Chapter 27 Problem 22
An electron moves with velocity $\mathbf{v} = (7.0\mathbf{i} - 6.0\mathbf{j}) \times 10^4 \text{m/s}$ in a magnetic field $\mathbf{B} = (-0.80\mathbf{i} + 0.60\mathbf{j}) \text{T}$. Determine the magnitude and direction of the force on the electron.

Chapter 27 Problem 23
A 6.0-MeV (kinetic energy) proton enters a 0.20-T field, in a plane perpendicular to the field. What is the radius of its path? See Section 23-8.

Chapter 27 Problem 29
A particle with charge $q$ and momentum $p$, initially moving along the $x$ axis, enters a region where a uniform magnetic field $\mathbf{B} = B_0 \mathbf{k}$ extends over a width $x = l$ as shown in Fig. 27-45. The particle is deflected a distance $d$ in the $+y$ direction as it traverses the field. Determine (a) whether $q$ is positive or negative, and (b) the magnitude of its momentum $p$.

Chapter 27 Problem 39
A 15-loop circular coil 22 cm in diameter lies in the $xy$ plane. The current in each loop of the coil is 7.6 A clockwise, and an external magnetic field $\mathbf{B} = (0.55\mathbf{i} + 0.60\mathbf{j} - 0.65\mathbf{k}) \text{T}$ passes through the coil. Determine (a) the magnetic moment of the coil, $\mu$. (b) the torque on the coil due to the external magnetic field; (c) the potential energy $U$ of the coil in the field (take the same zero for $U$ as we did in our discussion of Fig. 27-22).
Chapter 28 Question 1
The magnetic field due to current in wires in your home can affect a compass. Discuss the problem in terms of currents, depending on whether they are ac or dc, and their distance away.

Solution
Alternating currents will have little effect on the compass needle, due to the rapid change of the direction of the current and of the magnetic field surrounding it. Direct currents will deflect a compass needle. The deflection depends on the magnitude and direction of the current and the distance from the current to the compass. The effect on the compass decreases with increasing distance from the wire.

Chapter 28 Question 3
Two insulated long wires carrying equal currents $I$ cross at right angles to each other. Describe the magnetic force one exerts on the other.

Solution
The magnetic forces exerted on one wire by the other try to align the wires. The net force on either wire is zero, but the net torque is not zero.

Chapter 28 Question 6
Write Ampère’s law for a path that surrounds both conductors in Fig. 28–10. (b) Repeat, assuming the lower current, $I_2$, is in the opposite direction ($I_2 = -2I_1$).

Solution

(a) Let $I_2 = I_1$. \[ \oint \mathbf{B} \cdot d\mathbf{l} = \mu_0 I_{\text{encl}} = \mu_0 (I_1 + I_2) = \mu_0 2I_1 \]

(b) Let $I_2 = -I_1$. \[ \oint \mathbf{B} \cdot d\mathbf{l} = \mu_0 I_{\text{encl}} = \mu_0 (I_1 - I_2) = 0 \]

Chapter 28 Question 10
Use the Biot-Savart law to show that the field of the current loop in Fig. 28–21 is correct as shown for points off the axis.

Solution
The Biot-Savart law states that the net field at a point in space is the vector sum of the field contributions due to each infinitesimal current element. As shown in Example 28-12, the magnetic field along the axis of a current loop is parallel to the axis because the perpendicular field contributions cancel. However, for points off the axis, the perpendicular contributions will not cancel. The net field for a point off the axis will be dominated by the current elements closest to it. For example, in Figure 28-21, the field lines inside the loop but below the axis curve downward, because these points in...
space are closer to the lower segment of the loop (where the current
goes into the page) than they are to the upper segment (where the
current comes out of the page).

Chapter 28 Problem 3
Determine the magnitude and direction of the force between two
parallel wires 25 m long and 4.0 cm apart, each carrying 35 A in the
same direction.

Chapter 28 Problem 18
A rectangular loop of wire is placed next to a straight wire, as shown
in Fig. 28-37. There is a current of 3.5 A in both wires. Determine
the magnitude and direction of the net force on the loop.

Chapter 28 Problem 21
Two long wires are oriented so that they are perpendicular to each
other. At their closest, they are 20.0 cm apart (Fig. 28-39). What is
the magnitude of the magnetic field at a point midway between them
if the top one carries a current of 20.0 A and the bottom one carries
12.0 A?

