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Term 2191

Welcome
to
PHYS 212: Physics

Chapter#29

Magnetic Fields due to Currents

Topics

29.1 Magnetic Field due to a Current **(law of Biot and Savart).**

29.3 Ampere’s Law.

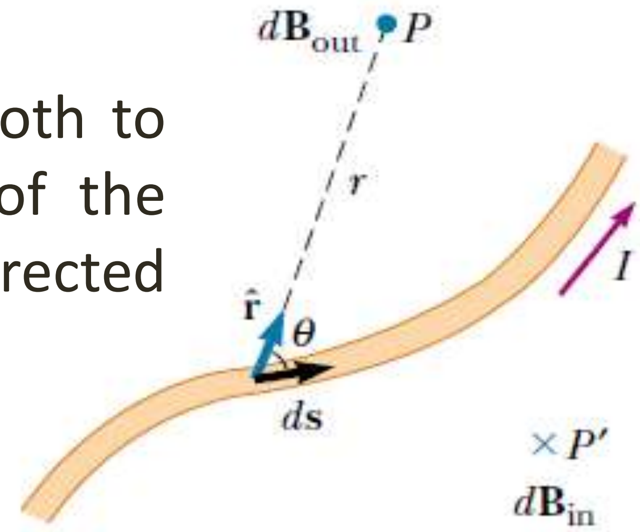
29.1 Magnetic Field due to a Current law of Biot and Savart).

- Shortly after Oersted's discovery in 1819 that a needle is deflected by a current-carrying conductor, Jean- Biot (1774–1862) and Félix Savart (1791–1841) performed quantitative experiments on the force exerted by an electric current on a nearby magnet.

- From their experimental results, Biot and Savart arrived at **a mathematical expression that gives** the magnetic field at some point in space in terms of the current that produces the field.

Magnetic Field due to a Current (law of Biot and Savart).

➢ **That expression is based on the following experimental observations:**



❖ The vector **dB** is perpendicular both to **ds** (which points in the direction of the current) and to the unit vector $\hat{\mathbf{r}}$ directed from **ds** toward **P**.

❖ The magnitude of **dB** is inversely proportional to $\mathbf{r}^2$, where **r** is the distance from **ds** to **P.**

❖ The magnitude of **dB** is proportional to the current and to the magnitude **ds** of the length element **ds**.

❖ The magnitude of **dB** is proportional to **sinθ**, where θ is the angle between the vectors **ds** and $\hat{\mathbf{r}}$.

Magnetic Field due to a Current (law of Biot and Savart).

- These observations are summarized in the mathematical expression known today as the **Biot–Savart law:**

$$d\mathbf{B} = \frac{\mu_0}{4\pi} \frac{I\, d\mathbf{s} \times \hat{\mathbf{r}}}{r^2}$$

Biot–Savart law

$$\mu_0 = 4\pi \times 10^{-7}\, \mathrm{T \cdot m/A} \approx 1.26 \times 10^{-6}\, \mathrm{T \cdot m/A}.$$

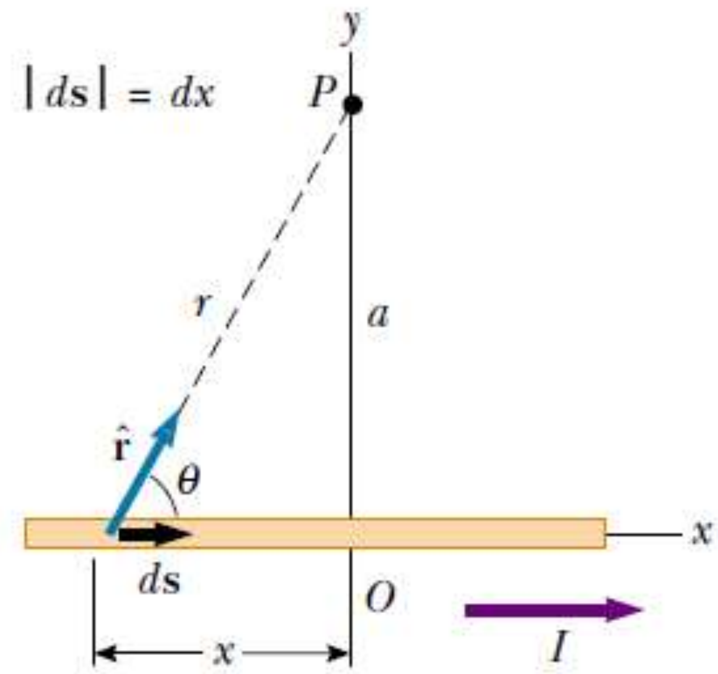
Permeability of free space

$$\mathbf{B} = \frac{\mu_0 I}{4\pi} \int \frac{d\mathbf{s} \times \hat{\mathbf{r}}}{r^2}$$

Magnetic Field due to a Current (law of Biot and Savart).

