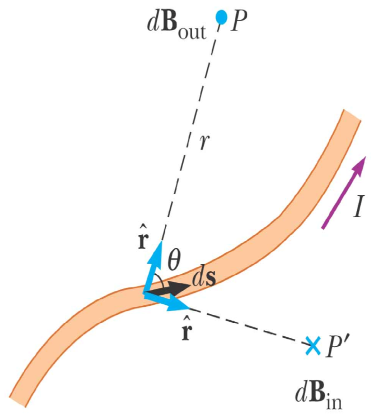
Chapter 30

Sources of the Magnetic Field

We discussed the magnetic force exerted on a charged particle moving in a magnetic field.

In this chapter, the origin of the magnetic field will be disccused—moving charges. We begin by showing how to use the law of Biot and Savart to calculate the magnetic field produced at some point in space by a small current element.

30.1 The Biot-Savart Law



Option:

Jean-Baptiste Biot (1774–1862) and Félix Savart (1791–1841) performed quantitative experiments on the force exerted by an electric current on a nearby magnet.

• The vector dB is perpendicular both to ds (which points in the direction of the current) and to the unit vector directed from ds to P.

• The magnitude of dB is inversely proportional to r^2, where r is the distance from ds to P.

• The magnitude of dB is proportional to the current and to the magnitude ds of the length element ds.

• The magnitude of dB is proportional to $\sin_\theta$, where θ is the angle between the vectors ds and $\hat{r}$.

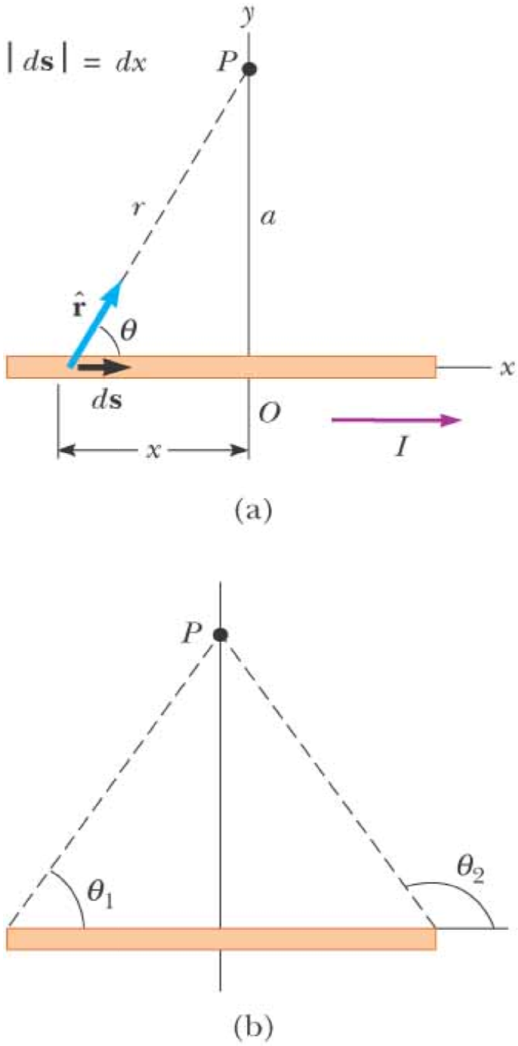
These observations can be summarized in the following equation,

$$d\vec{B} = \frac{\mu_0}{4\pi}\frac{I\ ds\ \sin_\theta}{r^2} = \frac{\mu_0}{4\pi}\frac{I\ d\vec{s}\ x\hat{r}}{r^2} \qquad 30.1$$

Where $\mu_0 = 4\pi \ x \ 10^{-7} Wb / A.m$ and called the permeability of the free space.

To find the total magnetic field B created at some point by a current of finite size, we must sum up contributions from all current elements *Ids that make up the current. That is, we* must evaluate B by integrating Equation 30.1,

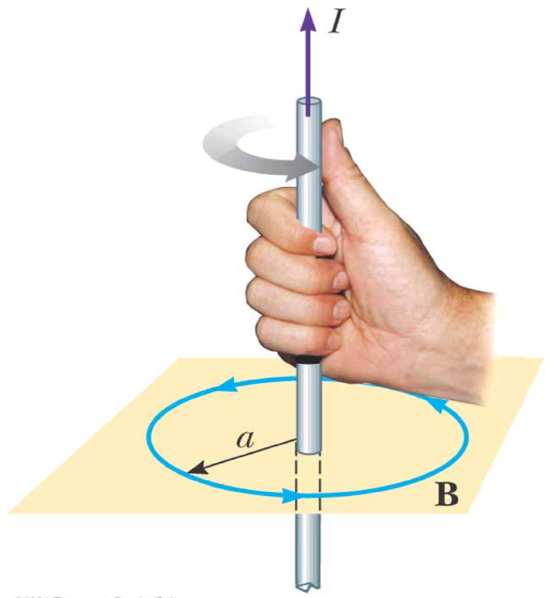
$$\vec{B} = \frac{\mu_0 I}{4\pi} \int \frac{d\vec{s} \ x \ \hat{r}}{r^2}$$



Application of Biot-Savart Law:

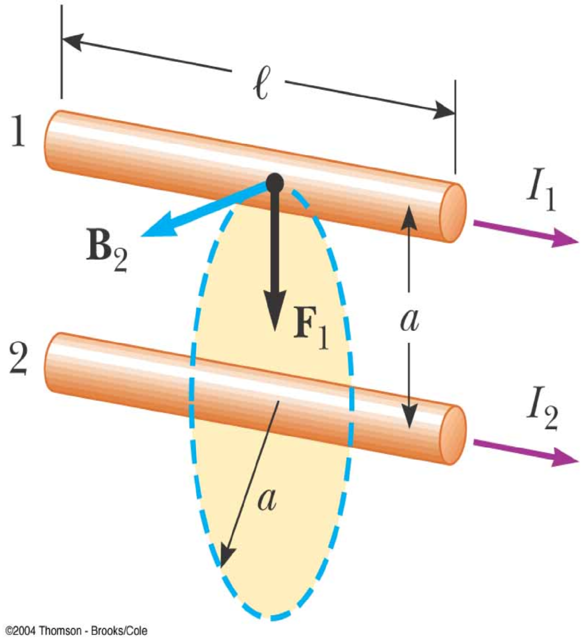
Magnetic field surrounding a thin, straight conductor,

$$B = \frac{\mu_0}{2\pi} \frac{I}{a} \qquad 30.2$$



The right-hand rule for determining the direction of the magnetic field surrounding a long, straight wire carrying a current. Note that the magnetic field lines form circles around the wire.

30.2 The magnetic force between two parallel conductors:



Consider two long, straight, parallel wires separated by a distance **a** and carrying currents **I_1** and **I_2** in the same direction.

We can determine the force exerted on one wire due to the magnetic field set up by the other wire.

From the figure, the magnetic field on wire 1 is,

$$B_2 = \frac{\mu_0}{2\pi} . \frac{I_2}{a} \qquad 30.3$$

The magnetic force acting on wire 1 is

$$F_1 = I_1 l B_2 \qquad 30.4$$

So, one can substitute eq. (30.3) in eq. (30.4) and get,

$$F_1 = I_1 l \left(\frac{\mu_0}{2\pi} . \frac{I_2}{a}\right)$$

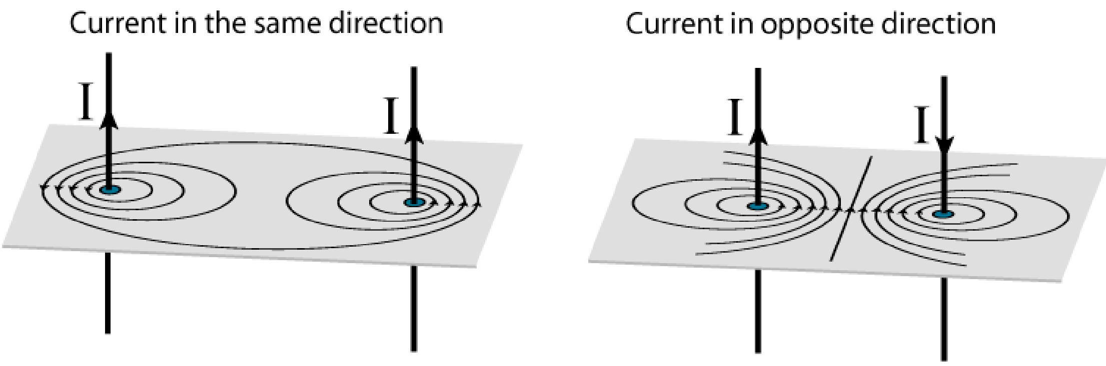
$$F_1 = \frac{\mu_0}{2\pi} . \frac{I_1 I_2}{a} l \qquad 30.5$$

This equation (30.5) can be rewritten in terms of the force per unit length,

$$F = \frac{\mu_0 l}{2\pi} . \frac{I_1 I_2}{a} \qquad 30.6$$

Or, $$\frac{F}{l} = \frac{\mu_0}{2\pi} . \frac{I_1 I_2}{a}$$

Note that: parallel conductors carrying currents in the same direction attract each other, and parallel conductors carrying currents in opposite directions repel each other.

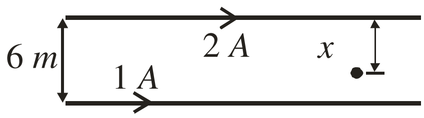


Catapult field produced by 2 straight curretn carrying conductors

Examples:

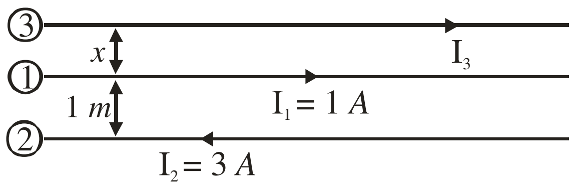
ما هي قيمة *x* التي يتلاشى عندها المجال المغناطيسي؟

Q21- What is the distance *x* at which the magnetic field vanishes?



A) 1 B) 2 C) 4 D) 5

المسافة *x* التي عندها تكون القوة المؤثرة على السلك رقم 3 تساوي الصفر هي:



A) 1.5 B) 1 C) 0.5 D) 0.25

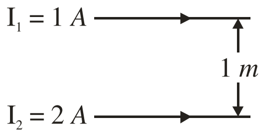
Q18- Two long, parallel conductors separated by 10 *cm* carry currents in the same direction, $I_1 = 5\ A$ and $I_2 = 8\ A$. The force per unit length exerted on each conductor by the other is:

س- موصلان طويلان متوازيان، تفصلهما مسافة 10 *cm* يحملان تيارين $I_1 = 5\ A$ و $I_2 = 8\ A$، القوة المؤثرة على وحدة الطول لكل من الموصلين هي:

A) 32×10^{-5}	B) 16×10^{-5}
C) 8×10^{-5}	D) 4×10^{-5}

س٩- القوة لوحدة الأطوال على الموصلين تساوي:

Q9- The force per unit length upon the wires is:



A) 16×10^{-7} B) 12×10^{-7} C) 8×10^{-7} D) 4×10^{-7}