Physics 10 Class Notes
CHAPTER NO 13
CHAPTER NO.13 ELECTROSTATICS

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CHAPTER NO.13 ELECTROSTATICS

Major Concepts

- Production of electric charges
- Electrostatic induction
- Electroscope and its uses
- Coulomb's law
- Electric field and electric field intensity
- Electric field lines
- Electrostatic potential
- Capacitors and capacitance
- Combination methods of capacitors.
- Types and uses of capacitors
- Solution of problems

Comprehensive Question

Q1. Define electrostatics and electric charge? How objects can be electrified? Describe with the help of experiments?

Electrostatics:

Electrostatics is composed of two words, Electro and statics, Electro mean charge and static mean rest. So it is defined as,the branch of physics which deal with the study of charges at rest is called electrostatics.

Electric charge:

The deficiency (or) excess of electrons on an object is called electric charge.

If there is excess of electrons on an object, then the object is called negatively charged. If there is deficiency of electrons on an object, then the object is called positively charged.

The properties of electric charge can be understood with the help of different experiments discussed as fellows.

Experiments No.1:

Take glass rod and rub it with silk cloth, we will observe that the glass rod will attract small pieces of paper toward itself.

Similarly the same type of behavior is observed by the silk cloth. If we suspend glass rod and bring the silk cloth near it, they will attract each other.

Experiment No.2:

Take a rubber rod and rub it with woolen cloth, again we observe that the rubber rod and woolen cloth, attract small pieces of paper toward itself. If we suspend the rubber rod and bring the woolen cloth near it, they will attract each other,

Conclusion:

Before these experiments we observe that both the rods and both the cloths did not have this property of attraction. Since gravitational force is also attractive in nature. But the property of attraction in these two experiments is not due to gravitational force because gravitational force was present before rubbing of rods with the cloths but it was not strong enough to attract clothes toward the rods. The attraction is due to 'electrical force between the charges placed on rods by cloths due to rubbing.

Experiment No.3:

Suspend glass rod rubbed with silk cloth and bring another glass rod rubbed with silk cloth near to the first glass rod. We will observe that these glass rods repel each other, Now suspend rubber rod rubbed with woolen cloth and bring a glass rod rubbed with silk cloth near to it, we will observe that these Two rods attract each other, By bribing rubber rod rubbed with woolen cloth to the suspended rubber rod, we well observe that they also repel each other as shown in figure.

Q 2: Define conductor and insulator. Give examples?

Ans: Conductor:

The substances through which electric current can flow easily are called conductors.

Explanation:

In a metallic substances such as solid copper, iron, aluminum etc. the valance electrons are not bound to any particular nucleus. They can move freely. They are called free electrons. Those substances which have a large number of free electrons per unit volume can easily conduct electric current are known as good conductors.

Insulators:

The substances through which electric current cannot flow easily are called insulators.

Examples:

Dry wood, plastic. glass. rubber etc.

In insulators the valance electrons are tightly bounded with the respective nucleus. Therefore, electric current cannot flow easily through insulator.

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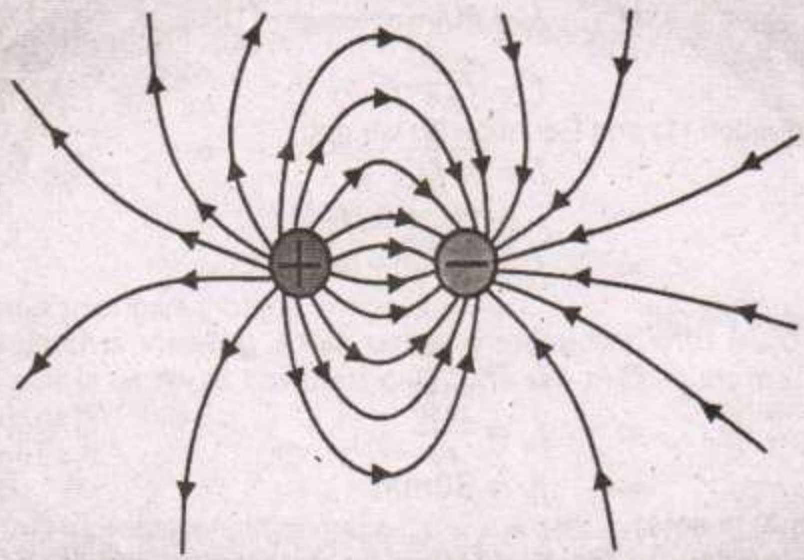

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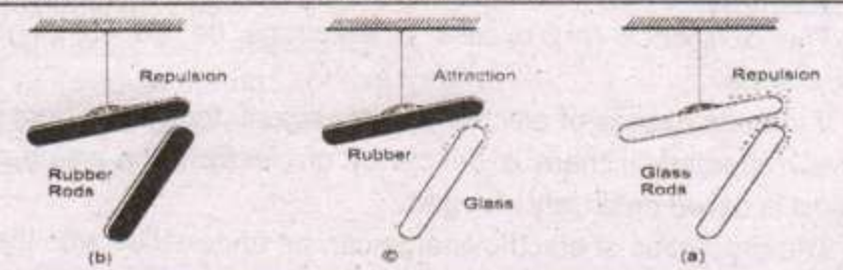

(a,b) Like charges repel each other © Unlike charges attract each other

Q2: Define conductor and insulator. Give examples?

Ans: Conductor:

The substances through which electric current can flow easily are called conductors.

Explanation:

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Insulators:

The substances through which electric current cannot flow easily are called insulators.

Examples:

Dry wood, plastic, glass, rubber etc.

In insulators the valance electrons are tightly bounded with the respective nucleus. Therefore, electric current cannot flow easily through insulator.

Q 3: A material is neither a perfect conductor nor perfect insulator, explain it?

Ans: A material is neither a perfect conductor nor perfect insulator because under certain cases an insulator may behave like a conductor and conductor may behave like an insulator. For example air is an insulator, but due to strong electric forces it may becomes a conductor temporarily.

Similarly the air between ground and charged clouds becomes a conductor and allow the flow of current.

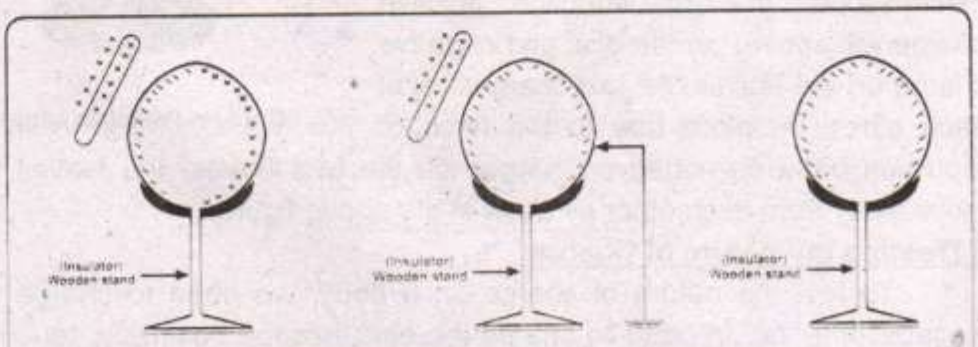
Q4: Explain the phenomena of electrostatic induction. How a conductor is charged by electrostatic induction?

Ans. Electrostatic induction:

The modification in the distribution of electric charge on one material under the influence of an electric charge on a nearby object is called electrostatic induction.

