CO Mapped with this Topic

CO101. 1 – Understand the principles of electrostatics and problems relating to electric field and electric potential. [U]

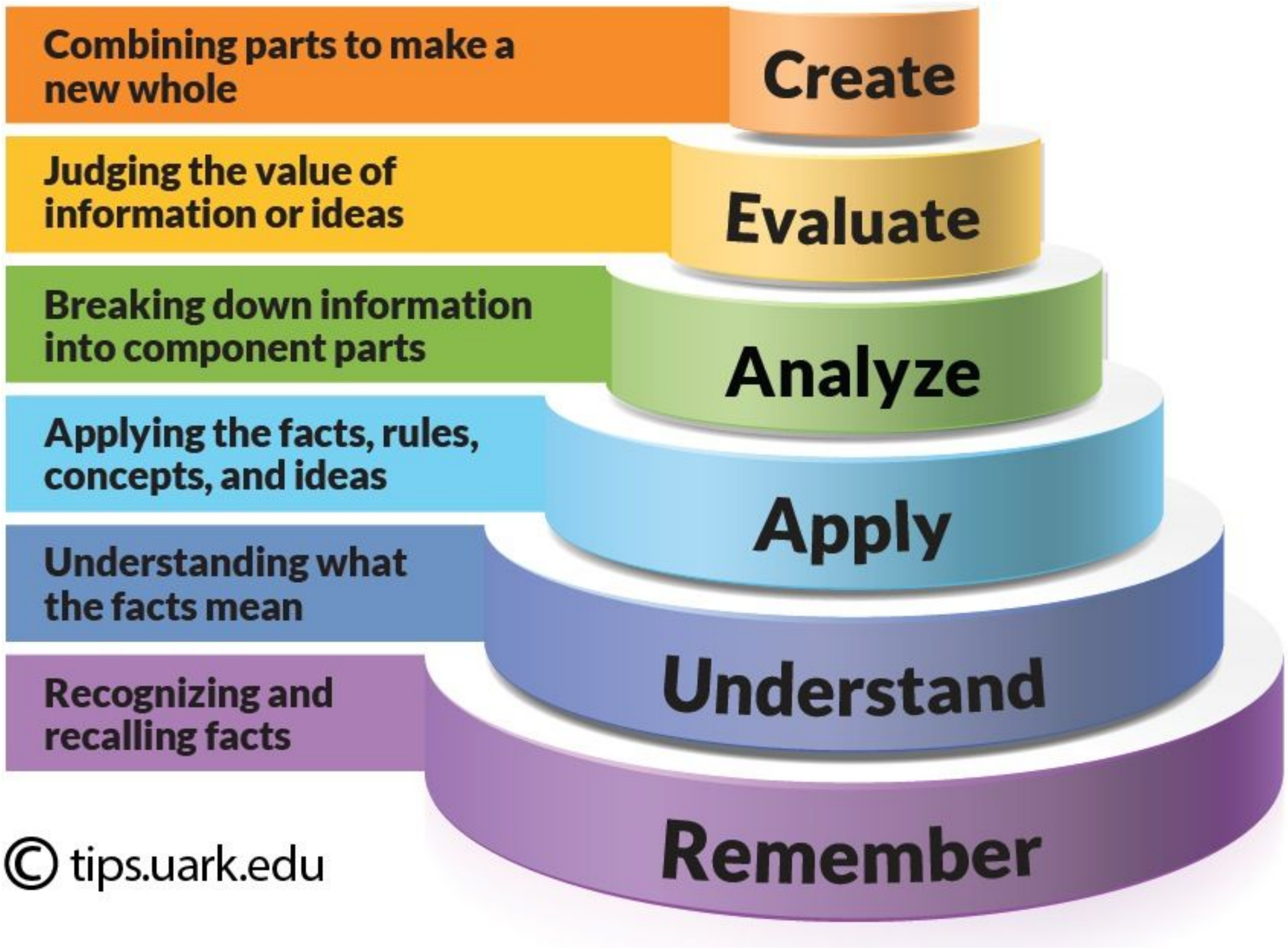
Charges and their conservation; Coulomb's law - superposition principle. Electric field – electric field due to a point charge, electric field lines; electric dipole, electric field intensity due to a dipole - behaviour of a dipole in a uniform electric field. Electric potential - potential difference – electric potential due to a point charge and dipole - equipotential surfaces – electrical potential energy of a system of two point charges. Electric flux-Gauss's law and its applications. Electrostatic induction-capacitor and capacitance – dielectrics- electric polarisation – parallel plate capacitor with and without dielectric – applications of capacitor – energy stored in a capacitor - Capacitors in series and in parallel – Van de Graaff generator.

Bloom's Taxonomy

Bloom's Taxonomy is a system of hierarchical models (arranged in a rank, with some elements at the bottom and some at the top) used to categorize learning objectives into varying levels of complexity (Bloom, 1956).

What is the Bloom's taxonomy?

Bloom's Taxonomy comprises three learning domains: the cognitive, affective, and psychomotor, and assigns to each of these domains a hierarchy that corresponds to different levels of learning. It's important to note that the different levels of thinking defined within each domain of the Taxonomy are hierarchical.


Combining parts to make a new whole
Create
Judging the value of information or ideas
Evaluate
Breaking down information into component parts
Analyze
Applying the facts, rules, concepts, and ideas
Apply
Understanding what the facts mean
Understand
Recognizing and recalling facts
Remember
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Curriculum and syllabus

23PHS01	APPLIED SCIENCE	4/0/0
Nature of the Course: Theory (N/A)		
Pre-requisite(s):		
Course Objectives:		
1	To learn the fundamental concepts of physics and apply this knowledge to both scientific and engineering problems.	
2	To make the students enrich basic knowledge in various fields such as Electrostatics and magnetism.	
3	To understand the principles and applications of electrochemistry and Polymer science, and explore the knowledge of various energy sources and storage devices.	
4	To understand the concepts of photophysical and photochemical processes in spectroscopy.	
Course Outcomes:		
CO1	Understand the principles of electrostatics and problems relating to electric field and electric potential.	U
CO2	Realize the nature of magnets, properties and the magnetic effect of electric current.	U
CO3	Describe the nature of electromagnetic wave and its propagation through different media and interfaces involved in different situations.	AP
CO4	Understand the principle and working of reference electrodes, energy storage devices and polymer products in engineering fields.	U
CO5	Interpret the principle and working of analytical techniques.	U

Course Content:	
Module 1: Electrostatics:	**15 Hrs**
Charges and their conservation; Coulomb's law - superposition principle. Electric field – electric field due to a point charge, electric field lines; electric dipole, electric field intensity due to a dipole - behaviour of a dipole in a uniform electric field. Electric potential - potential difference - electric potential due to a point charge and dipole - equipotential surfaces – electrical potential energy of a system of two point charges. Electric flux-Gauss's law and its applications. Electrostatic induction-capacitor and capacitance – dielectrics- electric polarisation – parallel plate capacitor with and without dielectric – applications of capacitor – energy stored in a capacitor - Capacitors in series and in parallel – Van de Graaff generator.	
Module 2: Magnetism	**15 Hrs**
Definitions of fundamental terms – Magnetic field around a current carrying conductor – Direction of magnetic field and current – Biot-Savart law and its application: Magnetic field due to Line charge – Ampere's law and its application: magnetic field due to a solenoid.Electromagnetic Induction and Alternating Current: Electromagnetic induction - Faraday's law - induced emf and current - Lenz's law. Self-induction - Mutual induction - self-inductance of a long solenoid - mutual inductance of two long solenoids. Methods of inducing emf - (i) by changing magnetic induction (ii) by changing area enclosed by the coil and (iii) by changing the orientation of the coil. AC generator - (Single phase, three phase). Eddy current - applications - transformer - Alternating current - AC circuit with resistance - AC circuit with inductor - AC circuit with capacitor - LCR series circuit - Resonance and Q - factor - power in AC circuits.	
Module 3: Chemistry of Batteries and Polymers	**15 Hrs**

Model question papers

QP CODE: (23PHS01) Reg. No.

SRI KRISHNA COLLEGE OF TECHNOLOGY

An Autonomous Institution, (Approved by AICTE and affiliated to Anna University)
Accredited by NAAC with "A" grade
Coimbatore, Tamil Nadu

Continuous Internal Examination – I

Programme(s)	Semester	Course Code(s)	Course Title
B. Tech IT & B.E. CSE	2	23PHS01	APPLIED SCIENCE

Time: 1.5 Hours
Date: : 04 .05.2024

Max Marks: 50
No. of Pages: 02

COURSE OUTCOMES:

CO1	Understand the principles of electrostatics and problems relating to electric field and electric potential.	U
CO2	Realize the nature of magnets, properties and the magnetic effect of electric current.	U
CO4	Understand the principle and working of reference electrodes, energy storage devices and polymer products in engineering fields.	U

	PART – A (9 X 2 = 18 MARKS)	RBT	CO	Marks
1.	Compare the fundamental characteristics of charges in atom.	U	CO1	2
2.	Calculate the electric potential at a point in space due to a point charge of +5 μC located 2 meters away.	AP	CO1	2
3.	Summarize electric potential and potential difference.	U	CO1	2
4.	List out the properties of electric field lines.	U	CO1	2
5.	Compare electrolytic and electrochemical cell.	U	CO4	2
6.	Show the cell representation for galvanic cell.	U	CO4	2
7.	Summarize the limitations of standard hydrogen electrode.	U	CO4	2
8.	Interpret the use of β-alumina as a solid electrolyte in Li-S batteries.	U	CO4	2
9.	Distinguish between primary and secondary batteries.	U	CO4	2

		PART – B (2 X 16 = 32 MARKS)	RBT/CO/ MARKS
10.	i)	Describe components required and the principle underlying its operation for Van de Graaff generator.	RBT: U CO:CO1 Marks: 8

10.	ii)	Design an experiment to analyze the impact of dielectric materials on the capacitance of a parallel plate capacitor, employing evaluation techniques to assess the relationship between the dielectric constant of various materials and the resulting changes in capacitance	RBT: U CO:CO1 Marks: 8
		OR	
11.	i)	Analyze the concept of electric potential energy. How does it relate to the work done in moving a charged particle within an electric field? Provide a mathematical expression for electric potential energy.	RBT: U CO:CO2 Marks: 8
	ii)	Describe Gauss's Law and how it relates to the distribution of electric charge within a closed surface. Discuss the mathematical representation of Gauss's Law and its implications.	RBT: U CO:CO2 Marks: 8
12.	i)	Illustrate the construction, working and limitations of a secondary reference electrode with a neat diagram.	RBT: U CO:CO4 Marks: 10
	ii)	Compare reversible and irreversible cell with examples.	RBT: U CO:CO4 Marks: 6
		OR	
13.	i)	Explain the construction and working of lithium battery with polymer as an electrolyte.	RBT: U CO:CO4 Marks: 8
13	ii)	Describe the components, structure and working of Lead-acid battery. List out their advantages and disadvantages?	RBT: U CO:CO4 Marks: 8

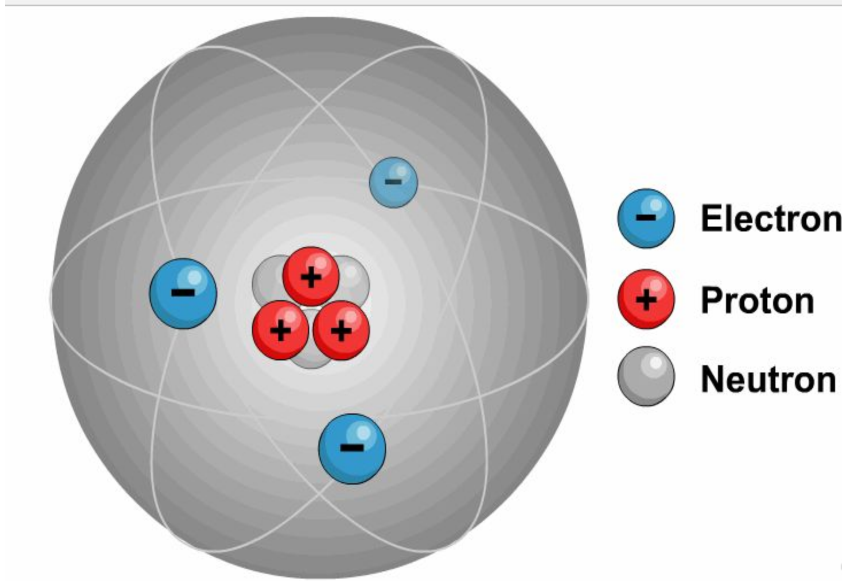
//END//

Conservation of charge

- **Electrostatics** is the branch of Physics, which deals with ***static electric charges or charges at rest.***
- We cannot destroy or create a charge. The number of charges in the nature are constant. We can only transfer

