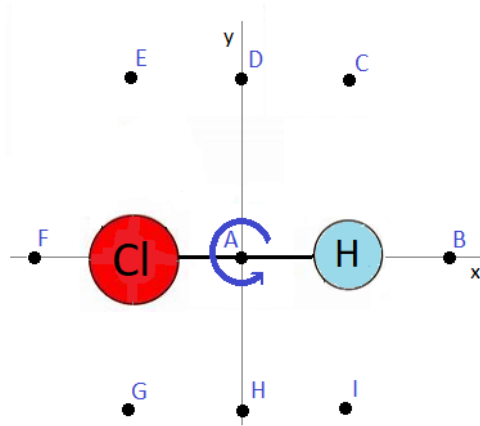


Homework 10: BF(ields)F

Due 6/6

Problem 1. Remember the HCl molecule? Recall it has a bond length of 127pm. Cl tends to 'borrow' H's electron, giving it an 'effective' charge of $-1e$, and leaving H with an 'effective' charge of $+1e$, where $e = 1.6 \times 10^{-19} \text{C}$. At room temperatures, it will rotate with a frequency of around $f = 10^{12} \text{Hz}$. Say it's rotating about the z axis with this frequency. Then,



- (a) Calculate the speed of each atom (remember PHY 141)?
- (b) Calculate the magnetic field at point A = (0pm,0pm).
- (c) Calculate the magnetic field at point B = (100pm,0pm).
- (d) Calculate the magnetic field at point C = (63.5pm, 100pm).
- (e) Calculate the magnetic field at point D = (0pm, 100pm).

(f) Calculate the magnetic field at point E = (-100pm, 63.5pm).

(g) Calculate the magnetic field at point F = (-100pm, 0pm).

(h) Calculate the magnetic field at point G = (-63.5pm, -100pm).

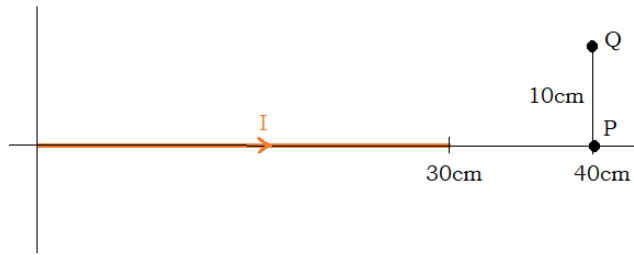
(i) Calculate the magnetic field at point H = (0pm, -100pm).

(j) Calculate the magnetic field at point I = (63.5pm, -100pm).

Problem 2. A lightning bolt carries a typical current of about 50kA. Approximating the current as following a straight line, infinitely long, what magnetic field would this current produce R = 100m away?



Problem 3. Consider the 30cm long wire segment carrying current $I = 5\text{A}$.

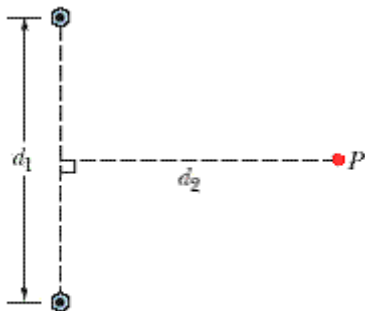


(a) What is the magnetic field at point P?

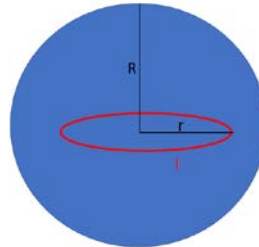
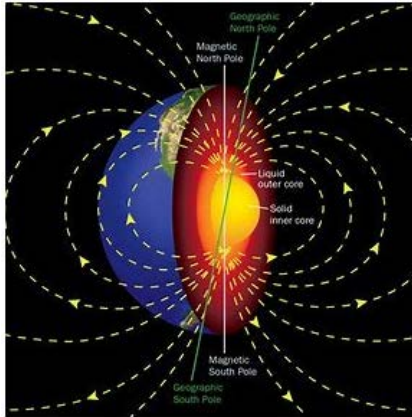
(b) What is the magnetic field at point Q?

(c) Where, generally do you think the field would be largest?

