Physics - Electrostatics Tutorial

Question 1 – Fun with Tape

a) Press a piece of sticky tape, about 15-20cm in length, firmly onto a smooth unpainted surface, for example, a notebook or an unpainted tabletop. (For ease of handling make little "handles" by folding over a small section at the end of each tape.) Then peel the tape off the table and hang it from the edge of the table.

Describe the behaviour of the tape as you bring objects toward it (e.g., a hand, a pen).

The piece of tape swings towards the objects.

b) Make another piece of tape a described above. Bring the second tape toward the first. Describe your observations.

The piece of tapes repel each other.

It is important, as you perform the experiment above, that you keep your hands and other objects away from the tapes. Explain why this precaution is necessary.

Your hands will attract the tape, so your not sure if you're seeing the tapp-tape interaction or a hand-tape interaction. Aslo, things can get messy.

How does the distance between the tapes affect the interaction between them?

The interaction gets stronger as you move them closer together.

c) Each member of your group should press a tape onto the table and write "*B*" (for bottom) on it. Then press another tape on top of each *B* tape and label it "*T*" (for top).

Pull each pair of tapes off the table as a unit. After they're off the table, separate the *T* and *B* Hang one of the tapes from the edge of your table.

Describe the interaction between the following pairs of tape when they're brought near one another.

• two *T* tapes — Repel

• two *B* tapes — Repel

• a *T* tape and a *B* tape — Attract!

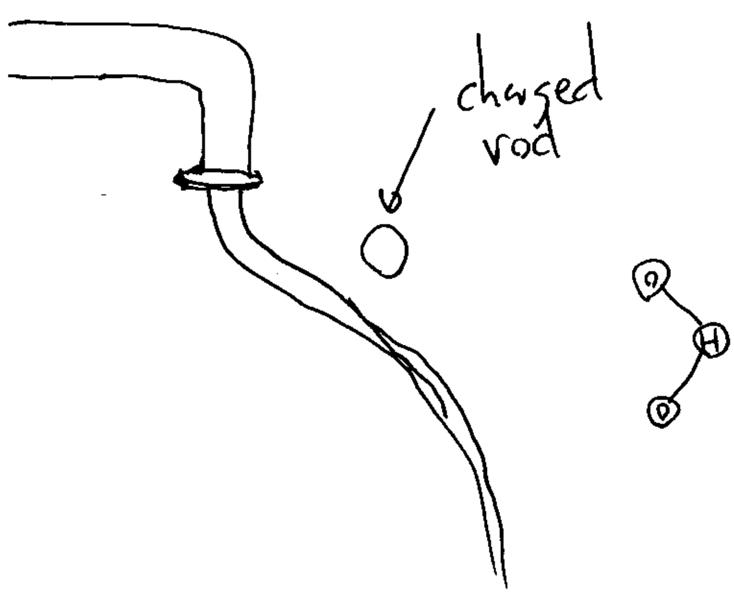
d) From this experiment can you identify which piece of tape is positively charged and which is negatively charged?

No, but you know that B and T have different charges.

Question 2 – Fun with Water

Use the silk to charge the glass rod or the fur to charge the plastic rod. Turn on a faucet a little such that the flow is gentle and smooth. Bring your charged rod near to the stream of water.

Explain what you observe. How is this consistent with Coulomb's Law?

