

PHYS 1220, Engineering Physics, Chapter 28 – Sources of Magnetic Field

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Goal of this chapter is to learn the how to calculate the magnetic field generated by moving charge or current

- Magnetic field, \vec{B} , could be produced by a moving charge or electric current.

- $\vec{B} = \frac{\mu_0}{4\pi} \frac{q\vec{v} \times \hat{r}}{r^2}$ (magnetic field from a moving charge)
- $d\vec{B} = \frac{\mu_0}{4\pi} \frac{I d\vec{l} \times \hat{r}}{r^2}$ (magnetic field from a section of current)
- $\mu_0 = 4\pi \times 10^{-7} T \cdot m / A$

You Do Example 28.1 on page 925.

I Do Exercise 28.9, and 28.13 on page 950.

- Starting with $d\vec{B} = \frac{\mu_0}{4\pi} \frac{I d\vec{l} \times \hat{r}}{r^2}$, we can calculate magnetic field produced by a long section of current by using integral. **(Please try to integrate by your own at least once. If you do integration enough times, you will realize that you don't need to memorize the following equations since you know you could do the integration in a very short time.)**

- Magnetic field produced by a long straight current-carrying wire: $|\vec{B}| = \frac{\mu_0 I}{2\pi r}$
- Magnetic field produced by a circular current loop: $\vec{B} = \frac{\mu_0 I a^2}{2(x^2 + a^2)^{3/2}} \hat{i}$ (on the axis of a circular loop who axis is aligned along \hat{i})
- Magnetic field produced by a circular current coil with N loops:
$$\vec{B} = \frac{\mu_0 N I a^2}{2(x^2 + a^2)^{3/2}} \hat{i}$$
- Magnetic field produced by a circular current coil with N loops at the center of the coil ($x = 0$): $\vec{B} = \frac{\mu_0 N I}{2a} \hat{i}$

- When two current-carrying wires are nearby and parallel to each other, they will feel magnetic force. (One current will produce magnetic field near it, then the second current-carrying wire will feel a magnetic force due to $\vec{F}_m = I \vec{l} \times \vec{B}$, and vice versa).

- Ampere's Law is using an imaginary Ampere's loop to calculate the magnetic field, \vec{B} , that you are interested. (similar to Gauss's Law is using an imaginary Gauss's

surface to calculate the electric field, \vec{E} , that you are interested).

- $\oint \vec{B} \cdot d\vec{l} = \mu_0 I_{encl}$
- Try: long straight current-carrying wire. (Example 28.7)
- Solenoid (Example 28.9)
- Toroidal Solenoid (Example 28.10)

- Magnetic Materials:

- Materials are made of atoms, which contain charged particles (electrons and protons). Electrons are moving around the nuclei, which give out magnetic dipole moment (remember, the magnetic dipole moment of a loop current I with area A is: $\vec{\mu} = I \vec{A}$). When materials are placed in magnetic field, the magnetic dipole moments in the materials will be re-arranged or changed and change the magnetic field around it.
- Very similar to dielectric materials (with dielectric constant, K) placed in electric field, \vec{E} . (Recall that: in capacitor with dielectric materials, the electric field is reduced due to the dielectric materials by a factor of K , the dielectric constant)
- When a material is placed in magnetic field, the total magnetic field will increase by a factor of K_m , **relative permeability**, which is related to the **permeability**, μ , of the materials as: $\mu = K_m \mu_0$.
- If the material has $K_m > 1$, it is categorized as “**paramagnetic**” materials. When placed in magnetic field, it will **increase** the total magnetic field.
- If the material has $K_m < 1$, it is categorized as “**diamagnetic**” materials. When placed in magnetic field, it will **decrease** the total magnetic field.
- Both paramagnetic and diamagnetic materials lost their magnetic dipole moment when the external magnetic field is removed.
- If the material has residual magnetic dipole moment even after the external magnetic field is removed, it is categorized as “**ferromagnetic**” material. These materials could be used for making permanent magnet.

Math Preview for Chapter 29:

- Vector integration

Questions to think about for Chapter 29:

- We learned that a current-carrying loop placed in a magnetic field will feel a magnetic torque. If we rotate a zero current loop in a magnetic field, could we generate current?