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Non-Effecteness of Volume by Storage of Electrostatistic charges

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Abstract

If Y and Z dimension of a three dimensional plane, be taken as summation of even amount of electric charges as planes Y+Z= 4 then the storage of electrostatic charges bounded by the cylinder $X^2+Y^2= 4$ at Z=0, will remain unaltered by the amount of electric charges and the The storage charges will be consumed by the statistical electrons of the solid cylinder. Charges consume as fuel to maintain the potential and kinetic energy. Nature of electric charge is neither like a gas nor like liquid. It means charge is of Non-fluid nature.

Keywords: **Electrostatistic, volumes of solid, double and triple integral.**

Introduction:

According to the established perception in the case of electrostatistic, electrons come on the surface of material when they are rubbed by some other material. **1**

Now imagine a small sphere charged with positive electricity and suspended by an insulating thread. It produces an electric field in space all around it. If we bring a second sphere suspended by an insulating thread charged with negative electricity near it, the second sphere will be acted on by force that urges it to move towards the positively charged sphere. We say the electric field caused by the positively charged sphere exerts a force on the negatively charged sphere in a manner similar to the action of the gravitational field on the object held in hand. **2** If the second sphere is also positively charged, the electric field will exert a force that urges it to move away from the first sphere. It is also true that the second sphere produce an electric field of its own, and it is correct to say that its field exerts a force on the first sphere. This force will urge the first sphere to move towards second sphere if second sphere is negatively charged and away form the second sphere, then we find that the space around a charge is always under stress, and experience a force on another charge when placed there. **3** The stress in the space is represented by the lines of force which are emanated from positive charge and end on negative charge. The lines of force of same direction repel each other but lines of force of opposite direction attract each other. **4** The direction of the line of force at any point is the direction of movement of a unit positive charge placed at that point if made to move freely. **5** They are always normal to the surface of the body from where they originate or terminate.

Charges which are free to move within a given substance(such as a conductor) under the action of an applied electric field, are not held from doing so by intermolecular forces, are called free charges.**6**

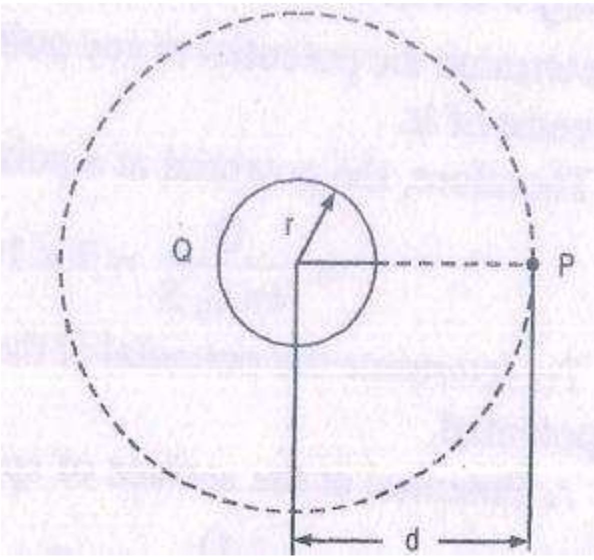
Conversely, bound charges (predominately in dielectrics) are those which are held fast in their position by molecular forces and so they don't move under the action of an applied electric filed. In a given substance the number of positive bound charges is equal to that of negative bund charges.

If a slab of dielectric be placed in an electrostatic field, it will go under polarization, which is defined as a definite orientation of bound charges in a material because of applied electric field. **7** This orientation manifests itself as the displacement of negative bound charges towards the higher potential and of positive bound charges towards the lower potential. The charges as displaced so that the effect of applied electric field is balanced by the effect of molecular force. As a result of polarization, bound charges expose themselves, as it were, on the material surface. **8**

Field due to a charged sphere:

Consider a uniformly charged sphere of radii r meters and having a charge of Q coulombs placed in a medium of relative permeability ε_r. Let the electric intensity be determined at a point P-(i)lying outside the sphere and (ii)lying inside the sphere.

(i)When the point P is outside the sphere. Let the distance of point P from the center of the sphere be d meters. Consider a sphere passing through point P concentric with the charged sphere, as depicted in figure given below: **9**



By Gauss's theorem electric flux crossing the sphere passing through point P.

