Lecture 21

PHYC 161 Fall 2016

EXAM 2 REVIEW

Energy stored in a capacitor

- The potential energy stored in a capacitor is:

Magnitude of charge on each plate

Potential energy stored in a capacitor

$$U = \frac{Q^2}{2C} = \frac{1}{2}CV^2 = \frac{1}{2}QV$$

Capacitance

Potential difference between plates

- The capacitor energy is stored in the *electric field* between the plates.
- The *energy density* is:

Electric energy density in a vacuum

$$u = \frac{1}{2}\epsilon_0 E^2$$

Magnitude of electric field

Electric constant

Q24.8

You want to connect a 12-μF capacitor and a 6-μF capacitor. How should you connect them so that when the capacitors are charged, the 12-μF capacitor will have a greater amount of stored energy than the 6-μF capacitor?

A. The two capacitors should be in series.

B. The two capacitors should be in parallel.

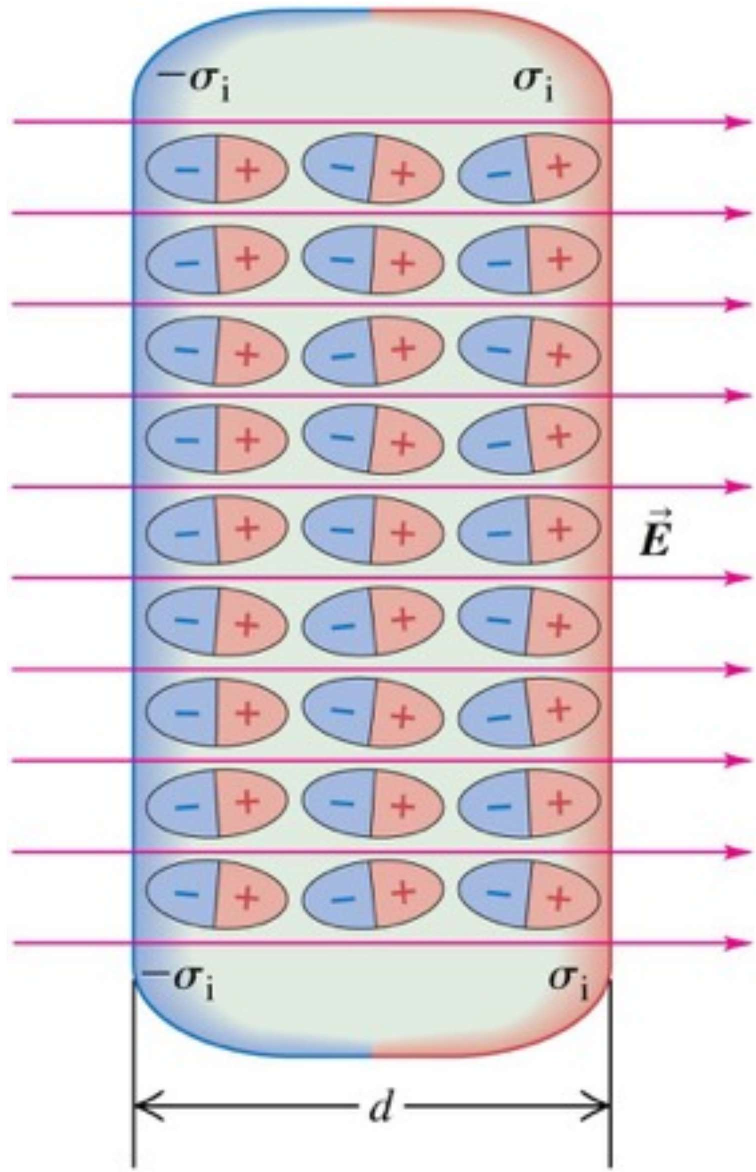
C. The two capacitors can be either in series or in parallel—in either case, the 12-μF capacitor will have a greater amount of stored energy.

D. The connection should be neither series nor parallel.

E. This is impossible no matter how the two capacitors are connected.

Molecular model of induced charge

- The polarization of molecules within a dielectric leads to the formation of a layer of charge on each surface of the dielectric material.
- These layers have a surface charge density of magnitude σ_i.



Q24.9

You slide a slab of dielectric between the plates of a parallel-plate capacitor. As you do this, the *charges* on the plates remain constant. What effect does adding the dielectric have on the *potential difference* between the capacitor plates?

