CONDUCTORS + CAPACITORS

Class Activities: Conductors + Capacitors (slide 1)

Whiteboard

E in cubical conductor

We whiteboarded the E field in a cubical conductor with a cubical cavity, with a +Q on the outside. Not enough time to finish!

Discussio n

Questions for Lecture (from UIUC)

1.) Important properties of a (good) electrical conductor are that: any free (or induced) electric charges must reside on the *surface* of the conductor. Why?

2.) Why is the boundary condition $\frac{\partial V}{\partial r}|_{\text{surface}}$ physically equivalent to specifying the electric field E(r) $|_{\text{surface}}$ at the surface of the conductor?

Visualization

Conductors

I showed them http://www.falstad.com/emstatic/, but it was just at the end of class. See next Wed for more details! Prep it ahead of class: Setup was "conducting box". You must first set mouse = "make floater",
then make the box floating potential, then set mouse = "adjust voltage", and adjust the voltage to zero. (It helps to temporarily increase brightness to REALLY set voltage=0) Then finally, turn brightness back down, and set mouse = add +draggable charge. You can put the charge outside, or drag it inside the box - you can see the polarization of the box, you can see the shielding, and the "shielding of position information" when Q is inside.
Then, I switched the setup to "charge and plane", which is a great setup for the method of images problem. And after SOLVING method of images, you can instantly "flip" the sim from "charge and plane" to dipole, it works great, you can visibly see that the E field on the upper half of the screen is unchanged!

Class Activities: Conductors + Capacitors (slide 2)

Kinesthetic
Room as a conductor
I reviewed last class by imagining one wall of the room a giant conductor at 0 V, the other a giant conductor at +100 V, and we "visualized" the e field and equipotential planes in the room.

Demo
Leyden Jar
(CU Demo # 5C30.05)
Energy of a capacitor. The jars hold a charge even after having been dissembled and reassembled.

Demo
Electrophorus
(CU Demo # 5A10.20)
The lecture demo area has a historical electrophorus, or you can make your own with pie plates and Styrofoam (http://www.exo.net/~pauld/summer_institute/summer_day14electrostatic/Electrophorus.html). Students rub wool on Styrofoam to charge it, and then transfer the charge to a metal plate via polarization. Some of the questions that arise in this activity are quite deep regarding the nature of insulators and conductors. It can also be a challenge for students to explain the process of charging the aluminum plate.

Demo
Charge distribution
(CU Demo # 5B30.20)
The effect of surface curvature on charge distribution is demonstrated with a curved metal body.

Class Activities: Conductors + Capacitors (slide 3)

Demo

Faraday's Ice Pail

(CU Demo # 5B20.10)

Charge is transferred to a conductor. Glass jar, filled with conducting water, wrap in al foil and charge. Capacitor. Remove glass jar from Al foil and pour out water. Another one… the glass jar has an induced polarization and that's stored and it discharges into new one. Nice intro to polarization.

Demo

Electric Whirlie

(CU Demo # 5B30.50)

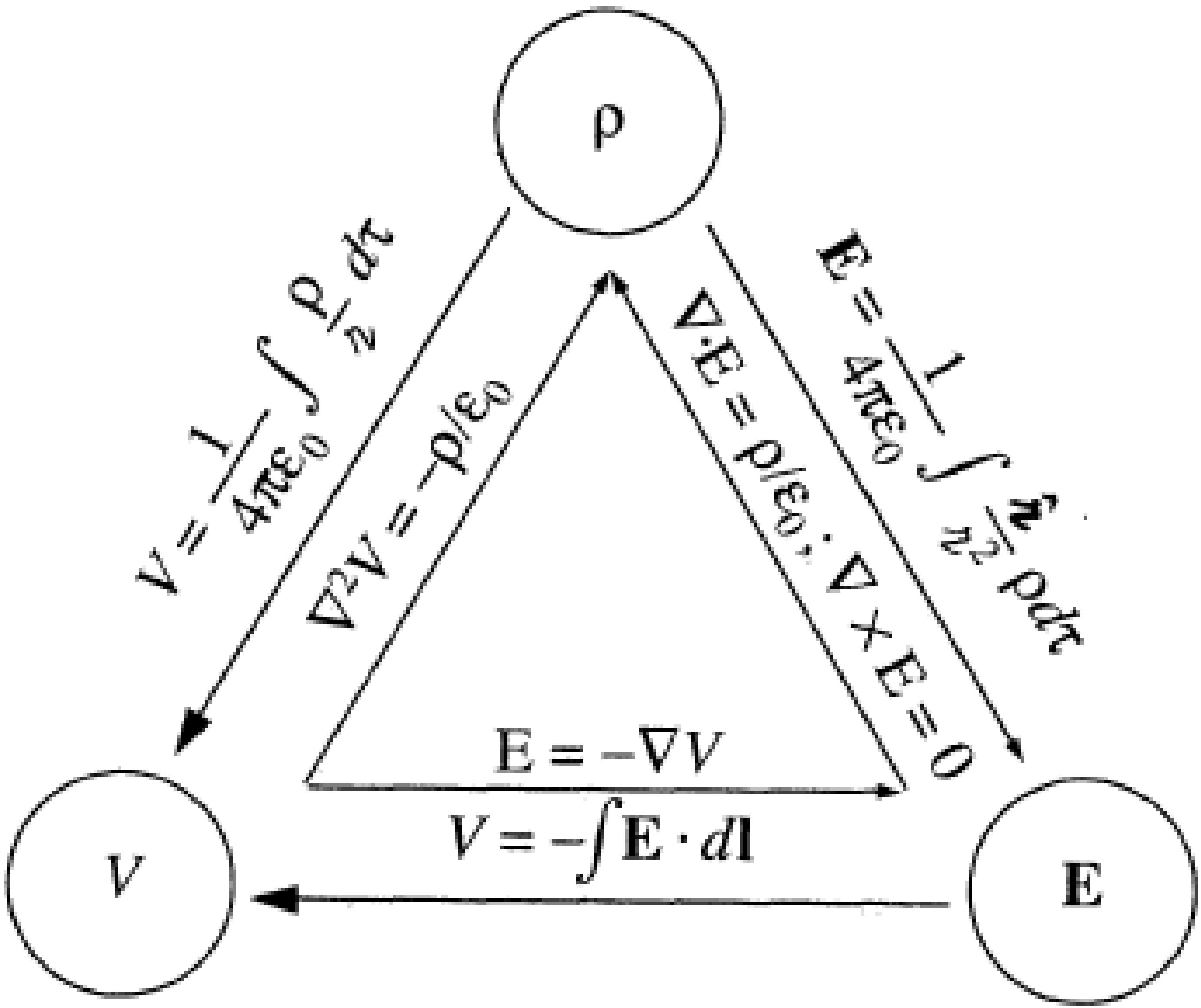
A "whirlie" is placed on top of the van de Graaf generator, and it will spin due to repulsions of the ions produced by electrical discharge.

