Chapter 29

1

Magnetic Fields

1

Lecture 03

2

Magnetic Force On A Current Carrying Conductor

2

Magnetic Force on a Current Carrying Conductor

3

A force is exerted on a current-carrying wire placed in a magnetic field.

The current is a collection of many charged particles in motion.

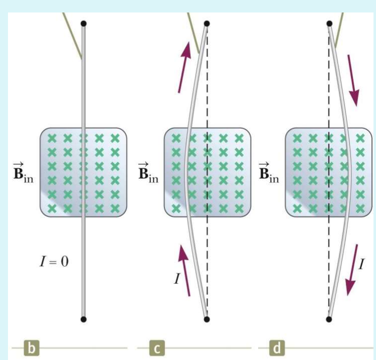
The direction of the force is given by the right-hand rule.

3

Force on a Wire

4

- In case (b):
  - There is no current, so there is no force.
  - Therefore, the wire remains vertical.
- In case (c):
  - The magnetic field is into the page
  - The current is up the page
  - The force is to the left
  - The wire deflects to the left
- In case (d):
  - The magnetic field is into the page
  - The current is down the page
  - The force is to the right
  - The wire deflects to the right



4

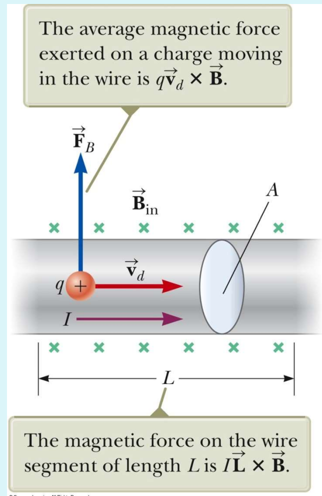
Force on a Wire, Equation.

5

- The magnetic force exerted on the wire is:

$$\vec{F}_B = I\vec{L} \times \vec{B}$$

  - I is the current.
  - $\vec{L}$ is a vector that points in the direction of the current.
    - Its magnitude is the length L of the segment.
  - $\vec{B}$ is the magnetic field.



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F_B on a wire carrying current-1

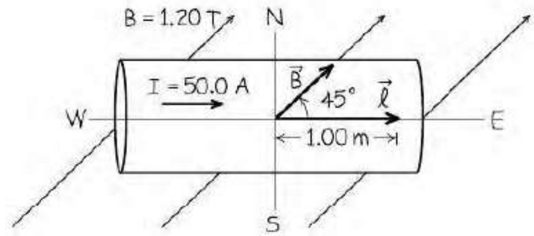
Monday, 1 March, 2021 21:38

Lecturer: Mustafa Al-Zyout, Philadelphia University, Jordan.

- [ ] R. A. Serway and J. W. Jewett, Jr., *Physics for Scientists and Engineers*, 9th Ed., CENGAGE Learning, 2014.
- [ ] J. Walker, D. Halliday and R. Resnick, *Fundamentals of Physics*, 10th ed., WILEY,2014.
- [x] H. D. Young and R. A. Freedman, *University Physics with Modern Physics*, 14th ed., PEARSON, 2016.
- [ ] H. A. Radi and J. O. Rasmussen, *Principles of Physics For Scientists and Engineers*, 1st ed., SPRINGER, 2013.

A straight horizontal copper rod carries a current of $50\,A$ from west to east in a region between the poles of a large electromagnet. In this region there is a horizontal magnetic field toward the northeast (that is, $45°$ north of east) with magnitude $1.2\,T$.

- Find the magnitude and direction of the force on a $1\,m$ section of rod.
- While keeping the rod horizontal, how should it be oriented to maximize the magnitude of the force? What is the force magnitude in this case?



The angle θ between the directions of current and field is $45°$. Then:

$$F = ILB\sin\theta = 50 \times 1 \times 1.2 \times \sin 45° = 42 \cdot 4N$$

The direction of the force is perpendicular to the plane of the current and the field, both of which lie in the horizontal plane. Thus the force must be vertical; the right-hand rule shows that it is vertically upward.

The magnetic force is maximum for $\theta = 90°$, so that $\vec{L}$ and $\vec{B}$ are perpendicular. To keep $\vec{F} = I\vec{L} \times \vec{B}$ upward, we rotate the rod clockwise by $45°$ from its orientation in, so that the current runs toward the southeast. Then:

$$F_{\max} = ILB\sin\theta = 50 \times 1 \times 1.2 \times \sin 90° = 60\ N$$

F_B on a wire carrying current-2

Monday, 1 March, 2021 21:38

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- [ ] R. A. Serway and J. W. Jewett, Jr., *Physics for Scientists and Engineers*, 9th Ed., CENGAGE Learning, 2014.
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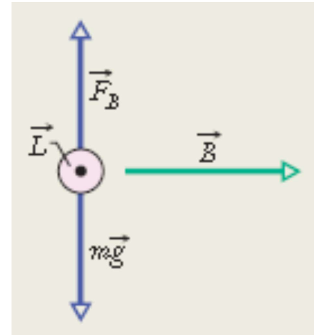
- [ ] H. A. Radi and J. O. Rasmussen, *Principles of Physics For Scientists and Engineers*, 1st ed., SPRINGER, 2013.

A straight, horizontal length of copper wire has a current $i = 28\,A$ through it. What are the magnitude and direction of the minimum magnetic field needed to suspend the wire that is, to balance the gravitational force on it? The linear density (mass per unit length) of the wire is $46.6\ g/m$.



Because the wire carries a current, a magnetic force $\vec{F}_B$ can act on the wire if we place it in a magnetic field $\vec{B}$. To balance the downward gravitational force $\vec{F}_g$ on the wire, we want $\vec{F}_B$ to be directed upward.

The direction of $\vec{F}_B$ is related to the directions of $\vec{B}$ and the wire's length vector $\vec{L}$ by ($\vec{F}_B = i\vec{L} \times \vec{B}$).

Because $\vec{L}$ is directed horizontally (and the current is taken to be positive), the right-hand rule for cross products tell us that $\vec{B}$ must be horizontal and rightward to give the required upward $\vec{F}_B$.

The magnitude of $\vec{F}_B$ is $F_B = iLB\sin\phi$. Because we want $\vec{F}_B$ to balance $\vec{F}_g$, , we want

$$iLB\sin\phi = mg,$$

where mg is the magnitude of $\vec{F}_g$ and m is the mass of the wire.

We also want the minimal field magnitude B for $\vec{F}_B$ to balance $\vec{F}_g$. Thus, we need to maximize $sin\phi$ .To do so ,we set $\phi = 90°$, thereby arranging for $\vec{B}$ to be perpendicular to the wire. We then have $\sin\phi = 1$, so

$$B = \frac{mg}{iL\sin\phi} = \frac{(m/L)g}{i}.$$

We write the result this way because we know m/L, the linear density of the wire. Substituting known data then gives us

$$B = \frac{(46.6 \times 10^{-3} kg/m)(9.8 m/s^2)}{28A} = 1.6 \times 10^{-2} T.$$

This is about 160 times the strength of Earth's magnetic field.