PH 221 Homework Assignment Chapter on B Field – 25 Problems Total

1. A long straight wire is carrying a current which will create a magnetic field of strength $(B = 2.37 \text{ x } 10^{-4} \text{ T})$ when you are a distance $(d = 3.42 \text{ x } 10^{-2} \text{ m})$ from the wire. What is the magnitude of the current in the wire?

Solution for Problem 1

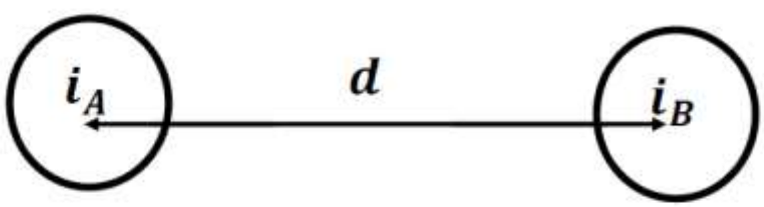
2. What is the force between two long straight wires carrying identical currents $(i_A = i_B = i = 47.2 \text{ A})$ but in opposite directions of each other. Assume each wire has length $(L_A = L_B = L = 56.9 \text{ m})$. The wires are separated by distance $(d = 1.23 \text{ x } 10^{-2} \text{ m})$.

Solution for Problem 2

3. A long straight wire is oriented vertically. A current $(i_A = 47.0 \text{ A})$ in wire A flows going from top to bottom of the wire. A short distance away $(d = 6.78 \text{ x } 10^{-2} \text{ m})$ there is a second wire B which is also vertical. Wire B experiences an attractive force per unit length of wire of $\left(F_{B\,A \to B} = 5.41 \text{ x } 10^{-3}\ {}^{\text{N}}\!/_{\text{m}}\right)$. What is the magnitude and direction of the current flowing in Wire B?

Solution for Problem 3

4. Two long straight wires are going in and out of the page as indicated in the picture below. The two wires are separated by a distance d. The wire on the left is Wire A and carries a current i_A while the wire on the right is Wire B and carries current i_B.



(a) Determine the magnitude and direction of the magnetic field at a point halfway between the two wires if the currents in both wires are directed into the paper.

(b) Determine the magnitude and direction of the magnetic field at a point halfway between the two wires if the current in wire A is into the paper while the current in wire B is out of the paper.

Solution for Problem 4

5. In a particular region, the horizontal component of the Earth's magnetic field is found to be

$$\overrightarrow{B_{E\ Hor}} = 5.00 \times 10^{-5}\ \mathrm{T}\ (\widehat{\mathrm{North}})$$

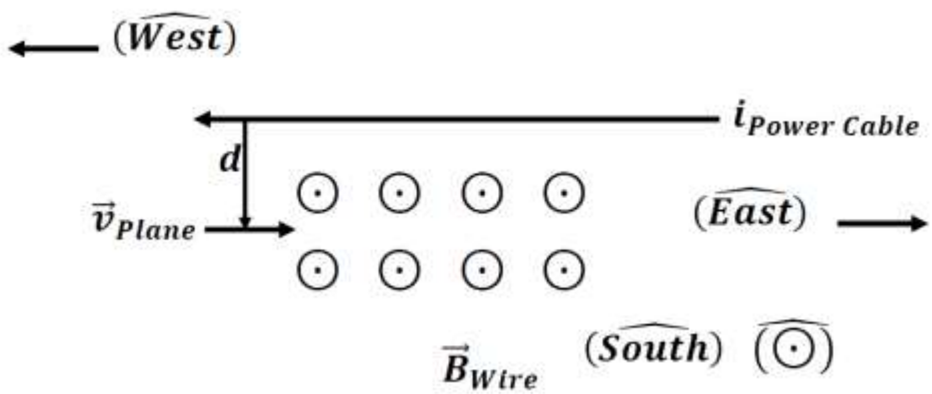
A power cable is carrying a current $\left(\mathrm{i} = 700.\ \mathrm{A}\ (\widehat{\mathrm{West}})\right)$ along utility poles where the cable sits $(\mathrm{h} = 55.9\ \mathrm{m})$ above the ground.

