1. Three small charges, labeled A, B, and C, are equally spaced on the x-axis, as shown. Charge A has negative charge \(-4Q\), charge B has positive charge \(+2Q\), and C has positive charge \(+Q\). What is the x-component of the net electrostatic force on C due to A and B?

A) \(-\frac{2kQ^2}{d^2}\)  
B) \(\frac{kQ^2}{d^2}\)  
C) \(\frac{2kQ^2}{d^2}\)  
D) zero  
E) None of these

2. Compare the following two situations: Situation A: a spherical surface S surrounding a positive point charge \(+Q\) at its center and no other charges present. Situation B: same as A except now there are two negative charges \(-Q\) and \(-Q\), just outside the surface S, as shown. How does the flux through the surface S \(\Phi = \oint_S \mathbf{E} \cdot d\mathbf{a}\) in these two situations compare?

A) \(\Phi_A = \Phi_B\)  
B) \(\Phi_A > \Phi_B\)  
C) \(\Phi_A < \Phi_B\)

3. What are the units of \(\varepsilon_0\), the constant that appears in Gauss's Law?

A) \(\frac{N \cdot m}{C}\)  
B) \(\frac{N^2 \cdot m^3}{C}\)  
C) \(\frac{C^3}{N \cdot m^2}\)  
D) \(\frac{N \cdot m^3}{C^3}\)  
E) \(\frac{C^2}{N \cdot m^2}\)
4. Two cylindrical resistors are made of the same material. Resistor 1 has length \( L \) and diameter \( d \). Resistor 2 has twice the length and twice the diameter of Resistor 1. What is the ratio \( \frac{R_2}{R_1} \)?

A) 1  B) 1/2  C) 2  D) 4  E) \( \frac{1}{4} \)

5. Three parallel, infinite planes (shown edge-on in the diagram) are all charged with the same magnitude charge per area \( \sigma \). The two planes on the right have a positive charge density \( +\sigma \), and the plane on the left has a negative charge density \( -\sigma \). The three planes divide space up into four regions labeled I, II, III, and IV, as shown. Note: these are planes of charge, not charged metal plates.

How does \( E_I \), the magnitude of the field in region II, compare to \( E_{IV} \), the magnitude in region IV?

A) \( E_I = 2 E_{IV} \)  B) \( E_I = 0, E_{IV} \neq 0 \)  C) \( E_I = \frac{1}{2} E_{IV} \)
D) \( E_I = 3 E_{IV} \)  E) None of these

6. The electric field in a region of space is accurately indicated by the electric field lines shown. The distance between point A to point B is the same as between points C and D. How do the magnitudes of the voltage differences \( |\Delta V_{AB}| \) and \( |\Delta V_{CD}| \) compare?

A) \( |\Delta V_{AB}| > |\Delta V_{CD}| \)  B) \( |\Delta V_{AB}| = |\Delta V_{CD}| \)  C) \( |\Delta V_{AB}| < |\Delta V_{CD}| \)
The following two questions refer to the circuit shown:

7. A student analyzing this circuit chooses the directions of the currents in the three resistors as shown. Which of the following equations is the correct current equation, given the choice of current directions?

A) \( I_2 + I_3 = I_1 \)  
B) \( I_1 + I_2 = I_3 \)  
C) \( I_3 + I_1 = I_2 \)  
D) None of these.

8. Which one of the following equations is correct, given the choice of current directions?

A) \( V_1 + I_1R_1 - I_2R_2 - I_3R_3 = 0 \)  
B) \( V_2 - I_2R_2 - I_3R_3 = 0 \)  
C) \( V_1 - V_2 + I_2R_2 - I_3R_3 = 0 \)  
D) \( V_1 - V_2 - I_1R_1 - I_3R_3 = 0 \)  
E) \( V_1 + V_2 - I_2R_2 - I_3R_3 = 0 \)

9. A small positive charge \( +q \) is released from rest a distance \( R \) from a large stationary charge \( +Q \). The only force on the small charge is the electrostatic repulsion from the large charge. After the charge \( q \) has traveled a distance \( R \), and is a distance \( 2R \) from the large charge, what is its final kinetic energy \( KE_f \)?

