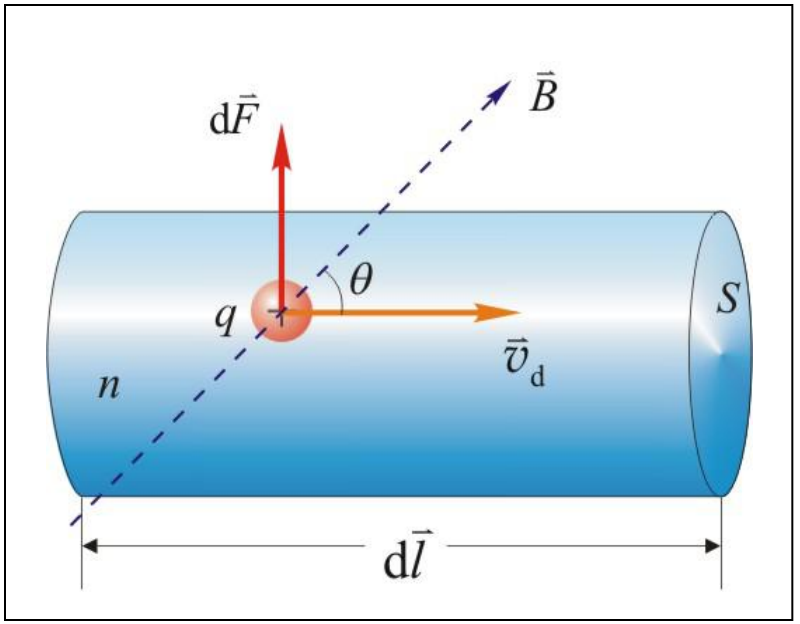
17.2 磁场对载流导线的作用

➢载流导线在磁场中受的力

设：载流子数密度 n

电流元截面积 S

载流子电荷量 q



$$\vec{F}_L = q\vec{v}_d \times \vec{B}$$

电流元中的电子数 $nSdl$

$$d\vec{F} = (nSdl)\cdot \vec{F}_L = nS|q|v_d d\vec{l} \times \vec{B} \qquad \because \quad I = |q|nSv_d$$

