Applied Physics

BS Software Engineering/Information Technology

1st Semester

Lecture # 22

Magnetic Fields Due to Currents

Presented By

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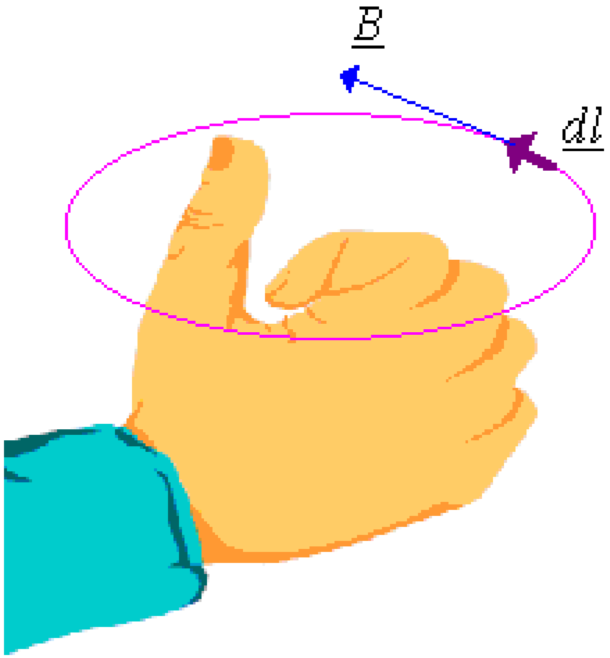
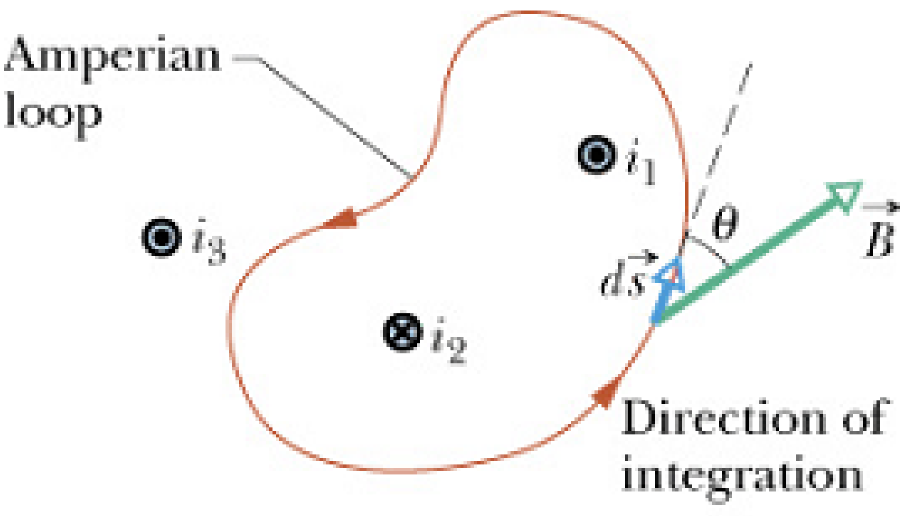
Lecture # 22

