

This print-out should have 16 questions. Multiple-choice questions may continue on the next column or page – find all choices before answering.

001 10.0 points

A student said, “The electric field at the center of a charged spherical shell is zero, so the potential at that location must be zero.” Is this statement true or false?

1. True

2. False

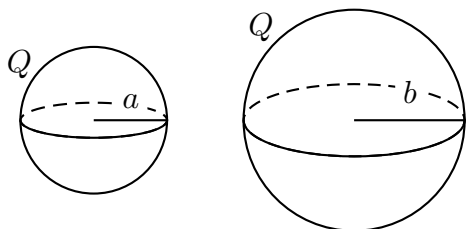
002 10.0 points

The energy density inside a certain capacitor is 14 J/m^3 . What is the magnitude of the electric field inside the capacitor? Note that $\epsilon_0 = 8.85 \times 10^{-12} \text{ C}^2\text{N}^{-1}\text{m}^{-2}$.

Answer in units of N/C

003 10.0 points

Consider two isolated spherical conductors, each having net charge Q . The spheres have radii a and b , where $b > a$.



Which sphere has the higher electric potential at its surface? Assume that the potential at ∞ is zero. Also assume the two spheres are far apart and neglect the effect on one sphere due to the other sphere.

1. Both spheres have the same potential.

2. The sphere of radius a

3. The sphere of radius b

004 (part 1 of 2) 5.0 points

An isolated parallel plate capacitor of area A_1 with an air gap of s_1 is charged up to a

potential difference of V_{1i} . A second parallel plate capacitor is initially uncharged, has an area A_2 and a gap of length s_2 filled with plastic whose dielectric constant is κ . Connect a wire from the positive plate of the first capacitor to one of the plates of the second capacitor and connect another one from the negative plate of the first capacitor to the other plate of the second capacitor.

The initial voltage of the first capacitor before connection is given by V_{1i} . Denote the final potential differences of the first and the second capacitors to be ΔV_{1f} and ΔV_{2f} respectively and the final field in the gap the second capacitor in presence of the dielectric be E_{2f} . After the connection, let the charge across the second capacitor be denoted by Q_2 .

Consider the following statements:

Ia. $\Delta V_{1f} = \Delta V_{2f}$

Ib. $\Delta V_{1f} > \Delta V_{2f}$

IIa. $E_{2f} = \frac{1}{\epsilon_0 \kappa} \frac{Q_2}{A_2}$

IIb. $E_{2f} = \frac{1}{2\epsilon_0 \kappa} \frac{Q_2}{A_2}$

IIIa. $\Delta V_{2f} = 2E_{2f} s_2$

IIIb. $\Delta V_{2f} = E_{2f} s_2$

1. Ia, IIb, IIIb

2. Ib, IIb, IIIa

3. Ib, IIa, IIIa

4. Ib, IIb, IIIb

5. Ia, IIa, IIIa

6. Ia, IIb, IIIa

7. Ia, IIa, IIIb

8. Ib, IIa, IIIb

005 (part 2 of 2) 5.0 points

For this part of the problem, we will simplify

the problem assuming that the two capacitors have identical geometry, i.e. $A_1 = A_2 = A$ and $s_1 = s_2 = s$. There is still the dielectric slab with dielectric constant κ in capacitor 2.

Before the connection let the initial voltage of the first capacitor be V_{1i} . Denote the final potential differences of the first and the second capacitor to be ΔV_{1f} and ΔV_{2f} . After the connection, let the charge across the second capacitor be denoted by Q_2 .

