

Names:

Electric Field Activity

By the end of this activity you will be able to do the following:

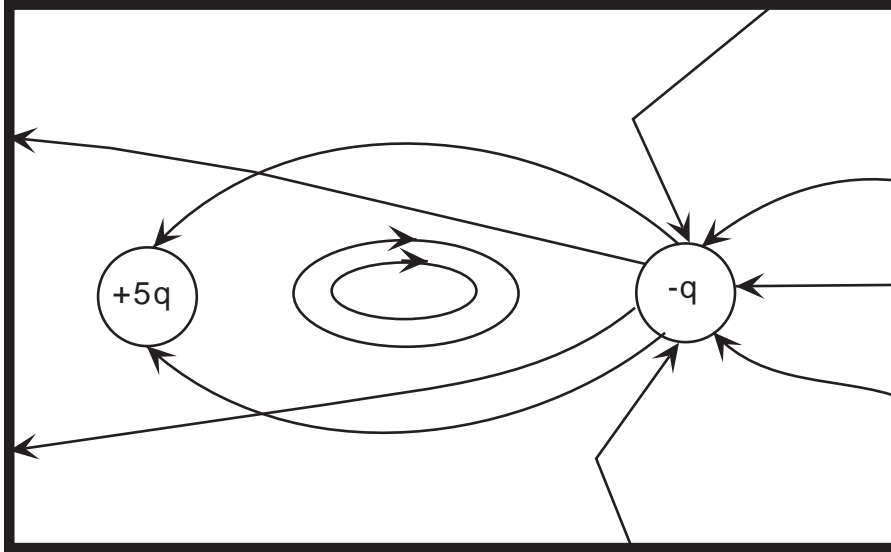
- Recognize correct and incorrect features in electric field lines.
- Qualitatively sketch field lines for a charge distribution.
- Qualitatively sketch the motion of a charge given the field lines.

1. **General Features of electric field lines** Electric field lines are a way of representing the electric field. There are three rules for drawing these lines:

- At each point \vec{E} is tangent to the field lines.
- The magnitude of \vec{E} is proportional to the density of field lines (i.e. to the number of field lines in a fixed area).
- They go away from positive charges and toward negative charges, or they start on positives and end on negatives.

Explain why these are sensible rules, given that the electric field is the force divided by the test charge.

Given these rules, look at the sketch of E field lines below. Some features of the lines are actually incorrect. Circle each incorrect feature, label it ($a, b, c...$) and explain on the next page why it is incorrect. Please consider only what is drawn inside the box, don't worry about what happens to the lines outside the box.

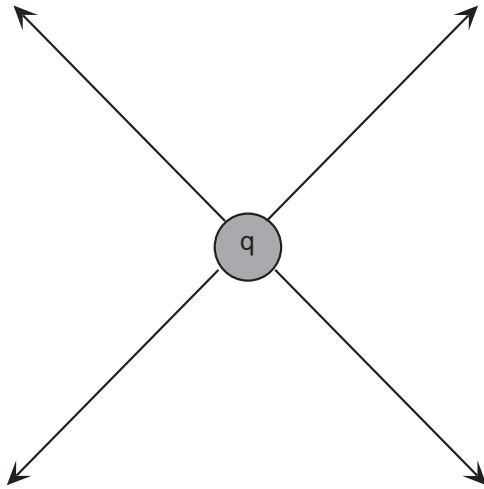


List the incorrect features on the sketch ($a, b, c...$) and explain why they are incorrect.

2. Learning how to sketch field lines

In this next section we will put together several pieces to learn how to qualitatively sketch field lines for some basic charge distributions.

- (a) A basic building block of drawing E field lines is knowing the E field lines for a single point charge.



- Verify that this is the correct sketch for a point charge by comparing the features here to each of the three rules listed on the first page.

- Draw a sketch of the E field lines for a single point charge $-q$.

- Draw a sketch of the E field lines for a single point charge of $+2q$.

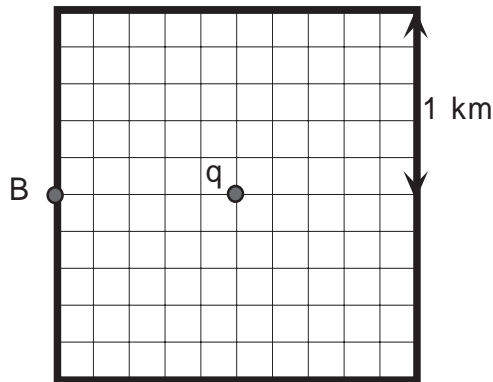
- For the rest of this worksheet we will take $1q = 4$ lines. Could we have taken $1q = 8$ lines? Explain.

