1. In the figure, a long circular pipe with outside radius \( R = 2.6 \text{ cm} \) carries a (uniformly distributed) current \( i = 8.00 \text{ mA} \) into the page. A wire runs parallel to the pipe at a distance of \( 3.00R \) from center to center. Find the (a) magnitude and (b) direction (into or out of the page) of the current in the wire such that the net magnetic field at point \( P \) has the same magnitude as the net magnetic field at the center of the pipe but is in the opposite direction.

2. The figure shows an idealized schematic drawing of a rail gun. Projectile \( P \) sits between two wide rails of circular cross section; a source of current sends current through the rails and through the (conducting) projectile (a fuse is not used). (a) Let \( w \) be the distance between the rails, \( R \) the radius of each rail, and \( i \) the current. Show that the force on the projectile is directed to the right along the rails and is given approximately by

\[
F = \frac{i^2 \mu_0 \ln \left( \frac{w+R}{R} \right)}{2\pi}
\]

(b) If the projectile starts from the left end of the rails at rest, find the speed \( v \) at which it is expelled at the right. Assume that \( i = 450 \text{ kA} \), \( w = 12 \text{ mm} \), \( R = 6.7 \text{ cm} \), \( L = 4.0 \text{ m} \), and the projectile mass is 10 g.

3. The figure shows a cross section of a long conducting coaxial cable and gives its radii \( (a, b, c) \). Equal but opposite currents \( i \) are uniformly distributed in the two conductors. Derive expressions for \( B(r) \) with radial distance \( r \) in the ranges (a) \( r < c \), (b) \( c < r < b \), (c) \( b < r < a \); and (d) \( r > a \). (e) Test these expressions for all the special cases that occur to you. (f) Assume that \( a = 2.0 \text{ cm} \), \( b = 1.8 \text{ cm} \), \( c = 0.40 \text{ cm} \), and \( i = 120 \text{ A} \) and plot the function \( B(r) \) over the range \( 0 < r < 3 \text{ cm} \).

4. A rectangular coil of \( N \) turns and of length \( a \) and width \( b \) is rotated at frequency \( f \) in a uniform magnetic field \( B \), as indicated in the figure. The coil is connected to co-rotating cylinders, against which metal brushes slide to make contact. (a) Show that the emf induced in the coil is given (as a function of time \( t \)) by

\[
\varepsilon = 2\pi f Nab \sin(2\pi ft) = \varepsilon_o \sin(2\pi ft)
\]

This is the principle of the commercial alternating-current generator. (b) What value of \( Nab \) gives an emf with \( \varepsilon_o = 150 \text{ V} \) when the loop is rotated at 60.0 rev/s in a uniform magnetic field of 0.500 T?
5. In the figure, a rectangular loop of wire with length \( a = 2.2 \text{ cm} \), width \( b = 0.80 \text{ cm} \) and resistance \( R = 0.40 \text{ m}\Omega \) is placed near an infinitely long wire carrying current \( i = 4.7 \text{ A} \). The loop is then moved away from the wire at constant speed \( v = 3.2 \text{ mm/s} \). When the center of the loop is at distance \( r = 1.5b \), what are (a) the magnitude of the magnetic flux through the loop and (b) the current induced in the loop?

6. In the figure, a long rectangular conducting loop, of width \( L \), resistance \( R \), and mass \( m \), is hung in a horizontal, uniform magnetic field \( \vec{B} \) that is directed into the page and that exists only above line \( aa \). The loop is then dropped; during its fall, it accelerates until it reaches a certain terminal speed \( v_f \). Ignoring air drag, find an expression for \( v_f \).

7. The figure shows a rod of length \( L = 10.0 \text{ cm} \) that is forced to move at constant speed \( v = 5.00 \text{ m/s} \) along horizontal rails. The rod, rails, and connecting strip at the right form a conducting loop. The rod has resistance \( 0.400 \text{ \Omega} \); the rest of the loop has negligible resistance. A current \( i = 100 \text{ A} \) through the long straight wire at distance \( a = 10.0 \text{ mm} \) from the loop sets up a (nonuniform) magnetic field through the loop. Find the (a) emf and (b) current induced in the loop. (c) At what rate is thermal energy generated in the rod? (d) What is the magnitude of the force that must be applied to the rod to make it move at constant speed? (e) At what rate does this force do work on the rod?

8. A circular loop (radius = 14 cm) of wire is placed in a magnetic field that makes an angle of 30° with the normal to the plane of the loop. The magnitude of this field increases at a constant rate from 30 mT to 60 mT in 15 ms. If the loop has a resistance of 5.0 \( \text{ \Omega} \), what is the magnitude of the current induced in the loop when the field magnitude is 50 mT?

9. A long straight wire carries a current \( i_1 \) as shown. A rectangular loop carries a current \( i_2 \). The top leg of the loop is parallel to the wire. The wire and loop are fixed in space. What is the force exerted by the wire on the loop?

10. The figure to the left shows a cross-section of a long cylindrical conductor of radius \( a \) containing a long cylindrical hole of radius \( b \). The central axes of the hole and cylinder are parallel and separated by a distance \( d \), as shown. A current \( i \) is uniformly distributed over the conductor. Find the magnetic field in the hole. Discuss the special cases \( b = 0 \) and \( d = 0 \).