Phys 0175 **Practice Midterm Exam III** Apr 1, 2009

Note: THIS IS A REPRESENTATION OF THE ACTUAL TEST. *It is a sample and does not include questions on* every topic covered since the start of the semester.

Also be sure to review

homework assignments on WebAssign

White board problems worked in the class

Exercises, Examples, and Review Questions (at the end of each chapter) in your textbook

On the actual test, do not use other paper. If you need more space, write on the blank page included at the beginning of the test, and indicate that you did this.

- **Read all problems carefully before attempting to solve them.**
- **Your work must be legible, and the organization must be clear.**
- **You must show all your work, including correct vector notation.**
- **Correct answers without adequate explanation will be counted wrong.**
- **Incorrect work or explanations mixed in with correct work will be counted wrong.** *Cross out anything you don't want us to read!*
- **Make explanations complete but brief. Do not write a lot of prose.**
- **Include diagrams!**
- **Show what goes into a calculation, not just the final number:**

$$\frac{a \cdot b}{c \cdot d} = \frac{(8 \times 10^{-3})(5 \times 10^{6})}{(2 \times 10^{-5}))(4 \times 10^{4})} = 5 \times 10^{4}$$

- **Give standard SI units with your results.**

Unless specifically asked to derive a result, you may start from the formulas given on the formula sheet, including equations corresponding to the fundamental concepts. If a formula you need is not given, you must derive it.

If you cannot do some portion of a problem, invent a symbol for the quantity you can't calculate(explain that you are doing this), and use it to do the rest of the problem.

NAME: ____

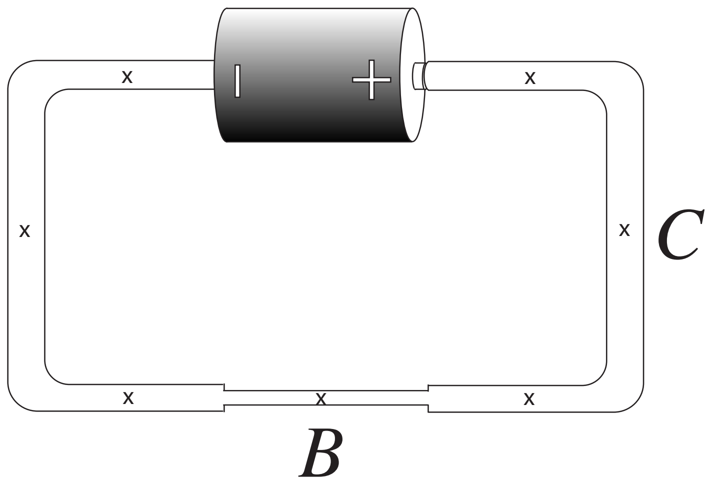
Phys 0175 **Practice Midterm Exam III** Apr 1, 2009

INSTRUCTIONS: Please print your name above in the space provided.

The exam consists of N questions worth differing number of points. WRITE NEATLY. Clearly mark your answers with a bounding box at the bottom of your work area. It is important to show your work to get credit. You may use calculators.

Question Number	Possible Points	Score
1	?	
2	?	
⋮	⋮	
N	?	
Total	100	

1. The wires in the circuit shown in the diagram are made of the same material, but one segment of wire is thinner than the other wires.



   (a) At each location inside the wire, marked by an "x", draw and label an arrow representing the electric field at that location. Relative magnitudes of the arrows should be correct. Label the arrows "E".

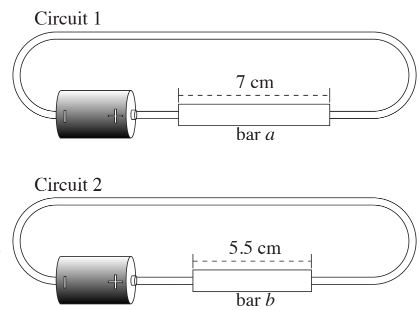
   (b) At locations B and C, draw and label arrows representing the drift speed of an electron at that location. Label the arrows "v".