- (b) Now consider two particles with the same charge q side by side, and look point A very close to one charge:



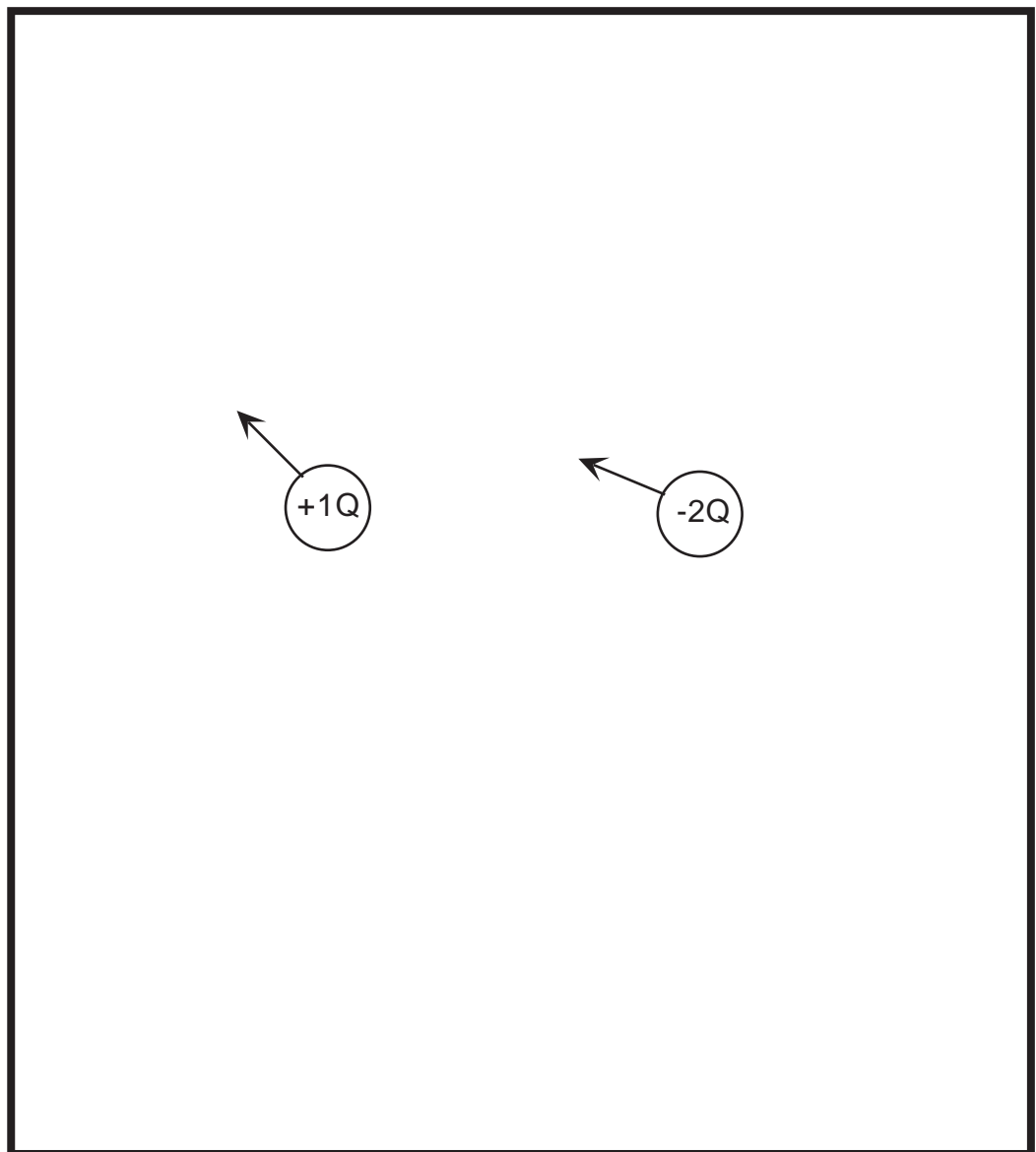
- Given that point A is 1 cm away from the left charge and 100 cm away from the right charge, write down the magnitude of the electric field due to each charge at point A . Leave your answer in terms of k (or $4\pi\epsilon_0$) and q , but put in values for r .
- How many times bigger is the field due to the left charge than the field due to the right charge?
- In the region much closer to the left charge than the right charge, is it reasonable to ignore the electric field due to the right charge? Explain.
- Given your answer to the last question, sketch the electric field in the region very close to the left charge.