A. The potential difference increases.

B. The potential difference decreases.

C. The potential difference remains the same.

D. Two of A, B, and C are possible.

E. All three of A, B, or C are possible.

The dielectric constant

- When an insulating material is inserted between the plates of a capacitor whose original capacitance is C_0, the new capacitance is greater by a factor K, where K is the **dielectric constant** of the material.

Capacitance of a parallel-plate capacitor, dielectric between plates

Dielectric constant

Area of each plate

Permittivity $= K\epsilon_0$

$$C = KC_0 = K\epsilon_0 \frac{A}{d} = \epsilon \frac{A}{d}$$

Capacitance without dielectric

Electric constant

Distance between plates

- The energy density in the capacitor DECREASES:

Dielectric constant

Permittivity $= K\epsilon_0$

Electric energy density in a dielectric

$$u = \tfrac{1}{2}K\epsilon_0 E^2 = \tfrac{1}{2}\epsilon E^2$$

Electric constant

Magnitude of electric field

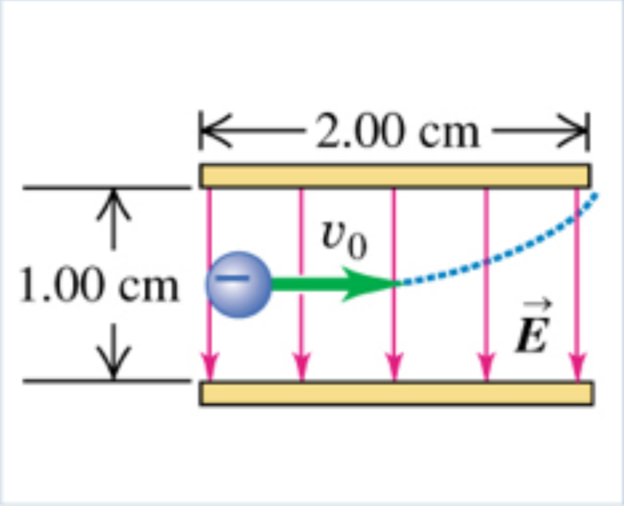
Table 24.1—Some dielectric constants

Material	K
Vacuum	*1*
Air (1 atm)	*1.00059*
Teflon	*2.1*
Mylar	*3.1*
Glass	*5 – 10*
Glycerin	*42.5*
Water	*80.4*

Exercise 21.31

Description: An electron is projected with an initial speed v_0 into the uniform field between the parallel plates in the figure. Assume that the field between the plates is uniform and directed vertically downward, and that the field outside the plates is zero...

An electron is projected with an initial speed 1.30×10^{6} $\mathrm{m/s}$ into the uniform field between the parallel plates in the figure. Assume that the field between the plates is uniform and directed vertically downward, and that the field outside the plates is zero. The electron enters the field at a point midway between the plates.



Part A

If the electron just misses the upper plate as it emerges from the field, find the speed of the electron as it emerges from the field?

Exercise 21.53

Description: Point charges q_1=- q and q_2=+ q are separated by a distance of d, forming an electric dipole. (a) Find the magnitude of the electric dipole moment. (b) Find the direction of the electric dipole moment? (c) The charges are in a...

Point charges $q_1 = -4.10\ \mathrm{nC}$ and $q_2 = +4.10\ \mathrm{nC}$ are separated by a distance of 3.70 mm , forming an electric dipole.

Part A

Find the magnitude of the electric dipole moment.

Part B

Find the direction of the electric dipole moment?

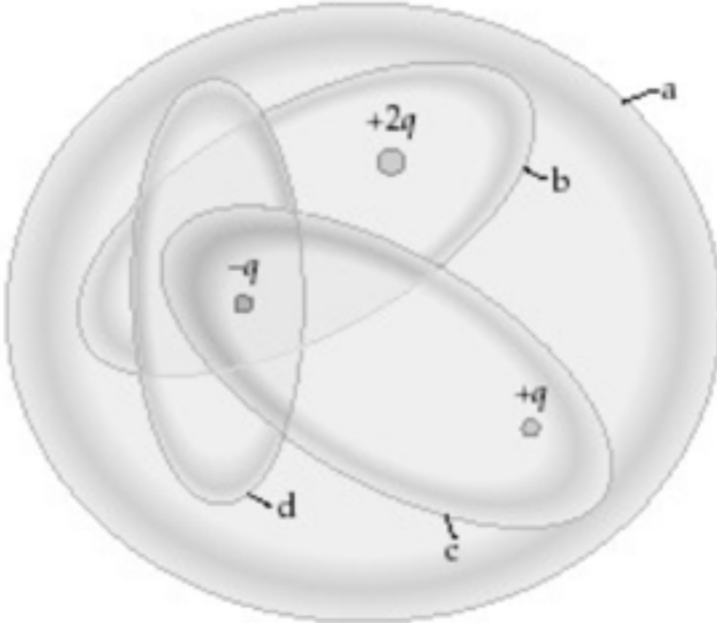
Part C

The charges are in a uniform electric field whose direction makes an angle of 36.5 ° with the line connecting the charges. What is the magnitude of this field if the torque exerted on the dipole has magnitude $7.70\times10^{-9}\ \mathrm{N\cdot m}$?

