الملف أوراق عمل الوحدة الأولى Electrostatics
موقع المناهج ⇦ المناهج الإماراتية ⇦ الصف الثاني عشر المتقدم ⇦ فيزياء ⇦ الفصل الأول

Electrostatics

Types of forces in the nature

1- **Gravitational forces** : are forces of attraction that operate between two or more objects .

2-**Electromagnetic forces** : are forces of attraction or repulsion, operating between electrically charged objects or objects Magnetic .

3-**Extreme nuclear force** : Forces within the atomic nucleus. It works to coherent its components and overcome the electrical repulsion force between protons . The secret of its success in keeping protons together in the nucleus of an atom is due to the fact that they are stronger than electromagnetic force .

4-**Weak nuclear force** : This force is responsible for the radioactivity associated with decomposition of subatomic bodies .

- **Types of electric charges** : *positive (+) and negative (-) .*

- Like charges **repel** each other , and opposite charges **attract** .

Atom is made of three particles :

1- **protons** : have positive charge (+) located inside nucleus .
2- **electrons** : have negative charge (-) located outside nucleus .
3- **neutrons** : no charge (neutral) located inside nucleus .
- **For neutral atom** : (the number of electrons = the number of protons)

Electrons only can transfer from one atom to another , but the numbers of protons and neutrons are **constant .**

If atom gained electrons , its charge will be negative , its called a negative ion .
If atom lost electrons , its charge will be positive , its called a positive ion .

Types of materials

1- **Conductors** : Materials that **conduct** electricity well such as metals (copper , iron , gold , ……………)

2-**Insulators** : Materials that **do not conduct** electricity such as (rubber , glass , plastic , ……)

3 - **Semiconductors**: Materials can change from Insulators to conductors to Insulators again .
(considered the basis of all computer and consumer electronics industries) .

Types of semiconductors :

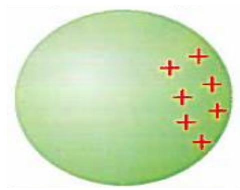
a - **Intrinsic** : (pure crystal) such as (Germanium , Silicon) .

b – **Extrinsic** : (Non pure crystal) we can get it by using a doping (adding material to another)

4- **Superconductors** : materials that have

a) zero resistance b) very law temperature c) no losses of energy .

distribution of charges for **<u>conductor</u>**
(uniform)



distribution of charges for **<u>insulator</u>**
(non – uniform)

Methods of electrostatic charging :

1) rubbing (triboelectric) **2) induction** **3) contact**

Charging by rubbing (triboelectric)

Is done by rubbing two materials together, one of them has ability to lose electrons and the other has ability to gain electrons .

Explain

1) When you rub a balloon with hair, the balloon is charged with a negative charge .

……

2) When you rub a ruler of plastic with a piece of wool , the wool is charged with a positive charge .

……

3) When you rub a bar of glass with a piece of silk , the silk is charged with a negative charge .

……

When you rub two objects :

both will get opposite charge . The mass will increase for the object has a negative charge , and the mass will decrease for the object has a positive charge .

Conductors and **insulators** materials can be charged by rubbing , but its more effective for insulators .

Law of charge conservation : The total electric charge of an isolated system is conserved .

(sum of electrons before rubbing = sum of electrons after rubbing)

The symbol of the charge is (q) and its **unit** in (SI) is *Coulomb* (C)

Charge of electron $(q_e) = -1.6 \times 10^{-19}$ C

The charge of proton (q_p) is the same magnitude the charge of electron but has the different type .

$$q_p = - q_e = 1.6 \times 10^{-19} C$$

Elementary charge (e) : the charge on a single proton . **$e = - q_e = q_p = 1.6 \times 10^{-19} C$**

What is the meaning of (the charge is quantized) ?

The charge (q) of the object is equal integer number (n) multiply by the elementary charge (e)

$$q = \mp n e \qquad n = 1 , 2 , 3 , 4 , \ldots\ldots\ldots\ldots$$

take : the sign (-) if the object gains electrons

(+) if the object looses electrons

To find the number of electrons (n) that are transferred to or (from) the object

$$n = \left| \frac{q}{e} \right|$$

Q1 : What is the charge on a neutral sphere if 2×10^{6} electrons are added to it ?

Q2 : : What is the charge on a neutral object if 4×10^{6} electrons are transferred from it ?

Q3 : How many electrons are required for a neutral object to get a total charge -3.2×10^{-12} C ?

