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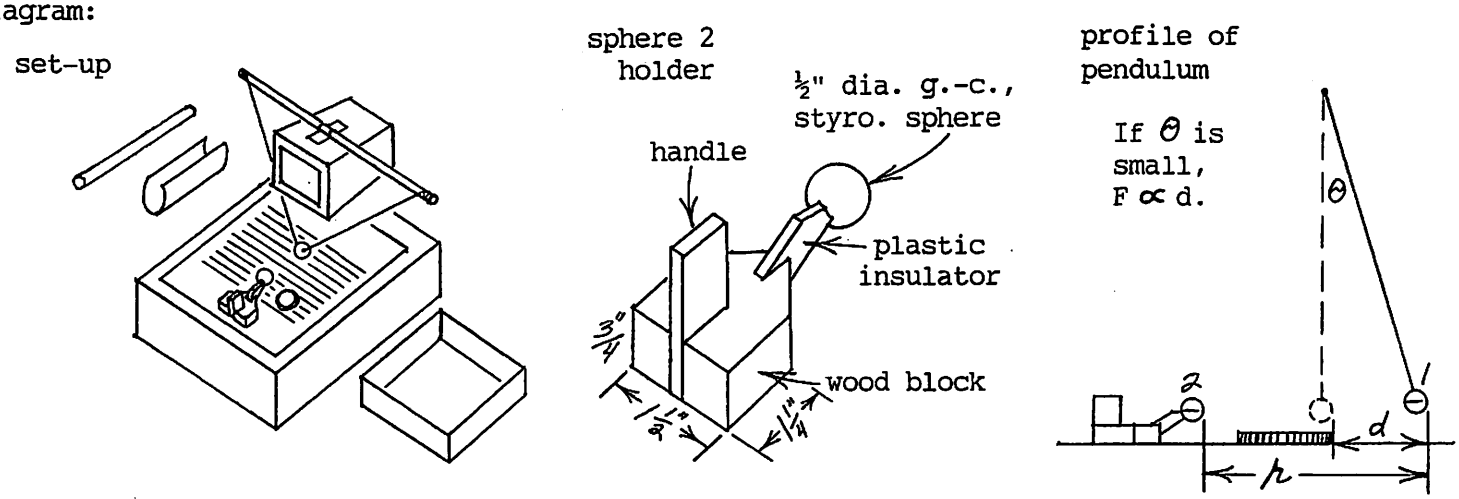
Electricity - Coulomb's Law. This demonstration-laboratory exercise has a little of everything in it, including history, math, graphing, and a special lab technique. It is easy to make and store, and the results are rewarding. Its origin is the 1960's national PSSC (M.I.T.) high school physics course. Since 1969, I have performed this demo-lab on an overhead projector (OHP). The OHP keeps the stage dry which helps retain the charges and makes data-collecting "class size". A major aspect of this exercise is the simple, but elegant, math involved. We don't often have the chance to work with an inverse proportion, a hyperbola, as we do here, and even better, a skewed hyperbola due to the inverse square.

A little history. Ben Franklin's experiments in the early 1750's were qualitative even though they did show that electrical charges exerted forces that were greater than gravity. In 1775, Ben's friend, Joseph Priestly, suggested an electrical adaptation of Newton's Law of Universal Gravitation, i.e., $F = k\, q\, q'/r^2$ where q is the electrical charge on an object rather than its mass. In 1785, Charles Coulomb invented a new apparatus and immediately tried to prove that $F \propto 1/r^2$. He made measurements and drew a graph. In doing so, Coulomb had taken electricity from qualitative to quantitative, a great scientific leap forward. He compared his graph to those from mathematics. His initial results would show that gravitational and electric fields had certain characteristics in common. Unified theory?

The set-up is illustrated in the diagram below.

Diagram:



Materials: OHP, "1 cm" grid, fence, 1¢, dowel with sphere 1, holder with sphere 2, masking tape, pvc rod, wool cloth

Preparation: (a) OHP's are disappearing; grab one with extra bulbs, and save it! (b) Make a transparency of the "1 cm" grid. (c) Make a "fence" 2½" high, 10" square out of manila cardboard with taped corners so it can be folded flat for storage. It blocks out air currents affecting sphere 1 and reduces charge loss from both spheres. (d) Make a bifilar pendulum out of a 3/8" dia. dowel, 16" long with a very small hole drilled in each end. Make a very small hole (pin?) through a ½" dia. graphite-coated, styrofoam sphere and thread a fine nylon thread 56" long through it. Thread the ends through the dowel holes and tie them. Roll up the thread and sphere 1 on the dowel until later. (e) Make a sphere 2 holder as shown in the diagram. Any similar design will work as long as the sphere is insulated (isolated) properly. Press sphere 2 onto a sharp point; the handle should be nonmetallic.