Charging a conductor by electrostatic induction:

Fix a metallic sphere on an insulating stand. Bring a positively charge rod near the sphere, the free electrons in the metallic sphere will move toward the charge rod. Negative charge will accumulates on the surface of the sphere toward the positively charge rod. Keeping the rod in its place, earth the conductor by touching it for short time with your finger. Now by removing the rod, the conductor is negatively charge. Due to mutual repulsion, the electrons spread uniformly on the surface of metallic sphere. The method of charging a conductor in this manner is called charging by induction as shown in the figure below.



Electrification of an insulated metallic sphere by electrostatic induction

Q5: Describe a gold leaf electroscope. By using an electroscope, how can we find the:

i) **The presence of charge on a body.**
ii) **The nature of charge present on a body.**

Ans: Electroscope:

An instrument which is used for the detecting and testing the nature of charge is called electroscope.

Construction:

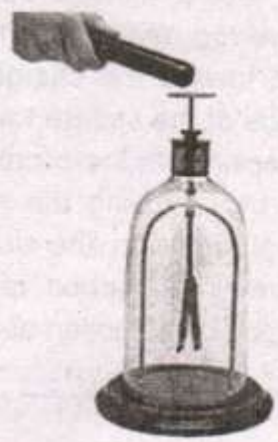
A gold leaf electroscope consists of a metal rod which has small metallic sphere at the upper end while the two gold metal leaves are attached to the lower end of the rod. The rod is fixed in a glass jar and is well insulated from the case, as shown in the figure.

Simple leaf electroscope

I) Detecting of charge:

In order to detect the presence of charge on a body, bring it near the disk of an uncharged electroscope as shown in figure.

If the body is charge, the leaves of the electroscope diverge to a definite extent otherwise they would remain in their normal position. The divergence between the leaves of electroscope is due to electrostatic induction. For example when a negatively charged body is brought near the electroscope, due to induction positive charge will appear on the disc and negative charge on the leaves. As like charges repel each other, therefore due to the force of repulsion between negative Charges on the two leaves, the leaves will move away from each other as show in the above figure.



Gold leaf electric scope

ii)Testing the nature of Charge:

To test the nature of charge on a body, we need to charge the electroscope first. In order to charge the electroscope positively, touch its disc with positively charged body. Similarly if we Charge the electroscope negatively, touch its disc with negatively charged body. In this process some of the charges present on the body are transferred to the disc and leaves of electroscope.

After charging electroscope bring the body under test near the disc of electroscope. If the divergence of leaves increases, the body has the same kind of charge as on the electroscope. On the other hand if the divergence decreases, the charge on the body will be opposite to the charge present on the electroscope.

Q 6: State Coulomb's Law. Explain and also define the unit of charge?

Ans: Coulomb's Law:

History:

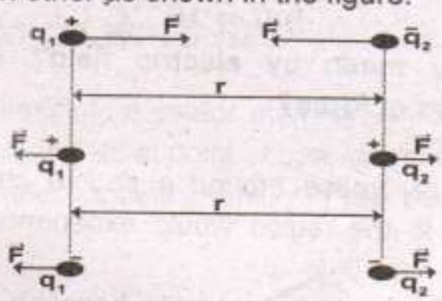
In 1785 French physicist Charles Coulomb formulated his law of electrostatics known as Coulomb law of electrostatics.

Statement:

This law states that; "the force of attraction (or) repulsion between two point charges is directly proportion to the product of charges and inversely proportional to the square of the distance between them."

Mathematical form:

Let us consider two point charges q_1 and q_2 are placed at a distance "r" from each other as shown in the figure.



According to the statement of coulomb's law, we have

$$F \propto q_1 q_2 \text{ ------------------ } (1)$$

$$\Rightarrow \quad F \propto \frac{1}{r^2} \text{ ---------------------- } (2)$$

Combining (1) and (2), we get,

$$\Rightarrow \quad F = k\frac{q1q2}{r^2} \text{ ---------------------- } (3)$$

Where "k" is constant of proportionality the value of "K" depends on the nature of the medium between the charges and the system of units in which F, r and q are measured.

In SI system the value of "k" for air (or) free space is given by;

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

Where "ϵ" is the permitivity of air (or) vacuum.

Thus equation (3) becomes:

$$F = \frac{1}{4\pi\epsilon o} \times \frac{q1\,q2}{r^2}$$

Unit of charge:

In SI system, coulomb is the unit of charge.

Definition:

One coulomb is the quantity of charge which when placed one meter apart from an equal and same charge in vacuum repel it with a force of 9×10^9N.

Numerically:

IC = 6.25×10^{18} electrons

Sub units of charge:

The commonly used sub unit of charge is micro coulomb.

$$I\mu C = 10^{-6}c$$

Q7: What do you mean by electric field? Illustrate how is it represented by lines of force?

Ans. Electric Field:

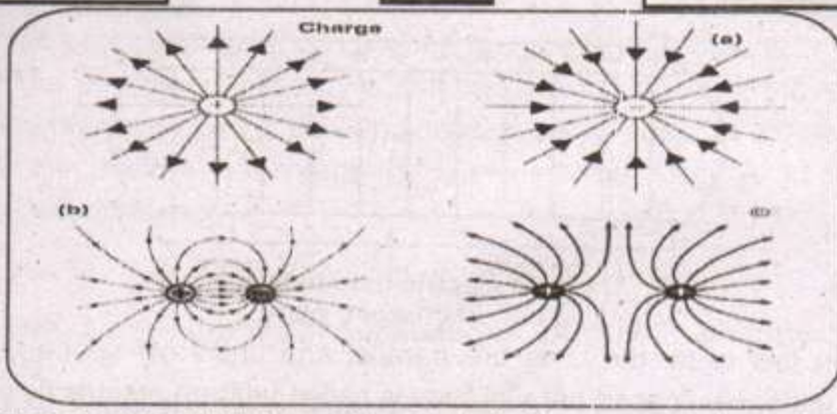
The region (or) space around a source charge in which a test charge, brought in to the region would experience an electric force is called electric field.

Electric field is a vector quantity because at each point in the electric field a test charge experiences a directed electric force.

Electric Lines of Force:

"The path followed by a test charge when a source charge exerts a force on it is called electric line of force."

The electric lines of force represent the direction of the electric field. The electric lines of force originating from positive charge and terminate at the negative charge as shown in figure.



Q8: Define electric field intensity. Explain its magnitude and direction by providing figures for illustration?

Ans. <u>Electric Field intensity:</u>

The force per unit positive test charge is called electric field intensity. It is denoted by "$\vec{E}$".

<u>Mathematically:</u>

$$\vec{E} = \frac{\vec{F}}{q_0}$$

<u>Unit:</u>

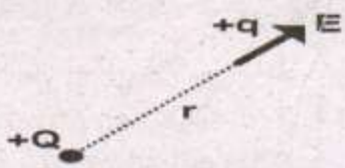
The unit of electric field intensity is $N/_C$.

<u>Direction and magnitude of electric field:</u>

<u>Intensity:</u>

Electric field intensity is a vector quantity which gives the strength and direction of the electric field at point of consideration.

The direction of electric field intensity is the same in which the test charge moves.

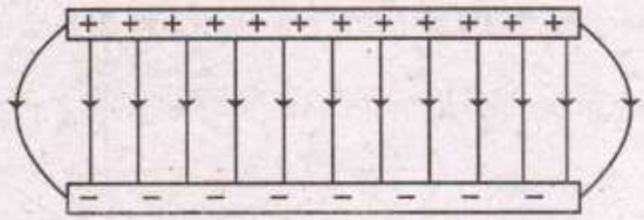


Electric field intensity

<u>Uniform Electric Field:</u>

The electric field of constant magnitude and unchanging direction is called uniform electric field.

