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ELECTRIC FIELD DUE TO CHARGED SPHERE

(విద్యుదావేశిత గోళం వల్ల విద్యుత్ క్షేత్ర తీవ్రత)

In this topic, three cases are possible for consideration

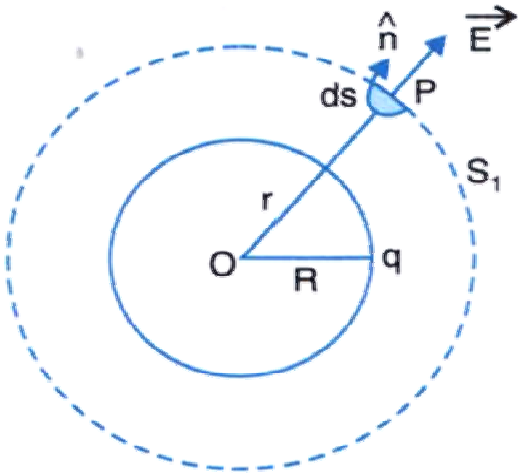
Case I: At a point outside the charged sphere

Case II: At a point on the surface of the sphere

Case III: At a point inside the charged sphere

Case I: At a point outside the charged sphere(గోళ బాహ్య బిందువు వద్ద)

Consider a sphere of radius 'R' with centre 'O' as shown in the following figure.



Let a charge 'q' is uniformly distributed over the sphere. Consider an outside point 'P' at a distance of 'r' from the centre 'O' as shown in the figure. Here, our aim is to derive an expression for the Electric field 'E'. For this purpose, construct a Gaussian surface with radius 'r' (OP). From the property of charge symmetry, the electric filed at points of Gaussian surface is the same and is directed perpendicular to the Gaussian surface. At point P, a small area element's dS vector is also directed parallel to it.

Therefore, for a small Gaussian surface at P,

$E.dS = EdSCos0^{\circ} = EdS$ (here, the angle between E and dS is zero.

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The electric flux through the entire Gaussian surface is given by

$\Phi_E = \oint E.dS = E\oint dS = E(4\pi r^2)$ (here, area of Gaussian surface is given by $4\pi r^2$) -----(1)

Further, 'E' is constant at all points on the surface. Therefore, 'E' taken out of the integral.

According to Gauss law, the electric flux over a closed surface is equal to $(1/\varepsilon_0)$ time of the charge enclosed within the surface.

Therefore,

$$E.4\pi r^2 = \left[\frac{q}{\varepsilon_0}\right] \Longrightarrow E = \frac{1}{4\pi\varepsilon_0} \times \frac{q}{r^2}\frac{newton}{coulomb} \quad \text{------(2)}$$

In vector form,

$$E = \frac{1}{4\pi\varepsilon_0} \times \frac{q}{r^3}\hat{r}newton/coulom \quad \text{-------(3)}$$

Here, r^ is a unit vector along radius.

Case II: At a point on the surface of the sphere{గోళ తలం పై}:

If the point 'P' is on the surface of the sphere, r =R. substituting this in equation (2), we get,

$$E = \frac{1}{4\pi\varepsilon_0} \times \frac{q}{R^2}\ newton/coulomb \quad \text{-------(4)}$$

Case III: At a point inside the charged sphere(గోళ లోపలి బిందువు వద్ద):

In this case, consider an inside point P' at a distance of r' from the centre. Here, a Gaussian surface with radius r' is constructed. The outward flux due to a small portion of Gaussian surface is given by

$E.dS = EdSCos0^{\circ} = EdS$ (here, the angle between E and dS is zero.

The electric flux through the entire Gaussian surface is given by

$\Phi_E = \oint E.dS = E\oint dS = E(4\pi r'^2)$ (here, area of Gaussian surface is given by $4\pi r'^2$) -----(5)

The total charge enclosed by the Gaussian surface q' = volume enclosed by the surface X charge per unit volume

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$q' = \frac{4}{3}\pi r'^3 \times \rho$

As the charge 'q' is distributed over a sphere of radius 'R',

$$\rho = \frac{Total\ charge}{volume} = \frac{q}{\left[\frac{4}{3}\pi R^3\right]} = \frac{3q}{4\pi R^3}$$

Therefore, the charge q' enclosed by the Gaussian surface is given by

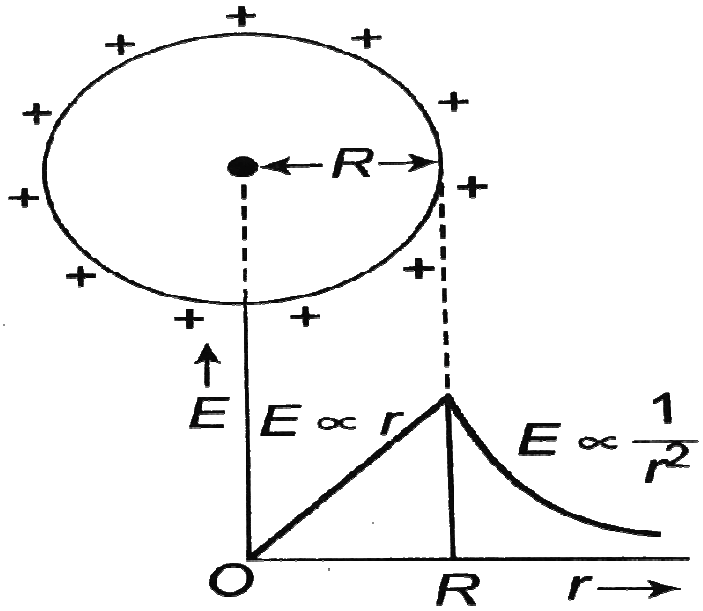
$$q' = \frac{4}{3}\pi r'^3 \times \frac{3q}{4\pi R^3} = q\left(\frac{r'}{R}\right)^3 \quad \text{-----(6)}$$

Using Gauss Law,

$$E\left(4\pi r'^2\right) = \left[\frac{1}{\varepsilon_0}\right] q\left(\frac{r'}{R}\right)^3 \Longrightarrow E = \frac{1}{4\pi\varepsilon_0} \times \frac{qr'}{R^3} \quad \text{------(7)}$$

From equation (7), one can conclude that the electric field at an inside point is directly proportional to the distance r'.

Using equations (3), (4) & (7), a graph can be plotted with respect to E and r. This plot may be shown below.



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Model Questions:

1. Discuss the salient features of Electric field due to a charged sphere
2. Using Gauss law, derive expressions for electric field due to charged sphere at1) a point outside 2) a point on the surface 3) an inside point.
3. The electric field due to a charged sphere at an outside point is inversely proportional to the square of the distance. Prove it.
4. The electric field due to a charged sphere at an inside point is inversely proportional to the distance. Prove it
5. The electric field due to a charged sphere is maximum at which point? Prove it.
6. Derive expressions for electric field due to a charged sphere at various places of possibility
7. Derive an expression for electric field due to a charged sphere at an outside point
8. Derive an expression for electric field due to a charged sphere at an inside point
9. With a neat diagram, derive expressions for electric field due to a charged sphere

References:

1. Unified Physics, Volume III, JAI PRAKASH NATH PUBLICATIONS, MEERUT
2. Internet

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