



PHYS 532.01W Electromagnetism: Analysis and Applications

COURSE SYLLABUS: Fall 2023

INSTRUCTOR INFORMATION

Instructor: Dr. Robynne Lock

Office Location: STC 238, or by Zoom

Office Hours: Monday, 9:00-10:00 pm, or by appointment

Office Phone: 903-213-5864

Office Fax: 903-886-5480

University Email Address: robynne.lock@tamuc.edu

Preferred Form of Communication: Email

Communication Response Time: Within 48 hours on weekdays and weekends

COURSE INFORMATION

Materials – Textbooks, Readings, Supplementary Readings

I have referenced a variety of materials in developing this course, and I will provide you access as needed. Some books you might find helpful are listed below, followed by a list of papers we will be reading:

Fleisch, *A Student's Guide to Maxwell's Equations* (ISBN: 9780521701471). This book is much more readable than a standard textbook. It's a nice overview of E&M. I really like how it builds around Maxwell's Equations as that is how I have structured the course.

Tallarida, *Pocket book of Integrals and Mathematical Formulas*

Any edition will work. This book is a useful reference containing trigonometric identities, integral tables, etc. It was one of my best friends when I was in college.

Bruce J. Hunt, *The Maxwellians* (1991). This book is a history of the physicists who developed Maxwell's ideas after his death. Maxwell's equations actually don't appear in his work. They are the work of these scientists

The syllabus/schedule are subject to change.

A. Zangwill, *Modern Electrodynamics* (2013). This is a graduate level textbook with many references to additional reading including both historical documents and modern research, another element I think important to include.

A. Garg, *Classical Electromagnetism in a Nutshell* (2012). This is another graduate level E&M textbook. The author explains in his preface how he wants to put more emphasis on physics than on mathematics compared to other grad level E&M books. Also noteworthy is that he fully treats E&M in a vacuum before moving into E&M in materials, which is also more similar to my approach.

Griffiths, *Introduction to Electrodynamics*. This is one of the standard upper division E&M textbooks. It's a useful reference.

E.M. Purcell and D.J. Morin, *Electricity and Magnetism* (The version I have was printed in 2020, but the original was published in 1963). This is a textbook at the upper division undergraduate level similar to Griffiths.

J.D. Jackson, *Classical Electrodynamics* (My edition was published in 1999, but the original is from 36 years before that.) This is the standard graduate E&M textbook.

R.W. Boyd, *Nonlinear Optics* (My edition is from 2003, but the first edition was from 10 years earlier). Nonlinear optics is a field with its beginnings in 1961 and is not part of the standard physics curriculum. It includes the world of frequency doubling and tripling among other things.

Readings

B.J. Hunt, "Our friend of brilliant ideas,' G.F. Fitzgerald and the Maxwellian Circle," *Eur. Rev.* 15, 531 (2007).

B. Franklin, "Letter XI," In *Benjamin Franklin's experiments and observations on electricity* (pp. 265-266), Cambridge, MA: Harvard University Press (1941).

T.M. Scaife and A.F. Heckler, "Interference between electric and magnetic concepts in introductory physics," *Phys. Rev. ST – Phys. Ed. Res.* 7, 010104 (2011).

D. Voss, "Synopsis: A crackling in the air," 2 May 2013. [Physics.aps.org](https://physics.aps.org).
<<https://physics.aps.org/synopsis-for/10.1103/PhysRevLett.110.185005>> 13 January 2016.

A.V. Gurevich and A.N. Karashtin, "Runaway breakdown and hydrometeors in lightning initiation," *PRL* 110, 185005 (2013).

M.W. Ray et al., "Observation of Dirac monopoles in a synthetic magnetic field," *Nature* 505, 657 (2014).

The syllabus/schedule are subject to change.

Y. Cao and B.M. Brizuela, "High school students' representations and understanding of electric fields," PRPER 12, 020102 (2016).

