2020

Electromagnetism I

North Carolina Agricultural and Technical State University

NORTH CAROLINA AGRICULTURAL AND TECHNICAL STATE UNIVERSITY

COURSE SYLLABUS

College Name: College of Science and Technology
Department Name: Physics
Course Name: Electromagnetism I

COURSE INFORMATION

- Course Number/Section: PHYS 415
- Term:
- Semester Credit Hours: 3
- Times and Days:
- Class Location:

INSTRUCTOR CONTACT INFORMATION

- Instructor:
- Office Location:
- Office Phone:
- Email Address:

Faculty must notify students of the approximate time and method they can expect to receive an answer to all communications (e.g., email, phone, course messages). Excluding holidays, the response should be provided within 48 hours.

If there's a graduate teaching assistant assigned to work with this course, please include their names also.

STUDENT HOURS

These are times students may visit the professor without an appointment to request the assistance they need.

NOTE: Students are responsible for reading, understanding, and following the syllabus.

: AM ☐ / PM ☐ – : AM ☐ / PM ☐

Monday ☐ Tuesday ☐ Wednesday ☐ Thursday ☐ Friday ☐

COURSE PREREQUISITES

MATH 132, MATH 231, PHYS 242, PHYS 305

COURSE DESCRIPTION

This is an intermediate course in electromagnetism which along with PHYS 416 includes the study of electric fields and potentials, electric current and magnetic fields, solutions to Maxwell's equations, plane waves, polarization, propagation in media, wave guides and resonant cavities, refraction, and dispersion.

STUDENT LEARNING OBJECTIVES/OUTCOMES (SLO)

Learning outcomes should be specific, measurable, and focused on the content knowledge the students are expected to master and not what the faculty will teach.

If the course is a General Education Course, the SLO should be listed and labeled as "General Education."

SLO 1:

a. Evaluate the integral from negative infinity to infinity of the delta function, δ(x)
b. Evaluate the 3-dimensional divergence of $1/r^2$in the r direction [4πδ3(r)]
c. Evaluate the integral of a function times the delta function.
d. Use vector algebra: vector addition, vector productse.
e. Use vector calculus-differentiation, line surface and volume integralsf.
f. Apply coordinate transformation-Cartesian,cylindrical and sphericalg.
g. Give a geometrical description of the divergence theorem, and fundamental theorem for curls.
h. Change a multidimensional integral in Cartesian coordinates to one in another coordinate system using the Jacobian.
i. Fourier Series.

SLO 2:

a. State Coulomb's Law and use it to solve for E above a line of charge, a loop of charge, and a circular disk of charge.
b. Solve surface and line integrals in curvilinear coordinates (when given the appropriate formulas, as in the inner-front cover of Griffiths).
c. Students should recognize when Gauss' Law is the appropriate way to solve a problem (by recognizing cases of symmetry; and by recognizing limiting cases, such as being very close to a charged body).
d. Recognize that E comes out of the Gaussian integral only if it is constant along the Gaussian surface.
e. Recognize Gauss' Law in differential form and use it to solvefor the charge densityr given an electric field E.
f. State two ways of calculating the potential (via the charge distribution and via the E-field); indicate which the appropriate formulation in different situations is; and correctly evaluate it via the chosen formulation.
g. Calculate the electric field of a charge configuration or region of space when given its potential.
h. State that potential is force per unit charge, and give a conceptual description of V and its relationship to energy.
i. Explain why we can define a vector potential V (because the curl of E is zero and E is a conservative field).

j. Defend the choice of a suitable reference point for evaluating V (generally infinity or zero), and explain why we have the freedom to choose this reference point (because V is arbitrary with respect to a scalar –its slope is important, not its absolute value)
k. Calculate the energy stored in a continuous charge distribution when given the appropriate formula
l. Explain in words what this energy represents.

SLO 3:

a. Sketchtheinduced charge distribution on a conductor placed in an electric field.
b. Explainwhat happens to a conductor when it is placed in an electric field, and sketch the E field inside and outside a conducting sphere placed in an electric field.
c. Explainhow conductors shield electric fields, and describe the consequences of this fact physical problems(e.g., conductors with cavities).
d. Statethat conductors are equipotential, that E=0 inside a conductor, that E is perpendicular to the surface of a conductor (just outside the conductor), and that all charge resides on the surface of a conductor.
e. Recognizethat the solution to Laplace's equation is unique.
f. Realizewhen the method of images is applicable and be able to solve simple cases.
g. Explainthe difference between the physical situation (surface charges) and the mathematical setup (image charges).
h. State the appropriate boundary conditions on V in electrostatics
i. Recognizewhere separation of variables is applicable and what coordinate system is appropriate to separate in.
j. Outlinethe general steps necessary for solving a problem using separation of variables.
k. Statewhat the basis sets are for separation of variables in Cartesian and spherical coordinates (ie., exponentials, sin/cos,and Legendre polynomials.)
l. Applythe physics andsymmetry of a problem to state appropriate boundary conditions.

SLO 4:

a. SolveforthecoefficientsintheseriessolutionforV,byexpandingthepotentialorchargedistribution intermsofspecialfunctionsandusingthecompleteness/orthogonalityofthespecialfunctions,andexpressthefinalanswerasasumoverthesecoefficients
b. Explain when and why approximate potentials are useful.
c. Identify and calculate the lowest-order term in the multipole expansion (i.e., the first non-zero term) for simple charge distributions (generally, monopole or dipole distributions)
d. Sketch the direction and calculate the dipole moment of a given charge distribution, and use that to calculate the potential and electric field.
e. Calculate current density J given the current I, and know the units for each.
f. Explain, in words, what the charge continuity equation means.
g. State the vector form of Ohm's Law (and when it applies.)
h. Calculate the current I, K and J in terms of the velocity of the particle or in terms of each other.

SLO 5:

a. Describe the trajectory of a charged particlein a givenmagnetic field.
b. Sketch the B field around a current distribution, and explain why any components of the field are zero.
c. Explain why the magnetic field does no work.
d. State when theBiot-Savart Law applies (magnetostatics; steady currents,dp/dt=0).
e. Compare similarities and differences between theBiot-Savart law and Coulomb's Law.

f. Choose when to useBiot-Savart Law versus Ampere's Law to calculate B fields, and to completethe calculation in simple cases.
g. Draw appropriate Amperian loops for the cases in which symmetry allows for solution of the B field using Ampere's Law (ie., infinite wire, infinite plane, infinite solenoid, toroids), and calculate Ienc.
h. Make comparisons between E and B in Maxwell's equations (what exactly do we want?)
i. Explain why the potential A is a vector for magnetostatics, whereas it's a scalar (V) in electrostatics.Ie., that the source of magnetic fields is a vector, not a scalar.
j. Students should recognize that A does not have a physical interpretation like V.

REQUIRED TEXTBOOKS AND MATERIALS

Any course-level subscriptions and tools linked in Blackboard Learn learning management system (LMS) should be listed here. The Blackboard LMS must have links to their student data privacy statement.

REQUIRED TEXTS:

1. Griffiths, D. J. (2017). *Introduction to electrodynamics.* Cambridge University Press.

REQUIRED MATERIALS:

SUGGESTED COURSE MATERIALS

SUGGESTED READINGS/TEXTS:

1. Reitz, J. R., Milford, F. J., & Christy, R. W. (1979). *Foundations of Electromagnetic Theory* (4th ed.). Addison-Wesley.
2. Wangsness, R. K. (n.d.). *Electromagnetic Fields* (3rd ed.). Wiley.