A) \( \frac{kQ}{R} \)  
B) \( \frac{kQ}{2R} \)  
C) \( \frac{kQq}{2R} \)  
D) \( \frac{2kQq}{3R} \)  
E) None of these.
10. Two charges, labeled 1 and 2, have the equipotential lines shown. An electron is released from rest at position i in the diagram (on the 0V equipotential line). After release, the electron feels...

A) zero net force.
(B) a net force to the left ←
(C) a net force to the right →
D) a net force up ↑
E) a net force down ↓

11. Two capacitors, labeled 1 and 2, are connected as shown. Capacitor 1 has charge \( Q \) (meaning \( +Q \) on one plate, \( -Q \) on the other) and capacitor 2 has charge \( 2Q \). Which capacitor has the larger capacitance?

A) Capacitor 1
B) Capacitor 2
C) Both have the same capacitance.
D) Impossible to tell from the information given.
12. Two points, labeled $a$ and $b$, are in a uniform electric field in the $+y$ direction of magnitude $5 \text{ V/m} = 5 \text{ N/C}$, as shown. What is the voltage difference $(V_b - V_a)$?

A) $+20 \text{ V}$  B) $-25 \text{ V}$  C) $+25 \text{ V}$  
D) $-15 \text{ V}$  E) None of these.

13. You have three identical resistors. If you connect just one of them to a battery, there is $30 \text{ W}$ of heat dissipated in the resistor. If you connect all three of them in series to the same battery, what total heat will be dissipated? (Hint: Draw a picture, work it out!)

A) $45 \text{ W}$  B) $90 \text{ W}$  C) $20 \text{ W}$  D) $2 \text{ W}$  E) $10 \text{ W}$

14. A charge $+Q$ is at a fixed location in space, and a small negative charge $-q$, starting far away, is brought near the stationary $+Q$ charge by an external agent at constant speed.

As the $-q$ charge is brought near, what is the sign of the work done by the external agent, and what is the sign of the change in electrostatic potential energy of this two-charge system?

A) $W_{\text{ext}} > 0$, $\Delta U > 0$  B) $W_{\text{ext}} < 0$, $\Delta U < 0$
C) $W_{\text{ext}} < 0$, $\Delta U > 0$  D) $W_{\text{ext}} > 0$, $\Delta U < 0$
E) $W_{\text{ext}} = 0$, $\Delta U = 0$

Vers:B
15. Two charges, $+Q$ and $-Q$, at fixed positions, form an electric dipole. A metal cube, with no net charge on it, is placed on the right side of the $-Q$ charge, as shown. What happens to the magnitude of the net electric force on the $+Q$ charge when the cube is placed as shown?

A) The net electric force on $+Q$ decreases.

B) The net electric force on $+Q$ is unchanged.

C) The net electric force on $+Q$ increases.

Before:

Before:

After:

After:

16. Consider two capacitors labeled I and II. Capacitor I is attached to a battery of voltage $V$. Capacitor II is charged and is electrically isolated (no wires or any electrical connections touching it). Both capacitors have their plates slowly pushed together. For each capacitor, does the total electrostatic energy $U$ stored in the capacitor increase ($\Delta U$ positive) or decrease ($\Delta U$ negative) or remain constant ($\Delta U = 0$) as the plates are pushed together?

<table>
<thead>
<tr>
<th>Capacitor I</th>
<th>Capacitor II</th>
</tr>
</thead>
<tbody>
<tr>
<td>A) $U$ increases,</td>
<td>$U$ decreases</td>
</tr>
<tr>
<td>B) $U$ decreases,</td>
<td>$U$ increases</td>
</tr>
<tr>
<td>C) $U$ decreases,</td>
<td>$\Delta U = 0$</td>
</tr>
<tr>
<td>D) $U$ increases,</td>
<td>$\Delta U = 0$</td>
</tr>
<tr>
<td>E) $\Delta U = 0$,</td>
<td>$U$ decreases</td>
</tr>
</tbody>
</table>
17. Two resistors \( R_1 \) and \( R_2 \) are hooked to a battery in parallel. \( R_2 \) is two times larger than \( R_1 \). How does the current \( I_{\text{bat}} \) from the battery compare to the current \( I_1 \) through \( R_1 \)?

