Electric Potential (III)

Text sections 25.5, 25.6

Fields, potential, and conductors

Practice: Chapter 25,
Conceptual Question 1
Problems 31, 37, 41, 43, 45, 65

Read page 765, Van de Graaff generator

Potential and Continuous Charge Distributions

We can use two *completely different* methods:

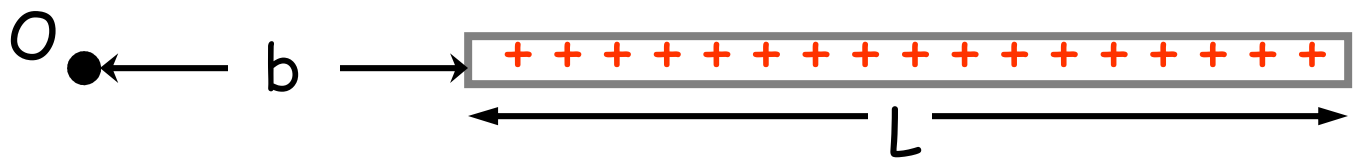
1. $$dV = k_e \frac{dq}{r}, \quad V = \int_{source} k_e \frac{dq}{r}$$

2. Find $\vec{E}$ from Gauss's Law, then...

$$dV = -\vec{E} \bullet d\vec{s},$$

$$V_B - V_A = -\int_A^B \vec{E} \bullet d\vec{s}$$

Example: Thin Uniformly Charged Rod

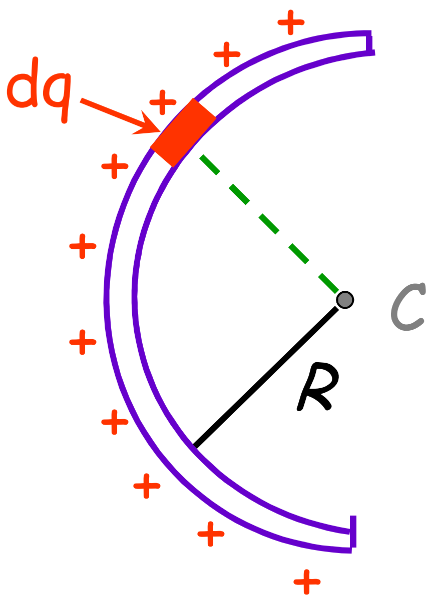


Total charge Q, <u>uniform</u> linear charge density λ

(So $\lambda = Q/L$)

<u>Find</u>: V at point O

Quiz: Charged Semicircle



Total charge Q, uniform linear density

Find: V at centre C

(Homework exercise: review the calculation for the electric field **E***)*

At the center of the semicircle, the potential is:

A) less than kQ/R

B) equal to kQ/R

C) greater than kQ/R

Example: Spherical Charges

1) Find the electric field as a function of r using Gauss's Law.

2) Imagine pushing a "test charge" in from infinity along a radial line: the potential change with each small change dr in distance is

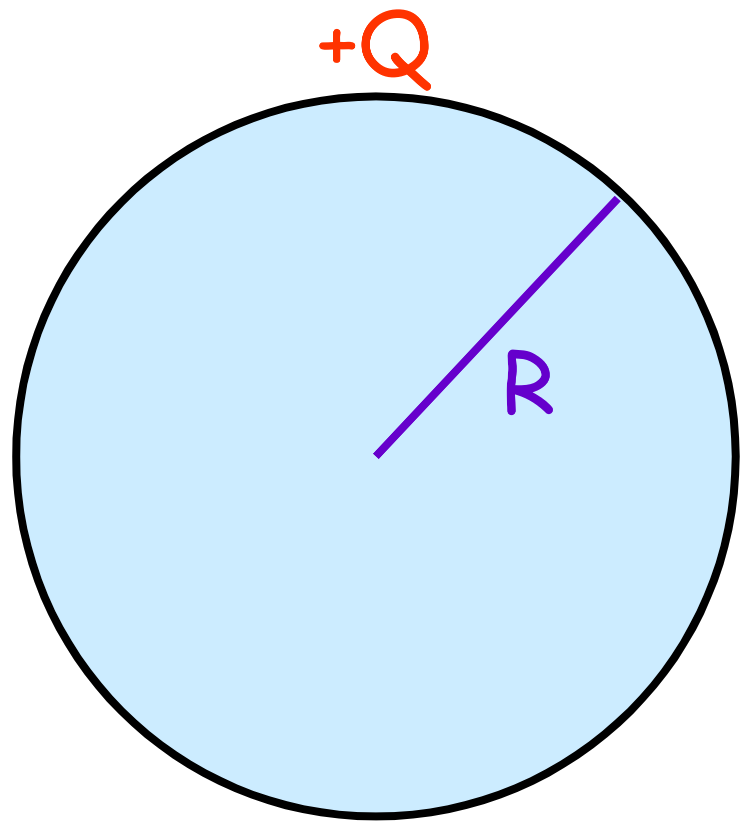
$$dV = -E(r)\,dr.$$

3) Integrate from R to infinity to find $V(R)$ (relative to infinity) at any position R.

