ELECTROSTATICS

UNIT 10

Student Learning Outcomes (SLOs)

The students will:

- state that an electric field is an example of a field of force.
- Define and calculate electric field strength [Use F = q E for the force on a charge in an electric field. Use E = $\Delta V/\Delta r$ to calculate the field strength of the uniform field between charged parallel plates].
- Represent an electric field by means of field lines.
- Describe the effect of a uniform electric field on the motion of charged particles.
- state that, for a point outside a spherical conductor, the charge on the sphere may be considered to be a point charge at its center.
- Explain how a Faraday cage works [by inducing internal electric fields that work to shield the inside from the influence of external electric fields].
- State and apply Coulomb's law [$F = k\frac{q_1 q_2}{r^2}$ for the force between two point charges in free space, where $k = \frac{1}{4\pi\varepsilon_0}$]
- Use $E = k\,Q/r^2$ for the electric field strength due to a point charge in free space.
- Describe how ferrofluids work [they make use of temporary soft magnetic materials suspended in liquids to develop fluids that react to the poles of a magnet and have many applications in fields such as electronics].

We know that all matter is made up of atoms. These atoms are composed of electrons, protons, and neutrons. Each proton has one unit of positive charge and each electron has one unit of negative charge. A neutron has no charge. Protons and neutrons are tightly packed in the nucleus while electrons can be thought of as small charged clouds that surround the nucleus of atoms. An atom normally has an equal number of electrons and protons making it electrically neutral. If an electron is removed from an atom, then the atom acquires a net positive charge. If an extra electron is added to an atom, it acquires a net negative charge. In the cover picture, it is shown that when we rub a comb in our hairs, the comb gets charged. When this charged comb is brought to the pieces of papers, these pieces get attracted due to induction. The study of electric charges at rest and the forces between them is referred to as electrostatics.

In this chapter, we investigate electric forces and discuss about the various phenomena associated with the positive and negative charges.

10.1 COULOMB'S LAW

A French physicist Charles Coulomb (1736-1806) performed experiments for the electrostatic force and proposed a formula to calculate it. The mathematical formula for the electrostatic force is called Coulomb's law. This law is defined as:

The force of attraction or repulsion between two charged bodies is directly proportional to the product of magnitude of charges and inversely proportional to the square of distance between them.

If we consider two point charges q_1 and q_2 separated by distance r, as shown in Fig. 10.1. According to Coulomb's law, the magnitude of the force F is given by:

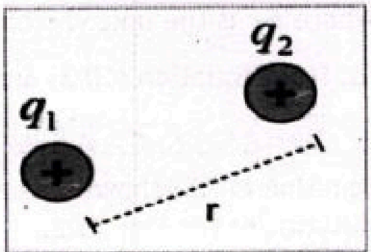


Figure 10.1: Two similar charges separated by a distance r.

$$F \propto q_1 q_2$$

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

By combining above two relations, we get:

$$F \propto \frac{q_1 q_2}{r^2}$$

or $$F = k\frac{q_1 q_2}{r^2} \qquad (10.1)$$

Here k is the constant of proportionality, known as Coulomb's constant. It is typically expressed in terms of permittivity of fee space ε_o. i.e. $k = \frac{1}{4\pi\varepsilon_o}$

Here $\varepsilon_o = 8.85\times10^{-12}\ C^2\ N^{-1}\ m^{-2}$.

So, $$F = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2} \qquad (10.2)$$

This is mathematical form of coulomb's law. The equation (10.2) represents the force between the two charges when there is vacuum between them.

The value of k depends upon system of units used and medium between the charges. In SI system, $k = 9 \times 10^9$ N m^2 C^{-2}. This value of k is applicable if there is vacuum between the charges. Coulomb's law is applicable to point charges and uniform spherical charge distribution. A point charge is an imaginary charge located at a single point in space. An electron can be considered a point charge.

A charged sphere also behaves as a point charge for a point outside the spherical conductor. This is due to the reason that the electric field at any point outside a spherical charge distribution is the same as the field that would be produced by a point charge located at its center. This is true only if the spherical conductor is isolated. If another charged object is brought near the spherical conductor, it will induce surface charges in the spherical conductor that are not spherically symmetric, and therefore, we can no longer treat it as a point charge.

