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Application of Gauss's law to find field due to uniformly charged thin spherical shell (field inside and outside).

CLASS-XII

SUBJECT : PHYSICS
CHAPTER NUMBER: 01
CHAPTER NAME : ELECTRIC CHARGES AND FIELDS

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LEARNING OUTCOME

- Students can understand electric flux and its application in the open and closed surface.
- Students should understand the physical information contained in Gauss's law and they should be able to apply this law to the calculation of field distributions in systems with specified symmetry.
- Students can calculate the electric field inside, outside and the surface of the spherical shell of charge.
- Students apply knowledge of electrostatics to explain natural physical processes and related technological advances.

QUICK REVIEW

1. What is the linear charge density?
2. What is surface charge density?
3. What is the expression for electric field intensity due to infinitely long straight wire?
4. What is the expression for electric field intensity due to uniformly charged infinite plane sheet?
5. Two plane sheets of charge densities + б and – б are kept in the air. What is the electric field intensity between two plane sheets?

INTRODUCTION

What is this phenomena called as?

Why is it safe to be inside car while lightning?

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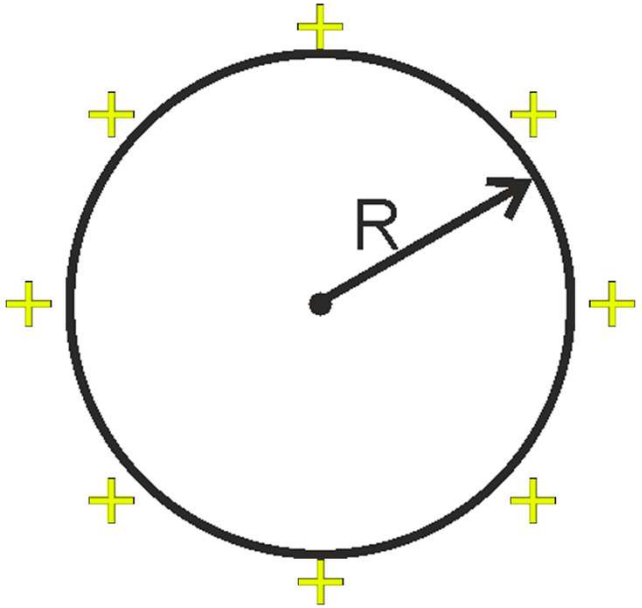
Electric field due to a uniformly charged thin spherical shell or solid conducting sphere

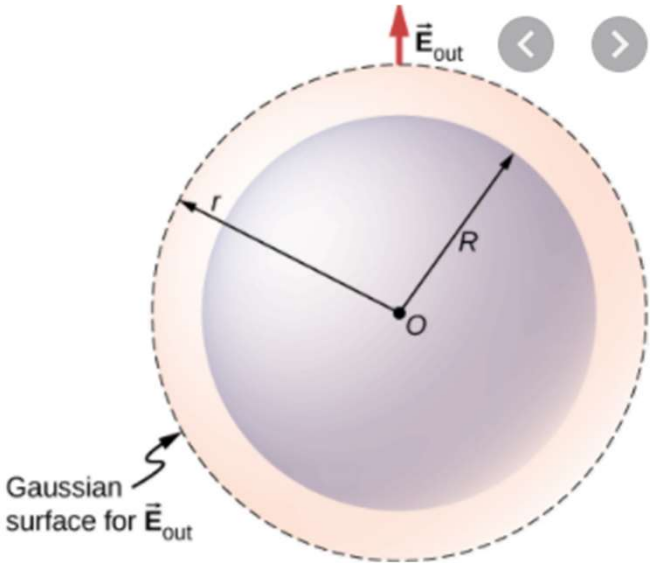
The figure shows a thin spherical shell of radius R with surface charge density σ.

The field at any point P must be radial.



Electric field due to a uniformly charged thin spherical shell or solid conducting sphere

The field at a point outside the shell:-



To find the field at P we take the Gaussian surface to be a sphere of radius r.

