Quick Review (CH 14: Fluid Mechanics)

- **Density** is defined as the mass per unit volume ($\rho = \frac{m}{V}$)
- Pressure defined as the force applied perpendicular to the surface of an object per unit area ($P = \frac{F}{A}$)
- A Fluid is a substance can flow, both liquids and gases are fluids.
- Pascal's Principle: **Any change in the pressure of a fluid is transmitted uniformly in all directions throughout the fluid.**
- Variation of Pressure with Depth ($P_{bottom} = P_{top} + \rho h g$)
- Atmospheric pressure knows as the pressure of the layer of air that surrounds the earth. At sea level, the atmospheric pressure is 10^5 Pa.

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Physics 042

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Ch 23: Electric Fields

For more for more examples
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What are we going to talk about today?

Ch 23: Electric Fields

- 23.1 Properties of Electric Charges
- 23.3 Coulomb's Law
- 23.4 Analysis Model: Particle in a Field (Electric)
- 23.6 Electric Field Lines

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- 23.1 Properties of Electric Charges
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- 23.4 Analysis Model: Particle in a Field (Electric)
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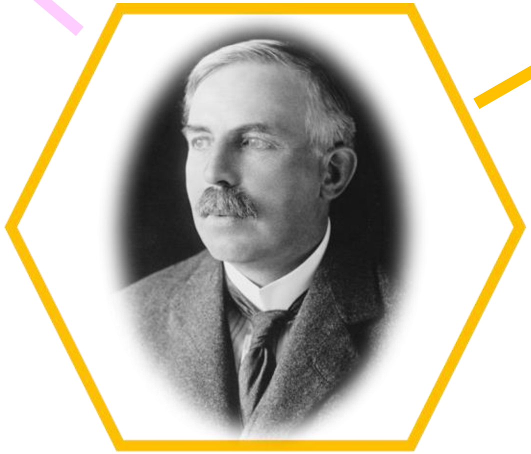
23.1 Properties of Electric Charges: (A Brief History)

Thales (600 B.C.)

Charles 1733 A.D.

Benjamin Franklin 1746 A.D.

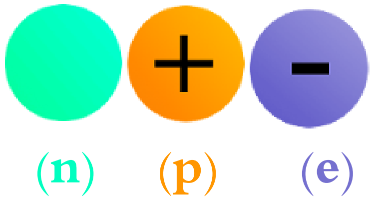


Ernest Rutherford 1911 A.D.

23.1 Properties of Electric Charges

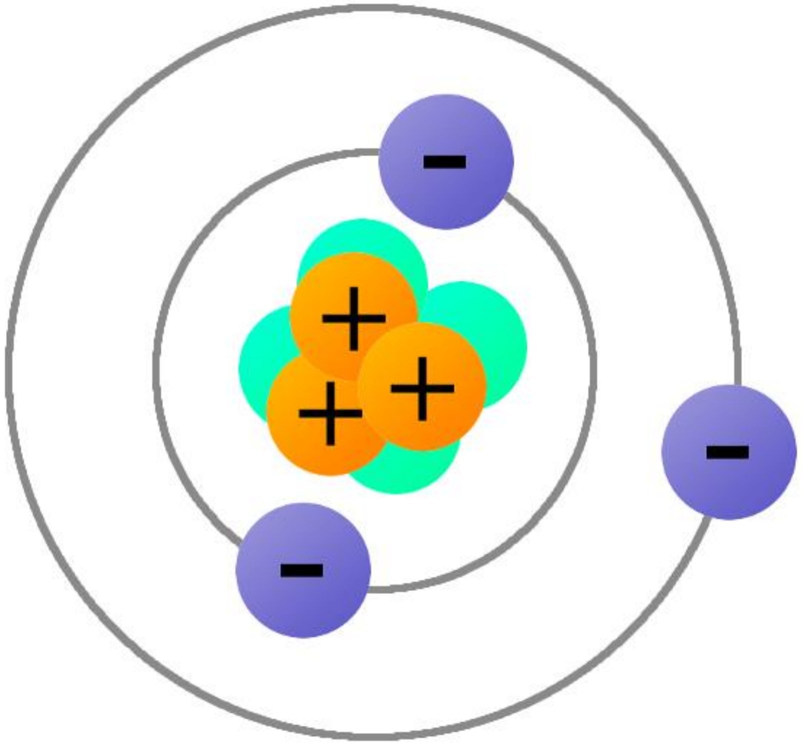
Electric Charge:

Everything in the world is made up of atoms. Each atom has smaller parts in it, neutrons, protons and electrons.



