BIOT SAVART LAW
Class Activities: Biot Savart

Discussion
Biot-Savart
Had them "think like an 18th century physicist" to *come up* with Biot-Savart.

Demonstration
Compass and dip angle
Brought a dip-compass needle to see the dramatic dip angle in the room (and brief discussion of geo-magnetic field).

Tutorials
Magnetic Field due to a Spinning Ring of Charge” activity
Oregon State University
Working in small groups students are asked to consider a ring with charge Q, and radius R rotating about its axis with period T and create an integral expression for the magnetic field caused by this ring everywhere in space. Students also develop the power series expansion for the potential near the center or far from the ring.

Visualization
Stokes’ Theorem
http://www.math.umn.edu/~nykamp/m2374/readings/stokesidea/
To find the magnetic field $B$ at $P$ due to a current-carrying wire we use the Biot-Savart law,

$$\vec{B}(\vec{r}) = \frac{\mu_0}{4\pi} \int \frac{d\vec{l} \times \hat{\mathbf{r}}}{r^2}$$

In the figure, with “dl” shown, what is $\hat{\mathbf{r}}$?
To find the magnetic field $\mathbf{B}$ at $P$ due to a current-carrying wire we use the Biot-Savart law,

$$\mathbf{B}(\mathbf{r}) = \frac{\mu_0}{4\pi} I \int \frac{d\mathbf{l} \times \mathbf{H}}{H^2}$$

In the figure, with “$dl$” shown, which purple vector best represents $\mathbf{B}(\mathbf{r})$?

![Diagram of current and magnetic field vectors]

- A
- B
- C
- D
- E) None of these!
To find the magnetic field $B$ at $P$ due to a current-carrying wire we use the Biot-Savart law,

$$\vec{B}(\vec{r}) = \frac{\mu_0}{4\pi} I \int \frac{d\vec{l} \times \hat{r}}{r^2}$$

What is the direction of the infinitesimal contribution $d\vec{B}(P)$ created by current in $d\vec{l}$?

A) Up the page

B) Directly away from $d\vec{l}$ (in the plane of the page)

C) Into the page

D) Out of the page

E) Some other direction
5.13 To find the magnetic field $\mathbf{B}$ due to a current-carrying wire, below, we use the Biot-Savart law,

$$\mathbf{B}(\mathbf{r}) = \frac{\mu_0}{4\pi} \mathbf{I} \int \frac{d\mathbf{l} \times \hat{r}}{r^2}$$

What is the magnitude of

$$\frac{d\mathbf{l} \times \hat{r}}{r^2}$$

?
5.13 To find the magnetic field $B$ due to a current-carrying wire, below, we use the Biot-Savart law, $\vec{B}(\vec{r}) = \frac{\mu_0}{4\pi} \int \frac{d\vec{l} \times \vec{r}}{r^2}$

What is the magnitude of $\frac{d\vec{l} \times \vec{r}}{r^2}$?

a) $\frac{dl \sin \theta}{2}$

b) $\frac{dl \sin \theta}{3}$

c) $\frac{dl \cos \theta}{2}$

d) $\frac{dl \cos \theta}{3}$
e) something else!

(And, what's here, given that $P = (x,y,z)$?)
To find the magnetic field $\mathbf{B}$ due to a current-carrying wire, below, we use the Biot-Savart law,

$$\mathbf{B}(\mathbf{r}) = \frac{\mu_0}{4\pi} I \int \frac{d\mathbf{l} \times \hat{\mathbf{R}}}{\mathbf{R}^2}$$

What is the value of

$$I \frac{d\mathbf{l} \times \hat{\mathbf{R}}}{\mathbf{R}^2} ?$$

(What's here, given that $P = (0,y,0)$?)
To find the magnetic field $\vec{B}$ due to a current-carrying wire, below, we use the Biot-Savart law,

$$\vec{B}(\vec{r}) = \frac{\mu_0}{4\pi} I \int \frac{d\ell \times \hat{\mathbf{k}}}{R^2}$$

What is the value of

$$\left| \frac{d\ell \times \hat{\mathbf{k}}}{R^2} \right| ?$$

a) $\frac{Iy \, dx' \, \hat{z}}{[(x')^2 + y^2]^{3/2}}$

b) $\frac{Ix' \, dx' \, \hat{y}}{[(x')^2 + y^2]^{3/2}}$

c) $\frac{Ix' \, dx' \, \hat{y}}{[(x')^2 + y^2]^{3/2}}$

d) $\frac{Iy \, dx' \, \hat{z}}{[(x')^2 + y^2]^{3/2}}$

e) Other!
What is $B$ at the point shown?

A) \[ \frac{0}{s} I \]

B) \[ \frac{0}{2s} I \]

C) \[ \frac{0}{4s} I \]

D) \[ \frac{0}{8s} I \]

E) None of these

(What direction does it point?)
What do you expect for direction of $\mathbf{B}(P)$?

How about direction of $d\mathbf{B}(P)$ generated JUST by the segment of current $dl$ in red?

A) $\mathbf{B}(p)$ in plane of page, ditto for $d\mathbf{B}(P, \text{by red})$
B) $\mathbf{B}(p)$ into page, $d\mathbf{B}(P, \text{by red})$ into page
C) $\mathbf{B}(p)$ into page, $d\mathbf{B}(P, \text{by red})$ out of page
D) $\mathbf{B}(p)$ complicated - has mult component ($not \perp$ or $\parallel$ to page), ditto for $d\mathbf{B}(P, \text{by red})$
E) Something else!!
I have two very long, parallel wires each carrying a current $I_1$ and $I_2$, respectively. In which direction is the force on the wire with the current $I_2$?

A) Up
B) Down
C) Right
D) Left
E) Into or out of the page

(How would your answer change if you reverse the direction of both currents?)
To find the magnetic field $\mathbf{B}$ due to a current-carrying loop, we use the Biot-Savart law,

$$\mathbf{B}(\mathbf{r}) = \frac{\mu_0}{4\pi} I \int \frac{d\mathbf{l} \times \hat{\mathbf{r}}}{\mathbf{r}^2}$$

What is the magnitude of $\frac{d\mathbf{l} \times \hat{\mathbf{r}}}{\mathbf{r}^2}$?

A) $\frac{dl \sin z}{z^2}$

B) $\frac{dl}{z^2}$

C) $\frac{dl \sin}{(z^2 + a^2)}$

D) $\frac{dl}{(z^2 + a^2)}$

E) Something quite different!

(Which colored arrow is $\mathbf{r}$? $\mathbf{r}'$?)
To find the magnetic field $\mathbf{B}$ due to a current-carrying loop, we use the Biot-Savart law,

$$\vec{B}(\vec{r}) = \frac{\mu_0}{4\pi} I \int \frac{d\vec{l} \times \hat{\mathbf{r}}}{\mathbf{r}^2}$$

What is $d\mathbf{B}_z$ (the contribution to the vertical component of $\mathbf{B}$ from this $d\vec{l}$ segment?)

A) $\frac{d\vec{l}}{(z^2 + a^2) \sqrt{z^2 + a^2}}$  \quad B) $\frac{d\vec{l}}{z^2 + a^2}$

C) $\frac{d\vec{l}}{z^2 + a^2} \frac{z}{\sqrt{z^2 + a^2}}$  \quad D) $\frac{d\vec{l} \cos \phi}{z^2 + a^2}$

E) Something quite different!
Consider the B-field a distance $z$ from a current sheet in the $z = 0$ plane:

The B-field has
A) $y$-component only
B) $z$-component only
C) $y$ and $z$-components
D) $x$, $y$, and $z$-components
E) Other