The electric field lines of force for oppositely charge pair of large and closely spaced plates as shown below.



Uniform electric field between
a pair of charged plate

In this case, the lines are parallel and uniformly spaced. Such a field of uniformly spaced parallel lines is called uniform electric field.

Q9: Explain electrostatic potential?

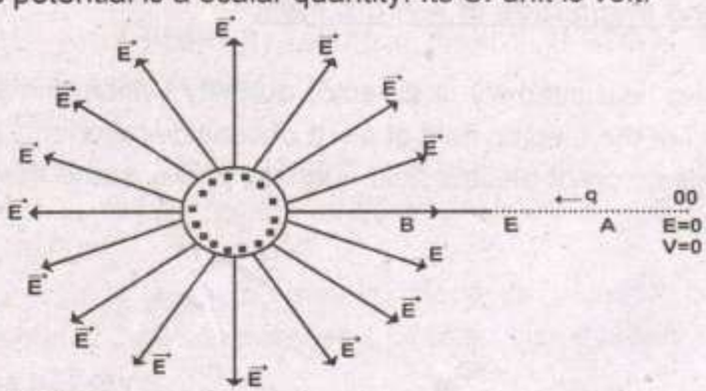
Ans. Electrostatic potential:

The electrostatic potential at any point in the electric field is defined as, "The potential energy gained by a unit positive charge when brought from infinity to a field point".

If "w" is the amount of work done in bringing a test charge "+q" from infinity to a certain point in the field, the electrostatic potential "v" at this point is given by;

$$V = \frac{W}{q}$$

Electrostatic potential is a scalar quantity. Its SI unit is volt.



Definition of volt:

The electrostatic potential is said to be one volt, if the potential energy of one coulomb positive charge at a point is one joule. **"OR"**

The potential difference is said to be one volt if one Joule work is required to move a unit positive charge of one coulomb from one point to another point against the electric field intensity.

Potential Difference:

The potential difference between two points is defined as,

"The energy supplied by a unit positive charge as it move form a point of higher to a point of lower potential is called potential difference.

A unit positive test charge "q_o" is moved from point "A" to point "B", the potential difference

$$\Delta V = V_A - V_B = \frac{W_{AB}}{q_o}$$

Q 10.Give some practical applications in which electric field is useful?

Ans. Application of Electrostatics:

Some important applications of electrostatics are as follows.

i) Electro painting:

Electro painting is used in applying paints on the surface of different articles. Electro – painting of the bodies of automobiles, refrigerator, metallic furniture etc. has become a standard technology. The body of the car to be paint is earthed. The particles of the paint emerge out of the nozzle of the spray machine; they acquire a positive charge as show in the figure.

When these positively charged particles reach near the body of the Car, they induce negative charges. Due to the force of attraction a very firm coating of the paint is formed on the surface of the car. This method is very effective, efficient and cheap. It also requires less paint as compared to other methods.

ii) Dust extraction:

Electrostatic phenomena is also used for separation of smoke and dust particles from a modern coal- burnings power stations by means of

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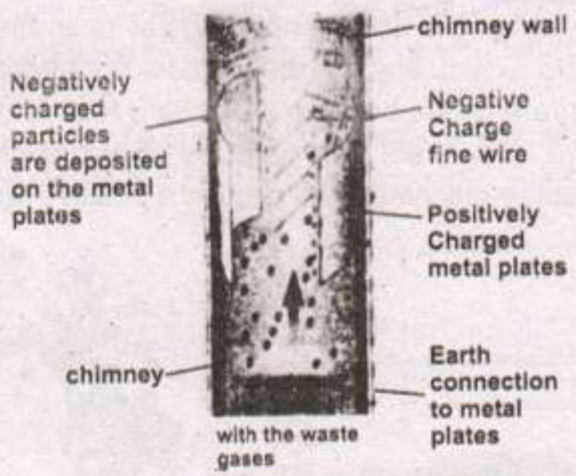
an electrostatic precipitator, if it is not separated it would cause a serious air pollution.

In a chimney wire gauze is fixed between to metallic plates. The plates are electrically earthed and the wire gauze is highly charged with positive charges. So the wire gauze induces negative charges on the inner surfaces of the plates. In this way strong electric field is produced between the wire gauze and the plates.

When gases exit through the chimney, they acquire positive charge by coming in contact with the wire gauze. So they are attracted to the negatively charged plate on reaching the plates, the smoke and other particles are deposited there. The dust and smoke particles are thus removed from the outgoing gases.



An electrostatic precipitator

Q11: What is a capacitor? Define and explain capacitance. Also define the unit of capacitance?

Ans. Capacitor:

"An electrical device which is used for storage of electrical charge and hence energy, is known as capacitor".

Construction:

Capacitor consists of two parallel metal plates separated by some insulator like air, paper, mica etc.

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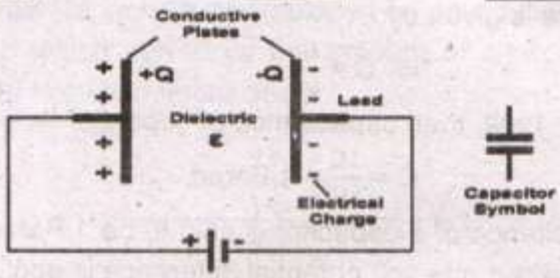

Parallel Plate capacitor

Charging of a capacitor:

When the plates of a capacitor are connected with the terminals of a battery, the positive terminal of a battery charges the plate "A" positively while negative terminal charges the plate "B" negatively. In this way some electrons are transferred through the battery from positive plate to the negative plate. Mutual attraction between the plates keeps them bound on the two plates. The Charges remain stored in the capacitor even, after the removal of battery.

Capacitance of a capacitor:

The capacity of a capacitor to store charge is called capacitance of the capacitor.

Experimentally, it has been observed that the charge "Q" on the plates of a capacitor is directly proportional to the potential difference "V" applied.

i.e.

$$Q \propto V$$
$$\Rightarrow Q = CV$$
$$\Rightarrow C = \frac{Q}{V}$$

Where "C" is constant known as capacitance of the capacitor. It value depends upon the area of the plates. Distance between the plates and medium between the plates.

The larger the plates, closer the plates and more insulating the medium between them, the higher is the capacitance of the capacitor.

Unit of capacitance:

Farad is the unit of capacitance of capacitor in the honour of Micheal faraday.

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Since capacitance is given by;

$$\Rightarrow C = \frac{Q}{V}$$

If Q = 1c and V = 1volt, then capacitance of capacitor is;

$$C = \frac{1C}{1V} = 1 \text{ Farad}$$

The capacitance of a capacitor is said to be 1 Farad, if it stores one coulomb charge when one volt potential difference is applied.

Convenient Sub multiples of farad are; $1\mu F = 10^{-6}$Farad

1 Pico Farad = 10^{-12} Farad

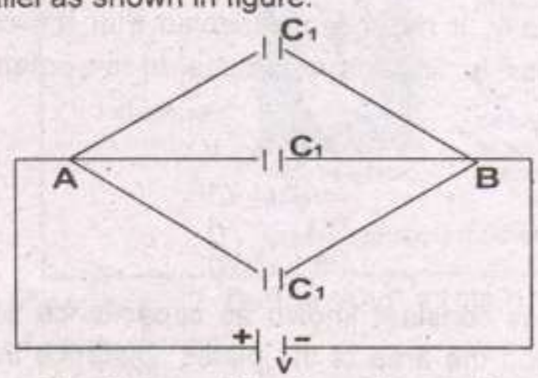
Q12: How are the capacitors connected in parallel? Describe the characteristic features of this combination.

