PHY-112

Principles of Physics-II

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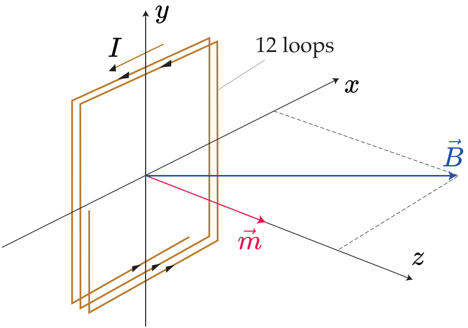
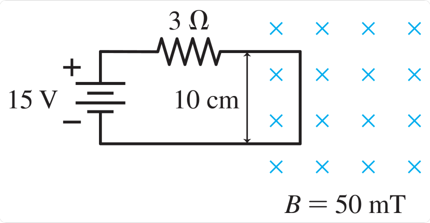
Spring-24 | Class-20

Tie in with Class-19: Testing Concepts (1)

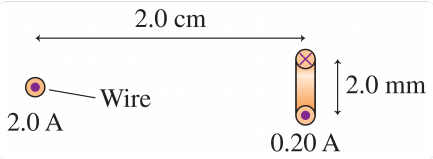
Q: A square 12-turn coil has an edge length equal to $40.0\,\text{cm}$ and carries a current of $3\,\text{A}$. It is placed in a uniform magnetic field $\vec{B} = 0.250\,\text{T}\,\hat{i} + 0.500\,\text{T}\,\hat{k}$. Find the torque (magnitude and direction) with which the coil spins.



Q: The right edge of the circuit extends into a $50\,\mathrm{mT}$ uniform magnetic field. What are the magnitude and direction of the net force on the circuit?



Q: What is the magnitude of the torque on the current loop?



Q: A small bar magnet experiences a $0.020\,\mathrm{N\,m}$ torque when the axis of the magnet is at $45°$ to a $0.10\,\mathrm{T}$ magnetic field. What is the magnitude of its magnetic dipole moment?

Ampère's Law & Line Integral of $\vec{B}$-fields

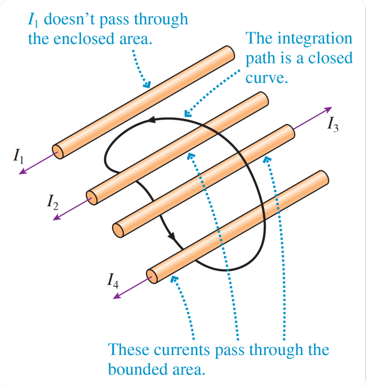
What it is:

- It determines the Line integral of $\vec{B}$-field across a chosen path around a source
- It determines the Curl of $\vec{B}$-field in a given region
- It utilizes the high symmetry of the source to make the calculation simpler, similar to what Gauss's Law did for $\vec{E}$-fields
- It holds as long as the currents are steady and continuous.

How it works:

- You choose a $\vec{B}$-field with high symmetry
- You choose a closed loop, called an *Ampèrian Loop*, on top of which the intensity does not change; only the direction does
- You take the line integral of $\vec{B}$-field in question across the closed loop
- You set it to $\mu_0 I_{\text{enc}}$, the algebraic sum of all currents within that loop
- Sign conventions for line integration help You calculate with no error

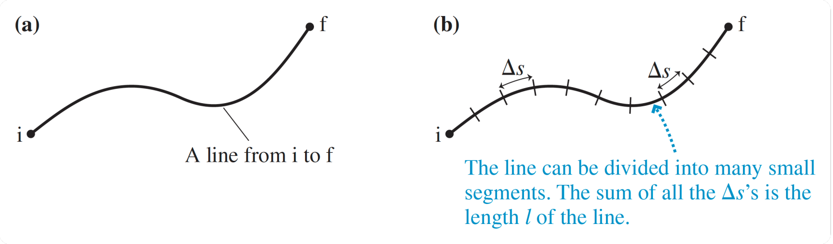
Curl your four fingers in the direction of the integration and you should have a unit vector $\hat{n}$, directed by Your thumb finger. Currents sharing $\hat{n}$'s direction shall be taken as **positive**. Any current outside of the loop does not factor into the calculation.



$$l = \sum_k \Delta s_k = \int_i^f ds$$

$$\sum_k \vec{B}_k \cdot \Delta\vec{s}_k \rightarrow \int_i^f \vec{B} \cdot d\vec{s} \equiv \text{ the line integral of } \vec{B} \cdot d\vec{s} \text{ from } i \text{ to } f$$

$$\int_i^f \vec{B} \cdot d\vec{s} = \int_i^f B ds = B \int_i^f ds = Bl$$



$$l = \sum_k \Delta s_k = \int_i^f ds$$

$$\sum_k \vec{B}_k \cdot \Delta\vec{s}_k \to \int_i^f \vec{B} \cdot d\vec{s} \equiv \text{ the line integral of } \vec{B} \cdot d\vec{s} \text{ from } i \text{ to } f$$

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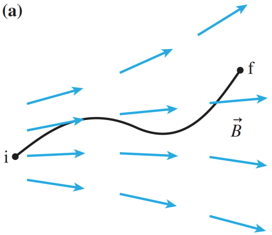
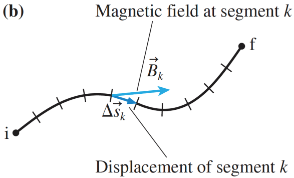
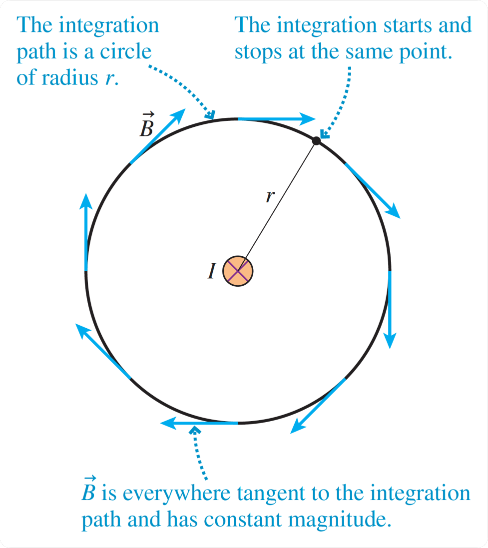


The line passes through a magnetic field.



