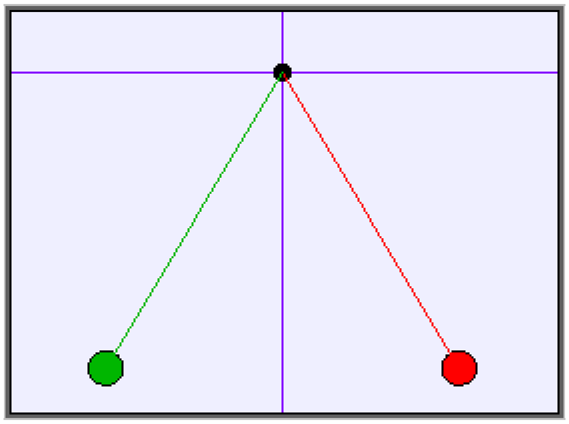


Screen shot of simulation showing a pendulum created by two charged particles.

Lesson Plan: Coulomb Pendulum Simulation

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

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

The EJS Coulomb Force 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.

Written by: Anne J Cox
Edited by: Mario Belloni and Wolfgang Christian

Physics Classroom Curriculum Alignment:

Static Electricity- Lesson 3: Newton's Laws and the Electrical Force

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.

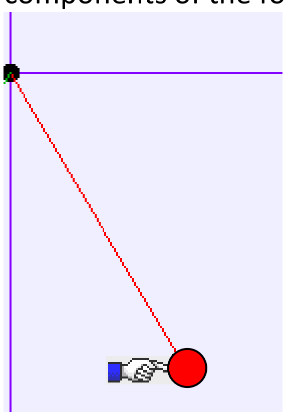
8.01 Analyze the nature of electrical charges.

- 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.

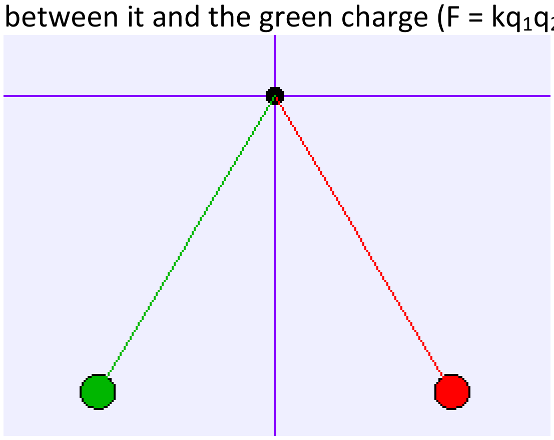
I. ENGAGEMENT/REVIEW

Review force diagrams and Coulomb's law. Complete as a whole group with a fast pace (about 15 minutes) and with students using their science notebooks.

Draw a force diagram for the pendulum below held at an angle, explicitly showing the x and y-components of the force.



Do the same for the right-hand (red) charge which is held in place by the Coulomb force between it and the green charge ($F = kq_1q_2/d^2$).



II. EXPLORATION

Have students work in pairs and open the EJS Coulomb Force simulations. 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

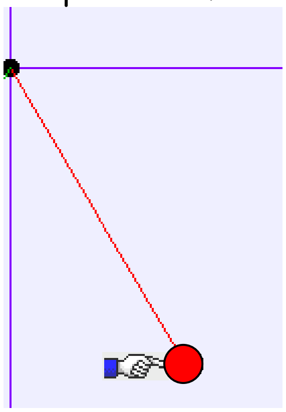
Ask students to write a brief description or make sketches to explain the motion observed.

V. EVALUATION

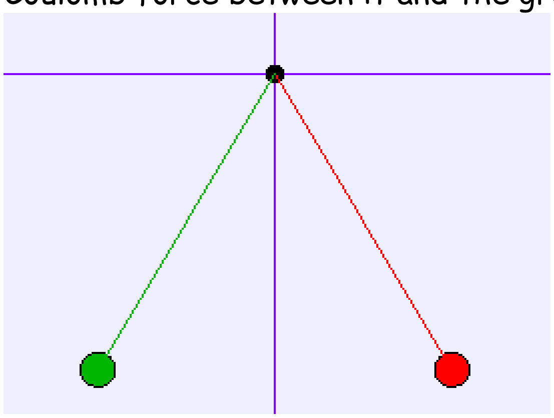
Teacher circulates to check that the Introduction and Coulomb Force Worksheet is completed and stapled into the science notebook.

Introduction: Force Diagrams

Draw a force diagram for the pendulum below held at an angle. Show the x and y-components of the force.



