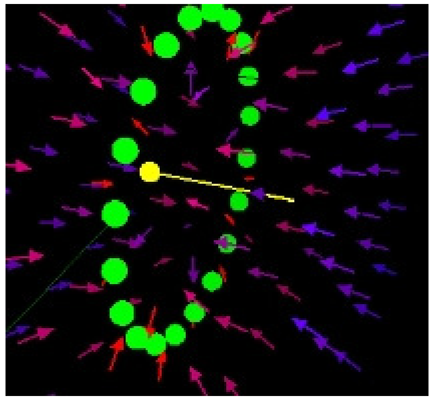

Screen shot of simulation showing a test charge (yellow) moving through a ring of charge.

Lesson Plan: Charge Ring Trajectory Simulation

Key Topic/Concept: Electric Field and Newton's 2nd Law

Materials:

- One guide sheet for each student
- Computer with simulation downloaded
- Science Notebook

The EJS Charge Ring Trajectory simulation can be downloaded from the comPADRE National Digital Library if it not available on the local computer:
< http://www.compadre.org/OSP/items/detail.cfm?ID=9683>

Safety Precautions: No special precautions needed for this lesson.

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Physics Classroom Curriculum Alignment:

Static Electricity- Lesson 3: Newton's Laws and the Electrical Force
Static Electricity- Lesson 4: Action-at-a-Distance
Static Electricity- Lesson 4: Electric Field Intensity

NC Curriculum Alignment (2004):

1.05 Analyze evidence to:

- Explain observations.
- Make inferences and predictions.
- Develop the relationship between evidence and explanation.

1.08 Use oral and written language to:

- Communicate findings.
- Defend conclusions of scientific investigations.

1.09 Use technologies and information systems to:

- Research.
- Visualize data.

8.01 Analyze the nature of electrical charges.

- Investigate the electrical charging of objects due to transfer of charge.
- Investigate the conservation of electric charge.
- Analyze the relationship among force, charge and distance summarized in Coulomb's law.

I. ENGAGEMENT

Review: Test Charge and Electric Field.

II. EXPLORATION

Have students work in pairs and open the EJS Electric Field simulation. Allow students about 5 minutes to explore with the simulation.

III. EXPLANATION/CONCEPT INVENTION

Ask students to reset the simulation begin with questions in the guide below. When most students have completed the guide, review the answers with the whole group.

IV. EXPANSION OF THE IDEA

Ask students to write a brief description or make sketches to explain the idea of a field.

V. EVALUATION

Teacher circulates to check that the Introduction and Electric Field Worksheet is completed and stapled into the science notebook.

Introduction: Field Review

Review: What is an Electric Field?

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What is a "test charge"?

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Activity Guide: EJS Charge Ring Trajectory Simulation

In this simulation, you can see the electric field around a ring of fixed charges (green) and a test charge (yellow) that moves in the field. You can use the slider to change the size of the ring (in cm). Above the simulation, you can see a record of the test charge's position and velocity which you can edit when the simulation is paused.

1. Run the Applet file on-line OR run the simulation by double-clicking on the ejs_electric_sampler.jar and then navigating to the Dipole Trajectory simulation and run the simulation by double-clicking on the green arrow. Push play ( ) to see the test charge move in the field.
2. You can `click-drag` in the window to rotate the view and `shift-click` to zoom in and out. The plot shows the x-component of position (blue) and x-component of the velocity (red) of the yellow test charge as a function of time. The convention is that a test charge is positive, but of small enough size so that its own electric field can be neglected. Therefore, the simulation only shows the electric field due to the green charges. Are the green charges positive or negative? Explain.

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3. Why does the test charge stay on the x-axis?

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4. Change the radius of the ring of green charges and observe the motion. How does the period of oscillation change as you change the radius?

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5. If you pause ( ) the simulation and move the test charge slightly off-axis, what happens? Why?

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6. Reset ( ) the simulation and play it with the initial parameters (test charge on the x-axis and a ring radius of 8 cm). Look at the data plot. What is the period of oscillation?

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Optional Quantitative Analysis:

7. The equation for the electric field along the central x-axis of a ring of charge is given by

$$E = \frac{1}{4\pi\varepsilon_0}\left(\frac{Qx}{\left(R^2 + x^2\right)^{3/2}}\right) \qquad (1)$$

where Q is the total charge on the ring and R, the radius of the ring. If the ring radius is fairly large in comparison with x (the location of the test charge), then explain why equation (1) can be approximated by

$$E \cong \frac{1}{4\pi\varepsilon_0}\left(\frac{Qx}{R^3}\right) \qquad (2)$$

Explanation (or show work):

Therefore, what is the force on the test charge of charge q?

F = ___________________ (3)

8. Comparing this with a Hooke's Law (spring) force for Simple Harmonic Motion:

F = -kx (4)

what is the expression of k for the test charge oscillation (in terms of q, Q and R)? _______________

For simple harmonic motion, the force needs to be a "restoring" force (i.e. a force that pulls the object back towards equilibrium). Explain why the electrical force on the test charge is a "restoring" force.

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9. Explain, then, why the plot of the motion versus time (for larger values of the ring radius and motion that is near the ring) is sinusoidal (it looks like a sine or cosine curve).

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10. Given that the frequency for a simple harmonic oscillator described by F=-kx is

$$f = 2\pi \sqrt{k/m} \qquad (5)$$

show that the frequency of oscillation (of this simple harmonic oscillator) is equal to

$$f = 2\pi\, (q|Q|/4\pi\varepsilon_0 m R^3)^{1/2} \qquad (6)$$

where q is the charge of the test charge, |Q|, the magnitude of the total charge on the ring and R, the radius of the ring. Show your work:

11. Using equation (6) above for the frequency of oscillation, if the total charge on the ring is one million times the charge of the test charge and the test charge has a mass of 1 μg (=10^{-9} kg), what is the magnitude of the green and yellow charges? (The radius of the ring is given in cm). Show your work: