Physics 152

Lecture 32

- Biot-Savart Law
- Parallel wires
- Current loop fields

Monday, April 16, 2007

Announcements

- Help sessions
  - W 9 - 10 pm in NSC 119
- MasteringPhysics
  - WU #21 due Fri., April 20
  - Rework #2 due Fri., April 20

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Ch. 32: The Magnetic Field

Worksheet Problem #1

Concept Quiz!

B & E Review

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Ch. 32: The Magnetic Field

Let's start by looking at the magnetic field generated by a small current-length element along a current carrying wire. We want to know the field at this location. 

\[ \vec{B} = \frac{\mu_0 I ds}{4\pi r^2} \sin \theta \]

And by the RH Rule, we know the direction of this field is into the page.

We want to know the field at this location.

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Ch. 32: The Magnetic Field

In a procedure analogous to our approach to the electric field due to a charge, we can guess a form for the magnetic field produced by this current-length element.

\[ I \hat{\sigma} \]

By experiment, we can determine the constant \( k_m \) and find it to be \( \mu_0 / 4\pi \). Rewriting the equation in vector form, we get

\[ d\vec{B} = \frac{\mu_0 I ds \times \hat{r}}{4\pi r^2} \]

We want to know the field at this location.

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Ch. 32: The Magnetic Field

The Biot-Savart Law

We want to know the field at this location.
Now, to get the whole field at point P, we just integrate the contribution from all current-length elements along the length of the wire.

\[ \vec{B} = \frac{\mu_0}{4\pi} \frac{lds \times \hat{r}}{r^2} \]

WARNING: The surgeon general has determined that the execution of such an integral may be hazardous to your health.

However, let us try to do this for a simple case: a very long, straight wire.

\[ \vec{B} = \int \frac{\mu_0}{4\pi} \frac{lds \times \hat{r}}{r^2} \]

First, we note that regardless of where I am along the wire, the current-length element contributes a \( dB \) that points into the page.

\[ \int l ds \]

\( dB \)

Axis of symmetry

So I can integrate from 0 to infinity and multiply my result by 2.

Let’s zoom in on the geometry

The magnetic field is a vector quantity, so it has a direction!!!!!
Worksheet Problem #2

Ch. 32: The Magnetic Field

Lecture 32
Phys 152

Two very long, parallel wires carry current in the same direction. The force exerted by the top wire on the bottom wire is...

1) attractive  
2) repulsive  
3) zero  
4) Need more information.

Worksheet Problem #3

Two very long, parallel wires carry current in the same direction. Determine force per unit length that the top wire exerts on the bottom wire given the geometry below.

Worksheet Problem #4

But what if the wire isn’t a very long, straight wire? What if it’s a loop of wire instead?

The magnetic field of such a current loop looks a lot like the field of a bar magnet! That also gives us some idea of how magnetic fields get generated in the first place.

Worksheet Problem #5

Predict the shape of the magnetic field in the space between two such current loops.

Worksheet Problem #6

But what if the wire isn’t a very long, straight wire?

Determine the magnetic field at the center of a current loop.
Now, let's look at the magnetic field created by a whole bunch of such loops combined...AKA

The Solenoid

\[ \mathbf{B}_{\text{inside}} = \mu_0 n I \]

where \( n \) is the number of turns per unit length of the solenoid.

\textbf{Solenoids} produce fairly uniform magnetic fields inside their boundaries, and generate negligible fields outside their boundaries.

The magnetic field is directed parallel to the axis of the solenoid. The right hand rule for currents will help you determine toward which end the field points.