ELECTROSTATICS

FYJC

Chap-10

ELECTROSTATICS

- A branch of physics, which deals with all physical quantity and phenomena linked with the charges, which are at rest.
- Eg. Force between charges, electric field, electric potential, potential energy in electric field etc.

ELECTRIC CHARGES

- HISTORICALLY, opposite electric CHARges were known to the greeks in the 600 bc
- they REALIZED THAT EQUAL AND opposite CHARges develop on AMBER AND fur when rubbed AGAINST EACH other
- Electric charge is A BASIC property of ELEMENTARY PARTICLES of which MATTER is MADE of
- These ELEMENTARY PARTICLES ARE proton, neutron, AND electron
- A proton is considered to be positively CHARged AND electron to be NEGATIVELY CHARged. Neutron is ELECTRICALLY NEUTRAL
- When CERTAIN DISSIMILAR SUBSTANCES, like fur AND AMBER or comb AND dry HAIR ARE rubbed AGAINST EACH other, electrons get TRANSFERRED to the other SUBSTANCE MAKING them CHARged
- The SUBSTANCE receiving electrons develops A NEGATIVE CHARge while the other is left with AN EQUAL AMOUNT of positive CHARge

ADDITIVE NATURE OF CHARGE

- Electric CHARge is ADDITIVE, SIMILAR to MASS
- The TOTAL electric CHARge on AN object is EQUAL to the ALGEBRAIC sum of ALL the electric CHARges distributed on different PARTS of the object
- while TAKING the ALGEBRAIC sum, the sign (positive or NEGATIVE) of the electric CHARges must be TAKEN into ACCOUNT
- Thus if two bodies HAVE EQUAL AND opposite CHARges, the net CHARge on the system of the two bodies is zero

QUANTIZATION OF CHARGE

- Charges are not continuously distributed throughout the material or on the surface of charged object.
- The minimum VALUE of the CHARges grouped together, AS determined by the MILIKAN'S oil drop experiment is $e = 1.6\times10^{-19}$ C i.e. on electron.
- This is CALLED the ELEMENTARY CHARge particle
- Since proton (+ve) AND electrons (-ve) ARE the CHARged PARTICLES of constituting MATTER, the CHARge on AN object must be AN INTEGRAL multiple of $\pm e$, i.e. $q = \pm ne$, where n is AN integer
- CHARge on AN object CAN be INCREASED or DECREASED in multiples of e
- It is BECAUSE, during the CHARging process AN INTEGRAL number of electrons CAN be TRANSFERRED from one body to the other body
- This is known AS **QUANTIZATION of CHARGE** or discrete NATURE of CHARge

CONSERVATION OF CHARGE

- In ANY given PHYSICAL system, CHARge MAY get TRANSFERRED from one PART of the system to ANOTHER, but the TOTAL CHARge in the system REMAINS CONSTANT.
- **for AN ISOLATED system** TOTAL CHARGE CANNOT be crEATED nor destroyed.

FORCES BETWEEN CHARGES

- CHARged objects experience force when brought close (not touching) to EACH other.
- This force CAN be ATTRACTIVE or repulsive
- **Like CHARGES repel EACH other AND unlike CHARGES ATTRACT EACH other.**

COULOMB'S LAW

- The electric INTERACTION between two CHARged bodies CAN be expressed in terms of the forces they exert on EACH other
- Coulomb used point CHARges AT rest to study the INTERACTION
- A point CHARge is A CHARge whose dimensions ARE negligibly SMALL COMPARED to its DISTANCE from ANOTHER bodies
- *The force of attraction or repulsion between two point charges at rest is directly proportional to the product of the magnitude of the charges and inversely proportional to the square of the distance between them.*
- This force ACTS ALONG the line joining the two CHARges
- Let and be two point CHARges AT rest with respect to EACH other AND SEPARATED by A DISTANCE r.
- The MAGNITUDE F of the force between them is given by, => where K is the CONSTANT of PROPORTIONALITY
- The force between the two CHARges will be ATTRACTIVE if they ARE unlike (one positive AND one NEGATIVE)
- The force will be repulsive if CHARges ARE SIMILAR (both positive or both NEGATIVE)

