APPC, E & M: Unit C HW 4

Name: ______________________________
Hr: ___ Due at beg of hr on: __________

UC, HW4, P1

Reference Videos: (1) "Magnetic Field of One Current-Carrying Wire on Another"
(2) "Magnetic Field Due to a Toroid"
YouTube, lasseviren1, SOURCES OF MAGNETIC FIELDS playlist

FYI: This problem begins as a continuation of Parts E-I of UC, HW3, P5.

K. Write the equation for the ***B*** field magnitude at some radial distance r away from a wire carrying a current I. This was your answer to Part A of UC, HW3, P5.

L. Use your Part K answer and the info in the last figure of UC, HW3, P5 to write expressions for:

- the ***B*** field at Wire 2's location due to I_1 (call this $B_{2\ due\ to\ 1}$) $B_{2\ due\ to\ 1}$ =

- the ***B*** field at Wire 1's location due to I_2 (call this $B_{1\ due\ to\ 2}$) $B_{1\ due\ to\ 2}$ =

M. Now, write the equation for the magnetic force $\boldsymbol{F_B}$ on a wire of length L that lies within a magnetic field of magnitude B and carries a current I. For a hint, refer back to your answer to Part A of UC, HW1, P4.

N. Combine your answers to Parts L and M to write expressions for:

- the force on Wire 2 (which has length L) as a consequence of $B_{2\ due\ to\ 1}$ $F_{B\ on\ 2\ due\ to\ 1}$ =

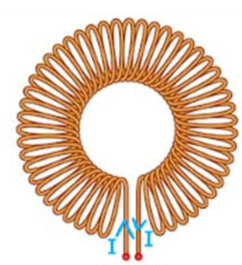
- the force on Wire 1 (which has length L) as a consequence of $B_{1\ due\ to\ 2}$ $F_{B\ on\ 1\ due\ to\ 2}$ =

O. From Part N…How do the magnitudes of the forces on the two wires compare?

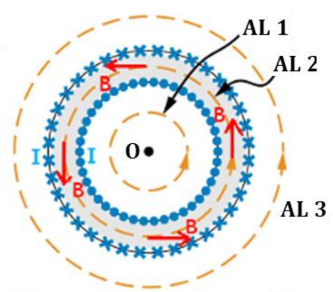
P. Whose law (and which number?) is demonstrated in your answers to Parts N and O?

Moving on to toroids…

These figures are a toroid and a sketch of the cross section of a toroid, as if it had been sliced like a bagel. Notice, on the cross section, that I is directed OUT OF the page in the inner windings and INTO the page in the outer windings. Assume there are N total windings (loops). <u>NOTE</u>: AL = Amperian loop.



Toroid



Toroid cross section, showing three Amperian loops

A. Refer to Ampere's law to state why the ***B*** field at the location of AL 1 is zero.

B. About AL 2... For N total loops, each carrying a current I, what is the total $I_{enclosed}$?

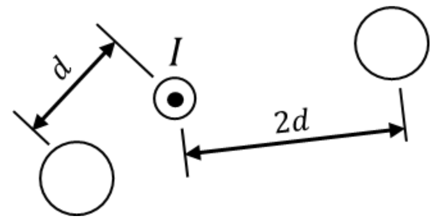
C. If AL 2 has a radius r, use Ampere's law to find the ***B*** field at that location.

D. Refer to Ampere's law to state why the ***B*** field at the location of AL 3 is zero.

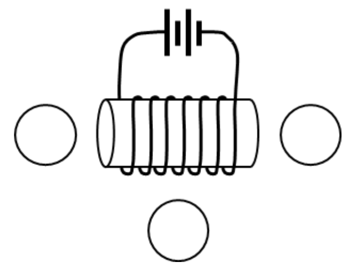
UC, HW4, P2

Reference Videos: (1) "Review of Unit on Sources of Magnetic Fields (Part I)"
(2) "Review of Unit on Sources of Magnetic Fields (Part II)"
YouTube, lasseviren1, SOURCES OF MAGNETIC FIELDS playlist

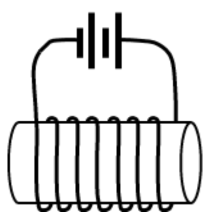
A. The figure shows a wire carrying a current I out of the page, and two nearby compasses. The distances between the wire and compasses are also shown. On the compasses, draw needles showing how the $\boldsymbol{B}$ field points, at that location. Also, next to each compass, write an expression for the magnitude of the $\boldsymbol{B}$ field there.



