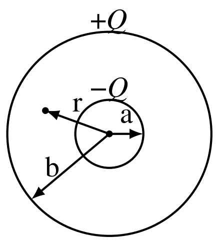
Student #: ___________________________ Student Name: ___________________________________

# AP PHYSICS C CLASS 16: CAPACITORS

**Questions 1–3**

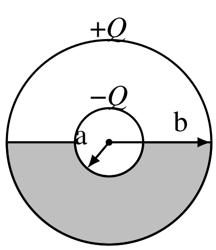



The spherical capacitor shown above consists of a conducting shell of radius $a$ inside a larger conducting shell of radius $b$. A charge $-Q$ is placed on the inner sphere and a charge $+Q$ is placed on the outer shell. The capacitance of the capacitor is $C_0$.

1. The magnitude of the electric field $E$ at a distance $r$ between the spheres is

   (A) $\dfrac{Q}{4\pi\epsilon_0 r^2}$
   (B) $\dfrac{Q}{4\pi\epsilon_0 r}$
   (C) $\dfrac{Q}{4\pi\epsilon_0 a^2}$
   (D) $\dfrac{Q}{4\pi\epsilon_0 b^2}$
   (E) zero

2. The bottom half of the space between the spheres is filled with oil of dielectric constant $\kappa = 3$, creating two capacitors connected to each other. Which of the following is true of the two capacitors?




   (A) They are connected in series.
   (B) They are connected in parallel.
   (C) The total capacitance has not changed.
   (D) The total capacitance of the spheres has decreased.
   (E) The total capacitance is now zero.

3. With the bottom half of the space between the spheres having been filled with oil of dielectric constant $\kappa = 3$, the new capacitance of the spheres is

   (A) zero
   (B) $C_0$
   (C) $2C_0$
   (D) $3C_0$
   (E) $4C_0$

**Questions 4–5**: The equation for determining the capacitance of a capacitor of plate area $A$ and separation $d$ is $C = \dfrac{\epsilon_0 A}{d}$.

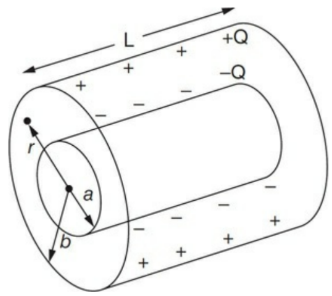
4. This equation can be derived from

   (A) Ampere's law
   (B) Faraday's law of induction
   (C) Gauss's law for electrostatics
   (D) Gauss's law for magnetism
   (E) Ohm's law of circuits

5. If a dielectric of constant $\kappa = 4$ is placed between the plates of the capacitor and the separation between the plates is decreased to $d/2$, the capacitance

   (A) increases by a factor of 4
   (B) decreases by a factor of 4
   (C) increases by a factor of 8
   (D) decreases by a factor of 8
   (E) is unchanged

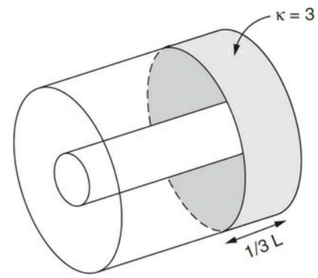
**Questions 6–8**: The cylindrical capacitor shown consists of a conducting shell of radius $a$ inside a larger conducting shell of radius $b$. A charge $-Q$ is placed on the inner sphere and a charge $+Q$ is placed on the outer shell. The length of the capacitor is $L$, which is very long compared to $a$ and $b$. The capacitance of the capacitor is $C_0$.




6. The magnitude of the electric field $E$ at a distance $r$ between the cylinders is

(A) $\dfrac{Q}{4\pi\epsilon_0 r^2}$
(B) $\dfrac{Q}{\pi\epsilon_0 r L}$
(C) $\dfrac{Q}{2\pi\epsilon_0 r L}$
(D) $\dfrac{Q}{2\pi\epsilon_0 L^2}$
(E) zero