□安培定律 ： $d\vec{F} = Id\vec{l} \times \vec{B}$

安培力的基本计算公式：$\vec{F} = \int_l d\vec{F} = \int_l Id\vec{l} \times \vec{B}$

例题1

计算长为L的载流直导线在均匀磁场B中所受的力。

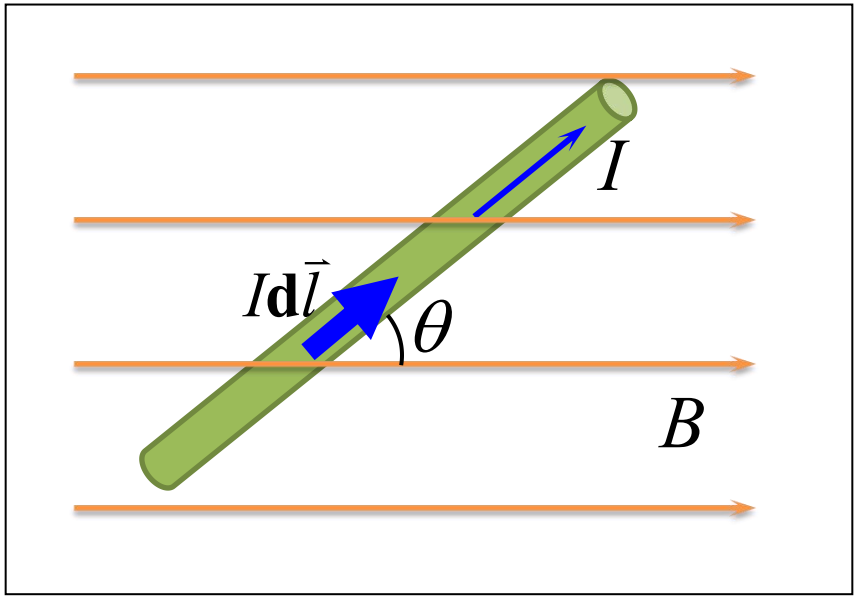
解：$d\vec{F} = Id\vec{l} \times \vec{B}$

$dF = IB\sin\theta\, dl$　　向内

$$F = \int_L IB\sin\theta\, dl$$

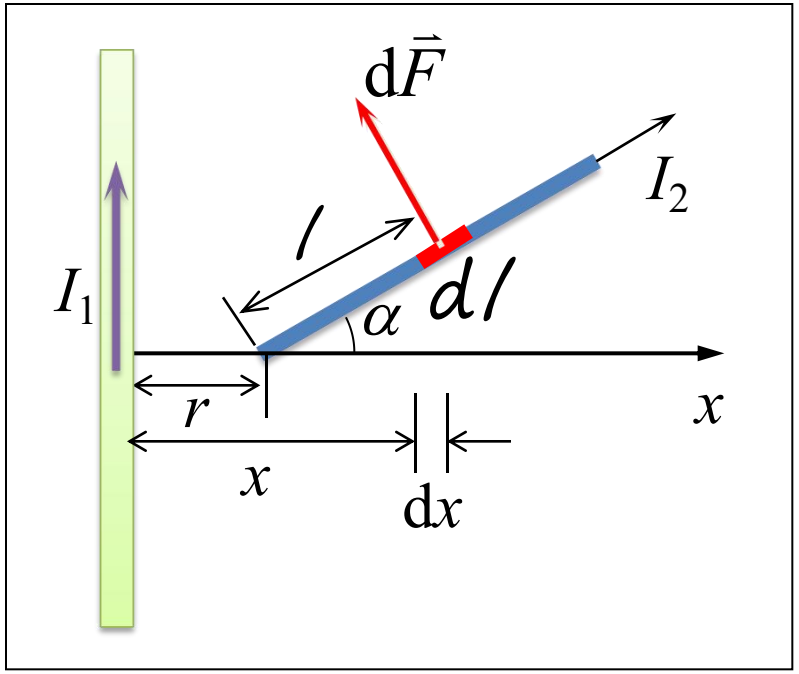
$$= IB\sin\theta \int_L dl$$

$$F = ILB\sin\theta$$



例题2

无限长直载流导线通有电流I_1，在同一平面内有长为L的载流直导线，通有电流I_2（如图所示）。求长为L的导线所受的磁场力。



解： $dF = I_2 dl B = I_2 dl \dfrac{\mu_0 I_1}{2\pi x}$

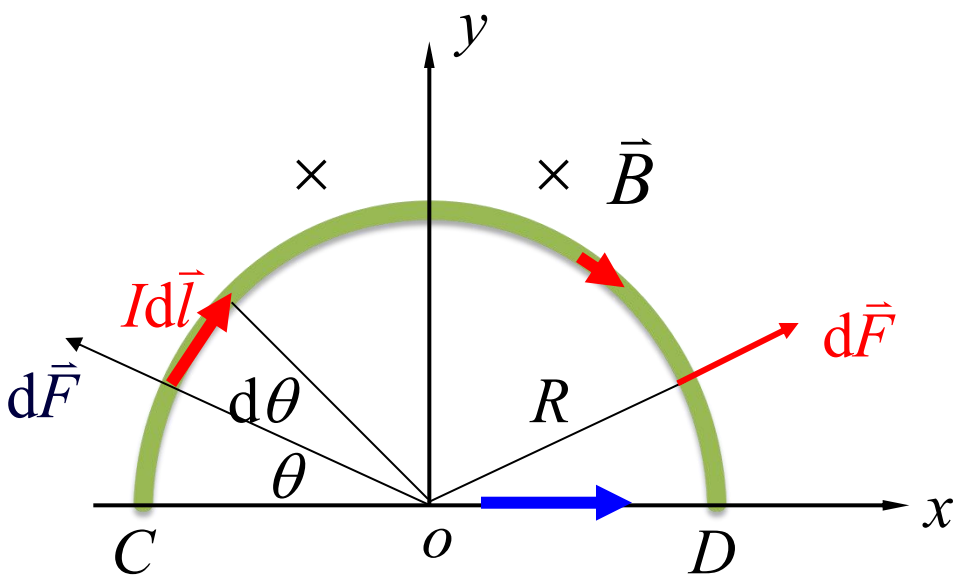
$x = r + l\cos\alpha \qquad dl = \dfrac{dx}{\cos\alpha}$

