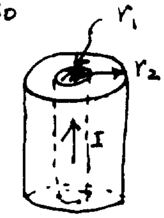
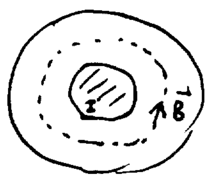
chp. 30

#17.



From the cylindrical symmetry, we know that the mag. field will be tangent to a circle centered on the axis of the cylinders and will depend only on the distance from the axis.

We use Ampere's law: $\oint \vec{B}\cdot d\vec{s} = \mu_0 I_{enclosed}$



$$\Rightarrow B\cdot 2\pi r = \mu_0 I$$

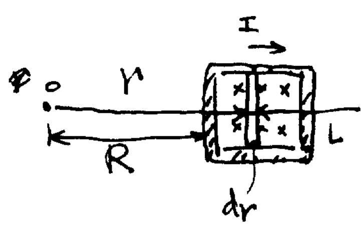
$$\Rightarrow B = 4\pi\times10^{-7}\times10 / 2\pi\times r$$

Thus at the midway where $r = \frac{0.1+0.5}{2} = 0.3$ cm

$$B = 4\pi\times10^{-7}\times10 / 2\pi\times0.3\times10^{-2} = 6.7\times10^{-4}\ \text{T}$$ in circular direction.

#31. The magnetic field inside the toroidal solenoid is circular and varies with the distance from the center of the torus r:

$$B = \frac{\mu_0 NI}{2\pi r} \quad (\text{from Ampere's law})$$



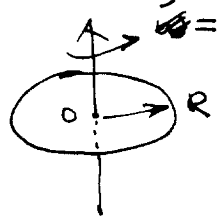
We find flux by integration.

$$\phi_B = \iint \vec{B}\cdot d\vec{A} = \int_R^{R+L} B(r)\cdot L\,dr$$

$$= \int_R^{R+L} \frac{\mu_0 NI}{2\pi r}\cdot L\,dr = \frac{\mu_0 NIL}{2\pi}\int_R^{R+L}\frac{dr}{r}$$

$$\Rightarrow \phi_B = \frac{\mu_0 NIL}{2\pi}\ln\left(\frac{R+L}{R}\right)$$

#38)



the rotating ring is equivalent to a circular current, which has a magnitude:

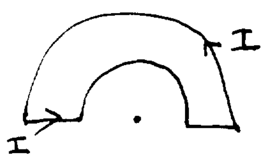
$$I = Q/T = Qf$$

thus the magnetic field at the center of the ring is:

$$B = \mu_0 I / 2R = \mu_0 Q f / 2R = 4\pi\times10^{-7} \times 2\times10^{-5} \times 200 / 2\times1.5\times10^{-2} = 1.7\times10^{-7}\ \mathrm{T}$$

along the axis.

#43



Because the point P is along the line of the two straight segments of the wire, there is no magnetic field from these segments.

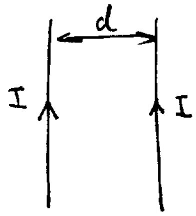
The magnetic field at the point P is the sum of two fields: $\vec{B} = \vec{B}_{\substack{inner \\ semi\text{-}circle}} + \vec{B}_{\substack{outer \\ semi\text{-}circle}}$

Each field is half that of a circular loop, with the field of the inner semicircle into the page and that of the outer semicircle out of the page, so:

$$B = \frac{1}{2}\frac{\mu_0 I}{2R_{inner}} - \frac{1}{2}\frac{\mu_0 I}{2R_{outer}} = \frac{\mu_0 I}{4}\cdot\frac{1}{R_{inner}} - \frac{\mu_0 I}{4}\frac{1}{R_{outer}}$$

$$= \pi\times10^{-7}\times12\left(\frac{1}{0.05} - \frac{1}{0.08}\right) = 2.8\times10^{-5}\ \mathrm{T}$$ into the page.

