PhyzSpringboard: Intro to Coulomb's Law

We all learned at some point in our science education that like charges repel and opposite charges attract. But now we wish to know *how much* charged objects attract or repel. What determines the strength of the electric force? To answer this, first write down a few generalizations. Next, examine the data from a carefully constructed experiment shown further below. Based on the evidence given, formulate a few *mathematical* relations that explain the electric force between two charged objects.

PREDICTIONS

1. Force and Charge Predictions. How does the *amount* of charge on two charged objects affect the strength of the electric force between them?

__ The greater the amount of charge on the objects, the greater the force between them.
__ The greater the amount of charge on the objects, the smaller the force between them.

Does this represent a direct or inverse proportionality? __DIRECT ($F \propto q$) __INVERSE ($F \propto 1/q$)

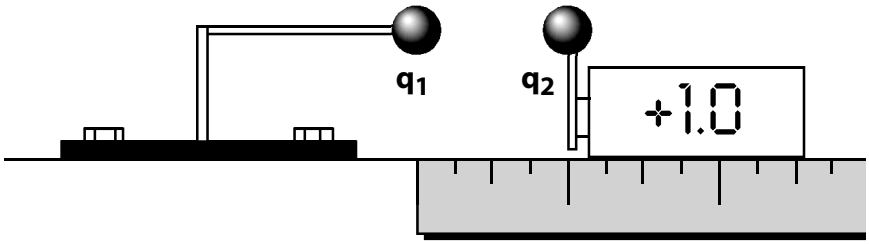
2. Force and Distance Prediction. How does the *distance* between two charged objects affect the strength of the force between them?

__ The greater the distance between the objects, the greater the force between them.
__ The greater the distance between the objects, the smaller the force between them.

Does this represent a direct or inverse proportionality? __DIRECT ($F \propto d$) __INVERSE ($F \propto 1/d$)

VIRTUAL OBSERVATIONS

Set-Up. One charged object is attached to the table and cannot move. The other charged object is attached to a heavy base in such a way that the force acting on the object can be measured.



Initial Set-Up:
q_1 (Charge 1): +1.0 unit of charge
q_2 (Charge 2): +1.0 unit of charge
d (Distance between charges): 1 unit of distance
F (Force between objects): +1.0 unit of force ("+" indicates repulsion)

3. Force and Charge Observations. The data given below was obtained by varying the charge on each object while holding the distance fixed at 1.0 unit. Negative force values indicate attraction. Complete the table to determine whether force is proportional to the charge on the first object, the charge on the second object, the product of the charges, or the sum of the charges.

Run	Charge 1: q_1	Charge 2: q_2	Product: $q_1 \cdot q_2$	Sum: $q_1 + q_2$	Force: F
1	+1.0	+1.0			+1.0
2	+1.0	–1.0			–1.0
3	+1.0	+2.0			+2.0
4	–2.0	–2.0			+4.0
5	–10.0	+5.0			–50.
6	–3.0	–7.0			+21.

Based on this information, what is the mathematical relationship between the charge on two objects and the force between them? (Which column of values looks most like those in the force column?)

__$F \propto q_1$ __$F \propto q_2$ __$F \propto q_1 \cdot q_2$ __$F \propto q_1 + q_2$

4. Force and Distance Observations. The data given below was obtained by varying the distance between the two objects while holding the charge on each object fixed at +1.0 unit. Complete the table to determine whether the force is inversely proportional to the distance, square root of the distance, or square of the distance.

Run	Distance d	Inverse : 1/d	Inverse Root: 1/ d	Inverse Sqr.: $1/d^2$	Force: F
1	0.250				+16.0
2	0.500				+4.00
3	1.00				+1.00
4	2.00				+0.250
5	4.00				+0.0625
6	7.00				+0.0204

Based on this information, what is the mathematical relationship between the charge on two objects and the force between them?

__$F \propto 1/d$ __$F \propto 1/\sqrt{d}$ __$F \propto 1/d^2$

5. The Complete Proportionality. Synthesize the results in parts 1 and 2: what is the relationship between electrostatic force, charge, and separation distance?

6. Turning the Proportionality into an Equation. To transform the proportionality above to a full-fledged equation, we must add a constant of proportionality to the expression. In other words, we will change the proportionality $F \propto X$ (where X is the expression derived in question 5) to the equation $F = kX$.

a. Write the full equation.

b. Use the numerical data below to determine the magnitude and units of measure of the constant k. When $q_1 = 0.004$ C, $q_2 = 0.006$ C, and $d = 50$ m, $F = 85$ N.

$k =$ _____