$$dF = \frac{\mu_0 I_1 I_2}{2\pi x}\frac{dx}{\cos\alpha}$$

$$F = \int dF = \frac{\mu_0 I_1 I_2}{2\pi\cos\alpha}\int_r^{r+L\cos\alpha}\frac{dx}{x} = \frac{\mu_0 I_1 I_2}{2\pi\cos\alpha}\ln\frac{r+L\cos\alpha}{r}$$

例题3

均匀磁场中半圆形电流所受安培力。



解： 取一段电流元 $Id\vec{l}$

$$d\vec{F} = Id\vec{l} \times \vec{B}$$

$$dF = IdlB = IBRd\theta$$

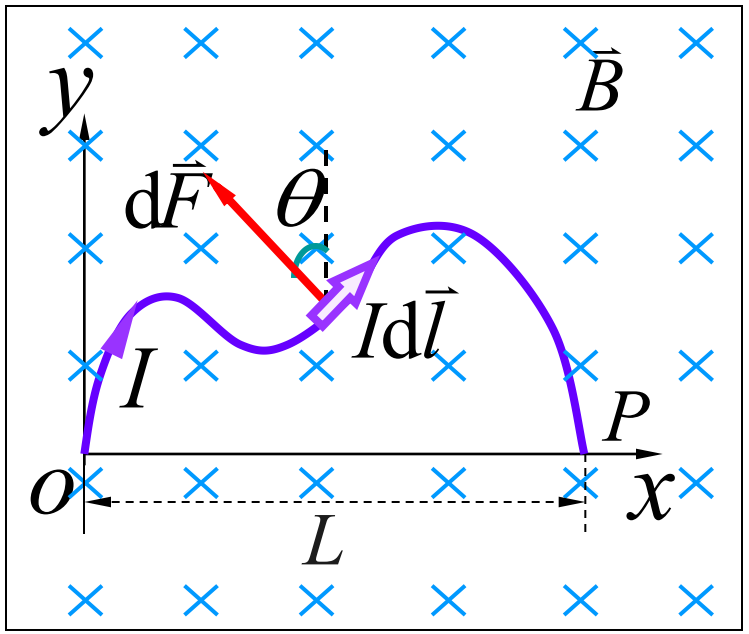
$$dF_y = IBRd\theta \cdot \sin\theta$$

与CD段直电流受力相同

$$F = F_y = \int dF_y = \int_0^{\pi} IBRd\theta \cdot \sin\theta = IB2R$$

例题4

求如图不规则的平面载流导线在均匀磁场中所受的力，已知 $\vec{B}$ 和 I 。



解： 取一段电流元 $Id\vec{l}$

$$d\vec{F} = Id\vec{l} \times \vec{B}$$

$$dF_x = dF\sin\theta = BIdl\sin\theta = BIdy$$

$$dF_y = dF\cos\theta = BIdl\cos\theta = BIdx$$

$$F_x = \int dF_x = BI\int_0^0 dy = 0$$