When using Coulomb's force law, remember that force is a vector quantity and must be treated accordingly. Coulomb's law in vector form for the electric force exerted on a charge q_1 by a second charge q_2, is written as:

$$\boldsymbol{F}_{12} = k\frac{q_1 q_2}{r^2}\hat{r}_{12} \qquad \text{______ (10.3)}$$

Where, $\hat{r}_{12}$ is unit vector in the direction of $\boldsymbol{F}_{12}$. Similarly, the electric force exerted on a charge q_2 by a charge q_1, is written as:

$$\boldsymbol{F}_{21} = k\frac{q_1 q_2}{r^2}\hat{r}_{21} \qquad \text{______ (10.4)}$$

Where $\hat{r}_{21}$ is the unit vector in the direction of $\boldsymbol{F}_{21}$. Since $\hat{r}_{12} = -\hat{r}_{21}$

So, from equation (10.3) and (10.4), we can write:

$$\boldsymbol{F}_{21} = -\boldsymbol{F}_{12} \qquad \text{______ (10.5)}$$

Equation (10.5) shows that two forces are equal in magnitude but opposite in direction which is illustrated in Fig. 10.2.

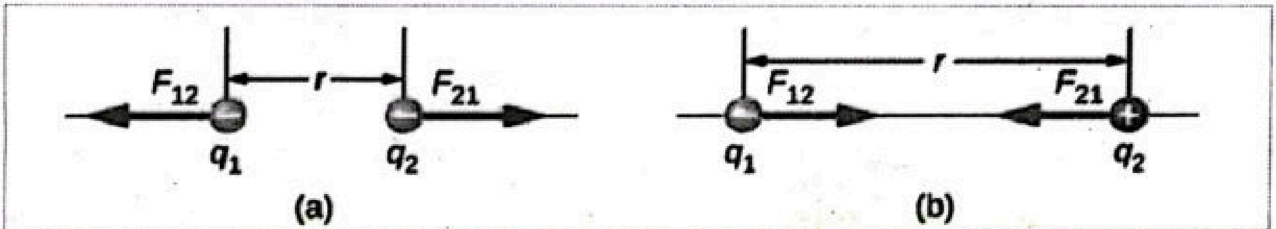


Figure 10.2: (a) Charges with the same sign repel each other. (b) Charges with opposite signs attract each other

For like charges, the product $q_1 q_2$ will be positive resulting in a force of repulsion between these two charges. For unlike charges, the product $q_1 q_2$ will be negative resulting in a force of attraction between these two charges.

Like other forces, electric forces obey Newton's third law; hence, the forces $\boldsymbol{F}_{12}$ and $\boldsymbol{F}_{21}$ are equal in magnitude but opposite in direction.

A comparison of coulomb's force and gravitational force shows that both act at a distance without direct contact, such force is called field force. Both are inversely proportional to the distance squared, with the force directed along a line connecting the two bodies. The mathematical form is the same, with the masses m_1 and m_2 in Newton's law replaced by charges q_1 and q_2 in Coulomb's law and with Newton's constant G replaced by Coulomb's constant k. There are two important differences: electric forces can be either attractive or repulsive, whereas gravitational forces are always attractive. Additionally, the electric force between charged elementary particles is far stronger than the gravitational force between the same particles.

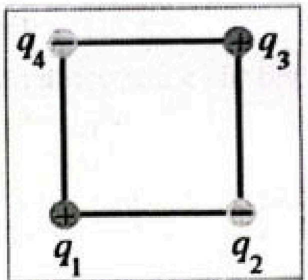


Figure 10.2 (c): Four charges q_1, q_2, q_3 and q_4 placed near each other.

The Superposition Principle of Force: When we have number of charges in a certain region, then each charge experiences a net force due to all other charges placed at suitable distance. These electric forces can all be computed separately, one at a time, then added as vectors. This is an example of the superposition principle.

For example, if four charges q_1, q_2, q_3 and q_4 are placed near each other, as shown in Fig. 10.2 (c), the resultant force exerted by charges q_2, q_3 and q_4 on charge q_1 is:

$$F = F_{12} + F_{13} + F_{14}$$

The following example illustrates this procedure in two dimensions.

Example 10.1: Three point charges are located at the corners of a right triangle, as shown in figure 10.3, where $q_1 = q_3 = 5.00\ \mu C$, $q_2 = -2.00\ \mu C$, and a = 0.100 m. Find the resultant force exerted on q_3.

Given: $q_1 = q_3 = 5.00\ \mu C$, $q_2 = -2.00\ \mu C$, a = 0.100 m.