#63) a) For the attractive magnetic force per unit length,



we have $F_B/L = \dfrac{I\mu_0 I}{2\pi d} = \dfrac{2\times10^{-7}\times1^2}{1\times10^{-2}} = 2.0\times10^{-5}\ N/m$

the linear charge density is:

$$\lambda = 10^{21}\times100\times1.6\times10^{-19} = 1.6\times10^{4}\ C/m$$

The electric field at a distance d from an infinite line of charge is $E = \dfrac{1}{2\pi\varepsilon_0}\dfrac{\lambda}{d}$ (23-31)

For the repulsive electric force per unit length, we have

$$F_E/L = \lambda E = \frac{1}{2\pi\varepsilon_0}\frac{\lambda^2}{d} = 2\times\frac{9\times10^9\times1.6\times10^{14}}{1\times10^{-2}} = 4.6\times10^{20}\ N/m$$

the ratio of the forces is:

$$\frac{F_B}{F_e} = 4.3\times10^{-26}$$

b) For the forces to be equal, we have:

$$\frac{\lambda^2}{\varepsilon_0} = \mu_0 I^2 \quad \text{or} \quad \lambda^2 = \varepsilon_0\mu_0 I^2$$

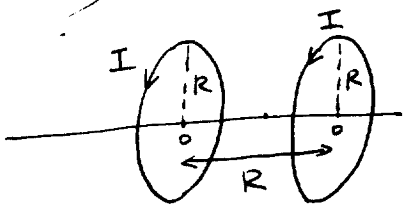
Since $\varepsilon_0\mu_0 = 1/c^2$ and $\lambda = ne$, we get:

$$n = I/ce = 1/(3\times10^8)\times(1.6\times10^{-19}) = 2.1\times10^{10}\ \text{electrons}/m = 2.1\times10^{8}\ /cm$$

c) For the fraction that is the excess, we have:

$$f = 2.1\times10^{8}/10^{21} = 2.1\times10^{-13}$$

#65)



(a) We choose $x=0$ at the left coil.

The magnetic fields on the axis from the coils are in the same direction, so we find the total magnetic field from:

$$B(x) = \frac{\mu_0 I}{2}\left\{\frac{R^2}{(R^2+x^2)^{3/2}} + \frac{R^2}{[R^2+(R-x)^2]^{3/2}}\right\}$$

$$= \frac{\mu_0 I}{2R}\left\{\frac{1}{[1+(\frac{x}{R})^2]^{3/2}} + \frac{1}{[2-2(\frac{x}{R})+(\frac{x}{R})^2]^{3/2}}\right\}$$

at $x=0$, $B(0) = \frac{\mu_0 I}{2R}\left(1+\frac{1}{2^{3/2}}\right) = 0.677\,\mu_0 I/R$

at $x=R/4$: $B(R/4) = \frac{\mu_0 I}{2R}\left(\left\{\frac{1}{[1+(\frac{1}{4})^2]^{3/2}}\right\} + \frac{1}{[2-2\times\frac{1}{4}+(\frac{1}{4})^2]^{3/2}}\right) = 0.713\,\mu_0 I/R$

at $x=R/2$: $B(R/2) = \frac{\mu_0 I}{2R}\left(\frac{1}{[1+(\frac{1}{2})^2]^{3/2}} + \frac{1}{[2-2\times\frac{1}{2}+(\frac{1}{2})^2]^{3/2}}\right) = 0.716\,\mu_0 I/R$

(b). $$\frac{dB}{dx} = -\frac{3\mu_0 I}{2R^2}\left\{\frac{x/R}{[1+(\frac{x}{R})^2]^{5/2}} + \frac{x/R-1}{[2-2(\frac{x}{R})+(\frac{x}{R})^2]^{5/2}}\right\}$$

$$\frac{d^2B}{dx^2} = -\frac{3\mu_0 I}{2R^3}\left\{\frac{1}{[1+(\frac{x}{R})^2]^{5/2}} - \frac{5(x/R)^2}{[1+(\frac{x}{R})^2]^{7/2}} + \frac{1}{[2-2(\frac{x}{R})+(\frac{x}{R})^2]^{5/2}} - \frac{5[(\frac{x}{R})-1]^2}{[2-2(\frac{x}{R})+(\frac{x}{R})^2]}\right.$$

$\therefore$ At $x=R/2$:

$$\frac{dB}{dx} = -\frac{3\mu_0 I}{2R^2}\left\{\frac{1/2}{[1+(1/2)^2]^{5/2}} + \frac{1/2-1}{[2-2(\frac{1}{2})+(1/2)^2]^{5/2}}\right\} = 0$$

$$\frac{d^2B}{dx^2} = -\frac{3\mu_0 I}{2R^3}\left\{\frac{1}{[1+(\frac{1}{2})^2]^{5/2}} - \frac{5(1/2)^2}{[1+(1/2)^2]^{7/2}} + \frac{1}{[2-2(\frac{1}{2})+(1/2)^2]^{5/2}} - \frac{5[1/2-1]^2}{[2-2(\frac{1}{2})+(1/2)^2]}\right.$$

$$= 0$$