.

Q4 : Which of these charges may be available in our physical world

a) -6.4×10^{-20} C b) 2.4×10^{-19} C c) 4.0×10^{-19} C d) -6.0×10^{-15} C

Q5 : An object has a charge -2×10^{-8} C , if the total charge of the object becomes -6×10^{-8} C

a) Did the object lose or gain electron ?

b) How many electrons are lost ore gained ?

Electric current (I): is magnitude of charge (q) that flows through a conductor during a time interval (t) .

$$I = \frac{q}{t}$$

so $t = \frac{q}{I}$ and $q = I \cdot t$

The unit of current in (SI) is (C / s or $C\ s^{-1}$) , called Ampere (A) (1 C = 1 A s)

Remember :

$mC = 10^{-3}\ C$ $\mu C = 10^{-6}\ C$ $nC = 10^{-9}\ C$ $pC = 10^{-12}\ C$

Q_6 **: A current of 4.0 mA flows through a wire ,** calculate the number of electrons flow through a wire after 2 s

To find the charge of any object (q) , where

$$q = e\,(N_p - N_e) = e\,N_{\Delta e}$$

$$N_{\Delta e} = N_p - N_e$$

N_p : number of protons

N_e : number of electrons

$N_{\Delta e}$: difference between the number of protons and electrons
(number of electrons are removed from the object)

Notes

If $N_p > N_e$ ⟶ q (+)
If $N_p < N_e$ ⟶ q (-)
If $N_p = N_e$ ⟶ q = 0 (neutral)

Q_7 **: An atom has (8) protons and (10) electrons ,** find its charge

Q_8 **: An object has (11) electrons , and its charge + 3.2 x 10^{-19} C ,** find the number of protons

Q_9 : An object has (N – 4) electrons and (N) protons find its charge

Q10 : If we wanted a block of iron of mass 3.25 kg to acquire a positive charge of 0.1 C . find

1)the number of iron atoms in the block (N_{atoms})

2) the total number of electrons in the block (Ne)

3) the number of electrons are removed from the block ($N_{\Delta e}$)

4) the fraction of the electrons would we have to remove.

Where atomic number of iron = (26) , mass number = 56

Avogadro's number (number of atoms in one mole) = 6.022×10^{23}

Q11: If we wanted a piece of sodium of mass 0.2 kg to acquire a positive charge of 0.2 C . find the fraction of the electrons would we have to remove?

Where atomic number of (Na) = (11) , mass number = 23

Charging by induction

Steps for charging a neutral connector (positive charge) by **induction**

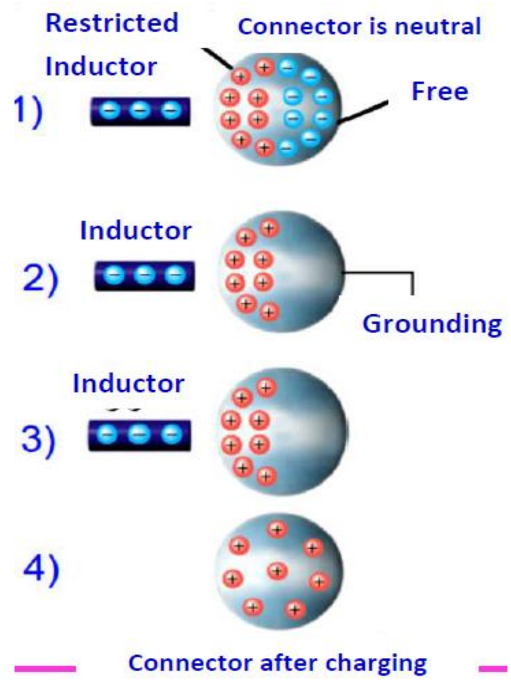
1 – close a negative inductor to a the sphere connector .

(free electrons of the sphere repel to the farthest distance from the (inductor)

2- connect the sphere by a wire to the earth (grounding) , the electrons of sphere transfer to the earth

3- disconnect the sphere from the earth (remove a wire) and moves the inductor away from the sphere .

4- the positive charges of sphere distribute (uniform) on the surface .



Conductors materials only can be charged by induction

The object has an opposite charge of an inductor by using induction .

Grounding : process of removing charge by connecting an object to the earth .

earth is considered a very large store for electrons .

Charging by contact

Touching a neutral object (A) with another charged object (B) , some charge of object (B) transfers from object (B) to object (A) .