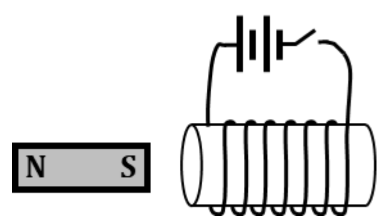
B. Draw needles on the three compasses to show the direction of the $\boldsymbol{B}$ field.



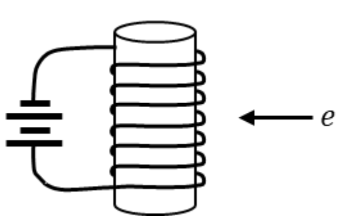
C. Label the ends of the iron bar with 'N' and 'S' to indicate the north and south poles.



D. The solenoid at right consists of a bar of iron wrapped with insulated wire. When the switch is closed and current begins to flow, the iron bar will become an ______________________________, and the small bar magnet shown will experience a force of… ATTRACTION REPULSION

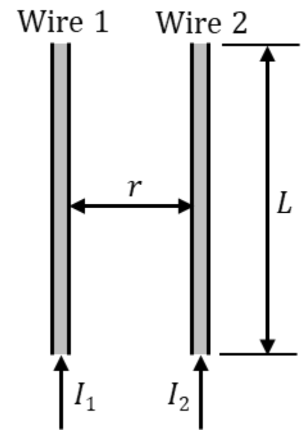


E. In which direction will the electron be pushed, as it approaches?

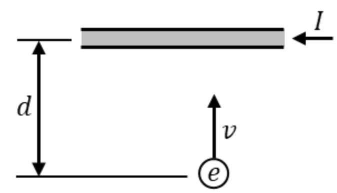


UC, HW4, P3

Reference Videos: (1) "Review of Unit on Sources of Magnetic Fields (Part I)"
(2) "Review of Unit on Sources of Magnetic Fields (Part II)"
YouTube, lasseviren1, SOURCES OF MAGNETIC FIELDS playlist

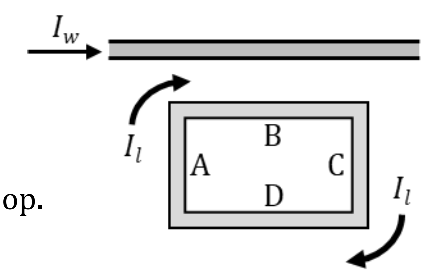


A. If I_1 = 2 A, I_2 = 3 A, r = 16 cm, and L = 38 cm, determine the magnitude and direction of the magnetic force on Wire 1. If you need a hint, refer back to Part N of UC, HW4, P1. Also, recall that $\mu_0 = 4\pi \times 10^{-7}$ T-m/A.



B. With reference to the figure at right, where the electron has a charge e:

- At the electron's location, in what direction is the ***B*** field pointing?
- In what direction will there be a force on the moving electron?
- At the instant shown, derive an expression for the magnitude of F_B on the electron.



The figure shows an overhead view of a straight, current-carrying wire; assume it is fixed to the surface on which it rests. Next to the straight wire is a loop, which sits freely on the frictionless surface. As shown, current flows clockwise around the loop, and the loops sides are labeled.

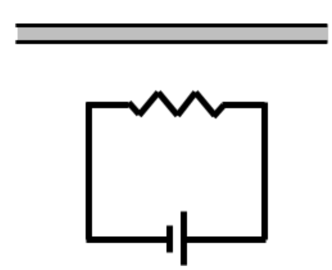
C. Below, draw arrows showing the direction of the F_B on each side of the loop.

i. A ii. B iii. C iv. D

D. How will the magnitudes of your answers to Parts Ci and Ciii compare?

E. How will the magnitudes of your answers to Parts Cii and Civ compare, and why? Explain.

F. Draw an arrow at right to show the direction the will loop accelerate.



Your work in Parts C-F should help you with this last question… In the figure, we wish for the circuit to hang, suspended motionless in midair, below the current-carrying wire.

G. In which direction must we run current through the straight wire?

TOWARD THE LEFT TOWARD THE RIGHT

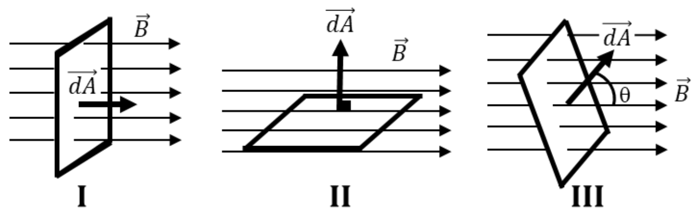
UC, HW4, P4
Reference Videos: (1) "Magnetic Flux"
(2) "Magnetic Flux (Part II)"
YouTube, lasseviren1, ELECTROMAGNETIC INDUCTION & FARADAY'S LAW playlist

A. Write the general equations for these three types of flux:

i. gravitational ii. electric iii. magnetic

B. What are two units that we could use for magnetic flux Φ_B?

The figures show three $\overrightarrow{dA}$ elements and the ***B*** field lines in the vicinity, which might (or might not) combine to yield a tiny magnetic flux $d\Phi_B$ through $\overrightarrow{dA}$.



