Unit -2 Electrostatics & Current Electricity

1. Define electric field, Electric Field Strength, electric flux

Electric field – The region around the charge where its effects such as attraction or reflection are observed is known as electric field.
Electric Field Strength - The electric field intensity at a point is the force experienced by a unit positive charge placed at that point.
Electric Field Intensity is a vector quantity. It is denoted by 'E'.

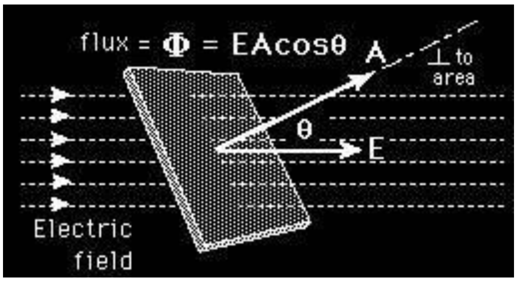
Electric Field = F/q

Unit – N/C or NC^{-1}
Electric flux – The number of electric field lines crossing a given area kept normal to the electric field lines is called electric flux. It is usually denoted by the Greek letter Φ_E and its unit is $N\,m^2\,C^{-1}$. Electric flux is a scalar quantity and it can be positive or negative.

Electric flux $\phi = EA\cos\theta$

Where,

- E is the magnitude of the electric field
- A is the area of the surface through which the electric flux is to be calculated
- Θ is the angle made by the plane and the axis parallel to the direction of flow of the electric field



If $\theta = 0$,Flux will be maximum.
$\theta < 90$,Flux will be positive.
$\theta > 0$,Flux will be negative.
$\theta = 90$,Flux will be zero.

2. State Coulomb's inverse square law.

Coulomb's law states that the force of attraction or repulsion between two-point charges is proportional to the product of charges and inversely proportional to the square of the distance between them.

Consider the charges of strengths Q_1 and Q_2 placed distance d apart. Let F be the force between them.

According to Coulomb's law

$$F \alpha \frac{Q_1 Q_2}{d^2}$$

$$F = K \frac{Q_1 Q_2}{d^2}$$

Where K = $1/4\pi\varepsilon_0$

The constant ε_0 is called permittivity of the medium. Its value depends upon the medium in which the charges are placed.

K = Relative permittivity or di-electric constant of the medium.

The dielectric constant K has value 1 for air and vacuum. The permittivity of the free space ε_0 is a fixed constant. Its value is 8.85 x 10^{-12} farad/m

The expression for the force can be written as,

$$F = \frac{1}{4\pi\varepsilon_0} \frac{Q_1 Q_2}{d^2}$$

Above equation shows the formula for the force acting between two charge particles.

3. State and derive Gauss law.

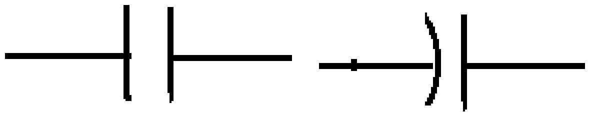
According to Gauss's theorem the net-outward normal electric flux through any closed surface of any shape is equivalent to $1/\varepsilon_0$ times the total amount of charge contained within that surface.

$$\varphi = \oint \vec{E} * \vec{ds} = \frac{1}{\varepsilon_0} q$$

4. What is a Capacitor?

The capacitor is a device in which electrical energy can be stored. It is an arrangement of two-conductor generally carrying charges of equal magnitudes and opposite sign and separated by an insulating medium. The non-conductive region can either be an electric insulator or vacuum such as glass, paper, air or semi-conductor called as a dielectric.

5. Draw Circuit Symbols of Capacitor.



6. Define Capacitance and state its units.

The charge on the capacitor (Q) is directly proportional to the potential difference (V) between the plates i.e. **Q = CV**

The constant of proportionality (C) is termed as the **capacitance of the capacitor**.

- **Unit of Capacitance:** Farad (F)

Commonly Used Scales

- $\mu F = 10^{-6} F$
- $nF = 10^{-9} F$
- $pF = 10^{-12} F$

7. State the factors Affecting the Capacitance

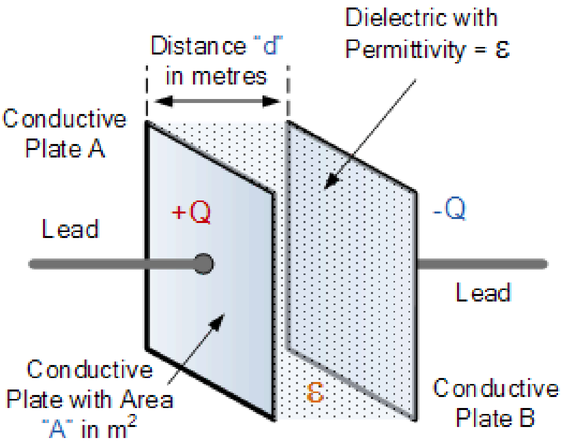
Capacitance depends on the following factor:

1. Shape and size of the conductor
2. Medium between them
3. Presence of other conductors near it.

8. Explain construction and working of Parallel Plate Capacitor

The parallel plate capacitor consists of two metal plates of Area, A and is separated by a distance d. The plate on the top is given a charge +Q and that at the bottom is given the charge –Q. A potential difference of V is developed between the plates.

Parallel plate capacitor is an arrangement of two parallel conducting plates of equal area separated by air medium or any other insulating medium such as paper, mica, glass, wood, ceramic, etc.



