Highly suggested: carefully read through the testing policies below on the practice exam. You may only have a few minutes at most to read them at the actual exam (outside of exam time), and will be held to them without exception.

GENERAL INSTRUCTIONS:
· This is a closed book test. You may use a calculator only. (Cell phone calculators not allowed)
· The attached formula sheet has all equations needed to start a problem.
  Your own copy of this (or any other) formula sheet are not allowed.
· You may not leave the exam room without permission.
· Violating any of these procedures is considered academic dishonesty.

FORMATTING YOUR ANSWERS (Long answer section):
· Justify your work sufficiently, with calculation or explanation, in order to receive credit.
· Make your answers clear, legible and organized. If I can’t read it, no credit.
· I cannot grade crossed out or erased work. Be sure before deleting work.
· I cannot give full credit for a correct response if it is accompanied by another contradicting one. However, “hedging your bets” will earn more credit than not having the correct response at all.
· Do not forget to include units and express vectors appropriately for full credit.

Scratch paper policies:
There should be plenty of room on the test to put your answers, but if you feel you need more space, you may choose to turn in work on separate scratch paper. However, you must:
· Put a note on the exam problem/part referring me to “see scratch paper” for further work.
· Number the problem(s) on the scratch.
· Plan ahead for which pages are just for you, and which will be submitted. Don’t turn in unorganized scratch paper “on a whim” at the end of the exam. If any work for the multiple choice questions (cannot be graded) happens to be on the same page, please cross it out or clearly label it as separate from work you need graded.
· All scratch paper will be provided by me. You may not supply your own.
· Though I will make every effort to keep your test together, I am not responsible for lost/mismatched scratch pages. Write your name on every piece of scratch for grading (or bring a pocket stapler).

GOOD LUCK!
SECTION I: MULTIPLE CHOICE. No partial credit. Each question = 5 points.

Questions #1-6 refer to the following:
The circuit below consists of a battery and three light bulb resistors, where $R_1 = R_2 > R_3$.

Use the following answer choices for probs #1-3.

a.) Bulb 1
b.) Bulb 2
c.) Bulb 3
d.) N/A – more than one bulb ties for this.
e.) Not enough info

1.) Which resistor has the **most current**?
2.) Which resistor has the **least current**?
3.) Which resistor dissipates the **least power**?

Now suppose an uncharged capacitor (with a dielectric already in it) is connected in parallel with $R_3$, as shown.

4.) At the moment the capacitor is connected, the current through $R_2$ will be:

a.) larger than before it was connected
b.) the same as before it was connected
c.) smaller than before it was connected, but not zero
d.) zero
e.) Not enough info

After the capacitor has been connected for a very long time (*use for probs #5-6*):

5.) The current through $R_2$ will be:

a.) larger than before the capacitor was connected.
b.) the same as before the capacitor was connected.
c.) less than before the capacitor was connected (but still more than zero).
d.) Zero.
e.) Not enough info.

6.) Now suppose the dielectric contained inside the capacitor is quickly removed. Bulb 2 will immediately ______ when the dielectric is removed, and then ______.

a.) get dimmer / stay that way
b.) get brighter / stay that way
c.) get brighter / return to its previous brightness (before the dielectric was removed)
d.) get dimmer / return to its previous brightness (before the dielectric was removed)
e.) turn off completely / return to its previous brightness (before the dielectric was removed)

7.) When is it possible for a **negative** charge to move into a region of **lower** voltage?

a.) Only if the charge is given some initial potential energy.
b.) Only if the charge is given some initial kinetic energy.
c.) This is impossible unless the charge is negative, not positive.
d.) This is impossible, regardless of the sign of the charge.
e.) Any time they are free to move; this is how negative charges behave usually.
Questions #8-10 refer to the following:
The circuit below consists of two batteries and four resistors. The correct directions of the currents flowing in the circuit are shown. All currents are non-zero.