Consider the following statements:

Ia. $\Delta V_{1f} = \Delta V_{2f}$

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IIa. $E_{2f} = \frac{1}{\epsilon_0 \kappa} \frac{Q_2}{A}$

IIb. $E_{2f} = \frac{1}{2\epsilon_0 \kappa} \frac{Q_2}{A}$

IIIa. $\Delta V_{1f} = \frac{\kappa}{1 + \kappa} V_{1i}$

IIIb. $\Delta V_{2f} = \frac{1}{1 + \kappa} V_{1i}$

1. Ia, IIb, IIIa

2. Ib, IIa, IIIa

3. Ib, IIb, IIIa

4. Ib, IIb, IIIb

5. Ib, IIa, IIIb

6. Ia, IIa, IIIb

7. Ia, IIb, IIIb

8. Ia, IIa, IIIa

006 (part 1 of 2) 5.0 points

Consider a parallel plate capacitor where the charge on the plate is Q and the plate area is A . One plate is fixed and the other plate is pulled by a force $\vec{F}$ which maintains an equilibrium with a gap width d .

Determine the magnitude of the force.

1. $Q \left(\frac{Q}{4d^2 \epsilon_0} \right)$

2. $Q \left(\frac{Q}{A \epsilon_0} \right)$

3. $Q \left(\frac{Q}{2d^2 \epsilon_0} \right)$

4. $Q \left(\frac{Q}{2A \epsilon_0} \right)$

5. $2Q \left(\frac{Q}{A \epsilon_0} \right)$

6. $2Q \left(\frac{Q}{d^2 \epsilon_0} \right)$

7. $Q \left(\frac{Q}{4A \epsilon_0} \right)$

8. $Q \left(\frac{Q}{d^2 \epsilon_0} \right)$

007 (part 2 of 2) 5.0 points

Now slowly increase the gap width by a distance Δs . Find the increase of the energy in the capacitor system ΔU . (Hint: consider only the electric field that exerts a force on the mobile plate.)

1. $Q \left(\frac{Q}{2A \epsilon_0} \right) d$

2. $Q \left(\frac{QA}{\epsilon_0} \right) \Delta s$

3. $Q \left(\frac{QA}{\epsilon_0} \right) (d + \Delta s)$

4. $Q \left(\frac{Q}{A \epsilon_0} \right) d$

5. $Q \left(\frac{Q}{A \epsilon_0} \right) (d + \Delta s)$

6. $Q \left(\frac{Q}{2A \epsilon_0} \right) \Delta s$

7. $Q \left(\frac{Q}{2A \epsilon_0} \right) (d + \Delta s)$

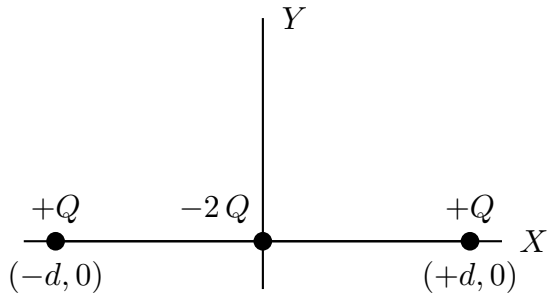
8. $Q \left(\frac{Q}{A \epsilon_0} \right) \Delta s$

9. $Q \left(\frac{QA}{2\epsilon_0} \right) (d + \Delta s)$

10. $Q \left(\frac{QA}{2\epsilon_0} \right) \Delta s$

008 (part 1 of 2) 5.0 points

The charge distribution shown in the figure is referred to as a linear quadrupole.



Find the exact expression for the potential at a point on the x axis where $x > d$, where the potential to be zero at infinity.

1. $V_x = k Q \left(\frac{2}{x+d} - \frac{1}{x} + \frac{2}{x-d} \right)$
2. $V_x = k Q \left(\frac{2}{x+d} + \frac{1}{x} + \frac{2}{x-d} \right)$
3. None of these
4. $V_x = k Q \left(\frac{2}{x+d} + \frac{1}{x} - \frac{2}{x-d} \right)$
5. $V_x = \frac{k Q}{x}$
6. $V_x = k Q \left(\frac{1}{x+d} + \frac{2}{x} - \frac{1}{x-d} \right)$
7. $V_x = k Q \left(\frac{1}{x+d} - \frac{2}{x} - \frac{1}{x-d} \right)$
8. $V_x = k Q \left(\frac{1}{x+d} - \frac{2}{x} + \frac{1}{x-d} \right)$
9. $V_x = k Q \left(\frac{1}{x+d} + \frac{2}{x} + \frac{1}{x-d} \right)$
10. $V_x = k Q \left(\frac{2}{x+d} - \frac{1}{x} - \frac{2}{x-d} \right)$

009 (part 2 of 2) 5.0 points

Approximate the potential when $x \gg d$.