➢ For a **<u>infinitely long straight wire</u>** carrying a current ***i***, the Biot–Savart law gives, for the magnitude of the magnetic field at a perpendicular distance ***a*** from the wire,

$$\boxed{B = \frac{\mu_0 I}{2\pi a}}$$



(a)

Problem-1

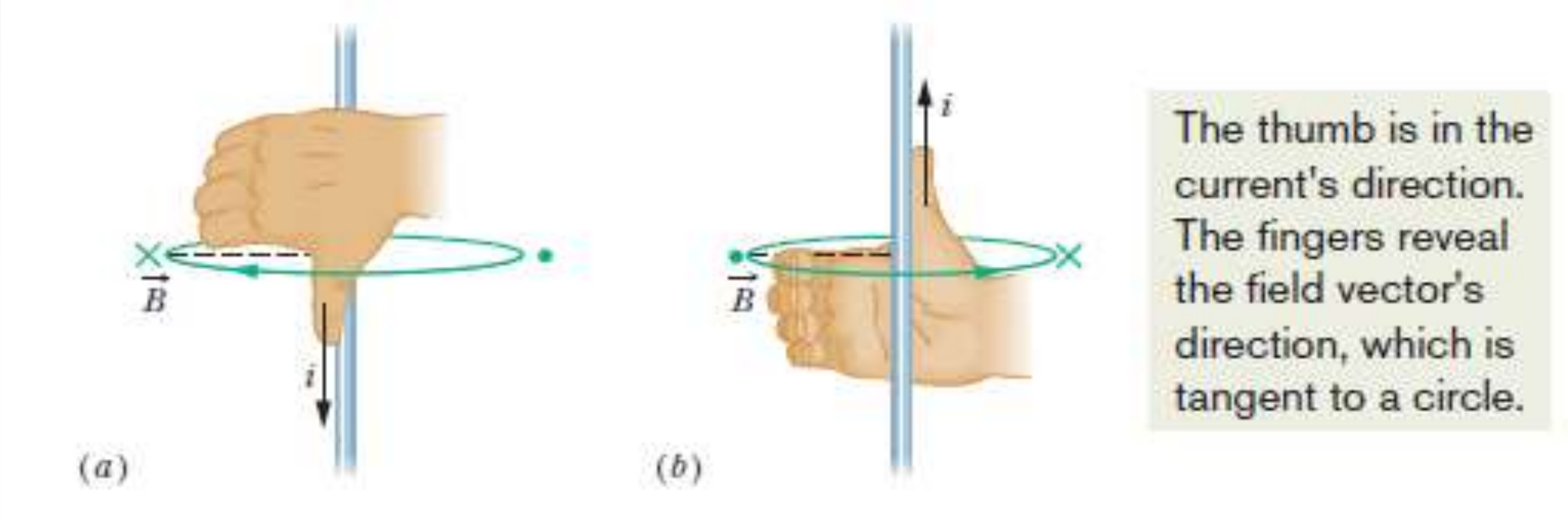
Calculate the magnitude of the magnetic field 4.0 cm from an infinitely long, straight wire carrying a current of 5.0 A.

