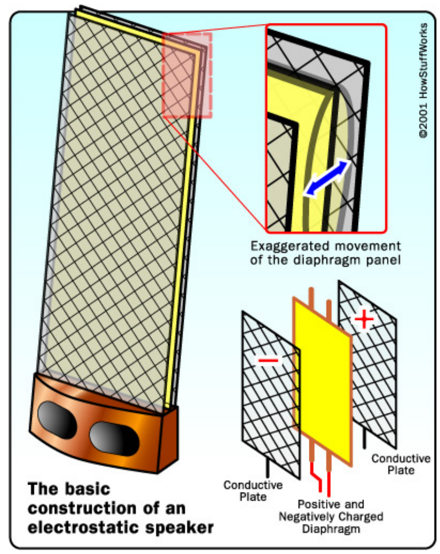
University of Calgary
Department of Physics and Astronomy
PHYS 259, Winter 2017

Labatorial 2: Electric Fields of Charge Configurations

The electric field is a rather abstract concept when you first learn about it, but it turns out to be a useful tool for situations where you are dealing with more than two point charges – that is, almost everything in real life. Instead of studying interactions between pairs of charges and adding them up (which can become quite cumbersome), you consider a property of space, generated by the source charge(s): the electric field.
A technical application is the electrostatic speaker. While most loudspeakers produce sound with magnetic fields that cause a diaphragm to vibrate, these speakers use an electric field generated by oppositely charged grids, and a diaphragm that fluctuates in this field due to its time-varying charge. (Image from electronics.howstuffworks.com, where you can find more information)



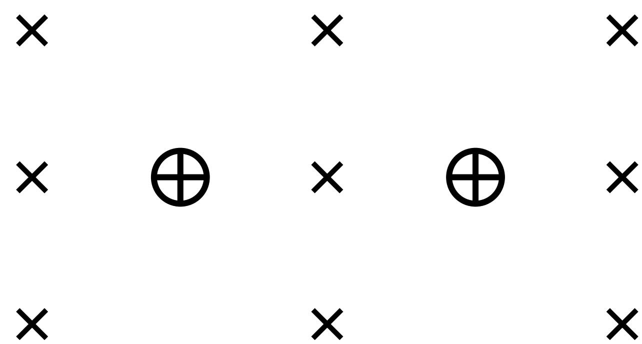
Goals:
To understand how electric fields and forces are related, and how electric fields are represented graphically. To understand what the electric field of a distribution of point charges looks like by using superposition. To practice calculating the electric field of a continuous charge distribution with integration.

Preparation:
Halliday, Resnick, and Walker, "Fundamentals of Physics" 10th edition, Wiley: 22.1–22.6.

Equipment:
Electric Fields from Point Charges applet
http://www.compadre.org/Physlets/electromagnetism/illustration23_2.cfm

1 The Electric Field of a Configuration of Point Charges

Question 1: At each point indicated by an ×, draw the individual electric field vectors due to the two positive charges, labeling which is which. In a different colour, draw the **net** electric field vector at each point ×.

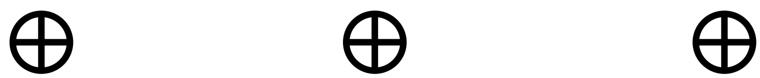


The following questions will require you to use the applet Electric Fields from Point Charges to explore the electric field generated by a series of point charges.

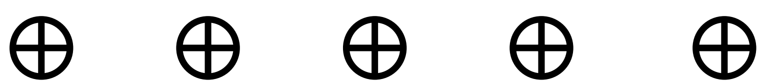
Open Firefox browser and select the bookmark "Physlets". Click on "Electromagnetism" from the top menu (do not use the drop down menu). On the left had side click on "Electric Fields", and then on "23.2: Electric Fields from Point Charges"

Question 2: Set up the configuration of two positive charges shown below and sketch the electric field lines into the diagram provided. Are these field lines consistent with your prediction in Question 1?

Question 3: Now add another charge halfway between the two, as in the diagram below, and sketch the electric field lines.



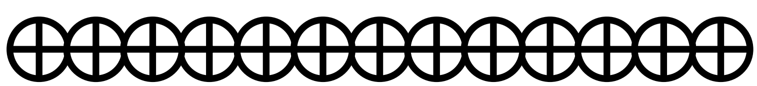
Question 4: Now add two more charges into the two gaps, as in the diagram below, and sketch the electric field lines.



Question 5: What do you notice about the electric field above and below the line of charges as the number of charges increases?

Question 6: Do electric field lines ever cross? Explain how you know using the idea of superposition.

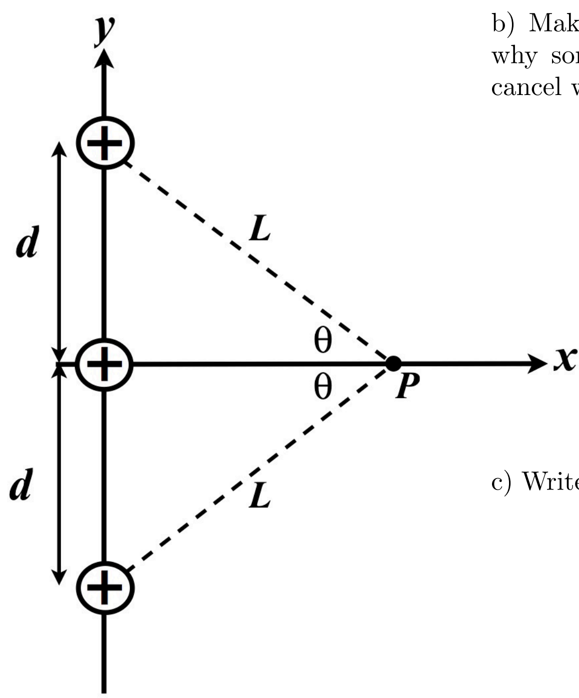
Question 7: What would you expect the electric field to look like for a string of positive charges without any spacing? Sketch this in the diagram below and verify using the applet.



