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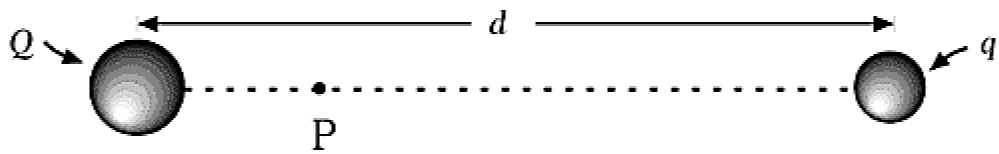
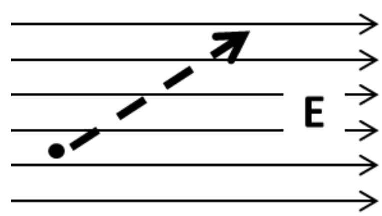


1. (4 pts.) Charges Q and q (Q > q), separated by a distance d, produce a potential $V_P = 0$ at point P. This means that

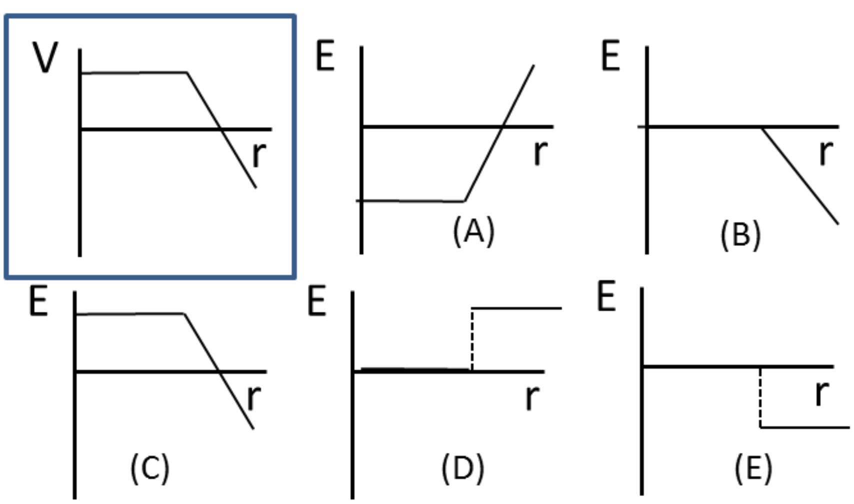
A) no force is acting on a test charge placed at point P.
B) Q and q must have the same sign.
C) the electric field must be zero at point P.
D) the net work in bringing Q to distance d from q is zero.
E) the net work needed to bring a charge from infinity to point P is zero.

2. (4 pts.) A charge of 5.0 μC is located in a uniform electric field of intensity 3.5×10^5 N/C. How much work is required to move this charge at constant speed 50 cm along a path making an angle of 33° with respect to the electric field direction?



A) 0.16 J
B) 0.27 J
C) 0.54 J
D) 0.73 J
E) 7.3 mJ

3. (4 pts.) Which graph below best shows the electric field E(r) corresponding to the potential V(r) shown in upper left graph?



Choose: (A) (B) (C) (D) (E)

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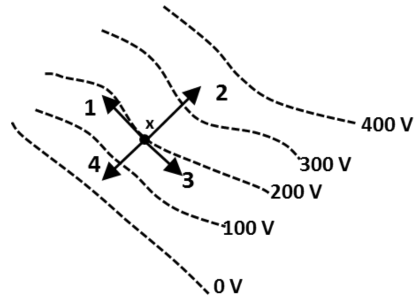
4. (3 pts.) The vector that best represents the direction of the electric field at point **x** on the 200 V equipotential line is



A) 1
B) 2
C) 3
D) 4
E) None of these is correct.

5. (3 pts.) Three charges are brought from infinity and placed at the corners of an equilateral triangle. Which of the following statements is true?

A. The work required to assemble the charges is always positive.
B. The electrostatic potential energy of the system is always positive.
C. The electrostatic potential energy does not depend on the order the charges are placed at the corners.
D. The work required to assemble the charges depends on which charge is placed at which corner.
E. The electrostatic potential energy depends on which charge is placed at which corner.

