PROGRAM	Electrical and electronics engineering	**SEMESTER**	II
COURSE NAME	Concepts of Electrical circuits	**TYPE OF COURSE**	Integrated
COURSE CODE	25EE21L	**CONTACT HOURS**	8hours/week(104 hours)
TEACHING SCHEME	L:T:P-4:0:4	**CREDITS**	6
CIE MARKS	50	**SEE MARKS**	50(Theory)

SESSION -1

1.ELECTRIC CHARGE

2.ELECTRIC FIELD

3.LAWS OF ELECTROSTATICS.

Electrostatics is the branch of physics that deals with **electric charges at rest/stationary** (not moving). It focuses on how these charges interact with each other and with the materials around them.

Definition's:

1)Electric charge: **Electric charge** is a fundamental property of matter that causes it to experience a forces when placed in an electric or magnetic field .

- There are two types of charges
  1.positive
  2.Negative.
- Like charges repel each other; unlike charges attract each other.
- SI unit of Charge is **coulombs (C).**
  - Proton → +1 elementary charge
  - Electron → –1 elementary charge

*Electric charge is the property of a particle that makes it attract or repel other particles.

2)Electric field: An electric field is the region around a charged object where it can exert a force on another charge.

- Every electric charge creates an electric field around it.
- It is represented by electric field lines .
  - Direction:Away from the Positive charge , and towards the negative charge.
  - Electric field (E) at a point is the force (F) experienced by a unit positive charge(q) at that point:

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

Electric field in N/C or volts/m. electric force in Newtons. charge in Coulombs

  - SI Unit is **newtons per coulomb (N/C) or volts per meter (V/m).**

*An electric field is an invisible force field around a charge that tells us how that charge will push or pull other charges.

Laws of Electrostatics:

The laws of electrostatics describe how electric charges behave when they are at rest. The three main laws are:

1. Like charges repel; unlike charges attract

- Positive ↔ Positive → repel
- Negative ↔ Negative → repel
- Positive ↔ Negative → attract
- This explains why charged objects push or pull each other.

2. Coulomb's Law:

It states that the electrostatic force between two point charges :

1.Directly proportional to then the product of their magnituteds,

2.Inversly proportional to the square of the distance between them,

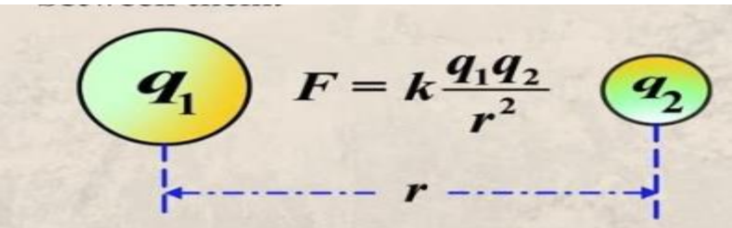
3. Acts along the line joining the two charges.

Coulomb's law gives the magnitude of the force between two charges:

$$F = k\frac{q_1 q_2}{r^2}$$

Where:

- F= electrostatic force
- q_1, q_2= charges
- r= distance between them
- k= Coulomb's constant (9×10^9 N/m^2/C^2)



Key ideas:

- Force increases with more charge.
- Force decreases rapidly as distance increases.

3. Charge is conserved Electric charge cannot be created or destroyed; it can only be transferred from one body to another.

Example: When you rub a balloon on your hair,   electrons move from your hair to the balloon, but the total charge remains the same.

