Electricity & Magnetism
Lecture 1

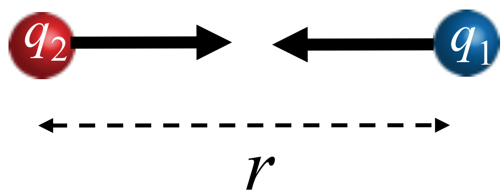
Today's Concepts:

A) Coulomb's Law

B) Superposition

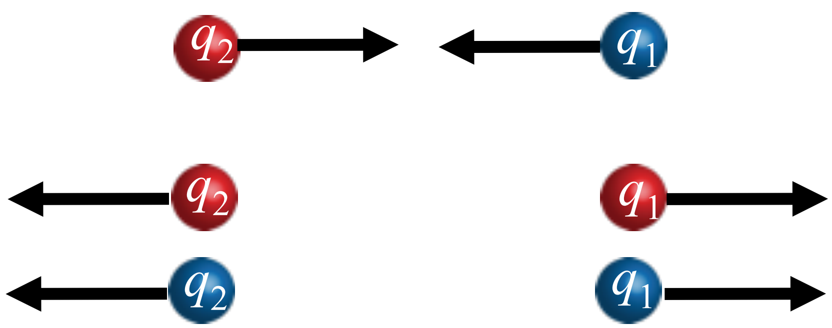
Coulomb's Law:

The force on a charge due to another charge is proportional to the product of the charges and inversely proportional to the separation squared.



$$F \propto \frac{q_1 q_2}{r^2}$$

The force is always parallel to a line connecting the charges, but the direction depends on the signs of the charges:

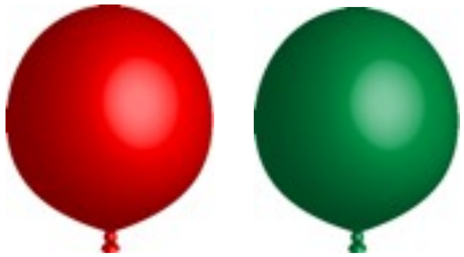


Opposite signs attract

Like signs repel

Balloons

Take two balloons and rub them both with a piece of cloth.
After you rub them they will:



A) Attract each-other
B) Repel each-other
C) Either – it depends on the material of the cloth

Coulomb's Law

$$\vec{F}_{1,2} = \frac{kq_1q_2}{r_{1,2}^2}\hat{r}_{1,2}$$

Our notation:

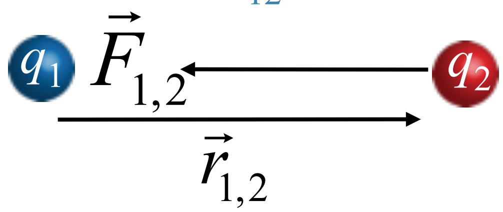
$\vec{F}_{1,2}$ is the force by 1 *on* 2 (think "*by-on*")

$\hat{r}_{12}$ is the unit vector that points *from* 1 *to* 2.

Examples:

If the charges have the same sign, the force **by** charge 1 on charge 2 would be in the direction of r_{12} (to the right).

If the charges have opposite sign, the force **by** charge 1 on charge 2 would be opposite the direction of r_{12} (left).



Example: Coulomb Force

Two paperclips are separated by 10 meters. Then you remove 1 electron from each atom on the first paperclip and place it on the second one.

$$\vec{F} = k\frac{q_1 q_2}{r_{12}^2}\hat{r}_{12}$$

$k = 9 \times 10^9$ N m^2 / C^2

electron charge = 1.6×10^{-19} Coulombs

$N_A = 6.02 \times 10^{23}$

What will the direction of the force be?

A) Attractive   B) Repulsive

F = 9e9 x (1.6e-19 * 3e22)^2 / 100 = 2 e 15 Newtons

Equivalent to weight of 2e14 kg object near surface of the earth

paperclip 1e-3 kg

textbook 1 kg

person 200 kg

car 2000 kg

Aircraft carrier 97000 tons = 1e5 x 1e3 = 1e 8 kg

Mt Everest 9000 m height,. Estimate volume as 1/3 h^3 = 1/3 * (9e3)^3 = 243 e 9 m^3. (if density = 1000 kg/m^3) = 2.43e14 kg.

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Which weight is closest to the approximate force between those paperclips (recall that weight = mg, $g = 9.8\ \mathrm{m/s^2}$)?

A) Paperclip (1 g x g)

B) Text book (1 kg x g)

C) Truck (10^4 kg x g)

D) Aircraft carrier (10^8 kg x g)

E) Mt. Everest (10^{14} kg x g)

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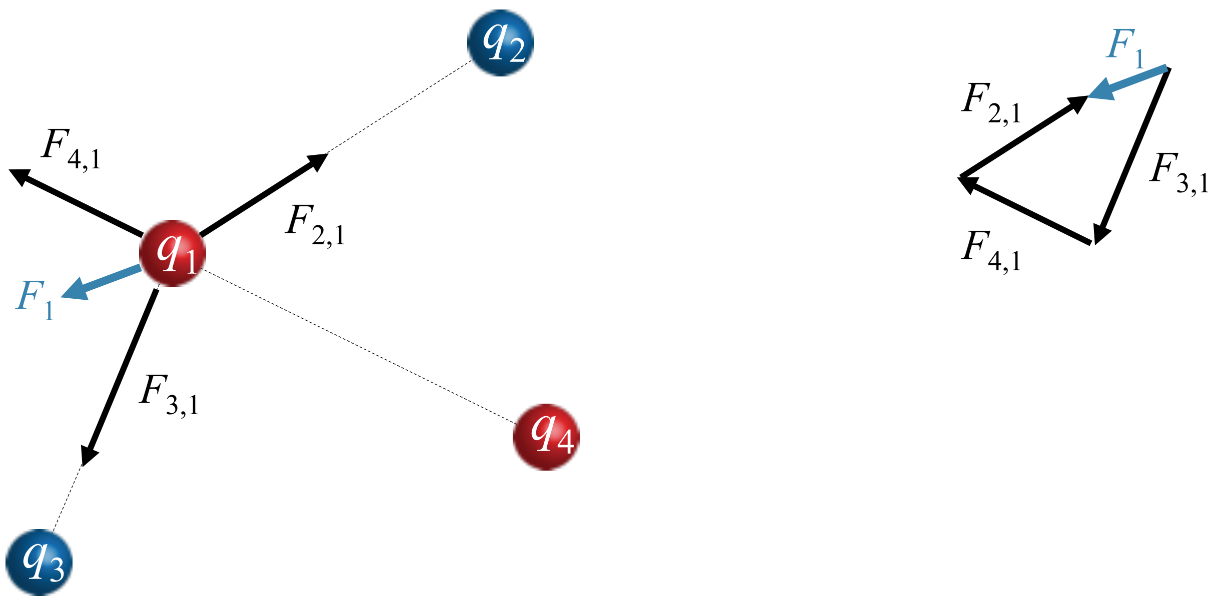
Superposition:

If there are more than two charges present, the total force on any given charge is just the vector sum of the forces due to each of the other charges:



$$\vec{F}_1 = \vec{F}_{2,1} + \vec{F}_{3,1} + \vec{F}_{4,1} + \ldots$$

Superposition Clicker Question

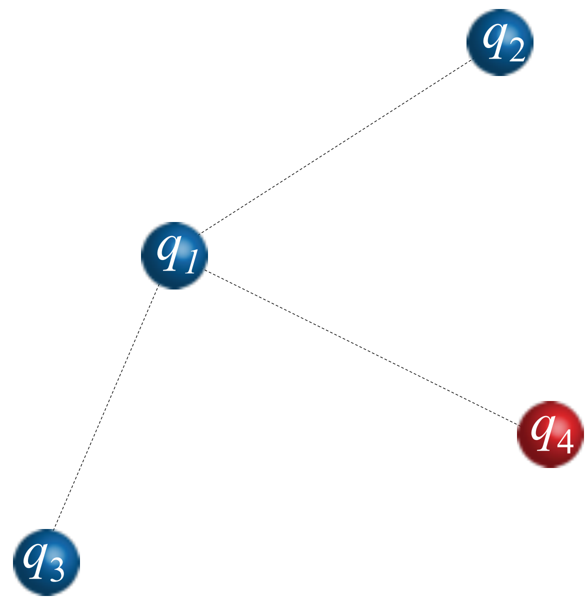
What happens to Force on q_1 if its sign is changed?

A) $|F_1|$ increases

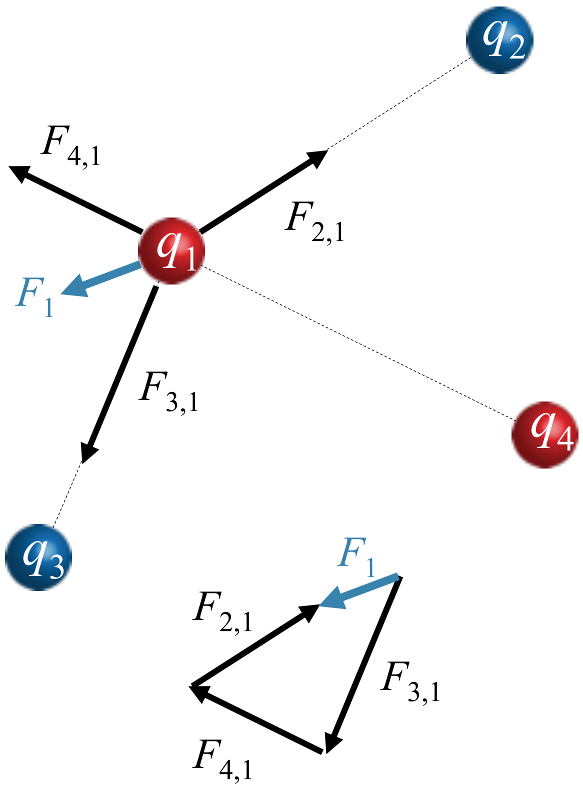
B) $|F_1|$ remains the same

C) $|F_1|$ decreases

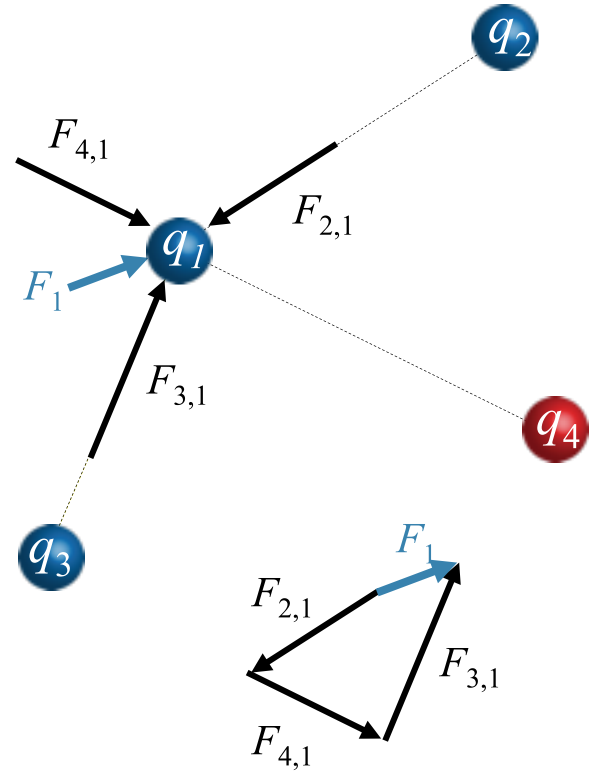
D) Need more information to determine



The direction of all forces changes by 180° – the magnitudes stay the same:



$$\vec{F}_1 = \vec{F}_{2,1} + \vec{F}_{3,1} + \vec{F}_{4,1} + \ldots$$



$$-\vec{F}_1 = -\vec{F}_{2,1} - \vec{F}_{3,1} - \vec{F}_{4,1} - \ldots$$

CheckPoint

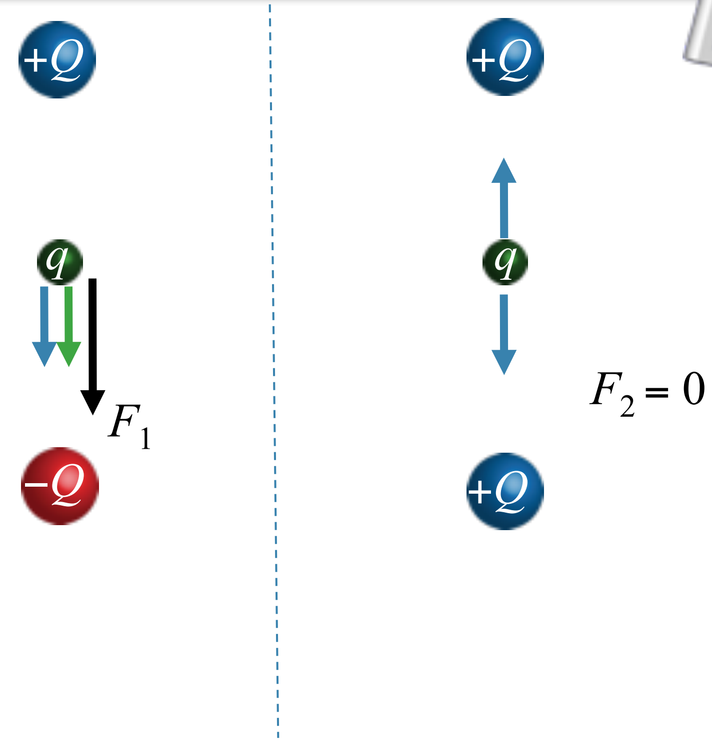
Compare the magnitude of the net force on q in the two cases.

A) $|F_1| > |F_2|$

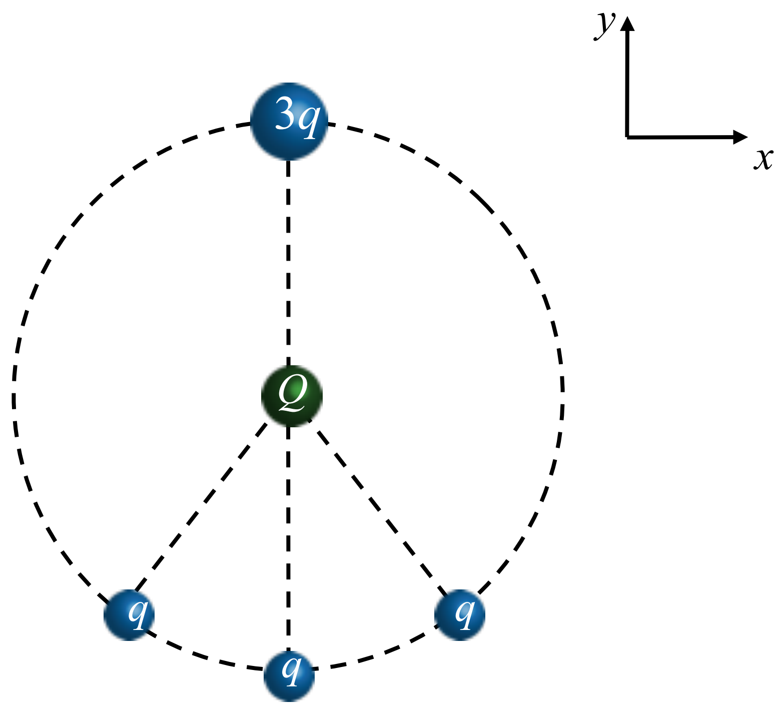
B) $|F_1| = |F_2|$

C) $|F_1| < |F_2|$

D) Depends on sign of q



Four charged particles are placed on a circular ring with radius 3 m as shown below. A particle with charge Q is placed in the center of the ring



What is the direction of horizontal force on Q?

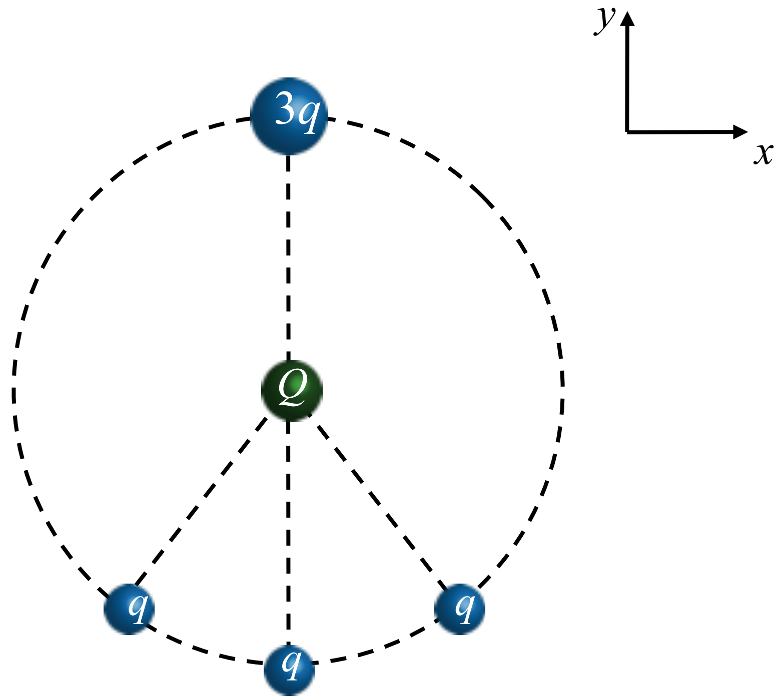
A) $F_x > 0$ B) $F_x = 0$ C) $F_x < 0$

CheckPoint

Four charged particles are placed on a circular ring with radius 3 m as shown below. A particle with charge Q is placed in the center of the ring

What is vertical force on Q?

A) $F_y > 0$ B) $F_y = 0$ C) $F_y < 0$



Next do calculation