Ans. **Parallel combination of capacitors:**

When two (or) more capacitors are connected in such a way that the potential difference across the plates of each capacitor is the same while the charge stored on the plates of each capacitor is different, then the combination is known as capacitors in parallel.

Explanation:

Let us consider three capacitors having capacitances C_1, C_2, C_3 are connected in parallel as shown in figure.



Parallel combination of capacitors

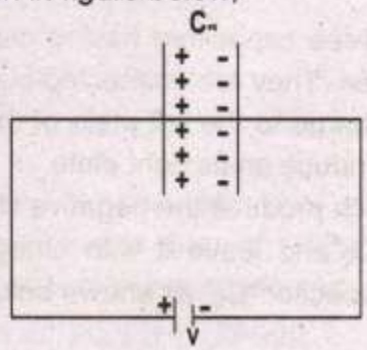
Since in case of parallel combination, the potential difference across the plates of each capacitor is the same while different charge is stored on the plates of each capacitor i.e. Q_1, Q_2 and Q_3 respectively.

So; $Q = Q_1 + Q_2 + Q_3$

$$\Rightarrow Q = C_1V + C_2V + C_3V \qquad (\because v_1 + v_2 + v_3 = v)$$

$$\Rightarrow Q = V(C_1 + C_2 + C_3) \text{-------------(1)}$$

Let the three Capacitors are replaced by an equivalent capacitor of capacitance "C_{eq}" which can store the amount of charge "Q" under the same condition as shown in figure below;



Now;

$$Q = C_{eq}V \text{-------------------} (2)$$

Comparing equation (1) and equation (2), we get;

$$\Rightarrow \quad C_{eq}V = V(C_1 + C_2 + C_3)$$

$$\Rightarrow \quad C_{eq} = C_1 + C_2 + C_3 \ldots\ldots\ldots C_n$$

Thus it is concluded that the capacitance of the equivalent capacitor is equal to the sum of the capacitances of all the capacitors which are connected in parallel.

Characteristic Features of parallel combination:

Parallel combination of capacitors has the following characteristics features.

i) In case of parallel combination the potential difference (V) across each of the capacitor is same i.e. $V_1 = V_2 = V_3 = V$
ii) In case of parallel combination of capacitors the charge stored on the plates of each capacitor is different.
iii) In case of parallel combination of capacitors the capacitance of the equivalent capacitor is equal to the sum of all the capacitors which are connected in parallel. i.e $C_{eq} = C_1 + C_2 + \ldots\ldots + C_n$
iv) The equivalent capacitance of parallel Combination is greater then the greatest capacitance of capacitor connected in parallel.

Q13: How are the capacitors connected in series? Describe the characteristic features of this combination?

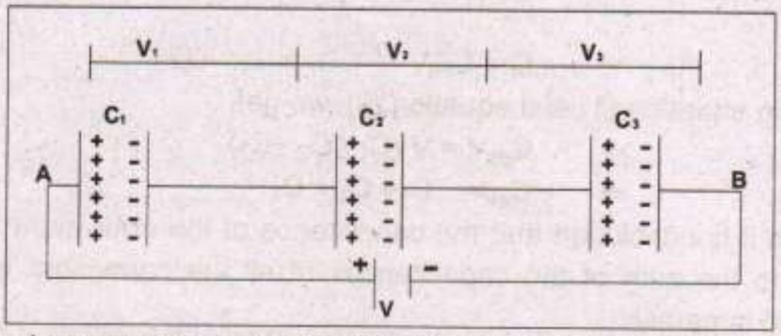
Ans. Series combination of capacitors:

When two or more capacitors are connected in such a way that the same charge is stored on eth plates of each capacitor, while potential difference across the plates of each capacitor is different, such combination of capacitors in known as series combination of capacitors.

Explanation:

Let us consider three capacitors having capacitances C_1, C_2, and C_3 are connected in series. They are connected plate to plate. A battery of voltage V supplies +Q charge to the left plate of the capacitor"C_1". Due to induction "-Q" charge is induce on its right plate.

The electrons which produce the negative charge on C_1 must come from the left plate of "C_2"and leave it with charge "+Q". This charging process continuous to capacitor "C_3" as shown below.



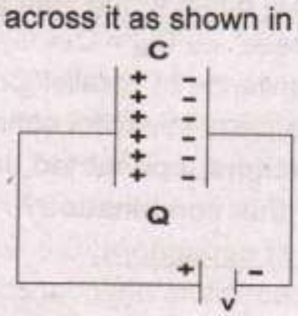
Since the charge on each capacitor is the same i.e, $Q = Q_1 = Q_2 = Q_3$ while the voltage across C_1, C_2,and C_3 and V_1, $V_2$and V_3 respectively. So,

$$V = V_1 + V_2 + V_3$$

$$\Rightarrow \quad V = \frac{Q}{C_1} + \frac{Q}{C_2} + \frac{Q}{C_3}$$

$$\Rightarrow \quad V = Q\left(\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}\right) \text{---------------} (1)$$

Now we are replacing these three capacitors by an equivalent capacitor of capacitance "C_{eq}" which can store equal amount of charge "Q" when voltage V is applied across it as shown in figure.



Now, $Q = C_{eq}V$

$$V = \frac{Q}{C_{eq}} \text{------------------------} (2)$$

Comparing equation (1) and equation (2);

$$\Rightarrow \quad \frac{Q}{C_{eq}} = Q\left(\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}\right)$$

$$\Rightarrow \quad \frac{1}{C_{eq}} = \left(\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}\right)$$

Thus it is concluded that the reciprocal of the capacitance of equivalent capacitor is equal to the sum of the reciprocal of individual capacitances of the capacitors which are connected in series.

Characteristic Features of series combination:

Series combination has the following Characteristic features.

i) In series combination of capacitors the charge stored on the plates of each capacitors is the same i.e. $Q_1 = Q_2 = Q_3 = Q$

ii) In series combination of capacitors the potential difference across the plates of each capacitor is different.

iii) In series combination of capacitors the reciprocal of the capacitance of equivalent capacitor is equal to the sum of the reciprocal of individual capacitances of the capacitors connected in series. i.e. $\frac{1}{C_{eq}} = \left(\frac{1}{C_1} + \frac{1}{C_2} + - \frac{1}{C_n}\right)$

iv) The equivalent capacitance of series combination is smaller than the smallest capacitance of capacitor connected in series.

Q14: What are the types of capacitors?

Ans. Type of capacitor:

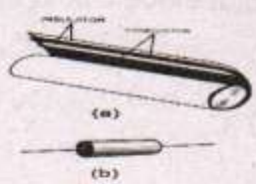
There are two type of capacitor which are given below.

i)**Fixed Capacitor:-**

A capacitor of constant capacitance is called Fixed Capacitor. In Fixed capacitor the plates are immovable.

Examples:

Paper capacitor and mica capacitor are examples of fixed capacitor.



Mica Capacitor

ii) **Variable Capacitor:**

A capacitor of variable capacitance is called variable capacitor. In parallel plates a capacitor some arrangements are made that the area of the plates facing each other can be change then it is called.variable capacitor as shown in figure.

For example: The capacitors used in tuning of a radio frequency.