SESSION -2

Definitions:

1. **Electrostatic Induction.**
2. **Electric Flux.**
3. **Electric field intensity.**
4. **Flux density.**

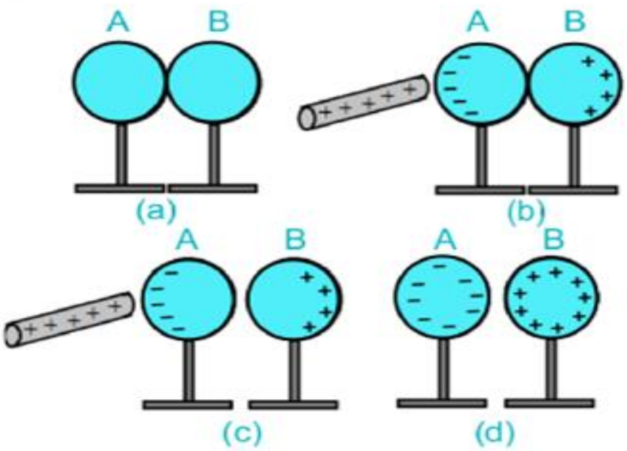
1)Electrostatic Induction:

1. Electrostatic induction

Definition:
Electrostatic induction is the phenomenon by which a charged object induces an opposite charge on a nearby conductor without direct contact.

- When a charged body is brought close to a neutral conductor:
  - It attracts opposite charges and
  - Repels like charges within the conductor.
- The conductor remains neutral overall, but the charges get separated.

Example:
If a positively charged rod is brought near a metal sphere, negative charges gather near the rod, and positive charges move to the far end.



(a) – Initial Condition

- Two metal spheres A and B are touching each other and are neutral (no charge).
- No external charged object is nearby.
- No net charge on either sphere.

(b) – Charging by Induction Begins

- A positively charged rod is brought near sphere A.
- Due to electrostatic induction:
  - Electrons in the spheres are attracted towards the positively charged rod.
  - Sphere A becomes negatively charged (more electrons).
  - Sphere B becomes positively charged (loses electrons).
- No direct contact is made with the rod — only influence.

(c) – Separation of Spheres

- While the rod is still nearby, the two spheres A and B are separated.
- The charges are trapped on each sphere:
- Sphere A keeps a negative charge. ○ Sphere B keeps a positive charge.

— (d) – Final Result

- The charged rod is removed.

Now: Sphere A has a permanent negative charge.
Sphere B has a permanent positive charge.

2)Electric Flux(Φ or ΦE):

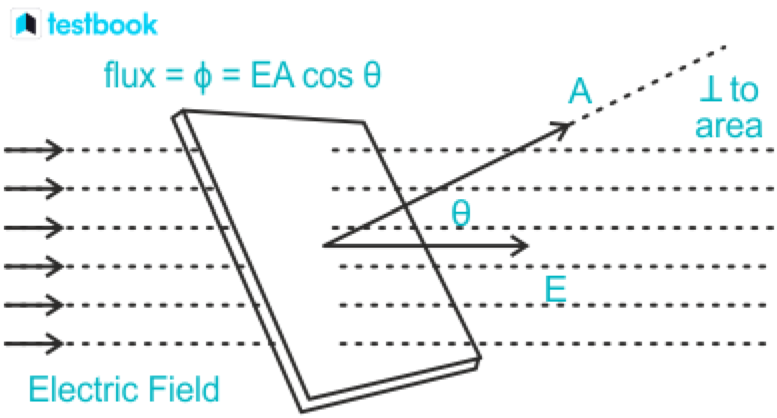
The **total number of electric field lines** passing a given area in a unit of time is defined as the electric flux.

Electric flux (Φ_e) through a surface is:

$$\Phi_E = \vec{E} \cdot \vec{A} = EA\cos\theta$$

Where:

- E = electric field strength
- A = area of the surface
- θ = angle between the electric field and the surface's normal (perpendicular) direction



*If more electric field lines pass through the surface → **larger electric flux**

*If fewer pass through → **smaller flux**

*If none pass through (field parallel to surface) → **zero flux**

3)Electric field intensity:

Electric field intensity is **the force experienced by a unit positive test charge** at a specific point in space.

Electric field intensity at a point is:

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

Where:

- E = electric field intensity (N/C or V/m)
- F = force experienced by a test charge
- q = magnitude of the test charge
- ϵ_0= permittivity of free space = 8.854×10^{-12} F/m
-

It tells us how strong the electric field is and in what direction it acts.

