5.1 A particle of charge q enters a region of uniform magnetic field **B** (pointing into the page). The field deflects the particle a distance d above the original line of flight, as shown in Fig 5.8. Is the charge positive or negative? In terms of a, b, c, d, B, and q, find the momentum of the particle.

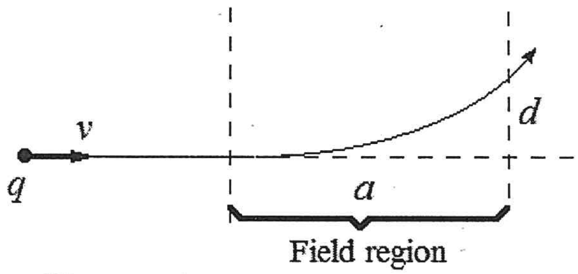
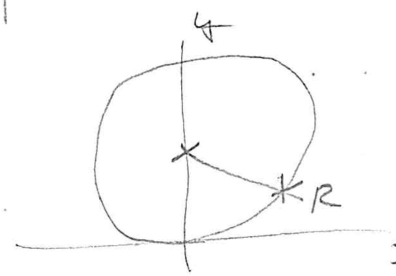


Figure 5.8

$\vec{F} = q\vec{v} \times \vec{B}$ $\quad B \otimes \to v$

a) $\overrightarrow{v \times B}$ is UP $\therefore$ q must be $\boxed{\text{Positive}}$
Since the particle moves UP.



b) the path is circular

$x^2 + (y-R)^2 = R^2$

$q\cancel{v}B = \frac{mv^{\cancel{2}}}{R}$

$p = mv = RqB$

$x^2 + (y-R)^2 = R^2$

@ $x = a$ $\quad y = d$

$a^2 + (d-R)^2 = R^2$

$a^2 + d^2 - 2Rd + \cancel{R^2} = \cancel{R^2}$

$R = \frac{a^2 + d^2}{2d}$

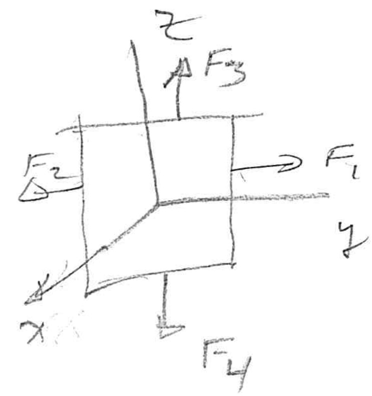
momentum $= p = mv = RqB = \boxed{\frac{qB}{2d}(a^2 + d^2)}$

5.4 Suppose that the magnetic field in some region has the form

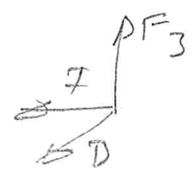
$$\mathbf{B} = k z \hat{x}$$

(where k is a constant). Find the force on a square loop (side a), lying in the $x\,y$ plane and centered at the origin, if it carries a current I, flowing counterclockwise, when you look down the x axis.

$\vec{F} = I\vec{L} \times \vec{B}$



$F_1 + F_2 = 0$



F

$\vec{F_3} = I L B \vec{z} = I a k \frac{a}{2} \vec{z}$

$\vec{F_4} = -I L B \vec{z} = -I a (-k (\frac{a}{2})) \vec{z}$

$$\boxed{\vec{F} = F_3 + F_4 = I a^2 k \vec{z}}$$

5.9 Find the magnetic field at point P for each of the steady current configurations shown in Fig. 5.23.

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

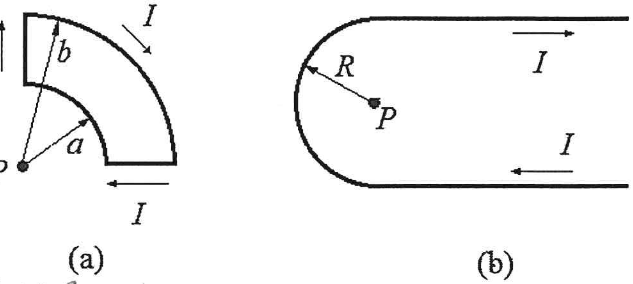


Figure 5.23

a) Straight Line Segments cancel

ARCS $\quad \vec{dl} \perp \vec{r} \quad dl = r\,d\theta$

$$dB = \frac{\mu_0 I}{4\pi} \frac{r\,d\theta}{r^2} = \frac{\mu_0 I}{4\pi r}\, d\theta$$

