Directions: Show the steps required to arrive at the answer (if applicable). Work the problems on separate page.

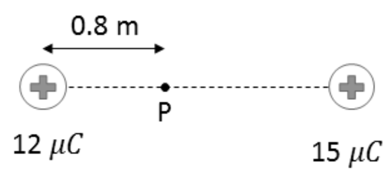
2.1 – Electric Potential

1. When charged particles are separated by an infinite distance, the electric potential energy of the pair is zero. When the particles are brought close, the electric potential energy of a pair with the same sign is positive, whereas the electric potential energy of a pair with opposite signs is negative. Give a physical explanation of this statement.

2. Distinguish between electric potential and electric potential energy.

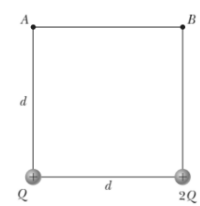
3. What work is required to move a 5.0 μC charge at a constant speed from infinity to r = 0.6 m from a 70 μC charge?

4. The particles below are 2 m apart. The left particle has a charge of 12 μC and the right particle has a charge of 15 μC. Point P is located 0.8 m to the right of the 12 μC charge as shown below.

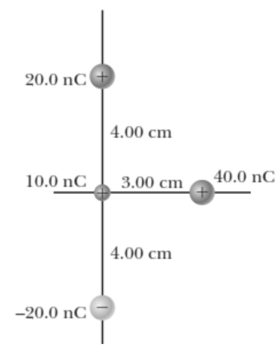


a) Calculate the electric potential at point P.
b) Calculate the work required to bring a particle with a charge of +10 nC from infinity to point P.

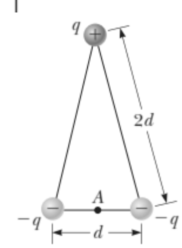
5. The two charges in the figure are separated by a distance d = 2.00 cm, and Q = 15.00 nC. Find the following:
a) the electric potential at A
b) the electric potential at B
c) the electric potential difference between B and A.



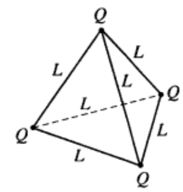
6. Two particles, with charges of 20.0 nC and -20.0 nC, are placed at the points with coordinates (0, 4.00 cm) and (0, -4.00 cm) as shown. A particle with charge 10.0 nC is located at the origin.
a) Find the electric potential energy of the configuration of the three fixed charges.
b) A fourth particle, with a mass of 2.00×10^{-13} kg and charge of 40.0 nC, is released from rest at the point (3.00 cm, 0). Find the speed after is has moved freely to a very large distance away.



7. The three charged particles in the figure are at the vertices of an isosceles triangle (where
d= 2.00 cm). Taking q = 7.00 mC, calculate the electric potential at point A, the midpoint of the base.



8. Four identical charged particles, each of charge Q, are fixed in place in the shape of an equilateral pyramid with side length L.

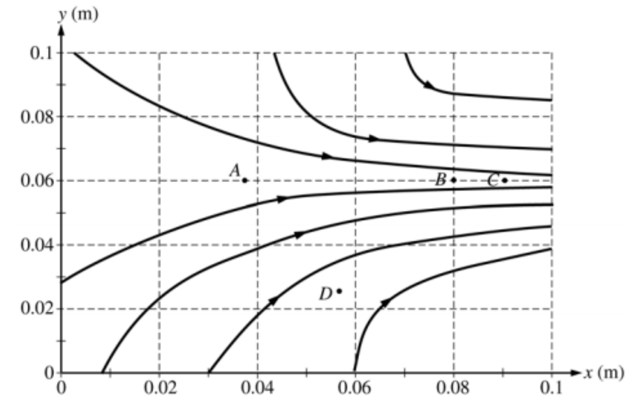


a) What is the electrical potential energy of this arrangement?

b) One of the four charged particles is released and allowed to move away under the influence of the electrostatic force from the other three chargers. How much kinetic energy will it have when it is very far away?

9. Two insulating spheres have radii 0.300 cm and 0.500 cm, masses 0.100 kg and 0.700 kg, and uniformly distributed charges -2.00 μC and 3.00 μC. They are released from rest when their centers are separated by 1.00 m. How fast will each be moving when they collide?