S. Kapon and H. Veksler, "Teaching nonscience majors about electromagnetic radiation," PRPER 16, 020141 (2020).

Course Description

This course covers electromagnetism from a variety of perspectives. The course will include traditional advanced electricity and magnetism content, history of electromagnetism, current events in physics, and physics education research relevant to electricity and magnetism.

Note that the traditional advanced E&M content (problem solving) requires calculus, including multivariable calculus. Review resources will be provided at the beginning of the semester. The first two weeks of class will include review of vector calculus.

University Catalog Description

Topics include vector analysis, electrostatics, electric fields, magnetostatics, magnetic fields, and electrodynamics. Connections to modern applications will be explored. Emphasis will be placed on conceptual understanding.

Student Learning Outcomes

1. Students will be able to analyze the divergence and curl of electric and magnetic fields.
2. Students will be able to apply Coulomb's Law and Gauss's Law.
3. Students will be able to apply Ampere's Law.
4. Students will be able to apply Faraday's law and Lenz's law.
5. Students will be able to conceptually explain the meaning of each of Maxwell's equations.
6. Students will be able to describe properties of electromagnetic waves both conceptually and mathematically.
7. Students will be able to discuss the application of findings of physics education research to their own teaching.
8. 8. Students will be able to incorporate history and current events in physics into their own teaching.

The syllabus/schedule are subject to change.

COURSE REQUIREMENTS

Minimal Technical Skills Needed

Students need to be able to use myLeo Online, scan assignments and include multiple pages as a single document, video conference, watch YouTube videos, and use Perusall.

Instructional Methods

Each electricity and magnetism content module contains 1-4 videos. Students should plan to watch ~1 video per week. There will be points during each video during which you should pause and work the sample problems before continuing to watch the video. A discussion board can be found in each electricity and magnetism module for you to discuss working problems with fellow students, including both the “in-class” problems for the videos and your homework problems. Each reading assignment will be available for discussion in the Perusall platform. You will have an assignment due approximately every other week alternating between problem sets and reading assignments. See the schedule at the end of the syllabus. There will be 1 midterm and a final covering the electricity and magnetism content. The final is not cumulative. To earn an A in the course, you will also need to complete an annotated bibliography on E&M physics education research AND an annotated bibliography on history and/or modern research/applications of E&M. You and your classmates will participate in peer review for these two assignments before the final versions are due.

Student Responsibilities or Tips for Success in the Course

Students are expected to watch the videos, participate in all discussions, complete all homework assignments, and complete all exams. Students are to be aware of all deadlines and ask questions when directions are unclear.

GRADING

In this course, we will be using specifications-based grading. This is a form of “mastery-based” grading or standards-based grading. In specs-based grading, the focus is not on assigning specific number grades to assignments and calculating averages, but rather completing specific assignments at sufficient quality. I expect anybody who makes a good faith effort throughout the course to be able to obtain a B. To earn an A, you must show a deeper level of understanding by completing additional assignments. The grade scheme is as follows:

Grade of A:

- Fulfill all the requirements for a B (see below)
- Complete annotated bibliography: PER at sufficient quality
- Complete annotated bibliography: history and/or modern research/applications at sufficient quality

Grade of B:

The syllabus/schedule are subject to change.

Complete pass 5 out of 6 Perusall assignments at sufficient quality
Complete 5 out of 6 Problem set assignments at sufficient quality
Demonstrate good understanding and skills on the Midterm and Final
Meet requirements for participation in 5 out of 6 Problem set discussions

Grade of C:

Complete 4 out of 6 Perusall assignments at sufficient quality
Complete 4 out of 6 Problem set assignments at sufficient quality
Demonstrate good understanding and skills on the Midterm and Final
Meet requirements for participation in 5 out of 6 Problem set discussions

Grade of D:

Complete 3 out of 6 Perusall assignments at sufficient quality
Complete 3 out of 6 Problem set assignments at sufficient quality
Demonstrate some understanding and skills on the Midterm and Final
Meet requirements for participation in 4 out of 6 Problem set discussions

Grade of F:

Does not meet the minimum requirements for a D

Exceptions: I am human, and I know you are too. If there are extenuating circumstances that you believe have prevented the grading system from properly reflecting your understanding and effort, please contact me, and we can talk about it. I can also be flexible with deadlines if needed.

