RC 2: 7th June

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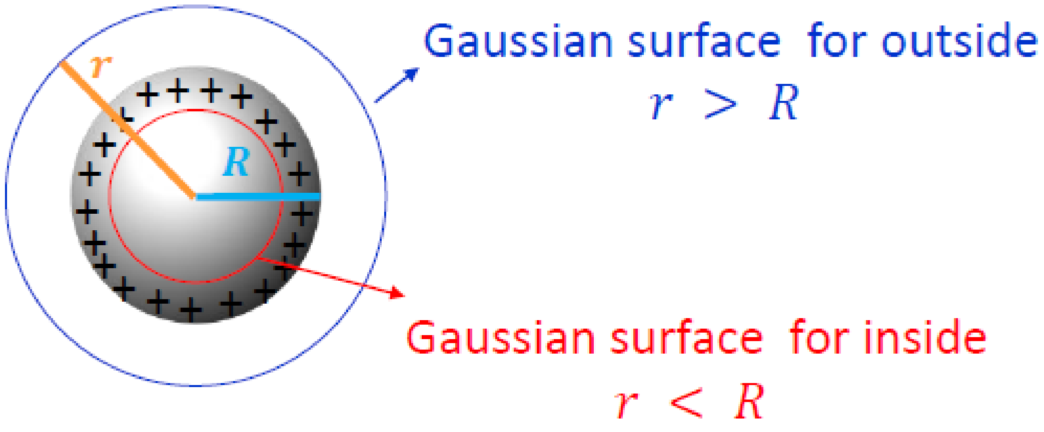
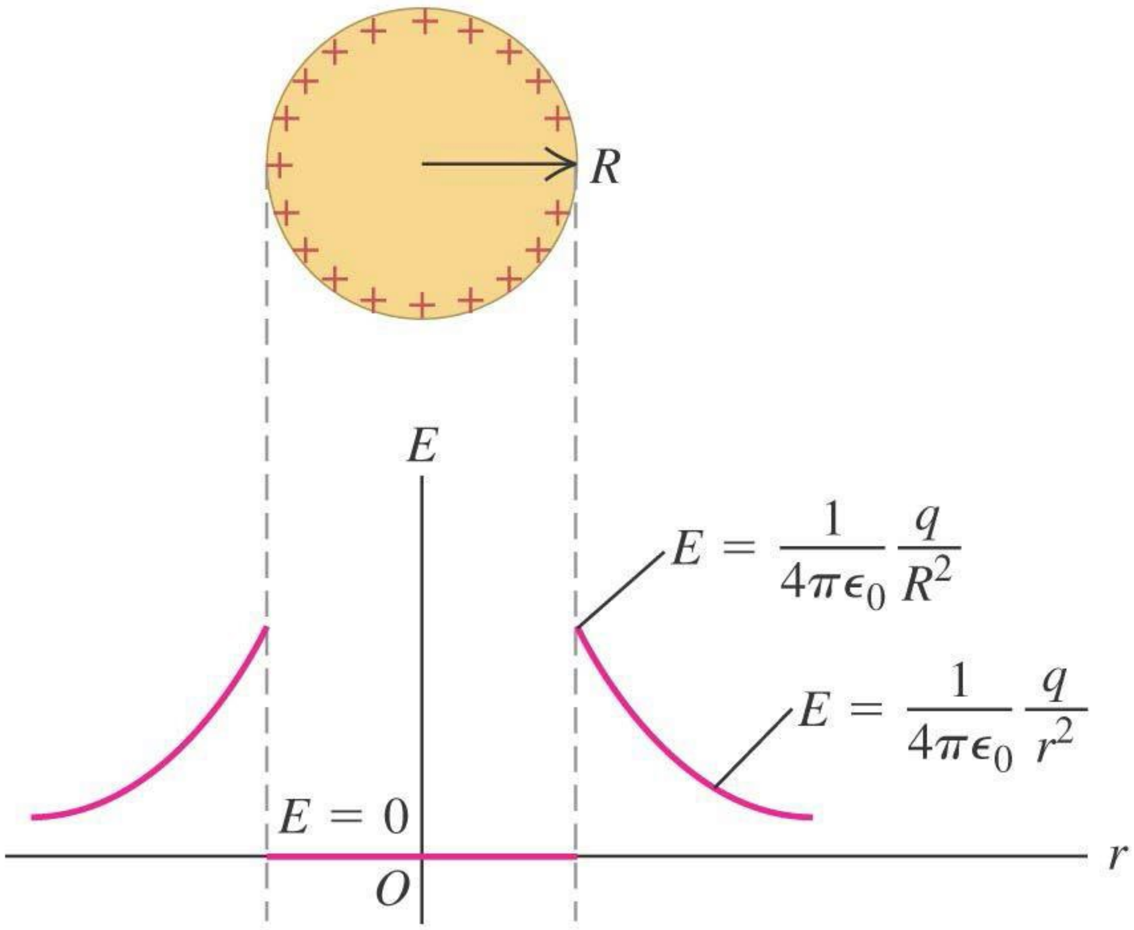
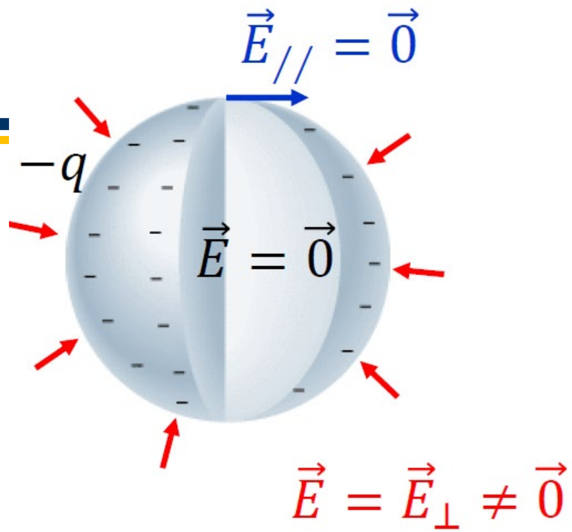
Solid Conducting Sphere

