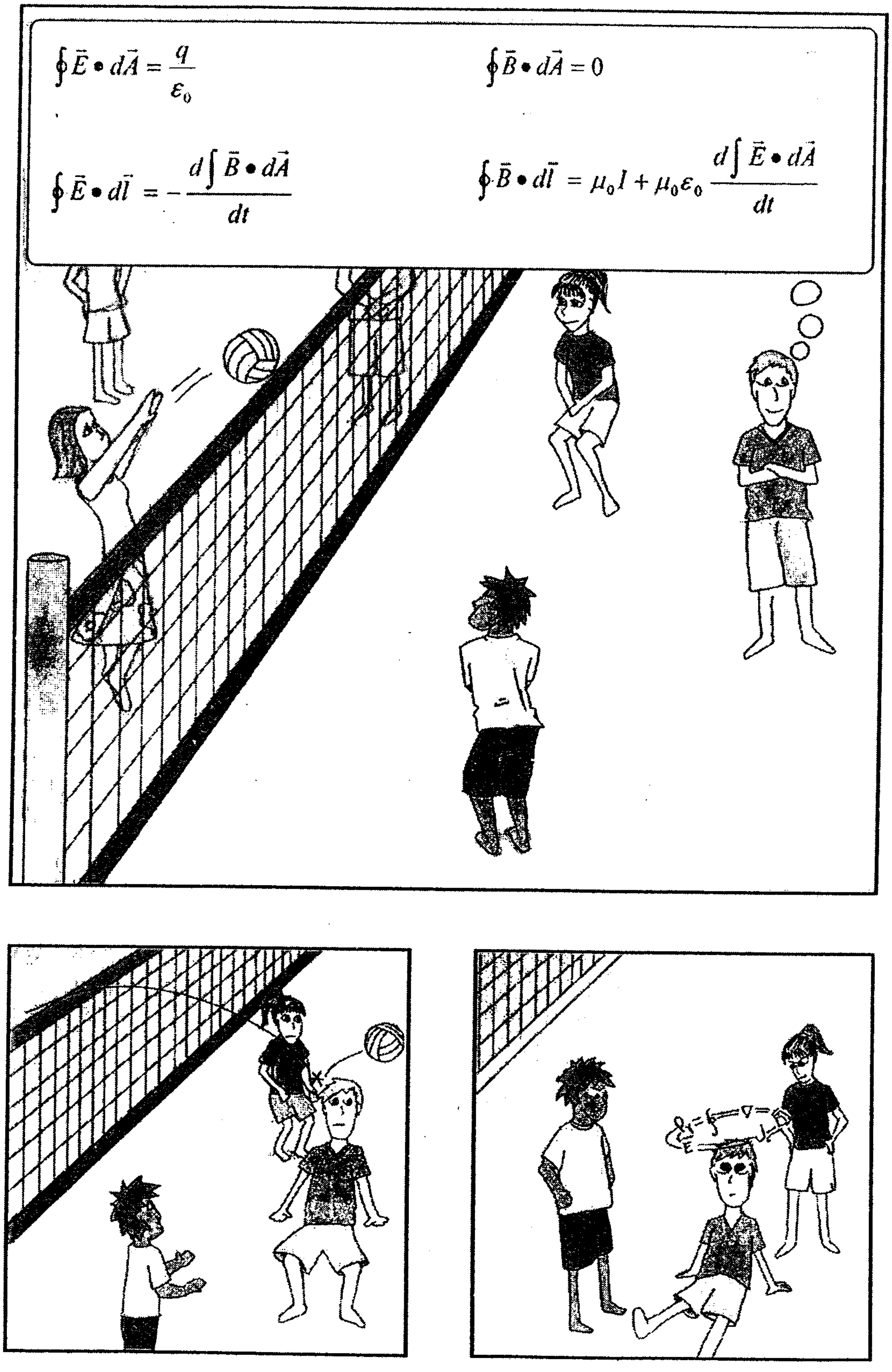


$\oint \vec{E} \bullet d\vec{A} = \frac{q}{\varepsilon_0}$
$\oint \vec{B} \bullet d\vec{A} = 0$
$\oint \vec{E} \bullet d\vec{l} = -\frac{d\int \vec{B} \bullet d\vec{A}}{dt}$
$\oint \vec{B} \bullet d\vec{l} = \mu_0 I + \mu_0 \varepsilon_0 \frac{d\int \vec{E} \bullet d\vec{A}}{dt}$

Last Name: First Name:

