GIRLS' HIGH SCHOOL AND COLLEGE, PRAYAGRAJ

2020-2021

CLASS – 12 A & B

PHYSICS

ASSIGNMENT – 02

Chapter : GAUSS' THEOREM

Topic : APPLICATIONS OF GAUSS' THEOREM

INSTRUCTIONS : Parents please ensure that your ward/child watches the video instructions for the assignment by clicking on the link : https://youtu.be/jk_NJTC7bDI

https://youtu.be/44360X6zAvI

She is also expected to revise the chapter in the prescribed book, learn it properly and then work on the assignment. Completed assignment is to be downloaded and filed/pasted in the subject file/register and kept ready for submission. The date and procedure of submission shall be notified later.

Answer the following questions:

Q1) What do you mean by a uniform charge distribution?

Q2) How many types of charge distributions are known? Name them.

Q3) What is charge density? Name its types. Define them and give their units.

Q4) When a distribution is infinite, what do we do to apply Gauss' theorem.

Q5) Apply Gauss' theorem to find electric field due to an infinite charged surface at a certain distance from it.

Q6) Write the expression for electric field as obtained above. What are the factors on which it depends?

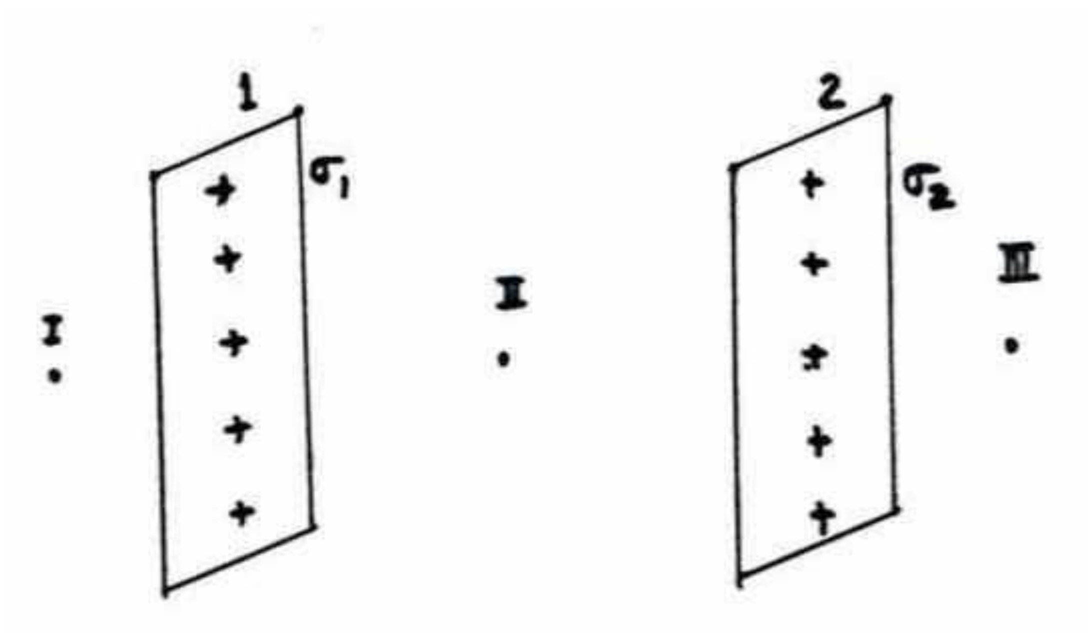
Q7) Is electric field due to an infinite charged surface depending upon the distance from the surface? Explain your answer.

Q8) Show with the help of a neat diagram the electric lines of force due to

a) a positively charged surface

b) a negatively charged surface.

