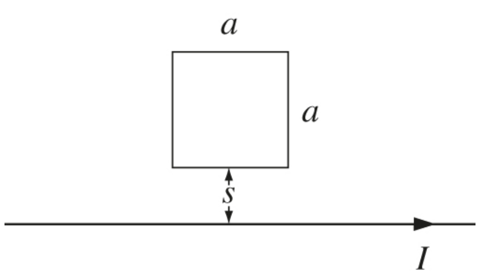
PHYS 301 – Assignment #5

Due Wednesday, Dec. 4 at 14:00

1. A square loop of wire, sides length a, lies on a table a distance s away from a very long straight wire that carries current I.

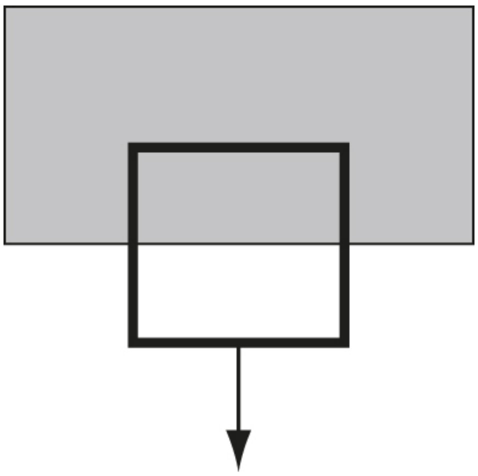


(a) Find the flux through the loop.

(b) If the loop is pulled directly away from the wire at speed v, what emf is produced? Does the induced current flow clockwise or counterclockwise?

(c) What is the instantaneous force required to pull the loop away with speed v when it is a distance s from the wire? Assume that the square loop has resistance R.

2. A square loop of wire, sides length a, is dropped from rest such that its top portion is in a uniform magnetic field $\mathbf{B}$ and its bottom portion is in a region where $\mathbf{B} = 0$. See the figure below. In this figure, the shaded region represents the region where $\mathbf{B} \neq 0$. Assume that the plane of the loop is vertical and perpendicular to the magnetic field.



(a) Assume that m and R are the mass and the resistance of the loop, respectively. If g is the gravitational acceleration, find an expression for the terminal velocity that the loop reaches.

(b) Determine the speed of the of loop as a function of time assuming that it was dropped from rest at $t = 0$.

3. A long solenoid with radius a and n turns per unit length carries a time-dependent current $I(t)$ in the $\hat{\phi}$ direction. Find the electric field (magnitude and direction) at a distance s from the axis for (a) $s < a$ and (b) $s > a$.

4. In a **perfect conductor**, the conductivity is infinite such that $\mathbf{E} = 0$ and any net charge resides on the surface (just as it does for an *imperfect* conductor in electro*statics*).

(a) Show that the magnetic field is constant inside a perfect conductor.

(b) Show that the magnetic flux through a perfectly conducting loop of wire is constant.

A **superconductor** is a perfect conductor with the additional property that the magnetic field inside, is not only constant, but precisely equal to *zero*, an effect known as the **Meissner effect**.

(c) Show that the current in a superconductor is confined to the surface.

(d) Superconductivity is lost above a certain critical temperature T_c, which varies from one material to another. Suppose you had a sphere of radius a above its critical temperature, and you held it in a uniform magnetic field $B_0\,\hat{z}$ while cooling it below T_c. Find the induced surface current density $\mathbf{K}$, as a function of the polar angle θ.