Department of Electrical & Electronics Engineering

Course File

ELECTROMAGNETIC FIELDS

(Course Code: GR20A2026)

II B.Tech I Semester

2022-23

Dr. Suresh Kumar Tummala

Professor

Gokaraju Rangaraju Institute of Engineering & Technology

(Autonomous)

Bachupally, Kukatpally, Hyderabad – 500 090, A.P., India.

Gokaraju Rangaraju Institute of Engineering and Technology
(Autonomous)

Department of Electrical & Electronics Engineering

ELECTROMAGNETIC FIELDS

Check List

Gokaraju Rangaraju Institute of Engineering and Technology
(Autonomous)

Department of Electrical & Electronics Engineering

Int. Marks:30 Ext. Marks:70 Total Marks:100

ELECTROMAGNETIC FIELDS

Course Code: GR20A2026 **L/T/P/C: 3/0/0/3**
II Year I Semester

UNIT I
STATIC ELECTRIC FIELD
Coulomb's law- Electric Field Intensity-Electrical Field due to Point charge, Line, Surface and Volume Charge distributions. Gauss Law and its Applications. Absolute Electric potential-Potential difference-Calculation of potential differences for different configurations. Electric Dipole- Electrostatic Energy density.

UNIT II
CONDUCTORS
Dielectrics and Capacitance Current and current density- Ohms Law in Point form- Continuity of current- Boundary conditions of perfect dielectric materials. Permittivity of dielectric materials- Capacitance-Capacitance of a two-wire line- Poisson's equation- Laplace's equation- Solution of Laplace and Poisson's equation- Application of Laplace's and Poisson's equations.

UNIT III
STATIC MAGNETIC FIELDS- Biot-Savart Law- Ampere Law-Magnetic flux and Magnetic Flux Density- Scalar and Vector Magnetic Potentials. Steady Magnetic Fields produced by current carrying conductors. Magnetic Forces-Materials and Inductance Force on a moving charge-Force on a differential current element- Force between differential current elements- Nature of magnetic materials- Magnetization and Permeability- magnetic boundary conditions- Magnetic Circuits- inductances and mutual inductances.

UNIT IV
TIME VARYING FIELDS and Ma xwell's Equations Faraday's law for Electromagnetic induction- Displacement current- Point form of Maxwell's equation- Integral form of Maxwell's equations- Motional Electromotive forces, Boundary Conditions.

UNIT V

WAVE EQUATIONS AND SOLUTIONS, Time-harmonic fields, Plane waves in lossless media, Plane waves in lossy media (low-less dielectrics and good conductors), Group Velocity, Electromagnetic power flow and poynting vector, Normal incidence at a plane conducting boundary, Normal incidence at a plane dielectric boundary.

Text/Reference Books:

1. Matthew N.O.Sadiku, "Principles of Electromagnetics", Oxford University Publication, 2014.
2. W. Hayt, John A. Buck "Engineering Electromagnetics", McGraw Hill Education, 2012.
3. Pramanik, "Electromagnetism -Problems with solution", Prentice Hall India, 2012.
4. G. W. Carter, "The electromagnetic field in its engineering aspects", Longmans, 1954.
5. Pramanik, "Electromagnetism - Theory and applications ", PHI Learning Pvt. Ltd, New Delhi, 2009

Timetable

II B.Tech. I Semester - EMF

Day/Hour	8.50-9.40	9.40-10.30	10.30-11.20	11.20-12.00	12.00-12.55	12.55-1.50	1.50-2.45
Monday	EMF						
Tuesday							
Wednesday							EMF
Thursday	EMF						
Friday					EMF		
Saturday							

Vision of the Institute

To be among the best of the institutions for engineers and technologists with attitudes, skills and knowledge and to become an epicenter of creative solutions.

Mission of the Institute

To achieve and impart quality education with an emphasis on practical skills and social relevance.

Vision of the Department

To impart technical knowledge and skills required to succeed in life, career and help society to achieve self sufficiency.

Mission of the Department

- To become an internationally leading department for higher learning.
- To build upon the culture and values of universal science and contemporary education.
- To be a center of research and education generating knowledge and technologies which lay groundwork in shaping the future in the fields of electrical and electronics engineering.
- To develop partnership with industrial, R&D and government agencies and actively participate in conferences, technical and community activities.

Program Educational Objectives (B.Tech. – EEE)

Graduates will be able to

PEO 1: Have a successful technical or professional career, including supportive and leadership roles on multidisciplinary teams.

PEO 2: Acquire, use and develop skills as required for effective professional practices.

PEO 3: Able to attain holistic education that is an essential prerequisite for being a responsible member of society.

PEO 4: Engage in life-long learning, to remain abreast in their profession and be leaders in our technologically vibrant society.

Program Outcomes (B.Tech. – EEE)

At the end of the Program, a graduate will have the ability to

PO 1: Apply knowledge of mathematics, science, and engineering.

PO 2: Design and conduct experiments, as well as to analyze and interpret data.

PO 3: Design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.

PO 4: Function on multi-disciplinary teams.

PO 5: Identify, formulates, and solves engineering problems.

PO 6: Understanding of professional and ethical responsibility.

PO 7: Communicate effectively.

PO 8: Broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context.

PO 9: Recognition of the need for, and an ability to engage in life-long learning.

PO 10: Knowledge of contemporary issues.

PO 11: Utilize experimental, statistical and computational methods and tools necessary for engineering practice.

PO 12: Demonstrate an ability to design electrical and electronic circuits, power electronics, power systems; electrical machines analyze and interpret data and also an ability to design digital and analog systems and programming them.

Academic Year	: 2022-23	Semester	: I
Name of the Program	: II B.Tech - EEE		
Course	: Electromagnetic Fields	Course Code	: GR20A2026
Name of the Faculty	: Dr. Suresh Kumar Tummala, Professor	Department	: EEE

COURSE OBJECTIVES

On completion of this Subject/Course the student shall be able to:

S.No	Objectives
1	Apply vector Calculus and different coordinates systems for Electro and Magnetic systems
2	Understand the knowledge of Electro field theory for Point, Line, Surface Charge
3	Understand the concept of conductors, dielectrics, inductance, capacitance
4	Ability to do Calculations of MFI for Line, Surface Conductors with different Shapes
5	Ability of mathematical representation and analysis of EM waves at media interfaces

COURSE OUTCOMES

The expected outcomes of the Course/Subject are:

S.No	Outcomes
1.	Solve the problems in different EM fields using Different Coordinates Systems
2.	Evaluate the Electric Field Density and Intensity for Different Charges
3.	Understand the Electromagnetic Relation using Maxwell Formulae
4.	Analyze circuits using Conductors in Time Varying Fields
5.	Analyze and solve problems of EM wave propagation at media interfaces

Signature of faculty

Note: Please refer to Bloom's Taxonomy, to know the illustrative verbs that can be used to state the outcomes.

GUIDELINES TO STUDY THE COURSE / SUBJECT

Academic Year	: 2022-23	Semester	: I
Name of the Program	: II B.Tech - EEE		
Course	: Electromagnetic Fields	Course Code	: GR20A2026
Name of the Faculty	: Dr. Suresh Kumar Tummala, Professor	Department	: EEE

Guidelines to study the Course/ Subject: Electromagnetic Fields

<u>Course Design and Delivery System (CDD):</u>

- The Course syllabus is written into number of learning objectives and outcomes.
- Every student will be given an assessment plan, criteria for assessment, scheme of evaluation and grading method.
- The Learning Process will be carried out through assessments of Knowledge, Skills and Attitude by various methods and the students will be given guidance to refer to the text books, reference books, journals, etc.

The faculty be able to –

- Understand the principles of Learning
- Understand the psychology of students
- Develop instructional objectives for a given topic
- Prepare course, unit and lesson plans
- Understand different methods of teaching and learning
- Use appropriate teaching and learning aids
- Plan and deliver lectures effectively
- Provide feedback to students using various methods of Assessments and tools of Evaluation
- Act as a guide, advisor, counselor, facilitator, motivator and not just as a teacher alone

Signature of HOD　　　　　　　　　　Signature of faculty

Date:　　　　　　　　　　Date:

Gokaraju Rangaraju Institute of Engineering and Technology
(Autonomous)

Department of Electrical & Electronics Engineering

COURSE SCHEDULE

Academic Year	: 2022-23	Semester	: I
Name of the Program	: II B.Tech - EEE		
Course	: Electromagnetic Fields	Course Code	: GR20A2026
Name of the Faculty	: Dr. Suresh Kumar Tummala, Professor	Department	: EEE

The Schedule for the whole Course / Subject is:

S. No.	Description	Duration (Date)		Total No. Of Periods
		From	To	
1.	**UNIT-I:** STATIC ELECTRIC FIELD Coulomb's Law-Electric Field Intensity-Electrical Field due to Point charge, Line, Surface and Volume Charge distributions. Gauss Law and its Applications. Absolute Electric potential- Potential difference-Calculation of potential differences for different configurations. Electric Dipole- Electrostatic Energy density	10.10.2022	28.10.2022	13
2.	**UNIT-II:** CONDUCTORS Dielectrics and Capacitance Current and current density- Ohms Law in Point form- Continuity of current- Boundary conditions of perfect dielectric materials. Permittivity of dielectric materials- Capacitance-Capacitance of a two-wire line – Poisson's Equation – Laplace Equation – Application of Laplace and Poisons Equation – Solution of Laplace and Poisons Equation	31.10.2022	21.11.2022	17
3.	**UNIT-III:** STATIC MAGNETIC FIELDS- Biot-Savart Law- Ampere Law-Magnetic flux and Magnetic Flux Density- Scalar and Vector Magnetic Potentials. Steady Magnetic Fields produced by current carrying conductors. Magnetic Forces-Materials and Inductance Force on a moving charge-Force on a differential current element- Force between differential current elements- Nature of magnetic materials-Magnetization and Permeability- magnetic boundary conditions- Magnetic Circuits- inductances and mutual inductances	23.11.2022	16.12.2022	15
4.	**UNIT-IV:** TIME VARYING FIELDS and Maxwells Equation – Faraday's Law for Electromagnetic Induction-Displacement current- Point form of Maxwell's Equation-Integral form of Maxwell's Equations - Motional Electromotive forces, Boundary Conditions	19.12.2022	18.01.2023	15
	UNIT-V:	19.01.2023	06.02.2023	13

5.	WAVE EQUATIONS AND SOLUTIONS, Time-harmonic fields, Plane waves in lossless media, Plane waves in lossy media (low-less dielectrics and good conductors), Group Velocity, Electromagnetic power flow and poynting vector, Normal incidence at a plane conducting boundary, Normal incidence at a plane dielectric boundary			

Total No. of Instructional periods available for the course: 73 Hours

ILLUSTRATIVE VERBS FOR STATING INSTRUCTIONAL OBJECTIVES

These verbs can also be used while framing questions for Continuous Assessment Examinations as well as for End – Semester (final)Examinations

ILLUSTRATIVE VERBS FOR STATING GENERAL OBJECTIVES/OUTCOMES

Know	Understand	Design

ILLUSTRATIVE VERBS FOR STATING SPECIFIC OBJECTIVES/OUTCOMES:

A. COGNITIVE DOMAIN (KNOWLEDGE)

1	2	3	4	5	6
Knowledge	Comprehension Understanding	Application of knowledge & comprehension	Analysis Of whole w .r.t. its constituents	Synthesis	Evaluation Judgment
Define	Convert	Demonstrate	Differentiate	Categorize	Compare
Identify	Describe (a	Prepare	Discriminate	Combine	
	Procedure)	Relate	Distinguish	Design	
	Distinguish	Show	Separate	Generate	
	Explain why/how	Solve		Plan	

B. AFFECTIVE DOMAIN (ATTITUDE)

Assist	Select
Change	Develop

C. PSYCHOMOTOR DOMAIN (SKILLS)

Bend	Dissect	Insert	Perform	Straighten
Calibrate	Draw	Keep	Prepare	Strengthen
Compress	Extend	Elongate	Remove	Time
Conduct	Feed	Limit	Replace	Transfer
Connect	File	Manipulate	Report	Type
Convert	Grow	Move Precisely	Reset	Weigh
Decrease	Increase	Paint	Set	

SCHEDULE OF INSTRUCTIONS
COURSE PLAN

Academic Year	: 2022-23	Semester	: I
Name of the Program	: II B.Tech - EEE		
Course	: Electromagnetic Fields	Course Code	: GR20A2026
Name of the Faculty	: Dr. Suresh Kumar Tummala, Professor	Department	: EEE

Unit No.	Lesson No.	Date	No. of Periods	Topics / Sub-Topics	Objectives & Outcomes Nos.	References (Textbook, Journal)
1.	1	10.10.2022	2	Introduction to Electromagnetic Fields	1 1	Principles of Electromagnetics - NO Sadiku
	2	12.10.2022	1	Coulomb's law	1 1	Principles of Electromagnetics - NO Sadiku
	3	13.10.2022 & 14.10.2022	2	Electric Field Intensity-Electrical Field due to Point charge	1 1	Principles of Electromagnetics - NO Sadiku
	4	17.10.2022	2	Electrical Field due to Line, Surface Charge distributions	1 1	Principles of Electromagnetics - NO Sadiku
	5	19.10.2022 & 20.10.2022	2	Electrical Field due to volume charge distributions	1 1	Principles of Electromagnetics - NO Sadiku
	6	21.10.2022	1	Gauss Law and its Applications. Absolute Electric potential	1 1	Principles of Electromagnetics - NO Sadiku
	7	26.10.2022	1	Potential difference-Calculation of potential differences for different configurations	1 1	Principles of Electromagnetics - NO Sadiku
	8	27.10.2022 & 28.10.2022	2	Electric Dipole- Electrostatic Energy density	1 1	Principles of Electromagnetics - NO Sadiku
2.	1	31.10.2022	2	Dielectrics and Capacitance Current and current density	2 2	Principles of Electromagnetics - NO Sadiku
	2	02.11.2022 & 03.11.2022	2	Ohms Law in Point form-Continuity of current	2 2	Principles of Electromagnetics - NO Sadiku
	3	04.11.2022	1	Fully controlled converter with R & RL load midpoint type, Bridge type	2 2	Principles of Electromagnetics - NO Sadiku
	4	07.11.2022 & 09.11.2022	3	Boundary conditions of perfect dielectric materials. Permittivity of dielectric	2 2	Principles of Electromagnetics - NO Sadiku

				materials		
	5	10.11.2022 & 11.11.2022	2	Capacitance-Capacitance of a two-wire equation	2 2	Principles of Electromagnetics - NO Sadiku
	6	14.11.2022	2	Poison's & Laplace Equation - Solution, Applications	2 2	Principles of Electromagnetics - NO Sadiku
	7	16.11.2022 & 17.11.2022	2	Problems	2 2	Principles of Electromagnetics - NO Sadiku
	8	18.11.2022	1	Problems	2 2	Principles of Electromagnetics - NO Sadiku
	9	21.11.2022	2	Revision	2 2	Principles of Electromagnetics - NO Sadiku
3.	1	23.11.2022 & 24.11.2022	2	Static Magnetic fields, Biot-Savart Law	3 3	Principles of Electromagnetics - NO Sadiku
	2	25.11.2022	1	Ampere Law-Magnetic flux and Magnetic Flux Density-Scalar and Vector Magnetic Potentials	3 3	Principles of Electromagnetics - NO Sadiku
	3	28.11.2022	2	Steady Magnetic Fields produced by current carrying conductors, Magnetic Forces	3 3	Principles of Electromagnetics - NO Sadiku
	4	30.11.2022 & 01.12.2022	2	Materials and Inductance Force on a moving charge, Force on a differential current element	3 3	Principles of Electromagnetics - NO Sadiku
	5	02.12.2022	1	Force between differential current elements, Nature of magnetic materials	3 3	Principles of Electromagnetics - NO Sadiku
	6	05.12.2022	2	Magnetization and Permeability, Magnetic boundary conditions	3 3	Principles of Electromagnetics - NO Sadiku
	7	12.12.2022	2	Magnetic Circuits, inductances and mutual inductances	3 3	Principles of Electromagnetics - NO Sadiku
	8	14.12.2022 & 15.12.2022	2	Problems	3 3	Principles of Electromagnetics - NO Sadiku
	9	16.12.2022	1	Problems	3 3	Principles of Electromagnetics - NO Sadiku
4	1	19.12.2022	2	Time varying fields and Maxwell's Equation	4 4	Principles of Electromagnetics - NO Sadiku
	2	21.12.2022 & 22.12.2022	2	Faraday's law of electromagnetic induction, Displacement current	4 4	Principles of Electromagnetics - NO Sadiku

	3	26.12.2022	2	Point form of Maxwell's Equation	4 4	Principles of Electromagnetics - NO Sadiku
	4	28.12.2022 & 29.12.2022	2	Integral form of Maxwell's equation	4 4	Principles of Electromagnetics - NO Sadiku
	5	02.01.2023	2	Motional Electromotive forces, Boundary Conditions	4 4	Principles of Electromagnetics - NO Sadiku
	6	04.01.2023 & 05.01.2023	2	Applications of Maxwell's Equation	4 4	Principles of Electromagnetics - NO Sadiku
	7	06.01.2022	1	Problems	4 4	Principles of Electromagnetics - NO Sadiku
	8	09.01.2022	2	Maxwell's Equation due to Gauss law, Ampere circuital law	4 4	Principles of Electromagnetics - NO Sadiku
	9	11.01.2022 & 12.01.2022	2	revision	4 4	Principles of Electromagnetics - NO Sadiku
	10	18.01.2022	1	old question paper discussions	4 4	Principles of Electromagnetics - NO Sadiku
5	1	19.01.2022 & 20.01.2022	2	Wave equation & solutions, Time-harmonic fields	5 5	Principles of Electromagnetics - NO Sadiku
	2	23.01.2022	2	Plane waves in lossless media, Plane waves in lossy media	5 5	Principles of Electromagnetics - NO Sadiku
	3	25.01.2022	1	low-less dielectrics and good conductors	5 5	Principles of Electromagnetics - NO Sadiku
	4	27.01.2022	1	Group Velocity, Electromagnetic power flow and poynting vector	5 5	Principles of Electromagnetics - NO Sadiku
	5	30.01.2022	2	Normal incidence at a plane conducting boundary	5 5	Principles of Electromagnetics - NO Sadiku
	6	01.02.2023	1	Normal incidence at a plane dielectric boundary, Problems	1,2,3,4,5 1,2,3,4,5	Principles of Electromagnetics - NO Sadiku
	7	02.02.2023	1	old question paper discussions	1 1	Principles of Electromagnetics - NO Sadiku
	8	03.02.2023	1	Revision of Unit I & II	2 2	Principles of Electromagnetics - NO Sadiku
	9	06.02.2023	2	Revision of Unit III & IV	3 3	Principles of Electromagnetics - NO Sadiku

Signature of HOD | Signature of faculty

Date: | Date:

Note:
1. ENSURE THAT ALL TOPICS SPECIFIED IN THE COURSE ARE MENTIONED.
2. ADDITIONAL TOPICS COVERED, IF ANY, MAY ALSO BE SPECIFIED IN BOLD
3. MENTION THE CORRESPONDING COURSE OBJECTIVE AND OUT COME NUMBERS AGAINST EACH TOPIC.

Gokaraju Rangaraju Institute of Engineering and Technology
(Autonomous)

Department of Electrical & Electronics Engineering

SCHEDULE OF INSTRUCTIONS
UNIT - I PLAN

Academic Year	: 2022-23	Semester	: I
Name of the Program	: II B.Tech - EEE		
Course	: Electromagnetic Fields	Course Code	: GR20A2026
Name of the Faculty	: Dr. Suresh Kumar Tummala, Professor	Department	: EEE

Lesson No.	Date	No. of Periods	Topics / Sub-Topics	Objectives & Outcomes Nos.	References (Textbook, Journal)
1	10.10.2022	2	Introduction to Electromagnetic Fields	1 1	Principles of Electromagnetics - NO Sadiku
2	12.10.2022	1	Coulomb's law	1 1	Principles of Electromagnetics - NO Sadiku
3	13.10.2022 & 14.10.2022	2	Electric Field Intensity- Electrical Field due to Point charge	1 1	Principles of Electromagnetics - NO Sadiku
4	17.10.2022	2	Electrical Field due to Line, Surface Charge distributions	1 1	Principles of Electromagnetics - NO Sadiku
5	19.10.2022 & 20.10.2022	2	Electrical Field due to volume charge distributions	1 1	Principles of Electromagnetics - NO Sadiku
6	21.10.2022	1	Gauss Law and its Applications. Absolute Electric potential	1 1	Principles of Electromagnetics - NO Sadiku
7	26.10.2022	1	Potential difference- Calculation of potential differences for different configurations	1 1	Principles of Electromagnetics - NO Sadiku
8	27.10.2022 & 28.10.2022	2	Electric Dipole- Electrostatic Energy density	1 1	Principles of Electromagnetics - NO Sadiku

Signature of HOD — Signature of faculty

Date: — Date:

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Department of Electrical & Electronics Engineering

SCHEDULE OF INSTRUCTIONS

UNIT - II PLAN

Academic Year	: 2022-23	Semester	: I
Name of the Program	: II B.Tech - EEE		
Course	: Electromagnetic Fields	Course Code	: GR20A2026
Name of the Faculty	: Dr. Suresh Kumar Tummala, Professor	Department	: EEE

Lesson No.	Date	No. of Periods	Topics / Sub-Topics	Objectives & Outcomes Nos.	References (Textbook, Journal)
1	31.10.2022	2	Dielectrics and Capacitance Current and current density	2 2	Principles of Electromagnetics - NO Sadiku
2	02.11.2022 & 03.11.2022	2	Ohms Law in Point form-Continuity of current	2 2	Principles of Electromagnetics - NO Sadiku
3	04.11.2022	1	Fully controlled converter with R & RL load midpoint type, Bridge type	2 2	Principles of Electromagnetics - NO Sadiku
4	07.11.2022 & 09.11.2022	3	Boundary conditions of perfect dielectric materials. Permittivity of dielectric materials	2 2	Principles of Electromagnetics - NO Sadiku
5	10.11.2022 & 11.11.2022	2	Capacitance-Capacitance of a two-wire equation	2 2	Principles of Electromagnetics - NO Sadiku
6	14.11.2022	2	Poison's & Laplace Equation - Solution, Applications	2 2	Principles of Electromagnetics - NO Sadiku
7	16.11.2022 & 17.11.2022	2	Problems	2 2	Principles of Electromagnetics - NO Sadiku
8	18.11.2022	1	Problems	2 2	Principles of Electromagnetics - NO Sadiku
9	21.11.2022	2	Revision	2 2	Principles of Electromagnetics - NO Sadiku

Signature of HOD   Signature of faculty

Date: Date:

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Department of Electrical & Electronics Engineering

SCHEDULE OF INSTRUCTIONS

UNIT - III PLAN

Academic Year	: 2022-23	Semester	: I
Name of the Program	: II B.Tech - EEE		
Course	: Electromagnetic Fields	Course Code	: GR20A2026
Name of the Faculty	: Dr. Suresh Kumar Tummala, Professor	Department	: EEE

Lesson No.	Date	No. of Periods	Topics / Sub-Topics	Objectives & Outcomes Nos.	References (Textbook, Journal)
1	23.11.2022 & 24.11.2022	2	Static Magnetic fields, Biot-Savart Law	3 3	Principles of Electromagnetics - NO Sadiku
2	25.11.2022	1	Ampere Law-Magnetic flux and Magnetic Flux Density-Scalar and Vector Magnetic Potentials	3 3	Principles of Electromagnetics - NO Sadiku
3	28.11.2022	2	Steady Magnetic Fields produced by current carrying conductors, Magnetic Forces	3 3	Principles of Electromagnetics - NO Sadiku
4	30.11.2022 & 01.12.2022	2	Materials and Inductance Force on a moving charge, Force on a differential current element	3 3	Principles of Electromagnetics - NO Sadiku
5	02.12.2022	1	Force between differential current elements, Nature of magnetic materials	3 3	Principles of Electromagnetics - NO Sadiku
6	05.12.2022	2	Magnetization and Permeability, Magnetic boundary conditions	3 3	Principles of Electromagnetics - NO Sadiku
7	12.12.2022	2	Magnetic Circuits, inductances and mutual inductances	3 3	Principles of Electromagnetics - NO Sadiku
8	14.12.2022 & 15.12.2022	2	Problems	3 3	Principles of Electromagnetics - NO Sadiku
9	16.12.2022	1	Problems	3 3	Principles of Electromagnetics - NO Sadiku

Signature of HOD | Signature of faculty

Date: | Date:

Note: 1. ENSURE THAT ALL TOPICS SPECIFIED IN THE COURSE ARE MENTIONED.
2. ADDITIONAL TOPICS COVERED, IF ANY, MAY ALSO BE SPECIFIED IN BOLD
3. MENTION THE CORRESPONDING COURSE OBJECTIVE AND OUT COME NUMBERS AGAINST EACH TOPIC.

SCHEDULE OF INSTRUCTIONS

UNIT - IV PLAN

Academic Year	: 2022-23	Semester	: I
Name of the Program	: II B.Tech - EEE		
Course	: Electromagnetic Fields	Course Code	: GR20A2026
Name of the Faculty	: Dr. Suresh Kumar Tummala, Professor	Department	: EEE

Lesson No.	Date	No. of Periods	Topics / Sub-Topics	Objectives & Outcomes Nos.	References (Textbook, Journal)
1	19.12.2022	2	Time varying fields and Maxwell's Equation	4 4	Principles of Electromagnetics - NO Sadiku
2	21.12.2022 & 22.12.2022	2	Faraday's law of electromagnetic induction, Displacement current	4 4	Principles of Electromagnetics - NO Sadiku
3	26.12.2022	2	Point form of Maxwell's Equation	4 4	Principles of Electromagnetics - NO Sadiku
4	28.12.2022 & 29.12.2022	2	Integral form of Maxwell's equation	4 4	Principles of Electromagnetics - NO Sadiku
5	02.01.2023	2	Motional Electromotive forces, Boundary Conditions	4 4	Principles of Electromagnetics - NO Sadiku
6	04.01.2023 & 05.01.2023	2	Applications of Maxwell's Equation	4 4	Principles of Electromagnetics - NO Sadiku
7	06.01.2022	1	Problems	4 4	Principles of Electromagnetics - NO Sadiku
8	09.01.2022	2	Maxwell's Equation due to Gauss law, Ampere circuital law	4 4	Principles of Electromagnetics - NO Sadiku
9	11.01.2022 & 12.01.2022	2	revision	4 4	Principles of Electromagnetics - NO Sadiku
10	18.01.2022	1	old question paper discussions	4 4	Principles of Electromagnetics - NO Sadiku

Signature of HOD　　　　　　　　　　　　　　　　　　　　Signature of faculty

Date:　　　　　　　　　　　　　　　　　　　　　　　　　　Date:

Note: 1. ENSURE THAT ALL TOPICS SPECIFIED IN THE COURSE ARE MENTIONED.
2. ADDITIONAL TOPICS COVERED, IF ANY, MAY ALSO BE SPECIFIED IN BOLD
3. MENTION THE CORRESPONDING COURSE OBJECTIVE AND OUT COME NUMBERS AGAINST EACH TOPIC.

Gokaraju Rangaraju Institute of Engineering and Technology
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Department of Electrical & Electronics Engineering

SCHEDULE OF INSTRUCTIONS

UNIT -V PLAN

Academic Year	: 2022-23	Semester	: I
Name of the Program	: II B.Tech - EEE		
Course	: Electromagnetic Fields	Course Code	: GR20A2026
Name of the Faculty	: Dr. Suresh Kumar Tummala, Professor	Department	: EEE

Lesson No.	Date	No. of Periods	Topics / Sub-Topics	Objectives & Outcomes Nos.	References (Textbook, Journal)
1	19.01.2022 & 20.01.2022	2	Wave equation & solutions, Time-harmonic fields	5 5	Principles of Electromagnetics - NO Sadiku
2	23.01.2022	2	Plane waves in lossless media, Plane waves in lossy media	5 5	Principles of Electromagnetics - NO Sadiku
3	25.01.2022	1	low-less dielectrics and good conductors	5 5	Principles of Electromagnetics - NO Sadiku
4	27.01.2022	1	Group Velocity, Electromagnetic power flow and poynting vector	5 5	Principles of Electromagnetics - NO Sadiku
5	30.01.2022	2	Normal incidence at a plane conducting boundary	5 5	Principles of Electromagnetics - NO Sadiku
6	01.02.2023	1	Normal incidence at a plane dielectric boundary, Problems	1,2,3,4,5 1,2,3,4,5	Principles of Electromagnetics - NO Sadiku
7	02.02.2023	1	old question paper discussions	1 1	Principles of Electromagnetics - NO Sadiku
8	03.02.2023	1	Revision of Unit I & II	2 2	Principles of Electromagnetics - NO Sadiku
9	06.02.2023	2	Revision of Unit III & IV	3 3	Principles of Electromagnetics - NO Sadiku

Signature of HOD | Signature of faculty

Date: | Date:

Note: 1. ENSURE THAT ALL TOPICS SPECIFIED IN THE COURSE ARE MENTIONED.
2. ADDITIONAL TOPICS COVERED, IF ANY, MAY ALSO BE SPECIFIED IN BOLD
3. MENTION THE CORRESPONDING COURSE OBJECTIVE AND OUT COME NUMBERS AGAINST EACH TOPIC.

LESSON PLAN (U-I)

Academic Year	: 2022-23	Semester	: I
Name of the Program	: II B.Tech - EEE		
Course	: Electromagnetic Fields	Course Code	: GR20A2026
Name of the Faculty	: Dr. Suresh Kumar Tummala, Professor	Department	: EEE

Lesson No: 01, 02 Duration of Lesson: 1hr30 MIN

Lesson Title: Introduction to Electromagnetic Fields, Coulomb's law

INSTRUCTIONAL/LESSON OBJECTIVES:

To make students understand Coulomb's Law, Electric Field Intensity
To familiarize students on EFI due to point, line, surface and volume charge distributions
To understand students the concept of Gauss Law, Absolute Electric potential and PD.
To provide information on Electric Dipole- Electrostatic Energy density.

TEACHING AIDS : PPTs, Digital Board
TEACHING POINTS :

5 mins for taking attendance 70 min for the class 15 min for doubts

Assignment / Questions:

Refer assignment – I & tutorial-I sheets

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.1,2,3,4 & 1,3..

LESSON PLAN (U-I)

Academic Year	: 2022-23	Semester	: I
Name of the Program	: II B.Tech - EEE		
Course	: Electromagnetic Fields	Course Code	: GR20A2026
Name of the Faculty	: Dr. Suresh Kumar Tummala, Professor	Department	: EEE

Lesson No: 03, 04 Duration of Lesson: 1hr30 MIN

Lesson Title: Electric Field Intensity-Electrical Field due to Point charge, Line, Surface Charge distributions

INSTRUCTIONAL/LESSON OBJECTIVES:
To make students understand Coulomb's Law, Electric Field Intensity
To familiarize students on EFI due to point, line, surface and volume charge distributions
To understand students the concept of Gauss Law, Absolute Electric potential and PD.
To provide information on Electric Dipole- Electrostatic Energy density.

TEACHING AIDS : PPTs, Digital Board
TEACHING POINTS :

5 mins for taking attendance
15 for revision of previous class
55 min for the class
15 min for doubts

Assignment / Questions: .
Refer assignment – I & tutorial-I sheets

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos..1,2,3,4 & 1,3.

Gokaraju Rangaraju Institute of Engineering and Technology
(Autonomous)

Department of Electrical & Electronics Engineering

LESSON PLAN (U-I)

Academic Year	: 2022-23	Semester	: I
Name of the Program	: II B.Tech - EEE		
Course	: Electromagnetic Fields	Course Code	: GR20A2026
Name of the Faculty	: Dr. Suresh Kumar Tummala, Professor	Department	: EEE

Lesson No: 05, 06 Duration of Lesson: 1hr30 MIN

Lesson Title: Design - Electrical Field due to volume charge distributions, Gauss Law and its Applications. Absolute Electric potential

INSTRUCTIONAL/LESSON OBJECTIVES:
To make students understand Coulomb’s Law, Electric Field Intensity
To familiarize students on EFI due to point, line, surface and volume charge distributions
To understand students the concept of Gauss Law, Absolute Electric potential and PD.
To provide information on Electric Dipole- Electrostatic Energy density.

TEACHING AIDS : PPTs, Digital Board
TEACHING POINTS :

5 mins for taking attendance
15 for revision of previous class
55 min for the class
15 min for doubts

Assignment / Questions: .

Refer assignment – I & tutorial-I sheets

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos..1,2,3,4 & 1,3.

Gokaraju Rangaraju Institute of Engineering and Technology
(Autonomous)

Department of Electrical & Electronics Engineering

LESSON PLAN (U-I)

Academic Year	: 2022-23	Semester	: I
Name of the Program	: II B.Tech - EEE		
Course	: Electromagnetic Fields	Course Code	: GR20A2026
Name of the Faculty	: Dr. Suresh Kumar Tummala, Professor	Department	: EEE

Lesson No: 07, 08 Duration of Lesson: 1hr30 MIN

Lesson Title: Potential difference, Electric Dipole- Electrostatic Energy density

INSTRUCTIONAL/LESSON OBJECTIVES:
To make students understand Coulomb's Law, Electric Field Intensity
To familiarize students on EFI due to point, line, surface and volume charge distributions
To understand students the concept of Gauss Law, Absolute Electric potential and PD.
To provide information on Electric Dipole- Electrostatic Energy density.

TEACHING AIDS : PPTs, Digital Board
TEACHING POINTS :

5 mins for taking attendance
15 for revision of previous class
55 min for the class
15 min for doubts

Assignment / Questions:
Refer assignment – I & tutorial-I sheets

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos..1,2,3,4 & 1,3.

Gokaraju Rangaraju Institute of Engineering and Technology
(Autonomous)

Department of Electrical & Electronics Engineering

LESSON PLAN (U-II)

Academic Year	: 2022-23	Semester	: I
Name of the Program	: II B.Tech - EEE		
Course	: Electromagnetic Fields	Course Code	: GR20A2026
Name of the Faculty	: Dr. Suresh Kumar Tummala, Professor	Department	: EEE

Lesson No: 01, 02 Duration of Lesson: 1hr30 MIN

Lesson Title: Dielectrics and Capacitance Current and current density, Ohms Law in Point form

INSTRUCTIONAL/LESSON OBJECTIVES:
To make students understand the concept of Dielectrics and Capacitance Current.
To familiarize students on Boundary Conditions, Ohms Law, Continuity Equation
To understand students the Poison's & Laplace Equation's and capacitance in wire.
To provide information on solution for Poison's & Laplace Equation's

TEACHING AIDS :PPTs
TEACHING POINTS :

5 mins for taking attendance
70 min for the class
15 min for doubts

Assignment / Questions: .
Refer assignment-II & tutorial-II sheets

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos..1,2,3,4 & 1,3.

LESSON PLAN (U-II)

Academic Year	: 2022-23	Semester	: I
Name of the Program	: II B.Tech - EEE		
Course	: Electromagnetic Fields	Course Code	: GR20A2026
Name of the Faculty	: Dr. Suresh Kumar Tummala, Professor	Department	: EEE

Lesson No: 03, 04 Duration of Lesson: 1hr30 MIN

Lesson Title: Fully controlled converter, Boundary conditions

INSTRUCTIONAL/LESSON OBJECTIVES:
To make students understand the concept of Dielectrics and Capacitance Current.
To familiarize students on Boundary Conditions, Ohms Law, Continuity Equation
To understand students the Poison's & Laplace Equation's and capacitance in wire.
To provide information on solution for Poison's & Laplace Equation's.

TEACHING AIDS :PPTs
TEACHING POINTS :

5 mins for taking attendance
15 for revision of previous class
55 min for the class
15 min for doubts

Assignment / Questions: .
Refer assignment-II & tutorial-II sheets

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos..1,2,3,4 & 1,3.

LESSON PLAN (U-II)

Academic Year	: 2022-23	Semester	: I
Name of the Program	: II B.Tech - EEE		
Course	: Electromagnetic Fields	Course Code	: GR20A2026
Name of the Faculty	: Dr. Suresh Kumar Tummala, Professor	Department	: EEE

Lesson No: 05, 06 Duration of Lesson: 1hr30 MIN

Lesson Title: Capacitance, Poison's & Laplace Equation

INSTRUCTIONAL/LESSON OBJECTIVES:
To make students understand the concept of Dielectrics and Capacitance Current.
To familiarize students on Boundary Conditions, Ohms Law, Continuity Equation
To understand students the Poison's & Laplace Equation's and capacitance in wire.
To provide information on solution for Poison's & Laplace Equation's.

TEACHING AIDS :PPTs
TEACHING POINTS :

5 mins for taking attendance 15 for revision of previous class 55 min for the class 15 min for doubts

Assignment / Questions:

Refer assignment-II & tutorial-II sheets.

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.1,2,3,4 & 1,3..