(a) What is the magnitude and direction of the magnetic field created by the power cable at the ground?

(b) At what distance from the wire, would the magnetic field created by power cable, exactly cancel the Earth's magnetic field?

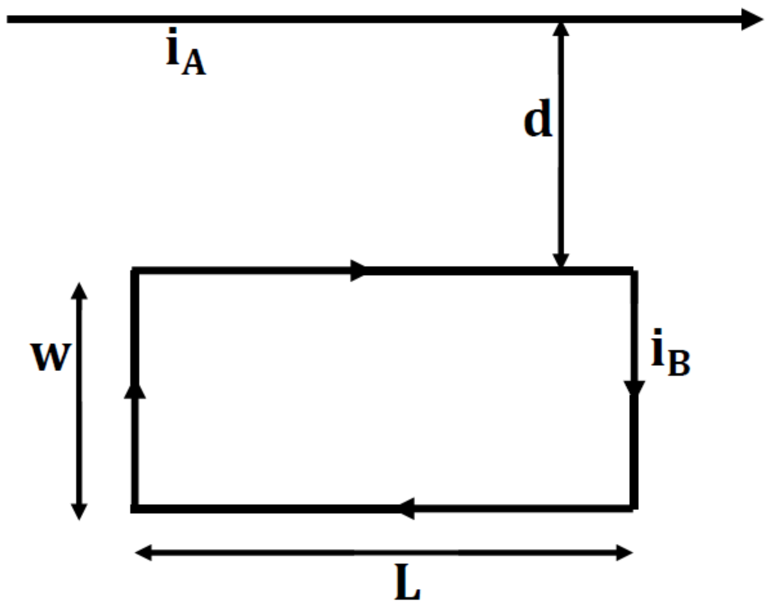
Solution for Problem 5

6. A radio-controlled model airplane $(\mathrm{m_{Plane}} = 0.256\ \mathrm{kg})$ is moving with a velocity $\left(\overrightarrow{\mathrm{v_{Plane}}} = 4.09\ {}^{\mathrm{m}}/{}_{\mathrm{s}}\ (\widehat{\mathrm{East}})\right)$. The airplane has a net charge $(270.\ \mathrm{mC})$ on it. A power wire is located a distance $(\mathrm{d} = 3.34\ \mathrm{m})$ directly above the flying plane. The wire is carrying a current $(\mathrm{i_{Wire}} = 65.8\ \mathrm{A})$ which is flowing in the Western direction. What is the magnitude and direction of the acceleration produced by the interaction between the plane and the magnetic field produced by the current in the wire?



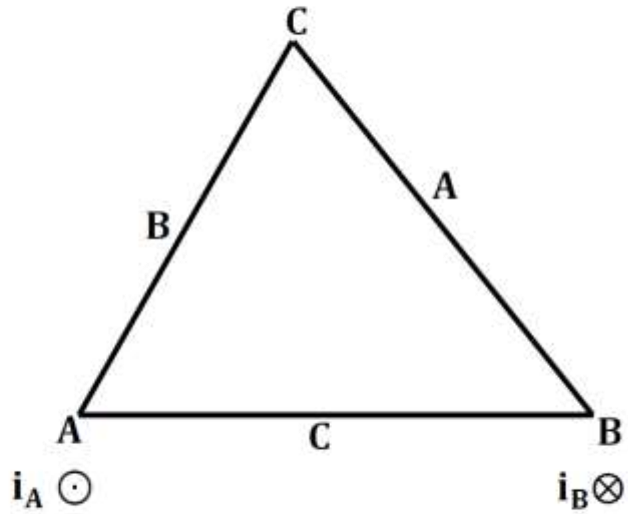
Solution for Problem 6

7. As shown below, there is a long straight wire A that has a current ($i_A = 6.77$ A) going to the right. A distance ($d = 5.47 \text{ x } 10^{-2}$ m) below the wire is a rectangular loop ($w = 4.32 \text{ x } 10^{-2}$ m and $L = 1.72 \text{ x } 10^{-1}$ m) which has a current ($i_B = 5.91$ A) which is going around the loop in a clockwise direction. What is the magnitude and direction of the net magnetic force acting on the loop due to the current in the long straight wire?



