Lecture (2)

Electric force

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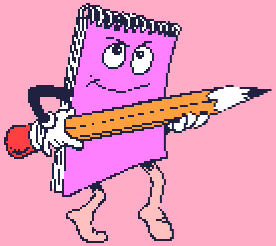
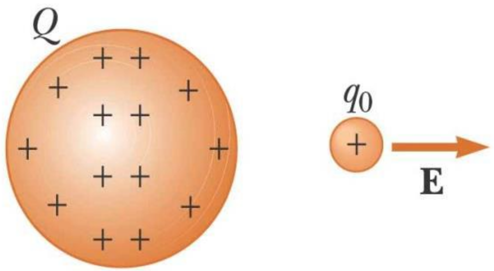


Electrostatic force

*Let (E) is the field of the charge (Q). If another charge (q_0) entered the space of (Q), it will suffer an **electrostatic force** (F) given by:*

$$\vec{F} = q_o \vec{E}$$

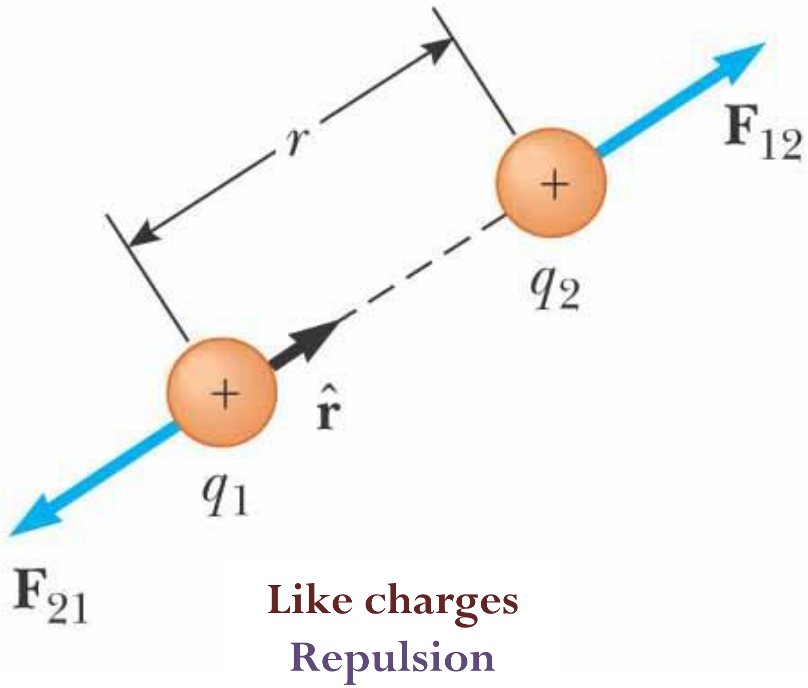


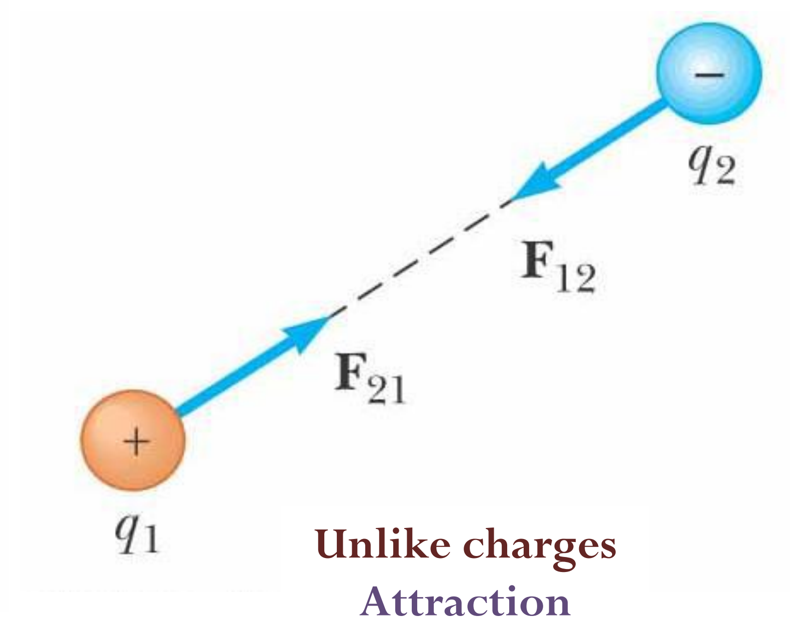
Applying Coulomb's law, for the electric field (E) of the charge (Q), we get:

$$F = k \frac{|Q q_o|}{r^2}$$

According to Newton's 3rd law of motion, (Q) will also suffer a force of the same value, but in the opposite direction:

$$\vec{F}_{12} = -\vec{F}_{21}$$





Example

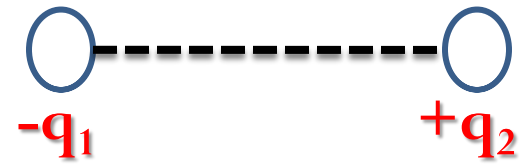
Two charged particles; +q and +5q are separated by a distance d:
Discuss each equation of the following? (right or wrong)

$\overrightarrow{F_1} = \overrightarrow{F_2}$	$\overrightarrow{F_1} = 5\overrightarrow{F_2}$	$5\overrightarrow{F_1} = \overrightarrow{F_2}$
$\overrightarrow{F_1} = -\overrightarrow{F_2}$	$\overrightarrow{F_1} = -5\overrightarrow{F_2}$	$5\overrightarrow{F_1} = -\overrightarrow{F_2}$
$F_1 = F_2$	$F_1 = 5F_2$	$5F_1 = F_2$
$F_1 = -F_2$	$F_1 = -5F_2$	$5F_1 = -F_2$

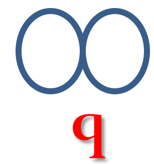
Example

Two identical metal spheres are 0.2m apart. A charge of $9\mu C$ is placed on one sphere while a charge of $-3\mu C$ is placed on the other. If the charges are touched and then returned to their original positions. What is the force on each charge?

$$q_1 = -3 \times 10^{-6}\ C$$
$$q_2 = 9 \times 10^{-6}\ C$$



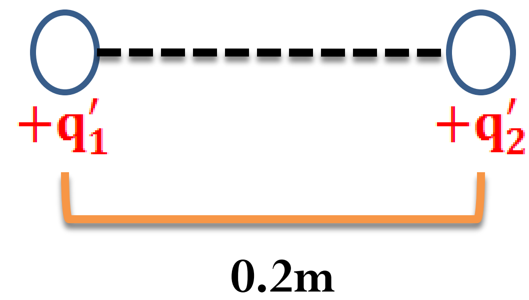
$$q = -3 + 9 = 6\ \mu C$$



$$q'_1 = q'_2 = \frac{6\mu C}{2} = 3\ \mu C$$

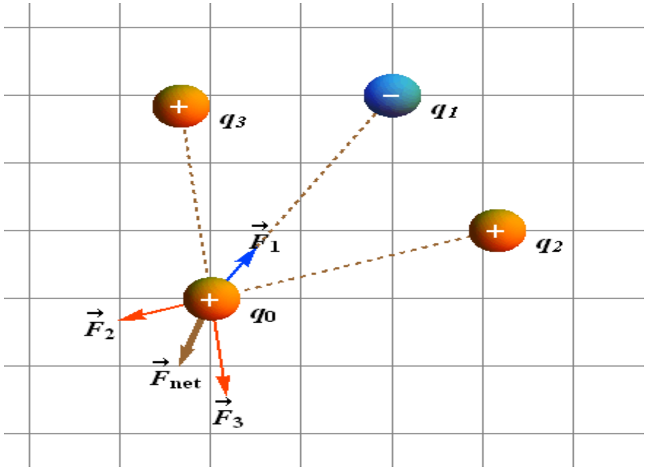
$$F = k\,\frac{|q'_1 q'_2|}{r^2}$$

$$F = 2.03\ N$$



Superposition of electric forces

The resultant electric force on a given charge due to a number of charges is the vector sum of electric forces of the individual charges on this charge:



$$\vec{F}_{tot} = \vec{F}_1 + \vec{F}_2 + \vec{F}_3 + \ldots\ldots \vec{F}_N$$

This means:

$$F_x = F_{1x} + F_{2x} + F_{3x} + \ldots\ldots F_{Nx}$$

$$F_y = F_{1y} + F_{2y} + F_{3y} + \ldots\ldots F_{Ny}$$

$$F = \sqrt{F_x^2 + F_y^2}$$ *magnitude*

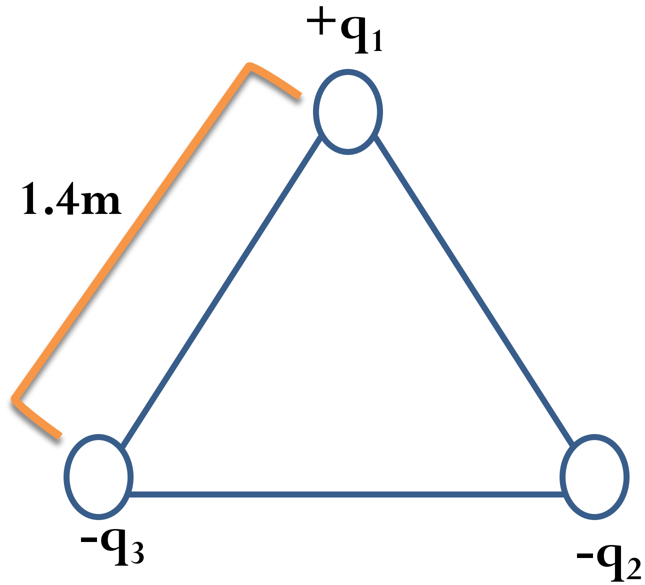
$$\theta = \tan^{-1}\frac{F_y}{F_x}$$ *direction*

Example

Three charged particles are placed at the corners of an equilateral triangle of side 1.4m. The charges are $+4\mu C$, $-3\mu C$ and $-5\mu C$ arranged clockwise starting from the apex. Calculate the magnitude and direction of the net force on the $+4\mu C$ due to the other two?

$q_1 = 4x10^{-6}$ C
$q_2 = -3x10^{-6}$ C
$q_3 = -5x10^{-6}$ C

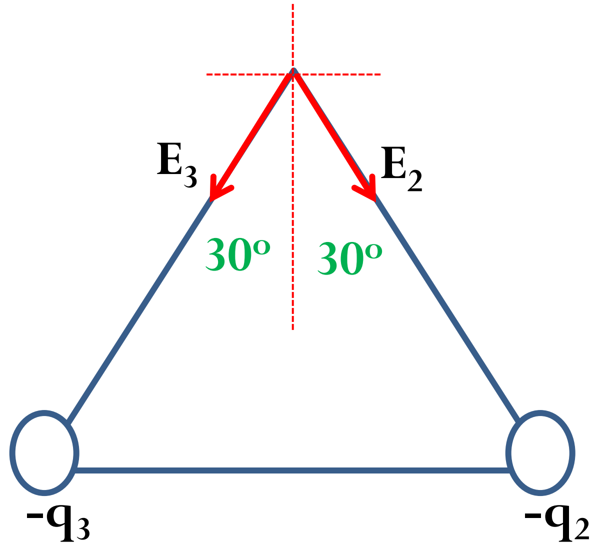
Let's calculate the field at (q_1) position:



$r_2 = r_3 = 1.4$ m
$\theta_2 = \theta_3 = 30^o$

$$E = k\frac{|q|}{r^2}$$

$E_2 = 13.7x10^3$ N/C ,
$E_3 = 22.9x10^3$ N/C



$E_{2x} = E_2 \sin 30 = 6.8\times10^3$ N/C

$E_{3x} = -E_3 \sin 30 = -11.5\times10^3$ N/C

$E_x = -4.7\times10^3$ N/C

$E_{2y} = -E_2 \cos 30 = -11.8\times10^3$ N/C

$E_{3y} = -E_3 \cos 30 = -19.8\times10^3$ N/C

$E_y = -31.6\times10^3$ N/C

The force acting on ($+q_1$) has the same direction of (E)

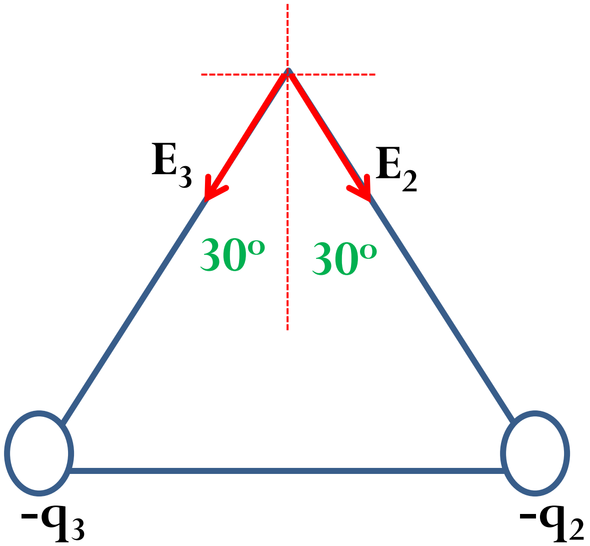
$F = |q_1| E$

$F_x = -18.8\times10^{-3}$ N

$F_y = -126.4\times10^{-3}$ N

$$F = \sqrt{F_x^2 + F_y^2} = 0.128 \text{ N}$$

$$\theta = \tan^{-1}\frac{F_y}{F_x} = -81.7^o$$



Motion of charge in an electric field

Any charged object present in the field space of another charged object will experience an ***electrostatic force***, resulting in accelerated motion according to Newton's 2nd law:

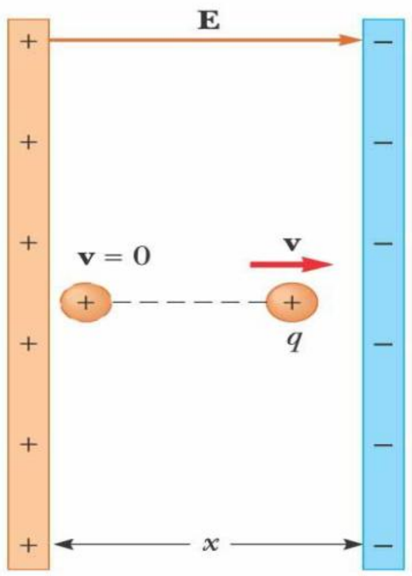
$$\vec{F} = m\,\vec{a}$$

For a (+ve) charge:

The force will be in the same direction of the electric field.

For a (-ve) charge:

The force will be in opposite direction of the electric field.



Example

An alpha particle has a mass of 6.64×10^{-27} Kg and a charge of +2e. What are the magnitude and direction of the electric field that will balance its weight? $e = 1.6 \times 10^{-19}$ C

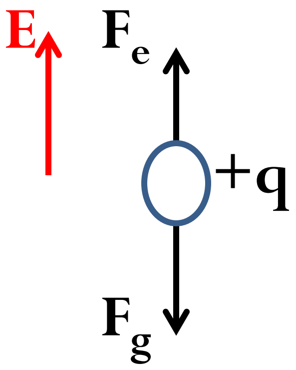
$q = +2e = 3.2\times10^{-19}$ C

$m = 6.64\times10^{-27}$ Kg

$F_e = F_g$ balance

$qE = mg$

$E = mg/q = 2\times10^{-7}$ N/C



The charge is +ve, so (E) is in the same direction of (F_e)

Example

Two equally charged particles, held 3.2m apart are released from rest. The initial acceleration of the 1st particle is observed to be $7 m/s^2$ and the 2nd to be $9 m/s^2$. The mass of the 1st is $6.3x10^{-7}$ Kg. Find:

i) The mass of the 2nd particle.

ii) The magnitude of the common charge.

iii) How many electrons on each charge.

$$k = 9x10^9 \ N.m^2/C^2 , \qquad e = 1.6x10^{-19} \ C$$

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$q_1 = q_2$

$r = 3.2$ m

$m_1 = 6.3\text{x}10^{-7}$ Kg

$a_1 = 7\ m/s^2$

$a_2 = 9\ m/s^2$

i) $F_1 = F_2$

$m_1\, a_1 = m_2\, a_2$

$m_2 = 4.9\text{x}10^{-7}$ Kg

ii) $$F = K\frac{|q_1 q_2|}{r^2} = K\frac{|q^2|}{r^2}$$

$$m_1 a_1 = K\frac{|q^2|}{r^2}$$ $q = 7.1\text{x}10^{-8}$ C

iii) $N = q/e = 4.4\text{x}10^{11}$ electron

Example

An electron accelerated eastward at $1.8x10^9$ m/s^2 by an electric field. Determine the magnitude and direction of that field?

$m_e = 9.11x10^{-31}$ Kg $\qquad\qquad$ $e = 1.6x10^{-19}$ C

$a = 7\ m/s^2$ **"eastward"**

$m_e = 9.11\text{x}10^{-31}$ Kg **$e = 1.6\text{x}10^{-19}$ C**

$F = qE$

$m\ a = qE$

$E = ma/e = 0.01\ N/C$ **"westward" because the charge is -ve**

To Remember

- Electrostatic force
- Superposition of electric force
- Motion of charge in an electric field