Name ____________________

University of Alabama
Department of Physics and Astronomy

PH 102-1 / LeClair Summer II 2008

Exam I

Instructions

1. **Answer all questions below.** All problems have equal weight.
2. Clearly mark the answer you choose using the tick boxes.
3. **There will be no partial credit given.**
4. You are allowed 2 sides of a standard 8.5x11 in piece of paper with notes/formulas and a calculator.

1. An electron is released a short distance above the surface of the Earth. A second electron directly below it exerts an electrostatic force on the first electron just great enough to cancel the gravitational force on it. How far below the first electron is the second?

- ☐ 5.1 m
- ☐ 7.5 m
- ☐ 10.2 m
- ☐ 2.5 m

2. A point charge q is located at the center of a spherical shell of radius a that has a charge $-q$ uniformly distributed on its surface. Find the electric field for a point a distance $r > a$ from the center of the shell (*i.e.,* outside the sphere).

- ☐ $E = \frac{k_e q}{r^2}$
- ☐ $E = \frac{k_e q}{4\pi r^2}$
- ☐ $E = 0$
- ☐ $E = \frac{k_e q^2}{r^2}$

3. Calculate the speed of a proton that is accelerated from rest through a potential difference of 130 V.

- ☐ 3.21×10^4 m/s
- ☐ 7.9×10^4 m/s
- ☐ 6.76×10^6 m/s
- ☐ 1.58×10^5 m/s

4. A parallel-plate capacitor is disconnected from a battery, and the plates are pulled a small distance further apart. Which quantities increase, which decrease, and which stay the same?

- ☐ C, Q decrease, ΔV increases, energy stays the same
- ☐ C decreases, Q stays the same, ΔV and energy increase
- ☐ $\Delta V, Q$ decrease, energy stays the same, C increases
- ☐ energy decreases, C, Q stay the same, ΔV increases

5. Two resistors, A and B, are separately connected across identical batteries. The resistance of A is twice that of B. Which resistor dissipates more power?

- ☐ resistor A
- ☐ resistor B
- ☐ both resistors dissipate the same power
- ☐ more information is needed.

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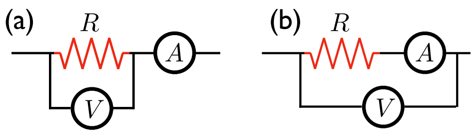
6. Referring to the circuit below, which of the following must be true? In both circuits, we attempt to measure a resistor R by separately measuring the current and voltage and using Ohm's law. Assume both meters have internal resistance.

- □ Circuit **a** overestimates R, circuit **b** underestimates it.
- □ Circuit **a** underestimates R, circuit **b** overestimates it.
- □ Both circuits overestimate R.
- □ Both circuits underestimate R.



7. If the current carried by a conductor is doubled, what happens to the electron drift velocity?

- □ it is halved
- □ it remains the same
- □ it is doubled
- □ it quadruples
- □ it decreases by four times

8. A battery having an ideal voltage of 11.00 V delivers 117 mA when connected to a 67.0 Ω load. What is the internal resistance of the battery?

- □ 9 Ω
- □ 83 Ω
- □ 27 Ω
- □ 54 Ω

9. A sphere the size of a basketball is charged to a potential of -1000 V. About how many extra electrons are on it, per cm^2 of surface? A basketball has a radius of $\sim$ 12 cm.

- □ 3×10^7
- □ 1×10^8
- □ 5×10^4
- □ 7×10^5

10. The basic rules we have used for analyzing circuits are: **(1)** the sum of voltage sources and drops around a closed circuit loop is zero, and **(2)** the amount of current entering a junction has to equal the amount of current leaving the junction. These rules result from two basic physical laws. What are they?