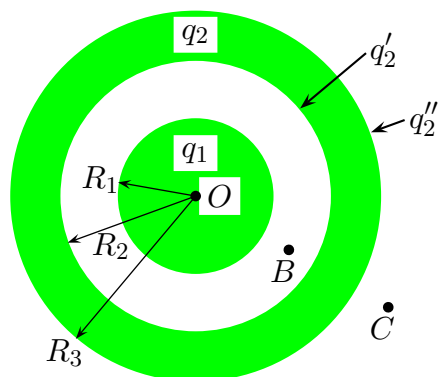
$$\frac{1}{1 \pm \epsilon} \approx 1 \mp \epsilon + \epsilon^2 \mp \epsilon^3 + \dots, \quad \text{and} \\ (1 + \epsilon)^n \approx 1 + n\epsilon + \dots \text{ for } \epsilon \ll 1.$$

1. $V_x = \frac{Q d^2}{k x^3}$
2. $V_x = \frac{2 k Q d^2}{x^3}$

3. $V_x = \frac{2 k Q x^2}{d^3}$
4. $V_x = \frac{2 k Q d}{x}$
5. $V_x = \frac{4 k Q d^2}{x^3}$
6. $V_x = \frac{4 k Q d^2}{x^3 - d^3}$
7. $V_x = \frac{2 k Q d^2}{x}$
8. $V_x = \frac{2 k Q d^2}{x^2}$
9. $V_x = \frac{2 k Q}{x^2}$
10. $V_x = \frac{k Q x^2}{d^3}$

010 (part 1 of 2) 5.0 points

Consider a system of a metallic ball with net charge q_1 and radius R_1 enclosed by a spherically symmetric metallic shell with net charge q_2 , inner radius R_2 and outer radius R_3 . If q_2'' is the charge on the outside surface of the shell and q_2' the charge on its inside surface, then $q_2'' + q_2' = q_2$.



Find the potential at C . $\overline{OB} = b$ and $\overline{OC} = c$.

1. $V_C = k \frac{q_1 + q_2}{c} - k \frac{q_1}{R_2} + k \frac{q_1}{b}$
2. $V_C = \sqrt{2} k \frac{q_2}{c}$
3. $V_C = k \frac{q_1 + q_2}{R_3} - k \frac{q_1}{R_2} + k \frac{q_1}{b}$

4. $V_C = k \frac{q_2}{c}$

5. $V_C = k \frac{q_1 + q_2}{r_3} - k \frac{q_1}{b} + k \frac{q_1}{R_1}$

6. $V_C = k \frac{q_1}{c}$

7. $V_C = 2k \frac{q_1}{c}$

8. $V_C = k \frac{q_1 + q_2}{R_3} - k \frac{q_1}{R_2} + k \frac{q_1}{R_1}$

9. $V_C = k \frac{q_1 - q_2}{\sqrt{2} c}$

10. $V_C = k \frac{q_1 + q_2}{c}$

011 (part 2 of 2) 5.0 points

Determine the potential at B .