Solution for Problem 7

8. Two long straight wires are at the apexes of the triangle as shown below. At Apex A, the current is coming out of the page with a value $(i_A = 17.9\ A)$, while at Apex B, the current is going into the paper with a value $(i_B = 21.2\ A)$. The distance between the two wires is $(C = 8.20 \text{ x } 10^{-2}\ m)$. The other two distances shown in the diagram are $(B = 1.20 \text{ x } 10^{-1}\ m)$ and $(A = 1.30 \text{ x } 10^{-1}\ m)$. What is the magnitude and direction of the total magnetic field at Apex C due to the two currents?



Hint: You might find the Law of Cosines useful!

<u>**Solution for Problem 8**</u>

9. You wish to create a constant magnetic field of strength $(B = 4.45 \text{ x } 10^{-3}\ T)$. You decide to use a solenoid. You select one that has a length $(L = 0.500\ m)$ and a radius $(R = 0.0680\ m)$. You plan to hook up a power source which produces a current $(i = 12.5\ A)$. How many turns of wire will be needed?

<u>**Solution for Problem 9**</u>

10. A solenoid has a length $(L = 4.34 \text{ x } 10^{-1}\ m)$, a diameter $(D = 1.79 \text{ x } 10^{-2}\ m)$, 18,000 turns of wire about it, and it carries a current $(i = 3.46\ A)$. What is the strength of the magnetic field at the center of the solenoid?

<u>**Solution for Problem 10**</u>

11. A toroid has an inner diameter ($D_{inner} = 0.560$ m) and an outer diameter ($D_{outer} = 0.786$ m). The toroid is wrapped by its wire making 1024 coils. The current applied to the wire is 36.0 A.

(a) What is the largest magnetic field strength in the toroid?

(b) What is the smallest magnetic field strength in the toroid?

Solution for Problem 11

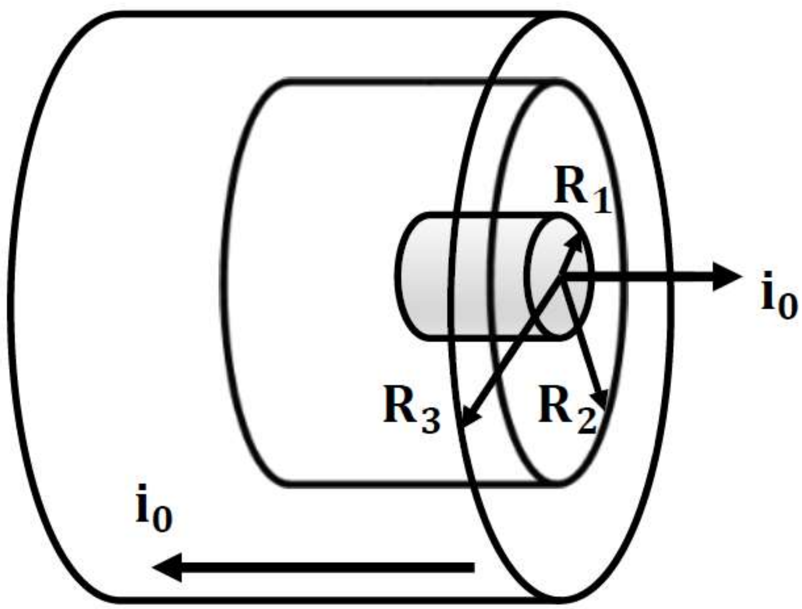
12. 10 Gauge copper wire has a diameter ($D_{Wire} = 2.588 \text{ x } 10^{-3}$ m). The wire is covered with an insulating film that prevents short circuits. It is wrapped tightly with adjacent coils touching into a single layer of coils forming a solenoid which has a diameter ($D_{Solenoid} = 4.65 \text{ x } 10^{-2}$ m). The copper wire has length ($L_{Wire} = 37.0$ m). A current ($i_{Wire} = 24.0$ A) is put into the wire.

