BEFORE CLASS: Pick up graded HW5
8th HOMEWORK ASSIGNMENT IS DUE IN CLASS NEXT MONDAY
next will be WED after spring break

class web site
http://www.physics.rutgers.edu/ugrad/272
Magnetic field is produced by a current distribution

Current carrying wires
Current density $\vec{J}(\vec{r}, t)$
Steady currents: time independent
No build-up or depletion of charge

$$\nabla \cdot \vec{J}(\vec{r}) = -\frac{\partial \rho(\vec{r})}{\partial t} = 0$$
Magnetic Field due to a Long Straight Wire:

\[
B = \frac{\mu_0 i}{2\pi R} \quad \text{(long straight wire)}.
\]

[Diagrams showing the magnetic field lines around a long straight wire.]

\[\mu_0 = 4\pi \times 10^{-7} \text{ kg m/C}^2\]
Symmetry
If current changes direction, B changes direction

Rotation
Reflection?

Magnetic field does NOT change sign under inversion
\[ \vec{r} \rightarrow -\vec{r} \quad \vec{F} = q\vec{v} \times \vec{B} \]
Superposition
Reminders about line integrals

– line integral along path from A to B

– line integral around closed loop C
the direction you go around the loop matters!

\[ \int_C \vec{B} \cdot d\vec{s} \]

LINE INTEGRAL AROUND CIRCULAR LOOP WITH WIRE AT CENTER

Around a two-arc loop that does not enclose the wire
LINE INTEGRAL  \[ \int_C \vec{B} \cdot d\vec{s} \]

AROUND CIRCULAR LOOP WITH WIRE AT CENTER

CIRCULAR LOOP WITH WIRE NOT AT CENTER

ANY LOOP THAT ENCLOSES THE WIRE

ANY LOOP THAT ENCLOSES 2 OR MORE WIRES

ANY LOOP THAT DOES NOT ENCLOSE THE WIRE
$i_{enc}$ Positive or negative?

Take the loop and stretch a surface across it. Any current that passes through the surface is included in $i_{enc}$. The positive direction is defined by a right-hand rule.

This is how to assign a sign to a current used in Ampere's law.

Fig. 29-12 A right-hand rule for Ampere's law, to determine the signs for currents encircled by an Amperian loop. The situation is that of Fig. 29-11.
If your loop direction is clockwise and the current in the central wire is out of the page, what is the sign of the enclosed current?

(a) Positive
(b) Negative
(c) Zero

This is how to assign a sign to a current used in Ampere's law.
If your loop direction is clockwise and the current in the central wire is out of the page, what is the sign of the enclosed current?
(a) Positive
(b) Negative
(c) Zero
Ampere’s law

\[ \oint \mathbf{B} \cdot d\mathbf{s} = \mu_0 i_{\text{enc}} \]
USE Ampere’s law for easy computation of the field INSIDE a long straight wire with uniform current density $j$.  

Only the current encircled by the loop is used in Ampere’s law. 

\[
\oint \vec{B} \cdot d\vec{s} = B \oint ds = B(2\pi r). 
\]

\[
i_{\text{enc}} = i \frac{\pi r^2}{\pi R^2}.
\]

\[
B(2\pi r) = \mu_0 i \frac{\pi r^2}{\pi R^2}
\]

\[
B = \left(\frac{\mu_0 i}{2\pi R^2}\right) r \quad \text{(inside straight wire)}.
\]
SHELL THEOREM FOR UNIFORM CURRENT DENSITY IN CYLINDER OR HOLLOW CYLINDER

Field is the same as if all current INSIDE is collapsed to a wire at the center
\[ i_{enc} = \int _S \vec{J} \cdot d\vec{a} \]

S is any surface that spans the loop C

C = circle, S = disk
Ampere’s law

\[ \oint \mathbf{B} \cdot d\mathbf{s} = \mu_0 i_{\text{enc}} \]
Ampere’s law

\[ \oint \vec{B} \cdot d\vec{s} = \mu_0 i_{\text{enc}} \]

\[ \int_C \vec{B} \cdot d\vec{s} = \mu_0 \int_S \vec{J} \cdot d\vec{a} \]

\[ \int_C \vec{B} \cdot d\vec{s} = \int_S (\nabla \times \vec{B}) \cdot d\vec{a} \]

\[ \nabla \times \vec{B} = \mu_0 \vec{J} \]
NEXT TIME:
Maxwell’s equations for time-independent charge and current distributions
The vector potential and “gauge choice”

How to find the B field for any current-carrying wire:
BIOT SAVART LAW
• Find the B field of ring, coil
• Find the B field of a current sheet