2-21

解 (1) 取半径为 $r(\dfrac{D_2}{2} < r < \dfrac{D_1}{2})$ 的环形回路,由对称性知该环路上的磁感应强度均沿切向,则由安培环路定理知

$$2\pi r B = \mu_0 N I$$

则

$$B = \frac{\mu_0 N I}{2\pi r}$$

(2)

$$\begin{aligned}
\Phi_B &= \int_{\frac{D_2}{2}}^{\frac{D_1}{2}} Bh\,\mathrm{d}r \\
&= \int_{\frac{D_2}{2}}^{\frac{D_1}{2}} \frac{\mu_0 N I}{2\pi r} h\,\mathrm{d}r \\
&= \frac{\mu_0 N I h}{2\pi} \ln \frac{D_1}{D_2}
\end{aligned}$$

2-22

解 由对称性知磁感应强度与平面平行且与电流方向垂直,取一穿过载流板的矩形回路则由安培环路定理知

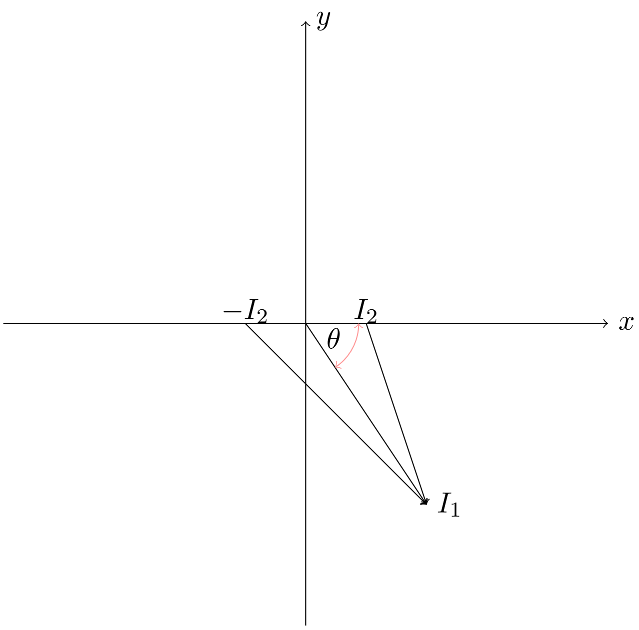
$$B \cdot 2l = \mu_0 \iota l$$

则

$$B = \frac{\mu_0 \iota}{2}$$

2-32

解 (1)



$$\begin{aligned}\vec{F}_1 &= \frac{\mu_0 I_1 I_2 a}{\pi\sqrt{a^2+b^2-2ab\cos\theta}}\frac{(b\cos\theta-a)\hat{x}-b\sin\theta\hat{y}}{\sqrt{(b\cos\theta-a)^2+b^2\sin^2\theta}}\\ &= \frac{\mu_0 I_1 I_2 a(b\cos\theta-a)}{\pi(a^2+b^2-2ab\cos\theta)}\hat{x}-\frac{\mu_0 I_1 I_2 ab\sin\theta}{\pi(a^2+b^2-2ab\cos\theta)}\hat{y}\end{aligned}$$

同理

$$\begin{aligned}\vec{F}_2 &= \frac{-\mu_0 I_1 I_2 a}{\pi\sqrt{a^2+b^2+2ab\cos\theta}}\frac{(b\cos\theta+a)\hat{x}-b\sin\theta\hat{y}}{\sqrt{(b\cos\theta+a)^2+b^2\sin^2\theta}}\\ &= \frac{-\mu_0 I_1 I_2 a(b\cos\theta+a)}{\pi(a^2+b^2+2ab\cos\theta)}\hat{x}+\frac{\mu_0 I_1 I_2 ab\sin\theta}{\pi(a^2+b^2+2ab\cos\theta)}\hat{y}\end{aligned}$$

故合力为

$$\begin{aligned}\vec{F} &= \vec{F}_1+\vec{F}_2\\ &= \frac{\mu_0 I_1 I_2 a}{\pi}\left(\frac{b\cos\theta-a}{a^2+b^2-2ab\cos\theta}-\frac{b\cos\theta+a}{a^2+b^2+2ab\cos\theta}\right)\hat{x}\\ &+\frac{\mu_0 I_1 I_2 ab\sin\theta}{\pi}\left(\frac{1}{a^2+b^2+2ab\cos\theta}-\frac{1}{a^2+b^2-2ab\cos\theta}\right)\hat{y}\end{aligned}$$

故合力矩为

$$\begin{aligned}\vec{L} &= \vec{r}_1\times\vec{F}_1+\vec{r}_2\times\vec{F}_2\\ &= a\hat{x}\times\vec{F}_1-a\hat{x}\times\vec{F}_2\\ &= a\hat{x}\times\left(\vec{F}_1-\vec{F}_2\right)\\ &= a(F_{1y}-F_{2y})\hat{z}\\ &= \frac{-\mu_0 I_1 I_2 a^2 b\sin\theta}{\pi}\left(\frac{1}{a^2+b^2+2ab\cos\theta}+\frac{1}{a^2+b^2-2ab\cos\theta}\right)\hat{z}\end{aligned}$$

(2) 欲使线圈平衡则

$$L=0$$

即 $\sin\theta=0$ 则

$$\theta=\begin{cases}0\\ \pi\end{cases}$$

(3)

$$\begin{aligned}W &= \int_0^{\frac{\pi}{2}} L\,\mathrm{d}\theta\\ &= -\frac{\mu_0 I_1 I_2 a}{\pi}\ln\frac{b-a}{b+a}\end{aligned}$$

2-33

解 由对称性知线圈受力一定垂直于导线方向

$$\begin{aligned} F &= \int \mathrm{d}F\cos\theta \\ &= 2\int_0^\pi \frac{\mu_0 I_1 I_2 \cos\theta\,\mathrm{d}\theta}{2\pi(l-r\cos\theta)} \\ &= \mu_0 I_1 I_2\left(1-\frac{l}{\sqrt{l^2-r^2}}\right) \end{aligned}$$

2-35

解 (1)

$$\begin{aligned} L_{磁} &= NIBS \\ &= NIabB \\ &= 1.0\times10^{-6}\mathrm{N\cdot m} \end{aligned}$$

(2)

$$\begin{aligned} D &= \frac{L_{磁}}{\varphi} \\ &= 1.9\times10^{-6}\mathrm{N\cdot m} \end{aligned}$$