According to Gauss's theorem

$$\oint_s \vec{E}.d\vec{s} = \frac{q_{in}}{\varepsilon_0}$$

We have

$$\Rightarrow E = \frac{\sigma 4\pi R^2}{4\pi\varepsilon_0 r^2} = \frac{\sigma}{\varepsilon_0}\frac{R^2}{r^2}$$

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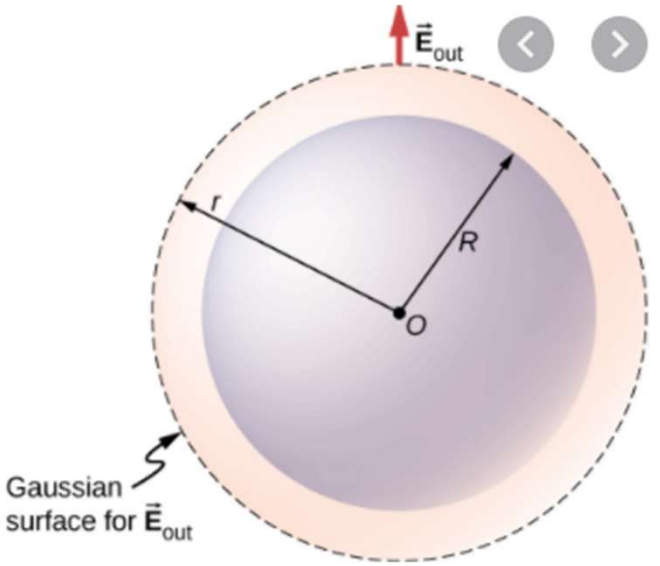
Electric field due to a uniformly charged thin spherical shell or solid conducting sphere

The field on the surface of the shell:-

$$E_{on\ surface} = \frac{1}{4\pi\varepsilon_0}\frac{q}{R^2} = \frac{\sigma}{\varepsilon_0}$$



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Electric field due to a uniformly charged thin spherical shell or solid conducting sphere

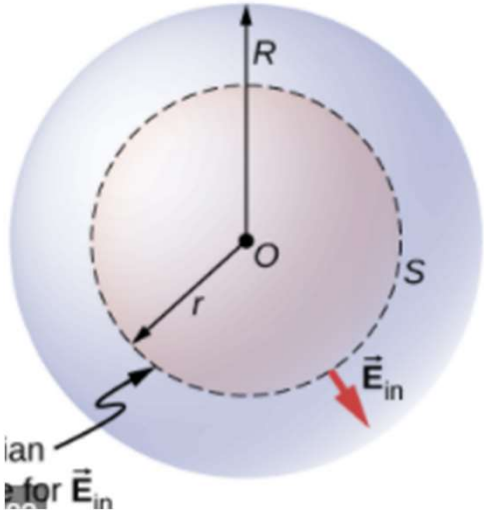
The field at a point inside the shell:-

Applying Gauss's law.

$$\oint_s \vec{E}.d\vec{s} = \frac{q_{in}}{\varepsilon_0} = \frac{0}{\varepsilon_0}$$

$$\Rightarrow \int Eds = 0$$

$$E = 0$$



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POINTS TO REMEMBER

1. The field at a point outside the shell:- $E = \frac{\sigma 4\pi R^2}{4\pi\varepsilon_0 r^2} = \frac{\sigma}{\varepsilon_0}\frac{R^2}{r^2}$

2. Field on the surface of a shell:- $E_{onsurface} = \frac{1}{4\pi\varepsilon_0}\frac{q}{R^2} = \frac{\sigma}{\varepsilon_0}$

