

NUCL 697: Pulsed Power and Vacuum Electronics

Instructor: Allen L. Garner, PhD, PE

Office: LMBS 5242

Phone: 765-494-0618

Email: algarner@purdue.edu

Office Hours: TU: 1500-1600 ET

Course Information

Spring 2025

TU/TH 1630-1745

GRIS 125

Course Description

This course will provide graduate students with background in pulsed power and vacuum electronics that is critical in various applications, including medicine, combustion, and security.

Prerequisites (if needed)

N/A

Terms Offered

Spring

Credit Hours

3

Schedule Type/Meeting Schedule

Lecture, 2 meetings per week, 75 minutes per meeting, offered over Spring semester.

Course Goals

Generally speaking, this course will introduce students to pulsed power and vacuum electronics, which are enabling technologies for multiple applications. Specifically, this course introduces the student to the design, constructions, and applications of high voltage pulsed power equipment and appropriate diagnostics. This course will further introduce students to the fundamental physics of high power microwaves and vacuum electronics devices and related devices.

Course Learning Outcomes

- 1) Describe and design pulsed power circuitry; apply fundamental transmission line theory and duality.
- 2) Distinguish between the applications and advantages of different pulsed power system designs, such as Marx banks, transmission lines, pulse transformers, and Blumlein generators, linear transformer drivers, and inductive adders.
- 3) Design and explain the function of switching systems, such as spark gaps and gas-pressure switches.

- 4) Describe common applications and technological state of the art of pulsed power.
- 5) Describe the operation of nonlinear transmission lines
- 5) Describe and derive equations for electron emission (e.g. space charge limited flow, field emission, thermionic emission, photoemission)
- 6) Describe and derive equations for operation of crossed-field devices.
- 7) Describe and derive equations for electron emission in nanogaps.
- 8) Describe typical devices and applications of pulsed power and vacuum electronics, including magnetrons, crossed field amplifiers, magnetically insulated transmission lines, and traveling wave tubes.

Course Requirements

Homework Assignments (40%), Literature Review (10%), Class Project Report (20%), Class Project Oral Presentation (15%), Take home final (15%)

Required Texts

- 1) J. Lehr and P. Ron, *Foundations of Pulsed Power Technology*, IEEE Press, 2017 (free from Purdue Library).
- 2) J. Benford, J. A. Swegle, and E. Schamiloglu, *High Power Microwaves 3rd Ed.* CRC Press, 2016 (free from Purdue Library)
- 3) S. E. Tsimring, *Electron Beams and Microwave Vacuum Electronics*, Wiley, 2006 (free from Purdue Library).
- 4) K. L. Jensen, *Introduction to the Physics of Electron Emission*, Wiley, 2018 (free from Purdue Library)
- 5) Journal articles provided during class.

Policies

General Course Policies

Class attendance is critical. Periodic assignments will emphasize critical aspects of pulsed power engineering and fundamental physics.

Grading

This course will consist of periodic homework assignments, a class project on some aspect of pulsed power or vacuum electronics, and take home final that is an extended homework assignment.

The minimum grade assignments will approximately be

>97% = A+

>85% = A

82-85% = B+

75-82% = B

72-75% = C+

65-72%=C

62-65% = D+

55-62% = D

Academic Dishonesty

Working together (even on the take home final) is encouraged, but everyone must turn in his/her own assignment. Please refer to Purdue's statement on academic integrity (http://www.purdue.edu/purdue/about/integrity_statement.html)

Purdue prohibits "dishonesty in connection with any University activity. Cheating, plagiarism, or knowingly furnishing false information to the University are examples of dishonesty." [Part 5, Section III-B-2-a, University Regulations] Furthermore, the University Senate has stipulated that "the commitment of acts of cheating, lying, and deceit in any of their diverse forms (such as the use of substitutes for taking examinations, the use of illegal cribs, plagiarism, and copying during examinations) is dishonest and must not be tolerated. Moreover, knowingly to aid and abet, directly or indirectly, other parties in committing dishonest acts is in itself dishonest." [University Senate Document 72-18, December 15, 1972]

Incidents of academic misconduct in this course will be addressed by the course instructor and referred to the Office of Student Rights and Responsibilities (OSRR) for review at the university level. Any violation of course policies as it relates to academic integrity will result minimally in a failing or zero grade for that particular assignment, and at the instructor's discretion may result in a failing grade for the course. In addition, all incidents of academic misconduct will be forwarded to OSRR, where university penalties, including removal from the university, may be considered.