Details about each type of assignment follow:

Perusall assignments: Perusall is an online system that enables students and instructors to collectively discuss a text as they read. There are 6 reading assignments within Perusall for this course, each a minimum of one journal paper. Reading assignments are due approximately every other week. See schedule at the end of the syllabus and in Perusall itself. On each assignment, I have written a short introduction. Then you read the paper(s) online. You make annotations (notes) as you read to share your thoughts and write questions. You can respond to each other and upvote each other. I will also be participating. I can see how much of the paper you have read and how much time you have spent reading. The system automatically calculates a percentage grade based on number and quality of annotations, interacting with each other, and time spent reading. I have set a threshold for passing. Only passing matters in specs-based grading, not a percentage grade. This should become clear with our first reading assignment, but if you have any questions, please ask.

Problem set assignments: There are 5 problem sets, assigned approximately every other week. See schedule at the end of the syllabus. Sufficient quality for full credit requires a good faith effort on the majority of the problems. You will complete problem sets on your own paper and then either scan them or take their picture and submit them

The syllabus/schedule are subject to change.

via myLeo Online. Problem Sets should be submitted as a single file. Do NOT upload several jpg files. You are strongly encouraged to discuss your problem set homework with fellow classmates on the class discussion boards. Problem set solutions will be made available after the deadline.

Midterm and Final: There will be 1 midterm and a final. See exam due dates at the end of the syllabus. The exams will be made available one week before the due date. Exams are treated as “take-home” exams. They are open note/open book and untimed. Collaboration is not permitted. The exams primarily test procedural knowledge, though some conceptual understanding is required. Demonstration of understanding is required for credit. Retesting may be possible in extenuating circumstances.

Problem Set discussion: You are expected to participate in the problem discussions to discuss the sample problems from the videos or to discuss the problem set homework. To receive full credit, you must make at least 3 posts, at least one of which must be a reply to another student. Due dates listed in D2L are for the first post. You may make additional posts after the deadline but generally within the time frame of the relevant unit.

Annotated bibliographies: An annotated bibliography is a reference list with comments (annotations) on each reference. Details for these assignments will be included in separate documents, but I will include a brief summary here. Inspired by the reading assignments in Perusall, the additional papers I have included in the Perusall library, and your own interests, you are to locate 5 journal papers on the relevant topic. For each paper, you will write a summary and a reflection on how useful the paper is for teaching practice including any ideas for lessons the paper has given you. Requirements for “sufficient quality” will be included in the other documents with full details. Peer review will be conducted about two-thirds of the way through the semester. Final versions will be due at the end of the semester. There are **two** annotated bibliographies required to earn an A:

- Annotated bibliography: Physics education research on E&M
- Annotated bibliography: History and/or modern research/applications

TECHNOLOGY REQUIREMENTS

Browser support

D2L is committed to performing key application testing when new browser versions are released. New and updated functionality is also tested against the latest version of supported browsers. However, due to the frequency of some browser releases, D2L cannot guarantee that each browser version will perform as expected. If you encounter any issues with any of the browser versions listed in the tables below, contact D2L

The syllabus/schedule are subject to change.

Support, who will determine the best course of action for resolution. Reported issues are prioritized by supported browsers and then maintenance browsers.

Supported browsers are the latest or most recent browser versions that are tested against new versions of D2L products. Customers can report problems and receive support for issues. For an optimal experience, D2L recommends using supported browsers with D2L products.

Maintenance browsers are older browser versions that are not tested extensively against new versions of D2L products. Customers can still report problems and receive support for critical issues; however, D2L does not guarantee all issues will be addressed. A maintenance browser becomes officially unsupported after one year.