Two kinds of charge

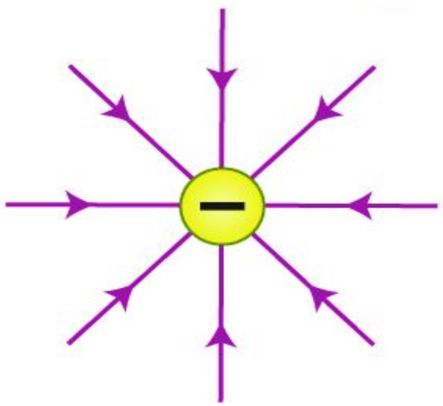
Positive charges & Negative charges



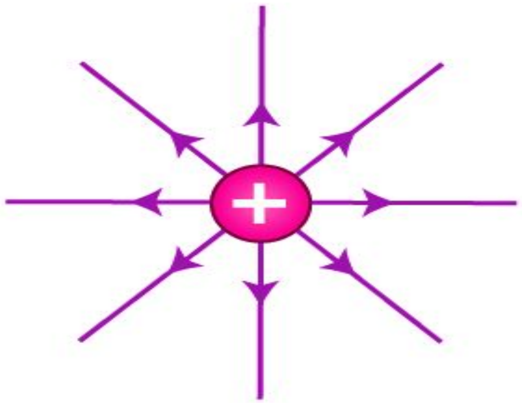
Positive and Negative

- Charge is the fundamental property associated with matter due to which it produces and experience magnetic and electric field.
- The excess or deficiency of electrons in a body gives the concept of charge.
- The **deficiency of electrons** on a body is known as <u>Positive charge.</u>
- The **excess of electrons** on a body is known as <u>Negative Charge.</u>

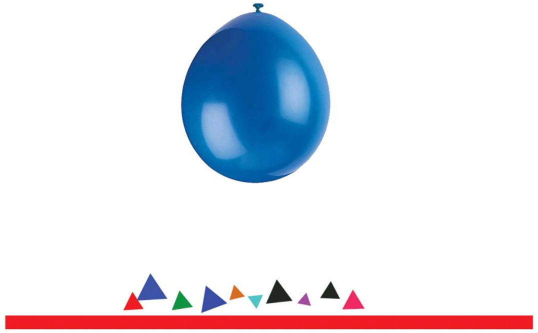
- When a positive charge is given to a body, its mass some what decreases
- When a negative charge is given to a body, its mass some what increases.
- Just as masses are responsible for the *gravitational force*, charges are responsible for *electric force.*
- The net charge of a neutral body is Zero and it's equal to sum of Positive and Negative charges on it.



Negative



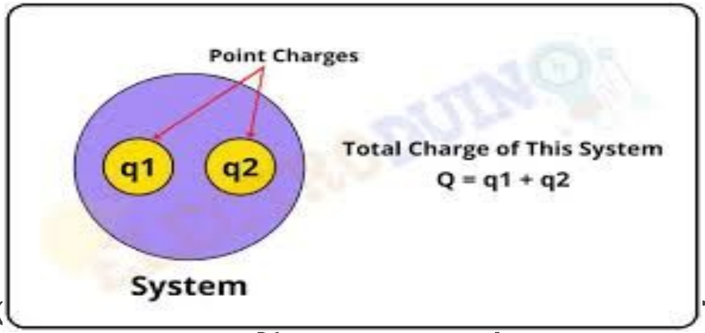
Positive



Basic properties of charges

Properties of Electric Charges

Consider the electric charges to be really small, known as the point charge in order to understand at the properties of electric charge



1. Additivity of Electric Charges

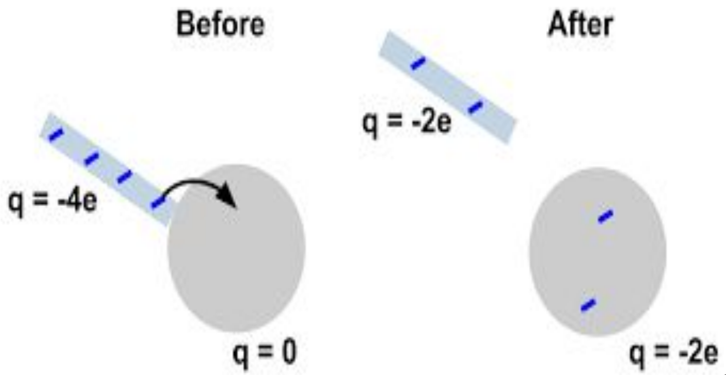
- ❖ Electric charges are scalar in nature but it is important to no ges, and still are positive and negative in nature.
- ❖ If inside a conductor there are 'n' number of charges present, the algebraic sum of the individual charges will be the total charge present in it.
- ❖ This is the additive property of electric charges. $Q = q1+q2+q3+......qn$

2. Conservation of Charges

The conservation of charges means that the charges are neither created nor destroyed.

They can be transferred from one body to another. The charges are always conserved

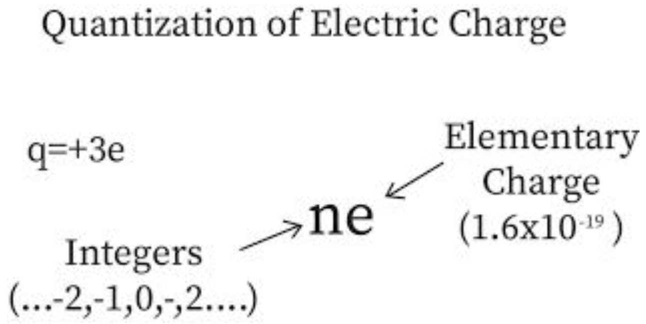
in an Isolated system.



3. Quantization of Charge

Electric charges are defined as the integral multiple of the charge present on them,

hence, in any system the charges will be, Q = ne



Methods of charge transfer

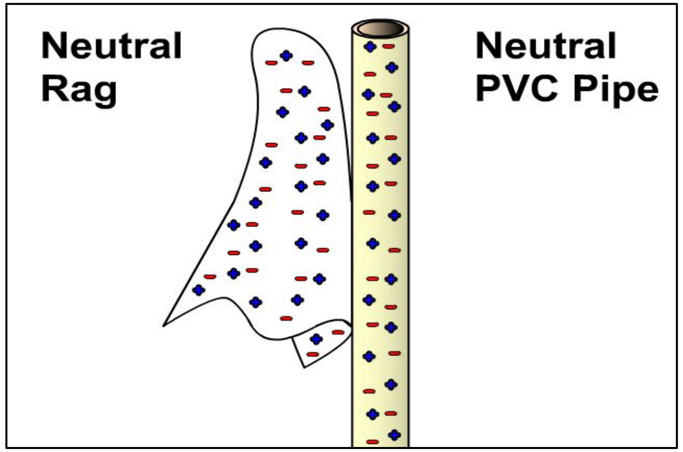
The process of supplying electric charge to an object or causing it to lose electric charge is referred to as charging. There are three distinct methods by which an initially uncharged object can acquire charge:

- **Charging by friction**
- **Charging by conduction**
- **Charging by induction**

1. Transfer by friction

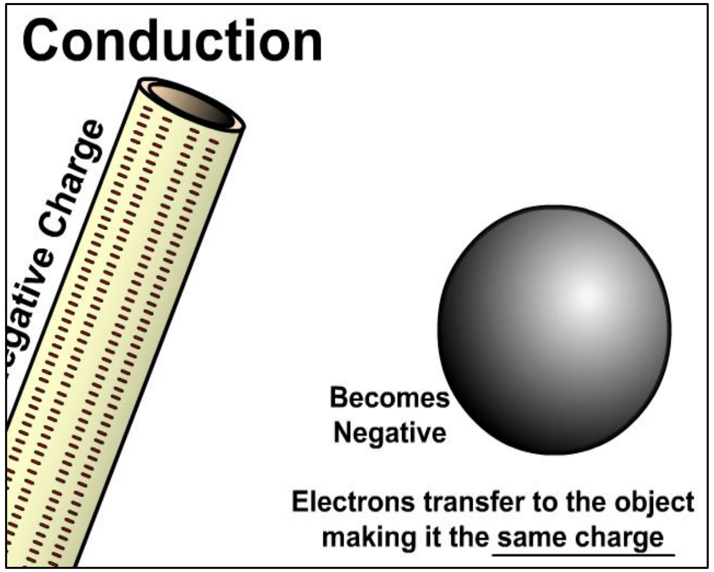
This method of charging an unchanged body by rubbing it.

Against another body is called charging by friction.



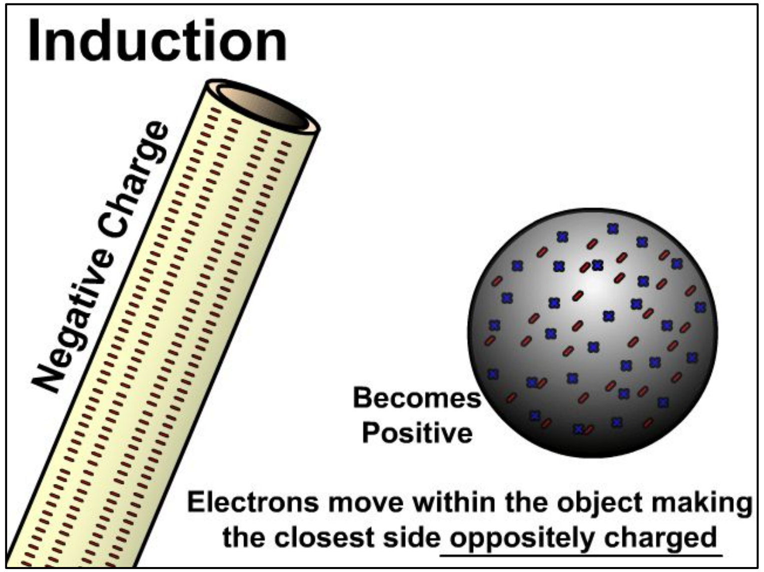
2. Transfer by conduction

Charges can be transferred to an object by bringing it in contact with a charged body. This method of transferring charges from one body to another body.



3. Transfer by Induction

The process of charging an uncharged body by bringing a charged body near to it but without touching it is called induction.



Important questions

1. What is the SI unit of charge?

Coulomb is the unit of electric charge in the metre-kilogram-second-ampere system, the basis of the SI system of physical units. It is abbreviated as C. The coulomb is defined as the quantity of electricity transported in one second by a current of one ampere. Named for the 18th–19th-century French physicist Charles-Augustin de Coulomb, it is approximately equivalent to 6.24×10^{18} electrons, with the charge of one electron, the elementary charge, being defined as $1.602176X10^{-19}$ C

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2. How does the human body use electricity?

The elements in our bodies, like sodium, potassium, calcium, and magnesium, have a specific electrical charge. Almost all of our cells can use these charged elements, called ions, to generate electricity. The contents of the cell are protected from the outside environment by a cell membrane. This cell membrane is made up of lipids that create a barrier that only certain substances can cross to reach the cell interior.

MCQ Questions

1. If the sizes of charged bodies are very small compared to the distances between them, we treat them as _____________.

1. Zero charges
2. Point charges
3. Single charge
4. No charges

Answer: (b) Point charges

Explanation: If the sizes of charged bodies are very small compared to the distances between them, we treat them as point charges.

2. The force per unit charge is known as _____________.

1. Electric current
2. Electric potential
3. Electric field
4. Electric space

Answer: (c) Electric field

Explanation: The force per unit charge is known as the electric field.

3. State true or false: The total charge of the isolated system is NOT conserved.

1. True (b) False

Answer: (b) False

Explanation: As per the conservation of charges, it is said that the total charge of the isolated system is always conserved.