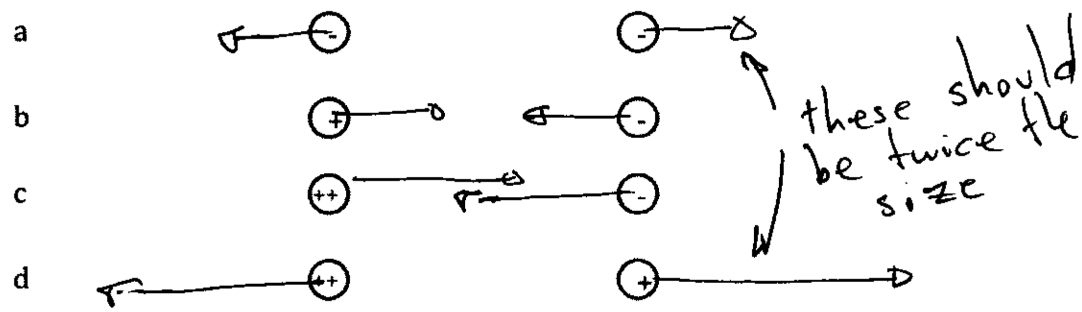


The water bends toward the rod.

Water is polar. As it falls, each molecule rotates, then wants to get attracted to the rod.

Question 2½ – Forces and Coulomb's Law

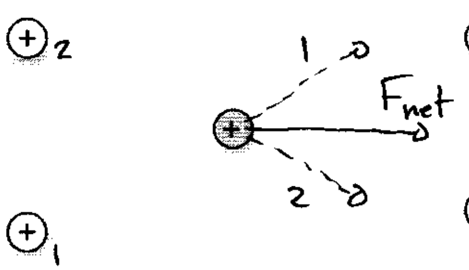
For each pair of charges, draw a force vector *on each charge* to show the electric force acting on that charge. The length of each vector should be proportional to the magnitude of the force. Each + and – symbol represents the same quantity of charge.



Question 3 – Drawing Forces

For each group of charges use a solid line to draw the force vectors acting on the grey charge and a dotted line to show the net force.

a)



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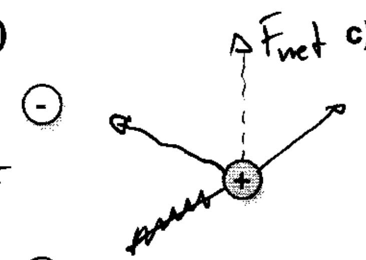

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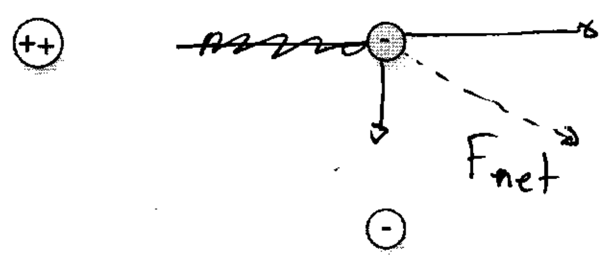
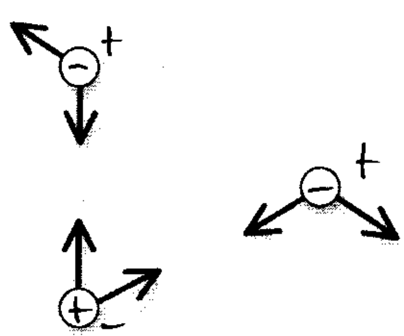


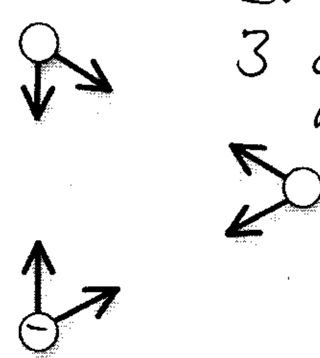
Question 4 – Assigning Charges

Can you assign charges such that the forces drawn are correct? If so, draw the charges, if not, explain why.

a)

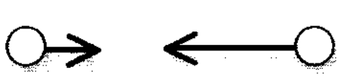


b)



Can't have 3 charges that all attract eachother in E&M.

c)