6. (4 pts.) If you increase the charge on a parallel-plate capacitor from 3 μC to 9 μC and increase the plate separation from 1 mm to 3 mm, the energy stored in the capacitor changes by a factor of

A) 27
B) 9
C) 8
D) 3
E) 1/3

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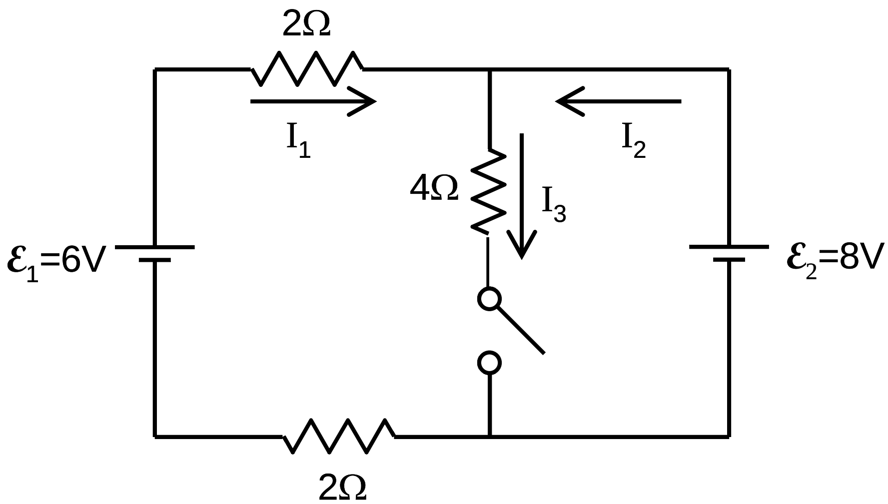
The next three questions pertain to the following circuit.



7. (4 pts.) With the switch open as shown, what is the current I_1?

(A) $I_1 = -7/2$ A
(B) $I_1 = -1/2$ A
(C) $I_1 = 1/2$ A
(D) $I_1 = 3/2$ A
(E) $I_1 = 7/2$ A

For the next two questions the switch is closed.

8. (4 pts.) What is the voltage across the 4 ohm resistor?

(A) 2 V
(B) 6 V
(C) 7 V
(D) 8 V
(E) 14 V

9. (3 pts.) Which of the currents have changed in magnitude after the switch is closed?

(A) Only I_3 has changed in magnitude.
(B) Only I_2 and I_3 have changed in magnitude.
(C) I_1, I_2, and I_3 have all changed in magnitude.
(D) No currents have changed in magnitude.

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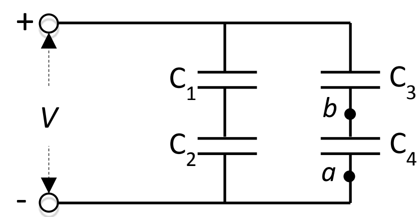
The next three questions pertain to the following situation.



Four capacitors are connected as shown in the figure below. The gaps between the plates of all three capacitors are filled with air (κ = 1.0); the values of the capacitances are:

C_1 = 2 μF
C_2 = 3 μF
C_3 = 8 μF
C_4 = 6 μF

A constant potential difference, ***V* = 12 V**, is maintained across the circuit, as shown.

10. (4 pts.) What is C_{tot}, the total equivalent capacitance of the four capacitors?

A) 0.89 μF
B) 3.68 μF
C) 4.63 μF
D) 4.75 μF
E) 19.0 μF

11. (5 pts.) What is V_b - V_a, the potential difference between points *b* and *a* (*i.e.*, the voltage across capacitor C_4)?

A) 5.14 V
B) 6.00 V
C) 6.86 V
D) 9.00 V
E) 16.00 V

12. (3 pts.) If capacitors C_1 and C_2 are removed from the circuit, how will the energy stored in C_4 change?

A) Increase
B) No change
C) Decrease

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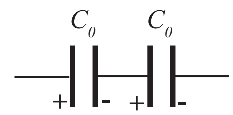
III. [25 pts] Parts A and B are independent.

A. A student charges two identical parallel-plate capacitors by connecting them one at a time across a 9-volt battery. Each capacitor is carefully disconnected from the battery so that it is not discharged. The student then connects the charged capacitors in series as shown at right. The capacitors are *not* connected to the battery.