Problem 4. The figure below shows two very long straight wires (in cross section) that each carry a current of 5 A directly out of the page. Distance $d_1 = 3\text{m}$ and distance $d_2 = 5\text{m}$. What is the magnitude of the net magnetic field at point P, which lies on a perpendicular bisector to the wires?



Problem 5. Earth's magnetic field has a strength of around $50\mu\text{T}$ at the poles. And it is thought to be caused by currents circulating in the core. Approximate the current as a current loop of radius $r = 2500\text{km}$.

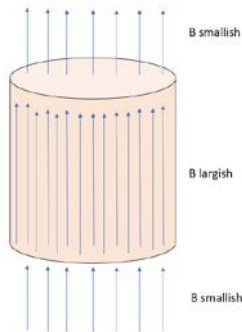


(a) which way would the current have to circulate, as viewed looking down, to create the field in the picture to the left?

(b) derive an expression for the magnetic field along the central axis of the current loop.

(c) use this expression to estimate the current, if the magnetic field is $50\mu\text{T}$ at the pole ($R = 6400\text{km}$)

Problem 6. Magnetic materials, like iron, will enhance the magnetic field that permeates them, resulting in the picture below. The picture is roughly true, but not exactly, as it violates Gauss's law. Why? And draw a Gaussian surface to substantiate your argument.



Problem 7. Consider a long hollow cylindrical wire carrying current $I = 4\text{A}$ to the right, uniformly distributed between the two radii $R_1 = 2\text{cm}$, and $R_2 = 5\text{cm}$.



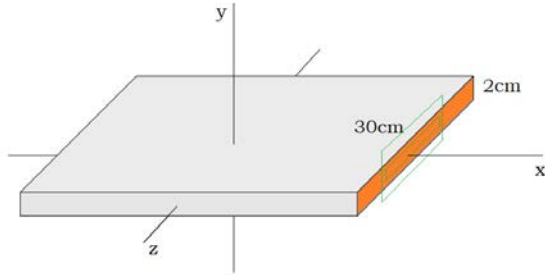
(a) The current density j , is defined to be the current flowing across some cross-section area, divided by that cross-section area. The units of j are A/m^2 . What is the current density here?

(b) Use Ampere's law and the inner green Amperian loop to derive a formula for the magnetic field for all radii $r < R_1$ in terms of r , μ_0 , and numbers.

(c) Use Ampere's law and the mid green Amperian loop to derive a formula for the magnetic field for all radii between R_1 and R_2 , in terms of r , μ_0 , and numbers.

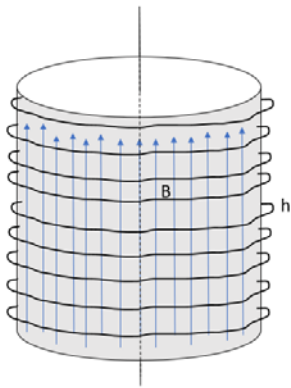
(d) Use Ampere's law and the outer green Amperian loop to derive a formula for the magnetic field for all radii $r > R_2$, in terms of r , μ_0 , and numbers.

Problem 8. Consider a really (fairly) wide sheet with width 30cm, and thickness 2cm. And suppose there is a current $I = 12\text{A}$ flowing through it from left to right (along the $+x$ direction). If the sheet is wide enough, then the magnetic field will point purely within the x - z plane both above and below the sheet.



- (a) What is the current density, j , flowing through the sheet?
- (b) What, specifically, is the direction of the field for $y > 0$. What, specifically, is the direction of the field for $y < 0$?
- (c) Use Ampere's law, and the inner Amperian loop, to derive a formula for the magnetic field at all heights y within the sheet in terms of y , μ_0 , and numbers.
- (d) Use Ampere's law, and the outer Amperian loop to derive a formula for the magnetic field at all heights y above the sheet in terms of y , μ_0 , and numbers.

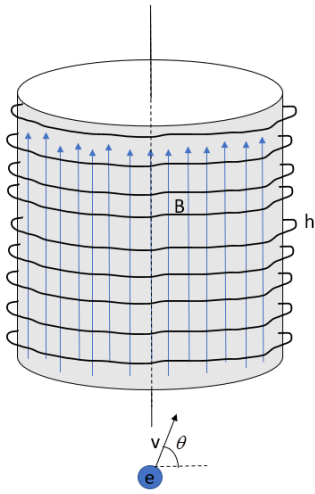
Problem 9. Say you wrap a wire 500 times round an $h = 20\text{cm}$ tall cylinder. And suppose the wire carries current $I = 2\text{A}$.



