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Lecture 11 Ch22.1-22-4 Gauss law iq09

1. From Coulomb field of point charge to Gauss law.
2. Field due to charges with spherical symmetry.

   Clicker **11.2**: Pint charge + a thick spherical conduction shell.
3. Field from charges with cylindrical symmetry. Clicker **10-2**.
4. Clicker **11-1**, A spherical shell + a long rod
5. Field due to charges with planar symmetry: Clicker **9-2**
   a. One plate field pattern
   b. Capacitor plate field pattern: Superposition principle
   c. Metal Foil in a capacitor clicker **10-3**.

Class Announcements:

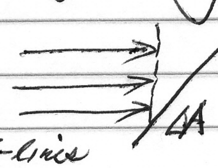
Please go through the physics content of summary-unit 1 page line by line.

Undergrad assistant, "Summer-CA for Chiu"

- We are looking for an undergrad computer assistant who can convert present handwritten classnotes (posted under the link Lectures in our homepage: http://www.ph.utexas.edu/~itiq/303Lsp13/chiu/) into quality editable efiles.
  - The text will be typed in Latex format.
  - The figures will be redrawn using an appropriate free download illustrator application so that each figure is editable.
- The applicant need to submit following documents together with his/her CV application to Lisa Gentry, ugaffairs@physics.utexas.edu The deadline for the application is on Friday, Feb. 15.

1. From Coulomb field of a point charge to G-law.

We first define electric flux.

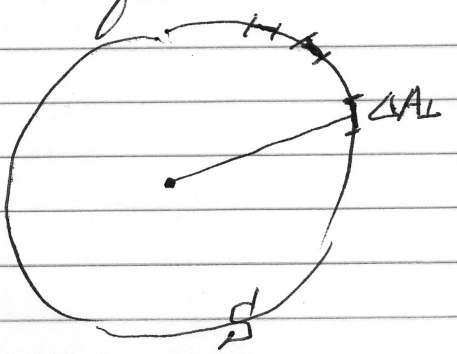


Consider E-lines hitting an area ΔA.

The electric flux through ΔA is defined by

$$\Delta\Phi = E\,\Delta A_\perp .$$

For point charge Q, the total electric flux hitting the spherical surface with radius r is given by



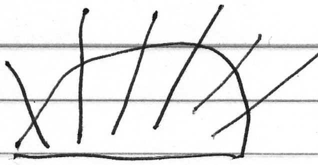
$$\sum_{\text{sphere}} \Delta\Phi = \sum_{\text{sphere}} E\,\Delta A_\perp = E \sum_{\text{sph}} \Delta A_\perp = E\,4\pi r^2 = \frac{kQ}{r^2}\cdot 4\pi r^2 = 4\pi k Q = \frac{Q}{\epsilon_0}.$$

In other words:

Total flux emitted by the point charge $= \frac{Q}{\epsilon_0}$

General statement of Gauss Law. Define Gaussian surface S to be ~~any~~ the surface which encloses the charge then flux emitted thru S equals $\frac{Q}{\epsilon_0}$. Turns S can be of arbitrary shape, Q can be any charge distribution within S.

We have $\Phi_S = \frac{Q_S}{\epsilon_0}$. Porcupine-needles analogy:

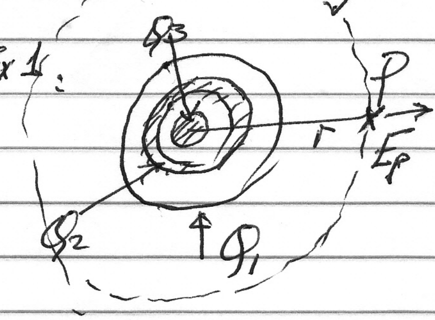


By counting the needle one can determine the size of the porcupine.

GL: Two new ingredients: $\Phi + S$.

2. Field due to charges which have a spherical symmetry.

Ex 1:



Find, E_P.

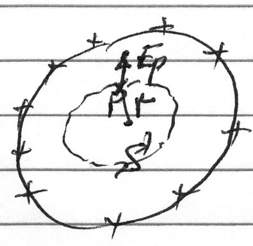
$$\Phi_S = \oint E_P \, dA_\perp = E_P 4\pi r^2 = \frac{Q_1+Q_2+Q_3}{\epsilon_0}$$

$$\therefore E_P = \frac{(Q_1+Q_2+Q_3)}{4\pi\epsilon_0 r^2}$$

So long as it is spherically symmetric $E_P = \frac{k(Q_1+Q_2+Q_3)}{r^2}$.

