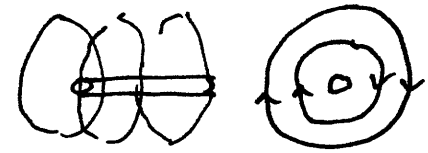
MAGNETIC FIELDS & CURRENTS

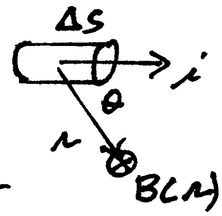
MAGNETS OR MOVING CHARGES Induce $\vec{B}$

$q^{\bullet}$ $v \neq 0$ $\qquad$ $q^{\bullet \longrightarrow v}$

$B = 0$ $\qquad$ $B > 0$



BIOT-SAVART LAW



θ - ∡ BETWEEN Δs & r

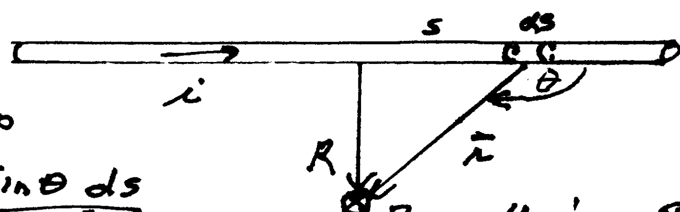
$$\Delta B = \frac{\mu_0}{4\pi} i \frac{\Delta s \sin\theta}{r^2} \quad (30.3)$$

$\mu_0 = 1.26 \times 10^{-6}$ T-m/A

Permeability CONSTANT

LONG STRAIGHT WIRE

$$B = 2\int_0^\infty dB$$



$$\vec{B} = \frac{\mu_0 i}{2\pi} \int_0^\infty \frac{\sin\theta \, ds}{r^2}$$

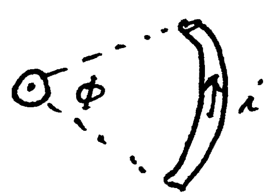
$$B = \frac{\mu_0 i}{2\pi R}$$

$\otimes$ $\vec{B}$ IS INTO THE PAGE

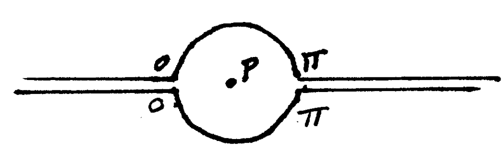
$r = \sqrt{s^2 + R^2}$

$$B_{\substack{\text{SEMI} \\ \infty \\ \text{WIRE}}} = \frac{\mu_0 i}{4\pi R}$$

CIRCULAR ARC



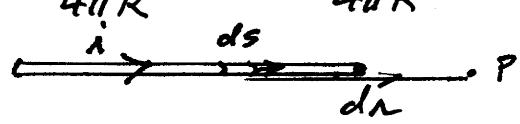
$$B = \frac{\mu_0 i \phi}{4\pi R}$$



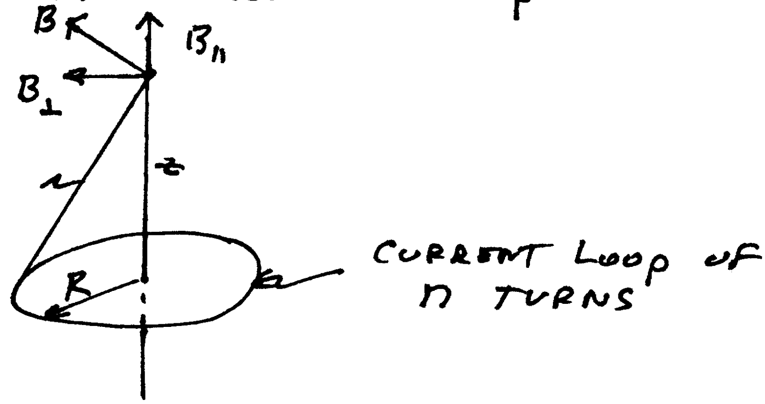
$$B_{\text{ARC}} = \frac{\mu_0 i \, \pi}{4\pi R} = \frac{\mu_0 i}{4R} \otimes$$