Worksheet

Taylor Series

Dawn Meredith – Meaning in Mathematics

Taylor series; worksheet (this is not really guided inquiry, but hits some key confusions). Reminds students of how to find Taylor series and convergence issues; introduces the idea that the expansion variable must be unitless; does an example; gives a practice proble m



ρ
V
$\mathbf{E}$
$V = \frac{1}{4\pi\epsilon_0}\int \frac{\rho}{\mathscr{r}}\, d\tau$
$\nabla^2 V = -\rho/\epsilon_0$
$\nabla\cdot\mathbf{E} = \rho/\epsilon_0;\ \nabla\times\mathbf{E} = 0$
$\mathbf{E} = \frac{1}{4\pi\epsilon_0}\int \frac{\hat{\boldsymbol{\mathscr{r}}}}{\mathscr{r}^2}\rho\, d\tau$
$\mathbf{E} = -\nabla V$
$V = -\int \mathbf{E}\cdot d\mathbf{l}$

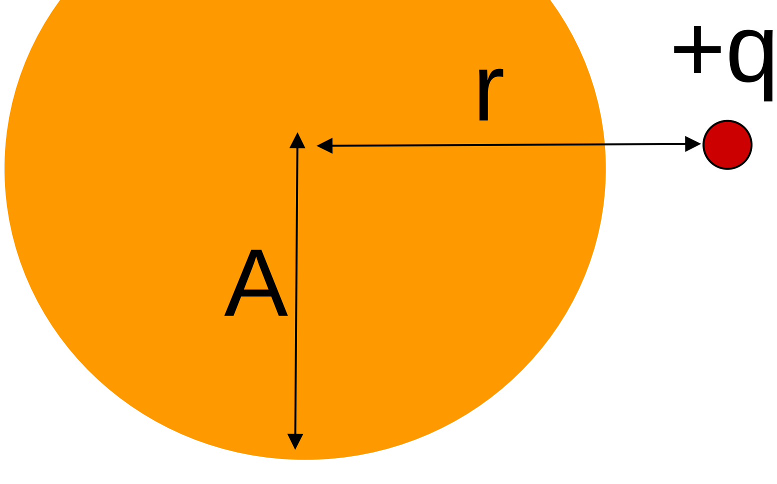
2.30

A point charge +q sits outside a solid *neutral conducting* copper sphere of radius A.

The charge q is a distance r > A from the center, on the right side.

What is the E-field at the center of the sphere?

(Assume equilibrium situation).



A) $|E| = kq/r^2$, to left

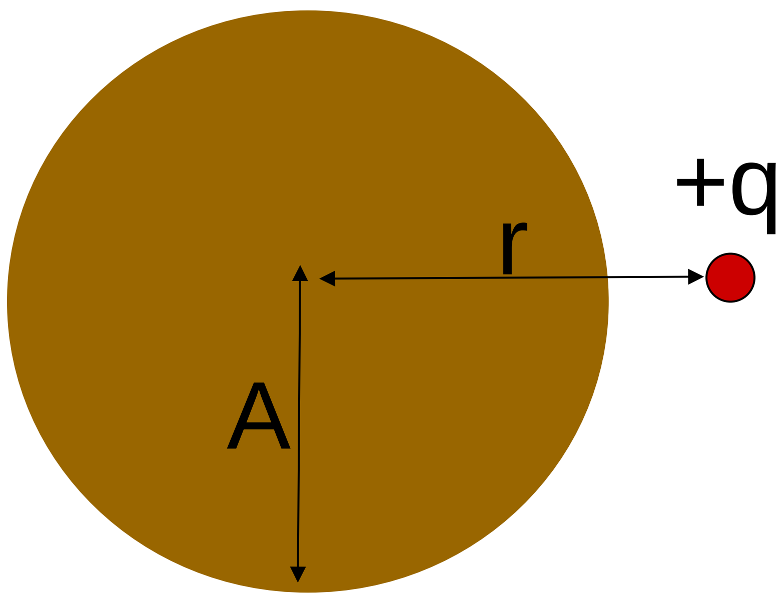
B) $kq/r^2 > |E| > 0$, to left

C) $|E| > 0$, to right

D) $E = 0$

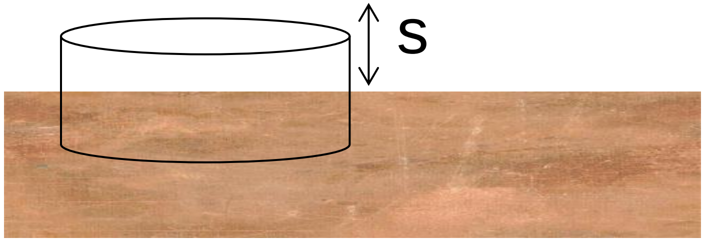
E)None of these

In the previous question, suppose the copper sphere is charged, total charge +Q.
(We are still in static equilibrium.)
What is now the magnitude of the E-field at the center of the sphere?



