MUTLIPLE CHOICE. Choose the one alternative that best completes the statement or answers the question. Show your work on the questions that request you to do so in the space provided for full credit. Each question is worth 5.5 points so in principle you can earn more than 100 points. These extra points are bonus points and will be counted towards your final grade.

1) A wire of resistivity \( \rho \) must be replaced in a circuit by a wire of the same material but 4 times as long. If, however, the resistance of the new wire is to be the same as the resistance of the original wire, the diameter of the new wire must be:

A) 1/2 the diameter of the original wire.
B) 1/4 the diameter of the original wire.
C) 2 times the diameter of the original wire.
D) the same as the diameter of the original wire.

2) A hydrogen nucleus, which has a charge \( e \), is situated to the left of a carbon nucleus, which has a charge \( 6e \).
Which statement is true?

A) The electrical force experienced by the hydrogen nucleus is to the left, and the magnitude is less than the force exerted on the carbon nucleus.
B) The electrical force experienced by the hydrogen nucleus is to the right, and the magnitude is equal to the force exerted on the carbon nucleus.
C) The electrical force experienced by the hydrogen nucleus is to the left, and the magnitude is equal to the force exerted on the carbon nucleus.
D) The electrical force experienced by the hydrogen nucleus is to the left, and the magnitude is greater than the force exerted on the carbon nucleus.

3) A parallel-plate vacuum capacitor is connected to a battery and charged until the stored electric energy is \( U_0 \).
The battery is removed, and then a dielectric material with dielectric constant \( K \) is inserted into the capacitor filling the space between the plates. What is the energy in the capacitor now with the dielectric inserted between the plates?

A) \( \frac{1}{2} KL_0 \)
B) KL_0
C) \( U_0 \)
D) \( \frac{1}{K} U_0 \)
E) 0

4) An air-filled parallel-plate capacitor is connected to a battery and allowed to charge up. Now a slab of dielectric material is placed between the plates of the capacitor while the capacitor is still connected to the battery. After this is done, we find that:

A) the voltage across the capacitor had increased.
B) the energy stored in the capacitor had decreased.
C) the charge on the capacitor had not changed.
D) the charge on the capacitor had decreased.
E) None of these choices are true.
5) X and Y are two uncharged metal spheres on insulating stands, and are in contact with each other. A positively charged rod R is brought close to X as shown in Figure (a).

Sphere Y is now moved away from X, as in Figure (b).

What are the final charge states of X and Y?
- A) X is negative and Y is positive.
- B) X is positive and Y is neutral.
- C) X is neutral and Y is positive.
- D) Both X and Y are neutral.
- E) Both X and Y are negative.

6) The charge on the square plates of a parallel-plate capacitor is Q. The potential across the plates is maintained with constant voltage by a battery as they are pulled apart to twice their original separation, which is small compared to the dimensions of the plates. The amount of charge on the plates is now equal to

A) Q/4.  B) Q/2.  C) 2Q.  D) 4Q.  E) Q.

7) As more resistors of the same resistance R are added in parallel across a constant voltage source, the power supplied by the source as the number of resistors increase

A) decreases.  B) increases.  C) does not change.

8) A conductor is inserted between the plates of very large capacitor of area 10.0 m$^2$ and separation 1.00 cm. The plates have charge of Q = 10.0 mC and -10.0 mC respectively. What is the Electric field inside the conductor if the conductor is not touching either of the plates? (Hint: It's helpful to contemplate the microscopic view of a conductor between the plates)

A) 0.0 N/C  B) 10.0 N/C  C) 100.0 N/C  D) 1.00 N/C
9) An electron is initially moving to the right when it enters a uniform electric field directed upwards. Which trajectory shown below will the electron follow?

- [ ] A) trajectory $X$
- [x] B) trajectory $Z$
- [ ] C) trajectory $Y$
- [ ] D) trajectory $W$

10) Two light bulbs, $B_1$ and $B_2$, are connected to a battery having appreciable internal resistance as shown in the figure. What happens to the brightness of bulb $B_1$ when we close the switch $S$? Hint: the brightness of the light bulb is proportional to the current going through it.

- [ ] A) The brightness of $B_1$ decreases temporarily but gradually increases back to its original brightness.
- [x] B) The brightness of $B_1$ decreases permanently.
- [ ] C) The brightness of $B_1$ increases temporarily but gradually decreases back to its original brightness.
- [ ] D) The brightness of $B_1$ increases permanently.
- [ ] E) The brightness of $B_1$ does not change.
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11) **Show your work!** A small glass bead has been charged to 1.9 nC. What is the strength of the electric field 2.0 cm from the center of the bead?

**A)** $8.1 \times 10^{-5} \text{ N/C}$  
**B)** $8.5 \times 10^{2} \text{ N/C}$  
**C)** $8.5 \times 10^{-7} \text{ N/C}$  
**D)** $3 \times 10^{4} \text{ N/C}$

\[
\vec{E} = \frac{k \cdot q}{r^2} = \frac{9 \times 10^9 \text{N} \cdot \text{m}^2/\text{C}^2 \cdot 1.9 \times 10^{-9} \text{C}}{(0.02 \text{m})^2} = 4.275 \times 10^4 \frac{\text{N}}{\text{C}}
\]

12) **Show your work!** A device with a resistance of 200.0 kΩ is connected to a 10.0 V battery. How much power does the device use?