Note the following:

- Ensure that your browser has JavaScript and Cookies enabled.
- For desktop systems, you must have Adobe Flash Player 10.1 or greater.
- The Brightspace Support features are now optimized for production environments when using the Google Chrome browser, Apple Safari browser, Microsoft Edge browser, Microsoft Internet Explorer browser, and Mozilla Firefox browsers.

Desktop Support

Browser	Supported Browser Version(s)	Maintenance Browser Version(s)
Microsoft® Edge	Latest	N/A
Microsoft® Internet Explorer®	N/A	11
Mozilla® Firefox®	Latest, ESR	N/A
Google® Chrome™	Latest	N/A
Apple® Safari®	Latest	N/A

Tablet and Mobile Support

Device	Operating System	Browser	Supported Browser Version(s)
Android™	Android 4.4+	Chrome	Latest

The syllabus/schedule are subject to change.

Device	Operating System	Browser	Supported Browser Version(s)
Apple	iOS®	Safari, Chrome	The current major version of iOS (the latest minor or point release of that major version) and the previous major version of iOS (the latest minor or point release of that major version). For example, as of June 7, 2017, D2L supports iOS 10.3.2 and iOS 9.3.5, but not iOS 10.2.1, 9.0.2, or any other version. Chrome: Latest version for the iOS browser.
Windows	Windows 10	Edge, Chrome, Firefox	Latest of all browsers, and Firefox ESR.

- You will need regular access to a computer with a broadband Internet connection. The minimum computer requirements are:
 - 512 MB of RAM, 1 GB or more preferred
 - Broadband connection required courses are heavily video intensive
 - Video display capable of high-color 16-bit display 1024 x 768 or higher resolution
- You must have a:
 - Sound card, which is usually integrated into your desktop or laptop computer
 - Speakers or headphones.
 - *For courses utilizing video-conferencing tools and/or an online proctoring solution, a webcam and microphone are required.
- Both versions of Java (32 bit and 64 bit) must be installed and up to date on your machine. At a minimum Java 7, update 51, is required to support the learning management system. The most current version of Java can be downloaded at: [JAVA web site http://www.java.com/en/download/manual.jsp](http://www.java.com/en/download/manual.jsp)
- Current anti-virus software must be installed and kept up to date.

Running the browser check will ensure your internet browser is supported.
Pop-ups are allowed.

The syllabus/schedule are subject to change.

JavaScript is enabled.
Cookies are enabled.

- You will need some additional free software (plug-ins) for enhanced web browsing. Ensure that you download the free versions of the following software:
 - [Adobe Reader](https://get.adobe.com/reader/) <https://get.adobe.com/reader/>
 - [Adobe Flash Player](https://get.adobe.com/flashplayer/) (version 17 or later) <https://get.adobe.com/flashplayer/>
 - [Adobe Shockwave Player](https://get.adobe.com/shockwave/) <https://get.adobe.com/shockwave/>
 - [Apple Quick Time](http://www.apple.com/quicktime/download/) <http://www.apple.com/quicktime/download/>
- At a minimum, you must have Microsoft Office 2013, 2010, 2007 or Open Office. Microsoft Office is the standard office productivity software utilized by faculty, students, and staff. Microsoft Word is the standard word processing software, Microsoft Excel is the standard spreadsheet software, and Microsoft PowerPoint is the standard presentation software. Copying and pasting, along with attaching/uploading documents for assignment submission, will also be required. If you do not have Microsoft Office, you can check with the bookstore to see if they have any student copies.

ACCESS AND NAVIGATION

You will need your campus-wide ID (CWID) and password to log into the course. If you do not know your CWID or have forgotten your password, contact the Center for IT Excellence (CITE) at 903.468.6000 or helpdesk@tamuc.edu.

Note: Personal computer and internet connection problems do not excuse the requirement to complete all course work in a timely and satisfactory manner. Each student needs to have a backup method to deal with these inevitable problems. These methods might include the availability of a backup PC at home or work, the temporary use of a computer at a friend's home, the local library, office service companies, Starbucks, a TAMUC campus open computer lab, etc.