3. The field at a point inside the shell:- **E = 0**

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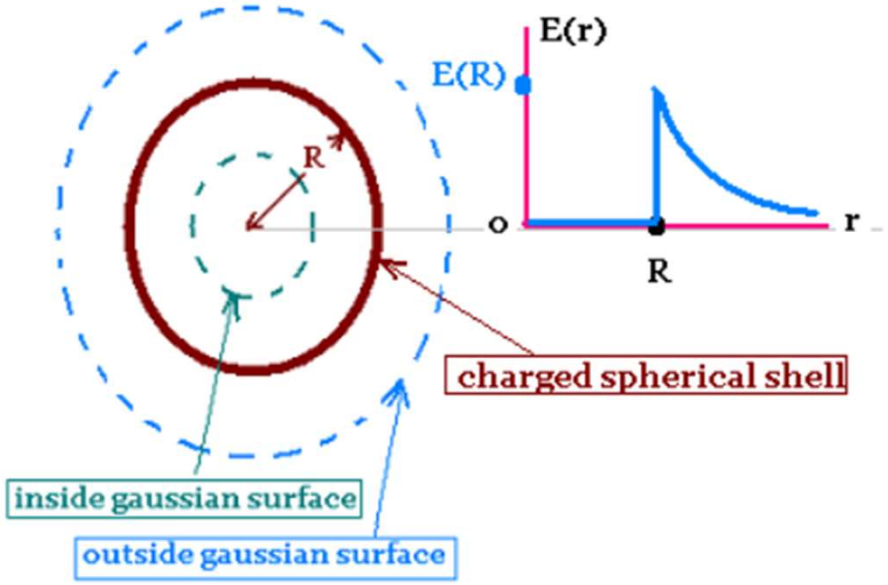
NUMERICAL

1. Draw the graph showing the variation of the electric field with distance r from the center of a uniformly positively charged thin spherical shell



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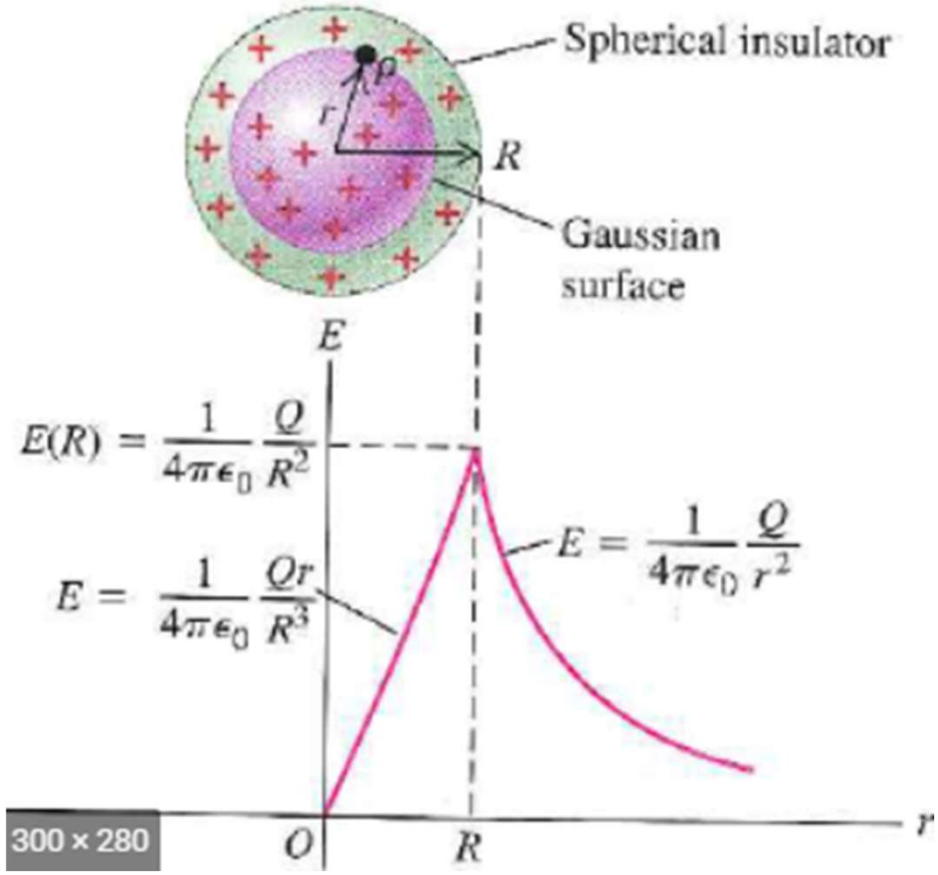
NUMERICAL

