Department of Physics

College of Science

University of Salahaddin-Erbil

Subject: Principles of Electromagnetic Theory

Course Book – (Year 4, General Branch)

Lecturer's name: Dr. Goran Muhammad Khalil, PhD

Academic Year: 2023/2024

First Semester

Course Book

1. Course name	**Electromagnetic Theory**
2. Lecturer in charge	**Dr. Goran Muhammad Khalil**
3. Department/ College	**Physics / Science**
4. Contact	**e-mail: goran.khalil@su.edu.krd**
5. Time (in hours) per week	**Theory: 3**
6. Office hours	**To be Return to the schedule on the office door**
7. Course code	
8. Teacher's academic profile	I graduate from Salahaddin - Erbil University in 1990. I worked as assistant physicist for two years and assist in different labs: solid state physics lab., nuclear physics lab., atomic lab., mechanics physics and properties of matter lab., thermodynamics lab., general physics lab., electricity and magnetism lab., optics lab., and electronics lab. In 1996 I finished my MSc degree in solid state physics and start as Assistant Lecturer Teaching different subjects as: general physics, electricity and magnetism, mechanics physics, analytical mechanics, computer, Practical solid state physics, practical optics, practical electronics. For 4 years I worked as a member of the examination committee for college of science. In 2010 I get my PhD degree in solid state physics and from that time, as a lecturer, I am in charge in teaching atomic physics for 2nd class students, teaching practical atomic physics and supervising its lab.. Teaching semiconductors physics for 4th class students. Teaching electromagnetic theory for medical branch physics 3rd class students. Teaching academic debate for 1st class students. Supervising the research projects of the 4th physics students. For 6 years worked as a member in Curriculum Development Committee in college of science and organize the curriculum development in physics department.
9. Keywords	Electromagnetic theory, Vector calculus, Electrostatics, Electric fields in matter, Magnetostatics, Magnetic fields in matter, Electrodynamics, Conservation laws, Electromagnetic waves.

10. Course overview:

This is an introductory course at the undergraduate level in Principles of electromagnetic theory. Electromagnetic theory is a discipline concerned with the study of charges at rest and in motion. Electromagnetic principles are fundamental to the study of electrical engineering and physics. Electromagnetic theory is also indispensable to the understanding, analysis and design of various electrical, electromechanical and electronic systems. Some of the branches of study where electromagnetic principles find application are: Electrical Machines such as X-ray machine and medical instruments used for electrocardiograms, scanning etc., RF communication, Microwave Engineering, Satellite Communication, Antennas, Atomic and nuclear research, Radar Technology, Remote sensing.

This course will introduce students to the foundations of electromagnetic theory, therefore the course is intended to cover some of the standard concepts in electromagnetic theory namely, Coulomb's Law and Electric Field Intensity, Electric Flux Density, Gauss's Law, and Divergence, Energy and Potential, Conductors and Dielectrics, The Steady Magnetic Field, Time-Varying Fields and Maxwell's Equations, The Uniform Plane Wave.

The lectures are easy to understand with simple language and lucid style, the mathematical treatment is clear and explanatory and the student will experience no difficulty in understanding the subject. The lectures also contain a moderate number of clearly illustrated diagrams and solved problems wherever necessary.

11. Course objective:

- To introduce the basic mathematical concepts related to electromagnetic vector fields.
- To impart knowledge on the concepts of electrostatics, electrical potential, energy density and their applications.
- To impart knowledge on the concepts of magnetostatics, magnetic flux density, scalar and vector potential and its applications.

12. Student's obligation

To get the best of the course, it is suggested that you attend classes as much as possible for all the material discussed in class. Come to class prepared physically and mentally. Before class, read the required lecture for that day, and then read the material again after class discussion of the topics. Lecture's notes are for supporting and not for submitting the reading material including the handouts. It is your responsibility to review the lecture notes and work on the problems at the end of every chapter in addition to the solved examples. Do not miss class; get notes from someone if you have an unavoidable absence and completion of all tests, exams, assignments.

13. Forms of teaching

Different teaching rules and manners will be used to fulfil the objectives of the course teaching subject: power point presentation for the head titles and definitions and summary of conclusions, classification of materials and any other illustration, solving problems on the white board, besides worksheet will be designed to let the chance for practicing on several aspects of the course.

To get the best of the course, it is suggested that you attend classes as much as possible, read the required lectures, teacher's notes regularly as all of them are foundation for the course. Try as much as possible to participate in classroom discussions and preparing the assignments given in the course.

14. Assessment scheme

The students are required to do two closed book examinations, one quiz (short examine) has 10 marks at the beginning of the course and one midterm examination which has 25 marks at the end of the course. In addition to these exams, assignments including classroom activities, home-work, reports and seminar presentations count for 5 marks and the final exam on 60 marks so that the final grade will be based upon the following criteria:

The quiz: 10%

The midterm exam: 25%

The assignments: 5%

The final exam: 60%

15. Student learning outcome:

Upon the successful completion of this course, the student should be able to

- Apply vector calculus to static electric-magnetic fields in different engineering situations.
- Have an ability to determine and describe static and dynamic electric and magnetic fields for technologically important structures: the coil, charge distributions, the dipole, the coaxial cable, dielectric and conducting spheres immersed in electric fields.
- Analyse Maxwell's equation in different forms (differential and integral) and their applications in electromagnetic problems.
- Examine the phenomena of wave propagation in different media.