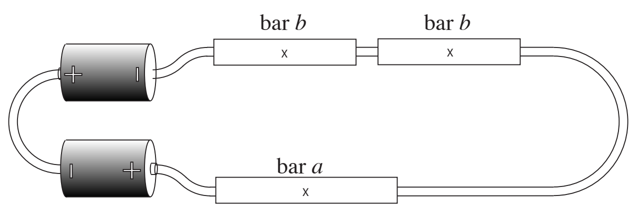
   (c) Draw an approximate distribution of charge on the surface of the wires. Make sure the distribution you show is consistent with your answer to (a).

2. A particular resistive metal has 3×10^{27} mobile charges per cubic meter, with a mobility of 4.2×10^{-5} (m/s)/(V/m). When a metal bar made of this material (bar a), 7 cm long, diameter unknown, is put into a circuit (circuit 1) with one battery whose emf is 1.5 V, and thick connecting wires, 1.2×10^{17} electrons per second enter bar a.

   When a different metal bar (bar b) made of the same material, 5.5 cm long, with a different diameter, is put into a different circuit (circuit 2), with one battery whose emf is 1.5 V, and thick connecting wires, 2.7×10^{17} electrons per second enter bar b.

   Circuit 3, shown in the diagram below, contains two batteries, each with emf 1.5 V, thick connecting wires, and three resistors: one resistor identical to bar a (same material and dimensions as bar a) and two resistors identical to bar b (same material and dimensions as bar b).





   (a) Calculate the magnitude of the electric field inside bar a in circuit 3. Clearly show all steps in your work.

   (b) The locations marked "x" on the diagram are inside the metal bars. At each "x" in the diagram of circuit 3, draw an arrow indicating the direction and relative magnitude of the electric field at that location.

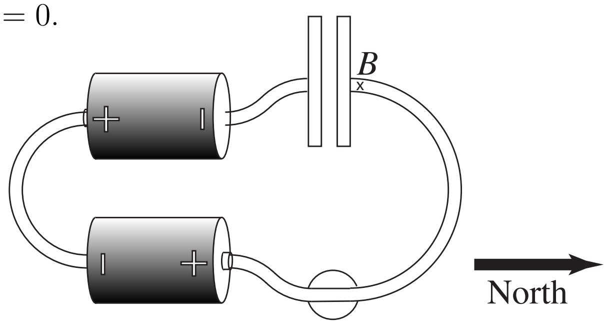
3. Circuit 1 consists of one battery, a single Nichrome wire, through which an electron current i_1 flows. For each new circuit described below, compare the current in the new circuit to the current in circuit 1; circle the parameters which are different in the two circuits. For each parameter, draw an up arrow (↑) if the parameter is larger in the new circuit, or a down arrow (↓) if the parameter is smaller in the new circuit than in circuit 1.

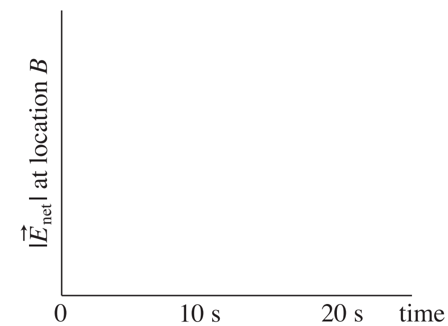
   For example, if the current in circuit n would be three times as large as the current in circuit 1, you would say $i_n = (3) \times i_1$. If "A" is larger in circuit n, you would circle "A" and write "↑" under it.

New Circuit	Differences (quantities not mentioned are the same in both circuits)	Current in new circuit compared to i_1	Circle changed parameters: For each circled parameter indicate ↑ (larger) or ↓ (smaller) (under the paramter)
circuit 2	Nichrome wire radius twice as large	$i_2 = (\_\_\_\_\_\_) \times i_1$	n A u E
circuit 3	Nichrome wire 1/3 as long	$i_3 = (\_\_\_\_\_\_) \times i_1$	n A u E
circuit 4	Nichrome wire 1/4 as long; radius twice as large	$i_4 = (\_\_\_\_\_\_) \times i_1$	n A u E
circuit 5	wire made of material with twice mobile e^- per m^3	$i_5 = (\_\_\_\_\_\_) \times i_1$	n A u E
circuit 6	three batteries instead of one	$i_6 = (\_\_\_\_\_\_) \times i_1$	n A u E

4. A capacitor, which is initially uncharged, is connected to a battery by a thing Nichrome wire, as shown in the diagram. A compass lying under the wire originally points North, but when the circuit is connected the compass needle deflects away from North. After 20 seconds, the compass needle again points North.

