First homework is due tomorrow THURSDAY 11:59PM – Sept 13th

BEFORE CLASS: come down and play with
• the electrostatic plastic sticks (rub hard with the wool!)
• the charged balloon near the van de Graaff – explore the electric field

Get your iclicker device or app ready to roll

Course web site
http://www.physics.rutgers.edu/~karin/227H
Field due to known distribution of charges

Forces on charged particles and dipoles in uniform field (need to explicitly say something about the moving charge) PHET for this?

Reformulation of Coulomb’s law = Gauss’ Law

Closed surfaces, electric flux through a surface
Reformulation of law of physics

Charge distribution determines field
Field determines charge distribution
Partial info about field gives partial information about charge distribution

Surface
Flux – “mathematics” of the surface integral
Field line counting

Show Gauss law equivalent to Coulomb law for a point charge
Symmetry for spherically symmetric case
Concentric shells – instant derivation of shell theorem

Intro to conductor – electrostatics – field is zero inside
Surface charge define -- arranges according to rule
Spherical case, spherical cavity, everything concentric
Relatively easy to understand using Gauss law
First apply to spheres but not concentric Cylinder/wire planes

More on conductors – general shape charge arranges according to rule Electric field just outside surface

End with Faraday cage demo
The Electric Field due to a Continuous Charge: Example

Thin wire of length L has total charge Q distributed uniformly. Find $E_x$ and $E_y$ at any point $x>L$.

Define a linear charge density: $\lambda = Q/L$

d$E_y = 0$ so $E_y = 0$
d$E_x = k \frac{dq}{r^2} = k \lambda \frac{ds}{(x-s)^2}$ integrate from $s=0$ to $s=L$

$E_x = k \lambda \frac{L}{x(x-L)}$

LINE INTEGRAL over curve $\vec{c}(s) = (s,0)$ with $0 \leq s \leq L$
The Electric Field due to a Continuous Charge: Example

A uniformly charged wire of total charge $Q$ is bent into semicircle of radius $R$. Find $E_x$ and $E_y$ at center.

Define charge density $\lambda = Q/\pi R$ so that element $ds$ of the wire has charge $dq = \lambda ds$.

Parametrize curve by $\theta$.

Integrate $dE_x = (k\lambda R d\theta / R^2)(-\cos \theta)$ from $\theta = \pi/2$ to $\theta = 3\pi/2$.

$E_y = 0$

$E_x = 2k\lambda / R$ (to the right).
Electric field of uniformly charged ring on its central axis

For $z \gg R$, looks like point charge $q$

$$E_x = E_y = 0$$

$$E_z = \frac{k q z}{(z^2 + R^2)^{3/2}}$$

For $z \gg R$, looks like point charge $q$
Electric field of uniformly charged spherical shell
The uniform electric field $\vec{E}(\vec{r}) = \vec{E}$
Given a uniform electric field \( E \), how will charge \( q \) move? Charge will feel force \( F = qE \) (same force for all positions). \( F = ma \), so \( a = \frac{F}{m} = \frac{qE}{m} \) (constant acceleration).
Clicker test

What device are you using to answer the clicker question?
(A) an iClicker
(B) the iClicker app on my smartphone
(C) the iClicker app on my laptop
The charge on the green particle in the figure is
(a) Positive
(b) Negative
(c) Zero
(d) There is not enough information to determine its charge
(e) If I put any of the other answers I would be just guessing
Given a uniform electric field $E$, how will charge $q$ move? Charge will feel force $F = qE$ (same force for all positions) $F = ma$, so $a = \frac{F}{m} = \frac{qE}{m}$ (constant acceleration).

For example:

$E = 10 \text{ N/C}$ and $v_{0x} = 5 \times 10^5 \text{ m/s}$

Find vertical deflection $y$ of electron after 4 cm

$y(t) = \frac{1}{2}a t^2$

$y(x) = \frac{1}{2}a \left(\frac{x}{v_{0x}}\right)^2$
Force on dipole in uniform field
Force on dipole in uniform field is ZERO.

Torque on dipole in uniform field.
Charge distribution determines electric field sum, line integral, surface integral, volume integral

--shouldn’t there be an easier way to prove the shell theorem?
--does the electric field determine the charge distribution?
--how do you find the charge distribution from the electric field?
Charge distribution determines electric field
sum, line integral, surface integral, volume integral

--shouldn’t there be an easier way to prove the shell theorem?
--does the electric field determine the charge distribution?
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REFORMULATION OF COULOMB’S LAW

\[ \oint \vec{E} \cdot d\vec{A} = q_{\text{enc}}/\varepsilon_0 \]  GAUSS’ LAW
Chapter 23

Gauss’ Law
What is a surface?

A surface is a set of points in three-dimensional space satisfying one equation (and optionally some inequalities)

\{(x,y,z) \text{ such that } z = 1\} \text{ (plane)}
\{(x,y,z) \text{ such that } x^2+y^2+z^2 = 100\} \text{ (sphere)}
\{(x,y,z) \text{ such that } z = 1 \text{ and } x^2+y^2 \leq 100\} \text{ (disk)}

Open surface: has a boundary

Closed surface: has no boundary, has an inside and an outside
What is the right hand side?

$q_{\text{enc}}$ is the NET charge inside the closed surface $S$

$\varepsilon_0 = 1/(4 \pi k)$ or $k = 1/(4 \pi \varepsilon_0)$

“permittivity of free space”
What is the left hand side?

“Electric flux” through closed surface $S$

\[ \oint E \cdot dA = \frac{q_{enc}}{\varepsilon_0} \]
Flux of a vector field $\vec{F}(\vec{r})$ through surface

simplest case:
- flat open surface of area $A$ and normal vector $\hat{n}$
- vector field $\vec{F}(\vec{r}) = \vec{F}$ is the same at all points on the surface

Flux $\Phi = (\vec{F} \cdot \hat{n})A$

Recall fluid flow
If $\vec{F}(\vec{r}) = \vec{v}$, then $\Phi$ would be the flow rate through the flat surface (volume/time)
Flux of a vector field $F(r)$ through **closed** surface

**simplest case:**
- **Cube:** 6 flat surfaces of area $A$
- $\hat{n}$ points from inside to outside
- vector field $F(r) = F$ which is the same at all points on the surface

$$\text{Flux } \Phi = \sum (F_i \cdot \hat{n}_i) A_i$$

Recall fluid flow
If $F(r) = \nu$, then $\Phi$ would be the net flow rate into/out of the enclosed region
\( \vec{E} = E \hat{z} \)

Front surface
\( \hat{n} = \hat{z} \)
\( \vec{E} \cdot \hat{n} = E \)

Multiply by \( A \) to get \( EA \)

Side surfaces
\( \vec{E} \cdot \hat{n} = 0 \)

Back surface
\( \hat{n} = -\hat{z} \)

contribution is \( -EA \)

Flux integral is \( EA - EA = 0 \)

CHECKPOINT 1

The figure here shows a Gaussian cube of face area \( A \) immersed in a uniform electric field \( \vec{E} \) that has the positive direction of the \( z \) axis. In terms of \( E \) and \( A \), what is the flux through (a) the front face (which is in the \( xy \) plane), (b) the rear face, (c) the top face, and (d) the whole cube?