Unit 4

Electricity and Magnetism

Electricity Review

Two types of electric charge:

- Positive
- Negative

Opposites attract and likes repel

Electricity Review

- All matter is made up of protons, neutrons, and electrons.
  - Protons + charge
  - Neutrons 0 charge
  - Electrons - charge
- Electricity is caused by moving electric charges, specifically electrons.

Electron Freedom

Conductors: electrons are free to move

- Silver
- Gold
- Iron
- Steel
- The Human Body

Insulators: electrons are not free to move

- Glass
- Plastic
- Wood
- Rubber
- Fiberglass

Static Electricity

Electric charge imbalance on the surface of an object.

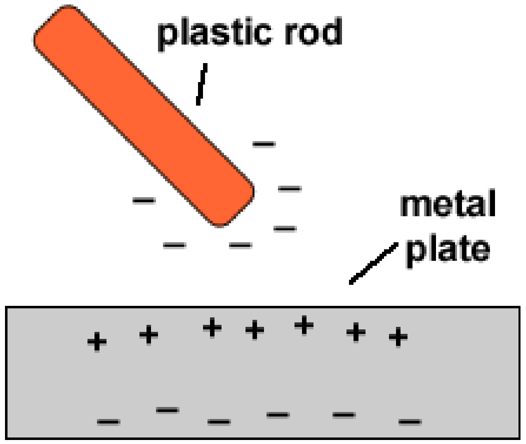
Common Occurrences:

- Getting out of your car
- Walking along carpet

Polarization

A surface charge can be induced (caused or created) on an *insulator*

Hair comb picking up paper



Induction

Conductors can be given a charge by letting excess electrons move from one object to another

Grounding: A conducting material that is attached to Earth by another conducting material is *grounded*.

Induction

- Excess electrons can be provided by or removed by Earth
- Charge will flow from one conductor to another until electrical equilibrium is established or connection is broken.

Conduction visuals

Electric Forces

Unit of Charge: C (Coulomb)

Coulomb's Law $$F_e = k\frac{q_1 q_2}{x^2}$$

This equation is to be used for MAGNITUDE

- $k = 9 \times 10^9$ N m^2/C^2
- q: electric charge

Comparing F_E and F_g

$$F_e = k\frac{q_1 q_2}{r^2} \qquad\qquad F_g = G\frac{m_1 m_2}{r^2}$$

<u>k & G</u>: constants (will be given)

<u>q & m</u>: How much stuff is there to exert a force

q can be negative but m can't

<u>r & r</u>: No difference between r's

Comparing F_E and F_g

$$F_e = k\frac{q_1 q_2}{r^2} \quad \text{and} \quad F_g = G\frac{m_1 m_2}{r^2}$$

Both forces have the same general form and are used the same way. Let us compare relative strengths of these two forces. Which is holding matter together, F_E or F_g?

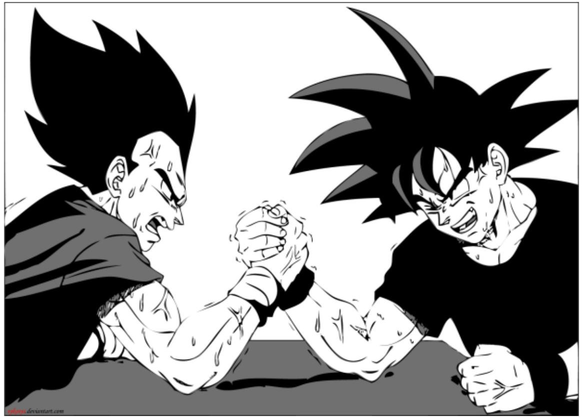
Comparing F_E and F_g

$r = 5.3x10^{-11}$

$G = 6.67x10^{-11}$

$m_p = 1.67x10^{-27}$

$m_e = 9.11x10^{-31}$



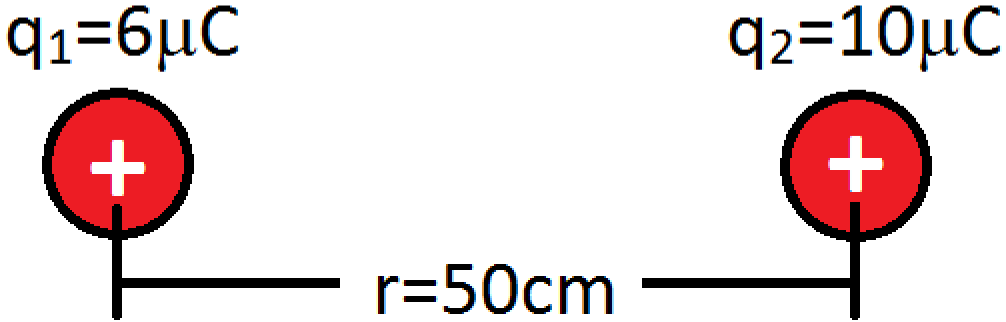
$k = 9x10^9$

$q_p = 1.6x10^{-19}$

$q_e = -1.6x10^{-19}$

Example 1: 2 Charges, 1 Dimension

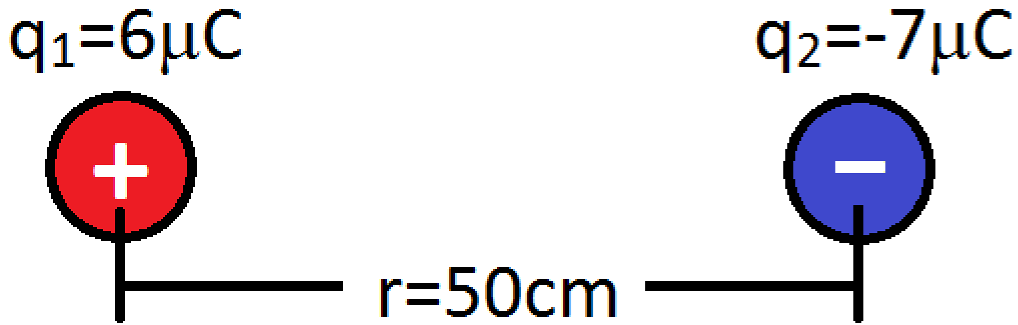
What is the force from q_1 on q_2?



F_e= 2.16N in the positive x-direction **or**
F_e= 2.16**i** + 0**j**

Example 2: 2 Charges, 1 Dimension

What is the force from q_1 on q_2?



F_e= 1.51N in the negative x-direction **or**
F_e= -1.51**i** + 0**j**

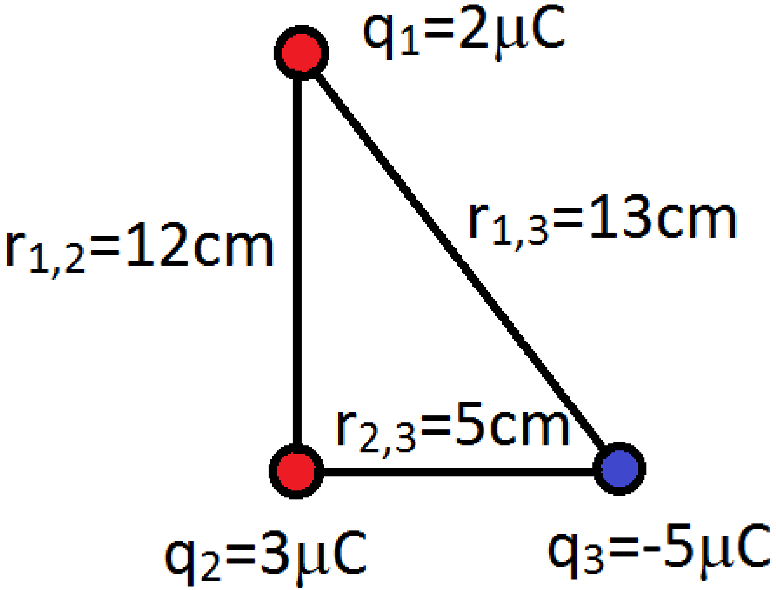
How to Solve

1. Determine the magnitude and direction of $F_{1,3}$ and $F_{2,3}$.
2. Convert to **i j** notation.
3. Add the components of each force
4. Determine the magnitude and direction of net force, F_{net}.