To Find: $F_3 = ?$

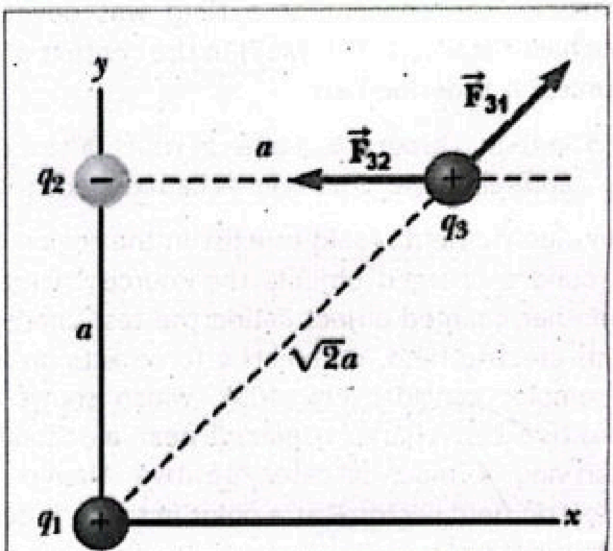


Figure 10.3: Three point charges located at the corners of a right triangle.

Solution: As charge q_3 is near two other charges, it will experience two electric forces. These forces are exerted in different directions, as shown in Fig. 10.3. Because two forces are exerted on charge q_3, we solve this example by using superposition principle.

The force F_{32} exerted on q_3 by q_2 is attractive because q_2 and q_3 have opposite signs. In the coordinate system, the attractive force F_{32} is to the left (in the negative x-direction). The force F_{31} exerted on q_3 by q_1 is repulsive because both charges are positive. The repulsive force F_{31} makes an angle of 45° with the x-axis.

Using Coulomb's law to find the magnitude of F_{32}

$$F_{32} = \frac{1}{4\pi\varepsilon_0}\frac{q_2 q_3}{r^2}$$

$$F_{32} = 9 \times 10^9 \frac{(2\times10^{-6})(5\times10^{-6})}{a^2}$$

$$= 9 \times 10^9 \frac{(2\times10^{-6})(5\times10^{-6})}{(0.100)^2} = 8.99 \text{ N}$$

To find the magnitude of F_{31} is

$$F_{31} = \frac{1}{4\pi\varepsilon_o}\frac{q_3 q_1}{r^2}$$

$$F_{31} = 9 \times 10^9 \frac{(5\times10^{-6})(5\times10^{-6})}{(\sqrt{2}a)^2}$$

$$= 9 \times 10^9 \frac{(2\times10^{-6})(5\times10^{-6})}{2(0.100)^2} = 11.2 \text{ N}$$

Find the x and y-components of the force F_{31}:

$$F_{31x} = F_{31}\cos 45° = 7.94 \text{ N}$$

$$F_{31y} = F_{31}\sin 45° = 7.94 \text{ N}$$

Find the components of the resultant force acting on q_3:

$$F_{3x} = F_{31x} + F_{32x} = 7.94 \text{ N} + (-8.99 \text{ N}) = -1.04 \text{ N}$$

$$F_{3y} = F_{31y} + F_{32y} = 7.94 \text{ N} + 0 = 7.94 \text{ N}$$

In vector form, the resultant force acting on q_3 is:

$$\boldsymbol{F}_3 = (-1.04\, i + 7.94\, j) \text{ N}$$

Assignment 10.1

What is the magnitude of the force of attraction between an iron nucleus bearing charge q=26e and its innermost electron, if the distance between them is 1×10^{-12} m.

10.2 ELECTRIC FIELD INTENSITY

An electric field, like other fields (e.g., gravitational or magnetic), is a vector field that surrounds the charged object. Electric fields are found around electric charges and help determine the direction and magnitude of force the charge exerts on a nearby charged particle. The concept of a field was developed by Michael Faraday (1791-1867) in the context of electric forces. It is defined as:

> The region around a charge in which a test charge can feel an electric force is called electric field.

An electric field is said to exist in the region of space around a charged object, the source charge. When another charged object called the test charge enters this electric field, an electric force acts on it. As an example, consider Fig. 10.4, which shows a small positive test charge q placed near a second object carrying a much greater positive charge Q. The electric field vector $\boldsymbol{E}$ at a point in space is defined as the electric force $\boldsymbol{F}$ acting on a positive test charge q placed at that point, divided by the magnitude of test charge. If test charge q is moved away from the source

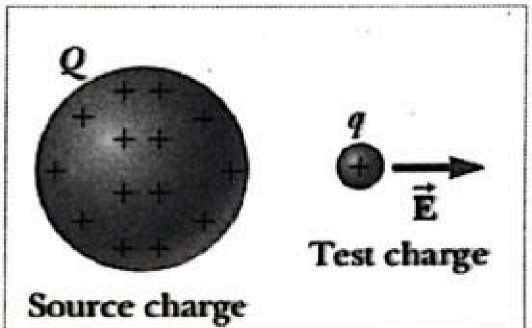


Figure 10.4: A small positive test charge q placed near an object carrying a much larger positive charge Q, experiences an electric field $\vec{E}$ established by the source charge Q. We always assume that the test charge is so small that the field of the source charge is unaffected by its presence.

charge Q, the force will decrease till a certain distance, and after that the force will practically reduce to zero. This is because of the fact that now q is not in the field of Q.

