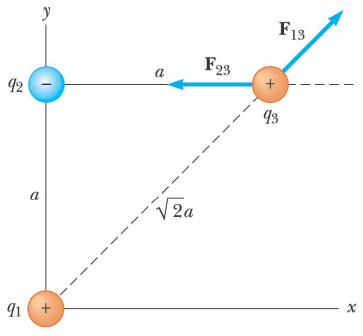
The Superposition Principle

- The resultant force on any one charge equals the vector sum of the forces exerted by the other individual charges that are present
  - Remember to add the forces *as vectors*
- The resultant force on q_1 is the vector sum of all the forces exerted on it by other charges: $\mathbf{F}_1 = \mathbf{F}_{21} + \mathbf{F}_{31} + \mathbf{F}_{41}$

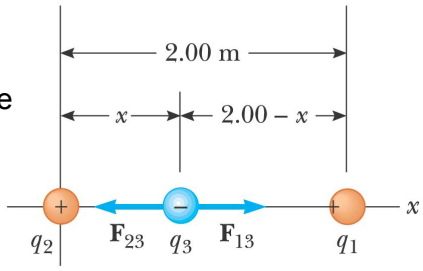
Superposition Principle, Example

- The force exerted by q_1 on q_3 is $\mathbf{F}_{13}$
- The force exerted by q_2 on q_3 is $\mathbf{F}_{23}$
- The *resultant force* exerted on q_3 is the vector sum of $\mathbf{F}_{13}$ and $\mathbf{F}_{23}$



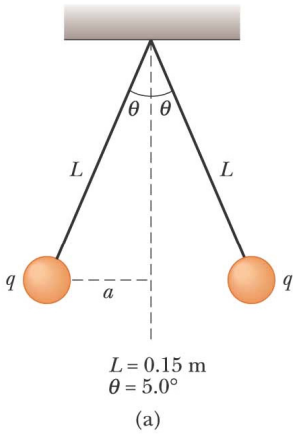
Zero Resultant Force

- Where is the resultant force equal to zero?
  - The magnitudes of the individual forces will be equal
  - Directions will be opposite
- Will result in a quadratic
- Choose the root that gives the forces in opposite directions



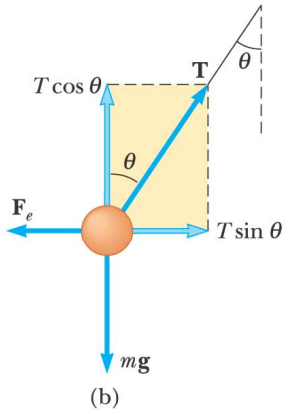
Electrical Force with Other Forces

- The spheres are in equilibrium
- Since they are separated, they exert a repulsive force on each other
  - Charges are like charges
- Proceed as usual with equilibrium problems, noting one force is an electrical force



Electrical Force with Other Forces

- The free body diagram includes the components of the tension, the electrical force, and the weight
- Solve for $|q|$
- You cannot determine the sign of q, only that they both have same sign



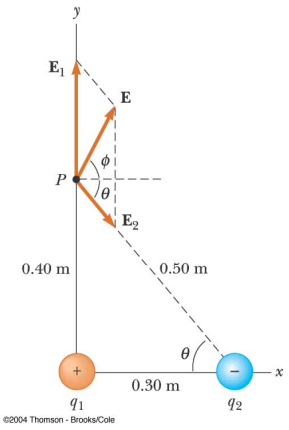
Superposition with Electric Fields

- At any point P, the total electric field due to a group of source charges equals the vector sum of electric fields of all the charges

$$\mathbf{E} = k_e \sum_i \frac{q_i}{r_i^2} \hat{\mathbf{r}}_i$$

Superposition Example

- Find the electric field due to q_1, $\mathbf{E}_1$
- Find the electric field due to q_2, $\mathbf{E}_2$
- $\mathbf{E} = \mathbf{E}_1 + \mathbf{E}_2$
  - Remember, the fields add as vectors
  - The direction of the individual fields is the direction of the force on a positive test charge



Electric Field – Continuous Charge Distribution

- The distances between charges in a group of charges may be much smaller than the distance between the group and a point of interest
- In this situation, the system of charges can be modeled as continuous
- The system of closely spaced charges is equivalent to a total charge that is continuously distributed along some line, over some surface, or throughout some volume

Charge Densities

- **Volume charge density**: when a charge is distributed evenly throughout a volume
  - $\rho = Q / V$
- **Surface charge density**: when a charge is distributed evenly over a surface area
  - $\sigma = Q / A$
- **Linear charge density**: when a charge is distributed along a line
  - $\lambda = Q / \ell$