LESSON PLAN (U-II)

Academic Year	: 2022-23	Semester	: I
Name of the Program	: II B.Tech - EEE		
Course	: Electromagnetic Fields	Course Code	: GR20A2026
Name of the Faculty	: Dr. Suresh Kumar Tummala, Professor	Department	: EEE

Lesson No: 07, 08, 09 Duration of Lesson: 2hr20 MIN

Lesson Title: Problems, Revision

INSTRUCTIONAL/LESSON OBJECTIVES:

To make students understand the concept of Dielectrics and Capacitance Current.
To familiarize students on Boundary Conditions, Ohms Law, Continuity Equation
To understand students the Poison's & Laplace Equation's and capacitance in wire.
To provide information on solution for Poison's & Laplace Equation's.

TEACHING AIDS :PPTs
TEACHING POINTS :

5 mins for taking attendance
15 for revision of previous class
105 min for the class
15 min for doubts

Assignment / Questions:

Refer assignment-II & tutorial-II sheets

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.1,2,3,4 & 1,3..

LESSON PLAN (U-III)

Academic Year	: 2022-23	Semester	: I
Name of the Program	: II B.Tech - EEE		
Course	: Electromagnetic Fields	Course Code	: GR20A2026
Name of the Faculty	: Dr. Suresh Kumar Tummala, Professor	Department	: EEE

Lesson No: 01, 02 Duration of Lesson: 1hr30 MIN

Lesson Title: Static Magnetic Field, Biot Savart , Ampere Law

INSTRUCTIONAL/LESSON OBJECTIVES:

To make students understand the concept of Static Magnetic Field, Biot Savart , Ampere Law.
To familiarize students with Magnetic Flux Density, Magnetic Forces.
To understand the concept of Forces on moving charges, differential current elements.
To provide information on Magnetization, Magnetic Currents, Inductances.

TEACHING AIDS :PPTs
TEACHING POINTS :

5 mins for taking attendance
70 min for the class
15 min for doubts

Assignment / Questions:

Refer assignment-III & tutorial-III sheets

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.1,2,3,4 & 1,3..

LESSON PLAN (U-III)

Academic Year	: 2022-23	Semester	: I
Name of the Program	: II B.Tech - EEE		
Course	: Electromagnetic Fields	Course Code	: GR20A2026
Name of the Faculty	: Dr. Suresh Kumar Tummala, Professor	Department	: EEE

Lesson No: 03, 04 Duration of Lesson: 1hr30 MIN

Lesson Title: Magnetic Flux Density, Magnetic Forces

INSTRUCTIONAL/LESSON OBJECTIVES:

To make students understand the concept of Static Magnetic Field, Biot Savart, Ampere Law.
To familiarize students with Magnetic Flux Density, Magnetic Forces.
To understand the concept of Forces on moving charges, differential current elements.
To provide information on Magnetization, Magnetic Currents, Inductances.

TEACHING AIDS :PPTs
TEACHING POINTS :

5 mins for taking attendance
15 for revision of previous class
55 min for the class
15 min for doubts

Assignment / Questions:

Refer assignment-III & tutorial-III sheets

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.1,2,3,4 & 1,3..

LESSON PLAN (U-III)

Academic Year	: 2022-23	Semester	: I
Name of the Program	: II B.Tech - EEE		
Course	: Electromagnetic Fields	Course Code	: GR20A2026
Name of the Faculty	: Dr. Suresh Kumar Tummala, Professor	Department	: EEE

Lesson No: 05, 06 Duration of Lesson: 1hr30 MIN

Lesson Title: Forces on moving charges, differential current elements

INSTRUCTIONAL/LESSON OBJECTIVES:

To make students understand the concept of Static Magnetic Field, Biot Savart, Ampere Law.
To familiarize students with Magnetic Flux Density, Magnetic Forces.
To understand the concept of Forces on moving charges, differential current elements.
To provide information on Magnetization, Magnetic Currents, Inductances.

TEACHING AIDS :PPTs
TEACHING POINTS :

5 mins for taking attendance 15 for revision of previous class 55 min for the class 15 min for doubts

Assignment / Questions:

Refer assignment-III & tutorial-III sheets

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.1,2,3,4 & 1,3..

LESSON PLAN (U-III)

Academic Year	: 2022-23	Semester	: I
Name of the Program	: II B.Tech - EEE		
Course	: Electromagnetic Fields	Course Code	: GR20A2026
Name of the Faculty	: Dr. Suresh Kumar Tummala, Professor	Department	: EEE

Lesson No: 07, 08, 09 Duration of Lesson: 2hr20 MIN

Lesson Title: Magnetization, Magnetic Currents, Inductances, Problems

INSTRUCTIONAL/LESSON OBJECTIVES:

To make students understand the concept of Static Magnetic Field, Biot Savart, Ampere Law.
To familiarize students with Magnetic Flux Density, Magnetic Forces.
To understand the concept of Forces on moving charges, differential current elements.
To provide information on Magnetization, Magnetic Currents, Inductances.

TEACHING AIDS :PPTs
TEACHING POINTS :

5 mins for taking attendance
15 for revision of previous class
105 min for the class
15 min for doubts

Assignment / Questions:

Refer assignment-III & tutorial-III sheets

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.1,2,3,4 & 1,3..

LESSON PLAN (U-IV)

Academic Year	: 2022-23	Semester	: I
Name of the Program	: II B.Tech - EEE		
Course	: Electromagnetic Fields	Course Code	: GR20A2026
Name of the Faculty	: Dr. Suresh Kumar Tummala, Professor	Department	: EEE

Lesson No: 01, 02 Duration of Lesson: 1hr30 MIN

Lesson Title: Time varying fields and Maxwell's Equation

INSTRUCTIONAL/LESSON OBJECTIVES:

To make students understand the concept of Time varying fields and Maxwell's Equation.
To familiarize students on Faraday's law of electromagnetic induction, Displacement current.
To understand the concept of Point form of Maxwell's, Motional Electromotive forces, Boundary Conditions.
To provide information on Maxwell's Equation due to Gauss law, Ampere circuital law.

TEACHING AIDS :PPTs
TEACHING POINTS :

5 mins for taking attendance 70 min for the class 15 min for doubts

Assignment / Questions:

Refer assignment-IV & tutorial-IV sheets.

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.1,2,3,4 & 1,3..

LESSON PLAN (U-IV)

Academic Year	: 2022-23	Semester	: I
Name of the Program	: II B.Tech - EEE		
Course	: Electromagnetic Fields	Course Code	: GR20A2026
Name of the Faculty	: Dr. Suresh Kumar Tummala, Professor	Department	: EEE

Lesson No: 03, 04 Duration of Lesson: 1hr30 MIN

Lesson Title: Faraday's law of electromagnetic induction, Displacement current

INSTRUCTIONAL/LESSON OBJECTIVES:

To make students understand the concept of Time varying fields and Maxwell's Equation.
To familiarize students on Faraday's law of electromagnetic induction, Displacement current.
To understand the concept of Point form of Maxwell's, Motional Electromotive forces, Boundary Conditions.
To provide information on Maxwell's Equation due to Gauss law, Ampere circuital law.

TEACHING AIDS :PPTs
TEACHING POINTS :

5 mins for taking attendance 15 for revision of previous class 55 min for the class 15 min for doubts

Assignment / Questions:

Refer assignment-IV & tutorial-IV sheets.

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.1,2,3,4 & 1,3..

LESSON PLAN (U-IV)

Academic Year	: 2022-23	Semester	: I
Name of the Program	: II B.Tech - EEE		
Course	: Electromagnetic Fields	Course Code	: GR20A2026
Name of the Faculty	: Dr. Suresh Kumar Tummala, Professor	Department	: EEE

Lesson No: 05, 06 Duration of Lesson: 1hr30 MIN

Lesson Title: Point form of Maxwell's, Motional Electromotive forces, Boundary Conditions

INSTRUCTIONAL/LESSON OBJECTIVES:

To make students understand the concept of Time varying fields and Maxwell's Equation.
To familiarize students on Faraday's law of electromagnetic induction, Displacement current.
To understand the concept of Point form of Maxwell's, Motional Electromotive forces, Boundary Conditions.
To provide information on Maxwell's Equation due to Gauss law, Ampere circuital law.

TEACHING AIDS :PPTs
TEACHING POINTS :

5 mins for taking attendance
15 for revision of previous class
55 min for the class
15 min for doubts

Assignment / Questions:

Refer assignment-IV & tutorial-IV sheets

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.1,2,3,4 & 1,3..

LESSON PLAN (U-IV)

Academic Year	: 2022-23	Semester	: I
Name of the Program	: II B.Tech - EEE		
Course	: Electromagnetic Fields	Course Code	: GR20A2026
Name of the Faculty	: Dr. Suresh Kumar Tummala, Professor	Department	: EEE

Lesson No: 07, 08 Duration of Lesson: 1hr30 MIN

Lesson Title: Maxwell's Equation due to Gauss law, Ampere circuital law

INSTRUCTIONAL/LESSON OBJECTIVES:

To make students understand the concept of Time varying fields and Maxwell's Equation.
To familiarize students on Faraday's law of electromagnetic induction, Displacement current.
To understand the concept of Point form of Maxwell's, Motional Electromotive forces, Boundary Conditions.
To provide information on Maxwell's Equation due to Gauss law, Ampere circuital law.

TEACHING AIDS :PPTs
TEACHING POINTS :

5 mins for taking attendance
15 for revision of previous class
55 min for the class
15 min for doubts

Assignment / Questions:

Refer assignment-IV & tutorial-IV sheets.

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.1,2,3,4 & 1,3..

LESSON PLAN (U-IV)

Academic Year	: 2022-23	Semester	: I
Name of the Program	: II B.Tech - EEE		
Course	: Electromagnetic Fields	Course Code	: GR20A2026
Name of the Faculty	: Dr. Suresh Kumar Tummala, Professor	Department	: EEE

Lesson No: 09, 10 Duration of Lesson: 1hr30 MIN

Lesson Title: Revision & Problems

INSTRUCTIONAL/LESSON OBJECTIVES:

To make students understand the concept of Time varying fields and Maxwell's Equation.
To familiarize students on Faraday's law of electromagnetic induction, Displacement current.
To understand the concept of Point form of Maxwell's, Motional Electromotive forces, Boundary Conditions.
To provide information on Maxwell's Equation due to Gauss law, Ampere circuital law.

TEACHING AIDS :PPTs
TEACHING POINTS :

5 mins for taking attendance 15 for revision of previous class 55 min for the class 15 min for doubts

Assignment / Questions:

Refer assignment-IV & tutorial-IV sheets.

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.1,2,3,4 & 1,3..

LESSON PLAN (U-V)

Academic Year	: 2022-23	Semester	: I
Name of the Program	: II B.Tech - EEE		
Course	: Electromagnetic Fields	Course Code	: GR20A2026
Name of the Faculty	: Dr. Suresh Kumar Tummala, Professor	Department	: EEE

Lesson No: 01, 02 Duration of Lesson: 1hr30 MIN

Lesson Title: Wave equation & solutions, Time-harmonic fields

INSTRUCTIONAL/LESSON OBJECTIVES:

To make students understand the concept of Wave equation & solutions, Time-harmonic fields.
To familiarize students on low-less dielectrics and good conductors.
To understand the concept of Group Velocity, Electromagnetic power flow and poynting vector.
To provide information on Normal incidence at a plane dielectric and conducting boundary.

TEACHING AIDS :PPTs
TEACHING POINTS :

5 mins for taking attendance 70 min for the class 15 min for doubts

Assignment / Questions:

Refer assignment-V & tutorial-V sheets

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.1,2,3,4 & 1,3..

LESSON PLAN (U-V)

Academic Year	: 2022-23	Semester	: I
Name of the Program	: II B.Tech - EEE		
Course	: Electromagnetic Fields	Course Code	: GR20A2026
Name of the Faculty	: Dr. Suresh Kumar Tummala, Professor	Department	: EEE

<u>Lesson No: 03, 04</u> Duration of Lesson: <u>1hr30 MIN</u>

<u>Lesson Title:</u> low-less dielectrics and good conductors

<u>INSTRUCTIONAL/LESSON OBJECTIVES:</u>

To make students understand the concept of Wave equation & solutions, Time-harmonic fields.
To familiarize students on low-less dielectrics and good conductors.
To understand the concept of Group Velocity, Electromagnetic power flow and poynting vector.
To provide information on Normal incidence at a plane dielectric and conducting boundary.

TEACHING AIDS :PPTs
TEACHING POINTS :

5 mins for taking attendance
15 for revision of previous class
55 min for the class
15 min for doubts

Assignment / Questions:

Refer assignment-V & tutorial-V sheets

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.1,2,3,4 & 1,3..

LESSON PLAN (U-V)

Academic Year	: 2022-23	Semester	: I
Name of the Program	: II B.Tech - EEE		
Course	: Electromagnetic Fields	Course Code	: GR20A2026
Name of the Faculty	: Dr. Suresh Kumar Tummala, Professor	Department	: EEE

Lesson No: 05, 06 Duration of Lesson: 1hr30 MIN

Lesson Title: Group Velocity, Electromagnetic power flow and poynting vector

INSTRUCTIONAL/LESSON OBJECTIVES:

To make students understand the concept of Wave equation & solutions, Time-harmonic fields.
To familiarize students on low-less dielectrics and good conductors.
To understand the concept of Group Velocity, Electromagnetic power flow and poynting vector.
To provide information on Normal incidence at a plane dielectric and conducting boundary.

TEACHING AIDS :PPTs
TEACHING POINTS :

5 mins for taking attendance
15 for revision of previous class
55 min for the class
15 min for doubts

Assignment / Questions:

Refer assignment-V & tutorial-V sheets.

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.1,2,3,4 & 1,3..

LESSON PLAN (U-V)

Academic Year	: 2022-23	Semester	: I
Name of the Program	: II B.Tech - EEE		
Course	: Electromagnetic Fields	Course Code	: GR20A2026
Name of the Faculty	: Dr. Suresh Kumar Tummala, Professor	Department	: EEE

Lesson No: 07, 08 Duration of Lesson: 1hr30 MIN

Lesson Title: Normal incidence at a plane dielectric and conducting boundary

INSTRUCTIONAL/LESSON OBJECTIVES:

To make students understand the concept of Wave equation & solutions, Time-harmonic fields.
To familiarize students on low-less dielectrics and good conductors.
To understand the concept of Group Velocity, Electromagnetic power flow and poynting vector.
To provide information on Normal incidence at a plane dielectric and conducting boundary.

TEACHING AIDS :PPTs
TEACHING POINTS :

5 mins for taking attendance 15 for revision of previous class 55 min for the class 15 min for doubts

Assignment / Questions:

Refer assignment-V & tutorial-V sheets.

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.1,2,3,4 & 1,3..

LESSON PLAN (U-V)

Academic Year	: 2022-23	Semester	: I
Name of the Program	: II B.Tech - EEE		
Course	: Electromagnetic Fields	Course Code	: GR20A2026
Name of the Faculty	: Dr. Suresh Kumar Tummala, Professor	Department	: EEE

Lesson No: 09 Duration of Lesson: 1hr30 MIN

Lesson Title: Problems & Revision

INSTRUCTIONAL/LESSON OBJECTIVES:

To make students understand the concept of Wave equation & solutions, Time-harmonic fields.
To familiarize students on low-less dielectrics and good conductors.
To understand the concept of Group Velocity, Electromagnetic power flow and poynting vector.
To provide information on Normal incidence at a plane dielectric and conducting boundary.

TEACHING AIDS :PPTs
TEACHING POINTS :

5 mins for taking attendance
15 for revision of previous class
55 min for the class
15 min for doubts

Assignment / Questions:

Refer assignment-V & tutorial-V sheets

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.1,2,3,4 & 1,3..

Gokaraju Rangaraju Institute of Engineering and Technology
(Autonomous)

Department of Electrical & Electronics Engineering

ASSIGNMENT SHEET – 1

Academic Year	: 2022-23	Semester	: I
Name of the Program	: II B.Tech - EEE		
Course	: Electromagnetic Fields	Course Code	: GR20A2026
Name of the Faculty	: Dr. Suresh Kumar Tummala, Professor	Department	: EEE

This Assignment corresponds to Unit No. 1

Q1. What is Coulomb's law. Derive necessary expressions required
Q2. Derive the expression for E due to surface charge density
Q3. Discuss the boundary condition of surface charge density laying on two different dielectric materials

Please write the Questions / Problems / Exercises which you would like to give to the students and mention the Objectives/Outcomes to which these Questions / Problems / Exercises are related.

Objective Nos.: 1

Outcome Nos.: 1

Signature of HOD

Date:

Signature of faculty

Date:

ASSIGNMENT SHEET – 2

Academic Year	: 2022-23	Semester	: I
Name of the Program	: II B.Tech - EEE		
Course	: Electromagnetic Fields	Course Code	: GR20A2026
Name of the Faculty	: Dr. Suresh Kumar Tummala, Professor	Department	: EEE

This Assignment corresponds to Unit No. 2

Q1. Discuss the solution of Laplace equation.

Q2. Find E at P (1,1,1) caused by four identical 3nC charges located at P1 (1,1,0), P2 (-1,1,0), P3 (-1,-1,0) & P4 (1,-1,0).

Q3. State Biot-Savart Law. Derive integral form of Biot-Savart Law for a differential element of a long current carrying conductor

Please write the Questions / Problems / Exercises which you would like to give to the students and also mention the Objectives/Outcomes to which these Questions / Problems / Exercises are related.

Objective Nos.: 2

Outcome Nos.: 2

Signature of HOD

Date:

Signature of faculty

Date:

ASSIGNMENT SHEET – 3

Academic Year	: 2022-23	Semester	: I
Name of the Program	: II B.Tech - EEE		
Course	: Electromagnetic Fields	Course Code	: GR20A2026
Name of the Faculty	: Dr. Suresh Kumar Tummala, Professor	Department	: EEE

This Assignment corresponds to Unit No. 3

Q1. What is the force exerted on a differential current element in a given magnetic field

Q2. Derive maxwell's equations from faraday's in a time varying magnetic field both in point and integral form

Please write the Questions / Problems / Exercises which you would like to give to the students and also mention the Objectives/Outcomes to which these Questions / Problems / Exercises are related.

Objective Nos.: 3

Outcome Nos.: 3

Signature of HOD | Signature of faculty

Date: | Date:

Gokaraju Rangaraju Institute of Engineering and Technology
(Autonomous)

Department of Electrical & Electronics Engineering

ASSIGNMENT SHEET – 4

Academic Year	: 2022-23	Semester	: I
Name of the Program	: II B.Tech - EEE		
Course	: Electromagnetic Fields	Course Code	: GR20A2026
Name of the Faculty	: Dr. Suresh Kumar Tummala, Professor	Department	: EEE

This Assignment corresponds to Unit No. 4

Q1. Discuss Displacement current and Displacement current density
Q2. Derive maxwell's equations from Gauss law in a static electric field both in point and integral form
Q3. Discuss pointing theorem and pointing vector

Please write the Questions / Problems / Exercises which you would like to give to the students and also mention the Objectives/Outcomes to which these Questions / Problems / Exercises are related.

Objective Nos.: 4

Outcome Nos.: 4

Signature of HOD

Date:

Signature of faculty

Date:

ASSIGNMENT SHEET – 5

Academic Year	: 2022-23	Semester	: I
Name of the Program	: II B.Tech - EEE		
Course	: Electromagnetic Fields	Course Code	: GR20A2026
Name of the Faculty	: Dr. Suresh Kumar Tummala, Professor	Department	: EEE

This tutorial corresponds to Unit No. 5

Q1. Discuss pointing vector

Q2. Discuss Displacement current density

Q3. Explain maxwell equation in point form

Please write the Questions / Problems / Exercises which you would like to give to the students and also mention the Objectives/Outcomes to which these Questions / Problems / Exercises are related.

Objective Nos.: 5

Outcome Nos.: 5

Signature of HOD — Signature of faculty

Date: — Date:

Gokaraju Rangaraju Institute of Engineering and Technology
(Autonomous)

Department of Electrical & Electronics Engineering

TUTORIAL SHEET – 1

Academic Year	: 2022-23	Semester	: I
Name of the Program	: II B.Tech - EEE		
Course	: Electromagnetic Fields	Course Code	: GR20A2026
Name of the Faculty	: Dr. Suresh Kumar Tummala, Professor	Department	: EEE

This tutorial corresponds to Unit No. 1

Q1. The region where a particular charge exerts a force on any other charge located in that region is called
a) Electric Filed b) Coulomb Law c) Potential d) Force

Q2. Volume charge density is expressed in
a) C/m^3 b) C/m^2 c) C/m d) $C\text{-}m^2$

Q3. For free space or vacuum, the relative permittivity ε_r =
a) 1 b) 2 c) 3 d) 4

Q4. Define Coulomb's Law.

Please write the Questions / Problems / Exercises which you would like to give to the students and also mention the Objectives/Outcomes to which these Questions / Problems / Exercises are related.

Objective Nos.: 1

Outcome Nos.: 1

Signature of HOD Signature of faculty

Date: Date:

TUTORIAL SHEET – 2

Academic Year	: 2022-23	Semester	: I
Name of the Program	: II B.Tech - EEE		
Course	: Electromagnetic Fields	Course Code	: GR20A2026
Name of the Faculty	: Dr. Suresh Kumar Tummala, Professor	Department	: EEE

This tutorial corresponds to Unit No. 2

Q1. Rate of flow of charge at a specified point is called
a) Electric Current b) Potential c) Gradient d) Intensity

Q2. The current passing through the unit surface area, when the surface is held normal to the direction of the current is
a) Current Density b) Current Intensity c) Flux Density d) Flux Intensity

Q3. Point for of Ohms Law
a) $J = \sigma E$ b) $E = \sigma J$ c) $J = \sigma/E$ d) $E = \sigma/J$

Please write the Questions / Problems / Exercises which you would like to give to the students and also mention the Objectives/Outcomes to which these Questions / Problems / Exercises are related.

Objective Nos.: 2

Outcome Nos.: 2

Signature of HOD Signature of faculty

Date: Date:

TUTORIAL SHEET – 3

Academic Year	: 2022-23	Semester	: I
Name of the Program	: II B.Tech - EEE		
Course	: Electromagnetic Fields	Course Code	: GR20A2026
Name of the Faculty	: Dr. Suresh Kumar Tummala, Professor	Department	: EEE

This tutorial corresponds to Unit No. 3

Q1. A _______________ has an large quantity of charge that is free to move

a) Conductor b) Dipole c) Insulator d) Force

Q2 Inside a conductor
a) $E = 0$, $\rho_V = 0$, $V_{ab} = 0$ b) $E = V$, $\rho_V = 0$, $V_{ab} = 0$
c) $E = V$, $\rho_V = 0$, $V_{ab} = \infty$ d) $E = 0$, $\rho_V = \infty$, $V_{ab} = \infty$

Q3. According to Ampere's Circuit Law, line integral of magnetic field intensity H around a closed path is _________ to the direct current enclosed by that path
a) Equal b) Greater c) Lesser d) Linear

Please write the Questions / Problems / Exercises which you would like to give to the students and also mention the Objectives/Outcomes to which these Questions / Problems / Exercises are related.

Objective Nos.: 3

Outcome Nos.: 3

Signature of HOD Signature of faculty

Date: Date:

TUTORIAL SHEET – 4

Academic Year	: 2022-23	Semester	: I
Name of the Program	: II B.Tech - EEE		
Course	: Electromagnetic Fields	Course Code	: GR20A2026
Name of the Faculty	: Dr. Suresh Kumar Tummala, Professor	Department	: EEE

This tutorial corresponds to Unit No. 4

Q1. The time varying fields are produced due to the ________
a) Time varying currents b) Time varying EMF
c) Time invariable currents d) Time invariable EMF

Q2. According to Lenz's law, the induced e.m.f. acts to produce an ____ flux
a) Opposing b) Same c) Normal d) Tangential

Q3. When an e.m.f. is induced in a stationary closed path due to the time varying B field, the e.m.f. is called or transformer e.m.f.
a) statically induced e.m.f. b) dynamically induced e.m.f. c) motional e.m.f.
d) mutual e.m.f

Please write the Questions / Problems / Exercises which you would like to give to the students and also mention the Objectives/Outcomes to which these Questions / Problems / Exercises are related.

Objective Nos.: 4

Outcome Nos.: 4

Signature of HOD Signature of faculty

Date: Date:

TUTORIAL SHEET – 5

Academic Year	: 2022-23	Semester	: I
Name of the Program	: II B.Tech - EEE		
Course	: Electromagnetic Fields	Course Code	: GR20A2026
Name of the Faculty	: Dr. Suresh Kumar Tummala, Professor	Department	: EEE

This tutorial corresponds to Unit No. 5

Q1. The _________ theorem is based on law of conservation of energy in electromagnetism
a) Poynting b) Lorentz c) Faraday's d) Gauss

Q2. The equations describing relationships between time varying electric and magnetic fields are known as __________ equations.

a) Maxwell's b) Lorentz c) Lenz's d) Faraday's

Q3. Ratio of the total flux linkage to the current flowing through the circuit is called ___________
a) Inductance b) Capacitance c) EMF d) Resistance

Please write the Questions / Problems / Exercises which you would like to give to the students and also mention the Objectives/Outcomes to which these Questions / Problems / Exercises are related.

Objective Nos.: 5

Outcome Nos.: 5

Signature of HOD Signature of faculty

Date: Date:

EVALUATION STRATEGY

Academic Year	: 2022-23	Semester	: I
Name of the Program	: II B.Tech - EEE		
Course	: Electromagnetic Fields	Course Code	: GR20A2026
Name of the Faculty	: Dr. Suresh Kumar Tummala, Professor	Department	: EEE

Target

a. Percentage of Pass : 95%

Method of Evaluation

a. Daily Attendance
b. Assignments
c. Online Quiz & Seminars
d. Internal Examinations
e. Semester / End Examination

List out any new topic(s) or any innovation you would like to introduce in teaching the subjects in this semester

Case Study of any one existing application

Signature of HOD

Date:

Signature of faculty

Date:

COURSE COMPLETION STATUS

Academic Year	: 2022-23	Semester	: I
Name of the Program	: II B.Tech - EEE		
Course	: Electromagnetic Fields	Course Code	: GR20A2026
Name of the Faculty	: Dr. Suresh Kumar Tummala, Professor	Department	: EEE

Actual Date of Completion & Remarks if any

Units	Remarks	No. of Objectives Achieved	No. of Outcomes Achieved
Unit 1	completed on 28.10.2022	1	1
Unit 2	completed on 21.11.2022	2	2
Unit 3	completed on 16.12.2022	3	3
Unit 4	completed on 12.01.2023	4	4
Unit 5	completed on 06.02.2023	5	5

Signature of HOD

Date:

Signature of faculty

Date:

Note: After the completion of each unit mention the number of Objectives & Outcomes Achieved.

Name of the Course: Electromagnetic Fields

Assessment methods:

1. Regular Attendance to Classes.
2. Mid Exam / Main Exam.
3. Written class tests clearly linked to learning objectives / Quiz through Moodle
4. Classroom assessment techniques via. Tutorials and assignments.
5. Seminars.

1. Program Educational Objectives (PEOs) – Vision/Mission Matrix
(Indicate the relationships by mark "X")

Vision / Mission PEOs	Vision of the Institute	Mission of the Institute	Mission of the Program
1	X		X
2	X	X	X
3	X	X	X
4		X	X

2. Program Educational Objectives(PEOs)-Program Outcomes(POs) Relationship Matrix
(Indicate the relationships by mark "X")

P-Outcomes PEOs	a	b	c	d	e	f	g	h	i	j	k	l
1	X	X	X	X	X			X	X	X	X	X
2	X	X	X	X	X			X	X	X	X	X
3		X	X	X		X	X	X	X	X		
4				X					X	X		X

3. Course Objectives-Course Outcomes Relationship Matrix
(Indicate the relationships by mark "X")

Course-Outcomes Course-Objectives	1	2	3	4	5
1	X		X		
2		X		X	
3			X		X
4	X		X		
5	X		X		

4. Course Objectives-Program Outcomes (POs) Relationship Matrix
(Indicate the relationships by mark "X")

P-Outcomes C-Objectives	a	b	c	d	e	f	g	h	i	j	k	l
1	X		X		X	X	X	X	X	X	X	
2	X	X	X		X	X	X	X			X	X
3	X	X	X		X	X	X	X	X		X	X
4	X	X		X	X		X	X		X	X	X
5	X	X		X	X		X	X		X	X	X

5. Course Outcomes-Program Outcomes (POs) Relationship Matrix
(Indicate the relationships by mark "X")

P-Outcomes / C-Outcomes	a	b	c	d	e	f	g	h	i	j	k	l
1	X				X	X	X	X	X		X	X
2	X	X	X	X	X		X	X	X		X	X
3	X	X		X	X		X	X	X	X	X	X
4		X	X				X			X		X
5			X		X		X		X			

6. Courses (with title & code)-Program Outcomes (POs) Relationship Matrix
(Indicate the relationships by mark "X")

P-Outcomes / Courses	a	b	c	d	e	f	g	h	i	j	k	l
EMF (GR20A2026)	X	X	X		X	X	X	X		X	X	X

7. Program Educational Objectives (PEOs)-Course Outcomes Relationship Matrix
(Indicate the relationships by mark "X")

P-Objectives (PEOs) / Course-Outcomes	1	2	3	4
1		X	X	X
2	X	X	X	X
3	X	X	X	X
4		X	X	X
5		X	X	X

8. Assignments & Assessments-Program Outcomes (POs) Relationship Matrix
(Indicate the relationships by mark "X")

P-Outcomes / Assessments	a	b	c	d	e	f	g	h	i	j	k	l
1	X			X	X	X	X	X	X	X		
2	X	X			X		X	X	X	X		
3	X				X	X			X			
4	X			X	X	X		X	X	X		X
5	X	X		X			X		X		X	

9. Assignments & Assessments-Program Educational Objectives (PEOs) Relationship Matrix (Indicate the relationships by mark "X")

P-Objectives (PEOs) / Assessments	1	2	3	4
1		X	X	X
2	X	X	X	X
3	X	X		X
4		X		X
5	X	X	X	X

Rubric

Performance Criteria	Unsatisfactory	Developing	Satisfactory	Exemplary
	1	**2**	**3**	**4**
Research & Gather Information	Does not collect any information that relates to the topic	Collects very little information some relates to the topic	Collects some basic Information most relates to the topic	Collects a great deal of Information all relates to the topic
Fulfill team role's duty	Does not perform any duties of assigned team role.	Performs very little duties.	Performs nearly all duties.	Performs all duties of assigned team role.
Share Equally	Always relies on others to do the work.	Rarely does the assigned work - often needs reminding.	Usually does the assigned work - rarely needs reminding.	Always does the assigned work without having to be reminded
Listen to other team mates	Is always talking—never allows anyone else to speak.	Usually doing most of the talking-- rarely allows others to speak.	Listens, but sometimes talks too much.	Listens and speaks a fair amount.

GOKARAJU RANGARAJU INSTITUTE OF ENGINEERING AND TECHNOLOGY
(Autonomous)
Department of Electrical and Electronics Engineering

Academic Year: **2022-23**	**MID Exam – I (Descriptive)**	Date: 08/12/2022
Year:**II**	**ELECTROMAGNETIC FIELDS**	Duration:**90 min**
Semester:**I**	**Subject Code: GR20A2026**	Max Marks: **15**

Note: Answer any ALL questions. All questions carry equal marks.

Answer ALL questions. All questions carry equal marks **3 * 5 = 15 Marks**					
Q.No	**Questions**	**Marks**	**CO**	**BL**	**PI**
1.	What is Coulomb's law. Derive necessary expressions required	**5**	**1**	**2**	**1.1**
	OR				
2.	Derive the expression for E due to surface charge density	**5**	**1**	**3**	**1.2**
3.	Discuss the boundary condition of surface charge density laying on two different dielectric materials	**5**	**2**	**3**	**1.2**
	OR				
4.	Discuss the solution of Laplace equation	**5**	**2**	**3**	**1.2**
5.	Find E at P (1,1,1) caused by four identical 3nC charges located at P1 (1,1,0), P2 (-1,1,0), P3 (-1,-1,0) & P4 (1,-1,0)	**5**	**1**	**4**	**1.2**
	OR				
6.	Calculate the capacitance of a parallel plate capacitor with the following details. Plate Area = 150 sq.cm. Dielectric $\varepsilon_{r1} = 3$, $d_1 = 4mm$; Dielectric $\varepsilon_{r2} = 5$, $d_1 = 6mm$ If 200V is applied across the plates what will be the voltage gradient across each dielectric.	**5**	**2**	**3**	**1.2**

GOKARAJU RANGARAJU INSTITUTE OF ENGINEERING AND TECHNOLOGY
(Autonomous)
Department of Electrical and Electronics Engineering

Academic Year: **2022-23**
Year:**II**
Semester:**I**

MID Exam – I (Objective)
ELECTROMAGNETIC FIELDS
Subject Code: GR20A2026

Date:08/06/2022
Duration: **10 min**
Max Marks:**5M**

Roll No:

Note: Answer ALL questions. All questions carry equal marks.

Answer all Objective Questions. All questions carry equal marks

Q.No	Questions	Option	CO	BL	PI
1	For free space or vacuum, the relative permittivity ε_r = a) 1 b) 2 c) 3 d) 4	[ ]	1	2	1.1
2	The region where a particular charge exerts a force on any other charge located in that region is called a) Electric Filed b) Coulomb Law c) Potential d) Force	[ ]	1	2	1.1
3	Volume charge density is expressed in a) C/m^3 b) C/m^2 c) C/m d) $C\text{-}m^2$	[ ]	1	3	1.2
4	Electric Flux is also called a) Displacement Flux b) Placement Flux c) Potential Gradient d) Electric Filed Intensity	[ ]	1	2	1.2
5	Relationship between D & E is a) $D = \varepsilon E$ b) $D = \varepsilon / E$ c) $E = D\,\varepsilon$ d) $E = \varepsilon / D$	[ ]	1	3	1.1
6	Rate of flow of charge at a specified point is called a) Electric Current b) Potential c) Gradient d) Intensity	[ ]	2	2	1.2
7	The current passing through the unit surface area, when the surface is held normal to the direction of the current is a) Current Density b) Current Intensity c) Flux Density d) Flux Intensity	[ ]	2	3	1.2
8	Point for of Ohms Law a) $J = \sigma E$ b) $E = \sigma J$ c) $J = \sigma/E$ d) $E = \sigma/J$	[ ]	2	3	1.2
9	A _______________ has an large quantity of charge that is free to move a) Conductor b) Dipole c) Insulator d) Force	[ ]	2	3	1.1
10	Inside a conductor a) $E = 0,\ \rho_V = 0,\ V_{ab} = 0$ b) $E = V,\ \rho_V = 0,\ V_{ab} = 0$ c) $E = V,\ \rho_V = 0,\ V_{ab} = \infty$ d) $E = 0,\ \rho_V = \infty,\ V_{ab} = \infty$	[ ]	2	4	1.2

BL – Bloom's Taxonomy Levels
CO – Course Outcomes
PI – Performance Indicator Code3

GOKARAJU RANGARAJU INSTITUTE OF ENGINEERING AND TECHNOLOGY
(Autonomous)
Department of Electrical and Electronics Engineering

Academic Year: **2022-23** Year:**II** Semester:**I**	**MID Exam – II (Descriptive)** **ELECTROMAGNETIC FIELDS** **Subject Code: GR20A2026**	Date: 11/02/2023 Duration:**90 min** Max Marks: **15**

Note: Answer any ALL questions. All questions carry equal marks.

Answer ALL questions. All questions carry equal marks **3 * 5 = 15 Marks**					
Q.No	**Questions**	**Marks**	**CO**	**BL**	**PI**
1.	State Biot-Savart Law. Derive integral form of Biot-Savart Law for a differential element of a long current carrying conductor	**5**	**3**	**2**	**1.1**
	OR				
2.	What is the force exerted on a differential current element in a given magnetic field	**5**	**3**	**3**	**1.2**
3.	Derive maxwell's equations from faraday's in a time varying magnetic field both in point and integral form	**5**	**4**	**4**	**1.2**
	OR				
4.	Discuss Displacement current and Displacement current density	**5**	**4**	**3**	**1.2**
5.	Derive maxwell's equations from Gauss law in a static electric field both in point and integral form	**5**	**5**	**4**	**1.2**
	OR				
6.	Discuss pointing theorem and pointing vector	**5**	**5**	**3**	**1.2**

GOKARAJU RANGARAJU INSTITUTE OF ENGINEERING AND TECHNOLOGY
(Autonomous)
Department of Electrical and Electronics Engineering

Academic Year: **2022-23**
Year:**II**
Semester:**I**

MID Exam – II (Objective)
ELECTROMAGNETIC FIELDS
Subject Code: GR20A2026

Date:11/02/2023
Duration: **10 min**
Max Marks:**5M**

Roll No:

Note: Answer ALL questions. All questions carry equal marks.