- (c) Now consider being very far away from the same two particle of equal charge q . Imagine that the two charges are a distance of 1 cm away from each other. Imagine that the field point B is 1 km away.

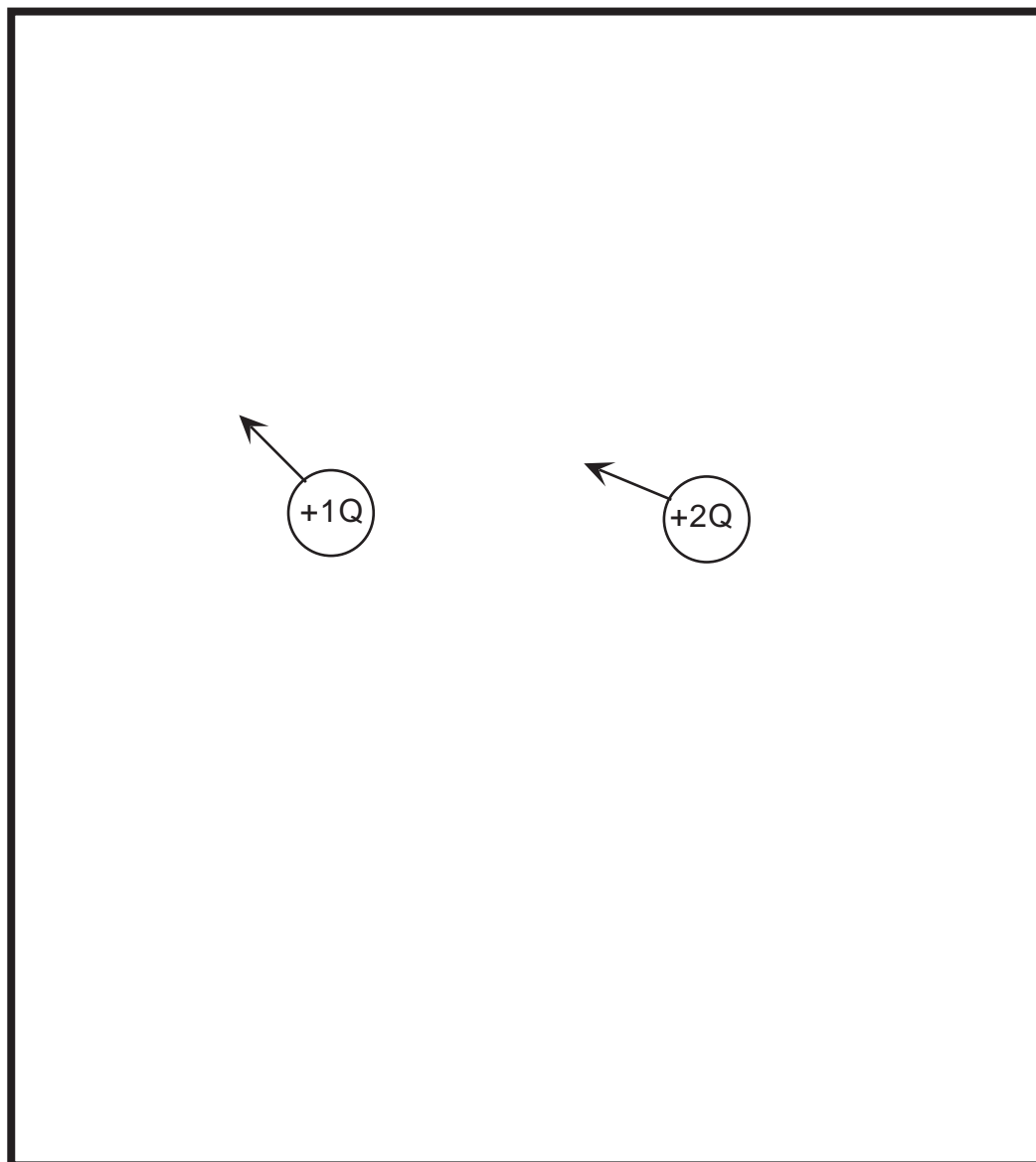


- On the sketch above a dot has been put at the center of the grid to represent one charge. Put a dot at the location of the other charge. Be sure that the distance between them is correct on the scale of the grid.
 - Given the location of the two charges, sketch the electric field lines of the two charges on the grid above.
 - What would the electric field lines look like on this 1 km scale if the two charges were $+q$ and $-q$ and still 1cm apart? Explain.