$$B_P = \overset{\otimes}{\frac{\mu_0 i \, \pi}{4\pi R}} + \overset{\odot}{\frac{\mu_0 i \, \pi}{4\pi R}} = 0$$

$$\underset{\text{STRAIGHT SECTION}}{dB_P} = \frac{\mu_0}{4\pi} \frac{i \, ds \sin\overset{\theta = 0}{\theta}}{r^2} = 0$$



$\vec{B}$ ALONG A CURRENT LOOP AXIS



$$B(z) = \frac{\mu_0 i R^2}{2(R^2+z^2)^{3/2}}$$

AT THE CENTER OF THE LOOP $z = 0$

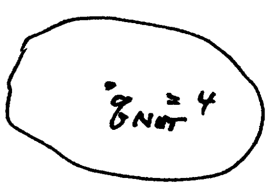
$$B(\text{CENTER}) = \frac{\mu_0 i R^2}{2(R^2)^{3/2}} = \frac{\mu_0 i}{2R}$$

FOR A CIRCULAR ARC WITH $\phi = 2\pi$

$$B = \frac{\mu_0 i (2\pi)}{4\pi R} = \frac{\mu_0 i}{2R}$$

GAUSS'S LAW

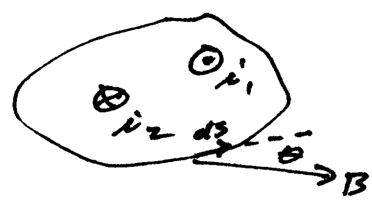
$$\epsilon_0 \oint \vec{E} \cdot d\vec{A} = q_{NET}$$



$$\epsilon_0 \oint \vec{E} \cdot d\vec{A} = 4$$

AMPERE'S LAW

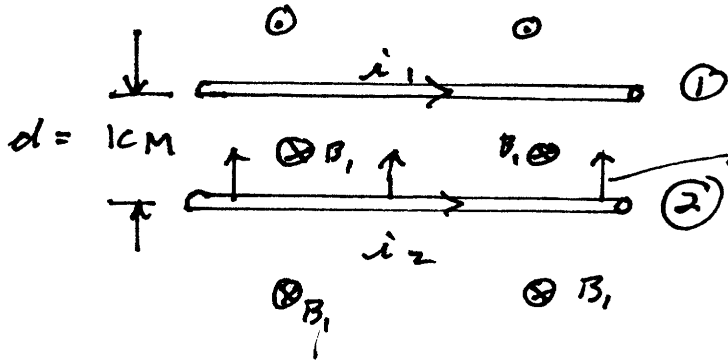
$$\oint \vec{B} \cdot d\vec{s} = \mu_0 i_{enc}$$



$$\oint \vec{B} \cdot d\vec{s} = \mu_0 (i_1 - i_2)$$

FORCES ACTING ON A WIRE

$i_1 = i_2 = 100\,A$

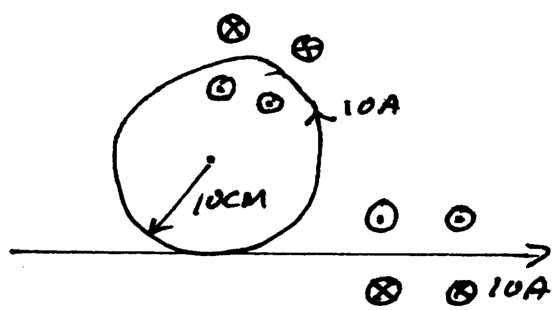


FORCE ON WIRE 2 DUE TO CURRENT IN WIRE 1

$$F_2 = i_2 \ell B_1 \qquad \text{BUT} \quad B_1 = \frac{\mu_0 i_1}{2\pi d}$$

$$\frac{F_2}{\ell} = \frac{\mu_0 i_1 i_2}{2\pi d} = \frac{(1.26\times10^{-7})(100)(100)}{2\pi(.01)} = 0.02\ N/m$$