(a) What is the magnetic field within the cylinder?

(b) Which way is the current circulating, as viewed from the top?

Problem 10. Say the magnetic field in the problem above was 5mT, and h was 5m. And an electron enters the solenoid with velocity $v = 5 \times 10^7 \text{ m/s}$, at angle $\theta = 65^\circ$.



(a) Which way, as viewed from top looking down, will the electron circulate around the field lines? And draw the path as best you can.

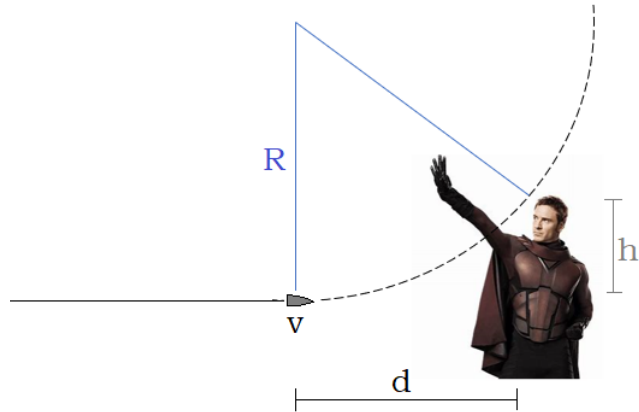
(b) What is the electron's orbital radius?

(c) What will be the orbital period of the electron?

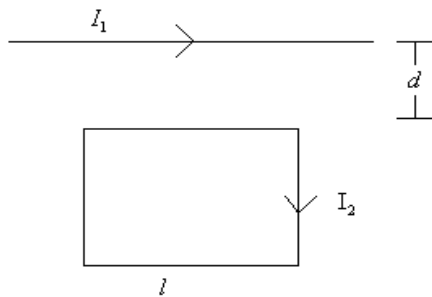
(d) How long until the electron exits the solenoid?

(e) How many loops will it complete before it exits?

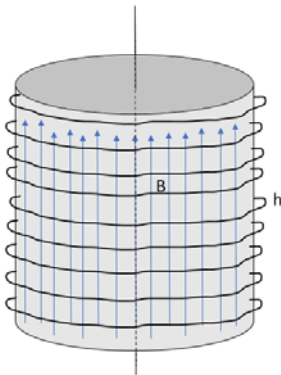
Problem 11. Suppose you're Magneto and you create a magnetic field to deflect a bullet traveling with speed $v = 500\text{m/s}$, and charge $q = 2\text{pC}$. Give the magnitude and direction of the magnetic field you must create if you must deflect the bullet by $h = 40\text{cm}$, when it's $d = 50\text{m}$ away? Let mass of bullet be $m = 10\text{g}$. And I've drawn the radius of the circle it'll partially execute, for your convenience.



Problem 12. Consider the two wires below. What is the net force the long straight wire exerts on the square current loop (with side length ℓ), and in what direction does it point? Let $I_1 = 4\text{A}$, $I_2 = 6\text{A}$, $d = 10\text{cm}$, and $\ell = 5\text{cm}$.



Problem 13. Going back to the solenoid in a previous problem, let's say the wire is wrapped 500 times round the $h = 20\text{cm}$ tall cylinder, with diameter $d = 10\text{cm}$, and carries a 2A current.



(a) What is the magnetic potential energy in the solenoid?

(b) Now say we have an iron core with the same dimensions as the solenoid, and with magnetic susceptibility $\chi_m = (\text{pretty like it}) 1999$. Will the core be attracted to the solenoid, or repelled?

(c) Now it's placed inside the solenoid. What is the magnetic field inside the solenoid now?

(d) What is the magnetic potential energy in the solenoid now?

(e) Heck, why stop now. Let's say we try to insert a perfect diamagnet, like a superconductor, with the same dimensions as the iron core, and susceptibility $\chi_m = -1$. Would it be attracted to or repelled by the solenoid?

(f) Now say we place it inside the solenoid, what would be the magnetic field inside the solenoid now?

(g) What is the magnetic potential energy in the solenoid now?