FINAL. PHYS 204. SPRING 2003. May 22, 2003

NAME:

- The grades will be posted in my office (Levich Institute, Steinman Hall, T1M-12) no later than Wednesday May 28. You can also contact me by email to makse@mailaps.org and I will send you the grades as soon as I have them.

1a. Electric Field (8 points).

Two point charges lie on the x axis. A charge of $+6.2\mu$C is at the origin, and a charge of -9.5μC is at $x = 10$ cm. What is the *net* electric field at (a) $x = -4.0$ cm and (b) $x = 4.0$ cm?

1b. Electric field lines (7 points).

Make a qualitative sketch of the electric field lines produced by four charges $+q, -q, +q, -q$, arranged clockwise on the four corners of a square with sides of length d.

2a. Electric Potential (8 points).

A positive charge $+q$ is fixed at the point $x = 0, y = -a$, and a negative charge $-q$ is fixed at the point $x = 0, y = a$. Take the electric potential V to be zero at infinity. (a) Draw a diagram showing the position of the charges. (b) What is the potential at a point on the x-axis, a distance x from the origin. (c) What is the answer to (b) if the two charges are interchanged.

2b. Electric Potential and Electric Field (8 points).

Consider a region in space where a uniform electric field $E = 7500\text{N/C}$ points in the negative x direction. (a) What is the orientation of the equipotential surfaces? Draw a picture. (b) If you move in the positive x direction, does the electric potential increase or decrease? Explain. (c) What is the distance between +14-V and the +16-V equipotentials?

3. Direct-current circuits (6 points).

(a) Find the equivalent resistance of the following circuit. (b) Find the current in the resistors R_1.

Magnetic fields.

4.1. (3 points) When a charged particle enters a region of uniform magnetic field it follows a circular path, as indicated in the figure. Is the particle positively or negatively charged?

4.2. (8 points) Two circular loops of wire, each containing a single turn, have the same radius of 4.0 cm and a common center. *The planes of the loops are perpendicular.* Each carries a current of 1.7 A. What is the magnitude of the *net* magnetic field at the common center?

5. Lenz's law.

5.1. (4 points) The figure shows a current-carrying wire and a circuit containing a resistor R. (a) If the current in the wire is constant, is the induced current in the circuit, clock, counterclockwise or zero? Explain. (b) If the wire current increases, is the induced current in the circuit, clock, counterclockwise or zero?

5.2 (7 points) The figure shows a circuit with a resistor and a uncharged capacitor in a uniform magnetic field. If the magnitude of the magnetic field increases with time, which plate of the capacitor (top or bottom) becomes positively charged? Explain.

6. Diffraction (8 points).

A single slit is illuminated with 660-nm light, and the resulting diffraction pattern is viewed on a screen 2.3 m away. (a) If the linear distance between the first and the second dark fringes of the pattern is 12 cm, what is the width of the slit? (b) If the slit is made wider, will the distance between the first and second dark fringes increase or decrease? Explain.

7. Relativity

7.1 (5 points) The positive muon is an unstable particle with an average lifetime of 2.2μs (measured in the rest frame of the muon). If the muon is made to travel at very high speed relative to a laboratory, its average lifetime is measured in the laboratory to be 19μs. Calculate the speed of the muon expressed as a fraction of c.

7.2 (5 points) A spacecraft flies over the earth at a speed of $0.8c$. A scientist on the Earth measures the length of the moving spacecraft to be 86.5 m. The spacecraft later lands on Earth, and the same scientist measures the length of the now stationary spacecraft. What value does the scientist get?

8. Modern Physics.

8.1. Relativity (5 points). The theory of relativity sets an upper limit on the speed that a particle can have. Are there also limits on its energy and momentum? Explain.

8.2. Photons. (5 points) In what ways do photons resemble other particles such as electrons? Do photon have mass? Can they be accelerated? Do they have electric charge?

8.3. Quantum Mechanics. (7 points) If quantum mechanics replaces the language of Newtonian Mechanics, why do we not have to use wave functions to describe the motion of macroscopic bodies such as baseballs and cars?

8.4. Bohr's atom. (6 points) A hydrogen atom that is initially in the ground level absorbs a photon, which excites it to the $n = 3$ level. Determine the frequency of the photon.