(a) What is the length of the wrapped solenoid?

(b) What is the magnetic field strength at the center of the solenoid when the current is flowing in it?

Solution for Problem 12

13. A coaxial cable is made from a solid inner conductor of radius (R_1). Concentric to this conductor is a hollow cylindrical conductor which has inner radius (R_2) and outer radius (R_3). The inner conductor has a current (i_0) which goes in one direction, while the outer conductor has the same current going in the opposite direction. Assume these currents are uniformly distributed across the two conductors. This is pictured below.



(a) Determine the expression for the magnetic field created in the region: $0 \leq r \leq R_1$.

(b) Determine the expression for the magnetic field created in the region: $R_1 \leq r \leq R_2$.

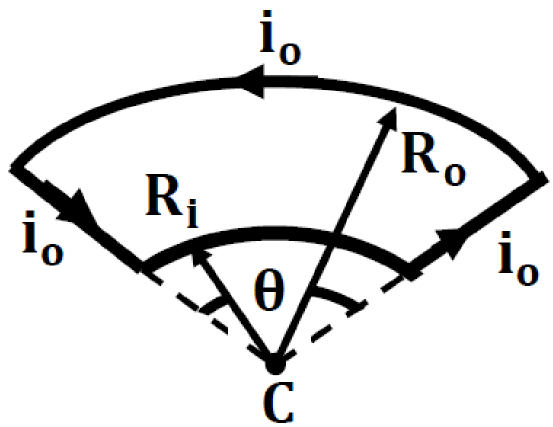
(c) Determine the expression for the magnetic field created in the region: $R_2 \leq r \leq R_3$.

(d) Determine the expression for the magnetic field created in the region: $R_3 \leq r \leq \infty$.

(e) Make a plot of Magnetic Field strength vs. radial distance for the region $0 \leq r \leq 7.00 \text{ x } 10^{-2}\text{m}$, if $i_0 = 3.00 \text{ A}$, $R_1 = 1.50 \text{ x } 10^{-2} \text{ m}$, $R_2 = 4.00 \text{ x } 10^{-2} \text{ m}$, and $R_3 = 6.00 \text{ x } 10^{-2} \text{ m}$.

Solution for Problem 13

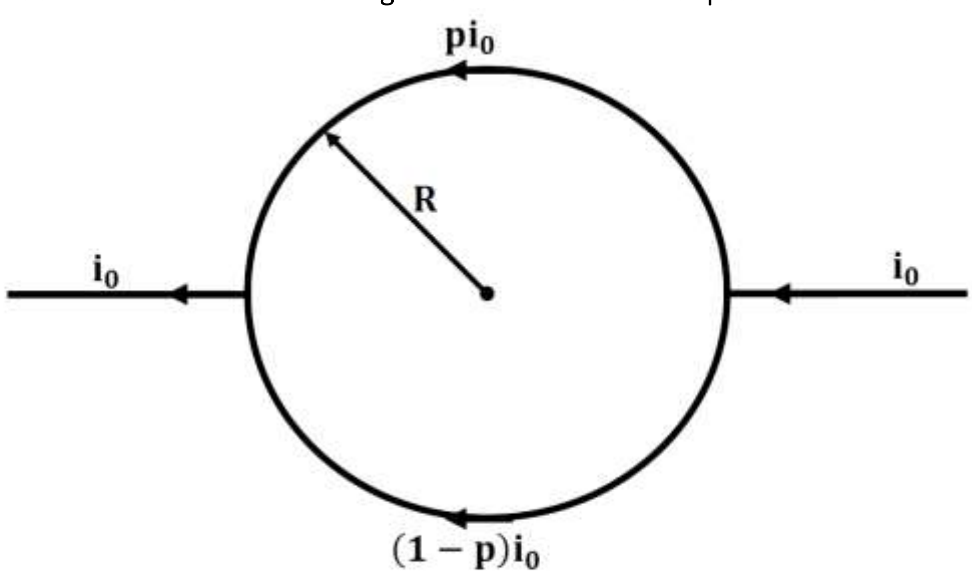
14. A wire loop is formed by two concentric circular arcs, one has a radius (R_o) while the second one has a radius (R_i) with $R_i < R_o$. The angle between the two side pieces of wire is (θ). A current (i_0) is going counter-clockwise. This is shown below:



