General Physics: Electromagnetism, Problem Set 10

Exercise 1 :

A long straight wire of radius a carries a current that is uniformly distributed over its cross-section. Find the magnetic field both inside and outside the wire.

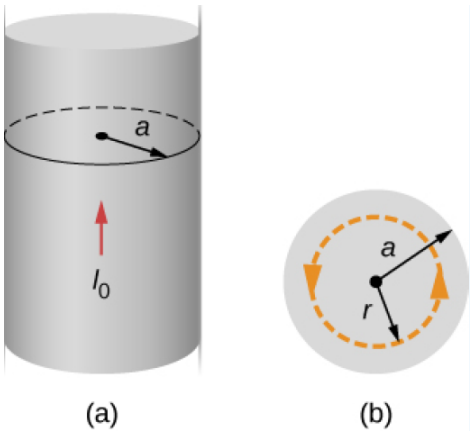

Figure 1: (a) A model of a current-carrying wire of radius a and current I_0 (b) A cross-section of the same wire showing the radius a and the Ampere's loop of radius r.

Exercise 2 :

Consider a toroid as shown in Figure 2 with a big radius R and a small radius a. The toroid contains N turns of the wire with current I. Suppose that the number of turns N is huge, such that we can consider cylindrical symmetry. Calculate the magnetic field $\overrightarrow{B}$ for:

(a) $r < R - a$;

(b) $R - a < r < R + a$;

(c) $r > R + a$;

and draw the lines of the field. What is the magnitude of the magnetic field in $r = R$ if $I = 500$ A, $N = 100$ and $R = 0.5$ m?

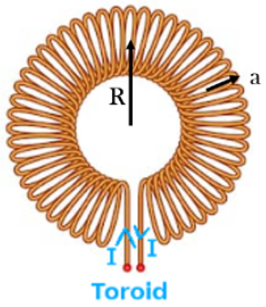

Figure 2: Toroid

Exercise 3 : A solenoid S with a diameter $D = 3.2$ cm has 200 turns/cm and carries a sinusoidal current $I = I_0 \sin(2\pi f t)$ (See Figure 3). In the center, we put a coil C of 130 tight turns with a diameter $d = 2.1$ cm. The amplitude of the current is $I_0 = 1.5$ A and the frequency is $f = 50$ Hz. What is the amplitude of the emf induced in the coil C?

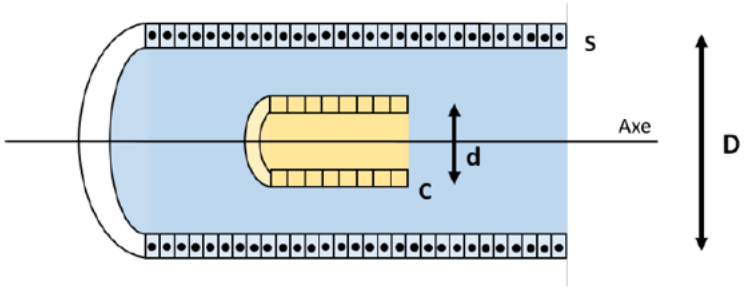

Figure 3: Solenoid S with sinusoidal current containing a coil C.

Exercise 4 :

A conductive rod of length l, mass m and resistance R slides down on a vertical conductive frame from the height $H \gg l$ in the presence of homogeneous magnetic field B which is perpendicular to the frame (Figure 1). Estimate the Kinetic energy of the rod, when it hits the grass.