Ψ = charge enclosed by it = Q coulombs …..(i)

Also , electric flux crossing the sphere at point P

Ψ = flux density X area

$= D \times 4\Pi d^2 = \varepsilon_o \varepsilon_r E \times 4\Pi d^2$ …..(ii)

Where E is electric intensity at point P

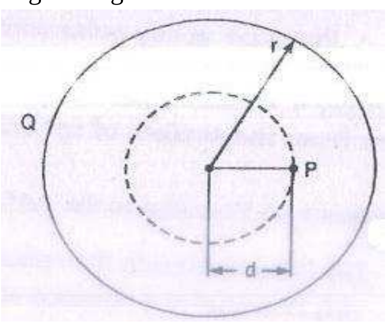
Comparing Eqs.(i) and (ii) we have

$Q = \varepsilon_o \varepsilon_r E \times 4\Pi d^2$

Or $E = Q/4\Pi\, \varepsilon_o \varepsilon_r\, d^2$ newtons/coulomb

Thus, the electric intensity at a point outside the sphere is the same as if the charge on the sphere were concentrated at the center of the sphere.

(ii)When the point P is inside the sphere. Let the point P be at a distance of d meters from the center of the charged sphere (d<r). Consider a sphere passing through point P concentric with the charged sphere as depicted in given figure.



By Gauss's theorem,

Electric flux crossing the dotted sphere passing through point P,

Ψ = charge enclosed by the dotted sphere = 0 …..(i)
Also, electric flux crossing the sphere at point P,
$\Psi = \varepsilon_o \varepsilon_r E \, 4\Pi d^2$ …..(ii)
Comparing Eqs.(i) and (ii) we have
E = 0
i.e. electric intensity at a point inside the charged sphere is zero.

Potential Gradient:

Practically the electric field intensity is not uniform, but varies from point to point. Let us consider that the electric filed intensity between two points separated by a very small distance ds is constant and let it be E. The work done in moving unit +ve charge from one point to the other up the gradient of potential is E ds and therefore, potential difference dV is given as:

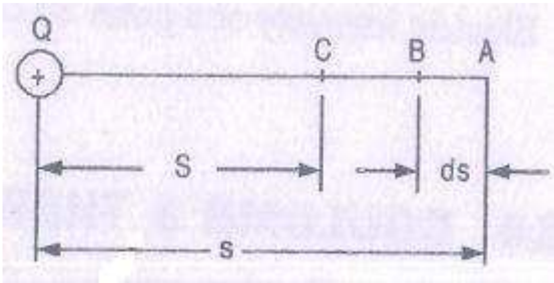
dV = -E ds (minus sign is used because of work is being done against the force due to electric field)

or E = -dV/ds = -g, potential gradient

Hence electric field intensity at any point is equal to the negative potential gradient at that point.

Potential at a Point:

Let us consider a positive charge of one coulomb at a distance of s meters from the charge of Q coulombs placed in air. The force acting on this unit +ve charge is given by:



$E = Q/4\Pi \, \varepsilon_o \, s^2$

Work done in moving this positive charge of one coulomb towards the charge of Q coulombs through a distance d

$dw = E(-ds) = Q/4\Pi \, \varepsilon_o \, s^2 \times (-ds)$

The negative sign is taken because ds is considered along the negative direction of s.

Total work done in bringing the +ve charge of one coulomb from infinity to any point, S meters from the charge of Q coulombs is given by:

$$W = \int_{\infty}^{S} -E \, ds = -\int_{\infty}^{S} Q/4\Pi \, \varepsilon_o \, s^2 \, ds = Q/4\Pi \, \varepsilon_o \, S$$

By definition, potential at any point

V = the work done in bringing a +ve charge of one coulomb from infinity to that point

$= Q/4\Pi \, \varepsilon_o \, S = 9 \times 10^9 \, Q/S$ volts in air

And $V = Q/4\Pi \, \varepsilon_o \, \varepsilon_r \, S = 9 \times 10^9 \, Q/\varepsilon_r \, S$ volts in medium of relative permittivity ε_r

Potential at a point due to number of charges

As already proved, the potential at any point at a distance of S meters from the charge of Q coulombs is given by:

$V = 9 \times 10^9 \, Q/\varepsilon_r \, S$

Similarly the potential at any point due to number of charges Q1, Q2, Q3, Q4 etc. placed at distances S1, S2, S3, S4 etc. respectively from it is given as:

$V = 9 \times 10^9 \, Q/\varepsilon_r \, [Q1/S1 + Q2/S2 + Q3/S3 + Q4/S4 + \ldots\ldots]$

Potential at a charged sphere:

To determine the potential at any point outside the sphere, the charge should be assumed to be concentrated at the center of it.

