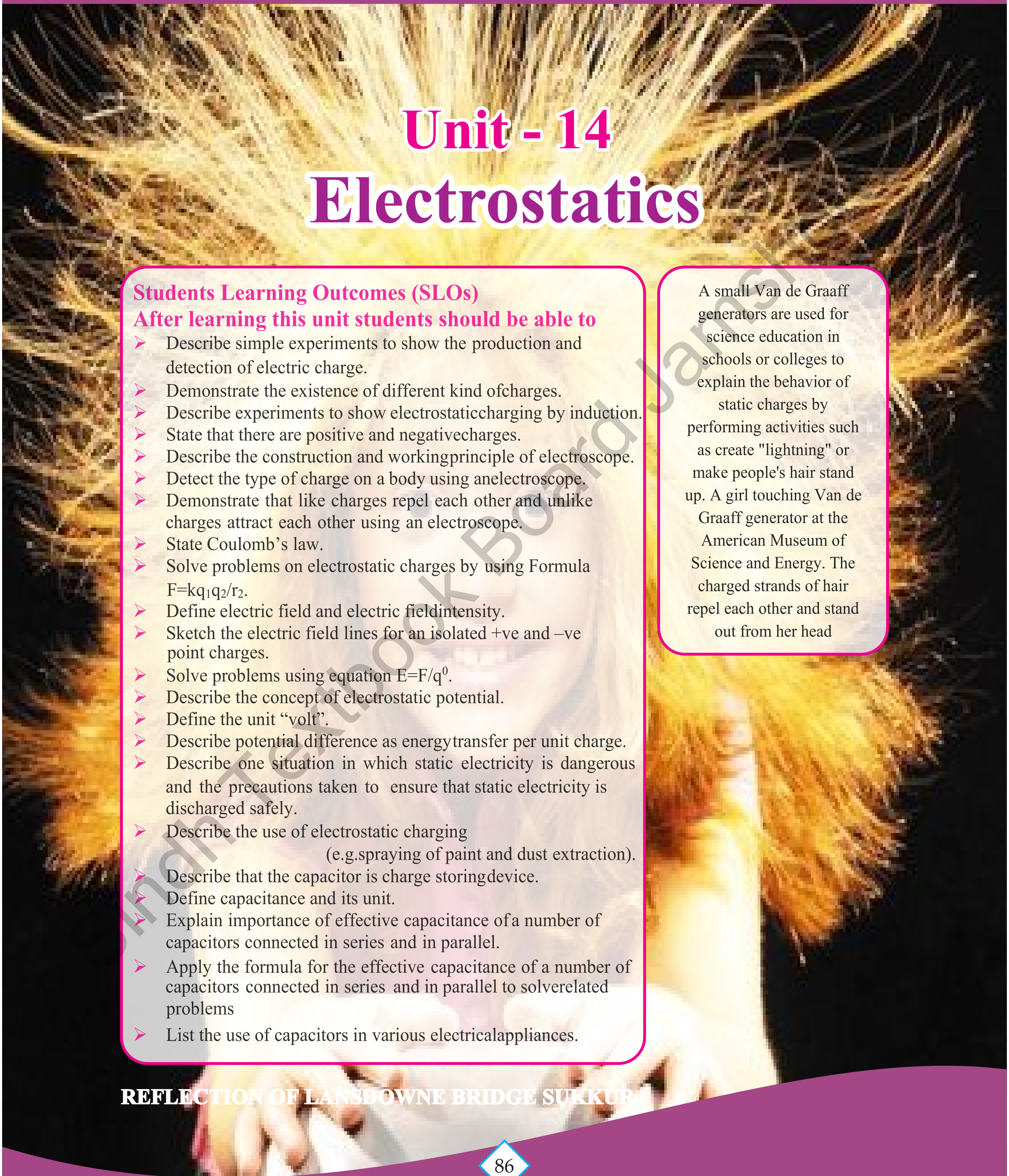
Unit - 14

Electrostatics



A small Van de Graaff generators are used for science education in schools or colleges to explain the behavior of static charges by performing activities such as create "lightning" or make people's hair stand up. A girl touching Van de Graaff generator at the American Museum of Science and Energy. The charged strands of hair repel each other and stand out from her head

Students Learning Outcomes (SLOs)

After learning this unit students should be able to

- Describe simple experiments to show the production and detection of electric charge.
- Demonstrate the existence of different kind ofcharges.
- Describe experiments to show electrostaticcharging by induction.
- State that there are positive and negativecharges.
- Describe the construction and workingprinciple of electroscope.
- Detect the type of charge on a body using anelectroscope.
- Demonstrate that like charges repel each other and unlike charges attract each other using an electroscope.
- State Coulomb's law.
- Solve problems on electrostatic charges by using Formula $F=kq_1q_2/r_2$.
- Define electric field and electric fieldintensity.
- Sketch the electric field lines for an isolated +ve and –ve point charges.
- Solve problems using equation $E=F/q^0$.
- Describe the concept of electrostatic potential.
- Define the unit "volt".
- Describe potential difference as energytransfer per unit charge.
- Describe one situation in which static electricity is dangerous and the precautions taken to ensure that static electricity is discharged safely.
- Describe the use of electrostatic charging (e.g.spraying of paint and dust extraction).
- Describe that the capacitor is charge storingdevice.
- Define capacitance and its unit.
- Explain importance of effective capacitance of a number of capacitors connected in series and in parallel.
- Apply the formula for the effective capacitance of a number of capacitors connected in series and in parallel to solverelated problems
- List the use of capacitors in various electricalappliances.

In this chapter, we will discuss the various characteristics of static charges, such as their electric force, electric field, and electric potential, among many other things. Additionally, several applications of static electricity as well as precautions against its use will be covered. The study of charges while they are not moving is referred to as electrostatics or static electricity.

14.1 Electric charge

Charge is a basic characteristic of matter that causes electrical processes. Charged particles are found in most materials. Protons and electrons have opposing unit charges. Neutral atoms have the same number of electrons and protons.