- □ Conservation of Energy and Charge Quantization
- □ Conservation of Energy and Conservation of Momentum
- □ Conservation of Charge and Conservation of Energy
- □ Coulomb's law and Conservation of Charge

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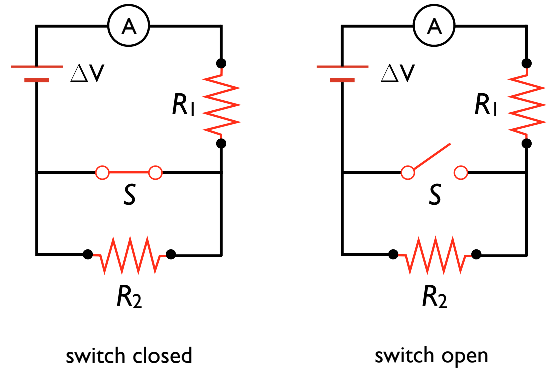
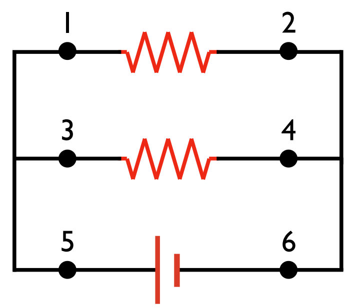
11. Refer to the figures at right. What happens to the reading on the ammeter when the switch S is opened? Assume the wires and switch are perfect, and have zero resistance.

- □ The reading goes up.
- □ The reading goes down.
- □ The reading does not change.
- □ More information is needed.



12. Rank the currents at points 1, 2, 3, 4, 5, and 6 from *highest to lowest*. The two resistors are identical.

- □ 5, 1, 3, 2, 4, 6
- □ 5, 3, 1, 4, 2, 6
- □ 5=6, 3=4, 1=2
- □ 5=6, 1=2=3=4
- □ 1=2=3=4=5=6



13. A parallel plate capacitor is shrunk by a factor of two in every dimension – the separation between the plates, as well as the plates' length and width are all two times smaller. If the original capacitance is C_0, what is the capacitance after all dimensions are shrunk?

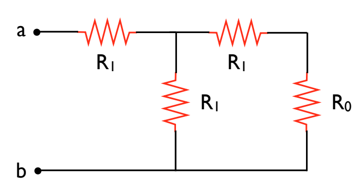
- □ $2C_0$
- □ $\frac{1}{2}C_0$
- □ $4C_0$
- □ $\frac{1}{4}C_0$

14. It takes 3×10^6 J of energy to fully recharge a 9 V battery. How many electrons must be moved across the 9 V potential difference to fully recharge the battery?

- □ 1×10^{25} electrons
- □ 2×10^{24} electrons
- □ 4×10^{12} electrons
- □ 8×10^{13} electrons

15. In the circuit at right, if R_0 is given, what value must the R_1 have for the equivalent resistance between the two terminals a and b to be R_0?

- □ $2R_0$
- □ $R_0/2$
- □ $2\sqrt{2}R_0$
- □ $R_0/\sqrt{3}$



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16. A spaceship moves away from earth at high speed. How do experimenters on earth measure a clock in the spaceship to be running? How do those in the spaceship measure a clock on earth to be running?

- ☐ slow; fast
- ☐ slow; slow
- ☐ fast; slow
- ☐ fast; fast

17. The period of a pendulum is measured to be 3.00 in its own reference frame. What is the period as measured by an observer moving at a speed of $0.950c$ with respect to the pendulum?

- ☐ 6.00 sec
- ☐ 13.4 sec
- ☐ 0.938 sec
- ☐ 9.61 sec

18. Suppose a (cylindrical) electrical wire is replaced with one of the same material, but having every linear dimension doubled - the length and radius are twice their original values. Does the new wire have:

- ☐ the same resistance
- ☐ twice the resistance
- ☐ half the resistance
- ☐ four times the resistance
- ☐ one quarter the resistance

19. In a region of uniform electric field $\vec{\mathbf{E}}$, a charged particle experiences an acceleration $\vec{\mathbf{a}}$. If a second particle with twice the charge and twice the mass of the first particle enters that same region, it will experience an acceleration

- ☐ $\frac{1}{4}\vec{\mathbf{a}}$
- ☐ $\frac{1}{2}\vec{\mathbf{a}}$
- ☐ $\vec{\mathbf{a}}$
- ☐ $2\vec{\mathbf{a}}$
- ☐ $4\vec{\mathbf{a}}$

20. Two particles are separated by a distance of 3.0 m; each exerts an electric force of 1.0 N on the other. If one particle carries 10 times as much electric charge as the other, what is the magnitude of the smaller charge?

- ☐ 10 pC
- ☐ 10 μC
- ☐ 10 nC
- ☐ 10 kC

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Constants:

$$k_e = 8.98755 \times 10^9\ \mathrm{N \cdot m^2 \cdot C^{-2}}$$
$$\epsilon_0 = 8.85 \times 10^{12}\ \mathrm{C^2/N \cdot m^2} = 4\pi k_e$$
$$e = 1.60218 \times 10^{-19}\ \mathrm{C}$$
$$c = 2.99792 \times 10^8\ \mathrm{m/s}$$
$$m_{e^-} = 9.10938 \times 10^{-31}\ \mathrm{kg}$$
$$m_{p^+} = 1.67262 \times 10^{-27}\ \mathrm{kg}$$
$$m_{n^0} = 1.67493 \times 10^{-27}\ \mathrm{kg}$$

Basic Equations:

$$0 = ax^2 + bx^2 + c \Longrightarrow x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$
$$\vec{\mathbf{F}}_{\text{net}} = m\vec{\mathbf{a}} \text{ Newton's Second Law}$$
$$\vec{\mathbf{F}}_{\text{centr}} = -\frac{mv^2}{r}\hat{\mathbf{r}} \text{ Centripetal}$$

Current:

$$I = \frac{\Delta Q}{\Delta t} = nqAv_d$$
$$J = \frac{I}{A} = nqv_d = \varrho E$$
$$v_d = \frac{-e\tau}{m}E \quad \tau = \text{scattering time}$$
$$R = \frac{\Delta V}{I} = \frac{\varrho l}{A}$$
$$\mathscr{P} = E \cdot \Delta t = I\Delta V = I^2 R = \frac{[\Delta V]^2}{R} \text{ power}$$

Electric Potential:

$$\Delta V = V_B - V_A = \frac{\Delta \text{PE}}{q}$$
$$\Delta PE = q\Delta V = -q|\vec{\mathbf{E}}||\Delta\vec{\mathbf{x}}|\cos\theta = -qE_x\Delta x$$
$\uparrow$ constant E field
$$V_{\text{point charge}} = k_e\frac{q}{r}$$
$$PE_{\text{pair of point charges}} = k_e\frac{q_1 q_2}{r_{12}}$$
$$PE_{\text{system}} = \text{sum over unique pairs} = \sum_{\text{pairs } ij} \frac{k_e q_i q_j}{r_{ij}}$$
$$-W = \Delta\text{PE} = q(V_B - V_A)$$

Electric Force & Field

$$\vec{\mathbf{F}}_{e,12} = q\vec{\mathbf{E}}_{12} = \frac{k_e q_1 q_2}{r_{12}^2}\hat{\mathbf{r}}_{12}$$
$$\vec{\mathbf{E}} = k_e\frac{|q|}{r^2}$$
$$\Phi_E = |\vec{\mathbf{E}}|A\cos\theta_{EA} = \frac{Q_{\text{inside}}}{\epsilon_0}$$
$$\Delta PE = -W = -q|\vec{\mathbf{E}}||\Delta\vec{\mathbf{x}}|\cos\theta = -qE_x\Delta x$$
$\uparrow$ constant E field

