Exam 2: Physics 2113 Fall 2014

6:00PM TUE 14 OCT 2014

Name (Last, First): _____

Section #_____

Instructor's name:_____

Answer all 3 problems & all 4 questions.

Be sure to write your name.   Please read the questions carefully.

You may use only scientific or graphing calculators. *In particular you may not use the calculator app on your phone or tablet!*

You may detach and use the formula sheet provided at the back of this test. No other reference materials are allowed.

You may not answer or use cell phones during the exam. Please note that the official departmental policy for exams is as follows: "During your test, the only electronic device you may have with you at your seat is a scientific or graphing calculator. You may not have your cell phone, tablet, smartphone, PDA, pager, digital camera, computer, or any other device capable of taking pictures or video, sending text messages, or accessing the Internet. This means not just on your person, but close enough to you that you could reach it during the test. Any student found with such a device during a test will be assumed to be violating the LSU Honor Code and will be referred to the Dean of Students for Judicial Affairs." The simplest remedy is to bring nothing to this test but the calculator, and leave your backpack or purse at home. *If you have brought your cell phone or tablet with you, please leave it at the front of the room under the watchful eye of your instructor.*

Some questions are multiple choice. You should work these problems starting with the basic equation listed on the formula sheet and write down all the steps. Although the work will not be graded, this will help you make the correct choice and to determine if your thinking is correct.

On problems that are not multiple choice, be sure to show all of your work since no credit will be given for an answer without explanation or work. These will be graded in full, and you are expected to show all relevant steps that lead to your answer.
Please use complete sentences where explanations are asked for. For numerical answers that require units you must give the correct units for full credit.

YOU GET 60 min (1 hr)

1. (Question) **[9 points]** A potential difference V is connected across a device with resistance R, causing current i through the device. Circle the correct changed rate at which electrical energy is converted to the thermal energy, assuming the original rate to be P.

(i)   **[3 points]** V is doubled with R unchanged.

P/4   P/2   P   2P   (4P) V^2/R

(ii)   **[3 points]** i is tripled with R unchanged $i^2 R$

P/9   P/3   P   3P   (9P)

(iii)   **[3 points]** R is doubled with i unchanged

P/4   P/2   P   (2P)   4P $i^2 R$

2. (Question) **[9 points]** A parallel-plate capacitor of capacitance C is charged using a battery of potential **V** between its terminals. Then the battery is **disconnected** and the size of the plates (A) of the *isolated* capacitor is **increased.** Circle **T** if the statement is true and **F** if the statement is false:

(i) **[3 points]** The capacitance of the capacitor has increased   (T)   F $C \sim \dfrac{A}{L}$

(ii) **[3 points]** The charge on the plates of the capacitor has increased   T   (F)   DISCONNECTED

CONST

(iv) **[3 points]** The potential difference across the capacitor has decreased   (T)   F $q = C V$

V^c DOWN

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3. (Question) [9 points]

The figure shows a uniform electric field, pointing to the right. The equipotential surfaces are indicated with dashed lines.
There are four points indicated on the figure (1, 2, 3, and 4). We define V = 0 at point 3 ($V_3 = 0$).
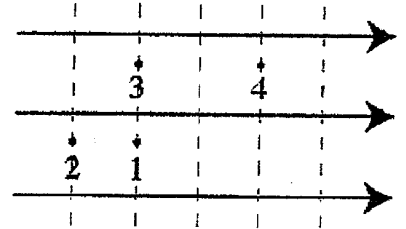
a) **[3 points]** What is the electric potential at the three other points?
Circle the right answer for each V.

i) $V_1 < 0$ $\boxed{V_1 = 0}$ $V_1 > 0$

ii) $V_2 < 0$ $V_2 = 0$ $\boxed{V_2 > 0}$

iii) $\boxed{V_4 < 0}$ $V_4 = 0$ $V_4 > 0$

$V_1 = V_3 = 0$

V DECREASES ALONG
FIELD LINE →

b) **[3 points]** What is the work done by the electric field on an electron if it is moved from point 2 to point 4? Circle the correct answer.

Positive   Zero   (Negative)   Not enough information to tell

$e < 0$

c) **[3 points]** What is the work done by the electric field on an electron if it is moved from point 1 to point 3? Circle the correct answer.

Positive   (Zero)   Negative   Not enough information to tell

$V_1 = V_3$

3

4. (Question) **[9 points]** The figure below shows three cylindrical copper conductors along with their face areas and lengths.