B=10^-7x2I/r

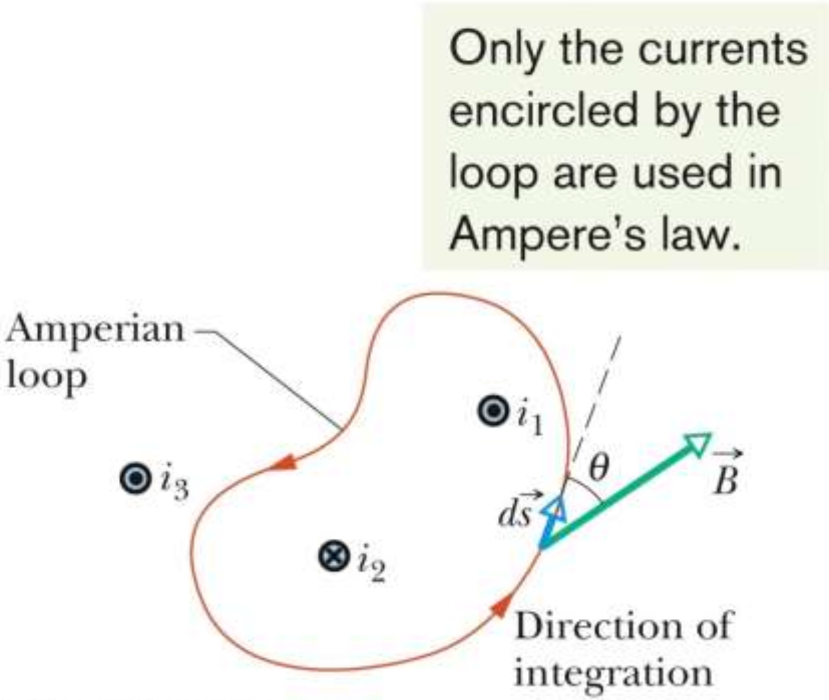
Answer:

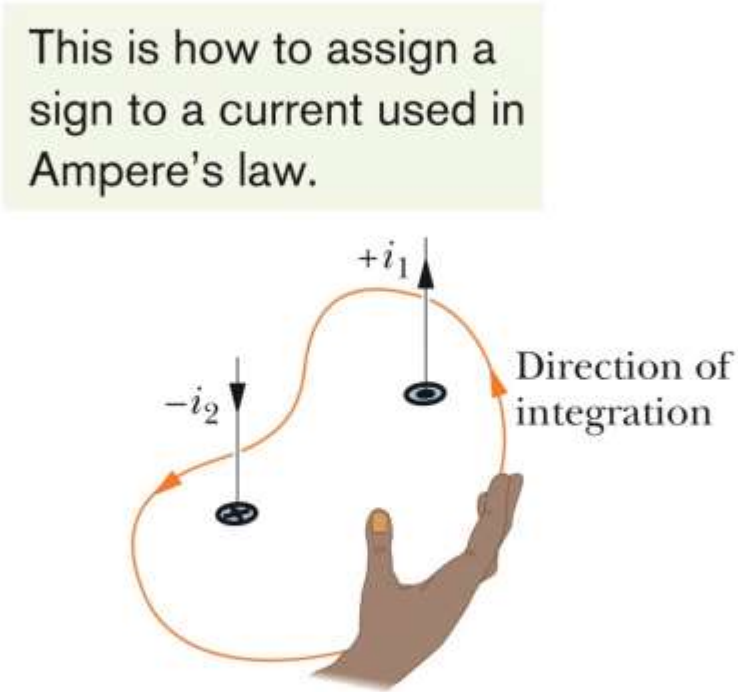
2.5×10^{-5} T.

Magnetic Field due to a Current (The Right Hand Rule).



29-3 Ampere's Law





Ampere's law applied to an arbitrary Amperian loop that encircles two long straight wires but excludes a third wire. Note the directions of the currents.

A right-hand rule for Ampere's law, to determine the signs for currents encircled by an Amperian loop.

Definition of Ampere's Law

The line integral of $\mathbf{B} \cdot d\mathbf{s}$ around any closed path equals $\mu_0 I$, where I is the total continuous current passing through any surface bounded by the closed path.

$$\oint \mathbf{B} \cdot d\mathbf{s} = B \oint ds = \frac{\mu_0 I}{2\pi r}(2\pi r) = \mu_0 I$$