In the 18th century, Benjamin Franklin experimented with charges. Franklin was the one who came up with the terms "positive" and "negative" to describe the two distinct types of electricity. He also used a kite's wet line to collect electricity from stormy clouds.

Electric charge is a fundamental feature of matter that is carried by some elementary particles and governs how the particles react to an electric or magnetic field. The charge is a scalar quantity with the coulomb as its SI unit.

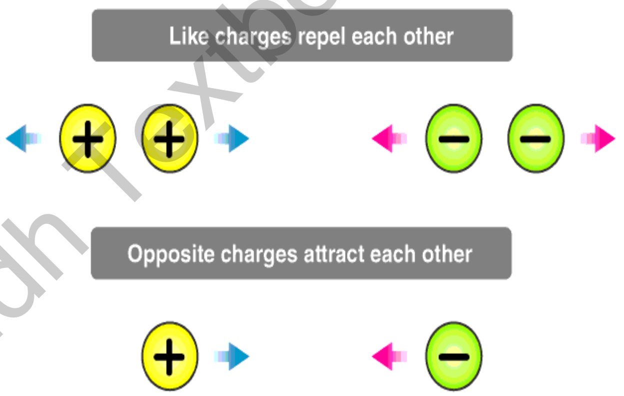


Fig: 14.1 Electric charge

Production of electric charge

When we comb our hair with a plastic comb and then bring it close to small pieces of paper, the comb will attract the paper pieces to itself as shown in figure 14.2.

Do You Know!

Electric charges at rest have been known much longer than electric currents.

Do You Know!

the word electricity comes from 'elektron', the Greek name for amber.currents.

Do You Know!

Charge introduced by
"Benjamin Franklin"
(1706-1790)

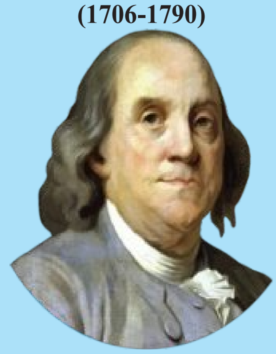


Fig: 14.2
Simple static electric experiment with hair comb

Fig: 14.3
The amber rubbed with silk attracts small pieces of paper

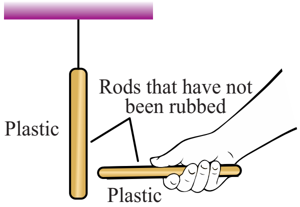


Fig: 14.4 (a)
No force is observed

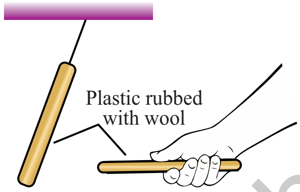


Fig: 14.4 (b)
Plastic rods repel each other

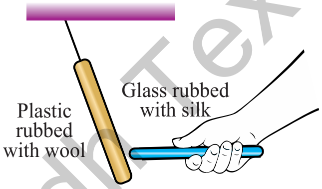


Fig: 14.4 (c)
Glass rod attracts plastic rod

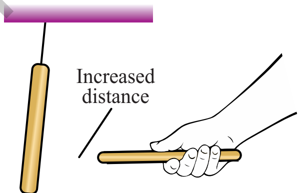


Fig: 14.4 (d)
At increased distance, forces are decreased

In the same way, rubbing amber with silk causes it to attract the small pieces of paper as shown in figure 14.3. The electric charges that are imparted to things through the process of rubbing are the cause of the properties of attraction and repulsion that are exhibited by different types of matter.

A static electric charge can be generated by rubbing together two neutral bodies. The experiments below demonstrate that rubbing can generate two distinct forms of electric charge.

Activity

Take two plastic rods. One of them should be suspended vertically as shown in figure 14.4 (a). Both rods should be rubbed with animal fur and bring them close to each other. In result we observe that the both rods have a repulsive effect on each other as shown in figure 14.4 (b). It indicates that the rods were charged as they were being rubbed.

Once again repeat same activity by taking two different rods one is of plastic and second made up of glass. Rub the glass rod with silk and in similar way plastic rod rubbed with animal fur. When we bring the glass rod that has been rubbed with silk close to the plastic rod that is suspended in the air, we notice that the rods attract each other Fig. 14.4 (c).

We observe that in the first part of activity when we take both rods made of plastic were rubbed with fur repel each other. As a result, we are going to make the assumption that the charge on both rods will be of the same kind.

In the second part of activity, the rods are different from one another, and the fact that they are attracted to one another suggests that the charges on the rods are not of the same kind but of opposite nature.

Positive charge and negative charge are the traditional names given to these different types of electrical charge. The act of rubbing causes a transfer of negative charge from one object to another as it moves from surface to surface.

The results of these experiments lead us to the following conclusions:

1. Charge is a fundamental property of a material body that determines whether or not it attracts or repels another object.
2. Two distinct types of charge are produced by friction on two distinct types of materials (such as glass and plastic).
3. Charges that are identical to one another always repel one another.
4. Charges that are not similar to one another always attract one another.
5. The only reliable indicator of charge on a body is repulsion.

Types of Charges

Electric charge, whether positive or negative, exists in discrete natural units and cannot be created or destroyed. Electric charge is a characteristic shared by many fundamental, or subatomic, matter particles. Electrons, for example, have a negative charge, while protons have a positive charge, but neutrons have no charge. Experiments show that the negative charge of each electron has the same magnitude as the positive charge of each proton charge is measured in natural units, which are equivalent to the charge of an electron or a proton, which is a fundamental physical constant. In the MKS and SI systems, the coulomb is the unit of electric charge. When the current in an electric circuit is one ampere, it is defined as the amount of electric charge that flows through a cross-section of a conductor in one second. A coulomb is made up of 6.24×10^{18} natural units of electric charge, such as single electrons or protons. According to the definition of an ampere, the electron has a negative charge of $1.602176634 \times 10^{-19}$ coulomb.

Methods of charge formation

There are three methods of formation of charges on a body as given below:

1. Induction 2. Conduction 3. Friction

Weblinks

Encourage students to visit below link for Static electric charge

https://www.youtube.com/watch?v=Vrh5FeGUTJA&ab_channel=FuseSchool-GlobalEducation

Do You Know!

Like charge repel and opposite attract by **"Charles Dufay" (1698-1739)**

Induction: It is a charging method in which a neutral object is charged without actually touching another charged object

Conduction: It is charging by contact where charge is transferred to the object.

Friction: The imbalance of electrons and protons can be easily created by fraction when two objects rubbing over one another. This process of charging is called charging by friction.

SELF ASSESSMENT QUESTIONS:

Q1: Why proton having positive charge?

Q2: Why neutron having neutral (zero) charge?

Q3: What causes electric charges?

Q4: How many methods used for formation of charges?

14.2 Electrostatic Induction

The formation of a charge through the influence of a nearby charged object, rather than the actual object, called electrostatic induction (Here induction means to influence without contact).

Electrostatic charging by induction.

In this section, we'll look at charge transfer through induction with a negatively charged item. Consider two metal spheres A and B, which are touching in the illustration. Take a rubber balloon that is negatively charged. When we put the charged balloon close to the spheres, the repulsion between the balloon's electrons and the spheres causes electrons in the two-sphere system to move away from the balloon. Following that, electrons from sphere A are transported to sphere B. As electrons migrate, sphere A becomes positively charged, whereas sphere B becomes negatively charged. As a result, the entire two-sphere system is electrically neutral. As depicted in the diagram, the spheres are then separated using an insulating cover such as gloves or a stand (avoiding direct contact with the metal). When the balloon is removed, the charge is redistributed throughout the spheres, as illustrated in Figure 14.8.

Weblinks

Encouraging students to visit below link for Electrostatic induction

https://www.youtube.com/watch?v=w80djqIZyBg&ab_channel=SimplyInfo

Do You Know!

- Proton composed by two up and one down quarks.
- Neutron composed by two down and one up quarks.

Quark	Symbol	Charge
Up	u	$+\frac{2}{3}e$
Down	d	$-\frac{1}{3}e$

Proton = u + u + d

$$P=\left(\frac{2}{3}+\frac{2}{3}-\frac{1}{3}\right)e$$

$$P=\left(\frac{2+2-1}{3}\right)e$$

$$P=\left(\frac{3}{3}\right)e$$

$$P=e$$

$$P=1.602176634\times10^{-19}C$$

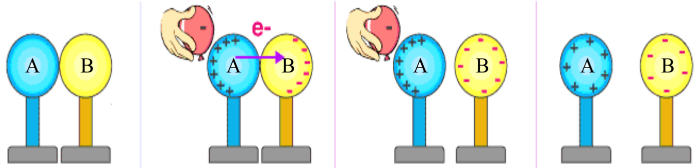


Fig: 14.5 Electric Charge

When a negatively charged balloon is introduced close to the sphere system, the electrons in the sphere are forced to go away due to repulsion. As electrons migrate, sphere A becomes totally positive and sphere B becomes completely negative.

SELF ASSESSMENT QUESTIONS:

Q1: What is tribo electric field?

Q2: Can a charge body attract neutral body?

14.3 Electroscope

In 1600, British physician William Gilbert constructed the first electroscope with a pivoting needle, called versorium.

An electroscope is a scientific instrument for detecting the presence of an electric charge on a body.

Electroscope detects test charge based on Coulomb electrostatic force. Because the electric charge of an item is proportional to its capacitance, an electroscope may be thought of as a rudimentary kind of voltmeter. Quantitative measurement of charge is performed with an electrometer.

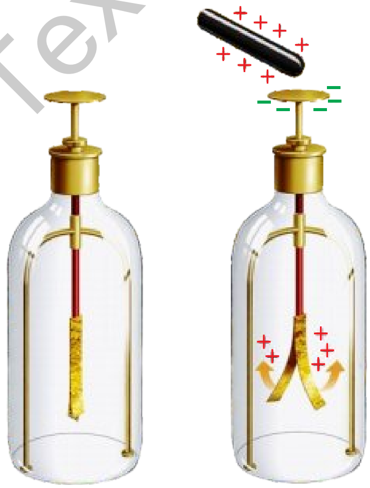


Fig: 14.7 Electroscope

Do You Know!

- Tribo electric effect is the part of static electricity.
- Formula for charge in term of current
  $q = I \cdot t$
- Charge are quantized, finding by
  $q = ne$

Fig: 14.6
William Gilbert
(1544–1603)

Construction and working of the electroscope.

The operation of an electroscope is based on the atomic structure of elements; charge induction, the internal structure of metal elements, and the concept that similar charges repel each other while unlike charges attract each other. These four concepts form the basis of the electroscope's working principle.

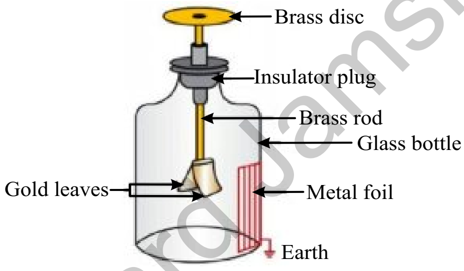


Fig: 14.8 Schematic diagram of electroscope

An electroscope has a metal detector knob on top and metal leaves on the connecting rod. When there is no charge present, the metals' leaves are allowed to hang. When an item with a charge is brought near an electroscope, one of two things may happen.

Positive charges attract electrons in the electroscope's metal, which migrate upward out of the leaves. This causes the leaves to have a transient positive charge, and since similar charges repel, the leaves split as illustrated in figure 14.9 (a). When the charge is released, the electrons return to their normal places and the leaves relax figure 14.9 (b).

When the charge is negative, the electrons in the electroscope metal reject and migrate toward the leaves. When the leaves are temporarily negatively charged, they split once again because opposite charges repel one another figure 14.9(c). If the charge is removed, the electrons return to their original location and the leaves relax.

An electroscope reacts to a charge by moving electrons into or out from the leaves. In both circumstances, the leaves separate. The electroscope cannot tell whether a charged item is positive or negative; it just detects an electrical charge.

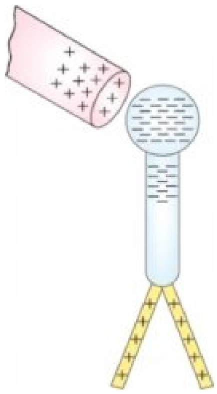


Fig: 14.9 (a)

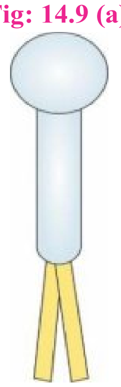


Fig: 14.9 (b)

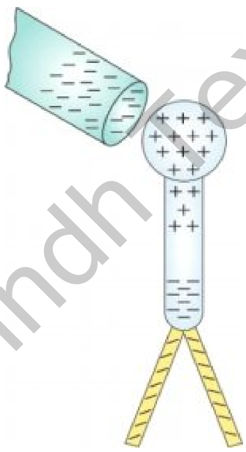


Fig: 14.9 (c)

SELF ASSESSMENT QUESTIONS:

Q1: When a charged body is brought near an electroscope, what happens?

Q2: How can we charge an electroscope?

Q3: Which device is used to detect whether an object is charged?

14.4 Coulomb's law

A French physicist Charles Augustin de Coulomb in 1785 coined a tangible relationship in mathematical form between two bodies that have been electrically charged. The force causing the bodies to attract or repel each other which is known as Coulomb's law or Coulomb's inverse-square law.

This law states that

The magnitude of electrostatic force of attraction or repulsion between two point charges is directly proportional to the product of magnitudes of charges and inversely proportional to the square of the distance between them.

Consider two point charges q_1 and q_2 which are (r) distance a part, than according to coulomb's law.

$$F \propto q_1 q_2 \qquad ...(14.1)$$

and $$F \propto \frac{1}{r^2} \qquad ...(14.2)$$

By combining the equation (14.1) and (14.2)

$$F \propto \frac{q_1 q_2}{r^2} \quad \text{OR} \quad F = K\frac{q_1 q_2}{r^2} \qquad (14.3)$$

Where k is the constant of proportionality

$$K = \frac{1}{4\pi\varepsilon}$$

$$F = \frac{1}{4\pi\varepsilon}\frac{q_1 q_2}{r^2}$$

$$\frac{1}{4\pi\varepsilon} = 8.99\times10^{9}\,N-m^2/C^2$$

$$K \cong 9.0\times10^{9}\,N-m^2/C^2$$

$$\varepsilon = 8.85\times10^{-12}\,C^2/N-m^2$$

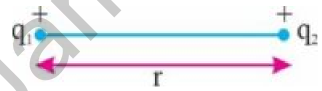


Fig: 14.10
Two point charges separated by distance r

Do You Know!

ε_o Its called permetivity of free space and read as **"Epsilon Naught"**

Weblinks

Encourage students to visit below link for notion of charges

https://www.youtube.com/watch?v=2GQTfpDE9DQ&ab_channel=KhanAcademy

Worked Example 1

Calculate the force of attraction between two point charge of +2mC and –3mC, if they apart of 1cm.

Solution

Step 1: Write down the known quantities and quantities to be found.

$$q_1 = 2mC = 2\times10^{-3}C$$

$$q_2 = -3mC = 3\times10^{-3}C$$

$$r = \frac{1cm}{100} = 10^{-2}m$$

Force = ?

Step 2: Write down the formula and rearrange if necessary.

$$F = \frac{kq_1q_2}{r^2}$$

Step 3: Put the values and calculate

$$F = \frac{(9\times10^9)(2\times10^{-3})(3\times10^{-3})}{(10^{-2})^2}$$

$$F = \frac{54\times10^9\times10^{-6}}{10^{-4}}$$

$$F = \frac{54\times10^9\times10^{-6}}{10^{-4}}$$

$$F = 54\times10^{9-6}\times10^4$$

$$F = 54\times10^{3+4}$$

$$F = 54\times10^7$$

$$\boxed{F = 5.4\times10^8 N}$$

Result: The required force of attraction between two point charge is $F = 5.4\times10^8 N$.

SELF ASSESSMENT QUESTIONS:

Q1: Calculate the coulombs force between two protons 10cm apart from each other? Charge on proton is 1.69×10^{-19} C and $K = 9.0\times10^9 N\text{–}m^2/C^2$

Q2: Is there any electrostatic force between electron and neutron?

14.5 Electric field and electric field intensity

we know that Like charges repel each other while opposite charges attract. Positively charged particle exerts a force of attraction on negatively charged while exerts a force of repulsion on positively charged particle. It is important to remember that the second charged particle also exerts an electrostatic force on the first one. As a result, it may be deduced that the area surrounding the charge is constantly under stress and exerts a force on another charge put around it. The area or space surrounding a charge or charged body where electrostatic force or stress occurs is termed electric field, dielectric field, or electrostatic field.

A region around the charged particle or object within which a force would be exerted on other charged particles or objects.

An electric field is often referred to as the electric force per unit of charge.

The formula of electric field is given as;

$$E = \frac{F}{Q}$$

Whereas,

E is the electric field.

F is a force.

Q is the charge.

Changing magnetic fields or electric charges are the most common causes of electric fields. The magnitude of an electric field is expressed using the SI unit is N/C.

The force acting on the positive charge is assumed to be pointing in the same direction as the field's direction. The electric field extends outwards radially from the positive point charge and inwards radially toward the negative point charge.

Electric field lines

The electric field that surrounds a charge may be imagined as the existence of a line of force all the way around it. Electric or electrostatic lines of force refer to a system of imaginary lines around a charged object and indicating the stress on that object. The configuration of lines of force around an isolated positive charge is seen in Fig. 14.11 (a).

