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AP Physics Review Sheet

Unit 6: Gauss's Law

Unit 6 in Electricity and Magnetism in AP Physics focuses on electric fields and electric flux, highlighting a key concept called "**Gauss's Law**". Gauss's Law relates electric flux within an enclosed surface to the charge it encloses, and will help us calculate electric fields and flux in problems with objects with very high symmetry (spherical, cylindrical, etc).

Major Topics:

I. Electric Flux
    A. Understanding how to calculate and understand the Electric field
II. Gauss's Law
III. Electric fields for symmetric distributions
IV. Charge distribution

Key Vocabulary:

a. *Electric field:* A vector field representing the force per unit charge exerted on a positive test charge
b. *Electric flux*: A measure of the number of electric field lines passing through a surface
c. *Gauss's Law:* A law stating that the net electric flux through a closed surface equals the enclosed charge divided by ε_0
d. *Gaussian surface:* A closed surface used to apply Gauss's Law–chosen based on symmetry
e. *Enclosed charge:* The total electric charge inside a closed Gaussian surface
f. *Electrostatic equilibrium:* A state in which all net movement of charge ceases, and electric fields inside conductors are zero.

Useful Equations:

Electric field from point charge: $E = \frac{kq}{r^2}$

Electric flux through a surface: $\Phi E = E \cdot A = EA\cos\theta$

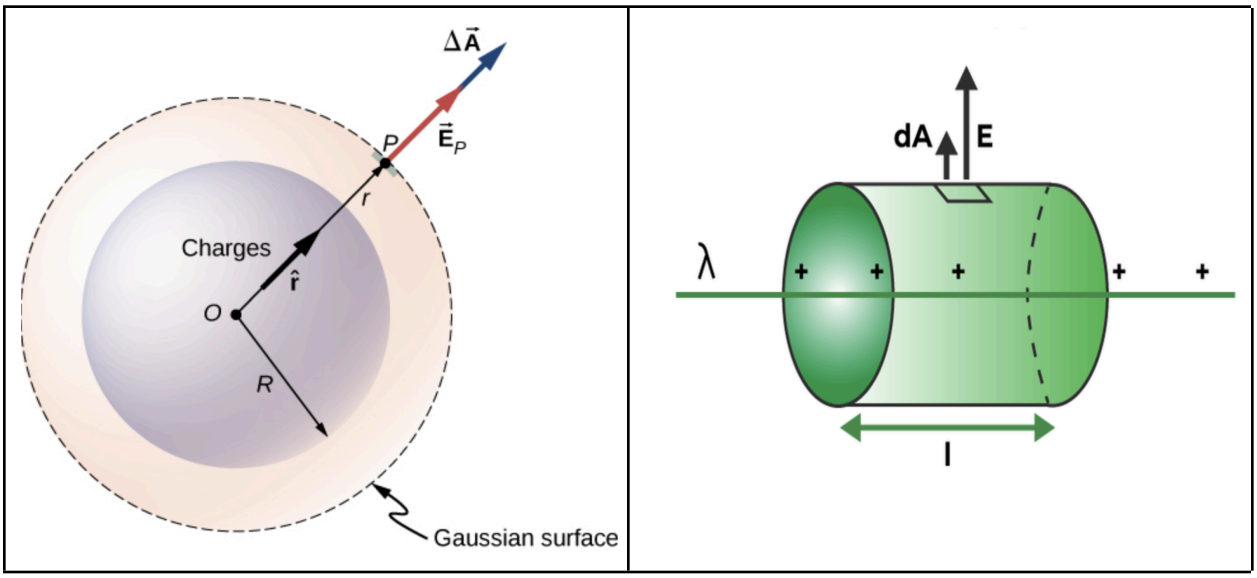
Gauss's Law : $\Phi E = \oint E \cdot dA = \frac{q_{enc}}{\epsilon_0}$

Charge density definition:

Linear: $\lambda = \frac{q}{l}$

Surface: $\sigma = \frac{q}{A}$

Volume: $\rho = \frac{q}{V}$



Practice problems:
(Easy):
Find the electric flux through a rectangular area 3cm×2cm between two parallel plates where there is a constant electric field of 30 N/C for the following orientations of the area: (a) parallel to the plates and (b) perpendicular to the plates

(Medium):
A point charge of 10μC is at an unspecified location inside a cube of side 2 cm. Find the net electric flux through the surfaces of the cube.

(Hard):
A long silver rod of radius 3 cm has a charge of −5μC/cm on its surface. (a) Find the electric field at a point 5 cm from the center of the rod (an outside point). (b) Find the electric field at a point 2 cm from the center of the rod (an inside point).

Work:

(Easy) :

Easy:

knowns:

Area (rectangular):

$A = 3cm \times 2cm = (0.03m)(0.02m) = 6.0 \times 10^{-4} m^2$

Electric field:

$E = 30 N/C$

b) perpendicular (or to plates):

$\theta = 0° \Rightarrow \cos\theta = \cos 0 = 1$

$\Phi_E = EA(1) = (30 N/C)(6.0 \times 10^{-4} m^2) = \boxed{0.018 N m^2/C}$

Electric flux:

$\Phi_E = \vec{E} \cdot \vec{A} = EA\cos\theta$ → between electric field and normal vector (area)

a) Parallel:

$\theta = 90° = \cos 90° = 0$

so $\Phi_E = EA\cos 90° = \boxed{0 N/m^2/C}$

(Medium) :

Medium:

Apply Gauss's Law:

$\Phi_E = \frac{q_{in}}{\varepsilon_0}$ → charge enclosed inside surface

$\varepsilon_0 = 8.854 \times 10^{-12} C^2/N/m^2$

Knowns:

$q_0 = 10 \mu C = 10 e{-}6 C$

Cube side = 2cm

$\Phi_E = \frac{10 e{-}6}{8.854 e{-}12} \approx \boxed{1.13 e6 N m^2/C}$

(Hard) :

Hard:

Known:

Radius of Copper rod: 0.01m

Point of measure: r = 2cm = 0.08m

Electric field at this point E = 3N/C

direction: outward from axis → positively charged

$\varepsilon_0 = 8.854e-12 C^2N/m^2$

a) find charge per unit length λ on the rod

cylindrical Gaussian surface r = 0.02m and length of ℓ

$$E \cdot (2\pi r\ell) = \frac{\lambda \ell}{\varepsilon_0} \Rightarrow E \cdot (2\pi r) = \frac{\lambda}{\varepsilon_0}$$

$\lambda = 2\pi r \varepsilon_0$ $E = 2\pi(0.08)(8.854\times10^{-12})(3)$

$\lambda \propto 2\pi \cdot 0.02 \cdot 8.854\times10^{-12} \cdot 3 \propto 3.34\times10^{-12} C/m$

$\lambda = 3.34\times10^{-12} C/m$

b) find electic flux through cube of side 5 cm:

$\Phi_E = \frac{q_{in}}{\varepsilon_0}$ → enclosed

rod passes perpendicularly through opposite faces of cube

$L = 0.05m$

$q_{enclosed} = \lambda \cdot \ell = (3.34\times10^{-12}) \cdot (0.05) = 1.67\times10^{-13} C$

$$\Phi_E = \frac{q_{in}}{\varepsilon_0} = \frac{1.67\times10^{-13}}{8.854\times10^{-12}} \approx 0.0189 Nm^2/C$$