PHYS 1444 – Section 003
Lecture #5

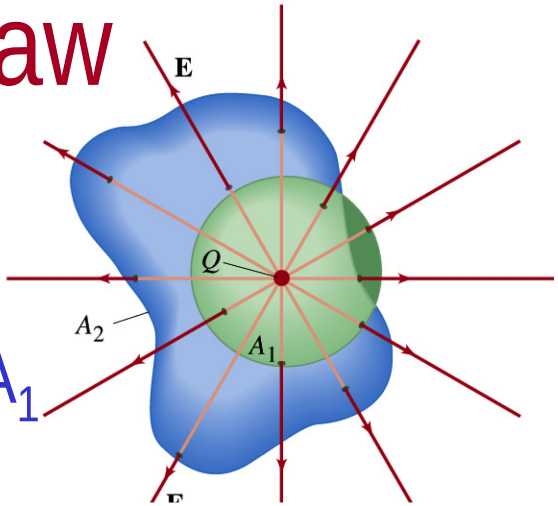
Wednesday, Sept. 14, 2005
Dr. Jaehoon Yu

- Gauss' Law
- How are Gauss' Law and Coulom's Law Related?
- Electric Potential Energy
- Electric Potential

Announcements

- I have all but 10 of you, of which 5 on the distribution list, sent me confirmation.
  - The other five are not on the distribution list.
- Extra credit opportunities
  - Attend two Einstein lectures and get your flier signed by the lecture: 5 extra credit each
    - One today at noon on the 6th floor central library
    - The other at 2pm Thursday in NH 100.
  - 15 point extra credit for presenting a professionally prepared 3 page presentation on any one of the exhibits at the UC gallery (till 9/16) and the subsequent themed displays at the central library.
    - Must include what it does, how it works and where it is used. Possibly how it can be made to perform better.
    - Due: Oct. 19, 2005

Gauss' Law from Coulomb's Law Irregular Surface



- Let's consider a single point static charge Q surrounded by a symmetric spherical surface A_1 and a randomly shaped surface A_2.
- What is the difference in the number of field lines passing through the two surface due to the charge Q?
  - None. What does this mean?
    - The total number of field lines passing through the surface is the same no matter what the shape of the enclosed surface is for the same enclosed charge.
  - So we can write: $$\oint_{A_1} \vec{E}\cdot d\vec{A} = \oint_{A_2} \vec{E}\cdot d\vec{A} = \frac{Q}{\varepsilon_0}$$
  - What does this mean?
    - The flux due to the given enclosed charge is the same no matter what the surface enclosing it is. ➔ Gauss' law, $\oint \vec{E}\cdot d\vec{A} = \frac{Q}{\varepsilon_0}$, is valid for any surface surrounding a single point charge Q.

Gauss' Law w/ more than one charge

- Let's consider several charges inside a closed surface.
- For each charge, Q_i, enclosed by the chosen surface,

$$\oint \vec{E}_i \cdot d\vec{A} = \frac{Q_i}{\varepsilon_0}$$

What is $\vec{E}_i$?

The electric field produced by Q_i alone!

- Since electric fields can be added vectorially, following the superposition principle, the total field E is equal to the sum of the fields due to each separate charge $\vec{E} = \sum \vec{E}_i$. So

$$\oint \vec{E} \cdot d\vec{A} = \oint \left(\sum \vec{E}_i\right) \cdot d\vec{A} = \sum \frac{Q_i}{\varepsilon_0} = \frac{Q_{encl}}{\varepsilon_0}$$

What is Q_{encl}?

The total enclosed charge!

- Gauss' law follows from Coulomb's law for any distribution of electric charge enclosed within a closed surface of any shape.

