Engineering Physics Module–5 Notes Electrostatics in Vacuum

MODULE–5 TOPICS

• Electric Field and Electrostatic Potential
• Charge Distribution
• Electric Displacement
• Dielectrics
• Gradient
• Divergence
• Curl
• Stokes' Theorem
• Gauss Theorem
• Continuity Equation
• Maxwell's Equations
• Poynting Vector

1. ELECTROSTATICS

Electrostatics is the branch of physics that deals with stationary electric charges and their effects.

Applications:
• Capacitors
• Electrostatic precipitators
• Xerox machines
• Laser printers

2. ELECTRIC FIELD

Electric field is the force experienced by unit positive charge placed at a point.

Expression:

$E = F / q$

Where:
E = electric field intensity
F = force
q = charge

Electric Field Due to Point Charge:

E = (1 / 4π■■) (q / r^2)

Where:
■■ = permittivity of free space
r = distance from charge

3. ELECTROSTATIC POTENTIAL

Electrostatic potential is the work done in bringing unit positive charge from infinity to a point.

Expression:

$V = W / q$

Potential Due to Point Charge:

V = (1 / 4π■■) (q / r)

Relation between Electric Field and Potential:

$E = - dV/dr$

4. ELECTRIC FIELD FOR CHARGE DISTRIBUTION

Electric field can be calculated for different charge distributions:

- Linear charge distribution
- Surface charge distribution
- Volume charge distribution

5. ELECTRIC DISPLACEMENT VECTOR (D)

Electric displacement vector represents effect of electric field in dielectric medium.

Expression:

D = ■E

Where:
■ = permittivity of medium

Units:
C/m^2

6. DIELECTRICS

Dielectrics are insulating materials that do not conduct electricity but become polarized in electric field.

Examples:
- Glass
- Rubber
- Plastic

Properties:
- High resistivity
- Polarization effect

Applications:
- Capacitors
- Electrical insulation

7. VECTOR CALCULUS

(a) Gradient

Gradient of scalar function gives rate of change and direction of maximum increase.

Expression:

$\text{grad } \phi = \nabla\phi$

(b) Divergence

Divergence measures outward flow of vector field.

Expression:

$\text{div } A = \nabla \cdot A$

(c) Curl

Curl measures rotational property of vector field.

Expression:

curl A = $\nabla \times A$

8. STOKES' THEOREM

Stokes' theorem relates surface integral of curl of vector field to line integral around boundary.

Expression:

■ $A \cdot dl$ = ■ $(\nabla \times A) \cdot ds$

Applications:
• Electromagnetic theory
• Fluid mechanics

9. GAUSS THEOREM

Gauss theorem relates electric flux through closed surface to total enclosed charge.

Expression:

■ $E \cdot ds = Q$ / ■■

Applications:
• Electric field calculations
• Symmetrical charge distributions

10. CONTINUITY EQUATION

Continuity equation represents conservation of electric charge.

Expression:

$\nabla \cdot J = - \partial\rho/\partial t$

Where:
J = current density
ρ = charge density

11. MAXWELL'S EQUATIONS

Maxwell equations describe behavior of electric and magnetic fields.

(a) Gauss Law for Electric Field

$\nabla \cdot E = \rho$ / ■■

(b) Gauss Law for Magnetism

$\nabla \cdot B = 0$

(c) Faraday's Law

$\nabla \times E = - \partial B/\partial t$

(d) Ampere-Maxwell Law

$$\nabla \times B = \mu_0 J + \mu_0 \varepsilon_0 \, \partial E/\partial t$$

Applications:
- Electromagnetic waves
- Communication systems
- Electrical engineering

12. POYNTING VECTOR

Poynting vector represents energy flow per unit area in electromagnetic waves.

Expression:

$$S = E \times H$$

Where:
S = Poynting vector
E = electric field
H = magnetic field

Units:
W/m^2

Applications:
- Electromagnetic power transmission
- Microwave engineering

MOST IMPORTANT 14 MARK QUESTIONS

1. Explain electric field and electrostatic potential for charge distribution.

2. Explain electric displacement vector and dielectric materials.

3. Explain gradient, divergence and curl with examples.

4. State and explain Stokes' theorem.

5. State and explain Gauss theorem with applications.

6. Explain continuity equation for current densities.

7. Explain Maxwell's equations in vacuum and non-conducting medium.

8. Explain Poynting vector and its significance.

IMPORTANT 7 MARK QUESTIONS

1. Define electric field intensity.

2. Explain electrostatic potential.

3. Explain dielectric polarization.

4. Explain electric displacement vector.

5. Explain divergence and curl.

6. Explain continuity equation.

7. Explain Poynting vector.

IMPORTANT NUMERICALS

1. Electric field calculation.

2. Electrostatic potential numerical.

3. Gauss law numerical.

4. Poynting vector calculation.

5. Electric displacement numerical.

EXAM TIPS

- Practice vector calculus carefully.
- Learn Maxwell equations properly.
- Revise formulas daily.
- Draw neat field diagrams.
- Focus on Gauss law and Poynting vector derivations.