1. Draw the graph showing the variation of the electric field with distance r from the center of a uniformly charged non-conducting solid spheres



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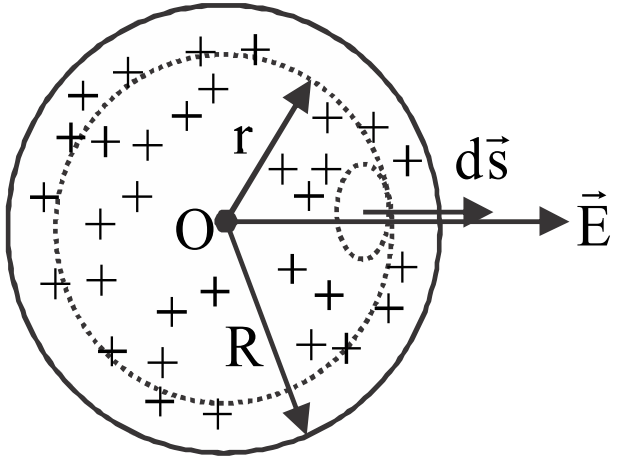
NUMERICAL

1. Inside the surface of a charged non conducting solid sphere prove that, electric field is directly proportional to the distance (r)

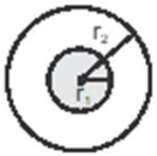


NUMERICAL

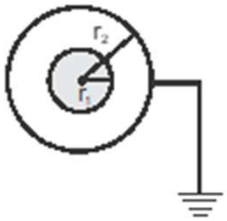
A metal sphere of radius r_1 with charge q is placed at the center of an uncharged thin conducting shell of radius r_2. Find the electric field in the following cases at the position

(a) $r > r_2$ (b) $r_2 > r > r_1$ (c) $r < r_1$

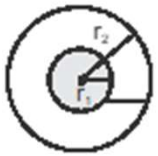
Case – I



Case– II

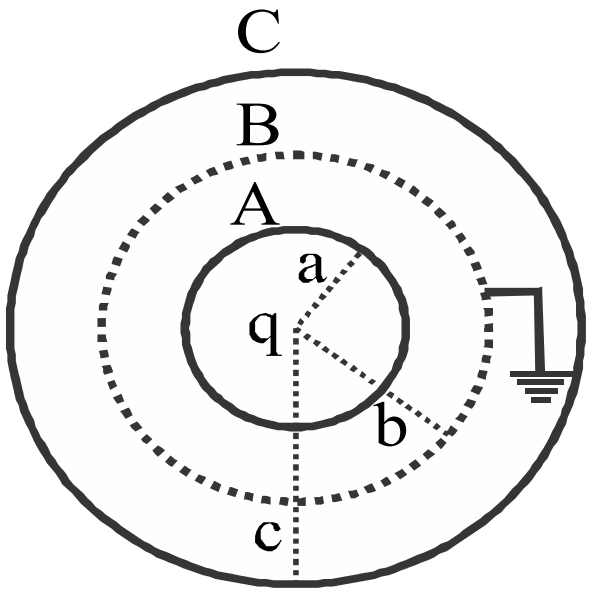


Case – III



NUMERICAL

1. The figure shows three concentric thin spherical shell A, B, and C of radii a, b and c respectively. The shell A and C are given charges q and –q respectively and the shell B is earthed. Find the charge appearing on the surface of B and C



HOME ASSIGNMENT

1. State Gauss's theorem in electrostatics and express it mathematically
2. Derive an expression for electric field due to a uniformly charged thin spherical shell
   (i) Outside the shell
   (ii) (ii) Inside the shell.
3. Electric charge is distributed uniformly on the surface of a spherical rubber balloon. Show how the value of electric field intensity varies
   (i)On the surface
   (ii) inside and
   (iii) outside?
4. Calculate the surface charge density of a spherical cell of radius 'R' having a total uniform charge Q.

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THANKING YOU

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