Chapter 28 Problem 27
A 2.5-mm-diameter copper wire carries a 33-A current (uniform
across its cross section). Determine the magnetic field: (a) at the
surface of the wire; (b) inside the wire, 0.50 mm below the surface;
(c) outside the wire 2.5 mm from the surface.
Chapter 28 Problem 34
A wire, in a plane, has the shape shown in Fig. 28–43, two arcs of a circle connected by radial lengths of wire. Determine $B$ at point C in terms of $R_1$, $R_2$, $\theta$ and the current $I$.

Chapter 28 Problem 41
A segment of wire of length $d$ carries a current $I$ as shown in Fig. 28–49. (a) Show that for points along the positive $x$ axis (the axis of the wire), such as point Q, the magnetic field $B$ is zero. (b) Determine a formula for the field at points along the $y$ axis, such as point P.
Challenge Problem

For part (a) you need only use the right-hand rule appropriately.

For a pole point

\[ |F| \]
\[ \theta \quad 90, \pi/2 \]

\[ |F_r| \]
\[ \theta \quad 90/11 \]
For the pivot point

The $|F_1|$ vs $\theta$ is always the same. Therefore we can actually solve part B. For any point between the pole $\rightarrow$ pivot point the plot should be something like.

$\phi = 90^\circ$
b) \[ F = l d \ell \times B \]

\[ |F| = |l d \ell| B \sin \theta \]

The force in the radial direction of the loop is counteracted by the tension due to the loop in both directions along the loop. This will cause the section to stretch.

We can equate the following:

\[ |F| = -2T = -\mu F_{\text{stretching}} \]

\[ = -(-k AD\ell) \quad \text{(From Hooke's Law)} \]

But for an arc segment \( d\ell = R d\phi \)

\[ \therefore AD\ell = R AD\phi \cdot R d\phi \]

But \( R AD\phi \) must be zero otherwise we are saying that \( d\phi \) is getting bigger. That is problematic because we are no longer looking at the same section of the loop.

\[ l d \ell B \sin \theta = k AD\ell \]

\[ = R d\phi B \sin \theta = k AD\phi \]

\[ \Rightarrow OR = \frac{IBR \sin \theta}{k} \]
c) The original circumference is
\[ C = \int_0^{2\pi} R \, d\phi = 2\pi R \]
The new circumference is
\[ C' = \int_0^{2\pi} (R + \Delta R) \, d\phi = 2\pi (R + \Delta R) \]
The change of circumference is
\[ \Delta C = C' - C = \int_0^{2\pi} (R + \Delta R) \, d\phi - \int_0^{2\pi} R \, d\phi \]
\[ = \int_0^{2\pi} \Delta R \, d\phi = \frac{EBR \sin \theta 2\pi}{\chi} \]
PHY 122, H W #8

Chapter 27, Problem 22

Given: \( \vec{V} = (8.0 \hat{i} - 6.0 \hat{j}) \times 10^4 \text{ m/s} \) for an electron
\( \vec{B} = (0.80 \hat{i} + 0.60 \hat{j}) \times 10^3 \text{ T} \)

1. \( \vec{E} = ? \) direction of \( \vec{E} = ? \)

Solution

\[
\vec{F} = q \vec{V} \times \vec{B} \\
= -1.6 \times 10^{-19} \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 7.0 & -6.0 & 0 \\ -0.80 & 0.60 & 0 \end{vmatrix} \times 10^4 \text{ m/s} \\
= - (67 - 77) \times 10^{-16} \text{ N} \times \hat{k} \\
= 1.6 \times 10^{-16} \text{ N} \times \hat{k}
\]
Chapter 27, Problem 2.3

Exactly like problem 19 from HW #7.

\[ R = 1.8 \text{ (m)} \]

\[ \frac{1}{2}mv^2 \Rightarrow v = \sqrt{\frac{2U}{m}} \]

And \[ qvB = F_B = \frac{mv^2}{R} = F_{\text{cent}} \]
Chapter 27, Problem 24

Given: charge \( q \), momentum \( \vec{P} = B_0 \vec{v} \)

Travels a distance \( L \) in the \( +x \) direction, and deflection \( d \).