What is the magnitude and direction of the magnetic field produced by this loop at point C the center of the circular pieces of wire?

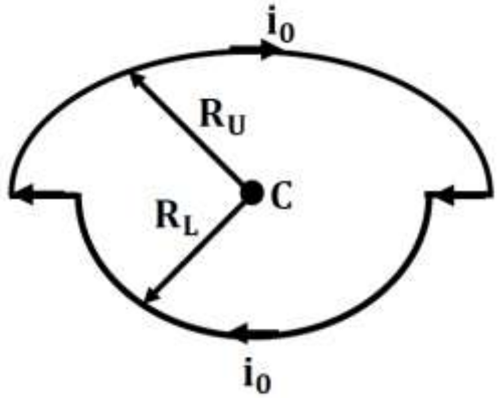
<u>**Solution for Problem 14**</u>

15. A circular loop of wire has a radius (R). As shown below a current (i_0) enters from the right and moves to the left. When it splits to around the circular loop, the resistance in the loop varies causing a fraction (pi_0) of the current to go around the top half of the circle, while the rest of the current $\left((1-p)i_0\right)$ goes around the bottom half of the circle. What is the magnitude and direction of the magnetic field at the center point of the circle?



<u>**Solution for Problem 15**</u>

16. As shown below, a wire loop is constructed with two semi-circles of different radii. The upper semicircle has a radius (R_U) while the lower one has a radius (R_L) with $R_L < R_U$. A current (i_0) flows clockwise around the loop as indicated.



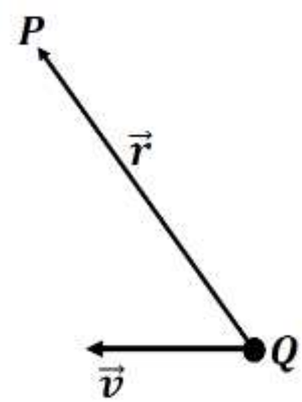
(a) Derive an expression for the magnitude and direction of the magnetic field created at the center of the Loop (C).

(b) Find an expression for the magnetic dipole moment of the loop.

<u>**Solution for Problem 16**</u>

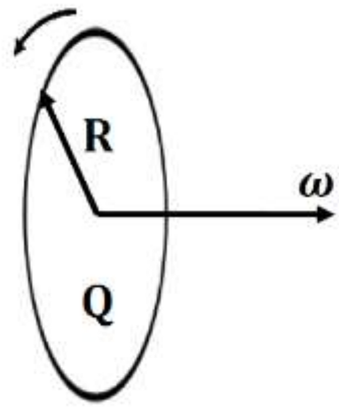
17. A single point charge (Q) is moving with a velocity $(\vec{v})$. Use the Biot-Savart law to show that the magnetic field created by this charge at a field point located by $(\vec{r})$ can be found by the expression:

$$\vec{B} = \frac{\mu_0}{4\pi}\frac{Q\vec{v}\ x\ \vec{r}}{r^3}$$



<u>**Solution for Problem 17**</u>

18. A non-conducting circular disk has a radius (R) , a charge (Q) which is uniformly distributed across the surface of the disk, and the disk is rotating about its center with an angular speed (ω).



