ECE 989 Advanced Topics in Plasma
Spring 2019

Instructor: Peng Zhang
Room 3213 EB
Tel. (517) 353-3654
E-mail: pz@egr.msu.edu

Schedule: Tu Th 12:40 PM – 2:00 PM, 2250 Engineering Building

Office Hours: Tu Th 2:00 PM – 3:00 PM

Recommended: ECE 850, ECE 835 or PHY 488

Course Website: D2L https://d2l.msu.edu/

Course Outline:

Topic	Textbook Chapters	Lectures
Introduction	1	1
Electron Collisions	3, 8 , Appendix A	2
Cross Sections and Rate Coefficients	3, 8	2
Gas Discharges	2	1
Electron Continuity Equation, Diffusion, Production, Loss	2, 5	3
Sheaths	6	2
Electron Distribution Functions	2, Appendix B	1
Transport Coefficients	5	1
Low Pressure DC Discharges	10, 14	3
High Pressure Discharges and Electron		1
Beam Pumped Plasmas		2
RF and Microwave Discharges	11, 12	2
Capacitive and Inductively Coupled Plasmas	4, 11, 12	2
Diagnostics	6.6	1
Basic plasma phenomena and contemporary topics		3

Textbook: M. Lieberman, Principles of Plasma Discharges and Material Processing

Reference books: Francis F. Chen, Introduction to Plasma Physics and Controlled Fusion
Paul M. Bellan, Fundamentals of Plasma Physics

Grading:

Points are distributed as follows:

Homework	Mid-term Exam	Final Project	Instructor’s discretion
30%	30%	30%	10%

Instructor's discretion includes my qualitative assessment of students' effort towards the course (e.g., class attendance and participation).

Exam Schedule: Midterm Exam: Thursday, March 14, 2019

Schedule for Spring 2019

Week	Date	Day	Class Topic (approximate)
1	Jan 8	Tu	1, Introduction
	Jan 10	Th	2, Electron Collisions
2	Jan 15	Tu	3, Electron Collisions
	Jan 17	Th	4, Cross Sections and Rate Coefficients
3	Jan 22	Tu	5, Cross Sections and Rate Coefficients
	Jan 24	Th	6, Gas Discharges
4	Jan 29	Tu	7, Electron Continuity, Diffusion, Sources
	Jan 31	Th	8, Electron Continuity, Diffusion, Sources
5	Feb 5	Tu	9, Sheaths
	Feb 7	Th	10, Sheaths
6	Feb 12	Tu	11, Electron Energy Distributions
	Feb 14	Th	12, Electron Energy Distributions and Transport Coefficients
7	Feb 19	Tu	13, Low Pressure DC Discharges
	Feb 21	Th	14, Low Pressure DC Discharges
8	Feb 26	Tu	15, High Pressure and e-beam pumped plasmas
	Feb 28	Th	16, RF Discharges
9	Mar 5	Tu	No class
	Mar 7	Th	No class
10	Mar 12	Tu	17, RF Discharges
	Mar 14	Th	Exam
11	Mar 19	Tu	18, Capacitively Coupled Plasmas
	Mar 21	Th	No class Graduate Symposium
12	Mar 26	Tu	19, Inductively Coupled Plasmas
	Mar 28	Th	20, Diagnostics
13	Apr 2	Tu	21, Basic Plasma Phenomena
	Apr 4	Th	22, Basic Plasma Phenomena
14	Apr 9	Tu	23, Basic Plasma Phenomena
	Apr 11	Th	24, Contemporary Topics
15	Apr 16	Tu	25, Contemporary Topics
	Apr 18	Th	26, Contemporary Topics
16	Apr 23	Tu	Final Project Presentation
	Apr 25	Th	Final Project Presentation, Final report (due at 5:00 pm)

Supplementary Texts and References

General Survey Texts

G. Bekefi **Principles of Laser Plasmas**
Specialty items such as recombination, discharge stability and vibrational excitation.

K. H. Becker et al. **Non-Equilibrium Air Plasmas at Atmospheric Pressure**

L. M. Biberman, et al. **Kinetics of Nonequilibrium Low-Temperature Plasmas**
Good general reference but difficult to read. (Russian Translation)

P. Chabert & N. Braithwaite **Physics of Radio-Frequency Plasmas**
Recent monograph on RF discharges of the type used for plasma materials processing.

F. F. Chen **Introduction to Plasma Physics**
Fully ionized plasmas with good treatment of Debye lengths, and magnetic field effects.