Use of Copyrighted Materials

Proper citations of any external sources must be noted. Additionally, the University policy is below:

Among the materials that may be protected by copyright law are the lectures, notes, and other material presented in class or as part of the course. Always assume the materials presented by an instructor are protected by copyright unless the instructor has stated otherwise. Students enrolled in, and authorized visitors to, Purdue University courses are permitted to take notes, which they may use for individual/group study or for other non-commercial purposes reasonably arising from enrollment in the course or the University generally.

Notes taken in class are, however, generally considered to be "derivative works" of the instructor's presentations and materials, and they are thus subject to the instructor's copyright in such presentations and materials. No individual is permitted to sell or otherwise barter notes, either to other students or to any commercial concern, for a course without the express written permission of the course instructor. To obtain permission to sell or barter notes, the individual wishing to sell or barter the notes must be registered in the course or must be an approved visitor to the class. Course instructors may choose to grant or not grant such permission at their own discretion, and may require a review of the notes prior to their being sold or bartered. If they do grant such permission, they may revoke it at any time, if they so choose.

Artificial Intelligence (AI)

(<https://www.purdue.edu/teaching-learning/instructors/ai.php>)

Current AI detection tools have very high false-positive rates, rendering them almost useless in practice. As such, AI assessment will not be made in this class. Given the level of the class, AI is not likely to be effective; however, it is not against class policy to use AI. Any results using AI should be considered with great skepticism. Novel approaches that use AI for assignments effectively would be interesting from a research perspective, but relying on AI alone to do assignments will most likely be ineffective.

Some AI based tools encourage users to upload copyrighted material as training data for specific AI models, particularly those used to create content for ‘personalized learning.’

- Sharing copyrighted material with third-party AI tools is prohibited.
- While faculty and instructors do not own copyright to facts or ideas in their discipline, they do own copyright to their expression, explanation, and presentation of those facts and ideas in course notes and PowerPoint slides, including assessments constructed for the course. **As such, those instructor-generated materials should never be uploaded to any third-party site (whether AI oriented or not).**

Attendance

Student attendance at the lectures is critical for learning the material.

Students should stay home and contact the Protect Purdue Health Center (496-INFO) if they feel ill, have any symptoms associated with COVID-19, or suspect they have been exposed to the virus. In the current context of COVID-19, in-person attendance will not be a factor in the final grades, but the student still needs to inform the instructor of any conflict that can be anticipated and will affect the submission of an assignment or the ability to take an exam. Only the instructor can excuse a student from a course requirement or responsibility. When conflicts can be anticipated, such as for many University-sponsored activities and religious observations, the student should inform the instructor of the situation as far in advance as possible. For unanticipated or emergency conflict, when advance notification to an instructor is not possible, the student should contact the instructor as soon as possible by email, through Brightspace, or by phone. When the student is unable to make direct contact with the instructor and is unable to leave word with the instructor’s department because of circumstances beyond the student’s control, and in cases of bereavement, quarantine, or isolation, the student or the student’s representative should contact the Office of the Dean of Students via [email](#) or phone at 765-494-1747.

Grief Absence Policy for Students

Purdue University recognizes that a time of bereavement is very difficult for a student. The University therefore provides the following rights to students facing the loss of a family member through the Grief Absence Policy for Students (GAPS). GAPS Policy: Students will be excused for funeral leave and given the opportunity to earn equivalent credit and to demonstrate evidence of meeting the learning outcomes for missed assignments or assessments in the event of the death of a member of the student's family.

Missed or Late Work

Homework due dates will be provided with the assignment. The expectation is that they will be submitted at the beginning of class on the due date. Missed assignments may only be made up when you notify me ahead of time with an explanation and plan for completion. These requests will be accepted at my discretion and may include a point penalty of 5% per day late. Asking for an extension does not guarantee it will be granted.

Incompletes

A grade of incomplete (I) will be given only in unusual circumstances. To receive an "I" grade, a written request must be **submitted prior to April 18** and approved by the instructor. The request must describe the circumstances, along with a proposed timeline for completing the course work. Submitting a request does not ensure that an incomplete grade will be granted. If granted, you will be required to fill out and sign an "Incomplete Contract" form that will be turned in with the course grades. Any requests made after the course is completed will not be considered for an incomplete grade.

*The final date to withdraw from the course with a W, which for a **Spring 2025 16-week course is Fri. April 18.***

Violent Behavior Policy

Below is Purdue's policy prohibiting violent behavior. See the following website for additional information:
http://www.purdue.edu/policies/pages/facilities_lands/i_2_3.shtml

Purdue University is committed to providing a safe and secure campus environment for members of the university community. Purdue strives to create an educational environment for students and a work environment for employees that promote educational and career goals. Violent Behavior impedes such goals. Therefore, Violent Behavior is prohibited in or on any University Facility or while participating in any university activity.