4. What is the dielectric constant of a metal?

1. -1
2. 0
3. 1
4. Infinite

Answer: (d) Infinite

Explanation: The dielectric constant of metals is infinite. The dielectric constant of metal is infinite, as the net electric field inside the metal is zero.

8. ———————— gives the information on field strength, direction, and nature of the charge.

1. Electric current
2. Electric flux
3. Electric field
4. Electric potential

Answer: (c) Electric field

Explanation: Electric field gives the information on field strength, direction, and nature of the charge.

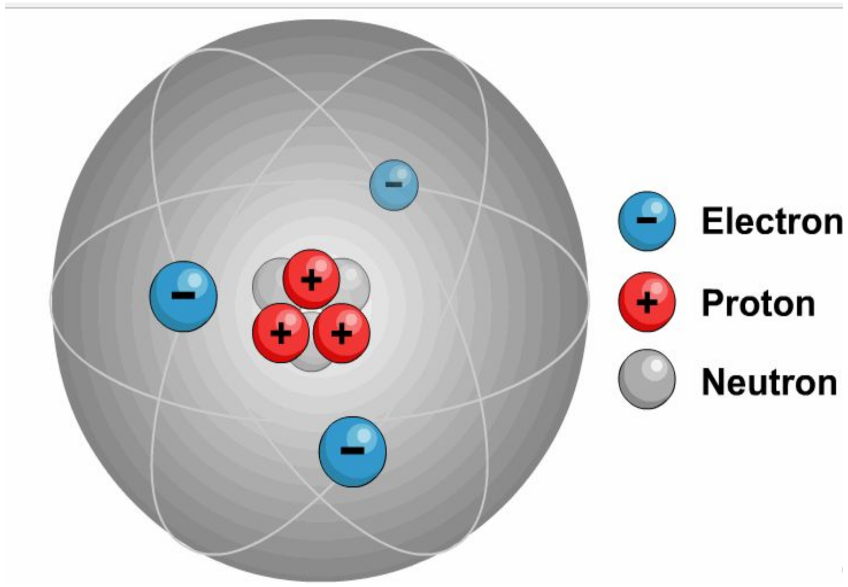
Video links

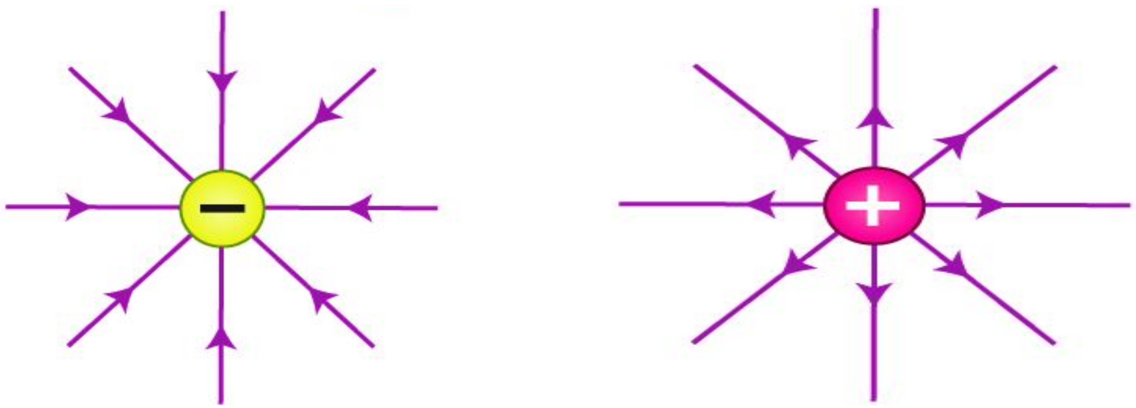
Video links

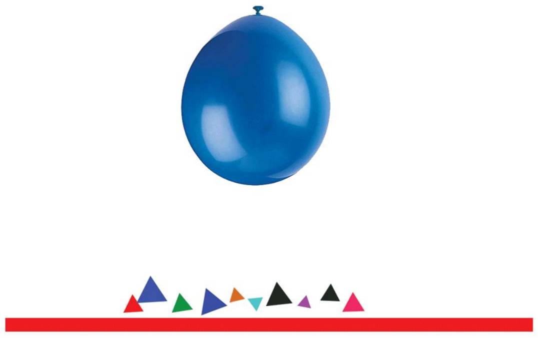
1. https://www.youtube.com/results?search_query=charges+and+their+conservation+animation
2. https://www.youtube.com/watch?v=owla5xPR268
3. https://www.youtube.com/watch?v=9gv2Kj6c_rA

Recall previous topics

- Kinds of charges
- Basic properties of charges
- Methods of charge transfer
- Questions







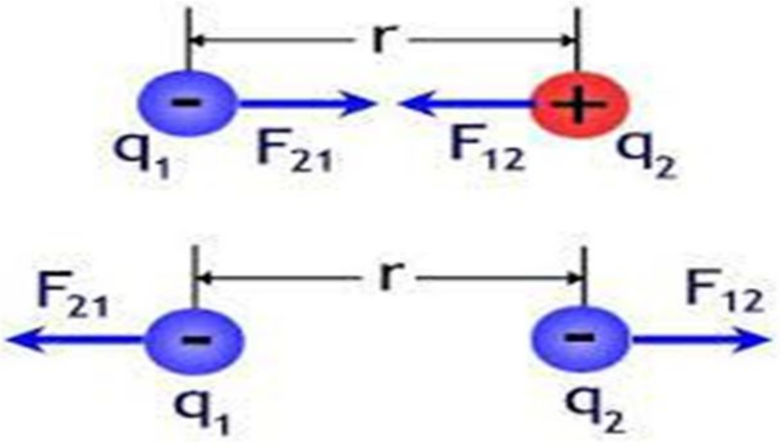
Coulombs law

History of Coulomb’s Law

Charles Augustin de Coulomb in 1785, French physicist formulated coulombs law. He coined a tangible relationship in mathematical form between two bodies that have been electrically charged. He published an equation for the force causing the bodies to attract or repel each other, which is known as Coulomb’s law or Coulomb’s inverse-square law. He invented a magnetoscope, a magnetometer, and a torsion balance that he employed in establishing coulombs law. The unit of electric charge the coulomb is named after him.

Definition

According to **Coulomb’s law**, the force of attraction or repulsion between two charged bodies is directly proportional to the product of their charges and inversely proportional to the square of the distance between them. It acts along the line joining the two charges considered to be point charges.



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

k = Coulomb's Constant = 9.0×10^9 Nm^2/C^2

q_1 = charge on mass 1

q_2 = charge on mass 2

r = the distance between the two charges

The electric force is much stronger than the gravitational force.

Applications

- ❖ To calculate Force (F) or distance between two charges.
- ❖ To calculate electric field
- ❖ To calculate force on one point due to several point's superposition theorem

Disadvantages

- ❖ We can't apply directly the coulombs law calculate charge on big planets.

MCQ Questions

1. Coulomb's Law is valid for ______

a) Only point charge

b) For both point charge and distributed charge

c) Only distributed charges

d) Neither distributed nor point charge

Answer:

Explanation: Coulomb's Law explains the force between two point charges only. A distributed charge can be considered as the sum of infinite point charges and thus the force between two distributed charge systems can be explained.

2. Coulomb's Law is valid for any distance between the particles.

a) False

b) True

Answer:

Explanation: Coulomb's Law is not valid for inter-atomic distance i.e. distance less than 10^{-15} m. Besides, if the distance between the two bodies is less than the size of any of the bodies, this law is also invalid. We can use this law only in all other cases.

3. Which one of the following is similar between electrostatic force and gravitational force?

a) Force can be attractive or repulsive

b) The force depends on the medium between the bodies

c) Both the forces are strong forces

d) Force is inversely proportional to the distance between the bodies

Answer: d

Explanation: Gravitational force cannot be repulsive and it is a very weak force. Gravitational force does not depend on the medium. But both the forces are inversely proportional to the distance between them.

4. Two 1 Coulomb charges are kept at 1m distance in air medium. Force of attraction or repulsion between them will be ________

a) $9*10^9$ N

b) 1 dyne

c) 1 N

d) $3*10^3$ N

Answer: a

Explanation: According to Coulomb's Law, $F=1/4\pi\varepsilon o*q1q2/r^2$. And $1/4\pi\varepsilon o = 9*10^9$ N in the SI system. In this case, q1=q2=1C and r=1m. Now substituting the values, we get $F=9*10^9$ N. Similarly, the electric field at a distance of 1m from a 1C charge is $9*10^9$ N/C.

5. Let B be the midpoint of AC. Two point charges Q are placed at A and C. What should be the value of charge placed at B so that the system remains at equilibrium?

a) –Q/2

b) –Q/4

c) +Q/2

d) +Q/4

Whatever the value of q be, it will undergo equal force on both sides, hence q will be steady.
Now, for stability of Q, net force on Q must be zero.

1/4πϵo Q2/d2+1/4πϵo Q.q/(d2)2 = 0

⇒ Q2/d2 = −Qq/d2/4

⇒ Q = -49 ⇒ q = –Q4

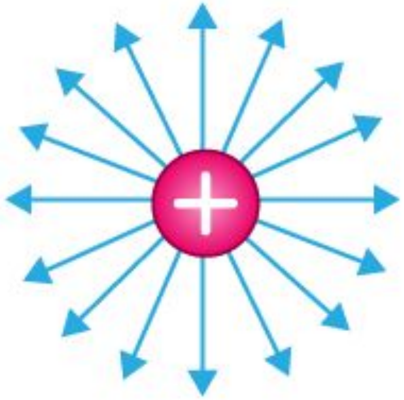
SRI KRISHNA COLLEGE OF TECHNOLOGY

(An Autonomous Institution)
Kovaipudur, Coimbatore

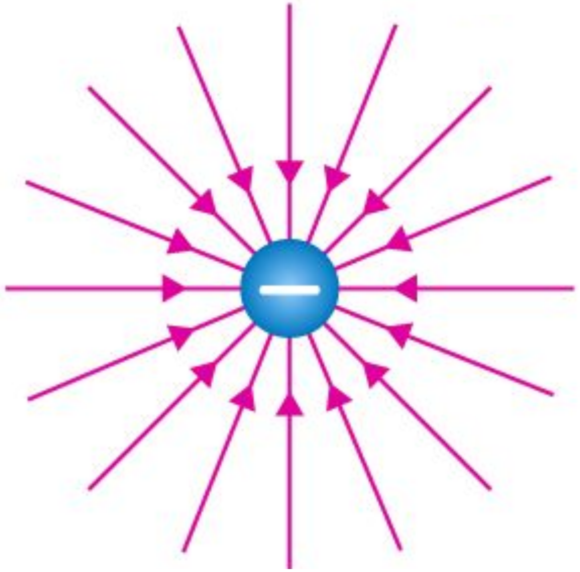
DEPARTMENT OF PHYSICS

COURSE CODE : 23AS101
COURSE TITLE : Applied Science

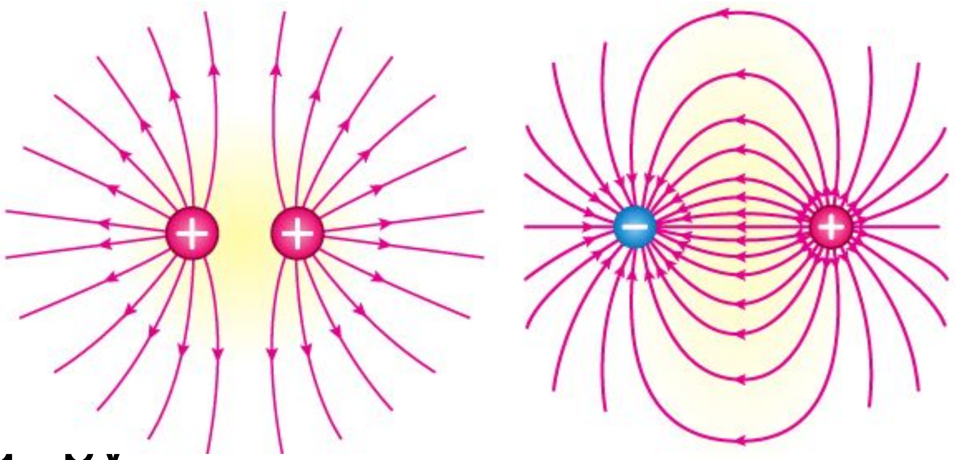
ACADEMIC YEAR : 2024 - 2025 (Even Sem)



Electric field lines

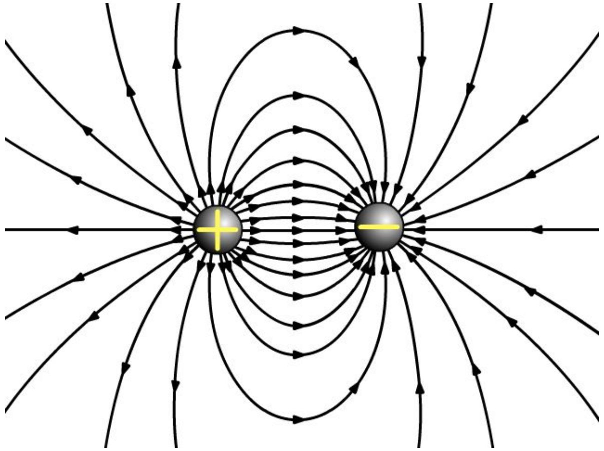


Electric field lines



- The concept of field lines was introduced by Michael Faraday
- It is an imaginary straight or curved path along which a unit positive charge tends to move in an electric field
- Lines of force start from positive charge and terminate at negative charge or infinity

Electric field lines



- Lines of force never intersect.
- The tangent to a line of force at any point gives the direction of the electric field at that point
- when the lines of force are close together, E is large and When they are far apart, E is small

Electric field lines

- Electric field lines are a useful conceptual tool in understanding electric fields and their interactions with charges and materials.
- Show interactions between electric and magnetic fields in electromagnetic radiation.
- Visualize how charge redistributes in response to external electric fields.
- Show how electric field lines are distorted in a dielectric material.