SUGGESTED MATERIALS:

GRADING POLICY

ASSIGNMENTS AND GRADING POLICY

94% and above	A		76% - 74%	C
93% - 90%	A-		73% - 70%	C-
89% - 87%	B+		69% - 67%	D+
86% - 84%	B		66% - 64%	D
83% - 80%	B-		63% - 0%	F
79% - 77%	C+			

For GRADUATE COURSES: See 2019-2020 Graduate Catalog p.38 for graduate grading scale and Non-Graded Courses

GRADING ALLOCATION

Course grades are based on a weighted grading scale of 100%. The breakdown for the course is as follows: *[Faculty, please adjust according to your course.]*

Category	# of Activities	Percentage Grade Weight
Assignments	11	20
Quizzes	9	20
Exams	3	30
Final Exam	1	20
Discussion Board	15	10
Total	**39**	**100%**

COURSE POLICIES

USE OF BLACKBOARD AS THE LEARNING MANAGEMENT SYSTEM

Blackboard is the primary online instructional and course communications platform. Students can access the course syllabus, assignments, grades, and learner support resources. Students are encouraged to protect their login credentials, complete a Blackboard orientation, and log in daily to the course.

Note: Uploading assignments through Blackboard presents a challenge for Chromebook users in locating the files for submission. If you use a Chromebook, please be sure you also have access to a Mac computer or Windows computer so you can fully participate in your Blackboard class. For more information about student computer recommendations, please visit https://hub.ncat.edu/administration/its/computer-recommendations.php.

MAKE-UP EXAMS

See << Update Academic Year >>*Undergraduate Bulletin:*

https://www.ncat.edu/provost/academic-affairs/bulletins/index.php

For GRADUATE STUDENTS: See 2019-20 Graduate Catalog p. 54

EXTRA CREDIT

LATE WORK

SPECIAL ASSIGNMENTS

For GRADUATE STUDENTS: FAILING TO MEET COURSE REQUIREMENTS (Graduate Catalog p.40)

For GRADUATE STUDENTS: CLASS ATTENDANCE (see 2019-20 Graduate Catalog p. 53-54)

Students are expected to attend class and participate on a regular basis in order to successfully achieve course learning outcomes and meet federal financial aid requirements (34 CFR 668.22). Class attendance in online courses is defined as active participation in academically-related course activities. Active participation may consist of course interactions with the content, classmates, and/or the instructor. Examples of academically-related course activities include, but are not limited to:

- Completing and submitting assignments, quizzes, exams, and other activities within Blackboard or through Blackboard (3rd-party products).

- Participating in course-related synchronous online chats, discussions, or meeting platforms such as Blackboard Collaborate in which participation is tracked.

CLASSROOM CITIZENSHIP

Courtesy, civility, and respect must be the hallmark of your interactions.

COMPLIANCE WITH THE AMERICANS WITH DISABILITIES ACT

North Carolina A&T State University is committed to following the requirements of the Americans with Disabilities Act Amendments Act (ADAAA) and Section 504 of the Rehabilitation Act.
If you need an academic accommodation based on the impact of a disability, you must initiate the request with the Office of Accessibility Resources (OARS) and provide documentation in accordance with the Documentation Guidelines at N.C. A&T. Once documentation is received, it will be reviewed. Once approved, you must attend a comprehensive meeting to receive appropriate and reasonable accommodations. If you are a student registered with OARS, you must complete the Accommodation Request Form to have accommodations sent to faculty.

OARS is located in Murphy Hall, Suite 01 and can be reached at 336-334-7765, or by email at accessibilityresources@ncat.edu. Additional information and forms can be found on the internet at https://www.ncat.edu/provost/academic-affairs/accessibility-resources/index.php.

Please note: Accommodations are not retroactive and begin once the Disability Verification Form is provided to faculty.

