Course Updates

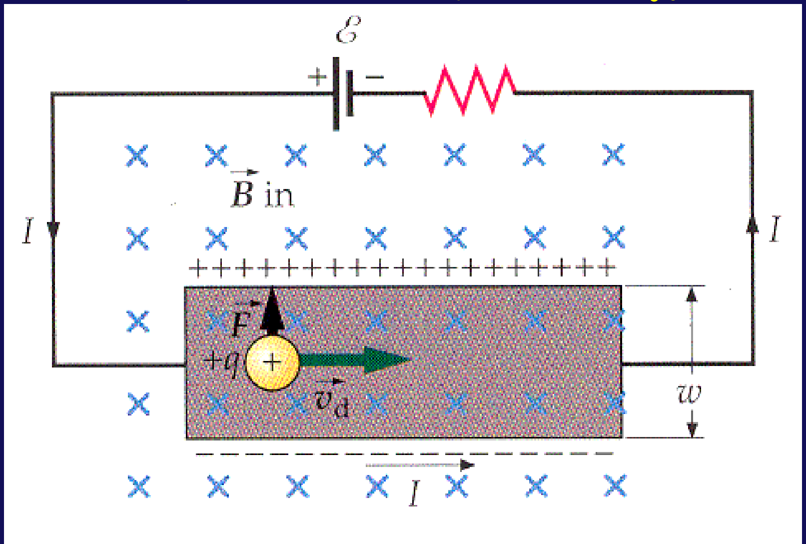
http://www.phys.hawaii.edu/~varner/PHYS272-Spr10/physics272.html

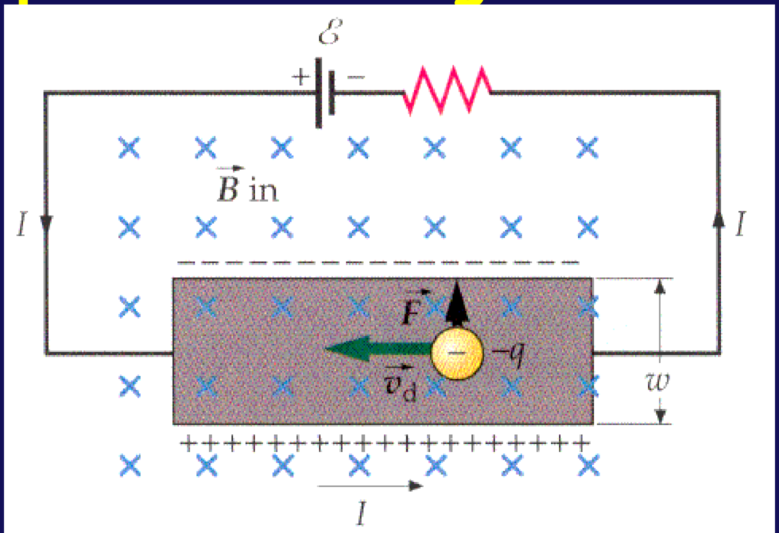
Reminders:

1) HW # 7 due today
2) Assignment #8 available
3) Chapter 28 this week

The Hall Effect

- **Is current due to motion of positive or negative**





- Positive charges moving CCW experience upward force
- Upper plate at *higher* potential

- Negative charges moving clockwise experience upward force
- Upper plate at *lower* potential

Equilibrium between electrostatic & magnetic forces:

$$F_{\text{up}} = qv_{\text{drift}}B \qquad F_{\text{down}} = qE_{\text{induced}} = q\frac{V_{\text{H}}}{\text{w}} \qquad V_{\text{H}} = v_{\text{drift}}Bw = \text{"Hall Voltage"}$$

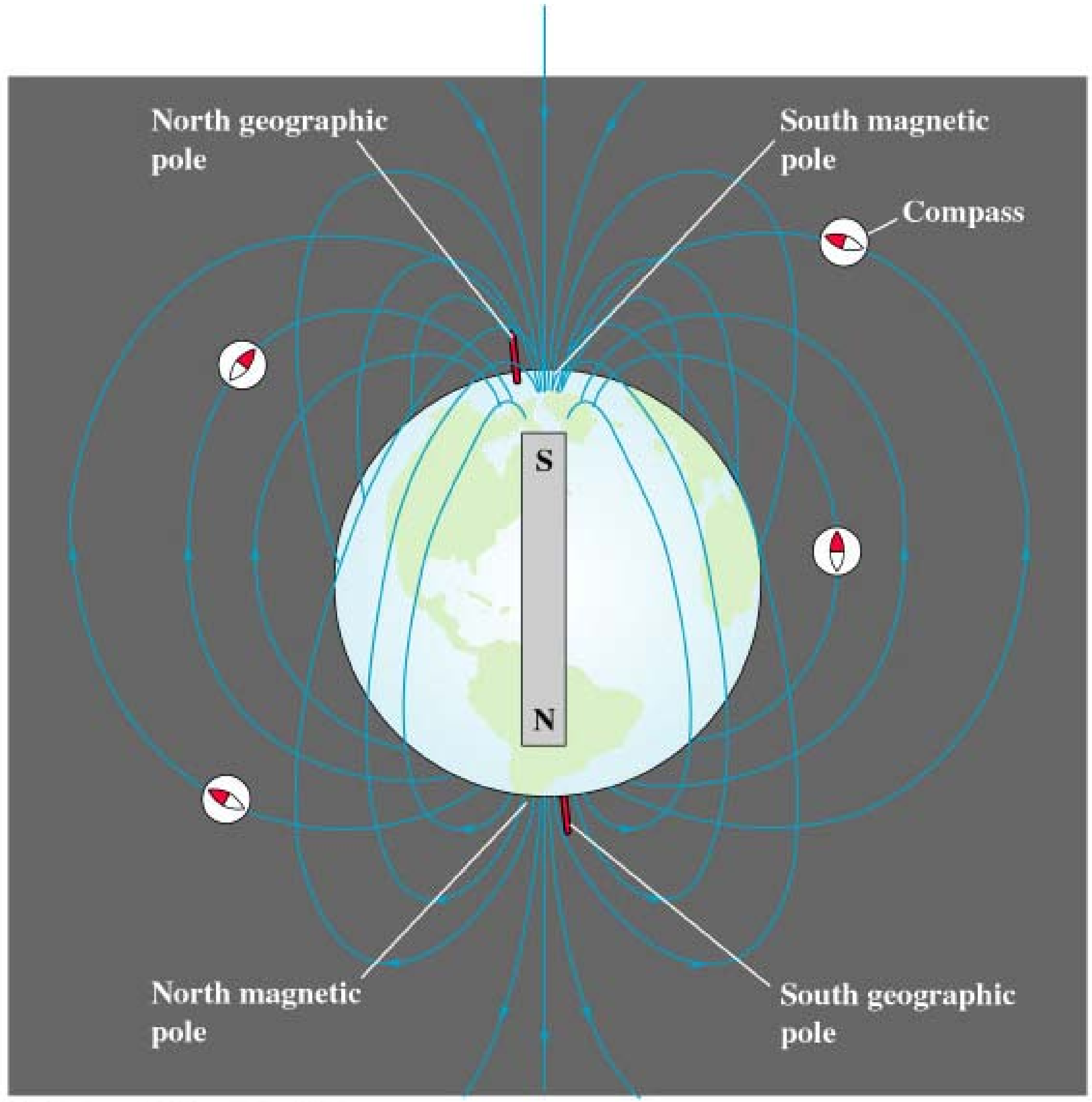
- This type of experiment led to the discovery (E. Hall, 1879) that current in conductors is carried by negative charges (not always so in semiconductors).
- Can be used as a B-sensor.

Example

Flight over North Pole

$$V_{\mathrm{H}} = v_{\mathrm{drift}} B w = \text{"Hall Voltage"}$$

600 mi/hr = 268 m/s
B vertical ~ 0.5×10^{-4} T
Wingspan ~ 30m



Sources of Magnetic Fields (chap 28)

In Chapter 27, we considered the magnetic field effects on a moving charge, a line current and a current loop.

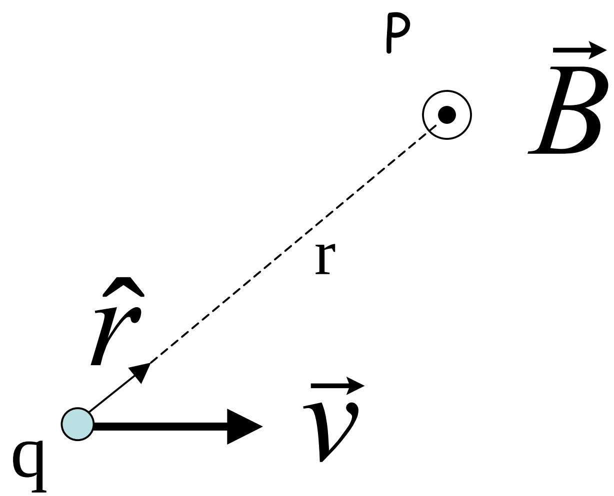
Now in Chap 28, we consider the magnetic fields that are created by:

- moving charges
- line current elements (Biot-Savart Law)
- line of current
- current loops

