Useful Constants:
\[ k = 9.0 \times 10^9 \text{ Nm}^2/\text{C}^2 \]
\[ \varepsilon_0 = 8.85 \times 10^{-12} \text{ C}^2/(\text{N m}^2) \]
\[ e = 1.6 \times 10^{-19} \text{ C} \]

Part I: Multiple Choice (4 points. ea.)

choose the best answer
"none of the above" may be a valid answer

1. If the charge on a given capacitor is doubled, then
   (a) the capacitance doubles.
   (b) the potential difference across the capacitor doubles.
   (c) the permeability of free space doubles.
   (d) the energy stored in the capacitor doubles.
   (e) all of the above.

2. The effective capacitance of two capacitors connected in parallel is
   (a) always less than the individual capacitance of either of the two capacitors.
   (b) always greater than the individual capacitance of either of the two capacitors.
   (c) always between the individual capacitances of the two capacitors.
   (d) none of the above always holds.

3. The dielectric strength for a material is
   (a) the factor by which the capacitance increases when the material is inserted between the plates of a parallel plate capacitor.
   (b) the factor by which the magnitude of the electric field decreases when the material is inserted between the plates of a parallel plate capacitor.
   (c) the factor by which the potential decreases when the material is inserted between the plates of a parallel plate capacitor.
   (d) the maximum electric field the material can withstand before dielectric breakdown.
   (e) (a) through (c) the above.

4. The principles used to to analyze electrical circuits in the last three chapters were
   (a) conservation of energy and conservation of momentum.
   (b) conservation of charge and conservation of momentum.
   (c) symmetry and conservation of energy.
   (d) conservation of energy and conservation of charge.
   (e) all of the above.
___ 5. The potential difference between the terminals of a real battery (emf $\mathcal{E}$, internal resistance $r$) will be less than the emf in magnitude (but with the same polarity) but not zero if
(a) the battery is shorted out (zero load resistance).
(b) there is an infinite load resistance (open circuit).
(c) the battery is being charged by an external source.
(d) an external source helps drive a large current through the battery in the direction it would naturally discharge.
(e) the battery is operated under normal conditions with a simple load resistance.

___ 6. Two wires of different metallic conductors with the same diameters are joined end to end. As the current from the wire with lower resistivity into the wire with higher resistivity,
(a) the current decreases.
(b) the current density decreases.
(c) the electric field decreases.
(d) the electric field increases.
(e) the electrons stop moving.

___ 7. Since the resistance of a human body can be as low as $1000\Omega$ and a current of $.1A$ can be fatal, a safety mechanism can be designed into a high-voltage power supply by
(a) having a low EMF to limit the maximum current which could be delivered.
(b) having a $1000\Omega$ to maximize the power delivered.
(c) having a high internal resistance to limit the maximum current which could be delivered.
(d) having a low internal resistance which will maximize the current delivered.

___ 8. The current-voltage characteristics at right indicate a device whose resistance is
(a) increasing with increasing current.
(b) remaining constant.
(c) decreasing with increasing current.
(d) changing uncontrollably with increasing current.
(e) none of the above.

___ 9. Two identical light bulbs are connected in series to an ideal battery as shown. In this configuration
(a) both bulbs will glow equally bright.
(b) Bulb A will glow brighter than Bulb B.
(c) Bulb B will glow brighter than Bulb A.
(d) Only Bulb A will glow.
(e) Only Bulb B will glow.
10. A series RC circuit with an initially uncharged capacitor is connected as shown. The switch is closed at \( t=0 \). Which graph below best describes charge on the capacitor as a function of time?

- (A)
- (B)
- (C)
- (D)
- (E) none of the above.
1) An air parallel plate capacitor is to be made using plates of area $A$. Their initial separation is given as $x$. The capacitor is charged with a charge $Q$ and then disconnected from its charging battery.

a) What is the capacitance of the capacitor in terms of the parameters given?

b) What is the energy stored in this capacitor in terms of the parameters given?

c) From mechanics we learned that the relationship between the force on an object and its potential energy was

$$ F(x) = -\frac{dU(x)}{dx} $$

Use this relation to find an expression for the force between the plates of a charged parallel plate capacitor in terms of the parameters given.

Suppose a capacitor has plates each of area $.02 \text{ m}^2$ separated by a distance of 4.00 mm, which is charged by a 10 V battery.

d) what is the capacitance of this capacitor?

e) what is the charge on this capacitor?

f) using your results (including your answer to part c) determine the force of attraction between the plates of this capacitor.
2) For the diagram shown at right
a) Calculate the equivalent capacitance of the capacitor network, and the energy stored in the equivalent capacitance.
b) Calculate the charge on each capacitor, the potential difference across each capacitor.
3) A resistor is made of a cylinder of graphite 2 cm long and .2 cm in diameter. At 20°C graphite has a resistivity of $3.5 \times 10^{-5} \, \Omega \cdot \text{m}$ and a temperature coefficient of resistivity of $-0.0005 \, (^\circ \text{C})^{-1}$.

(a) What is the resistance of the resistor at 20°C?

(b) What would be the resistance at 250°C?

(c) At what temperature would the resistance be 0.25% higher than at 20°C?
4) For the diagram, determine the five currents indicated. Clearly indicates the loops and junctions you are using for your application of Kirchoff’s rules on the diagram. Clearly write the loop and junction equations you generate. Use your calculator to solve these simultaneous equations. Hint: to find the 5 unknown currents will require 5 equations. Each current must appear in at least one junction rule, and each branch must appear in at least one loop rule. 2 junction rules and 3 branch rules will most likely work.

Warning: there are no serial or parallel combinations of resistors in this problem.