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- What would the electric field lines look like on this scale if the two charges were $+2q$ and $-q$? Explain.

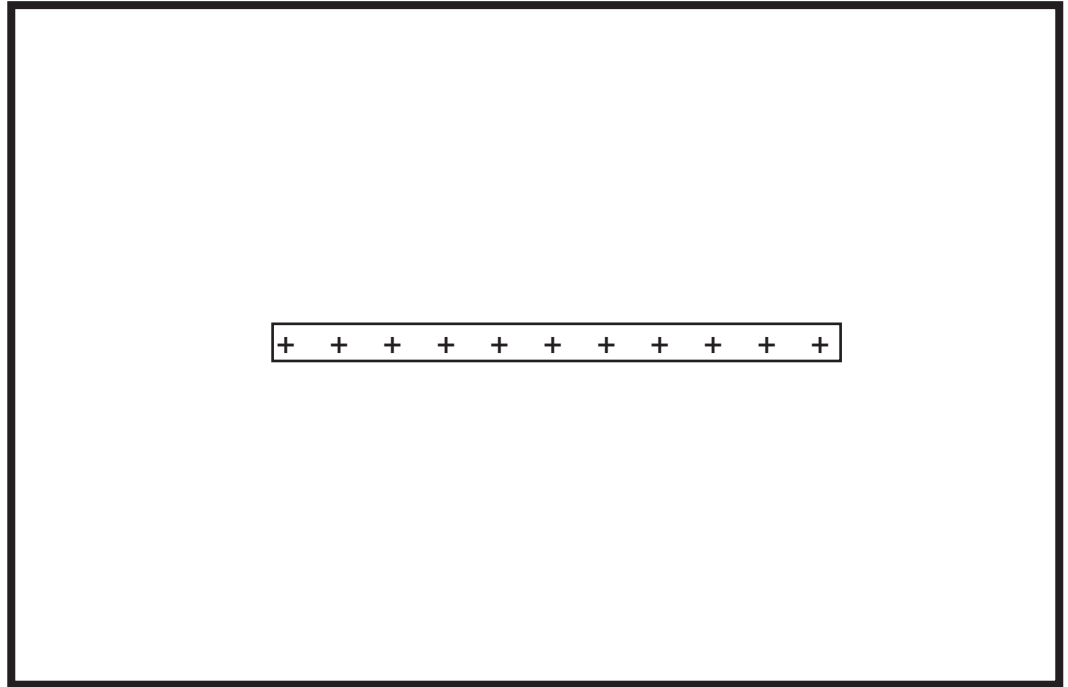
- (d) Now you will use what you have learned about the electric field to sketch the lines in a few cases. You should do this in pieces:
- Use what you know about the field very near a charged particle to draw the field very near both particles. One of the lines needed has been drawn in each case.
 - Use what you know about the field very far away to mark on the edge of the rectangle where the field lines should hit.
 - Use what you know about the general behavior of the lines to connect up the lines you have drawn.
- Two opposite charges.