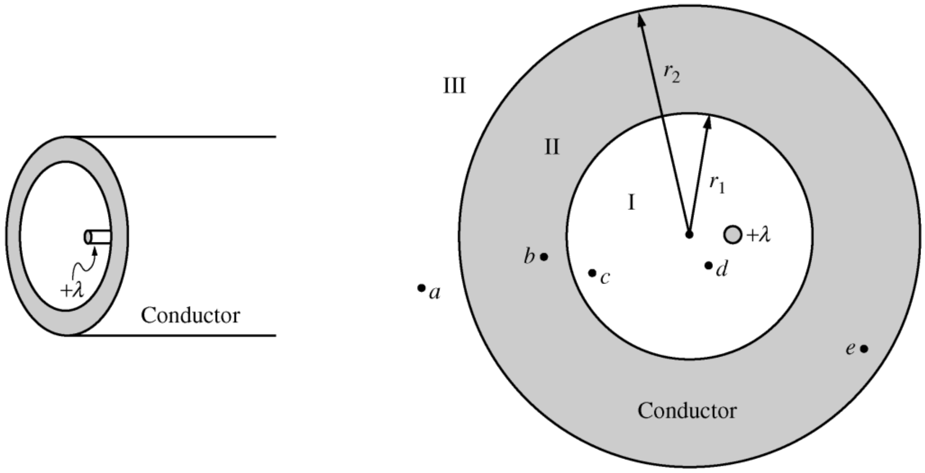
7. One-third of the length of the space between the cylinders is filled with oil of dielectric constant $\kappa = 3$, creating two capacitors connected to each other. Which of the following is true of the two capacitors?




(A) They are connected in series.
(B) They are connected in parallel.
(C) The total capacitance has not changed.
(D) The total capacitance of the spheres has decreased.
(E) The total capacitance is now zero.

8. With one-third of the space between the cylinders having been filled with oil of dielectric constant $\kappa = 3$, the new capacitance of the spheres is

(A) zero
(B) $C_0$
(C) $C_0/3$
(D) $5C_0/3$
(E) $4C_0$




Cross Section

9. The figure above left shows a hollow, infinite, cylindrical, uncharged conducting shell of inner radius $r_1$ and outer radius $r_2$. An infinite line charge of linear charge density $+\lambda$ is parallel to its axis but off center. An enlarged cross section of the cylindrical shell is shown above right.

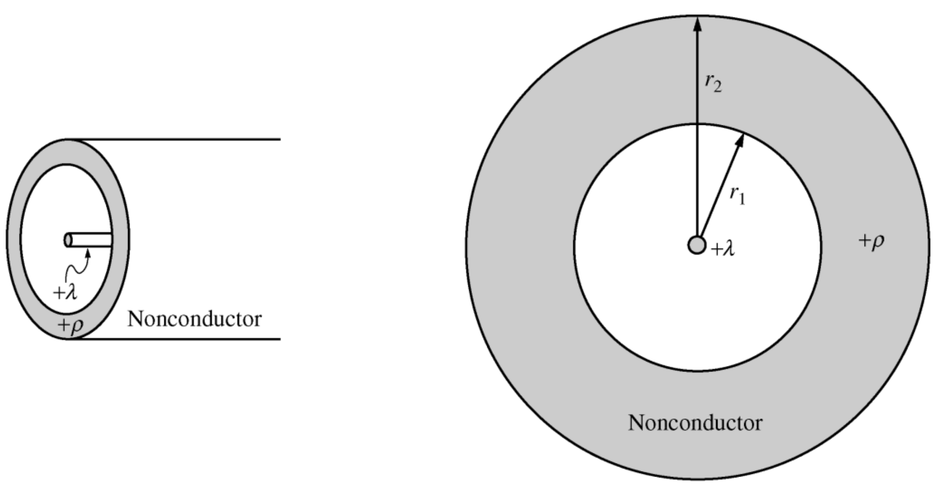
   (a) On the cross section above right,

      i. sketch the electric field lines, if any, in each of regions I, II, and III and

      ii. use + and − signs to indicate any charge induced on the conductor.

   (b) In the spaces below, rank the electric potentials at points $a$, $b$, $c$, $d$, and $e$ from highest to lowest (1 = highest potential). If two points are at the same potential, give them the same number.