$\vec{E} = \vec{0}$ everywhere inside a conducting shell





Conductors in Static Electric Field



Inside a Conductor (Under Static Conditions)
$\rho = 0$ $\mathbf{E} = 0$

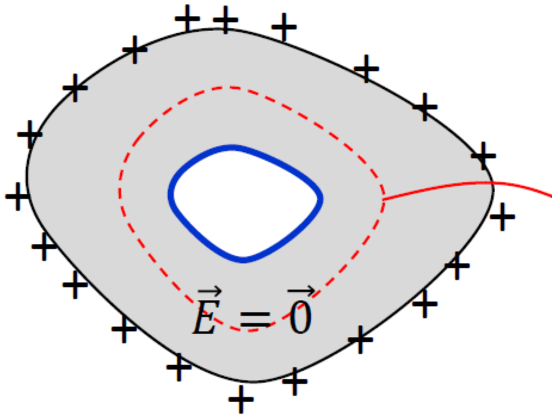
Under static conditions the $\mathbf{E}$ field on a conductor surface is everywhere normal to the surface. In other words, the surface of a conductor is an equipotential surface under static conditions.

Boundary Conditions at a Conductor/Free Space Interface
$E_t = 0$ $E_n = \frac{\rho_s}{\epsilon_0}$

Conductors in Static Electric Field

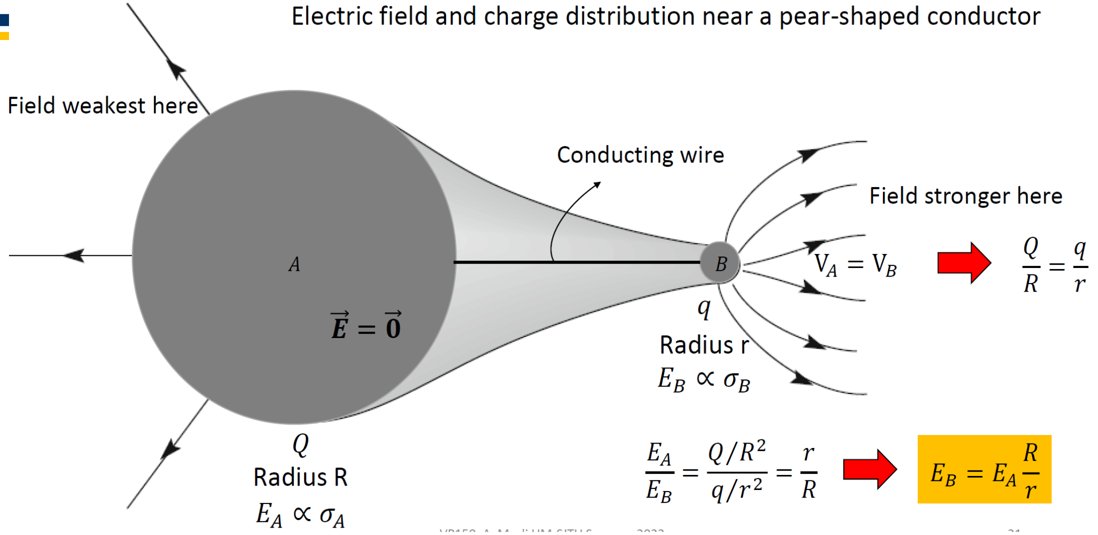
In an **EMPTY** cavity of a conductor there can be

- **NO** charges in the inner surface thus **NO** field
- **NO** matter what is outside or on the outer surface