Example 3: 3 Charges, 2 Dimensions

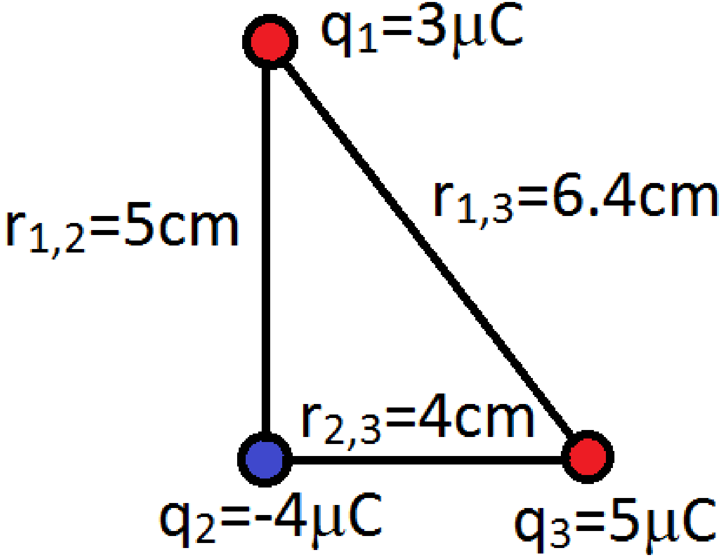
What is the force on q_3 from q_1 and q_2?

F_{net} = 56.27 N @ 5.02º above negative x-axis



Example 4: 3 Charges, 2 Dimensions

What is the force on q_3 from q_1 and q_2?

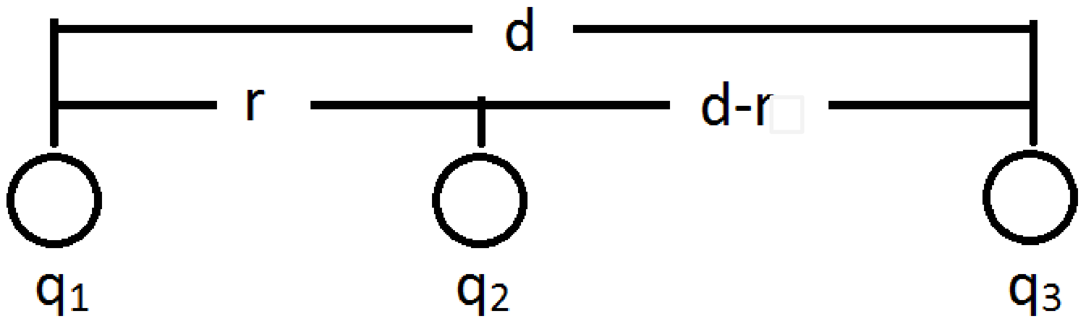


F_{net} = 95.45 N @ 15.65° below negative x-axis

Example 5: Electrical Equilibrium

At what distance from q_1 will q_2 be at equilibrium?

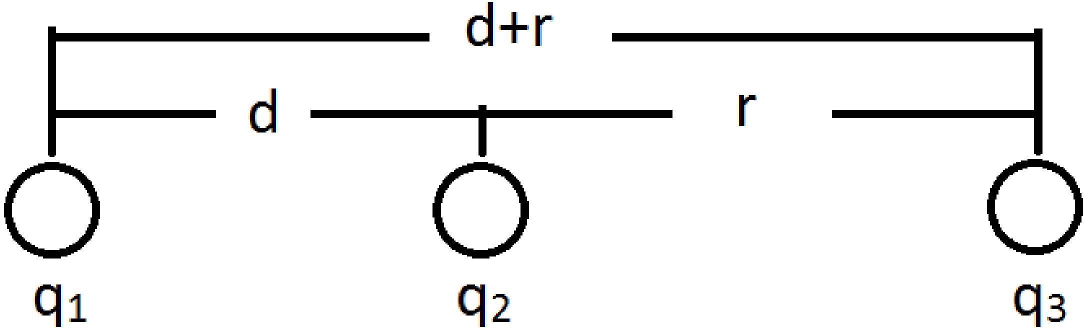
$q_1=1\mu C$, $q_2=-2\mu C$, $q_3=3\mu C$, $d=2m$



Example 6: Electrical Equilibrium

At what distance from q_2 will q_3 be at equilibrium?