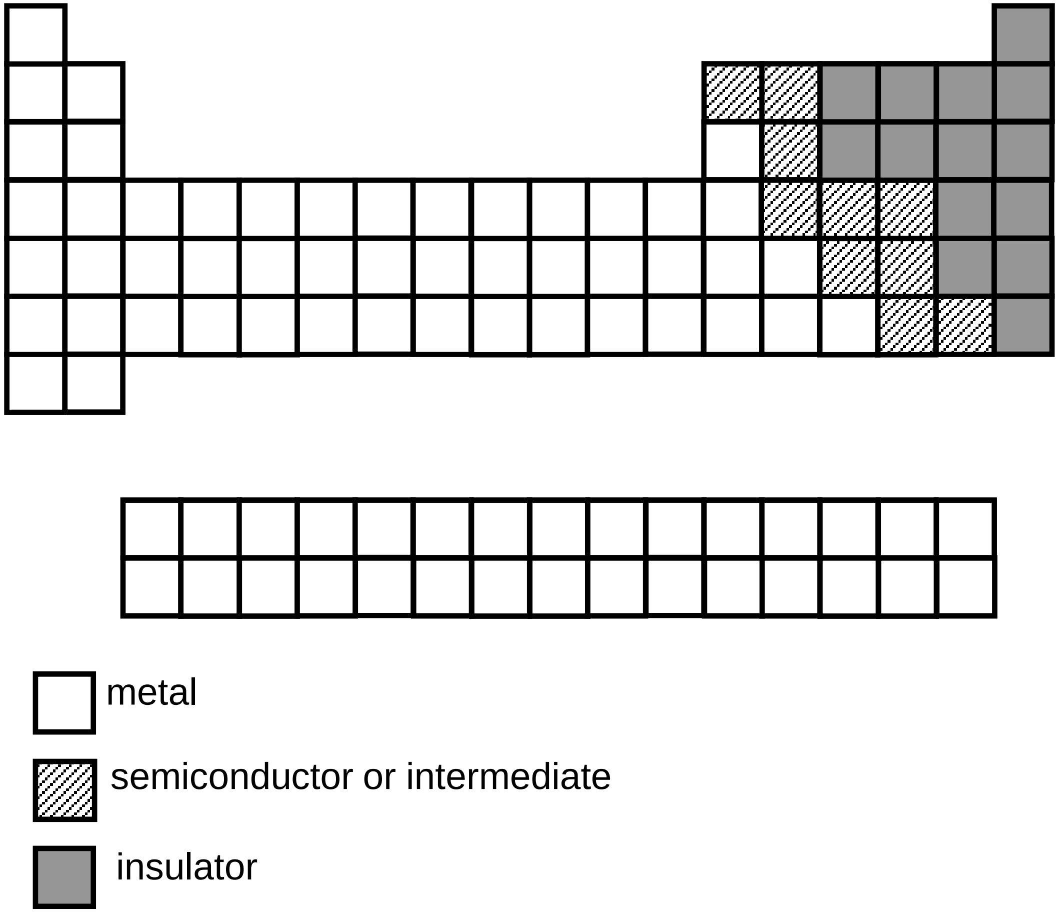
A) $|E| = kq/r^2$
B) $|E| = kQ/A^2$
C) $|E| = k(q-Q)/r^2$
D) $|E| = 0$
E) None of these! / it's hard to compute

We have a large copper plate with uniform surface charge density σ. Imagine the Gaussian surface drawn below. Calculate the E-field a small distance s *above* the conductor surface.



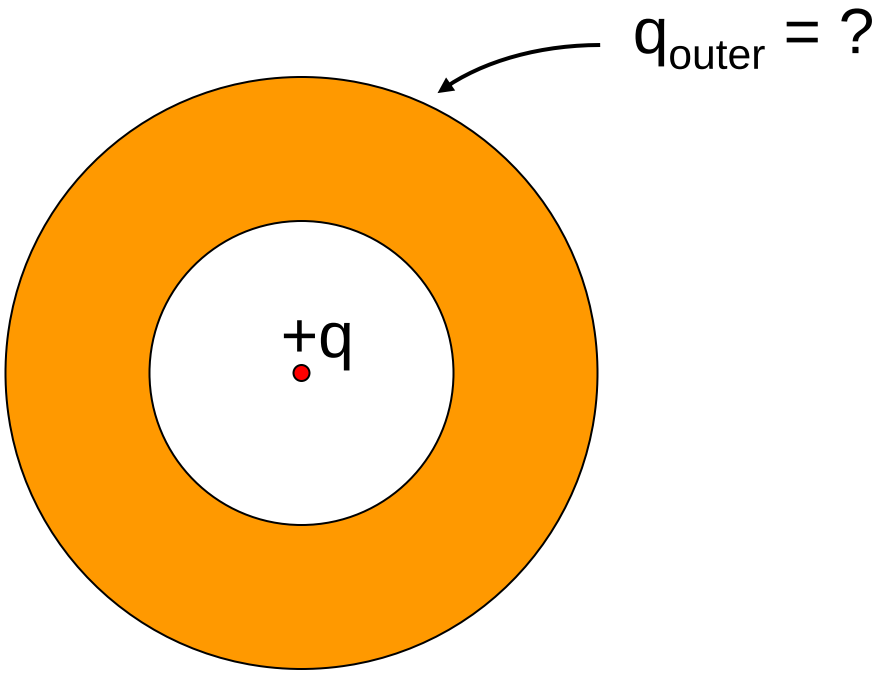
A) $|E| = \sigma/\varepsilon_0$
B) $|E| = \sigma/2\varepsilon_0$
C) $|E| = \sigma/4\varepsilon_0$
D) $|E| = (1/4\pi\varepsilon_0)(\sigma/s^2)$
E) $|E| = 0$

The Periodic Table



A **neutral** copper sphere has a spherical hollow in the center. A charge +q is placed in the center of the hollow. What is the total charge on the *outside* surface of the copper sphere?

