Physics 102 Spring 2012 Problem Set 1 due Fri. Jan. 27, 4 pm

Reading: Chapter 16

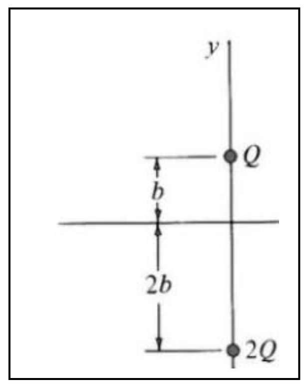
Some notes about problem sets & the course:

Always give your answers in SI units and use the correct number of significant figures. (For most problems, this means that you should keep any intermediate results to four significant figures, and quote the final result to 3 significant figures.)

IMPORTANT: Ordinarily, you should work with symbols all the way to the end of the problem. Only after you have solved for the desired unknown should you plug in numbers. This makes it easier to follow your logic, improves your understanding of the physics, makes it less likely that you will make mistakes, and makes it easier to fix a mistake if you make one. (There are occasional exceptions. For example, if the algebraic expression is very messy, but you know all the quantities in it, then you should plug in the numbers, since this will save a lot of writing.)

Our regular problem sets will be structured so you get practice in doing initial problems that involve very basic straightforward calculations (just beyond or at the almost plug-and-chug level so you know how to use the equations and handle the relevant quantities) to the level of complex problems requiring you to process a complex description and assemble tools to solve it from our course. This is why you are taking the course, whether you're satisfying bare-bones prehealth requirements (look at some sample MCAT problems if you don't believe me!) or whether you're planning a career in science (in which case solving complex problems will be your stock-in-trade) or whether you're taking the course as part of your liberal arts training. (In that case, learning about complex problem-solving and communicating your results clearly likely are the *main* skills you'll take away!)

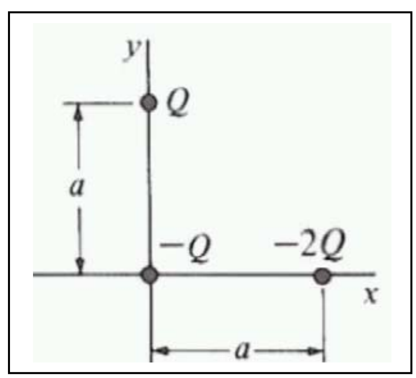
Independent Problem = You must do this problem without group assistance. You may talk with me or a dean-assigned tutor. You may not talk with physics clinic personnel about this problem.



1) (Independent Problem) Electric forces. Use the figure here in answering the following questions. Here b = 0.100 m and Q = + 1.00 μC. (1 μC is one "microcoulomb", i.e. 10^{-6} C).

a) What is the magnitude and direction of the electrical force on the top charge, Q? On the bottom charge, $2Q$? (*Think* about how the second question can be made easy once you have the first! Physics 101 will never leave us this semester…)

b) An additional charge Q is now placed at the origin in the figure below. What is the direction and magnitude of the electrical force it experiences?



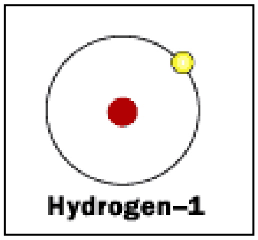
2) (Independent problem) Electric forces Refer to the figure to the right for this problem. Write down the force on the charge $-Q$ below in terms of a) vector components along the x and y axes (using unit vectors) and b) a magnitude and direction (given now as an angle with respect to the positive x-axis). Express your answers in terms of Q and a.

3) (Independent problem) Electric field. A test-charge of +5.00 nC placed at the origin of a coordinate system experiences a force of 4.00 x 10^{-6} N in the positive y-direction. What is the electric field at that location?

4) Electric fields and acceleration. In a particle accelerator used in our Physics 212 sophomore laboratory, we use an electric field of 1.00 x 10^{6} N/C to accelerate charged particles in vacuum in order to study their interaction with matter. (We will see how this works later in 102.) The particles start at rest and experience the same constant electric field as they accelerate across a gap 1.00 cm wide. If the particles being accelerated are electrons with an elementary charge *e* (See below for charge and mass): (a) how great is the acceleration each electron experiences? (b) How much energy do they have at the end of the gap?

5) Dynamics & electrical forces. Imagine that a Hydrogen atom really did look like the tiny solar system you may have seen in elementary school science books. It is made of a positively charged proton and a negatively charged electron. They have exactly the same magnitude of charge, but with opposite signs, so they attract one another.