Do You Know!

Concept of electric field given by
"Michael Farady"
(1791-1867)

Do You Know!

Point charge is an electric charge. When the linear sizes of charged bodies are much smaller than the distance between them, their sizes may be ignored.

Test charge is a charge with a magnitude so small that placing it at a point has a negligible affect on the field around the point.

The fact that all observable charges are always some integral multiple of elementary charge $e = 1.6\times10^{-19}$ C is known as **quantization of electric charge.**

Thus $q = \pm ne$, where $n=1,2,3,\ldots$

$e = 1.6\times10^{-19}$ C is the magnitude of the lowest possible charge which is carried by an electron and proton.

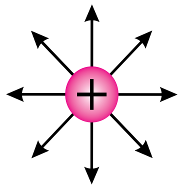


Fig: 14.11 (a)
Isolated positive charge

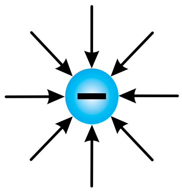


Fig: 14.11 (b)
Isolated negative charge

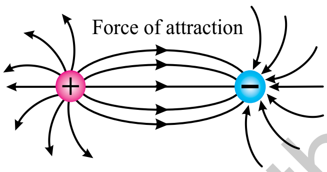


Fig: 14.11 (c)
Two equal unlike charges

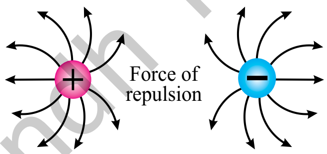


Fig: 14.11 (d)
Two equal like charges

while the arrangement of lines of force around an isolated negative charge is shown in Fig. 14.11 (b). such lines of force originate from the positive charge and terminate on the negative charge, when these charges are placed near each other. They exert the force of attraction on each other. This is shown in Fig 14.11 (c). while when two like charges are near each other, such lines will be in opposite direction as shown in Fig 14.11 (d). there exists a force of repulsion between them.

Worked Example 2

Calculate the electric field intensity if 9μN force acting on 3μc charge.

Solution

Step 1: Write down the known quantities and quantities to be found.

$$F = 9\mu N = 9\times10^{-6} N$$
$$q = -3\mu C = 3\times10^{-6} C$$

Step 2: Write down the formula and rearrange if necessary.

$$E = \frac{F}{q}$$

Step 3: Put the values and calculate

$$E = \frac{9\times10^{-6} N}{3\times10^{-6} C}$$
$$E = 3\frac{N}{C}$$

Result: The required E is $3\frac{N}{C}$.

SELF ASSESSMENT QUESTIONS:

Q1: What is meant by electric field and electric intensity?
Q2: Is electric intensity a vector quantity? What will be its direction?
Q3: calculate the force acting on a charge of 3microC, when the electric field intensity is 5N/C.

14.6 Electrostatic potential

The electrostatic potential, also known as the electric field potential, electric potential, or potential drop, is defined as The amount of work that is done in order to transport a unit charge from a reference point to a given location within the field without causing an acceleration.

The volt is the standard SI unit for measuring electrostatic potential.

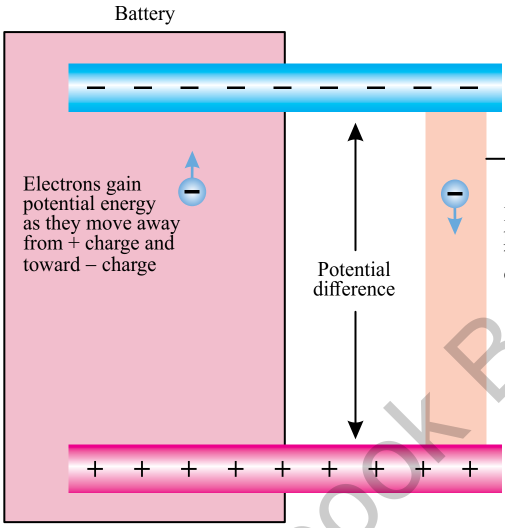


Fig: 14.12 Electrostatic potential

Electric potential energy is possessed by an object by the virtue of two elements, those being, the charge possessed by an object itself and the relative position of an object with respect to other electrically charged objects. The magnitude of electric potential depends on the amount of work done in moving the object from one point to another against the electric field as shown in figure 14.12.

When an object is moved against the electric field it gains some amount of energy which is defined as the electric potential energy. For any charge, the electric potential is obtained by dividing the electrical potential energy to the quantity of charge.

$$V = \frac{W}{q} = \frac{\text{Electrical potential energy}}{\text{Charge}}$$

Do You Know!

Electrostatic potential is measured in statvolt

Weblinks

Encourage students to visit below link for Electric potential

https://www.youtube.com/watch?v=PEcPcNMfNks&ab_channel=7activestudio

Do You Know!

S.I unit of potential difference and electromotive force is same **"Volt"**

Weblinks

Encourage students to visit below link for Electric potential difference

https://www.youtube.com/watch?v=SNlOPxZ-Ev4&ab_channel=Don%27tMemorise

Volt:

Volt is the unit of electrical potential, potential difference, and electromotive force in the SI system;

The potential difference that exists across a resistance of one ohm while a current of one ampere is flowing through it.

The unit of voltage known as the volt was named after the Italian scientist Alessandro Volta (1745–1827).

Worked Example 3

Calculate the p.d of 300mJ of workdone on a 150mc charge?

Solution

Step 1: Write down the known quantities and quantities to be found.

W = 300mJ
C = 150mC
V = ?

Step 2: Write down the formula and rearrange if necessary.

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

Step 3: Put the values and calculate

$$V = \frac{300mJ}{150mC}$$

V = 2volts

Result: The required voltage is 2 volt.

Potential difference:

The energy possessed by Electric charges is known as electrical energy. A charge with higher potential will have more electric potential energy and the charge with lesser potential will have less electric potential energy. The current always moves from higher electric potential to lower electric potential. The difference in these energies per unit charge is known as the electric potential difference.