Magnetic Fields from a moving charge

Magnetic fields are created by a moving charge. If the charge is stationary, there is NO magnetic field. If the charge is moving, the magnetic field law is

$$\vec{B} = \frac{\mu_0}{4\pi}\frac{q\vec{v}\times\hat{r}}{r^2}$$



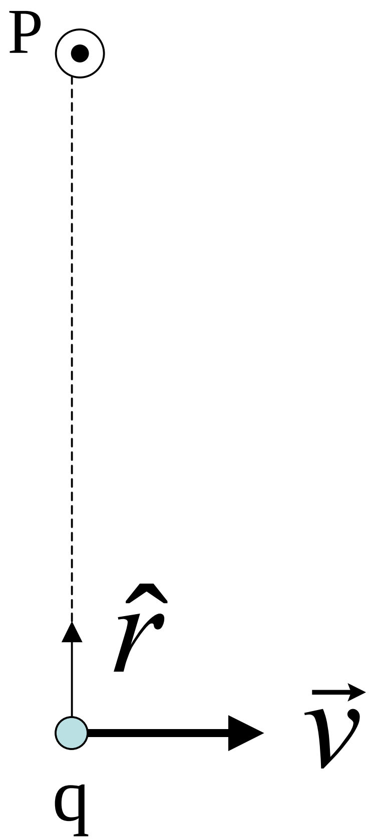
$\mu_0 = 4\pi \times 10^{-7}\ \mathrm{T \cdot m / A}$

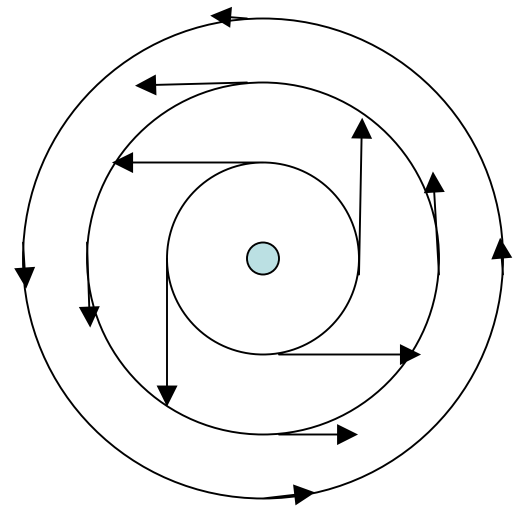
Use right hand to get direction of field

Magnetic Fields from a moving charge at a position perpendicular to velocity

$$\sin\theta = 1$$

$$\left|\vec{B}\right| = \frac{\mu_0}{4\pi} q \left|\vec{v}\right| \frac{1}{r^2}$$



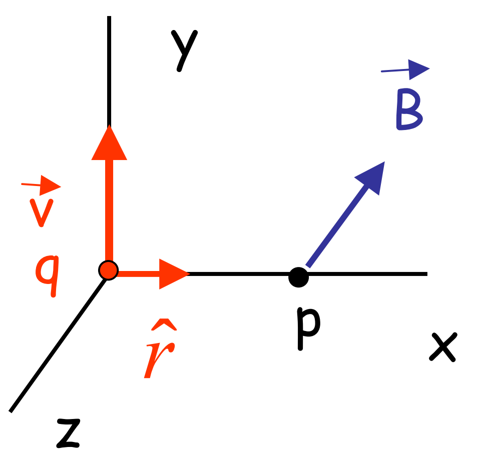


v is out of screen.
B field lines have circular path.

Example

A q=6μC point charge at the origin is moving with a v=8x10⁶m/s in the +y direction. What is the B field it produces at the following points?

A) x=0.5m, y=0, z=0



$$\vec{B} = \frac{\mu_0}{4\pi}\frac{q\vec{v}\times\hat{r}}{r^2}$$

$$\mu_0 = 4\pi\times10^{-7}\ \mathrm{T\cdot m/A}$$

$$= \frac{\mu_0}{4\pi}\frac{(6x10^{-6}C)(8x10^{6}\frac{m}{s}\hat{j})\times\hat{i}}{(0.5m)^2}$$

$$= -1.9x10^{-5}T\,\hat{k}$$

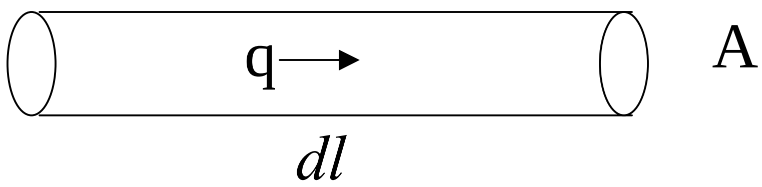
B) x=0m, y=0.5, z=0m

$$\vec{B} = 0$$ since

$$\vec{v}\ and\ \hat{r}\ parallel.$$

Magnetic Fields from a current element

Suppose we have a current element of length *dl*, cross sectional area *A* and particle density *n*, #charges/volume. The total charge, *dQ* is