Conductors in Static Electric Field

Electric field and charge distribution near a pear-shaped conductor



$\vec{E} = \vec{0}$ everywhere inside a conducting shell

Charges are distributed on the outer surface

No charges on the inner surface.
No electric field in the cavity

Charges tend to accumulate in greatest number at locations of greatest curvature

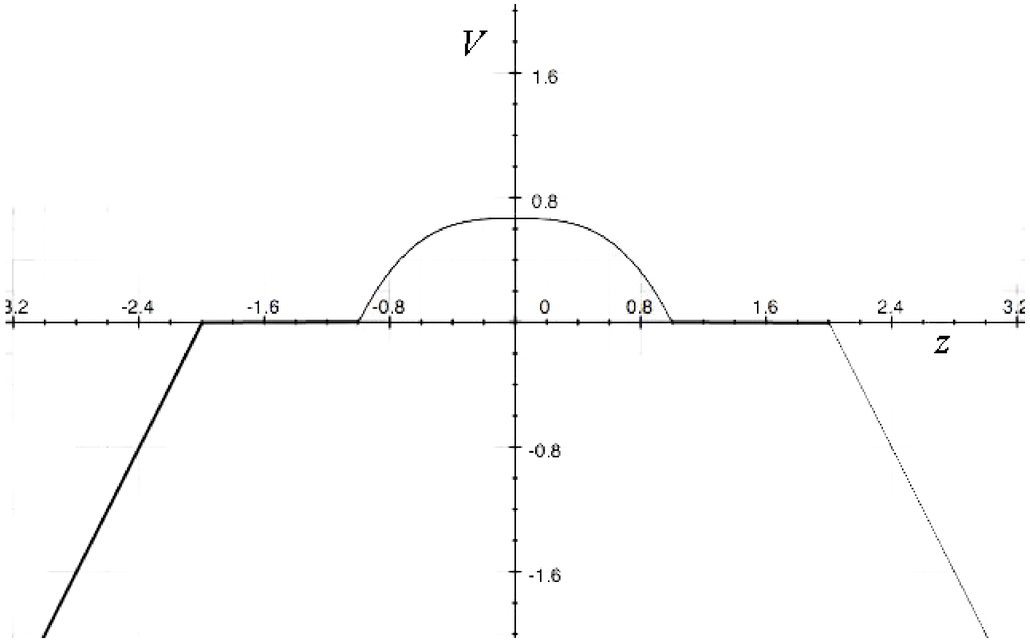
The conductor is equipotential

Electric field on the surface is normal to the surface

Exercise 1

An electric potential $V(z)$ is described by the function

$$V(z)=\begin{cases}(-2\,\mathrm{V}\cdot\mathrm{m}^{-1})z+4\,\mathrm{V}\,; & z>2.0\,\mathrm{m}\\ 0\,; & 1.0\,\mathrm{m}<z<2.0\,\mathrm{m}\\ \frac{2}{3}\,\mathrm{V}-\left(\frac{2}{3}\,\mathrm{V}\cdot\mathrm{m}^{-3}\right)z^{3}; & 0\,\mathrm{m}<z<1.0\,\mathrm{m}\\ \frac{2}{3}\,\mathrm{V}+\left(\frac{2}{3}\,\mathrm{V}\cdot\mathrm{m}^{-3}\right)z^{3}; & -1.0\,\mathrm{m}<z<0\,\mathrm{m}\\ 0\,; & -2.0\,\mathrm{m}<z<-1.0\,\mathrm{m}\\ (2\,\mathrm{V}\cdot\mathrm{m}^{-1})z+4\,\mathrm{V}\,; & z<-2.0\,\mathrm{m}\end{cases}$$

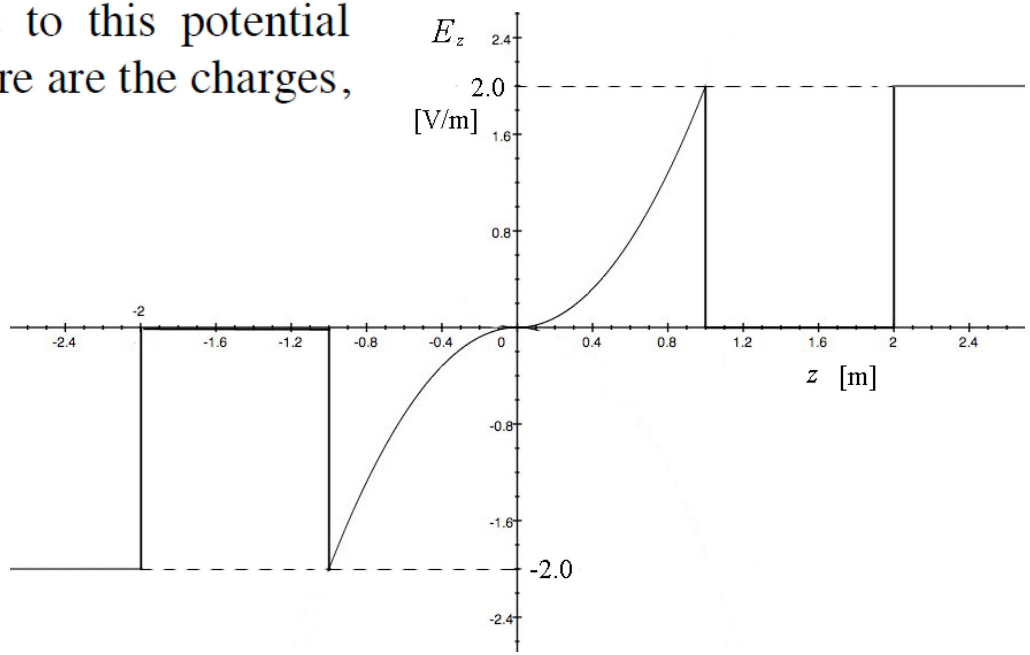


a) Give the electric field vector $\vec{\mathbf{E}}$ for each of the six regions in (i) to (vi) below?

b) Make a plot of the z-component of the electric field, E_z, as a function of z. Make sure you label the axes to indicate the numeric magnitude of the field.