Ampère's Law in Action: Long Straight Wire



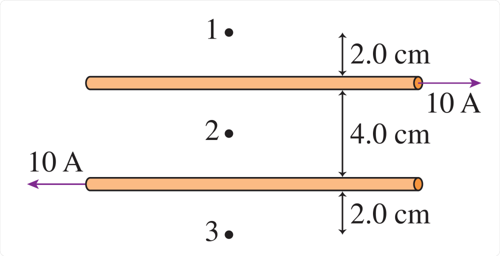
Ampère's Law in Action: Long Straight Wire

Magnetic Field produced by a long (realistic), straight wire at a distance r from its center

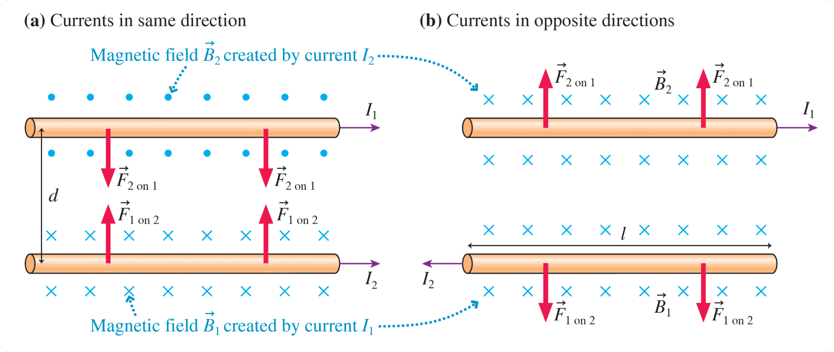
$$\vec{B} = \frac{\mu_0 I}{2\pi r};$$ direction is found using the Right-Hand Method

Right-Hand Method: Point Your right hand's thumb finger in the direction of the current, your other curled four fingers will give the $\vec{B}$-field direction.

Q: What are the magnetic field strength and direction at points 1 to 3.



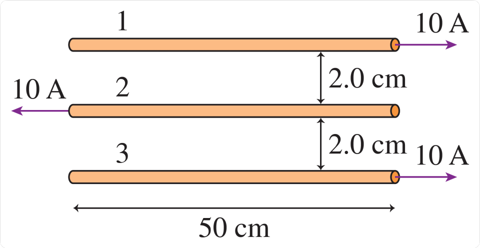
Revisiting Parallel Current-Carrying Wire Setup



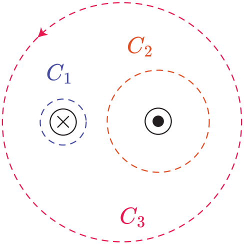
$$F_{1\text{ on }2} = I_1 l B_2 = I_1 l \frac{\mu_0 I_2}{2\pi d} = \frac{\mu_0 I_1 I_2 l}{2\pi d}$$

$$F_{2\text{ on }1} = I_2 l B_1 = I_2 l \frac{\mu_0 I_1}{2\pi d} = \frac{\mu_0 I_1 I_2 l}{2\pi d}$$

Q: What is the net force (magnitude and direction) on each wire?

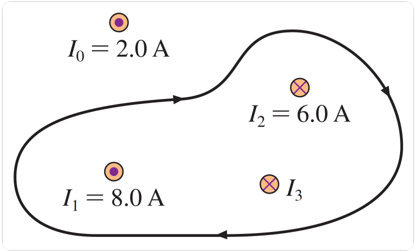


Q: The left wire carries $8\,\mathrm{A}$ current into the page, and the other current $10\,\mathrm{A}$ is out of the page. Each curve is a circular path. C_1 has radius $1\,\mathrm{cm}$, C_2: $2.25\,\mathrm{cm}$, and C_3: $4\,\mathrm{cm}$.

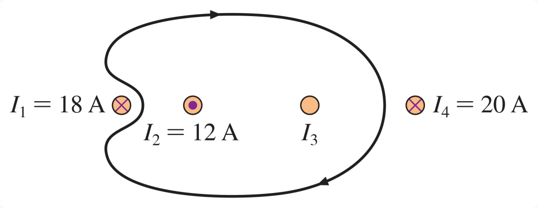


(i) Find $\oint \vec{B} \cdot d\vec{l}$ for each path, assuming that each integral is to be evaluated in the counterclockwise direction. (ii) Use C_3 to find the net $\vec{B}$-field intensity.

Q: The value of the line integral of $\vec{B} \cdot d\vec{s}$ around the closed path is 3.77×10^{-6} T m. What is I_3?



Q: The value of the line integral of $\vec{B} \cdot d\vec{s}$ around the closed path is 1.38×10^{-5} T m. What are the direction (into or out of the figure) and magnitude of I_3?



Electromagnetic Induction