Answer all Objective Questions. All questions carry equal marks

Q.No	Questions	Option	CO	BL	PI
1	Ratio of the total flux linkage to the current flowing through the circuit is called ___________ a) Inductance b) Capacitance c) EMF d) Resistance	**[ ]**	**3**	**2**	**1.1**
2	The Biot-Savart law allows us to obtain the differential________ a) MFI b) EFI c) Potential d) Force	**[ ]**	**3**	**2**	**1.1**
3	According to Ampere's Circuit Law, line integral of magnetic field intensity H around a closed path is _________ to the direct current enclosed by that path a) Equal b) Greater c) Lesser d) Linear	**[ ]**	**3**	**3**	**1.2**
4	Vector magnetic potential denoted as _________ a) A b) H c) B d) E	**[ ]**	**3**	**2**	**1.2**
5	Gold is a ______________ material a) Diamagnetic b) Paramagnetic c) Ferromagnetic d) Ferro Alloy	**[ ]**	**3**	**4**	**1.2**
6	The time varying fields are produced due to the ________ a) Time varying currents b) Time varying EMF c) Time invariable currents d) Time invariable EMF	**[ ]**	**4**	**3**	**1.2**
7	According to Lenz's law, the induced e.m.f. acts to produce an ____ flux a) Opposing b) Same c) Normal d) Tangential	**[ ]**	**4**	**3**	**1.2**
8	When an e.m.f. is induced in a stationary closed path due to the time varying B field, the e.m.f. is called or transformer e.m.f. a) statically induced e.m.f. b) dynamically induced e.m.f. c) motional e.m.f. d) mutual e.m.f	**[ ]**	**4**	**4**	**1.2**
9	The equations describing relationships between time varying electric and magnetic fields are known as __________ equations. a) Maxwell's b) Lorentz c) Lenz's d) Faraday's	**[ ]**	**4**	**3**	**1.1**
10	The _________ theorem is based on law of conservation of energy in electromagnetism a) Poynting b) Lorentz c) Faraday's d) Gauss	**[ ]**	**5**	**4**	**1.2**

First Mid Examination Marks

Programme**: BTech** Year: **II** Course: **Theory** **A.Y: 2022-23**

Course: Electromagnetic Fields Section: A Faculty Name: Dr. Suresh Kumar T

S. No	Roll No	Objective Marks (5)	Subjective Marks (15)	Total Marks (20)
1	21241A0201	2	10	12
2	21241A0202	1.5	9	11
3	21241A0203	2.5	7	10
4	21241A0204	A	A	A
5	21241A0205	3	14	17
6	21241A0206	2	9	11
7	21241A0207	3	14	17
8	21241A0208	3	13	16
9	21241A0209	2.5	1	4
10	21241A0210	1	7	8
11	21241A0211	3.5	6	10
12	21241A0212	3	11	14
13	21241A0213	2	8	10
14	21241A0214	3.5	10	14
15	21241A0215	1.5	7	9
16	21241A0216	2.5	3	6
17	21241A0217	3	11	14
18	21241A0218	4	3	7
19	21241A0219	3	14	17
20	21241A0220	2	9	11
21	21241A0221	2.5	6	9
22	21241A0222	2	8	10
23	21241A0223	2.5	9	12
24	21241A0224	3.5	12	16
25	21241A0225	4	13	17
26	21241A0226	2.5	4	7
27	21241A0227	2.5	14	17
28	21241A0228	2.5	12	15
29	21241A0229	2.5	11	14
30	21241A0230	2.5	14	17
31	21241A0231	1.5	8	10
32	21241A0232	1.5	10	12
33	21241A0233	2.5	6	9
34	21241A0234	2.5	11	14
35	21241A0235	1.5	14	16
36	21241A0236	4	13	17
37	21241A0237	3	12	15

38	21241A0238	5	3	8
39	21241A0239	2	13	15
40	21241A0240	5	11	16
41	21241A0241	4	6	10
42	21241A0242	2	14	16
43	21241A0243	2.5	13	16
44	21241A0244	5	10	15
45	21241A0245	5	14	19
46	21241A0246	2.5	10	13
47	21241A0247	5	11	16
48	21241A0248	2	12	14
49	21241A0249	4	10	14
50	21241A0250	2	6	8
51	21241A0251	1	10	11
52	21241A0252	4.5	15	20
53	21241A0253	5	4	9
54	21241A0254	2	9	11
55	21241A0255	2	10	12
56	21241A0256	2.5	9	12
57	21241A0257	2	15	17
58	21241A0258	A	A	A
59	21241A0259	5	12	17
60	21241A0260	3	12	15
61	21241A0261	3.5	14	18
62	21241A0262	0	5	5
63	21241A0263	5	5	10
64	22245A0201	5	10	15
65	22245A0202	5	15	20
66	22245A0203	3	11	14
67	22245A0204	2	12	14
68	22245A0205	4	12	16
69	22245A0206	3	10	13

No. of Absentees: **02**

Total Strength: **69**

Signature of Faculty

Signature of HOD:

Signature of Principal

Second Mid Examination Marks

Programme**: BTech** Year: **II** Course: **Theory** **A.Y: 2022-23**

Course: Electromagnetic Fields Section: A Faculty Name: Dr. Suresh Kumar T

S. No	**Roll No**	**Objective Marks (5)**	**Subjective Marks (15)**	**Total Marks (20)**
1	21241A0201	2	10	12
2	21241A0202	1.5	9	11
3	21241A0203	2.5	7	10
4	21241A0204	A	A	A
5	21241A0205	3	14	17
6	21241A0206	2	9	11
7	21241A0207	3	14	17
8	21241A0208	3	13	16
9	21241A0209	2.5	1	4
10	21241A0210	1	7	8
11	21241A0211	3.5	6	10
12	21241A0212	3	11	14
13	21241A0213	2	8	10
14	21241A0214	3.5	10	14
15	21241A0215	1.5	7	9
16	21241A0216	2.5	3	6
17	21241A0217	3	11	14
18	21241A0218	4	3	7
19	21241A0219	3	14	17
20	21241A0220	2	9	11
21	21241A0221	2.5	6	9
22	21241A0222	2	8	10
23	21241A0223	2.5	9	12
24	21241A0224	3.5	12	16
25	21241A0225	4	13	17
26	21241A0226	2.5	4	7
27	21241A0227	2.5	14	17
28	21241A0228	2.5	12	15
29	21241A0229	2.5	11	14
30	21241A0230	2.5	14	17
31	21241A0231	1.5	8	10
32	21241A0232	1.5	10	12
33	21241A0233	2.5	6	9
34	21241A0234	2.5	11	14
35	21241A0235	1.5	14	16
36	21241A0236	4	13	17
37	21241A0237	3	12	15

38	21241A0238	5	3	8
39	21241A0239	2	13	15
40	21241A0240	5	11	16
41	21241A0241	4	6	10
42	21241A0242	2	14	16
43	21241A0243	2.5	13	16
44	21241A0244	5	10	15
45	21241A0245	5	14	19
46	21241A0246	2.5	10	13
47	21241A0247	5	11	16
48	21241A0248	2	12	14
49	21241A0249	4	10	14
50	21241A0250	2	6	8
51	21241A0251	1	10	11
52	21241A0252	4.5	15	20
53	21241A0253	5	4	9
54	21241A0254	2	9	11
55	21241A0255	2	10	12
56	21241A0256	2.5	9	12
57	21241A0257	2	15	17
58	21241A0258	A	A	A
59	21241A0259	5	12	17
60	21241A0260	3	12	15
61	21241A0261	3.5	14	18
62	21241A0262	0	5	5
63	21241A0263	5	5	10
64	22245A0201	5	10	15
65	22245A0202	5	15	20
66	22245A0203	3	11	14
67	22245A0204	2	12	14
68	22245A0205	4	12	16
69	22245A0206	3	10	13

No. of Absentees: **02**

Total Strength: **69**

Signature of Faculty

Signature of HOD:

Signature of Principal

Electromagnetic Fields

By

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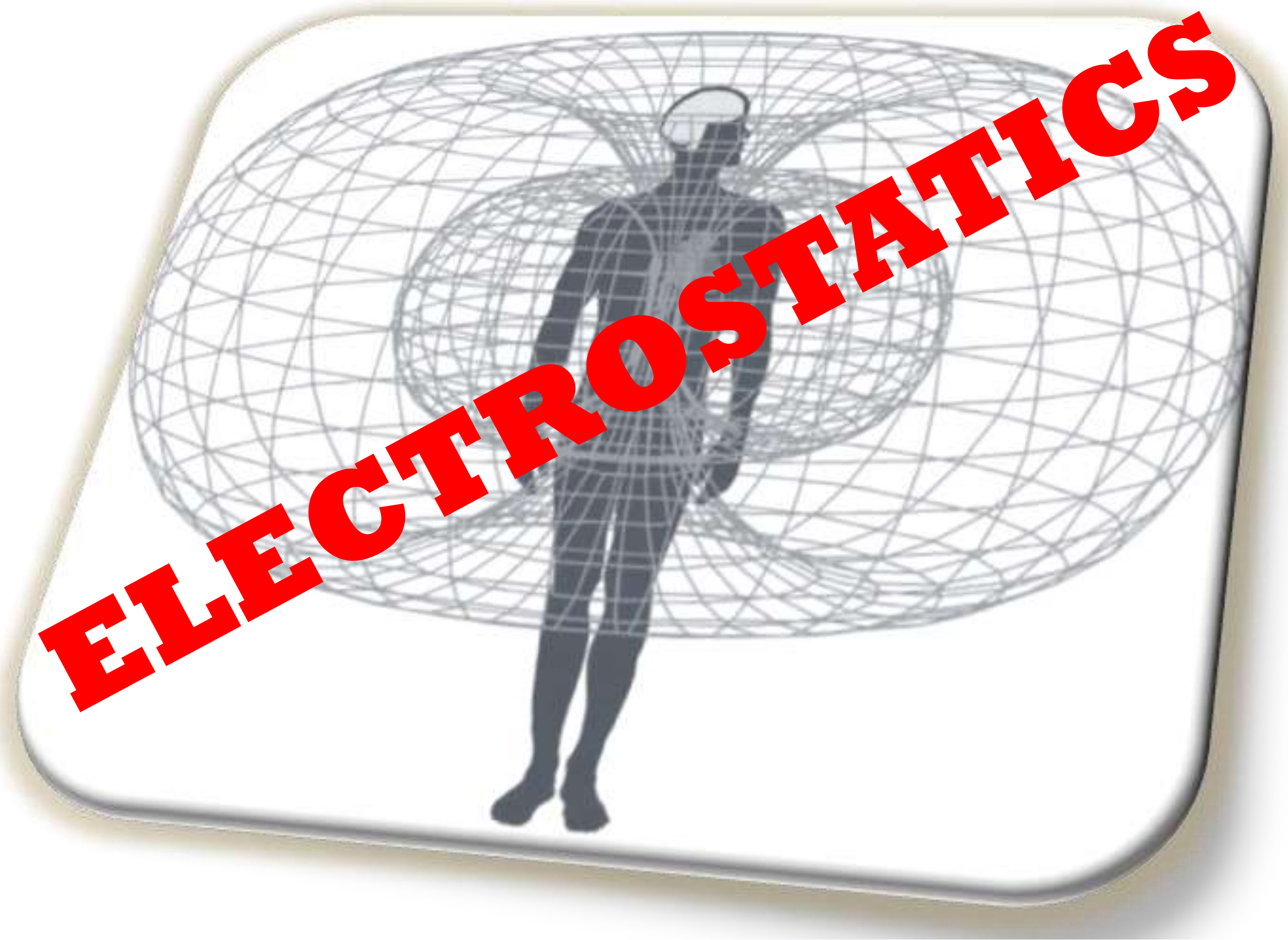
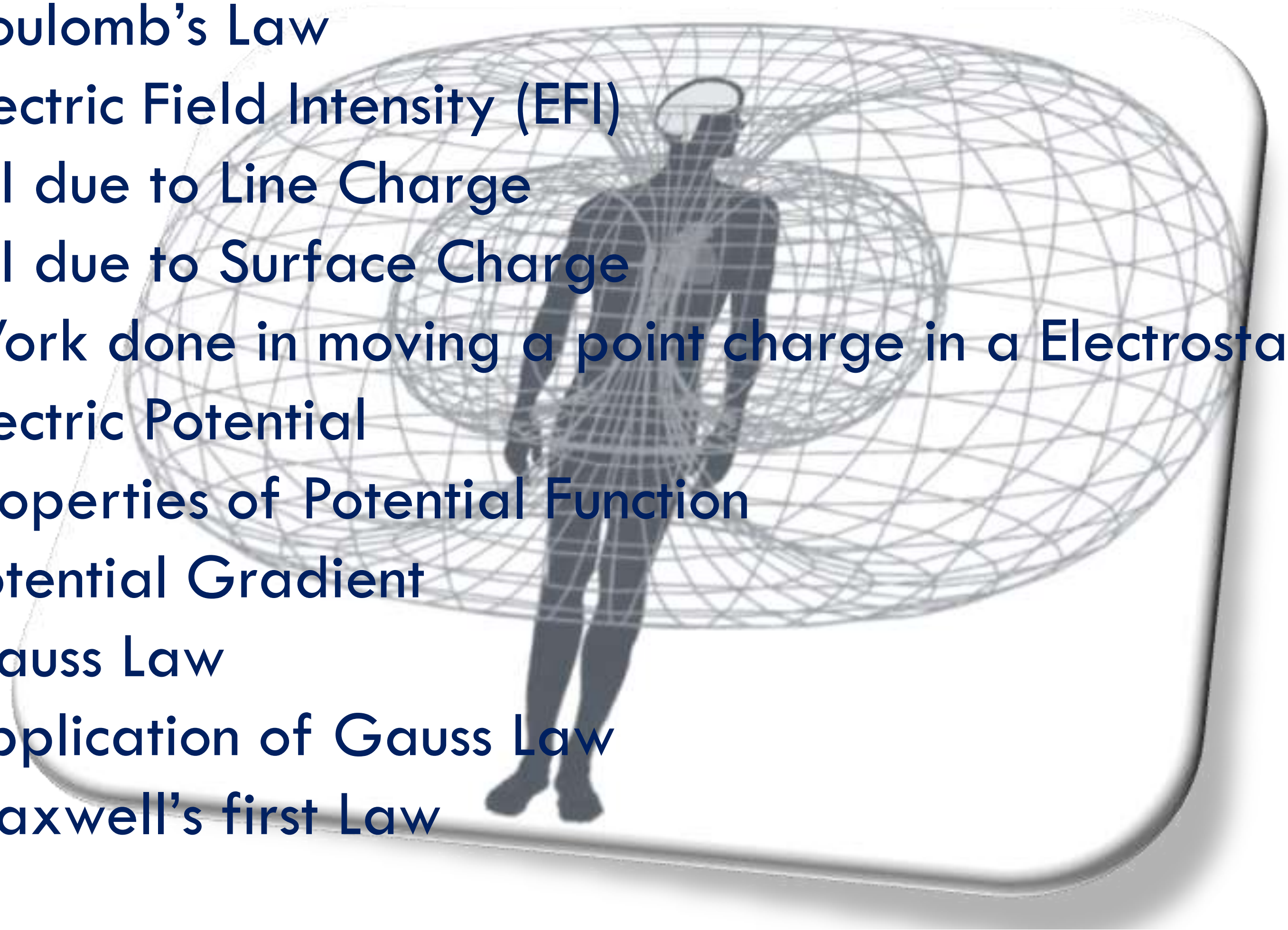
Professor, EEE Dept.,
GRIET

UNIT - I



ELECTROSTATICS

- ✓ Electrostatic Fields
- ✓ Coulomb's Law
- ✓ Electric Field Intensity (EFI)
- ✓ EFI due to Line Charge
- ✓ EFI due to Surface Charge
- ✓ Work done in moving a point charge in a Electrostatic Field
- ✓ Electric Potential
- ✓ Properties of Potential Function
- ✓ Potential Gradient
- ✓ Gauss Law
- ✓ Application of Gauss Law
- ✓ Maxwell's first Law

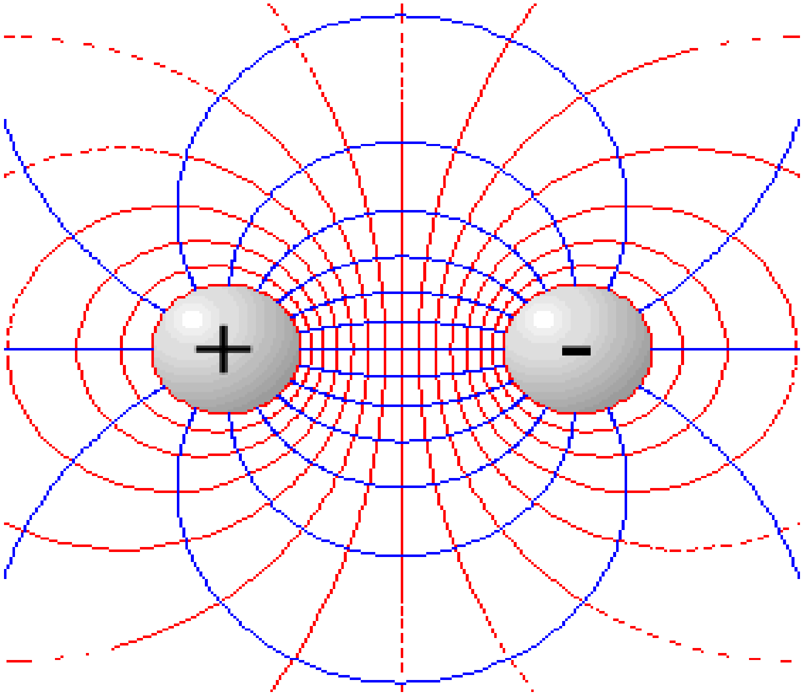


Basic Key Words

- Field
- Charge
- Force
- Field Intensity

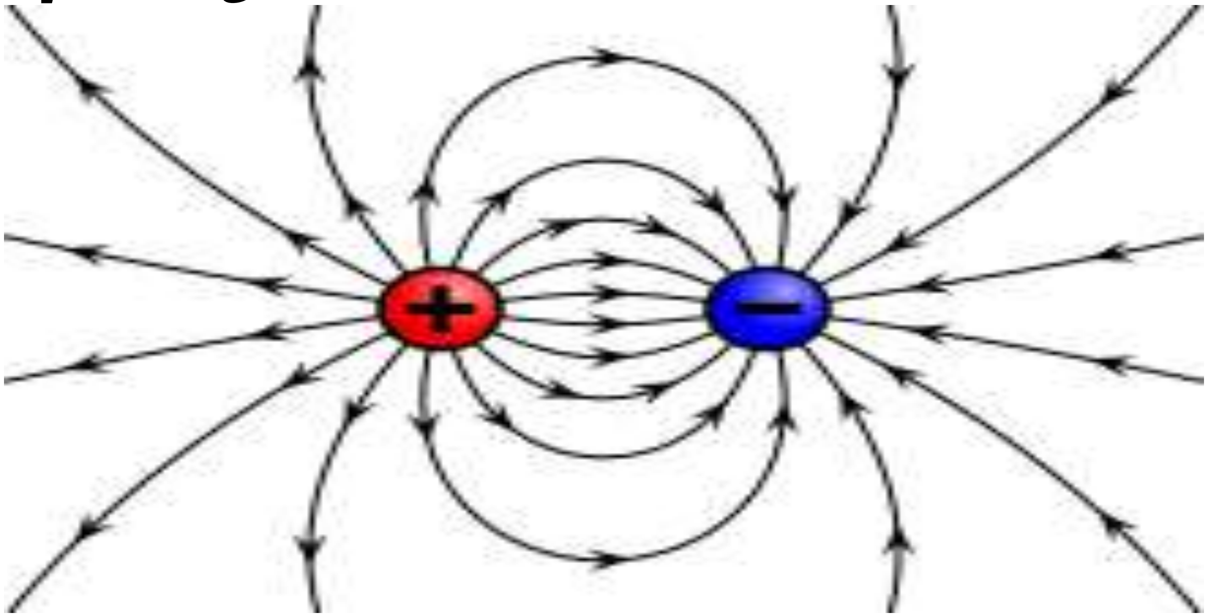
Field

- A field is a function that specifies a particular quantity every where in a system.



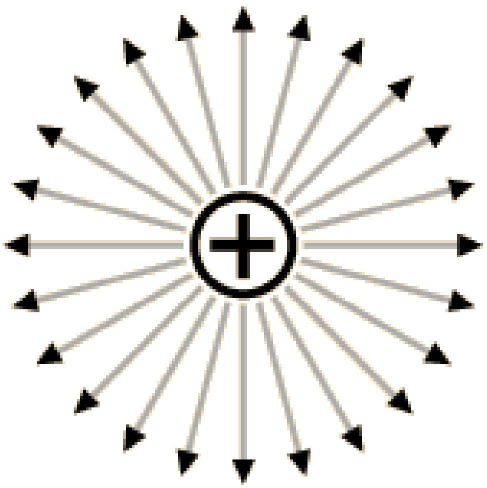
Charge

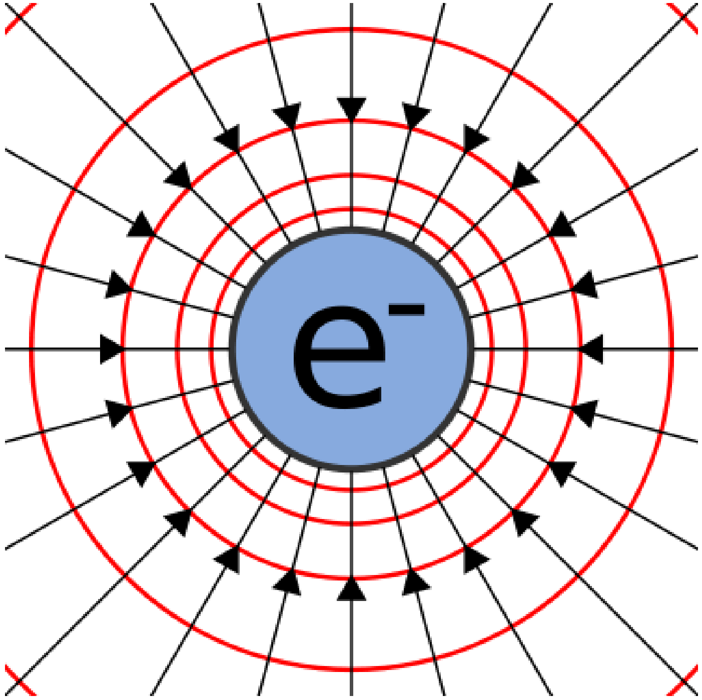
- Electric charge is a physical property of matter that causes it to experience a force when near other electrically charged matter.



ELECTROSTATICS - CHARGE (Types)

- Point Charge.
- Line Charge.
- Surface Charge.

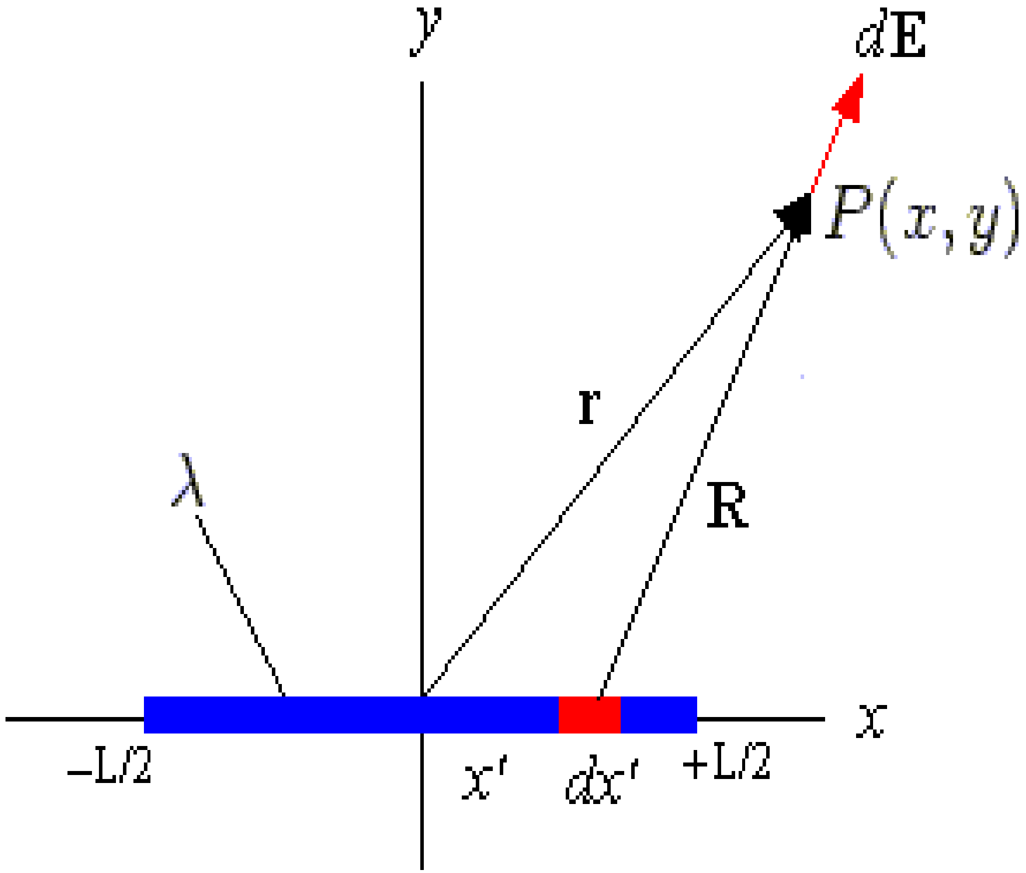




- Point Charge:

These are very small charges assumed to have infinite small volume, although they have finite volume – considered as a Single charge

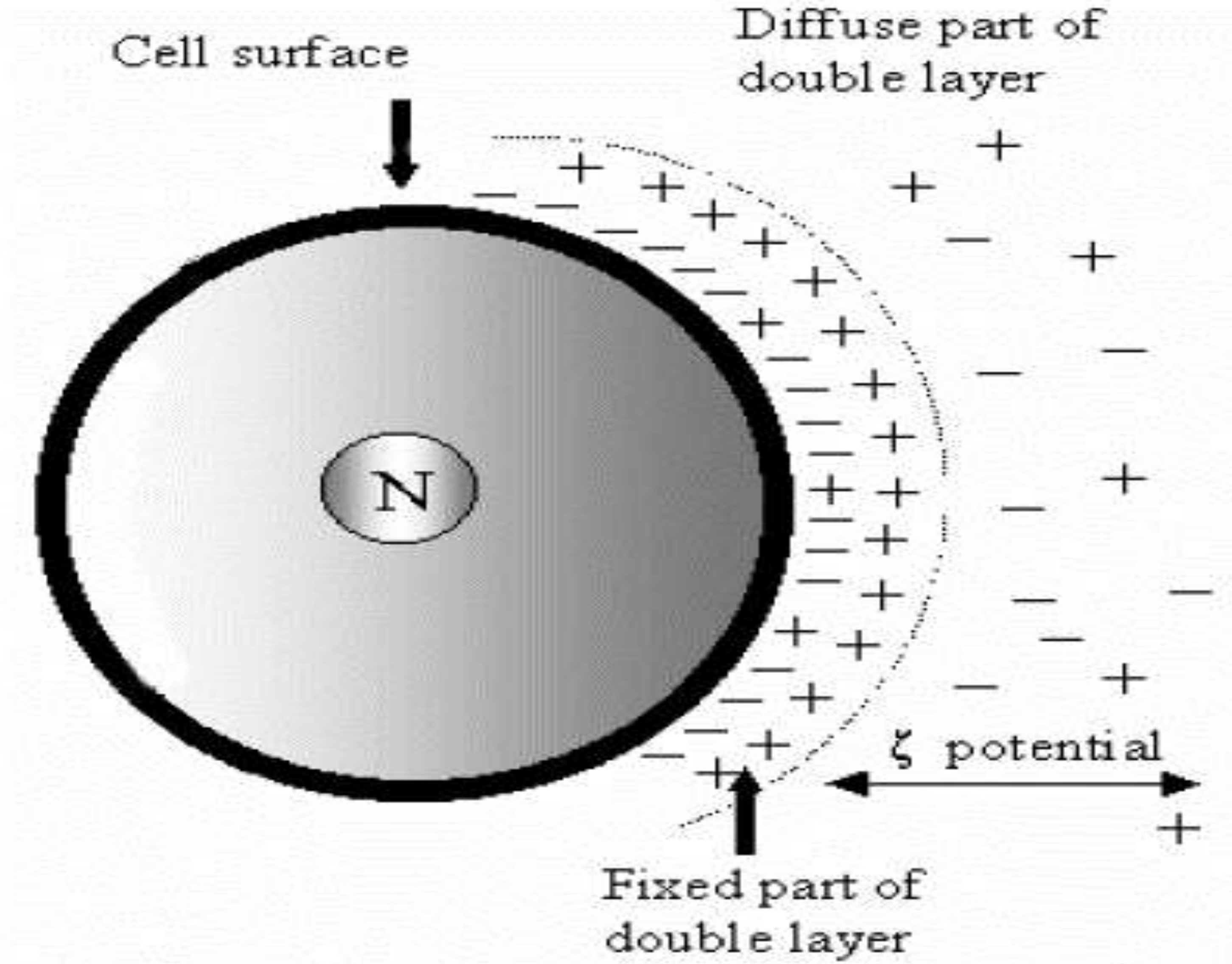
- Line Charge:



- ## Surface Charge:

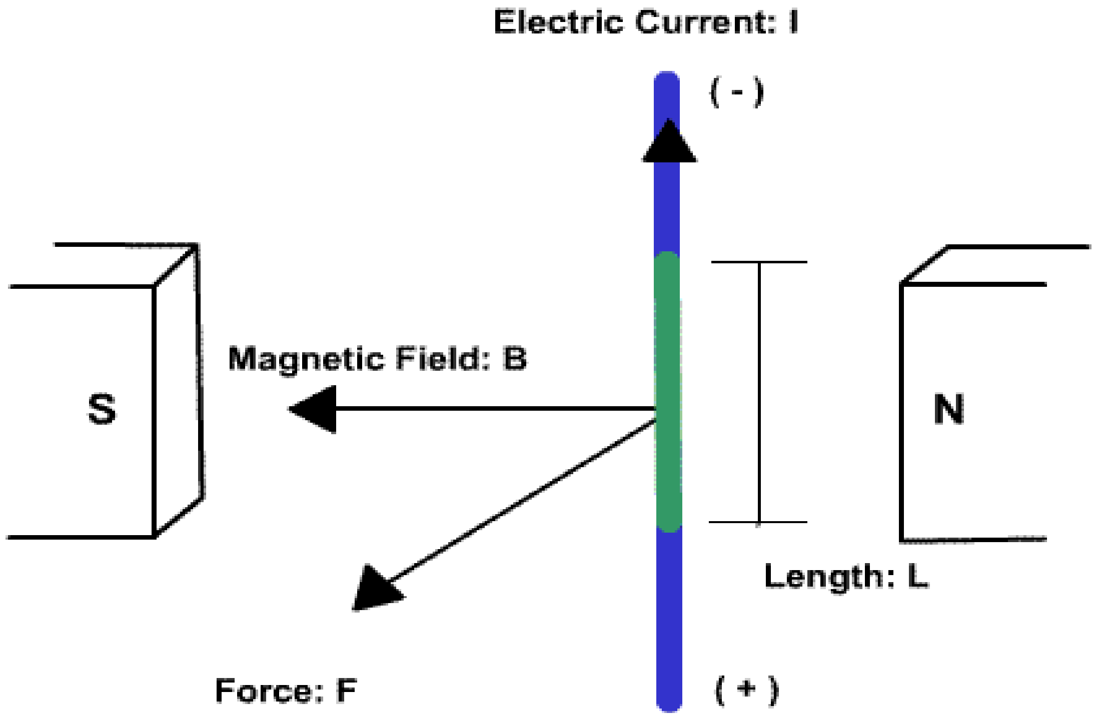
Electric surface charge practically always appears on an object surface when it is placed into a fluid. All fluids contain ions, positive (cations) and negative (anions). These ions interact with the object surface. This interaction might lead to the adsorption of some of them on the surface. If the number of adsorbed cations exceeds the number of adsorbed anions, the surface would gain total positive electric charge.

ELECTROSTATICS - CHARGE (Surface)



Force

- Force is any influence that causes an object to undergo a certain change, either concerning its movement, direction, or geometrical construction.



Field Intensity (Strength)

- Force Experienced by a unit +ve test Charge placed in a Electric Field. (EFI)

$$E = \frac{\text{Force}(F)}{\text{Charge}(Q)}$$

Coulomb's Law

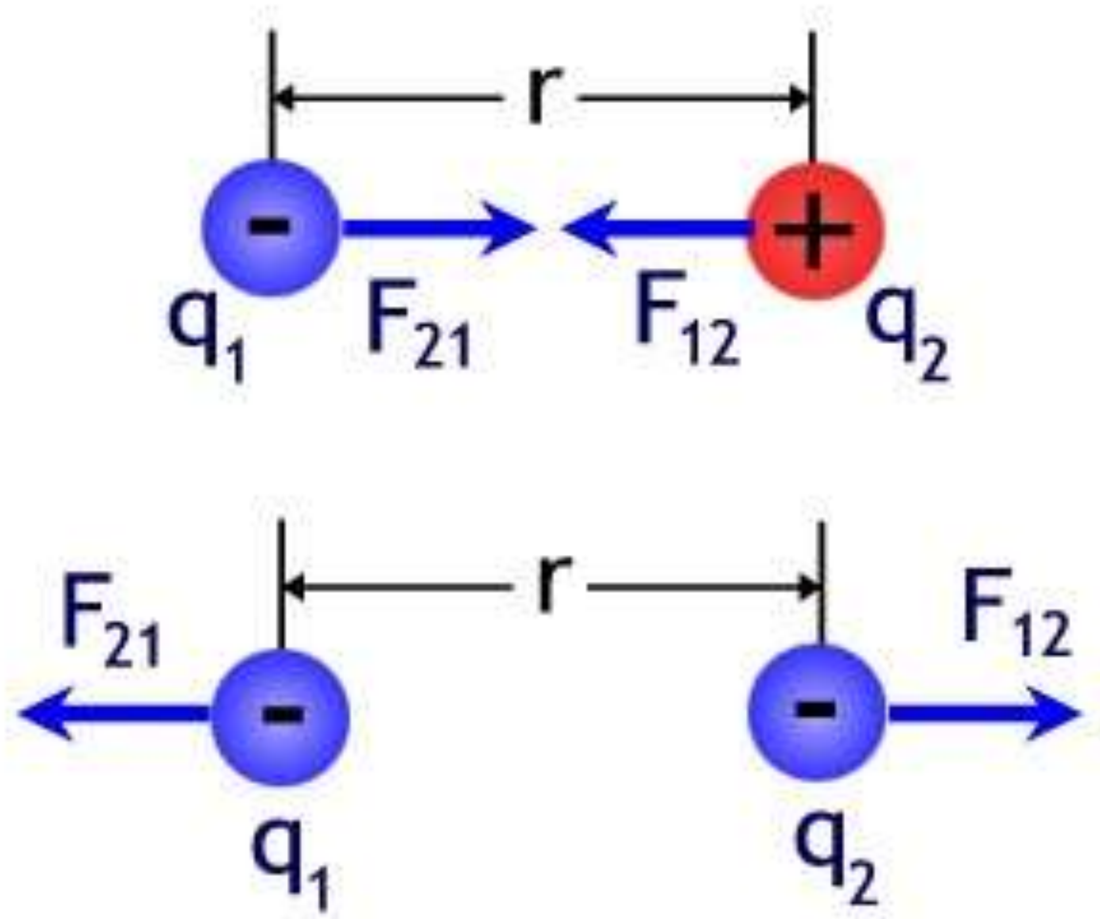
- Also called as Coulomb's Inverse Square Law (or)
- Law of Physics describing Electrostatic Interaction between Electrically charged particles.

- This law states that each electric point charge exerts a mechanical force on the other & this force exhibits five characteristics …....

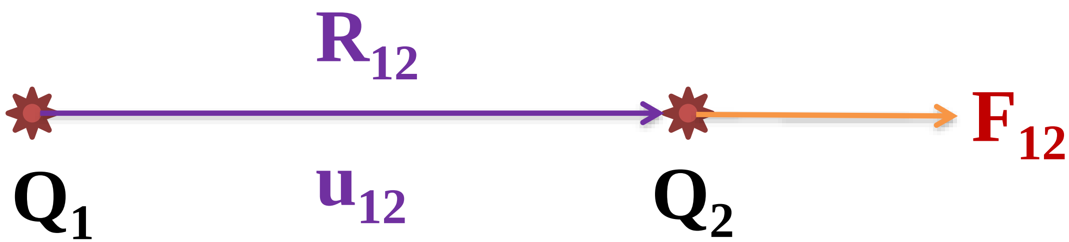
- Force is proportional to the product of the magnitude Q_1 & Q_2 of the two electric charges.