Presentation: (a) Discuss Coulomb's experiment and complete the data tables and their two graphs using numbers without units. What do the graphs look like? (b) Place the "1 cm" grid on the OHP and focus it on a screen (wall?). (c) Place sphere 2 and the penny on the grid and install the fence. (d) With the dowel on top of the OHP head, unroll sphere 1 directly below the head until sphere 1 is at the same level as sphere 2; tape the dowel to the head. (e) Refocus the spheres and the grid as best you can; readjust sphere 1; and retape the dowel. (f) Place a negative charge from the pvc rod on spheres 1 and 2. Be patient!

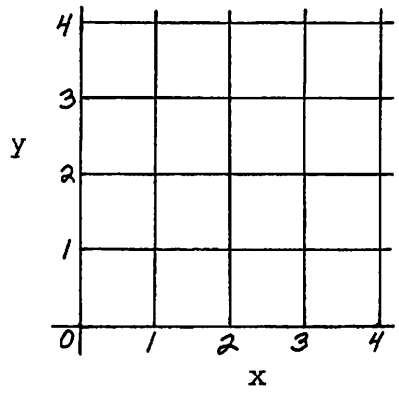
(g) Place the penny on a convenient "starting line" with sphere 1 as in the "profile" illustration. Tape down the grid. (h) Carefully move sphere 2 straight toward sphere 1. When d = 0.5 cm, stop and let the students read and record r. (i) Continue to move sphere 2 forward to d = 1 cm, 2 cm, etc. until the students have six data points. Take data quickly to reduce charge loss. (j) Have the students plot the graph. Is it like either of the two previous "math" graphs? Was Coulomb on the right track, i.e., is $F \propto 1/r^2$? Could $F = k\, q\, q'/r^2$ be correct and thus Coulomb's law? You have just learned what Coulomb learned over 200 years ago! Neat! Why did C. Coulomb's name become a unit?

You may wish to use the following data tables and graphs as part of your lab exercise write-up. Comparisons are an important learning tool in advancing physics knowledge.

Complete the data tables and their graphs.

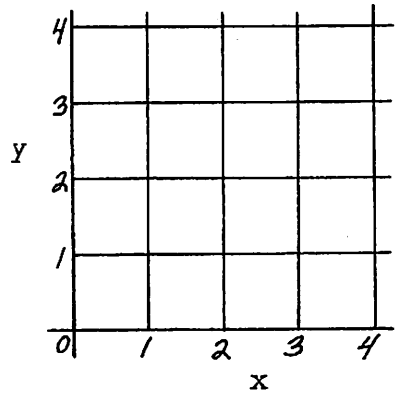
$y = 1/x$

x	y
.25	
.33	
.5	
1	
2	
3	
4	

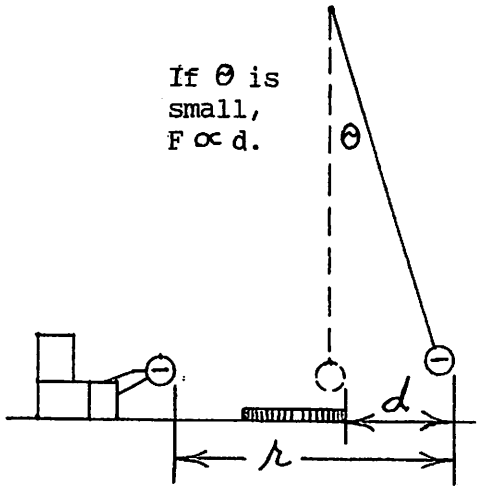


$y = 1/x^2$

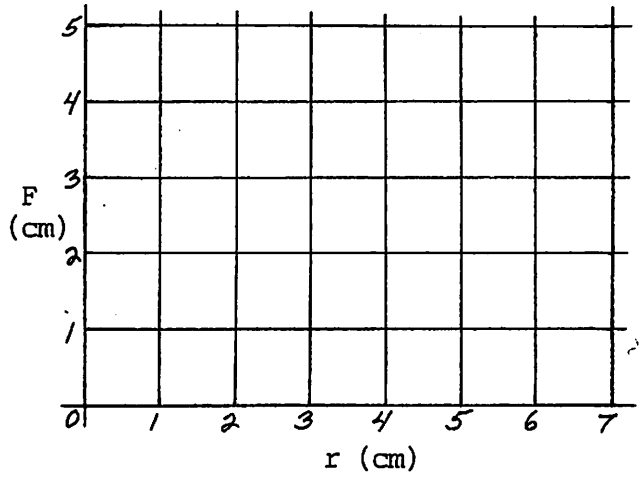
x	y
.5	
.6	
.7	
1	
2	
3	
4	



Complete the data table and the graph.



d or F (cm)	r (cm)
0.5	
1	
2	
3	
4	
5	



Note that the F vs r graph is very much like the right graph above, a skewed hyperbola to the right and down. Coulomb had hit the jackpot; his intuition had paid off!