COMMUNICATION AND SUPPORT

Brightspace Support

Need Help?

Student Support

If you have any questions or are having difficulties with the course material, please contact your Instructor.

The syllabus/schedule are subject to change.

Technical Support

If you are having technical difficulty with any part of Brightspace, please contact Brightspace Technical Support at 1-877-325-7778 or click on the **Live Chat** or click on the words “[click here](#)” to submit an issue via email.



System Maintenance

D2L runs monthly updates during the last week of the month, usually on Wednesday. The system should remain up during this time unless otherwise specified in an announcement. You may experience minimal impacts to performance and/or look and feel of the environment.

Perusall

We will be using Perusall for reading assignments. This is a browser-based platform. Technical support can be found here: <https://support.perusall.com/hc/en-us/categories/360002173133-Students>

Interaction with Instructor Statement

The best method to reach the instructor is through email. You can send an email to robynne.lock@tamuc.edu with **PHYS 532 in the subject line**. If you do not receive a response within 48 hours, send a reminder email.

The instructor will hold office hours on Zoom. The URL will be posted in myLeo Online/D2L.

The instructor will participate in Perusall and on class discussion boards. Please restrict these discussion boards to their labeled topics.

COURSE AND UNIVERSITY PROCEDURES/POLICIES

Course Specific Procedures/Policies

1. You are responsible for knowing when all deadlines are.
2. You are responsible for asking for clarification whenever directions are unclear to you.
3. **When emailing the instructor, include the course number in the subject line.**
4. You are expected to check your email and myLeo Online/D2L for class announcements at least once per day. Emails will be sent to the email addresses you provided to MyLeo.
5. Homework and exams are due at the times indicated in D2L and Perusall. Late work will be accepted in extenuating circumstances.
6. Students are expected to be professional and respectful and follow netiquette.

The syllabus/schedule are subject to change.

Syllabus Change Policy

The syllabus is a guide. Circumstances and events, such as student progress, may make it necessary for the instructor to modify the syllabus during the semester. Any changes made to the syllabus will be announced in advance.

University Specific Procedures

Student Conduct

All students enrolled at the University shall follow the tenets of common decency and acceptable behavior conducive to a positive learning environment. The Code of Student Conduct is described in detail in the [Student Guidebook](#).

<http://www.tamuc.edu/Admissions/oneStopShop/undergraduateAdmissions/studentGuidebook.aspx>

Students should also consult the Rules of Netiquette for more information regarding how to interact with students in an online forum: [Netiquette](#)

<http://www.albion.com/netiquette/corerules.html>

TAMUC Attendance

For more information about the attendance policy please visit the [Attendance](#) webpage and [Procedure 13.99.99.R0.01](#).

<http://www.tamuc.edu/admissions/registrar/generalInformation/attendance.aspx>

<http://www.tamuc.edu/aboutUs/policiesProceduresStandardsStatements/rulesProcedures/13students/academic/13.99.99.R0.01.pdf>

Academic Integrity

Students at Texas A&M University-Commerce are expected to maintain high standards of integrity and honesty in all of their scholastic work. For more details and the definition of academic dishonesty see the following procedures:

[Undergraduate Academic Dishonesty 13.99.99.R0.03](#)

<http://www.tamuc.edu/aboutUs/policiesProceduresStandardsStatements/rulesProcedures/13students/undergraduates/13.99.99.R0.03UndergraduateAcademicDishonesty.pdf>

[Graduate Student Academic Dishonesty 13.99.99.R0.10](#)

<http://www.tamuc.edu/aboutUs/policiesProceduresStandardsStatements/rulesProcedures/13students/graduate/13.99.99.R0.10GraduateStudentAcademicDishonesty.pdf>

The syllabus/schedule are subject to change.