- The coulomb (Unit: C) is (SI) unit of electric charge
- One coulomb is equivalent to the charge of approximately 6.242×10^{18} proton.

Atomic Particle	Charge	Mass
Neutron (n)	0	1.675×10^{-27} Kg
Proton (p)	$+1.6 \times 10^{-19}$ C	1.673×10^{-27} Kg
Electron (e)	-1.6×10^{-19} C	9.110×10^{-31} Kg



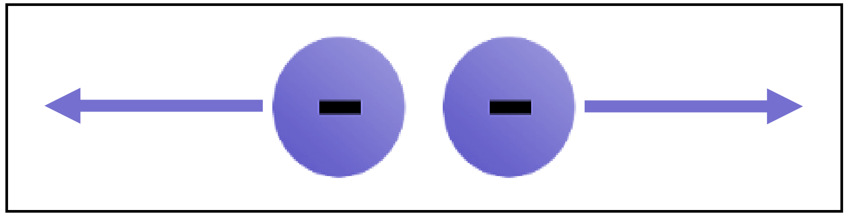
Properties of Electric Charges:

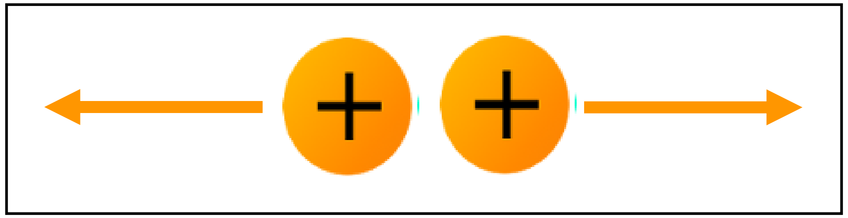
1- Charge is conserved.

2- Charge is quantized.

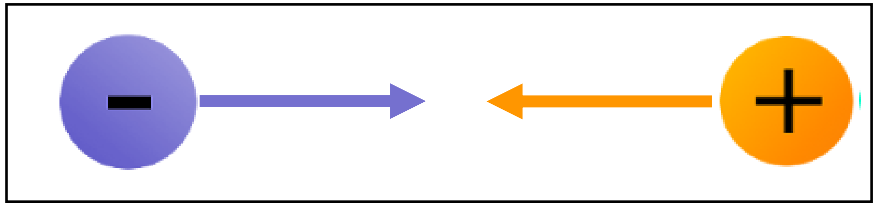
3- Charges of the same sign repel one another and charges with opposite signs attract one another, e.g.

- Like charges repel each other (positive to positive or negative to negative)





- Proton are positively charged and electron are negatively charged, so they are attracted to each other.



Checkpoint 1:

If you rub an inflated balloon against your hair, the two materials attract each other, as shown in figure. Is the amount of charge present in the balloon and your hair after rubbing.........................the amount of charge present before rubbing ?

A. less than

B. the same as ✓ (Charge is conserved)

C. more than

23.1 Properties of Electric Charges

23.1 Properties of Electric Charges

Two basics type of materials

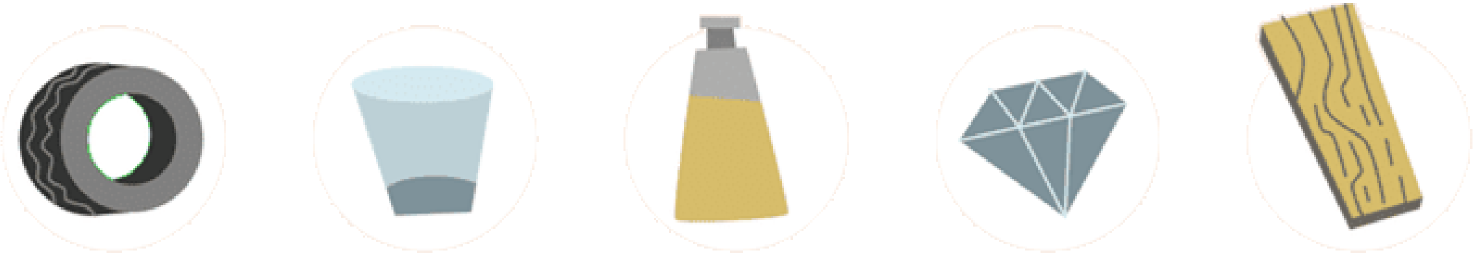
1- Conductors:

Materials, that allow the free movement of charges, such as :