Therefore, the potential at a point, S meters from the center of the sphere having the charge Q coulombs

$= Q/4\Pi\, \varepsilon_o\, S = 9 \times 10^9\, Q/S$ volts

To determine the potential at the surface of sphere of radius r meters substitute S=r in above expression for potential,

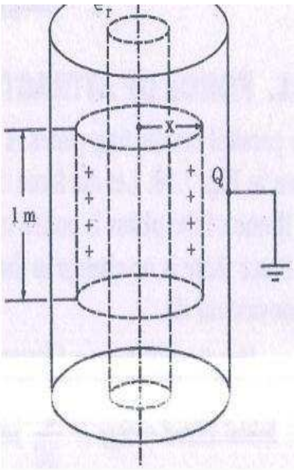
Therefore, potential at the surface of sphere of radius r meters and consisting of charge Q,

$V = Q/4\Pi\, \varepsilon_o\, r = 9 \times 10^9\, Q/r$ volts

Capacitance of a Cylindrical Capacitor:

The cable can be considered to be two coaxial cylinders of inner diameter d and outer diameter D. In actual cable, d represents the diameter of core and D represents the inner diameter of lead sheath which is at earth potential. Let the relative permittivity of dielectric in between the core and sheath be ε_r .**10**

Let the charge per meter length of the cable on the outer surface of the core be +Q coulombs and on the inner surface of the lead sheath be –Q coulombs. For all practical purposes, the charge of +Q coulombs/m on the surface of the core can be assumed to be located along its axis. The metal sheath is earthed.



Surface area of the coaxial cylinder of radius x meters and length one meter is $2\Pi x\ m^2$.

Therefore, electric field intensity at a point x meters from the center of the inner cylinder,

$E_x = Q/2\Pi\, \varepsilon_o\, \varepsilon_r\, x = Q/2\Pi\, \varepsilon_o\, \varepsilon_r.\ 1/x$ V/m

Potential difference between the capacitor plates,**11** (between core and sheath)

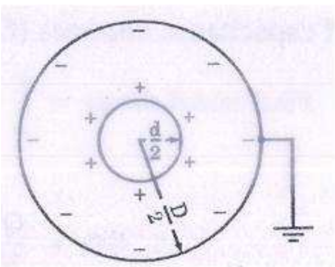
$$V = \int_{d/2}^{D/2} E_x\, dx = \int_{d/2}^{D/2} Q/2\Pi\, \varepsilon_o\, \varepsilon_r.\ 1/x\, dx = Q/2\Pi\, \varepsilon_o\, \varepsilon_r\, \log_e D/d \text{ volts}$$

capacitance of cable,

$C = Q/V = Q/\ Q/2\Pi\, \varepsilon_o\, \varepsilon_r\, \log_e D/d$ F/m

$= 2\Pi\, \varepsilon_o\, \varepsilon_r / \log_e D/d = 2\Pi \times 8.854 \times 10^{-12}\, \varepsilon_r / 2.303 \log_{10} D/d$

$= \varepsilon_r\, 10^{-9} / 41.4 \log_{10} D/d$ F/m or $0.024\, \varepsilon_r / \log_{10} D/d$ μF/km

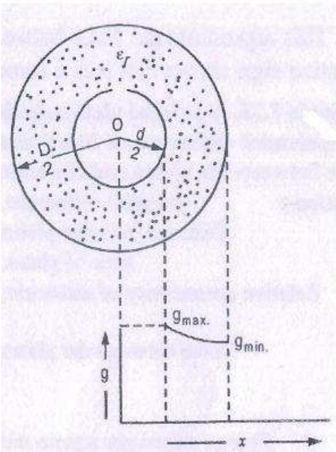


In case of capacitor having compound dielectric, the expression for capacitance becomes **12**

$C = 2\Pi\, \varepsilon_o / \sum \log_e D/d/\ \varepsilon_r$ F/m

Potential Gradient in the Cable:

Since cable is a form of cylindrical condenser, electric intensity at a distance x from the center O of the cable is given by (as determined in foregoing article) the equation **13**



$E_x = Q/2\Pi\, \varepsilon_o\, \varepsilon_r.\ 1/x$ V/m

Since potential gradient = Electric intensity,

$g = Q/2\Pi\, \varepsilon_o\, \varepsilon_r.\ 1/x$ V/m …(i)

From above article

$V = Q/2\Pi\, \varepsilon_o\, \varepsilon_r \log_e D/d$

Or $Q = 2\Pi\, \varepsilon_o\, \varepsilon_r V/ \log_e D/d$ …(ii)

Substituting the value of Q from Eq. (ii) in Eq. (i) we have

$g = 2\Pi\, \varepsilon_o\, \varepsilon_r V/ \log_e D/d\ .\ 1/2\Pi\, \varepsilon_o\, \varepsilon_r\ .\ 1/x = V/x \log_e D/d$ volts/meters

Since potential gradient g varies inversely as x (as obvious from the above expression), potential gradient will be maximum when x is minimum **14** i.e., x = d/2 and potential gradient will be minimum when x is maximum i.e. x=D/2.