- Force is attractive if the two charges are unlike & repulsive if they are like charges.

- Force is inversely proportional to the square of the distance between the two charges.
- Force depends upon the medium in which the two charges are located.
- Force always acts along the straight line going to the charges Q_1 & Q_2.


r
-
+
q_1
F_{21}
F_{12}
q_2
r
F_{21}
-
-
F_{12}
q_1
q_2

- Q_1 & Q_2 are the two electric charges separated by a distance R_{12}



- Force Exerted by Q_1 & Q_2 is F_{12}

$$F_{12} \propto \frac{Q_1 Q_2}{R_{12}^2}$$

$$F_{12} = k\frac{Q_1 Q_2}{R_{12}^2}$$

k is proportionality Constant

$$k = \frac{1}{4\pi\varepsilon_o} = 9*10^9$$

$$\varepsilon_o = 8.854*10^{-12}\,F/m$$

ELECTROSTATICS - COULOMB's LAW

- F_{12} is the force exerted by Q_1 on Q_2
- F_{21} is the force exerted by Q_2 on Q_1
- F_{12} is a vector & it acts in the direction of u_{12}

$$\overrightarrow{F_{12}} = \frac{Q_1 Q_2}{4\pi\varepsilon_o R_{12}^2}\overrightarrow{u_{12}} \qquad \text{Newtons}$$

- u_{12} is unit vector in the direction of R_{12}

$$u_{12} = \frac{\overrightarrow{R_{12}}}{\left|R_{12}\right|} = \frac{r_2 - r_1}{\left|r_2 - r_1\right|}$$

Note:

If the Medium is other than vacuum or air then

$$\overrightarrow{F_{12}} = \frac{Q_1 Q_2}{4\pi\varepsilon R_{12}^2}\overrightarrow{u_{12}} \quad \text{Newtons}$$

$$\varepsilon = \varepsilon_o \varepsilon_r$$

Relative permeability for air & vacuum is I

Note:

If there are 'n' charges $Q_{1,}$ $Q_{2,}$ …. Q_n then force on Q_i due to charges Q_j where j=1,2,…n & j≠i is given by

$$\overrightarrow{F_{12}} = \sum_{\substack{j=1 \\ j\neq i}}^{n} \frac{Q_i Q_j}{4\pi\varepsilon r_{ij}} \overrightarrow{u_{ij}} \qquad N$$

Coulomb's Law is applied only when the charges are at rest

Note:

Force expressed by Coulomb's law is a mutual force, for each of the two charges experiences a force of the same magnitude, although of opposite direction.

$$\overrightarrow{F_{12}} = -\overrightarrow{F_{21}} = \frac{Q_1 Q_2}{4\pi\varepsilon R_{12}^2}\overrightarrow{u_{12}} = \frac{Q_2 Q_1}{4\pi\varepsilon R_{21}^2}\overrightarrow{u_{21}}$$

$$R_{12} = R_{21}$$

Note:

If the permittivity of the medium is ε_I at the location of Q_I & ε_2 at the location of Q_2.

$$\overrightarrow{F_{12}} = \frac{Q_1 Q_2}{4\pi\varepsilon_2 R_{12}^2}\overrightarrow{u_{12}}$$

$$\overrightarrow{F_{21}} = \frac{Q_2 Q_1}{4\pi\varepsilon_1 R_{21}^2}\overrightarrow{u_{21}}$$

Electric Field Intensity

It is defined as the force experience by a unit +ve test charge placed in a Electric Field.

$$\overrightarrow{F_t} = \frac{Q_1 Q_t}{4\pi\varepsilon_O R_{1t}^2}\overrightarrow{u_{1t}}$$

$$\frac{F_t}{Q_t} = \frac{Q_1}{4\pi\varepsilon_O R_{1t}^2}\overrightarrow{u_{1t}}$$

Force/Unit Charge - EFI

$$E = \frac{F_t}{Q_t}$$

Defining Expression of EFI

$$\vec{E} = \frac{Q_1}{4\pi\varepsilon_O R_{1t}^2}\overrightarrow{u_{1t}}$$

Expression of EFI due to Single point Charge Q_I in vacuum or air

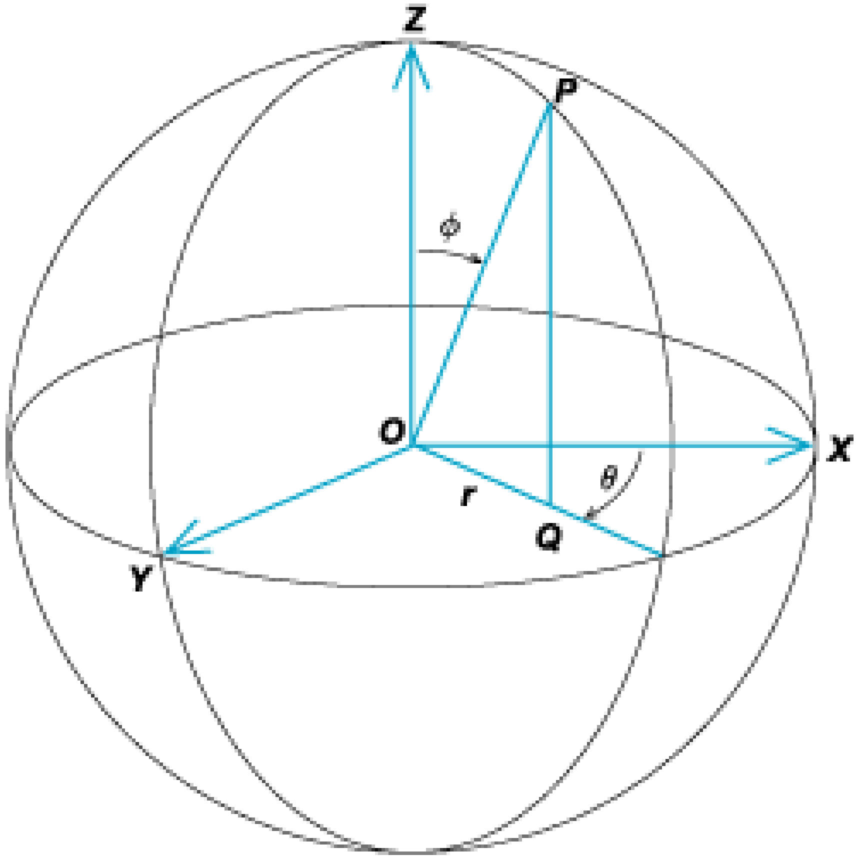
EFI is written in general terms as

$$\vec{E} = \frac{Q}{4\pi\varepsilon_O R^2}\overrightarrow{u_R}$$

R is magnitude of $\overline{R}$

$\overline{u_R}$ is unit vector directed along $\overline{R}$

Let us arbitrarily locate Q_I at the centre of a spherical coordinate system



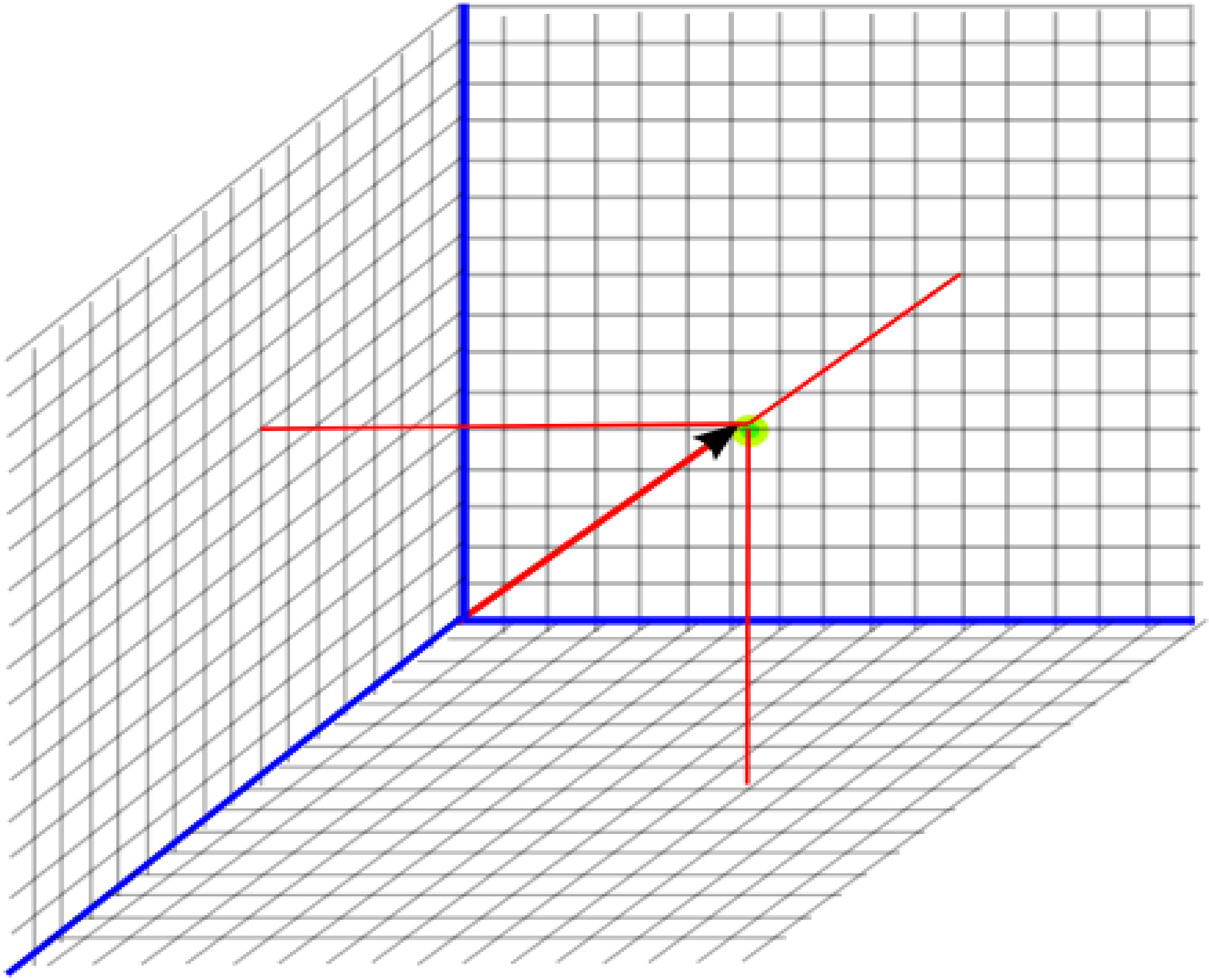
Unit vector $\overrightarrow{u_R}$ becomes the radial unit vector $\overrightarrow{u_r}$ & R is 'r'

$$\vec{E} = \frac{Q_1}{4\pi\varepsilon_O r^2}\overrightarrow{u_r}$$

$$E_r = \frac{Q_1}{4\pi\varepsilon_O r^2}$$

Expressing the above expression in rectangular coordinate system for a charge 'Q' at origin

ELECTROSTATICS - ELECTRIC FIELD INTENSITY (EFI)



$$R = r = x * \overrightarrow{u_x} + y * \overrightarrow{u_y} + z * \overrightarrow{u_z}$$

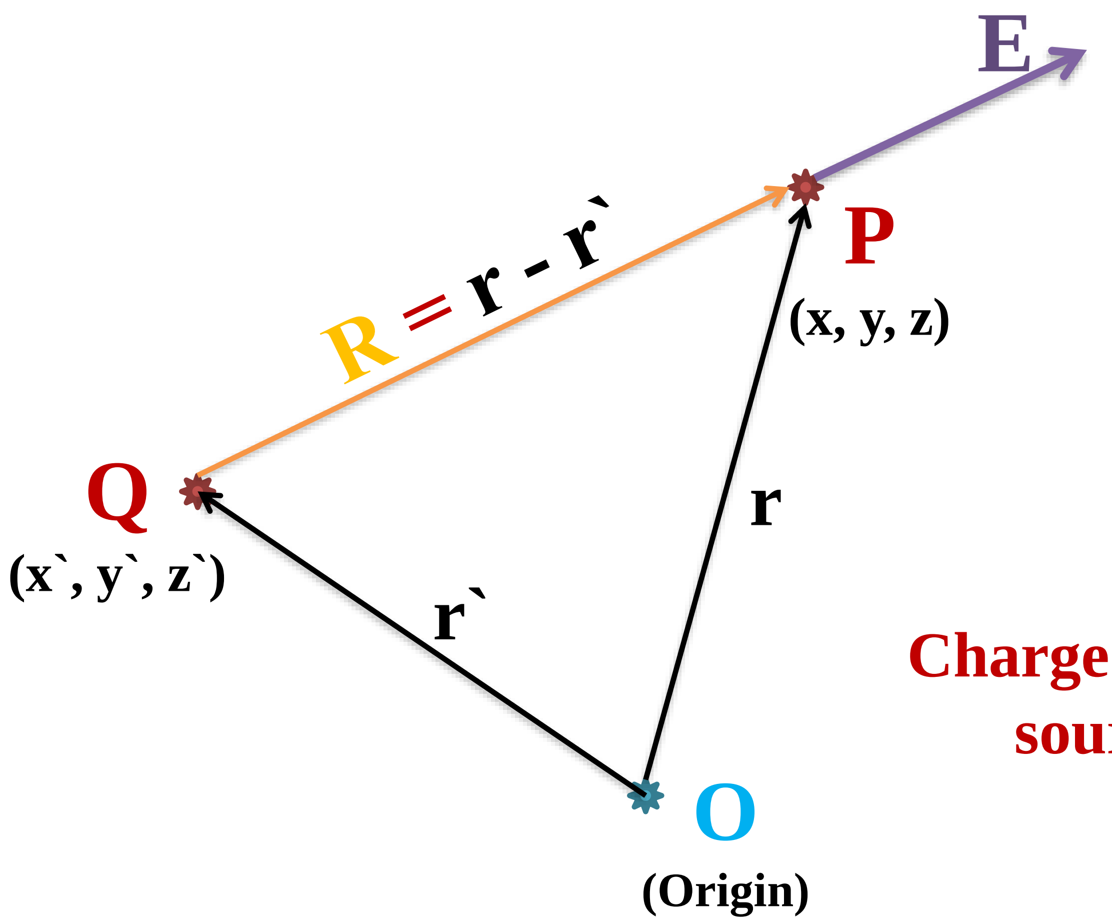
$$\overrightarrow{u_R} = \overrightarrow{u_r} = \frac{x * \overrightarrow{u_x} + y * \overrightarrow{u_y} + z * \overrightarrow{u_z}}{\sqrt{x^2 + y^2 + z^2}}$$

$$E = \frac{Q}{4\pi\varepsilon_O (x^2 + y^2 + z^2)} \left(\begin{array}{l} \dfrac{x}{\sqrt{x^2 + y^2 + z^2}} \overrightarrow{u_x} + \\ \dfrac{y}{\sqrt{x^2 + y^2 + z^2}} \overrightarrow{u_y} + \dfrac{z}{\sqrt{x^2 + y^2 + z^2}} \overrightarrow{u_z} \end{array} \right)$$

Expression is big & complex for solving the problem

In order to obtain the equation we have to break up the magnitude of the EFI into three components by finding the projection on each coordinate axis.

Now let suppose the charge is not at the Origin (RCS), the field no longer possesses spherical symmetry nor cylindrical symmetry unless the charge lies on z-axis.



Charge Q located at source point

E = Electric Field Intensity (EFI)

$$r' = x' * \overrightarrow{u_x} + y' * \overrightarrow{u_y} + z' * \overrightarrow{u_z}$$

We find the field at a general field point

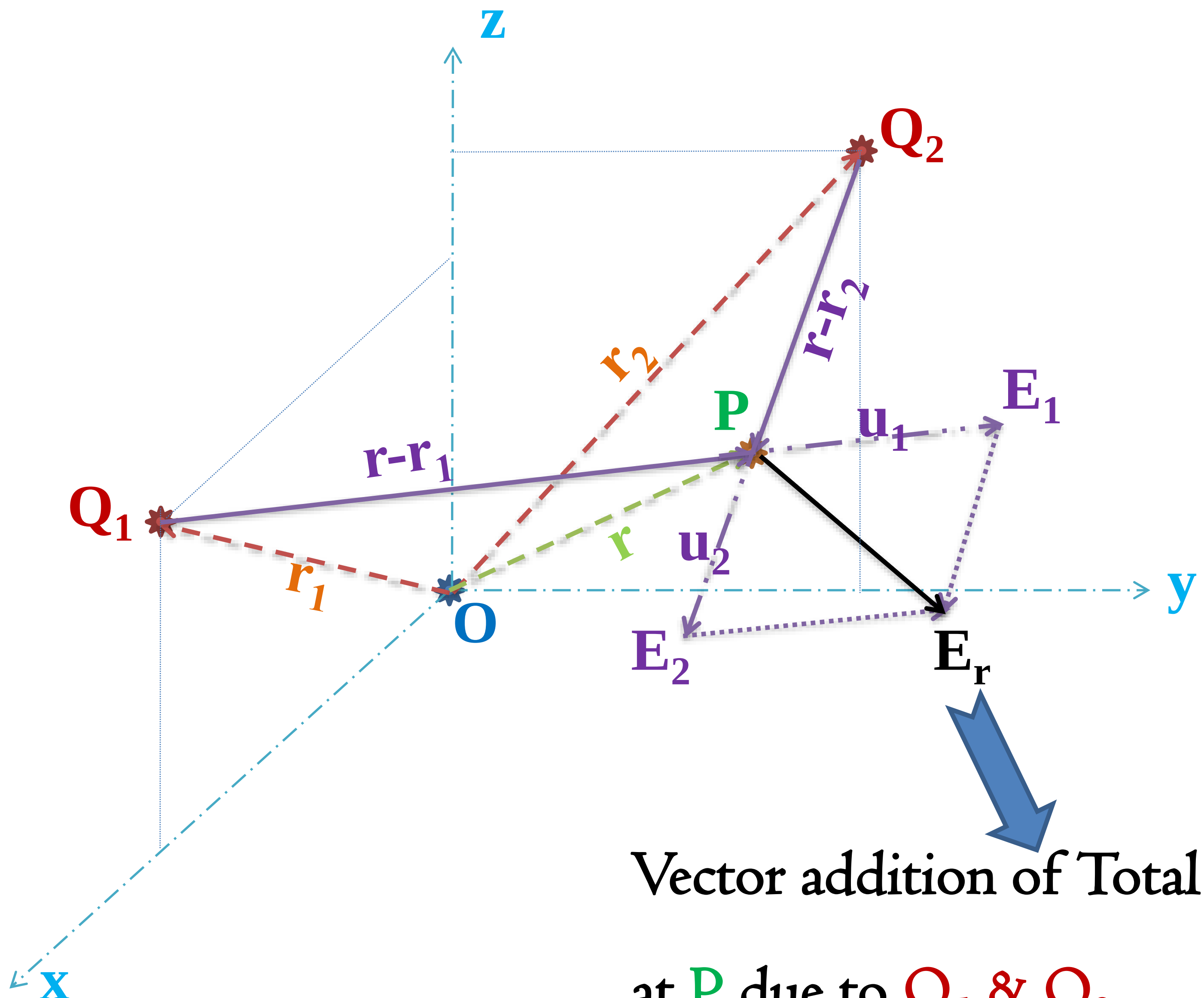
$$\vec{r} = x * \overrightarrow{u_x} + y * \overrightarrow{u_y} + z * \overrightarrow{u_z} \quad \text{by expressing } \overrightarrow{R} = \vec{r} - \overrightarrow{r^{|}}$$

$$E(r) = \frac{Q}{4\pi\varepsilon_O \left|\vec{r} - \overrightarrow{r^{|}}\right|^2} * \frac{\vec{r} - \overrightarrow{r^{|}}}{\left|\vec{r} - \overrightarrow{r^{|}}\right|} = \frac{Q * (\vec{r} - \overrightarrow{r^{|}})}{4\pi\varepsilon_O \left|\vec{r} - \overrightarrow{r^{|}}\right|^3}$$

$$E(r) = \frac{Q\left[(x - x')\overrightarrow{u_x} + (y - y')\overrightarrow{u_y} + (z - z')\overrightarrow{u_z}\right]}{4\pi\varepsilon_O \left[(x - x')^2 + (y - y')^2 + (z - z')^2\right]^{3/2}}$$

Since the coulomb force are linear, the EFI due to two point charges Q_1 at r_1 & Q_2 at r_2 is the sum of the forces on Q_t caused by Q_1 & Q_2 acting alone.

$$E(r) = \frac{Q_1}{4\pi\varepsilon_o |r - r_1|^2} \overrightarrow{u_1} + \frac{Q_2}{4\pi\varepsilon_o |r - r_2|^2} \overrightarrow{u_2}$$



Vector addition of Total EFI

at P due to Q_1 & Q_2

$\overrightarrow{u_1}$ & $\overrightarrow{u_2}$ are unit vectors in the direction of

$\vec{r} - \overrightarrow{r_1}$ & $\vec{r} - \overrightarrow{r_2}$ respectively.

If we add more charges at other position, the field due to 'n' point charges is

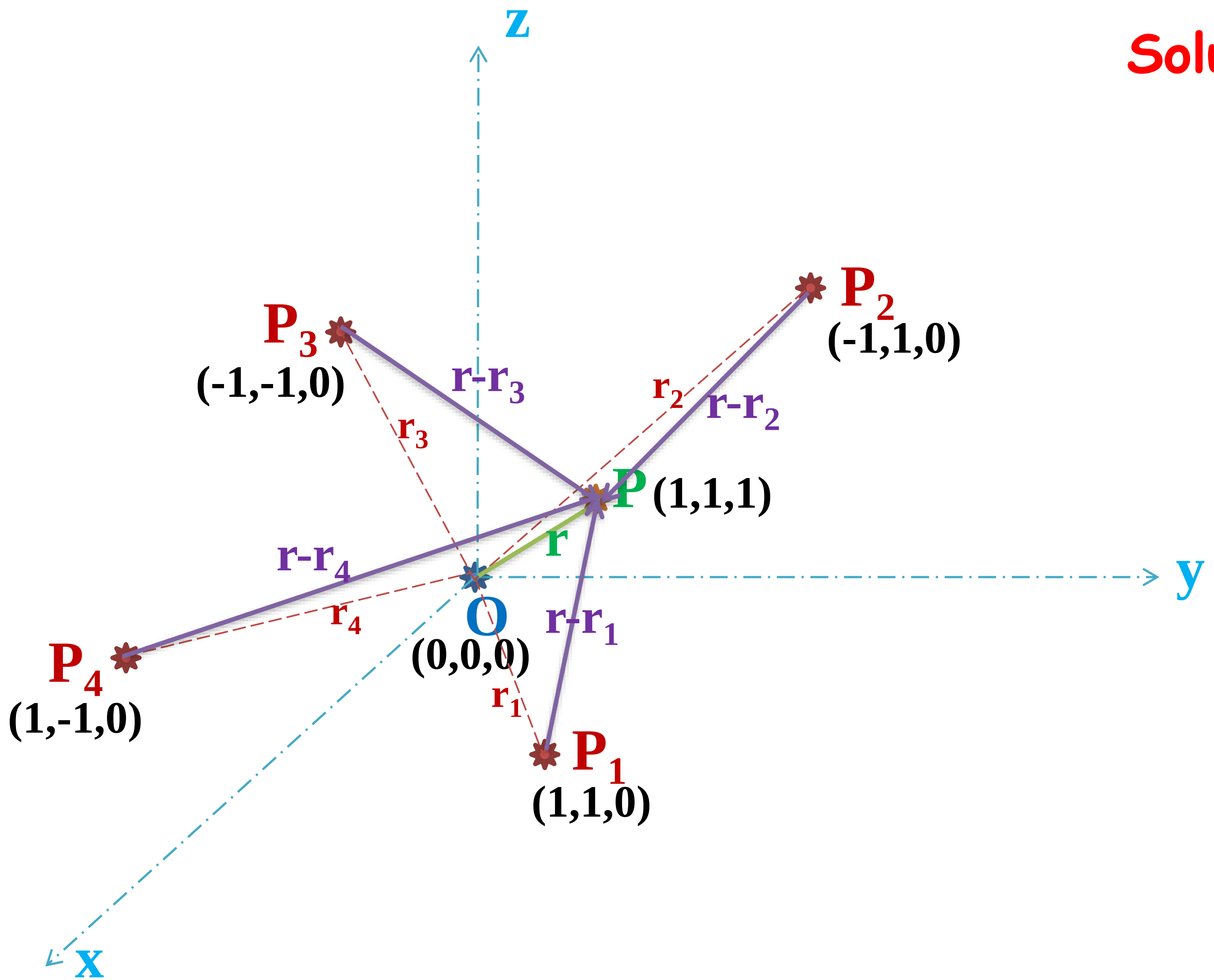
$$E(r) = \frac{Q_1}{4\pi\varepsilon_O |r - r_1|^2}\overrightarrow{u_1} + \frac{Q_2}{4\pi\varepsilon_O |r - r_2|^2}\overrightarrow{u_2} + \ldots\ldots\ldots + \frac{Q_n}{4\pi\varepsilon_O |r - r_n|^2}\overrightarrow{u_n}$$

$$E(r) = \sum_{m=1}^{n} \frac{Q_m}{4\pi\varepsilon_O |r - r_m|^2}\overrightarrow{u_m}$$

PROBLEM

Find E at P (1,1,1) caused by four identical 3nC (Nano Coulomb) charges located at P_1 (1,1,0), P_2 (-1,1,0), P_3 (-1,-1,0) & P_4 (1,-1,0)

Solution


z
y
x
P
(1,1,1)
O
(0,0,0)
r
P1
(1,1,0)
P2
(-1,1,0)
P3
(-1,-1,0)
P4
(1,-1,0)
r1
r2
r3
r4
r-r1
r-r2
r-r3
r-r4

$$\vec{r} = \overrightarrow{u_x} + \overrightarrow{u_y} + \overrightarrow{u_z}$$

Solution

$$\overrightarrow{r_1} = \overrightarrow{u_x} + \overrightarrow{u_y} \qquad \overrightarrow{r_2} = -\overrightarrow{u_x} + \overrightarrow{u_y}$$

$$\overrightarrow{r_3} = -\overrightarrow{u_x} - \overrightarrow{u_y} \qquad \overrightarrow{r_4} = \overrightarrow{u_x} - \overrightarrow{u_y}$$

$$\vec{r} - \overrightarrow{r_1} = \overrightarrow{u_z} \qquad \vec{r} - \overrightarrow{r_2} = 2\overrightarrow{u_x} + \overrightarrow{u_z}$$

$$\vec{r} - \overrightarrow{r_3} = 2\overrightarrow{u_x} + 2\overrightarrow{u_y} + \overrightarrow{u_z} \qquad \vec{r} - \overrightarrow{r_4} = 2\overrightarrow{u_y} + \overrightarrow{u_z}$$

$$|r - r_1| = 1 \qquad |r - r_2| = \sqrt{5}$$

$$|r - r_3| = 3 \qquad |r - r_4| = \sqrt{5}$$

Solution

$$\frac{Q}{4\pi\varepsilon_O} = \frac{3*10^{-9}}{4*\pi*8.854*10^{-12}} = 26.96\,\mathrm{V-m}$$

$$E = 26.96\left[\begin{array}{c}\left(\frac{1}{1^2}\cdot\frac{u_z}{1}\right)+\left(\frac{1}{\left(\sqrt{5}\right)^2}\cdot\frac{2u_x+u_z}{\sqrt{5}}\right)+ \\ \left(\frac{1}{(3)^2}\cdot\frac{2u_x+2u_y+u_z}{3}\right)+\left(\frac{1}{\left(\sqrt{5}\right)^2}\cdot\frac{2u_y+u_z}{\sqrt{5}}\right)\end{array}\right]$$

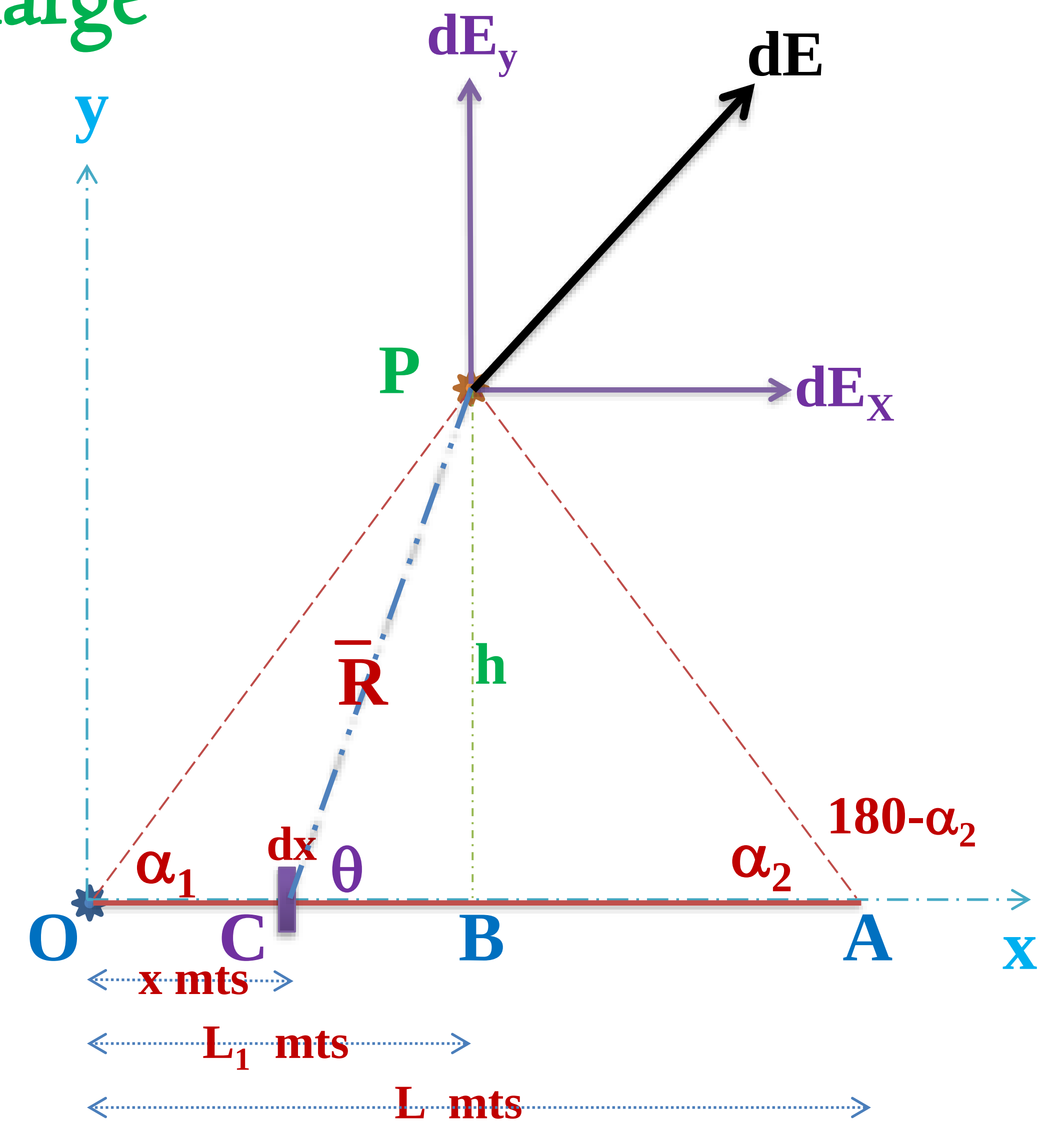
$$\boxed{E = 6.82u_x + 6.82u_y + 32.8u_z\,\mathrm{V/m}}$$

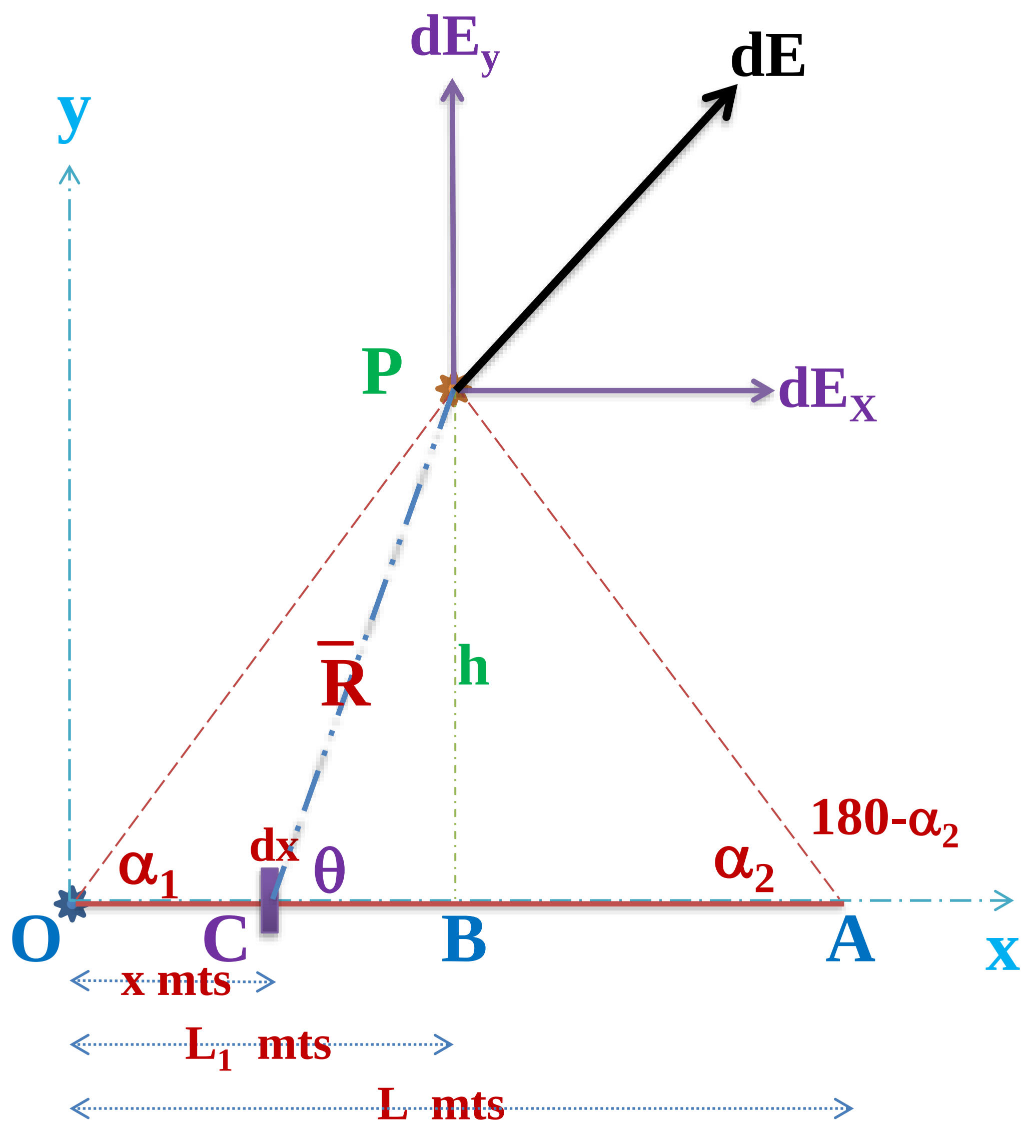
Answer

EFI due to Line Charge

Consider a line charge with uniform charge density ρ_l C/m extending from O to A along x-axis.