Silver Gold Copper Steel Sea water

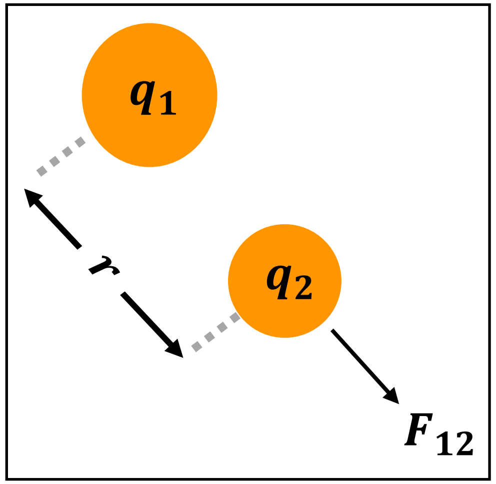
2- Insulators:

Materials, that don’t allow the free movement of charges, such as:



Rubber Glass Oil Diamond Dry wood

23.3 Coulomb's Law



Coulomb found that the electric force between two charged q_1 and q_2 objects is:

1– Proportional to the product of the charges on the objects.

$$F_{12} \propto q_1 q_2$$

2–Inversely proportional to the separation of the objects squared.

$$F_{12} \propto \frac{1}{r^2}$$

Therefore, the equation giving the magnitude of the electric force between two charges, which called Coulomb's law can be written as:

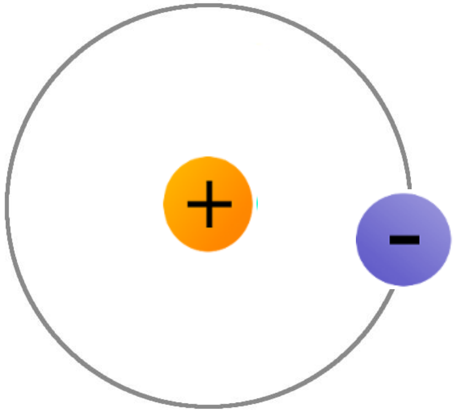
$$F_{12} = k_e \frac{|q_1||q_2|}{r^2}$$

k_e being a proportionality constant, having a value of $8.9875 \times 10^9 \ \mathrm{Nm^2/C^2}$

Example 23.1 The Hydrogen Atom

The electron and proton of a hydrogen atom are separated by a distance of approximately 5.3×10^{-11}m. Find the magnitudes of the electric force.

$q_1 = 1.6 \times 10^{-19}$ C $\quad q_2 = -1.6 \times 10^{-19}$ C $\quad r = 5.3 \times 10^{-11}$m



Hydrogen Atom

Use Coulomb's law to find the magnitude of the electric force:

$$F_{12} = k_e \frac{|q_1||q_2|}{r^2}$$

$$F_{12} = 8.9875 \times 10^9 \frac{|1.6 \times 10^{-19}||-1.6 \times 10^{-19}|}{(5.3 \times 10^{-11})^2}$$

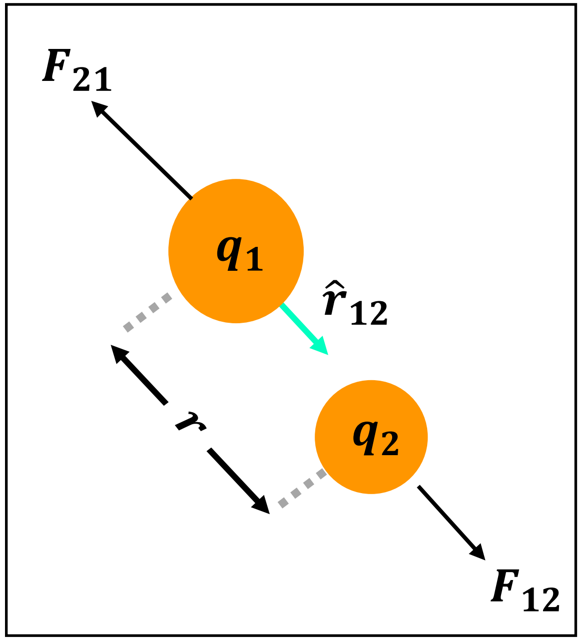
$$F_{12} = 8.2 \times 10^{-8}\text{N}$$

Simulation
Coulomb's law
(Try me!)

