

Homework 8

Chapter 22

Problem 33. In studies of the possibility of migrating birds using the Earth's magnetic field for navigation, birds have been fitted with coils as “caps” and “collars” as shown in Figure P22.33. (a) If the identical coils have radii of $r = 1.20$ cm and are $d = 2.20$ cm apart, with $N = 50$ turns of wire apiece, what current should they both carry to produce a magnetic field of $B = 4.50 \cdot 10^{-5}$ T halfway between them? (b) If the resistance of each coil is $R = 210\Omega$, what voltage should the battery supplying each coil have? (c) What power is delivered to each coil?

(a) From page 745 we have the magnetic field along the axis of symmetry of a loop of wire as

$$\mathbf{B} = \frac{\mu_0 I r^2}{2(x^2 + r^2)^{3/2}} \hat{\mathbf{i}} \quad (1)$$

All of our $2N$ loops are equidistant from the center, with $x = d/2$ so

$$B = \frac{\mu_0 I r^2}{2(x^2 + r^2)^{3/2}} \cdot (2N) \quad (2)$$

$$I = \frac{(x^2 + r^2)^{3/2} B}{\mu_0 N r^2} = 21.4 \text{ mA} \quad (3)$$

(b) Using Ohm's law

$$V = IR = 4.51 \text{ V} \quad (4)$$

(c)

$$P = IV = 96.7 \text{ mW} \quad (5)$$

Problem 39. A packed bundle of $N = 100$ long, straight, insulated wires forms a cylinder of radius $R = 0.500$ cm. (a) If each wire carries $I = 2.00$ A, what are the magnitude and direction of the magnetic force per unit length acting on a wire located $r = 0.200$ cm from the center of the bundle? (b) Would a wire on the outer edge of the bundle experience a force greater or smaller than the value calculated in (a).

(a) Drawing an Amperian loop at a radius r , the number of enclosed wires is

$$N_{enc} = N \frac{\pi r^2}{\pi R^2} = N \frac{r^2}{R^2} \quad (6)$$

So the magnetic field is

$$B = \frac{\mu_0 I N r^2 / R^2}{2\pi r} = \frac{\mu_0 I N r}{2\pi R^2} = 3.17 \cdot 10^{-3} \text{ T} , \quad (7)$$

and the force per unit length is

$$\frac{F}{l} = IB = \frac{\mu_0 I^2 N r}{2\pi R^2} = 6.34 \text{ mN/m} . \quad (8)$$

(b) From the previous equation, you can see the force increases linearly with r (so long as we stay inside the wire), so the force will be **greater** at the outer edge.

Problem 56. An $m = 0.200$ kg metal rod carrying a current of $I = 10.0$ A glides on two horizontal rails $l = 0.500$ m apart. What vertical magnetic field is required to keep the rod moving at a constant speed if the coefficient of kinetic friction between the rod and rails is $\mu_k = 0.100$?

Balancing the forces on the rod in the $\hat{\mathbf{j}}$ direction

$$N - mg = 0 \quad (9)$$

$$N = mg , \quad (10)$$

and in the $\hat{\mathbf{i}}$ direction

$$IlB - \mu_k N = 0 \quad (11)$$

$$B = \frac{\mu_k mg}{Il} = 39.2 \text{ mT} , \quad (12)$$

where we are ignoring the magnetic field generated by the current in the rails.