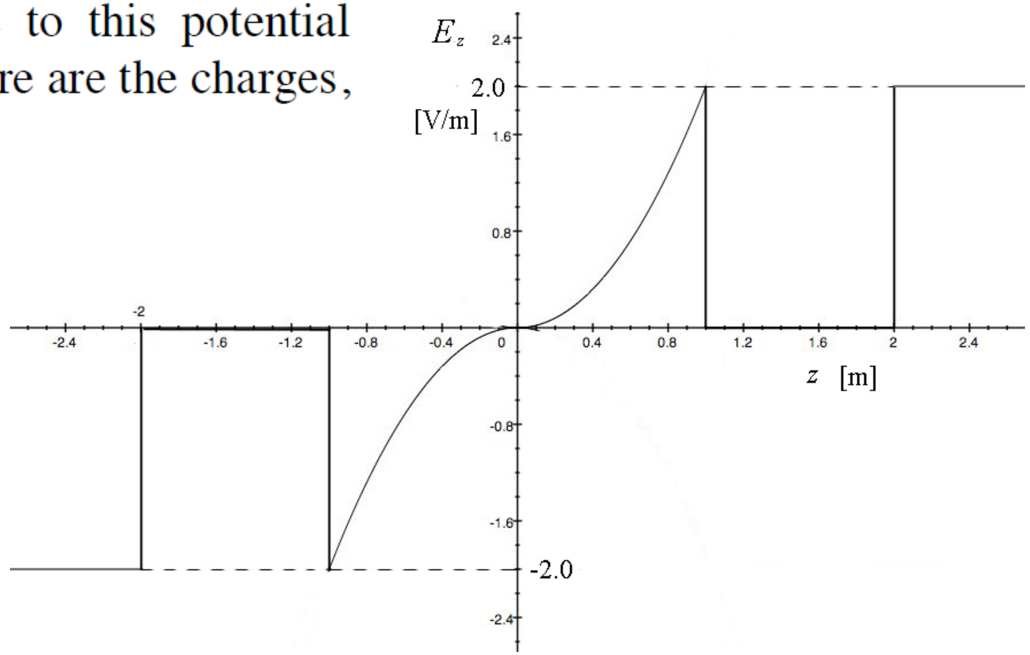
Exercise 1

c) Qualitatively describe the distribution of charges that gives rise to this potential landscape and hence the electric fields you calculated. That is, where are the charges, what sign are they, what shape are they (plane, slab…)?



Exercise 1

c) Qualitatively describe the distribution of charges that gives rise to this potential landscape and hence the electric fields you calculated. That is, where are the charges, what sign are they, what shape are they (plane, slab…)?



In the region $-1.0\text{ m} < z < 1.0\text{ m}$ there is a non-uniform (in the z-direction) slab of positive charge. Note that the z-component of the electric field is zero at $z = 0\text{ m}$, negative for the region $-1.0\text{ m} < z < 0\text{ m}$, and positive for $0\text{ m} < z < 1.0\text{ m}$ as it should for a positive slab that has zero field at the center.

In the region $1.0\text{ m} < z < 2.0\text{ m}$ there is a conductor where the field is zero.

On the plane $z = 2.0\text{ m}$, there is a positive uniform charge density σ that produces a constant field pointing to the right in the region $z > 2.0\text{ m}$ (hence the positive component of the electric field).

On the plane $z = 1.0\text{ m}$, there is a negative uniform charge density $-\sigma$.

In the region $-2.0\text{ m} < z < -1.0\text{ m}$ there is a conductor where the field is zero.