After touching both objects have the same type of charge , so the two objects will repel each other .

The sum of the charges before touching is <u>**equal** the sum</u> of the charges after touching **(law of charge conservation)**

Conductors and insulators materials can be charged by contact , but in conductors more effective .

Q12 : Two identical spherical conductors , the first has no charge and the charge of the second $+ 4 \times 10^{-12}$ C , if the two conductors are touching to each other

a – find the charge for each conductors after touching

b – which conductors loses , gains electrons ?

c – how many electrons that are lost ?

Q13 : Two identical spherical conductors , the charge of the first $+ 6 \times 10^{-8}$ C and the charge of the second $- 12 \times 10^{-8}$ C , if the two conductors are touching to each other

find the charge for each conductors after touching

Q14 : Two identical spherical conductors , the charge of the first $+ 6 \times 10^{-8}$ C and the charge of the second $- 12 \times 10^{-8}$ C , if the two conductors are touching to each other

a – find the charge for each conductors after touching

b – which conductors loses , gains electrons ?

c – how many electrons that are lost ?

Electroscope

is a device that gives an observable response when it is charged.

The uses of electroscope

- to determine the object is charged or not .
- to determine the type charge of the object .

Parts of the electroscope: -

charged electroscope

neutral electroscope

two leaves are separated(farther)
(separated at an angle)

two leaves are closer together
(in the vertical position)

Q15 : An object has a positive charge is moving toward a neutral electroscope , what happens to its leaves (explain)

the two leaves separated (farther)

because the negative charges of electroscope move up (knob) , and the positive charges of electroscope move down (leaves) , so the positive charges repel each other (separated further)

Q16 : An object has a negative charge is connected to a neutral electroscope , what happens to its leaves ?   (explain)

the two leaves separated (farther)

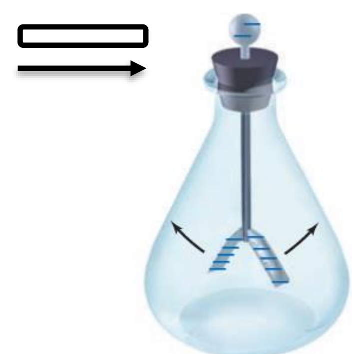
because some negative charges of the object transfer to the electroscope and the negative charges on the two leaves , so they repel each other , so the two leaves (separated further)

Q17 : An electroscope has a negative charge , if a conductor is moving toward an electroscope without touching , what is the charge of the conductor for each the following

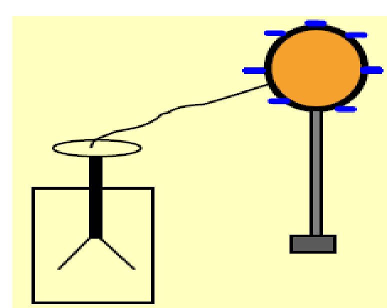
A) if the distance between the two leaves increasing ……………

B) if the distance between the two leaves decreasing   ………………..

C) if the distance between the two leaves remains constant ……………………



Q19: A spherical conductor has a negative charge and stands on insulator , its surface is connected to an electroscope **by a copper wire** , what happens to its leaves for each following



a) if insulator object touches a spherical conductor ………………

b) if a positive charged conductor is moving toward the sphere …………

c) if a negative charged conductor is moving toward the sphere …………

- If you put your finger on the knob of the electroscope that has a negative charge , the leaves will be closer to each other . (explain) ………………………………

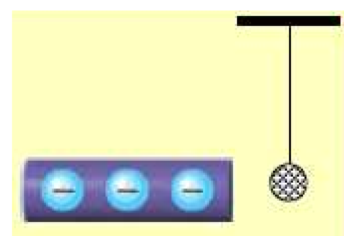
Because a negative electrons of electroscope transfer from electroscope to the earth (grounding)until becomes neutral , so the two leaves are closer to each other .

………………………………………………………………………..

- If you put you finger on the knob of the electroscope that has a positive charge , the leaves will be closer to each other . (explain)

Because a negative electrons transfer from the earth to the electroscope (grounding) until becomes neutral , so the two leaves are closer to each other .

Q_{19} : A bar has a negative charge is moving toward a neutral ball , we note the ball attract to the bar then repel with a bar (explain why ?)



Positive charge in the ball will move to the left side , that is close to the bar and negative charge of the ball move to the right so the bar and the ball attract each other , after that when the bar touches the ball some electrons transfer from the bar to the ball , both of them have the same charges , so they repel each other .