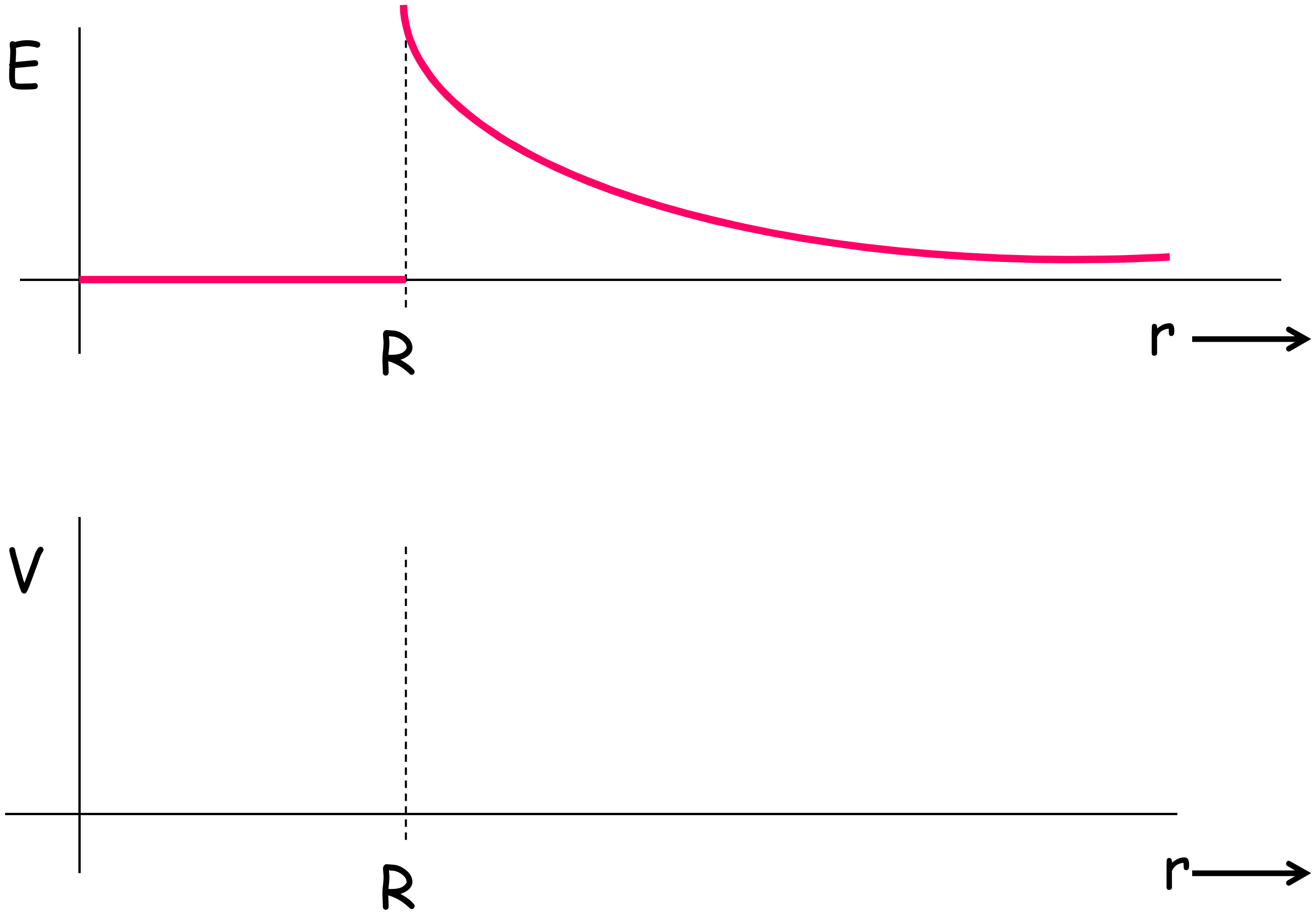
Example

Solid conducting sphere,
radius R, total charge +Q

Find V(r).