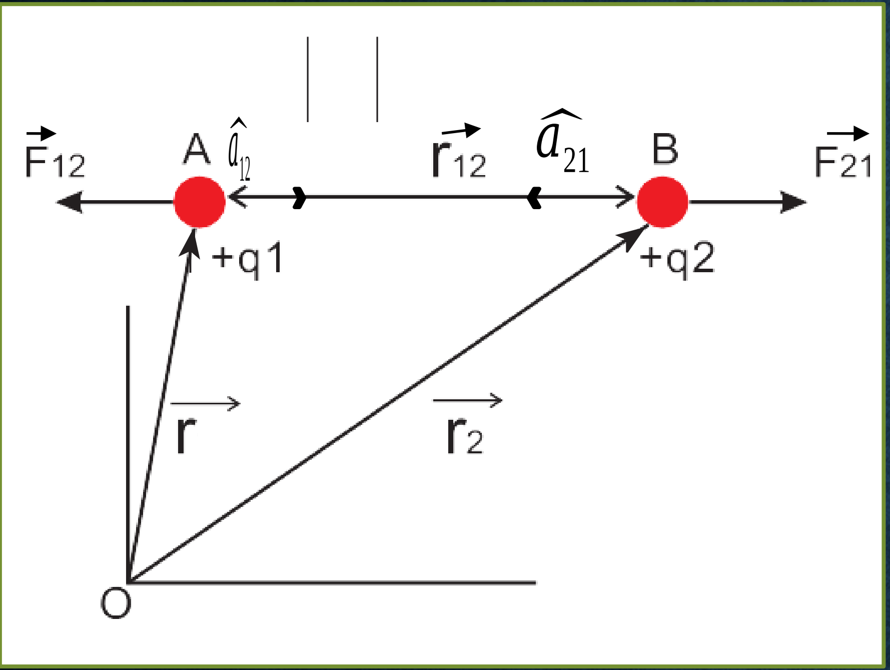
RELATIVE PERMITTIVITY OR DIELECTRIC CONSTANT

- While discussing the coulomb's LAW it WAS ASSUMED THAT the CHARges ARE held STATIONERY in VACUUM.
- When the CHARges ARE kept in A MATERIAL medium, such AS WATER, MICA or PARAFINED PAPER, the medium AFfects the force between the CHARges
- As force between the two CHARges PLACED in A medium found to be
- Where K found for a given medium is (where is permittivity of medium)
- Hence force between point charge in given medium is,
- If both point charge kept in vacuum, the force will (whereis permittivity of vacuum)
- The relation between permittivity of medium and permittivity of vacuum is =k, where k is called relative permittivity or dielectric constant.
- Thus dielectric constant of medium can be defined as the ratio of permittivity of medium to permittivity of vacuum i.e. k () =
- IT CAN ALSO BE DEFINE RATIO of the force between two point CHARges PLACED A CERTAIN DISTANCE APART in free SPACE or VACUUM to the force between the SAME two point CHARges when PLACED AT the SAME DISTANCE in the given medium i.e. k ()=