$$F_y = \int dF_y = BI\int_0^L dx = BIL$$

$$\vec{F} = \vec{F}_y = BIL\vec{j}$$

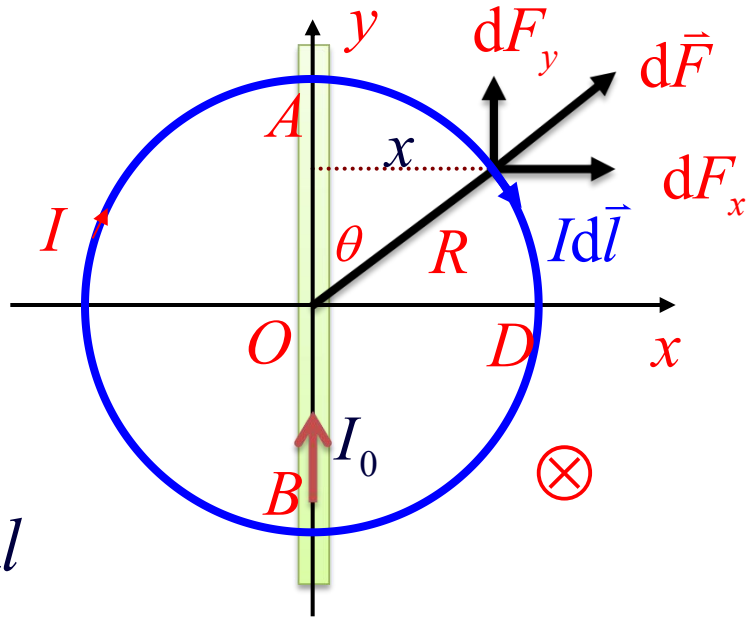
结论：任意平面载流导线在均匀磁场中所受的力，与其始点和终点相同的载流直导线所受的磁场力相同。

例题5

载流为I_0的无限长直导线,沿一半径为R的圆电流I的直径AB放置。求:

(1)半圆弧ADB受到的安培力;

(2) 整个圆电流受到的安培力。



解:(1)在半圆弧ADB上任取一电流元 $Id\vec{l}$

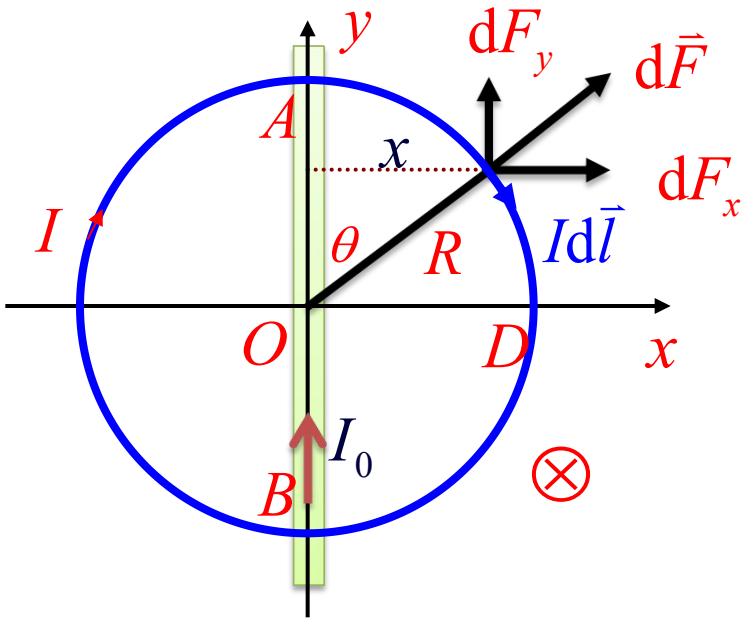
$$dF = BIdl = \frac{\mu_0 I_0 I}{2\pi x}dl = \frac{\mu_0 I_0 I}{2\pi R\sin\theta}dl$$

$$\begin{cases} dF_x = dF\sin\theta = \dfrac{\mu_0 I_0 I}{2\pi R}dl \\ dF_y = dF\cos\theta \end{cases}$$

由对称性 $F_y = \int_{ACB} \mathrm{d}F_y = 0$

$$F_{ACB} = F_x = \int_{ACB} \mathrm{d}F_x$$

$$= \int_0^{\pi R} \frac{\mu_0 I_0 I}{2\pi R} \mathrm{d}l = \frac{1}{2}\mu_0 I_0 I$$



(2) 整个圆电流受到的安培力？

$$F = \int_0^{2\pi R} \frac{\mu_0 I_0 I}{2\pi R} \mathrm{d}l = \mu_0 I_0 I$$