Physics 4B
Chapter 21: Electric Charge

"Anyone who has never made a mistake has never tried anything new." – Albert Einstein

"Experience is the name that everyone gives to his mistakes." – Oscar Wilde

"The only real mistake is the one from which we learn nothing." – John Powell

"An expert is a person who has made all the mistakes that can be made in a very narrow field."
Niels Bohr

Reading: pages 561 – 573

Outline:

⇒ electric charge
    introduction
    charge is quantized
    conservation of charge
⇒ conductors and insulators (PowerPoint)
⇒ 3 ways of charging an object (PowerPoint)
⇒ Coulomb's Law
    two shell theorems
    principle of superposition

Problem Solving Techniques

The fundamental problems of this chapter deal with Coulomb's law. Given two charges and their separation, you should be able to calculate the force (both magnitude and direction) each exerts on the other. You should know how to use vector addition to find the resultant force when more than one charge interacts with the charge of interest. Variations include problems that ask you to find one of the charges or the position of a charge, given the force.

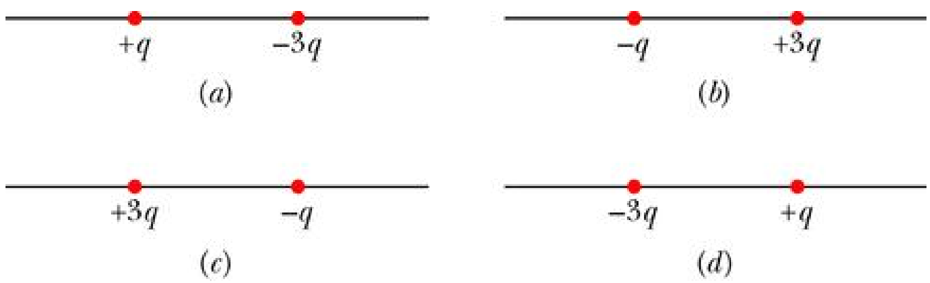
To find the value of one or more of the charges in some problems, a preliminary calculation must be performed prior to using Coulomb's law. For example, you may need to calculate the total positive charge in an object. The number of atoms in an object can be found from the mass of an atom and the mass of the object; the number of protons in an atom is given by the atomic number. Sometimes the molar mass is given (or can be found in the periodic table of the chemical elements) and you will need to divide that quantity by the Avogadro constant (6.022×10^{23} mol^{-1}) to calculate the mass of an atom.

Other problems deal with conducting spheres and you will need to apply the shell theorems. In addition, you should know that when two identical conducting spheres touch each other, the total charge is shared equally between them.

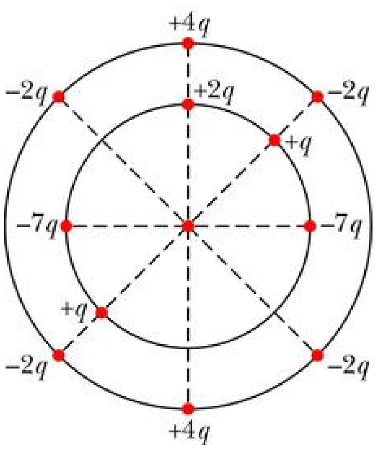
Finally, you should know the relationship between charge and current: current is the charge that moves into or out of a region per unit time.

Questions and Example Problems from Chapter 21

Question 1
The figure below shows four situations in which charged particles are fixed in place on an axis. In which situation(s) is there a point to the left of the particles where an electron will be in equilibrium?

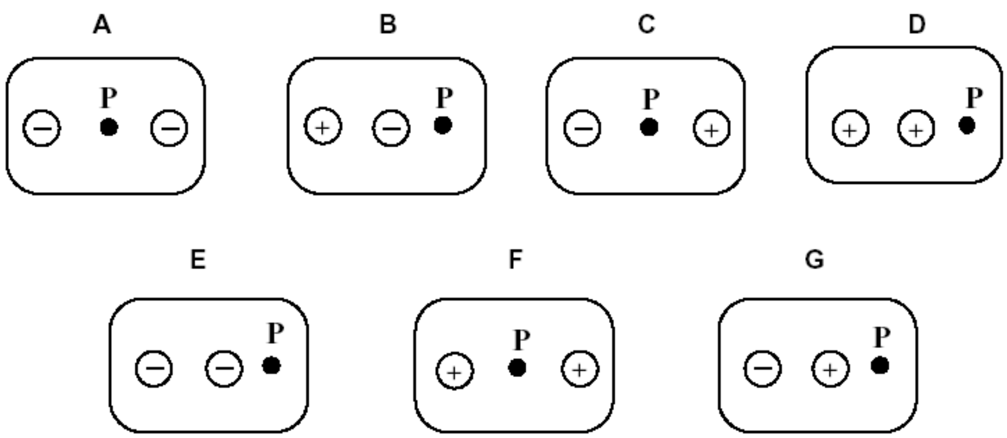


Question 2
In the figure to the right, a central particle of charge -q is surrounded by two circular rings of charged particles, of radii r and R, with R > r. What are the magnitude and direction of the net electrostatic force on the central particle due to the other particles?