Electric field intensity $\boldsymbol{E}$ is a single vector quantity containing information about the field strength and its direction at a point. The strength of the field at a point in space determines the amount of force that a charge will experience if it is placed at that point. The direction in which this unit positive test charge will move or tends to move is the direction of the electric field. The test charge is so small that it does not distort the original field due to the primary source.

The force per unit positive test charge at any point is called electric field intensity at that point.

If $\boldsymbol{F}$ is the force experienced by a test charge q placed inside the field, then the value of electric intensity $\vec{E}$ at that point is given as:

$$\boldsymbol{E} = \frac{\boldsymbol{F}}{q} \qquad \text{\_\_\_\_\_\_ (10.6)}$$

If we use coulomb's law, $\boldsymbol{F} = k\frac{Qq}{r^2}\hat{r}$, then the above equation appears as:

$$\boldsymbol{E} = k\frac{Q}{r^2}\hat{r} \qquad \text{\_\_\_\_\_\_ (10.7)}$$

The SI unit of E is newton per coulomb (N C^{-1}) or volt per metre (V m^{-1}). The strength of the field is proportional to the magnitude of the source charge. Its strength decreases as the test charge moves away from source charge. $\boldsymbol{E}$ is always directed from positive to negative charges.

Example 10.2: Determine electric field at the surface of a sphere of radius 3.0 m if a point charge of 9 μC is placed at the centre.

Given: Electric field = E = ? Radius of sphere = r = 3.0 m

Point charge at the centre = q = 9 μC = 9×10^{-6} C

To Find: Electric field intensity = ?

Solution: Using the formula for electric field intensity:

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

By putting the above values in the equation, we get:

$$E = 9\times10^{9}\times\frac{9\times10^{-6}}{(3)^2} = 9\times10^{9-6}$$

$$E = 9\times10^{3}\ \text{N C}^{-1}$$

Assignment 10.2

A conducting sphere carries a charge of 200 μC. Find the electric field intensity at a distance 60 cm from the centre of the sphere.

10.3 ELECTRIC FIELD LINES

A way of visualizing electric field patterns is to draw lines, called electric field lines. Electric field lines were first introduced by Faraday.

The *direction* and *intensity* of electric field in the vicinity of a charge body can be represented by drawing imaginary lines called electric lines of force.

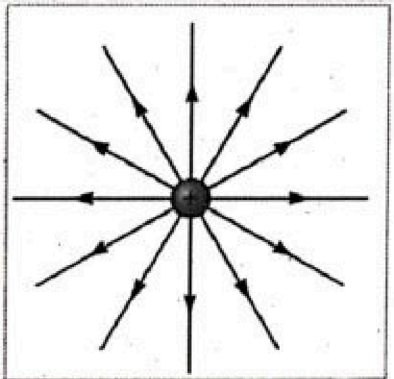


Figure 10.5: Electric field lines of isolated positive charge in 2-dimension.

It is important to remember that electric fields are three-dimensional. Two-dimensional representation of electric field lines for the field due to a single positive point charge is shown in Fig. 10.5. This two-dimensional drawing shows only the field lines that lie in the plane containing the point charge.

The electric field lines are actually directed radially outward from positive charge in all directions; therefore, instead of the flat "wheel" of lines shown, you should picture an entire spherical distribution of lines.

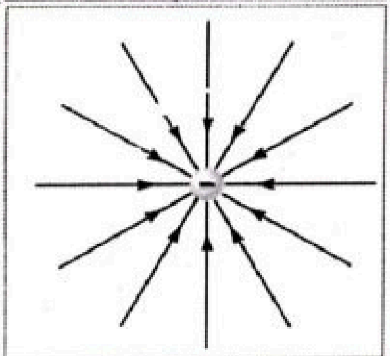


Figure 10.6: Electric field lines of isolated negative charge in 2-dimension.

The electric field lines representing the field due to a single negative point charge are directed toward the charge (Fig. 10.6).