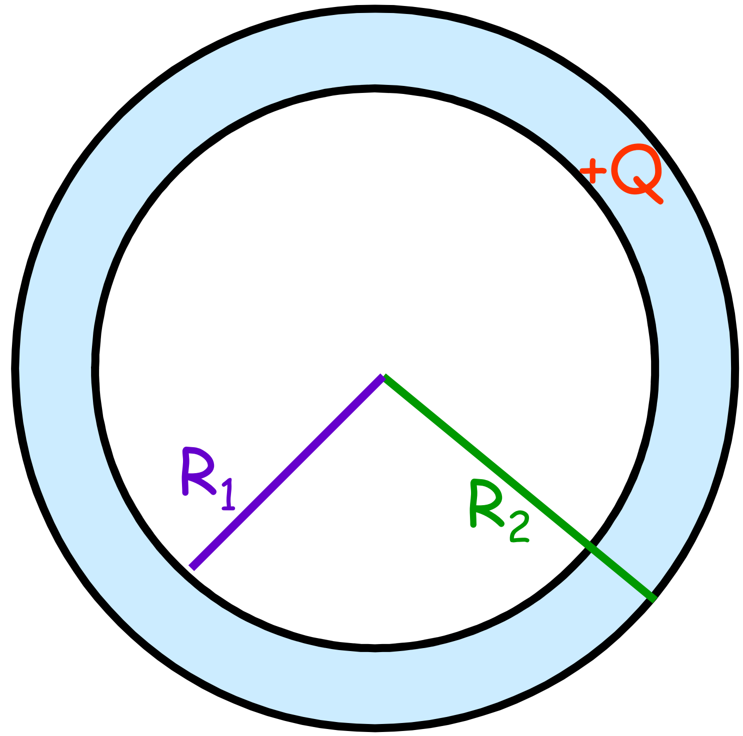
Solid Conducting Sphere, radius R



Quiz

A charge +Q is placed on a spherical conducting shell. What is the potential (relative to infinity) at the centre?

A) $k_e Q/R_1$
B) $k_e Q/R_2$
C) $k_e Q/(R_1 - R_2)$
D) *zero*



Example:

Fields $\geq$ 3 x 10^6 V/m will cause a spark in dry air. Find the maximum potential on a metal sphere of radius… a) 1 mm

b) 1 m

Conductors in Electrostatic Equilibrium (Again)

1) $\vec{E} = 0$ inside $\Leftrightarrow$ conductor is an equipotential.

2) $\vec{E} \perp$ surface (just outside.)

3) Excess charge is on the surface; and $\left|\vec{E}\right| = \dfrac{\sigma}{\epsilon_o}$