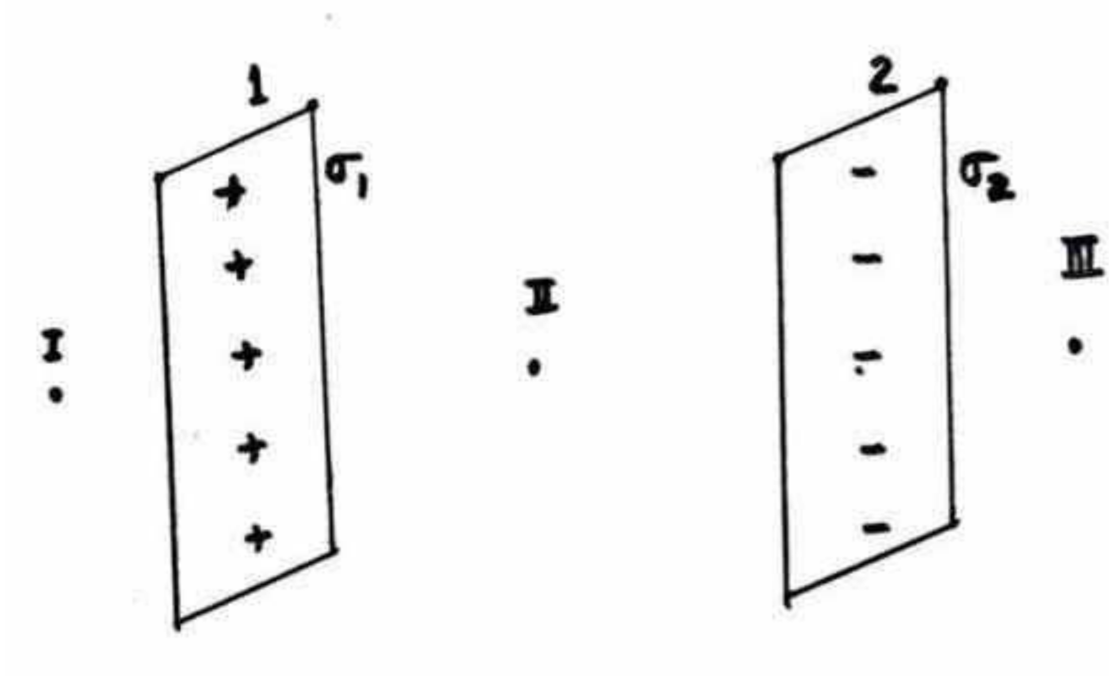
Q9) Look at the figure



There are two parallel plane charged surfaces with charge densities σ_1 and σ_2. Mark electric fields $\overrightarrow{E_1}$ and $\overrightarrow{E_2}$ in each of the regions I, II and III due to surfaces 1 and 2 respectively and hence obtain the expressions for electric field in the region around the two parallel sheets .

Q10) What happens to the field in the above case if both surfaces have the same charge density σ.

Q11) Applying the same method as above obtain the expressions for electric field in and around two parallel but oppositely charged sheets. Note the variation in the directions of electric field when surfaces have different charges.



Mark $\overrightarrow{E_1}$ and $\overrightarrow{E_2}$ as fields for surfaces 1 and 2 respectively and obtain the resultant field in each of the regions I, II and III. Also state what happens if charge densities are same.

Q12) What special do you observe in the electric fields in the different regions around two charged parallel sheets with same charge densities when,

a) they are similarly charged

b) they are oppositely charged

Q13) Two large, thin metal plates are placed parallel and close to each other. Their inner faces have equal and opposite charges with a surface charge density of 17.0×10^{-12} C m^{-2}. What are the magnitudes of electric fields to the left of the plates, to the right of the plates and in between the plates.

Q13) Two large metal plates of area 1.0 m^2 face each other. They are 5.0 cm apart and have equal but opposite charges on their inner surfaces. If the electric field between the plates is 55 NC^{-1} find the charges on the plates.

NOTE : In practical life a thick charged metal plate behaves like two parallel similarly charged sheets with same surface charge density. In that case the field just outside a conductor is σ/ε_0 and inside is zero.

On the other hand a parallel plate capacitor will behave like two parallel oppositely charged plates with same surface charge density i.e they will have the entire field inside the plates will be σ/ε_0 and there will be no field outside.

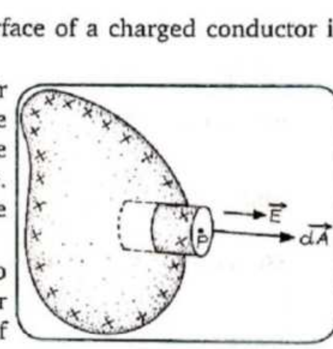
You must know now that the entire charge on a conductor resides on its surface. See the following explanation carefully.

(v) Electric Field Intensity Just Outside a Charged Conductor

Gauss' law can be used to relate the electric field just outside the surface of a charged conductor in equilibrium to the charge distribution on the conductor.

Suppose a positively charged conductor is placed in vacuum or in air (Fig. 14). As it is a conductor, thus the entire charge given to the conductor lies on its surface. The conductor is in equilibrium to the charge distribution therefore the electric field is normal to its surface. However, due to irregular shape of the conductor the surface charge density is different at different places.

Let P be a point near the conductor where electric field intensity is to be evaluated. Let σ be the surface charge density of the conductor near point P. To find the electric field at P, a Gaussian surface in the form of a cylinder is drawn. The one plane end of the closed cylinder contains point P, the other plane end of the cylinder is inside the conductor and is parallel to the front face of the conductor. Let the area of each plane face of the cylinder be A.