Students with Disabilities

Purdue University is required to respond to the needs of the students with disabilities as outlined in both the Rehabilitation Act of 1973 and the Americans with Disabilities

Act of 1990 through the provision of auxiliary aids and services that allow a student with a disability to fully access and participate in the programs, services, and activities at Purdue University.

If you have a disability that requires special academic accommodation, please make an appointment to speak with me within the first three (3) weeks of the semester to discuss any adjustments. It is important that we talk about this at the beginning of the semester. It is the student's responsibility to notify the Disability Resource Center (<http://www.purdue.edu/drc>) of an impairment/condition that may require accommodations and/or classroom modifications.

Mental Health Statement

If you find yourself beginning to feel some stress, anxiety and/or feeling slightly overwhelmed, try [Therapy Assistance Online \(TAO\)](#), a new web and app-based mental health resource available courtesy of Purdue Counseling and Psychological Services (CAPS). TAO is available to students, faculty, and staff at any time.

If you need support and information about options and resources, please contact or see the [Office of the Dean of Students](#) (ODOS). Call 765-494-1747.

If you find yourself struggling to find a healthy balance between academics, social life, stress, etc., sign up for free one-on-one virtual sessions with a [Purdue Wellness Coach at RecWell](#). Student coaches can help you navigate through barriers and challenges toward your goals throughout the session. Sign up is free and can be done on BoilerConnect.

If you're struggling and need mental health services: Purdue University is committed to advancing the mental health and well-being of its students. If you or someone you know is feeling overwhelmed, depressed, and/or in need of mental health support, services are available. For help, such individuals should contact [Counseling and Psychological Services \(CAPS\)](#) at 765-494-6995 during and after hours, on weekends and holidays.

Emergencies

In the event of a major campus emergency, course requirements, deadlines and grading percentages are subject to changes that may be necessitated by a revised semester calendar or other circumstances beyond the instructor's control. Relevant changes to this course will be posted onto the course website or can be obtained by contacting the instructors or TAs via email or phone. You are expected to read your @purdue.edu email on a frequent basis.

Nondiscrimination

Purdue University is committed to maintaining a community that recognizes and values the inherent worth and dignity of every person; fosters tolerance, sensitivity, understanding, and mutual respect among its members; and encourages each individual to strive to reach his or her potential. In pursuit of its goal of academic excellence, the

University seeks to develop and nurture diversity. The University believes that diversity among its many members strengthens the institution, stimulates creativity, promotes the exchange of ideas, and enriches campus life. See Purdue's full [Nondiscrimination Policy Statement](#).

Accessibility

Purdue University strives to make learning experiences accessible to all participants. If you anticipate or experience physical or academic barriers based on disability, you are encouraged to contact the Disability Resource Center at: drc@purdue.edu or by phone: 765-494-1247, as soon as possible.

If the Disability Resource Center (DRC) has determined reasonable accommodations that you would like to utilize in my class, you must send me your Course Accommodation Letter. Instructions on sharing your Course Accommodation Letter can be found by visiting: <https://www.purdue.edu/drc/students/course-accommodation-letter.php> Additionally, you are strongly encouraged to contact me as soon as possible to discuss implementation of your accommodations.

Basic Needs

Any student who faces challenges securing their food or housing and believes this may affect their performance in the course is urged to contact the Dean of Students for support. There is no appointment needed, and Student Support Services is available to serve students 8 a.m.-5 p.m. Monday through Friday.

Course Evaluation

During the last two weeks of the semester, you will be provided with an opportunity to give feedback on this course and your instructor. Purdue uses an online course evaluation system. You will receive an official email from evaluation administrators with a link to the online evaluation site. You will have up to 10 days to complete this evaluation. Your participation is an integral part of this course, and your feedback is vital to improving education at Purdue University. I strongly urge you to participate in the evaluation system.

General Course Schedule/Outline (Guideline)

- 1) Transmission line background, including nonlinear transmission lines (Weeks 1 through 2)
- 2) Distinguish between the applications and advantages of different pulsed power system designs, such as Marx banks, transmission lines, pulse transformers, Blumleins, and nonlinear transmission lines. (Weeks 3 through 4)
- 3) Design and explain the function of switching systems, such as spark gaps and gas-pressure switches. (Weeks 5 and 6)
- 4) Electrical breakdown in liquids, gases, and vacuum (Week 7)
- 5) Describe and derive expression for diode physics (e.g. space charge limited emission, thermionic emission, field emission). (Weeks 8-10)

- 6) Describe and derive expressions for operation of crossed-field devices.
(Weeks 11-13)
- 7) Applications and devices (gryotrons, magnetrons, TWTs) (Weeks 14).
- 8) Final project presentation (Week 15)