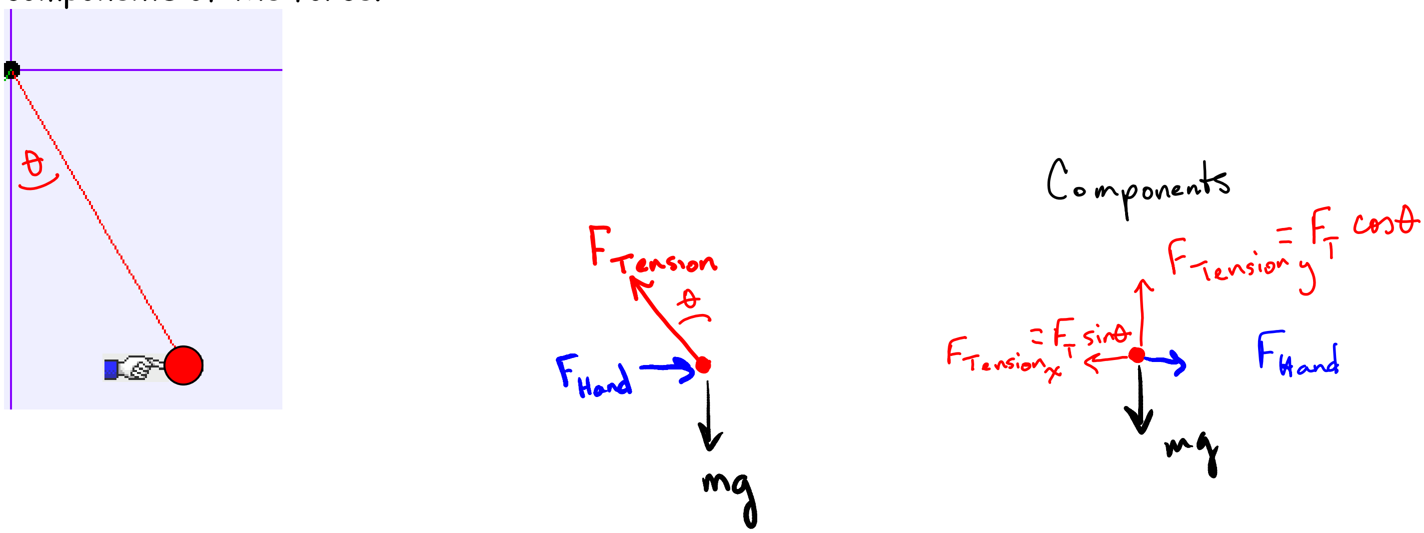
Draw a force diagram for the right-hand (red) charge which is held in place by the Coulomb force between it and the green charge.



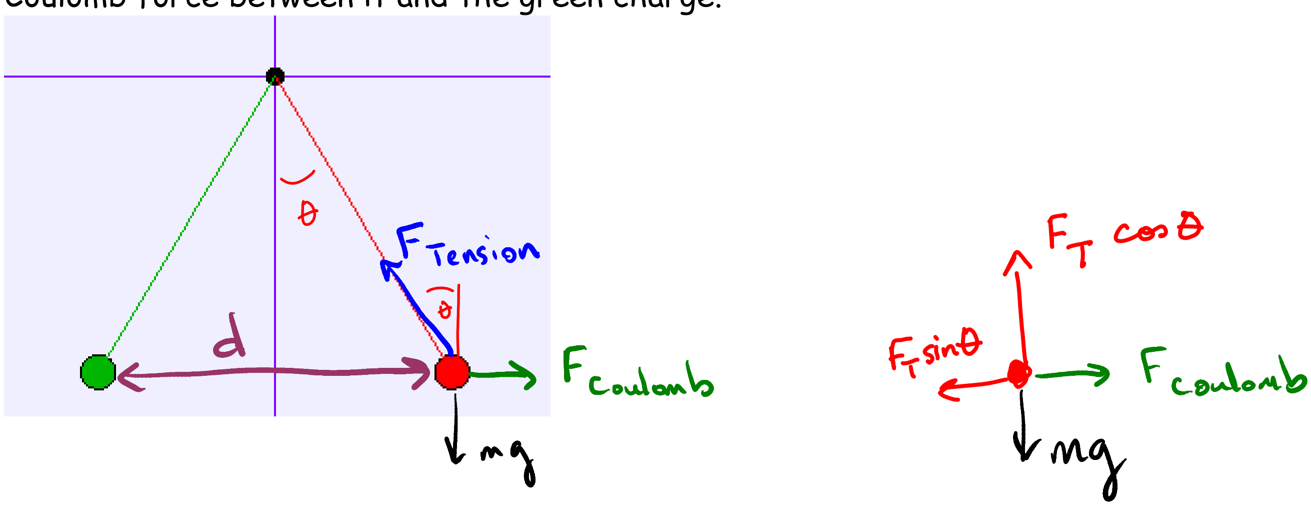
The Coulomb force on the red charge is $F = kq_{red}q_{green}/d^2$. Show the distance d in the diagram.

Introduction: Force Diagrams-Answer Key

Draw a force diagram for the pendulum below held at an angle. Show the x and y-components of the force.



Draw a force diagram for the right-hand (red) charge which is held in place by the Coulomb force between it and the green charge.



The Coulomb force on the red charge is $F = kq_{red}q_{green}/d^2$. Show the distance d in the diagram.

Activity Guide: EJS Coulomb Pendulum Simulation

In this simulation, you can change the initial position of the charges, change the amount of charge on a particle and damp the motion.

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 Coulomb Pendulum simulation and run the simulation by double-clicking on the green arrow. Push the play ( ) button to start the simulation.
2. Reset the simulation. With the same initial charge on each, push the v=0 button until the charges balance. What is the angle?