Let P be the field point which is at a perpendicular distance of 'h' mts from the line charge.





dEy
dE
y
P
dEX
R̄
h
180-α2
dx
α1
θ
α2
O
C
B
A
x
x mts
L1 mts
L mts

Consider a small differential length ‘dx’ at distance of ‘x’ from the origin

Line charge associated with that element is given by

$$dQ = \rho_L dl \qquad dQ = \rho_L dx$$

$$\overrightarrow{dE} = \frac{dQ}{4\pi\varepsilon_O R^2}\overrightarrow{u_R} \qquad dE = \frac{dQ}{4\pi\varepsilon_O R^2}$$

$$dE = \frac{\rho_L dx}{4\pi\varepsilon_O R^2} \qquad (\because dQ = \rho_L dl)$$

(Eqn. 1)

From Δ PBC $\quad \cot\theta = \dfrac{l_1 - x}{h}$

$$l_1 - x = h\cot\theta \qquad -dx = -h(\operatorname{cosec}^2\theta)d\theta$$

$$dx = h(\operatorname{cosec}^2\theta)d\theta$$

(Eqn. 2)

$$\operatorname{cosec}\theta = \frac{R}{h} \qquad h(\operatorname{cosec}\theta) = R$$

(Eqn. 3)

$$dE = \frac{\rho_L dx}{4\pi\varepsilon_O R^2}$$

From Eqn. 1, 2 & 3

$$dE = \frac{\rho_L * h * \operatorname{cosec}^2\theta * d\theta}{4\pi\varepsilon_O h^2 * \operatorname{cosec}^2\theta}$$

$$dE = \frac{\rho_L}{4\pi\varepsilon_O h} d\theta$$

(Eqn. 4)

$$dE_x = dE \cos\theta$$

(Eqn. 5)

From Eqn. 4 & 5 $$dE_x = \frac{\rho_L}{4\pi\varepsilon_o h}\cos\theta d\theta$$

Component of Total EFI due to the whole line charge along x-axis is:

$$E_x = \int_{\alpha_1}^{\beta} \frac{\rho_L}{4\pi\varepsilon_o h}\cos\theta d\theta \qquad \beta = 180 - \alpha_2$$

$$E_x = \int_{\alpha_1}^{180-\alpha_2} \frac{\rho_L}{4\pi\varepsilon_o h}\cos\theta d\theta$$

$$E_x = \frac{\rho_L}{4\pi\varepsilon_O h}\left(\sin\theta\right)_{\alpha_1}^{180-\alpha_2}$$

$$E_x = \frac{\rho_L}{4\pi\varepsilon_O h}\left(\sin\alpha_2 - \sin\alpha_1\right)$$

Component of Total EFI due to the whole line charge along y-axis is:

$$dE_y = dE \sin\theta$$

$$dE_y = \frac{\rho_L}{4\pi\varepsilon_O h} \sin\theta d\theta$$

$$E_y = \int_{\alpha_1}^{\beta} \frac{\rho_L}{4\pi\varepsilon_O h} \sin\theta d\theta$$

$$\beta = 180 - \alpha_2$$

$$E_y = \int_{\alpha_1}^{180-\alpha_2} \frac{\rho_L}{4\pi\varepsilon_O h} \sin\theta d\theta$$

$$E_y = \frac{\rho_L}{4\pi\varepsilon_o h}\left(-\cos\theta\right)_{\alpha_1}^{180-\alpha_2}$$

$$E_y = \frac{\rho_L}{4\pi\varepsilon_o h}\left(\cos\alpha_2 + \cos\alpha_1\right)$$

Total EFI due to the whole line charge:

$$\overrightarrow{E} = \overrightarrow{E_x} + \overrightarrow{E_y}$$

$$\overrightarrow{E} = E_x \overrightarrow{u_x} + E_y \overrightarrow{u_y}$$

$$\overrightarrow{E} = \frac{\rho_L}{4\pi\varepsilon_O h}\left[(\sin\alpha_2 - \sin\alpha_1)\overrightarrow{u_x} + (\cos\alpha_2 + \cos\alpha_1)\overrightarrow{u_y}\right]$$

Note

For an infinite line charge extending from $-\infty$ to $+\infty$ on x-axis α_I to α_2 becomes '0'.

$$\vec{E} = \frac{\rho_L}{4\pi\varepsilon_O h}\left[2\overrightarrow{u_y}\right] \qquad \vec{E} = \frac{\rho_L}{2\pi\varepsilon_O h}\overrightarrow{u_y}$$

Note

If the field point 'P' is located on the perpendicular drawn from middle point of a line charge then

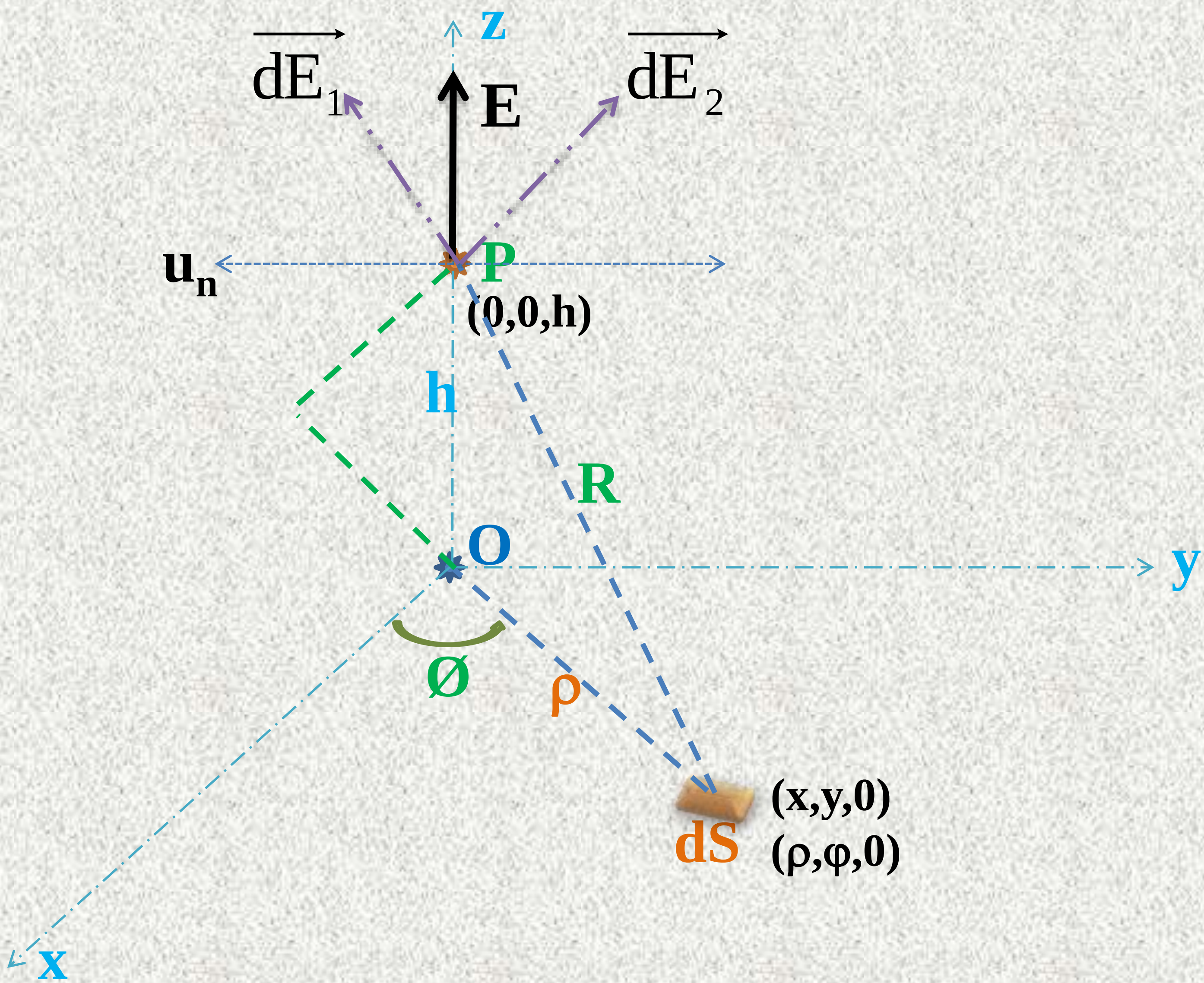
$$\alpha_1 = \alpha_2 = \alpha$$

$$\vec{E} = \frac{\rho_L}{4\pi\varepsilon_o h}\left[2\cos\alpha\,\overrightarrow{u_y}\right] \qquad \vec{E} = \frac{\rho_L}{2\pi\varepsilon_o h}\cos\alpha\,\overrightarrow{u_y}$$

EFI due to Surface Charge

Consider a infinite sheet of charge in x-y plane with uniform charge density ρ_S C/m^2.

ELECTROSTATICS - EFI – Due to Surface Charge



The charge associated with element dS is

$$dQ = \rho_S dS$$

$$\text{Total Charge 'Q'} = \int_S \rho_S dS$$

$$\text{EFI due to element is } \overrightarrow{dE} = \frac{dQ}{4\pi\varepsilon_O R^2}\overrightarrow{u_R}$$

$$R = \left|\overrightarrow{R}\right| = -x\overrightarrow{u_x} - y\overrightarrow{u_y} + h\overrightarrow{u_z}$$

$$-(x\overrightarrow{u_x} + y\overrightarrow{u_y}) + h\overrightarrow{u_z}$$

$$\therefore R = \sqrt{x^2 + y^2 + h^2} \qquad \text{But } \rho^2 = x^2 + y^2$$

$$\therefore R = \sqrt{\rho^2 + h^2} \qquad \& \qquad \vec{R} = -\rho\,\overrightarrow{u_\rho} + h\,\overrightarrow{u_z}$$

u_ρ is the unit vector along ρ

$$\overrightarrow{dE} = \frac{dQ}{4\pi\varepsilon_O R^3}\vec{R} \qquad \overrightarrow{dE} = \frac{\rho_S dS}{4\pi\varepsilon_O R^3}\vec{R}$$

But $dS = \rho * d\rho * d\emptyset$

$$\overrightarrow{dE} = \frac{\rho_S(\rho * d\rho * d\phi)}{4\pi\varepsilon_O R^3}\vec{R}$$

$$\overrightarrow{dE} = \frac{\rho_S(\rho * d\rho * d\phi)}{4\pi\varepsilon_O(\rho^2 + h^2)^{3/2}}\left(-\rho\overrightarrow{u_\rho} + h\overrightarrow{u_z}\right)$$

Due to symmetry of the charge distribution for every element (I), there is a corresponding element (2) whose contribution along u_ρ cancels with that of element (I)

$E_\rho = 0$ & E has only z-component

$$\overrightarrow{dE} = \frac{\rho_S(\rho * d\rho * d\phi)}{4\pi\varepsilon_O(\rho^2 + h^2)^{3/2}} h\overrightarrow{u_z}$$

$$\vec{E} = \int_S \frac{\rho_S(\rho * d\rho * d\phi)}{4\pi\varepsilon_o(\rho^2 + h^2)^{3/2}} h\overrightarrow{u_z}$$

$$\vec{E} = \frac{\rho_S h}{4\pi\varepsilon_o} \int_{\rho=0}^{\infty} \int_{\phi=0}^{2\pi} \frac{\rho * d\rho * d\phi}{(\rho^2 + h^2)^{3/2}} \overrightarrow{u_z}$$

$$\vec{E} = \frac{\rho_S h}{4\pi\varepsilon_o} 2\pi \int_{\rho=0}^{\infty} \frac{\rho * d\rho}{(\rho^2 + h^2)^{3/2}} \overrightarrow{u_z}$$

$$\vec{E} = \frac{\rho_S h}{2\varepsilon_o} \int_{\rho=0}^{\infty} (\rho^2 + h^2)^{-3/2} \rho * d\rho \overrightarrow{u_z}$$

$$\vec{E} = \frac{\rho_S h}{2\varepsilon_o}\left[-(\rho^2 + h^2)^{-1/2}\right]_0^\infty \overrightarrow{u_z}$$

$$\vec{E} = \frac{\rho_S h}{2\varepsilon_o}\left[\frac{1}{\sqrt{(\rho^2 + h^2)}}\right]_0^\infty \overrightarrow{u_z}$$

$$\vec{E} = \frac{\rho_S h}{2\varepsilon_o}\left[\frac{1}{h}\right]\overrightarrow{u_z}$$

$$\vec{E} = \frac{\rho_S}{2\varepsilon_o}\overrightarrow{u_z} \quad \text{V/m}$$

Note

In general EFI due to an infinite surface area with uniform surface charge density $\rho_S C/m^2$ is given by

$$\vec{E} = \frac{\rho_S}{2\varepsilon_O}\overrightarrow{u_n} \quad V/m$$

Where u_n is the normal to the surface

Note

The electric field intensity at any point in between the parallel plate capacitor is

$$\vec{E} = \frac{\rho_S}{\varepsilon_O} \vec{u_n} \quad V/m$$

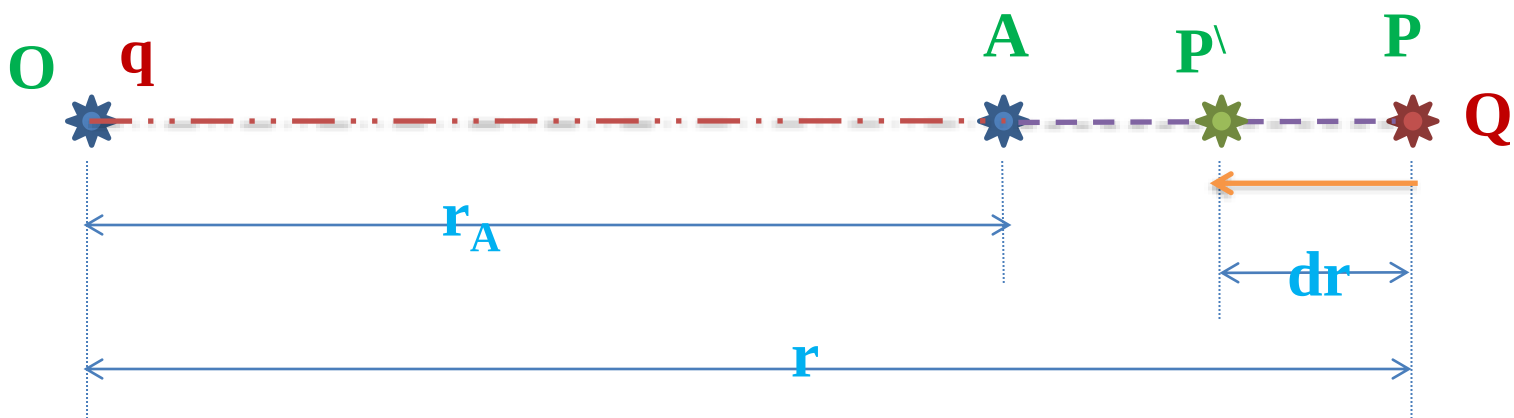
Work done in moving a Point Charge

In electrostatic case, the zero reference potential is considered to be at infinity. Thus the electrostatic potential at a point is the work done in bringing a point charge from infinity upto the point per unit charge.

If ‘Q’ is the point charge which is imagined to be brought from infinity upto a point &

‘W’ is the work done in the process, then the electrostatic potential ‘V’ at the point is given by

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



For understanding, let us consider that both q & Q both have a +ve sign. Then the coulomb force between them is that of repulsion. The magnitude of this force 'F' :

$$F = \frac{q*Q}{4\pi\varepsilon_o r^2}$$

(Eqn. 1)

The element of work done dW in moving the point charge Q against this coulomb force from P to P\ through the infinitesimal (tiny or microscopic) distance dr is

$$dW = \frac{q*Q}{4\pi\varepsilon_o r^2} dr$$

(Eqn. 2)

Work done (W) in moving the point charge from infinity ($r = \infty$) upto ($r=r_A$) is obtained by integrating Eqn.2

$$W = \int dW = \int_{r_A}^{\infty} \frac{q*Q}{4\pi\varepsilon_o r^2} dr$$

$$W = \frac{q*Q}{4\pi\varepsilon_o}\left[-\frac{1}{r}\right]_{r_A}^{\infty}$$

$$W = \frac{q*Q}{4\pi\varepsilon_o r_A}$$

Electrostatic Potential (V_A)

$$V_A = \frac{W}{Q} = \frac{q}{4\pi\varepsilon_o r_A}$$

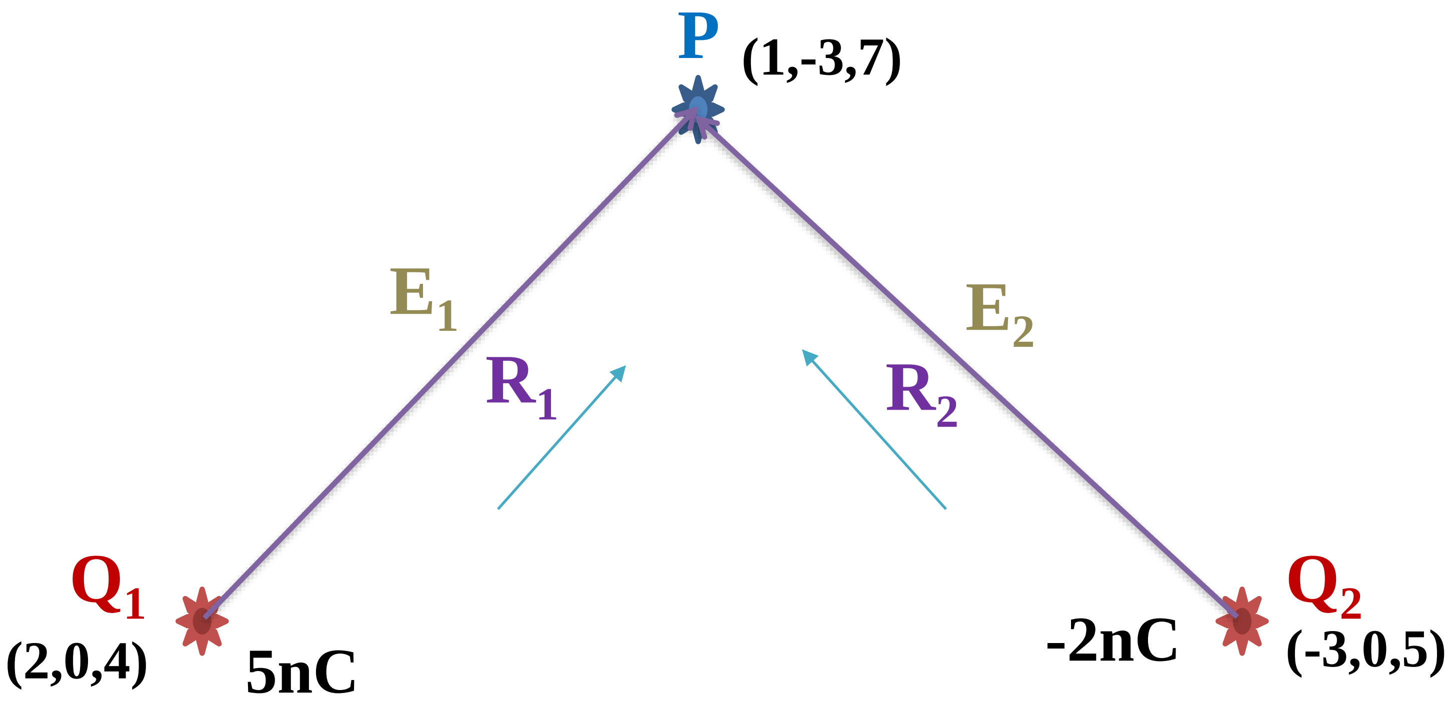
Electrostatic Potential V at a distance 'r' from the point charge q may be written as

$$V = \frac{q}{4\pi\varepsilon_o r}$$

PROBLEM

Point charges 5nC & -2nC are located at (2,0,4) & (-3,0,5) respectively. Find E at (1,-3,7)

Solution



Solution

$$\overrightarrow{E_1} = \frac{Q_1}{4\pi\varepsilon_O R_1^{\ 2}}\overrightarrow{u_{R1}}$$

$$\overrightarrow{R_1} = -1\overrightarrow{u_x} - 3\overrightarrow{u_y} + 3\overrightarrow{u_z} \qquad \left|\overrightarrow{R_1}\right| = \sqrt{1+9+9} = \sqrt{19}$$

$$\overrightarrow{E_1} = \frac{5*10^{-9} \times 9*10^{9}}{19\times\sqrt{19}}\left(-\overrightarrow{u_x} - 3\overrightarrow{u_y} + 3\overrightarrow{u_z}\right)$$

$$\overrightarrow{E_1} = \left(-0.543\overrightarrow{u_x} - 1.63\overrightarrow{u_y} + 1.63\overrightarrow{u_z}\right)$$

$$\overrightarrow{E_2} = \left(-0.46\overrightarrow{u_x} + 0.346\overrightarrow{u_y} - 0.23\overrightarrow{u_z}\right)$$

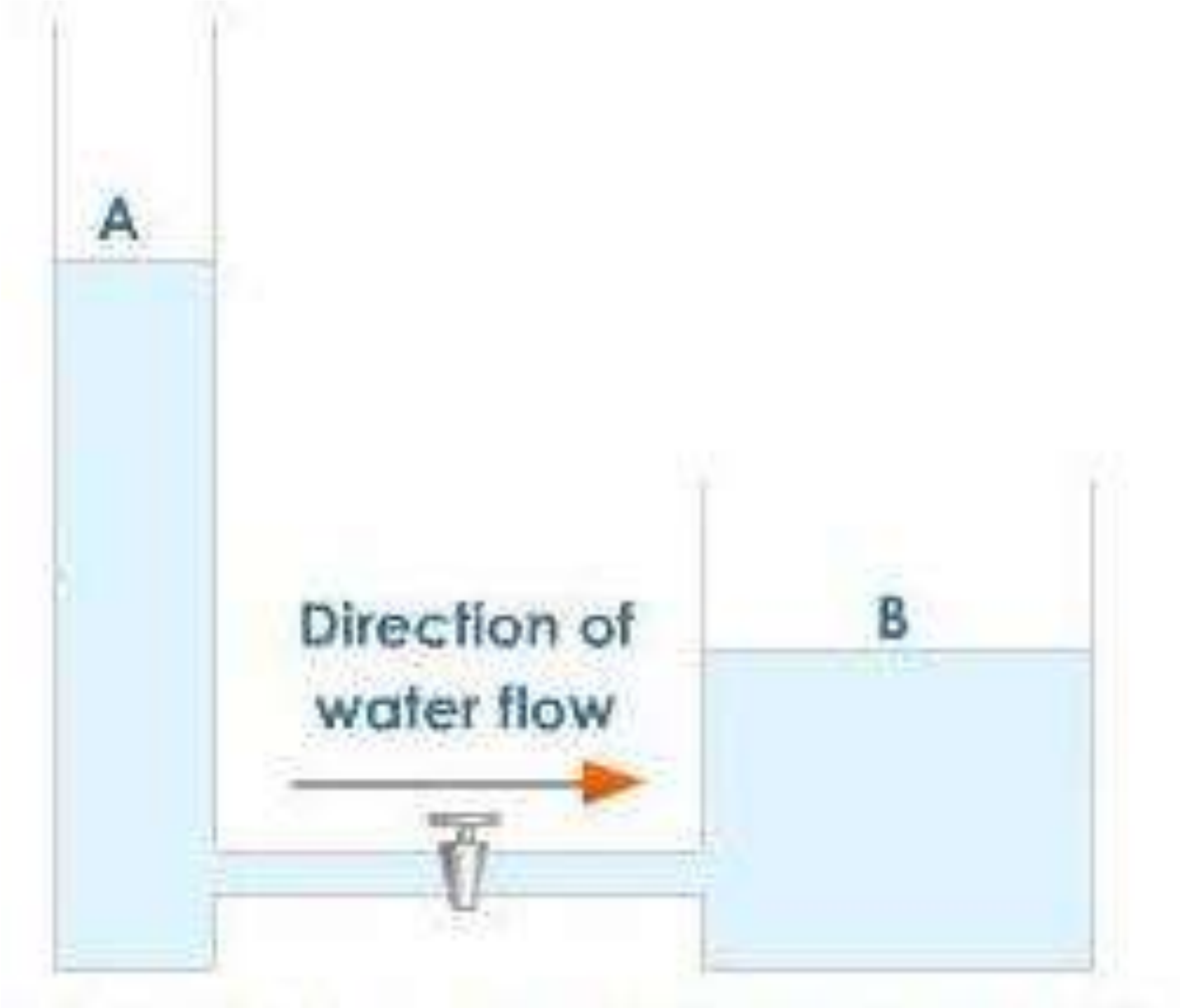
Solution

$$\vec{E} = \vec{E_1} + \vec{E_2}$$

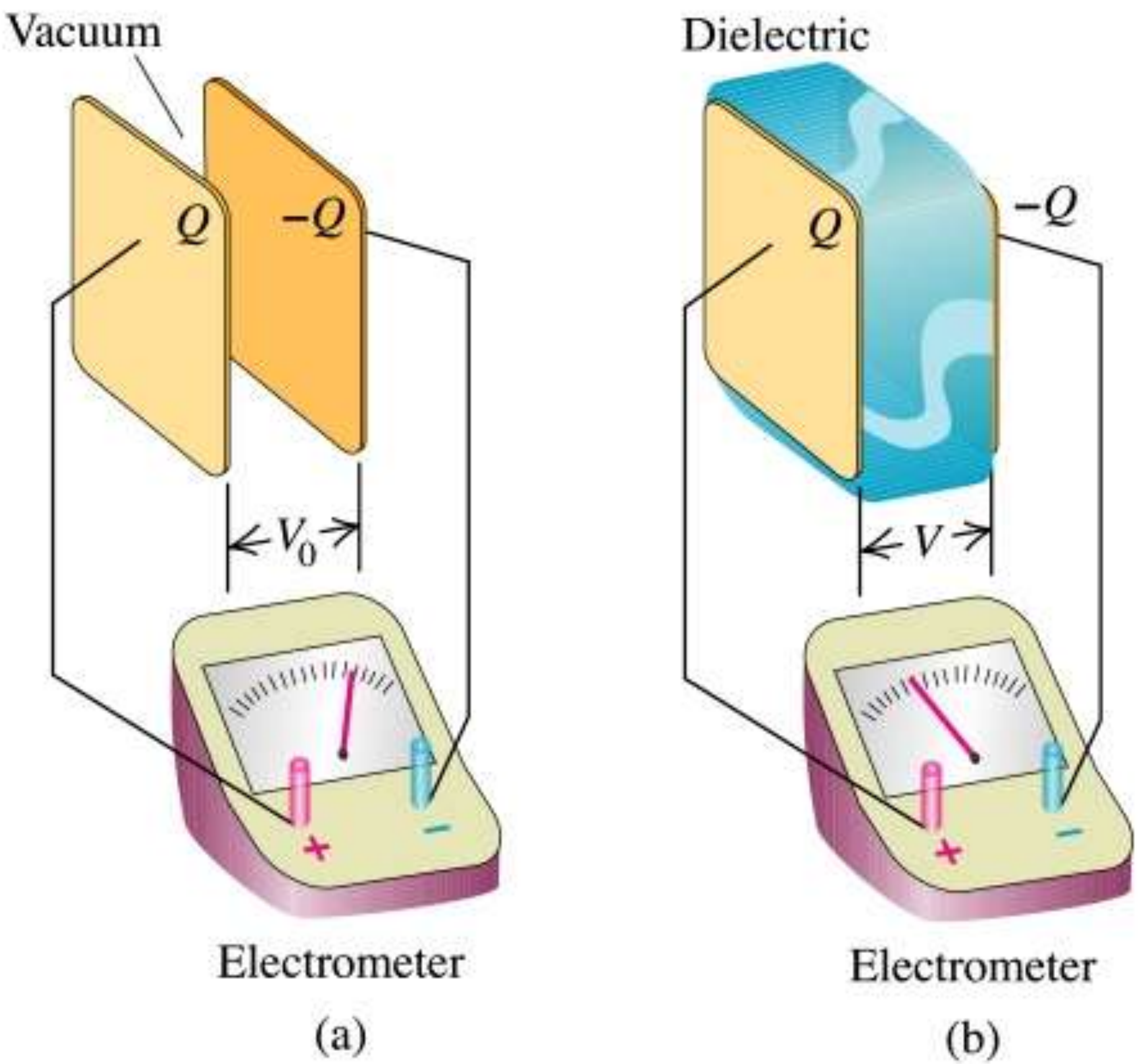
$$\boxed{\vec{E} = -\vec{u_x} - 1.284\vec{u_y} + 1.43\vec{u_z}}$$

Answer

Potential Difference (PD)



ELECTROSTATICS - Potential Difference



Potential Difference (PD)

$$W = -Q \int_{\text{Initial}}^{\text{Final}} E \, dL$$

Work done in moving a unit positive charge from one point to another in an Electric Field.

$$PD = V = \frac{W}{Q} = -\int_{\text{Initial}}^{\text{Final}} E \, dL$$

PD will be between two points.

$$V_{AB} = -\int_A^B E \, dL$$

V_{AB} is +ve if work done in carrying the +ve charge from A to B.

$$\vec{E} = E_r \vec{u_r}$$

'r' is the distance of A & B from origin

$$\vec{E} = \frac{Q}{4\pi\varepsilon_o r^2}\vec{u_r}$$

$$dL = d_r \overrightarrow{u_r}$$

$$V_{AB} = -\int_A^B E\, dL$$

$$V_{AB} = -\int_{r_A}^{r_B} \frac{Q}{4\pi\varepsilon_O r^2}\, dr$$

$$V_{AB} = \frac{Q}{4\pi\varepsilon_O}\left(\frac{1}{r_B} - \frac{1}{r_A}\right)$$

If $r_A > r_B$, the PD V_{AB} is +ve

A point rather than the potential difference between two points is said to be 'Potential'.

Measure every PD with respect to specified reference point which we consider to have zero potential.

Potential at any point is the PD between that point & a chosen point (reference point) at which potential is zero.

$$V_{AB} = V_A - V_B$$

V_A - Potential at point A

V_B - Potential at Point B

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

$$W_E = \frac{1}{2}\int_L \rho_L V \, dL \rightarrow \text{line charge}$$

$$W_E = \frac{1}{2}\int_S \rho_S V \, dS \rightarrow \text{Surface charge}$$

$$W_E = \frac{1}{2}\int_V \rho_V V \, dv \rightarrow \text{Volume charge}$$

$$\rho_v = \nabla D$$

$$D = \varepsilon E$$

$$E = -\nabla V$$

$$W_E = \frac{1}{2}\int_V D E \, dv = \frac{1}{2}\int_V \varepsilon E^2 \, dv$$

$$w_E = \frac{1}{2}\varepsilon E^2$$ ← electrostatic energy density

energy stored in a given system or region of space

Charge / unit area that would be displaced across a layer of conductor placed across electric field

Vector operator that operates on vector field produces scalar of VF

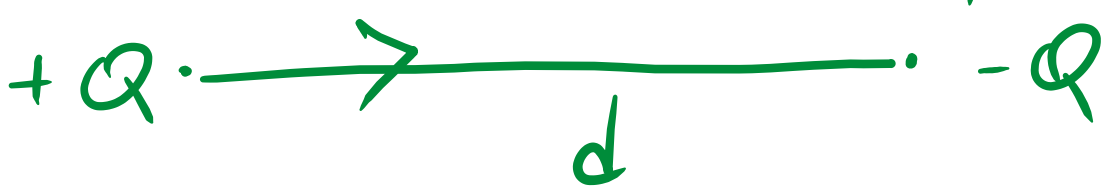
Charge / unit area

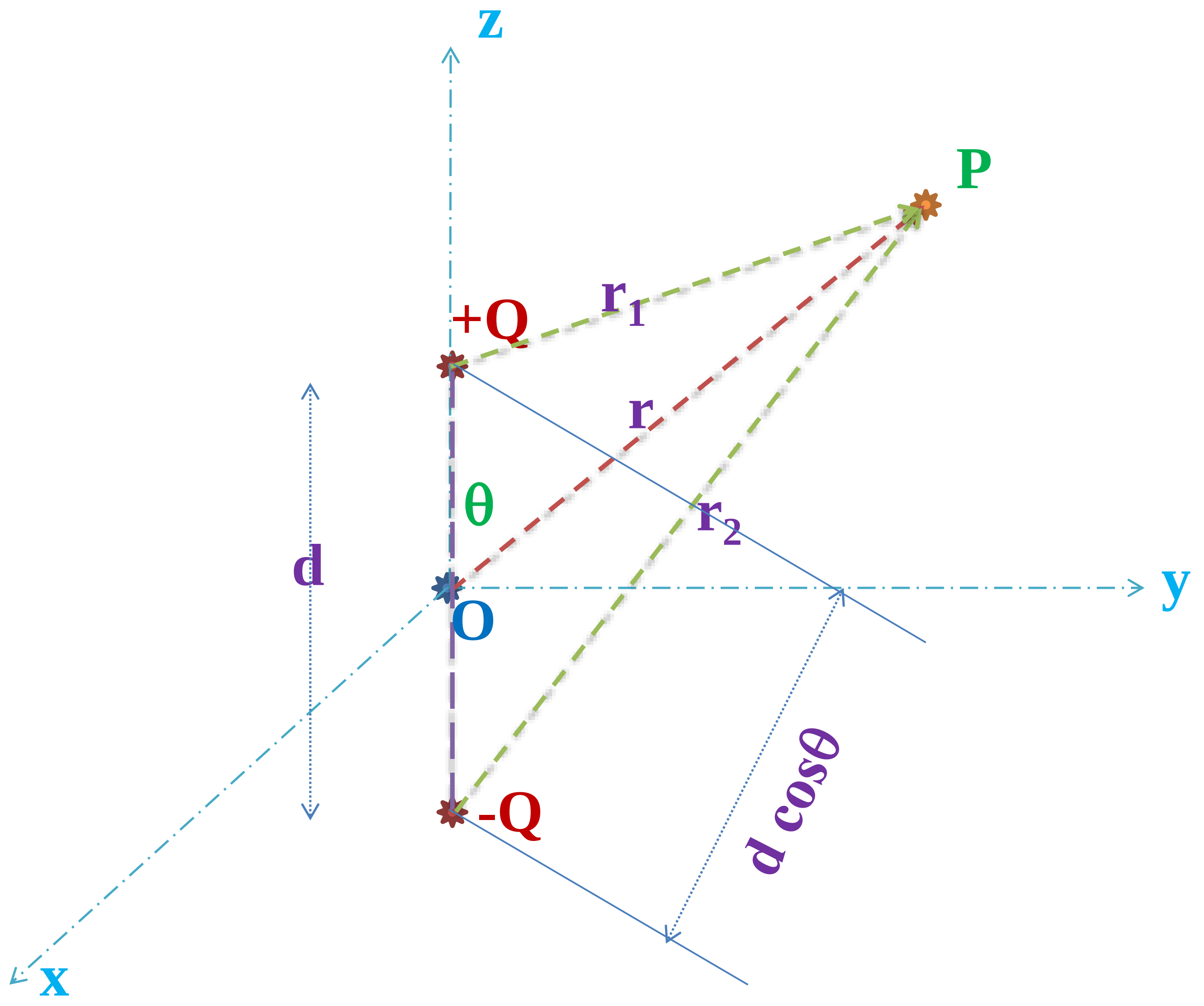
Electric Dipole

- Dipoles are quite important because they form the basis for the behavior of dielectric materials in electric fields.

- An electric dipole is the name given to two point charges of equal magnitude & opposite sign, separated by a distance which is small compared to the distance to the point P at which we want to know the electric & potential fields.