Two original capacitors connected in series



After the left capacitor is modified

Suppose now that the **left** capacitor is modified such that the distance between the plates is increased, as shown below right.

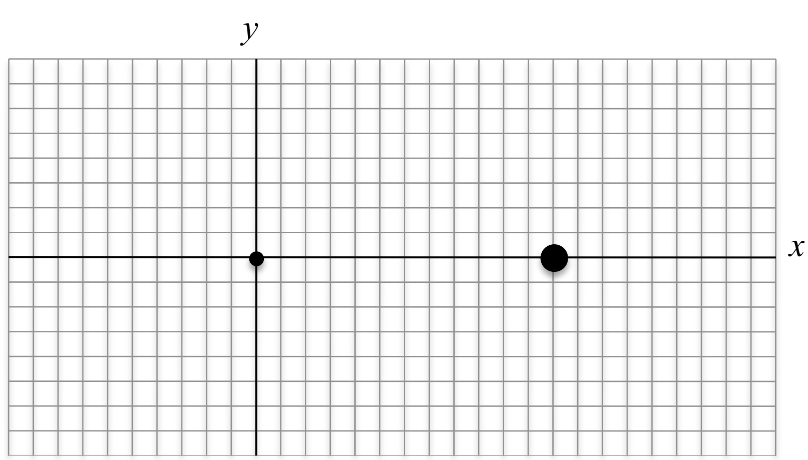
1. [6 pts] After the change, does the charge on the **left** capacitor *increase, decrease,* or *remain the same?* Explain.

2. [6 pts] After the change, does the potential difference across the **left** capacitor *increase, decrease,* or *remain the same?* Explain.

3. [7 pts] After the change, does the potential difference across the **right** capacitor *increase, decrease,* or *remain the same?* Explain.

B. [6 pts] Two point charges +Q (small dot) and −2Q (large dot) are located on the x-axis in the x-y plane.

On the grid at right, sketch a qualitatively correct set of **electric field lines** and **equipotential lines**. Use dashed lines for the equipotentials. If any of the equipotentials represents $V = 0$, mark it clearly.



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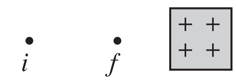
V. [20 points total] This question consists of two independent parts, A and B.

A. A negatively charged point charge is released at point *i* near a cube with a uniform positive charge distribution. It crosses point *f* with speed v_f.

i. [4 pts] Consider the system consisting of the point charge alone.

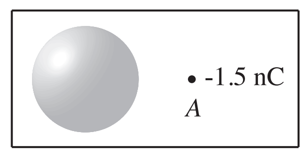
Is the total energy of the system *increasing, decreasing,* or *remaining the same?* Briefly explain.

ii. [4 pts] Suppose the cube is moved to the left, closer to points *i* and *f* as shown. The point charge is again released at point *i*.



Is the magnitude of the electric potential difference between points *i* and *f* *greater than, less than,* or *equal to* what it was before the cube was moved? Briefly explain.

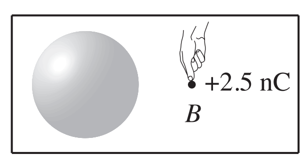
B. Test charge *A* (-1.5 nC) is held at rest 10 cm from the surface of a positively charged insulating sphere that is fixed in place. Charge *A* is released from rest, and reaches the surface of the sphere with 14 J of kinetic energy.



i. [4 pts] During the motion of charge *A*, does the electric potential energy U_E of the system consisting of charge *A* and the sphere *increase, decrease,* or *remain the same?* Briefly explain.

ii. [4 pts] Find the absolute value of the electric potential difference ΔV_A between charge *A*'s starting point and the surface of the sphere.

Test charge *B* (+2.5 nC) is also initially held at rest 10 cm from the surface of a positively charged sphere identical to the one above. Charge *B* is moved by a hand at constant velocity to the sphere's surface.



iii. [4 pts] Is the magnitude of the electric potential difference between charge *B*'s starting point and the surface of the sphere, ΔV_B, *greater than, less than,* or *equal to* the magnitude of ΔV_A? Briefly explain.