23.3 Coulomb's Law

As with all forces, the electric force is a vector quantity, and must be treated accordingly. Coulomb's law expressed in vector form for the electric force exerted by a charge q_1 on a second charge q_2, written $\vec{F}_{12}$ as

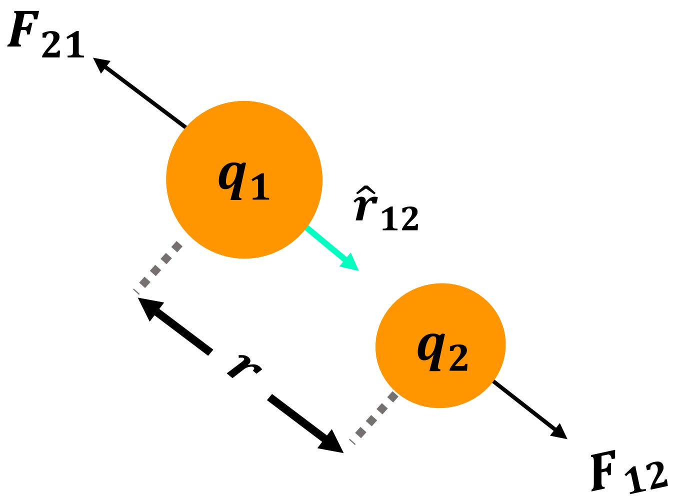
$$\vec{F}_{12} = k_e \frac{|q_1||q_2|}{r^2}\,\hat{r}_{12}$$



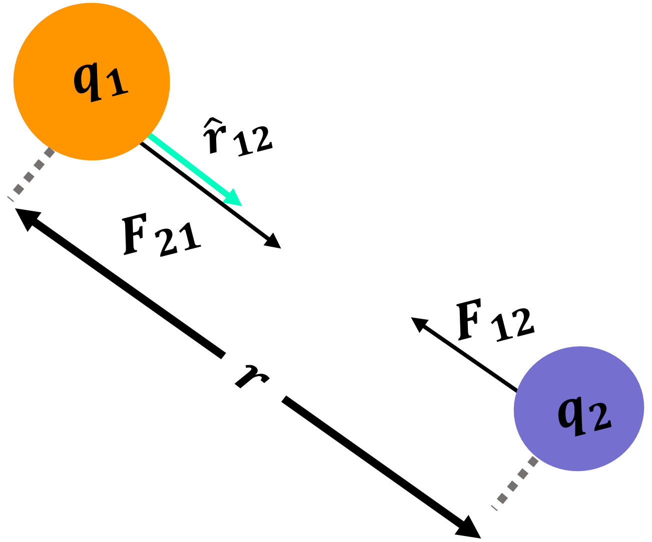
- $\hat{r}_{12}$ is a unit vector pointing from object 1 to object 2
- Because the electric force obeys Newton's third law, the electric force exerted by q_2 on q_1 is equal in magnitude to the force exerted by q_1 on q_2 and in the opposite direction; that is, $\vec{F}_{12} = -\vec{F}_{21}$.

23.3 Coulomb's Law

- The direction of the force is either parallel or antiparallel to this unit vector depending upon the relative signs of the charges , e.g.



(a) When the charges are of the same sign the force is repulsive.
The force F_{21} exerted by q_2 on q_1 is equal in magnitude and opposite in direction to the force F_{12} exerted by q_1 on q_2.



(b) When the charges are of opposite signs, the force is attractive.
The force F_{21} exerted by q_2 on q_1 is equal in magnitude and opposite in direction to the force F_{12} exerted by q_1 on q_2.

Checkpoint 2:

Object A has a charge of $+2\ \mu C$, and object B has a charge of $+6\ \mu C$. Which statement is true about the electric forces on the objects?

A. $\vec{F}_{AB} = -3\vec{F}_{BA}$

B. $\vec{F}_{AB} = -\vec{F}_{BA}$ ✔ (Newton's third law)

C. $3\vec{F}_{AB} = -\vec{F}_{BA}$

Exercise 1: A positive charge q is near a positive charge Q and a negative charge – Q

(a) Find the magnitude and direction of the force on q.

According to Coulomb's Law ,the force on q due the charge +Q is:

$$\vec{F}_+ = k_e \frac{|q||Q|}{a^2}\,\hat{y} = k_e \frac{qQ}{a^2}\,\hat{y}$$

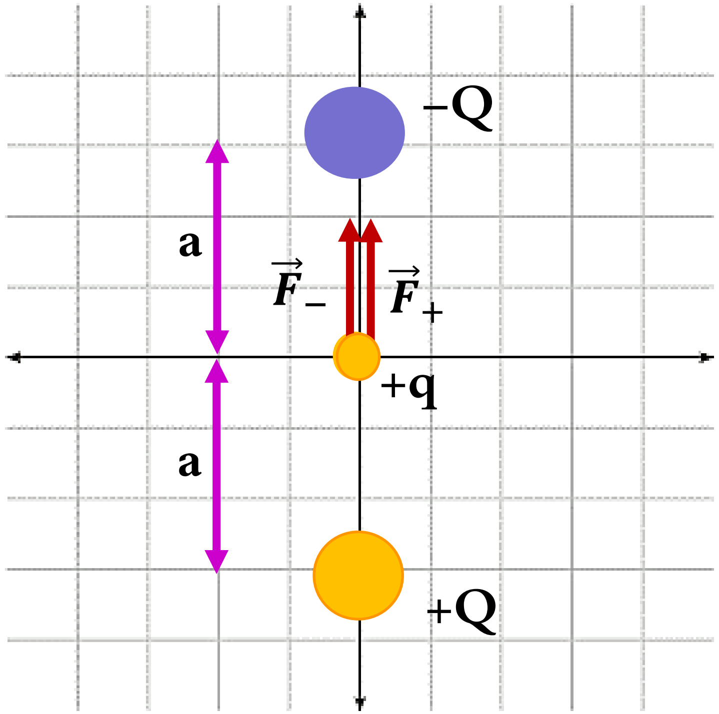
and the force on q due the charge –Q is:

$$\vec{F}_- = k_e \frac{|q||-Q|}{a^2}\,\hat{y} = k_e \frac{qQ}{a^2}\,\hat{y}$$

The net force on q is :

$$\vec{F}_{net} = \vec{F}_+ + \vec{F}_-$$

$$\vec{F}_{net} = 2\,k_e \frac{qQ}{a^2}\,\hat{y}$$



Exercise 1: A positive charge q is near a positive charge Q and a negative charge – Q

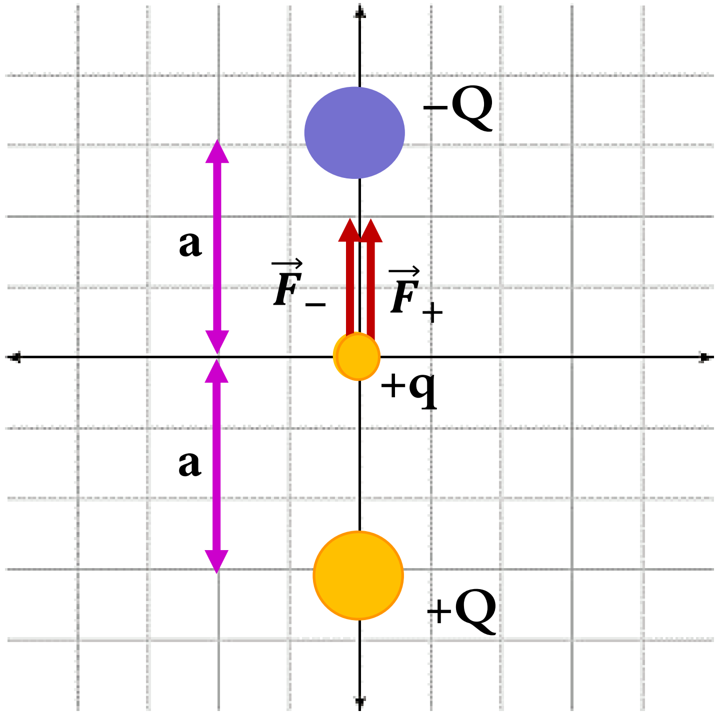
(b) If q=10^{-6}C, Q=2×10^{-6}C, and a= 1m, find the force on q

Substitution the numerical values given, the net force on q is

$$\vec{F}_{net} = 2\, k_e \frac{qQ}{a^2}\, \hat{y}$$

$$\vec{F}_{net} = 2 \times \frac{(8.9875 \times 10^9) \times (10^{-6}) \times (2 \times 10^{-6})}{1^2}\, \hat{y}$$

$$\vec{F}_{net} = 3.6 \times 10^{-2} \hat{y}\ \text{N}$$



23.4 Analysis Model: Particle in a Field (Electric)

Electric Field:

We define the **electric field** due to the source charge at the location of the test charge q_o to be the electric force on the test charge per unit charge.

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

then the electric field of a point charge given by

$$\vec{E} = k_e \frac{q}{r^2}\hat{r}$$

- Electric field is a **vector quantity**.
- The S.I unit of electric field is the N/C

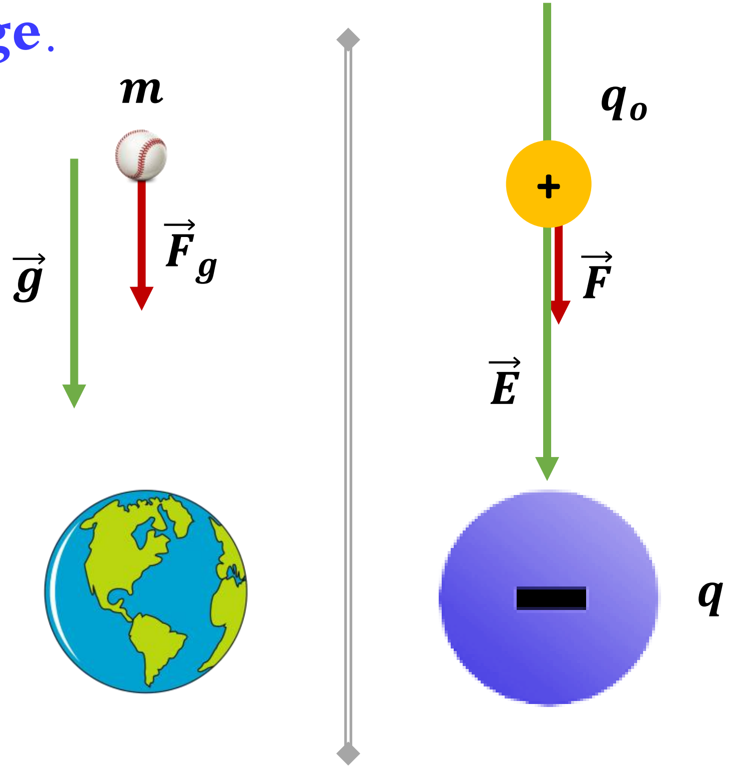


Fig. a: If q is negative, the force on the test charge q_o is directed toward q.

23.4 Analysis Model: Particle in a Field (Electric)

- For a positive source charge, the electric field radially outward from q. (Fig. a)
- For a negative source charge, the electric field radially inward toward q. (Fig. b)

Electric field due to a finite number of point charges

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

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

where r_i is the distance from the ith source charge q_i to the point P and $\hat{r}_i$ is a unit vector directed from q_i toward P.

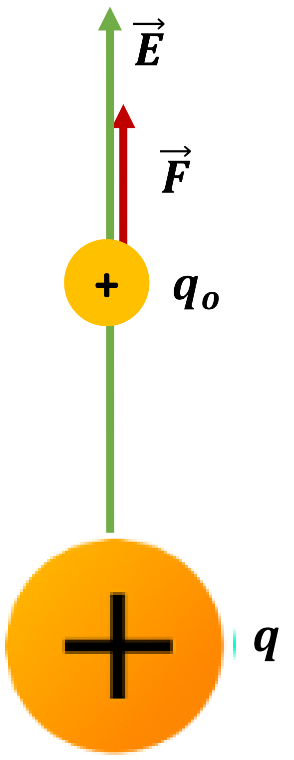


Fig. b: If q is positive, the force on the test charge q_o is directed away from q.

23.4 Analysis Model: Particle in a Field (Electric)

Checkpoint 3:

A test charge of $+3\ \mu C$ is at a point P where an external electric field is directed to the right and has a magnitude of 4×10^6 N/C. If the test charge is replaced with another test charge of $-3\ \mu C$, what happens to the external electric field at P ?

A. It is unaffected.

B. It reverses direction.

C. It changes in a way that cannot be determined.

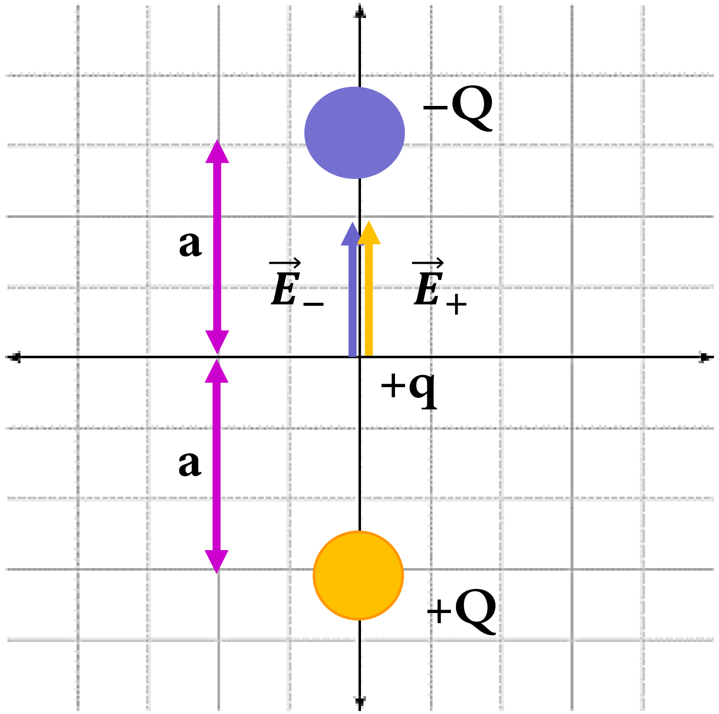
Exercise 2: The charges +Q and –Q of the preceding example are shown again in Fig.

(a) Q=2 $\times 10^{-6}$C, and a= 1m, find the electric field at the origin.

The field at the origin due to charge +Q is: $\vec{E}_{+} = k_e \frac{|Q|}{a^2}\,\hat{y} = k_e \frac{Q}{a^2}\,\hat{y}$

and the filed due the charge –Q is: $\vec{E}_{-} = k_e \frac{|-Q|}{a^2}\,\hat{y} = k_e \frac{Q}{a^2}\,\hat{y}$

The net electric filed at the origin is : $\vec{E}_{net} = \vec{E}_{+} + \vec{E}_{-} = 2\,k_e \frac{Q}{a^2}\,\hat{y}$



$$\vec{E}_{net} = 2 \times (8.9875 \times 10^{9}) \times \frac{(2 \times 10^{-6})}{1^2}\,\hat{y}$$

$$\vec{E}_{net} = 3.6 \times 10^{4}\,\hat{y}\ \text{N/C}$$

The net filed is directed upward.

23.4 Analysis Model: Particle in a Field (Electric)

Exercise 2: The charges +Q and −Q of the preceding example are shown again in Fig.

(b) Find the force on the charge q=10^{-6}C. Placed at the origin.

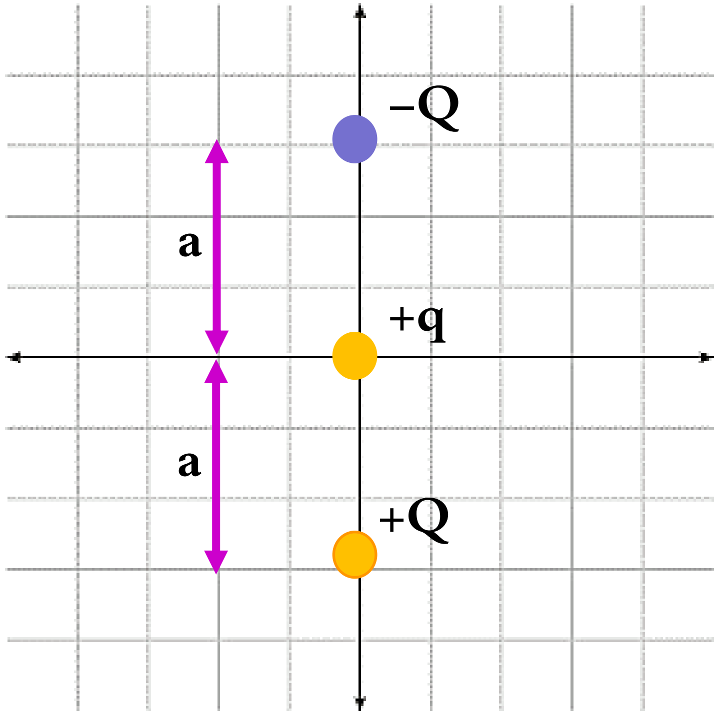
$\vec{E}_{net} = 3.6 \times 10^4\ \hat{y}$ N/C $\qquad q_o = 10^{-6}$ C $\qquad \vec{F}_{net} = ?$