Questions

- Electric field lines originate from ____________ charge

  Positive

- Where do the electric field lines end?

  Negative Charge

- The field lines are _______________ to the surface of the charge.

  Perpendicular

- Two field lines can cross each other(True/False)

  False

Electric field

- The electric field is the region around an electric charge where its influence can be observed.
- The existence of an electric field can be experienced when another charge is brought into the field.
- According to the incoming charge's nature, the electric field will either attract or repel the charge.
- The electric field can be considered as a property of any electric charge. The electric field strength or intensity is defined by the charge and electrical force acting in the field.
- The charge is denoted by q and the force experienced by it is denoted by F, then the direction of the Field lines is determined by both F and q.

What is The Electric Field Formula?

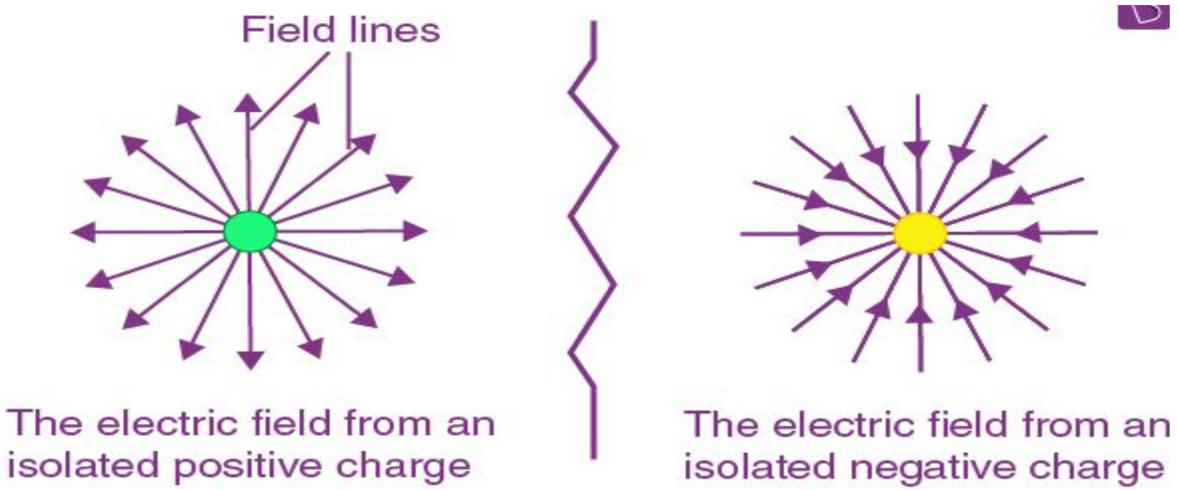
The Electric field formula is

$E = F/q$

Where E is the electric field

Electric field

The direction of the field is taken as the direction of the force which is exerted on the positive charge. The electric field is radially outwards from the positive charge and radially towards the negative point charge.



Application of Electric Field

1. Electroporation- electroporation is an invasive technique where electric fields are used to make pores in cell membranes to insert drugs, medicines, or genes. It is widely used in cloning processes.

2. It is used to study tissue dynamics.

3. The electric field is used to control different crystallization processes like nucleation, crystal growth, etc.

Electric field

Electric field

- ❖ An electric field is also described as the electric force per unit charge.
- ❖ Electric fields are usually caused by varying magnetic fields or electric charges.
- ❖ Electric field strength is measured in the SI unit.

$$E = F/q$$

$$F = K\frac{qq_o}{r^2}$$

$$E = F/q$$

$$E = K\frac{q_o}{r^2}$$

Electric field

Let q be the point charge placed at O in air (Fig.1.4). A test charge q_o is placed at P at a distance r from q. According to Coulomb's law, the force acting on q_o due to q is

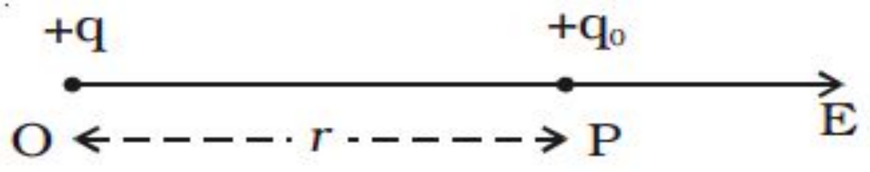


Fig 1.4 Electric field due to a point charge

$$F = \frac{1}{4\pi\varepsilon_o}\frac{q\,q_o}{r^2}$$

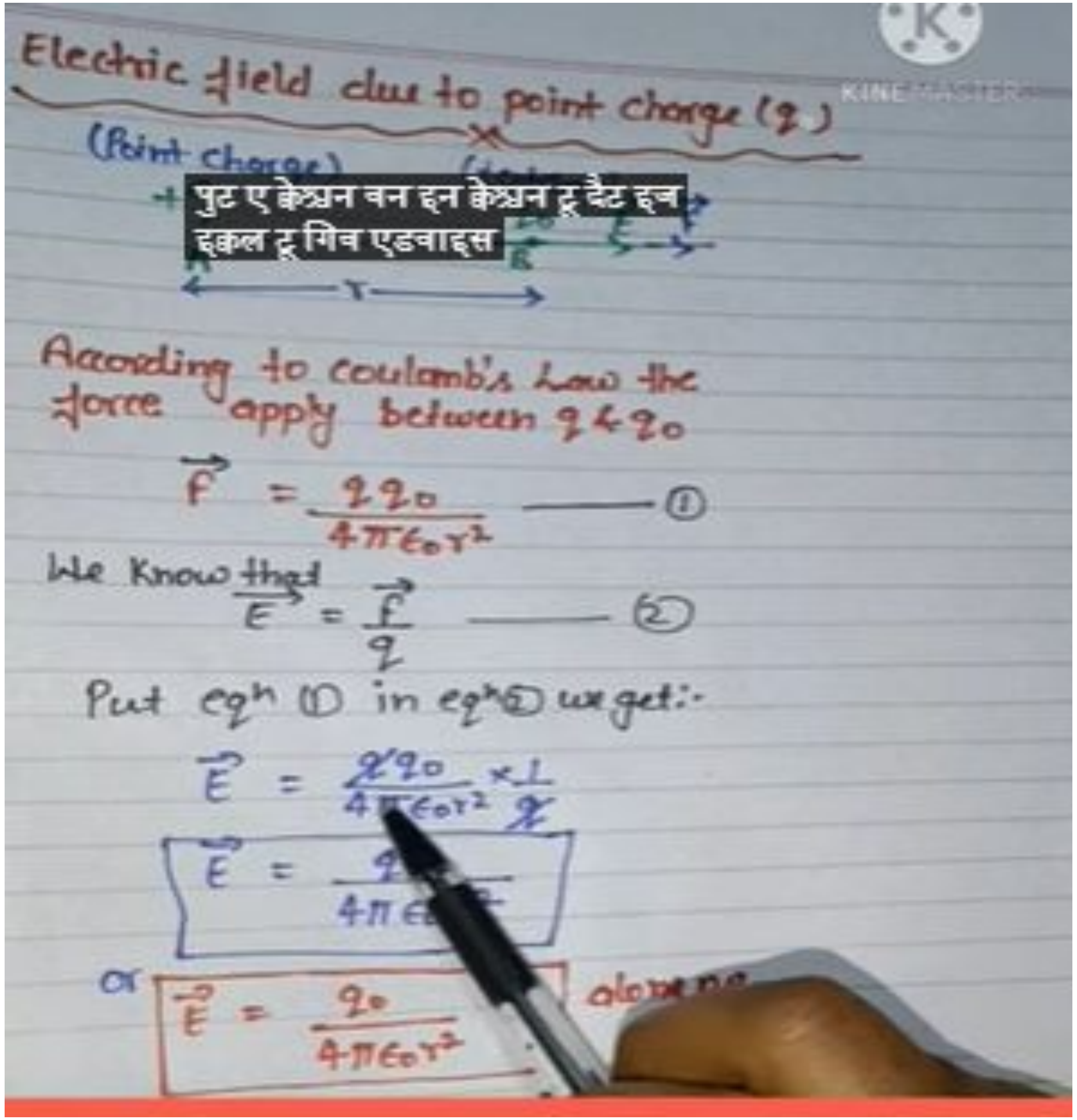
The electric field at a point P is, by definition, the force per unit test charge.

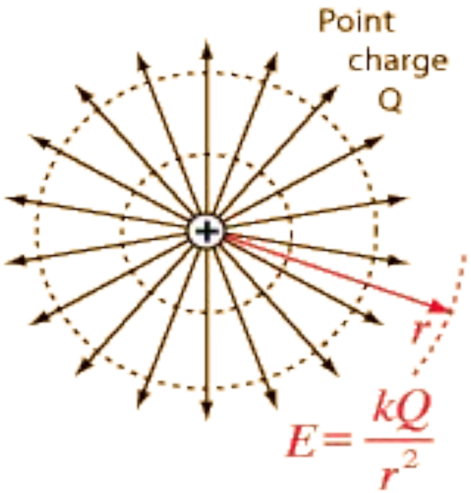
$$E = \frac{F}{q_o} = \frac{1}{4\pi\varepsilon_o}\frac{q}{r^2}$$

The direction of E is along the line joining O and P, pointing away from q, if q is positive and towards q, if q is negative.

In vector notation $\vec{E} = \frac{1}{4\pi\varepsilon_o}\frac{q}{r^2}\hat{r}$, where $\hat{r}$ is a unit vector pointing away from q.

Electric field at point charge



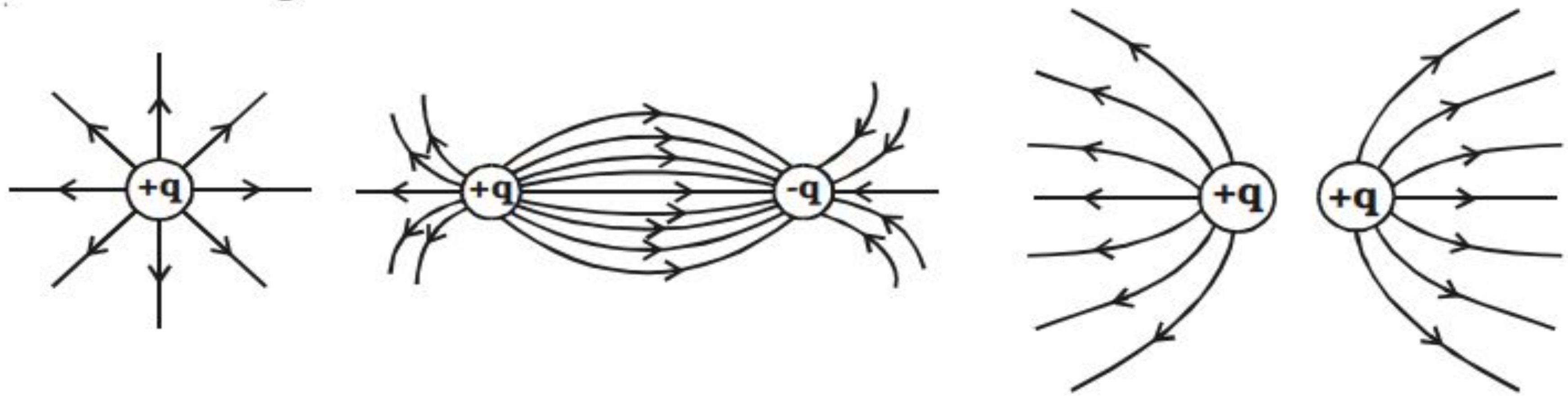


Electric field lines

The concept of field lines was introduced by Michael Faraday as an aid in visualizing electric and magnetic fields.

Electric line of force is an imaginary straight or curved path along which a unit positive charge tends to move in an electric field.

The electric field due to simple arrangements of point charges are shown in Fig 1.5.



(a) *Isolated charge* (b) *Unlike charges* (c) *Like charges*

Properties of Electric field lines

Properties of lines of forces:

(i) Lines of force start from positive charge and terminate at negative charge.

(ii) Lines of force never intersect.

(iii) The tangent to a line of force at any point gives the direction of the electric field (E) at that point.

(iv) The number of lines per unit area, through a plane at right angles to the lines, is proportional to the magnitude of E. This means that, where the lines of force are close together, E is large and where they are far apart, E is small.

(v) Each unit positive charge gives rise to $\frac{1}{\varepsilon_o}$ lines of force in free space. Hence number of lines of force originating from a point charge q is $N = \frac{q}{\varepsilon_o}$ in free space.

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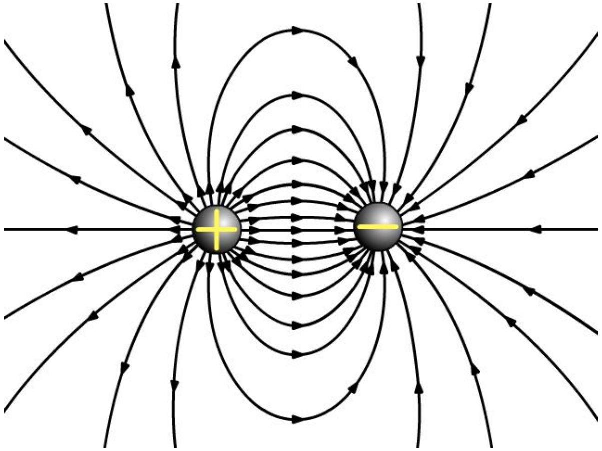
DEPARTMENT OF PHYSICS

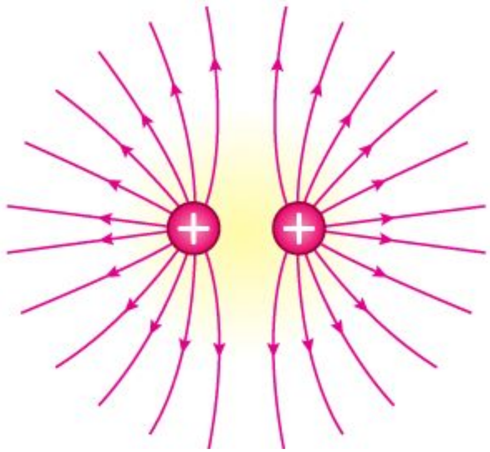
COURSE CODE : **23AS101**
COURSE TITLE : **Applied Science**

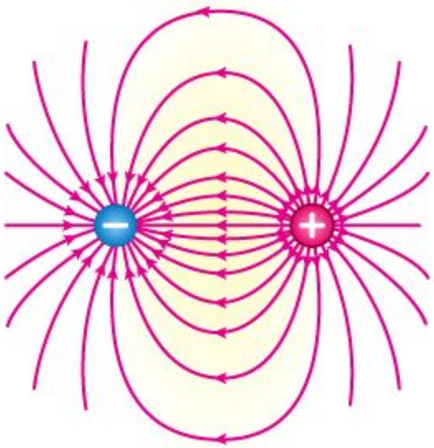
ACADEMIC YEAR : **2024 - 2025 (Even Sem)**

Topics discussed in last class

- ❖ Electric field lines
- ❖ Properties of field lines
- ❖ Applications of electric field lines

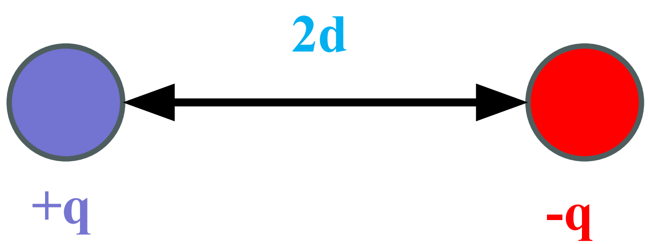






Electric dipole

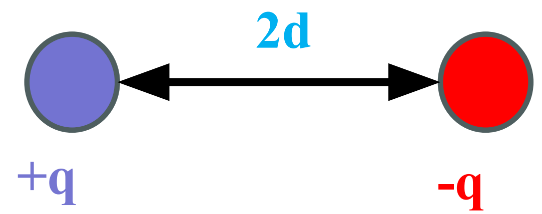
Electric dipole



"Two equal and opposite charges separated by a very small distance constitute an electric dipole"

Electric dipole

- "Two point charges +q and –q are kept at a distance 2d apart



- The magnitude of the dipole moment is given by

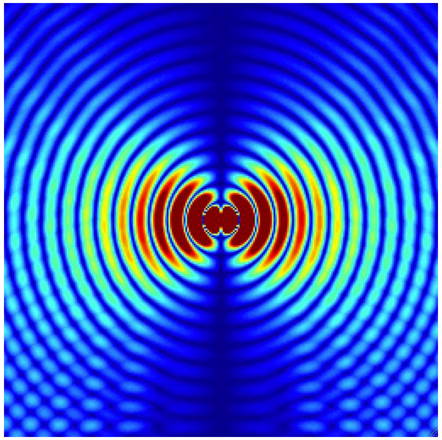
Dipole moment (p) = 2qd

- It is the product of the magnitude of the one of the charges and the distance between them.

- The electric field produced by a dipole is known as dipole field

Electric dipole

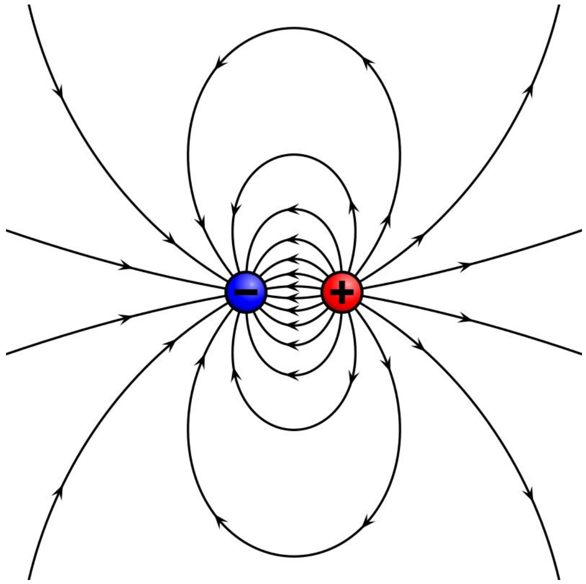
- Electric dipole moment is a vector quantity used to measure the strength of an electric dipole.
- The direction is electric field is from positive to negative charge
- The SI unit of ‘p’ is coulomb metre - Cm.



- An ideal dipole is the dipole in which the charge becomes larger and larger and the separation becomes smaller and smaller.

Electric dipole

- **Examples of dipoles:** Water(H_2O), Ammonia(NH_3), carbon−dioxide(CO_2) and chloroform($CHCl_3$) molecules
- The centers of positive and negative charge of the above-mentioned molecules do not coincide and are separated by a small distance.



Electric dipole Quiz

1. Which among the following molecule is not a dipole?

a) NH_3

b) H_2O

c) HCl

d) CH_4

Ans: d

2. Dipole moment depends on _______

a) Charge only

b) Charge and length of a dipole

c) Charge, length of a dipole and dielectric constant of the medium

d) Charge and dielectric constant of the medium

Ans:b

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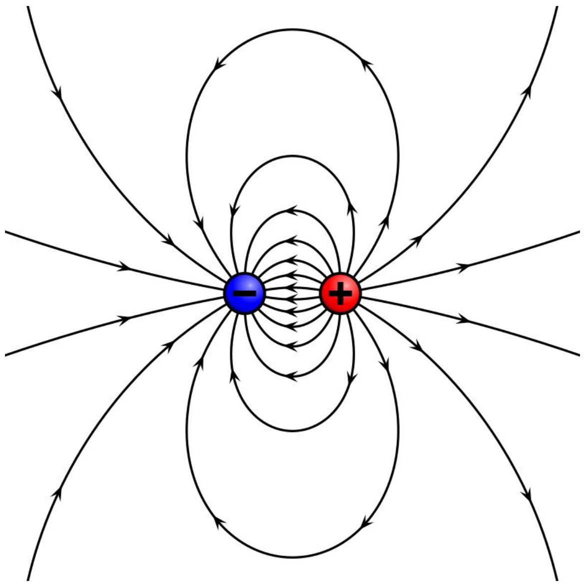
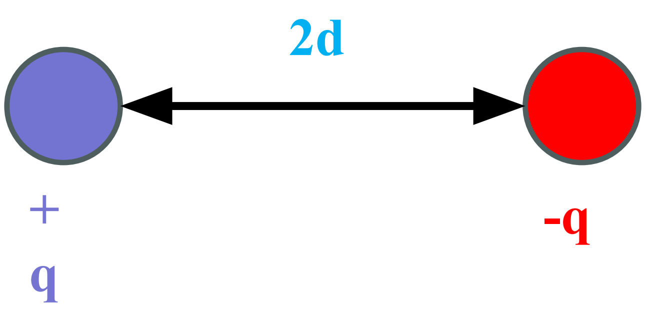
Topics discussed in last class

- ❖ Electric dipole
- ❖ Dipole moment
- ❖ Examples for electric dipoles



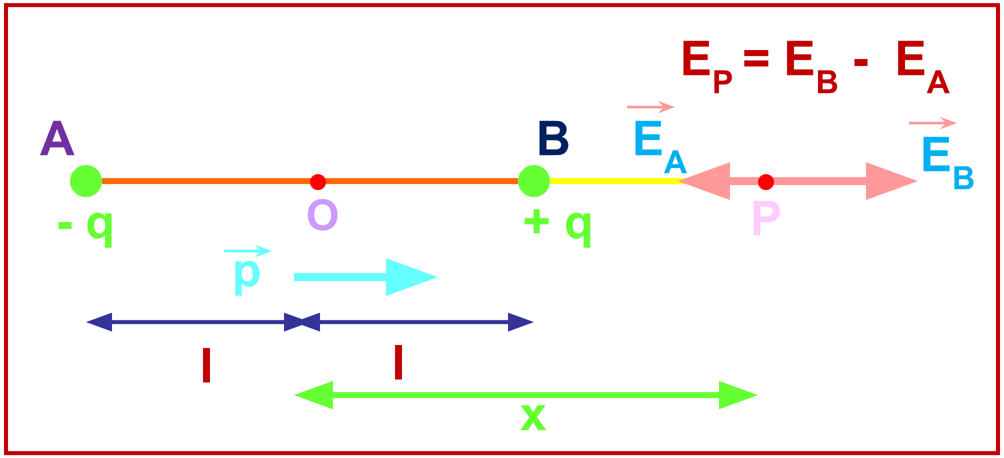


Electric field Intensity due to a dipole

Electric Field Intensity due to an Electric Dipole:

i) At a point on the axial line:

Resultant electric field intensity at the point P is



The vectors E_A and E_B are collinear and opposite.