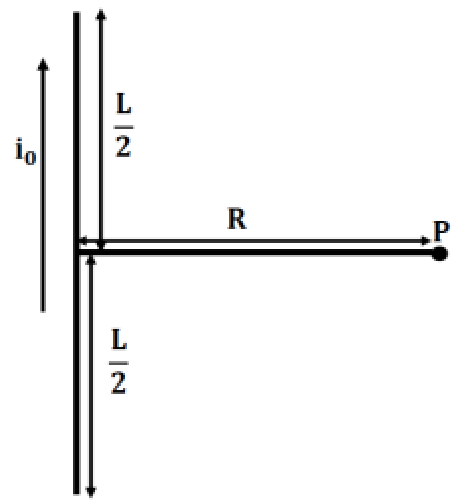
(a) Determine an expression for the magnetic dipole moment.

(b) Determine an expression for the magnetic field along the axis of rotation, a distance x from the center of the disk.

(c) What does this expression reduce to if the distance is much larger than the radius of the disk $(x \gg R)$?

<u>Solution for Problem 18</u>

19. Below there is a wire that has length (L) and carries current $(\mathrm{i_0})$. A field point P exists a distance (R) from the center of the wire.



(a) Determine an expression for the magnetic field at point P.

(b) How does this expression change if the length of the wire is extended to infinity?

Solution for Problem 19

20. A square loop of wire of side length (d) is carrying a current $(\mathrm{i_S})$. Find the magnetic field at the center of the square. Note: if the current is going counter-clockwise, the field would point out of the paper. If the current were going clockwise, the field would go into the paper.

Hint: review Homework Problem 19

Solution for Problem 20

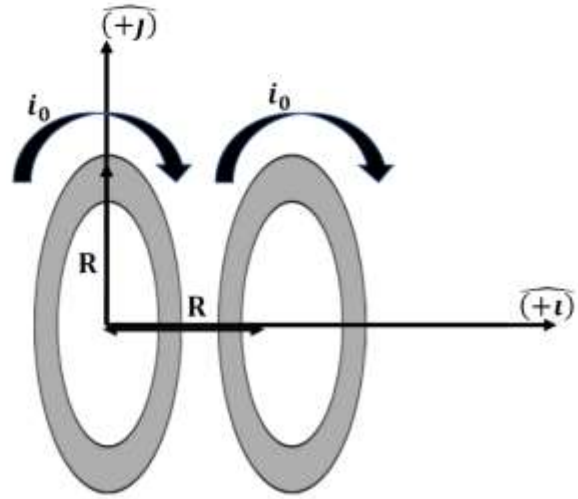
21. Homework Problem 20 found that the magnetic field at the center of a square loop of wire of side length (d) could be expressed as:

$$\mathrm{B_{Square}} = 2\sqrt{2}\left(\frac{\mu_0 \mathrm{i_0}}{\pi \mathrm{d}}\right)$$

If you reshaped the same length of wire into a circle, what would be the ratio of the two magnetic fields $\frac{\mathrm{B_{Circle}}}{\mathrm{B_{Square}}}$? Assume the current $(\mathrm{i_0})$ is the same.

Solution for Problem 21

22. When scientist want very uniform magnetic fields they often use a pair of Helmholtz coils which are pictured below. Helmholtz coils are a pair of identical coils each having (N) turns of wire, carrying current (i_0) going in the same direction in each coil, and both coils having the same radius (R). One coil is placed so that the center to center distance of the coils is equal to their radius The left coil is placed so that its center is at $(x = 0)$ and the second coil is placed at $(x = R)$.



(a) Find the magnitude and direction of the magnetic field at any point along the x – axis.

(b) In order to demonstrate that the magnetic field is uniform, find the first and second derivative of the magnetic field with respect to the x coordinate. Show that at the midway point between the coils $\frac{\partial B}{\partial x}\Big|_{x=\frac{R}{2}} = 0$ and $\frac{\partial^2 B}{\partial x^2}\Big|_{x=\frac{R}{2}} = 0$.