Plagiarism

Plagiarism is a criminal activity. You must cite all sources of information. Unreferenced copying of material, whether parts of sentences, whole sentences, paragraphs, or entire articles can result in a score of zero for your assignment and may result in further disciplinary action. This includes self-plagiarism. Do not reuse work from another course.

ADA Statement

Students with Disabilities

The Americans with Disabilities Act (ADA) is a federal anti-discrimination statute that provides comprehensive civil rights protection for persons with disabilities. Among other things, this legislation requires that all students with disabilities be guaranteed a learning environment that provides for reasonable accommodation of their disabilities. If you have a disability requiring an accommodation, please contact:

Office of Student Disability Resources and Services

Texas A&M University-Commerce

Gee Library- Room 162

Phone (903) 886-5150 or (903) 886-5835

Fax (903) 468-8148

Email: studentdisabilityservices@tamuc.edu

Website: [Office of Student Disability Resources and Services](#)

<http://www.tamuc.edu/campusLife/campusServices/studentDisabilityResourcesAndServices/>

Nondiscrimination Notice

Texas A&M University-Commerce will comply in the classroom, and in online courses, with all federal and state laws prohibiting discrimination and related retaliation on the basis of race, color, religion, sex, national origin, disability, age, genetic information or veteran status. Further, an environment free from discrimination on the basis of sexual orientation, gender identity, or gender expression will be maintained.

Campus Concealed Carry Statement

Texas Senate Bill - 11 (Government Code 411.2031, et al.) authorizes the carrying of a concealed handgun in Texas A&M University-Commerce buildings only by persons who have been issued and are in possession of a Texas License to Carry a Handgun. Qualified law enforcement officers or those who are otherwise authorized to carry a concealed handgun in the State of Texas are also permitted to do so. Pursuant to Penal Code (PC) 46.035 and A&M-Commerce Rule 34.06.02.R1, license holders may not carry a concealed handgun in restricted locations.

For a list of locations, please refer to the [Carrying Concealed Handguns On Campus](#)

The syllabus/schedule are subject to change.

document and/or consult your event organizer.

Web url:

<http://www.tamuc.edu/aboutUs/policiesProceduresStandardsStatements/rulesProcedures/34SafetyOfEmployeesAndStudents/34.06.02.R1.pdf>

Pursuant to PC 46.035, the open carrying of handguns is prohibited on all A&M-Commerce campuses. Report violations to the University Police Department at 903-886-5868 or 9-1-1.

Resources for Students

Life is hard, especially now. I understand that you have a life beyond this class. I am here to support you as best I can, but there are many university offices on that can help you. I put this list together myself after helping previous students through some tough times. I wanted to make it easier for you to find what you need. I hope you find it helpful.

Mental health issues

Counseling is available to all students for free. They have virtual counseling available.

Call or drop by in-person to make an appointment
Halladay Student Serv. #204
903-886-5145

Student conduct issues

If you believe a student has violated the code of conduct, you can report it here:
<https://bit.ly/33WRMOK>

Violations of the code of conduct include altercations, disorderly conduct, disruptive activity, discrimination, and sexual harassment.

Student of concern/distress

If there is a student you are concerned about for reasons such as threatening behavior, talk of suicide, or homelessness, you can report those concerns using the CARE Report Form:

<https://bit.ly/35VC5cf>

Concerns about the university

You can report any concerns you have about the university to:
StudentConcern@tamuc.edu

The Student Concern form is available at: <https://bit.ly/33Qv1f9>

The syllabus/schedule are subject to change.

Title IX: Sexual harassment and assault

If you have experienced or are aware of sexual harassment, sexual misconduct, domestic violence, dating violence, or stalking, you can report this to the Title IX office.

TitleIX@tamuc.edu
McDowell Administration (BA) Building 259
903-468-3104

Title IX makes it clear that violence and harassment based on sex and gender are Civil Rights offenses subject to the same kinds of accountability and the same kinds of support applied to offenses against other protected categories such as race, national origin, etc. If you or someone you know has been harassed or assaulted, you can find the additional resources here:

Crisis center of NorthEast Texas: <http://www.ccnex.org>
Know your IX: <http://knowyourix.org>
End rape on campus: <http://endrapeoncampus.org>
Clery Center for Security on Campus: <http://clerycenter.org>
Not Alone: <https://www.notalone.gov>

Don't know where to go?