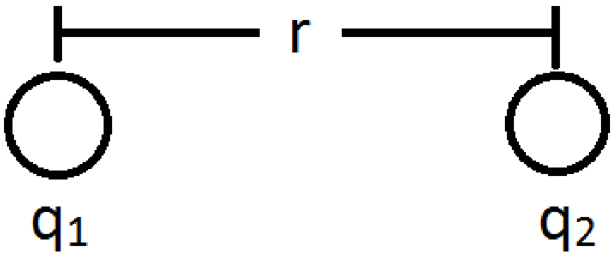
q_1=15μC, q_2=-6μC, q_3=2μC, d=2m



Electric Fields

What is the force on q_2 from q_1 in each of the following examples?

- $q_1=2\mu C$, $q_2=2\mu C$, $r=0.5m$
- $q_1=2\mu C$, $q_2=4\mu C$, $r=0.5m$
- $q_1=2\mu C$, $q_2=6\mu C$, $r=0.5m$



Electric Fields

- Notice that in every force equation there was something that was exactly the same in each example.
- $\frac{kq_1}{r^2}$ is the same in every equation!
- This is known as the electric field produced by q_1.

Electric Fields

- A charged particle interacts with the electric field of another charged particle to produce electric forces
- $$E_1 = \frac{kq_1}{r^2} \Rightarrow E_1 q_2 = \frac{kq_1 q_2}{r^2} = F_{1,2} \qquad E_1 q_2 = F_{1,2}$$
- Electric fields are also vectors but just like forces, this equation is meant for magnitude.

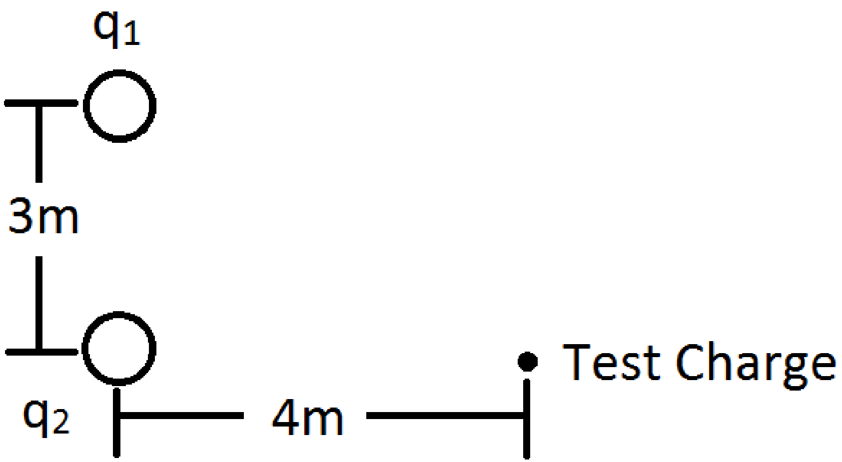
Test Charge

- When working with Magnetic fields we often use a “test charge” to help with direction.
- Test charges are always positive and exist ONLY to show what direction a field will push/pull a positive charge.
- **Test charges** being **positive** is a **convention** so that all physicists agree on how electric fields behave

Example 7: Electric Field of 2 Charges

What is the magnitude and direction of the magnetic field a distance of 4m to the right of q_2?
(q_1=10 C, q_2=5 C)

μ μ



Electric Field Visualization

- The electric field of a charge = invisible hands that want to smack other electric charges around
- $E = k\frac{Q}{r^2}$ states that the invisible hands are weaker farther away from the charge.