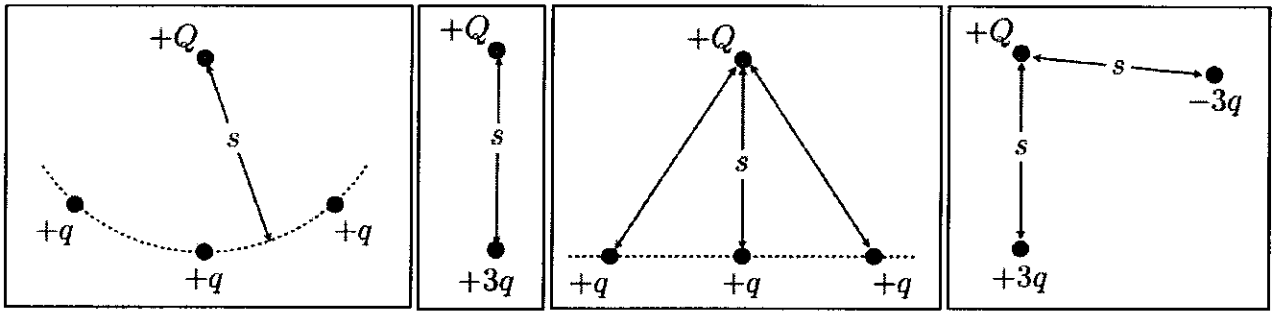


Forces aren't equal

d)

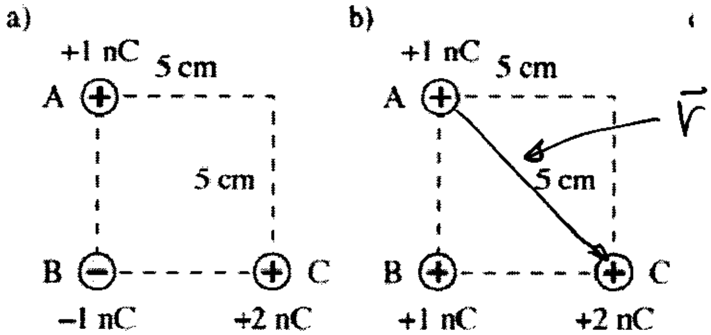
Question 5: Ranking Superposition of Charges

Rank the four cases below according to the magnitude of the net electric force on the +Q charge. Explain how you determined your ranking.



3 2 4 1

Question 6: Superposition



$$\hat{r} = \frac{\vec{r}}{|\vec{r}|} = \frac{0.05\,\hat{x}}{\sqrt{0.005}} - \frac{0.05\,\hat{y}}{\sqrt{0.005}}$$

$$\hat{r} = \frac{1}{\sqrt{2}}\hat{x} - \frac{1}{\sqrt{2}}\hat{y}$$

a) Calculate the net force on charge B.

$$\vec{F}_{A\,on\,B} = \frac{k\,1(nC)^2}{(0.05m)^2}(+\hat{y}) = 3.6\times10^{-6}\,N\,\hat{y}$$

$$\vec{F}_{C\,on\,B} = \frac{9\times10^9\,2(nC)^2}{(0.05m)^2}(+\hat{x}) = 7.2\,\mu N\,\hat{x}$$

$$\vec{F} = 3.6\times10^{-6}\,N\hat{y} + 7.2\,\mu N\,\hat{x}$$

b) Calculate the net force on charge C

$$\vec{F}_{B\,on\,C} = 7.2\times10^{-6}\,N\,\hat{x}.$$

$$\vec{F}_{A\,on\,C} = |\vec{F}|\,\hat{r} = \frac{k\,2(nC)^2}{(\sqrt{0.005})^2}\left(\frac{1}{\sqrt{2}}\hat{x} - \frac{1}{\sqrt{2}}\hat{y}\right)$$

$$= 3.6\times10^{-6}\left(\frac{1}{\sqrt{2}}\hat{x} - \frac{1}{\sqrt{2}}\hat{y}\right)N$$

$$= (2.5\,\hat{x} - 2.5\,\hat{y}\;N)\times10^{-6}$$

$$\vec{F}_{net} = 7.2\times10^{-6}\,N\,x + 2.5\times10^{-6}\,N\,\hat{x} - 2.5\times10^{-6}\,N\,\hat{y}$$