In either case, the lines are along the radial direction and extend all the way to infinity. Notice that the lines become closer as they approach the charge, indicating that the strength of the field increases as we move towards the source charge.

Figure 10.7 shows the symmetric electric field lines for two point charges of equal magnitude but opposite sign. This charge configuration is called an electric dipole. Note that the field lines start from positive charge and ends at negative charge. The high density of lines between the charges indicates a strong electric field in this region. Thus, field is stronger in the region between the charges because the resultant intensity is equal to the sum of the intensities due to positive and negative charges. The number of lines that begin at the positive charge must equal the number of lines that terminate at the negative charge.

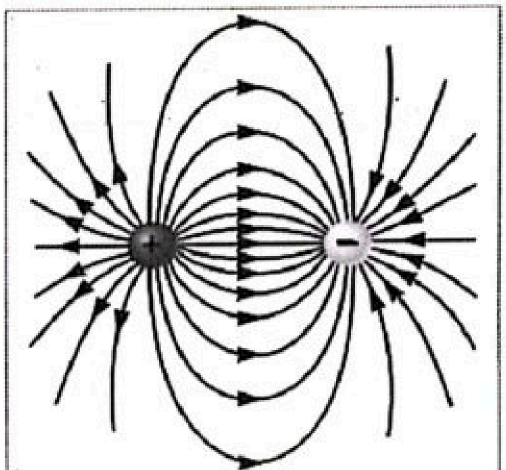


Figure 10.7: Two-dimensional drawing of electric field lines of two opposite charges placed near each other.

Figure 10.8 shows the field lines of two positive charges. At some points, situated between the two charges, the resultant intensity is zero, which creates a field free region. Two negative charges also produce the fields very similar to the field produced by two positive charges, except that the directions are reversed.

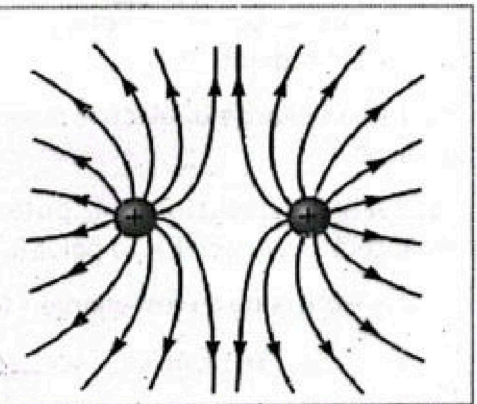


Figure 10.8: Two-dimensional drawing of electric field lines of two similar charges placed near each other.

The electric lines of force between two oppositely charged parallel plates separated by a small distance is shown in Fig. 10.9. One plate has a uniform positive charge distribution while the other has a uniform negative charge distribution. The field lines start from the positive plate and end at negative plate. The field between the plates is uniform in strength. If the plates have finite length, then field lines at the ends of plates will curve, as shown in Fig. 10.9. Such curved field at the ends of plates is called "fringing field". Fringing field shows that field is not uniform at the ends.

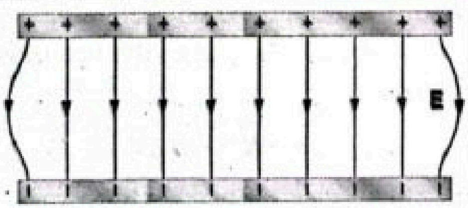


Figure 10.9: Fringing field at the ends of oppositely charged plates.

From the above discussion, we conclude that:

- The field lines never intersect each other.
- To represent field lines starting or ending at infinity, a single charge must be used.
- Electric lines of force originate from a positive charge and terminate at a negative charge.
- The tangent drawn to any point on a field line indicates the direction of electric intensity at that point. The arrows indicate the direction of electric field at various points.
- The intensity of electric field is proportional to the number of electric field lines per unit area.
- Electric lines of force are close in the region where field is strong and far apart in the weaker regions.
- The electric lines of force have the tendency to contract in length. This explains attraction between oppositely charged bodies.

10.4 POTENTIAL GRADIENT

The potential gradient represents the rate of change of electric potential with respect to displacement. In other words, it represents the slope along which potential is changing.

Potential difference between two points is the difference between the electric potential at points A and the electric potential at point B, as shown in Fig. 10.10 (a). If V_A and V_B is measured potential at these two points, then $V_A - V_B$ is the potential difference. If ΔV is

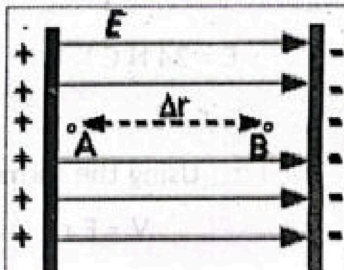


Figure 10.10 (a): Potential difference between two points A and B.

the change in potential between two points separated by a distance Δr, then, $\Delta V/\Delta r$ will be potential gradient.