Physics 102 Spring 2007: Final Exam, May 4, 2007
Free Response and Instructions

- Print your LAST and FIRST name on the front of your blue book, on this question sheet, the multiple-choice question sheet and the multiple-choice answer sheet.
- TIME ALLOWED 3 HOURS
- The test consists of three free-response questions and 25 multiple-choice questions.
- The test is graded on a scale of 180 points; the free-response questions account for 105 points (35 points each), and the multiple-choice questions account for 75 points (3 points each).
- Answer the three free-response questions in your blue book. Answer the multiple-choice questions by marking a dark X in the appropriate column and row in the table on the multiple-choice answer sheet.
- Consult no books or notes of any kind. You may use a hand-held calculator in non-graphing, non-programmed mode.
- Do NOT take test materials outside of the class at any time. Return this question sheet along with your blue book and multiple-choice question sheet.
- Write and sign the Pledge on the front of your blue book.

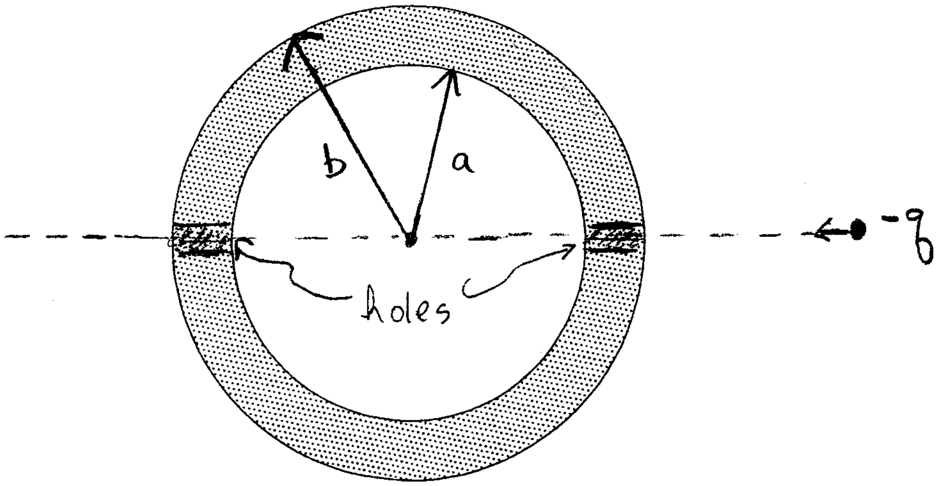
Show your work for the free-response problems, including neat and clearly labeled figures, in your blue book. Answers without explanation (even correct answers) will not be given credit.

I. A shell of conducting material has inner radius a and outer radius b. The shell carries a total charge $+Q$. The coordinate r measures the distance from the center of the shell.

(a) Determine the electric field $\vec{E}$ everywhere in space. Sketch $\vec{E}(r)$ vs. r.
(b) Determine the electrostatic potential V everywhere in space. Sketch $V(r)$ vs. r.
(c) Determine the electrostatic energy density u_E everywhere in space. Integrate u_E over all space to determine the total energy stored in the electric field.

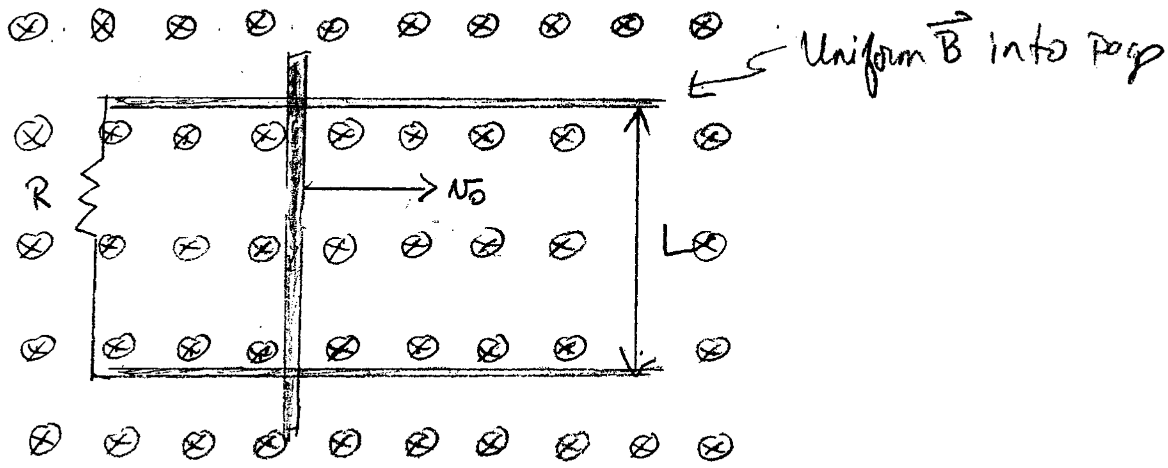
Now suppose two small holes are drilled through the shell along a diameter. The holes are small enough that the electric field is not changed significantly. A small negative charge $-q$ is released from rest a distance $2b$ from the center of the conducting shell. The charge $-q$ passes through one hole, through the center of the shell, and exits through the hole on the other side.