$P = Qd$




z
P
r_1
+Q
r
θ
r_2
d
y
O
d cosθ
-Q
x

- Potential at Point P(r,θ,ϕ) is given by

$$V = \frac{Q}{4\pi\varepsilon_o}\left[\frac{1}{r_1} - \frac{1}{r_2}\right]$$

$$V = \frac{Q}{4\pi\varepsilon_o}\left[\frac{r_2 - r_1}{r_1 r_2}\right]$$

(Eqn. 1)

- r_I is the distance between P & +Q
- r_2 is the distance between P & -Q

If r>>d

Then $r_2 - r_1 = d\cos\theta$

$$r_1 r_2 = r^2$$

$$V = \frac{Q}{4\pi\varepsilon_o}\left[\frac{d*\cos\theta}{r^2}\right]$$

(Eqn. 2)

$$d*\cos\theta = \vec{d}.\overrightarrow{u_r}$$

$$\vec{d} = d.\overrightarrow{u_z}$$

Dipole moment p=Qd

(Eqn. 3)

Eq. 2 is written as

$$V = \frac{p u_r}{4\pi\varepsilon_O r^2}$$

(Eqn. 4)

Dipole moment p is directed from –Q to +Q. If the dipole centre is not at the origin but at r^I

Eq (4) becomes as

$$V(r) = \frac{p(r - r^1)}{4\pi\varepsilon_O \left| r - r^1 \right|^3}$$

Electric Field due to dipole with centre at origin can be obtained from $E = -\nabla V$

$$E = -\left[\frac{\partial V}{\partial r} u_r + \frac{1}{r} \frac{\partial V}{\partial \theta} u_\theta \right]$$

$$E = \frac{P}{4\pi\varepsilon_O r^3} \left(2\cos\theta u_r + \sin\theta u_\theta \right)$$

Gauss Theorem:

Total flux enclosed by the Surface is $\propto$ total charge enclosed

$$\phi \propto q_{\text{(enclosed surface)}}$$

$$\phi = \frac{1}{\varepsilon_0} \cdot q$$

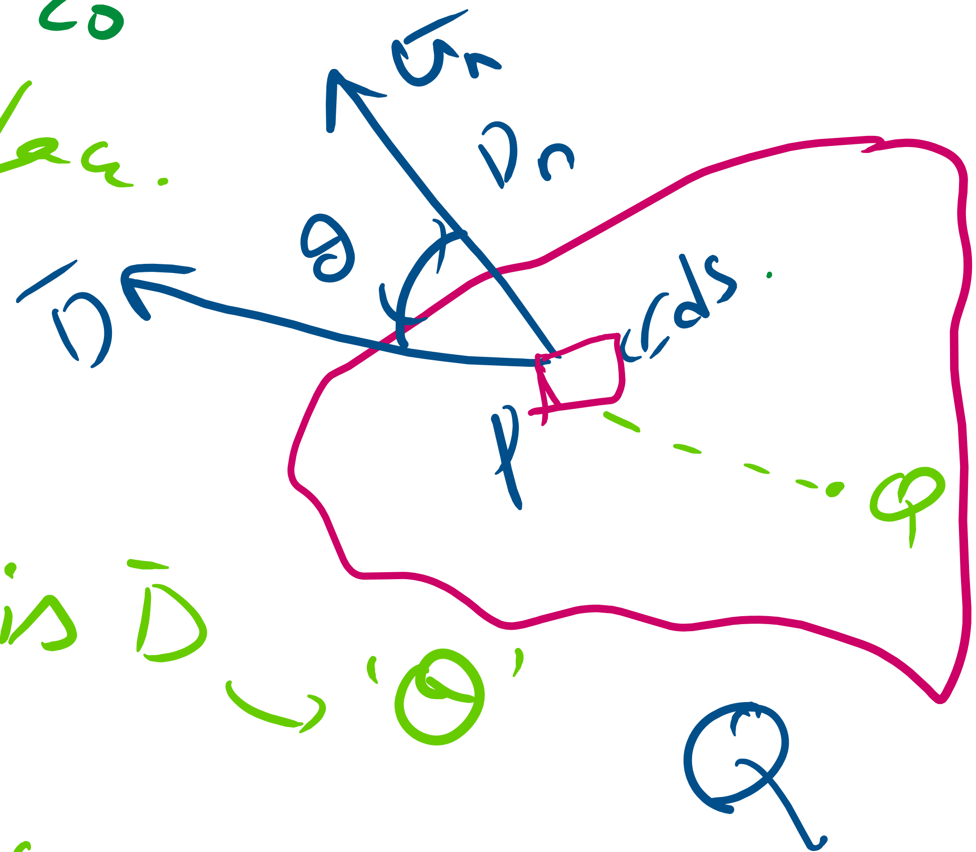
$$\phi = \frac{q}{\varepsilon_0}$$

Surface

$$\oint_S \bar{E}\, d\bar{s} = \frac{q}{\varepsilon_0} = \phi_{enclosed}$$

Gaussian Surface

$$d\bar{S} = ds\, \bar{u}_n$$



Flux density is $\bar{D}$ → 'Θ'

$$d\Psi = D_n\, ds$$

$$D_n = \bar{D} \cos\theta$$

$$\psi = Q = \int_L \rho_L \, dL$$

$$\psi = Q = \int_S \rho_S \, dS$$

$$\psi = Q = \int_V \rho_V \, dV$$

Common form

$$\psi = Q = \oint_S \bar{D} \cdot d\bar{S} = \int_V \rho_V \, dV$$

D = Electric flux density

$$\bar{D} = \frac{d\psi}{ds}\,\bar{u}_n$$

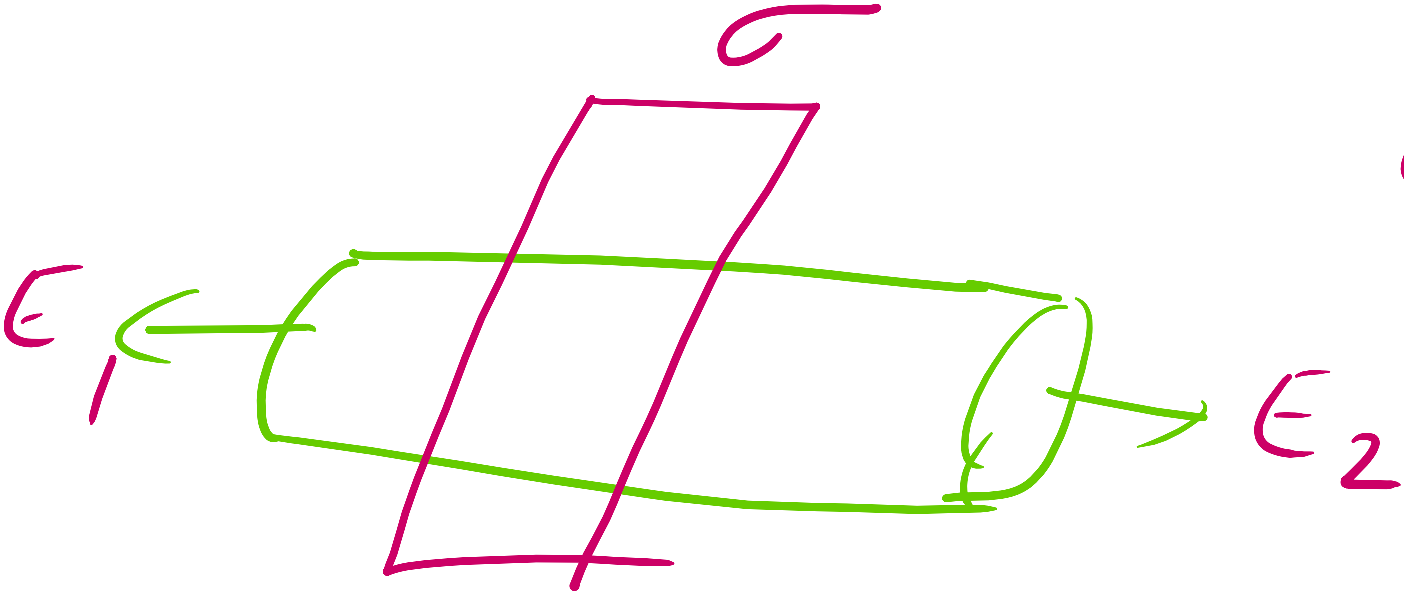
$$\bar{D} = \varepsilon\bar{E}$$

$\psi = Q$

$S = 4\pi r^2$

$$|\bar{D}| = \frac{Q}{4\pi r^2}$$

$$\bar{D} = \frac{Q}{4\pi r^2}\,\bar{u}_n \ C/m^2$$



$$E = \frac{\sigma}{2\varepsilon_0}$$

$$\phi_{net} = \oint \bar{E} \cdot d\bar{s} = \frac{q_{en}}{\varepsilon_0}$$

$$E_1(ds) + 0 + E_2(ds) = \sigma(ds)/\varepsilon_0$$

$$2E(\cancel{ds}) = \sigma(\cancel{ds})/\varepsilon_0$$

EFI – volume charge d

ΔQ in a small volume Δv

$$\Delta Q = \rho_v \Delta V$$

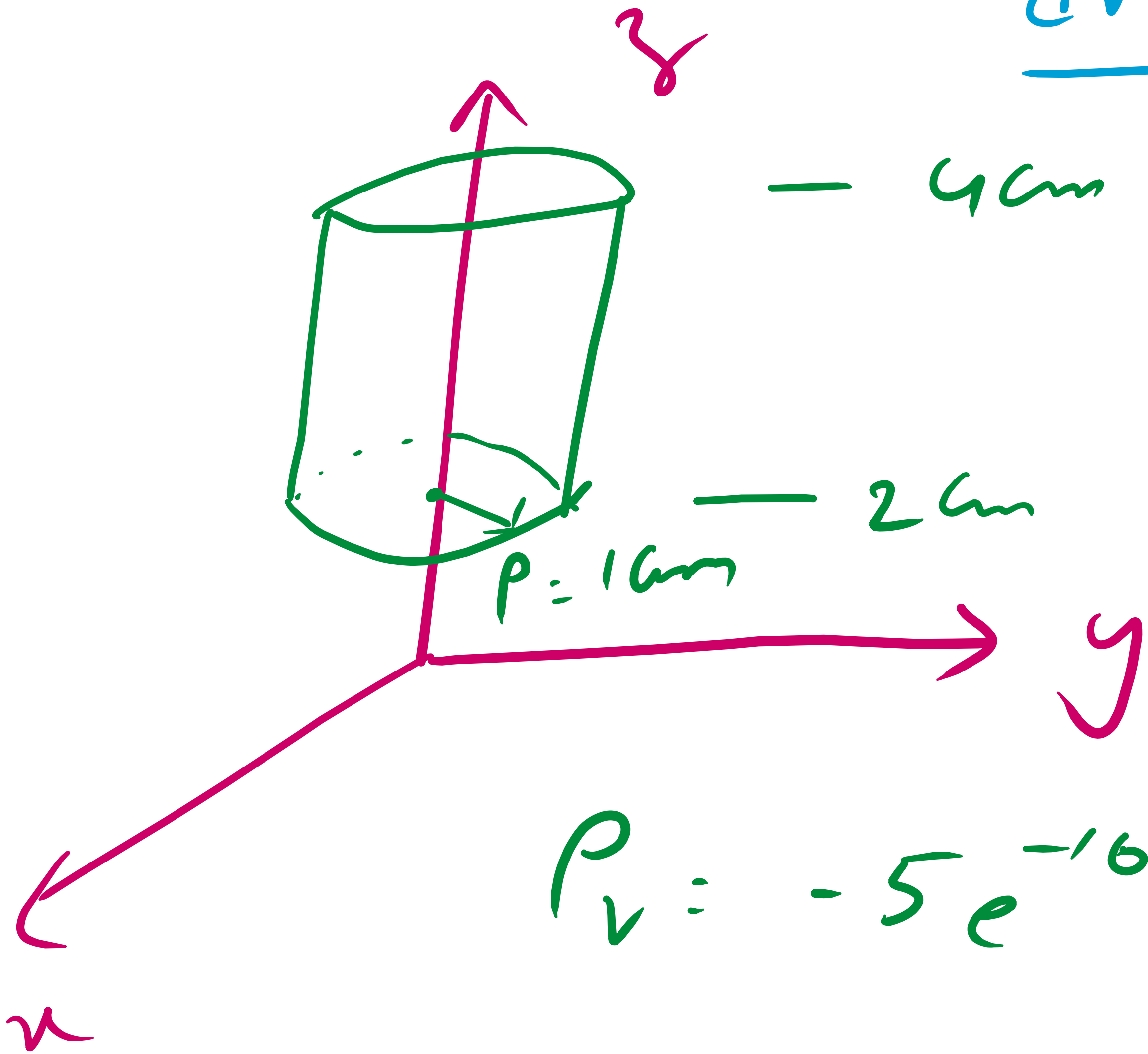
$$\rho_v = \left.\frac{\Delta Q}{\Delta v}\right|_{\Delta v \to 0}$$

$$Q = \int_v \rho_v \, dv$$

$$\bar{E} = \frac{Q}{4\pi\epsilon_0 |R|} \bar{u}_r$$

$$\bar{E} = \frac{\int \rho_v \, dv}{4\pi\epsilon_0 r^2} \bar{u}_r$$

$dv = \rho \, d\phi \, d\rho \, dz$



$\rho_v = -5e^{-10\rho z} \; \mu C/m^3$

$$\Phi = \int_V \rho_v \, dv$$

$$= \int_{\rho=0}^{0.01} \int_{\phi=0}^{2\pi} \int_{z=0.02}^{0.04} -5e^{-10} \rho \, d\phi \, d\rho \, dz$$

$$= -7.854 \times 10^{-14} \, C$$

Find the force of interaction two charges spaced 10cm apart in a vaccum. The charges are 4 x 10^{-8} and 4 x 10^{-5} Coulomb respectively if the same charges are separated by the same distance in kerosene what is the corresponding force interaction?

$$\mathrm{q}_1 = 4 \times 10^{-8}\ \text{coulomb}$$

$$\mathrm{q}_2 = 6 \times 10^{-5}\ \text{coulomb}$$

$$r_{12} = 10cm = 0.1m$$

$$\epsilon_0 = \left(\frac{1}{36\pi \times 10^9}\right)$$

$$K = \frac{1}{4\pi\epsilon_0} = \frac{1}{4\pi} 36\pi 10^9 = 9 \times 10^9$$

$$F_{12} = K\left(\frac{q_1 q_2}{r_{12}^2}\right)\mu_{12} = \frac{9\times10^9\times4\times10^{-8}\times6\times10^{-5}}{(0.1)^2} = \mu_{12} \quad = 2.16$$

For Kerosene $\epsilon_r = 2$

$$F_{12} = \frac{2.16}{2} = 1.08\, NW$$

Two small identical conducting spheres have charge of -1 nano coulombs and 2 nano coulombs respectively if they are brought in contact & separate by 5cm what in the force b/w then?

$$q_1 = -1 \times 10^{-9} c \qquad\qquad r = 4 \times 10^{-2}\mathrm{m}$$

$$\mathrm{q}_2 = 2 \times 10^{-9}\mathrm{c}$$

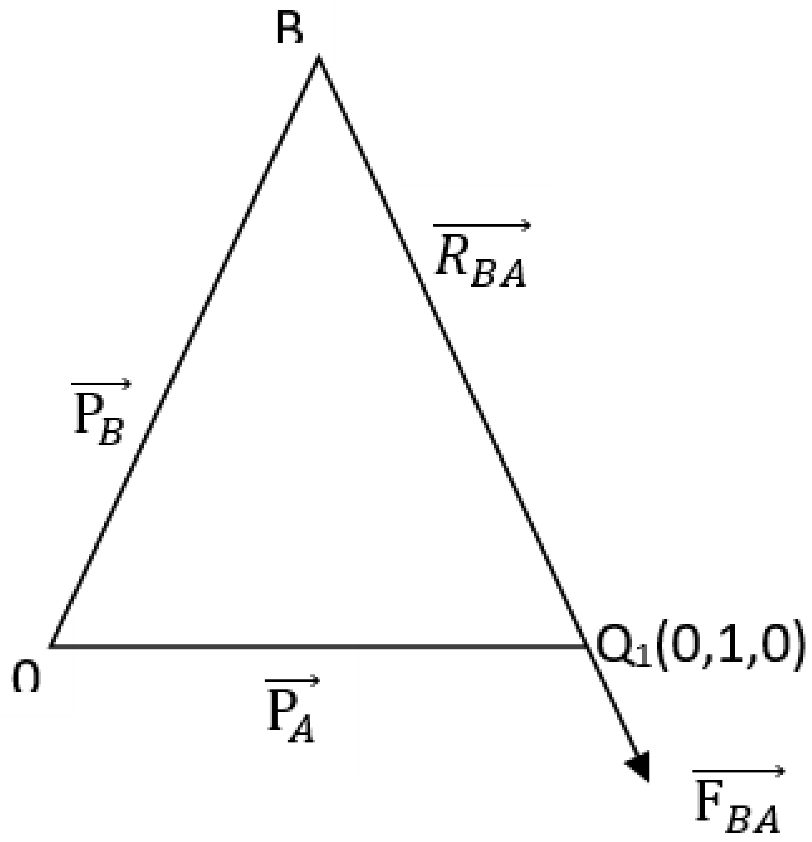
$$\mathrm{q} = \frac{\mathrm{q}_1 + \mathrm{q}_2}{2} = \frac{(-1+2)\times 10^{-9}}{2}$$

$$= 0.5 \times 10^{-9} c$$

$$F = \frac{q_1 q_2}{4\pi\epsilon_0 r^2}$$

$$= \frac{\left(0.5\times10^{-9}\right)^2}{4\pi\mathrm{r}\frac{1}{36\pi\times10^9}} \times 4 \times 10^{-4} = 5.625\ \mu\mathrm{N}$$

Find the force on a charge Q_1 given by 20µc due to charge Q_2 given by 300µc where Q_1 is at (0,1,2)m and Q_2 at (2,0,0)m



Position vectors of Q1, & Q2 are given, force is found out using the equation

$$\overrightarrow{F_{BA}} = \frac{Q_1 Q_2}{4\pi\epsilon_0 R^3}\overrightarrow{R_{BA}}$$

$$\overrightarrow{R_{BA}} = \overrightarrow{R_A} - \overrightarrow{R_B}$$

$$R = \left|\overrightarrow{R_{BA}}\right|$$

$$Q_1 = 20 \times 10^{-6}C$$

$$Q_2 = -300 \times 10^{-6}C$$

$$\overrightarrow{\mathrm{r_A}} = (0,1,2), \qquad \overrightarrow{\mathrm{r_B}} = (2,0)$$

$$\overrightarrow{\mathrm{R_{BA}}} = (0,1,2) - (2,0,0) \quad = (-2,1,2)$$

$$\mathrm{R} = \sqrt{(-2)^2 + (1)^2 +} (2)^2 = 3\mathrm{m}$$

$$\overrightarrow{\mathrm{F_{BA}}} = \frac{20 \times 10^{-6} \times (-300) \times 10^{-6}}{4\pi \times 8.87 \times 10^{-12} \times 3^3} \ (-2,1,2)$$

$$= -1.99(-2\overrightarrow{a_x} + \overrightarrow{a_y} + 2\overrightarrow{a_z}$$

$$\overrightarrow{\mathrm{F_{BA}}} = 3.98\overrightarrow{a_x} - 1.99\overrightarrow{a_y} - 3.98\overrightarrow{a_z}$$

Calculate the electric field intensity that will just sufficient to balance the gravitational force of an electron $(\mathbf{Q = 1.6 \times 10^{-9} c})$ and $(\mathbf{m = 9.1 \times 10^{-31} kg})$ for an electrons.

$$m = 9.1 \times 10^{-31} kg$$

$$g = 9.81\ N - m$$

$$F_g = m \times g$$

$$= 9.1 \times 10^{-31} \times 9.81$$

$$= 8.927 \times 10^{-30} N$$

$$F_g = F_e$$

$$F_e = 8.927 \times 10^{-30} N$$

Electric field intensity $E = \dfrac{F_e}{Q}$

$$\frac{F_e}{Q} = \frac{8.927 \times 10^{-30}}{1.6 \times 10^{-19}} = 5.5 \times 10^{-11} v/m$$

The force on a point charge situated 20cm away from another point charge of the same magnitude in a dielectric medium of relative permittivity 81 is 0.1N determine the magnitude of charge

$$\vec{F} = \frac{q_1 q_2}{4\pi\epsilon_0\epsilon_r R^2}\overrightarrow{a_e}$$

$$q_1 = q_2$$

$$R = 20cm = 0.2m$$

$$\vec{F} = 0.1N$$

$$q_1 q_2 = 0.1 \times 4 \times \pi \times 8.87 \times 10^{-12} \times 81 \times (0.2)^2$$

$$\mathrm{q}^2 = 3.6 \times 10^{-11}$$

$$q = 6 \times 10^{-6}$$

$$q = 6\mu c$$

Determine the potential difference b/w two points $'a'$ and $'b'$ which are at a distance of 0.5m & 0.1m from the positive charge of 20×10^{-10} coulomb.

$$V_{ab} = -\int_a^b \frac{Q}{4\pi\epsilon_0 r^2} dr$$

$$V_{ab} = \frac{Q}{4\pi\epsilon_0}\left(\frac{1}{b} - \frac{1}{a}\right)$$

$$= \frac{20 \times 10^{-10}}{4\pi \times 8.87 \times 10^{-12}} \frac{1}{0.1} - \frac{1}{0.5}$$

$$V_{ab} = 143.5V$$

Find the potential at r = 40cm , and r = 10 cm from a charge and also the potential difference b/w these two points

r = 40cm = 0.4m

$$V = \frac{Q}{4\pi\varepsilon_0 r} = \frac{2\times10^{-4}\times10^{-5}}{4\pi\times8.85\times10^{-12}\times0.4} = 4.49V$$

r = 10cm = 0.1m

$$V = \frac{2\times10^{-4}\times10^{-6}}{4\pi\times8.85\times10^{-12}\times0.1} = 17.98V$$

Potential difference = 17.98 - 4.49

= 13.49V

A uniform line charge with $\rho_L = \mu\, c/m$ lies along the x-axis find $\overline{D}$ at (6, 4, 2)m

Since, the line charge lies along x-axis Y & Z component will be zero.

The Co-ordinate of line joining line charge along x-axis & the point (6, 4, 2) is (4, 2) - (0, 0) = (4, 2) = $4\overline{a_y} + 2\overline{a_z}$

$$a_P = \frac{4\overrightarrow{a_y} + 2\overrightarrow{a_z}}{\sqrt{16+4}} = \frac{4\overrightarrow{a_y} + 2\overrightarrow{a_z}}{\sqrt{20}}$$

$$\overline{E} = \frac{\rho L}{2\pi\varepsilon_0 \rho}\overrightarrow{a_P} = 10 \times \frac{10^{-6}}{2\pi \times 8.854 \times 10^{-12}} \times \frac{4\overrightarrow{a_y} + 2\overrightarrow{a_z}}{\sqrt{20}}$$

$$\overline{E} = 40\,194.4\left(4\overrightarrow{a_y} + 2\overrightarrow{a_z}\right)$$

Electromagnetic Fields

By

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M.Tech., Ph.D., SMIEEE

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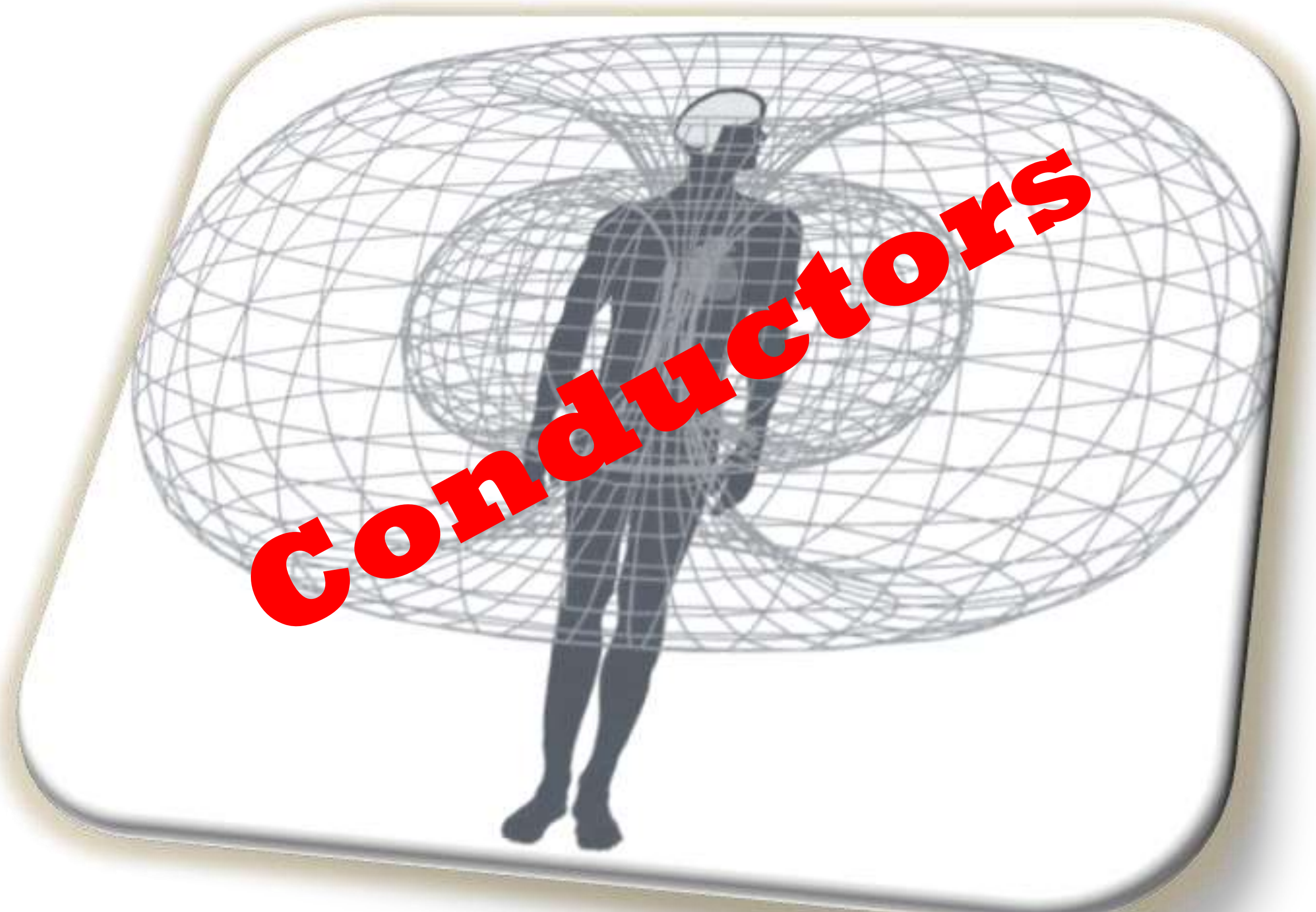
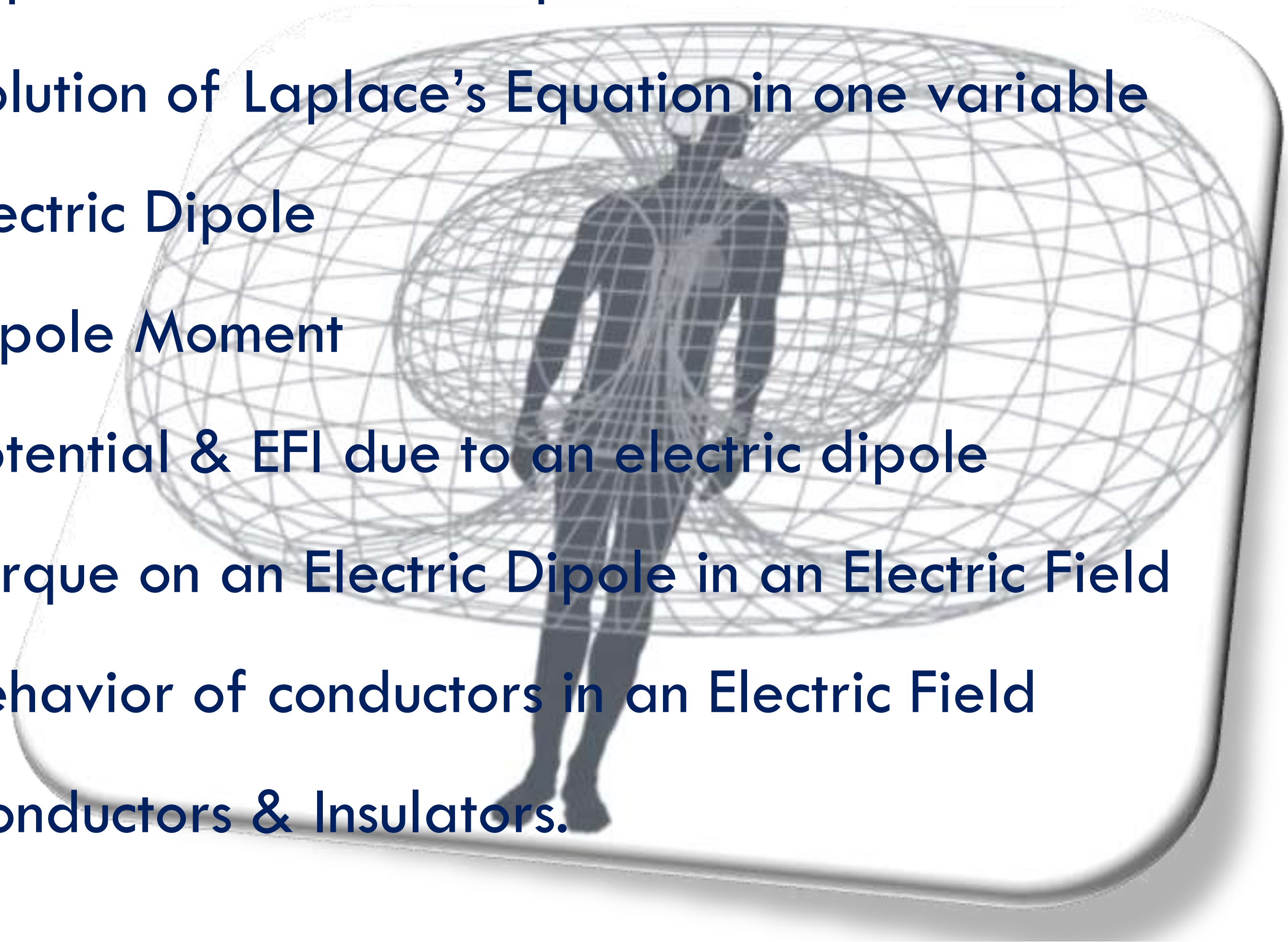
GRIET

UNIT - II



Conductors



- ✓ Laplace's & Poison’s Equation
- ✓ Solution of Laplace’s Equation in one variable
- ✓ Electric Dipole
- ✓ Dipole Moment
- ✓ Potential & EFI due to an electric dipole
- ✓ Torque on an Electric Dipole in an Electric Field
- ✓ Behavior of conductors in an Electric Field
- ✓ Conductors & Insulators.

Poison's & Laplace's Eq.

- We shall consider practical electrostatic problems where only electrostatic conditions at some boundaries are known & it is desired to find E & V throughout the region.
- For this Poison's (or) Laplace's Eq. are used.
- They are usually referred to boundary value problems. Concept of resistance & capacitance will be covered.
- Laplace's Eq. is used in deriving the resistance of an object & capacitance of a capacitor.

Poison's & Laplace's Eq.

- Poison's & Laplace's Eq. are easily derived from Gauss Law.

$$\nabla D = \rho V = \nabla \varepsilon E$$

(Eqn. 1)

$$E = -\nabla V$$

(Eqn. 2)

- 'ε' is not constant for non-homogenous equation.

Substitute in Eq. (2) in (I)

$$\nabla\left(-\varepsilon\nabla V\right)=\rho V$$

(Eqn. 3)

- For homogenous medium eq(3) become

$$\nabla^{2}V=-\frac{\rho V}{\varepsilon}$$

(Eqn. 4)

Poisson's Equation

Special case of this equation occurs when ρV=0 (charge free region)

$$\boxed{\nabla^2 V = 0} \quad \text{(Eqn. 5)}$$

Laplace Equation

Laplace Equation for RCS, CCS & SCS are

$$\frac{\partial^2 V}{\partial x^2}+\frac{\partial^2 V}{\partial y^2}+\frac{\partial^2 V}{\partial z^2}=0$$

RCS

$$\frac{1}{\rho}\frac{\partial}{\partial \rho}\left(\rho\frac{\partial V}{\partial \rho}\right)+\frac{1}{\rho^2}\frac{\partial^2 V}{\partial \phi^2}+\frac{\partial^2 V}{\partial z^2}=0$$

CCS

$$\frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\frac{\partial V}{\partial r}\right)+\frac{1}{r^2\sin\theta}\frac{\partial}{\partial \theta}\left(\sin\theta\frac{\partial V}{\partial \theta}\right)+\frac{1}{r^2\sin^2\theta}\frac{\partial^2 V}{\partial \phi^2}=0$$

SCS

1. Given V, use $E=-\nabla V$ to find E.
2. Use $D=\varepsilon E$ to find D.
3. Evaluate D at either capacitor plate $D=D_S$ $=D_N\ u_N$
4. Recognize that $\rho_S = D_N$
5. Find Q by a surface integration over the capacitor plate

We have

$$V = V_O \frac{x}{d}$$

$$E = -\frac{V_O}{d} u_X$$

$$D = -\varepsilon \frac{V_O}{d} u_X$$

$$D_S = D_{X=0} = -\varepsilon \frac{V_O}{d} u_X$$

$$Q = \int_S \rho_S dS$$

$$u_N = u_X$$

$$D_N = -\varepsilon \frac{V_O}{d} = \rho_S$$

$$Q = \int_S -\frac{\varepsilon V_O}{d} dS = -\varepsilon \frac{V_O S}{d}$$

$$C = \frac{|Q|}{V_O} = \frac{\varepsilon S}{d}$$

Conductors

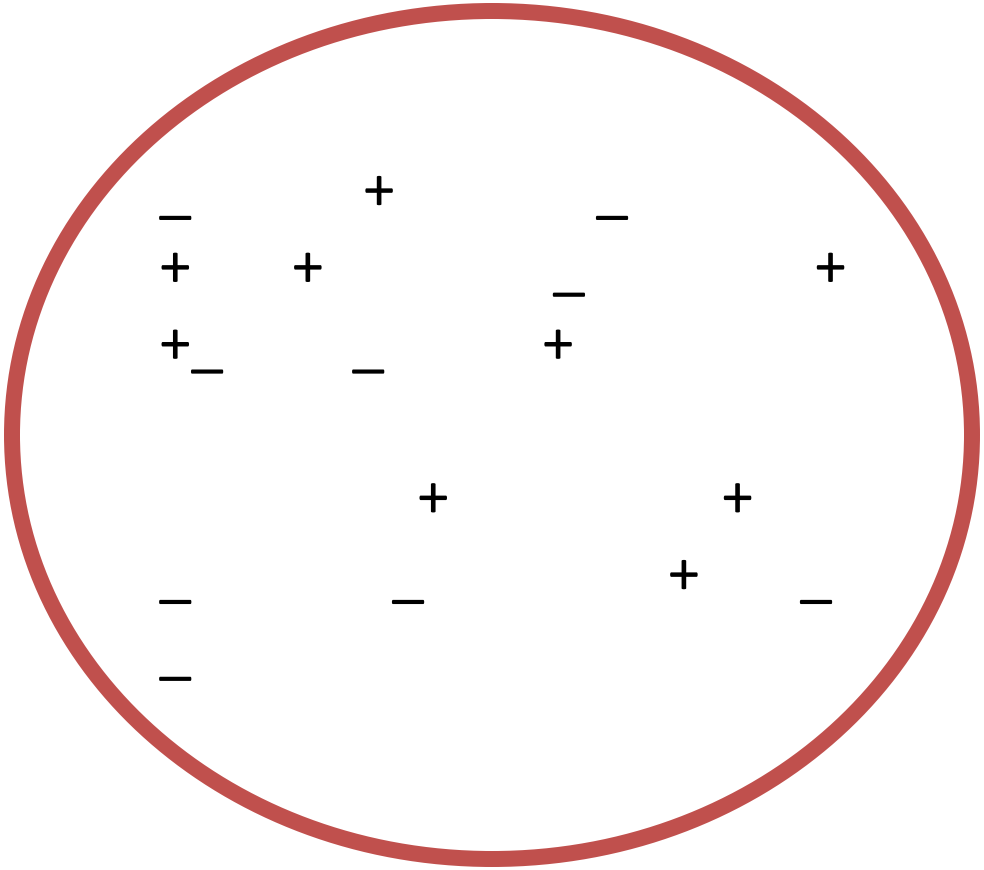
A conductor has an large quantity of charge that is free to move.

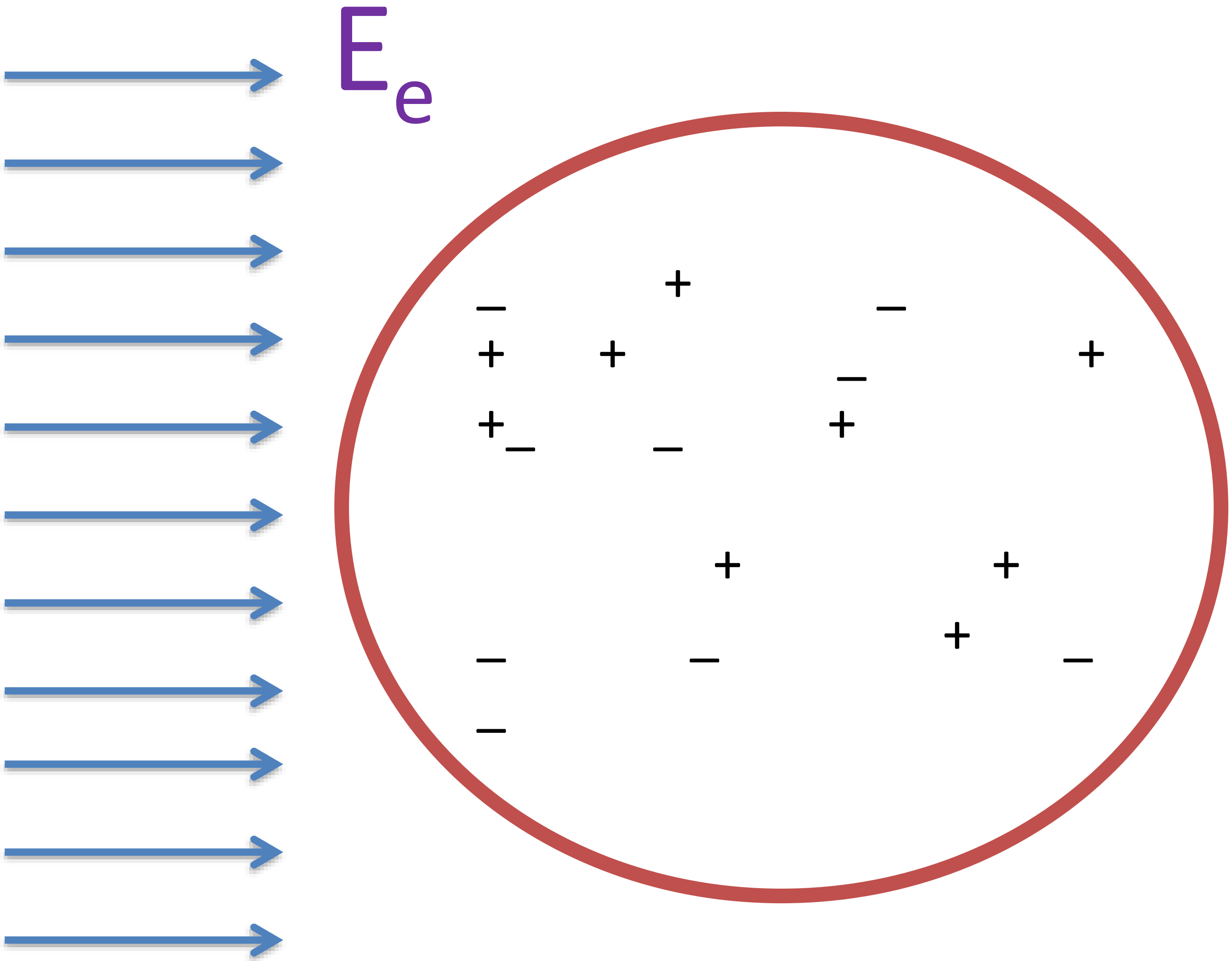
When a external Electric Field E_e is applied the +ve free charges are pushed along the same direction as the applied field.