   ___ $V_a$ ___ $V_b$ ___ $V_c$ ___ $V_d$ ___ $V_e$




Cross Section

   (c) The shell is replaced by another cylindrical shell that has the same dimensions but is nonconducting and carries a uniform volume charge density $+\rho$. The infinite line charge, still of charge density $+\lambda$, is located at the center of the shell as shown above. Using Gauss's law, calculate the magnitude of the electric field as a function of the distance $r$ from the center of the shell for each of the following regions. Express your answers in terms of the given quantities and fundamental constants.

      i. $r < r_1$

      ii. $r_1 \le r \le r_2$

      iii. $r > r_2$

10. A nonconducting, thin, spherical shell has a uniform surface charge density $\sigma$ on its outside surface and no charge anywhere else inside.

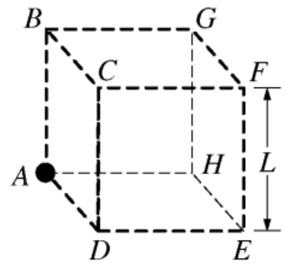
(a) Use Gauss's law to prove that the electric field inside the shell is zero everywhere. Describe the Gaussian surface that you use.

(b) The charges are now redistributed so that the surface charge density is no longer uniform. Is the electric field still zero everywhere inside the shell?

____ Yes ____ No ____ It cannot be determined from the information given.

Justify your answer.

Now consider a small conducting sphere with charge $+Q$ whose center is at corner $A$ of a cubical surface, as shown below.




(c) For which faces of the surface, if any, is the electric flux through that face equal to zero?

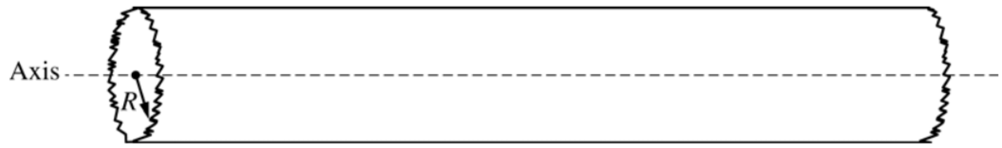
____ $ABCD$ ____ $CDEF$ ____ $EFGH$ ____ $ABGH$ ____ $BCFG$ ____ $ADEH$

Explain your reasoning.

(d) At which corner(s) of the surface does the electric field have the least magnitude

(e) Determine the electric field strength at the position(s) you have indicated in part (d) in terms of $Q$, $L$, and fundamental constants, as appropriate.

(f) Given that one-eighth of the sphere at point A is inside the surface, calculate the electric flux through face $CDEF$.

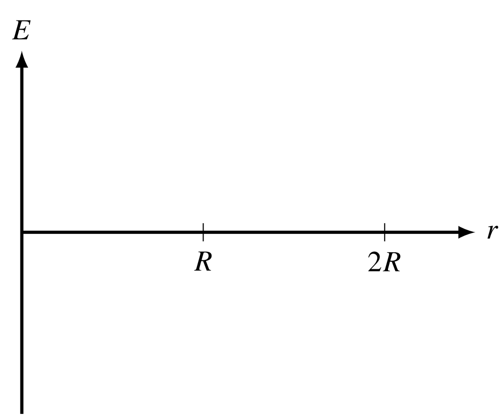



11. A very long, solid, nonconducting cylinder of radius $R$ has a positive charge of uniform volume density $\rho$. A section of the cylinder far from its ends is shown in the diagram above. Let $r$ represent the radial distance from the axis of the cylinder. Express all answers in terms of $r$, $R$, $\rho$, and fundamental constants, as appropriate.

(a) Using Gauss's law, derive an expression for the magnitude of the electric field at a radius $r < R$. Draw an appropriate Gaussian surface on the diagram.

(b) Using Gauss's law, derive an expression for the magnitude of the electric field at a radius $r > R$.

(c) On the axes below, sketch the graph of electric field $E$ as a function of radial distance $r$ for $r = 0$ to $r = 2R$. Explicitly label any intercepts, asymptotes, maxima, or minima with numerical values or algebraic expressions, as appropriate.



(d) i. Derive an expression for the magnitude of the potential difference between $r = 0$ and $r = R$.

ii. Is the potential higher at $r = 0$ or $r = R$?

____ $r = 0$ ____ $r = R$

(e) The nonconducting cylinder is replaced with a conducting cylinder of the same shape and same linear charge density. On the axes below, sketch the electric field $E$ as a function of $r$ for $r = 0$ to $r = 2R$. Explicitly label any intercepts, asymptotes, maxima, or minima with numerical values or algebraic expressions, as appropriate.