Gauss' Law

Part A

The figure shows four Gaussian surfaces surrounding a distribtuion of charges.



(a) Which Gaussian surfaces have an electric flux of $+q/\epsilon_0$ through them?

Conceptual Question 22.03

Description: (a) Which of the following statements about Gauss's law are correct? (There may be more than one correct choice.)...

Part A

Which of the following statements about Gauss's law are correct? (There may be more than one correct choice.)

Choose all that apply.

ANSWER:

- [ ] Gauss's law is valid only for symmetric charge distributions, such as spheres and cylinders.
- [x] The electric flux passing through a Gaussian surface depends only on the amount of charge inside that surface, not on its size or shape.
- [x] If a Gaussian surface is completely inside an electrostatic conductor, the electric field must always be zero at all points on that surface.
- [ ] If there is no charge inside of a Gaussian surface, the electric field must be zero at points of that surface.
- [ ] Only charge enclosed within a Gaussian surface can produce an electric field at points on that surface.

Concentric spheres with uniform charge

Part A

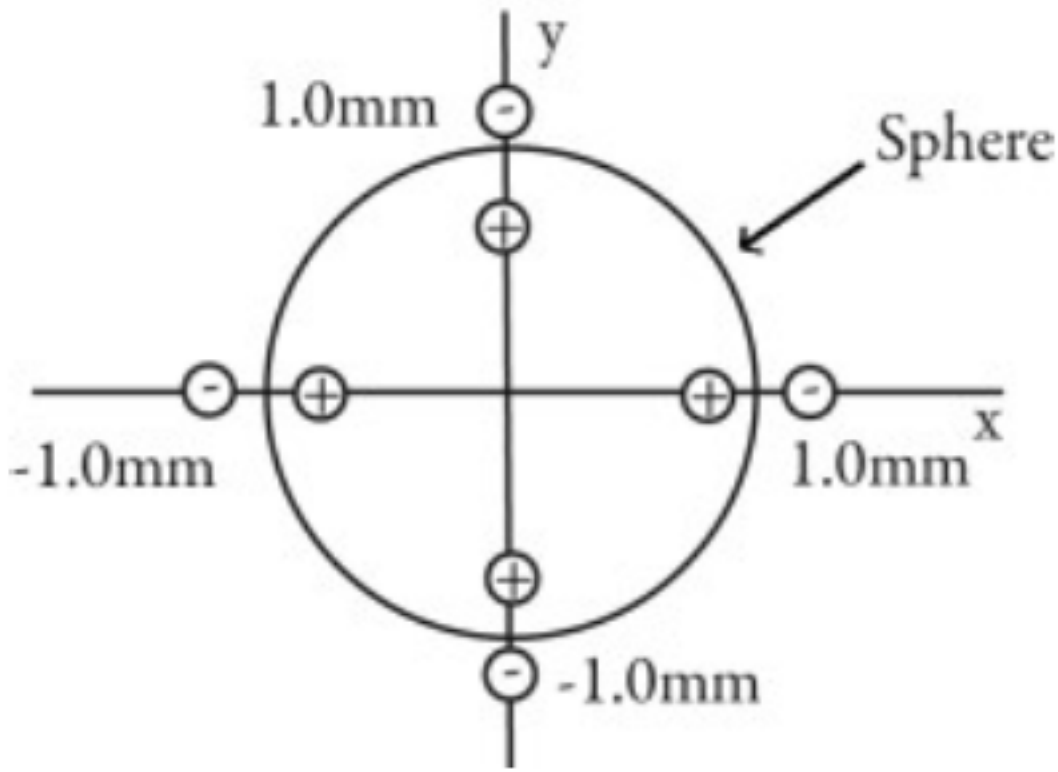
The graph in the figure shows the electric field strength (*not* the field lines) as a function of distance from the center for a pair of concentric uniformly charged spheres. Which of the following situations could the graph plausibly represent? (There may be more than one correct choice.)

- [x] a positively charged conducting sphere within another positively charged conducting sphere
- [ ] a solid nonconducting sphere, uniformly charged throughout its volume, inside of a positively charged conducting sphere
- [x] a positively charged nonconducting thin-walled spherical shell inside of a positively charged conducting sphere
- [ ] a positively charged conducting sphere within an uncharged conducting sphere
- [ ] a positively charged nonconducting thin-walled spherical shell inside of another positively charged nonconducting thin-walled spherical shell

Gauss

Part A

Four dipoles, each consisting of a +10-μC charge and a -10-μC charge, are located in the *xy*-plane with their centers 1.0 mm from the origin, as shown. A sphere passes through the dipoles, as shown in the figure. What is the electric flux through the sphere due to these dipoles? (ε_0 = 8.85 × 10^{-12} $C^2/N \cdot m^2$)



Alternative Exercise 22.81

Description: (a) A flat, square surface with sides of length L is described by the equations x = Lquad quad quad quad ((0 <= y <= L, 0 <= z <= L)). Draw this square and show the x-, y-, and z-axes. Find the electric flux through the square due to a...

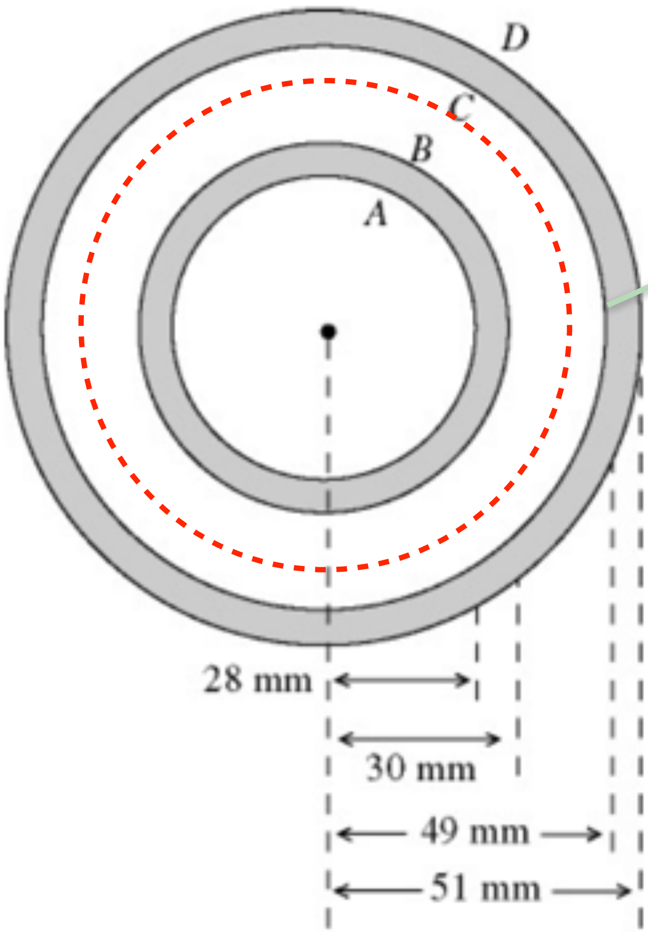
Part A

A flat, square surface with sides of length L is described by the equations
$x = L \qquad (0 \le y \le L, 0 \le z \le L)$.
Draw this square and show the x-, y-, and z-axes. Find the electric flux through the square due to a positive point charge q located at the origin $(x = 0, y = 0, z = 0)$. (*Hint:* Think of the square as part of a cube centered on the origin.)

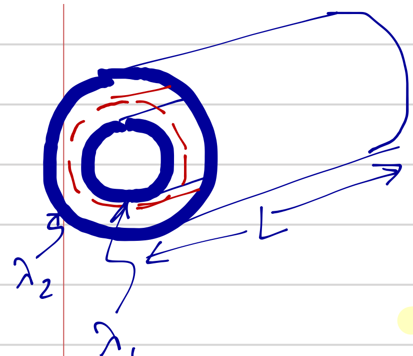
Express your answer in terms of the variables q, L, and constant ϵ_0.

