Friday March 31, 2017

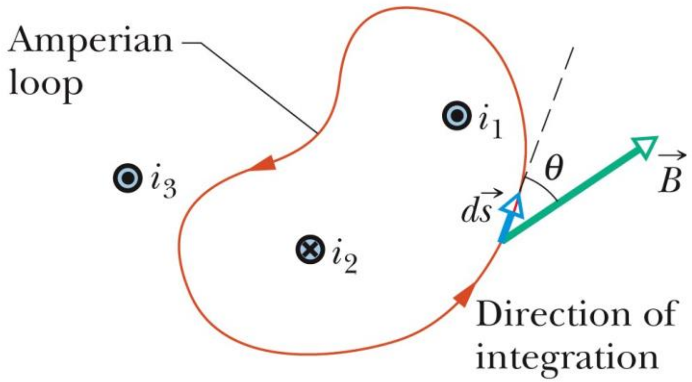
Last time:

- Biot-Savart Law (like Coulomb's Law for magnetism)
- B-field of a line of current
- Magnetic force between parallel current-carrying wires
- Ampère's Law: Like Gauss' Law, but named after Ampère

Today:

- Applying Ampère's Law:
  - ➢ Magnetic field of a long wire (inside and outside)
  - ➢ Magnetic field of solenoid and toroid
- Applying the Biot-Savart Law: Circular arc of current (take-home example)

Only the currents encircled by the loop are used in Ampere's law.



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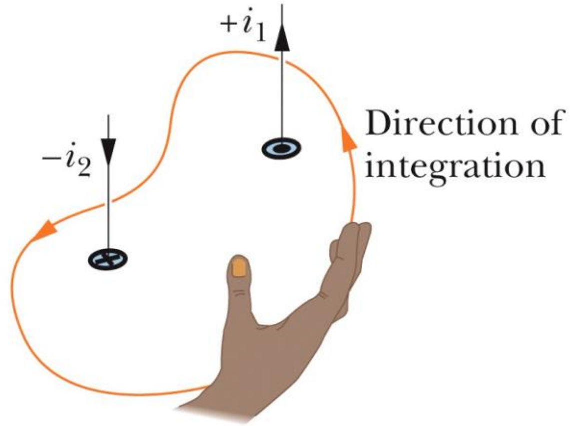
This is how to assign a sign to a current used in Ampere's law.



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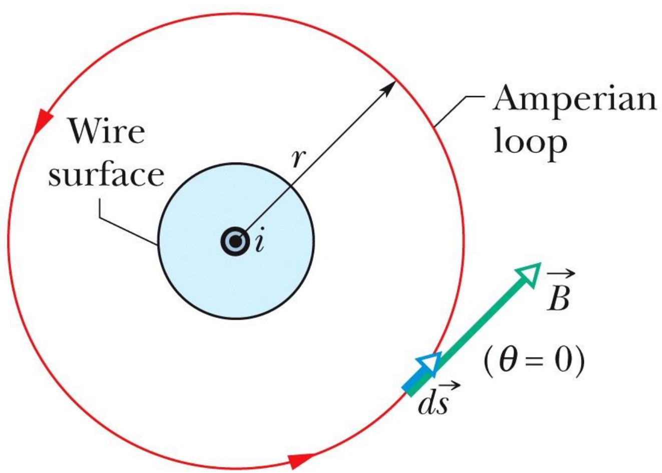
All of the current is encircled and thus all is used in Ampere's law.



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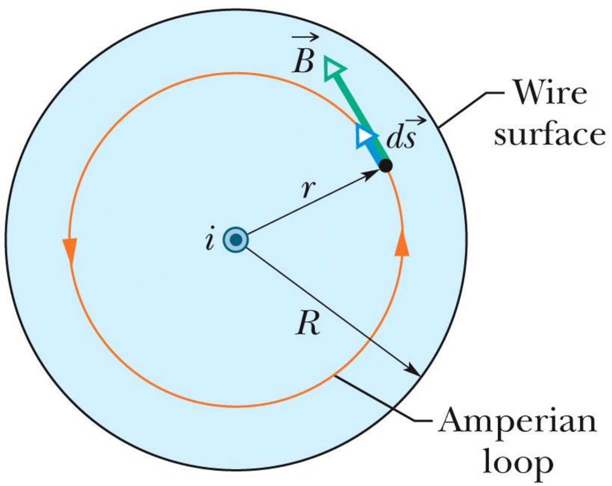
Only the current encircled by the loop is used in Ampere's law.