(Assume Electrostatic equilibrium.)



A) Zero

B) -q

C) +q

D) $0 < q_{outter} < +q$

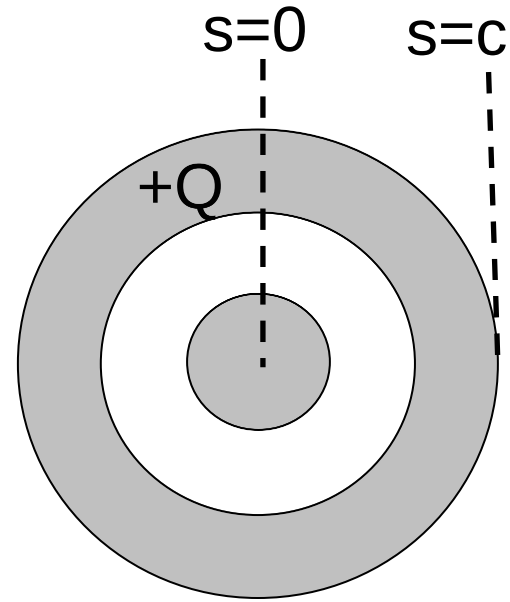
E) $-q < q_{outer} < 0$

To think about: What about on the *inside* surface?

Click A as soon as you start page 2!

Click B as soon as you START page 3!

When done, answer this:



A long coax has total charge +Q on the OUTER conductor.

The INNER conductor is neutral.

What is the sign of the potential difference, $\Delta V = V(c)-V(0)$, between the center of the inner conductor (s=0) and the outside of the outer conductor?

C) Positive

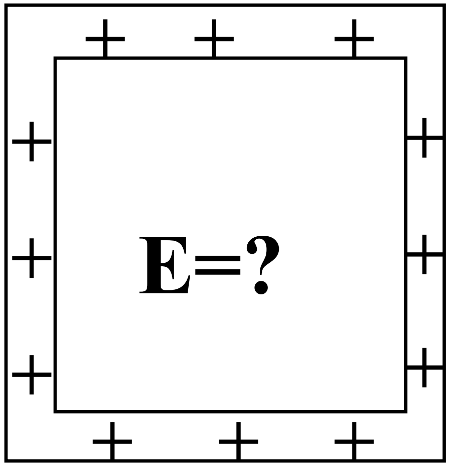
D) Negative

E) Zero

(To think about: how and where do charges distribute on surfaces?)

A cubical non-conducting *shell* has a ***uniform*** positive charge density on its surface. (There are no other charges around)

What is the field inside the box?



A: **E**=0 everywhere inside

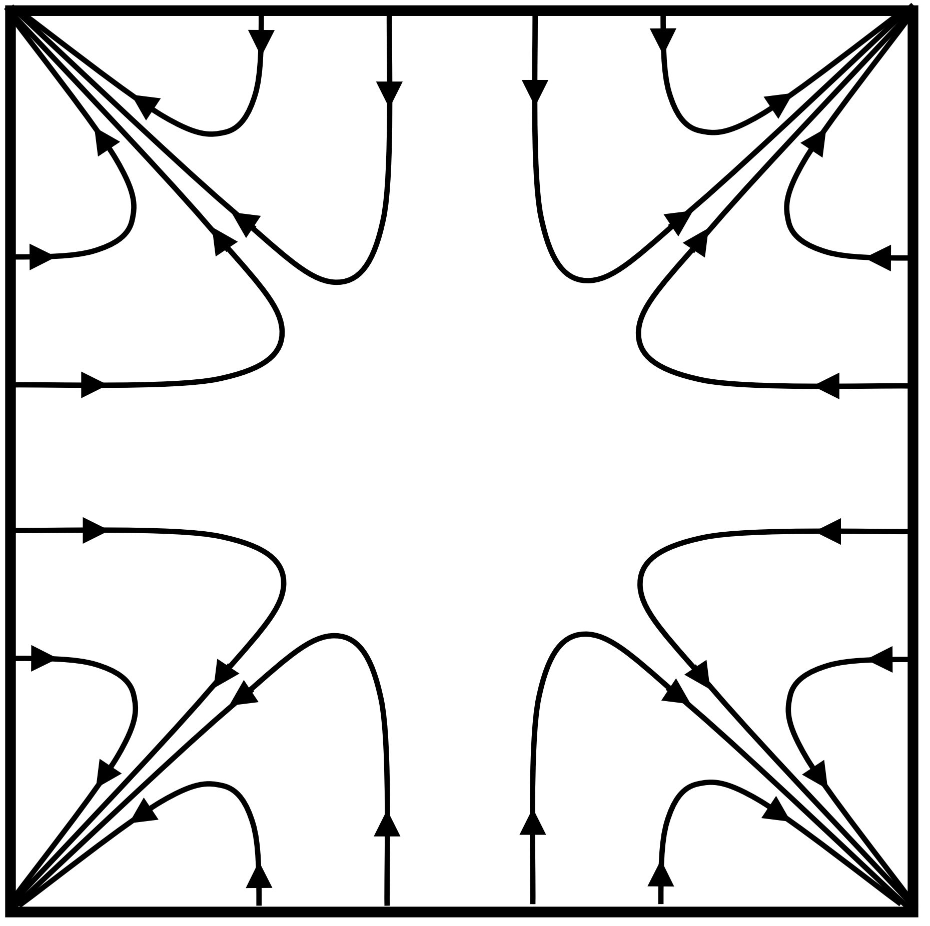
B: **E** is non-zero everywhere inside

C: **E**=0 only at the very center, but non-zero elsewhere inside.