DEFINITION OF UNIT CHARGE FROM THE COULOMB'S LAW

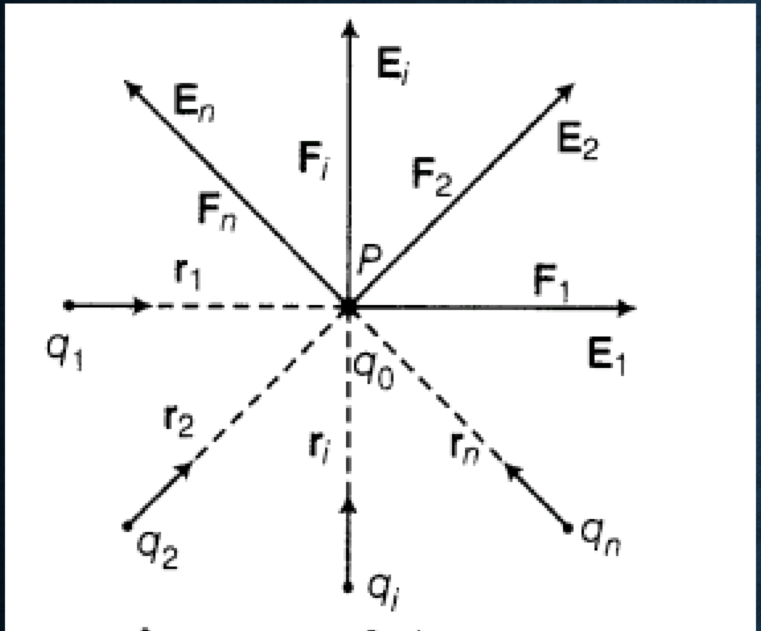
- When equal AMOUNT of two point CHARGE PLACED AT A DISTANCE of one meter apart from each other in VACUUM, experiences A force of 9 N,The magnitude of charge said to be 1 coulomb.
- Since the force acting between two point charge in vacuum is given by
- Let are equal in magnitude i.e. = q , is separated by distance 1 m apart i.e. r=1m and F= 9 N.
- since = 9
- Thus using above data in given equation, i.e. => 9 =9 => =1
- Thus q=1 and unit is allocated as per name of scientist coulomb i.e. q=1C

COULOMB'S LAW IN VECTOR FORM



- As shown in the figure, are point charge separated by distance .
- is force acting on by is unit vector along vector
- Thus, force can be expressed in vector form, =
- Similarly is force acting on by is unit vector along vector
- Thus, force can be expressed in vector form, =
- Since directing opposite to each other with unit magnitude, hence
- Thus, = -

PRINCIPLE OF SUPERPOSITION



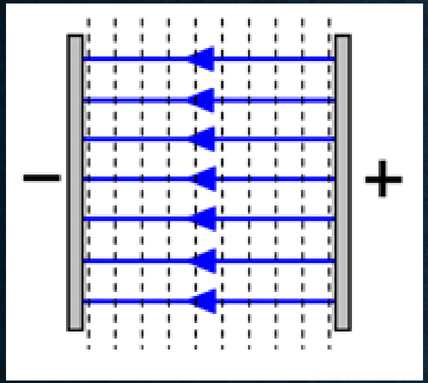
A system of charges

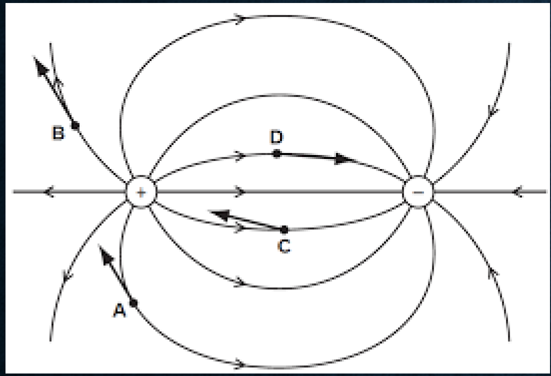
- The principle of superposition STATES THAT *when a number of charges are interacting, the resultant force on a particular charge is given by the vector sum of the forces exerted by individual charges*
- *Consider, charges , , , , interacting each other and the force exerted by , , , on are , , and respectively.*
- *The total force action on () can be found by using principle of super position. i.e. = +*