- A) \( I_{\text{bat}} = 2I_1 \)
- B) \( I_{\text{bat}} = 3I_1 \)
- C) \( I_{\text{bat}} = \frac{1}{2}I_1 \)
- D) \( I_{\text{bat}} = \frac{2}{3}I_1 \)
- E) \( I_{\text{bat}} = \frac{3}{2}I_1 \)

18. What does the voltmeter read in this circuit?

- A) \( V \)
- B) \( \frac{V}{2} \)
- C) \( \frac{V}{3} \)
- D) \( \frac{2V}{3} \)
- E) zero

19. What is the total resistance seen by the battery in the following circuit? Notice that three of the 4 resistors are identical, all with resistance \( R \), and the fourth resistor has resistance \( \frac{R}{2} \). (Another way to ask the question is: The current through the battery can be written as \( I = \frac{V}{R_{\text{tot}}} \). What is \( R_{\text{tot}} \)?)

- A) \( R \)
- B) \( 2R \)
- C) \( 3.5R \)
- D) \( \frac{R}{2} \)
- E) None of these

Ver:B
20. In the circuit shown, all bulbs are identical, and all batteries are ideal and identical. Rank bulbs A, B, and C in order of brightness from brightest to dimmest.

A) A > B = C
B) B = C > A
C) A > B > C
D) A = B = C
E) None of the above

The next two questions refer to this situation: Four point charges are arranged on the corners of a square as shown. Point a is in the middle of the square. Point b is on the bottom edge of the square, midway between the bottom charges. Point c is on the right edge of the square, midway between the two positive charges. As usual, assume that the voltage at infinity is zero, and assume that there are no other charges. There are no charges at points a, b, and c; these are just points in empty space.

21. At which of the three points a, b, c, is the voltage zero?
A) Point a only.
B) Point b only.
C) Point c only.
D) Points a and b only.
E) Points a and c only.

22. What is the direction of the electric field at point a, in the middle of the square?
A) straight up ↑
B) straight right →
C) straight left ←
D) upper left, some non-zero angle above the horizontal
E) E-field is zero
23. A parallel plate capacitor is charged up as shown. Initially, the distance between the plates is \( d = 2 \text{ mm} \), the voltage difference between the plates is 100 V, and the charge \( Q \) on the capacitor is 1.0 mC (meaning, as usual, +\( Q \) on one plate and −\( Q \) on the other). The plates are so large that they can be taken to be effectively infinite in extent.

\[
\begin{array}{c}
+Q = 1.0 \text{ mC} \\
-\text{Q} = -1.0 \text{ mC} \\
d = 2.0 \text{ mm}
\end{array}
\]

There is no battery connected to the plates; the capacitor is isolated.

Suppose now that the plates are carefully pushed together to a separation of 1.0 mm, while the charge remains constant. What happens to the energy stored in the capacitor and the energy density (energy per volume) between the plates as the separation decreased?

A) Both the energy and the energy density increase.
B) Both the energy and the energy density decrease.
C) Both the energy and the energy density stay the same.
D) The energy decreases and the energy density stays the same.
E) The energy remains the same and the energy density increases.

24. What does the ideal Ammeter in the circuit shown read?

A) 12.0 A  
B) 6.0 A  
C) 0.5 A  
D) 3.0 A  
E) None of the above is correct

25. A circuit consists of two identical light bulbs, labeled A and B, connected to an ideal battery, as shown. When the switch S is closed, what happens to the brightness of the two bulbs?

A) A remains the same, B goes dark.
B) A gets brighter, B goes dark.
C) Both bulbs become brighter.
D) A gets dimmer, B remains the same brightness.
E) Closing the switch has no effect on the brightness of either bulb.

Vers.B