$$|\vec{E}_P| = |\vec{E}_B| - |\vec{E}_A|$$

$$\vec{E}_B = \frac{1}{4\pi\varepsilon_0} \frac{q}{(x - l)^2}$$

$$\vec{E}_A = \frac{1}{4\pi\varepsilon_0} \frac{q}{(x + l)^2}$$

Electric Field Intensity due to an Electric Dipole:

$$|\vec{E}_P| = \frac{1}{4\pi\varepsilon_0}\left[\frac{q}{(x - l)^2} - \frac{q}{(x + l)^2}\right]$$

$$|\vec{E}_P| = \frac{1}{4\pi\varepsilon_0}\frac{2\,(q\,.\,2l)\,x}{(x^2 - l^2)^2}$$

$$\boxed{|\vec{E}_P| = \frac{1}{4\pi\varepsilon_0}\frac{2\,p\,x}{(x^2 - l^2)^2}}$$

$$\boxed{\vec{E}_P = \frac{1}{4\pi\varepsilon_0}\frac{2\,p\,x}{(x^2 - l^2)^2}}$$

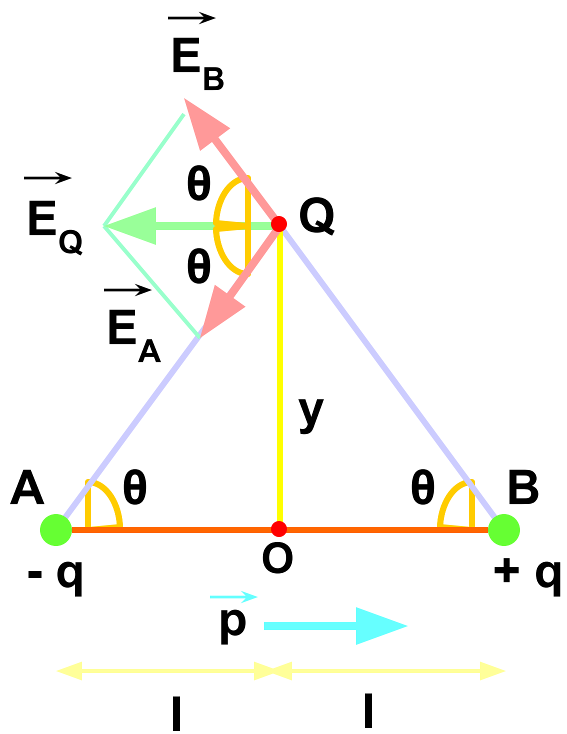
If $l \ll x$, then

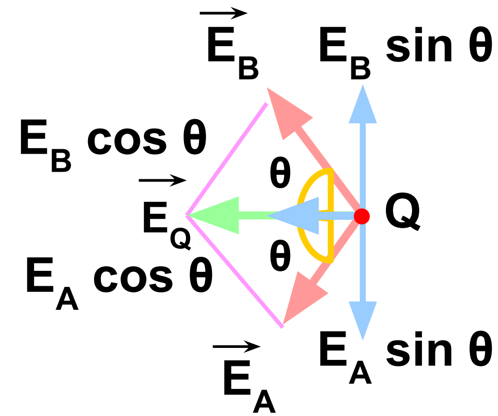
$$\boxed{E_P = \frac{2\,p}{4\pi\varepsilon_0\;x^3}}$$

The direction of electric field intensity at a point on the axial line due to a dipole is always along the direction of the dipole moment.

Electric Field Intensity due to an Electric Dipole:

ii) At a point on the equatorial line:





Resultant electric field intensity at the point Q is

$$\vec{E}_Q = \vec{E}_A + \vec{E}_B$$

The vectors E_A and E_B are acting at an angle 2θ.

Electric Field Intensity due to an Electric Dipole:

$$\vec{E}_A = \frac{1}{4\pi\varepsilon_0} \frac{q}{(x^2 + l^2)}$$

$$\vec{E}_B = \frac{1}{4\pi\varepsilon_0} \frac{q}{(x^2 + l^2)}$$

The vectors E_A sin θ and E_B sin θ are opposite to each other and hence cancel out.

The vectors E_A cos θ and E_B cos θ are acting along the same direction and hence add up.

$$\therefore \quad E_Q = E_A \cos\theta + E_B \cos\theta$$

$$E_Q = \frac{2}{4\pi\varepsilon_0} \frac{q}{(x^2 + l^2)} \frac{l}{(x^2 + l^2)^{1/2}}$$

$$E_Q = \frac{1}{4\pi\varepsilon_0} \frac{q \cdot 2l}{(x^2 + l^2)^{3/2}}$$

$$\boxed{E_Q = \frac{1}{4\pi\varepsilon_0} \frac{p}{(x^2 + l^2)^{3/2}}}$$

$$\vec{E}_Q = \frac{1}{4\pi\varepsilon_0} \frac{p}{(x^2 + l^2)^{3/2}}$$

If l << x, then

$$\vec{E}_Q = - \frac{p}{4\pi\varepsilon_0 \, x^3}$$

The direction of electric field intensity at a point on the equatorial line due to a dipole is parallel and opposite to the direction of the dipole moment.

If the observation point is far away or when the dipole is very short, then the electric field intensity at a point on the axial line is double the electric field intensity at a point on the equatorial line.

i.e. If $l << x$ and $l << y$, then $E_P = 2 E_Q$

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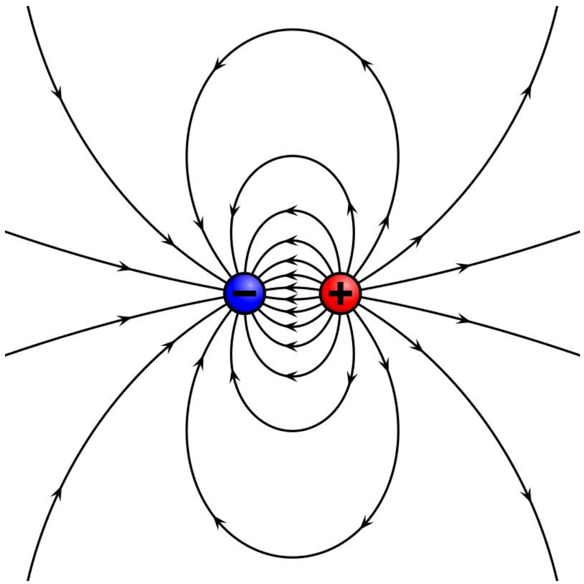
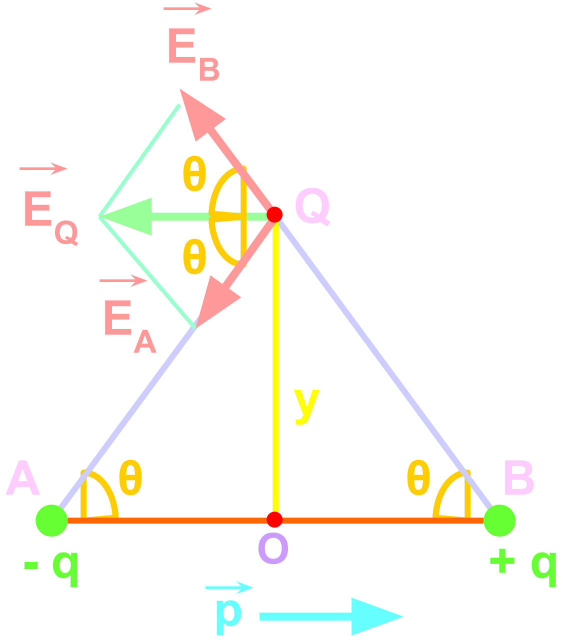
- ❖ Electric field Intensity due to a dipole
- ❖ At a point on the axial line
- ❖ At a point on the equatorial line

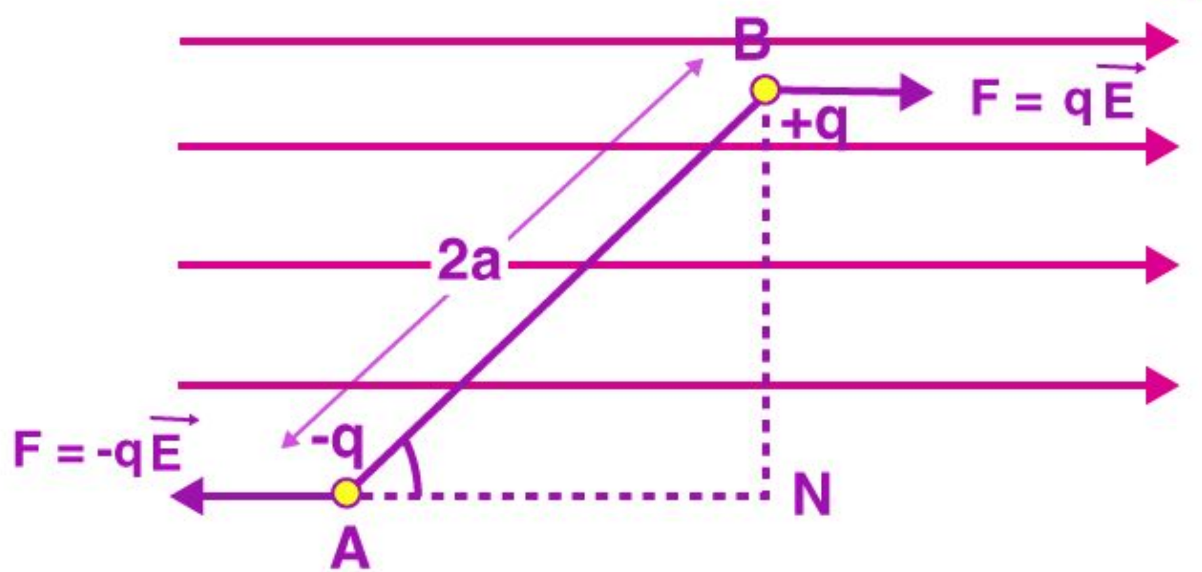




Electric Dipole in a Uniform Electric Field

Electric Dipole in a Uniform Electric Field

- Consider a dipole AB of dipole moment p placed at an angle θ in a uniform electric field E.



- Charge +q experiences a force F = qE in the same direction of the field.

- Charge –q experiences an equal force in the opposite direction.

Electric Dipole in a Uniform Electric Field

- The forces of magnitude qE act opposite to each other and hence net force acting on the dipole due to external uniform electric field is zero. So, there is no translational motion of the dipole.
- However the forces are along different lines of action and constitute a couple. Hence the dipole will rotate and experience torque.

Torque = Electric Force x ⊥ distance

$$t = q\,E\,(2a \sin \theta)$$

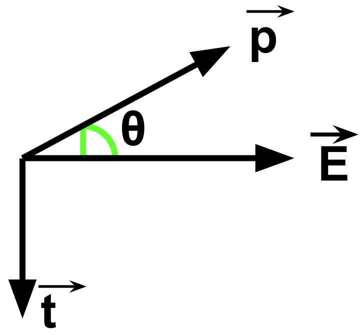
$$= p\,E \sin \theta$$

$$\boxed{\vec{t} = \vec{p} \times \vec{E}}$$

Direction of Torque is perpendicular and into the plane containing p and E.

SI unit of torque is newton metre (Nm).

Electric Dipole in a Uniform Electric Field



Case i: If $\theta = 0°$, then $t = 0$.

Case ii: If $\theta = 90°$, then $t = pE$ (maximum value).

Case iii: If $\theta = 180°$, then $t = 0$.