Examples

Examples13.1: The two protons and two neutrons in the nucleus of the helium atom are held together by the strong force, which is required to overcome the electrostatic repulsion between the protons. The charge of each proton is $q_p = +1.6 \times 10^{-19}$ C.A distance of approximately $r = 2 \times 10^{-15}$m separates the two protons. Calculate the magnitude of the electrostatic force between the protons.

Given:

Charge on proton $q_p = +1.6 \times 10^{-19}$ C

Distance $r = 2 \times 10^{-15}$m

Coulomb Constant 'K' = $9 \times 10^{9} Nm^2/C^2$

Required: Force 'F_E'=?

Solution:

Using Coulomb's Law, we can find the force

$$F_E = k\frac{q_p \times q_p}{r^2}$$

Putting the value

$$F_E = \frac{(1.6 \times 10^{-19}C)\times(1.6 \times 10^{-19}C)}{(2\times 10^{15})^2}$$

Hence,

F_E = 57.6N = 58N--------------- Answer

Example 13.2: A positive test charge of 30μC is placed in an electric field. Force on it is 0.600N. What is the magnitude of electric field at the location of test charge?

Given:

Test charge q_o= 30μC= 30×10^{-6}C.

Force 'F_E'= 0.600N

Required:

Electric field intensity 'E'=?

Solution: By definition of electric field intensity

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

Putting the value

$$\vec{E} = \frac{0.600N}{30 \times 10^{-6} c}$$

Hence, $\vec{E} = 2.00 \times 10^4 NC^{-1}$**------------- Answer**

Example 13.3: Work done

How much work must be done to increase the potential of a charge 2.5×10^{-7}C by 100 V?

Given:

Charge 'q' = 2.5×10^{-7}C

Change in potential 'ΔV'=100 V

Required:

Work done 'W'=?

Solution:

By definition of electric potential

$$V = \frac{W}{q} \; or \; W = qV$$

Putting values w= 2.5×10^{-7} Cx100 V

Hence, **W=2.5×10^{-5}J-------------Answer**

Example 13.4: Capacitor of MP3 Player

A typical capacitor in an MP3 player has C=0.10μF. if a charge 5.0 μC is placed on the plates, what is the voltage across the capacitor?

Given:

Charge q=5$\mu C = 5x10^{-6}C$

Capacitance 'C'=0.10$\mu F = 0.10x10^{6}F$

Required:

Voltage 'V'=?

Solution:

The capacitance of capacitor is $C = \frac{Q}{V}$ Or $V \frac{Q}{C}$

Putting values $V=\frac{5x10^{-6}C}{0.10x10^{-6}F}$

Or $V=\frac{5x10^{-6}C}{0.10x10^{-6}C/V}$

Hence **V=50 V-------------- Answer**

Example 13.5:

Two capacitors of 5μF and 10 μF are connected in series with the external source of voltage is 100V. Calculate the total capacitance and the potential drop across each capacitor.

Given:

Capacitor C_1=5 μF=5x10^{-6}F

Capacitor C_2=10 μF=10x10^{-6}F

Voltage V=100 V

Required:

Equivalent capacitance C_{eq}=?

Potential drops V_1 and V_2=?

Solution:

For series combination the equivalent capacitance is

$\frac{1}{C_e}=\frac{1}{C_1}+\frac{1}{C_2}$ or $\frac{1}{C_e}=\frac{C_2+C_1}{C_1C_2}$ or $C_e=\frac{C_1C_2}{C_2+C_1}$

Putting value $C_e=\frac{5\times10^{-6}F\times10\times10^{-6}F}{5\times10^{-6}F+10\times10^{-6}F}$

Or $\Rightarrow$ $C_e=\frac{50\times10^{-12}F^2}{15\times10^{-6}F}$

C_e= 3.33x10^{-6}F=3.33μF ----------- Answer

In series combination, the charge remains the same $q_1 = q_2 = Q$

The charge on each capacitor is Q= C_eV.

Putting values Q=3.33x10^{-6}Fx100V

Hence Q=3.33x10^{-4}C

Therefore $q_1=q_2$=Q=3.33 x 10^{-4}C

However, series combination of circuit elements the voltage splits, the voltage across capacitor C_1 and capacitor C_2 as V_1 and V_2, respectively

$\Rightarrow$ $V_1=\frac{Q}{C_1}$

Putting value $V_1=\frac{3.33\times10^{-4}C}{5\times10^{-6}F}$

V_1=0.666x10^2V = 66.6V------------Answer

$$\Rightarrow \quad V_2=\frac{Q}{C_2}$$

Putting value $V_2 = \frac{3.33\times10^{-4}C}{10\times10^{-6}F}$

$V_2=0.333\times10^2V=33.3V$--------------- Answer

Note that $V_1+V_2=66.6+33.3=100=V$, That is the battery voltage is split between the two capacitors.

Example 13.6: Parallel combination of Capacitor

Two capacitors of $4\,\mu F$ and $8\,\mu F$ are in parallel. In each case the external source of voltage is 100 V.Calculate the total capacitance and the charge on each capacitor.

Given:

Capacitor $C_1=4\,\mu F= 4\times10^{-6}$ F

Capacitor $C_2=8\,\mu F=8\times10^{-6}$ F

Required:

Equivalent capacitance C_{eq} =?

Charge Q_1 and Q_2 =?

Solution:

For Parallel combination, the equivalent capacitance is $C_e=C_1+C_2$

Putting values, $C_e=4\times10^{-6}F+8\times10^{-6}F$

Therefore, $C_e=12\times10^{-6}F=12\,\mu F$

In parallel combination the voltage remains the same $V_1=V_2=V$

Since the applied voltage V=100 V, Therefore $V_1=V_2=V=100V$

In parallel combination the charge splits, the charge stored in first capacitor C_1 is

$q_1=C_1V$

Putting values $q_1=4\times10^{-6}C\times100V$

$q_1=400\times10^{-6}=400\mu C$------------- Answer

In parallel combination the charge splits, the charge stored in second capacitor C_2 is

$q_2=C_2V$

putting values $q_2=8\times10^{-6}C\times100V$

$q_1=800\times10^{-6}C=800\,\mu C$-------------Answer

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Assignment

Assignment 13.1: A small metal sphere with a charge of -2.10×10^{-6}C is brought near an identical sphere with a positive charge of 1.5×10^{-6}C so that the distance between the Centres of the two spheres is 3.30cm. Calculate the magnitude of the force that each charge exerts on the other?

Solution:

Given:

Charge on 1st sphere $q_1 = -2.10 \times 10^{-6}$C

Charge on 2st sphere $q_1 = 1.5 \times 10^{-6}$ C

Distance between the Centres of the sphere=r=3.30cm= 0.033m

Coulomb constant= $k = 9 \times 10^9$ Nm^2/C^2

Required:

Force = F_E=?

Calculation:

$$F_E = \frac{Kq_{1\times}q_2}{r^2}$$

Putting values, we get;

$$F_E = \frac{(9 \times 10^9)(-2.10 \times 10^{-6})(1.5 \times 10^{-6})}{(0.033^2)}$$

$\Rightarrow$ $F_E = 26033 \times 10^{-3}$N

$\Rightarrow$ $F_E = -26$N

The –ve sign shows that the force is attractive.

Conclusion: Hence;

Electrostatic attractive force F_E = 26N---------------- Answer

Assignment13.2: If a charge of $4\mu c$ is placed in a uniform field of strength $2NC^{-1}$, what force will it experience?

