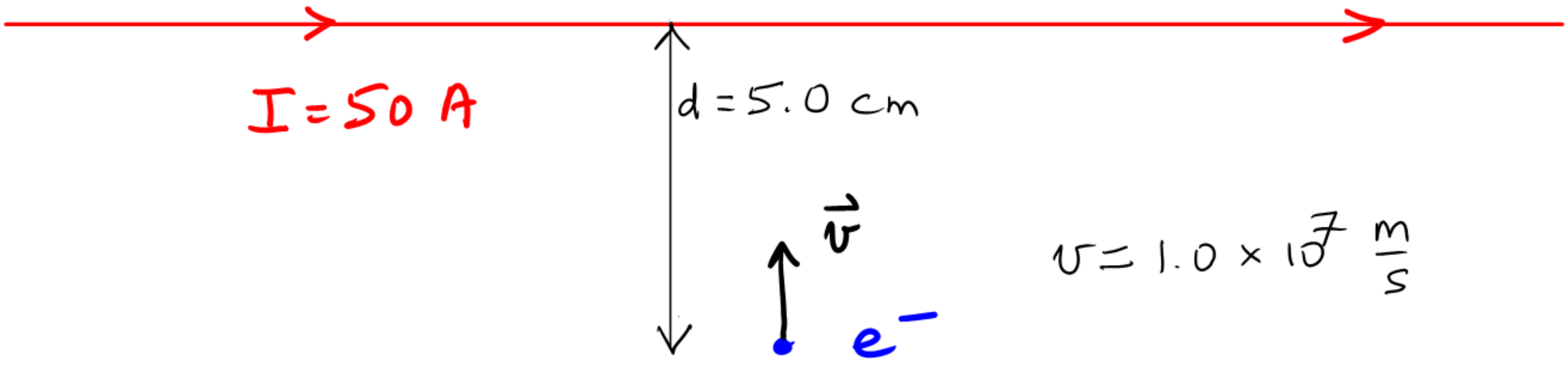
PhysicsTutor

Current and moving electron

Giambattista 19.65

Problem:

- A long straight wire carries a current of 50.0 A. An electron, traveling at $1.0{\times}10^7$ m/s at a right angle toward the wire, is 5.0 cm from the wire. What force (magnitude and direction) acts on the electron?



Relevant ideas:

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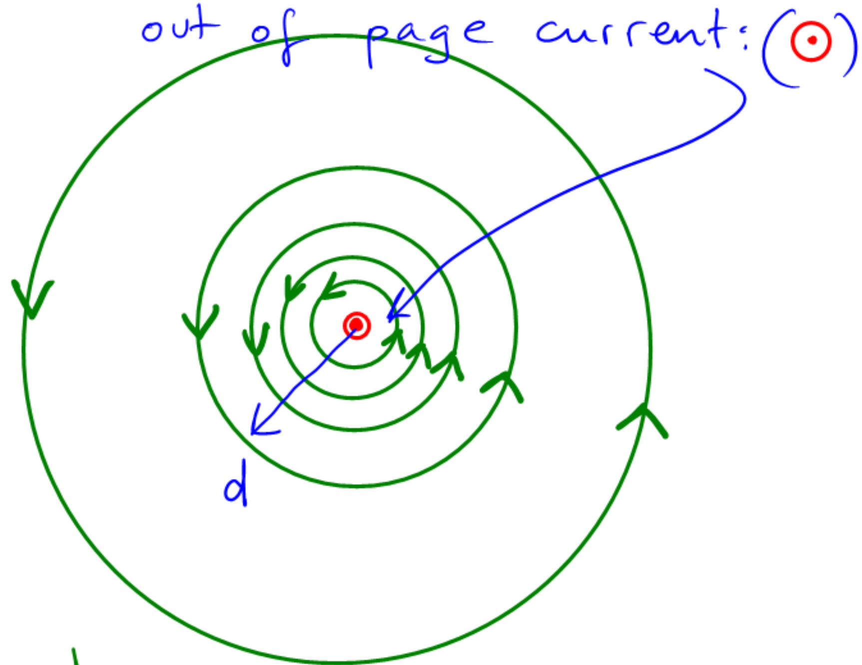
- A long current-carrying wire is surrounded by a magnetic field whose strength drops as 1/d.

