PHYS 212E **Name ____________________**

First Hour Exam **February 17, 2005**

<u>Show all work for full credit</u>! Answers must have correct units and appropriate number of significant digits. For all the problems (except for multiple choice questions), start with either (a) a generally applicable equation or statement; (b) a sentence explaining your approach; or (c) a sketch. Solutions must proceed systematically from your starting point.

$k = \frac{1}{4\pi\varepsilon_0} = 9.0\times 10^{9}\ \mathrm{N\cdot m^2/C^2}$ $\quad \frac{\mu_0}{4\pi} = 10^{-7}\ \mathrm{T\cdot m^2/A} = 10^{-7}\ \mathrm{N/A^2}$ $\quad 1\ \mathrm{eV} = 1.6\times 10^{-19}\ \mathrm{J}$

$m_{\mathrm{electron}} = 9.11\times 10^{-31}\ \mathrm{kg} = 511\mathrm{keV/c^2}$ $\quad m_{\mathrm{protom}} = 1.67\times 10^{-27}\ \mathrm{kg} = 938\mathrm{MeV/c^2}$

$e = 1.6\times 10^{-19}\ \mathrm{C}$ $\quad c = 3.0\times 10^{8}\ \mathrm{m/s}$ $\quad G = 6.67\times 10^{-11}\ \mathrm{N\cdot m^2/kg^2}$ $\quad g = 9.8\ \mathrm{m/s^2}$

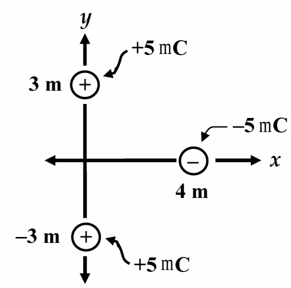
1. (9 points) Captain Planet and the Planeteers need your physics help! They want to remove some of the dust and smoke particles emitted from the smokestack of a local coal plant. The factory owners have already installed an “electrostatic precipitator” which they bought cheap from eBay. This precipitator consists of a large positively charged plate held at constant high potential which they have placed along one wall of the smokestack. The factory owners claim that the precipitator will attract the little particles of dust and smoke onto the plate and keep them from leaving the smokestack.

a) Captain Planet objects. He says that this electrostatic precipitator will only attract negatively charged particles, and that all the neutral particles will just be released into the atmosphere. How would you address Captain Planet’s concern?

b) There **<u>is</u>** a problem with this precipitator. What is this problem?

c) Briefly discuss a simple way you can fix this problem.

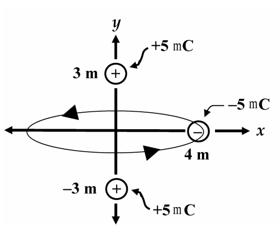
2. (20 points) Chuck Coulomb holds two positively charged point-like particles (q = +5 μC) fixed on the y-axis at +3 m and –3 m as shown in the figure. A third negatively charged point-like particle (q = –5 μC) is on the x-axis at +4 m.



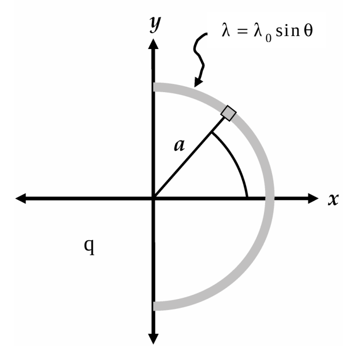
a) Determine the magnitude and direction of the net electric force acting on the –5 μC particle.

(continued on next page)

2b) Izzy Newton sets the –5 μC particle moving such that it makes a circular orbit in the x-z plane (orbiting around the y-axis) with an orbital radius of 4 m as shown. If the –5 μC particle has a mass of 0.2304 kg, and the only forces acting on the particle are the electrical interactions with the fixed positively charged particles, determine the speed of the orbiting particle.



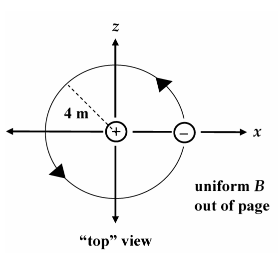
3. (14 points) The figure shows a semicircular arc with radius a. The arc has charge distributed non-uniformly along its length such that the charge density varies with angle: $\lambda = \lambda_0 \sin\theta$.



Set up the integral that will allow you to calculate E_y, the -component of the electric field, at the center of the arc.