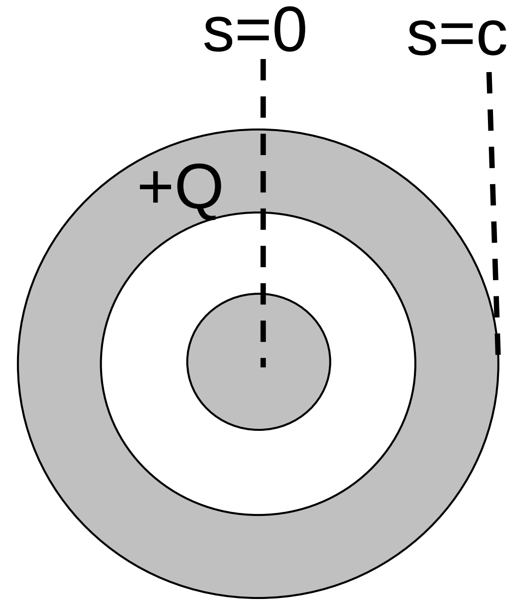
D: Not enough info given

E-field inside a cubical box with a **uniform** surface charge.

The E-field lines sneak out the corners!



A long coax has total charge +Q on the OUTER conductor.
The INNER conductor is neutral.

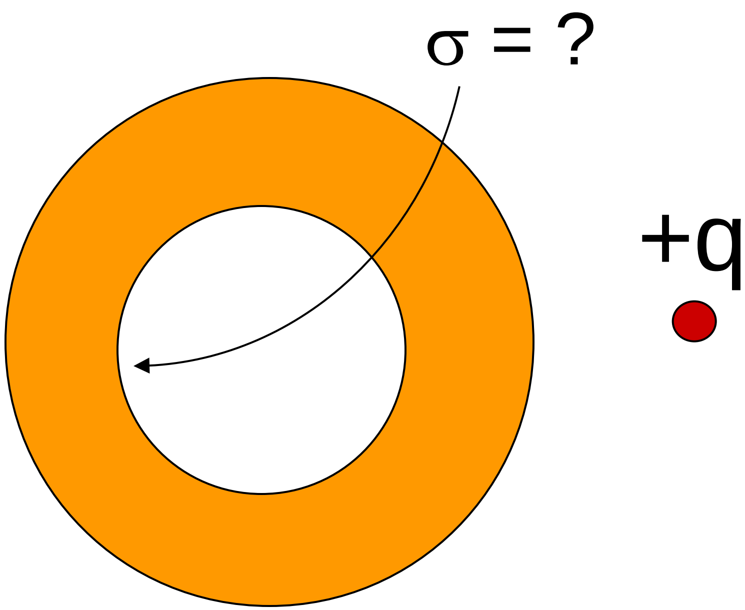


What is the sign of the potential difference, $\Delta V = V(c)-V(0)$, between the center of the inner conductor (s=0) and the outside of the outer conductor?

C) Positive
D) Negative
E) Zero

(To think about FIRST: how and where do charges distribute on all surfaces?)

A point charge +q is near a neutral copper sphere with a hollow interior space. In equilibrium, the surface charge density σ on the interior of the hollow space is..



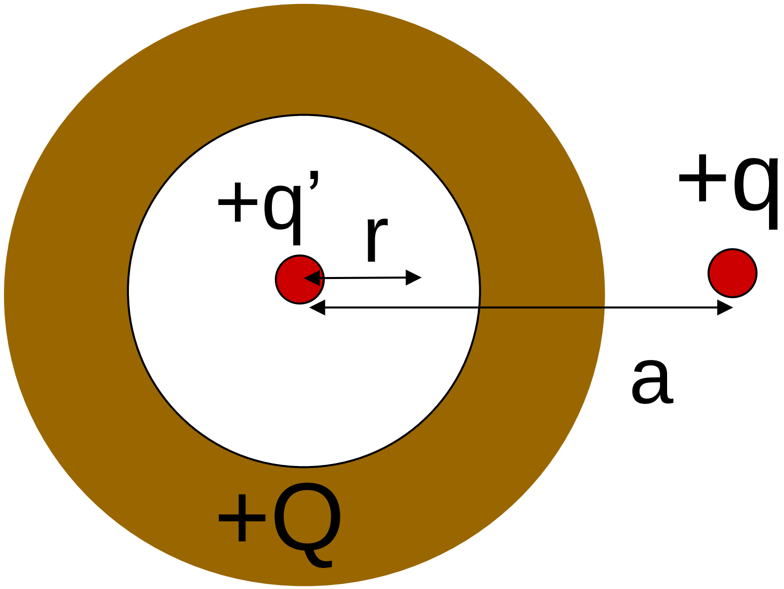
A) Zero everywhere

B) Non-zero, but with zero net total charge on interior surface

C) Non-zero with non-zero net total charge on interior surface.