Electric Field Vectors

- So what do physicists use to represent these invisible hands?
- Little arrows called VECTORS! :D

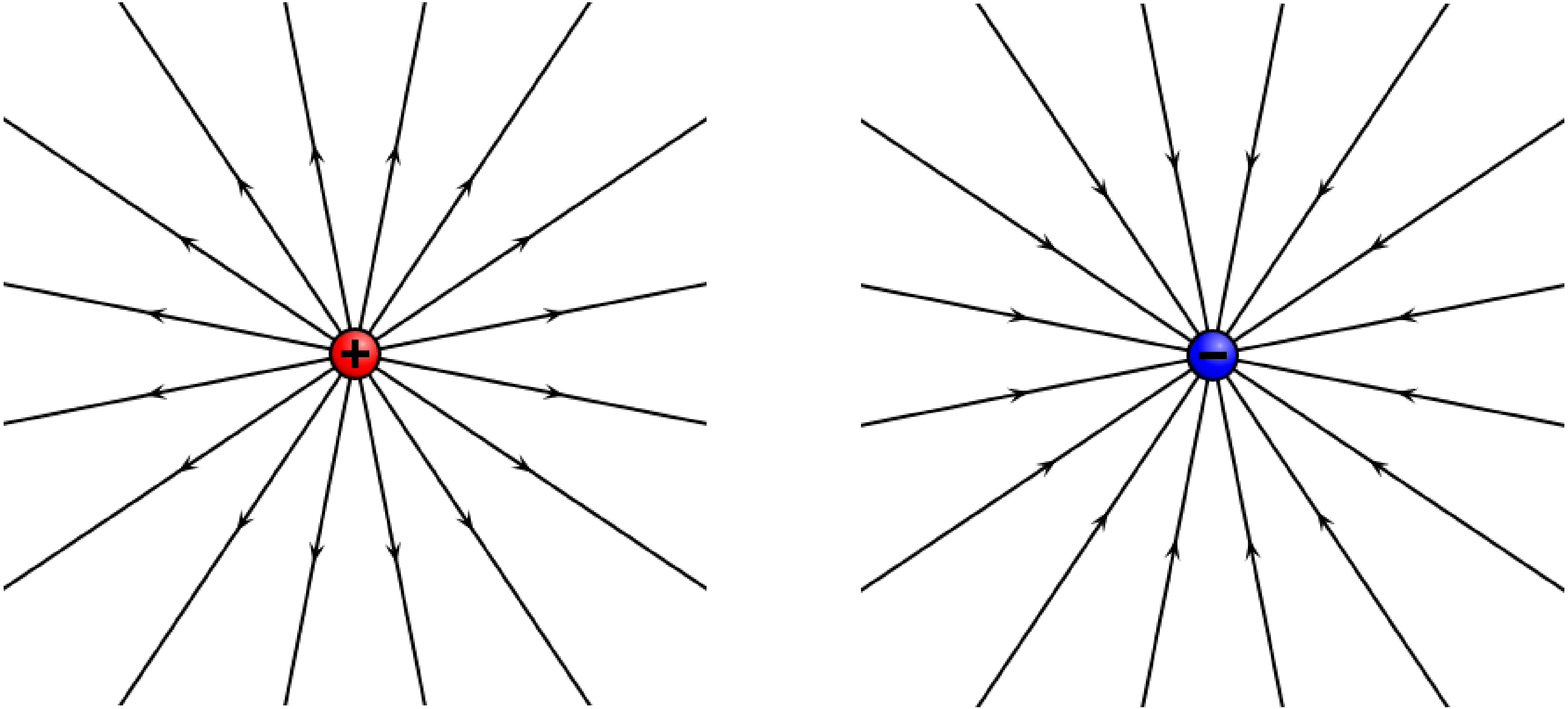
Electric Field Lines

- Instead of leaving an image of a bunch of little arrows, physicists connect the dots to form *Electric Field Lines*.

