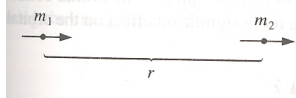
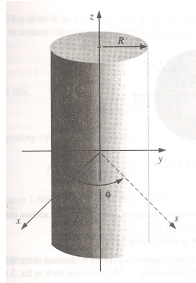


1. [G 6.3] Find the force of attraction between two magnetic dipoles,  $\mathbf{m}_1$  and  $\mathbf{m}_2$ , oriented as shown in the Fig., a distance  $r$  apart, (a) using  $F = 2\pi IRB \cos \theta$ , and (b) using  $\mathbf{F} = \nabla(\mathbf{m} \cdot \mathbf{B})$ .



2. [G 6.8] A long circular cylinder of radius  $R$  carries a magnetization  $\mathbf{M} = ks^2\hat{\phi}$ , where  $k$  is a constant,  $s$  is the distance from the axis, and  $\hat{\phi}$  is the usual azimuthal unit vector (Fig.). Find the magnetic field due to  $\mathbf{M}$ , for points inside and outside the cylinder.

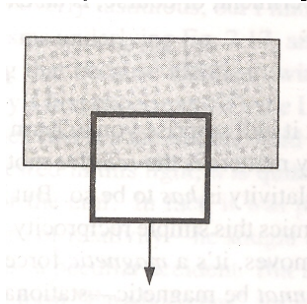


3. [G 6.12] An infinitely long cylinder, of radius  $R$ , carries a “frozen-in” magnetization, parallel to the axis,

$$\mathbf{M} = ks\hat{\mathbf{z}},$$

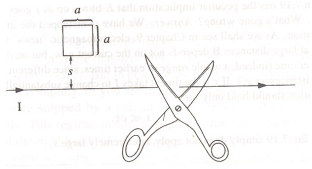
where  $k$  is a constant and  $s$  is the distance from the axis; there is no free current anywhere. Find the magnetic field inside and outside the cylinder by two different methods:

- (a) Locate all bound currents, and calculate the field they produce.  
 (b) Use Ampere's law  $\oint \mathbf{H} \cdot d\mathbf{l} = I_{enc}$ , to find  $\mathbf{H}$ , and then get  $\mathbf{B}$  from  $\mathbf{H} \equiv \frac{1}{\mu_0}\mathbf{B} - \mathbf{M}$ .
4. [G 7.11] A square loop is cut out of a thick sheet of aluminum. It is then placed so that the top portion is in a uniform magnetic field  $\mathbf{B}$ , and allowed to fall under gravity (Fig.). (In the diagram, shading indicates the field region;  $\mathbf{B}$  points into the page.) If the magnetic field is 1 T, find the terminal velocity of the loop (in m/s). Find the velocity of the loop as a function of time. How long does it take (in seconds) to reach, say, 90% of the terminal velocity? What would happen if you cut a tiny slit in the ring, breaking the circuit?



5. [G 7.12] A long solenoid of radius  $a$ , is driven by an alternating current, so that the field inside is sinusoidal:  $\mathbf{B}(t) = B_0 \cos(\omega t)\hat{\mathbf{z}}$ . A circular loop of wire, of radius  $a/2$  and resistance  $R$ , is placed inside the solenoid, and coaxial with it. Find the current induced in the loop, as a function of time.
6. [G 7.18] A square loop, side  $a$ , resistance  $R$ , lies a distance  $s$  from an infinite straight wire that carries current  $I$  (Fig.). Now someone cuts the wire, so that  $I$  drops to zero. In what direction does the induced current in the square loop flow, and what total charge passes a given point in the loop during the time this current flows? If you don't like the scissors model, turn the current down *gradually*:

$$I(t) = \begin{cases} (1 - \alpha t)I, & \text{for } 0 \leq t \leq 1/\alpha, \\ 0, & \text{for } t > 1/\alpha. \end{cases}$$



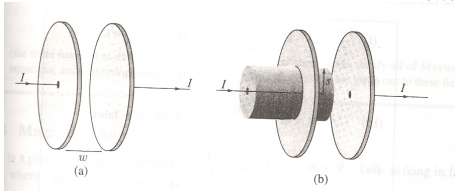
7. [G 7.24] An alternating current  $I_0 \cos(\omega t)$  (amplitude 0.5 A, frequency 60 Hz) flows down a straight wire, which runs along the axis of a toroidal coil with rectangular cross section (inner radius 1 cm, outer radius 2 cm, height 1 cm, 1000 turns). The coil is connected to a  $500 \Omega$  resistor.

- (a) In the quasistatic approximation, what emf is induced in the toroid? Find the current,  $I_r(t)$ , in the resistor.  
 (b) Calculate the back emf in the coil, due to the current  $I_r(t)$ . What is the ratio of the amplitudes of this back emf and the “direct” emf in (a)?

8. [G 7.26] Find the energy stored in a section of length  $l$  of a long solenoid (radius  $R$ , current  $I$ ,  $n$  turns per unit length), (a) using  $W = \frac{1}{2}LI^2$ ; (b) using  $W = \frac{1}{2} \oint (\mathbf{A} \cdot \mathbf{I}) dl$ ; (c) using  $W = \frac{1}{2\mu_0} \int_{all\ space} B^2 d\tau$  (d) using  $W = \frac{1}{2\mu_0} [\int_{\nu} B^2 d\tau - \oint_S (\mathbf{A} \times \mathbf{B}) \cdot d\mathbf{a}]$  (take as your volume the cylindrical tube from radius  $a < R$  out to radius  $b > R$ ).

9. [G 7.32] Imagine *thin* wires connecting to the centers of plates as shown in Fig. (a), carrying constant current  $I$ . The radius of the capacitor is  $a$  and the separation of the plates is  $w \ll a$ . Assume that the current flows out over the plates in such a way that the surface charge is uniform, at any given time, and is zero at  $t = 0$ .

- (a) Find the electric field between the plates, as a function of  $t$ .  
 (b) Find the displacement current through a circle of radius  $s$  in the plane midway between the plates. Using this circle as your “Amperian loop”, and the flat surface that spans it, find the magnetic field at a distance  $s$  from the axis.  
 (c) Repeat part (b), but this time use the cylindrical surface in Fig. (b), which extends to the left through the plate and terminates outside the capacitor. Notice that the displacement current through this surface is zero, and there are two contributions to  $I_{enc}$ .



10. [G 7.34] Suppose

$$\mathbf{E}(\mathbf{r}, t) = -\frac{1}{4\pi\epsilon_0} \frac{q}{r^2} \theta(vt - r) \hat{\mathbf{r}}; \mathbf{B}(\mathbf{r}, t) = 0$$

Show that these fields satisfy all of Maxwell’s equations, and determine  $\rho$  and  $\mathbf{J}$ . Describe the physical situation that gives rise to these fields.