COLLAB #6
Magnetic forces, RC circuits

PART 1 (20 points)
A square loop, of dimensions $a \times b$, has $N$ turns of wire carrying current $I$. The loop is mounted on the face of a wooden block as shown. The block can be moved in the vertical (i.e., $z$) direction along a mounting post. This configuration is in the region of a magnetic field that is described by

$$\mathbf{B} = -B_0 \left( \frac{z}{L} \right) \mathbf{x}.$$

By evaluating the force on the appropriate sides of the loop, find the net force $\mathbf{F}$ on the wire loop. Give the answer as a vector, and express the answer in terms of $B_0$, $L$, and the magnetic moment $\mu$ of the loop.

PART 2 (10 points)
Find the energy stored in the configuration, as a function of the vertical position of the block along the post. Give your answer in terms of $B_0$, $L$, $\mu$, and the $z$ location of the loop.

PART 3 (10 points)
Explain how you can derive the force answer to PART 1 from the energy answer to PART 2.

PART 4 (20 points)
The figure above shows a 100 m brass sphere connected to 1 km of 10 AWG wire (resistance = $3 \times 10^{-3}$ $\Omega$/meter.) The other end of the wire is “attached to infinity” (it is buried in the earth). The wire is straight and, as shown, a battery of $10^4$ V is in the path from “infinity” to the sphere. At time $t = 0$, the switch is closed, connecting the battery, etc., to the sphere. What is the current in the wire as a function of time?

PART 5 (20 points)
A post is located perpendicular to the 1 km wire. A very compact magnetic dipole, oriented as shown, can slide along the post. The magnetic dipole has a magnitude of $\mu = 100$ A·m$^2$, and a mass of 100 g. It slides without friction on the post. (Ignore gravity.) The dipole is at rest and at a distance of 1 cm from the wire, when the switch is closed. What is the force on the dipole immediately after the switch is closed?

PART 6 (20 points)
How much time is required after the switch is closed until the magnetic dipole hits the wire?