Electrostatic Force – Coulomb's Law

What is the importance of Coulomb' s law ?

to find the electric force (F) between two charges .

Electric force between two charges depends on three factors

1) amount of two charges (q_1 and q_2)

Electric force is **direct proportional** the **product** of the two charges (q_1) and (q_2)

$$F \propto |q_1 . q_2|$$

2) distance (r) between the two charges

Electric force is **inversely proportional** to the **square of the distance** between the centers of the two charges . **inverse square law**

$$F \propto \frac{1}{r^2}$$

3) medium separates between the two charges

Is related to a constant (ϵ) **electric permittivity** of medium

For free space $\epsilon = \epsilon_o$ and

ϵ : is related to another constant **Coulomb' s constant (k)**

Where $\epsilon_o = 8.85 \times 10^{-12} C^2 / N.m^2$

and $K = \frac{1}{4\pi\epsilon_o} = 8.99 \times 10^9 N.m^2 / C^2$

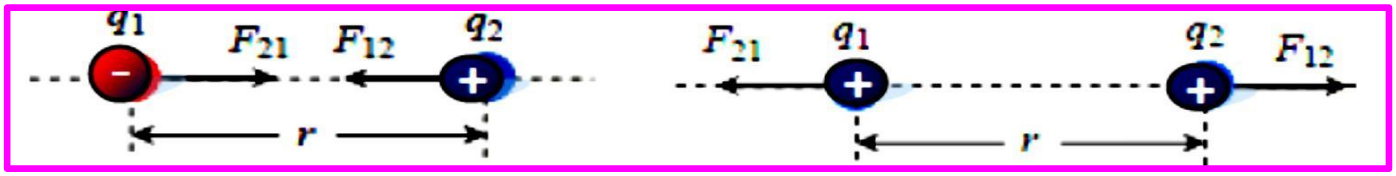
Coulomb' s Law : state

The force between two charges is equal to a constant (k) times the product of the two charges divided by the square of distance between them .

$$F = \frac{|k \; q1 . \; q2|}{r^2}$$

Coulomb ' s Law

F : is a vector quantity (has magnitude and direction) , its direction depends on the type of the objects charges .



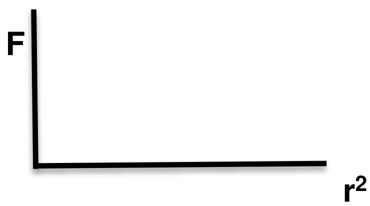
Where $\mathbf{F_{12}}$: is a force that q_1 exerts on q_2 and $\mathbf{F_{21}}$: is a force that q_2 exerts on q_1

What is the relation between F_{12} and F_{21} (magnitude and direction)

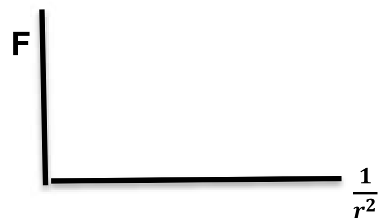
……

Q20 : Graph the relation between

a) square distance (r^2) and the force between the two charges



b) inverse square distance ($\frac{1}{r^2}$) and the force between the two charges



slope represents ……………………….

Q21: A negative charge of -2×10^{-4} C and a positive charge of 5×10^{-4} C are separated by a distance 10 cm find the electric force between the two charges , determine its type

Q22 : a positive charge of 1.0×10^{-8} C exerts an attractive force of 2.0×10^{-3} N on a second charge that is 30 cm away

a) what is the type of the second charge ? ……………………..

b) find the magnitude of second charge

Q23 : Two charges $q_1 = -2 \times 10^{-8}$ C , $q_2 = +4 \times 10^{-8}$ C , the electric force between them 7.2×10^{-4} N
find the distance between the two charges

Q24 : Two charges (q_1 , q_2) , the distance between them (r) and the electric force (F)

What happens to the force between the two charges ? if

a) the distance between the charges increased three times

……………………………………………………………………………………

b) the distance between the charges decreased to half

……………………………………………………………………………………

c) the first charge increased four times and the second decreased to half

……………………………………………………………………………………

d) all the first charge , the second charge and the distance between them decreased to half

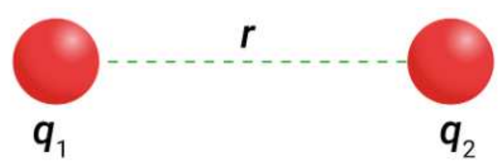
……………………………………………………………………………………..