C. Which diagram(s) show(s)…
(CIRCLE all correct answers)

i. (+) $d\Phi_B$? I II III none

ii. (−) $d\Phi_B$? I II III none

iii. zero $d\Phi_B$? I II III none

D. Briefly explain your answer to… Ci.

Cii.

Ciii.

E. For a closed surface, such as a sphere or cylinder, the $\overrightarrow{dA}$ elements point in what direction?

…and at what angle, relative to the surface?

F. Write out the Gauss's law equation for the following: (In Unit A, we used only the electrostatics one.)

i. gravity

ii. electrostatics

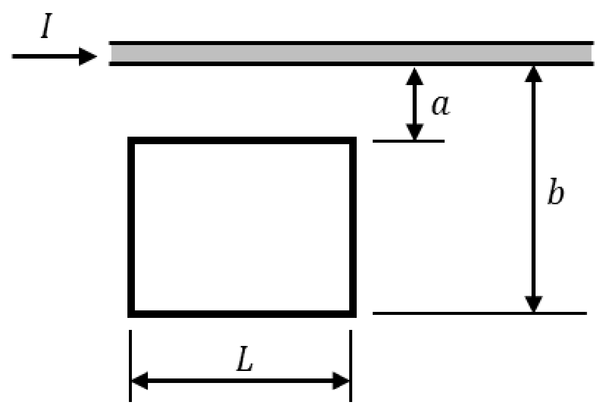
iii. magnetism

G. Let's review a bit: Gravitational field lines originate at infinity and terminate on ____________. Electric field lines originate on ____________________ and terminate on ____________________. Magnetic field lines do not originate or terminate anywhere; they can be visualized to be continuous __________. It is for this reason that the net magnetic flux Φ_B through any CLOSED, 3-D surface is always __________.

UC, HW4, P5

Reference Video: "Calculating the Magnetic Flux for a Non-uniform Magnetic Field"
YouTube, lasseviren1, ELECTROMAGNETIC INDUCTION & FARADAY'S LAW playlist

Here, you will derive an expression for the total magnetic flux Φ_B through a surface. With reference to the figure… The ***B*** field will be generated by the current I in the wire, and the flux Φ_B that you will calculate will be the Φ_B through the rectangular shape shown. NOTE: The rectangle need NOT be a conductor; there doesn't even have to be any material in that space, at all; it could be just a rectangle in empty space that we give boundaries to.



A. The expression that you derive will NOT be equal to zero. Why not? i.e., What must we have for the Φ_B to be zero? (For a hint, refer to your Part G answer from HW4, P4.)

B. Write the equation for the ***B*** field magnitude at some radial distance r away from a wire carrying a current I. This was your answer to Part K of HW4, P1.

C. Write the equation for magnetic flux Φ_B. This was your answer to Part Aiii of HW4, P4.

D. Rewrite your Part C answer, substituting in your Part B answer in the proper place.

You should have a $\overrightarrow{dA}$ in your Part D answer. In physics, any $\overrightarrow{dA}$ element (always!) represents an area over which the OTHER quantity (that we are multiplying by the $\overrightarrow{dA}$) is constant. Hopefully you see that, here, the $\overrightarrow{dA}$ element must be a VERY THIN STRIP within the rectangle. The $\overrightarrow{dA}$ strip will run parallel to the current-carrying wire; only in this way can the ***B*** field be constant for each part of the $\overrightarrow{dA}$ strip.

E. Into the figure, draw and label a $\overrightarrow{dA}$ element. Label its thickness as dr and show that it is a distance r away from the wire. Check now to make sure that this r appears in your answers to both Parts B and D.

It's time to solve what you wrote in Part D…

F. Into your Part D answer, substitute the dimensions of each $\overrightarrow{dA}$ element. Also, note in the figure at top that r will be going from $r = a$ to $r = b$, so be sure to include the proper integration limits on your answer here.

G. Solve and simplify your Part F answer, and there you have it: an expression for the total magnetic flux Φ_B through the surface shown.