   ____

   ____

3. The particles have the same mass. If you increase the amount of charge on only one of the charges, what difference do you expect in the angles where they will balance? Will it still be symmetric? Explain?

   ____

   ____

   ____

4. Now, use one of the sliders on the left to change the charge on either the red charge or the green charge. Push the v=0 button until the charges balance. What are the angles?

   ____

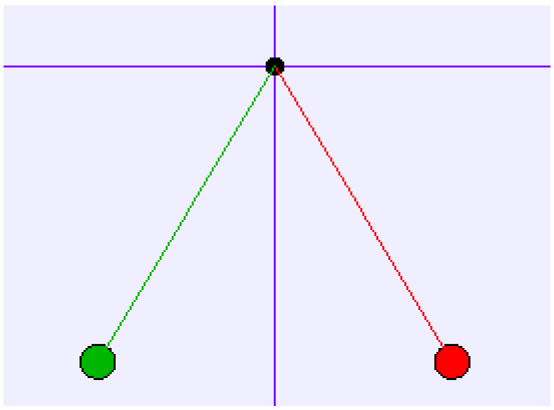
   Are the charges symmetrically balanced? Explain.

   ____

   ____

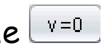
   ____

5. The charge on each is given in μC (10^{-6} C) and the angle is given in degrees (from the vertical). The support cord is 1-m long. When the charges are balanced and at rest (use the v=0 button as needed), record the angle and draw a force diagram for one of the charges. Use this to determine the mass of the charge (both charges have the same mass). Show your work:



Activity Guide: EJS Coulomb Pendulum Simulation-Answer Key

In this simulation, you can change the initial position of the charges, change the amount of charge on a particle and damp the motion.

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 Coulomb Pendulum simulation and run the simulation by double-clicking on the green arrow. Push the play () button to start the simulation.
2. Reset the simulation. With the same initial charge on each, push the 

button until the charges balance. What is the angle?
_______30-31°____
____

3. The particles have the same mass. If you increase the amount of charge on only one of the charges, what difference do you expect in the angles where they will balance? Will it still be symmetric? Explain?
_____ angle will increase, but still be symmetric (both experience same Coulomb force ____
____

4. Now, use one of the sliders on the left to change the charge on either the red charge or the green charge. Push the 

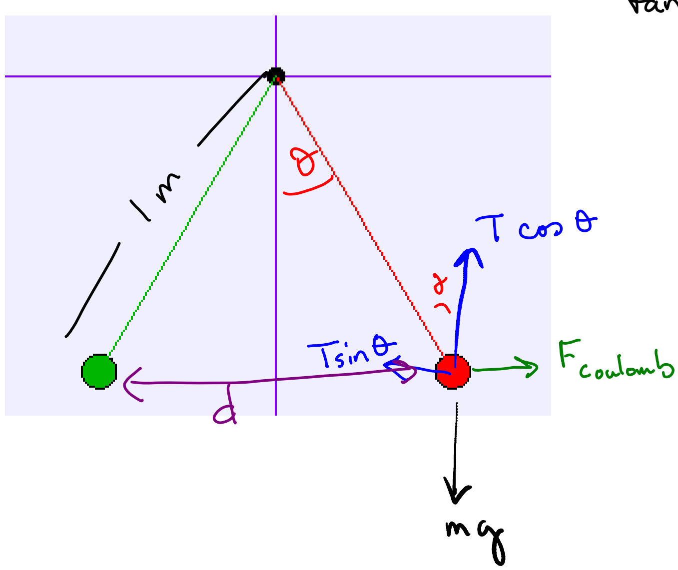
button until the charges balance.
_____answers will vary ____________________

Are the charges symmetrically balanced? Explain.
________ symmetrically balanced ____________________________
____
____

5. The charge on each is given in μC (10^{-6} C) and the angle is given in degrees (from the vertical). When the charges are balanced and at rest (use the [v=0] button as needed), record the angle and draw a force diagram for one of the charges. Use this to determine the mass of the charge (both charges have the same mass). Show your work:

$$\tan\theta = \frac{d/2}{1\,m}$$

$$d = (2\tan\theta)$$



$$|F_{coulomb}| = k\frac{q_{red}\,q_{green}}{d^2}$$

$\underline{\text{x-component}}$

$$T\sin\theta = k\frac{q_{red}\,q_{green}}{d^2}$$

$\underline{\text{y-component}}$

$$T\cos\theta = mg$$

Divide x-component by y-component (to eliminate T):

$$\frac{\cancel{T}\sin\theta}{\cancel{T}\cos\theta} = \frac{\frac{k\,q_r\,q_g}{d^2}}{mg} \implies mg = \frac{k\,q_r\,q_g}{d^2\tan\theta}$$

When $q_r = q_g = 2\mu C$, $\theta = 31^\circ$:

$$m = \frac{k\,q_r\,q_g}{4g\tan^3\theta}$$

$$q_r = q_g = 2\times10^{-6}\,C$$

$$k = 9\times10^{9}\ N\,m^2/C^2$$

$$m = .004\ kg$$

$$m = 4\,g$$