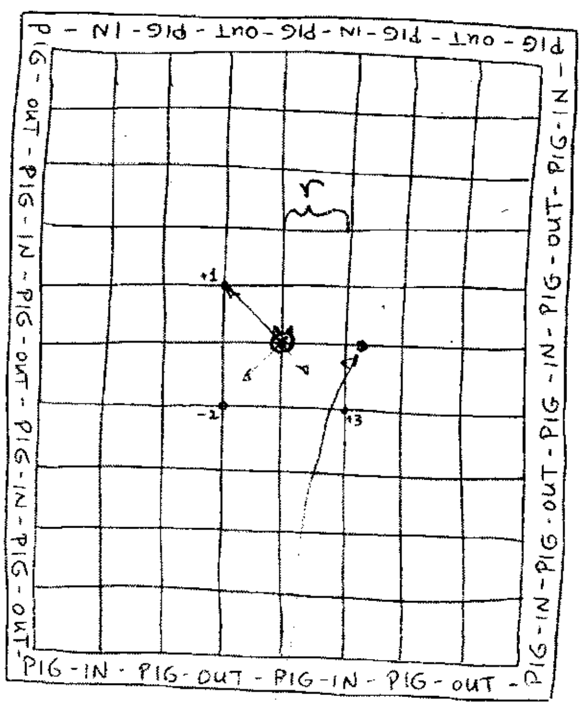
$$= (9.7\,\hat{x} - 2.5\,\hat{y})\times10^{-6}\,N$$

Question 7 – *Pig-In Pig-Out*

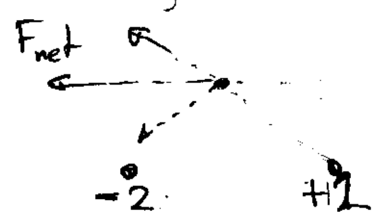
Pip and Jed are playing a game of *Pig-In Pig-Out*. The players draw charged stones from a bag and place them on the board. The first player (Jed) tries to place stones so that the pig will be *in* an electric field, while the second player (Pip) tries to place stones so that there is no net field where the pig is (i.e., to keep the pig *out* of the field). It's Pip's turn and she draws a stone with charge -2. Where should she place it to cancel out the field at the pig?

Note: the ***electric field*** *is the electric force the pig would feel if it had a charge Q, divided by the charge Q. The electric field vanishes at a point if and only if the electric force on a charge placed at that point is zero.*

Hint: Start by drawing the field due to the +1 charge.



Find the $\vec{E}$ of the charges there. Situation is the same as taking +3 and changing it to +2 while removing the +1.



$$|\vec{E}_{+2}| = \frac{kq}{(\sqrt{2}r)^2} = \frac{k2}{2r^2} = \frac{k}{r^2}$$

The x component is

$$E_x = \frac{k}{r^2}\left(-\frac{1}{\sqrt{2}}\hat{x}\right) = -\frac{k}{\sqrt{2}r^2}\hat{x}$$

The -2nC charge contributes similarly

So $\tilde{E}_{pig} = -\frac{2}{\sqrt{2}}\frac{k}{r^2}\hat{x}$

The -2 stone must be placed to the right to cancel.

Also, To cancel this field

$$\vec{E}_{pig} + \tilde{E}_{stone} = 0 \Rightarrow E_{stone} = \frac{(-2)k}{(2^{1/4}r)^2}$$

(q)

So stone is at $(2^{1/4}r)$

$2^{1/4}r$ to the right!

Question 8

The diagram below shows parallel insulating plates carrying charge density -σ (top plate) and +2σ (bottom plate). On the diagram, draw vector arrows to represent the electic field at various locations where the field is non-zero, letting the lengths of the arrows represent the relative magnitude of the field.