Electric Force and Electric Field
Electrostatics

Sources
- Stationary Charge

Outcomes
- Electric Force
- Electric Field
- Electric Potential
- Capacitors

Maxwell’s Equation
- Gauss’s Law
Electric Forces and Electric Fields plan for the week

1. Introduction to ACL classroom and methodology
2. Summary of material from first part of ch21 (point charges and forces)
3. Iclicker questions (balloons)
4. Balloons simulation
5. Iclicker questions- electric forces
6. Electric forces simulation
7. Iclicker question
8. Electric force problem (two charges)
9. Iclicker question – electric field for point charges
10. E-field simulation
11. E-field problems for point charges
12. Iclicker questions for continuous charge distribution
13. Animation for continuous charge distribution
14. E-field problems for continuous charge distribution
15. Mini exam – one problem similar to problems done in class

16.
Electric Charge

• There are two types of charge: positive and negative
• The unit of charge is the *coulomb* (C)
• The charge of the electron (-) or proton (+) is
  \[ \pm e = 1.602 \times 10^{-19} \text{ C} \]
• Charge is quantized: \[ Q = \pm Ne \]
• Charge is conserved
Electric Charge

Glass rods, plastic tubes, silk, and fur can be used to demonstrate the movement of electrons and how their presence or absence make for powerful forces of attraction and repulsion.

Metal – conductor

Wood – insulator
Static Electricity

• Due to the force between electric charges, **like charges attract** and **unlike charges repel**.
Iclicker - balloons
Run the simulation
Coulomb’s Law

- Coulomb’s Law describes the relationship of charge to electric force by the following equation:

\[ \mathbf{F}_{12} = k_e \frac{q_1 q_2}{r_{12}^2} \mathbf{\hat{r}}_{12} \]

\[ k_e = \frac{1}{4\pi\varepsilon_0} = 8.9875 \times 10^9 \frac{Nm^2}{C^2} \]

\[ \mathbf{\hat{r}}_{12} = \frac{\mathbf{\hat{r}}}{r} \]

Charge is measured in Coulombs C
Since a coulomb is a large amount of charge, expressions of static electricity involve:

- 1 micro-coulomb = 1 \( \mu C \) = \( 10^{-6} \) C
- 1 nano-coulomb = 1 \( nC \) = \( 10^{-9} \) C
- 1 pico-coulomb = 1 \( pC \) = \( 10^{-12} \) C
Problem Solving Strategies

• Coulomb’s Law describes electric force as a vector
• Adding or subtracting vectors is best done with components
• There may be other forces involved (in macroscopic situations)
• Look for symmetries, it will cut your work in half
• Put all of your electric force problems together for better review
Iclicker – electric force
Simulation

Electric force simulator settings:
Use your mouse to move the charges. Distances are given in meters.
Use the sliders to vary the values of the electric charges in milliCoulombs ($10^{-3}$C)
Positive charges are shown in red, negative charges are blue
The magnitude of the force is given in Newtons using $k = 9 \times 10^9 \text{Nm}^2/\text{C}^2$

Distance between the charges: $d = 1.18 \text{ m}$
Magnitude of the Force: $F = 0.63 \times 10^4 \text{ N}$
Problem

Two point charges are located on the $y$-axis as follows:
one charge $q_1 = -1.40 \text{ nC}$ located at $y = -0.645 \text{ m}$, and a second charge $q_2 = 3.40 \text{ nC}$ at the origin ($y=0$).

What is the magnitude of the total force exerted by these two charges on a third charge $q_3 = 5.25 \text{ nC}$ located at $y_3 = -0.440 \text{ m}$?

What is the direction of the total force?  

$(1 \text{ nC} = 10^{-9} \text{ C})$
Iclicker – electric force 2
Problem
Three charges are on the corners of equilateral triangle of side $a = 0.60\text{m}$. Charges are all equal with $|Q| = 4 \text{ } \mu\text{C} \ (1 \text{ } \mu\text{C} = 10^{-6} \text{ C})$. Two of the charges are positive and one is negative. Calculate the force on one of the positive charges.
Attention – You must first solve the problem using variables and only in the last line substitute numerical values.
Start from sketching the situation.
Remember that forces are vectors.
The Electric Field

• The electric field created at point P, by the point charge, $q$, a distance $r$:

$$\vec{E} = k_e \frac{q}{r^2} \hat{r}$$

• The electric field can be measured by placing a test charge, $q_0$, a distance $r$ away, and measuring the force felt on the test charge:

$$\vec{E} = \frac{\vec{F}}{q_0}$$
Electric field

Force at positive charge

Force on negative charge
Electric Field Lines

• The direction of the field line at any point is **tangent** to the field at that point.
• Field lines point **away** from positive charges and **terminate** on negative charges.
• Field lines *never* cross each other.
A tiny ball of mass 0.0140 kg carries a charge of \(-43.0 \mu C\). What size of electric field is needed to cause the ball to float above the ground?
What direction must the electric field have to cause the ball to float?

An electric charge of 4.80 \(\mu C\) is at rest at the origin. An electric force of \(74.1 \times 10^{-6} \text{ N}\) acts on the charge as shown in the figure. What is the \(\mathbf{x}\)-component of the electric field at the origin?
(Note: \(1 \text{ V/m} = 1 \text{ N/C}\))