Solution:

Given:

Charge = $q_o = 4\mu c = 4 \times 10^{-6}$C

Electric field intensity =E= 2 N/c

Required:

Force = F_E=?

Calculation:

$$\Rightarrow \quad E = \frac{F_E}{q_o}$$

$\Rightarrow \quad F_E = E \times q_o$

Putting the value, we get;

$\Rightarrow \quad F_E = (4\times10^{-6})(2)$

$\Rightarrow \quad F_E = 8 \times10^{-6}$

$\Rightarrow \quad F_E = 8\mu N$

Conclusion: Hence;

Force experienced by charge =F_E =$8\mu N$ ----------------- Answer

Assignment 13.3: How much work is done in moving a charge of 3c from a point at 118V to a point at 138v in an electric field?

Solution:

Given:

Charge =q= 3c

Change in potential =v= 138-118=20v

Required:

Work done=W=?

Calculation:

We know that:

$$v=\frac{W}{q}$$

$$W=qv$$

Putting values; we get

$$W= (3)(20)$$

$$W=60j$$

Conclusion: Hence;

Work done = W=60j ------------------ Answer

Assignment 13.4:-The potential difference across the plates of the capacitor is 500V. The charge on each plate is 0.02C. What is the capacitance of the capacitor?

Solution:

Given:

Charge =q= 0.02c

Electric potential =v=5

Required:

Capacitance =c=?

Calculation:

We know that;

$$C = \frac{Q}{V}$$

$$C = \frac{0.02}{5}$$

$$C = 0.00004F$$

Conclusion: Hence;

Capacitance of capacitor = C = 0.00004 F Or 4×10^{-5} F

Assignmetn13.5: Two capacitors of capacitance $3\mu F$ and $6\mu F$ are connected is series to a 100v battery. Calculate the equivalent capacitance and the voltage across each capacitor.

Solution: Combination = series

Given:

$$C_1 = 3\mu F$$

$$C_2 = 6\mu F$$

$$V = 100V$$

Required:

(a) **Equivalent capacitance = C_{eq} =?**

(b) **Voltage across** $C_1 = V_1 = ?$

(c) **Voltage across** $C_2 = V_2 = ?$

(a) Equivalent capacitance = C_{eq} =?

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2}$$

Putting the value;

$$\Rightarrow \quad \frac{1}{C_{eq}} = \frac{1}{3} + \frac{1}{6}$$

$$\Rightarrow \quad \frac{1}{C_{eq}} = \frac{2+1}{6}$$

$$\Rightarrow \quad \frac{1}{C_{eq}} = \frac{3}{6}$$

$$c_{eq} = 2\mu F$$

Change of each capacitor:

In series combination, same charge is stored on the plates of each capacitor i.e. $Q_1 = Q_2 = Q$ this the "Q" on each capacitor is given by;

$$Q = C_{eq}V$$

$$\Rightarrow \quad Q = (2\mu F)(100v)$$

$$\Rightarrow \quad Q = 2.10 \times 10^{-4}C$$

Voltage across C_1 and C_2:

In series combination voltage across each capacitor is different therefore;

$$\Rightarrow \quad V_1 = \frac{Q}{C_1}$$

$$\Rightarrow \quad V_1 = \frac{2\times10^{-4}}{3\times10^{-6}}$$

$$\Rightarrow \quad V_1 = 66.6V$$

and

$$V_2 = \frac{Q}{C_2}$$

$$\Rightarrow \quad V_2 = \frac{2\times10^{-4}}{6\times10^{-6}}$$

$$\Rightarrow \quad V_2 = 33.3V$$

Conclusion: Hence;

(a) Equivalent capacitance = $C_{eq} = 2\mu F$

(b) Voltage across $C_1 = V_1 = 66.6V$

(c) Voltage across $C_2 = V_2 = 33.3v$

Assignment 13.6: Two capacitors of capacitance3μF and 6μF are connected is parallel to a 800v battery. Find the equivalent capacitance and charge across each capacitor.

Solution:

Given: Combination = parallel

Capacitance "$C_1 = 3\mu F = 3 \times 10^{-6}F$

Capacitance "$C_1 = 6\mu F = 6 \times 10^{-6}F$

Voltage =V= 800V

Required:

(a) Equivalent capacitance $=C_{eq}=?$

(b) Change Q_1 and Q_2 =?

Calculation:

(a) C_{eq}=?

For parallel combination, the equivalent capacitance is given;

$$C_{eq}= C_1 + C_2$$

$$\Rightarrow \quad C_{eq}= 3\mu F + 6\mu F$$

$$\Rightarrow \quad C_{eq}= 9\mu F$$

(b) Change Q_1 and Q_2 =?

In parallel combination of capacitors, voltage remains constant i.e $V_1= V_2= v= 800v$ this Change Q_1 and Q_2 is given by;

$$Q_1= C_1V$$

$$\Rightarrow \quad Q_1= (3 \times 10^{-6})(800)$$

$$\Rightarrow \quad Q_1= 2400 \times 10^{-6}C$$

$$\Rightarrow \quad Q_1=2.4 \times 10^{-3}C$$

$$\Rightarrow \quad Q_1=2.4\text{mc}$$

And $\Rightarrow \quad Q_2= C_2V$

$$\Rightarrow \quad Q_2= (6 \times 10^{-6})(800)$$

$$\Rightarrow \quad Q_2= 4800 \times 10^{-6}C$$

$$\Rightarrow \quad Q_2= 4.8 \times 10^{-3}C$$

$$\Rightarrow \quad Q_2= 4.8mc$$

Conclusion: Hence;

(a) Equivalent capacitance $=C_{eq}= 9$ F

(b) Q_1= 2.4 mc and Q= 4.8mc

EXERCISE

1. Choose the correct answer for each of the following;

i. When combing our hair, we shift electrons from our hair onto the comb. The charge on our hairs is:

a. Positive b. negative c. zero d. infinite

ii. The unit of charge is

a. Farad **b. coulomb** c. volt d. electron volt

iii. Initially, sphere A has a charge of -50e and sphere B has a charge of +20e. The spheres are made of conducting material and are identical in size. If the spheres then touch, what is the resulting charge on sphere A?

a. +15e **b. -15e** c.+35e d. -35e

iv. If the distance between two charged particles is halved, the coulomb force between the two charged particles become

a. Half b. one quarter c. double **d. four times**

v. The value of coulomb constant k, depend on

a. Value of charges **b. material medium**

c. separation between charges d. all of these

vi. An additional capacitor is added to a group of capacitors already connected in series , the equivalent capacitance

a. Increase b. stay the same **c. decrease** d. goes to zero

vii. The unit of electric potential is

a. Farad b. coulomb **c. volt** d. NC^{-1}

viii. Four identical 1μF capacitors are connected together electrically. What is the least possible capacitance of the combination?

a. 4μF b. 1μF **c. 1/4μF** d. 1/8μF

ix. A capacitor C 'has a charge Q'. the actual charges on its plates are:

a. Q,Q b. Q,0 **c. Q,-Q** d. Q/2,-Q/2

Conceptual Questions

Q1: Normally, objects with large number of electrons are electrically neutral. Why?

Ans: Objects with large Number of electrons:

Objects with large number of electrons are electrically neutral because they have the same number of positively charged protons and negatively charged electrons.

Explanation:

Electrically neutral objects contain the same number of positively charged protons and negatively charged electron. Therefor no net charge exists on such objects.

Every object is a combination of a large number of atoms. Every atom has positively charged nucleus and negatively charged electrons revolving around the nucleus. As the number of electrons increases. The number of protons also increases. They balance the charge and the body as a whole becomes electrically neutral.