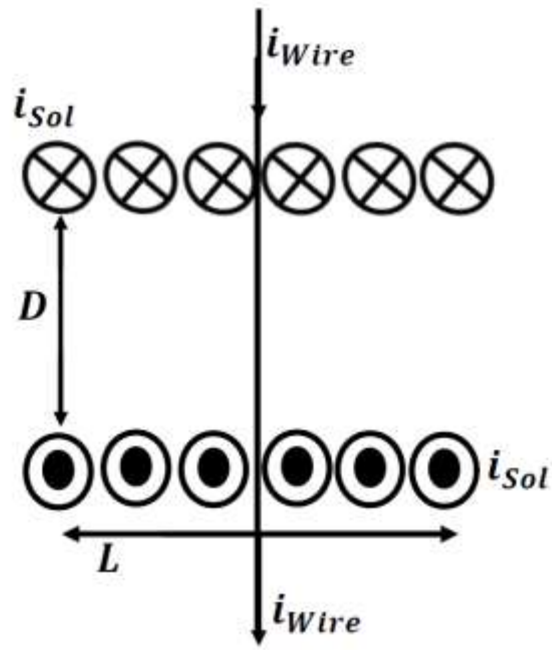
(c) Find the magnetic field at the point $\left(x = {}^{R}/_{2}\right)$ if $(N = 350)$, $(i_0 = 3.50\text{ A})$, and $(R = 0.150\text{ m})$

Solution for Problem 22

23. Near the Earth's North and South poles, the Earth's magnetic field has a strength of about 1.00×10^{-4} T. Using a simplistic (and incorrect model) that the field is created by a current loop around the Earth's equator. What would the strength of the current have to be?

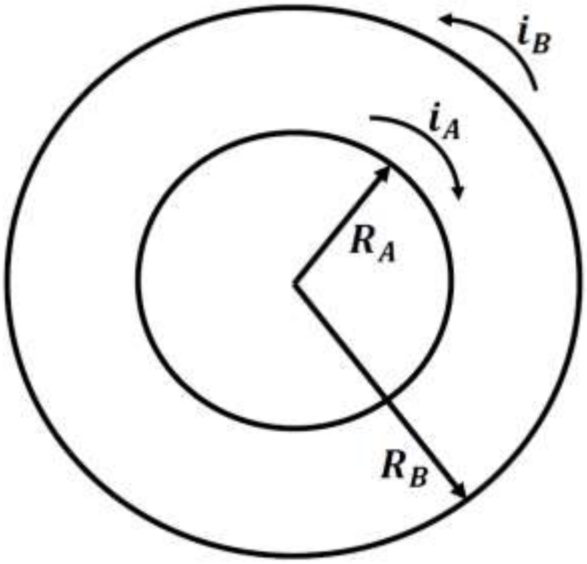
Solution for Problem 23

24. A solenoid has a diameter ($D_{Sol} = 4.24 \text{ x } 10^{-2}$ m), a length ($L_{Sol} = 0.250$ m), and carries a current ($i_{Sol} = 44.2$ A) through the coils ($N_{Sol} = 775$ Turns) surrounding the solenoid as shown below. The current is going into the paper on the top of the solenoid and out of the paper on the bottom of the solenoid. In the center of the solenoid a long straight wire has a current ($i_{Wire} = 37.9$ A) going down as shown below. What is the magnitude and direction of the magnetic force acting on the wire inside the solenoid?



Solution for Problem 24

25. Pictured below is a pair of solenoids that are concentric about the same center point. The inner solenoid has a radius (R_A), a length $(L_A = L_0)$, a number of coils (N_A) with a current $(i_A = i_0)$ which as shown is going clockwise. The outer solenoid has a radius (R_B), a length $(L_B = L)$, a number of coils (N_B) with a current $(i_B = i_0)$ which as shown is going counter-clockwise. The magnetic field in the inner solenoid goes in the opposite direction than the magnetic field in between the solenoids. If the ratio of the two magnetic fields $\frac{B_A - B_B}{B_B} = \frac{1}{3}$, what is the ratio of the number of turns of the solenoids $\frac{N_A}{N_B}$?



Solution for Problem 25

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