Question 3
Given below are seven arrangements of two electric charges. In each figure, a point labeled P is also identified. All of the charges are the same size, 20 C, but they can be either positive or negative. The charges and point P all lie on a straight line. The distances between adjacent items, either between two charges or between a charge and point P, are all 5 cm. There are no other charges in this region.

For this problem, we are going to place a +5 C charge at point P. Rank these arrangements from greatest to least on the basis of the strength of the electric force on the +5 C charge when it is placed at point P. That is, put first the arrangement that will exert the strongest force on the +5 C charge at point P, and put last the arrangement that will exert the weakest force on the +5 C charge when it is placed at point P.



Strongest 1 ______ 2 _______ 3 _______ 4 _______ 5 _______ 6 _______ 7 _____ Weakest

Or, all of these arrangements exert the same strength force on the +5 C charge. _________

Or, all of these arrangements will exert zero force on the +5 C charge. ___________

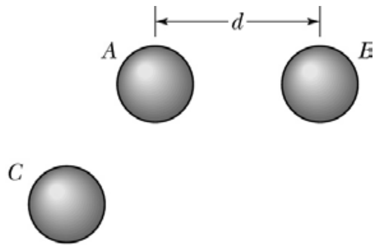
Please carefully explain your reasoning.

Problem 1
How many electrons would have to be removed from a coin to leave it with a charge of $+1.0 \times 10^{-7}$ C?

Problem 2
A current of 0.300 A through your chest can send your heart into fibrillation, ruining the normal rhythm of heartbeat and disrupting the flow of blood (and thus oxygen) to your brain. If that current persists for 2.00 min, how many conduction electrons pass through your chest?

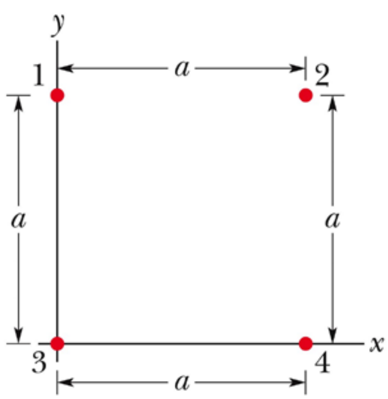
Problem 3

The initial charges on the three identical metal spheres in the figure below are the following: sphere A, Q; sphere B, -Q/4; and sphere C, Q/2, where $Q = 2.00 \times 10^{-14}$ C. Spheres A and B are fixed in place, with a center-to-center separation of d = 1.20 m, which is much larger than the spheres. Sphere C is touched first to sphere A and then to sphere B and then it is removed. What then is the magnitude of the electrostatic force between spheres A and B?



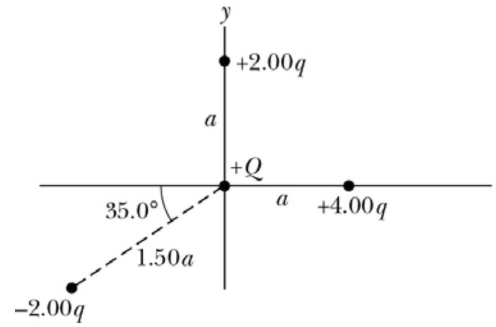
Problem 4

In the figure below, four particles form a square. The charges are $q_1 = q_4 = Q$ and $q_2 = q_3 = q$. What is Q/q if the net electrostatic force on particles 1 and 4 is zero?



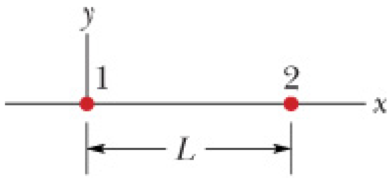
Problem 5

In the figure to the right, if Q = +3.20 × 10^{-19} C, q = 1.60 × 10^{-19} C, and a = 2.00 cm, what is the electrostatic force on the particle at the origin due to the other charged particles?



Problem 6

In the figure below, particle 1 of charge +q and particle 2 of charge +4.00 q are held at separation L = 9.00 cm on an x axis. If particle 3 of charge q_3 is to be located such that the three particles remain in place when released, what must be (a) the ratio q_3/q and the (b) x and (c) y coordinates of particle 3?



Problem 7

In the figure below, two tiny conducting balls of identical mass *m* and identical charge *q* hang from nonconducting threads of length L. Assume that θ is so small that tan θ can be replaced by its approximate equal, sin θ. (a) Show that

$$x = \left(\frac{q^2 L}{2\pi \varepsilon_0 m g} \right)^{1/3}$$

gives the equilibrium separation x of the balls.