The rate of change of electric potential ΔV with respect to displacement Δr is known as potential gradient.

To derive a relation for potential gradient, consider a test charge q moving a small distance Δr from point A to point B. Using definition of work:

Work done on test charge = force acting on test charge × displacement moved by test charge

$$W = F\,\Delta r \qquad \text{(10.8)}$$

For a charge q is in an electric field E, force is given by F = q E.

So, equation (10.8) becomes:

$$W = q\,E\,\Delta r \qquad \text{(10.9)}$$

Also, the work done on the test charge q moving through potential difference ΔV is equal to the decrease of electric potential energy, i.e.,

$$W = -\,q\Delta V \qquad \text{(10.10)}$$

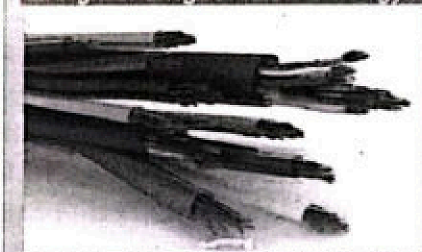
Negative sign indicates that the work done on q is against field force. Comparing equation (10.9) and equation (10.10), we get:

$$q\,E\,\Delta r = -\,q\,\Delta V$$

$$E\,\Delta r = -\,\Delta V$$

$$E = -\frac{\Delta V}{\Delta r} \qquad \text{(10.11)}$$

Potential Gradient in Electrical Engineering and Technology



During the manufacturing of cables, the value of dielectric insulation provided is kept higher than the potential gradient of the conductor, else the cable is not safe. If the value of potential gradient is kept high in power systems, then it may affect the person on touching.

Equation (10.11) shows that strength of the electric field E is equal to the potential gradient $\Delta V/\Delta r$. The negative sign indicates that the electric potential increases in the opposite direction of the electric field vector. Also, equation (10.11) shows that the unit of electric field E is volt per metre.

Example 10.3: The electric field at a point due to a point charge is 24 N C^{-1} and the electric potential at that point is 6 J C^{-1}. Calculate the distance of the point from the charge.

Given: E = 24 N C^{-1} V = 6 J C^{-1}

To Find: r = ?

Solution: Using the formula for potential gradient, we have:

$$V = E\,r$$

or $$r = V/E$$

Putting values, we get:

$$r = 6/24 = 0.25\text{ m}$$

Assignment 10.3

Show that: $\frac{\text{volt}}{\text{metre}} = \frac{\text{newton}}{\text{coulomb}}$

10.4.1 Motion of a Charged Particle in an Electric Field

When a charge +q is placed in an electric field E, as shown in the Fig. 10.10 (b), it experiences a force in the electric field E.

- If the charge is allowed to move freely in the electric field, it will move from positive plate to the negative plate and gain kinetic energy.
- If the charge is moved against the electric field, an external force ($F = +q E$) is required. This increases the potential energy of the charge. When the charge is released from its position, it will move back and gain an equivalent amount of K.E.

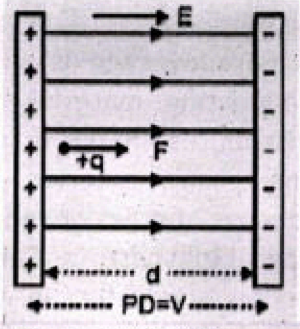


Figure 10.10 (b): Charged Particle in an electric field.

10.5 FERROFLUID

A ferrofluid is a liquid which becomes highly magnetized in the presence of a magnetic field. Ferrofluid is composed of very small, nanometer-sized particles (diameter usually 10 nm or less) of magnetite, hematite or some other compound containing iron, and a liquid (usually oil). These particles are suspended in liquid. In the absence of magnetic field, ferrofluid acts like a liquid. The magnetite particles move freely in the fluid. In the presence of magnetic field, the particles are temporarily magnetized that react to the poles of a magnet. Removing the external field will lead to the disappearance of induced magnetic field.