Diagram:

\[ R - d \]

\[ R \]

\[ L \]

\[ B_0 \]

a) determine sign of change

b) Radius of curvature

Magnitude of Momentum
Solution

a) Using the right hand rule would result in showing the particle should move down. Therefore we must use the left hand rule. Therefore it must be a negatively charged particle.

b) From the triangles drawn we can use Pythagorean theorem to determine

\[(R - d)^2 + e^2 = R^2\]

\[\Rightarrow R^2 - d^2 - 2Rd e = R^2\]

\[\Rightarrow R = \frac{d^2 + e^2}{2d}\]

We also know that the magnetic force is equal to the centripetal force for a free particle in a uniform magnetic field

\[F_B = F_{cent} \Rightarrow qvB = \frac{mv^2}{R} = \frac{pR}{R} \quad (Recall \quad p = mv)\]

\[\Rightarrow p = qvBR\]

\[= qB \left( \frac{d^2 + e^2}{2d} \right)\]
Given \( N = 15 \); loop of diameter \( d = 22 \text{ cm} = 0.22 \text{ m} \) with \( I = 7.6 \text{ A} \) clockwise.

\[ B = (0.55 \hat{i} + 0.60 \hat{j} - 0.65 \hat{k}) \]

Determine (a) \( \vec{a} = ? \); (b) \( \tau = ? \); (c) \( U = ? \)

Solution

\[ \vec{a} = \frac{N I A}{\hat{A}} \]

a) \( \vec{a} = N I A \hat{A} = (15 \times 7.6 \hat{i} + 0.61 \hat{j} - \hat{k}) \)

\[ = -4.3 \hat{k} \text{ A m}^2 \]

(The direction of \( \vec{a} \) will be towards the \(-z\) direction because it is perpendicular to the plane of the loop (x-y plane) and \(-\hat{k}\) because it is clockwise)

b) \( \tau = \vec{a} \times \vec{B} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 0 & 0 & -4.3 \\ 0.55 & 0.60 & -0.65 \end{vmatrix} = i(2.6) - j(2.4) \text{ m N} \)

C) \( U = \vec{a} \cdot \vec{B} = -(4.3)(-0.65) = 2.8 \text{ J} \)

Only \( \hat{k} \) direction because nothing in \( \hat{i} \) or \( \hat{j} \) direction.
Chapter 28, Problem 3

Given: \( F_1 = ? \)  Direction of \( F_1 = \) both between two wires.
\( L = 2.5 \text{ m} \)  \( d = 0.04 \text{ m} \)  \( A = 35 \text{ A} \)
Both have current in the same direction

**Formulation**

The wires will create a magnetic field around them. The easiest way to visualize it is to use the right hand curl rule. Wrap your right hand around the wire with your thumb in the direction of the current. We see that to the right of wire our fingers point into away from us and to the left it is towards us. Now that we have determined the direction of the magnetic field using the regular right hand rule with the magnetic field from the first on the current from the first we see that the two wires will feel forces pulling them closer together.

It is attractive

**Solution**

\[
F_2 = F_2 = \frac{\mu_0}{2\pi} \frac{I_1 I_2 L}{d} = 0.15 \text{ N}
\]
\[
\left[ \frac{4 \times 10^{-7} \text{ T} \cdot \text{m}}{2\pi} \right] \left[ \frac{(25 \text{ A})(25 \text{ A})}{0.04 \text{ m}} \right] = [1 \text{ m A}] = \text{ N}
\]
Chapter 28 Problem 18

Formulation

Wire section 1 will be attracted to the long straight wire. Wire section 2 of 0 will have no resultant feel no net force since they are perpendicular to the magnetic field created by the long straight wire. Wire section 3 will be repelled by the long straight wire.

Solution

Net force will be

\[ F_{\text{net}} = F_0 - F_2 - \frac{\mu_0 I_1}{2\pi} \frac{\ell_0}{d_0^2} - \frac{\mu_0 I_1 I_2}{\ell_1} \frac{\ell_0}{d_0} \]

\[ = \frac{\mu_0 I_1}{2\pi} \left( \frac{\ell_0}{d_0} - \frac{\ell_0}{d_2} \right) = 5.1 \times 10^{-6} \text{ N upwards.} \]
Chapter 28 Problem 21

Given/Diagram

\[ I_I = 20.0 A \]

\[ I_B = 12.0 A \]

Formulation

The magnetic field due to \( I_I \) will point to the left from the right hand rule and the magnetic field due to \( I_B \) will point out of the page.

We can calculate the magnetic field by a superposition of Ampere's law as shown.

Solution

\[ \oint \mathbf{B} \cdot d\mathbf{l} = \mu_0 I_{\text{enclosed}} \]

\[ \Rightarrow B_I \cdot 2\pi r = \mu_0 I_I \Rightarrow B_I = \frac{\mu_0 I_I}{2\pi r} \text{ to the left.} \]

\[ \oint \mathbf{B} \cdot d\mathbf{l} = \mu_0 I_{\text{enclosed}} \]

\[ \Rightarrow B_B \cdot 2\pi r = \mu_0 I_B \Rightarrow B_B = \frac{\mu_0 I_B}{2\pi r} \text{ out of the page.} \]

\[ |\mathbf{B}| = \sqrt{B_I^2 + B_B^2} = 4.65 \times 10^{-5} T \]
Chapter 28 Problem 27