10. Consider the field diagram shown.

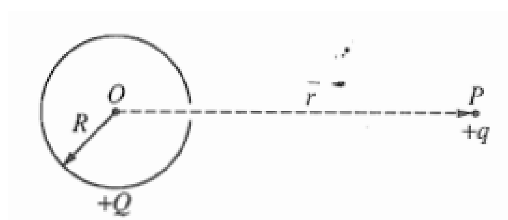


a) i. At which of these three points is the magnitude of the electric field the greatest?
   ii. At which of these three points is the electric potential the greatest?

b) An electron is released from rest at point B.
   i. Qualitatively describe the electron's motion in terms of direction, speed, and acceleration.
   ii. Calculate the electron's speed after it has moved through a potential difference of 10 V.

c) On the diagram, draw an equipotential line through D that passes through at least 3 field lines.

11. The nonconducting hollow sphere of radius R shown carriers a large charge +Q, which is uniformly distributed on its surface. There is a small hole in the sphere. A small charge +q is initially located at point P, a distance r from the center of the sphere. What work must be done to move the charge +q from point P to the center of the sphere?



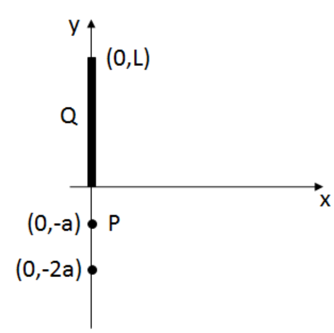
12. In a region of space, a spherically symmetric electric potential is given as a function of r, the distance from the origin, by the equation $V(r) = kr^2$, where is k is some positive constant.

a) What is the magnitude of the electric field at a point a distance R from the origin?

b) What is the direction of the electric field at the point a distance R from the origin?

13. A uniformly charged insulating rod of length 14.0 cm is bent into the shape of a semicircle as shown. The rod has a total charge of 27.50 mC. Find the electric potential at *O*, the center of the semicircle.

14. A long uniform line of charge has a total charge of Q an extends from the origin to (0, L) as shown on the diagram.



a) Write, but do not solve, a differential equation that could be used to solve the electric potential at point P, which is located at (0,-a).

b) Solve the equation from part a) to determine an expression for the potential at point P.

c) A charged particle of charge q is placed at point P. The particle is moves from point P to (0,-2a). Derive an expression for the kinetic energy of the particle when it reaches (0,-2a).

2.2 – Capacitors

1. A 20 μF capacitor is connected to a 20 V source.

   a) How much charge flows from the source?

   b) The plates of the capacitor are separated by 7 mm. What is the electric field intensity in the air gap?

   c) What is the area of the plates of the capacitor?

2. The area of each plate in an air gap capacitor is .20 m^2. The capacitance of the capacitor is 600 pF. The electric field between the plates of the capacitor is $4.3x10^4\ V/m$.

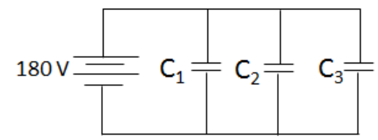
   a) What distance separates the plates?

   b) What is the potential difference across the plates?

   c) How much charge is stored on each plate?

3. The area of capacitor A's plates is double the area of capacitor B's plates. Both capacitors store the same amount of charge and the plate separation is equal. Find the ration of energy stored in A to B.

4. In the circuit shown, $C_1 = 3.0\ \mu F$, $C_2 = 4.0\ \mu F$, and $C_3 = 2.0\ \mu F$



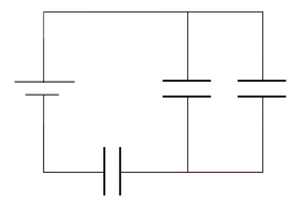
   a) Calculate the equivalent capacitance.

   b) How much charge does the battery supply?

   c) What fraction of the total charge is stored in C_2?

   d) How much energy is stored in C_3?

5. Three 425 μF capacitors are connected in the combination shown to a 6.00 V battery.



   a) What is the equivalent capacitance?

   b) What is the charge on each capacitor?

   c) What is the voltage on each capacitor?