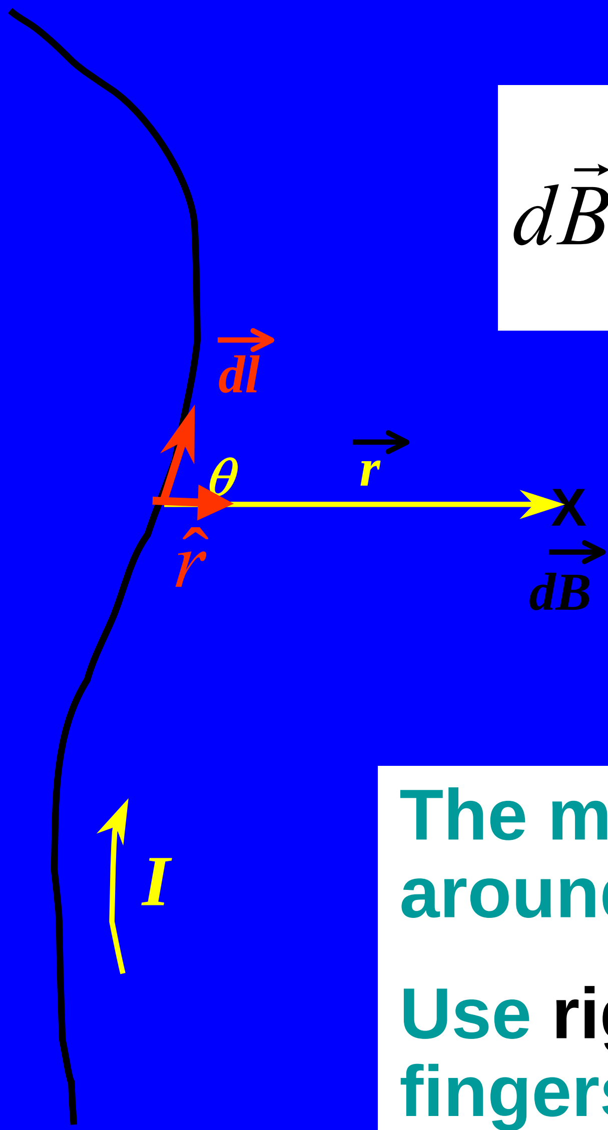
$dQ = n\,q\,A\,dl$. And recall that current is $I = n\,q\,v\,A$. The B field becomes,

$$d\vec{B} = \frac{\mu_0}{4\pi}\frac{dQ\,\vec{v}\times\hat{r}}{r^2} = \frac{\mu_0}{4\pi}nqA\frac{\vec{v}\times\hat{r}}{r^2} = \frac{\mu_0}{4\pi}\frac{Id\vec{l}\times\hat{r}}{r^2}$$

Vector, $\vec{dl}$, is the length of the current element in the direction of the current flow. This is called the **Biot-Savart Law**

Since n above is very large, a current (element) will give a much bigger magnetic field than that of a single charge.

Biot-Savart Law



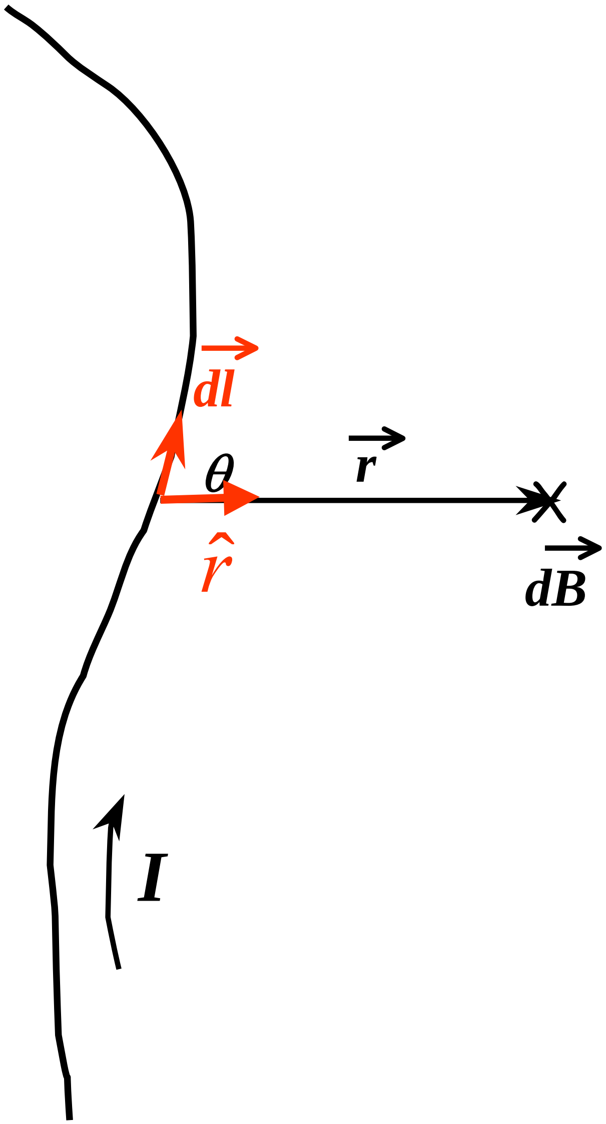
$$d\vec{B} = \frac{\mu_0 I}{4\pi}\frac{d\vec{l} \times \hat{r}}{r^2}$$