Given:
\[ d = 0.0025 \text{ m} \]
\[ I = 33 \text{ A} \]

Determine:

a) \[ \vec{B}(r = \frac{d}{2}) = ? \]

b) \[ \vec{B}(r = 0.0020 \text{ m}) = ? \]

c) \[ \vec{B}(r = 0.0050 \text{ m}) = ? \]

Solution:

**Amper's Law**

\[ \oint \vec{B} \cdot d\vec{l} = \mu_0 I_{\text{enclosed}} \]

\[ \Rightarrow \vec{B}(2\pi r) = \mu_0 \frac{I_{\text{Total}}}{A_{\text{Total}}} \]

General solution:

\[ \frac{\mu_0 I (\pi r^2)}{(\pi d^2/4)} \frac{1}{2\pi r} = \vec{B} \]

a) \[ r = \frac{d}{2} \]

\[ \vec{B} = \frac{\mu_0 I}{2\pi \frac{d}{2}} = 5.3 \times 10^{-3} \text{ T} \]

b) \[ r = 0.0020 \text{ m} \]

\[ \vec{B} = 3.2 \times 10^{-3} \text{ T} \]

c) \[ r = 0.0050 \text{ m} \]

\[ \vec{B} = 1.8 \times 10^{-3} \text{ T} \]
Chapter 28 Problem 34

Formulation

From Biot-Savart's law we know that \( d\vec{E} \times \vec{r} = 0 \)
for sections \( \Omega \neq \varnothing \).

For sections \( \varnothing \neq \varnothing \) we know that \( d\vec{B} \times \vec{r} = 0 \). From Biot-Savart's law \( \vec{B} = 0 \) from \( \varnothing \neq \varnothing \).

Consider a single curved arc

We realize that every possible arc segment \( d\vec{C} \) will have have the same \( \vec{r} \). Therefore \( d\vec{c} \times \vec{r} \) will always be out of the page (right hand rule).
Solution

\[ \theta = \frac{\mu_0 I}{4\pi} \int_0^\theta \frac{dl \cdot \frac{x_r}{R_1}}{R_1^2} + \frac{\mu_0 I}{4\pi} \int_0^\theta \frac{dl \cdot x_n}{R_2} \]

\[ = -\frac{\mu_0 I}{4\pi} \int_0^\theta \frac{R_d d\theta}{R_1^2} + \frac{\mu_0 I}{4\pi} \int_0^\theta \frac{R_d d\theta}{R_2} \]

Flip bounds of integration

\[ = \frac{\mu_0 I \theta}{4\pi} \left( \frac{1}{R_1} - \frac{1}{R_2} \right) \]
Chapter 28 Problem 1

Given

\[ \mathbf{B} = ? \]

\[ \mathbf{a} \]

\[ \mathbf{d} \]

Solution

a) at Q, \( \mathbf{B} = 0 \). From Biot-Savart's Law since \( d\mathbf{c} \parallel \mathbf{r} \), therefore \( d\mathbf{B} \times \mathbf{r} = 0 \).

b) \( \mathbf{B} = \frac{\mu_0 I}{4\pi} \int \frac{d\mathbf{c} \times \mathbf{r}}{r^2} \)

\[ d\mathbf{c} = dx(-\hat{x}) \]

\[ \hat{n} = \sin \theta \hat{y} + \cos(\theta)(-\hat{x}) = \frac{a}{\sqrt{a^2 + x^2}} \hat{y} - \frac{x}{\sqrt{a^2 + x^2}} \hat{x} \]

\[ d\mathbf{c} \times \mathbf{r} = \begin{vmatrix} \hat{x} & \hat{y} & \hat{z} \\ \frac{a}{\sqrt{a^2 + x^2}} & -\frac{x}{\sqrt{a^2 + x^2}} & 0 \\ \frac{-x}{\sqrt{a^2 + x^2}} & \frac{a}{\sqrt{a^2 + x^2}} & 0 \end{vmatrix} = \frac{-d(x)dx}{\sqrt{a^2 + x^2}} \hat{z} \]

\[ = \]
\[ \vec{B} = \frac{\mu_0 I}{4\pi} \left( \frac{-x}{\sqrt{x^2 + y^2}} \right) \left( \frac{-d}{\sqrt{a^2 + x^2}} \right) \]

\[ = \frac{\mu_0 I}{4\pi} \left[ \left( \frac{1}{\sqrt{a^2 + d^2}} \right) - \left( \frac{1}{\sqrt{a^2}} \right) \right]^{\frac{1}{2}} \]