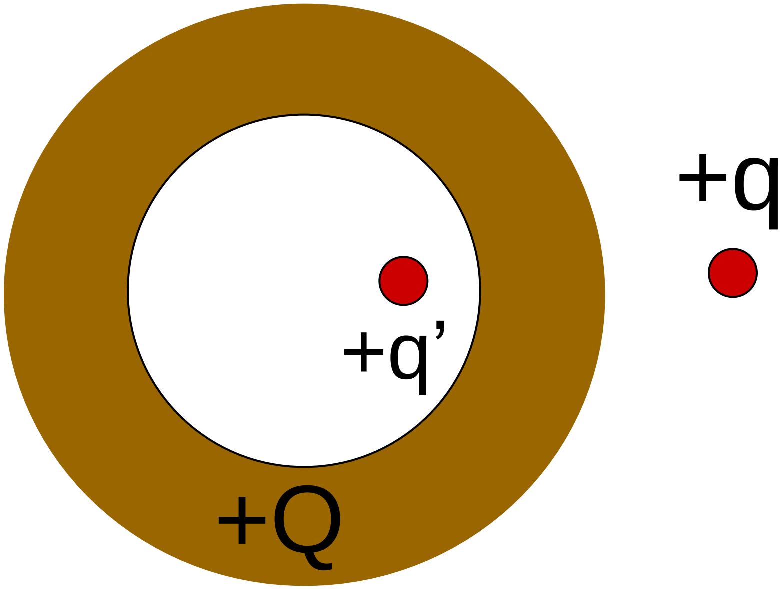
2.30a

A HOLLOW copper sphere has total charge +Q.
A point charge +q sits outside at distance a.
A charge, q', is in the hole, at the center.
(We are in static equilibrium.)
What is the magnitude of the E-field a distance r from q', (but, still in the "hole" region)



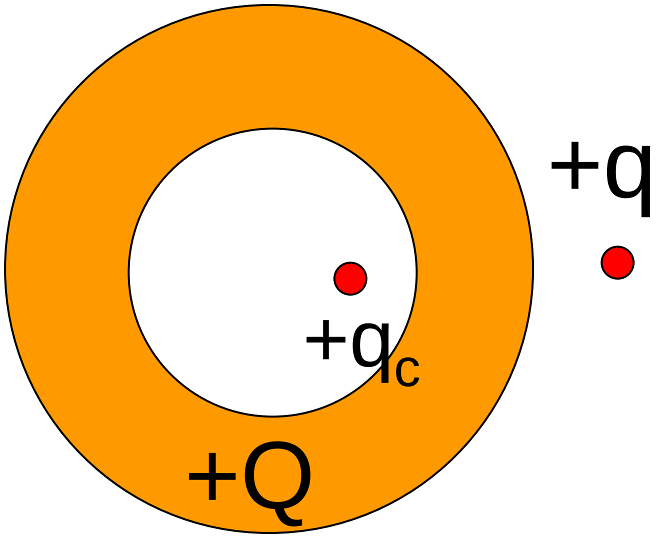
A) $|E| = kq'/r^2$
B) $|E| = k(q'-Q)/r^2$
C) $|E| = 0$
D) $|E| = kq/(a-r)^2$
E) None of these! / it's hard to compute

A HOLLOW copper sphere has total charge +Q.
A point charge +q sits outside.
A charge, q', is in the hole, SHIFTED right a bit.
(We are in static equilibrium.)
What does the E field look like in the "hole" region?



A) Simple Coulomb field (straight away from q', right up to the wall)
B) Complicated/ it's hard to compute

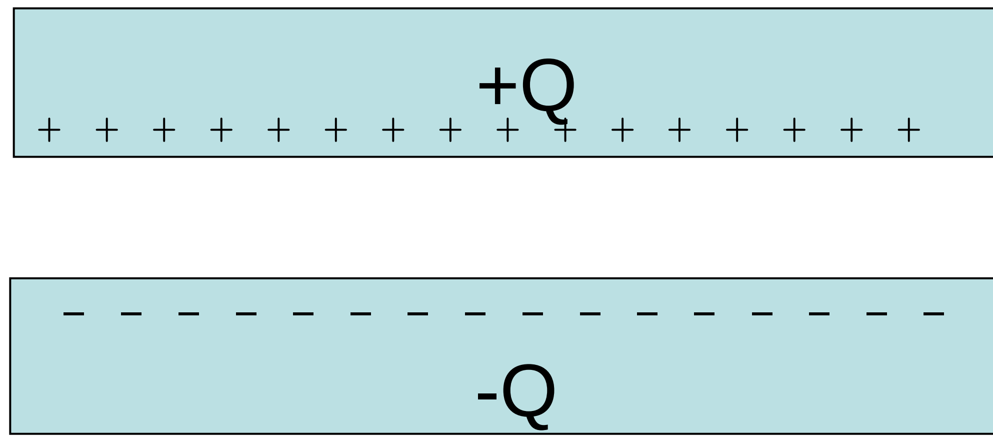
A HOLLOW copper sphere has total charge +Q.
A point charge +q sits outside.
A charge, $+q_c$, is in the hole, SHIFTED right a bit.
(Assume static equilibrium.)
What does the charge distribution look like on the inner surface of the hole?



A) All - charges, uniformly spread around
B) - charges close to q_c, + charges opposite q_c
C) All - but more close to q_c and fewer opposite
D) All + but more opposite q_c and fewer close
E) Not enough information

CAPACITORS

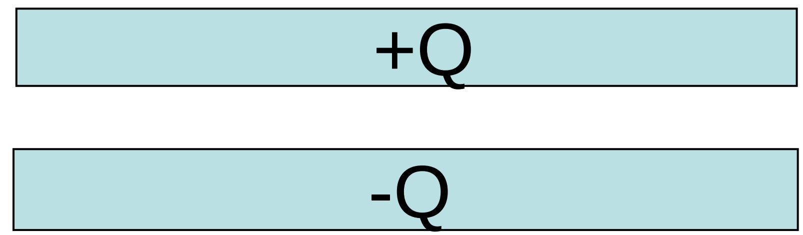
2.49 Given a pair of very large, flat, conducting capacitor plates with surface charge densities +/- σ, what is the E field in the region between the plates?