Your integral should contain only physical constants, given quantities from the figure, the integration variable, and mathematical functions/symbols. You do **<u>NOT</u>** need to evaluate the integral, but make sure that the only thing left to do would be to evaluate the definite integral.

c) Magneto, the arch-foe of both the X-Men and great physicists of the past, turns on a uniform magnetic field that points in the positive y-direction (out of the page in the top view shown on right). Izzy still wants to have the –5 μC particle orbit at a radius of 4 m from the y-axis. Compared to the speed the particle had when there was no magnetic field, what should Izzy do to the speed of the particle? (Circle one)

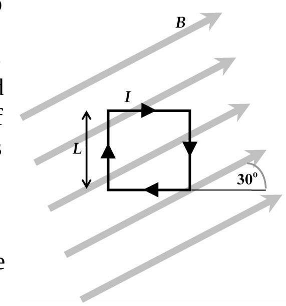


Increase the speed **Decrease the speed**

Keep speed the same **Not enough info to decide**

4. (12 points) The electric field in a certain region of space points in the positive x-direction with magnitude $E = \frac{10}{x^3}$, where the electric field and position are in standard (MKS) units. A proton, released from rest at $x = 1$ m, travels far far away from its release position. Determine the final kinetic energy of the proton.

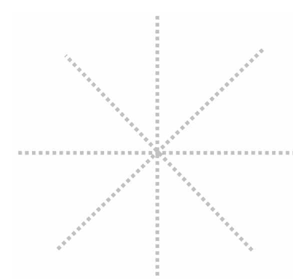
5. (18 points) At the instant pictured, a square loop of current lies in the plane of the page. The square has sides of length $L = 2$ cm, and carries current $I = 5$ A. A uniform magnetic field $B = 0.03$ T points towards the top and the right of the page, at an angle of 30° above horizontal, as shown.



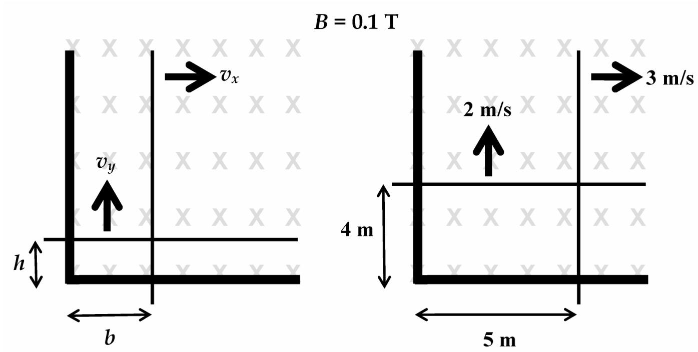
a) Determine the magnitude of the magnetic force acting on the **right hand piece** of the square loop.

b) Determine the magnitude of the torque acting on the loop about its center.

c) Sketch an arrow representing the direction of the torque acting on the loop. If the torque is into the page, out of the page, or zero, just write that down. Use the dashed lines on the right as a guide if the torque is in the plane of the page.



6. (15 points) The mad scientist Dr. Phibes has invented the Two-Dimensional Sliding Rail Generator! In this scheme, a uniform magnetic field (B = 0.1 T) points into the page. There are two sliding conducting rails, one which can move to the right with speed v_x, and the other which can move up with speed v_y, as shown in the figures below.



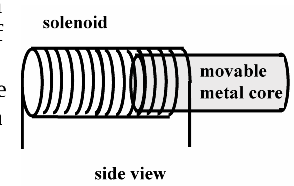
a) Does Dr. Phibes's idea work? Calculate the magnitude of the induced emf (if any) for the situation pictured above on the right.

b) What direction does the induced current in this situation flow?

Clockwise **Counterclockwise**

No induced current **Not enough info to decide**

7. (12 points) Consider a hollow solenoid with a movable metal core; the core can slide in or out of the solenoid, or spin inside the solenoid. The magnetic field of the solenoid points out on the side where the movable metal core is located, and can reach very high field strengths.



a) Consider the case where the movable metal core is made of highly conductive copper, and is placed halfway into the solenoid as shown in the side view above. The large magnetic field from the solenoid is **constantly increasing**. What happens to the movable metal core? (Circle one)

Moves into solenoid **Moves out of solenoid**

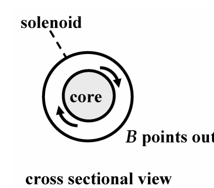
No motion **Not enough info to decide**

b) Now, consider the case where the movable metal core is made of ferromagnetic iron, and is placed halfway into the solenoid as shown in the side view above. The large magnetic field from the solenoid is **constant**. What happens to the movable metal core? (Circle one)

Moves into solenoid **Moves out of solenoid**

No motion **Not enough info to decide**

c) Finally, consider the case where again the movable metal core is made of highly conductive copper. Now, the core is placed all the way inside the solenoid. The solenoid produces a **constant** uniform magnetic field pointing out of the page, as indicated in the cross sectional view to the right. The core is spinning clockwise in the uniform magnetic field as shown. Which of the following is correct about any induced emf in the conducting metal core? (Circle one)



Induced emf with higher potential on outer edge of conductor **Induced emf with higher potential at center of conductor**

No induced emf **Not enough info to decide**