Chapter 25

1

Electric Potential

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Lecture 05

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Properties Of A Conductor In Electrostatic Equilibrium

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Properties of a Conductor in Electrostatic Equilibrium

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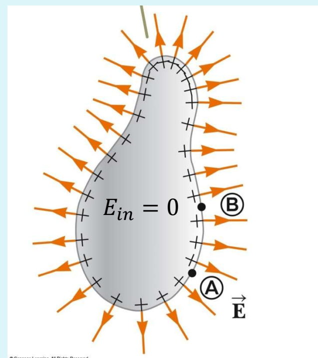
When there is **NO** net motion of charge within a conductor, the conductor is said to be in electrostatic equilibrium, it has the following properties:

1)The electric field is **ZERO** everywhere inside the conductor. Whether the conductor is solid or hollow

2)If the conductor is isolated and carries a charge, **the charge resides on its surface**.



Properties of a Conductor in Electrostatic Equilibrium

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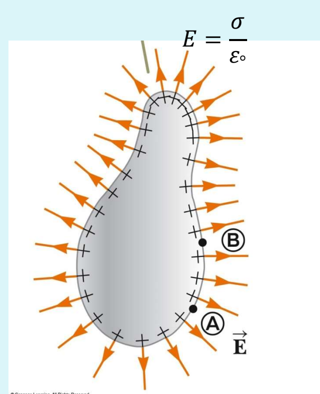
3) The electric field at a point just outside a charged conductor is **perpendicular to the surface** and has a magnitude of: $E = \frac{\sigma}{\varepsilon_\circ}$.

4) On an irregularly shaped conductor, the surface charge density is **greatest** at locations where the radius of curvature is the smallest.



Potential Due to a Charged Conductor

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Consider two points on the surface of the charged conductor as shown.(A and B)

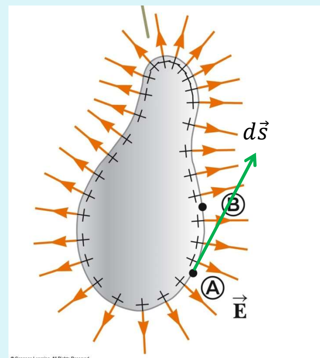
$\vec{E}$ is always perpendicular to the displacement $d\vec{s}$.

Therefore,

$$V_B - V_A = -\vec{E} \cdot d\vec{s} = 0$$

$$V_B = V_A$$

The surface of any charged conductor in electrostatic equilibrium is an **equipotential surface**.



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V Due to a Charged Conductor, cont.

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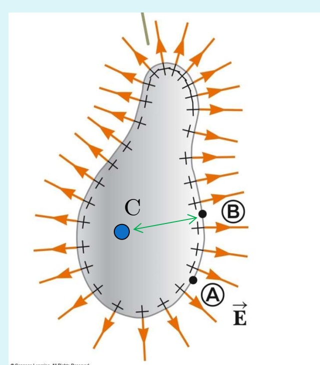
Because the electric field is zero inside the conductor, consider a third point C inside the conductor, the potential difference:

$$V_C - V_B = -\vec{E} \cdot d\vec{s} = 0$$

$$V_A = V_B = V_C$$

We **conclude** that: the electric potential is constant everywhere inside the conductor and equal to the value at the surface.



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Irregularly Shaped Objects

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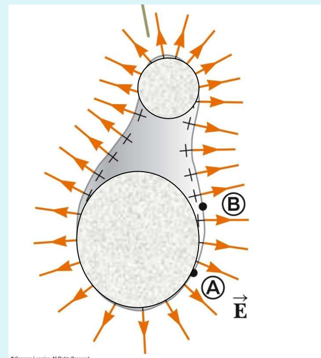
The charge density is high where the radius of curvature is small. And low where the radius of curvature is large:

$$\sigma = \frac{Q}{A} = \frac{Q}{4\pi r^2}$$

The electric field is large near the convex points having small radii of curvature and reaches very high values at sharp points.