A) $\sigma/2\varepsilon_0$
B) σ/ε_0
C) $2\sigma/\varepsilon_0$
D) $4\sigma/\varepsilon_0$
E) Something else

2.49m

Given a pair of very large, flat, conducting capacitor plates with total charges +Q and –Q. Ignoring edges, what is the equilibrium distribution of the charge?



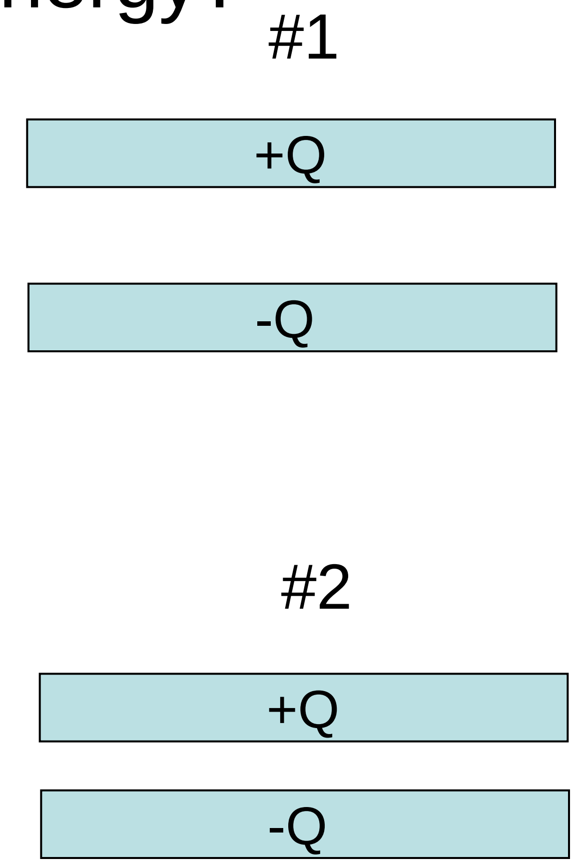
A) Throughout each plate
B) Uniformly on both side of each plate
C) Uniformly on top of + Q plate and bottom of –Q plate
D) Uniformly on bottom of +Q plate and top of –Q plate
E) Something else

2.50

You have two very large parallel plate capacitors, both with the same area and the same charge Q.

Capacitor #1 has twice the gap of Capacitor #2.

Which has more stored potential energy?



A) #1 has twice the stored energy

B) #1 has *more* than twice

C) They both have the same

D) #2 has twice the stored energy

E) #2 has more than twice.

2.51

You have two parallel plate capacitors, both with the same area and the same gap size.
Capacitor #1 has twice the charge of #2.
Which has more capacitance? More stored energy?

