Don't forget to write your name here:

PART I: Conceptual Questions

1. Circle the circuit below for which the voltage source has to do the most work per unit time. (All resistors are identical.)

   ![Circuit Diagrams]

2. Suppose you have a piece of chewed gum of fixed volume. How should you shape this gum in order to fashion a resistor of maximum resistance? (Include a sketch if you like; no real gum, please.)
3. Suppose there exists a uniform magnetic field into the paper as shown below. At the point P (marked) you launch two equal-mass charged particles with equal speeds in the upward direction: one has charge $+Q$, and the other has charge $+2Q$. Sketch qualitatively the orbits of these two particles, being as accurate as possible. (Ignore the electric force between the two particles; if you like, assume that you launch one particle, observe its orbit, then take it away and launch the other.)

If the particles come back to the same point, which gets there first?
PART II:

Consider an infinite conducting cylinder of radius $R$, surrounded by a conducting cylindrical shell of inner radius $R$ and outer radius $2R$; both are infinite in length and aligned with the $y$-axis.

There is a current $I$ flowing in the $+y$ direction in the conducting cylinder, uniformly distributed within it. There is a current $4I$ flowing in the conducting cylindrical shell, also in the $+y$ direction and uniformly distributed within the cylindrical shell.

Calculate the direction and magnitude of the magnetic field everywhere in space as a function of $r$, the distance from the $y$-axis. (Hint: calculate it separately for all three regions: $r < R$, $R < r < 2R$, and $r > 2R$.)

![Diagram of a conducting cylinder and shell with current directions.]
PART III:
Suppose that the magnetic field is everywhere in the z-direction (out of the paper in the sketch below), but the magnitude of the field is larger as you go to the right (in the +x-direction) according to this formula: $B = bx$, where $b$ is a constant.

A square loop with its sides oriented parallel to the x- and y-axes moves with a constant speed $v$ to the right (in the +x-direction). The loop has sides of length $L$. There is a total resistance $R$ around the loop. At the instant shown, its left edge is a distance $x_0$ from the y-axis.

(a) (Conceptual) What direction is the current induced in the loop? (circle appropriate answer.)

- clockwise
- counterclockwise
- no current induced

(b) (Conceptual) What direction is the net magnetic force on the loop? (circle appropriate answer.)

- up
- down
- left
- right
- out of paper
- into paper
- no net force

(c) (Conceptual) What direction is the net torque on the loop? (circle appropriate answer.)

- up
- down
- left
- right
- out of paper
- into paper
- no net torque
(d) (Quantitative) Calculate the magnitude of the induced current as a function of $L, x_0, v, b,$ and $R$. (Hint: you might start by getting an expression for the total flux of the magnetic field through the loop when it is in the position $x_0$ as shown.)