6. As a person moves in a low humidity environment, electric charge accumulates on the person's body. Once it is at high voltage, either positive or negative, the body can discharge via shocks. Consider a human body isolated from ground, with typical capacitance of 150 pF.

   a) What charge on the body will produce a potential of 10.0 kV?

   b) Sensitive electronics can be destroyed by electrostatic discharge from a person. A certain device can be destroyed by a discharge releasing 250 mJ. To what voltage on the body does this correspond?

7. Three capacitors having capacitance of 8, 8, and 4 μF are connected in series with a 12 V battery.

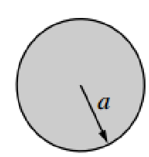
   a) What is the charge in the 4 μF capacitor?

   b) What is the total energy is the three capacitors?

   C) The capacitors are disconnected from the line and reconnected in parallel, with the positively charged plates connected together. What is the total energy now stored in the capacitors?

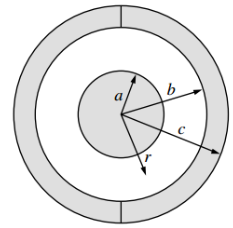
8. A parallel-plate capacitor has charge +Q on one plate and -Q on the other. The plates, each of area A, are distance d apart and separated by air. A single proton of charge +e is released from rest at the surface of the positively charge plate. With what kinetic energy will it arrive at the other plate with?

9. An isolated conducting sphere of radius $a = 0.20$ m is at a potential of -2,000 V.



   a) Determine the charge Q_0 on the sphere.

The charge sphere is then concentrically surrounded by two uncharged conducting hemispheres of inner radius $b = 0.40\ m$ and outer radius $c = 0.50\ m$, which are joined together as shown above, forming a spherical capacitor. A wire is connected from the outer sphere to ground, and then removed.



b) Determine the magnitude of the electric field in the following regions as a function of the distance r from the center of the inner sphere.
   i. $r < a$
   ii. $a < r < b$
   iii. $b < r < c$
   iv. $r > c$

c) Determine the magnitude of the potential difference between the sphere and the conducting shell.

2.3 – Dielectrics

1. Explain the function of the dielectric in a parallel plate capacitor. How does it increase the capacity?

2. Describe three ways you can increase the capacity of a parallel plate capacitor.

3. A capacitor is formed from two identical conducting parallel plates separated by a distance d. One plate is charged +Q, the other plate is charged -Q. A dielectric slab(an insulator) fills the space between the two plates. Where is the energy stored in this capacitor?

4. A 425 μF capacitor will be manufactured using a dielectric having a permittivity of $5.25\varepsilon_0$ and circular plates having a diameter of 1.75 cm.
   a) What should the plate separation (and the thickness of the dielectric) be?
   b) Is it likely that this large a capacity could be constructed using parallel plate architecture? Why?

5. A capacitor having no dielectric has a capacitance of 150. pF. It is charged up to 6.00 V by momentarily attaching it to a battery, and then disconnecting it.
   a) What is the energy stored in the capacitor at this voltage?
   b) What is the charge on the capacitor?
   c) A dielectric having a dielectric constant of 4.25 is now carefully inserted between the plates of the capacitor. What is its new capacitance?
   d) What is the charge on the new capacitor? What is the voltage on the new capacitor?
   e) What is the energy stored in the new capacitor? Explain the discrepancy between this answer and that of the same capacitor without the dielectric.

6. A capacitor consists of two parallel plates of area 25 cm^2 separated by a distance of 0.2 cm. The material between the plates has a dielectric constant of 5. The plates of the capacitor are connected across a 300 V battery.
   a) What is the capacitance of the capacitor?
   b) What is the charge on either plate?
   c) What is the energy in the charged capacitor?
   d) What is the energy density in the dielectric?

7. A capacitor is constructed of two identical conducting plates parallel to each other and separated by a distance *d*. The capacitor is charged to a potential difference of V_o by a battery, which is then disconnected.
   a) If an edge effects are negligible, what is the magnitude of the electric field between the plates?
   b) A sheet of insulating plastic material is inserted between the plates. What effect does this have on the capacitance?