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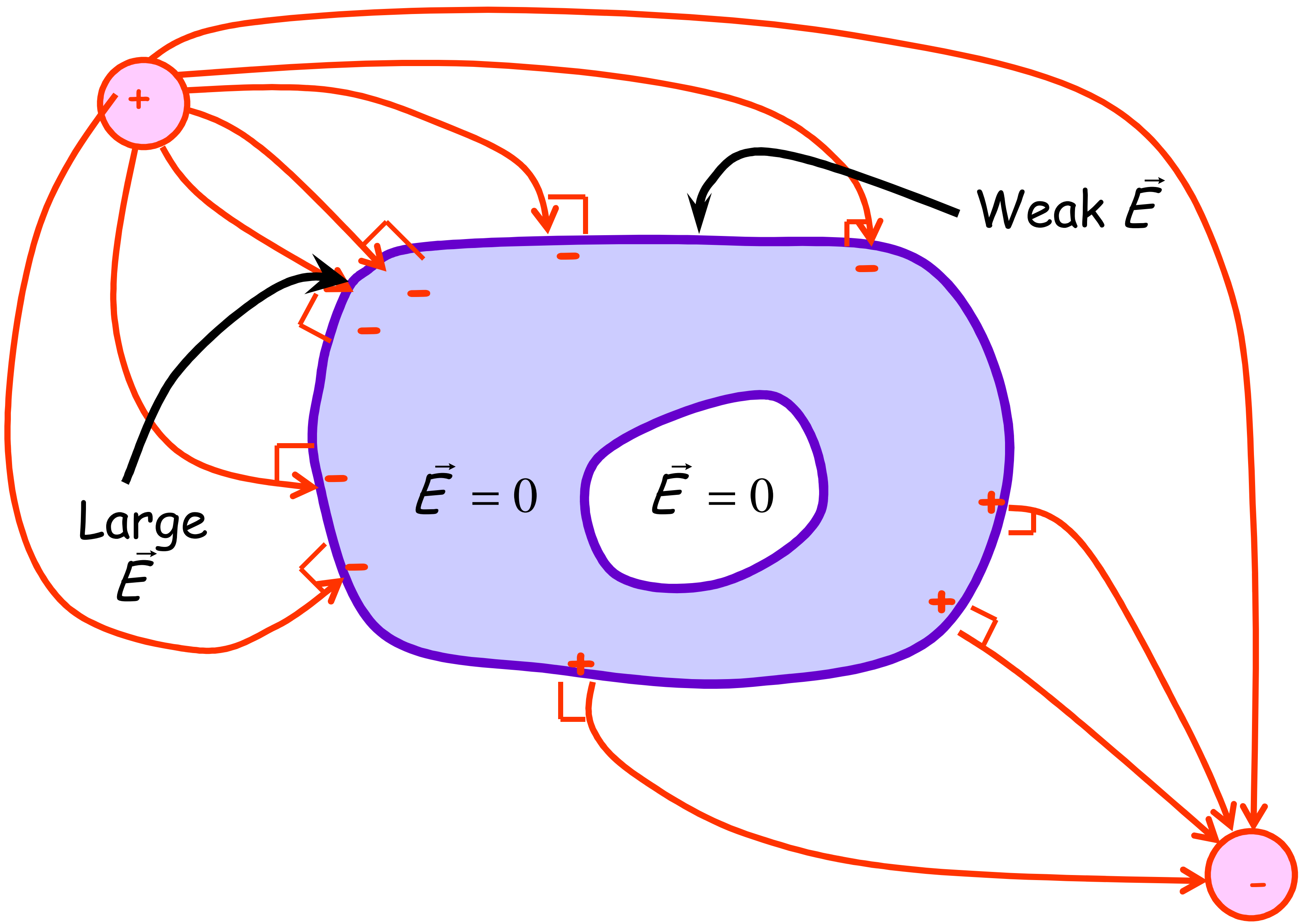
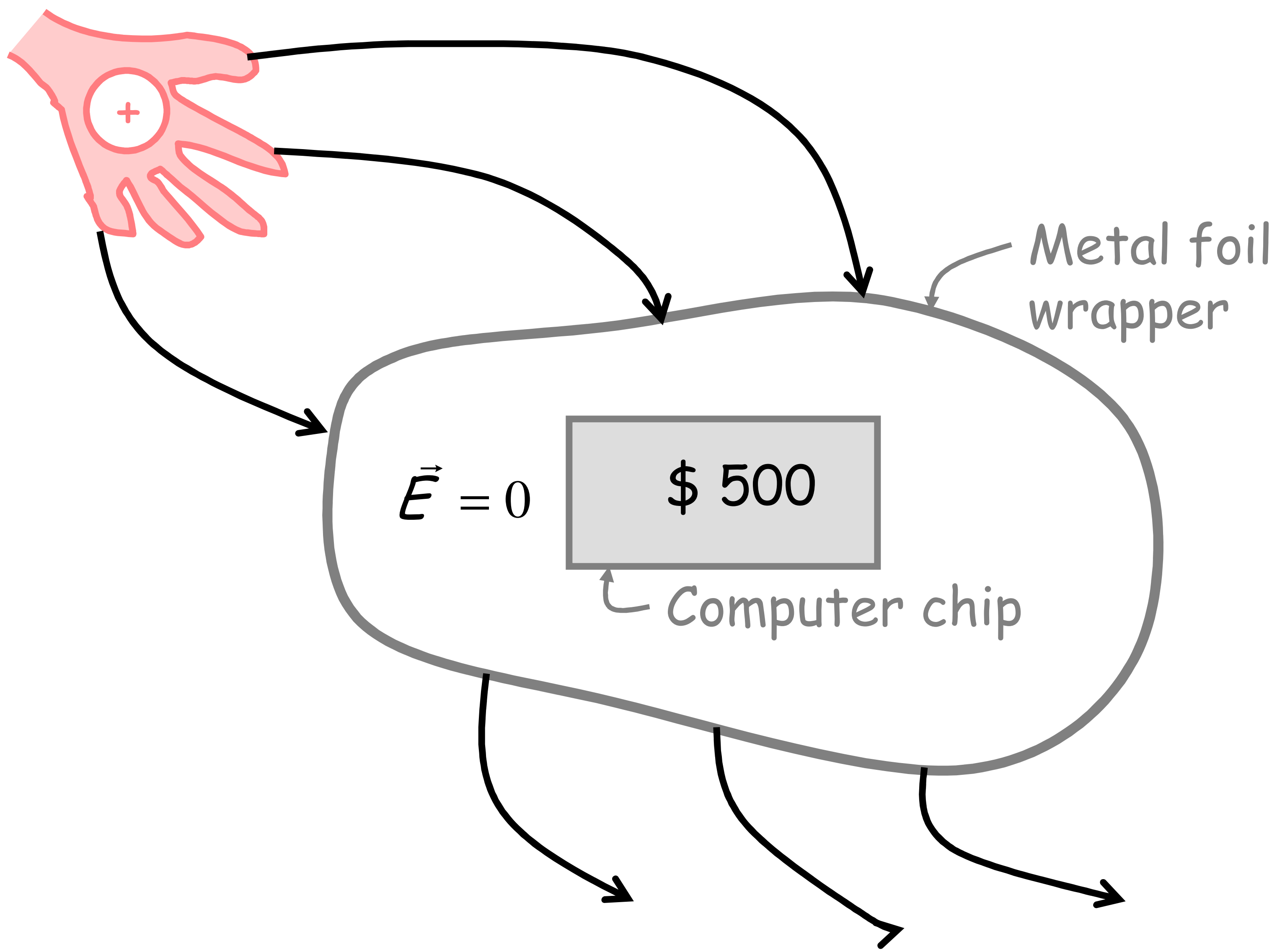
4) <u>Empty</u> cavity inside a conductor, $\vec{E} = 0$ as well.