Outer ARC $\quad r = b \quad \int d\theta = \int_{\pi/2}^{0} d\theta = -\frac{\pi}{2} \quad \Delta\theta = \frac{\pi}{2}$

$$B_1 = \frac{\mu_0 I}{4\pi b} \frac{\pi}{2} = \frac{\mu_0 I}{8b}$$

INTO the paper by The RIGHT Hand Rule

INNER ARC

$$B_2 = \frac{\mu_0 I}{8a} \quad \text{OUT of the page}$$

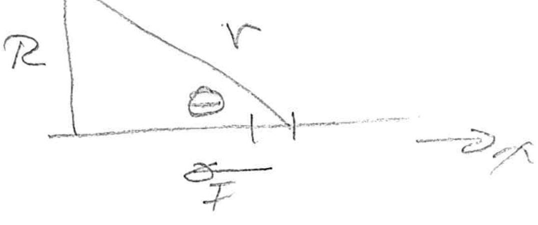
$$B = \frac{\mu_0 I}{8}\left[\frac{1}{a} - \frac{1}{b}\right] \quad \text{OUT of the PAPER}$$

b) Circular Arc $\quad$ here $\Delta\theta = \pi$

$$B_1 = \frac{\mu_0 I}{4R}$$

STRAIGHT Segments Contribute $\quad B_2 = 2 \times \frac{\mu_0 I/2}{2\pi R}$

The 2 Segments Are equal to one Long straight wire. $\quad B_2 = \frac{\mu_0 I}{2\pi r}$



$$\boxed{\begin{aligned} B &= B_1 + B_2 \\ B &= \frac{\mu_0 I}{4R}\left[1 + \frac{2}{\pi}\right] \end{aligned}}$$

5.10

a. Find the force on a square loop placed as shown in Fig 5.24(a) near an infinite straight wire. Both the loop and the straight wire carry a steady current I.

b. Find the force on the triangular loop in Fig 5.24(b).

F_3 & F_4 are equal and CANCEL

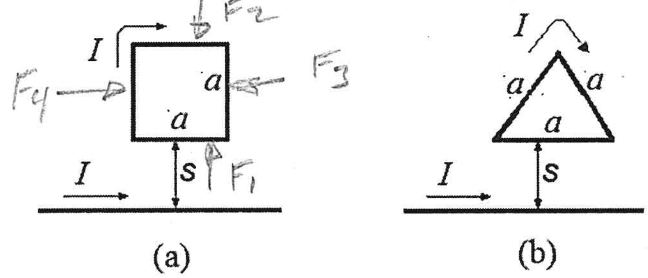


Figure 5.24

$$F_1 = ILB$$

$$B = \frac{\mu_0 I}{2\pi s} \qquad L = a$$

$$\vec{F}_1 = \frac{I^2 a \mu_0}{2\pi s}\hat{s}$$

$$\vec{F}_2 = \frac{I^2 a \mu_0}{2\pi(a+s)}(-\hat{s})$$

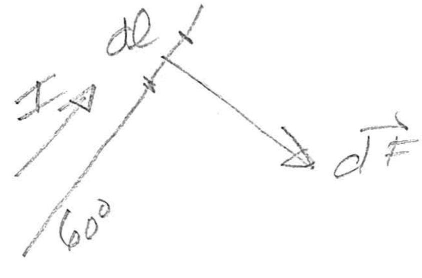
$$\vec{F} = \vec{F}_1 + \vec{F}_2 = \frac{I^2 a \mu_0}{2\pi}\left[\frac{1}{s} - \frac{1}{s+a}\right]\hat{s}$$

$$= \frac{I^2 a \mu_0}{2\pi}\left(\frac{a}{s(s+a)}\right)\hat{s}$$

a) $$\vec{F} = \frac{\mu_0 I^2 a^2}{2\pi} * \frac{\hat{s}}{s(s+a)}$$

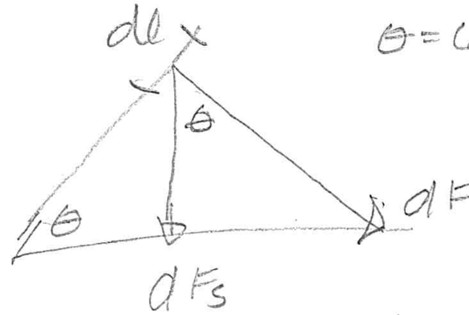
b) The Force on the bottom side of the Triangle is $\vec{F}_1 = IaB\hat{s} = \frac{\mu_0 I^2 a}{2\pi s}\hat{s}$

