



Coulomb's Law

- *Coulomb's law* describes the force that one charged body exerts on another.
- Coulomb developed the following equation for the force \mathbf{F} on a charged particle, Q_2 , in the presence of another charged particle, Q_1 :

$$\mathbf{F} = k \frac{Q_1 Q_2}{R^2} \mathbf{a}_{12} \quad N$$

- k is a constant of proportionality given by $k = 1/(4\pi\epsilon_0)$
- $\epsilon_0 = 8.854 \times 10^{-12} \text{ F/m}$ (ϵ_0 is known as the permittivity of free space[†])
- Q_1 and Q_2 are the charges on each of the objects under consideration
- R is the distance between them
- \mathbf{a}_{12} is a unit vector which specifies the direction of the force.



- The direction in which the force acts will be dependent on the charge on each particle. We can see from the equation that if both charges are either positive or negative then the force will be repulsive, and if the charges are of opposite sign then the force will be attractive.
- The magnitude of the force on the particles is mutual (the same) but the direction of the force is opposite.
- The force is linearly proportional to both of the charges, so if the charge on one particle is increased, then the total force will be increased by the same factor.
- **Extension:** To solve for the force on a charged particle in the presence of more than one other charged particle, the laws of superposition apply and the total force can be found by summing the individual forces from each particle (remember that you are summing vector quantities!)

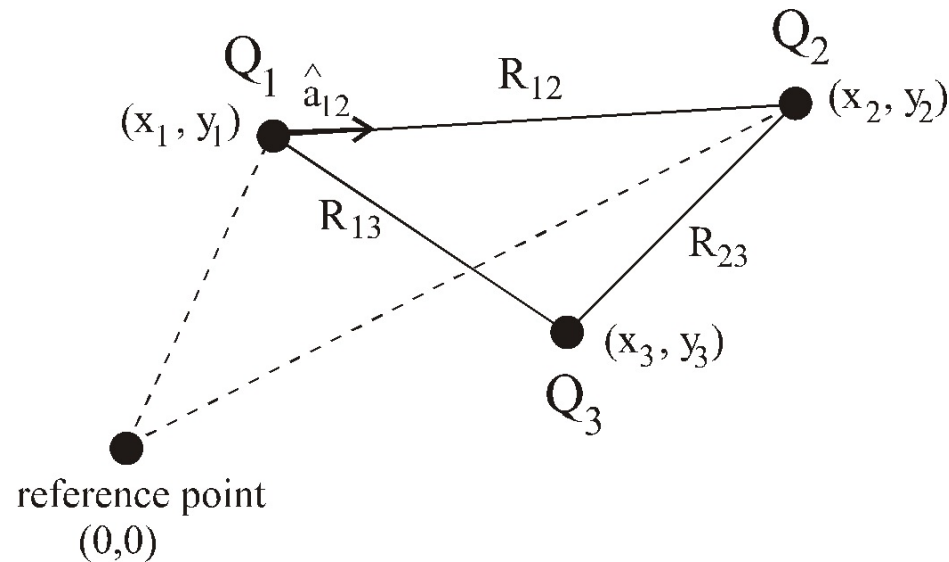


Figure 1. Example with 3 charged particles.

Problem: Figure 1 shows an example of a 3 particle system. If we had:

$Q_1 = 1 \text{ nC}$ ($1 \times 10^{-9} \text{ C}$) located at $(1,2)$

$Q_2 = 2 \text{ nC}$ located at $(5,3)$

$Q_3 = 3 \text{ nC}$ located at $(3,1)$

Find the force on particle 2 due to particles 1 and 3.



Design and Analysis Tips

- draw a good diagram (big enough to clearly label important quantities)
- before solving the problem, look at the diagram and see if you can predict anything about the answer
- after solving the problem, compare the answer to your predictions – does your answer make sense?
- don't forget units (and for vectors don't forget magnitude and direction)

† **A little more about permittivity:** Permittivity is a physical quantity that describes how an electric field affects and is affected by a dielectric medium, and is determined by the ability of a material to polarize in response to the field, and thereby reduce the field inside the material. Thus, permittivity relates to a material's ability to transmit (or "permit") an electric field. We will discuss this more as the course progresses.