This attractive force provides the centripetal pull which allows the electron to remain in a circular orbit of radius r. It plays the same role that gravity does in the solar system. So, there's much to be said for this analogy!



a) Given these parameters, estimate the speed with which such an electron would have to travel:
Proton mass: m_p=1.673x10^{-27} kg
Electron mass: m_e=9.109x10^{-31} kg
Charge on both: e=1.602x10^{-19} C
Radius of orbit: r_e=5.00x10^{-11} m

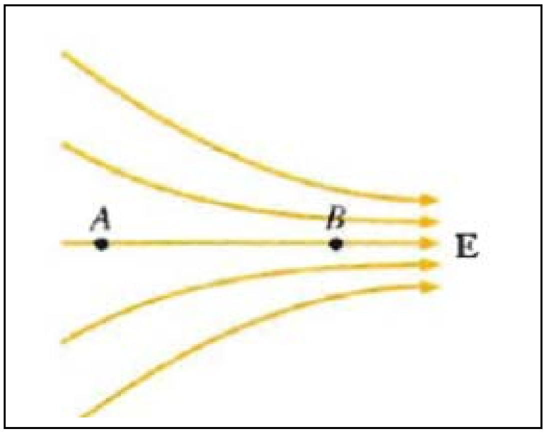
b) If the proton pulls on the electron, then the electron pulls with an equal and opposite force on the proton. If that's the case, why do we imagine the proton sitting still while the electron orbits around it?

6) (problem written by Prof. Catherine Crouch) You and a friend are blowing up balloons for your four-year-old nephew's birthday party, and idly decide to investigate some physics. You rub one balloon on your wool sweater until it acquires a charge of +3q, and rub another balloon on your fleece scarf until it acquires a charge of -2q. You hold these two balloons a distance *d* apart (*d* >> diameter of the balloons). If your friend now charges up a third balloon, where can your friend hold that balloon so that there is no net electrostatic force on it, and does it matter how much charge is on the third balloon?

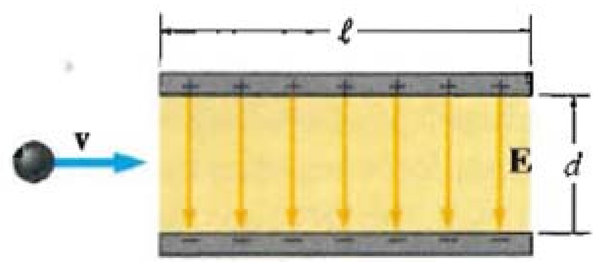
Hint: The three balloons must all be in a line, and you can choose that line to be the x-axis (or any other axis) to simplify the calculation. *Also*: The quadratic formula is useful for solving this problem.

7) **Sketching electric field** A charge of +2q and a charge of -1q are near each other. Draw the charges and sketch some field lines for this charge distribution, using the convention of 8 field lines for a charge of magnitude q (here q > 0). (That is, each point charge has associated with it 8 field lines for every q of charge.) Explain your reasoning briefly.

8) **Electric field line & equipotentials** The figure here shows electric field lines in a region that contains no charge.
(a) If identical charged particles are placed at points A and B in figure (a), which experiences the greater magnitude of electrical force from the field shown? Explain your reasoning.
(b) Draw an equipotential line in that passes through point A. Draw one that passes through point B. Be careful to show graphically how your answer relates to the nearby electric field lines. Explain your reasoning.



9) Using electric fields. (Adapted from Wolfson & Pasachoff) The figure here shows a schematic diagram of how charged particles can be steered using a uniform electric field, **E**, set up in a capacitor as shown. We will see this idea at work in many devices. The incoming particle at left represents an ink drop with charge q and mass m in an inkjet printer; the electric field is used to steer the ink drop onto the correct spot on the page. (You may ignore gravity in this problem, since it will exert a force weak compared to electrical forces here.) The ink drop enters the region of electric field exactly half-way between the plates, traveling with the velocity $\boldsymbol{v}$ as shown. Find the minimum speed v such that the drop avoids hitting the edges of the capacitor plates shown.



10) (From Wolfson & Pasachoff) A solid sphere contains positive charge uniformly distributed throughout its volume. Is the potential (the voltage) at its center higher, lower, or the same as at its surface? Explain your reasoning.

11) (Adapted from Walker) Honeybees acquire an electrostatic charge of up to 93 pC, because their wings "rub" against the air. (The process is analogous to the charge transfer from your hair to a balloon.) This charge is thought to play a significant role in pollination – the bee can detach grains of pollen from a distance, like a charged balloon attracting bits of paper. **a)** Given that the force required to detach pollen from an avocado stigma is 0.400 nN, find the minimum distance at which the electrostatic force between the bee and the grain of pollen is sufficient to detach the pollen. Treat the bee and pollen as point charges, and assume that the pollen has charge opposite in sign and equal in magnitude to the bee. **b)** The assumption that the pollen grain has opposite charge to the bee might initially seem outrageous, since the pollen is uncharged, at least when the bee is far away. However, if we assume that the avocado plant (including the pollen grain) is somewhat electrically conductive (because of the water that makes up many parts of the plant), explain qualitatively how the pollen grain could acquire a positive charge.


Image from honey.com