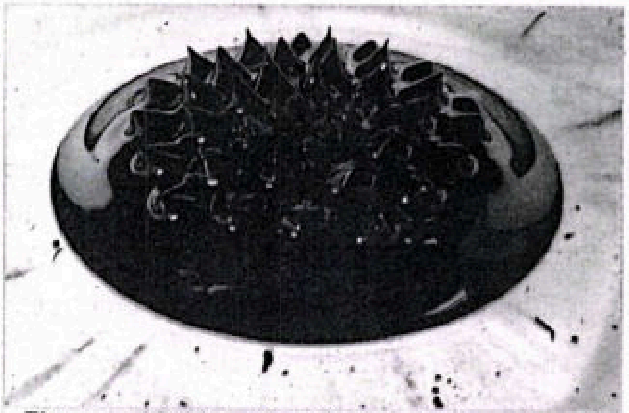


Figure 10.11: Magnified photograph of ferrofluid when influenced by a magnetic field.

Ferrofluids are colloidal suspensions of magnetic nanoparticles in a liquid.

The nano-particles are usually iron oxide (Fe_3O_4) and liquids are water or an organic solvent like kerosene.

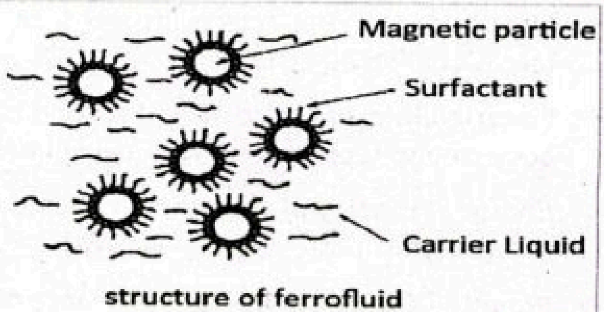
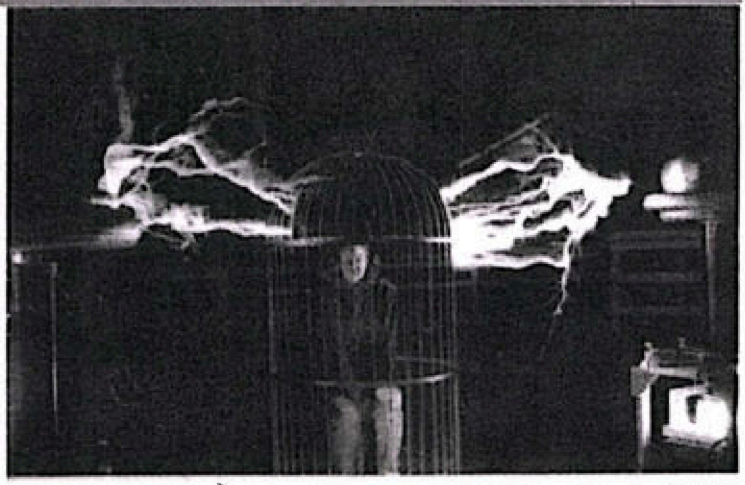


Figure 10.12: Microscopic view of a ferrofluid.

Ferrofluids are fascinating materials with a range of applications in different fields such as electronics, optics and medical physics. These materials are used in magnetic resonance imaging (MRI), bio-sensing, medical imaging, medicinal therapy, dynamic loudspeakers, magneto-optic sensors, heat transfer/dissipation and many more. In the near future, ferrofluids may be used to carry medications to specific locations in the body.

For Your Information

A **Faraday cage** is a cage made of a conducting material. A Faraday cage distributes charge or radiation around the cage's exterior, it cancels out electric charges or radiation within the cage. In short, a Faraday cage is a hollow conductor, in which the charge remains on the external surface of the cage.



The fields within a conductor cancel out with any external fields, so the electric field within a conductor is zero. The Faraday cages act as big hollow conductors. We can put things into the Faraday cage to shield them from electrical fields.

SUMMARY

- **Coulomb's law:** The force of attraction or repulsion between two charged bodies is directly proportional to the product of the magnitude of charges and inversely proportional to the square of distance between them.
- **Coulomb's law is applicable** to point charges and uniform spherical charge distribution.
- **The Superposition Principle of Force:** When a number of separate charges act on the charge of interest, each exerts an electric force. These electric forces can all be computed separately, one at a time, then added as vectors. This is known as the superposition principle of force.
- **Electric Field:** The region around a charge where a test charge experiences an electric force is called electric field.
- **Electric Lines of Force:** The direction and intensity of the electric field around a charged body can be represented by drawing imaginary lines called electric lines of force.
- **Charge:** Property of matter that causes a force when near another charge. Charge comes in two forms: positive and negative.
- **Potential Gradient:** The rate of change of electric potential ΔV with respect to displacement Δr is known as potential gradient.
- **Ferrofluids:** Ferrofluids are colloidal suspensions of magnetic nanoparticles in a liquid. The

nano-particles are usually iron oxide (Fe_3O_4). The liquids are usually water or an organic solvent like kerosene.