8.) Which of the following equations is correct?
   a.) $+\varepsilon_1 - I_1R_1 - I_3R_3 = 0$
   b.) $+\varepsilon_1 - I_1R_1 - I_3R_2 + \varepsilon_2 - I_2R_4 = 0$
   c.) $-\varepsilon_2 + I_2R_2 + I_3R_3 + I_2R_4 = 0$
   d.) More than one of these.
   e.) None of these.

9.) Which end of resistor $R_2$ has a higher voltage?
   a.) the left end
   b.) the right end
   c.) Neither; both ends are at the same voltage.
   d.) There is not enough info to determine this.

10.) Suppose the current directions indicated in the diagram are only initial guesses. Which of them could possibly be incorrect?
    a.) $I_1$ only  
    b.) $I_2$ only  
    c.) $I_3$ only  
    d.) Two of these.  
    e.) All of these.

Questions #11-14 refer to the following:
A large point charge is fixed in space. Two points in space ($P_1$ & $P_2$) are marked to its right.

You will (without touching it) use it to generate a net charge on each of two solid conducting spheres, both initially neutral. While in contact with each other, the two spheres are brought nearby the point charge (you may assume their exact midpoint is placed at either point $P_1$ or $P_2$), in one of the orientations shown.

In order to produce the most net charge on each sphere, the spheres should be: (use for probs #11-12)

11.) placed at:
    a.) Point $P_1$  
    b.) Point $P_2$  
    c.) Either would result in the same charge.  
    d.) Not enough info.

12.) in the orientation which is:
    a.) "stacked"  
    b.) "side-by-side"  
    c.) Either would result in the same charge.  
    d.) Not enough info.

13.) If the two-sphere system is to feel a net force to the left (when at $P_1$ or $P_2$), which of these is a list of the minimum requirements for the external electric field it experiences?
    a.) non-zero
    b.) non-zero, non-uniform
    c.) non-zero, non-uniform, made by a positive charge
    d.) non-zero, non-uniform, made by positive charge, strong enough
    e.) All of these and additional criteria.
14.) If you want each sphere to retain a net charge when taken far away, while they are nearby the point charge you will need to:
   a.) momentarily connect the spheres to ground
   b.) separate the spheres from each other
   c.) Either a or b.
   d.) Both a and b.
   e.) Not enough info.

END OF MULTIPLE CHOICE SECTION.
SECTION II: LONG ANSWER. Partial credit will be assigned. An answer with insufficient or no explanation and/or calculation to make it clear that the problem was done correctly will receive NO CREDIT. The questions are worth 25 and 30 points, respectively.

1.) Three identical charges \( q_1 = q_2 = q_3 = +2 \mu C \) are placed at the following xy coordinates: the origin, \((0 \text{ m, } +5 \text{ m})\), and \((+5 \text{ m, } 0 \text{ m})\), respectively.

a.) What is the voltage at \( q_3 \)'s location (due to the other two charges)?

Now, if the charge \( q_3 \) becomes **unfixed**, 

b.) Calculate the exact direction the charge will initially move in.

c.) How much kinetic energy will this charge have when it gets very far away?

After \( q_3 \) is **far away**, 

d.) Please sketch the voltage that would be seen along the y-axis for the remaining two charges \( (q_1 \text{ and } q_2) \). Mark on your graph where the electric field is zero. Justify your answers briefly.
2.) The circuit below consists of a battery ($\varepsilon = 100 \text{ V}$), four resistors ($R_1 = R_2 = 2 \ \Omega \ \text{ and } R_3 = 12 \ \Omega \ \text{ and } R_4 = 5 \ \Omega$) and a capacitor ($C = 4 \ \text{ F}$, initially empty at $t=0$).

a.) At $t=0$, calculate the current through each resistor.

![Circuit Diagram]

When the capacitor is 25% of the way to its eventual full charge: (use for parts b-c)

b.) How much power does resistor #4 dissipate at this moment?

c.) What is the voltage across resistor #3 at this moment?

d.) On the $V$ vs. $t$ graph below, please sketch both $V_C$ (voltage across the cap) and $V_{R4}$ (voltage across resistor #4), from $t=0$ until a long time has passed. Justify conceptually (no need to indicate numerical values).

![Graph Diagram]