(a) (b) (c)
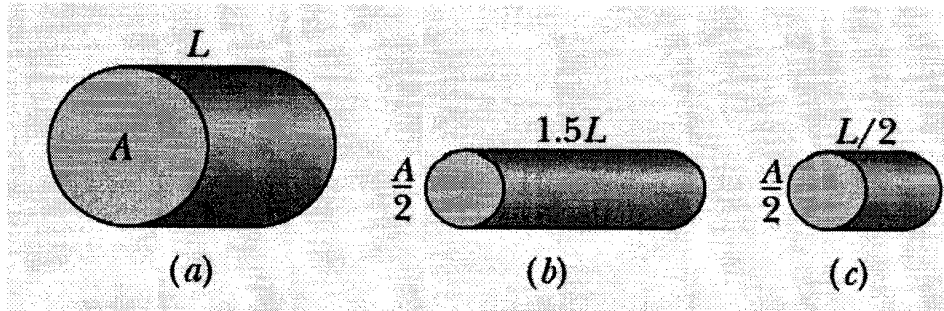
a) **[3 points]** Rank them according to their resistance, greatest first.

a) $R = \rho \dfrac{L}{A}$

b) $R = \rho \dfrac{1.5 L}{\frac{A}{2}} = \dfrac{3\rho L}{A}$

$$\boxed{R = \rho \dfrac{L}{A}}$$

$(b) > (c) = (a)$

c) $R = \rho \dfrac{L}{2 \cdot \frac{A}{2}}$

b) **[3 points]** Rank them according to the current through them, greatest first, when the same potential difference V is placed across their lengths.

$i = \dfrac{V}{R}$

$(c) = (a) > (b)$

c) **[3 points]** Rank them according to their current density, greatest first, when the same potential difference V is placed across their lengths.

$J = \dfrac{i}{A} = \dfrac{V}{RA}$

$J_a = \dfrac{V}{\rho \frac{L}{A} A} = \dfrac{V}{\rho L}$

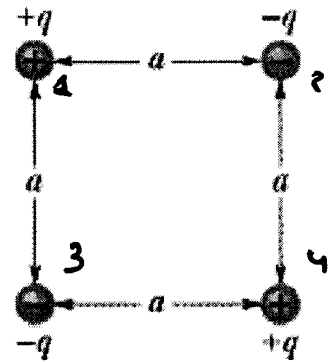$J_b = \dfrac{V}{3\rho \frac{L}{A} A} = \dfrac{V}{3\rho L}$

$J_c = \dfrac{V}{\rho \frac{L}{A} \cdot \frac{A}{2}}$

$J_c > J_a > J_b$

$J_c = \dfrac{2V}{\rho L}$

5. (Problem) [21 points]

The figure shows an arrangement of 4 charged particles at the corners of a square. Particles are initially infinitely far apart and at rest. Use that $q = 2.2\times10^{-12}C$ and $a = 30$ cm.

(a) [7 points] Find the electric potential in the center of the square. Show the calculations or state why.

$V = 0$ TWO POSITIVE CHGS. AND TWO NEGATIVE CHARGES EQUIDISTANT

(b) [7 points] Find how much work is required to set up the arrangement.

$$W_1 = 0 \qquad W_2 = -\frac{qq}{4\pi\epsilon_0 a} \qquad W_3 = \frac{-qq}{4\pi\epsilon_0 a} + \frac{qq}{4\pi\epsilon_0 \sqrt{2}a}$$

$$W_4 = \frac{qq}{4\pi\epsilon_0 \sqrt{2}a} - \frac{qq}{4\pi\epsilon_0 a} - \frac{qq}{4\pi\epsilon_0 a}$$

$$U = W_1 + W_2 + W_3 + W_4 = \frac{qq}{4\pi\epsilon_0 a}\left(-1 - 1 + \frac{1}{\sqrt{2}} + \frac{1}{\sqrt{2}} - 1 - 1\right)$$

$$= \frac{2qq}{4\pi\epsilon_0 a}\left(\frac{1}{\sqrt{2}} - 2\right) =$$

(c) [7 points] How much work would be required to bring an electron form infinite distance to the center of the square?

$$V_\infty = 0 \qquad V_0 = 0 \qquad \Delta W = 0$$

$$= \frac{2(2.2)^2\times10^{-24}\,C^2 \times 8.99\times10^9\,\frac{Nm^2}{C^2} \times (-1.29)}{0.3\,m}$$