Q25 : The electric force between two charges (1.6) N , if the distance between them decreased to half the electric force becomes

a) 0.4 N b) 3.2 N c) 0.8 N d) 6.4 N

Q26 :

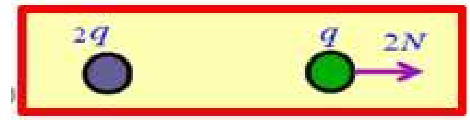
Two positively charged particles are separated at a distance, r, as shown in the image on the right. The two particles exert a repulsive force on each other of magnitude F. Sami wants to know how to double this force. Which of the following options describes one way he can double this electrostatic force?



- decrease the distance between the charged particles to $\frac{r}{\sqrt{2}}$
- decrease the distance between the charged particles to $\frac{r}{2}$
- increase the distance between the charged particles to $\frac{r}{\sqrt{2}}$
- increase the distance between the charged particles to $\frac{r}{2}$

Q27: Two <u>identical</u> positive charges separated by a distance 20 cm repel each other with a force 0.225 N find the magnitude of the two charges

Q28: According to data in the figure, If the right charge (q) is positive

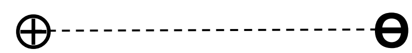


a) what is the kind of charge in the left side ....

b) What is the magnitude and direction of the force affecting on the left charge ? and why ?

....

Q29: If the charge q_1 is exerted by an electric force 4N



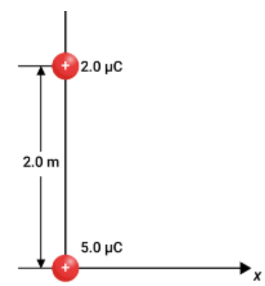
q_2 will be exerted by electric force

$q_1 = 4\times10^{-7}$ C **$q_2 = -8\times10^{-7}$ C**

a) 4N to the right b) 8N to the right c) 8N to the left d) 4N to the left

Q30 :

Suppose that you have two positively charged particles, $q_1 = 2\ \mu C$ and $q_2 = 5.0\ \mu C$, that are 2.0 m apart. The charge q_2 is fixed at the origin. What will happen to q_1 when it is free to move? The charge q_1 has a mass of 2.3 g.



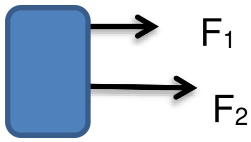
- The charge q_1 will stay at rest since its weight is equal to the electrostatic force acting on it.
- The charge q_1 will move downward since its weight is greater than the electrostatic force acting on it.
- The charge q_1 will move upward since its weight is less than the electrostatic force acting on it.
- The charge q_1 will move to the right since there is no relation between its weight and the electrostatic force acting on it.

Superposition Principle (The sum of the resultant forces acting on electric charge)

- parallel forces

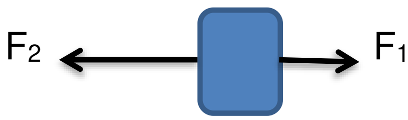
Note : To find the net force (F_{net}) for two parallel forces

- same direction



$F_{net} = F_1 + F_2$ (right) (Add)

- opposite direction



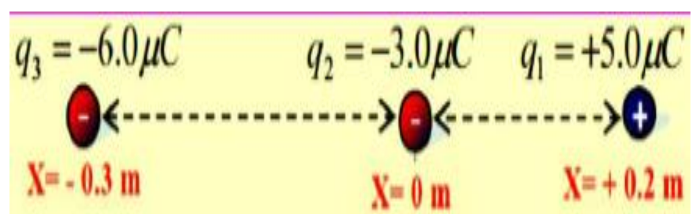
$F_{net} = F_2 - F_1$ (left) (Subtract)

The net force (F_{net}) for two parallel forces (F_1) and (F_2) equals

- the sum of the two forces if the two forces have the same direction and its direction has the same direction of the two forces .