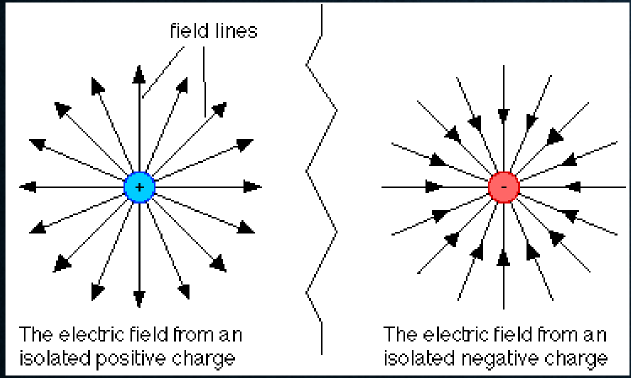
ELECTRIC FIELD AND ELECTRIC FIELD INTENSITY

- Electric field: The space surrounded around any point charge in which, other charge experience force is called electric field.
- Electric field intensity: the strength of electric field at a given point is called electric field intensity Or In electric field of charge, the force acting on per unit charge is called electric field intensity.
- Thus, in general electric field intensity can be expressed, E=
- Let *Q* AND *q* be two CHARges SEPARATED by A DISTANCE r, as per coulomb's law, force acting on q by Q is given by,
- Hence, the electric field intensity due to point charge Q at distance r is E = =
- In vector form = where is unit vector along the line joining from Q to q.
- The electric field exists ARound A CHARGE irrespective of the presence of other CHARGES
- SI unit of electric intensity is newton per coulomb (NC^{-1})
- The electric field intensity in A medium is given by = where k is dielectric constant.

TYPES OF ELECTRIC FIELD

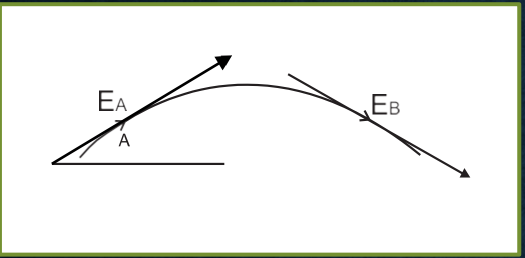




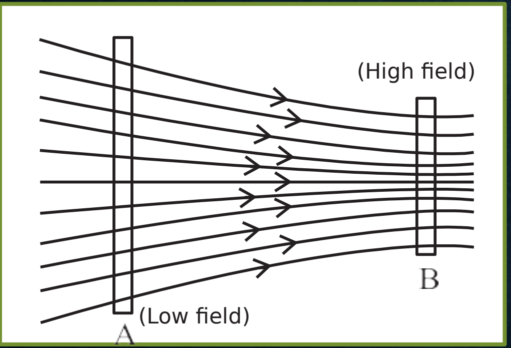


- Uniform electric field: A uniform electric field is A field in which, the MAGNITUDE AND direction of electric field intensity is SAME AT ALL points.
- For EXAMPLE, field between two PARALLEL PLATES
- **Non uniform electric field:** A field in which the MAGNITUDE AND direction of electric field intensity is not the SAME AT ALL points.
- For EXAMPLE, field due to SYSTEM OF TWO INTERACTING CHARGE.
- RADIAL ELECTRIC FIELD: A field in which the direction of electric field intensity is directing towards a common point or outward from a common point
- For example field due to positive or negative point charge.