**A)** 1.25 mW  
**B)** 20.00 kW  
**C)** 0.050 mW  
**D)** 200 kW

\[
P = IV = \frac{V^2}{R} = \frac{(10 \text{V})^2}{200 \times 10^3 \Omega} = 0.5 \times 10^{-3} \text{ W}
\]

13) **Show your work!** A proton with speed $1.5 \times 10^5 \text{ m/s}$ travels through a potential difference of 100 volts, gaining speed. What is the speed reached in m/s?

**A)** $1.55 \times 10^6$  
**B)** $8.80 \times 10^5$  
**C)** $0.04 \times 10^5$  
**D)** $3.55 \times 10^5$  
**E)** $4.56 \times 10^5$

\[
E_f = \frac{1}{2} m v^2 + qV_e
\]

\[
E_f = \frac{1}{2} m v_f^2
\]

\[
\sqrt{\frac{1}{2} m v_f^2} + qV_e = \frac{1}{2} m v^2
\]

\[
\sqrt{\frac{1}{2} m v_f^2} + q(100 \text{V}) = \frac{1}{2} m (1.5 \times 10^5 \text{m/s})^2
\]
14) **Show your work!** The charge in the bottom right corner of the Figure below is \( Q = -90 \text{ nC} \). What is the magnitude of the electrical force on \( Q^2 \)?

- **A) 5.3 \times 10^{-2} \text{ N}**
- **B) 3 \times 10^{-2} \text{ N}**
- **C) 5 \times 10^{-2} \text{ N}**
- **D) 2.8 \times 10^{-2} \text{ N}**

\[
F_F = \frac{k(90 \text{ nC})(15 \text{ nC})}{(0.03^2 + 0.01^2)} \left( \cos \theta - \hat{x} \right) + 5 \sin \theta \hat{y}
\]

\[
F_F = \frac{k(90 \text{ nC})(5 \text{ nC})}{(0.01^2)} \left( \frac{5\text{ nC}}{0.03^2 + 0.01^2} \hat{y} \right)
\]

\[
F = 0.0117 \hat{x} \text{N} + 0.057355 \hat{y} \text{N}
\]

\[
\| F \| = \sqrt{(F_x)^2 + (F_y)^2} = 0.039 \text{ N}
\]

15) **Show your work!** The resistors in the circuit shown in Figure 19.2 each have a resistance of 700 \( \Omega \). What is the equivalent resistance of the circuit?

\[
\text{parallel} \rightarrow R = \frac{1}{700} + \frac{1}{700} = 350 \Omega
\]

\[
\text{parallel} \rightarrow R = \frac{1}{700} + \frac{1}{700} = 350 \Omega
\]

\[
R_{\text{eq}} = \frac{350 \Omega + 350 \Omega}{2} = 700 \Omega
\]
16) **Show your work!** Consider the group of charges in Figure below. All three charges have Q = 8.8 nC. What is their electric potential energy?

A) 6.2 \times 10^{-5} \text{ J}    \quad  B) 5.9 \times 10^{-5} \text{ J}    \quad  C) 5.5 \times 10^{-5} \text{ J}    \quad  D) 5.7 \times 10^{-5} \text{ J}

\[ U = \frac{kQ_1Q_2}{r_{12}} \]

\[ U_{12} = \frac{1}{0.04} + \frac{1}{0.05} + \frac{1}{0.03} \]

\[ U_{12} = 5.4595 \times 10^{-5} \text{ J} \]

17) **Show your work!**

In the Figure above, a small spherical insulator of mass $10.00 \times 10^{-2}$ kg and charge +0.910 \mu C is hung by a thin wire of negligible mass. A charge of -0.170 \mu C is held 0.260 m away from the sphere and directly to the right of it, so the wire makes an angle \( \theta \) with the vertical (see drawing). What is the angle \( \theta \)? (Hint: a free body diagram would be helpful here)

A) 2.23°    \quad  B) 1.21°    \quad  C) 1.97°    \quad  D) 1.44°    \quad  E) 1.70°
18) The batteries shown in the circuit in the Figure below have negligibly small internal resistances. Assume that EMF source $E = 30.0 \, \text{V}$ and $R = 20.0 \, \Omega$. Find the magnitude of the current through the 20 Ohm resistor.

A) 5.00 A  
B) 0.50 A  
C) 1.00 A  
D) 1.25 A

19) For the circuit depicted in the Figure above find the current through the resistor.

A) 2.00 A  
B) 1.75 A  
C) 1.00 A  
D) 2.25 A

20) For the circuit depicted in the Figure above find the current through the 30.0 V battery.

A) 1.00 A  
B) 1.25 A  
C) 2.75 A  
D) 2.00 A

Kirchhoff's loop rule:

\[ \sum V_i = 0 \]

\[ 30V + 20I_2 = 0 \rightarrow I_2 = \frac{-30}{20} = -1.5 \, \text{A} \]

Kirchhoff's loop rule:

\[ \sum V_i = 0 \]

\[ -30I_2 - 20I_x - 5V = 0 \rightarrow -30(-1.5) - 20I_x - 5 = 0 \]

\[ I_x = \frac{30}{20} = 1.5 \, \text{A} \]

\[ I_3 = \frac{1.25}{1} = 1.25 \, \text{A} \]

$I_3$ is the current through the $R$ resistor.