$$\mu_0 = 4\pi \times 10^{-7}\ \frac{\mathrm{N}}{\mathrm{A}^2}$$

The magnetic field "circulates" around the wire

Use right-hand rule: thumb along I, fingers curl in direction of B.

Magnetic Fields from a arbitrary wire



If we have an arbitrary wire with current I flowing, and we wish to get the B at a specific point from the entire wire, we integrate the formula

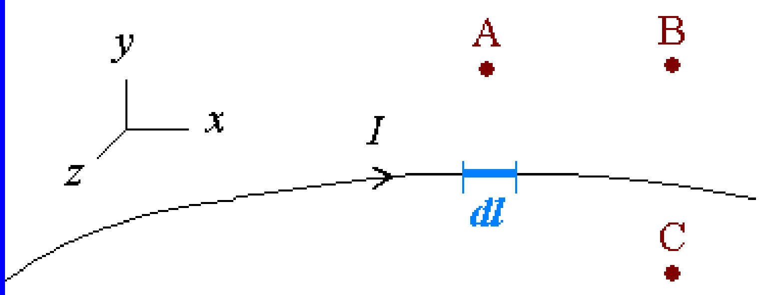
$$\boxed{d\vec{B} = \frac{\mu_0}{4\pi} \frac{I d\vec{l} \times \hat{r}}{r^2}}$$

and obtain a line integral of a cross product

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

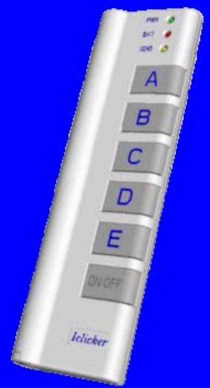
Question 1:

A current carrying wire (with no remarkable symmetry) is oriented in the x-y plane. Points A,B, & C lie in the same plane as the wire. The z-axis points out of the screen.



What direction is the magnetic field contribution from the segment dl at point A?

A)	B)	C)	D)	E)
$+x$	$-x$	$+y$	$+z$	$-z$



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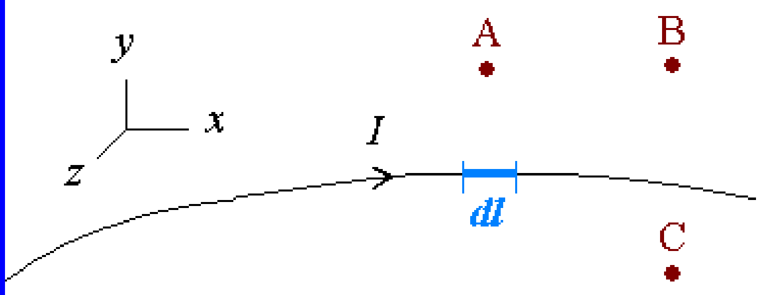
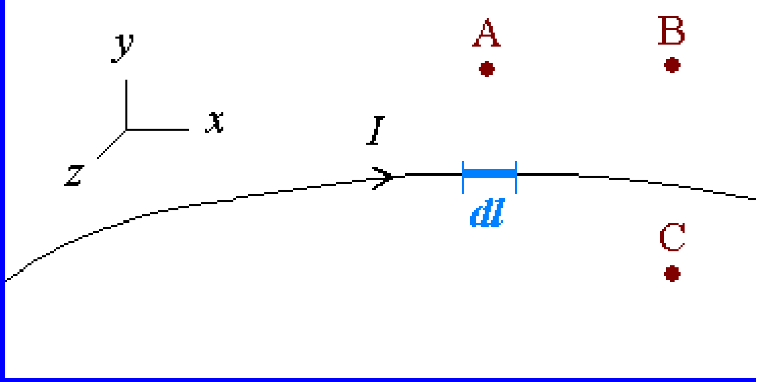


What direction is the magnetic field contribution from the segment dl at point A?