$$E = \frac{\sigma}{\epsilon_\circ}$$



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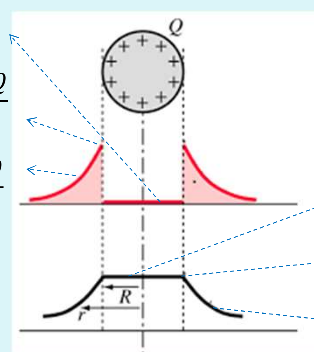
E and V of a Charged Isolated Conducting Sphere (OR) Conducting Spherical Shell

$$E_{inside} = 0$$

$$E_{surface} = \frac{k_e Q}{R^2}$$

$$E_{outside} = \frac{k_e Q}{r^2}$$



$$V_{inside} = \frac{k_e Q}{R}$$

$$V_{surface} = \frac{k_e Q}{R}$$

$$V_{outside} = \frac{k_e Q}{r}$$

R = Radius
Q = Charge
r = distance from the center

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Two Connected Charged Spheres

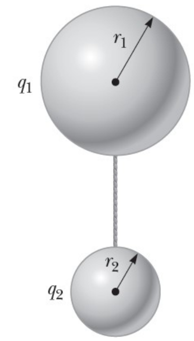
Friday, 29 January, 2021 20:57

Lecturer: Mustafa Al-Zyout, Philadelphia University, Jordan.

- R. A. Serway and J. W. Jewett, Jr., *Physics for Scientists and Engineers*, 9th Ed., CENGAGE Learning, 2014.
- J. Walker, D. Halliday and R. Resnick, *Fundamentals of Physics*, 10th ed., WILEY,2014.
- H. D. Young and R. A. Freedman, *University Physics with Modern Physics*, 14th ed., PEARSON, 2016.
- H. A. Radi and J. O. Rasmussen, *Principles of Physics For Scientists and Engineers*, 1st ed., SPRINGER, 2013.

Two charged spherical conductors are connected by a long conducting wire and a 1.2 μC charge is placed on the combination. One sphere has a radius of 6 cm, the other has a radius of 2 cm.

- What is the electric potential of each sphere?
- What is the electric field at the surface of each sphere?



Solution

$$r_1 = 0.06m \ , \ r_2 = 0.02m \ , \ q_1 + q_2 = 1.2\mu c \ , \ q_2 = 1.2 - q_1$$

Because they are so far apart, the field of one does not affect the charge distribution on the other. The conducting wire between them ensures that both spheres have the same electric potential. Set the electric potentials at the surfaces of the spheres equal to each other:

$$V_1 = V_2$$

$$\frac{kq_1}{r_1} = \frac{kq_2}{r_2}$$

Substitute given values:

$$\frac{q_1}{0.06} = \frac{1.2 - q_1}{0.02}$$

Solve for q_1 and q_2:

$$q_1 = 0 \cdot 9\mu C$$

$$q_2 = 0 \cdot 3\mu C$$

Calculate V_1 and V_2:

$$V_1 = \frac{kq_1}{r_1} = \frac{9 \times 10^9 \times 0.9 \times 10^{-6}}{0.06} = 1.35 \times 10^5 V$$

$$V_2 = \frac{kq_2}{r_2} = \frac{9 \times 10^9 \times 0.3 \times 10^{-6}}{0.02} = 1.35 \times 10^5 V$$

Calculate E_1 and E_2:

$$E_1 = \frac{kq_1}{r_1^2} = \frac{9 \times 10^9 \times 0 \cdot 9 \times 10^{-6}}{0.06^2} = 2 \cdot 25 \times 10^6 \ V/m$$

$$E_2 = \frac{kq_2}{r_2^2} = \frac{9 \times 10^9 \times 0 \cdot 3 \times 10^{-6}}{0.02^2} = 6.75 \times 10^6\, V/m$$

Calculate σ_1 and σ_2:

$$\sigma_1 = \frac{q_1}{A_1} = \frac{q_1}{4\pi r_1^2} = \frac{0 \cdot 9 \times 10^{-6}}{4\pi(0.06)^2} = 2 \times 10^{-5}\, C/m^2$$

$$\sigma_2 = \frac{q_2}{A_2} = \frac{q_2}{4\pi r_2^2} = \frac{0 \cdot 3 \times 10^{-6}}{4\pi(0.02)^2} = 6 \times 10^{-5}\, C/m^2$$

The field is stronger in the vicinity of the smaller sphere even though the electric potentials at the surfaces of both spheres are the same.