1. $V_B = k \frac{q_1 + q_2}{R_3} - k \frac{q_1}{R_2} + k \frac{q_1}{b}$

2. $V_B = k \frac{q_1 + q_2}{c} - k \frac{q_1}{R_2} + k \frac{q_1}{b}$

3. $V_B = k \frac{q_2}{b}$

4. $V_B = \sqrt{2} k \frac{q_2}{c}$

5. $V_B = 2k \frac{q_1}{b}$

6. $V_B = k \frac{q_1 - q_2}{\sqrt{2} c}$

7. $V_B = k \frac{q_1}{b}$

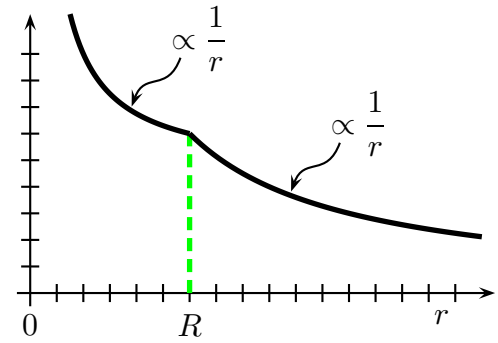
8. $V_B = k \frac{q_1 + q_2}{R_3} - k \frac{q_1}{b} + k \frac{q_1}{R_1}$

9. $V_B = k \frac{q_1 + q_2}{R_3} - k \frac{q_1}{R_2} + k \frac{q_1}{R_1}$

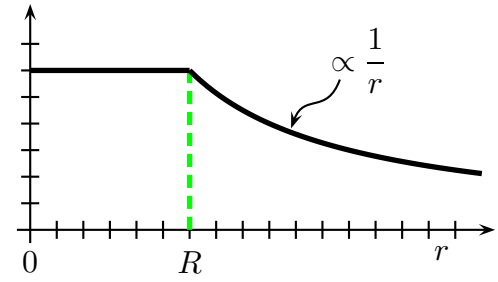
10. $V_B = k \frac{q_1 + q_2}{b}$

012 (part 1 of 2) 5.0 points

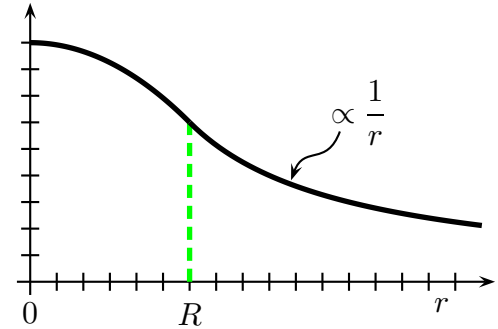
Consider a sphere with radius R and charge Q and the graphs $\mathcal{S}$.



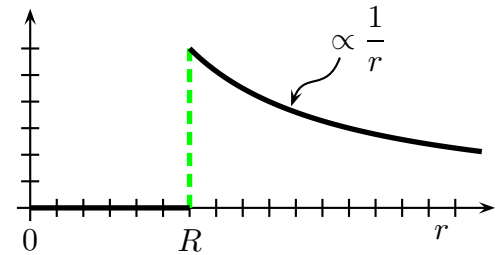
$\mathcal{M}$.



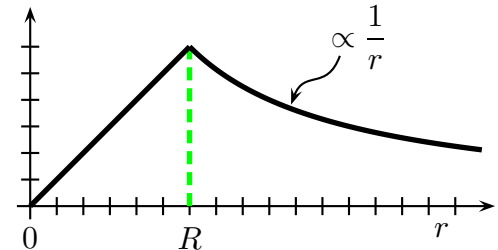
$\mathcal{P}$.



$\mathcal{G}$.



$\mathcal{L}$.



Which diagram describes the $V(r)$ function (electric potential vs radial distance) for a *conducting* sphere?

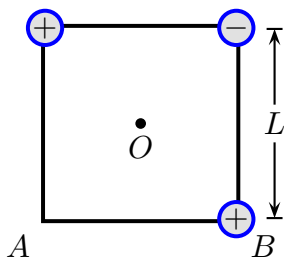
1. $\mathcal{P}$

2. $\mathcal{G}$ 3. $\mathcal{L}$ 4. $\mathcal{M}$ 5. $\mathcal{S}$ **013 (part 2 of 2) 5.0 points**

Which diagram describes the $V(r)$ function (electric potential vs radial distance) for a *uniformly charged non-conducting sphere*?