EXAMPLE I FIND $\vec{B}$ AT THE CENTER OF THE LOOP



THE DIRECTION OF B FROM

1. THE LOOP IS OUT OF THE PAGE WITHIN THE LOOP
2. THE WIRE IS OUT OF THE PAGE ABOVE THE WIRE

SO BOTH CONTRIBUTIONS CAN BE ADDED TOGETHER

FOR A STRAIGHT WIRE $B = \frac{\mu_0}{2\pi}\frac{i}{r}$

FOR A LOOP AT THE CENTER $B = \frac{\mu_0 i}{4\pi r}(2\pi) = \frac{\mu_0 i}{2r}$

$$B_{TOTAL} = \frac{\mu_0 i}{2r}\left(\frac{1}{\pi} + 1\right)$$

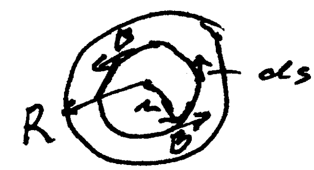
$$= \frac{1.26\times10^{-6}(10)}{2(0.1)}(1 + .318) = 83\times10^{-6}\ T$$

EXAMPLE II A WIRE OF RADIUS a CARRIES A CURRENT i UNIFORMLY DISTRIBUTED OVER THE WIRE

FIND B INSIDE & OUTSIDE THE WIRE

WE WILL USE AMPERE'S LAW

1ST INSIDE THE WIRE



$$\oint \vec{B} \cdot d\vec{s} = \mu_0 i_{enc}$$

$$i_{enc} = \frac{i}{\pi R^2}(\pi r^2) \qquad \oint \vec{B} \cdot d\vec{s} = B \oint d\vec{s} = B(2\pi r)$$

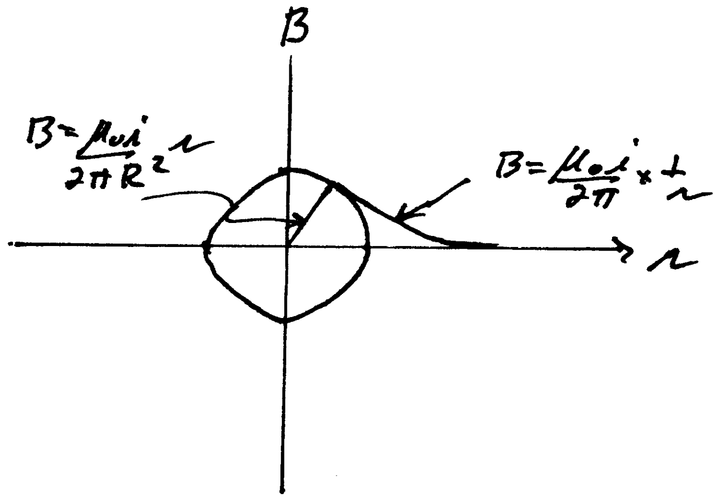
$$B(2\pi r) = \mu_0 i \frac{\pi r^2}{\pi R^2}$$

$\vec{B}$ is ∥ TO ds ON ANY CIRCLE

$\cos 0 = 1$

$$\oint \vec{B} \cdot d\vec{s} = B \int ds = B(2\pi r)$$

$$\boxed{B = \frac{\mu_0 i}{2\pi R^2} r}$$



OUTSIDE THE WIRE

$$\oint \vec{B} \cdot d\vec{s} = \oint B \cos\theta \, ds = B(2\pi r)$$

$\theta = 0$

B is ∥ to s

$$\oint \vec{B} \cdot ds = \mu_0 i$$

$$B(2\pi r) = \mu_0 i$$

$$B = \frac{\mu_0 i}{2\pi} \times \frac{1}{r}$$