The charge density on each plate of parallel plate capacitor has a magnitude of σ

$$\sigma = Q/A$$

From Gauss law, $E = Q/\varepsilon_0 A$

$$\text{Also, } \mathbf{E = V/d}$$

$$\textbf{Thus } \mathbf{V/d} = Q/\varepsilon_0 A$$

$$Q/V = \varepsilon_0 A/d$$

$$C = Q/V = \varepsilon_0 A/d$$

Capacitance of a parallel plate capacitor is

(i) directly proportional to the area of the plates and
(ii) inversely proportional to the distance of separation between them.

9. Derive equation for parallel combination of capacitance.

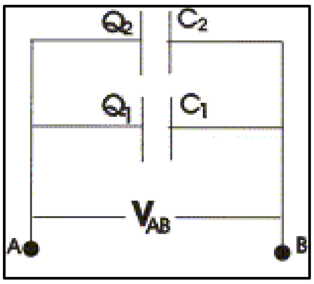


Figure below shows two capacitors connected in parallel .
In Parallel Connection potential difference $V_{AB}=V_A-V_B$ would be same for both the capacitors, and charges Q_1 and Q_2 on both the capacitors are not necessarily equal. So,

$$Q_1=C_1V \text{ and } Q_2=C_2V$$

Thus charge stored is divided amongst both the capacitors in direct proportion to their capacitance.
Total charge on both the capacitors is,

$$Q=Q_1+Q_2=V(C_1+C_2) \quad \text{and} \quad Q/V= C_1+C_2 \quad \text{---- (1)}$$

So system is equivalent to a single capacitor of capacitance

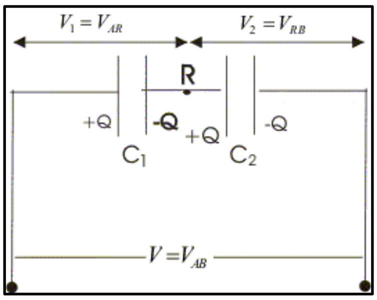
$$C=Q/V = C_1+C_2$$

If there are number of capacitors connected in parallel then their equivalent capacitance would be

$$C=C_1+C_2+ C_3.......... \qquad (2)$$

10. Derive equation for series combination of capacitance.

Figure below shows two capacitors connected in series combination between points A and B.



In series combination of capacitors all the capacitors would have same charge.
Now potential difference across individual capacitors are given by

$$V_{AR}=Q/C_1 \quad \text{and} \quad V_{RB}=Q/C_2$$

Sum of V_{AR} and V_{RB} would be equal to applied potential difference V so,

$$V=V_{AB}=V_{AR}+V_{RB}$$

$$=Q(1/C_1 + 1/C_2)$$

or,

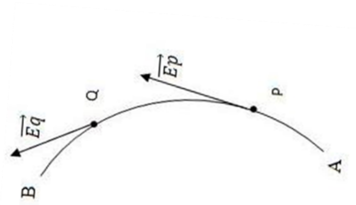
$$\frac{V}{Q}=\frac{1}{C_1}+\frac{1}{C_2}=\frac{Q}{C}$$

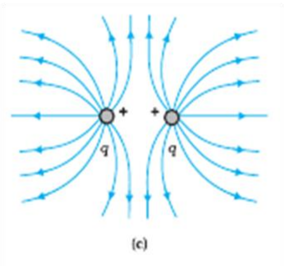
where

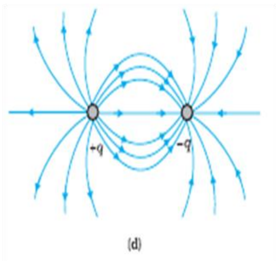
$$\frac{1}{C}=\frac{1}{C_1}+\frac{1}{C_2}$$

i.e., resultant capacitance of series combination C=Q/V, is the ratio of charge to total potential difference across the two capacitors connected in series.

11. State characteristics of electric field lines.







a.Electric field lines start from positive charges and end at negative charges.

b.The tangent drawn at any points on the electric field lines -shows the direction of electric field at that point.

c.Two field lines never cross each other.

d. Electric field lines of stationary electric charge distribution do not form closed loops.

e.The separation of neighbouring field lines in a region at electric field indicates the strength of electric field in that region.

12. The amount of charge stored on either plate of capacitor 4 μF when connected across a battery of 12 V.

C = 4 μF
V=12 V
Q = ?

$C = Q/V$

$Q= C.V$

$= 4 \times 10^{-6} \times 12$

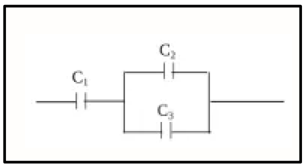
$= 48 \times 10^{-6}$ C

13. **A capacitor is constructed from two conductive metal plates 30 cm x 50 cm which are spaced 6 mm apart from each other and uses dry air as its only dielectric material. Calculate the capacitance of the capacitor (€= 8.75 * 10^{-12}).**

A = 30 x 50 = 1500 cm^2 = 0.15 m^2
d= 6 mm = 0.6 cm = 0.006 m
$€_0$ = 8.85 x 10^{-12} C^2 N^{-1} m^{-2}

$C = \epsilon_0 \cdot \frac{A}{d} = 8.85 \times 10^{-12} \times \frac{0.15}{0.006} = 221.25 \quad \times 10^{-12}\ F = 221.25\ pF$

14. **Three capacitors C1=2μF, C2=4μF, C3=4μF are connected in series and parallel. Determine the capacitance of a single capacitor that will have the same effect as the combination.**



C1= 2μF
C2= 4μF
C3=4μF

C2 and C3 capacitors are connected in parallel

C_p = C2 + C3
= 4 + 4
C_p = 8 μF

C_p and C1 capacitors are connected in series

$$\frac{1}{C} = \frac{1}{Cp} + \frac{1}{C1} = \frac{1}{8} + \frac{1}{4}$$

$$\frac{1}{C} = \frac{3}{8}$$

C = 2.6 μF