16. Course Reading List and References:

1- `` Engineering Electromagnetics'', William H. Hayt, Jr. & John A. Buck, McGraw Hill, 6th Edition (2001).
2- "Elements of Electromagnetics", M. N. Sadiku, Oxford University Press (2018).
3- ``Introduction to Electrodynamics'', David J. Griffiths, Prentice Hall, Inc. 4th Edition (2013).
4- `` Schaum's outline of Theory and Problems of Electromagnetics'', Joseph A. Edminister, Schaum's outline Series, McGraw-Hill, New York, 2nd Edition (1995)

17. The Topics:	**Lecturer's name**
Vector analysis: Scalars and Vectors, Unit vector, A vector in Cartesian (or Rectangular) coordinate system, Vector Algebra, Position and Distance Vectors, The difference between a point and a vector, Vector Multiplication,	D. Goran M. Khalil (3 hrs) **Week 1**
Coordinate Systems and Transformations: Cartesian Coordinates, Circular Cylindrical coordinates, Cylindrical coordinates – Transformation, Spherical coordinates, Spherical coordinates – Transformation, Distance between two points, Constant Coordinate Surfaces,	D. Goran M. Khalil (3 hrs) **Week2**
Vector Calculus: Differential Length, Area, and Volume; In Cartesian Coordinate Systems, In Cylindrical Coordinate Systems, In Spherical Coordinate Systems.	D. Goran M. Khalil (3 hrs) **Week3**
Line, Surface, and Volume Integrals: Line integral, Surface integral, Volume Integral.	D. Goran M. Khalil (3 hrs) **Week4**

Del Operator, Gradient of a Scalar, Divergence of a Vector and Divergence Theorem.	D. Goran M. Khalil (3 hrs) **Week5**
Curl of a Vector and Stokes's Theorem, Laplacian of a Scalar, Classification of Vector Fields.	D. Goran M. Khalil (3 hrs) **Week6**
Electrostatic field, Coulomb's Force, Electric Field Intensity, Charge Distribution, Standard Charge Distribution.	D. Goran M. Khalil (3 hrs) **Week7**
The Electric Potential, Electric Flux, Gauss's Law, Maxwell's First Eq. , Energy Distribution in Electrostatic Field	D. Goran M. Khalil (3 hrs) **Week8**
Conductor, Dielectric & Capacitance, Current &Current Density, Continuity of Current, Conductor Property &Boundary Eq.	D. Goran M. Khalil (3 hrs) **Week9**
Conductor-Free Space Boundaries, Dielectric Materials, Example, Boundary Condition For Perfect Dielectric	D. Goran M. Khalil (3 hrs) **Week10**
Interface Between Dielectric & Conductor, Examples	D. Goran M. Khalil (3 hrs) **Week 11**
Capacitor(Parallel Plates , Multiple Dielectric Capacitor)	D. Goran M. Khalil (3 hrs) **Week 12**
Example, Capacitor of tow Coaxial Cylinder, Capacitor of two Parallel Wires	D. Goran M. Khalil (3 hrs) **Week 13**

The Steady Magnetic Field, The Biot-Savart Law, Magnetic Intensity, Ampere's Law, Magnetic (Flux & Flux Density)	D. Goran M. Khalil (3 hrs) **Week 14**

18. Examinations:
Examination's sample:

Q1/ Write (T) for correct statement and (F) for wrong statement & correct the wrong statement:

1- Faraday's law is customarily stated as

$$emf = -\frac{d\varphi}{dt}(volt) \qquad \textit{This eqution implies a closed path}$$

2- The Biot-savart law states that: $dH \propto R^2$ & $dH \propto \frac{1}{Idl \cdot \sin\theta}$

3- Amperes' Law is: $\oint H \cdot dl = I_{enc}$

4- $[\nabla \times H = J]$ Refer to Maxwell's Eq. in time varying field.

5- $\left(C = \frac{Q}{V_0}\right)$ It's the capacitance of the system of two near conductors, dependent on the V_0 or Q and the dielectric material situated between the parallel plates

Answer:

1- T

2-F/ The Biot-savart law states that: $dH \propto Idl \cdot \sin\theta$ & $dH \propto \frac{1}{R^2}$

3- T

4- F/ $\left[\nabla \times H = J + \frac{\partial D}{\partial t}\right]$ Refer to Maxwell's Eq. in time varying field.

5-F/ $\left(C = \frac{Q}{V_0}\right)$ It's the capacitance of the system of two near conductors, independent on the V_0 or Q but is a function of geometric dimensions and the dielectric material situated between the parallel plates.

Q2/ Write the Maxwell's Equations in time varying field.