TITLE IX

North Carolina A&T State University is committed to providing a safe learning environment for all students—free of all forms of discrimination and harassment. Sexual misconduct and relationship violence in any form are inconsistent with the university's mission and core values, violates university policies, and may also violate federal and state law. Faculty members are considered "Responsible Employees" and are required to report incidents of sexual misconduct and relationship violence to the Title IX Coordinator. If you or someone you know has been impacted by sexual harassment, sexual assault, dating or domestic violence, or stalking, please visit the Title IX website to access information about university support and resources. If you would like to speak with someone confidentially, please contact Counseling Services at 336-334-7727 or the Student Health Center at 336-334-7880.

TECHNICAL SUPPORT

If you experience any problems with your A&T account, you may call Client Technology Services (formerly Aggie Tech Support and Help Desk) at 336-334-7195, or visit https://hub.ncat.edu/administration/its/dept/ats/index.php.

FIELD TRIP POLICIES / OFF-CAMPUS INSTRUCTION AND COURSE ACTIVITIES

If applicable:

Off-campus, out-of-state, foreign instruction, and activities are subject to state law and university policies and procedures regarding travel and risk-related activities. Information regarding these rules and regulations may be found at https://www.ncat.edu/campus-life/student-affairs/index.php.

STUDENT HANDBOOK

https://www.ncat.edu/campus-life/student-affairs/departments/dean-of-students/student-handbook.php

STUDENT TRAVEL PROCEDURES AND STUDENT TRAVEL ACTIVITY WAIVER

https://hub.ncat.edu/administration/student-affairs/staff-resources/studen_activity_travel_waiver.pdf

OTHER POLICIES *(e.g., Copyright Guidelines, Confidentiality, etc.)*

STUDENT HANDBOOK

https://www.ncat.edu/campus-life/student-affairs/departments/dean-of-students/student-handbook.php

Graduate Catalog

SEXUAL MISCONDUCT POLICY

https://www.ncat.edu/legal/title-ix/sexual-harassment-and-misconduct-policies/index.php

FAMILY EDUCATIONAL RIGHTS AND PRIVACY ACT (FERPA)

https://www.ncat.edu/registrar/ferpa.php

STUDENT COMPLAINT PROCEDURES

https://www.ncat.edu/current-students/student-complaint-form.php

STUDENT CONDUCT AND DISCIPLINE

North Carolina A&T State University has rules and regulations that govern student conduct and discipline meant to ensure the orderly and efficient conduct of the educational enterprise. It is the responsibility of each student to be knowledgeable about these rules and regulations.

Please consult the following about specific policies such as academic dishonesty, cell phones, change of grade, disability services, disruptive behavior, general class attendance, grade appeal, incomplete grades, make-up work, student grievance procedures, withdrawal, etc.:

- Undergraduate Bulletin
  https://www.ncat.edu/provost/academic-affairs/bulletins/index.php
- Graduate Catalog
  https://www.ncat.edu/tgc/graduate-catalog/index.php
- Student Handbook

https://www.ncat.edu/campus-life/student-affairs/departments/dean-of-students/student-handbook.php

ACADEMIC DISHONESTY POLICY

Academic dishonesty includes but is not limited to the following:

1. Cheating or knowingly assisting another student in committing an act of cheating or other academic dishonesty;
2. Plagiarism (unauthorized use of another's words or ideas as one's own), which includes but is not limited to submitting exams, theses, reports, drawings, laboratory notes or other materials as one's own work when such work has been prepared by or copied from another person;
3. Unauthorized possession of exams or reserved library materials; destroying or hiding source, library or laboratory materials or experiments or any other similar actions;
4. Unauthorized changing of grades, or marking on an exam or in an instructor's grade book or such change of any grade record;
5. Aiding or abetting in the infraction of any of the provisions anticipated under the general standards of student conduct;
6. Hacking into a computer and gaining access to a test or answer key prior to the test being given. N.C. A&T reserves the right to search the emails and computers of any student suspected of such computer hacking (if a police report of the suspected hacking was submitted prior to the search); and
7. Assisting another student in violating any of the above rules.