Power	Prefix	Abbreviation
10^{-12}	pico	p
10^{-9}	nano	n
10^{-6}	micro	µ
10^{-3}	milli	m
10^{-2}	centi	c
10^{3}	kilo	k
10^{6}	mega	M
10^{9}	giga	G
10^{12}	tera	T

Capacitors:

$$Q_{\text{capacitor}} = C\Delta V$$
$$C_{\text{parallel plate}} = \frac{\epsilon_0 A}{d}$$
$$E_{\text{capacitor}} = \frac{1}{2}Q\Delta V = \frac{Q^2}{2C}$$
$$C_{\text{eq, par}} = C_1 + C_2$$
$$C_{\text{eq, series}} = \frac{C_1 C_2}{C_1 + C_2}$$
$$C_{\text{with dielectric}} = \kappa C_{\text{without}}$$

Resistors:

$$R_{\text{eq}} = R_1 + R_2 \quad \text{series}$$
$$\frac{1}{R_{\text{eq}}} = \frac{1}{R_1} + \frac{1}{R_2} \quad \text{parallel}$$
$$R_{\text{eq}} = \frac{R_1 R_2}{R_1 + R_2} \quad \text{series}$$

Vectors:

$$|\vec{\mathbf{F}}| = \sqrt{F_x^2 + F_y^2} \quad \text{magnitude}$$
$$\theta = \tan^{-1}\left[\frac{F_y}{F_x}\right] \quad \text{direction}$$

Units

$$1\,\mathrm{eV} = 1.6 \times 10^{-19}\ \mathrm{J}$$
$$1\,\mathrm{J} = 1\,\mathrm{N \cdot m} = 1\,\mathrm{kg \cdot m^2/s^2}$$
$$1\,\mathrm{N} = 1\,\mathrm{kg \cdot m/s^2}$$
$$1\,\mathrm{W} = 1\,\mathrm{J/s} = 1\,\mathrm{kg \cdot m^2/s^3}$$
$$1\,\mathrm{F} = 1\,\mathrm{C/V}$$
$$1\,\mathrm{C} = 1\,\mathrm{A/s}$$
$$1\,\mathrm{N/C} = 1\,\mathrm{V/m}$$

Relativity

$$\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$$
$$\Delta t'_{\text{moving}} = \gamma\Delta t_{\text{stationary}} = \gamma\Delta t_p$$
$$L'_{\text{moving}} = \frac{L_{\text{stationary}}}{\gamma} = \frac{L_p}{\gamma}x' = \gamma(x - vt)$$
$$\Delta t' = t'_1 - t'_2 = \gamma\left(\Delta t - \frac{v\Delta x}{c^2}\right)$$
$$p = \gamma mv$$
$$v_{\text{obj}} = \frac{v + v'_{\text{obj}}}{1 + \frac{vv'_{\text{obj}}}{c^2}} \qquad v'_{\text{obj}} = \frac{v_{\text{obj}} - v}{1 - \frac{vv_{\text{obj}}}{c^2}}$$
$$\text{KE} = (\gamma - 1)mc^2$$
$$E_{\text{rest}} = mc^2$$
$$E^2 = p^2c^2 + m^2c^4$$

Derived unit	Symbol	equivalent to
newton	N	$\mathrm{kg{\cdot}m/s^2}$
joule	J	$\mathrm{kg{\cdot}m^2/s^2 = N{\cdot}m}$
watt	W	$\mathrm{J/s{=}m^2{\cdot}kg/s^3}$
coulomb	C	$\mathrm{A{\cdot}s}$
V	$\mathrm{W/A = m^2{\cdot}kg/{\cdot}s^3{\cdot}A}$	
farad	F	$\mathrm{C/V = A^2{\cdot}s^4/m^2{\cdot}kg}$
ohm	Ω	$\mathrm{V/A = m^2{\cdot}kg/s^3{\cdot}A^2}$
tesla	T	$\mathrm{Wb/m^2 = kg/s^2{\cdot}A}$