CHECKPOINT 1: Before moving on to the next part, have your TA check the results you obtained so far.

2 Using Symmetry to Calculate Electric Fields

Question 8: The figure below shows three equal positive point charges q equally spaced on the y-axis. Calculate the electric field $\vec{E}(x)$ at the point P marked on the positive x-axis by following the steps below:



a) For each of the three charges, draw and label the corresponding individual electric field vectors at point P.

b) Make an argument based on the symmetry of the problem why some components cancel and others add. The ones that cancel we can simply ignore.

c) Write down expressions for $\sin\theta$ and $\cos\theta$ in terms of d and x.

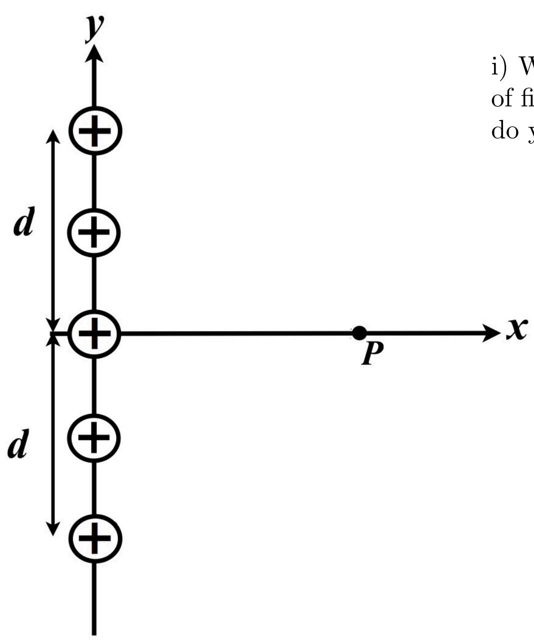
d) For each of the three charges, write down the magnitude of the electric field in terms of q, x, d.

e) For each of the three charges, write down the x-component of the electric field in terms of q, x, and d. Why don't we need to calculate the y-components?

f) Use these results to calculate the net electric field at point P. What direction does it point?

g) If point P is very far away from the charges, what do you expect the electric field to be and why? Check by considering $x \gg d$ in your answer to part (f).

h) If point P is very close to the middle charge, what do you expect the electric field to be and why? Check by considering $x \ll d$ in your result for part (f).



i) Write down what the electric field at point P is for the string of five identical charges q shown in the diagram to the left. Hint: do you need to do any additional calculations?

Last Checkpoint! Clean up your area, and put the equipment back the way you found it. Call your TA over to check your work and your area before you can get credit for the labatorial.

Equations and Constants

$$
\begin{aligned}
F_g(r) &= G\frac{m_1 m_2}{r^2} \\
U_{grav}(y) &= mgy \\
K &= \frac{1}{2}mv^2 \\
v_x(t) &= v_{0x} + a_x t \\
x(t) &= x_0 + v_{0x}t + \frac{1}{2}a_x t^2 \\
v_x^2(t) &= v_{0x}^2 + 2a_x(x(t) - x_0) \\
\omega &= \frac{d\theta}{dt} \\
v &= \frac{2\pi r}{T} = \omega r \\
a_{rad} &= \frac{v^2}{r} = \omega^2 r \\
F_C(r) &= \frac{1}{4\pi\epsilon_0}\frac{|q_1 q_2|}{r^2} \\
\vec{E} &= \frac{\vec{F}}{q}
\end{aligned}
$$

$$
\begin{aligned}
g &= 9.81\frac{m}{s^2} \\
G &= 6.67 \times 10^{-11}\frac{Nm^2}{kg^2} \\
\frac{1}{4\pi\epsilon_0} &= 8.99 \times 10^{9}\, Nm^2C^{-2} \\
\epsilon_0 &= 8.85 \times 10^{-12}\, C^2N^{-1}m^{-2} \\
e &= 1.60 \times 10^{-19}\, C \\
m_e &= 9.11 \times 10^{-31}\, kg \\
m_p &= 1.67 \times 10^{-27}\, kg \\
m_n &= 1.67 \times 10^{-27}\, kg
\end{aligned}
$$

$$
\begin{aligned}
\int \frac{dx}{(x^2 \pm a^2)^{3/2}} &= \frac{\pm x}{a^2\sqrt{x^2 \pm a^2}} \\
\int \frac{xdx}{(x^2 \pm a^2)^{3/2}} &= -\frac{1}{\sqrt{x^2 \pm a^2}} \\
\int \frac{dx}{x^2 + z^2} &= \frac{1}{z}\arctan(\frac{x}{z}) \\
\arctan(x) &= -\arctan(-x)
\end{aligned}
$$