The force on a charge q at the origin is

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

$$\vec{F} = 10^{-6} \times (3.6 \times 10^4)$$

$$\vec{F} = 3.6 \times 10^{-2}\ \hat{y}\ \text{N}$$

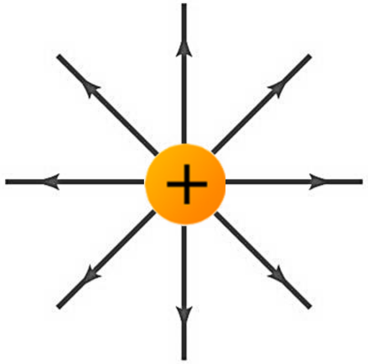


23.6 Electric Field Lines

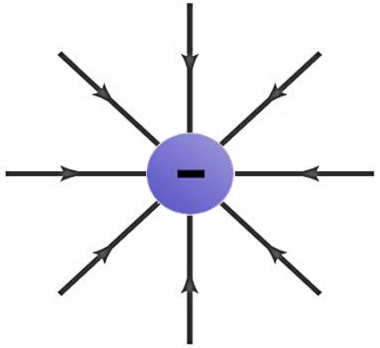
The electric field can be represented by field lines.

The rules for drawing electric field lines are as follows:

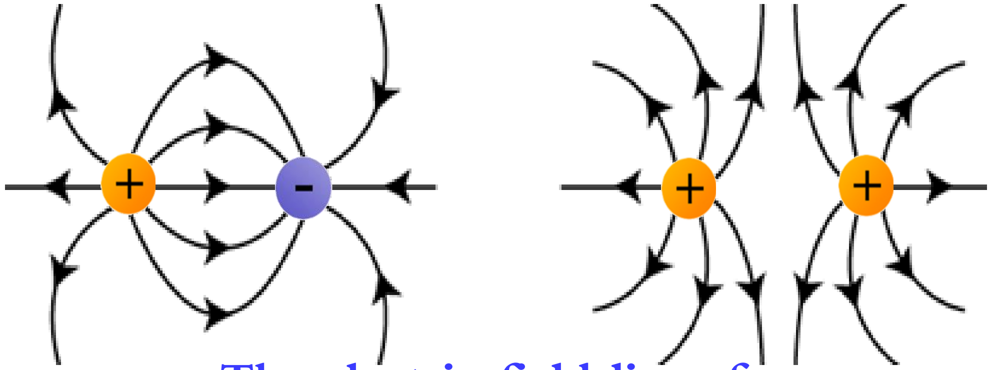
1. The lines must begin on a positive charge and terminate on a negative charge.
2. The number of lines drawn leaving a positive charge or approaching a negative charge is proportional to the magnitude of the charge. $(N \propto |q|)$



A positive charge sets up an electric field pointing away from the charge.



A negative charge sets up an electric field pointing towards the charge.



The electric field lines for opposite charges and like charges.

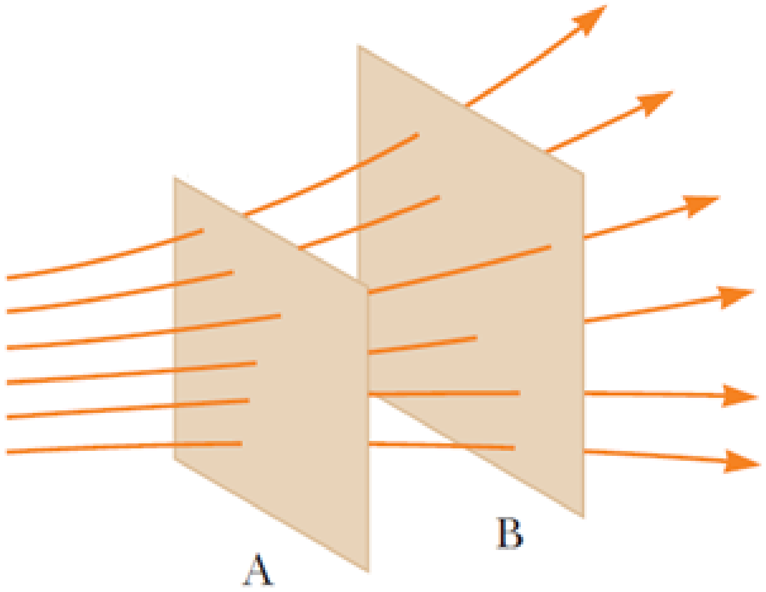
23.6 Electric Field Lines

The rules for drawing electric field lines are as follows:

3. No two field lines can cross.

4. The number of lines per unit area through a surface perpendicular to the lines is proportional to the magnitude of the electric field in that region. ($N \propto \vec{E}$)

Electric field lines penetrating two surfaces. The magnitude of the field is greater on surface A than on surface B.



Checkpoint 4:

Rank the magnitudes of the electric field at points A, B, and C shown in Fig. (greatest magnitude first).

A. (A, B, C). ✓ rule 4 ($N \propto \vec{E}$)

B. (C, B, A).

C. (B, A, C).