A)	B)	C)	D)	E)
$+x$	$-x$	$+y$	$+z$	$-z$

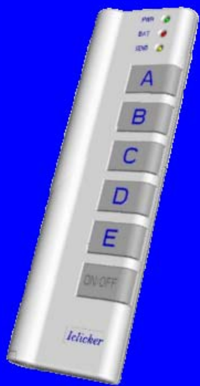
Question 2:

A current carrying wire (with no remarkable symmetry) is oriented in the x-y plane. Points A,B, & C lie in the same plane as the wire. The z-axis points out of the screen.



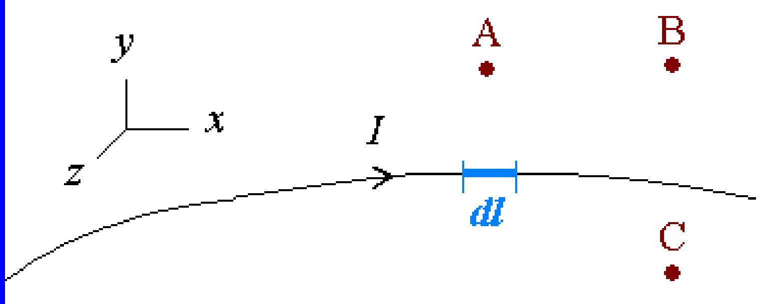
What direction is the magnetic field contribution from the segment dl at point B?

A)	B)	C)	D)	E)
$+x$	$-x$	$+y$	$+z$	$-z$



Question 2:

A current carrying wire (with no remarkable symmetry) is oriented in the *x*-*y* plane. Points A,B, & C lie in the same plane as the wire. The *z*-axis points out of the screen.

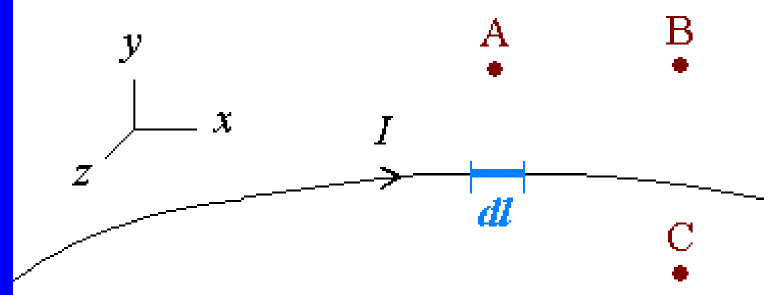


What direction is the magnetic field contribution from the segment *dl* at point B?

A)	B)	C)	D)	E)
$+x$	$-x$	$+y$	$+z$	$-z$

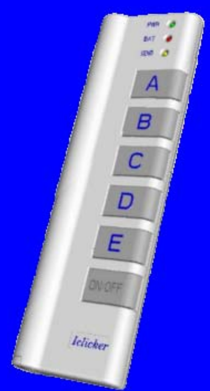
Question 3:

A current carrying wire (with no remarkable symmetry) is oriented in the *x-y* plane. Points A,B, & C lie in the same plane as the wire. The *z*-axis points out of the screen.



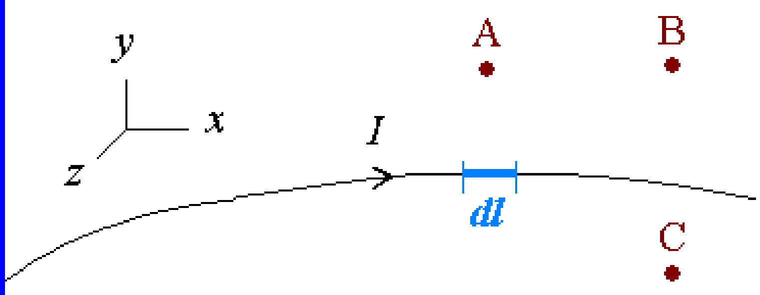
What direction is the magnetic field contribution from the segment *dl* at point C?

A)	B)	C)	D)	E)
$+x$	$-x$	$+y$	$+z$	$-z$



Question 3:

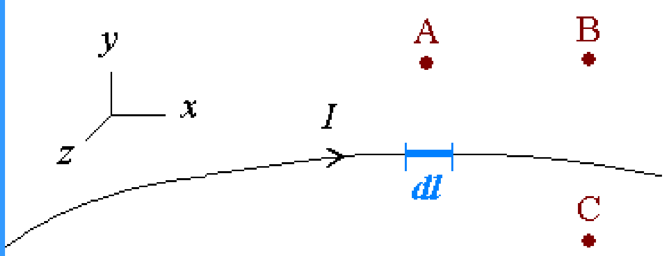
A current carrying wire (with no remarkable symmetry) is oriented in the *x*-*y* plane. Points A,B, & C lie in the same plane as the wire. The *z*-axis points out of the screen.