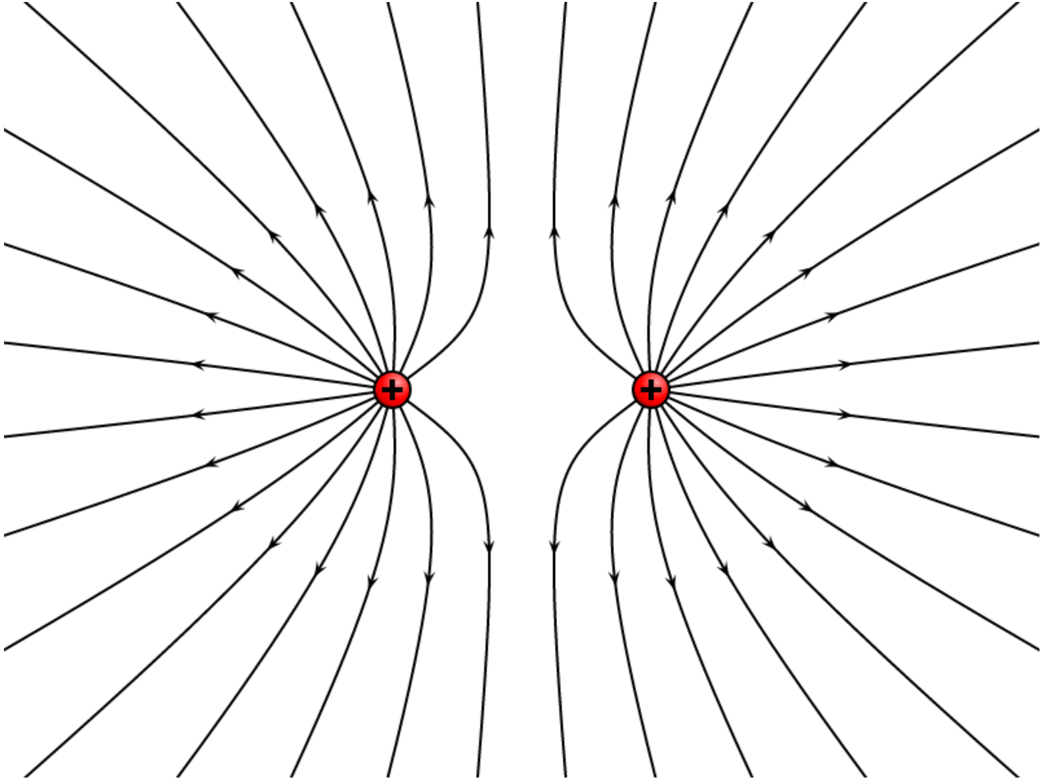
Becomes

- Physicists remember farther away = weaker

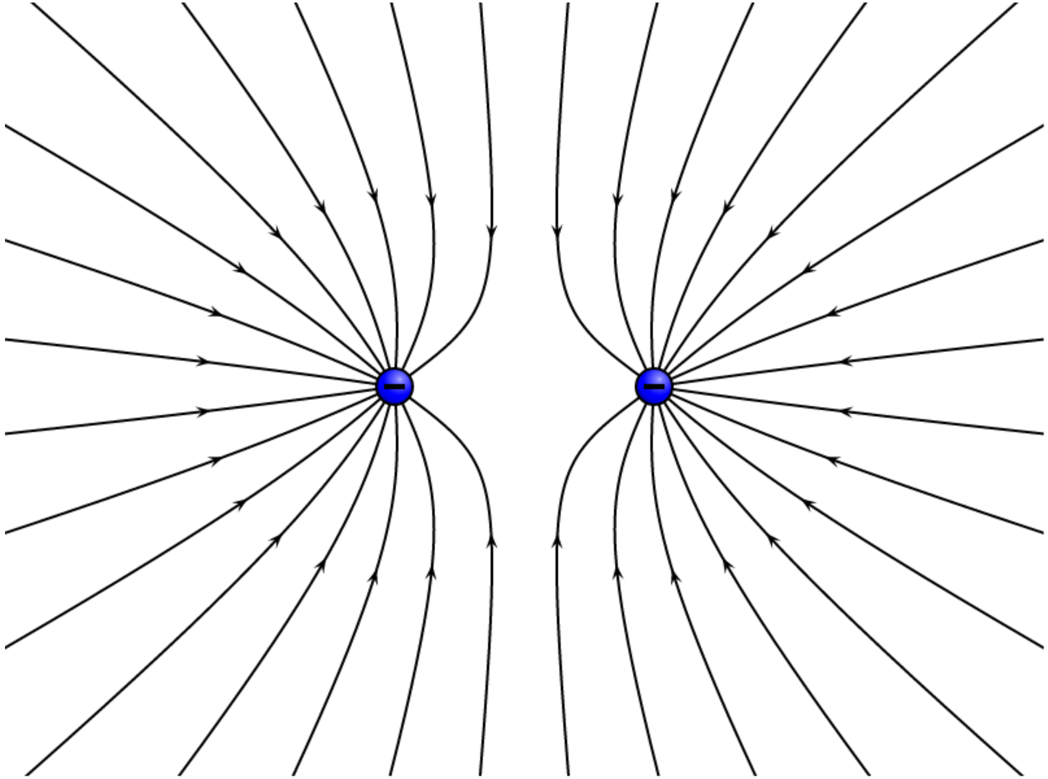
Positive and Negative Charges



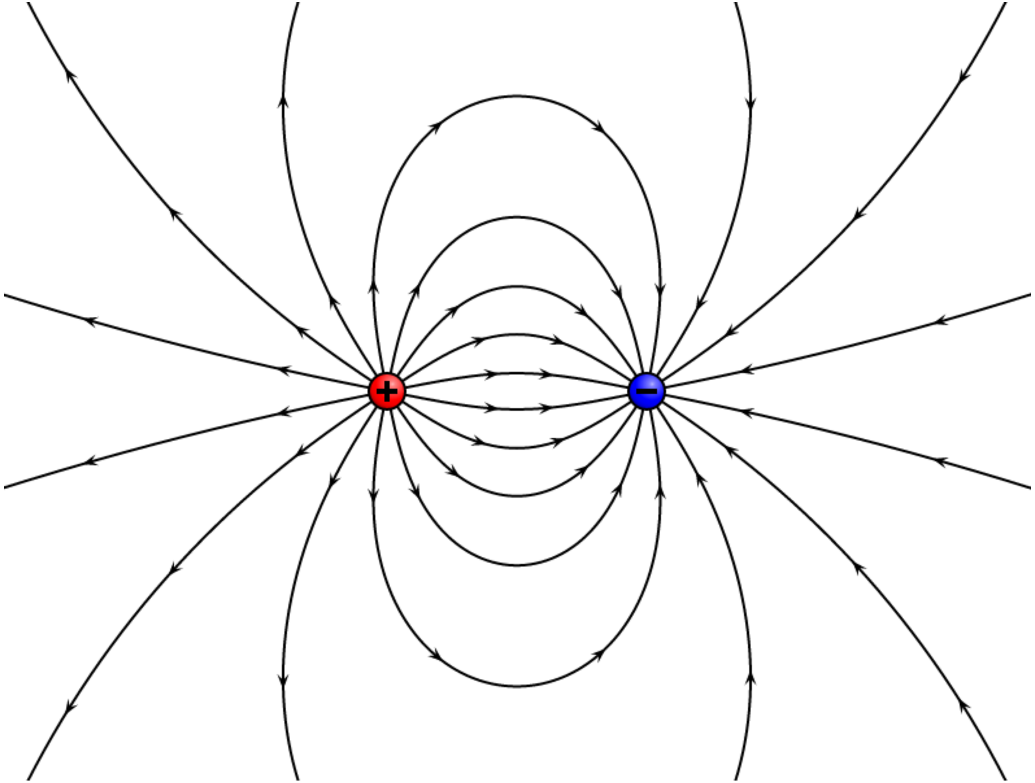
Positive-Positive



Negative-Negative



Positive-Negative



General Rules about Field Lines

- Field lines NEVER intersect!
- Field lines BEGIN on (point away from) positive charges
- Field lines END on (point toward) Negative charges

Force Fields? No. Forces AND Fields

- Non-contact forces can be described using the concept of a ***field***.
- A field is produced by charge Q is defined as

$E = k\frac{Q}{r^2}$ or $E = \frac{F}{q}$ where q is the charge

that would experience an electric force from Q.

Visualizing Electric Fields

- What direction does a test charge get "pushed/pulled" by a positive charge?
- What direction does a test charge get "pushed/pulled" by a negative charge?
- Draw arrows in the direction of the force that would be experienced if there were a charge there.

Calculating Electric Fields

What is the magnitude of the electric field at the center of this rectangular arrangement?

Figure 1: