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PH102 Exam 1

PH 102 / LeClair
Summer 2009

Instructions

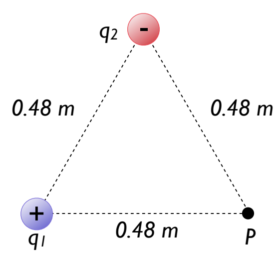
1. **Answer all questions below.** All problems have equal weight.
2. **There will be no partial credit given.** Clearly mark your answer using the tick boxes.
3. You are allowed 2 sides of a standard 8.5x11 in piece of paper and a calculator.

1. A spherical surface surrounds a point charge q. Describe what happens to the total flux through the surface if the charge is moved outside the surface.

- ☐ The flux is increased.
- ☐ The flux is decreased.
- ☐ The flux remains constant.
- ☐ The flux goes to zero.

2. 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



3. Two charges of $q_1 = 1.0\,\mu\text{C}$ and $q_2 = -2.1\,\mu\text{C}$ are 0.48 m apart at two vertices of an equilateral triangle, as shown at left. What is the total electric potential at point P, the third vertex? Take the zero of electric potential to be infinitely far away.

- ☐ 18700 V
- ☐ −39300 V
- ☐ −20600 V
- ☐ 11423 V

4. Car batteries are often rated in ampere-hours (amps times hours). This unit by itself designates the amount of which of the following that can be drawn from the battery?

- ☐ charge
- ☐ power
- ☐ energy
- ☐ current

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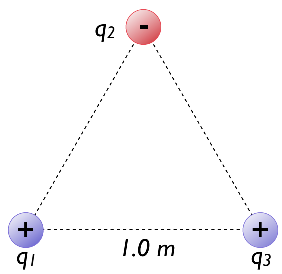
5. A potential difference of 100 mV exists between the outer and inner surfaces of a cell membrane. The inner surface is negative relative to the outer. How much work is required to move a sodium ion Na^+ outside the cell from the interior? A singly-charged ion has a charge of 1e, $1\,\text{eV} = 1.6 \times 10^{-19}\,\text{J}$.

- □ $1.6 \times 10^{-20}\,\text{J}$
- □ $6.4 \times 10^{-14}\,\text{J}$
- □ $2.8 \times 10^{-8}\,\text{J}$
- □ $5.7 \times 10^{-17}\,\text{J}$

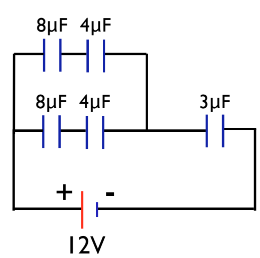


6. Three charges are arranged in an equilateral triangle, as shown at left. All three charges have the same *magnitude* of charge, $|q_1| = |q_2| = |q_3| = 10^{-9}\,\text{C}$ (note that q_2 is negative though). What is the **total potential energy** of this system of charges? Take the zero of potential energy to be when all charges are infinitely far apart. Note $n = 10^{-9}$.

- □ $-9.0\,\text{nJ}$
- □ $-7.1\,\text{nJ}$
- □ $+4.6\,\text{nJ}$
- □ $+8.6\,\text{nJ}$

7. What is the equivalent capacitance for the five capacitors at right?

- □ $3.6\,\mu\text{F}$
- □ $2.0\,\mu\text{F}$
- □ $9.0\,\mu\text{F}$
- □ $8.3\,\mu\text{F}$



8. 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

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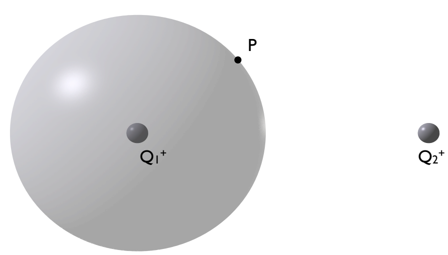
9. Consider a simple parallel-plate capacitor whose plates are given equal and opposite charges and are separated by a distance D. The capacitor is not connected to a battery. Suppose the plates are pushed together until they are separated by a distance $d < D$. How does the final electrostatic energy stored in the capacitor compare to the initial energy?

- □ The final stored energy is smaller than the initial stored energy.
- □ The final stored energy is greater than the initial stored energy.
- □ They are the same.

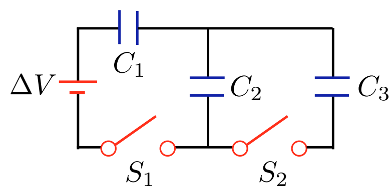
10. In the figure below, a point charge $1Q^+$ is at the center of an imaginary spherical Gaussian surface and another point charge $2Q^+$ is outside of the Gaussian surface. Point P is on the surface of the sphere. Which one of the following statements is true?

- □ Both contribute to the net electric flux through the sphere but only charge $1Q^+$ contributes to the electric field at point P.
- □ Both charges contribute to the net electric flux through the sphere but only charge $2Q^+$ contributes to the electric field at point P.
- □ Only the charge $1Q^+$ contributes to the net electric flux through the sphere but both charges contribute to the electric field at point P.
- □ Only the charge $2Q^+$ contributes to the net electric flux through the sphere but both charges contribute to the electric field at point P.
- □ Only the charge $1Q^+$ contributes to the net electric flux through the sphere and to the electric field at point P on the sphere.
- □ Only the charge $2Q^+$ contributes to the net electric flux through the sphere and to the electric field at point P on the sphere.



11. In the circuit at right, $C_1 = 2.0\,\mu\text{F}$, $C_2 = 6.0\,\mu\text{F}$, $C_3 = 3.0\,\mu\text{F}$, and $\Delta V = 10.0\,\text{V}$. Initially all capacitors are uncharged and the switches are open. What is the charge on C_2 when switch S_2 is open and switch S_1 is closed?

- □ 0
- □ 5 μC
- □ 10 μC
- □ 15 μC



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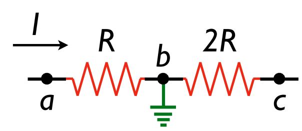
12. A current I flows through two resistors in series of values R and 2R. The wire connecting the two resistors is connected to ground at point b. Assume that these resistors are part of a larger complete circuit, such that the current I is constant in magnitude and direction. What is the electric potential relative to ground at points **a** and **c**, V_a and V_c, respectively? *Hint: what is the potential of a ground point?*

- □ $V_a = -IR$, $V_c = -2IR$
- □ $V_a = 0$, $V_c = -3IR$
- □ $V_a = +IR$, $V_c = +2IR$
- □ $V_a = +IR$, $V_c = -2IR$



13. If the average collision time gets longer, what happens to the **resistivity**? What happens to the resistivity when the electron density increases?

- □ increases, increases
- □ increases, decreases
- □ decreases, increases
- □ decreases, decreases

14. Suppose that a wire has a nonuniform cross section (thicker in some parts than others). Is the drift velocity of the electrons the same everywhere along this wire? The resistivity?

- □ yes; yes
- □ yes; no
- □ no; yes
- □ no; no

15. Two copper wires have the same diameter, but one is 3 times as long as the other. How much larger is the resistance of the second? Two other copper wires have the same length, but one has twice the diameter of the other. How much smaller is the resistance of the second?

- □ 3 times; 4 times
- □ 9 times; 2 times
- □ 3 times; 2 times
- □ 9 times; 4 times

16. In the headlight of an automobile, a current of 8.0 A flows through the filament of the lightbulb. How many electrons flow through the filament in a minute?

- □ 2×10^{7} electrons
- □ 6×10^{11} electrons
- □ 1×10^{17} electrons
- □ 3×10^{21} electrons

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17. Two identical empty capacitors, each with a capacitance C_0, are connected in series. Both are then filled with a material with dielectric constant $\kappa = 2.0$. What is the final net capacitance of the series combination?

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

18. A potential difference of 6.0 V applied across the ends of a thin conductor produces a current of 30 A. What is the resistance of the conductor?

- □ 0.20 Ω
- □ 5.0 Ω
- □ 1.5 Ω
- □ 18 Ω

19. If we decrease the separation between the plates of a parallel-plate capacitor by a factor 2 while holding the amount of charge constant, by what factor does the potential difference change?

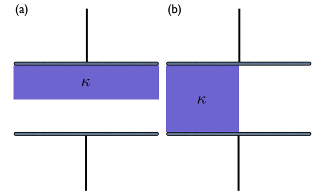
- □ down 4 times
- □ down 2 times
- □ up 2 times
- □ up 4 times

20. A wire commonly used for electrical installations in homes is No. 10 copper wire, which has a radius of 0.129 cm. What is the resistance of a piece of this wire 30 m long? The resistivity of copper is approximately $\rho = 1.7 \times 10^{-8}\,\Omega\,\text{m}$.

- □ 4.72 Ω
- □ 0.098 Ω
- □ 0.76 Ω
- □ 1.03 Ω

21. A parallel plate capacitor has a capacitance C when there is vacuum between the plates. The gap between the plates is half filled with a dielectric with dielectric constant κ in two different ways, as shown below. Which one has the higher capacitance? *Hint: try breaking each situation up into two equivalent capacitors.* Note $\kappa \geqslant 1$.

- □ (a)
- □ (b)
- □ they are equivalent
- □ need more information



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22. A point charge Q is at the center of an uncharged spherical conducting shell. How much charge is on the inner surface of the shell? The outer surface?

- ◻ $Q, -Q$
- ◻ $-Q, Q$
- ◻ $Q, 0$
- ◻ $0, Q$
- ◻ $0, 0$

23. Three equal positive charges are located at the three corners of a square, and a negative charge is located at the fourth corner. What is the direction (if any) of the electric field at the **center** of the square?

- ◻ toward the negative charge
- ◻ no direction, since the field is zero
- ◻ away from the negative charge
- ◻ perpendicular to the diagonal through the negative charge

24. If two charges of $+1\,\mu$C are separated by 1 cm ($= 10^{-2}$ m), what is the force between them?

- ◻ 1.8×10^{-9} N
- ◻ 90 N
- ◻ 8.2×10^{13} N
- ◻ 1.0×10^{-4} N

25. 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? Note $p = 10^{-12}$, $n = 10^{-9}$, $\mu = 10^{-6}$, $k = 10^{3}$.

- ◻ 10 pC
- ◻ 10 μC
- ◻ 10 nC
- ◻ 10 kC

Constants:

$$k_e = 8.98755 \times 10^9\,\mathrm{N \cdot m^2 \cdot C^{-2}}$$
$$\epsilon_0 = 8.85 \times 10^{12}\,\mathrm{C^2/N \cdot m^2}$$
$$e = 1.60218 \times 10^{-19}\,\mathrm{C}$$
$$c = 2.99792 \times 10^8\,\mathrm{m/s}$$
$$m_{e^-} = 9.10938 \times 10^{-31}\,\mathrm{kg}$$
$$m_{p^+} = 1.67262 \times 10^{-27}\,\mathrm{kg}$$
$$m_{n^0} = 1.67493 \times 10^{-27}\,\mathrm{kg}$$
$$g \approx 9.81\,\mathrm{m/s^2}$$

Current:

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

Electric Force & Field

$$\vec{F}_e = q\vec{E}$$
$$\vec{E} = k_e\frac{q}{r^2}\hat{r}$$
$$\Phi_E = |\vec{E}|A\cos\theta_{EA} = \frac{Q_{\text{inside}}}{\epsilon_0} \qquad \text{Gauss}$$
$$\Delta PE = -W = -q|\vec{E}||\Delta\vec{x}|\cos\theta = -qE_x\Delta x$$
$$\uparrow \text{ constant E field}$$

Units

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

Quadratic formula:

$$0 = ax^2 + bx^2 + c \Longrightarrow x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

Basic Equations:

$$\vec{F}_{\text{net}} = m\vec{a} \text{ Newton's Second Law}$$
$$\vec{F}_{\text{centr}} = -\frac{mv^2}{r}\hat{r} \text{ Centripetal}$$
$$KE = \frac{1}{2}mv^2$$
$$KE_{\text{initial}} + PE_{\text{initial}} = KE_{\text{final}} + PE_{\text{final}}$$

Electric Potential:

$$\Delta V = V_B - V_A = \frac{\Delta PE}{q}$$
$$\Delta PE = q\Delta V = -q|\vec{E}||\Delta\vec{x}|\cos\theta = -qE_x\Delta x$$
$$\uparrow \text{ constant E field}$$
$$V_{\text{point charge}} = k_e\frac{q}{r}$$
$$PE_{\text{pair of point charges}} = k_e\frac{q_1q_2}{r_{12}}$$
$$PE_{\text{system}} = \text{sum over unique pairs of charges}$$
$$PE_{\text{system}} = \sum_{\text{pairs } ij}\frac{k_eq_iq_j}{r_{ij}}$$
$$-W = \Delta PE = q(V_B - V_A)$$

Capacitors:

$$Q_{\text{capacitor}} = C\Delta V$$
$$C_{\text{parallel plate}} = \frac{\epsilon_0A}{d}$$
$$E_{\text{capacitor}} = \frac{1}{2}Q\Delta V = \frac{Q^2}{2C} = \frac{1}{2}C(\Delta V)^2$$
$$\uparrow \text{ energy stored}$$
$$C_{\text{eq, 2 par}} = C_1 + C_2$$
$$C_{\text{eq, 2 series}} = \frac{C_1C_2}{C_1 + C_2}$$
$$C_{\text{with dielectric}} = \kappa C_{\text{without}}$$