While the –ve free charges move in the opposite direction.

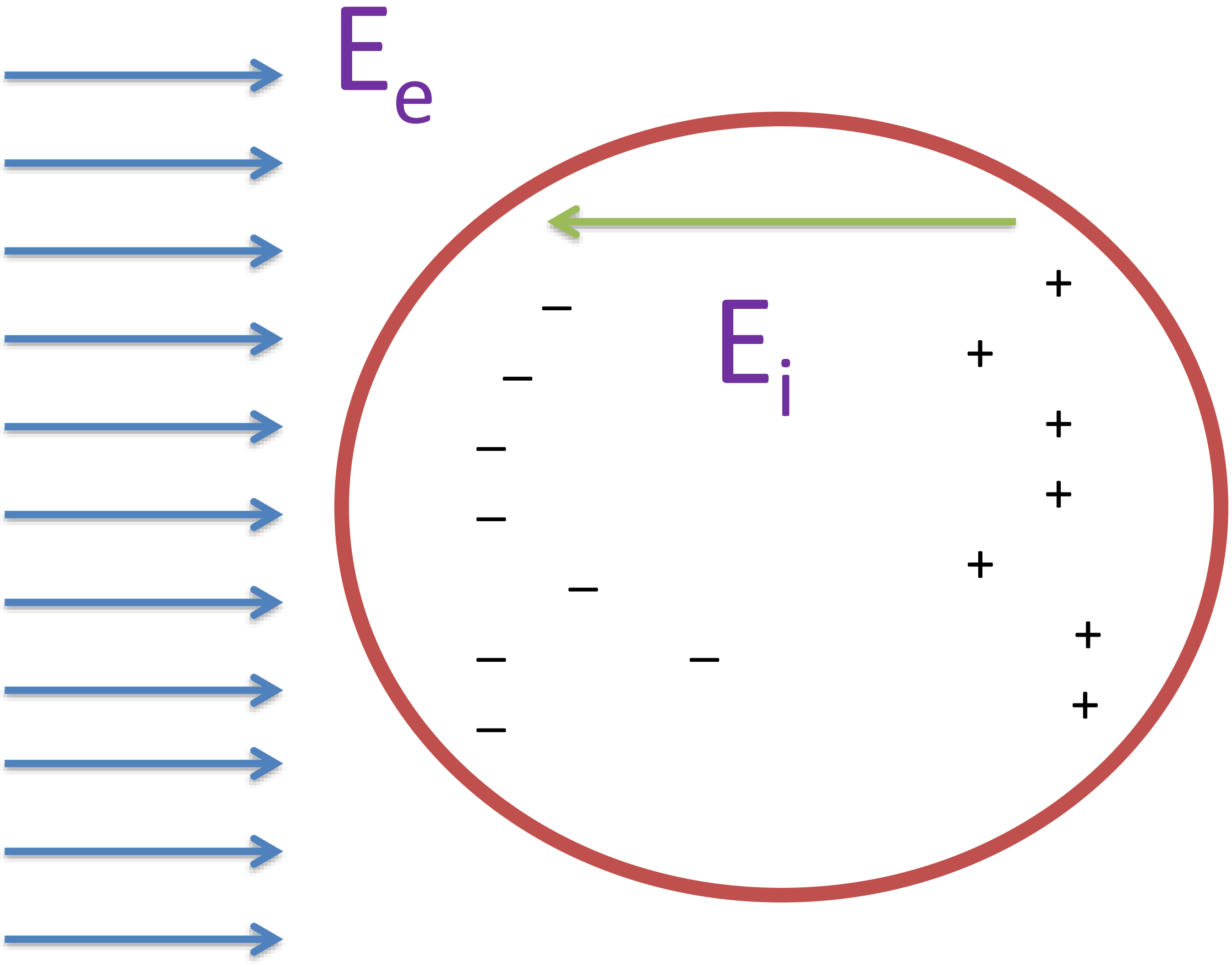
This charge migration takes place very quickly.

CONDUCTORS - CONDUCTORS

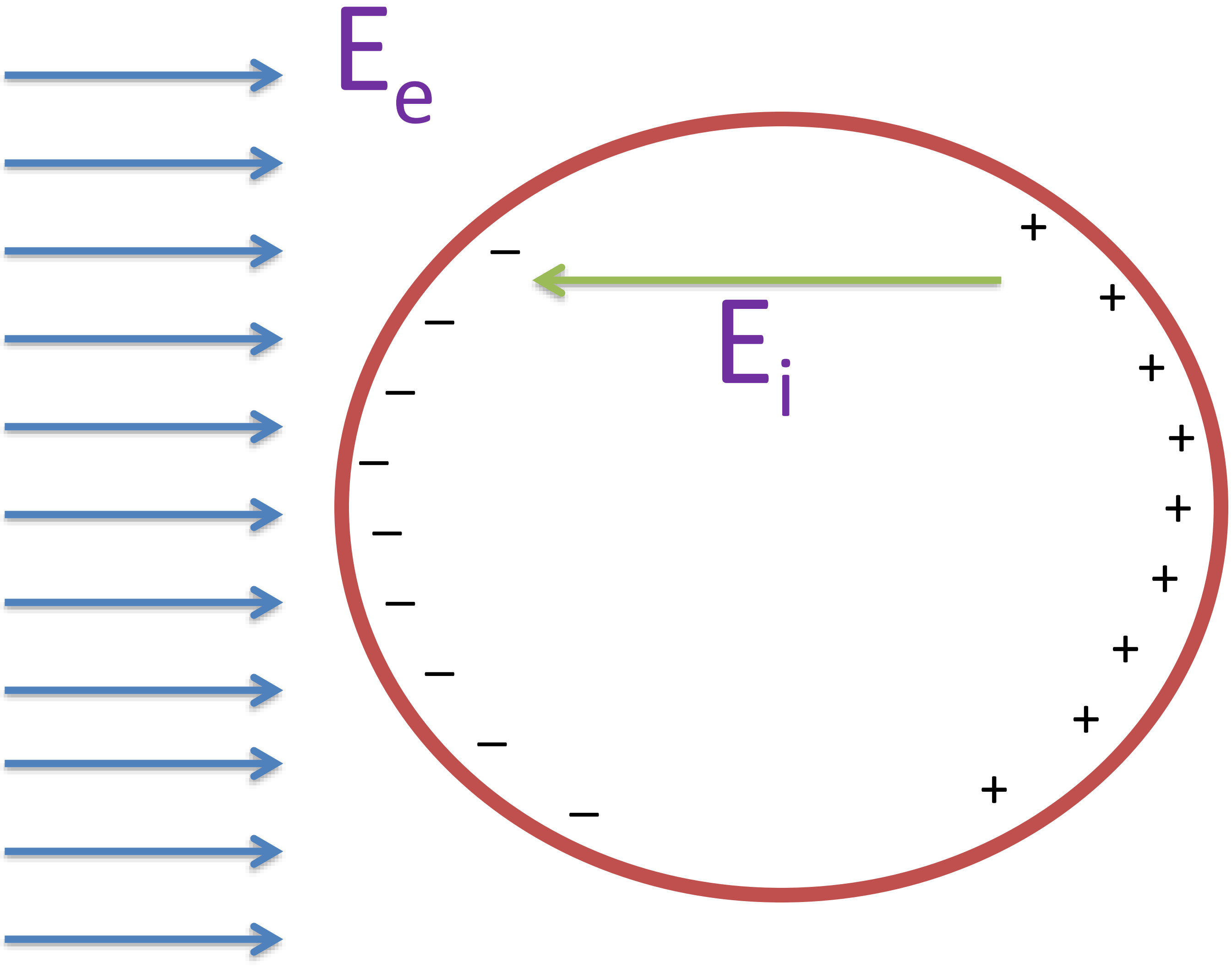




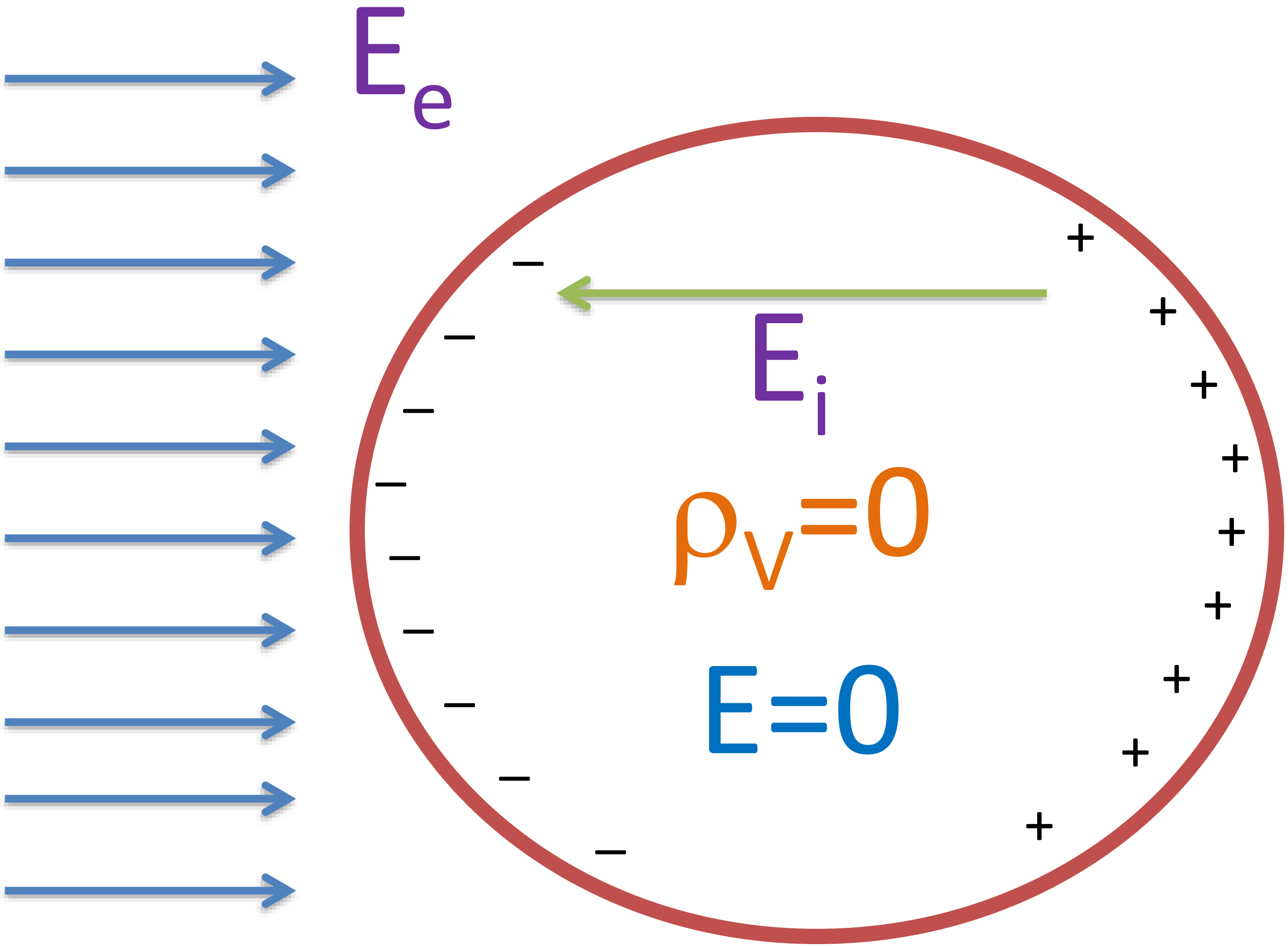
E_e



E_e
E_i



E_e
E_i



Zero Electric Field

Free charge do two things:

1. They accumulate on the surface of the conductor & form an induced surface charge.
2. Induced charges set up an internal induced field E_i, which cancels the externally applied field E_e

A perfect conductor cannot contain an electrostatic field within it.

Perfect Conductor $\sigma = \infty$

Conductor is called an equi-potential body.

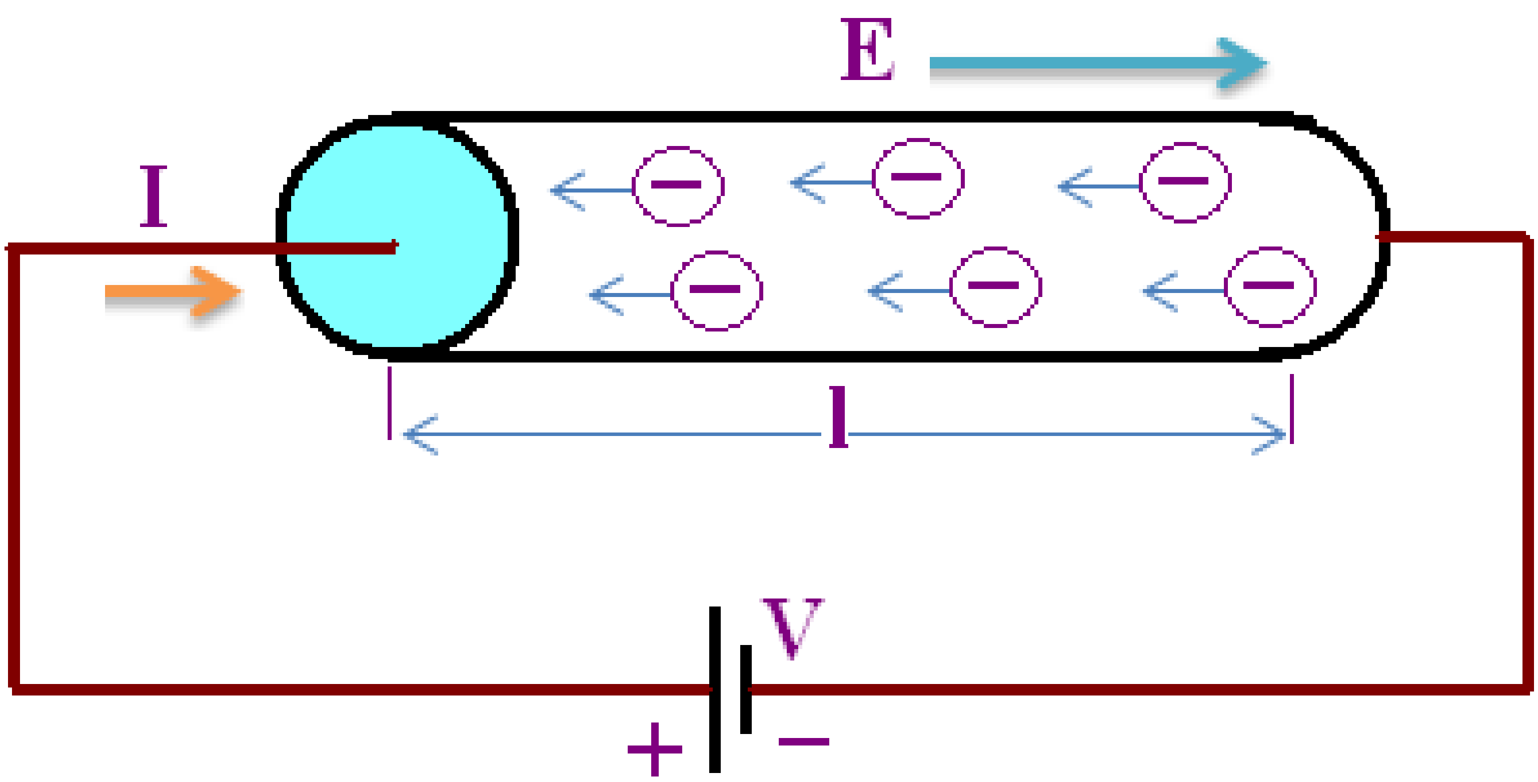
Potential is same every where in the conductor, due to

$$E = -\nabla V = 0$$

Inside a conductor $E = 0, \ \rho_V = 0, V_{ab} = 0.$

According to Gauss Law if $E = 0$, charge density ρ_V must be zero

Therefore perfect conductor cannot contain an electrostatic field within it.



$$E = \frac{V}{l}$$

(Eqn. 1)

Since, Conductor has a uniform cross section, current density is given as

$$J = \frac{I}{S}$$

(Eqn. 2)

We know, conduction current density

$$J = \sigma E$$

$$J = \rho_V u$$

(Eqn. 3)

Substituting eqn. (I) & (3) in (2)

$$\frac{I}{s} = \sigma E = \frac{\sigma V}{l} \qquad \frac{I}{s} = \frac{\sigma V}{l}$$

$$\frac{V}{I} = \frac{l}{\sigma s} = R \qquad \because \frac{1}{\sigma} = \rho_C$$

$$R = \frac{\rho_C l}{s}$$

'R' is the ratio of PD (V) between two ends of the conductor to the current (I) through the conductor.

$$\because R = \frac{V}{I} = \frac{\int_{V} E.dl}{\int_{S} \sigma E.ds}$$

'P' Power – Rate of change of energy W (Joules).

$$P = \int_{V} \rho_{V} dv.E.u = \int_{V} E.\rho_{V}.u.dv$$

From Joules Law $\qquad P = \int_{V} E.J.dv$

Power density $W_P\ (w/m^3)$

$$W_P = \frac{dP}{dV} = E.J = \sigma E^2$$

Conductor is having uniform cross section

$$dV = ds.dl$$

$$P = \int_L E.dl = \int_S J.ds = VI$$

A wire of diameter 2mm and the conductivity 5×10^7 ℧/m has 10^{29} free electrons per m^3. It is subjected to an electric field of 10mV/m.

Determine a) Free electron charge density

b) Current density

c) Current in the wire

$n = 10^{29}$ electrons$/m^3$

$e = -1.6 \times 10^{-19} C$

$\rho_e = n \times e$

$= -1.6 \times 10^{10} C/m^3$

b) $J = \sigma E = 5 \times 10^7 \times 10 \times 10^{-3}$

$= 500 \ KA/m^2$

c) $I = JA$

$= J \frac{\pi}{4} d^2$

$= 500 \times 10^3 \times \frac{\pi}{4} (2 \times 10^{-3})^2$

$= 1.5707\,A$

Drift velocity $J = \rho v_d$

CONDUCTORS - CONDUCTORS

$$E = V/L$$

$$I = \int_S J \cdot ds = JA$$

$$J = I/A = \sigma E$$

$$J = \sigma \frac{V}{L}$$

$$V = \frac{JL}{\sigma} = \frac{IL}{\sigma A} = I\left(\frac{L}{\sigma A}\right)$$

$$\frac{V}{I} = \frac{L}{\sigma A} = \underline{\underline{R}}$$

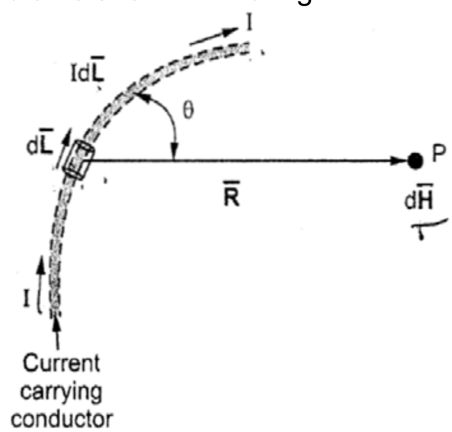
Unit-III

STATIC MAGNETIC FIELDS

Biot-Savart Law

Consider a conductor carrying a direct current I and a steady magnetic field produced around it. The Biot-Savart law allows us to obtain the **differential magnetic field intensity dH,** produced at a point P, due to a differentia1 current element IdL.

The current carrying conductor is shown in the Fig



Consider a differential length dL hence the differential current element is IdL. This is very small part of the current carrying conductor.

The point P is at a distance R from the differential current element.
θ is the angle between the differential current element and the line joining point P to the differential current element.

The **Biot-Savart** law states as
Magnetic field intensity **dH** produced at a point **p** due to a differential current element IdL is:

1. Proportional to the product of the current I and differential length dL.
2. The sine of the angle between the element and the line joining point P to the element. and
3. Inversely proportional to the square of the distance R between point P and the element.

Mathematically, the Biot-Savart law can be stated as,

$$d\bar{H} \propto \frac{I\,dL\sin\theta}{R^2}$$

$\therefore$
$$\boxed{d\bar{H} = \frac{k\,I\,dL\sin\theta}{R^2}}$$

where k = Constant of proportionality

In SI units, $k = \frac{1}{4\pi}$

$\therefore$
$$d\bar{H} = \frac{I\,dL\sin\theta}{4\pi R^2}$$

Let us express this equation in vector form

Then from rule of cross product,

$$d\bar{L}\times\bar{a}_R = dL\,|\bar{a}_R|\sin\theta = dL\sin\theta$$

Replacing in equation (3),

$$d\bar{H} = \frac{I\,d\bar{L}\times\bar{a}_R}{4\pi R^2}\ \text{A/m}$$

But
$$\bar{a}_R = \frac{\bar{R}}{|\bar{R}|} = \frac{\bar{R}}{R}$$

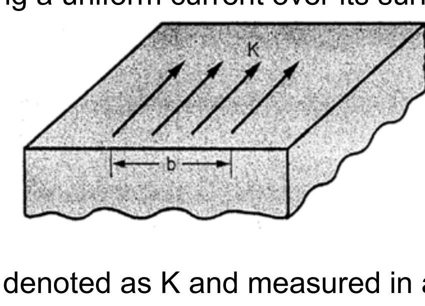
Hence,
$$\boxed{d\bar{H} = \frac{I\,d\bar{L}\times\bar{R}}{4\pi R^3}\ \text{A/m}}$$

Integral form of Biot Savart Law

$$\bar{H} = \oint \frac{I\,d\bar{L}\times\bar{a}_R}{4\pi R^2}$$

Ampere Law

Consider a surface carrying a uniform current over its surface as shown in the Fig.



surface current density is denoted as K and measured in amperes per metre (A/m)
for uniform current density, the current I in any width b is given by

I = Kb
width b is perpendicular to the direction of current flow

dS is the differential surface area considered of a surface having current density K then

$$I\,d\bar{L} = \bar{K}\,dS$$

current density in a volume

$$I\,d\bar{L} = \bar{J}\,dv$$

Biot-Savart law can be expressed for surface current considering K dS while for volume current considering Jdv

$$\bar{H} = \int_S \frac{\bar{K} \times \bar{a}_R\,dS}{4\pi R^2} \quad A/m$$

$$\bar{H} = \int_{vol} \frac{\bar{J} \times \bar{a}_R\,dv}{4\pi R^2} \quad A/m$$

Biot-Savart law is also called **Ampere's law** for the current element

Ampere Circuital Law

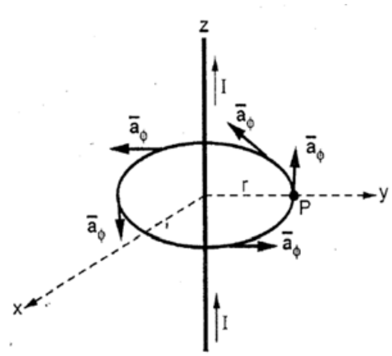
In the magnetostatics, the complex problems can be solved using a law called **Ampere's circuital law or Ampere's work law**

Statement: Line integral of magnetic field intensity **H** around a closed path is exactly equal to the direct current enclosed by that path

Mathematical representation of Ampere's circuital law is

$$\oint \bar{H} \bullet d\bar{L} = I$$

Consider a long straight conductor carrying direct current I placed along z axis as shown in the Fig



$$d\bar{L} = r\,d\phi\,\bar{a}_\phi$$

$$\overline{H} = \frac{I}{2\pi r}\overline{a}_\phi$$

$$\overline{H}\cdot d\overline{L} = \frac{I}{2\pi r}\overline{a}_\phi \cdot r\,d\phi\,\overline{a}_\phi$$

$$= \frac{I}{2\pi r}r\,d\phi = \frac{I}{2\pi}d\phi$$

Integrating $\overline{H}\cdot d\overline{L}$ over the entire closed path,

$$\oint \overline{H}\cdot d\overline{L} = \int_{\phi=0}^{2\pi}\frac{I}{2\pi}d\phi = \frac{I}{2\pi}[\phi]_0^{2\pi} = \frac{I\,2\pi}{2\pi}$$

$$= I = \text{Current carried by conductor}$$

This proves that the integral H • dL along the closed path gives the direct current enclosed by that closed path

Procedure to apply ACL:

Step 1 : Consider a closed path preferably symmetrical such that it encloses the direct current I once. This is Amperian path.

Step 2 : Consider differential length dL depending upon the co-ordinate system used.

Step 3 : Identify the symmetry and find in which direction H exists according to the co-ordinate system used.

Step 4 : Find H • dL, the dot product. Make sure that dL i and H are in same direction.

Step 5 : Find the integral of H • dL around the closed path assumed. And equate it to current I enclosed by the path.

Magnetic flux and Magnetic Flux Density

Flux ϕ crossing the area is given by

$$\phi = \int_S \overline{B}\cdot d\overline{S} \quad \text{webers (Wb)}$$

Because flux passing through the unit area is not exactly at right angles to the plane consisting of the area but making some angle with the plane

where

ϕ = Magnetic flux in webers

B = Magnetic flux density in Wb/m ^{2} or Tesla (T)

dS = Open surface through which flux is passing

Magnetic flux density B is analogous to the electric flux density D. The relation between B and H is related through the property of medium called permeability μ. The relation is given by

$$\overline{B} = \mu\overline{H}$$

$$\overline{B} = \mu_0\overline{H} \quad \text{for free space}$$

$$\text{For the free space, } \mu = \mu_0 = 4\pi\times10^{-7} \quad \text{H/m}$$

Magnetic flux density has units Wb/m^2 and hence it can be defined as the flux in webers passing through unit area in a plane at right angles to the direction flux.

Scalar and Vector Magnetic Potentials

In case of magnetic fields there are two types of potentials which can be defined:

1. The scalar magnetic potential denoted as V_m
2. The vector magnetic potential denoted as A.

To define scalar and vector magnetic potentials, let us use two vector identities which are listed as the properties of, curl,

$$\nabla \times \nabla V = 0, \qquad V = \text{Scalar}$$

$$\nabla \bullet (\nabla \times \bar{A}) = 0, \qquad \bar{A} = \text{Vector}$$

Every Scalar V and Vector A must satisfy these identities

Scalar Magnetic Potential

If V m is the scalar magnetic potential then it must satisfy

$$\nabla \times \nabla V_m = 0$$

But the scalar magnetic potential is related to the magnetic field intensity **H** as

$$\bar{H} = -\nabla V_m$$

$$\nabla \times (-\bar{H}) = 0 \qquad \text{i.e.} \quad \nabla \times \bar{H} = 0$$

$$\nabla \times \bar{H} = \bar{J} \qquad \text{i.e.} \quad \bar{J} = 0$$

Scalar magnetic potential V m can be defined for source free region where J i.e. current density is zero

Magnetic scalar potential can be expressed in terms of H as

$$V_{m\,a,b} = -\int_b^a \bar{H} \bullet d\bar{L}$$

Vector Magnetic Potential

Vector magnetic potential is denoted as A and measured in Wb/m

$$\nabla \bullet (\nabla \times \bar{A}) = 0 \qquad \text{But} \qquad \nabla \bullet \bar{B} = 0$$

$$\bar{B} = \nabla \times \bar{A}$$

curl of vector magnetic potential is the flux density

$$\nabla \times \bar{H} = \bar{J}$$

$$\nabla \times \frac{\bar{B}}{\mu_0} = \bar{J}$$

$$\nabla \times \bar{B} = \mu_0 \bar{J}$$

$$\nabla \times \nabla \times \bar{A} = \mu_0 \bar{J}$$

Using vector identity to express left hand side we can write,

$$\nabla(\nabla \bullet \bar{A}) - \nabla^2 \bar{A} = \mu_0 \bar{J}$$

$$\bar{J} = \frac{1}{\mu_0}\left[\nabla \times \nabla \times \bar{A}\right] = \frac{1}{\mu_0}\left[\nabla(\nabla \bullet \bar{A}) - \nabla^2 \bar{A}\right]$$

Steady Magnetic Fields produced by current carrying conductors

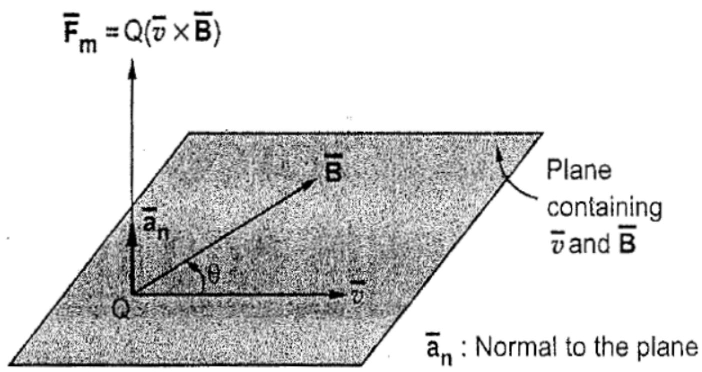
Magnetic Forces - Force on a moving charge

Consider that a charge is placed in a steady magnetic field. It experiences a force only if it is moving.

A magnetic force (Fm) exerted on a charge Q, moving with a velocity *v* in a steady magnetic field B is given by

$$\bar{F}_m = Q\left(\bar{v} \times \bar{B}\right) \text{N}$$

The magnitude of the magnetic force Fm is directly proportional to the magnitudes of Q, *v* and B and also the sine of the angle between *v* and B. The direction of Fm is perpendicular to the plane containing *v* and B both



The electric force Fe is independent of the velocity of the moving charge.

The magnetic force Fm is dependent on the velocity of the moving charge. But Fm cannot perform work on a moving charge as it is at right angle to the direction of motion of charge. (F • d l= 0).

$$\bar{F} = \bar{F}_e + \bar{F}_m = Q\left(\bar{E} + \bar{v} \times \bar{B}\right) \quad \text{N}$$

Above equation is called Lorentz Force Equation which relates mechanical force to the electrical force. If the mass of the charge is m, then we can write

$$\bar{F} = m\,\bar{a} = m\frac{d\bar{v}}{dt} = Q\left(\bar{E} + \bar{v} \times \bar{B}\right) \text{ N}$$

Force on a differential current element

Force exerted on a differential element of charge dQ moving in a steady magnetic field is given by:

$$d\bar{F} = dQ\,\bar{v} \times \bar{B} \text{ N}$$

Current density J can be expressed in terms of velocity of a volume charge density

$$\bar{J} = \rho_v\,\bar{v}$$

But the differential element of charge can be expressed in terms of the volume charge density as

$$dQ = \rho_v\,dv$$

$$d\bar{F} = \rho_v\,dv\,\bar{v} \times \bar{B}$$

$$d\bar{F} = \bar{J} \times \bar{B}\,dv$$

the relationship between current element is

$$\bar{J}\,dv = \bar{K}\,dS = I\,d\bar{L}$$

Then the force exerted on a surface current density is given by

$$d\bar{F} = \bar{K} \times \bar{B}\,dS$$

the force exerted on a differential current element is given by

$$d\bar{F} = \left(I\,d\bar{L} \times \bar{B}\right)$$

Integrating above equation over a volume, the force is given by

$$\bar{F} = \int_{vol} \bar{J} \times \bar{B}\,dv$$

Integrating above equation over either open or closed surface

$$\bar{F} = \int_{S} \bar{K} \times \bar{B}\,dS$$

$$\bar{F} = \oint I\,d\bar{L} \times \bar{B}$$

Force between differential current elements

Consider that two current carrying conductors are placed parallel to each other. Each of this conductor produces its own flux around it.
When such two conductors are placed closed to each other, there exists a force due to the interaction of two fluxes. The force between such parallel current carrying conductors depends on the directions of the two currents.

If the directions of both the currents are same, then the conductors experience a force of attraction as shown in the Fig.

if the directions of two currents are opposite to each other, then the conductors experience a force of repulsion as shown in the Fig.

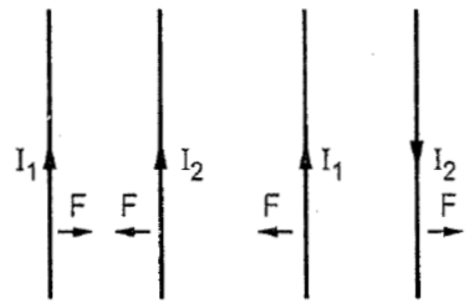


Fig: Force between two parallel current carrying conductors

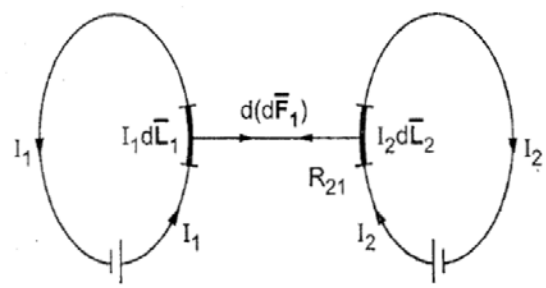


Fig. Force between two current elements

Consider two current elements 11 d L1 and 12 d L2 as shown in the above Fig. Note that the directions of 11 and 12 are same

From the equation of force, the force exerted on a differential current element is given by,

$$d\left(d\bar{F}_1\right) = I_1 d\bar{L}_1 \times d\bar{B}_2$$

According to Biot-Savart's law,

$$d\bar{B}_2 = \mu_0 \, d\bar{H}_2 = \mu_0 \left[\frac{I_2 d\bar{L}_2 \times \bar{a}_{R21}}{4\pi R_{21}^2}\right]$$

Substituting value of dB_2

$$d(d\bar{F}_1) = \mu_0 \frac{I_1 d\bar{L}_1 \times \left(I_2 d\bar{L}_2 \times \bar{a}_{R21}\right)}{4\pi R_{21}^2}$$

The above equation represents force between two current elements. It is very much similar to Coulomb's law.

By integrating $d(dF_2)$ twice,

$$\bar{F}_1 = \frac{\mu_0 I_1 I_2}{4\pi} \oint_{L_1} \oint_{L_2} \frac{d\bar{L}_1 \times \left(d\bar{L}_2 \times \bar{a}_{R21}\right)}{R_{21}^2}$$

Exactly following same steps, we can calculate the force F2 exerted on the element 2 due to the magnetic field B1

$$\bar{F}_2 = \frac{\mu_0 I_2 I_1}{4\pi} \oint_{L_2} \oint_{L_1} \frac{d\bar{L}_2 \times \left(d\bar{L}_1 \times \bar{a}_{R12}\right)}{R_{12}^2}$$

$$F_2 = - F_1$$

Above condition indicates that both the forces obey Newton's third law that for every action there is equal and opposite reaction

Nature of magnetic materials

The magnetic materials are classified based on presence of magnetic dipole moments in the materials.

Based on the magnetic behaviour, the magnetic materials are classified as diamagnetic, paramagnetic, ferromagnetic.

Diamagnetic materials.
These materials are barely magnetised when placed in a magnetic field. Magnetic dipoles in these substances tend to align in opposition to the applied field. In effect, they produce an internal magnetic field that opposes the applied field, and the substance tends to repel the external field around it.
This opposing field disappears as soon as the external field is removed.
Ex: Gold, water, mercury and even animals!

Paramagnetic materials.
In these materials, the magnetic dipoles in the magnetic materials tend to align along the applied magnetic field and thus reinforcing the applied magnetic field. Such substances are attracted by a magnet if it applies a sufficiently strong field.
Ex: Liquid oxygen, sodium, platinum, salts of iron and nickel.

Ferromagnetic materials.
We are most familiar with these materials as they exhibit the strongest magnetic behaviour. Magnetic dipoles in these materials are arranged into domains where the arrangements of individual magnetic dipoles are essentially perfect that can produce strong magnetic fields. Normally, these domains are usually randomly arranged and thus the magnetic field of each domain is cancelled by another, and the entire material does not show any magnetic behaviour.

Magnetization and Permeability

In any magnetic material, the electrons revolve in the orbits around the positive central nucleus. Simultaneously the electrons also rotate or spin about their own axes.

The field produced due to movement of bound charges is called **magnetization** represented by M.