ELECTRIC LINES OF FORCE

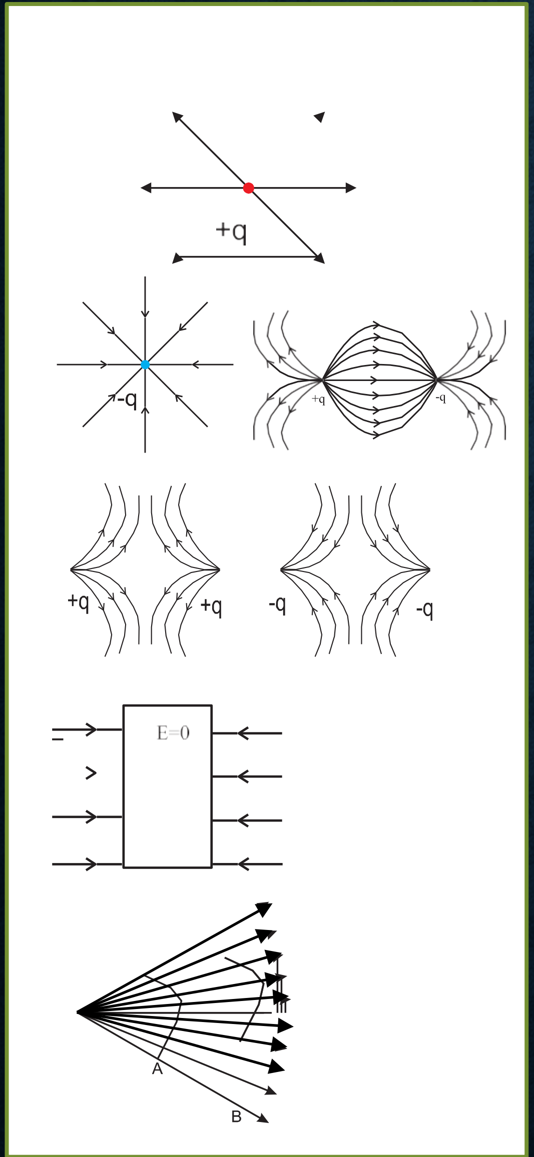


- MICHAEL FARADAY (1791-1867) introduced the concept of lines of force for VISUALISING electric AND MAGNETIC fields
- *An electric line of force is an imaginary curve drawn in such a way that the tangent at any given point on this curve gives the direction of the electric field at that point*



- If a test CHARge is PLACED in AN electric field it would be ACTED upon by A force AT every point in the field AND will move ALONG A PATH.
- **Hence The PATH ALONG which the unit positive CHARGE moves in electric field is CALLED A line of force**
- The density of field lines INDICATES the strength of electric fields AT the given point in SPACE

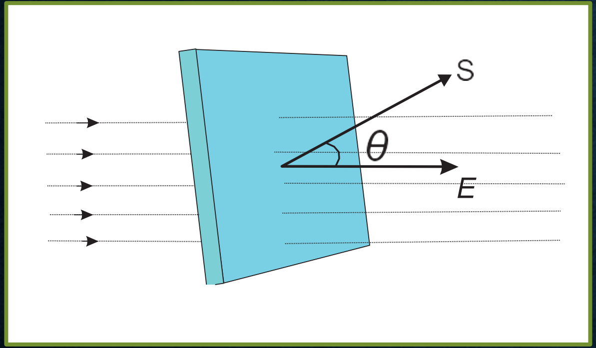
CHARACTERISTICS OF ELECTRIC LINES OF FORCE



- The lines of force ORIGINATE from A positively CHARged object AND TERMINATE on A NEGATIVELY CHARged object
- The lines of force neither intersect nor meet EACH other.
- The lines of force LEAVE or TERMINATE on A conductor NORMALLY
- The lines of force do not PASS through conductor i.e. electric field inside A conductor is ALWAYS zero, but they PASS through INSULATORS
- MAGNITUDE of the electric field intensity is PROPORTIONAL to the number of lines of force per unit AREA of the SURFACE held PERPENDICULAR to the field
- Electric lines of force ARE crowded in A region where electric intensity is LARge
- Electric lines of force ARE widely SEPARATED from EACH other in A region where electric intensity is SMALL
- The lines of force of AN uniform electric field ARE PARALLEL to EACH other AND ARE EQUALLY SPACED

ELECTRIC FIELD INTENSITY AND ELECTRIC FLUX

- Electric field intensity: electric field intensity can also be defined as number of line of force passing through unit area i.e. E= number of line of force/area enclose line of force
- Hence, number of line of force passing through area = E Area
- Electric flux: The number of line of force passing through given area normally.
- Hence is all line of force will pass normally through given area then flux ()= E Area



- Let the ANGLE between electric field *E* AND AREA VECTor *ds* be , then the electric flux PASSING through AREA *dS* is given by,

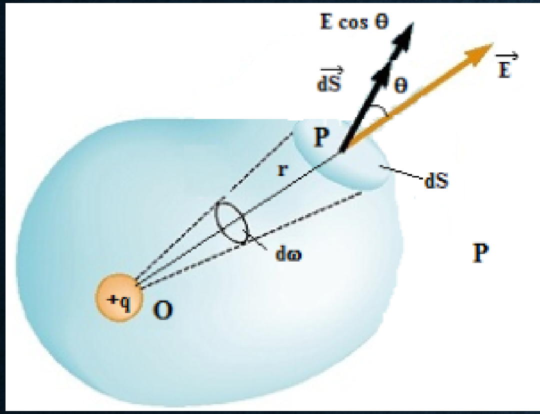
  d = (component of *ds* ALONG *E*).(INTENSITY AT THAT POINT)

