small "test" charge q is defined as the electric force $\vec{F}$ exerted by Q on q divided by the test charge q.

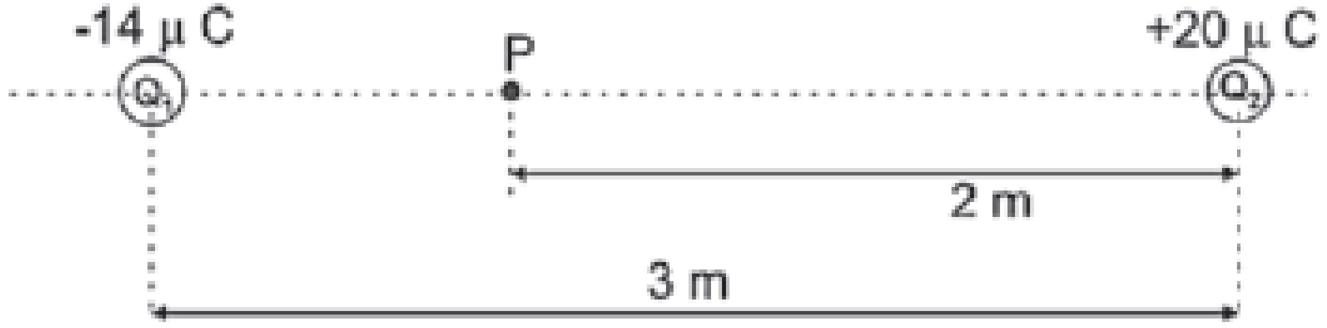
$$\vec{E} = \frac{\vec{F}}{q}$$ **SI unit: (NC^{-1})**

Question

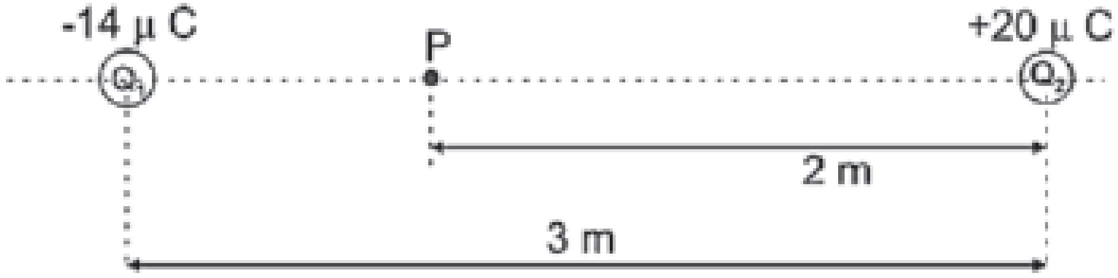
- Two point charges, Q_1 and Q_2, at a distance of 3 m apart, are shown below. The charge on Q_1 is –14 µC and the charge on Q_2 is +20 µC.

a) Define the electric field strength at a point.

b) Calculate the net (resultant) electric field at point P situated 2 m from Q_2.



Solution



a) Electric field strength at a point is the electric force per unit positive charge experienced at the point.

b) Electric field at P due to Q_1 :

$\vec{E} = k\frac{Q}{r^2} = \frac{9\times10^9(14\times 10^{-6})}{(1)^2}$ = 1,26 × 10^5 N·C^{-1} to the left

Electric field at P due to Q2:

$\vec{E} = k\frac{Q}{r^2} = \frac{9\times10^9(20\times 10^{-6})}{(1)^2}$ = 4,5 × 10^4 N·C^{-1} to the left

$E_{net} = E_{Q1} + E_{Q2}$ = (+1,26 × 10^5) + (+4,5 × 10^4 N·C^{-1}) = 1,71 × 10^5N·C^{-1} to the left