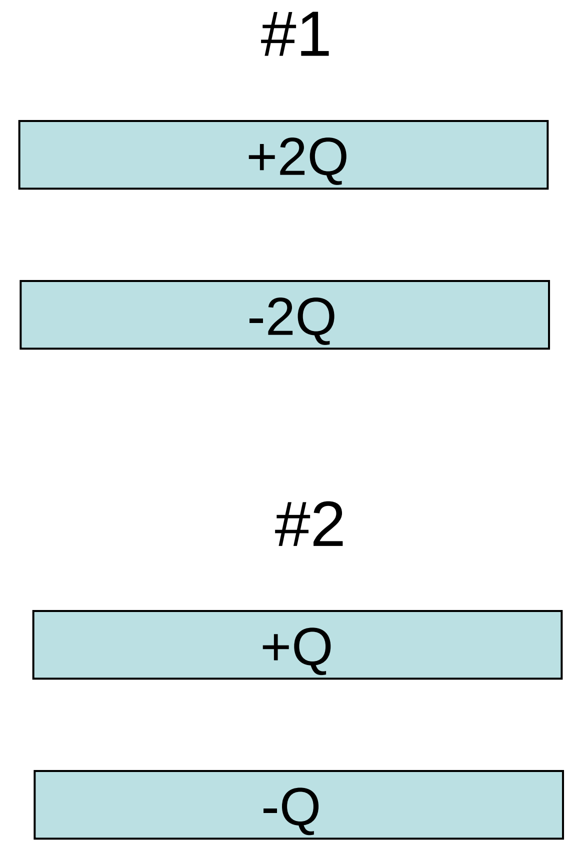
A) C1>C2, PE1>PE2

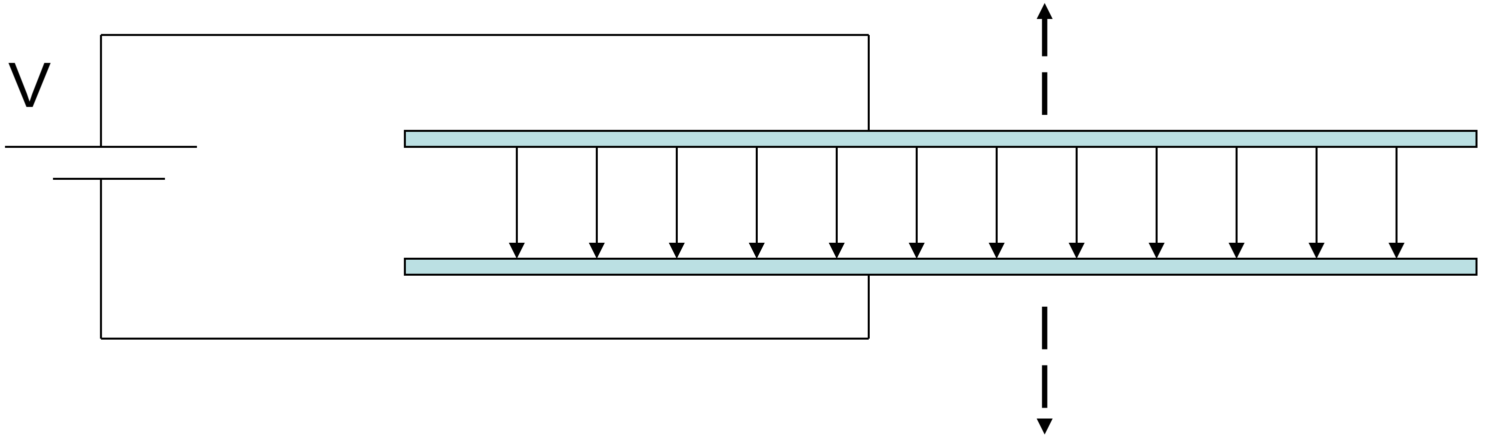
B) C1>C2, PE1=PE2

C) C1=C2, PE1=PE2

D) C1=C2, PE1>PE2

E) Some other combination!





A parallel plate capacitor is attached to a battery which maintains a constant voltage difference V between the capacitor plates. While the battery is attached, the plates are pulled apart. The electrostatic energy stored in the capacitor

A) increases

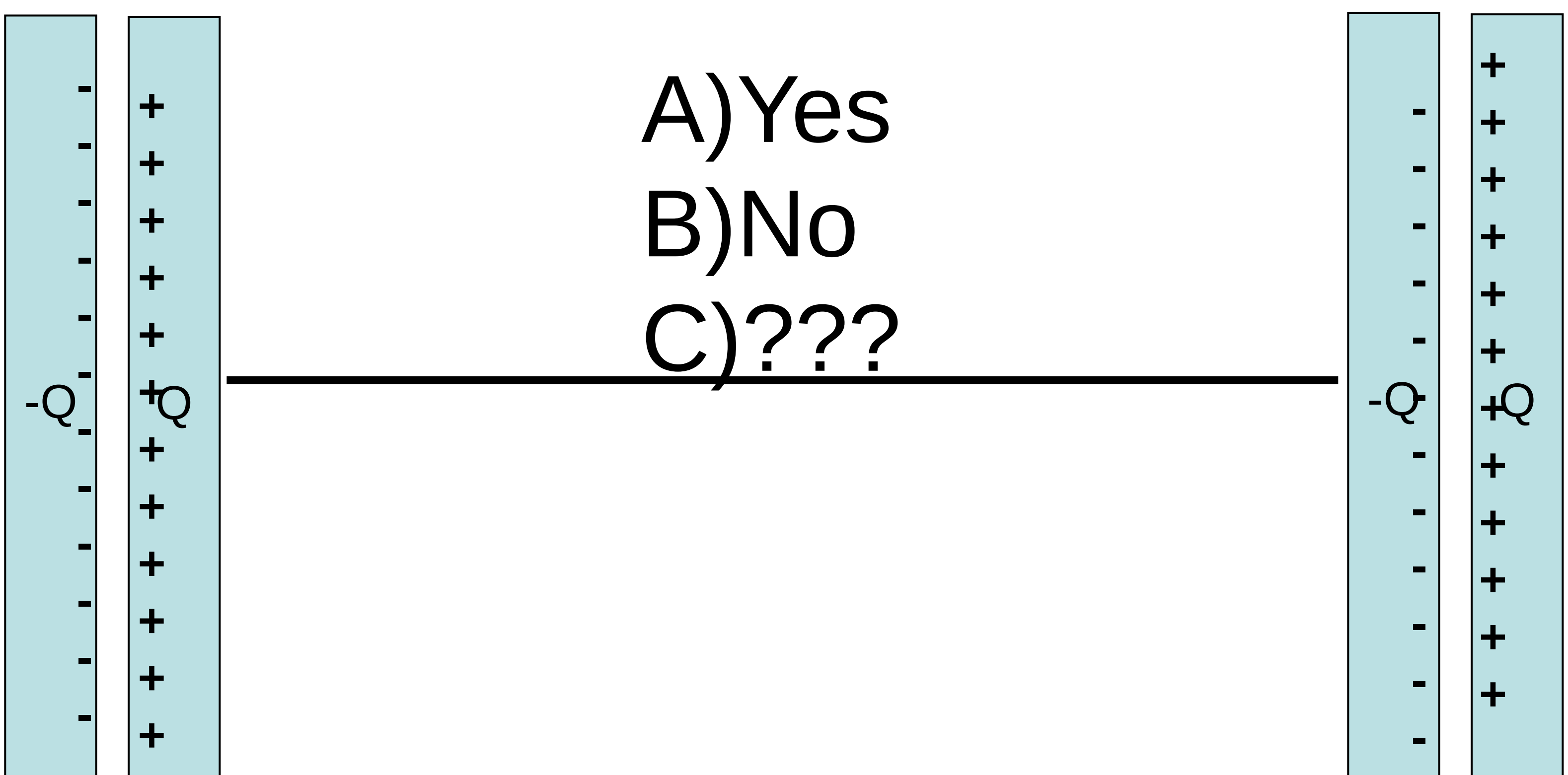
B) decreases

C) stays constant.

3.4

Two very strong (big C) ideal capacitors are well separated.

What if they are connected by one thin conducting wire, is this electrostatic situation physically stable?



A)Yes

B)No

C)???