It is the work done per unit charge to move a unit charge from one point to another in an electric field. Electric potential difference is usually referred as Voltage difference.

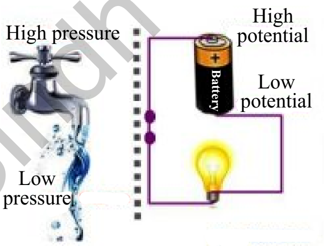


Fig: 14.13 Simple example to understand the potential difference

14.7 Applications of electrostatics.

There are many applications of electrostatics which are given below:

- The Van de Graaff Generator. ...
- Xerography. ...
- Laser Printers. ...
- Ink Jet Printers and Electrostatic Painting. ...
- Smoke Precipitators and Electrostatic Air Cleaning.

Spray painting:

The friction that occurs when the spray exits the nozzle gives it an electrical charge. The droplets all have the same charge, which means that they will repel each other since similar charges repel; as a result, the droplets disperse themselves equally throughout the surface.

Fig: 14.14
Spray paint

Electrostatic Air Cleansing:

Electrostatic precipitators is another name for these types of devices. It is possible to ionise the dust and smoke particles in the air by passing them through an electric cell. By bringing a charged collecting plate into touch with the charged dust and smoke particles, an attraction is created between the two.

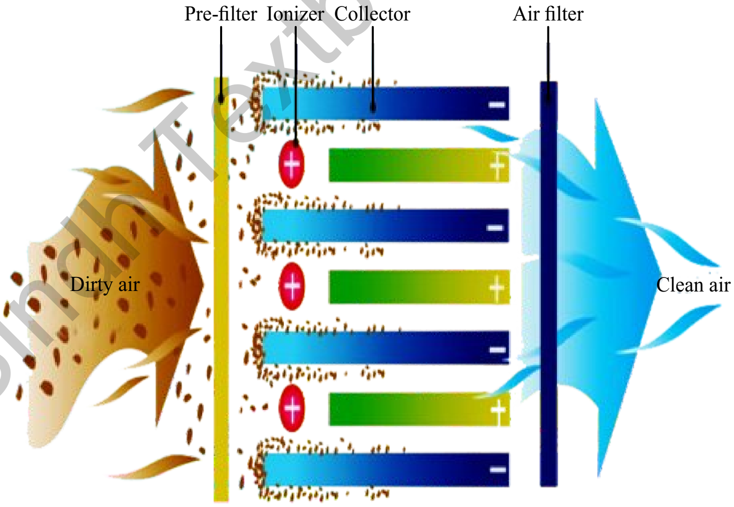


Fig: 14.15 Systematic diagram of electrostatic air cleansing

Do You Know!

Capacitor also called **"Condensor"**
Condenser is a term used for a capacitor in the past. In time the term ceased to be used, with capacitor turning into the most commonly used term from 1926. Condenser and capacitor are one and the same viewed from electrical perspective.

Fig: 14.18
Capacitor of different capacitance

Do You Know!

Energy of capacitor finding by:

$$E = \frac{1}{2}CV^2$$

14.8 Capacitor and capacitance

The capacitor is a simple electronic device or component and is used to store charge. It is a system of two isolated conductors that can store electric charge as shown in the figure 14.16

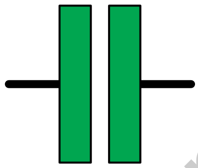


Fig: 14.16 Symbol of capacitor

A Capacitor stores a large amount of charge per volt in a very small area of the conductor.

Two conductors of any shape (plates) carrying equal and opposite charges, separated from each other by an insulating material medium called Dielectric formed a Capacitor. Different types of capacitors categorized according to the shape of plates as shown in figure 14.17.

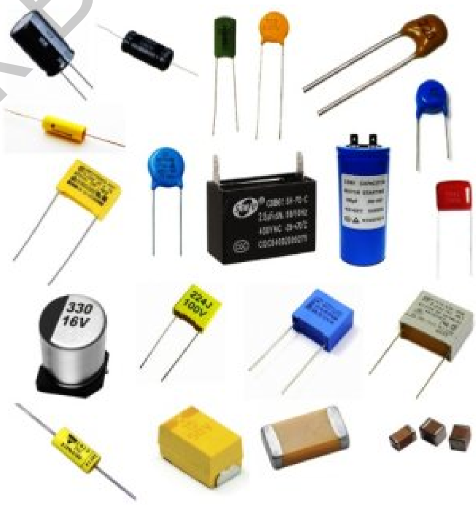


Fig: 14. 17 Capacitor of different size and shapes

Capacitance:

The ability of storing charges in a Capacitor is known as Capacitance. When the Capacitor is connected to a battery of V volts, one plate draws positive charge and the other plate draws negative charge from the battery till the potential difference between the plates also becomes V volts.

Charge Q which resides on any one of the plate is directly proportional to the potential difference between the plates.

$Q \propto V$

Or $Q = CV$

The constant C is called Capacitance of the Capacitor and the equation Q = CV is called equation of Capacitor.

So,

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

This shows that unit of capacitance is Coul / Volt and this unit is also called Farad because 1Farad = 1Coul /Volt. Thus, if a charge of 1Coulomb given to any one of the plate produces a potential difference of 1Volt between the plates, then the Capacitance of Capacitor is said to be 1Farad.

So, Capacitance is the ratio of the charge on one of the conductors (q) to the potential difference (V) between them.

Symbolically:

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

$$\text{Capacitance} = \frac{\text{Magnitude of charge on conductor}}{\text{Magnitude of potential difference}}$$

Factors on which capacitance depends:

Capacitance depends on these factors:

- Area of the plate. Capacitance increases if area of the plate increases.
  Hence $C \propto A$.
- Distance between the plates. Capacitance increases if the separation distance between the plates decreases.
  Hence $C \propto \frac{1}{d}$
- Dielectric Constant (ϵ_r) capacitance increases if insulating medium of high dielectric constant is used.
  Hence $C \propto \epsilon_r$.