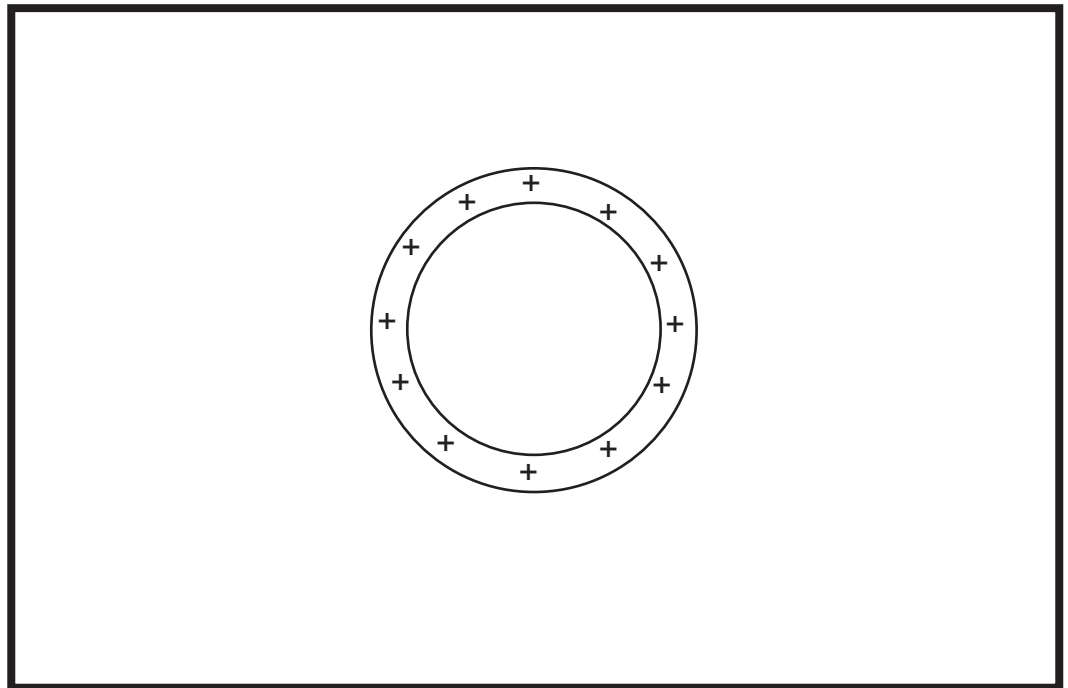
- Two like charges.



- Bar of charge.



- Ring of charge.



3. **Checking your work with a computer program** In this section we will work with the program **EM Field** to generate E field lines with the configurations we just sketched E field lines for. Part of this section is simply to familiarize you with the program and to convince you that it is working correctly, the other part is to see if your E field lines were qualitatively correct.

- Turn on the computer, click on **408 Student** and then on the **408 Student Folder** and on **EM Field**.
 - Under the **Sources** menu go to **3D point charges**.
 - From the **Display** menu choose **Show Grid** and **Constrain to Grid**.
 - Pull out a **+1** charge from the bottom and put it in the center of the grid.
 - From the **Field and Potential** Menu chose **Field Lines**.
 - Click on several places on the grid to see the field lines. Are the field lines what you expect, that is, do they seem to be drawn correctly? Explain and sketch.
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- Notice that the program allows electric field lines to start anywhere. You could, for example, have 10 lines between zero and 45 degrees, and none anywhere else. Explain why such a set of E field lines is inconsistent with the rules for drawing these lines.
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- Describe how you would use this program to correctly generate the E field lines for a single charge. That is, where would you click?

- Choose **Add more charges** from the **Sources** Menu. Drag out a -2 charge, and put it three grid points away from the $+1$ charge. Create some E field lines by clicking in appropriate places around the -2 charge. (Hint - don't click along the $+x$ or $-x$ direction; these are special directions and won't be so helpful.) Do these E field lines agree with those that you sketched? Reconcile any disagreements.