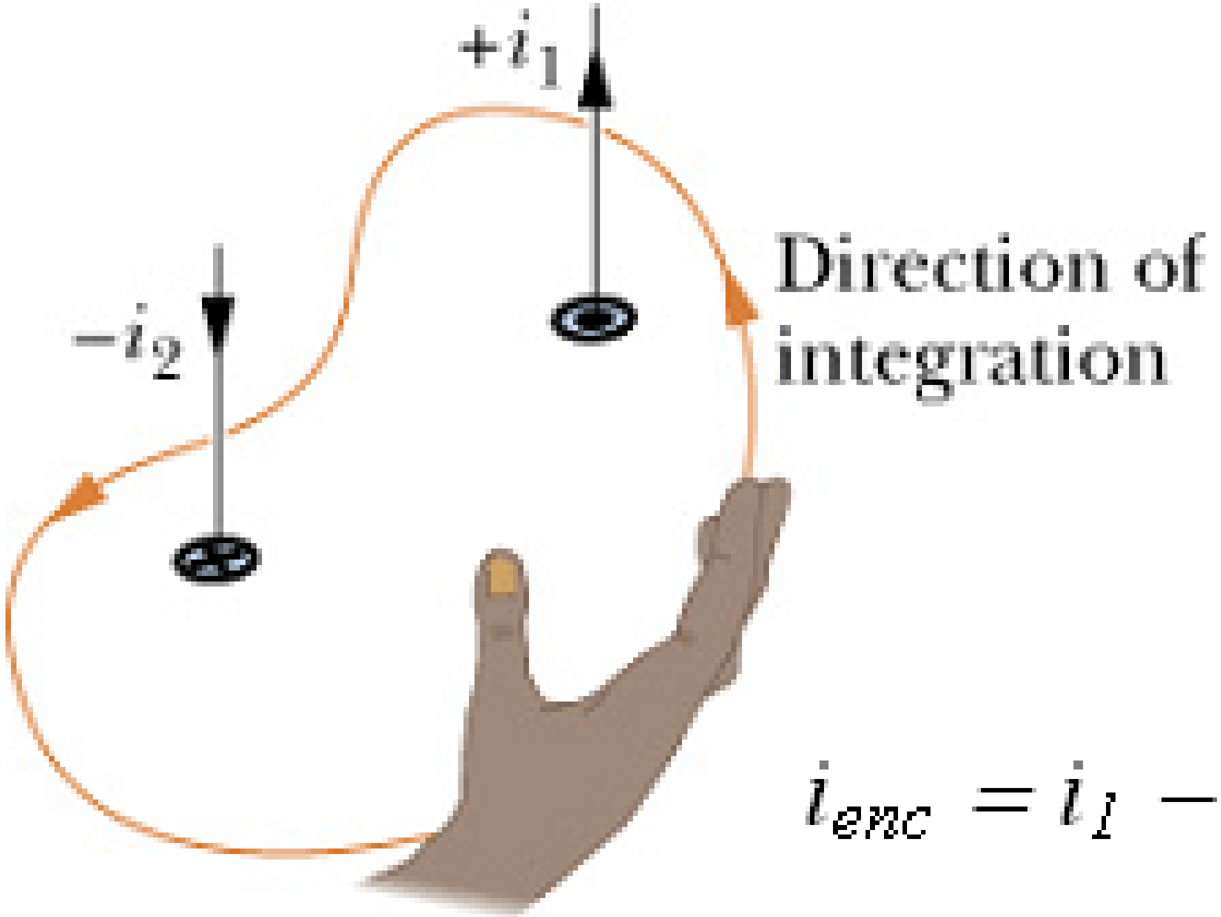
- Amperes’ s Law
- Applications
  - Straight Wire
  - Solenoid
  - Toroid
- Problems

