Exercise 1. Magnetic Field of a Gold Nucleus I

Suppose that a gold nucleus, Au^{79+}, with a mass of 197 [amu] is traveling at a uniform velocity of 1000 [km/s] $\hat{x}$ passes the origin at $t = 0$. What is the magnetic field at the origin as a function of time? Hint: $e = 1.602 \times 10^{-19}$ [C], 1 [amu] = 1.66×10^{-27} [kg].

(a) 0 [μT]*

(b) 0.63 [μT] $\hat{z}$

(c) 1.27 [μT] $\hat{z}$

(d) -0.63 [μT] $\hat{z}$

(e) -1.27 [μT] $\hat{z}$

(f) Cannot be determined from the information given.

Exercise 2. Magnetic Field of a Gold Nucleus II

Suppose that a gold nucleus, Au^{79+}, with a mass of 197 [amu] is traveling at a uniform velocity of 1000 [km/s] $\hat{x}$ passes the origin at $t = 0$. What is the magnetic field at a point $y = 1$ [μm] above origin at $t = 0$?

(a) 0 [μT]*

(b) 0.63 [μT] $\hat{z}$

(c) 1.27 [μT] $\hat{z}$

(d) -0.63 [μT] $\hat{z}$

(e) -1.27 [μT] $\hat{z}$

(f) Cannot be determined from the information given.

Exercise 3. Magnetic Field of a Gold Nucleus III

Suppose that a gold nucleus, Au^{79+}, with a mass of 197 [amu] is traveling at a uniform velocity of 1000 [km/s] $\hat{x}$ passes the origin at $t = 0$. What is the magnetic field at a point $y = 1$ [μm] above origin at $t = 1$ [ps]?

(a) 0 [μT]*

(b) 0.63 [μT] $\hat{z}$

(c) 1.27 [μT] $\hat{z}$

(d) -0.63 [μT] $\hat{z}$

(e) -1.27 [μT] $\hat{z}$

(f) Cannot be determined from the information given.

Exercise 4. Two Cables I

Suppose that two long thin straight cables carry currents I and $-I$ and are parallel to each other with separation s. Assume that the charge carriers move at a velocity v. (a) Describe where the electric field is zero. (b) Describe where the magnetic field is zero. Note: Gauss's Law and Ampere's Law don't help too much in integral form because this problem doesn't have high enough symmetry.

Exercise 5. Two Cables II

Suppose that two long thin straight cables carry currents I and $-I$ and are parallel to each other with separation s. Assume that the charge carriers move at a velocity v. What is the force between the cables? Hint: $F/L = \mu_0 I I'/2\pi s$.

Exercise 6. Current Loop

In what way could a current loop be realistic? Consider the existence of non-classical materials such as superconductors, and how classical current loops must have leads that go in and out. How does this alter the field created by the current loop?

Exercise 7. Ampere's Law vs Gauss's Law

(a) Write Ampere's Law and Gauss's Law in integral form. (b) How are the integrals in (a) different? (c) Maxwell's equations in differential form are $\nabla \cdot E = \rho/\epsilon_0$ and $\nabla \times B = \mu_0 I + (1/c^2)\partial E/\partial t$. One of the "Laws" you wrote down in (a) is likely incorrect. Fix it. Hint: $\int_A dA\, \partial E/\partial t = \partial \Phi_E/\partial t$.

Exercise 8. Ampere's Law

Suppose that the magnetic field at the perimeter of a circle of radius r has a field strength $|B|\hat{\theta}$ and $d\ell = r d\theta \hat{\theta}$. What is the enclosed current?

Exercise 9. Neodymium Magnets

Suppose that a neodymium magnet $Nd_2Fe_{14}B$, has a magnetization of 2.58×10^6 [A/m]. What is the magnetic field inside a 1 inch cube of this material if $\mu_r = 1.05\mu_0$? How is this different for a 2 inch cube? Hint: $\mu_{\text{total}} = MV$, and $B \approx \mu_r \mu_{\text{total}}/(2\pi V)$. Hint: 1 inch is 2.54 [cm].

Exercise 10. Meissner Effect

Suppose that a magnet is suspended over a superconductor connected to a current force. Supposing that the magnet is a perfect dipole with moment μ, mass M, it can then be shown that the force the superconductor exerts on the magnet is:

$$F = \frac{3\mu_0 \mu^2}{2\pi z^4}$$

(a) What is the equilibrium height of the magnet?

(b) Is this equilibrium height stable or unstable?