Electricity and Magnetism
Force on Parallel Wires

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Last time

- Gauss's Law for magnetic fields
- Ampère's Law
- magnetic field around a straight wire
- solenoids

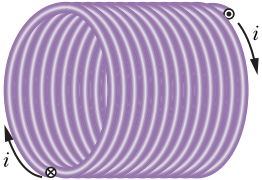
Overview

- magnetic field inside a solenoid
- forces between current-carrying wires

Solenoids

solenoid

A helical coil of tightly wound wire that can carry a current.



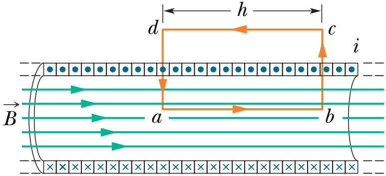
turn

A single complete loop of wire in a solenoid. "This solenoid has 10 turns," means it has 10 complete loops.

Magnetic Field of an ideal solenoid

In an ideal solenoid (with infinite length) the field outside is small (and perpendicular to the Amp. loop) and inside is uniform. (Similar to a capacitor!)

Can use an Amperian loop to find the B-field inside:



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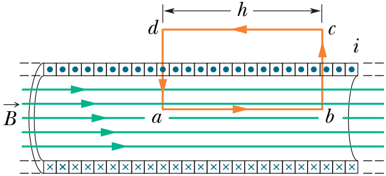


$$\oint \mathbf{B} \cdot d\mathbf{s} = \mu_0 I_{enc}$$

Here, suppose there are n turns per unit length in the solenoid, then $I_{enc} = Inh$

$$Bh = \mu_0 Inh$$

Inside an ideal solenoid:

$$B = \mu_0 In$$

Two Wires carrying Current

With two long, straight current carrying wires, each creates its own magnetic field:

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

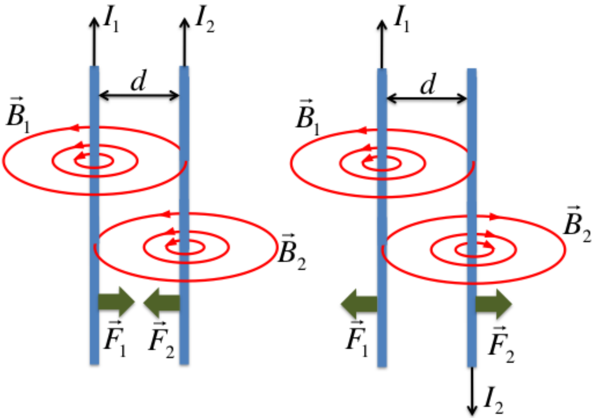
The result is that the wires interact, much like two bar magnets producing magnetic fields would.

Forces on parallel wires

Currents in opposite directions repel, currents in the same direction attract.

[1]Figure from salisbury.edu.

Forces on parallel wires



[1]Figure from Stonebrook Physics ic.sunysb.edu.

Forces on parallel wires

To find the magnitude of the force, we need to recall how force relates to the magnetic field for a wire.

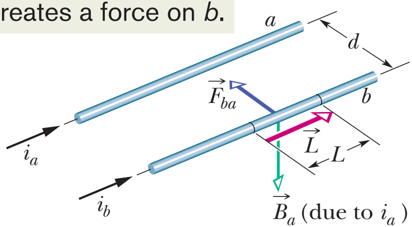
The force on a long, straight current carrying wire is:

$$\mathbf{F} = I\mathbf{L} \times \mathbf{B}$$

Forces on parallel wires

Suppose that wire a produces a field at b: $B_a = \frac{\mu_0 I_a}{2\pi d}$

The field due to a at the position of b creates a force on b.



The force on wire b is:

$$\mathbf{F}_b = I_b \mathbf{L} \times \mathbf{B}_a = I_b L \frac{\mu_0 I_a}{2\pi d} \sin(90^\circ) \text{ [toward } a\text{]}$$

$$F_B = \frac{\mu_0 I_a I_b}{2\pi d} L$$

Forces on parallel wires

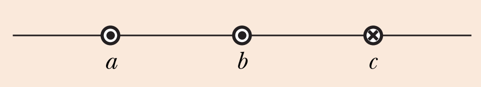
It is a bit more intuitive to think about the force per unit length on the wires (since longer wires will experience larger forces).

The force per unit length on a wire due to another parallel wire at a distance d:

$$\frac{F_B}{L} = \frac{\mu_0 I_1 I_2}{2\pi d}$$

Question

The figure here shows three long, straight, parallel, equally spaced wires with identical currents either into or out of the page. Rank the wires according to the magnitude of the force on each due to the currents in the other two wires, greatest first.



A a, b, c

B b, c, a

C c, b, a

[1] Halliday, Resnick, Walker, pg 771.

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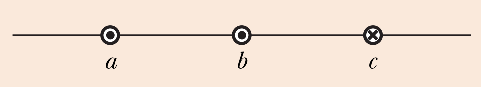

A a, b, c

B b, c, a ←

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Definition of the Ampère (Amp)

This relation:

$$\frac{F_B}{L} = \frac{\mu_0 I_1 I_2}{2\pi d}$$

gives us the formal definition of the Ampère.

Ampère Unit

Two long parallel wires separated by 1 m are said to each carry 1 A of current when the force per unit length on each wire is 2×10^{-7} N/m.

Summary

- Solenoids and Ampère's Law
- Forces on parallel wires

3rd Test Friday, Mar 9.

Homework

- Collected homework 3, posted online, due on Monday.

Serway & Jewett:

- PREVIOUS: Ch 30, Problems: 21, 25, 31, 33, 34, 47
- NEW: Ch 30, Problems: 41, 45