- the difference between the two forces if the two forces have the opposite direction and its direction is the same direction of the largest force

Q31: Three charges (q_1, q_2 , q_3) are located on horizontal axes at (x= 0.2 m) , (x= 0 m) and (x= - 0.3 m) as shown in figure



where $q_1 = +5.0\ \mu C$

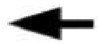
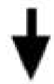
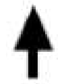
$q_2 = -3.0\ \mu C$

$q_3 = -6.0\ \mu C$

Find the net force on q_2

Find the net force on q_1

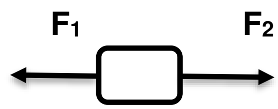
Q32: Three identical charges are arranged on a straight line as shown in the figure. What is the direction of the electrostatic force on the *middle* charge?

a- ..  b-  c-  d-  e- No Force

Equilibrium Position

Is a point where the net electric force acting on a charge located at this point equals zero

For two forces (F_1) and (F_2) acting on the object , the object will be at equilibrium if the two forces are



1) the same in magnitude

2) the opposite in direction

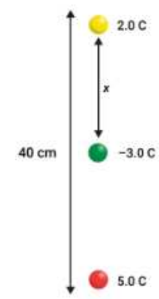
Q33 :Two charged particles q_1 = + 1 μC is located at the origin, and q_2 = + 4 μC is located on the positive *x*-axis at x = 1. 0 m. Where should a third charged particle q_3 = - 5 μC be placed to be at an equilibrium point (the sum forces on it = zero)?

Q34 : Two charged particles q_1 = 4 μC is located at the origin, and q_2 = -9 μC is located on the positive *x*-axis at x = 0.5 m. Where should a third charged particle q_3 be placed to be at an equilibrium point ?

Q35 :

Select the correct choice.

Three charged particles lie along the *y*-axis, as shown in the image on the right. The charge of each particle is as follows:



- $q_{yellow} = 2.0$ C
- $q_{green} = -3.0$ C
- $q_{red} = 5.0$ C

You are told the green particle is at equilibrium. What is the separation distance, in centimeters, between the yellow particle and green particle?

You can assume that the mass of each particle is very small so you can neglect any gravitational forces.

- 25 cm
- 31 cm
- 11 cm
- 15 cm

Result :

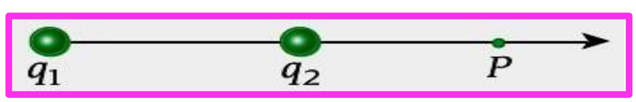
Equilibrium Position for two charges is located

a) between the two charges , if the two charges have the same type , and closes to the smallest charge .

b) outside the two charges , if the two charges have different type , and closes to the smallest charge .

- if the two charges identical (have the same magnitude and type) the equilibrium position located at the the midpoint for the two charges .

Q36 : A positive point charge +*q* is placed at point *P,* to the right of two charges q_1 and q_2, as shown in the figure. The net electrostatic force on the positive charge +*q* is found to be zero. Identify each of the following statements as true or false.



a) Charge q_2 must have the opposite sign from q_1 and be smaller in magnitude.

b) The magnitude of charge q_1 must be smaller than the magnitude of charge q_2.

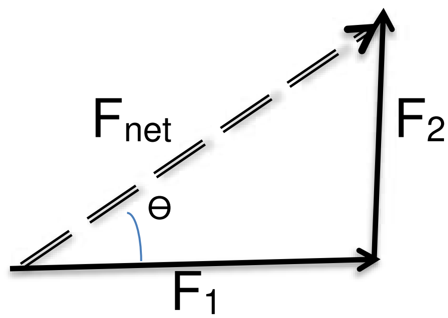
c) Charges q_1 and q_2 must have the same sign.

d) If q_1 is negative, then q_2 must be positive.

e) Either q_1 or q_2 must be positive

Note : To find the net force (F_{net}) for two perpendicular forces we use (Pythagorean law)

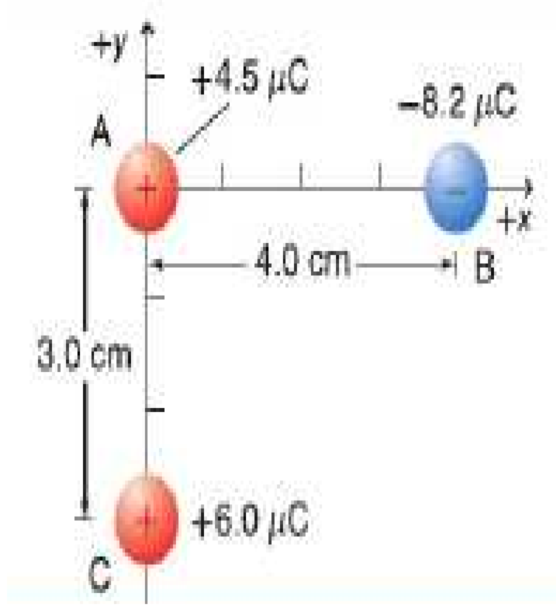
$$F_{net} = \sqrt{(F_1^2 + F_2^2)}$$



to determine the direction

find an angle (ϴ) where **$\theta = \tan^{-1} (\frac{F_2}{F_1})$**

Q37 :Three charged spheres are at position shown in figure
find the force on sphere A and its direction



Q38 : According to the figure , the first charge (q_1) exerts an attractive force of 0.4 N on the third charge (q_3)

a) What is the type of (q_3) ? …………..

b) find (q_3)

c) find the net force acting on (q_3) and determine the direction

where : **$q_1 = 4 \times 10^{-6}$ C** **and** **$q_2 = -2 \times 10^{-6}$ C** **$r_{13} = 0.3$ m** **$r_{23} = 0.2$ m**

To find the speed (v) of electron **with mass (m) and charge (- e)** that is moving in a circular orbit with **radius (r)** round the nucleus in (hydrogen atom) ($^{1}_{1}H$) has one electron and one proton

centripetal force (Fc) = electric force (Fe)

$$m \frac{v^2}{r} = \frac{k\,e^2}{r^2}$$

so v = ……….

To find the acceleration of the electron F = ma

$$\frac{k\,e^2}{r^2} = ma$$

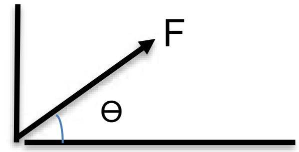
so a = ………………..

Q39 : An electron moves in the first orbit round the nucleus in hydrogen atom find

a) the speed of electron b) the acceleration of the electron if (the radius of the first orbit = 5.3×10^{-11} m)

Note : To find the net force , If the two forces are not parallel or perpendicular (any angle) we use the components of the vector (F)

remember

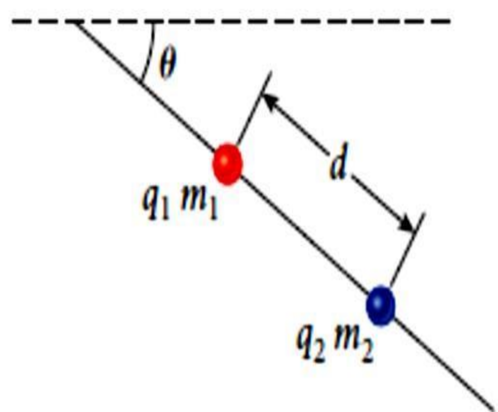


ϴ : the angle between (F) and horizontal axis (x) axis

F has two components x – component **(F_x) = F cos (ϴ)**

y – component **(F_y) = F sin (ϴ)**

Q40 : A bead with charge q_1 = +2.0 μC is fixed in place on an insulating wire that makes an angle of θ = 40.0° with respect to the horizontal as in Figure . A second bead with charge q_2 = –5.0 μC slides without friction on the wire. At a distance *d* = 0.4 m between the beads, the net force on the second bead is zero. What is the mass, m_2, of the second bead?



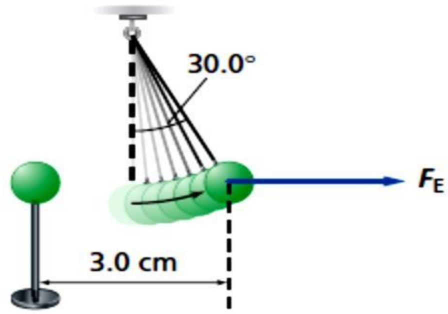
Q41 : The two balls (in the figure) each have a mass of 1.0 g and an equal charge. One ball is suspended by an insulating thread. The other is brought to 3.0 cm from the suspended ball. The suspended ball is now hanging with the thread forming an angle of 30.0° with the vertical. The ball is in equilibrium with F_E, F_g, and F_T. Calculate each of the following.

a) F_g on the suspended ball

b) the tension force in thread

c) the electric force (F_E)

d) the charge on the balls



Q42 : Two identical charged balls hang from the ceiling by insulated ropes of equal length , l = 1.50 m , a charge q= 25 μ C is applied to each ball . then the two balls hang at rest and each rope has an angle 25.0 ^{0} with respect to the vertical (shown figure) . What is the mass of each ball ?

…