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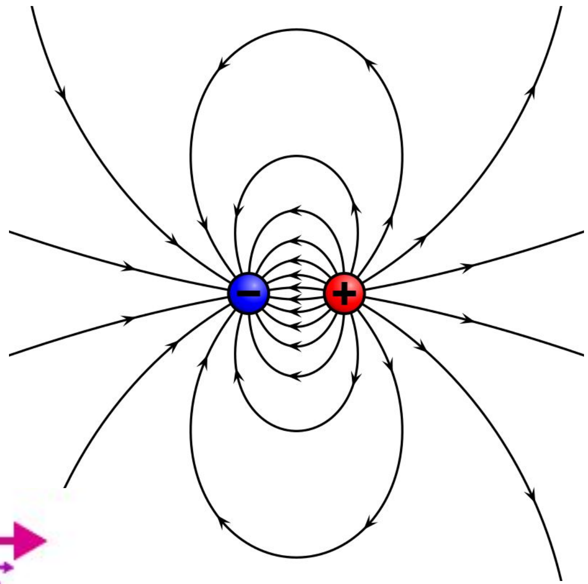
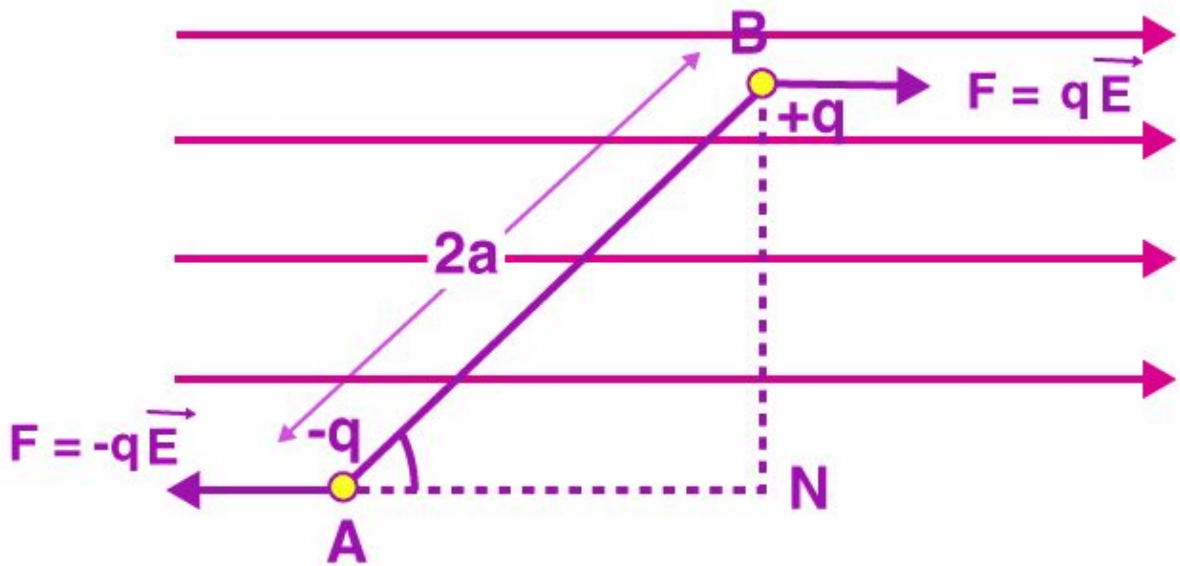
Topics discussed in last class

- Dipole in uniform electric field
- Torque experienced





Electric Potential

Electric Potential:

Electric potential is a physical quantity which determines the flow of charges from one body to another.

It is a physical quantity that determines the degree of electrification of a body.

Electric Potential at a point in the electric field is defined as the work done in moving (without any acceleration) a unit positive charge from infinity to that point against the electrostatic force irrespective of the path followed.

$$W_{AB} = -\int_A^B \vec{E} \cdot \vec{dl} = \frac{qq_0}{4\pi\varepsilon_0}\left[\frac{1}{r_B} - \frac{1}{r_A}\right] \quad \text{or} \quad \frac{W_{AB}}{q_0} = \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{r_B} - \frac{1}{r_A}\right]$$

According to definition, $r_A = \infty$ and $r_B = r$

(where r is the distance from the source charge and the point of consideration)

$$\therefore \frac{W_{\infty B}}{q_0} = \frac{q}{4\pi\varepsilon_0 r} = V \qquad \therefore \boxed{V = \frac{W_{\infty B}}{q_0}}$$

SI unit of electric potential is volt (V) or J C^{-1} or Nm C^{-1}.

Electric potential at a point is one volt if one joule of work is done in moving one coulomb charge from infinity to that point in the electric field.

Potential Difference

Definition: Potential difference refers to the work done to move a unit charge from one point to another in an electric field. It measures the difference in electric potential (or voltage) between two points.

$$V = V_B - V_A = \frac{W}{Q}$$

V_B and V_A = Electric potentials at points B and A, respectively

W = Workdone (in joules)

Q = Charge (in Coulombs)

The potential difference is related to the electric field (E) by:

$$V = -\int E.dl$$

Where **E** is the electric field strength and **dl** is the infinitesimal path length.

$$W_{AB} = -\int_A^B \vec{E}.\vec{dl} = \frac{qq_0}{4\pi\varepsilon_0}\left[\frac{1}{r_B} - \frac{1}{r_A}\right]$$

$$\frac{W_{AB}}{q_0} = \frac{q}{4\pi\varepsilon_0}\frac{1}{r_B} - \frac{q}{4\pi\varepsilon_0}\frac{1}{r_A} = V_B - V_A$$

$$\boxed{\Delta V = V_B - V_A = \frac{W_{AB}}{q_0}}$$

Points to be remembered

- ❖ Unlike the electric field, which is a vector, potential difference is a **scalar quantity**. It only has magnitude, not direction.
- ❖ It directly relates to the energy expenditure or **gain per unit charge** in moving between two points in an electric field.
- ❖ It is the fundamental **cause of current flow** in a conductor, as charges move from a region of higher potential to lower potential.
- ❖ The potential difference between two points depends only on the **initial and final positions**, not the path taken, as it is derived from a conservative electric field.
- ❖ It is directly related to the **electric field strength** and **distance**.
- ❖ Potential difference is always measured **between two points, making it relative**. A reference point (often taken as the ground or zero potential) is needed to define it.
- ❖ Measured in **volts (V),** it represents one joule of work done to move one coulomb of charge.
- ❖ If the potential difference between two points is **zero, no current flows,** regardless of the presence of charges.

Quiz

1) What is the SI unit of electric potential difference?

a) Ampere b) Volt c) Coulomb d) Joule

2) Which of the following is true about the electric potential difference?

a) It is a vector quantity b) It depends on the path taken c) It is measured in volts d) It is always zero

3) What does a potential difference of 1 volt represent?

a) 1 joule of work per coulomb of charge b) 1 joule of work per ampere of charge

c) 1 coulomb of charge per joule d) 1 joule of work per meter of distance

4) Which instrument is used to measure the electric potential difference?

a) Ammeter b) Voltmeter c) Galvanometer d) Thermometer

5) What does a negative potential difference imply?

a) Work is done by the electric field b) Work is done against the electric field c) The charge is neutral

d) No work is done

6) The electric potential difference between two points is calculated by:

a) V=I x R b) $V = \frac{W}{Q}$ c) $V = \frac{Q}{W}$ d) V=R x Q

7) Which of the following factors does NOT affect the electric potential difference?

a) The distance between the points b) The magnitude of the electric field c) The material through which the charge moves d) The path taken between the points

8) What is the relationship between the electric potential difference and the electric field?

a) $V=E\times d$ b) $V=-\int E.dl$ c) $V=E\times r$ d) $V=E\times Q$

9) Which of the following describes the electric potential difference best?

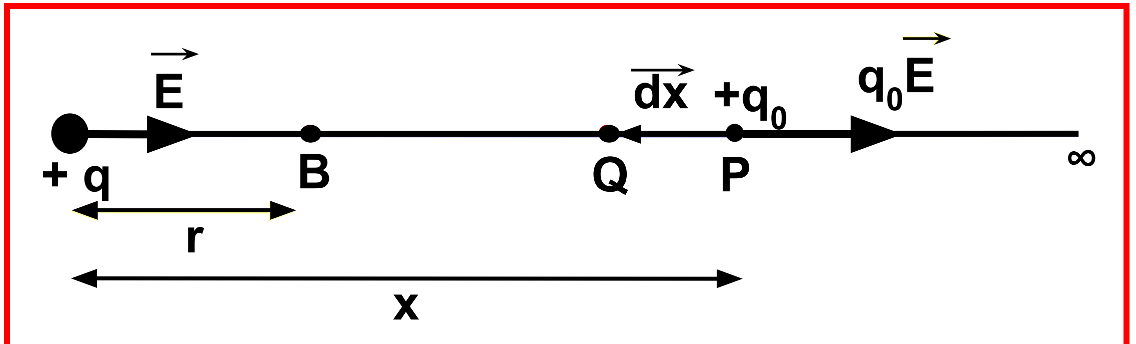
a) It is the force per unit charge b) It is the energy required to move a charge c) It is the speed at which charges move d) It is the resistance to charge flow

10) In which of the following situations will the potential difference be zero?

a) When the points are at the same potential b) When there is no charge c) When the electric field is absent d) When a resistor is present in the circuit

Electric Potential due to a Single Point Charge:

Let $+q_0$ be the test charge placed at P at a distance x from the source charge +q.



The force $F = +q_0E$ is radially outward and tends to accelerate the test charge.

To prevent this acceleration, equal and opposite force $-q_0E$ has to be applied on the test charge.

Work done to move q_0 from P to Q through 'dx' against q_0E is

$dW = \vec{F} \cdot \vec{dx} = q_0\vec{E} \cdot \vec{dx}$ or $dW = q_0E\, dx \cos 180° = -q_0E\, dx$

$$dW = -\frac{q\, q_0}{4\pi\varepsilon_0\, x^2}\, dx \quad \because \quad E = \frac{q}{4\pi\varepsilon_0\, x^2}$$

Total work done to move q_0 from A to B (from ∞ to r) is

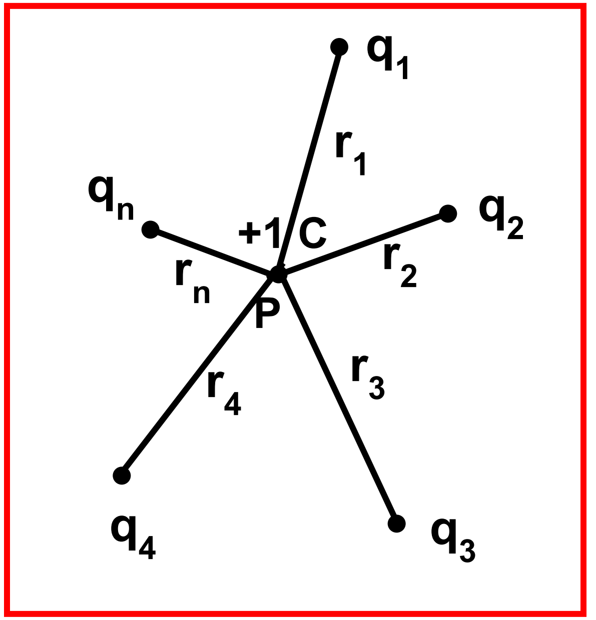
$$W_{\infty B} = \int_{\infty}^{B} dW = -\int_{\infty}^{r} \frac{q\, q_0}{4\pi\varepsilon_0\, x^2}\, dx = -\frac{q\, q_0}{4\pi\varepsilon_0} \int_{\infty}^{r} \frac{1}{x^2}\, dx$$

$$\frac{W_{\infty B}}{q_0} = \frac{q}{4\pi\varepsilon_0\, r}$$

$$\boxed{V = \frac{q}{4\pi\varepsilon_0\, r}}$$

Electric Potential due to a Group of Point Charges:

The net electrostatic potential at a point in the electric field due to a group of charges is the algebraic sum of their individual potentials at that point.



$$V_P = V_1 + V_2 + V_3 + V_4 + \ldots\ldots\ldots\ldots + V_n$$

$$\boxed{V = \frac{1}{4\pi\varepsilon_0} \sum_{i=1}^{n} \frac{q_i}{r_i}}$$

$$V = \frac{1}{4\pi\varepsilon_0} \sum_{i=1}^{n} \frac{q_i}{\left|\vec{r} - \vec{r}_i\right|}$$

(in terms of position vector)

1. Electric potential at a point due to a charge is not affected by the presence of other charges.
2. Potential, $V \propto 1 / r$ whereas Coulomb's force $F \propto 1 / r^2$.
3. Potential is a scalar whereas Force is a vector.
4. Although V is called the potential at a point, it is actually equal to the potential difference between the points r and ∞.