Q2: How does shuffling feet across a carpet cause hair to stand on our body?

Ans: Shuffling Feet across a carpet:

Shuffling feet across a carpet cause hair to stand on your body because static charge produces due to friction.

Explanation:

The transferring of electrons takes place as a result of rubbing of certain materials against one another. The body which loses electrons becomes positively charged and the body which gains electrons becomes negatively charged. For example, when you shuffle (rub) your feet across a carpet, you are allowing electrons to transfer to you. These electrons are accumulate on our body's hair and these negatively charged hair try to repel each other. That is why the hair stands on our body when we shuffle feet across a carpet.

Q3: Why neutral objects are always attracted by charged object? Not repelled.

Ans: Neutral objects Attracted By charged objects:

Neutral objects are always attracted by charged objects because opposite charges come toward the charged body and same charges to the other end.

Explanation:

When a charged body is brought near a neutral body, then due to electrostatic induction, opposite charge is appeared on the neutral body toward the charged body.

For example, if a negatively charged rod is brought near a neutral sphere. Positive charges inside the neutral sphere came toward negatively charged rod while negative charges to the other end. As we know that opposite charges attract each other. Therefore the negatively charge rod attract positively charged side of the neutral body

Conclusion:

Hence; neutral objects are always attracted by charged objects.

Q4: Why the pieces of paper initially attracted by charged comb fly away when they touch it?

Ans: Pieces of paper attracted by charged comb:

The charged comb when gets closer to some pieces of paper, the paper pieces are initially attracted by the comb due to electrostatic induction. The part of paper pieces with positive charge is attracted by the comb, some of the excess negative in the comb is transferred to the paper pieces and paper pieces become negatively charged particles. As similar charges repel each other, therefore these paper pieces will now be repelled by the charged comb due to electrostatic induction and fly away when they touch the comb.

Conclusion:

Hence, the pieces of paper initially attracted by charged comb due to electrostatic induction and fly away when they touch the comb.

Q5: Is it necessary for a charged body actually to touch the ball of the electroscope for the leaves to diverge? Defend your answer.

Ans: Charge body and ball of electroscope:

No, it is not necessary for the charged body to touch the ball of an electroscope.

Dependence:

If we bring negative charge body near the ball of an electroscope, some electrons in the ball are repelled and driven to the gold leaves, leaving the ball positively charged. Similarly, if we bring positively charge near the ball, some electrons will attracted and move up to the ball to make the ball negative and leaving the leaves positively charged. Tis charge separation takes pace due to electrostatic induction.

Conclusion:

Hence, it is not necessary for a charged body to actually touch the ball of the electroscope for the leaves to diverge.

Q6: How electrostatic painting is better than conventional spray painting?

Ans: Electrostatic painting:

Electrostatic painting is better than conventional spray painting because it reduces the paint usage, helps to distribute paint particles uniformly and get uniform coverage.

Explanation:

Electrostatic painting is a method in which electrically charged paint is applied. In electrostatic painting, when the paint leaves the nozzle of the spray sun, it is given a positive change. The grounded object (the object being painted) is negatively charged in order to attract the positively charged paint particles to its surface. By creating this electrostatic field, the grounded object acts like a magnet, pulling the paint particles to its surface. This makes the particles less likely to stay in the air.

Q7: Why are lightning rods normally at a higher elevation than the buildings they protect?

Ans: Position of lightning Rods:

The lightning rods are normally at higher elevation than the buildings they protect because lightning (composed of huge amount of change) first hit rods and not the buildings.

Explanation:

Lightning occurs when the electric field between clouds and ground gets high to overcome the resistance of the air between them. The lightning rods give an easy path to the charge, so buildings become safe. Lightning hits the tallest objects in its path e.g. trees, high rise buildings etc. therefore, lightning rods should be taller in order to be hit first by the lightning leaving the building safe. If the lightning rods were shorter than the building, then the lightning will hit the building first causing damage to it.

Conclusion:

Hence, the lightning rods are normally at a higher elevation than the buildings they protect.

Q8: What would happen if two insulating plates were used instead of conducting plates to construct a capacitor?

Ans: It will be the same capacitor with slight changes as we will need high potential battery to charge it and the dielectric material between the plates must be different from that of the plates material.

In case of insulating material plates a high potential will be needed to deposit charges on the plates. The other change we need to do is that the dielectric material (insulator) between the plates must be different from the material of the plates.

Q9: The sum of the charge on both plates of a capacitor is zero. What does a capacitor store?

Ans: Storage of capacitor:

The capacitor actually stores energy in the form of an electric field between its plates.

Explanation:

Capacitor stores energy in the form of an electric field between its plates. Because the plate's equal but oppositely charged, a potential difference exists between them which mean that there is energy available to do work. Since there is a potential difference between the plates of a capacitor. This implies that there is an electric field which points from the positive plate to the negative plate.

Conclusion:

Hence, the capacitor actually stores energy in an electric field.

Q10: If you wish to store a large amount of energy in a capacitor bank, would you connect capacitors in series or parallel? Explain.

Ans: If I wish to store a large amount of energy in a capacitor bank, I will connect all the capacitors in parallel.

Explanation:

In parallel combination of capacitor, the equivalent capacitance is equal to the sum of capacitances of capacitors connected in parallel i.e. the capacitance become large and energy storage goes in proportion. In case of a given fixed voltage, parallel combination is the only way to store a large amount of energy in a capacitor bank.

Conclusion:

Hence, the capacitors must be connected in parallel, to store a large amount of energy in a capacitor bank.

Numerical Problem

P1: A 5μC point charges is placed 20 cm from the 10μC point charges. (a) Calculate the force experienced by the 5μC charge. (b) What is the force on 10μC charges? (c) What is the field strength 20 cm from the 10 μC point charges?

Solution:

Given:

1stCharge= q_1=5μC=5×10^{-6}C.

2nd Charge =q_1= 10μC = 10 × 10^{-6}C

Separation between the charge=r=20cm= 0.2

Coulomb constant=k= 9 ×10^{9}Nm^2/C^2

Required:

(a) Force on 1st charge = F_1=?

(b) Force on 2st charge = F_2=?

(c) Electric field strength=E=?

Calculation:

(a) Force on 1st charge = F_1=?

According to coulomb's law;

$$F_1= \frac{Kq_{1\times}q_1}{r^2}$$

Putting values, we get;

$$F_1= \frac{(9\times10^9)(5\times10^{-6})(10\times10^{-6})}{(0.2^2)}$$

$\Rightarrow$ F_1= 11.25N

$\Rightarrow$ F_E= -26N

(b)Force on 2st charge = F_2=?

Since bot h the charges exert an equal and oppositely directed forces on each other therefore, force on 2nd charge is also11.25i.e

F_2= 11.25N

(c) Electric field strength= E=?

We know that;

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

$$\Rightarrow \quad E = \frac{(9\times10^{9})(10\times10^{-6})}{(0.2^2)}$$

$$\Rightarrow \quad E = 2.25\times10^{6} N/C$$

Conclusion: Hence;

(a) Force on 1st charge = F_1= 11.25N

(b) Force on 2st charge = F_2=11.25N

(c) Electric field strength=E=2.25 × 10^6N/C

P 2: Determine the magnitude of the electric force on the electron of a hydrogen atom is exerted by the single proton that is the atom's nucleus. Assume the average distance between the electron and proton is r= 5.3 × 10^{11} m and charge on electron and proton is 1.6×10^{19} C.