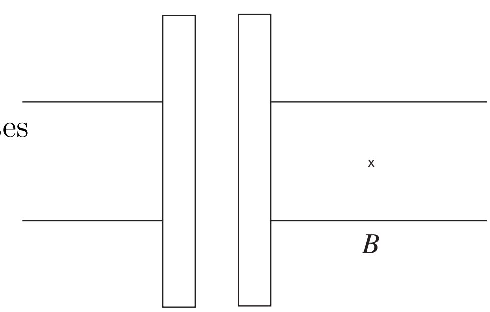
   (a) On the axis below, draw a graph showing the magnitude of the **net electric field at location** B (marked by an "x") inside the Nichrome wire, as a function of time. The circuit (batteries, wire, uncharged capacitor) is connected at time $t = 0$.





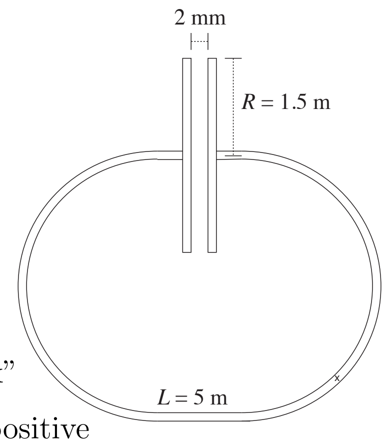
   (b) The expanded diagram at right shows location B at $t = 30$ s. On the diagram draw and label three arrows representing

   - The electric field $\vec{E}_{cap}$ at that location due to the charges on the capacitor plates
   - The electric field $\vec{E}_{surf}$ at that location due to the charges on the battery and the surface of the wires
   - The net electric field $\vec{E}_{net}$ at that location



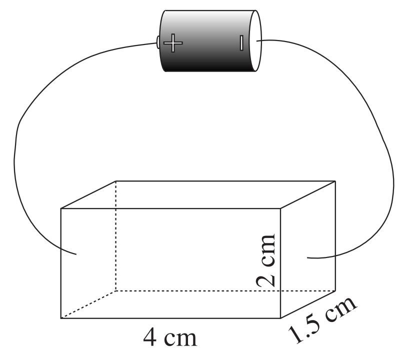
   If any quantity is zero, state this explicitly. The directions and relative magnitudes of the arrows should be correct.

5. A capacitor consists of two circular plates, each 1.5 m in radius, separated by a 2 mm gap. The capacitor is charged and is connected to a resistive wire 5 m long, as shown in the diagram, and current runs through the wire. At a particular instant, the magnitude of the electric field at the location inside the wire marked by "x" is 3.5 V/m. At this instant, how much charge is on the positive plate of the capacitor? Show your work.

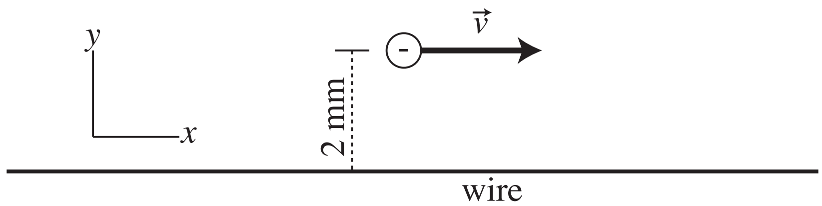


6. A copper bar is 4 cm long, 2 cm high, and 1.5 cm deep, as shown in the diagram. Copper has about 8.4×10^{28} mobile electrons per cubic meter, and the electron mobility in copper is about 4.5×10^{-3} (m/s)/(V/m).

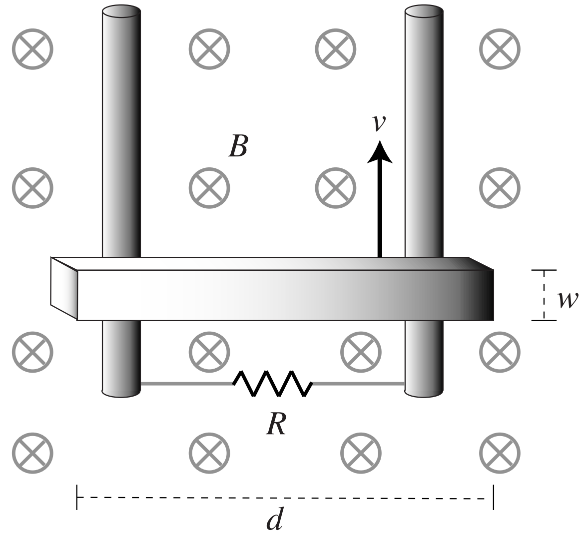
If the bar is connected to a battery by connecting wires as shown in the diagram at right, what is the resistance of the bar? Show your work.



7. A long straight wire lies on a table, oriented along the x-axis. A conventional current of 9 A runs through the wire in the +x direction. At a particular instant, an electron traveling at a speed of 3×10^7 m/s in the +x direction passes 2 mm above the center of the wire. What is the force on the electron at this instant? Your answer must be a vector. Show your work. If you made any assumptions or approximations, state them.



8. A rectangular copper bar with length d = 0.55 m, height = depth = w = 0.02 m, is pulled upward by a rope (which is not shown), at a constant speed v = 0.3 m/s, through a region in which there is a uniform magnetic field of 0.43 tesla, directed into the page. The copper bar slides along metal rails, with negligible friction. (You may not need to use all the information given in this problem.)



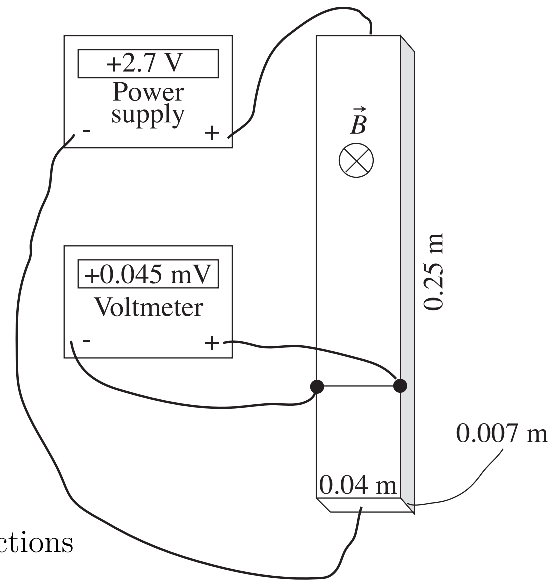
In the following questions, if any quantity is zero, state this explicitly.

(a) On the diagram, draw pluses and minuses indicated the charge distribution in and/or on the bar.

(b) On the diagram, draw an arrow indicating the direction of conventional current through the resistor, and label it "*conventional current*".

(c) What is the absolute value of the potential difference between the ends of the bar? Start from fundamental principles (do not start with a formula that is not on the formula sheet). Show all steps in your work.

9. A bar made out of a conducting material is 0.25 m high with a rectangular cross section 0.04 m wide and 0.007 m deep. The bar is connected to a power supply and carries a steady current. A uniform magnetic field of 0.85 tesla is applied perpendicular to the bar, going into the page (using some coils that are not shown in the the diagram.



A voltmeter is connected across the bar and reads a steady voltage as shown. The connections across the bar were carefully placed directly across from each other to eliminate false readings corresponding to the much larger voltage along the bar. Remember that a voltmeter gives a positive reading if the positive lead is connected to the higher potential location. Assume that there is only one kind of mobile charge in this material.

(a) On the diagram draw and label an arrow showing the direction of $E_{\parallel}$, the electric field inside the bar due to charges on the surface of the wire and the supply.

(b) Draw the distribution of charge on the bar due to polarization of the bar by the magnetic force.

(c) Draw and label an arrow showing the direction of $E_{\perp}$, the transverse electric field due to the polarization of the bar by the magnetic force.

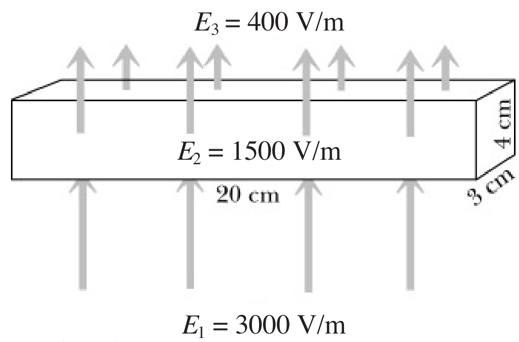
(d) What is the sign of the mobile charges, and which way do they move? Explain carefully. Your explanation must be consistent with your answers to parts (a-c) above.

Question continued on next page.

(e) What is the drift speed v of the mobile charges? Start only from principles, relations, and equations on the formula sheet. Explain your reasoning using words, equations, and/or diagrams.

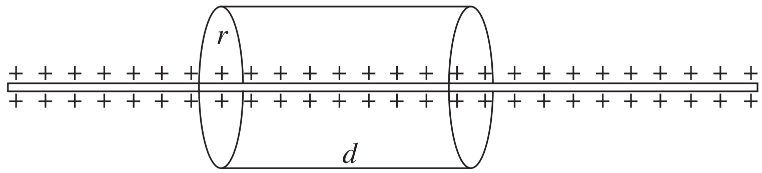
(f) What is the mobility u of the mobile charges?

10. The electric field is measured all over a box-shaped surface, as shown in the diagram. What is the net charge inside the box? Show all steps in your work, and explain how you evaluated any quantities related to angles or dot products. If any quantity is zero, state this explicitly.

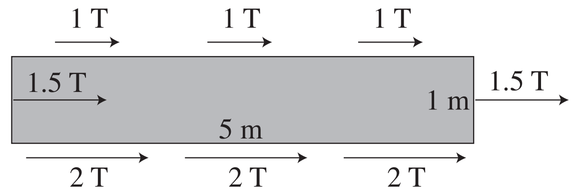


11. Here is a very long uniformly charged rod, around which we have drawn a cylindrical Gaussian surface of radius r and length d.

What is the total electric flux on this closed surface in terms of the electric field? Show all your work and explain how you evaluated any quantities related to angles or dot products. If any quantity is zero, state this explicitly.



12. Here is a pattern of magnetic field. Calculate the amount and direction of the current passing through the shaded region. Show all your work.



Things you must know

Relationship between electric field and electric force

Electric field of a point charge

Magnetic field of a moving point charge

Conservation of charge

The Superposition Principle

Other Fundamental Concepts

$$\Delta U_{el} = q\Delta V$$

$$\Delta V = -\int_i^f \vec{E} \cdot d\vec{l} \approx -\Sigma(E_x\Delta x + E_y\Delta y + E_z\Delta z)$$

$$\Phi_{\text{el}} = \int \vec{E} \cdot \hat{n}\, dA$$

$$\Phi_{\text{mag}} = \int \vec{B} \cdot \hat{n}\, dA$$

$$\oint \vec{E} \cdot \hat{n}\, dA = \frac{\sum q_{\text{inside}}}{\epsilon_0}$$

$$\oint \vec{B} \cdot \hat{n}\, dA = 0$$

Ampere without Maxwell (no displacement current) $\oint \vec{B} \cdot d\vec{l} = \mu_0 \sum I_{\text{inside path}}$

Specific Results

$\vec{E}$ due to uniformly charged spherical shell: *outside* like point charge; *inside* zero

$$|\vec{E}_{dipole,\ axis}| \approx \frac{1}{4\pi\epsilon_0}\frac{2qs}{r^3} \text{ (on axis, } r \gg s)$$

$$|\vec{E}_{dipole,\ \perp}| \approx \frac{1}{4\pi\epsilon_0}\frac{qs}{r^3} \text{ (on } \perp \text{ axis, } r \gg s)$$

$$|\vec{E}_{rod}| = \frac{1}{4\pi\epsilon_0}\frac{Q}{r\sqrt{r^2 + (L/2)^2}} \text{ (} r \perp \text{ from center)}$$

$$|\vec{E}_{rod}| \approx \frac{1}{4\pi\epsilon_0}\frac{2Q/L}{r} \text{ (if } r \ll L)$$

Electric dipole moment $p = qs$

$$|\vec{E}_{ring}| = \frac{1}{4\pi\epsilon_0}\frac{qz}{(z^2 + R^2)^{3/2}} \text{ (} z \text{ alongaxis)}$$

$$|\vec{E}_{disk}| = \frac{Q/A}{2\epsilon_0}\left[1 - \frac{z}{\sqrt{z^2 + R^2}}\right] \text{ (} z \text{ alongaxis)}$$

$$|\vec{E}_{disk}| \approx \frac{Q/A}{2\epsilon_0}\left[1 - \frac{z}{R}\right] \approx \frac{Q/A}{2\epsilon_0} \text{ (if } z \ll R)$$

$$|\vec{E}_{capacitor}| \approx \frac{Q/A}{\epsilon} \text{ (} +Q \text{ and } -Q \text{ disks)}$$

$$|\vec{E}_{fringe}| \approx \frac{Q/A}{\epsilon}\left(\frac{s}{2R}\right) \text{ (just outside capacitor)}$$

$$\Delta\vec{B} = \frac{\mu_0}{4\pi}\frac{I\Delta\vec{l} \times \vec{r}}{r^2} \text{ (shortwire)}$$

$$|\vec{B}_{wire}| = \frac{\mu_0}{4\pi}\frac{LI}{r\sqrt{r^2 + (L/2)^2}} \approx \frac{\mu_0}{4\pi}\frac{2I}{r} \text{ (} r \ll L)$$

$$|\vec{B}_{loop}| = \frac{\mu_0}{4\pi}\frac{2I\pi R^2}{(z^2 + R^2)^{3/2}} \approx \frac{\mu_0}{4\pi}\frac{2I\pi R^2}{z^3} \text{ (on axis, } z \gg R)$$

$$\mu = IA = I\pi R^2$$

$$|\vec{B}_{dipole,\ axis}| \approx \frac{\mu_0}{4\pi}\frac{2\mu}{r^3} \text{ (on axis, } r \gg s)$$

$$|\vec{B}_{dipole,\ \perp}| \approx \frac{\mu_0}{4\pi}\frac{\mu}{r^3} \text{ (on } \perp \text{ axis, } r \gg s)$$

$i = nA\bar{v}$ $\qquad I = |q|nA\bar{v}$ $\qquad \bar{v} = uE$

$\sigma = |q|nu$ $\qquad J = \dfrac{I}{A} = \sigma E$ $\qquad R = \dfrac{L}{\sigma A}$

$E_{dielectric} = \dfrac{E_{applied}}{K}$ $\qquad \Delta V = \dfrac{q}{4\pi\epsilon_0}\left[\dfrac{1}{r_f} - \dfrac{1}{r_i}\right]$ (due to a point charge)

$Q = C|\Delta V|$ $\qquad$ Power $= I\Delta V$ $\qquad I = \dfrac{|\Delta V|}{R}$ (ohmic resistor)

$K \approx \dfrac{1}{2}mv^2$ if $v \ll c$ $\qquad$ circular motion : $\left|\dfrac{d\vec{p}_\perp}{d_t}\right| = \dfrac{|\vec{v}|}{R}|\vec{p}| \approx \dfrac{mv^2}{R}$

Constant	Symbol	Approximate Value
Speed of light	c	3×10^8 m/s
Gravitational constant	G	6.7×10^{-11} N · m^2/kg^2
Approx. grav field near Earth's surface	g	9.8 N/kg
Electron mass	m_e	9×10^{-31} kg
Proton mass	m_p	1.7×10^{-27} kg
Neutron mass	m_n	1.7×10^{-27} kg
Electric constant	$\dfrac{1}{4\pi\epsilon_0}$	9×10^9 N · m^2/C^2
Epsilon-zero	ϵ_0	8.85×10^{-12} C^2/(N · m^2)
Magnetic Constant	$\dfrac{\mu_0}{4\pi}$	1×10^{-7} T · m/A
Mu-zero	μ_0	$4\pi \times 10^{-7}$ T · m/A
Proton charge	e	1.6×10^{-19} C
Electron volt	1 eV	1.6×10^{-19} J
Avogadro's number	N_A	6.02×10^{23} molecules/mole
Atomic radius	R_a	$\approx 1 \times 10^{-10}$ m
Proton radius	R_p	$\approx 1 \times 10^{-15}$ m
E to ionize air	E_{ionize}	$\approx 3 \times 10^6$ V/m
B_{Earth} (horizontal component)	B_{Earth}	$\approx 2 \times 10^{-5}$ T