If you need help and you do not know where to go, Campus Life and Student Development can direct you to the most relevant office.

Campuslife@tamuc.edu
Halladay 201
903-886-5195

COURSE OUTLINE / CALENDAR

Advanced Electricity and Magnetism Content Schedule

Weeks are labeled by the Monday of each week. Classes begin Tuesday, 1/17.

1/16 Week 1: Vector calculus review and application
1/23 Week 2: Vector calculus review and application
1/30 Week 3: Electrostatics
2/6 Week 4: Electrostatics
2/13 Week 5: Electrostatics
2/20 Week 6: Electrostatics
2/27 Week 7: Magnetostatics

The syllabus/schedule are subject to change.

3/6 Week 8: Magnetostatics
 3/13 Spring Break
 3/20 Week 9: Electrodynamics
 3/27 Week 10: Electrodynamics
 4/3 Week 11: Electrodynamics
 4/10 Week 12: Electrodynamics
 4/17 Week 13: Electromagnetic waves
 4/24 Week 14: Electromagnetic waves
 5/1 Week 15: Electromagnetic waves
 5/8 Final exam week

Problem Set Homework Deadlines:

Homework 1: Vector calculus	2/1
Homework 2: Electrostatics	3/1
Homework 3: Magnetostatics	3/22
Homework 4: Electrodynamics	4/19
Homework 5: Electromagnetic waves	5/3

Physics Education Research Reading Schedule:

Perusal assignments will be on the following journal papers.

Homework 1: History

B.J. Hunt, "Our friend of brilliant ideas,' G.F. Fitzgerald and the Maxwellian Circle," *Eur. Rev.* 15, 531 (2007).

B. Franklin, "Letter XI," In *Benjamin Franklin's experiments and observations on electricity* (pp. 265-266), Cambridge, MA: Harvard University Press (1941).

Homework 2: Physics Education Research I

Y. Cao and B.M. Brizuela, "High school students' representations and understanding of electric fields," *PRPER* 12, 020102 (2016).

Homework 3: Modern research/applications I

D. Voss, "Synopsis: A crackling in the air," 2 May 2013. [Physics.aps.org](http://physics.aps.org).
 <<https://physics.aps.org/synopsis-for/10.1103/PhysRevLett.110.185005>> 13 January 2016.

A.V. Gurevich and A.N. Karashtin, "Runaway breakdown and hydrometeors in lightning initiation," *PRL* 110, 185005 (2013).

Homework 4: Modern research/applications II

E. Gibney, "Quantum cloud simulates magnetic monopole," *Nature* (2014).

<https://doi.org/10.1038/nature.2014.14612>

M.W. Ray et al., "Observation of Dirac monopoles in a synthetic magnetic field," *Nature* 505, 657 (2014).

Homework 5: Physics Education Research II

The syllabus/schedule are subject to change.

T.M. Scaife and A.F. Heckler, "Interference between electric and magnetic concepts in introductory physics," Phys. Rev. ST – Phys. Ed. Res. 7, 010104 (2011).

Homework 6: Physics Education Research III

S. Kapon and H. Veksler, "Teaching nonscience majors about electromagnetic radiation," PRPER 16, 020141 (2020).

Perusall due dates:

Homework 1	1/25
Homework 2	2/8
Homework 3	2/22
Homework 4	3/29
Homework 5	4/12
Homework 6	4/26

Exam due dates:

Exams will be made available 1 week before the deadline.

Midterm	3/8
Final	5/10

Annotated bibliography: PER due dates

For peer review	3/22
Final version	5/8

Annotated bibliography: History and/or Modern research/applications due dates

For peer review	4/5
Final version	5/8