

Reference: Cutnell & Johnson, 18.1-18.5. (charge, Coulomb's Law, conductors/insulators, induction)

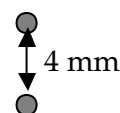
For this and all assignments, please be sure that what you hand in is neat, clean, and easily legible. **If your assignment isn't easily legible, we will not accept it.** (The reason for that is simple consideration for your TA, who has a lot of assignments to read...)

And, for every question, you should explain your thinking. You can explain using mathematics or words or diagrams, and in many cases the explanation can be very brief. But for this and all assignments, I'm asking the TAs to give no credit for answers without any explanation, even if the answer is correct.

- 1) Suppose you have a particle with a negative charge $-q$ exactly between two identical particles with equal, positive charge Q , as shown.



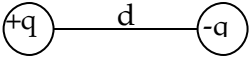
- a) If you moved the particle in the middle a tiny bit to the right, what direction would the total force be on it by the other two charges?
- b) Start with that particle back dead center again, and now move it a tiny bit up. In what direction would the total force be?
- 2) Rub a balloon on your head and stick it to the wall. And it sticks—very nice. We've talked in lecture about why it *sticks*. This question is about why, after a while, it *fall off*. Consider each of the following explanations.
- i) It falls because it uses up the energy you put on it when you rubbed it.
- ii) It falls because it uses up the charge you put on it when you rubbed it.
- iii) It falls because the energy you put on it slowly leaks off into the wall or the air.
- iv) It falls because the charge you put on it slowly leaks off into the wall or the air.
- a) Which explanation fits best with the model we've discussed, for why the balloon stays on the wall?
- b) Given your choice for part a, would it be possible, in principle under ideal circumstances, for a balloon to stick to a wall indefinitely?
- 3) Someone just showed me this last week: If you go to a crafts store and buy "glitter beads," you get a little plastic tube of tiny, metal covered glass or plastic beads. On a nice dry day, you can get a charge on the beads, and some of them will "hover" in the air inside the tube, maybe 4 mm apart from each other. It's pretty cool.



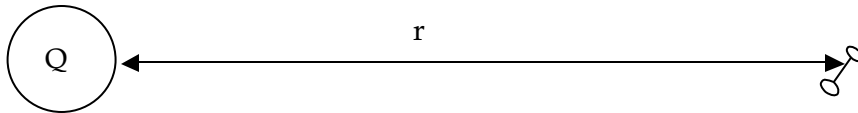
a) To make it even more cool, let's estimate how much charge there is on a bead. For that, let's just assume there are only two beads, one under the other, and it's the electrostatic repulsion that's holding the top bead up. If the beads are 4 mm apart, they each have a mass of (I'm guessing) 0.1 grams, and we can assume they have the same charge, about how much is that charge?

b) If the amount of the charge on the beads were to drop by 1/2, what would you expect to happen to the distance between them?

4) One more on those beads, another estimate: How much of a difference in the *mass* of a bead does that charge make?

5) Lots of things that are electrically neutral overall have one side that's electrically negative and one side positive (a water molecule, for example). We call such things "electric dipoles," and we can model them as  pairs of charged particles separated by a distance d . Usually d is a very small distance. (For water it would be around 10^{-11} m, thinking of a few protons worth of charge on one end – about 6×10^{-19} C -- and a few electrons worth at the other.)

Suppose you have a dipole that's free to move in any way (including rotate – imagine it floating in space). And there's an object with charge Q a distance r away. That distance r would be much larger than d , the distance of the dipole, so I've drawn the dipole small.



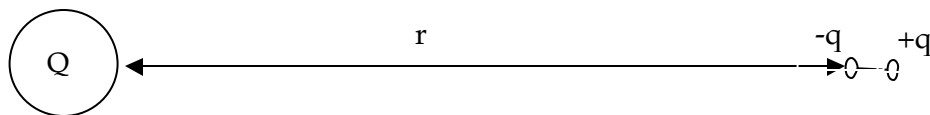
a) Would the dipole end up attracted to the charge, repelled, or neither?

b) Would the charge Q be attracted, repelled, or neither to the dipole?

c) Does the answer to parts a and b depend on the sign of Q ?

d) Since water molecules are dipoles, you can test your idea: Rub some wool or flannel on a hard rubber comb to get a charge on it, and then hold it near a thin stream of water coming from a faucet. What happens?

6) OK, we're not done with that dipole. Think of the dipole as lined up the way I've drawn here, so the $-q$ end is a distance r from Q , and the $+q$ end is a distance $r+d$.



a) Write a formula for the total force on the dipole by the charge Q .

b) If you were to double the distance r between Q and the dipole, what would happen to the magnitude of the force? Would it double? Cut in half? Something else?

You could work on this in a couple of ways; pick whichever one you prefer. One way would be to try numbers. You could use the water molecule if you like, $q = 6 \times 10^{-19} \text{ C}$ and $d = 10^{-11} \text{ m}$. A reasonable amount of charge for Q might be 10^6 Coulombs , and r could be $1/2 \text{ cm} = 5 \times 10^{-3} \text{ m}$. Find F , and then double r . Or you could make up your own numbers – you could pick easier numbers – just be sure d is much smaller than r .

The other way would be to simplify the formula you found in part a. The tricky part about that is figuring out what you can ignore along the way. Remember that d is a very small number, and so d^2 is a very very small number. When you're adding numbers, and you know one is very tiny compared to the others, you can often ignore that one – just cross it out. (So $1,000,000 + 2$ is about equal to $1,000,000$; $a + b \sim a$ for very small b .)