What direction is the magnetic field contribution from the segment *dl* at point C?

A)	B)	C)	D)	E)
$+x$	$-x$	$+y$	$+z$	$-z$

dB points in the direction of $d\vec{l} \times \vec{r}$



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

A: dl is to the right, and r is up $\Rightarrow$ dB is out of the page

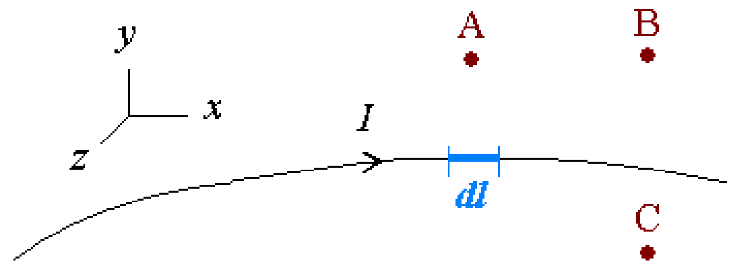
B: dl is to the right, and r is up and right $\Rightarrow$ dB is out of the page

C: dl is to the right, and r is down and right $\Rightarrow$ dB is into the page

Conclusion: at every point above the wire, dB is $\odot$. Below the wire, dB is $\otimes$

Check:

Would any of your answers for questions 1-3 change if we integrated *dl* over the whole wire?



NO.

Why or why not?

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

dB points in the direction of $d\vec{l} \times \vec{r}$

At point A: *dl* is to the right, and *r* is up $\Rightarrow$ *dB* is out of the page

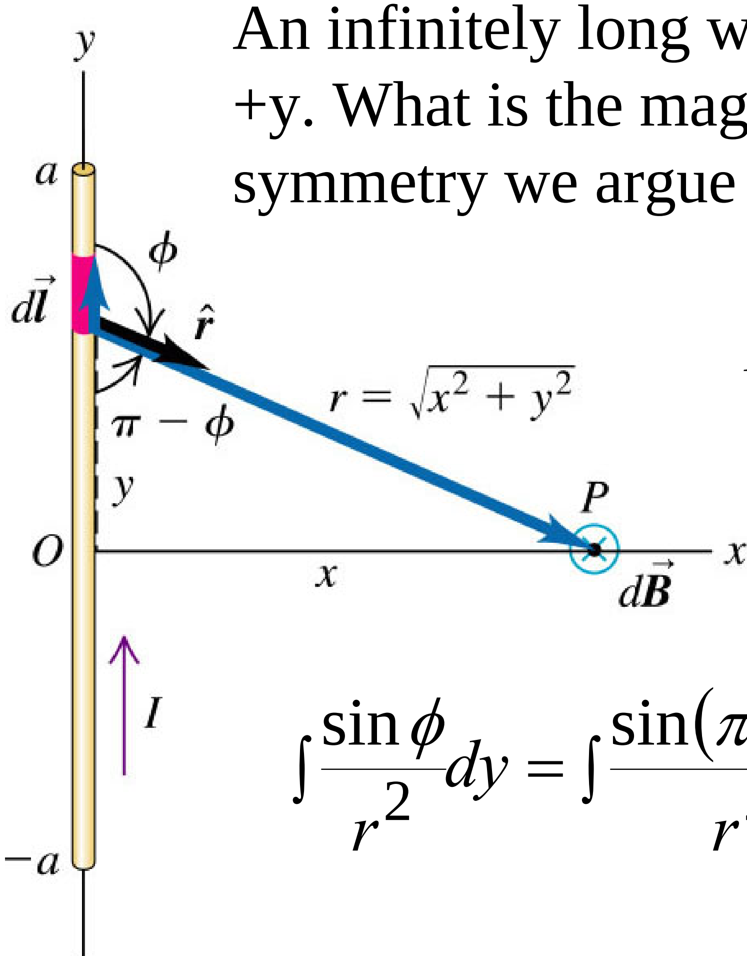
At point B: *dl* is to the right, and *r* is up and right $\Rightarrow$ *dB* is out of the page

At point C: *dl* is to the right, and *r* is down and right $\Rightarrow$ *dB* is into the page

For every point in the *x-y* plane and every piece of wire *dl*:
every *dl* and every *r* are always in the *x-y* plane
Since *dB* must be perpendicular to *r* and *dl*, *dB* is always in the $\pm z$ direction!

Conclusion:
At every point above the wire, the *dB* due to every piece *dl* is $\odot$.
Below the wire, the *dB* due to every piece *dl* is $\otimes$

Magnetic Fields from a long wire



An infinitely long wire along the y-axis with the current moving +y. What is the magnetic field at position x on the x-axis? By symmetry we argue the field must be in the –z direction only.