Do You Know!

If dielectric placed between plates of capacitor its electric field and electric potential will be decrease

Do You Know!

If parallel plate capacitor without oil between the plates (dielectric constant of oil, K=2) has a capacitance c. If the oil is removed, then the capacitance of the capacitor becomes half

Combination of capacitors:

For a circuit the capacitance of a desired value can be obtained by different combination of capacitors and that combination may be:

- Parallel combination
- Series combination
- Series Parallel combination.

1. Parallel combination of capacitors:

Let suppose capacitor consists on such a combination that positive terminal of each capacitor is connected with the positive terminal of the other capacitor and negative terminal of each capacitor is connected with the negative terminal of the other capacitor. Then the combination is said to be Parallel combination.

If three Capacitors C_1, C_2 and C_3 are connected in Parallel and further connects them with a battery of V volts then:

C_1 draws charge Q_1, C_2 draws charge Q_2 and C_3 draws charge Q_3. Then:

$$Q = Q_1 + Q_2 + Q_3.$$

By applying Capacitor equation. We get:

$$Q_1 = C_1V,\ Q_2 = C_2V,\ Q_3 = C_3V,\ Q = C_eV$$

So capacitance becomes:

$$C_eV = C_1V + C_2V + C_3V$$

$$C_eV = (C_1 + C_2 + C_3)\ V$$

$$C_e = C_1 + C_2 + C_3$$

So now according to the equation the equivalent capacitance or overall total capacitance is equal to the sum of individual Capacitors.

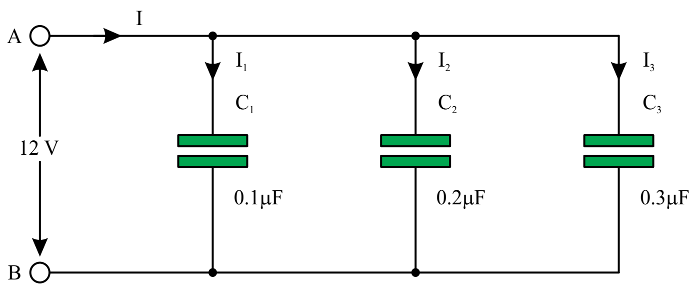


Fig: 14.19 Parallel combination of three capacitors

Weblinks

Encourage students to visit below link for How capacitor works

https://www.youtube.com/watch?v=5hFC9ugTGLs&ab_channel=NationalMagLab

Do You Know!

In parallel combination of capacitor voltage same on each one capacitor

Weblinks

Encourage students to visit below link for Combination of capacitors in parallel

https://www.youtube.com/watch?v=BIPi0vXdssE&ab_channel=PhysicsVideosbyEugeneKhutoryansky

Worked Example 4

Find the net capacitance of four capacitors. When capacitance of each capacitor is 1μF and connected parallel.

Solution

Step 1: Write down the known quantities and quantities to be found.

$$C_1 = C_2 = C_3 = C_4 = 1\mu F$$
$$C_{net} = ?$$

Step 2: Write down the formula and rearrange if necessary.

$$C_{net} = C_1 + C_2 + C_3 + C_4$$

Step 3: Put the values and calculate

$$C_{net} = (1+1+1+1)\mu F$$
$$\boxed{C_{net} = 4\mu F}$$

Result: The required capacitance becomes is 4μF.

Weblinks

Encourage students to visit below link for Combination of capacitors in series

https://www.youtube.com/watch?v=P_hCvjKdG4I&ab_channel=7activestudio

2. Series combination of capacitors:

Let suppose Capacitors are consists on such a combination that positive terminal of one Capacitor connected with the negative terminal of the other Capacitor and the negative terminal of first Capacitor is connected with the positive terminal of the other Capacitor. Then the combination is said to be Series combination.

If three Capacitor C_1, C_2 and C_3 are connected in Series and further connects them with a battery of V volts. Then:

Positive plate of Capacitor C_1 draws charge +Q from the battery ad negative plate of C_3 draws charge – Q from the battery.

The charge +Q on the positive terminal (Left Plate) of C_1 attracts free electrons from the left plate of C_2 and these free electrons are accumulated on the right plate of C_1. Thus right plate of C_1 becomes negatively charged with a charge – Q. in this way every Capacitor becomes charged.

If voltage acquired by each Capacitor is V_1, V_2, V_3 by applying Capacitor equation on C_1, C_2 and C_3. We get:

Do You Know!

In series combination of capacitor charges equally stored on each capacitor.

$$Q = C_1V_1, Q = C_2V_2, Q = C_3V_3, Q = C_eV$$

$$V_1 = \frac{Q}{C_1}, V_2 = \frac{Q}{C_2}, V_3 = \frac{Q}{C_3}$$

$$\frac{Q}{C_e} = Q\left(\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}\right)$$

$$\frac{1}{C_e} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

So now according to the equation:

The reciprocal of equivalent capacitance is equal to the sum of reciprocals of individual capacitance.

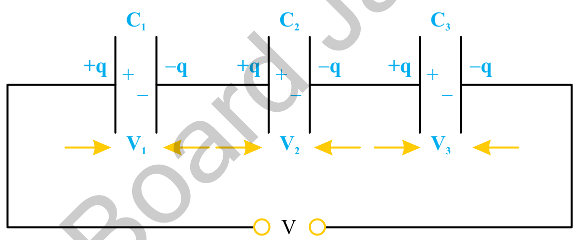


Fig: 14.20 Series combination of three capacitors

Weblinks

Encourage students to visit below link for Capacitor physics and applications

https://www.youtube.com/watch?v=L6cgSxpGmDo&ab_channel=HowToMechatronics

Uses of Capacitors:

Electrical and electronic circuits use capacitors in a broad variety of ways. They are utilized, for instance, in the process of tuning transmitters, receivers, and transistor radios. Also, they are utilized to run table fans, ceiling fans, exhaust fans, air conditioner motors, coolers, washing machines, air conditioners, and many other appliances to keep them running at a high efficiency.