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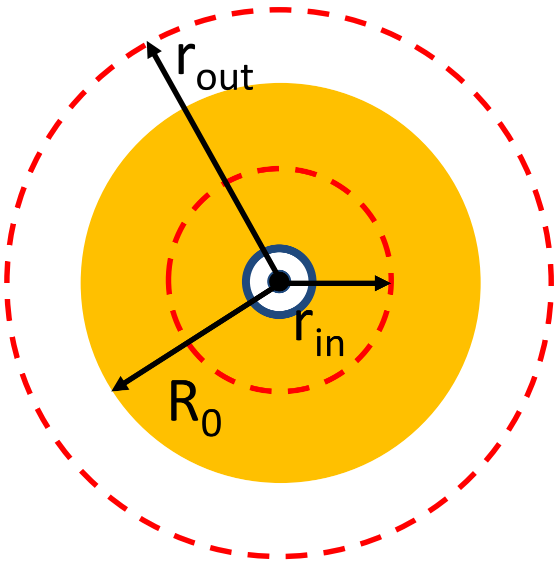
Ampère's law: application

(a) Using Ampère's law, calculate the magnetic field inside a solid current carrying wire a distance r_{in} from its axis.
(The length of the solid wire is infinite and the current I is uniformly distributed throughout the solid wire)



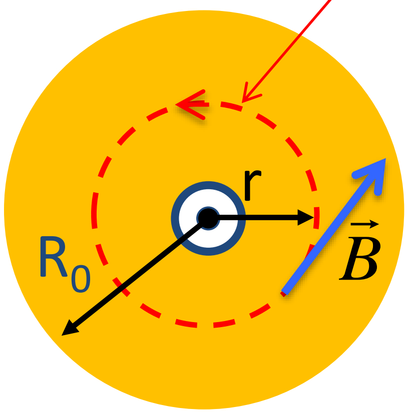
End view:
Wire with radius R
and current I

b) Calculate the magnetic field outside a solid current carrying wire a distance r_{out} from its axis.

Ampère's law: application

(a) B-field inside

We want to know the B-field a distance r, so we choose an Amperian circular loop with radius $r < R_0$.



Ampère's Law: $$\oint \vec{B} \cdot d\vec{l} = \mu_0 I_{enc}$$

Left hand side: $$\oint \vec{B} \cdot d\vec{l} = BL = B2\pi r$$

Right hand side: $$\mu_0 I_{enc} = \mu_0 JA = \mu_0 \frac{I}{pR_0^2} pr^2$$

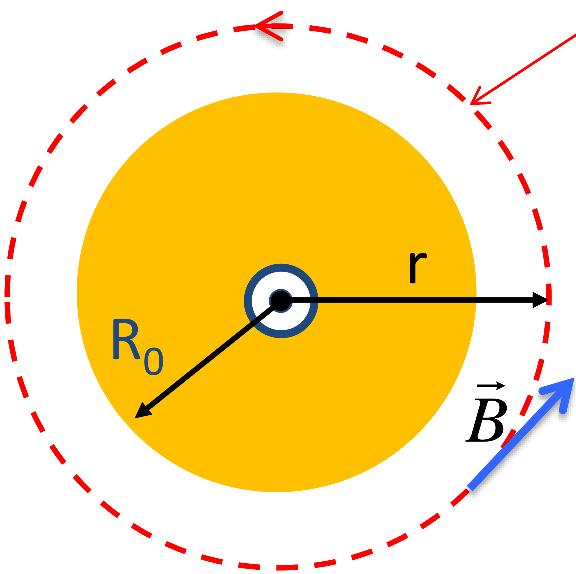
Combine together: $$B2pr = \mu_0 \frac{I}{R_0^2} r^2$$

$$\boxed{B = \frac{\mu_0 I r}{2pR_0^2}}$$

Ampère's law: application

(a) B-field outside

We want to know the B-field a distance r, so we choose an Ampèrian loop with radius r > R_0.



Ampère's Law: $\oint \vec{B}\cdot d\vec{l} = \mu_0 I_{enc}$

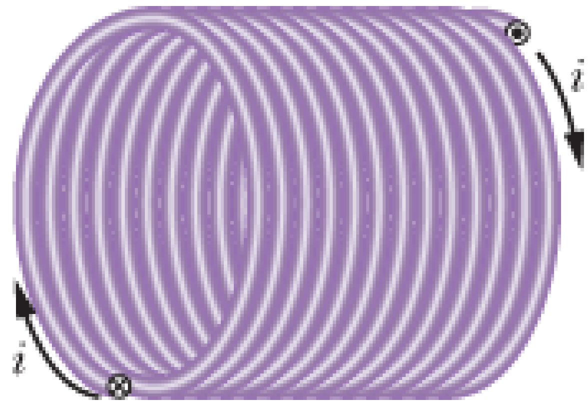
Left hand side: $\oint \vec{B}\cdot d\vec{l} = BL = B2\pi r$

