Teachers Guide for set of Electric Fields Mini-Games
by
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Game 5 in the series of 7 – Mitey Fields

Knowledge Intro: Your students should know that a charged particle will experience an electromagnetic force if placed in the electric field of another charged particle.

A relationship exists among:

- the strength of the electromagnetic force between the two particles
- the net charge for each particle and
- the distance between the two particles

The relationship can be expressed mathematically:

$$F \propto (q_1 * q_2)/ r^2$$

q_1 = net charge of particle 1
q_2 = net charge of particle 2
r = distance between the two particles

We are careful to call this a "relationship" and not Coulomb's Law explicitly because we have left out the very small constant, $k = 8.99\times10^9\ \mathrm{N\ m^2\ C^{-2}}$. For novice students it can be confusing to include the constant.

This relationship can also be described in words:

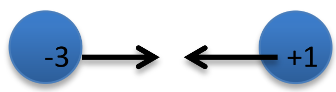
- The Force between charges is directly proportional to the product of the net charges of each particle
  (Meaning: As the net charge of each particle increases, the force they exert on each other increases.)

- Force is inversely proportional to the square of the distance between the two particles
  (Meaning: As the distance between the two particles increases, the force they exert on each other decreases in a non-linear fashion.)

When both particles carry a positive net charge, they will *repel* each other. Their product will yield a *positive* force value.

When both particles carry a negative net charge, they will *repel* each other as well. Yet, their product will yield a *positive* force value.

When the particles carry opposite charges, they will *attract* each other. Their product will yield a *negative* force value. (Note: The absolute value is used in Coulomb's Law.)



When a net force acts on charged particles, they undergo an acceleration, or change in velocity. As the particles move, the distance between them changes, and the electromagnetic force changes. A change in the electromagnetic force will result in a change in acceleration.

Sometimes charged particles can move around freely. This is generally true of electrons (they are almost 2000 times less massive than protons). Protons are also bound to neutrons within the nucleus by the "strong nuclear force".

In order to simplify calculations, we will treat a charged particle as "pinned" or fixed in one location.

The Gameplay: The game Mitey Fields starts with a short tutorial including a dragon on how to place and activate charges to create an E-field. The player is then able to move "Mitey", a mischievous, escaped mite with a charge of +1. In an embodied manner the students then drag and place "pinned" charges anywhere on the screen and can observe the multiple vectors in the changing E-field by clicking on the "sunglasses" icon.

There are multiple levels in this game that can help students learn about forces. The interactions are based on Coulomb's Law so that acceleration and electrostatic forces are represented accurately.

Students will learn:

- And receive reinforcement that like charges repel each other
- That opposite charges attract each other
- That the magnitudes of the pinned charges affect the acceleration of the unpinned charge (Mitey)
- That distance affects positive acceleration and negative acceleration
- The E-field is highly interactive, all charges affect each other into infinity

You should remind students that the game disregards gravity. It is clearly a 2D simplification of our universe's 3D E-field. The goal is to encourage students to visualize the multiple charge interactions in a game-like manner.

Distance between charges is a factor in play, and a component in Coulomb's Law - the **denominator** is the square of the distance between the two charged particles.

The game mechanic allows students to explore how the magnitude of the charges affects how Mitey moves through the field – essentially the **numerator** in Coulomb's Law which is the product of the two charges. The **valence of the charges** (whether they are positive or negative) is also taken into account with direction that Mitey travels.

You may also want to discuss with students constant velocity.
Will Mitey move with a constant velocity in the presence of another charge?

Higher Levels with Gold Bars – In the later levels, students will see gold bars. The bars allow the E-field to pass through, but not the larger atom called Mitey. These levels encourage learners to conceptualize curves in the E-field. Some students will enjoy trying again and again to get Mitey in the hole. Others will stop after a couple of tries, that perseverance is just a trait of the player, it is not to be penalized.

Also, play around with the *sunglasses icon* (top left – "vector view").