Physics 152
Lecture 19

• Dipole in E Field
• Conductors in E Fields
• Electric Flux

Announcements

• Help sessions
  • W 9 - 10 pm in NSC 119
  • MasteringPhysics
  • WU #11 due Wednesday
• No class on Friday, March 2

Announcements

Worksheet Problem #1

Dipole Torque

Although the electric dipole does not experience a net force in a uniform external field, case (d) does result in a torque.

\[ \vec{\tau} = \vec{p} \times \vec{E} \]

No torque if dipole moment is parallel or anti-parallel to the field.

Ch. 26: The Electric Field

Chapter 27

Gauss’ Law

Applying the field model to electrostatics, we can predict the behavior of charges when placed in the field. We’ll look at the fields associated with a variety of charge distributions.

Conductors in Electric Fields

What happens to a conductor when you place it in an electric field and allow the charges on it to attain equilibrium?

(Remember, charges are free to move around on the surface of conductors.)
1) no electric field exists inside conductor.

What if it did?

- Then an electrical force would be exerted on
  the charges present in the conductor.
- In a good conductor, charges are free to
  move around, and will when a force is
  exerted on them.
- If charges are moving around, we are not in
  equilibrium.

Contradiction!

2) Excess charges on an isolated conductor
   are found entirely on its surface.

The $1/r^2$ nature of the electrostatic repulsive
force is responsible for this one. The excess
charges are trying to get as far away from
one another as possible. It turns out,
therefore, they all end up on the surface of
the conductor.

3) The electric field just outside of a conductor
   must be perpendicular its surface.

Again, what if this were not the case?

Then a component of the electric field would
exist along the conductor’s surface. This would
yield an electrical force along the surface. As a
good conductor, charges would move around in
the presence of the force.

Contradiction!

4) On an irregularly shaped conductor,
   charges build up near the points (regions
   with smallest curvature).

Charges build up here: in order to satisfy
boundary condition of perpendicular $\mathbf{E}$
at surface and $\mathbf{E} = 0$ inside.

Flux in general: How many of SOMETHING
pass through a given area in a given time.

Demo with paper wads.
The “flux” of blue wads is simply the number that pass through the loop in a given amount of time. All the wads within a distance \( d = vt \) of the loop can pass through the hoop in time \( t \).

If we know the density, \( \rho \), of the blue wads, we can compute the number, \( N \), that pass through the hoop in time \( t \) as

\[
N = \rho A v t
\]

What if the surface is NOT perpendicular to the direction of motion of the blue wads? Clearly, fewer wads will make it through the loop. By how many fewer?

The direction normal (i.e., perpendicular to the plane of the loop). The direction of motion of the blue wads.

The controlling area for the flux is going to be the area that is perpendicular to the moving blue wads. By geometry, we see that it is

\[
A_{\text{eff}} = A \cos \theta
\]

Generally, we can write our flux of blue wads as

\[
N = \rho A_{\text{eff}} v t
\]

or

\[
N = \rho A(\cos \theta) v t
\]
Now, just change out the flying blue wads for electric field lines.

\[ \Phi = \mathbf{E} \cdot \mathbf{A} \cos \theta \]

\[ |\Phi| = |\mathbf{E}| |A| |\cos \theta| \]

\[ |\Phi| = (N/C)(m^2) \]

\[ |\Phi| = N \text{ m}^2/C \]

Worksheet Problem #2

This formulation of electric flux works great for simple, planar surfaces, but what if the surface through which we wish to compute the flux is warped through 3D?

Well, you can always break up such a surface into a bunch of little, infinitesimal surfaces of area \( dA \), each of which is flat and has its own normal direction and angle with the electric field, then integrate over all such little \( dA \)'s.

What is the electric flux through a sphere of radius \( r \) centered on a point charge of magnitude \( q \)?

We know that the electric field of a point charge is
The electric field is constant everywhere on our spherical surface and pointed radially outward. It therefore can be passed through the integral.

\[
\hat{n} \cdot q = \vec{E} \cdot dA
\]

\[
\sum dA = \text{SURFACE AREA of the sphere.}
\]

\[
E = kq \hat{r} \frac{r^2}{4}
\]

What is the electric flux through a sphere of radius \( r \) centered on a point charge of magnitude \( q \)?

The result tells us that it doesn’t matter how large a sphere we examine, the flux through the sphere is always the same! That makes good sense.

Since the electric field lines are radial, the number which pass through all spheres centered on the charge is the same, regardless of the radius of the sphere itself!