$$\oint \mathbf{B} \cdot d\mathbf{s} = \mu_0 I$$

Remarks

1. In order to apply Ampere's law all currents have to be steady.

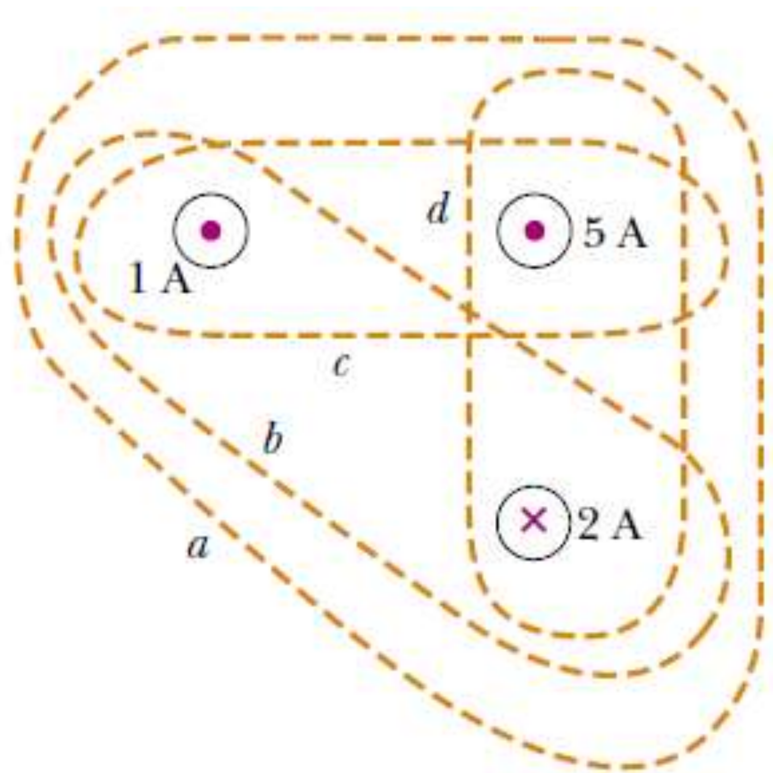
2. Only currents crossing the area inside the path are taken into account and have some contribution to the magnetic field.

3. Currents have to be taken with their algebraic signs (those going "out" of the surface are positive, those going "in" are negative- use right hand's rule to determine directions and signs.

Problem-2

Rank the magnitudes of $\oint \mathbf{B} \cdot d\mathbf{s}$ for the closed paths in Figure 30.9, from least to greatest.

$$\oint \mathbf{B} \cdot d\mathbf{s} = \mu_0 I$$



Answer:

b, *d*, *a*, *c*. Equation 30.13 indicates that the value of the line integral depends only on the net current through each closed path. Path *b* encloses 1 A, path *d* encloses 3 A, path *a* encloses 4 A, and path *c* encloses 6 A.

Problem-3

•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.

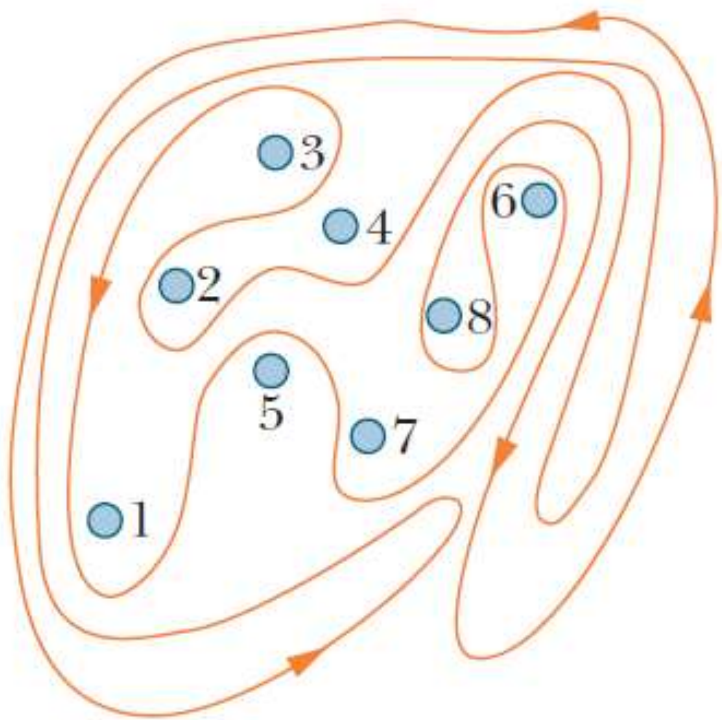


Figure 29-70 Problem 46.

Answer:

46. A close look at the path reveals that only currents 1, 3, 6 and 7 are enclosed. Thus, noting the different current directions described in the problem, we obtain

$$\oint \vec{B} \cdot d\vec{s} = \mu_0 (7i - 6i + 3i + i) = 5\mu_0 i = 5(4\pi \times 10^{-7}\,\mathrm{T \cdot m/A})(4.50 \times 10^{-3}\,\mathrm{A}) = 2.83 \times 10^{-8}\,\mathrm{T \cdot m}.$$