PART I: MULTIPLE CHOICE [32 pts]

Each multiple choice question has one best answer -- circle the letter of the best answer. **Partial credit will be given on the multiple choice questions.** If you circle two answers, one of which is correct, you will receive half credit for the question. No credit will be given for more than two answers, even if one of them is correct. (4 points each for full credit)

1. Sphere A carries a net positive charge and sphere B is neutral. Both are conducting spheres and they are placed near each other on an insulated table. Sphere B is briefly touched with a wire that is grounded. Which statement is correct after the ground wire is removed?
   
   a) Sphere B remains neutral.
   b) Sphere B is now positively charged.
   c) Sphere B is now negatively charged.
   d) The charge on sphere B cannot be determined without additional information.

2. For a positive charge moving spontaneously in the direction of an electric field,

   a) its potential energy increases and its potential decreases.
   b) its potential energy decreases and its potential increases.
   c) its potential energy increases and its potential increases.
   d) its potential energy decreases and its potential decreases.

3. If you use 10 joules of work to push +1 C of charge into an electric field, the voltage difference between the charge's final position and its starting position will be

   a) less than 10 volts.
   b) 10 volts.
   c) more than 10 volts.
   d) -10 volts.
4. The plates of a parallel-plate capacitor are maintained at constant voltage by a battery as they are pulled apart. What happens to the strength of the electric field during this process?

a) It increases.
b) It decreases.
c) It remains constant.
d) There is no way to tell from the information given.

5. A parallel-plate capacitor is connected to a battery and becomes fully charged. The capacitor is then disconnected (from the battery), and the separation between the plates is increased in such a way that no charge leaks off. The energy stored in this capacitor has

a) increased.
b) decreased.
c) not changed.
d) become zero.

6. For a circuit where the resistance increases with the current (R is non-ohmic), which graph most closely represents the relation between current and voltage?
7. R₄ shown in the circuit below, is a variable resistor (the resistance of R₄ is continuously adjustable from zero ohms to infinite ohms). In order for there to be no current through resistor R, R₄ must be equal to:

a) R₂  
b) R₃  
c) R₃R₂/R₃  
d) R₃R₂/R₂  
e) R₃R₂/R₄

8. What is the maximum number of 100-W light bulbs you can connect in parallel to a single 120-V circuit without tripping the 20-A circuit breaker?

a) 11  
b) 17  
c) 23  
d) 27
PART II: FREE RESPONSE [68 pts]
Do problems 9, 10, and 11. Choose either problem 12 or 13. Be sure to cross out the problem that you don’t do.

9. Two balloons are filled with air and hung from the ceiling with strings. The distance from the point of suspension on the ceiling to the **center** of each balloon is 1m. When the balloons are charged positively, they hang at a 30° angle with the vertical. Assume both balloons have the same charge, +Q.

(a) Draw electric field lines in the sketch so as to indicate the relative strength and direction of the field from each balloon. [3 pts]
(b) Assuming each balloon has a mass of 10 grams, calculate the charge on each balloon. [8 pts]
(c) Is there any location near the balloons where the electric field would be zero? Where would that location be? Explain [3 pts]
(d) Now discharge one of the balloons while keeping the charge +Q on the other. What happens to the two balloons when you let them swing freely again? Explain. [3 pts]
10. A capacitor is assembled by placing two 30-cm diameter pie pans 0.6 cm apart and then connecting each plate to the terminals of a 12-volt battery.

(a) Calculate the capacitance. [3 pts]
(b) Calculate the charge on each plate. [3 pts]
(c) What is the magnitude and direction of the electric field half way between the two plates? [3 pts]
(d) How much work was done by the battery to charge the plates? [4 pts]
(e) How do the above four values change if the plates are separated by an additional 0.6 cm. Assume that the battery remains connected. State clearly if a value increases, decreases, or remains the same. [4 pts]
11. In a television picture tube electrons are accelerated by thousands of volts through a vacuum. A highly simplified model of the picture tube consists of two conducting electrodes separated by 30 cm. A potential difference of 30,000 V gives rise to a constant field between the electrodes.

(a) Find the kinetic energy and the velocity of the electron at its final position after being accelerated across this 30kV. [9pts]

(b) If the television set was placed on its back such that the electrons where being accelerated upward by the E field away from the Earth, would electrons still be able to move upward against the force of gravity? What is the net acceleration of an electron? [8pts]
12. Consider the circuit shown. The battery supplies a constant 50 volts and each resistor is 100 ohms.
That is, $R_1 = R_2 = R_3 = R_4 = 100\,\Omega$.

(a) What is the voltage across each resistor when the switch is open? [3 pts]
(b) What is the voltage across each resistor when the switch is closed? [3 pts]
(c) What is the current through each resistor when the switch is open? [3 pts]
(d) What is the current through each resistor when the switch is closed? [3 pts]
(e) What is the power output of the battery when the switch is open and when it is closed? [5 pts]
13. A certain teaching fellow’s two young daughters have just discovered the joy of blow drying their hair. Of course they both must have their own identical Britney Spears high heat model. This dryer is typically operated at 120 V and has a resistance of 8 ohms.

a) What is the power used by each hair dryer? [4 pts]
b) If both hair dryers are connected in parallel to a 120V circuit that is protected by a single 20A fuse, what will happen? Will the fuse blow? Explain. [4 pts]
c) Being clever children, the girls decide to wire the two hair dryers in series instead of parallel. What is the power used by each dryer in this series arrangement? What is the total power used by both hair dryers? Will the 20A fuse blow? Explain. [4 pts]
d) What would be the fastest way for the girls to dry their hair? Should they learn to share and use a single dryer connected to the 120V outlet (sharing by passing the dryer back and forth)? Or would it be quicker to use the dryers connected in series and run both of them at the same time? Explain. [5 pts]