A student who has committed an act of academic dishonesty has failed to meet a basic requirement of satisfactory academic performance. Thus, academic dishonesty is not only a basis for disciplinary action, but may also affect the evaluation of a student's level of performance. Any student who commits an act of academic dishonesty is subject to disciplinary action.

In instances where a student has clearly been identified as having committed an act of academic dishonesty, an instructor may take appropriate disciplinary action, including loss of credit for an assignment, exam, or project; or awarding a grade of "F" for the course, **subject to review and endorsement by the chairperson and dean**.

For GRADUATE STUDENTS: Reference for academic dishonesty – 2010-2020 Graduate Catalog, p.58-59

For GRADUATE STUDENTS: STUDENT RELIGIOUS OBSERVANCE (see Graduate Catalog, p.55)

ASSIGNMENTS AND ACADEMIC CALENDAR

Include topics, reading assignments, due dates, exam dates, withdrawal dates, pre-registration and registration dates, all holidays, and convocations.*

THE WEEK OF MM/DD/YY	SUBJECT	UNIT LEARNING OUTCOMES (ULO)	READING IN TEXT, ACTIVITY, HOMEWORK, EXAM
	Unit 1: Vector Algebra, Electric force and field	ULO 1: Explain vector algebra in electrostatics. (SLO 1) ULO 2: Explain Coulombs Law and apply vectors in	1. **Read Textbook:** Griffiths, D. J. (2017). *Introduction to electrodynamics.* Cambridge University Press. a. Chapter 1: Vector Analysis b. Chapter 2: Electrostatics

		calculating electric forces. (SLO 2) ULO 3: Describe the concept of electric field and use vectors to evaluate electric fields. (SLO 2) ULO 4: Evaluate electric fields for continuous charge distributions. (SLO 2)	2. Assignment #1 (ULO 1-4) 3. Discussion Board #1: Self-Introduction (N/A) 4. Discussion Board #2 (ULO 1-4)
	Unit 2: Vector differential calculus, Divergence and Curl of Electrostatic Fields	ULO 1: Evaluate vector differentiation (SLO 1) ULO 2: Explain divergence, gradient and curl (SLO 1) ULO 3: Describe divergence and curl of electrostatic fields (SLO 2) ULO 4: Explain and apply Gauss's law (SLO 2) ULO 5: Explain Gauss's law in integral and differential form (SLO 2)	1. **Read Textbook:** Griffiths, D. J. (2017). *Introduction to electrodynamics.* Cambridge University Press. a. Chapter 1: Vector Analysis b. Chapter 2: Electrostatics 2. Assignment #2 (ULO 1-5) 3. Discussion Board #3 (ULO 1-5) 4. Quiz #1 (Unit-1 ULO 1-4)
	Unit 3: Vector integration: line, surface, volume integrals, Gauss's Law	ULO 1: Evaluate vector integration (SLO 1) ULO 2: Evaluate line, surface and volume integral (SLO 1) ULO 3: Describe divergence and Stokes' theorem (SLO 1) ULO 4: Evaluate to Gauss's Law (SLO 2)	1. **Read Textbook:** Griffiths, D. J. (2017). *Introduction to electrodynamics*. Cambridge University Press. a. Chapter 1: Vector Analysis b. Chapter 2: Electrostatics 2. Assignment #3 (ULO 1-4) 3. Discussion Board #4 (ULO 1-4) 4. Quiz #2 (Unit-2 ULO 1-5)
	Unit 4: Electric Potential, work and energy in Electrostatics	ULO 1: Explain electric potentials and calculate electric potentials for discrete and continuous charge distributions (SLO 2) ULO 2: Explain electric potentials from electric fields and vice versa (SLO 2) ULO 3: Evaluate Poisson and Laplace equations (SLO 2)	1. **Read Textbook:** Griffiths, D. J. (2017). *Introduction to electrodynamics*. Cambridge University Press. a. Chapter 1: Vector Analysis b. Chapter 2: Electrostatics 2. Assignment #4 (ULO 1-5) 3. Discussion Board #5 (ULO 1-5) 4. Quiz #3 (Unit-3 ULO 1-4)