Part A

The cross section of a long coaxial cable is shown in the figure, with radii as given. The linear charge density on the inner conductor is -40 nC/m and the linear charge density on the outer conductor is -80 nC/m. The inner and outer cylindrical surfaces are respectively denoted by *A*, *B*, *C*, and *D*, as shown. ($\varepsilon_0 = 8.85 \times 10^{-12}$ $C^2/N \cdot m^2$) The radial component of the electric field at a point that 44 mm from the axis is closest to



Use Gauss' Law



$$\oint \bar{E} \cdot d\bar{A} = \frac{Q_{enc}}{\epsilon_0}$$

By symmetry, $\bar{E}$ radial and constant on Gaussian sphere

$$\Rightarrow E(2\pi r L) = \frac{Q_{enc}}{\epsilon_0} = \frac{\lambda_1 L}{\epsilon_0}$$

$$E = \frac{\lambda_1}{2\pi\epsilon_0 r}$$

Finding the potential…

Exercise 23.28

Description: A solid conducting sphere has net positive charge and radius R. At a point 1.20 m from the center of the sphere, the electric potential due to the charge on the sphere is V. Assume that V = 0 at an infinite distance from the sphere. (a) ...

A solid conducting sphere has net positive charge and radius R = 0.400 m . At a point 1.20 m from the center of the sphere, the electric potential due to the charge on the sphere is 18.0 V . Assume that V = 0 at an infinite distance from the sphere.

Part A

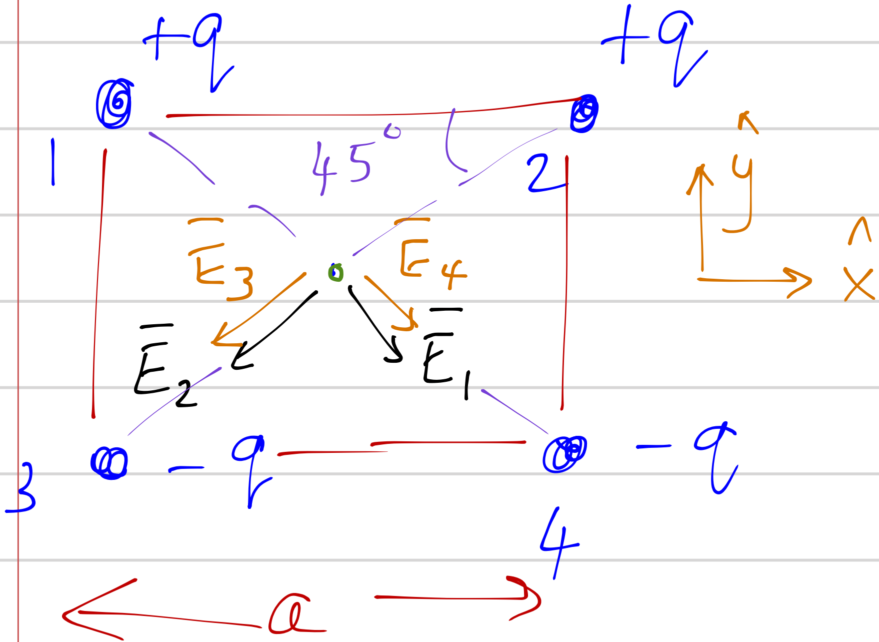
What is the electric potential at the center of the sphere?

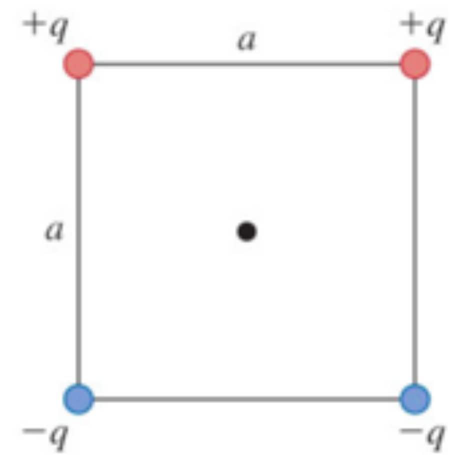
Express your answer with the appropriate units.

ANSWER:

$$V = \frac{1.2V}{R} = 54.0\mathrm{V}$$

Field and potential at center?





Field and potential at center?

$$\bar{E} = \bar{E}_1 + \bar{E}_2 + \bar{E}_3 + \bar{E}_4$$

$$\bar{E}_3 = \frac{-q}{4\pi\epsilon_0}\left(\frac{1}{2\sqrt{a}}\right)^2 \cos(45^\circ)\,\hat{x} - \frac{q}{4\pi\epsilon_0}\left(\frac{1}{2\sqrt{a}}\right)^2 \sin(45^\circ)\,\hat{y}$$

$$V = V_1 + V_2 + V_3 + V_4$$

$$V = 2\left(\frac{+q}{4\pi\epsilon_0}\,\frac{1}{2\sqrt{a}}\right) - 2\left(\frac{q}{4\pi\epsilon_0}\,\frac{1}{2\sqrt{a}}\right)$$

$$= 0$$

Alternative Exercise 23.97

Description: Identical point charges q = 15.00mu C are placed at opposite corners of a square. The length of each side of the square is 0.200 m. A point charge q_0 = - 2.00mu C is placed at one of the empty corners. (a) How much work is done on q_0 by the...