Ampere's Law

$$\oint \vec{B} \cdot d\vec{s} = \mu_0 i_{enc}$$

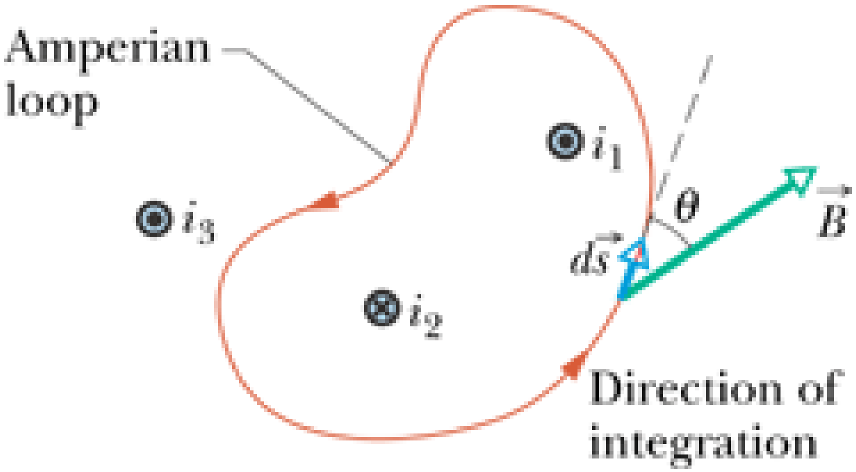






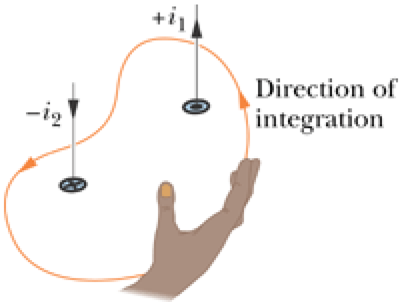
$$i_{enc} = i_1 - i_2$$

Ampere's Law



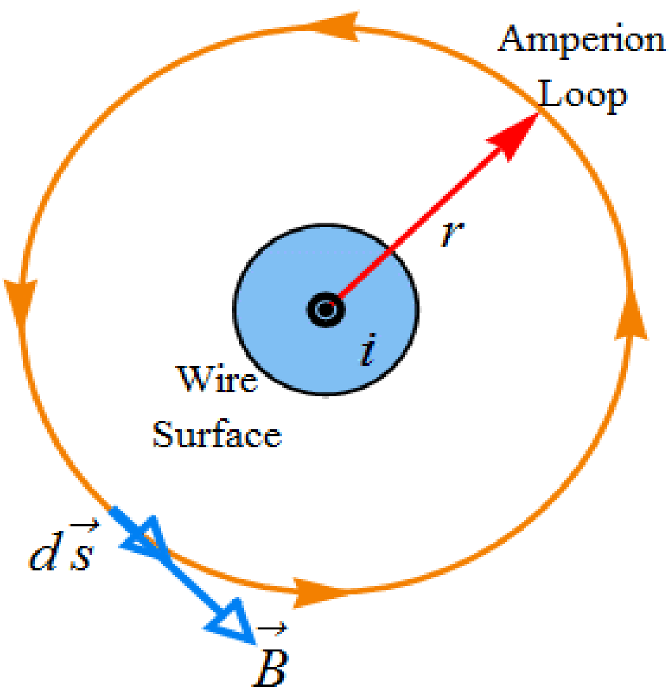
$$\oint \vec{B} \cdot d\vec{s} = \mu_0 i_{enc} \quad \text{(Ampere's law)}.$$

- The loop on the integral sign means that is to be integrated around a *closed* loop, called an *Amperian loop*. The current i_{enc} is the *net* current encircled by that closed loop.
- Curl your right hand around the Amperian loop, with the fingers pointing in the direction of integration. A current through the loop in the general direction of your outstretched thumb is assigned a plus sign, and a current generally in the opposite direction is assigned a minus sign.



Application of Ampere' s Law

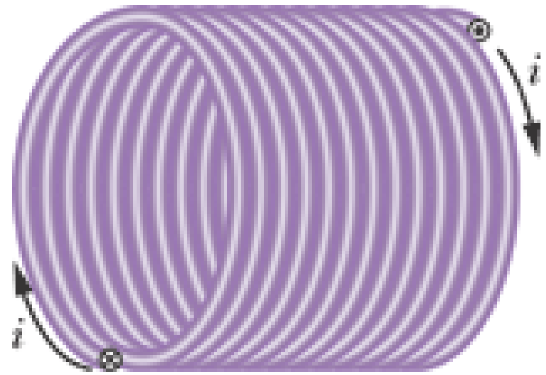
External Points of a wire

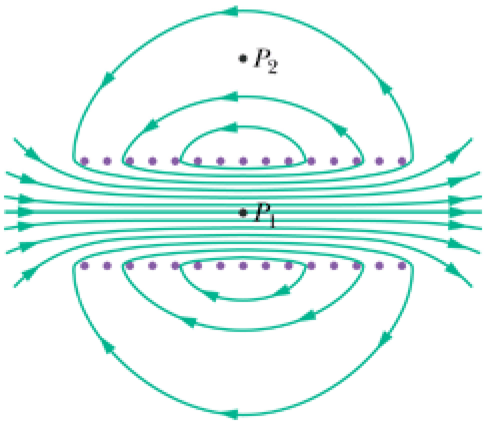


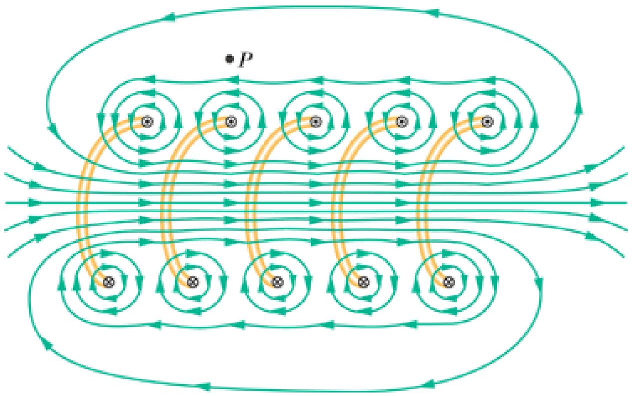
$$B = \frac{\mu_0 i}{2\pi r}.$$

$$\oint \vec{B} \cdot d\vec{s} = \oint B \; ds \, Cos \, 0^\circ = B \oint ds = B(2\pi r)$$