On the plane $z = -2.0\text{ m}$, there is a positive uniform charge density σ that produces a constant field pointing to the left in the region $z < -2.0\text{ m}$ (hence the positive component of the electric field).

On the plane $z = -1.0\text{ m}$, there is a negative uniform charge density $-\sigma$.

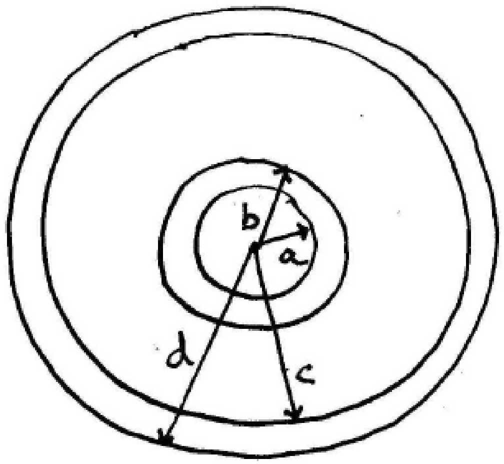
Exercise 2

A charge $-Q$ is at the center of a neutral metal (conducting) sphere of radius R_1 that is in turn centered in a larger metal (conducting) sphere of radius R_2, which carries a net charge of $+Q$. The potentials of the inner and outer spheres with respect to infinity are respectively:

Inner	Outer
A. $k_e Q(\frac{1}{R_2} - \frac{1}{R_1})$	$k_e \frac{Q}{R_2}$
B. $-k_e \frac{Q}{R_1}$	0
C. 0,	$k_e Q(\frac{1}{R_1} - \frac{1}{R_2})$
D. $k_e Q(\frac{1}{R_2} - \frac{1}{R_1})$	0

Exercise 3

Consider two nested, spherical conducting shells. The first has inner radius a and outer radius b. The second has inner radius c and outer radius d.

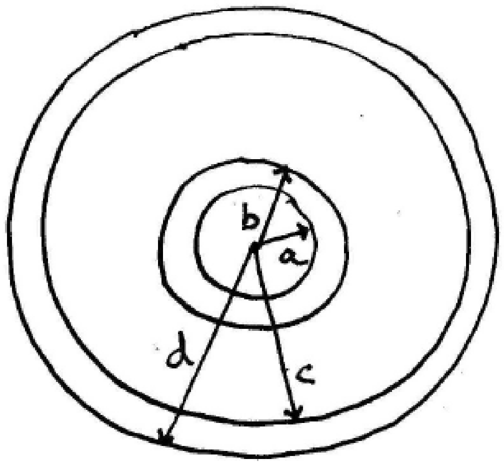


In the following four situations, determine the total charge on each of the faces of the conducting spheres (inner and outer for each), as well as the electric field and potential everywhere in space (as a function of distance r from the center of the spherical shells). In all cases the shells begin uncharged, and a charge is then instantly introduced somewhere.

a) Both shells are not connected to any other conductors (floating) – that is, their net charge will remain fixed. A positive charge $+Q$ is introduced into the center of the inner spherical shell. Take the zero of potential to be at infinity.

Exercise 3

Consider two nested, spherical conducting shells. The first has inner radius a and outer radius b. The second has inner radius c and outer radius d.

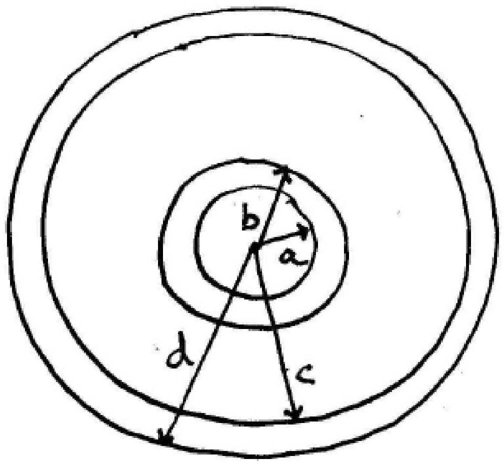


In the following four situations, determine the total charge on each of the faces of the conducting spheres (inner and outer for each), as well as the electric field and potential everywhere in space (as a function of distance r from the center of the spherical shells). In all cases the shells begin uncharged, and a charge is then instantly introduced somewhere.

b) The inner shell is floating but the outer shell is grounded – that is, it is fixed at $V = 0$ and has whatever charge is necessary on it to maintain this potential. A negative charge $-Q$ is introduced into the center of the inner spherical shell.

