Department of Physics

College of Science

University of Salahaddin-Erbil

Subject: Application of Electromagnetic Theory

Course Book – (Year 4, General Branch)

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

Academic Year: 2022/2023

Second Semester

Course Book

1. Course name	**Application of 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, Electrostatics, Electric fields in matter, Magnetostatics, Magnetic fields in matter, Electrodynamics, Conservation laws, Electromagnetic waves, Application of Electromagnetic Theory.

10. Course overview:

This is an introductory undergraduate course on electromagnetic theory's Principles of Application. This subject basically consists of static electric fields, static magnetic fields, time-varying fields & it's applications. The study of charges in motion and at rest is central to the field of electromagnetic theory. The study of electrical engineering and physics is fundamentally based on electromagnetic concepts. The study, analysis, and design of various electrical, electromechanical, and electronic systems all depend on electromagnetic theory. Electrical devices, such as X-ray machines and medical equipment used for electrocardiograms, scanning, etc., RF communication, Microwave Engineering, Satellite Communication, Antennas, Atomic and Nuclear Research, Radar Technology, and Remote sensing are some of the fields of study where electromagnetic principles are applied.

The goal of this course is to introduce students to the fundamentals of applying electromagnetic theory. As a result, it will cover some of the fundamental ideas in the field, including Gauss' Law and Divergence, Energy and Potential, Conductors and Dielectrics, The Steady Magnetic Field, Time-Varying Fields and Maxwell's Equations, and The Uniform Plane Wave.

The lectures are straightforward to grasp with clear explanations and simple language, and the mathematical material is presented in a way that makes sense to the student. The lectures also include a fair number of pictures with good illustrations and answered problems when applicable.

11. Course objective:

- To teach students about electrical potential, energy density, and related electrostatics principles and applications.
- To teach students about the fundamentals of magnetostatics, magnetic flux density, scalar and vector potential, and how they are applied.

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 understand the big ideas of electromagnetics, including:

- Static and dynamic electromagnetic (EM) fields, energy, and power
- EM fields and waves within and at the boundaries of media
- EM radiation and propagation in space and within transmission lines
- Circuit behavior of simple EM devices and transmission lines
- EM forces on charges, currents, and materials; mechanically produced fields

16. Course Reading List and References:

1- “Elements of Electromagnetics”, M. N. Sadiku, Oxford University Press (2018).
2- "Engineering Electromagnetics’’, William H. Hayt, Jr. & John A. Buck, McGraw Hill, 6th Edition (2001).
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**
Energy Expended in Moving a Point Charge in an Electric Field, The Line Integral, Definition of Potential Difference and Potential, The Potential Field of a Point Charge, The Potential Field of a System of Charges: Conservative Property, Examples.	D. Goran M. Khalil (3 hrs) **Week 1**
Relationship Between E and V—Maxwell's Equation, The Electric Dipole, Dipole moment, Equipotential Lines, Energy Density in Electrostatic Field, Examples, Application Note-Electrostatic Discharge.	D. Goran M. Khalil (3 hrs) **Week2**
Electric Fields in Material Space, Properties of Materials, Convection and Conduction Currents, Conductors, To derive Resistance, Examples.	D. Goran M. Khalil (3 hrs) **Week3**
Polarization in Dielectrics, Nonpolar and polar Dielectrics, Linear, Isotropic, and homogeneous Dielectrics, Examples.	D. Goran M. Khalil (3 hrs) **Week4**

Continuity Equation and Relaxation Time, Boundary conditions, Dielectric-dielectric Boundary conditions, Conductor-dielectric Boundary conditions, Conductor-Free space Boundary conditions, Examples.	D. Goran M. Khalil (3 hrs) **Week5**
Electrostatic Boundary Value Problems, Poisson's and Laplace's Equations; Laplace's Equation, Poisson's Equation, Uniqueness Theorem, General Procedure for Solving Poisson's or Laplace's Equation, Examples, Applications; EHD pumps, The xerographic copying machine.	D. Goran M. Khalil (3 hrs) **Week6**
Magnetostatic Fields, Magnet and Magnetic Field, Applications, Biot-Savart's Law, line current, surface current, volume current, Magnetic Field of straight Conductor, Examples. .	D. Goran M. Khalil (3 hrs) **Week7**
Ampere's Circuit Law - Maxwell's Equation, Applications of Ampere's Circuit Law Infinite Line Current, Infinite Sheet of Current, Infinitely Long Coaxial Transmission Line, Magnetic Field of a Toroid, Examples.	D. Goran M. Khalil (3 hrs) **Week8**
Magnetic Flux Density, Magnetic Flux Lines, Broken Magnet, Gauss's Law for magnetostatic fields, Maxwell's Equations for Static Fields, Examples.	D. Goran M. Khalil (3 hrs) **Week9**
Magnetic Scalar and Vector Potentials; Magnetic scalar potential, Magnetic Vector Potential, Magnetic flux from vector potential, Application Note—Lightning, Application Note—Polywells, Examples.	D. Goran M. Khalil (3 hrs) **Week10**
Magnetic forces, Materials, and Devises; Forces Due To Magnetic Fields, Force on a Charged Particle, Force on a Current Element, Force between Two Current Elements, Magnetic Torque and Moment, A Magnetic Dipole, Magnetization In Materials, Examples.	D. Goran M. Khalil (3 hrs) **Week 11**

Classification Of Materials, Magnetic Boundary Conditions, Magnetic Energy, Magnetic Circuits, Force On Magnetic Materials, Application Note—Magnetic Levitation, Application Note —Squids, Example.	D. Goran M. Khalil (3 hrs) **Week 12**
Faraday's Law, Transformer And Motional Electromotive Forces, Displacement Current, Maxwell's Equations In Final Forms, Time-Varying Potentials, Application Note—Memristor, Application Note—Optical Nanocircuits, Application Note—Wireless Power Transfer and Qi Standard, Examples	D. Goran M. Khalil (3 hrs) **Week 13**
Electromagnetic Wave Propagation; Waves In General, Wave Propagation In Lossy Dielectrics, Plane Waves In Lossless Dielectrics, Plane waves in free space, Wave representation, Plane Waves in Good Conductors, Power and the Poynting Vector, Reflection Of A Plane Wave At Normal Incidence, Reflection Of A Plane Wave At Oblique Incidence, Application Note—Microwaves, Examples.	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

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

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

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

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

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

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

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

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

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:

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

<u>Answer:</u>

$1 - At\ a < r < b$

The current enclosed I_{enc}

$I_{enc} = +I$

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

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

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

$2 - At\ r > c$

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

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