1. $\mathcal{S}$ 2. $\mathcal{G}$ 3. $\mathcal{L}$ 4. $\mathcal{M}$ 5. $\mathcal{P}$ **014 10.0 points**

Three point charges, each of magnitude q , are placed at 3 corners of a square with sides of length L . The charge farthest from the empty corner is negative ($-q$) and the other two charges are positive ($+q$).



What is the potential at point A ?

1. $V = \left(2 - \frac{1}{\sqrt{2}}\right) \frac{kq}{L^2}$

2. $V = 2 \frac{kq}{L^2}$

3. $V = 2\sqrt{2} \frac{kq}{L^2}$

4. $V = 2 \frac{kq^2}{L}$

5. $V = 2 \frac{kq}{L}$

6. $V = \left(2 - \frac{1}{\sqrt{2}}\right) \frac{kq}{L}$

7. $V = 2\sqrt{2} \frac{kq}{L}$

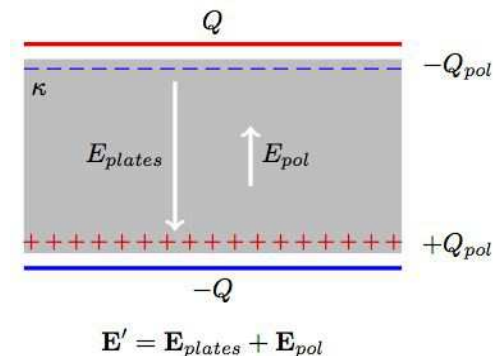
8. $V = \frac{kq}{L}$

9. $V = 2\sqrt{2} \frac{kq^2}{L}$

10. $V = \left(2 - \frac{1}{\sqrt{2}}\right) \frac{kq^2}{L}$

015 (part 1 of 2) 5.0 points

When a dielectric is present in a charged capacitor, the dielectric is polarized. The figure below shows a simple model: a layer of polarized charge forms at the upper and lower surfaces of the dielectric, leading to a reduction of the “effective” plate charge and a reduced field $\vec{E}'$.



In reality, each individual molecule of the dielectric is polarized, becoming a dipole (see the illustration Fig 17.42 in M&I v.II). The sum of the dipole contributions gives the electric field due to the polarization of the dielectric E_{pol} . The simple model shown above is justified by assuming that the effects of the polarized charges in the interior of the dielectric largely cancel, leaving only the *outermost* layer of dipole charge at the top and bottom surfaces to contribute.

Given a dielectric constant κ , plate charge Q , and plate area A , determine the magnitude of the polarized charge Q_{pol} .

$\left\{ \text{Hint: within the dielectric, } E' = \frac{(Q/A)}{\kappa\epsilon_0}. \right\}$

1. $Q \left(\frac{\kappa - 1}{\kappa + 1} \right)$

2. $Q(\kappa - 1)$

3. κQ

4. $Q \left(1 - \frac{1}{\kappa} \right)$

5. $Q \left(1 + \frac{1}{\kappa} \right)$

6. $\frac{Q}{\kappa}$

016 (part 2 of 2) 5.0 points

The capacitance of a parallel plate capacitor in free space is given by

$$C = \frac{Q}{V} = \frac{Q}{\left(\frac{(Q/A)d}{\epsilon_0} \right)} = \epsilon_0 \frac{A}{d},$$

where V is the potential difference across the gap.

When the gap is filled with a medium of dielectric constant κ , the electric field is reduced from its free-space value E to $E' = E/\kappa$. Determine V' and C' , the potential difference and capacitance in the presence of the dielectric.

1. $V' = \kappa V, C' = \kappa C$

2. $V' = \kappa V, C' = \frac{C}{\kappa}$

3. $V' = \frac{V}{\kappa}, C' = \frac{C}{\kappa}$

4. $V' = \frac{V}{\kappa}, C' = \kappa C$