It is also common to find capacitors in the electronic circuitry of computers and other products like smartphones.

It is possible to utilize capacitors to distinguish between high and low frequency signals, which makes them valuable in electronic circuits. For instance, resonant circuits, which are responsible for tuning radios to specific frequencies, require the use of **variable capacitors**. These kinds of circuits are referred to as filter circuits. One capacitor may not work in all situations. In general, ceramic capacitors outperform other types and can be found in a wide variety of applications.

Weblinks

Encourage students to visit below link for Types of capacitors and How to use capacitors

https://www.youtube.com/watch?v=XXWlCUiUxuY&ab_channel=EcoSignX

SUMMARY

- Electric charge is the basic physical property of matter that causes it to experience a force when kept in an electric or magnetic field.
- Electrostatic induction is the physical phenomenon in which a material can be charged without any actual contact with a charged body.
- Scientific equipment used for detecting presence of an electric charge on a body is known as electroscope.
- Coulomb's law states that the magnitude of the force between two point charges is directly proportional to the product of the magnitudes of the charges and inversely proportional to the square of the distance between them.
- Electric field is the region around a charge in which an electric test charge would experience an electric force.
- The electric Intensity is a measure of the force exerted by one charged body on another. It is a vector quantity and has unit of NC^{-1}.
- Electrostatic potential is The amount of work needed to move a unit charge from a reference point to a specific point against an electric field.
- The volt is the derived unit for electric potential, electric potential difference (voltage), and electromotive force
- Capacitor is a device which is used for storing electric charges.
- In series combination of capacitors, the reciprocal of Equivalent capacitance is equal to the sum of reciprocals of individual capacitance.
- In parallel combination of capacitors, the total capacitance always equals to the sum of individual capacitors.
- Electron volt (eV): the unit of energy and is related to joule as 1 eV= 1.602×10^{-19} J.

CONCEPT MAP

Electrostatics

- Study of Charges at Rest
  - Electric field electric lines/ electric field intensity $E=\frac{Kq}{r^2}$
  - Applications
    - Photo copier
    - Inkjet printer
    - Laser printer
  - Electric intensity
  - Electric potential
    - Electric potential at a point in an electric field $V=\frac{W}{q}$
    - Electric volt (ev) is a unit of electrical energy $1ev=1.6\times10^{-19}J$
    - Electric potential at a point due to point charge $V=\frac{q}{r}$
    - Electric field as potential gradient $E=\frac{\Delta V}{\Delta r}$
  - Capacitor
    - Series combination of capacitor
    - Parallel combination of capacitor

Section (A) Multiple Choice Questions (MCQs)

Choose the correct answer from the following choices:

1. Branch of physics which deals with the charges at rest is called
   (a) Electricity (b) Electrostatic
   (c) Quantum (d) Magnetism
2. The magnitude of force between two unit positive charges when the distance between them is 1m would be
   (a) 0N (b) 1N (2) 2N (d) Coulombs Constant
3. Coulombs law most closely resembles with
   (a) Law of conservation of Energy (b) Newton's Law of Gravitation
   (c) Newton's 2^{nd} law of Motion (d) Faraday's law
4. If the electrostatic force between two electrons is ***F*** Newton, then the electrostatic force between two protons at the same distance is
   (a) 0N (b) 2F (c) 2/3 F (d) F
5. The direction of electric force and electric field intensity is
   (a) Parallel to each other (b) Perpendicular to each other
   (c) opposite to each other (d) In any direction
6. The work done on a unit charge against electric field intensity is called
   (a) Electric field (b) Electric current
   (c) Electric potential (d) electric field
7. The capacitance of capacitors increases when they connected in
   (a) Parallel (b) Series (c) both (d) none of them
8. Two capacitors of 8μF are connected in series then the equivalent capacitance is
   (a) ¼ μF (b) 2 μF (c) 3 μF (d) 6 μF
9. The presence of a dielectric between the plates of capacitors, the capacitance of capacitor
   (a) Increases (b) decreases
   (c) remain constant (d) remain uncharged
10. If the area of the parallel plate capacitor is doubled then the capacitance will be
    (a) Remain uncharged (b) half
    (c) Double (c) increased two times

Section (B) Structured Questions

1. Explain how electric charge can be generated and measured in very simple experiments.
2. Explain how an electroscope is built and how it operates.
3. State and explain the Coulomb's law.
4. Define electric field and electric field intensity.
5. Describe the concept of electrostatic potential.
6. Describe potential difference as energytransfer per unit charge.
7. Provide an example of when static electricity could cause harm, as well as the measures taken to prevent injury.
8. Describe how the capacitor works as a device that stores electrical charges.
9. Explain why it's important to know the effective capacitance of a number of capacitors connected in series and in parallel.
10. Give some examples of where capacitors are used in different kinds of electrical devices..
11. In what direction will a positively charged particles move in an electric field?
12. Does a series connection between capacitors always result in an equal amount of charge being stored in each capacitor?

Section (C) Numericals

1. What is the electric force of repulsion between two electrons at a distance of 1 m? **(2.3×10^{-28} N)**
2. Two point charges $q_1 = 5\mu C$ and $q_2 = 3\ \mu C$ are placed at a distance of 5 cm. What will be the coulomb's force between them? **(54 N)**
3. If 2 μC charge is placed in the field of 3.42×10^{11} N/C, what will be the force on it? **(684×10^{3} N)**
4. What is the charge on the capacitor, if a 40 μF capacitor has a potential difference of 6 V across it? **(2.4×10^{-4} C)**
5. The potential difference between two points is 100 V. If an unknown charge is moved between thee points, the amount of work done is 500J. Find the amount of charge. **(5 C)**
6. Find the equivalent capacitance when a 4μF, 3 μF and 2 μF capacitor are connected in series. **(0.92 μF)**

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