Physics 202, Lecture 4

Today's Topics

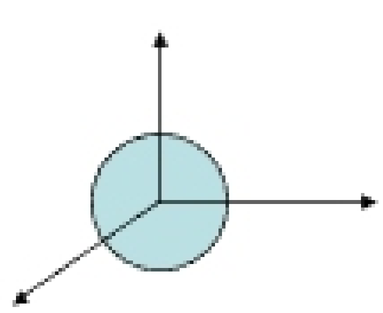
- Review: Gauss's Law
- Electric Potential (Ch. 25-Part I)
  - Electric Potential Energy and Electric Potential
  - Electric Potential and Electric Field
- Next Tuesday: Electric Potential (Ch. 25-Part II)
- Homework #1 due tomorrow (9/14) at 10 PM
  Homework #2 (now on WebAssign) due 9/24 at 10 PM

Gauss's Law: Review

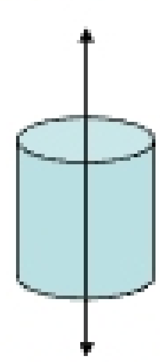
$$\Phi_E = \oint \vec{E} \cdot d\vec{A} = \frac{\sum q_{in}}{\varepsilon_0}$$

Fundamental equation of electrostatics
(equivalent to Coulomb's Law)

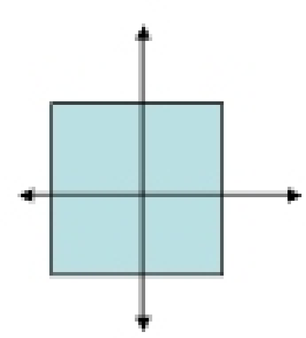
Can use it to obtain E for highly symmetric charge distributions.
Method: evaluate flux over carefully chosen "Gaussian surface":



spherical
(point chg, uniform sphere, spherical shell,…)



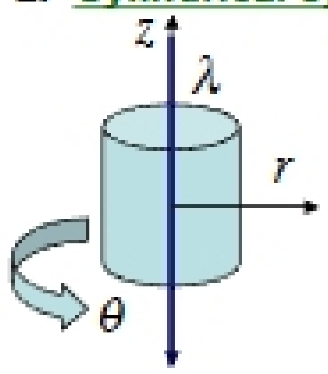
cylindrical
(infinite uniform line of charge or cylinder…)



planar
(infinite uniform sheet of charge,…)

Gauss's Law: Examples

1. Spherical symmetry (last lecture).
2. Cylindrical symmetry. Example: infinite uniform line of charge.



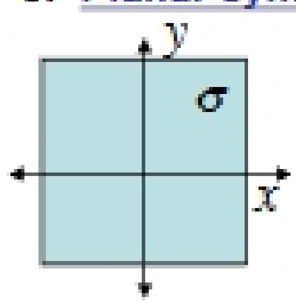
Symmetry: E indep of z, θ, in radial direction

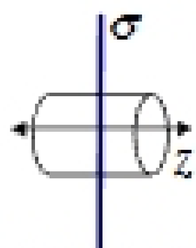
Gaussian surface: cylinder of length L

$$\oint \vec{E}\cdot d\vec{A} = E(r)2\pi rL = \frac{q_{in}}{\varepsilon_o} = \frac{\lambda L}{\varepsilon_o}$$

$$\Rightarrow \vec{E}(r) = \frac{\lambda}{2\pi\varepsilon_o r}\hat{r}$$

3. Planar symmetry. Example: infinite uniform sheet of charge.





Symmetry: E indep of x,y, in z direction

Gaussian surface: pillbox, area of faces=A

$$\oint \vec{E}\cdot d\vec{A} = 2EA = \frac{q_{in}}{\varepsilon_o} = \frac{\sigma A}{\varepsilon_o} \Rightarrow \vec{E} = \frac{\sigma}{2\varepsilon_o}\hat{z}$$

Exercise: try for E field just outside of a conductor

Electric Potential Energy and Electric Potential

Review: Conservation of Energy (particle)

- Kinetic Energy (K) $K = \frac{1}{2}mv^2$
- Potential Energy U: conservative forces (work independent of path) $U(x,y,z)$
- If only conservative forces present in system, conservation of mechanical energy: $K + U =$ constant
- Examples of conservative forces:
  - Springs: elastic potential energy $U = k_{spring}x^2/2$
  - Gravity: gravitational potential energy
  - Electrostatic: electric potential energy (today)
- Examples of nonconservative forces
  - Friction, viscous damping (terminal velocity)

Electric Potential Energy (I)

Compare with gravitational force (Ch. 13):

$$\vec{F}_{12} = -G\frac{m_1 m_2}{r^2}\hat{r}_{12} \Rightarrow W = \int_{path} \vec{F} \bullet d\vec{s} = \frac{Gm_1 m_2}{r_f} - \frac{Gm_1 m_2}{r_i}$$

path independent!

➔ Gravitational Potential energy:

$$U = -\frac{Gm_1 m_2}{r}$$

- Electric Force:

$$\vec{F}_{12} = k_e\frac{q_1 q_2}{r^2}\hat{r}_{12}$$

Electric Potential Energy

$$U = \frac{k_e q_1 q_2}{r}$$

Electric Potential Energy (II)

Given two positive charges q and q_0:

Initially charges very far apart: $U_i = 0$

(we are free to define the potential energy zero somewhere)

To push particles together requires work (they want to repel).

Final potential energy will increase! $\Delta U = U_f - U_i = \Delta W$

Now, suppose q is fixed at the origin. What is work required to move q_0 from infinity to a distance r away from q?

$$\Delta W = \int_{\infty}^{r} \vec{F}_{us} \bullet d\vec{s} = -\int_{\infty}^{r} \vec{F}_e \bullet d\vec{s} = -\int_{\infty}^{r} \frac{k_e q q_0}{r'^2} dr' = \frac{k_e q q_0}{r}$$

Note: if q negative, final potential energy negative

Particles will move to minimize their final potential energy!