Magnetic Field of a Solenoid

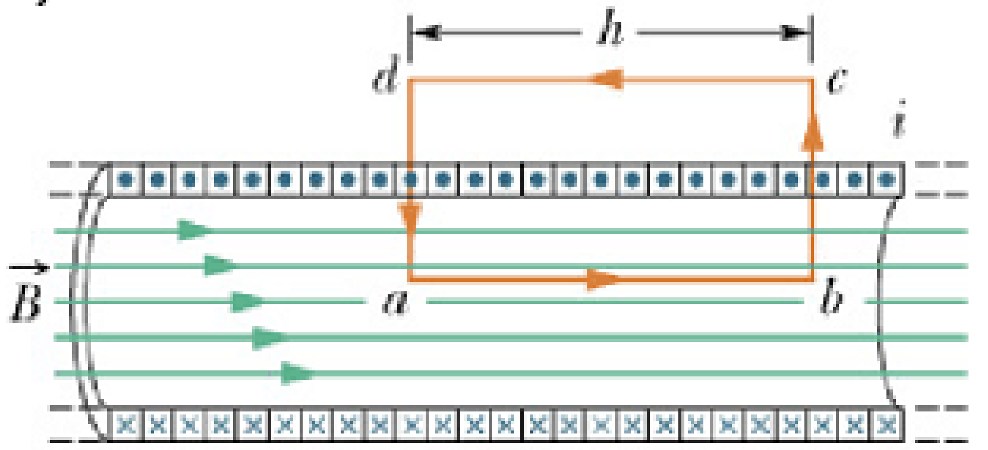






Magnetic of a solenoid

$$\oint \vec{B} \cdot d\vec{s} = \mu_0 i_{enc}$$



$$\oint \vec{B} \cdot d\vec{s} = \int_a^b \vec{B} \cdot d\vec{s} + \int_b^c \vec{B} \cdot d\vec{s} + \int_c^d \vec{B} \cdot d\vec{s} + \int_d^a \vec{B} \cdot d\vec{s}.$$

Net Current. The net current i_{enc} encircled by the rectangular Amperian loop in Fig. 29-20 is not the same as the current i in the solenoid windings because the windings pass more than once through this loop. Let n be the number of turns per unit length of the solenoid; then the loop encloses nh turns and