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

$$= \frac{-\hat{z}I\mu_0}{4\pi}\int\frac{\sin\phi}{r^2}dy;$$

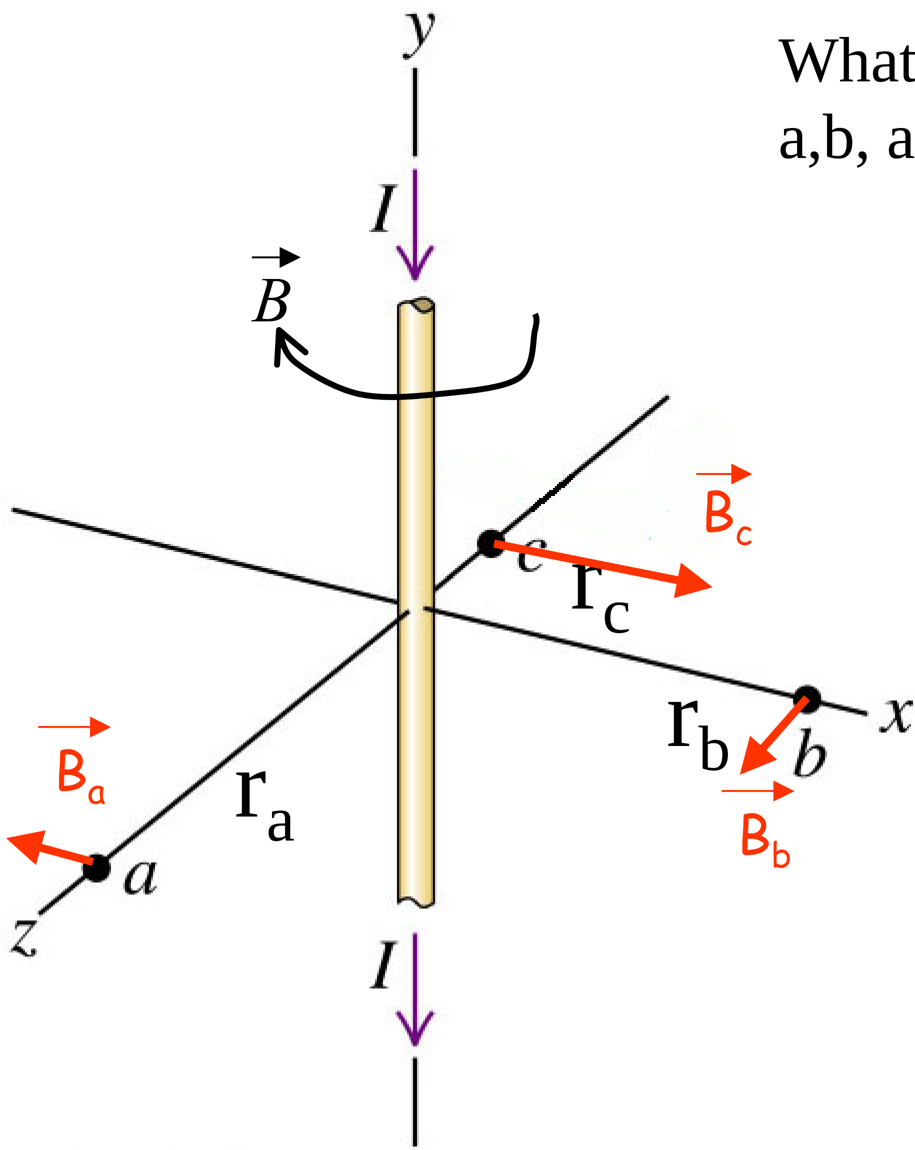
Since, sin(ϕ)= sin(π−ϕ), we have

$$\int\frac{\sin\phi}{r^2}dy = \int\frac{\sin(\pi-\phi)}{r^2}dy = \int_{-\infty}^{+\infty}\frac{x}{r^3}dy = x\int_{-\infty}^{+\infty}\frac{1}{\left(y^2+x^2\right)^{3/2}}dy$$

$$= x\left[\frac{1}{x^2}\frac{y}{\sqrt{y^2+x^2}}\right]_{-\infty}^{+\infty} = \frac{2}{x}$$

$$\boxed{\vec{B} = \frac{\mu_0 I}{2\pi\ x}(-\hat{z})}$$

Magnetic Fields from a long wire



What are the magnetic fields at points a,b, and c?

$$\left|\vec{B}\right| = \frac{\mu_0 I}{2\pi\, r}$$

Into the 2nd half

- HW #8 → need magnetic equivalent of Gauss' Law
- Office Hours immediately after this class
  (9:30 – 10:00) in WAT214 (1:30-2/1-1:30 M/WF)
- Last day to drop soon – grade feedback on webpage