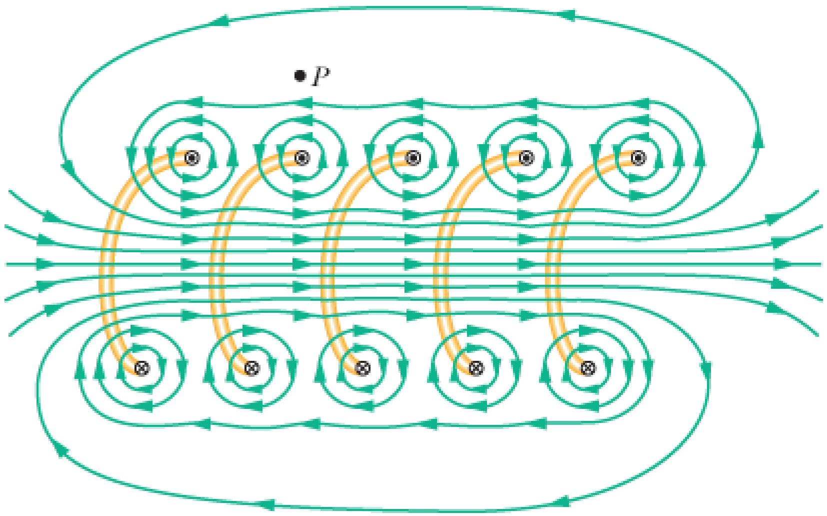
Right hand side: $\mu_0 I_{enc} = \mu_0 I$

Combine together: $B2pr = \mu_0 I$

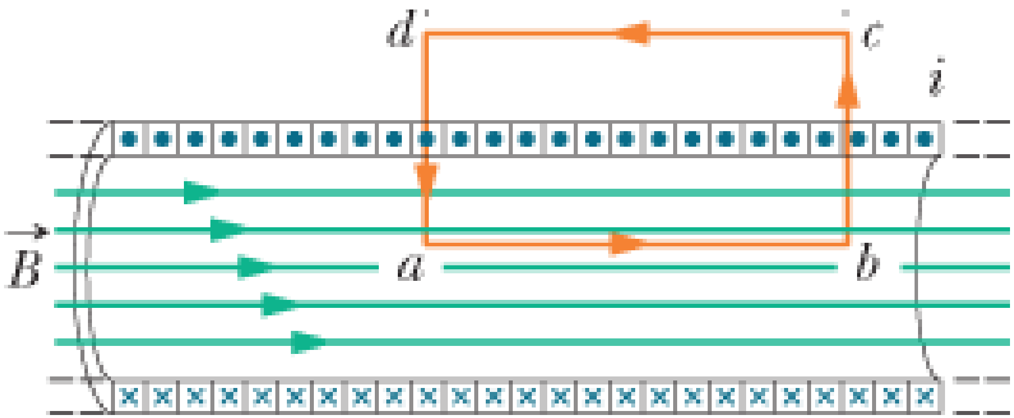
$$\boxed{B = \frac{\mu_0 I}{2pr}}$$

Magnetic field of solenoid

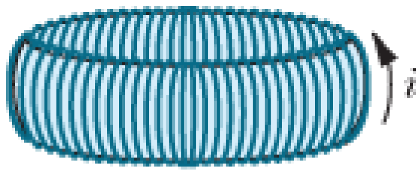




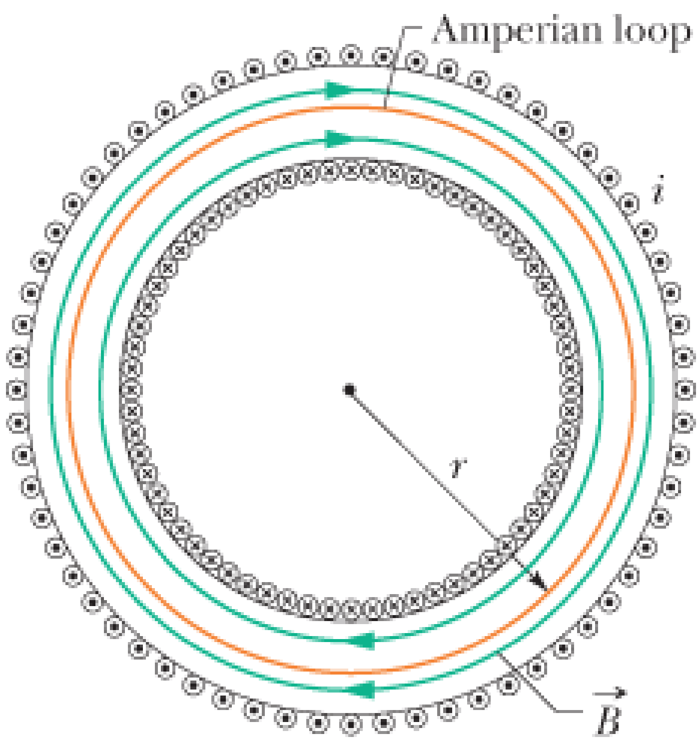
$$B = \mu_0 i n \quad \text{(ideal solenoid)}$$



Magnetic field of toroid



(a)



(b)

$$B = \frac{\mu_0 i N}{2\pi}\frac{1}{r} \quad \text{(toroid)}$$