Exercise 3

Consider two nested, spherical conducting shells. The first has inner radius a and outer radius b. The second has inner radius c and outer radius d.

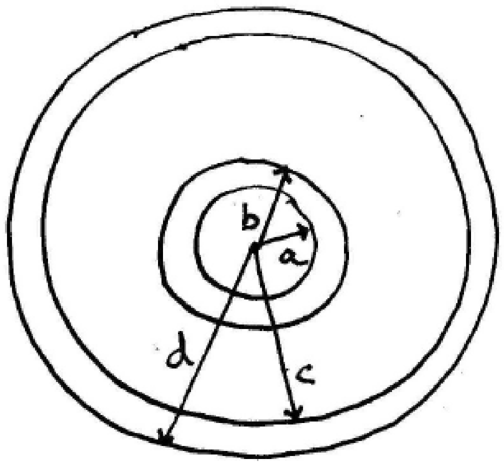


In the following four situations, determine the total charge on each of the faces of the conducting spheres (inner and outer for each), as well as the electric field and potential everywhere in space (as a function of distance r from the center of the spherical shells). In all cases the shells begin uncharged, and a charge is then instantly introduced somewhere.

c) The inner shell is grounded but the outer shell is not connected to ground. A positive charge $+Q$ is introduced into the center of the inner spherical shell.

Exercise 3

Consider two nested, spherical conducting shells. The first has inner radius a and outer radius b. The second has inner radius c and outer radius d.



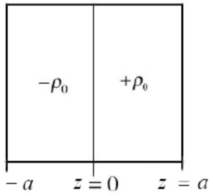
In the following four situations, determine the total charge on each of the faces of the conducting spheres (inner and outer for each), as well as the electric field and potential everywhere in space (as a function of distance r from the center of the spherical shells). In all cases the shells begin uncharged, and a charge is then instantly introduced somewhere.

d) Finally, the outer shell is grounded and the inner shell is floating. This time the positive charge $+Q$ is introduced into the region in between the two shells.

Exercise 4

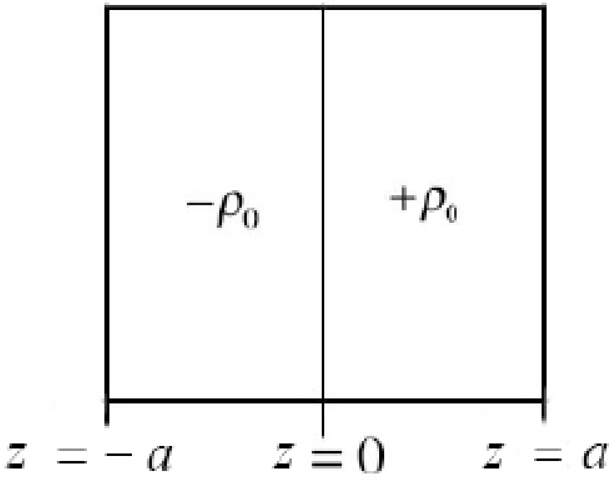
When two slabs of n-type and p-type semiconductors are put in contact, the relative affinities of the materials cause electrons to migrate out of the n-type material across the junction to the p-type material. This leaves behind a volume in the n-type material that is positively charged and creates a negatively charged volume in the p-type material.