The Force on the Left Side $\vec{dF} = I\vec{dl} \times \vec{B}$



5.10 CONTINUED

$dF = \left| I\,d\ell \times B \right|$



$\theta = 60^\circ \quad \cos 60^\circ = \frac{1}{2}$

$\sin 60^\circ = \frac{\sqrt{3}}{2}$

Horizontal Components of 2 sides cancel

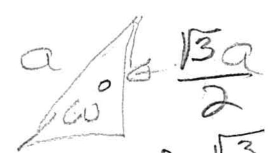
$dF_2 = dF\cos\theta$
$= dF\cos 60^\circ$
$= \frac{dF}{2}$

The vertical component

$dF_s = \frac{dF}{2}$

Multiply by 2 to Account for 2 sides

$d\ell = \frac{ds}{\sin 60^\circ} = \frac{2ds}{\sqrt{3}}$



$\sin 60^\circ = \frac{\sqrt{3}}{2}$

$dF_s = dF = I\,d\ell \times B$

$= I\frac{2ds}{\sqrt{3}} \times B = \frac{2I}{\sqrt{3}}\left(\frac{\mu_0 I}{2\pi s}\right)ds$

$s_1 = s$

$F_s = \int dF_s = \frac{\mu_0 I^2}{\sqrt{3}\pi}\ln\left(\frac{s_2}{s_1}\right)$

$s_2 = s + \frac{\sqrt{3}}{2}a$

$F_2 = \frac{\mu_0 I^2}{\sqrt{3}\pi}\ln\left(1 + \frac{\sqrt{3}}{2}\frac{a}{s}\right)$

$\frac{s_2}{s_1} = 1 + \frac{\sqrt{3}}{2}\frac{a}{s}$

$\vec{F} = \vec{F}_1 - \vec{F}_2$

$$\boxed{\vec{F} = \frac{\mu_0 I^2}{2\pi}\left[\frac{a}{s} - \frac{2}{\sqrt{3}}\ln\left(1 + \frac{\sqrt{3}}{2}\frac{a}{s}\right)\right]\hat{s}}$$

5.16

Two long coaxial solenoids each carry a current I, but in opposite directions, as shown in Fig 5.42. The inner solenoid (radius a) has n_1 turns per unit length, and the outer one (radius b) has n_2 turns per unit length. Find **B** in each of the three regions: (i) inside the inner solenoid, (ii) between them, and (iii) outside both.

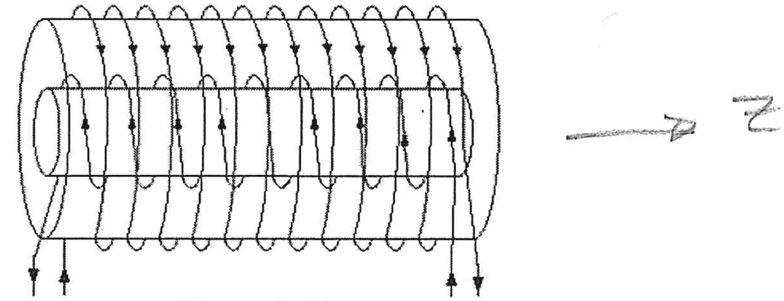


Figure 5.42

Use Super Position

The Field Inside a solenoid is $B = \mu_0 n I$

For the outer solenoid

$$\vec{B}_2 = \begin{cases} \mu_0 n_2 I \, \hat{z} & r < b \\ 0 & r > b \end{cases}$$

The RIGHT HAND RULE Gives the Direction

For THE inner solenoid

$$\vec{B}_1 = \begin{cases} -\mu_0 n_1 I \, \hat{z} & r < a \\ 0 & r > a \end{cases}$$

$$\vec{B} = \vec{B}_1 + \vec{B}_2$$

$$\vec{B} = \begin{cases} \mu_0 I (n_2 - n_1) \, \hat{z} & r < a \\ \mu_0 I n_2 \, \hat{z} & a < r < b \\ 0 & r > b \end{cases}$$