The **magnetization** is defined as the magnetic dipole moment per unit volume. Its unit is A/m.

$$\overline{\mathbf{M}} = \lim_{\Delta v \to 0} \frac{1}{\Delta v} \sum_{a=1}^{n\Delta v} \overline{\mathbf{m}}_a$$

For any magnetic material we can write

$$\overline{\mathbf{B}} = \mu \overline{\mathbf{H}} = \mu_0 \mu_r \overline{\mathbf{H}}$$

Comparing equations, the relative permeability can be expressed in terms of magnetic susceptibility as

$$\mu_r = (1 + \chi_m) = \frac{\mu}{\mu_0}$$

In general, $\mu = \mu_0 \mu_r$ is called **permeability** of a material. It is measured in henry /meter (H/m). But the relative permeability is a dimensionless quantity like the magnetic susceptibility.

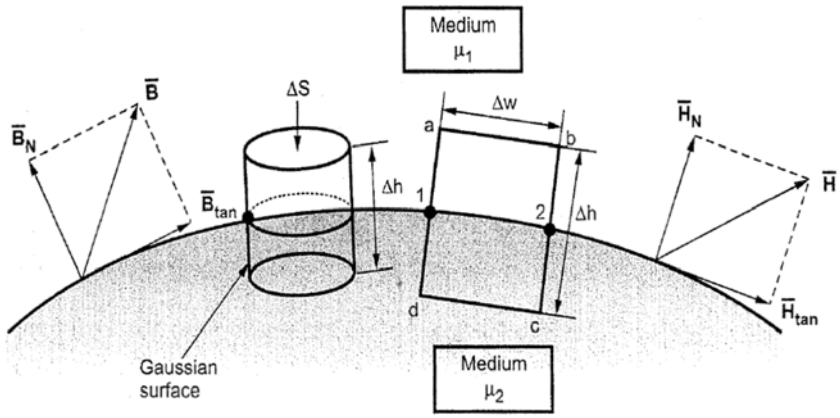
Magnetic boundary conditions

Conditions of the magnetic field existing at the boundary of the two media when the magnetic field passes from one medium to other are called boundary conditions for magnetic fields or simply magnetic boundary conditions.

The boundary between the two different magnetic materials is considered. To study conditions of B and H at the boundary, both the vectors are resolved into two components,

a) tangential to boundary and
b) normal (perpendicular) to boundary

To determine the boundary conditions, let us use the closed path and the Gaussian surface.



Boundary Conditions for Normal Component

To find the normal component of **B,** select a closed Gaussian surface in the form of a right circular cylinder as shown in the Fig. Let the height of the cylinder be Δh and be placed in such a way that Δh /2 is in medium 1 and remaining Δh/2 is in medium 2.

Also, the axis of the cylinder is in the normal direction to the surface.

According to the Gauss's law for the magnetic field,

$$\oint_S \overline{\mathbf{B}} \bullet d\overline{\mathbf{S}} = 0$$

Surface integral must be evaluated over three surfaces, (i) Top, (ii) Bottom and (iii) Lateral.

$$\oint_{top} \overline{\mathbf{B}} \bullet d\overline{\mathbf{S}} + \oint_{bottom} \overline{\mathbf{B}} \bullet d\overline{\mathbf{S}} + \oint_{lateral} \overline{\mathbf{B}} \bullet d\overline{\mathbf{S}} = 0$$

For top surfaces :

$$\oint_{Top} \overline{\mathbf{B}} \bullet d\overline{\mathbf{S}} = B_{N_1} \oint_{Top} d\overline{\mathbf{S}} = B_{N_1} \Delta S$$

For bottom surface :

$$\oint_{Bottom} \overline{\mathbf{B}} \bullet d\overline{\mathbf{S}} = B_{N_2} \oint_{Bottom} d\overline{\mathbf{S}} = B_{N_2} \Delta S$$

For lateral surface

$$\oint_{Lateral} \overline{\mathbf{B}} \bullet d\overline{\mathbf{S}} = 0$$

Putting values of surface integrals in equation, we get

$$B_{N_1} \Delta S - B_{N_2} \Delta S = 0$$

Note that the negative sign is used for one of the surface integrals because normal component in medium 2 is entering the surface while in medium 1 the component is leaving the surface. Hence B_{N1} and B_{N2} are in opposite direction.

$$B_{N_1} = B_{N_2}$$

Normal component of B is continuous at the boundary.

As the magnetic flux density and the magnetic field intensity are related by

$$\overline{B} = \mu\overline{H}$$

$$\frac{H_{N_1}}{H_{N_2}} = \frac{\mu_2}{\mu_1} = \frac{\mu_{r2}}{\mu_{r1}}$$

The normal component of **H** is not continuous at the boundary. The field strengths in two media are inversely proportional to their relative permeabilities.

Boundary Conditions for Tangential Component

According to Ampere's circuital law,

$$\oint \overline{H} \bullet d\overline{L} = I$$

Consider a rectangular closed path abcda as shown in the Fig. It is traced in clockwise direction as a-b-c-d-a. This closed path is placed in a plane normal to the boundary surface. Hence it is divided into 6 parts.

$$\oint \overline{H} \bullet d\overline{L} = \int_a^b \overline{H} \bullet d\overline{L} + \int_b^1 \overline{H} \bullet d\overline{L} + \int_1^c \overline{H} \bullet d\overline{L} + \int_c^d \overline{H} \bullet d\overline{L} + \int_d^2 \overline{H} \bullet d\overline{L} + \int_2^a \overline{H} \bullet d\overline{L} = I$$

This closed path is placed in such a way that half of its portion is in medium 1 and the remaining is in medium 2.

The rectangular path is an elementary rectangular path with elementary height Δh and elementary width Δw.

Assume that **K** is the surface current normal to the path.

$$K \bullet dw = H_{tan1}(\Delta w) + H_{N1}\left(\frac{\Delta h}{2}\right) + H_{N2}\left(\frac{\Delta h}{2}\right) - H_{tan2}(\Delta w)$$

$$- H_{N2}\left(\frac{\Delta h}{2}\right) - H_{N1}\left(\frac{\Delta h}{2}\right)$$

To get conditions at boundary, $\Delta h \to 0$. Thus,

$$K \bullet dw = H_{tan1}(\Delta w) - H_{tan2}(\Delta w)$$

$$H_{tan1} - H_{tan2} = K$$

In vector form, we can express above relation by a cross product as

$$\boxed{\overline{H}_{tan1} - \overline{H}_{tan2} = \overline{a}_{N_{12}} \times \overline{K}}$$

Consider a special case that the boundary is free of current. In other words, media are not conductors; so K = 0

$$H_{tan1} - H_{tan2} = 0$$

or $$H_{tan1} = H_{tan2}$$

For tangential components of $\bar{B}$ we can write,

$$\frac{B_{tan1}}{\mu_1} - \frac{B_{tan2}}{\mu_2} = 0$$

$$\therefore \quad \frac{B_{tan1}}{\mu_1} = \frac{B_{tan2}}{\mu_2}$$

$$\therefore \quad \boxed{\frac{B_{tan1}}{B_{tan2}} = \frac{\mu_1}{\mu_2} = \frac{\mu_{r1}}{\mu_{r2}}}$$

Magnetic Circuits

In general, in magnetic circuits, we determine the magnetic fluxes and magnetic field intensities in various parts of the circuits. We can directly use the concepts of the electric circuits in solving the magnetic circuit problems.

Common examples of the magnetic circuits are transformers, toroids motors, generators, relays, and magnetic recording devices.

Like electromotive force (e.m.f.) in an electric circuit, we can define a new quantity in case of a magnetic circuit called magnetomotive force (m.m.f.). The magnetomotive force (m.m.f.) is defined as

$$e_m = NI = \oint \bar{H} \bullet d\bar{L}$$

In magnetic circuits, the source of m.m.f. is a coil carrying conductors with N number of turns. In an electric circuit, resistance is defined as the ratio of voltage to current.

In case of magnetic circuits, we define a new quantity reluctance as the ratio of the magnetomotive force to the total flux.

$$\Re = \frac{e_m}{\phi}$$

The reluctance is measured in Ampere Turn / Weber

We can also define reluctance as

$$\Re = \frac{l}{\mu S}$$

The magnetic flux density is analogous to the current density, thus we can write

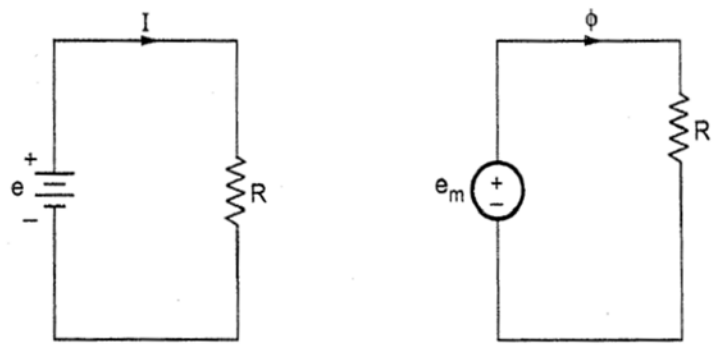
$$\bar{B} = \mu \bar{H}$$

The total current in the magnetic circuit is given by

$$I = \int_S \bar{J} \cdot d\bar{S}$$

The total magnetic flux density flowing through the cross-section of the magnetic circuit is given by

$$\phi = \int_S \bar{B} \cdot d\bar{S}$$



(a) Electric circuit (b) Magnetic circuit

Kirchhoff's m.m.f. law states that the resultant m.m.f. around a closed magnetic circuit is equal to the algebraic sum of products of flux and reluctance of each part of the closed circuit.

Inductances and mutual inductances

A wire or conductor of certain length, when twisted into coil becomes a basic inductor.

For every conductor carrying current I and producing magnetic field B, there exists a self-Inductance.

When two such coils are placed very close to each other, there exists a mutual inductance between the two.

Self Inductance

When a closed conducting path or a circuit carries current I, a magnetic field B, is produced. This causes a magnetic flux $ which is given by,

$$\phi = \int_S \bar{B} \cdot d\bar{S}$$

The flux linkage is defined as the product of number of turns N and the total flux $linking each of the turn.

$$\lambda = N \cdot \phi \qquad wb \cdot t$$

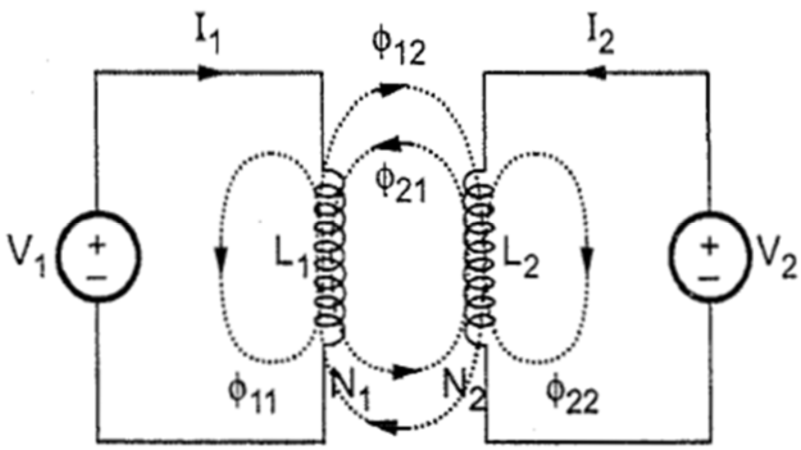
The ratio of the total flux linkage to the current flowing through the circuit is called **inductance** and it is given by

$$L = \frac{N\phi}{I} = \frac{\lambda}{I}\ H$$

The inductance is also known as **self-inductance** of the circuit as the flux produced by the current flowing through the circuit links with the same circuit.

Mutual Inductance

Consider that two different circuits with self-inductances L1 and L2 are kept close to each other as shown in the Fig.



The **mutual inductance** between the two circuits is defined as the flux linkage of one circuit to the current in other circuit.

$$L_{12} \quad M_{12} = \frac{\text{Flux linkage of circuit 1}}{\text{Current in circuit 2}} = \frac{N_1\phi_{21}}{I_2}$$

$$L_{21}, \quad M_{21} = \frac{\text{Flux linkage of circuit 2}}{\text{Current in circuit 1}} = \frac{N_2\phi_{12}}{I_1}$$

Thus, for linear medium around two circuits, we can write

$$M_{12} = M_{21} = M$$

$$K = \frac{M}{\sqrt{L_1 L_2}}$$

K is called **coefficient of coupling** between two coils

Unit-IV

TIME VARYING FIELDS

TIME VARYING FIELDS

The fields which do not change with respect to time are considered as static fields or time invariant fields. In case of static electromagnetic fields, the electric and magnetic fields are independent of each other.

The time varying fields are produced due to the time varying currents. In case of such dynamic fields, the time varying electric field can be produced by the time varying magnetic field.

Thus, unlike static fields, in the dynamic or time varying fields, the electric and magnetic fields are interdependent.

Faradays Law of Electromagnetic induction

A static magnetic field cannot produce any current flow. But with a time varying field, an electromotive force (e.m.f.) induces which can drive a current in a closed path or circuit.

Statement: The electromotive force (e.m.f.) induced in a closed path is proportional to rate of change of magnetic flux enclosed by the closed path

Simply, when a closed path moves in a magnetic field, current is generated and hence e.m.f. similarly when closed path kept fixed and the magnetic field was varied, we can commonly refer as **electromagnetic induction**

$$e = -N\frac{d\phi}{dt} \text{ volts}$$

N = Number of turns in the circuit
e = Induced e.m.f.

The minus sign in equation indicates that the direction of the induced e.m.f. is such that to produce a current which will produce a magnetic field which will oppose the original field.

According to ***Lenz's law***, the induced e.m.f. acts to produce an opposing flux.

Statement of Lenz's Law: The direction of induced e.m.f. is such that it opposes the cause producing it i.e. changes in the magnetic flux

Let us consider Faraday's law. The induced e.m.f. is a scalar quantity measured in volts. Thus, the induced e.m.f. is given by,

$$e = \oint \bar{E} \bullet d\bar{L}$$

The induced e.m.f. in above equation indicates a voltage about a closed path such that if any part of the path is changed, the e.m.f. will also change.

The magnetic flux ϕ passing through a specified area is given by

$$\phi = \int_S \bar{B} \bullet d\bar{S}$$

Substituting and equating the above equations we have

$$e = \oint \bar{E} \cdot d\bar{L} = -\frac{d}{dt}\int_S \bar{B} \cdot d\bar{S}$$

The variation of the flux ϕ with respect to time t can be caused by having

a) Stationary closed path in a time varying **B** field,
b) Time varying closed path in a static **B** field,
c) Time varying closed path in a time varying field **B.**

When an e.m.f. is induced in a stationary closed path due to the time varying **B** field, the e.m.f. is called **statically induced e.m.f. or transformer e.m.f.**

When the e.m.f. is induced in a time varying closed path due to the static field **B,** then the e.m.f. is called **dynamically induced e.m.f. or motional e.m.f.**

Displacement current and Displacement current density

For static electromagnetic fields, according to Ampere's circuital law, we can write,

$$\nabla \times \bar{H} = \bar{J}$$

Taking divergence on both the sides,

$$\nabla \cdot (\nabla \times \bar{H}) = \nabla \cdot \bar{J}$$

According to vector identity, 'divergence of the curl of any vector field is zero'.

$$\nabla \cdot (\nabla \times \bar{H}) = \nabla \cdot \bar{J} = 0$$

Equation of continuity is given by

$$\nabla \cdot \bar{J} = -\frac{\partial \rho_v}{\partial t}$$

Above two equations are not compatible for time varying fields. We must modify first equation by adding one unknown term say N.

$$\nabla \times \bar{H} = \bar{J} + \bar{N}$$

Again taking divergence on both the sides

$$\nabla \cdot (\nabla \times \bar{H}) = \nabla \cdot \bar{J} + \nabla \cdot \bar{N} = 0$$

As $\nabla \cdot \bar{J} = -\frac{\partial \rho_v}{\partial t}$, to get correct conditions we must write

$$\nabla \cdot \bar{N} = \frac{\partial \rho_v}{\partial t}$$

according to Gauss's law

$$\rho_v = \nabla \cdot \bar{D}$$

replacing

$$\nabla \bullet \overline{N} = \frac{\partial}{\partial t}(\nabla \bullet \overline{D}) = \nabla \bullet \frac{\partial \overline{D}}{\partial t}$$

Comparing two sides of the equation

$$\overline{N} = \frac{\partial \overline{D}}{\partial t}$$

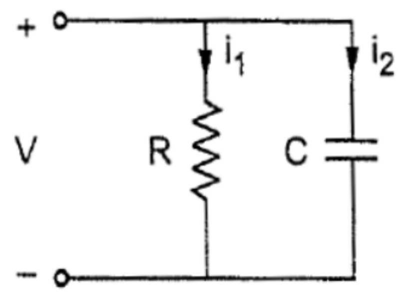
we can write Ampere's circuital law in point form as

$$\nabla \times \overline{H} = \overline{J}_C + \frac{\partial \overline{D}}{\partial t}$$

The first term in above equation is conduction current density denoted by J_c

The second term in equation represents current density expressed in ampere per square meter. As this quantity is obtained from time varying electric flux density. This is also called displacement density. Thus, this is called **displacement current density** denoted by J_D.

Significance of displacement current



Let the current flowing through resistor R be i_1 and the current flowing through capacitor C be i_2. Nature of the current flowing through the resistor R is different than that flowing through the capacitor.

Current through resistor is due to the actual motion of charges and can be written as

$i_1 = V/R$
This current is called **conduction current.**

Assume the initial charge on a capacitor is zero. Then for time varying voltage applied across parallel plate capacitor, the current through the capacitor is given by,

$$i_2 = C\frac{dv}{dt}$$

The two plates of area A are separated by distance d with dielectric having permittivity ε in between the plates. Then we can write

$$i_2 = \frac{\varepsilon A}{d}\frac{dv}{dt}$$

This current is called **displacement current.**

Maxwell’s Equations

The equations describing relationships between time varying electric and magnetic fields are known as Maxwell's equations. These equations can be represented in integral and differential (point) form. Maxwell's equations are nothing but a set of four expressions derived from Ampere's circuit law, Faraday's law, Gauss's law for electric field and Gauss's law for magnetic field.

Point & Integral form of Maxwell’s Equation

the Maxwell's equations in point form or differential form explains the characteristics of different field vectors at a given point to each other. Basically, the Maxwell's equations are very important equations as they are found to be the basic mathematical background for the theory of an electromagnetic waves, transmission lines.
Maxwell’s equations will be derived for both time variant (dynamic) & invariant system (static).

Maxwell's Equations for Static Field

Derived from Faraday's Law

Basic concept from an electrostatic field,

$$\oint \bar{E} \bullet d\bar{L} = 0$$

This is **integral form** of Maxwell's equation derived from Faraday's law for static field.

Using Stoke's theorem converting the closed line integral into the surface integral

$$\oint \bar{E} \bullet d\bar{L} = \int_S (\nabla \times \bar{E}) \bullet d\bar{S} = 0$$

$$\int_S (\nabla \times \bar{E}) \bullet d\bar{S} = 0$$

But dS cannot be zero

$$\nabla \times \bar{E} = 0$$

This is called **point or differential form** of Maxwell's equation derived from Faraday's law for static fields.

Derived from Ampere's Circuit Law

Ampere's circuital law states that the line integral of magnetic field intensity H around a closed path is exactly equal to the direct current enclosed by that path.

$$\oint \bar{H} \bullet d\bar{L} = I$$

the current enclosed is equal to the product of current density normal to closed path and area of closed path.

$$I = \int_S \bar{J} \bullet d\bar{S} \text{ where } \bar{J} = \text{Current density}$$

Equating above equations

$$\oint \bar{H} \bullet d\bar{L} = \int_S \bar{J} \bullet d\bar{S}$$

This is **integral form** of Maxwell's equation derived from Ampere's circuit law for static field.
Converting closed line integral of the equation to surface integral using Stoke's theorem

$$\oint \overline{H} \bullet d\overline{L} = \int_S (\nabla \times \overline{H}) \bullet d\overline{S} = \int_S \overline{J} \bullet d\overline{S}$$

$$\nabla \times \overline{H} = \overline{J}$$

This is **point or differential form** of Maxwell's equation derived from Ampere's circuit law for static field.

Derived from Gauss's Law

For Electrostatic Fields

The electric flux passing through any closed surface is equal to the total charge enclosed by that surface

$$\psi = \oint \overline{D} \bullet d\overline{S} = Q_{enclosed}$$

$$\oint \overline{D} \bullet d\overline{S} = \int_v \rho_v \, dv$$

This is called **integral form** of Maxwell's equation derived from Gauss's law for static electric field

Converting closed surface integral into volume integral using divergence theorem

$$\oint \overline{D} \bullet d\overline{S} = \int_v (\nabla \bullet \overline{D}) \, dv$$

Comparing above equations

$$\int_v (\nabla \bullet \overline{D}) \, dv = \int_v \rho_v \, dv$$

$$\nabla \bullet \overline{D} = \rho_v$$

This is called **point or differential form** of Maxwell's equation derived from Gauss's law for static electric field.

For Magnetostatic Fields

Magnetic flux cannot reside in a closed surface due to the non existance of single magnetic pole

$$\oint_S \overline{B} \bullet d\overline{S} = 0$$

This is called **integral form** of Maxwell's equation derived from Gauss's law for static magnetic field.

Using divergence theorem

$$\oint_S \overline{B} \bullet d\overline{S} = \int_v (\nabla \bullet \overline{B}) \, dv = 0$$

$$\int_v (\nabla \bullet \overline{B}) \, dv = 0$$

Now dv cannot be zero

$$\nabla \bullet \overline{\mathbf{B}} = 0$$

This is called **point or differential form** of Maxwell's equation derived from Gauss's law for static magnetic field

Maxwell's Equations for Time varying Fields

Derived from Faraday's Law

e.m.f. induced in a circuit to the time rate of decrease of total magnetic flux linking the circuit

$$\oint \overline{\mathbf{E}} \bullet d\overline{\mathbf{L}} = -\int_S \frac{\partial \overline{\mathbf{B}}}{\partial t} \bullet d\overline{\mathbf{S}}$$

This is called **integral form** of Maxwell's equation derived from Faraday's law for time varying field.

The total electromotive force (e.m.f.) induced in a closed path is equal to the negative surface integral of the rate of change of flux density with respect to time over an entire surface bounded by the same closed path.

Using Stoke's theorem, converting line integral to the surface integral

$$\int_S \left(\nabla \times \overline{E}\right) \bullet d\overline{S} = -\int_S \frac{\partial \overline{\mathbf{B}}}{\partial t} \bullet d\overline{S}$$

Integration is carried out over the same surface on both the sides

$$\nabla \times \overline{E} = -\frac{\partial \overline{\mathbf{B}}}{\partial t}$$

This is called **point or differential form** of Maxwell's equation derived from Faraday's law for time varying field.

Derived from Ampere's Circuit Law

The line integral of magnetic field intensity H around a closed path is equal to the current enclosed by the path.

$$\oint \overline{H} \bullet d\overline{L} = I_{enclosed}$$

Replacing current by the surface integral of conduction current density

$$\oint \overline{H} \bullet d\overline{L} = \int_S \overline{J} \bullet d\overline{S}$$

Above expression can be made further general by adding displacement current density to conduction current density as follows

$$\oint \overline{H} \bullet d\overline{L} = \int_S \left[\overline{J} + \frac{\partial \overline{D}}{\partial t}\right] \bullet d\overline{S}$$

This is called **integral form** of Maxwell's equation derived from Ampere’s Circuit law for time varying field.

Applying Stoke's theorem

$$\int_S \left(\nabla \times \overline{H}\right) \bullet d\overline{S} = \int_S \left[\overline{J} + \frac{\partial \overline{D}}{\partial t}\right] \bullet d\overline{S}$$

surface considered for both the integrations is same

$$\nabla \times \overline{H} = \overline{J} + \frac{\partial \overline{D}}{\partial t}$$

This is called **point or differential form** of Maxwell's equation derived from Ampere's Circuit law for time varying field.

Derived from Gauss's Law

For Electric Fields

The total flux out of the closed surface is equal to the net charge within the surface.

$$\int_S \overline{D} \bullet d\overline{S} = Q_{enclosed}$$

Charge enclosed is equal to volume charge density

$$\int_S \overline{D} \bullet d\overline{S} = \int_v \rho_v \, dv$$

This is called **integral form** of Maxwell's equation derived from Gauss's law for time varying field

The total flux leaving out of a closed surface is equal to the total charge enclosed by a finite volume.

Using divergence theorem

$$\int_v \left(\nabla \bullet \overline{D}\right) dv = \int_v \rho_v \, dv$$

same volume for integration on both the sides

$$\nabla \bullet \overline{D} = \rho_v$$

This is called **point or differential form** of Maxwell's equation derived from Gauss's law for time varying field.

For Magnetic Fields

The surface integral of **B** over a closed surface S is always zero, due to nonexistence of monopole in the magnetic fields

$$\int_S \overline{B} \bullet d\overline{S} = 0$$

This is called **integral form** of Maxwell's equation derived from Gauss's law for time varying field

The surface integral of magnetic flux density over a closed surface is always equal to zero.

Using divergence theorem

$$\int_V \left(\nabla \bullet \overline{B}\right) dv = 0$$

But being a finite volume, $dv \neq 0$,

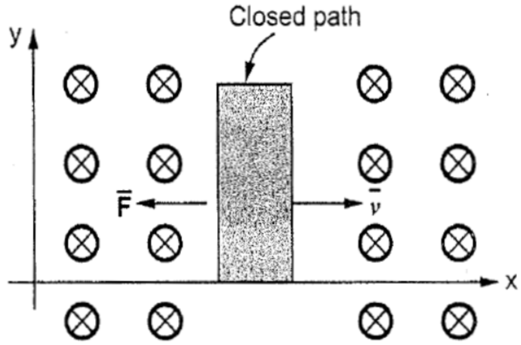
$$\nabla \bullet \overline{B} = 0$$

This is called **point or differential form** of Maxwell's equation derived from Gauss's law for time varying field

Motional Electromotive forces

When the e.m.f. is induced in a time varying closed path due to the static field **B,** then the e.m.f. is called **dynamically induced e.m.f. or motional e.m.f.**

Here the field is stationary while the closed path is moved to get a relative motion between them. This action is similar to the generator action. Hence the induced e.m.f. is also called **motional e.m.f. or generator e.m.f.**



Consider that a charge **Q** is moved in a magnetic field **B** at a velocity ***v***. Then the force on a charge is given by

$$\bar{F} = Q\,\bar{v} \times \bar{B}$$

But the motional electric field intensity is defined as the force per unit charge. It is given by

$$\bar{E}_m = \frac{\bar{F}}{Q} = \bar{v} \times \bar{B}$$

the induced e.m.f. is given by

$$\oint \bar{E}_m \cdot d\bar{L} = \oint \left(\bar{v} \times \bar{B}\right) \cdot d\bar{L}$$

Equation represents total e.m.f. induced when a conductor is moved in a uniform constant magnetic field.

A moving closed path in a time varying **B** field represents a general case in which both the e.m.f.s i.e. transformer e.m.f. and motional e.m.f are present.

Total induced e.m.f = Transformer e.m.f + Motional e.m.f

$$\oint \bar{E} \cdot d\bar{L} = -\int \frac{\partial \bar{B}}{\partial t} \cdot d\bar{S} + \oint \left(\bar{v} \times \bar{B}\right) \cdot d\bar{L}$$

Boundary Conditions

The relationship between the electric flux density **D**, electric field intensity **E**, magnetic flux density **B** and magnetic field intensity **H** can be explained with the help of the point form or the integral form of Maxwell's equations.

Consider the boundary between medium 1 with parameters ε_1, μ_1 and σ_1 and medium 2 with parameters ε_2, μ_2 and σ_2. In general, the boundary conditions for time varying fields are same as those for static fields. Thus, at the boundary, referring boundary conditions for static electric magnetic fields, we can write

1. The tangential component of electric field intensity **E** is continuous at the surface.
   $E_{tan1} = E_{tan2}$
2. Tangential component of the magnetic field intensity is continuous across the surface except for a perfect conductor.
   $H_{tan1} = H_{tan2}$
   At the surface of the perfect conductor, the tangential component is discontinuous at the boundary.
   $H_{tan1} - H_{tan2} = K$
3. Normal component of the electric flux density is continuous at the boundary if the surface charge density is zero
   $D_{N1} = D_{N2}$
   If the surface charge density is nonzero, then the normal component is discontinuous at the boundary.
   $D_{N1} - D_{N2} = \rho_s$
4. The normal component of the magnetic flux density is continuous at the boundary
   $B_{N1} = B_{N2}$

Unit - V

WAVE EQUATIONS AND SOLUTIONS

Poynting Theorem (Electromagnetic Power Flow) & Poynting Vector

The time varying fields or the dynamic electromagnetic fields constitute the electromagnetic waves. These waves may travel through the free space or a dielectric. The common example of the electromagnetic waves is the radio waves.

In case of the electromagnetic waves, the power and energy relationships can be explained in terms of the amplitudes of the electric and magnetic fields.

The resulting theorem is the most fundamental relationships of the electromagnetic theory which is known as Poynting theorem.

An energy can be transported from transmitter to receiver.

The energy stored in an electric field and magnetic field is transmitted at a certain rate of energy flow which can be calculated with the help of Poynting theorem.

we know **E** and **H** are basic fields.

E is electric field expressed in V /m; while **H** is magnetic field measured in A/m. So, if we take product of two fields, dimensionally we get a unit V · A/m^2 or watt/m^2.

So this product of **E** and **H** gives a new quantity which is expressed as watt per unit area. Thus this quantity is called **power density.**

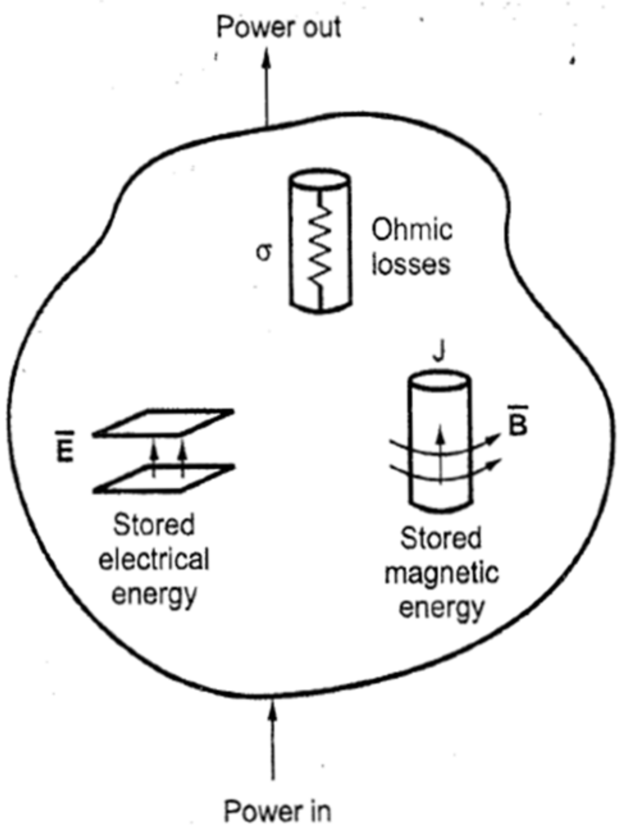
As **E** and **H** both are vectors, to get power density we may carry out either dot product or cross product. The power radiated from antenna has a particular direction. Hence to calculate a power density, we must carry out a cross product of **E** and **H**. The power density is given by,

$$\bar{P} = \bar{E} \times \bar{H}$$

P is called Poynting Vector

The Poynting theorem is based on law of conservation of energy in electromagnetism.
Poynting theorem can be stated as follows:

The net power flowing out of a given volume v is equal to the time rate of decrease in the energy stored within volume v minus the ohmic power dissipated.



Suppose $\bar{E} = E_x \bar{a}_x$

and $\bar{H} = H_y \bar{a}_y$, then

$$\bar{P} = \bar{E} \times \bar{H} = (E_x \bar{a}_x) \times (H_y \bar{a}_y)$$

$$= E_x H_y \bar{a}_z = P_z \bar{a}_z$$

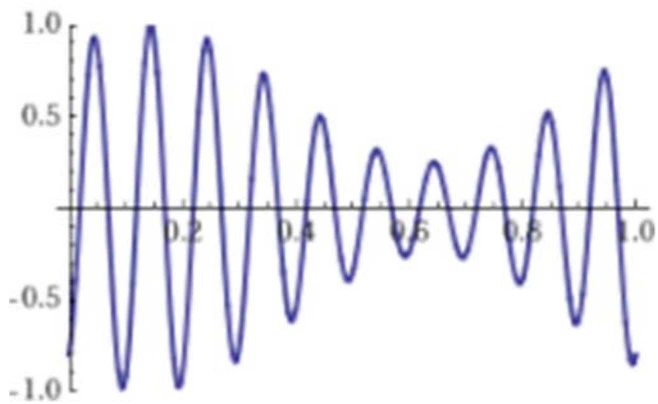
Thus, the power passing particular area is given by,

Power = Power density × Area

Group Velocity

The group velocity of a wave is the velocity with which the overall envelope shape of the wave's amplitudes—known as the modulation or envelope of the wave—propagates through space.

For example, if a stone is thrown into the middle of a very still pond, a circular pattern of waves with a quiescent center appears in the water, also known as a capillary wave. The expanding ring of waves is the wave group, within which one can discern individual waves that travel faster than the group as a whole. The amplitudes of the individual waves grow as they emerge from the trailing edge of the group and diminish as they approach the leading edge of the group.



Plane waves in lossless media

A lossless medium is a medium with zero conductivity and finite permeability and permittivity.

When an electromagnetic wave propagates through a lossless medium, the amplitude of its electric field or magnetic field remains constant throughout the propagation.

The properties of the lossless medium affect the speed of propagation, and it is reduced by a factor of 1/ (√**μ**r**ε**r) compared to the speed of the electromagnetic waves in the vacuum.

A lossless medium for electromagnetic waves is a medium with zero conductivity (**σ**) and finite permeability (**μ**) and permittivity(**ε**). It can be described using the equation below:

$$\text{Lossless media} \Rightarrow \quad (\sigma=0,\ \mu=\mu_r\mu_o,\ \epsilon=\epsilon_o\epsilon_r)$$

The solution of the wave equation describes the characteristics of electromagnetic waves the velocity of propagation, frequency, attenuation, wavelength, and the direction of propagation.

The characteristics of an electromagnetic wave vary with parameters such as the conductivity, permeability, and permittivity of the medium. A medium can be considered a lossless medium for electromagnetic waves when its conductivity is equal to zero, with specific permeability and permittivity values.

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(Autonomous)
Department of Electrical Engineering

Academic Year: **2022-23** **Assignment – I**

Year: II B.Tech **Sub: Electromagnetic Fields** Duration: **03 days**

Semester: **I** **Code: GR20A2026** Max Marks: **05**

S. No.	Question	Marks	CO	BL
1.	What is Coulomb's law. Derive necessary expressions required	01	1	2
2.	Derive the expression for E due to surface charge density	02	1	3
3.	Discuss the boundary condition of surface charge density laying on two different dielectric materials	02	1	3

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Academic Year: **2022-23** **Assignment – II**

Year: II B.Tech **Sub: Electromagnetic Fields** Duration: **03 days**

Semester: **I** **Code: GR20A2026** Max Marks: **05**

S. No.	Question	Marks	CO	BL
1	Discuss the solution of Laplace equation	01	2	2
2	Find E at P (1,1,1) caused by four identical 3nC charges located at P1 (1,1,0), P2(-1,1,0), P3 (-1,-1,0) & P4 (1,-1,0).	02	2	3
3	State Biot-Savart Law. Derive integral form of Biot-Savart Law for a differential element of a long current carrying conductor	02	2	3

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Academic Year: **2022-23** **Assignment – III**

Year: II B.Tech **Sub: Electromagnetic Fields** Duration: **03 days**

Semester: **I** **Code: GR20A2026** Max Marks: **05**

S. No.	Question	Marks	CO	BL
1	What is the force exerted on a differential current element in a given magnetic field	02	3	3
2	Derive maxwell's equations from faraday's in a time varying magnetic field both in point and integral form	03	3	4

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Academic Year: **2022-23** **Assignment – IV**

Year: II B.Tech **Sub: Electromagnetic Fields** Duration: **03 days**

Semester: **I** **Code: GR20A2026** Max Marks: **05**

S. No.	Question	Marks	CO	BL
1	Discuss Displacement current and Displacement current density	01	4	2
2	Derive maxwell's equations from Gauss law in a static electric field both in point and integral form	02	4	3
3	Discuss pointing theorem and pointing vector	02	4	3

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Department of Electrical Engineering

Academic Year: **2022-23** **Assignment – V**

Year: II B.Tech **Sub: Electromagnetic Fields** Duration: **03 days**

Semester: **I** **Code: GR20A2026** Max Marks: **05**

S. No.	Question	Marks	CO	BL
1	Discuss pointing vector	01	5	2
2	Discuss Displacement current density	02	5	3
3	Explain maxwell equation in point form	02	5	3