Electric Potential due to an Electric Dipole:

i) At a point on the axial line:

$$V_{P\,q+} = \frac{1}{4\pi\varepsilon_0}\,\frac{q}{(x-l)}$$

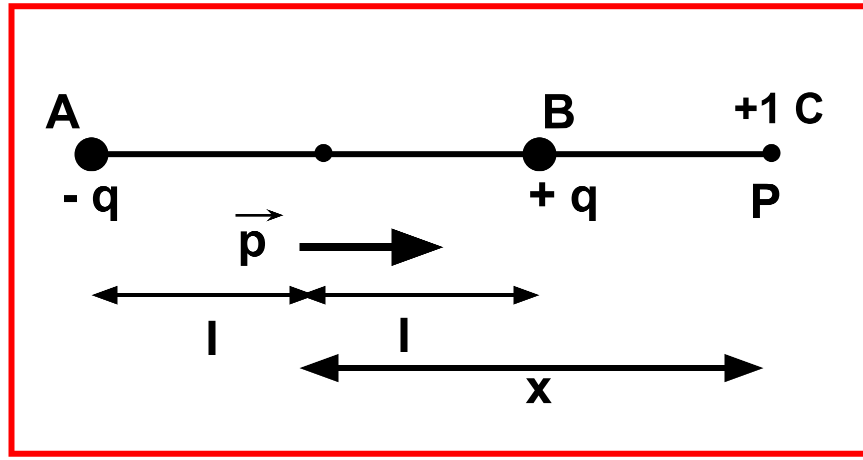
$$V_{P\,q-} = \frac{1}{4\pi\varepsilon_0}\,\frac{-q}{(x+l)}$$

$$V_P = V_{P\,q+} + V_{P\,q-}$$

$$V_P = \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{(x-l)} - \frac{1}{(x+l)}\right]$$

$$V_P = \frac{1}{4\pi\varepsilon_0}\,\frac{q\,.\,2l}{(x^2-l^2)}$$

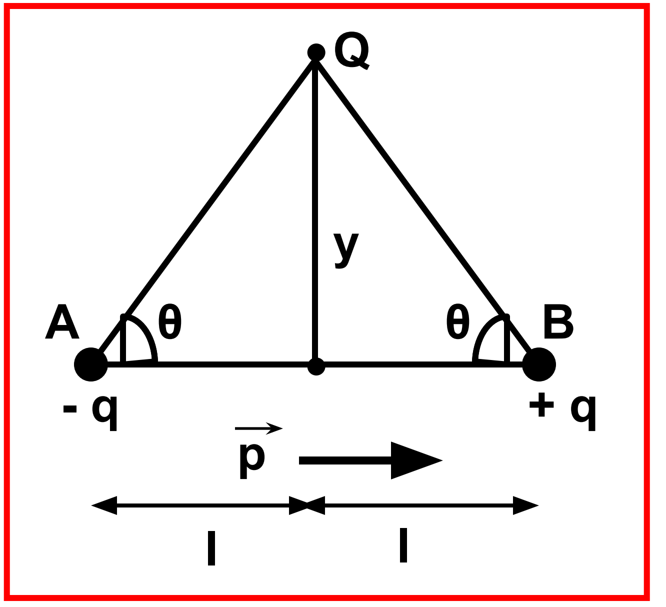
$$\boxed{V_P = \frac{1}{4\pi\varepsilon_0}\,\frac{p}{(x^2-l^2)}}$$



ii) At a point on the equatorial line:

$$V_{Q\,q+} = \frac{1}{4\pi\varepsilon_0}\frac{q}{BQ}$$

$$V_{Q\,q-} = \frac{1}{4\pi\varepsilon_0}\frac{-q}{AQ}$$



$$V_Q = V_{P\,q+} + V_{P\,q-}$$

$$V_Q = \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{BQ} - \frac{1}{AQ}\right]$$

$$\boxed{V_Q = 0} \qquad \because \quad BQ = AQ$$

The net electrostatic potential at a point in the electric field due to an electric dipole at any point on the equatorial line is zero.

Quiz

1) What is the formula for the electric potential V at a distance r from a point charge q in a medium with permittivity ϵ?

a) $V = \frac{q}{4\pi r^2}$ b) $V = \frac{1}{4\pi\varepsilon}\frac{q}{r}$ c) $V = \frac{q}{r^2}$ d) $V = \frac{1}{4\pi\varepsilon}\frac{q}{r^2}$

2) The electric potential at a point due to a negative charge is:

a) Positive b) Negative c) Zero d) Infinity

3) What happens to the electric potential due to a point charge as the distance r increases?

a) Increases b) Decreases c) Remains constant d) Oscillates

4) If there are multiple charges, the total potential at a point is:

a) The vector sum of the potentials b) The scalar sum of the potentials

c) The difference of potentials d) Zero

5) What is the electric potential at the midpoint between two equal and opposite charges?

a) Zero b) Positive c) Negative d) Depends on the distance

6) What is the potential at a point PP on the equatorial line of a dipole?

a) Maximum b) Minimum c) Zero d) Depends on the distance from the dipole

7) Which of the following correctly describes the electric potential?

a) It is a vector quantity

b) It is always positive

c) It is a scalar quantity

d) It is always negative

8) For a point charge q, what is the work done in moving a test charge q_0 from infinity to a distance r from q?

a) $W = \frac{1}{4\pi\varepsilon}\frac{qq_0}{r^2}$

b) $W = \frac{1}{4\pi\varepsilon}\frac{qq_0}{r}$

c) $W = \frac{1}{4\pi\varepsilon}qq_0r$

d) $W = 0$

9) What is the electric potential due to a point charge at infinity?

a) Maximum

b) Minimum

c) Zero

d) Infinite

10) If the distance between two charges in a dipole is halved, how does the potential at a distant point on the axial line change?

a) Becomes twice as large

b) Becomes half as large

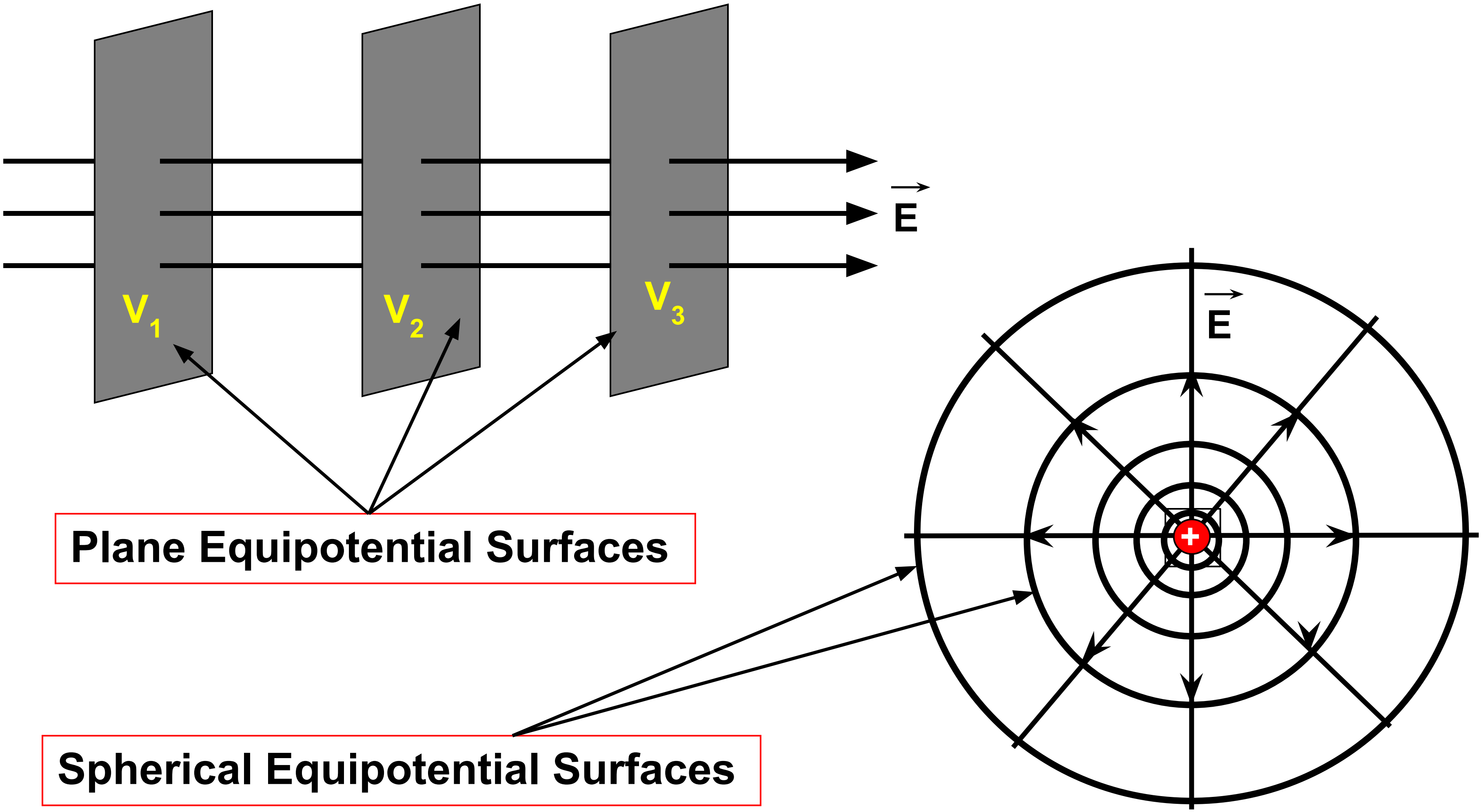
c) Becomes one-fourth as large

d) Remains unchanged

Equipotential Surfaces:

A surface at every point of which the potential due to charge distribution is the same is called equipotential surface.

i) For a uniform electric field:



ii) For an isolated charge:

Properties of Equipotential Surfaces:

1. **No work is done in moving a test charge from one point to another on an equipotential surface.**

$$\boxed{V_B - V_A = \Delta V = \frac{W_{AB}}{q_0}}$$

If A and B are two points on the equipotential surface, then $V_B = V_A$.

$$\therefore \quad \frac{W_{AB}}{q_0} = 0 \qquad \text{or} \qquad W_{AB} = 0$$

2. **The electric field is always perpendicular to the element dl of the equipotential surface.**

Since no work is done on equipotential surface,

$$W_{AB} = -\int_A^B \vec{E} \cdot \vec{dl} = 0 \qquad \text{i.e.} \qquad E\ dl \cos\theta = 0$$

As $E \neq 0$ and $dl \neq 0$, $\cos\theta = 0$ **or** $\theta = 90°$

3. Equipotential surfaces indicate regions of strong or weak electric fields.

Electric field is defined as the negative potential gradient.

$$\therefore \quad E = -\frac{dV}{dr} \quad \text{or} \quad dr = -\frac{dV}{E}$$

Since dV is constant on equipotential surface, so

$$dr \propto \frac{1}{E}$$

If E is strong (large), dr will be small, i.e. the separation of equipotential surfaces will be smaller (i.e. equipotential surfaces are crowded) and vice versa.

4. Two equipotential surfaces can not intersect.

If two equipotential surfaces intersect, then at the points of intersection, there will be two values of the electric potential, which is impossible.

(Refer to properties of electric lines of force)

Note:

Electric potential is a scalar quantity whereas potential gradient is a vector quantity.

The negative sign of the potential gradient shows that the rate of change of potential with distance is always against the electric field intensity.

Quiz

1) What is an equipotential surface?

a) A surface where the electric field is constant

b) A surface where the electric potential is constant

c) A surface where charge density is constant

d) A surface where the potential difference is maximum

2) What is the work done in moving a charge along an equipotential surface?

a) Equal to the charge multiplied by the electric field

b) Equal to the charge multiplied by the distance moved

c) Zero

d) Proportional to the potential difference

3) Which of the following is true for an equipotential surface?

a) It is parallel to the electric field lines

b) It is perpendicular to the electric field lines

c) It intersects the electric field lines

d) It is independent of the electric field

4) What is the shape of the equipotential surfaces for a point charge?

a) Cylindrical

b) Concentric spheres

c) Parallel planes

d) None of the above

5) In a uniform electric field, the equipotential surfaces are:

a) Concentric circles b) Concentric spheres c) Parallel planes

d) Distorted spheres

6) What happens to the spacing of equipotential surfaces as the electric field strength increases?

a) It increases b) It decreases c) It remains the same

7) Equipotential surfaces never intersect because:

a) They are perpendicular to the electric field

b) The electric potential cannot have two values at the same point

c) Electric field lines intersect them

d) Their shapes are spherical