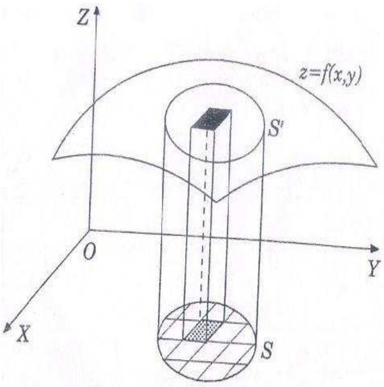
Maximum and minimum values of potential gradient are given by

$g_{max} = 2V/d \log_e D/d$ volts/meter

And $g_{min} = 2V/D \log_e D/d$ volts/meter

Conclusion:

Let consider a surface z = f(x,y). Let the orthogonal projection on XY-plane of its portion S` be the area S.



Divide S into elementary rectangles of area δx δy by drawing lines parallel to X and Y axes with each of these rectangles as base, erect a prism having its length parallel to OZ.

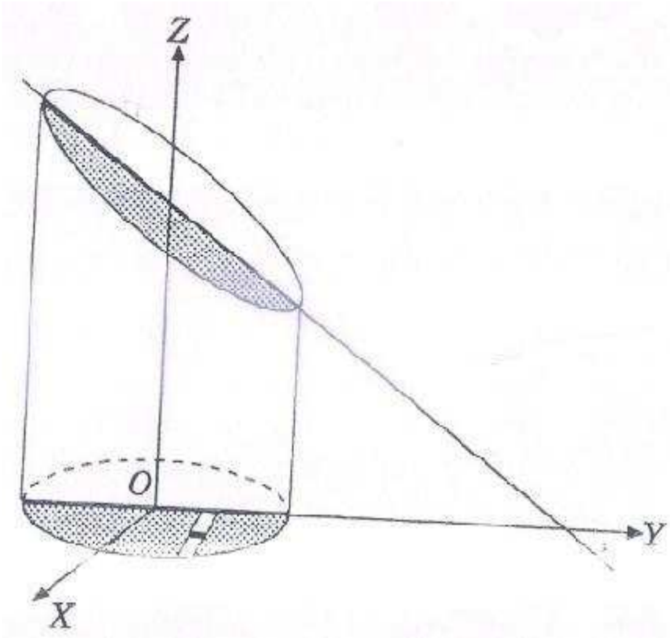
Therefore, volume of this prism between S and the given surface z = f(x,y) is z δx δy.

Hence the volume of the solid cylinder on S as base, bounded by the given surface with generators parallel to the Z-axis.

$$= \lim_{\substack{\delta x \to 0 \\ \delta y \to 0}} \sum\sum z\, \delta x\, \delta y$$

$$= \iint z\, dx\, dy \quad \text{or} \quad \iint f(x,y)\, dx\, dy$$

Where the integration is carried over the area S.
Now the volume bounded by the cylinder $x^2 + y^2 = 4$ and the plane $y + z = 4$ and $z = 0$. From figure (ii), it is self – evident that $z = 4-y$ is to be integrated over the circle $x^2 + y^2 = 4$ in the XY- plane. To cover the shaded half of the circle, x varies from 0 to $\sqrt{(4-y^2)}$ and y varies from -2 to 2



Therefore , required volume

$$= 2\int_{-2}^{2}\int_{0}^{\sqrt{(4-y^2)}} z\,dx\,dy$$

$$= 2\int_{-2}^{2}\int_{0}^{\sqrt{(4-y^2)}} (4-y)\,dx\,dy$$

$$= 2\int_{-2}^{2} (4-y)[x]_{0}^{\sqrt{(4-y2)}}\,dy$$

$$= 2\int_{-2}^{2} (4-y)\sqrt{(4-y^2)}\,dy$$

$$= 2\int_{-2}^{2} 4\sqrt{(4-y^2)}\,dy - 2\int_{-2}^{2} y\sqrt{(4-y^2)}\,dy$$

$$= 8\int_{-2}^{2} \sqrt{(4-y^2)}\,dy$$ [The second term vanishes as the integrand is an odd function]

$$= 8\left| y\sqrt{(4-y^2)}/2 + 4/2\sin^{-1}y/2 \right|_{-2}^{2} = 16\,\Pi.$$

Hence, non – effeteness of volume by storage of electrostatistic charge and other charges.

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