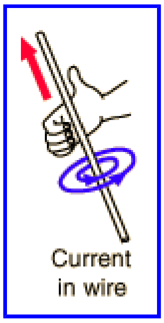
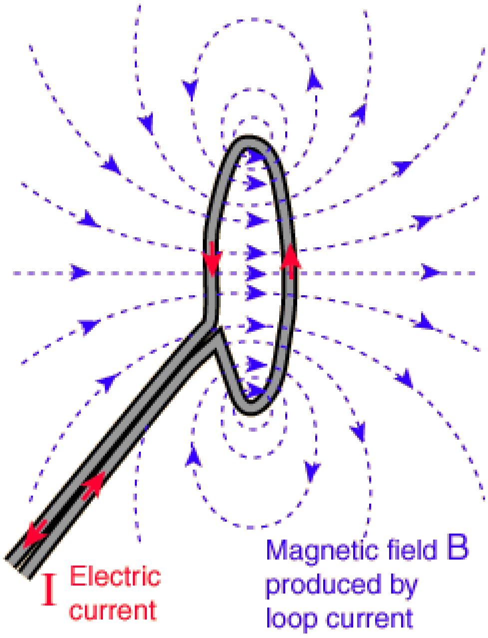
Magnetic Field of Current Loop

Examining the direction of the magnetic field produced by a current-carrying segment of wire shows that all parts of the loop contribute magnetic field in the same direction inside the loop.



Electric current in a circular loop creates a magnetic field which is more concentrated in the center of the loop than outside the loop. Stacking multiple loops concentrates the field even more into what is called a solenoid.



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Field at Center of Current Loop

The form of the magnetic field from a current element in the Biot-Savart law becomes

$$d\vec{B} = \frac{\mu_0 I d\vec{L} \times \hat{\vec{r}}}{4\pi R^2} = \frac{\mu_0 I dL \sin\theta}{4\pi R^2}$$

which in this case simplifies greatly because the angle =90 ° for all points along the path and the distance to the field point is constant. The integral becomes

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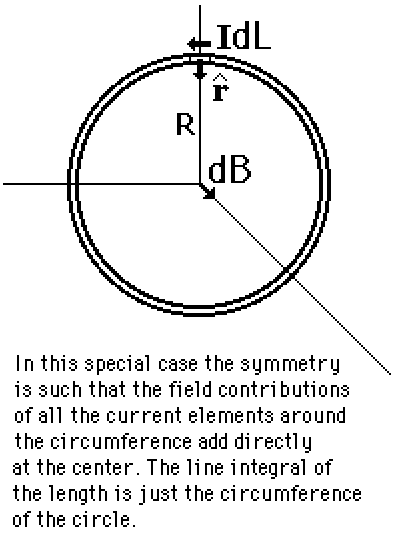

$$B = \frac{\mu_0 I}{4\pi R^2}\oint dL = \frac{\mu_0 I}{4\pi R^2} 2\pi R = \frac{\mu_0 I}{2R}$$

$$\mu_0 = 4\pi \ x \ 10^{-7} T \cdot m / A$$

Magnetic field concepts

Currents as magnetic sources

For a current I = ______ Amperes and

loop radius **R** = ______ m, the magnetic field at the center of the loop is

B = ______ Tesla = ______ Gauss.

At a distance z = ______ m out along the centerline of the loop, the axial magnetic field is

B = ______ Tesla = ______ Gauss.

The current used in the calculation above is the total current, so for a coil of N turns, the current used is Ni where i is the current supplied to the coil.

The Earth's magnetic field at the surface is about 0.5 Gauss.

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Field on Axis of Current Loop

The application of the Biot-Savart law on the centerline of a current loop involves integrating the z-component.

$$dB_z = \frac{\mu_0 \, IdL}{4\pi} \frac{R}{(z^2 + R^2)^{3/2}}$$

The symmetry is such that all the terms in this element are constant except the dL, which when integrated just gives the circumference of the circle. The magnetic field is

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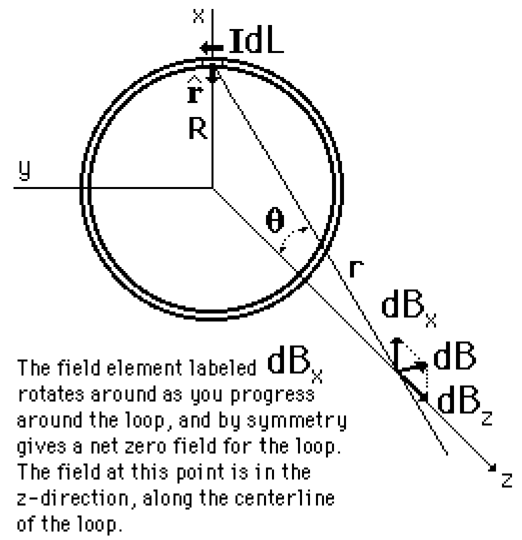


then

$$B_z = \frac{\mu_0}{4\pi}\frac{2\pi R^2 I}{(z^2+R^2)^{3/2}}$$

Calculation

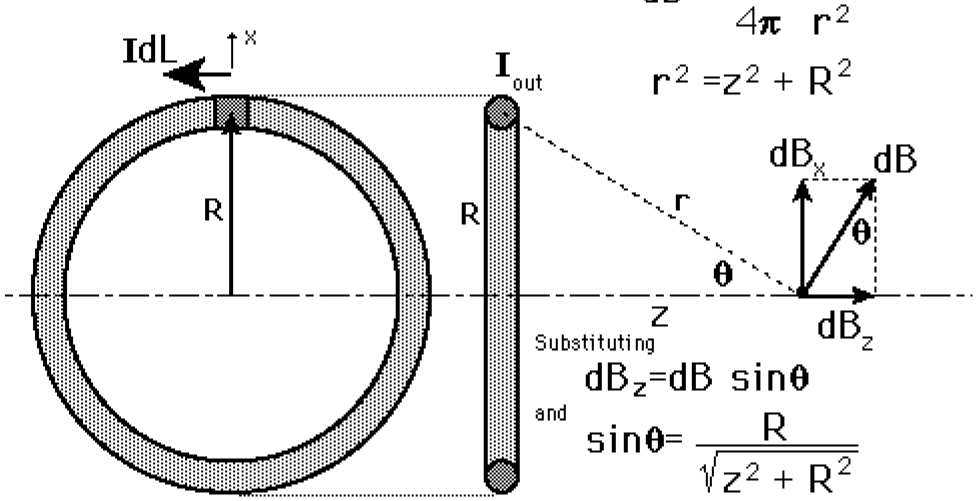
Show geometric details

Discussion of current loop

Geometry: Field on Axis of Current Loop

$$dB = \frac{\mu_0}{4\pi}\frac{IdL}{r^2}$$

$$r^2 = z^2 + R^2$$



Substituting

$$dB_z = dB\sin\theta$$

and

$$\sin\theta = \frac{R}{\sqrt{z^2+R^2}}$$

gives

$$dB_z = \frac{\mu_0 IdL}{4\pi}\frac{R}{(z^2+R^2)^{3/2}}$$

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