(d) Determine the speed at which the charge $-q$ is traveling when it reaches the surface $r = b$.
(e) What acceleration does the charge $-q$ experience in the region $r < b$? What is its speed when it exits the shell on the other side?
(f) Describe qualitatively the subsequent motion of the charge after it exits the shell on the opposite side.



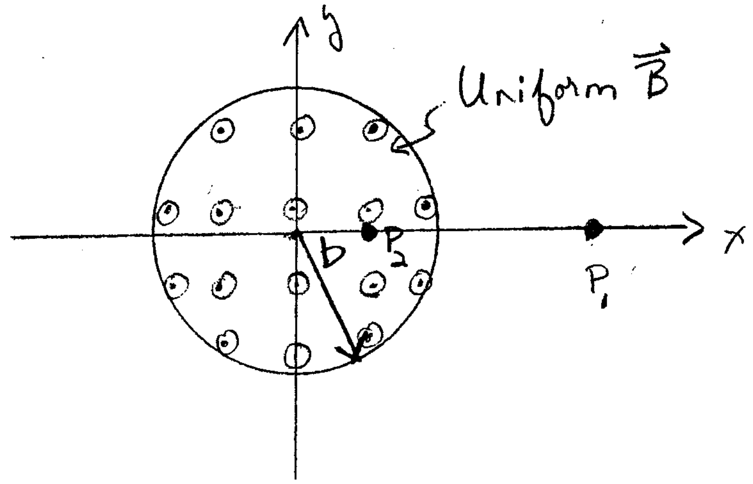
II. The figure below shows a pair of parallel conducting rails of negligible resistance, a distance L apart. A uniform magnetic field $\vec{B}$ is directed into the page. A resistance R is connected across the rails, and a conducting bar of negligible resistance is being pulled across the rails with constant velocity v_o to the right. Friction between the moving bar and rails is negligible.

(a) Determine the direction and magnitude of the current in the resistor.
(b) Determine the constant external force which must be applied to the bar to keep it moving with constant velocity v_o to the right.
(c) Determine the rate at which work must be done by the external force to maintain a constant velocity v_o.
(d) Compare the rate at which the external agent does work to the power dissipated in the resistor.



III. A cylindrical region of space has a uniform magnetic field $\vec{B}$ pointing up out of the page as shown in the figure below. The coordinate r measures the distance from the axis of the cylindrical region. For purposes of this problem, we will neglect fringe field effects, so that we can assume the field drops abruptly to zero at $r = b$. Although the field is uniform in space, its magnitude is increasing at a constant rate $\frac{d|\vec{B}|}{dt} = \alpha$.

(a) Determine the electric field $\vec{E}$ everywhere in space due to the changing magnetic field. Be sure to indicate both the direction and magnitude of the field. Plot the magnitude of the field $|\vec{E}(r)|$ vs. r.
(b) If an electron is released from rest at the point P_1 $(x = 2b, y = 0)$ what acceleration if any does it experience immediately after it is released? If an electron is released from rest at the point P_2 $(x = \frac{b}{2}, y = 0)$ what acceleration if any does it experience immediately after it is released?



Now consider a similar situation, except that instead of a uniform magnetic field in the cylindrical region of space we now have a uniform electric field. As before, the magnitude of the electric field is increasing with time at a constant rate $\frac{d|\vec{E}|}{dt} = \alpha$.

(c)Determine the magnetic field $\vec{B}$ everywhere in space due to the changing electric field. Be sure to indicate both the direction and magnitude of the magnetic field. Plot the magnitude of the field $|\vec{B}(r)|$ vs. r.
(d) Determine the displacement current I_D that passes through the region enclosed by the contour C shown in the figure below.
(e) If an electron is released from rest at the point P_1 $(x = 2b, y = 0)$, what acceleration if any does it experience immediately after it is released? If an electron is released from rest at the point P_2 $(x = \frac{b}{2}, y = 0)$, what acceleration if any does it experience immediately after it is released?