  d= ds cos. E

  d = E.ds cos

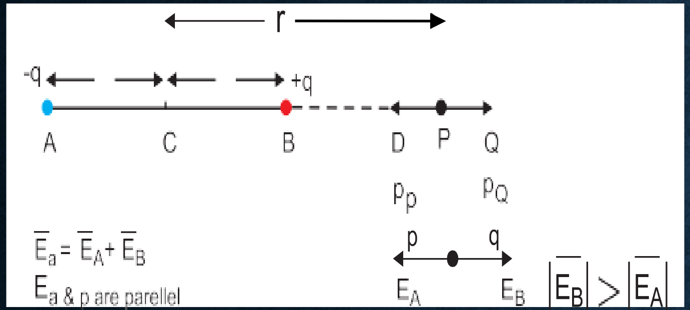
  d =
- Total flux over the surface () =
- SI unit is weber or Vm

GAUSS' LAW



- The flux of the net electric field through A closed SURFACE EQUALS the net CHARge enclosed by the SURFACE divided by
- The MAGNITUDe of electric field intensity AT point P on ds due to CHARge +q AT point O is, E=
- Let q be the ANGLE subtended by NORMAL DRAWN to AREA *dS* AND the direction of E
- Electric flux, *d*, PASSING through AREA *ds* = *E*cos *ds*
- *Hence, d =* cos *ds =*
- *but is solid angle denoted by*
- *hence d =*
- *Total flux() on close surface can be given by, = = = =q/*

ELECTRIC INTENSITY AT A POINT ON AXIS OF ELECTRIC DIPOLE



- Consider AN electric dipole consisting of two CHARges -q AND +q SEPARATED by A DISTANCE 2*l* AS SHOWN in Fig
- Let P be A point AT A DISTANCE r from the centre C of the dipole.
- The electric intensity *E* AT P due to the dipole is the vector sum of the field due to the CHARge - q AT A AND + q AT B
- Electric field intensity AT P due to the CHARge -q AT A is given by
- Electric intensity AT P due to CHARge +q AT B is given by,
- Total electric field intensity at point P, is given by, E = +