EXERCISE

Multiple Choice Questions

Encircle the Correct option.

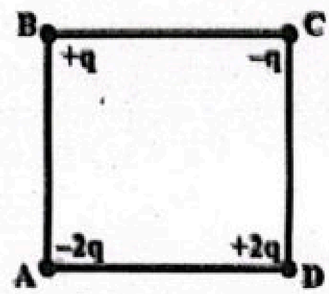
1) Which of the following is equivalent to 1 volt?

A. newton/second B. joule/second C. joule/coulomb D. coulomb/joule

2) Two positive charges are placed on a screen. Which statement describes the electric field produced by the charges?

A. It is constant everywhere. B. It is zero near each charge.
C. It is zero halfway between the charges. D. It is strongest halfway between the charges.

3) Four charges are placed at the corners of a square ABCD as shown. The force on a positive charge placed at the centre of the square is



A. 0
B. Along diagonal AC
C. Along diagonal BD
D. perpendicular to side AB

4) The bob of a pendulum with mass m, length l and a charge q is in the rest position in a uniform horizontal electric field of E. The tension in the string of the pendulum is:

A. mg B. qE C. $[(mg)^2 + (qE)^2]^{1/2}$ D. $[(mg)^2 + (qE)^2]^{1/4}$

5) A negatively charged particle is placed in a uniform electric field directed from South to North. In which direction will the particle move after it is released?

A. East B. South C. North D. North-West

6) If two points are at the same potential, are there any electric field lines connecting them?

A. yes B. No C. may or may not D. insufficient information.

7) Coulomb law is usually applied in the area of:

A. Magnetism B. Electrostatics C. Electromagnetism D. Gravitation

8) Let F be the force between two equal point charges at some distance. If the distance between them is doubled and individual charges are also doubled, what will be the force acting between the charges?

A. F B. 2F C. 4F D. $\frac{F}{2}$

Short Questions

Give short answers to the following question:

10.1 When an air passenger touches the knob of the toilet door during a flight, he may get an electric shock. Why it is so?

10.2 How will the radius of a flexible ring change if it is given a positive charge?

10.3 Write some applications of electrostatics in real life.

10.4 What are the limitations of coulomb's law?

10.5 If two points are at the same potential, are there any electric field lines connecting them?

10.6 What is the difference between electric field and electric field strength?

10.7 Draw electric field lines for (a) an isolated positive charge (b) oppositely charged parallel plates.

10.8 How can we say that 'a charged sphere also behaves as a point charge for a point outside the spherical conductor'.

10.9 Describe the effect of a uniform electric field on the motion of charged particles.

Comprehensive Questions

Answer the following questions in detail.

10.1 Define and explain Coulomb's law?

10.2 What is electric field strength? Explain with the help of examples.

10.3 What is meant by the term potential gradient? Show that $E = \Delta V / \Delta r$.

10.4 Describe the motion of a charged particle in a uniform electric field.

10.5 What are ferrofluids? Explain.

10.6 Explain how a Faraday cage works?

10.7 Describe the effect of a uniform electric field on the motion of charged particle.

Numerical Problems

10.1 Charges of magnitude 100 microcoulomb each are located in vacuum at the corners A, B and C of an equilateral triangle measuring 4 meters on each side. If the charge at A and C are positive and the charge at B negative, what is the magnitude and direction of the total force on the charge at C? **(Ans:5.625 N, force is parallel to AB)**

10.2 What is the magnitude of a point charge that would create an electric field of 1.00 N C^{-1} at a points 1.00 m away? **(Ans: 1.11×10^{-10} C)**

10.3 Consider a point charge +q placed at the origin and another point charge -2q placed at a distance of 9 m from the charge +q. Determine the point between the two charges at which the electric potential is zero. **(Ans:3 m from +q)**

10.4 An object with a net charge of 24 μC is placed in a uniform electric field of 610 N C^{-1} directed vertically. What is the mass of this object if it floats in the field? **(Ans:1.5 g)**

10.5 What will be the electric field at a distance of 30 cm from a 3 μC point charge.

(Ans: 3×10^{5} N C^{-1})

10.6 The electric field at a point due to a point charge is 26 N C^{-1} and the electric potential at that point is 13 J C^{-1}. Calculate the distance of the point from the charge. **(Ans: 0.5 m)**

10.7 The electric field at a point 0.5 m from a charge is 2.5 N C^{-1}. Find the value of electric potential at that point. **(Ans: 1.25 V)**