4. **Electric Flux Density (D)**

(Also called **Electric Displacement Field**)

Definition:
Electric flux density is the **electric flux per unit area** passing through a surface perpendicular to the electric field.

$$\vec{D} = \frac{\vec{\Phi}_E}{A} \quad \text{or} \quad \vec{D} = \varepsilon\vec{E}$$

Where:
- D = Electric flux density
- ε = Permittivity of the medium
- E = Electric field intensity

Unit: Coulomb per square meter (C/m^2)

SESSION 3

- Electric potential and potential difference
- Potential gradient

Electric Potential and Potential Difference:

Electric Potential (V):
The electric potential at a point is the amount of work needed to move a unit positive charge from a reference point (usually infinity) to that point. It's a scalar quantity measured in volts (V).
Formula: $V = \frac{W}{q}$

Where:
- V = Electric Potential (Volt)
- W = Work done (Joule)
- q = Charge (Coulomb)

Unit:
Volt (V) → 1 Volt=1 Joule/Coulomb1

Potential Difference (ΔV):

The potential difference between two points is the work done per unit charge to move a charge between those two points. It's also measured in volts. A positive potential difference indicates that work is done against the electric field, while a negative potential difference indicates that work is done by the field.

Formula: V= w/q

Where:

- V = Electric Potential (Volt)
- W = Work done (Joule)
- q = Charge (Coulomb

Unit: Volt (V) → 1 Volt=1 Joule/Coulomb1

Potential difference tells **how much energy** a charge gains or loses when moving between two points.

- If the potential difference is **high**, the electric "push" is strong.
- If it's **zero**, no work is done moving the charge between those points.

Potential Gradient

Definition:
The **rate of change of electric potential** with respect to distance in the direction of the electric field.
Formula:
Potential Gradient= $\frac{dV}{dx}$
Where:

- dV = Change in potential
- dx = Change in distance

SESSION 4

Breakdown voltage and dielectric strength

1. Breakdown Voltage

Definition:
Breakdown voltage is the minimum voltage at which an insulating material becomes conductive, allowing current to flow through it.

Key Points:

- When the applied voltage exceeds the breakdown voltage, the material fails as an insulator and becomes electrically conductive.
- It is measured in volts (V) or kilovolts (kV).
- It depends on the material thickness, temperature, and humidity.

Example:

- If air has a breakdown voltage of 3 kV/mm, then 3,000 volts applied across a 1 mm air gap will cause it to conduct.

2. Dielectric Strength

Definition:
Dielectric strength is the maximum electric field a material can withstand without breakdown.
Formula:
Dielectric Strength= $\frac{Breakdown\ Voltage}{Thickness\ of\ the\ material}$
Units:

- Measured in volts per unit thickness, typically:
  - kV/mm
  - MV/m (megavolts per meter)

Key Points:

- It is a property of the material (not dependent on shape or size). ● Higher dielectric strength means better insulating capacity.

Example:

- Mica has a dielectric strength of 118 kV/mm.
- If a mica sheet is 2 mm thick, it can withstand up to: 2×118=236 kV2

Potential gradient:

Potential gradient is the rate at which electric potential changes with distance at a point in an electric field.

It tells you how quickly the voltage drops from one point to another.

Definition

$$\text{Potential Gradient} = \frac{dV}{dx}$$

Where:

- dV = change in electric potential
- dx = change in distance

Unit: V/m (volt per meter)

Breakdown voltage:

Breakdown voltage is the minimum voltage at which an insulating material becomes conductive (allows electric current to pass through it).

In simple words:

It is the voltage at which an insulator "breaks down" and electricity suddenly jumps across it.

Dielectric strength:

Dielectric strength is the maximum electric field an insulating material can withstand without breaking down (i.e., without becoming conductive).

In simple words:

Dielectric strength tells how much voltage an insulator can tolerate before it fails and allows a spark to pass through.

Formal Definition

$$\text{Dielectric Strength} = \frac{\text{Breakdown Voltage}}{\text{Thickness of the material}}$$

Unit: V/m (volt per meter)
Often also expressed as kV/mm or MV/m