$$= -3.75 \times 10^{-13}\,Nm \qquad 5$$

6. (Problem) [21 points] In the figure, a potential difference V= 5.0 V is applied across a capacitor arrangement with capacitances $C_1 = 3.0\mu F$, $C_2 = 2.0\mu F$, and $C_3 = 1.0\mu F$.
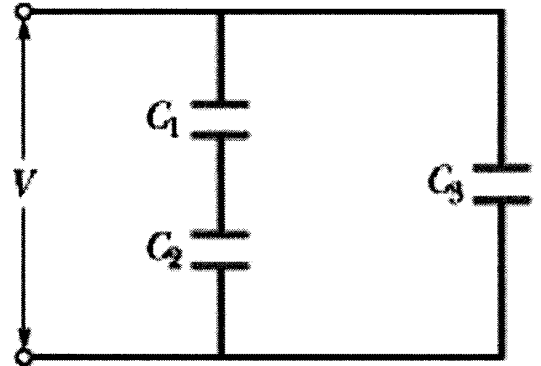
a) [7 points] Find the equivalent capacitance of the combination

$$C_{12} = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2}} = \frac{1}{\frac{1}{3} + \frac{1}{2}} = \frac{6}{5}\mu F = 1.2\mu F$$

$$C_{123} = 2.2\mu F$$

b) [7 points] Find the charge on C_1.

$$q = C_{12} V = 1.2\mu F \times 5.0 V = 6\mu C$$

c)) [7 points] Find the stored energy U_3 in capacitor C_3.

$$U_3 = \frac{1}{2} C_3 V^2 = \frac{1}{2} \times 1.0\mu F \times 25 V^2 = 12.5\mu J$$

7. (Problem) [22 points] In the figure, a nonconducting spherical shell of inner radius a=2.00 cm and outer radius b=2.40 cm has (within its thickness) a positive volume charge density ρ=A/r, where A is a constant and r is the distance from the center of the shell. In addition, a small ball of charge q=45.00 nC is located in the center.
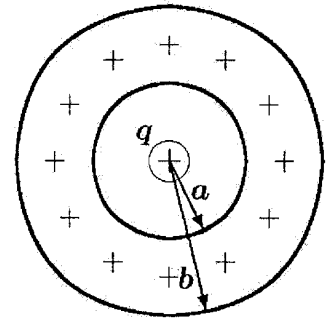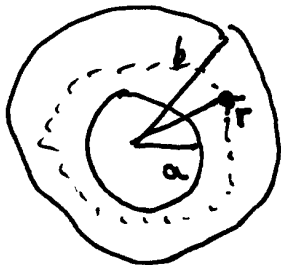

a) [7 points] If A=10 nC/cm², what is the value of the electric field at r=1.90 cm?

$$E = \frac{q}{4\pi\epsilon_0 r^2} = \frac{8.99\times 10^9 \frac{Nm^2}{C^2} \times 45\times 10^{-9} C}{(1.9)^2 \times 10^{-4} m^2}$$

$$= 1.12 \times 10^6 \, N/c$$

b) [7 points] If A=10 nC/cm², what is the value of the electric field at r=2.20 cm, ignoring the contribution of the charge q (just compute the effect of the shell)?

USE GAUSS

$$E_r = \frac{q_r}{4\pi\epsilon_0 r^2}$$

$$E_r = \frac{52.7\times 10^{-9} \times 8.99\times 10^9}{(2.2)^2\times 10^{-4} m^2} \frac{Nm^2}{C^2}$$

$$= 9.7\times 10^5 \, N/c$$

$$q_r = \int_a^r 4\pi r'^2 \rho \, dr' =$$

$$= 4\pi \int_a^r (r')^2 \frac{10 \, mC}{r'/cm^2} \, dr =$$

$$= 4\pi \times 10 \, mC \times \frac{r^2}{2}\Big|_{2cm}^{2.2cm} =$$

$$= 4\pi \times 10 \, mC \frac{(2.2^2 - 2.0^2) cm^2}{2} \frac{1}{cm^2} = 52.7 \, mC$$

c) [8 points] What value of A would make the field within the shell (a<r<b) constant?

AS BEFORE   PART a>

$$E_r = \frac{+q}{4\pi\epsilon_0 r^2} + \frac{q_r}{4\pi\epsilon_0 r^2}$$

$$= \frac{q}{4\pi\epsilon_0 r^2} + \frac{4\pi A}{2\times 4\pi\epsilon_0} \frac{r^2}{r^2} - \frac{4\pi A}{2\times 4\pi\epsilon_0} \frac{a^2}{r^2}$$

CONST

IF THESE CANCEL

$$E_r = CONST$$

$$q_r = 4\pi \int_a^r \rho r'^2 \, dr = 4\pi \int_a^r \frac{A}{r'} r'^2 \, dr$$

$$= \frac{4\pi A}{2} (r^2 - a^2)$$

$$2\pi A a^2 = q \Rightarrow A = \frac{q}{2\pi a^2}$$

$$\Rightarrow A = \frac{45 \, mC}{2\pi \times 4 cm^2} = 1.79 \frac{mC}{cm^2}$$

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