$$i_{enc} = i(nh).$$

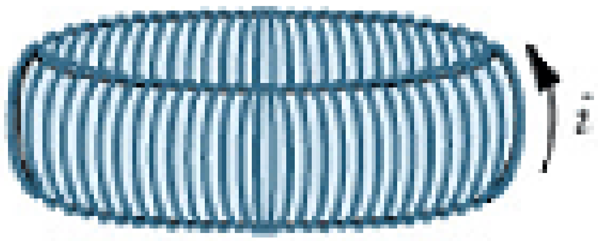
Ampere's law then gives us

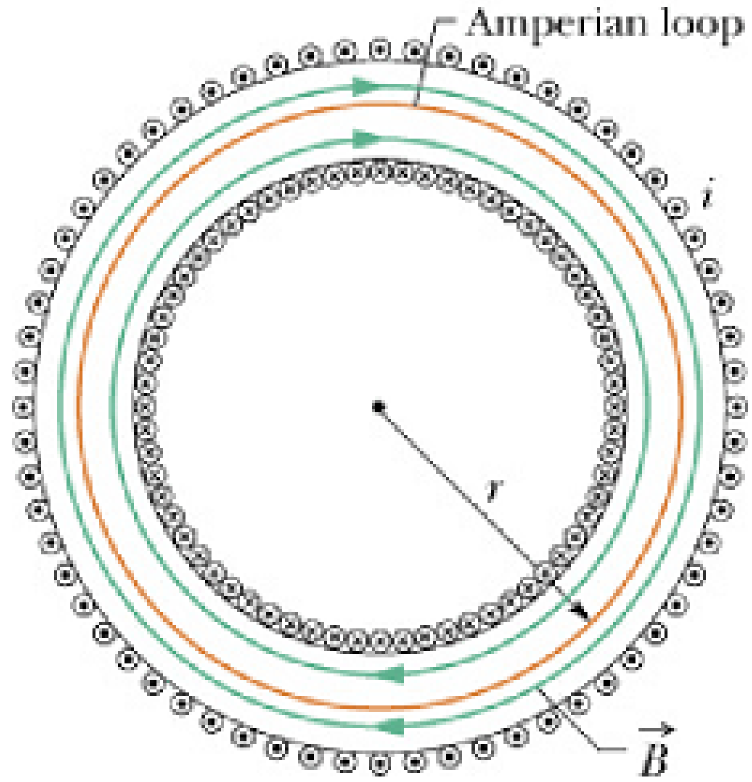
$$Bh = \mu_0 inh$$

or $$B = \mu_0 in \quad \text{(ideal solenoid).} \tag{29-23}$$

Magnetic of a Toroid

$$\oint \vec{B} \cdot d\vec{s} = \mu_0 i_{enc}$$





$$B = \frac{\mu_0 N i}{2\pi} \frac{1}{r} \qquad \text{(toroid)}.$$

Magnetic Field of a Toroid

Figure 29-21*a* shows a **toroid,** which we may describe as a (hollow) solenoid that has been curved until its two ends meet, forming a sort of hollow bracelet. What magnetic field $\vec{B}$ is set up inside the toroid (inside the hollow of the bracelet)? We can find out from Ampere's law and the symmetry of the bracelet.

From the symmetry, we see that the lines of $\vec{B}$ form concentric circles inside the toroid, directed as shown in Fig. 29-21*b*. Let us choose a concentric circle of radius r as an Amperian loop and traverse it in the clockwise direction. Ampere's law (Eq. 29-14) yields

$$(B)(2\pi r) = \mu_0 i N,$$

where i is the current in the toroid windings (and is positive for those windings enclosed by the Amperian loop) and N is the total number of turns. This gives

$$B = \frac{\mu_0 i N}{2\pi} \frac{1}{r} \quad \text{(toroid).} \tag{29-24}$$

•45 SSM Each of the eight conductors in Fig. 29-69 carries 2.0 A of current into or out of the page. Two paths are indicated for the line integral $\oint \vec{B} \cdot d\vec{s}$. What is the value of the integral for (a) path 1 and (b) path 2?

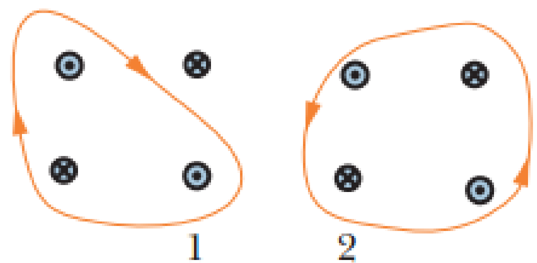


Figure 29-69 Problem 45.

•46 Eight wires cut the page perpendicularly at the points shown in Fig. 29-70. A wire labeled with the integer k ($k = 1, 2, \ldots, 8$) carries the current ki, where $i = 4.50$ mA. For those wires with odd k, the current is out of the page; for those with even k, it is into the page. Evaluate $\oint \vec{B} \cdot d\vec{s}$ along the closed path indicated and in the direction shown.

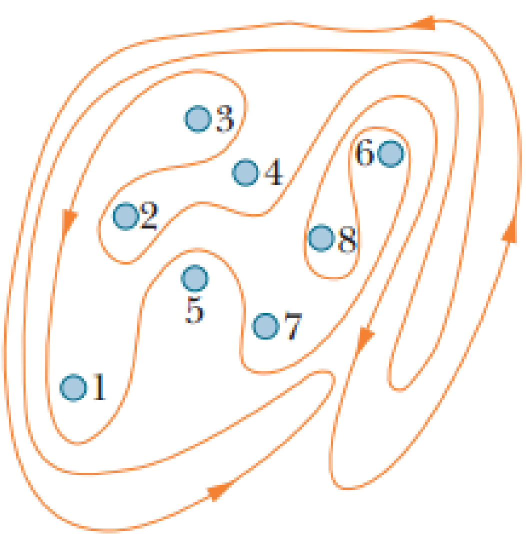


Figure 29-70 Problem 46.