Ch. 20-21 Notes

John Yang

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20 Magnetic Forces and the Magnetic Field

20.1 The Magnetic Field

- The end of a compass needle that points generally in a northerly direction at most places on earth is defined to be the North magnetic pole of the compass needle
- The opposite end is defined to be its south pole.
- Magnets always occur in dipoles. If you break a permanent magnet in half you get two magnets.
- Like poles repel and unlike poles attract
- Force on a charged particle moving through a uniform field:

$$\vec{F}_{\text{magnet on q}} = q\vec{v} \times \vec{B}$$

- Magnetic field $\vec{B}$ is in Teslas (T)
- Use the pointing rhr for positive charges, where the index finger is the velocity, the thumb is the force, and the other fingers are the field. The left hand can be used for negative charges but do not get confused!

20.2 Applications

- Velocity selectors; charged particles are shot through perpendicular electric and magnetic fields; only those with a certain velocity make it through without being deflected due to imbalanced forces, given by $v_0 = \dfrac{E}{B}$
- Mass spectrometers: A charged particle is shot into a region of a uniform magnetic field at a known velocity. The semicircular radius it makes before hitting a plate depends on its mass and is given by $R = \dfrac{mv}{|q|B}$
  - Can be used to separate a compound into its constituent ions to find its composition.
- Hall effect: charges moving through a magnetic field experience a force, but moving magnetic fields can also induce a current. Using semiconductors, the Hall effect can be used to measure the proximity of a moving magnet by measuring the way charges move in a semiconductor in response to the change in magnetic field.

20.3 Magnetic Forces on Currents

- Magnetic force on a current-carrying wire:

$$\vec{F}_{\text{magnet}} = I \int_{\text{wire}} d\vec{\ell} \times \vec{B}$$

20.4 Work Done by Magnetic Forces

- Work done by magnetic forces is always 0 because it is perpendicular to the motion of the charge.

20.5 Torque on a Current Loop in a Magnetic Field

- Magnetic dipole moment:

$$\vec{\mu} \equiv I\vec{A}$$

where $\vec{A}$ is the area vector.

- Torque on a current loop inside a uniform magnetic field:

$$\vec{\tau} = \vec{\mu} \times \vec{B} = I\vec{A} \times \vec{B}$$

- The current loop inside the magnetic field executes simple harmonic motion.

20.6 The Biot-Savart Law

- To find the magnetic field caused by the entire wire,

$$\vec{B} = \frac{\mu_0}{4\pi} I \int_{\text{wire}} \frac{d\vec{\ell} \times \vec{r}}{r^2}$$

- Some commonly used magnetic fields:

– At the center of a circular loop of radius R

$$\vec{B}_{\text{center}} = \frac{\mu_0}{4\pi}\frac{2\pi I}{R}\hat{k}$$

– On the axis of a circular current loop

$$\vec{B}_{axis} = \frac{\mu_0}{4\pi}\frac{I(2\pi R)^2}{(R^2+z^2)^{3/2}}\hat{k}$$

– For a circular coil of n loops, all of the same radius, multiply the preceding results by n

– A distance d from an infinite wire

$$B = \frac{\mu_0}{4\pi}\frac{2I}{d}$$

use grabbing rhr for direction

– Inside a long solenoid having n turns per meter of its length, each carrying current I, far from its ends

$$B = \mu_0 n I$$

20.7 Forces of Parallel Currents on Each Other and the definition of the Ampere

- Forces on parallel wires - attractive if currents in the same direction, repulsive if currents are antiparallel

- Two infinitely long parallel straight current carrying wires exert forces on a length ℓ of either wire of magnitude

$$F = \frac{\mu_0}{4\pi}\frac{2I_1I_2}{d}\ell$$

20.8 Gauss' Law for the Magnetic Field

- The flux of the magnetic field through any closed surface must always be zero:

$$\int_{\text{clsd surf}} \vec{B}\cdot d\vec{S} = 0\ \mathrm{T}\cdot\mathrm{m}^2$$

20.9 Magnetic Poles and current loops

- Magnetic field forms closed loops in accordance with Gauss's law for magnetic field

- Field lines come out of the north pole and enter into the south pole

20.10 Ampere's Law

- Ampere's law is:

$$\int_{\text{clsd path}} \vec{B}\cdot d\ell = \mu_0 I$$

20.11 The Displacement Current and the Ampere-Maxwell Law

- Displacement current - current due to changing electric flux, where

$$I_D \equiv \epsilon_0 \frac{d\Phi_{\text{elec}}}{dt}$$

- Ampere-Maxwell law - right side of Ampere's law should include both displacement and conduction currents:

$$\int_{\text{clsd path}} \vec{B}\cdot d\vec{r} = \mu_0(I+I_D)_{\text{threading the path}}$$

- Makwell realized that magnetic fields are produced by:
  – Electric charges in motion (conduction current)
  – Time-varying electric fields (displacement current)

- The magnetic field induced by the displacement current is perpendicular to the (changing) electric field that causes it

20.12 Magnetic Materials

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20.13 The Magnetic Field of the Earth

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21 Faraday's Law of Electromagnetic Induction

21.1 Faraday's Law of Electromagnetic Induction

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21.2 Lenz's Law

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21.3 An ac generator

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21.4 Summary of the Maxwell Equations of Electromagnetism

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21.5 Electromagnetic Waves

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21.6 Self-Inductance

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21.7 Series and Parallel Combinations of Inductors

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21.8 A Series LR Circuit

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21.9 Energy stored in a magnetic field

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21.10 A Parallel LC Circuit

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21.11 Mutual Inductance

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21.12 An Ideal Transformer

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