$r<R$:

Ex2



$E_P = 0$. Proof:-

Thru P, draw Gaussian surface S

$$E_P 4\pi r^2 = \frac{Q_S}{\epsilon_0} = 0 \Rightarrow E_P = 0.$$

Clicker 11-2 Given: Q at O. Surface charges on the thin metal shell. Inner surface: Q', outer surface Q''. [Proof there is no charge in the interior of the conducting shell, charges can only reside on the surface)

11-2a. $Q_S = ?$ $\oint_S E \Delta A_\perp = ?$ Why must it be 0

11-26. Determine Q' and Q''. Assume net charge on conducting shell is Q_1

Gauss Law: $\Phi_S = 0 = \frac{Q + Q'}{\epsilon_0}$ $\therefore Q' = -Q$,

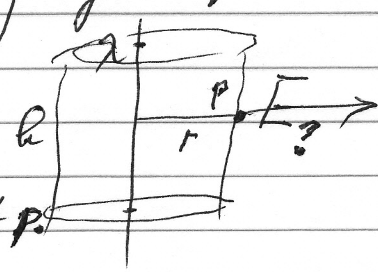
What is Q''? Ans: $Q' + Q'' = Q_1$, $Q'' = Q_1 - Q' = Q_1 +$

$\therefore$ Ans = choice 1.

GL with Cylindrical Symmetry:

Given: Long uniformly charged

$$\lambda = \frac{\Delta Q}{\Delta y}$$



Find: Field at P.

Gaussian surface — Cylinder through P

$E_?$ radially outward

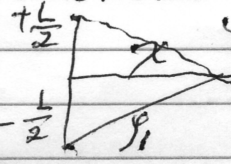
$$\oint_S = \oint E_? \, dA_\perp = \frac{Q_s}{\epsilon_0}$$

$$E_? \oint dA_\perp = h\, 2\pi r\, E_? = \frac{\lambda h}{\epsilon_0}$$

$$\therefore E_? = \frac{\lambda}{2\pi r \epsilon_0} \qquad \text{Ans} = 2$$

Agree with integration result for $\frac{L}{2} \gg R$.

$$E_X = \frac{k\lambda L}{x\, \rho_1}$$

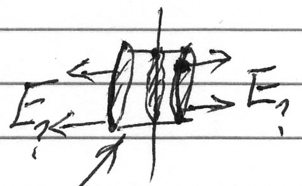


$$\frac{k\lambda}{x} \cdot \frac{L}{\left(\frac{L}{2}\right)} = \frac{2k\lambda}{r} = \frac{1}{2\pi\epsilon_0} \cdot \frac{\lambda}{r}$$

5. Planar symmetry one plate:

~~From analytic integration results we have~~

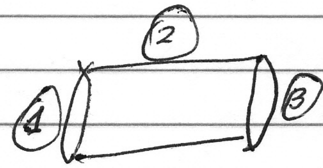
$$E_x = \frac{\sigma}{2\epsilon_0} = \frac{\Delta Q/\Delta A}{2\epsilon_0}$$



ΔQ in the shaded area

ΔA: Ends of the cylinder

Gaussian Surface S



$$\Phi_S = \frac{Q_S}{\epsilon_0}$$

$\Phi = EA_\perp \Rightarrow \Phi_S = \Phi_1 + \Phi_2 + \Phi_3 = 2E_? \Delta A = \frac{\Delta Q}{\epsilon_0}$

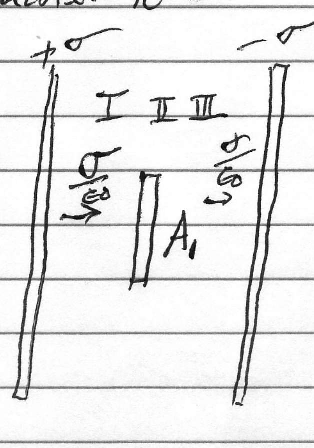
$\Phi_1 = E_? \Delta A$, $\Phi_2 = 0$, $\Phi_3 = E_? \Delta A$

$E \perp$ to ΔA

$\therefore E_? = \frac{\Delta Q/2\Delta A}{\epsilon_0} = \frac{\sigma}{2\epsilon_0}$

There is no field which passes thru ΔA

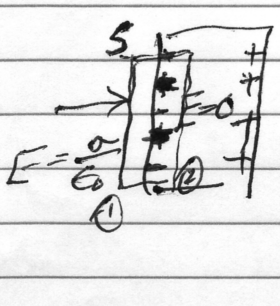
Clicker 10-3



Without foil: $\frac{\sigma}{\epsilon_0}$ throughout

With foil $\Phi_S = \frac{Q_S}{\epsilon_0}$

① + ②



$$\frac{\sigma}{\epsilon_0} A_1 + 0 = \frac{q_{left}}{\epsilon_0}$$

$q_{left} = \sigma A_1$ Ans = 1