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

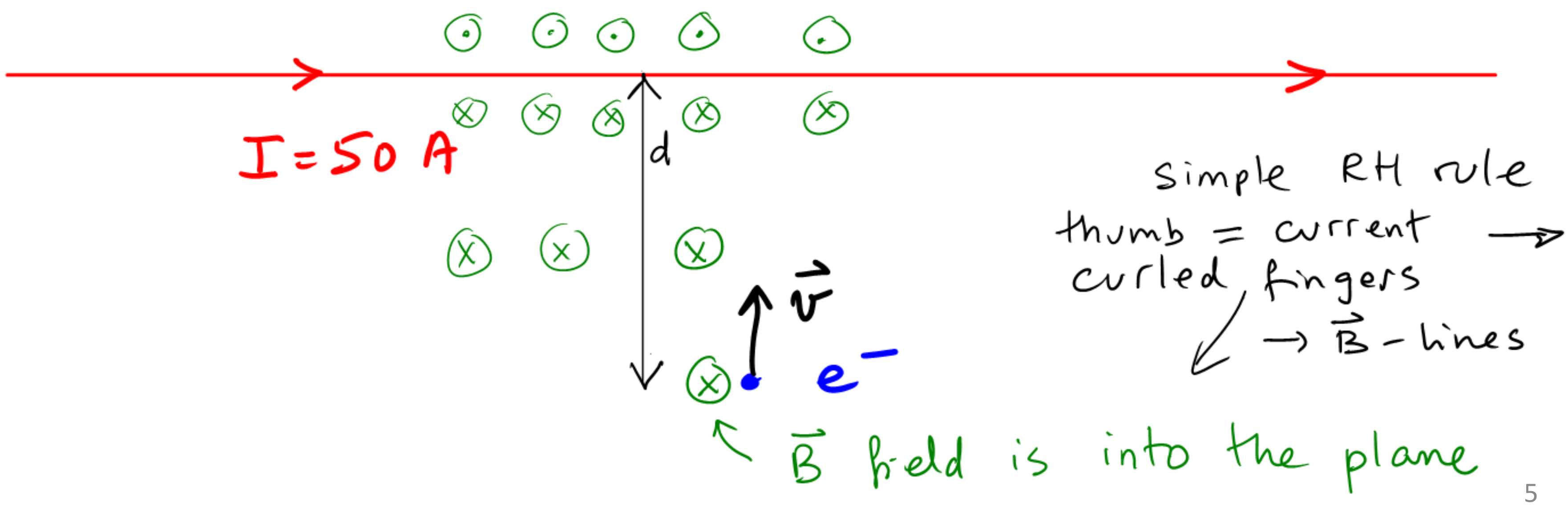
strength of B falls off with distance d



Spacing of field lines grows with d.

Relevant ideas:

- A long current-carrying wire is surrounded by a magnetic field whose strength drops as 1/d.
- The field lines are circles about the wire. Use the Right-Hand rule to find the direction of **B**.



Relevant ideas:

- A long current-carrying wire is surrounded by a magnetic field whose strength drops as 1/d.
- The field lines are circles about the wire. Use the Right-Hand rule to find the direction of **B**.
- The magnetic force on a moving charged particle is given by a cross product involving velocity **v** and magnetic field vector **B**. The charge sign of the particle is also important.

RH rule $\vec{v} \times \vec{B}$ is to the left, but $q_{e^-} = -e < 0$ flips sign: $\vec{F}_M = q\,\vec{v} \times \vec{B}$ is to the right.

Equations associated with ideas:

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

$$\vec{F}_M = q\,\vec{v} \times \vec{B}$$

$$F_M = q v B \sin(\measuredangle\, \vec{v}, \vec{B})$$ ← has sign info.

$$|F_M| = |q v B \sin\alpha| \qquad \alpha = \measuredangle\, \vec{v}, \vec{B}$$

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- State the orientation of the **B** field at the electron’s location.
- Figure out the direction of the magnetic force from the cross-product and q- sign, and state it.
- Calculate the magnitude of the magnetic force.

Solution

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- $B = \frac{\mu_0 I}{2\pi d} = \frac{4\pi \cdot 10^{-7} \cdot 50.0}{2\pi \cdot 0.05} \frac{Tm}{A} \frac{A}{m} = 2.0 \times 10^{-4} T$

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- $\vec{B}$ is into page; $\vec{v} \times \vec{B}$ to the left; $\vec{F}_M = q\vec{v} \times \vec{B}$ to the right $(q<0)$

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- $\alpha = \measuredangle \vec{v}, \vec{B} = 90^\circ$ $\sin\alpha = 1$ $\therefore |F_M| = |qvB|$

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- $B = \frac{\mu_0 I}{2\pi d} = \frac{4\pi \cdot 10^{-7} \cdot 50.0}{2\pi \cdot 0.05} \frac{\text{Tm}}{\text{A}} \frac{\text{A}}{\text{m}} = 2.0 \times 10^{-4}\ \text{T}$
- $\vec{B}$ is into page; $\vec{v} \times \vec{B}$ = to the left; $\vec{F}_M = q\vec{v} \times \vec{B}$ = to the right $(q<0)$
- $\alpha = \sphericalangle \vec{v}, \vec{B} = 90^\circ$ $\quad \sin\alpha = 1$ $\quad \therefore |F_M| = |qvB|$
- $|F_M| = 1.60 \times 10^{-19} \cdot 1.0 \times 10^{7} \cdot 2.0 \times 10^{-4}\ \frac{\text{CTm}}{\text{s}}$

$= 3.2 \times 10^{-16}\ \text{N} = 0.32\ \text{fN}$

femto

$\vec{F}_M$ is 3.2×10^{-16} N parallel to the current. (to the right)