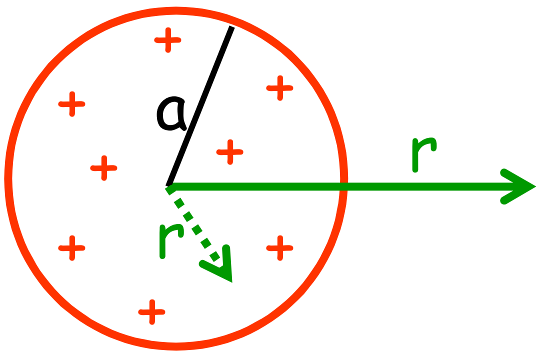
5) $\left|\vec{E}\right| \propto \dfrac{1}{\text{radius of curvature}}$


Weak $\vec{E}$
Large $\vec{E}$
$\vec{E} = 0$
$\vec{E} = 0$
+
-

Electrostatic Shielding



Homework Exercise: Charged Solid Ball



Radius a, total charge Q

Uniform volume charge density ρ

Find: V(r) for r<a

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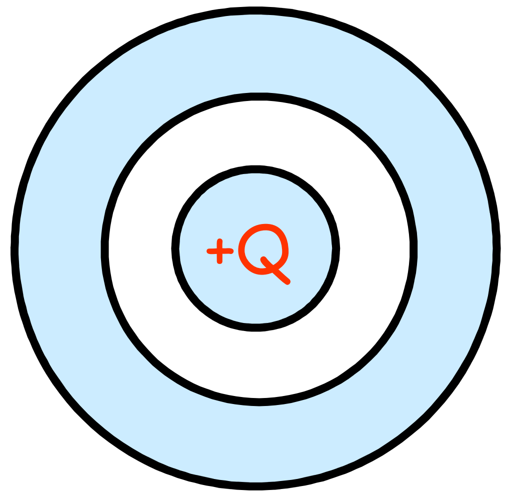
answer: $V(r) = -\int_{\infty}^{r} E dr = -\int_{\infty}^{a} E dr - \int_{a}^{r} E dr$

$$\Rightarrow V(r) = \frac{k_e Q}{a^3}\left[\frac{3}{2}a^2 - \frac{1}{2}r^2\right]$$

Extra Quiz: Concentric Spherical Conductors

A conducting sphere of radius R_1, carrying charge Q, is surrounded by a *thick* conducting shell with **no net charge**. What is the potential of the inner sphere, relative to infinity?



A) V = zero
B) $0 < V < k_e Q/R_1$
C) $V = k_e Q/R_1$
D) $V > k_e Q/R_1$