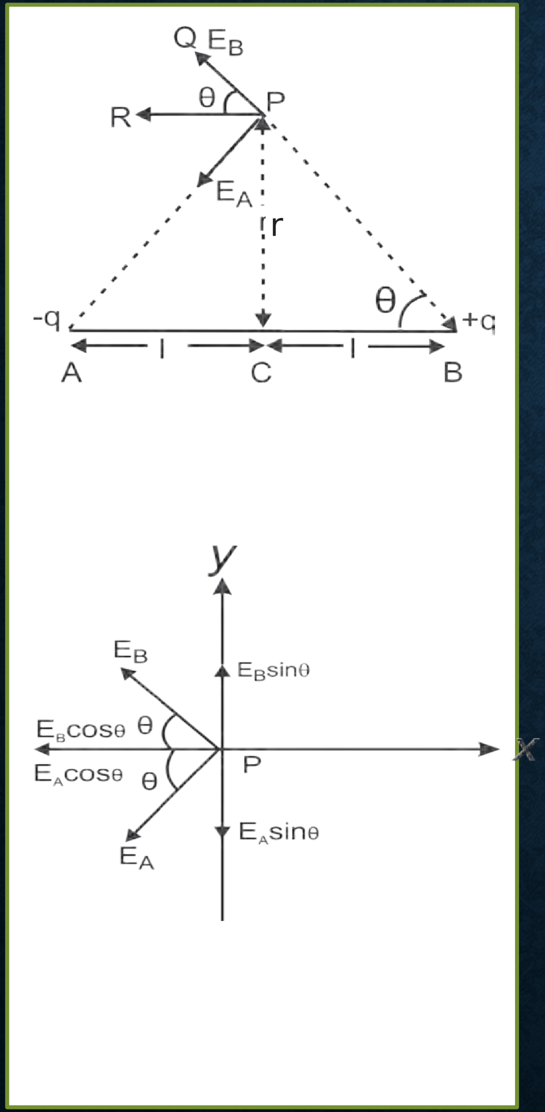
+ =

= = = as l<<r, we can neglect higher order of l,

= = =

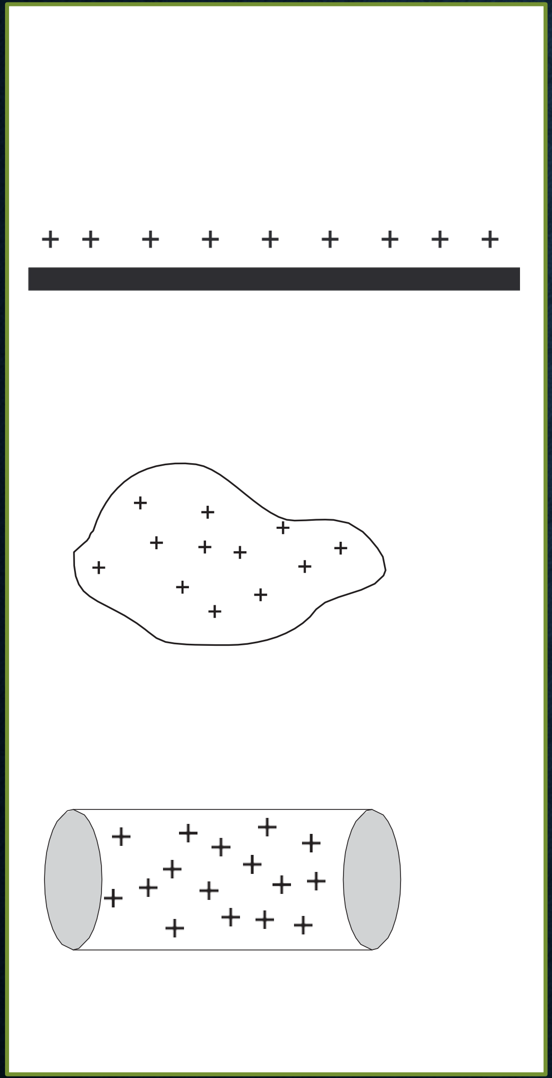
(since, p = q. 2l) =

ELECTRIC INTENSITY AT A POINT ON EQUATORIAL OF ELECTRIC DIPOLE



- As shown in Fig, Electric field AT point P due to CHARge –q is given by,
- Electric field AT point P due to CHARge +q is given by
- As P is equidistance from A and B, hence PA= PB
- Hence, = =
- As shown in diagram 2, vertical component of and are equal in magnitude and opposite in direction, so it will cancel each other at point p.
- Hence total electric field intensity is sum of horizontal component of and i.e. E= cos+ cos = 2 cos
- In = and cos=
- = and cos=
- Hence E = 2. . = = (as p =)
- As we can neglect higher order term of
- = =
- This shows that electric field intensity at a point on axis is twice of the intensity at a point on equatorial line

CONTINUOUS CHARGE DISTRIBUTION



- A system of CHARges CAN be considered AS A CONTINUOUS CHARge distribution, if the CHARges ARE LOCATED very close together, COMPARED to their DISTANCES from the point where the intensity of electric field is to be found out
- To find the electric field due to continuous CHARge distribution, we define following terms for different types of CHARge distribution
- LINEAR CHARGE density (λ): As shown in Fig. 1 CHARge q is uniformly distributed ALONG A liner conductor of length *l*. The LINEAR CHARge density λ is defined AS, $\lambda = q/l$
- SI unit of λ is (C/m).
- For EXAMPLE, CHARge distributed uniformly on A STRAIGHT thin rod
- SURFACE CHARGE density (σ): Suppose A CHARge *q* is uniformly distributed over A SURFACE of AREA *A*, As shown in Fig.2, then the SURFACE CHARge density σ is defined AS, $\sigma = q/A$.
- SI unit of s is (C/m^2)
- For EXAMPLE, CHARge distributed uniformly on A thin disc
- **Volume CHARGE density (ρ):** Suppose A CHARge *q* is uniformly distributed throughout A VOLUME *V*, then the volume CHARge density ρ is defined AS the CHARge per unit volume. i.e. $\rho = q/V$.
- S.I. unit of r is (C/m^3)
- For EXAMPLE, CHARge throughout A SOLID PLASTIC sphere