		ULO 4: Describe boundary conditions (SLO 2) ULO 5: Evaluate work and energy in electric fields (SLO 2)	
	Unit 5: Curvilinear coordinates, the Dirac delta function, and conductors	ULO 1: Evaluate coordinate transformation (SLO 1) ULO 2: Evaluate curvilinear coordinates (SLO 1) ULO 3: Describe the delta Dirac function (SLO 1) ULO 4: Describe conductors and insulators (SLO 2) ULO 5: Describe and evaluate capacitance (SLO 2)	1. **Read Textbook:** Griffiths, D. J. (2017). *Introduction to electrodynamics*. Cambridge University Press. a. Chapter 1: Vector Analysis b. Chapter 2: Electrostatics 2. Assignment #5 (ULO 1-5) 3. Discussion Board #6 (ULO 1-5) 4. Quiz #4 (Unit 4 ULO 1-5)
	Unit 6: Laplace Equations	ULO 1: Explain Laplace equation in one dimension (SLO 3) ULO 2: Evaluate Laplace equation in 2 and 3 dimensions (SLO 3) ULO 3: Explain the uniqueness theorem (SLO 3)	1. **Read Textbook:** Griffiths, D. J. (2017). *Introduction to electrodynamics*. Cambridge University Press. a. Chapter 3: Potentials 2. Discussion Board #7 (ULO 1-3) 3. Exam #1 (All ULOs Unit 1-5)
	Unit 7: The Method of Images	ULO 1: Evaluate the method of images in calculating electric potentials (SLO 3) ULO 2: Explain method of images to determine the potential for a charge and a conducting plane (SLO 3) ULO 3: Evaluate the method of images to determine the potential for a charge and a conducting sphere (SLO 3)	1. **Read Textbook:** Griffiths, D. J. (2017). *Introduction to electrodynamics*. Cambridge University Press. a. Chapter 3: Potentials 2. Assignment #6 (Unit-6 ULO 1-3) 3. Discussion Board #8 (ULO 1-3)

	Unit 8: Separation of Variables: Laplace equations in Cartesian coordinate system	ULO 1: Evaluate Fourier series (SLO 1) ULO 2: Evaluate Laplace equation in Cartesian coordinates (SLO 3) ULO 3: Describe boundary conditions in Cartesian coordinates (SLO 3)	1. **Read Textbook:** Griffiths, D. J. (2017). *Introduction to electrodynamics*. Cambridge University Press. a. Chapter 3: Potentials 2. Assignment #7 (Unit 7 ULO 1-3) 3. Discussion Board #9 (ULO 1-3) 4. Quiz #5 (Unit-6 ULO 1-3)
	Unit 9: Laplace Equations in spherical coordinates	ULO 1: Describe Laplace Equation in spherical coordinates (SLO 3) ULO 2: Evaluate the Laplace equation in spherical coordinates (SLO 3) ULO 3: Evaluate Legendre polynomials (SLO 3) ULO 4: Describe spherical boundary conditions (SLO 3)	1. **Read Textbook:** Griffiths, D. J. (2017). *Introduction to electrodynamics*. Cambridge University Press. a. Chapter 3: Potentials 2. Assignment #8 (Unit 8 ULO 1-3) 3. Discussion Board #10 (ULO 1-4) 4. Quiz #6 (Unit 7 ULO 1-3)
	Unit 10: Laplace Equations and Multipole expansions	ULO 1: Evaluate boundary value problems in spherical coordinates (SLO 4) ULO 2: Evaluate multipole expansion of electric potential of a discrete charge distribution and continuous distribution (SLO 4) ULO 3: Explain monopoles, dipoles (SLO 4) ULO 4: Evaluate electric potential and electric field due to dipoles (SLO 4) ULO 5: Evaluate dipole moments of charge distributions (SLO 4)	1. **Read Textbook:** Griffiths, D. J. (2017). *Introduction to electrodynamics*. Cambridge University Press. a. Chapter 3: Potentials 2. Discussion Board #11 (ULO 1-5) 3. Exam #2 (All ULOs Unit 5-9)
	Unit 11:	ULO 1: Evaluate Vector	1. **Read Textbook:** Griffiths, D.