Answer:

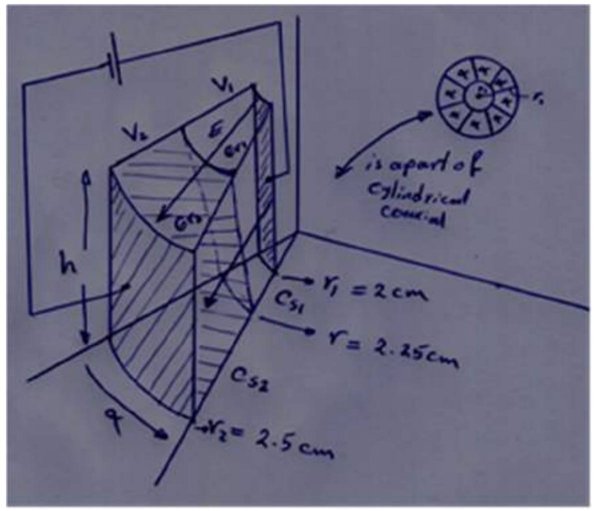
$$\nabla \cdot D = \rho$$

$$\nabla \times E = -\frac{\partial B}{\partial t}$$

$$\nabla \times H = J + \frac{\partial D}{\partial t}$$

$$\nabla \cdot B = 0$$

Q3/ Find the voltage drop across each dielectric in the figure below, where ($\varepsilon_{r1} = 2 , \varepsilon_{r2} = 5$) the inner conductor is at (r=2cm) and the outer at (r=2.5 cm) with dielectric interface at half way between them.



Answer:

The capacitance of two coaxial cylindrical

$$C = \frac{2\pi\varepsilon l}{\ln\frac{r_2}{r_1}}$$

The capacitance of each segment

$$C_s = \frac{\alpha}{2\pi} \cdot \frac{2\pi\varepsilon l_r}{\ln\frac{r_2}{r_1}}$$

$$C_{s1} = \frac{\alpha\varepsilon_0 \times 2 \times h}{\ln\frac{2.25cm}{2cm}}$$

$$C_{s2} = \frac{\alpha\varepsilon_0 \times 5 \times h}{\ln\frac{2.5cm}{2.25cm}}$$

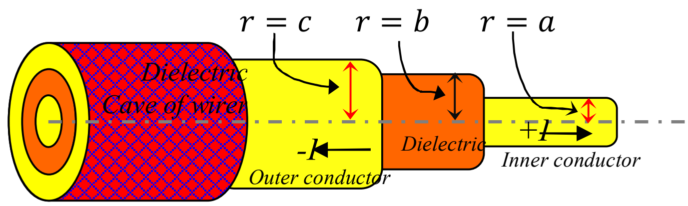
$$Q = Q_1 = Q_2 \ , \quad C_1V_1 = C_2V_2 \quad \rightarrow \quad V_1 = \frac{C_2V_2}{C_1} = \frac{C_2}{C_1}(V - V_1)$$

$$V_1 + \frac{C_2V_1}{C_1} = \frac{C_2}{C_1}V \quad , \quad V_1 = V\left(\frac{C_2}{C_1 + C_2}\right)$$

$$\therefore \ V_1 = V\left(\frac{C_{s2}}{C_{s1} + C_{s2}}\right) = 74 \ volt \qquad\qquad V_2 = V\left(\frac{C_{s1}}{C_{s1} + C_{s2}}\right) = 26volt$$

Q4/ Consider an infinite along coaxial cable carrying a uniformly total current in the center conductor of (+I) and (-I) in the outer conductor. Find H at:

$1 - a < r < b$
$2 - r > c$



Infinite coaxial cable

Answer:

$1 - At\ a < r < b$

The current enclosed I_{enc}

$I_{enc} = +I$

$$\oint H \cdot dl = I_{enc}$$

$$\oint H \cdot dl = \oint_0^{2\pi} H \cdot r d\varphi a_\varphi = +I$$

$$H = \frac{I}{2\pi r} a_\varphi$$

$2 - At\ r > c$

$I_{enc} = (+I) + (-I) = o$ $\oint H \cdot dl = 0$ $\therefore H = 0$

Q5/ The cylindrical surface $(r = 8cm, 1cm < z < 5cm, 30^0 < \varphi < 90^0)$ contains the surface charge
density $\left(\rho_s = 5e^{-20z} \frac{nc}{m^2}\right)$.How much flux (*totalflux*) leaves this surface?

Answer:

We just integrate the charge density on that surface to find the flux that leaves it.

$$\Phi = Q' = \int_{.01}^{.05} \int_{30^\circ}^{90^\circ} 5e^{-20z}(.08)\, d\phi\, dz \text{ nC} = \left(\frac{90-30}{360}\right) 2\pi(5)(.08)\left(\frac{-1}{20}\right) e^{-20z}\Big|_{.01}^{.05}$$

$$= 9.45 \times 10^{-3} \text{ nC} = \underline{9.45 \text{ pC}}$$

20. Extra notes:

This syllabus may be subject to changes, i.e. we may take either longer or shorter time to finish a topic, if any changes happened you will be notified well in advance.

21. Peer review