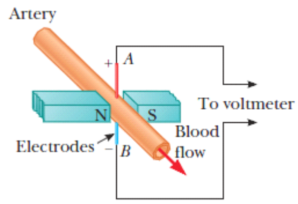
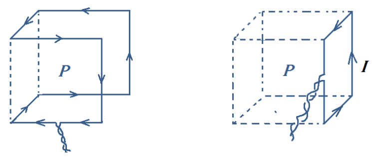
1[10pts] The wires in your house create negligible magnetic fields because the wires always come in pairs, carrying the same current in opposite directions. Consider two long, straight parallel wires, separated by a distance d, and carrying current i_0 in opposite directions. What is approximate magnetic field at r far away from one of the wires, $r \gg d$. Use your answer to estimate the size of B-field at $r = 10\,\text{cm}$, if $d = 2\,\text{mm}$, $i_0 = 10\,\text{A}$.

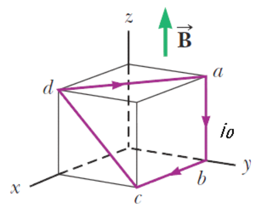
2[5pts] An electromagnetic flowmeter is to be used to measure blood speed. Blood containing ions (primarily Na^+) flows through an artery with a diameter of $3.8\,\text{mm}$. A magnetic field of $0.115\,\text{T}$ is applied across an artery. The Hall voltage is measured to be $88\,\mu\text{V}$. What is the average speed of the blood flowing in the artery?



3[10pts] Current I is flows about the wire frames in the figure. The length of each edge is 2ℓ.
(a) What is the direction of the magnetic field at P, the center of the cube.
(b) Show by using superposition that the field at P is the same as if the frame were replaced by the single square loop shown on the right.

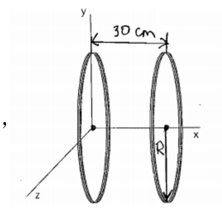


4[10pts] Each edge of cube shown in figure is ℓ. Four straight segments of wire-ab, bc, cd, da form a closed loop that carries a current i_0 in the direction shown. A uniform magnetic field of magnitude B is in the positive z-direction. Determine the magnitude and direction of the magnetic force on each segment.



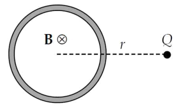
5[15pts] A long and straight coaxial cable consists of a thin hollow cylinder of radius a, surrounded by a concentric thin hollow cylinder of radius b. The cylinders carry equal and opposite currents i_0 distributed uniformly across their cross-sections.
(a) Calculate the magnetic field for $r < a$, $a < r < b$, and $r > b$.
(b) Find the magnetic energy density u_B in those three regions.
(c) Show that the self inductance of length ℓ of the cable is $L = \dfrac{\mu_0}{2\pi}\ell \ln\dfrac{b}{a}$.

6[10pts] The figure shows two coaxial coils, each of $N = 500$ turns and radius $R = 30\,\text{cm}$, separated by a distance $30\,\text{cm}$. Two coils carry equal current $I = 10\,\text{A}$ in the same direction. Calculate the resultant field B_x at $x = 10\,\text{cm}$, $x = 15\,\text{cm}$, $x = 30\,\text{cm}$, $x = 35\,\text{cm}$, $x = 40\,\text{cm}$, and sketch B_x vs x from $x = 0$ to $x = 40\,\text{cm}$.



7[10pts] Shown in cross-section is a long solenoid of radius R with a B-field into the page inside its windings, and negligible outside. A positive charge Q is at rest at a point outside the solenoid.

The solenoid current is increasing at rate dI/dt.

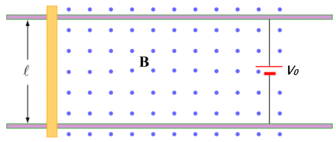


(a) What direction is the induced E-field at the location of the charge?

(b) What is the magnitude of the force on the charge?

(c) How would your answers change if $r < R$?

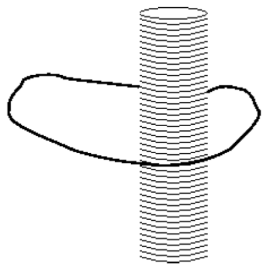
8[10pts] A conducting bar of mass m and resistance R slides on two frictionless parallel rails that are separated by a distance ℓ and connected by a battery which maintains a constant emf V_0, as shown. A uniform magnetic field B is directed out of the page. The bar is initially at rest. Show that at a later time t, the speed of the bar is



$$v = \frac{V_0}{B\ell}(1 - e^{-t/\tau}), \quad \tau = \frac{mR}{B^2\ell^2}.$$

(Note, the general solution of $\frac{dx}{dt} + \frac{1}{\tau}x = A$ is given by $x(t) = A\tau + Be^{-t/\tau}$)

9[10pts] Consider a single loop of wire wrapped around the outside of an long solenoid as shown. The solenoid is circular in cross section, of radius R and has N coils per length ℓ. The single loop is irregular in shape.



(a) Find the mutual inductance M between the loop and the solenoid.

(b) Suppose now that the loop goes around the solenoid twice. Again, find the mutual inductance M. How does it compare to the answer from part (a)?

10[10pts] In the circuit the switch is closed for several seconds, then opened. Make a graph with the abscissa time in milliseconds, showing the potential of point A with respect to ground, just before and then for 10 milliseconds after the opening of switch. Show also the variation of the potential at point B in the same period of time.