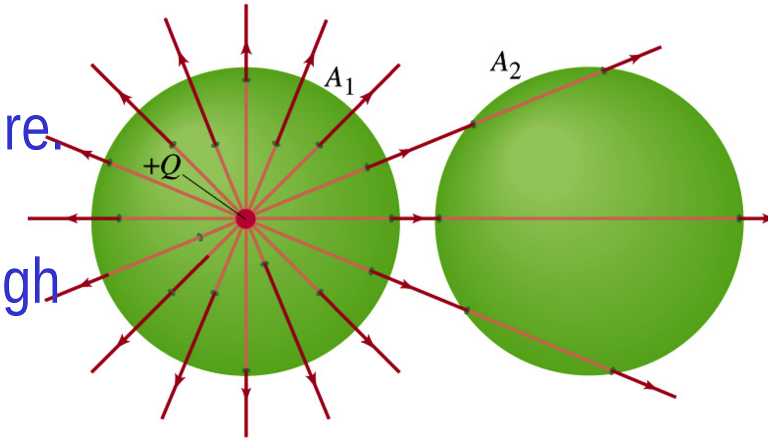
So what good is Gauss' Law?

- Derivation of Gauss' law from Coulomb's law is only valid for static electric charge.
- Electric field can also be produced by changing magnetic fields.
  - Coulomb's law cannot describe this field while Gauss' law is still valid
- Gauss' law is more general than Coulomb's law.
  - Can be used to obtain electric field, forces or obtain charges

Gauss' Law: Any **difference** between the input and output flux of the electric field over any enclosed surface is due to the charge within that surface!!!

Example 22 – 2

Flux from Gauss' Law: Consider the two gaussian surfaces, A_1 and A_2, shown in the figure. The only charge present is the charge Q at the center of surface A_1. What is the net flux through each surface A_1 and A_2?



- The surface A_1 encloses the charge +Q, so from Gauss' law we obtain the total net flux

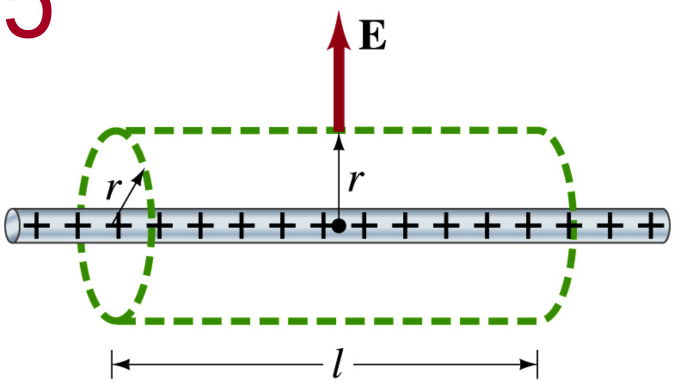
$$\oint \vec{E} \cdot d\vec{A} = \frac{+Q}{\varepsilon_0}$$

- The surface A_2 the charge, +Q, is outside the surface, so the total net flux is 0.

$$\oint \vec{E} \cdot d\vec{A} = \frac{0}{\varepsilon_0} = 0$$

Example 22 – 5

Long uniform line of charge: A very long straight wire possesses a uniform positive charge per unit length, λ. Calculate the electric field at points near but outside the wire, far from the ends.



- Which direction do you think the field due to the charge on the wire is?
  - Radially outward from the wire, the direction of radial vector r.
- Due to cylindrical symmetry, the field is the same on the gaussian surface of a cylinder surrounding the wire.
  - The end surfaces do not contribute to the flux at all. Why?
    - Because the field vector E is perpendicular to the surface vector dA.
- From Gauss' law

$$\oint \vec{E} \cdot d\vec{A} = E \oint dA = E\left(2\pi r l\right) = \frac{Q_{encl}}{\varepsilon_0} = \frac{\lambda l}{\varepsilon_0}$$

Solving for E

$$E = \frac{\lambda}{2\pi\varepsilon_0 r}$$

Electric Potential Energy

- Concept of energy is very useful solving mechanical problems
- Conservation of energy makes solving complex problems easier.
- When can the potential energy be defined?
  - Only for a conservative force.
  - The work done by a conservative force is independent of the path but only dependent on??
    - The difference between the initial and final positions
  - Can you give me an example of a conservative force?
    - Gravitational force
- Is the electrostatic force between two charges a conservative force?
  - Yes. Why?
  - The dependence of the force to the distance is identical to that of the gravitational force.