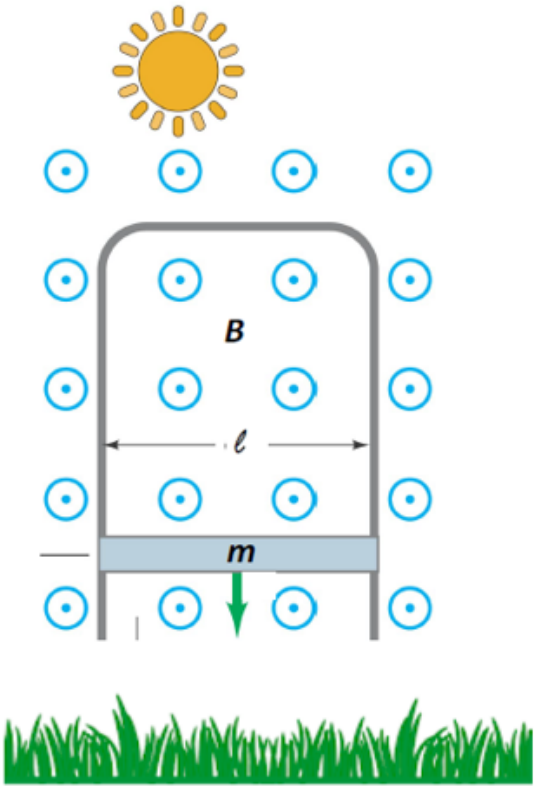

Figure 4: Conductive rod sliding down a conductive frame in a homogeneous magnetic field.

Exercise 5 :

A square $b \times b = 5 \times 5$ cm conductive frame is moved by an external force with constant velocity $v = 1$ m/s through the area of width $d = 20$ cm of homogeneous magnetic field $B = 1$ T, which is orthogonal to v (see Figure 5). The external work required to pass the field was $W = 2.5 \cdot 10^{-3}$ J. What is the resistance R of the frame?

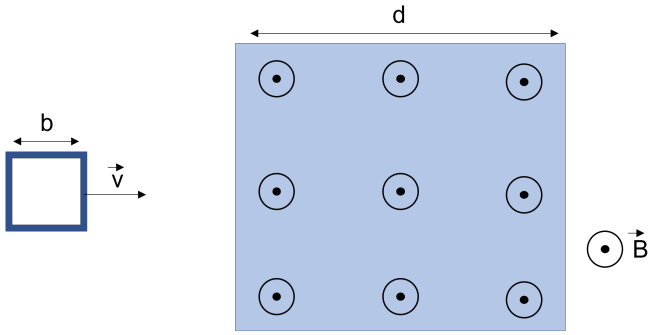

Figure 5: Conductive frame moved by an external force with constant velocity in a homogeneous magnetic field.

Exercise 6 :

Consider a conductive rod of mass m and resistance R that can freely slide along a horizontal solid conductive frame of width w and length l, which is much longer than the width (Figure 6). The homogeneous magnetic field B is orthogonal to the frame. The field is changing with time t as $B = B_0 t$. In which direction and by what distance Δl will the rod be displaced from its initial position at $t = 0$ after a short time $t = T$, assuming that the displacement is small compared to l?

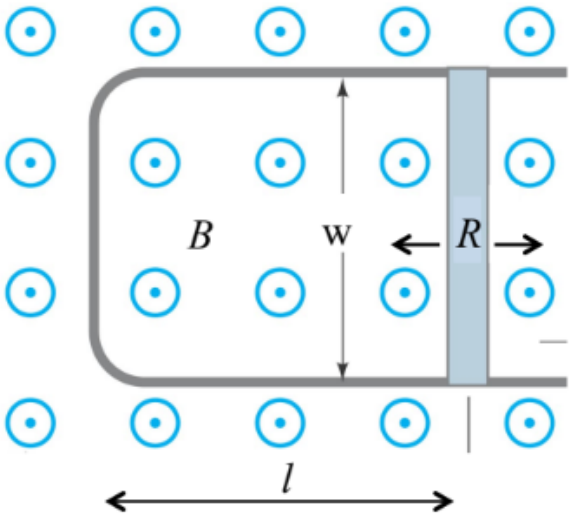

Figure 6: Conductive rod sliding along a conductive frame in a homogeneous magnetic field.