

NUCL 697: Pulsed Power and Vacuum Electronics

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Office Hours: W: 1630-1730 ET

Virtual Office Hours are a synchronous session (through WebEx) to discuss questions related to weekly readings and/or assignments. To connect to the weekly session, go to [WebEx](#).

<https://mycourses.purdue.edu/>

Course Information

Fall 2020

TU/TH 1630-1745

[WebEx](#)

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

Fall

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 Blumleins, 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 expression for electron emission (e.g. space charge limited flow, field emission, thermionic emission)
- 6) Describe and derive expressions for operation of crossed-field devices.
- 7) Describe and derive expressions 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) Journal articles provided during class.

Policies

General Course Policies

Class attendance (either synchronously or asynchronously) 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

- >85% = A
- 75-85% = B
- 65-75% = C
- 55-65% = 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.

Classroom Guidance Regarding Protect Purdue

The [Protect Purdue Plan](#), which includes the [Protect Purdue Pledge](#), is campus policy and as such all members of the Purdue community must comply with the required health and safety guidelines. Required behaviors in this class include: staying home and contacting the Protect Purdue Health Center (496-INFO) if you feel ill or know you have been exposed to the virus, properly wearing a mask [in classrooms and campus building](#), at all times (e.g., mask covers nose and mouth, no eating/drinking in the classroom), disinfecting desk/workspace prior to and after use, maintaining appropriate social distancing with peers and instructors (including when entering/exiting classrooms), refraining from moving furniture, avoiding shared use of personal items, maintaining robust hygiene (e.g., handwashing, disposal of tissues) prior to, during and after class, and following all safety directions from the instructor.

Students who are not engaging in these behaviors (e.g., wearing a mask) will be offered the opportunity to comply. If non-compliance continues, possible results include instructors asking the student to leave class and instructors dismissing the whole class. Students who do not comply with the required health behaviors are violating the University Code of Conduct and will be reported to the Dean of Students Office with sanctions ranging from educational requirements to dismissal from the university.

Any student who has substantial reason to believe that another person in a campus room (e.g., classroom) is threatening the safety of others by not complying (e.g., not wearing a mask) may leave the room without consequence. The student is encouraged to report the behavior to and discuss next steps with their instructor. Students also have the option of reporting the behavior to the [Office of the Student Rights and Responsibilities](#). See also [Purdue University Bill of Student Rights](#).

Related Considerations:

1. *A listing of recommended safe practices for the specific class or laboratory setting (other PPE or safety behavior) can be found at the links below.*
 - [Overarching SOP for Classrooms, Instructional Laboratories, and Experiential Courses](#)
2. *References Supporting Protect Purdue Compliance:*
 - Office of the Dean of Students [Protect Purdue Compliance Plan: Ask, Offer, Leave, Report](#)
 - Office of the Dean of Students [Managing Classroom Behavior and Expectations](#)

Attendance

Student attendance at the lectures (either synchronously or asynchronously) 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.

Academic Guidance in the Event a Student is Quarantined/Isolated

If you become quarantined or isolated at any point in time during the semester, in addition to support from the Protect Purdue Health Center, you will also have access to an Academic Case Manager who can provide you academic support during this time. Your Academic Case Manager can be reached at acmq@purdue.edu and will provide you with general guidelines/resources around communicating with your instructors, be available for academic support, and offer suggestions for how to be successful when learning remotely. Importantly, if you find yourself too sick to progress in the course, notify your academic case manager and notify me via email or Brightspace. We will make arrangements based on your particular situation. The Office of the Dean of Students (odos@purdue.edu) is also available to support you should this situation occur.

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 December 1, 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.

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 [WellTrack](#). Sign in and find information and tools at your fingertips, available to you at any time.

If you need support and information about options and resources, please contact or see the [Office of the Dean of Students](#). Call 765-494-1747. Hours of operation are M-F, 8 am- 5 pm.

If you find yourself struggling to find a healthy balance between academics, social life, stress, etc. sign up for free one-on-one virtual or in-person sessions with a [Purdue Wellness Coach at RecWell](#). Student coaches can help you navigate through barriers and challenges toward your goals throughout the semester. Sign up is completely free and can be done on BoilerConnect. If you have any questions, please contact Purdue Wellness at evans240@purdue.edu.

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, or by going to the CAPS office of the second floor of the Purdue University Student Health Center (PUSH) during business hours.

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.

Netiquette

Your instructor and fellow students wish to foster a safe online learning environment. All opinions and experiences, no matter how different or controversial they may be perceived, must be respected in the tolerant spirit of academic discourse. You are encouraged to comment, question, or critique an idea, but you are not to attack an individual. Our differences, some of which are outlined in the University's nondiscrimination statement below, will add richness to this learning experience. Please consider that sarcasm and humor can be misconstrued in online interactions and generate unintended disruptions. Working as a community of learners, we can build a polite and respectful course ambience. Please read the Netiquette rules for this course:

- Do not dominate any discussion. Give other students the opportunity to join in the discussion.
- Do not use offensive language. Present ideas appropriately.
- Be cautious in using Internet language. For example, do not capitalize all letters since this suggests shouting.
- Avoid using vernacular and/or slang language. This could possibly lead to misinterpretation.
- Keep an “open-mind” and be willing to express even your minority opinion.
- Think and edit before you push the “Send” button.
- Do not hesitate to ask for feedback.

Nondiscrimination

Purdue University is committed to maintaining a community which 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 own 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.

Purdue University prohibits discrimination against any member of the University community on the basis of race, religion, color, sex, age, national origin or ancestry, genetic information, marital status, parental status, sexual orientation, gender identity and expression, disability, or status as a veteran. The University will conduct its programs, services and activities consistent with applicable federal, state and local laws, regulations and orders and in conformance with the procedures and limitations as set forth in [Executive Memorandum No. D-1](#), which provides specific contractual rights and remedies. Any student who believes they have been discriminated against may visit www.purdue.edu/report-hate to submit a complaint to the Office of Institutional Equity. Information may be reported anonymously.

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 4 through 5)
- 3) Design and explain the function of switching systems, such as spark gaps and gas-pressure switches. (Weeks 6 and 7)
- 4) Electrical breakdown in liquids, gases, and vacuum
- 5) Describe and derive expression for diode physics (e.g. space charge limited emission, thermionic emission, field emission). (Weeks 9-11)
- 6) Describe and derive expressions for operation of crossed-field devices. (Weeks 11-12)
- 7) Applications and devices (gryotrons, magnetrons, TWTs, NLTLs, LTDs) (Weeks 13-14).
- 8) Final project presentation (Week 15)