Let us model this as two infinite slabs of charge, both of thickness a with the junction lying on the plane $z=0$. The n-type material lies in the range $0<z<a$ and has uniform charge density $+\rho_0$. The adjacent p-type material lies in tl



0 and has uniform charge density $-\rho_0$. Thus:

$$\rho(x,y,z)=\rho(z)=\begin{cases}+\rho_0 & 0<z< \\ -\rho_0 & -a<z<0 \\ 0 & |z|>a\end{cases}$$

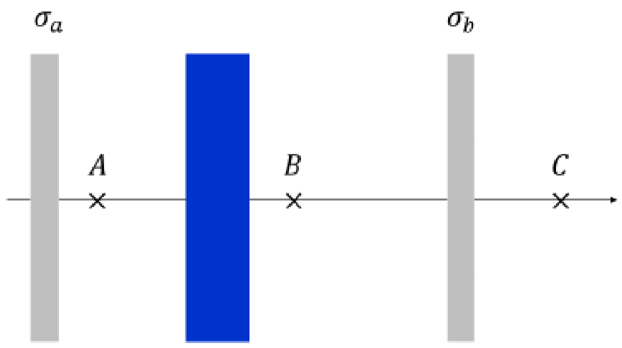


a) Find the electric field everywhere.

b) Find the potential difference between the points P_1 and P_2. The point P_1 is located on a plane parallel to the slab a distance $z_1>a$ from the center of the slab. The point P_2 is located on plane parallel to the slab a distance $z_2<-a$ from the center of the slab.

Exercise 5

3. Two non-conducting slabs of infinite area are given a charge-per-unit area of $\sigma_a = -4C/m^2$ and $\sigma_b = +1.5C/m^2$ respectively. A third slab, made of metal, is placed between the first two plates. Initially the charge density σ_m on the metal slab is 0.



(a) Find the magnitude and direction of the electric field at points A, B, and C.

(b) Charges are induced in the metallic slab on both sides which we call σ_{mL} *and* σ_{mR} for left and right respectively. What are these surface charges and how do they distribute?

(c) If we add a *net* charge per unit area of $\sigma_m = +3C/m^2$ to the metal slab, what is the new configuration of the charges on the metal slab?

Exercise 6

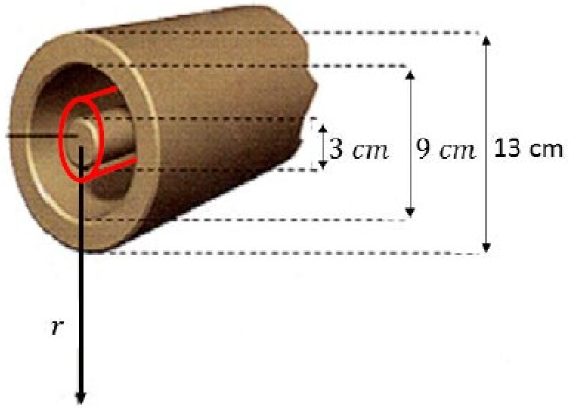
P.3–9 Three uniform line charges—$\rho_{\ell 1}$, $\rho_{\ell 2}$, and $\rho_{\ell 3}$, each of length L—form an equilateral triangle. Assuming that $\rho_{\ell 1} = 2\rho_{\ell 2} = 2\rho_{\ell 3}$, determine the electric field intensity at the center of the triangle.

Exercise 7

The figure below shows a portion of an infinitely long, concentric cable in cross section. The inner conductor has a linear charge density of $\lambda = 6.00\ nC/m$ *and the outer conductor has no net charge.*

(a) Find the electric field for $r < 1.5\ cm, r = 1.5\ cm,\ 4.5\ cm < r < 6.5\ cm$ *and* $r > 6.5\ cm$*, where* r *is the perpendicular distance from the common axis of the cylindrical system.*

(b) What are the surface charge densities on the inside and the outside surfaces of the outer conductor?



Thank You

Presented by Minjie