Solution:

Given:

Charge on proton = q_p= +1.6 × 10^{-19}C

Charge on electron = q_e= -1.6 × 10^{-19}C

Separation between the charges =r=2 ×10^{-11}

Coulomb constant=k= 9 ×10^9Nm^2/C^2

Calculation:

According to coulomb's law ;

$$\Rightarrow \quad F = \frac{Kq_{p\times}q_e}{r^2}$$

Putting values, we get;

$$\Rightarrow \quad F = \frac{(9\times10^{9})(+1.6\times10^{-19})(-1.6\times10^{-19})}{(2\times10^{-11})^2}$$

$$\Rightarrow \quad F = 8.2\times10^{-8} N$$

The -ve sign shows that the force is attractive in nature.

Conclusion: Hence;

The attractive force between electron and proton =F= F= 8.2 × 10^{-8}N

P3: In a certain region of space, a uniform electric field has a magnitude of 4.60×10^4 n/c and point in the position x-direction. Find the magnitude and direction of force this field exert on a charge of (a) +2.80 μC (b) 9.30 μC.

Solution:

Given:

1stCharge= q_1=+2.8μC=+2.8 ×10^{-6}C.

2nd Charge =q_2= $-9.30\mu C$ = -9.30 × 10^{-6}C

Electric field strength =E= 4.6×10^4 N/C
Coulomb constant=k= $9 \times 10^9 Nm^2/C^2$

Required:

(a) Force on 1st charge = F_1=?
(b) Force on 2st charge = F_2=?

Calculation:

(a) Force on 1st charge = F_1=?

$$E = \frac{F_1}{q_1}$$

$$\Rightarrow F_1 = Eq$$

Putting values, we get;

$$\Rightarrow F_1 = (4.6 \times 10^4)(2.8 \times 10^{-6})$$

$$\Rightarrow F_1 = +0.13$$

Direction:

Since the force is positive, thus the force and electric field have the same direction i.e. force also points toward the positive

(b) Force on 2st charge = F_2=?

We know that;

$$E = \frac{F_2}{q_2}$$

$$\Rightarrow F_2 = Eq_2$$

Putting value, we get;

$$F_2 = (4.6 \times 10^4)(-9 \times 10^{-6})$$

$$\Rightarrow F_2 = -0.43 \text{ N}$$

Direction:

Since the force is negative, thus force and electric field are oppositely directed i.e. force points in the negative x- direction.

P4: *The potential difference between two points is 110 V. when the unknown charge is moved between these points, the work done 550 J. What is the amount of charge?*

Solution:

Given:

Work done= W = 550j
Electric potential =v= 110v

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Required:

Charge=q=?

Calculation:

We know that;

$$V=\frac{W}{q} \qquad q=\frac{W}{V}$$

Putting the value, we get;

$$q = 5c$$

Conclusion: Hence;

Amount of charge=5c

P 5: The capacitor of capacitance is 1 μF, 2 μF and 3 μF are connected in series to a 110V battery. Calculate the equivalent capacitance and voltage of each capacitor.

Solution:

Given:

Electrical potential =V=220v

Capacitance =C= 3200PF= 3200PF=3200×10^{-12}F

Required:

Charge=Q=?

We know that;

Q=CV

Putting the value;

$$Q= (3.2 \times 10^{-9})(220)$$

$$\Rightarrow \quad Q= 704 \times 10^{-9}$$

$$\Rightarrow \quad Q= 7.04 \times 10^{-7}C$$

$\frac{6+3+2}{6}$

$\frac{9+2}{6}$

$\frac{1}{C_{eq}} \quad \frac{11}{6}$

$C_{eq}=\frac{4}{6}$

Conclusion: Hence;

Charge on each plate of the capacitor= $Q= 7.04 \times 10^{-7}C$

P 6: The capacitor of capacitance is 1 μF, 2 μF and 3 μF are connected in series to a 110V battery. Calculate the equivalent capacitance and voltage of each capacitor.

Solution:

Given:

Electric potential =V=110v

C_1= 1μF = 1×10^{-6}F

C_2= 2 μF= 2×10^{-6}F

C_3= 4 μF= 3×10^{-6}F

Required:

(a) Equivalent capacitance= C_{eq}=?

(b) Potential Drops V_1, V_2 and V_3 =?

Calculation:

In series combination, we have;

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

Putting the value

$$\frac{1}{C_{eq}} = \frac{1}{1\mu F} + \frac{1}{2\mu F} + \frac{1}{3\mu F}$$

$$\Rightarrow \quad \frac{1}{C_{eq}} = \frac{6+3+2}{6}$$

$$\Rightarrow \quad \frac{1}{C_{eq}} = \frac{11}{6}$$

$$\Rightarrow \quad C_{eq} = \frac{6}{11}$$

$$\Rightarrow \quad C_{eq} = 0.54\mu F$$

In series combination of capacitors, charge on the plates of each capacitor in the same i.e. $q_1 = q_2 = q$

Now; $Q = C_{eq}V$

Putting values, we get;

$$Q = (0.54 \times 10^{-6})(110)$$

$$\Rightarrow \quad Q = 59.4 \times 10^{-6} C$$

Since, series combination splits voltage across capacitors. Therefore;

voltage across $C_1 = V_1 = \frac{Q}{C_1} = \frac{59.4 \times 10^{-6}}{1 \times 10^{-6}}$

$$\Rightarrow \quad V_1 = 59.4V$$

Voltage across $C_2 = V_2 = \frac{Q}{C_2} = \frac{59.4 \times 10^{-6}}{2 \times 10^{-6}}$

$$\Rightarrow \quad V_2 = 29.7V$$

Voltage across $C_3 = V_3 = \frac{Q}{C_3} = \frac{59.4 \times 10^{-6}}{3 \times 10^{-6}}$

$$\Rightarrow \quad V_3 = 19.8V$$

Conclusion: Hence;

(a) Equivalent capacitance= 0.54 μF

(b) Voltage across $C_1=V_1=$ 59.4V

Voltage across $C_2=V_2=$ 29.7V

Voltage across $C_3 = V_3=$ 19.8V

P7: Two capacitor of capacitance 2pF and 3pF are connected in parallel to a 9 V battery. Calculate the equivalent and the charge on each capacitor.

Solution:

Given:

Electric potential =V= 9v

C_1= 2pF and C_2= 3FP

$\frac{1}{2pf} + \frac{1}{3pf}$

$\frac{1}{3}$

Required:

(a) Equivalent capacitance= C_{eq} =?

(b) Charge Q_1 and Q_2=?

Calculation:

In parallel combination of capacitors, we have;

$C_{eq} = C_1 + C_2$ = 2PF +3PF= 5PF

$\Rightarrow$ C_{eq}= 5PF

In parallel combination voltage remain constant i.e. $V_1= V_2=V=9V$

Now;

Charge of capacitor "C1" = Q1=C_1V= (2PF)(9v)

$\Rightarrow$ Q_1=18PC

And Charge on Capacitor "C_2"=Q_2=C_2V = (3PF)(9V)

$\Rightarrow$ Q_2= 27PC

Conclusion: Hence;

(a) Equivalent capacitance = C_{eq} = 5PF

(b) Q_1 18PC and Q= 27PC

CHAPTER NO.13 ELECTROSTATICS

MORE PHYSIC NOTES CHAPTER WISE

- Physics 10 Class Notes CHAPTER NO 10
- Physics 10 Class Notes CHAPTER NO 11
- Physics 10 Class Notes CHAPTER NO 12