	Lorentz force, magnetic fields, filed due to currents	products (SLO 1) ULO 2: Describe magnetic fields and Lorentz forces (SLO 5) ULO 3: Explain vector products to calculate magnetic forces (SLO 5) ULO 4: Evaluate forces due to current carrying wires (SLO 5) ULO 5: Explain line surface and volume currents (SLO 5)	J. (2017). *Introduction to electrodynamics*. Cambridge University Press. a. Chapter 1: Vectors b. Chapter 5: Magnetic Fields 2. Assignment #9 (Unit 10 ULO 1-5) 3. Discussion Board #12 (ULO 1-5) 4. Quiz #7 (Unit 10 ULO 1-5)
	Unit 12: The Biot Savart Law, Magnetic fields of steady currents	ULO 1: Introduction of Biot Savart Law and explanation (SLO 5) ULO 2: Evaluate Boit-Savart Law to calculate fields due to current carrying wires in different geometries (SLO 5)	1. **Read Textbook:** Griffiths, D. J. (2017). *Introduction to electrodynamics*. Cambridge University Press. a. Chapter 5: Magnetic Fields 2. Assignment #10 (Unit-10 ULO 1-5) 3. Discussion Board #13 (ULO 1-2) 4. Quiz #8 (Unit 10 ULO 1-5)
	Unit 13: The divergence and curl of B, Amperes Law	ULO 1: Evaluate the divergence and curl of magnetic fields (SLO 5) ULO 2: Describe Amperes Law (SLO 5) ULO 3: Explain Amperes Law (SLO 5) ULO 4: Express Amperes law in integral and differential form (SLO 5)	1. **Read Textbook:** Griffiths, D. J. (2017). *Introduction to electrodynamics*. Cambridge University Press. a. Chapter 1: Vectors b. Chapter 5: Magnetic Fields 2. Discussion Board #14 (ULO 1-4) 3. Exam #3 (All ULOs Unit 10-13)
	Unit 14: Magnetic Vector potential	ULO 1: Explain the difference between electric and magnetic fields and potentials (SLO 5) ULO 2: Explain the magnetic vector potential (SLO 5)	1. Read Textbook: Griffiths, D. J. (2017). *Introduction to electrodynamics*. Cambridge University Press. a. Chapter 5: Magnetic Fields 2. Assignment #11 (All ULOs Unit 11-12) 3. Discussion Board #15 (ULO 1-4)

		ULO 3: Evaluate magnetic vector potentials for current distributions (SLO 5) ULO 4: Explain magnetic boundary conditions (SLO 5)	4. Quiz #9 (All ULOs Unit 11-12)
	Unit 15: Multipole expansion of the Magnetic Vector Potential, Magnetic dipoles	ULO 1: Explain magnetic vector potential to determine magnetic multipoles (SLO 5) ULO 2: Evaluate magnetic dipoles (SLO 5) ULO 3: Evaluate Torque and force on dipoles (SLO 5) ULO 4: Evaluate energy of dipoles (SLO 5)	1. Read Textbook: Griffiths, D. J. (2017). *Introduction to electrodynamics*. Cambridge University Press. a. Chapter 5: Magnetic Fields 2. Discussion Board #16 (ULO 1-4) 3. Final Exam (All ULOs Unit 1-15)

** These descriptions and timelines are subject to change at the discretion of the instructor.*