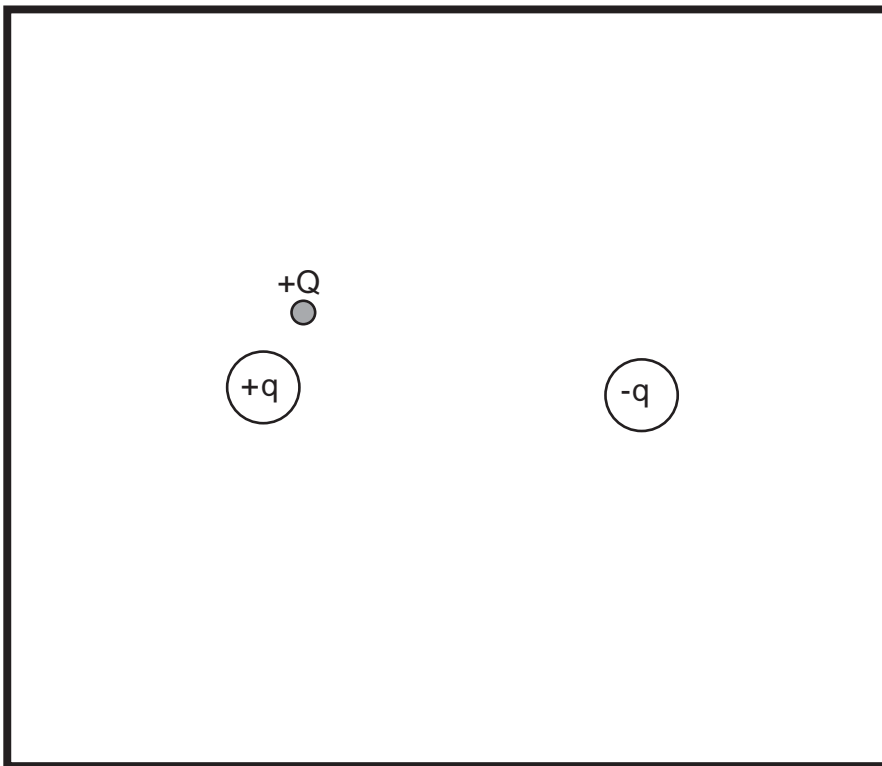
- Drag the -2 charge off the screen and replace it with a $+2$ charge. Create some E field lines by clicking in appropriate places around the $+2$ charge. Do these E field lines agree with those that you sketched? Reconcile any disagreements.

- Challenge question (only for those students who have time). You may have noticed a region of space which the field lines appear to be avoiding. Is the electric field there very large or very small? How can you tell?

- Take a few minutes to explore the E field for any charge configuration of interest to you. Sketch the lines below.

4. **How does a charge move in an electric field?** We are now experts at drawing the E field, but how do we use it to find the motion of a charged particle? We will find that out in the following steps.

- Consider two charges ($+q$ and $-q$) that are nailed down, and a third, much smaller charge $+Q$ that is free to move. On the picture below,
 - sketch the E field lines **due to the fixed charges $+q$ and $-q$ only**,
 - sketch (with a different color) the path of $+Q$ if it is released from rest where it is. Explain why you chose this path.



- Now you can check your answer with a computer simulation:
 - Open up Electric Field Hockey on the computer.
 - From the **Level Menu** select level zero.
 - Move charges from the upper right hand corner so that we have a $+q$ and $-q$ as in the picture above.
 - Then move the “puck” to the location of the $+Q$ and let it go. (If your puck is negatively charged, put it near the fixed negative charge.)
 - Sketch it’s motion on the picture above with a different color. (You can see the motion again by clicking on the **repeat** button in the lower right corner.) Did your prediction agree with the actual motion?

- In order to make sense of the motion of the puck, we can look at the simpler case of the gravitational field near the earth. In the space below, sketch the gravitational field near the earth. (Hint: what is the direction of the gravitational force?)

- On the same sketch, but using different colors, draw the path of an object dropped in the gravitational field, and the path of an object initially thrown upward at about a 45 degree angle.
- In the light of your above sketch, comment on the following remark of a fellow student: *A charged particle must follow the electric field lines since field lines are in the direction of the force.* Do you agree or disagree? Explain.

- In the tutorial on "Motion in two dimensions" we figured out the acceleration of a particle given the path and some information about the speed (e.g. constant, increasing, or decreasing). How do you estimate the acceleration graphically if you have the velocity vectors at two different times?

- Invert the process above to say how you would find the velocity at the new time if you know the old velocity and the acceleration.

- Use your scheme to get a qualitative sketch of the path of the charged particle given on a previous page. (Hint: you will probably need a large sheet of paper and several different colored pencils.)

- In the remainder of the activity you can play with **Electric Field Hockey** to learn a bit more about motion in an electric field. Start by selecting level 1. Try to get the puck in the goal using **only one charge**. Can you do it? Explain, draw pictures.

- Now try to use only two charges to get it in the goal (think about the exercise above). Can you do it? Explain and draw pictures.

Continue adding charges until you can get the puck in the goal, but use as few charges as possible. Once you do get the puck in the goal, sketch the configuration of charges that worked.

- Once you have done level one, move to the other levels, trying to use as few charges as possible to get the puck in the goal.