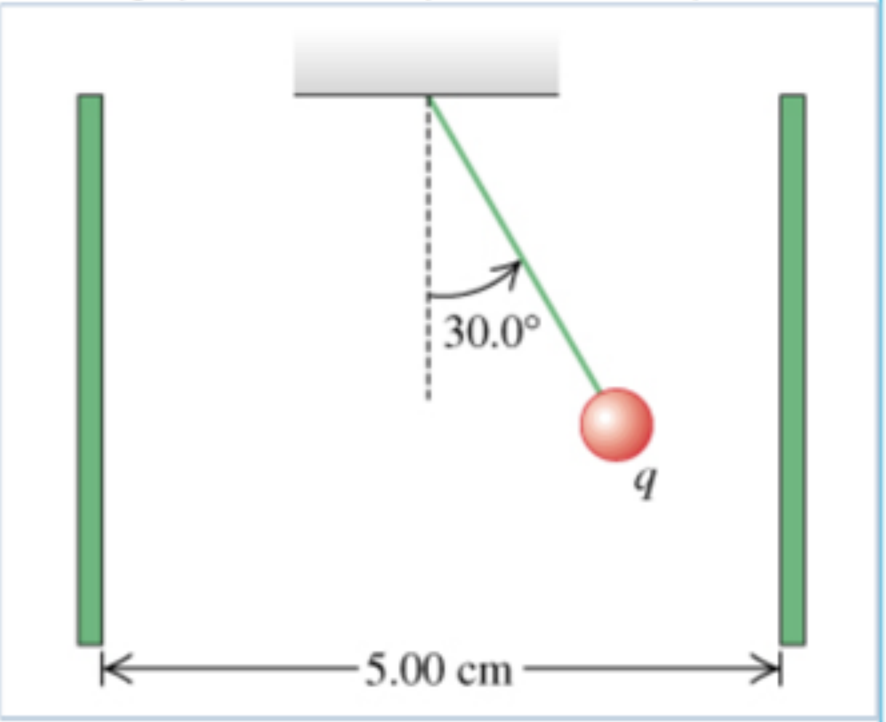
Identical point charges q = 15.00$\mu\mathrm{C}$ are placed at opposite corners of a square. The length of each side of the square is 0.200 m. A point charge q_0 = - 2.00$\mu\mathrm{C}$ is placed at one of the empty corners.

Part A

How much work is done on q_0 by the electric force when q_0 is moved to the other empty corner?

Find potential difference

A small sphere with mass 1.70 g hangs by a thread between two large parallel vertical plates 5.00 cm apart . The plates are insulating and have uniform surface charge densities $+\sigma$ and $-\sigma$. The charge on the sphere is q = 9.30×10^{-6} C .



Part A

What potential difference between the plates will cause the thread to assume an angle of 30.0° with the vertical?

Conceptual Question 24.03

Description: (a) Equal but opposite charges Q are placed on the square plates of an air-filled parallel-plate capacitor. The plates are then pulled apart to twice their original separation, which is small compared to the dimensions of the plates. Which of the...

Part A

Equal but opposite charges Q are placed on the square plates of an air-filled parallel-plate capacitor. The plates are then pulled apart to twice their original separation, which is small compared to the dimensions of the plates. Which of the following statements about this capacitor are true? (There may be more than one correct choice.)

Choose all that apply.

ANSWER:

- [x] The potential difference across the plates has doubled.
- [ ] The energy density in the capacitor has increased.
- [x] The energy stored in the capacitor has doubled.
- [ ] The electric field between the plates has increased.
- [ ] The capacitance has doubled.

Discharging a capacitor

The four identical capacitors in the circuit shown in the figure are initially uncharged. Let the charges on the capacitors be Q_1, Q_2, Q_3, and Q_4 and the potential differences across them be V_1, V_2, V_3, and V_4. The switch is thrown first to position A and kept there for a long time. It is then thrown to position B. Which of the following conditions is true with the switch in position B?