(Fig. 14)

Since, the electric field inside a charged conductor is zero and at the entire curved portion of the cylinder $\vec{E}$ and $d\vec{A}$ are at right angles to each other. Therefore, these two surfaces of Gaussian cylinder do not contribute any flux. Thus, the net flux is contributed by the plane face of the cylinder outside the charged conductor. So, the flux through the Gaussian cylindrical surface.

$$\Phi_E = \oint \vec{E} \cdot d\vec{A} = \oint E \cdot dA \cos 0° = E \oint dA$$

or

$$\Phi_E = EA \qquad \ldots(i)$$

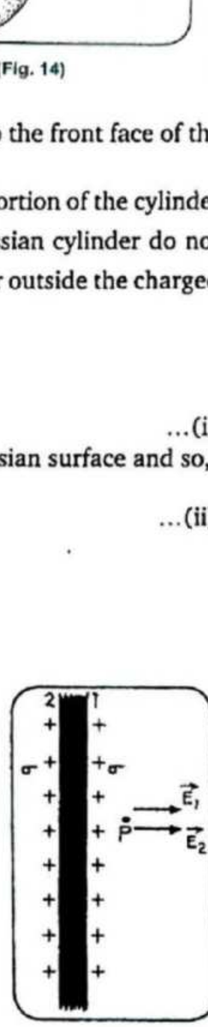
But from Gauss' law, $\Phi_E = q/\varepsilon_0$, where q $(= \sigma A)$ is the net charge enclosed by Gaussian surface and so,

$$\Phi_E = \frac{\sigma A}{\varepsilon_0} \qquad \ldots(ii)$$

Now, from eqs. (i) and (ii), we have

$$EA = \frac{\sigma A}{\varepsilon_0} \quad \text{or} \quad E = \frac{\sigma}{\varepsilon_0}$$

This result is also valid for a large conducting sheet of finite thickness. We can obtain the same result by considering the conducting plates to be formed by two parallel long plane conducting sheets 1 and 2 (Fig. 15).



(Fig. 15)

The magnitude of the field intensity $\vec{E}_1$ at P due to the sheet 1 is

$$E_1 = \frac{\sigma}{2\varepsilon_0} \qquad \text{(away from the sheet 1)}$$

Similarly, the magnitude of the intensity $\vec{E}_2$ at P due to the sheet 2 is

$$E_2 = \frac{\sigma}{2\varepsilon_0} \qquad \text{(away from the sheet 2)}$$

Since, $\vec{E}_1$ and $\vec{E}_2$ are in the same direction, the resultant intensity $\vec{E}$ at P due to both the sheets is given by

$$\vec{E} = \vec{E}_1 + \vec{E}_2.$$

$$\therefore \quad E = \frac{\sigma}{2\varepsilon_0} + \frac{\sigma}{2\varepsilon_0} \quad \text{or} \quad E = \frac{\sigma}{\varepsilon_0}$$

away from the conductor. If the conductor were negatively-charged, E would be directed towards the conductor.

Q14) An isolated conductor of any shape has a net charge of +10 µC. Inside the conductor is a cavity within which is a point charge of +3.0 µc. What is the charge on the cavity wall and the outer surface of the conductor?

Q15) Show that the field just outside a charged conductor is σ/ε_0.

Q16) What do you mean by a spherical shell? What kind of charge distribution will it have?

Q17) If a spherical shell of radius R has Q charge on it then obtain the expression for electric field outside, on and inside the charged spherical shell in terms of its surface charge density.

Q19) How does the shell behave for electric field at points outside the shell.

Q20) On what factors does the electric field due to a charged spherical shell depend?

Q21) Show with the help of a graph how electric field varies with distance from the centre of a charged spherical shell.

Q22) A uniformly charged conducting sphere of 1.2 m radius has a surface charge density of 80.0 $\mu C/m^2$. What is the charge on the sphere and the total electric flux leaving the surface of the sphere?

NOTE : If you observe the behavior of a conductor you will notice the following-

a) its charge resides on its surface

b) electric field inside the conductor is zero

c) electric field on its surface or just outside it is σ/ε_0.

Q24) Compare the behavior of a charged spherical shell with that of a charged conductor.

Q25) The electric field due to a charged conducting sphere of radius 10 cm, at a distance of 20 cm from the centre of the sphere is 1.5×10^3 NC^{-1} and points radially inwards. What is the charge on the sphere?

Q26) A sphere of metal has a radius of 12 cm and carries a charge of 1.6×10^{-7} C distributed uniformly on its surface. Calculate the electric field intensity at a point (i) inside the sphere , (ii) just outside it and (iii) 18 cm from the centre of the sphere.

Q27) For a charged solid sphere, what will be a suitable Gaussian surface.

Q28) Derive an expression for electric field due to a charged solid sphere using Gauss' theorem.

Q29) Graphically represent the variation of electric field with distance from the centre of a charged solid sphere.

END