A. Fridman & L. A. Kennedy **Plasma Physics and Engineering**
Comprehensive text on low temperature plasmas

A. Fridman **Plasma Chemistry**
Physics of low temperature plasmas and application to gas phase and surface chemistry.

L. Huxley **Diffusion and Drift of Electrons in Gases**
Advanced monograph on Boltzmann Equation and Transport Coefficients.

Y. Itikawa **Molecular Processes in Plasmas**
Basics of electron and ion collisions with molecules

M. Keidar and I. I. Gelis **Plasma Engineering: Applications from Aerospace To Bio and Nanotechnology**
Good connection of basic concepts to applications

U. Kortshagen **Electron Kinetics and Applications of Glow Discharges**
Proceedings of NATO Workshop. Very good overview articles

T. Makabe and Z. L. Petrovic **Plasma Electronics in Microelectronics Fabrication**

T. Mark **Electron Impact Ionization**
Thorough treatment of electron impact collisions producing ionization

E. McDaniel **Ion Molecule Reactions**
Advanced monograph on reactions between ions and neutral atoms/molecules.
Good tables of reaction rate coefficients.

M. Mitchner **Partially Ionized Gases**

Mostly for fully ionized plasmas but good treatment of sheaths, continuity equations, and electron-ion collisions.

M. Moisan and J. Pelleier **Physics of Collisional Plasmas: Introduction to High Frequency Discharges**

V. N. Ochkin. **Spectroscopy of Low Temperature Plasmas**
Excellent overview of basics of optical emission and absorption

L. C. Pitchford, et al. **Swarm Studies and Inelastic Electron-Molecule Collisions**
Compilation of papers on fundamental studies in nonequilibrium electron transport and obtaining cross sections from swarm data.

Y. Razier **Gas Discharge Physics**
It has all the material that's important, but is difficult to read.

J. R. Roth **Industrial Plasma Engineering. Vol 1 & 2**
Practical view of low temperature plasma physics from an engineering perspective.

A. von Engel **Electric Plasmas; Their Nature and Uses**
Simplified view of gas discharges but good introduction.

Application Oriented or Specialty

*C. K. Birdsall & A. B. Langdo*n **Plasma Physics via Computer Simulation**
Introductory text on the use of Particle-in-Cell simulations for modeling plasmas.

B. Chapman **Glow Discharge Processes**
Good "gut level" monograph. Good source for RF discharges.

P. K .Chu **Low Temperature Plasma Technology: Methods and Applications**

A Fridman and G. Friedman **Plasma Medicine**

D. M. Goebel and I. Katz **Fundamentals of Electric Propulsion: Ion and Hall Thrusters**

R. Hippler et. al. **Low Temperature Plasmas: Fundamentals, Technologies and Techniques Vol. 1 & 2.**

M. Larousii et al. **Plasma Medicine**
Multi-author collection of basic concepts in plasma medicine.

D. Manos and *D. Flamm* **Plasma Etching: An Introduction**
Compilation on methods in plasma processing.

Y. Razier **Radio Frequency Capacitive Discharges**
Exhaustive treatment of this important discharge device for plasma etching.

D. N. Ruzic **Electric Probes for Low Temperature Plasmas**

S. Rossnagel **Handbook of Plasma Processing Technology**
Compilation of papers on basics of plasma etching and deposition.

J. Waymouth **Electric Discharge Lamps**
Defining text for fluorescent lamp physics.

<u>Older (in some cases very old!) Classic Texts – (You will learn something!)</u>

S. C. Brown **Basic Data of Plasma Physics**

L. Loeb **Basic Processes of Gaseous Electronics**

B. Cherrington **Gaseous Electronics and Gas Lasers**

A. von Engel **Ionized Gases**
Collection of lectures given at Oxford. Considered a classic for introduction to field.

B. M. Smirnov **Physics of Ionized Gases**
Good general reference but difficult to read. (Russian Translation)

J. Cobine **Gaseous Conductors**
Classic, but very, very dated test. Extremely empirical treatment but good presentation.
(You can learn something from this book on the first reading.)

Projects

In place of a final exam, there will be a final project. The project should consist of developing a model for, or performing an in depth analysis of, a low temperature plasma, vacuum electronics or electric discharge system.

The project should include a literature search to provide the background on how these devices operate and summarize how other researchers have analyzed them. Some of the models which appear in the literature are quite involved and complex. The intent of the project is not for you to duplicate the complexity of those models. Rather, the intent is to give you some sense of how the device, physical parameters, or the "final product" (e.g., current, power absorption, laser power, deposition rate, etch rate, radical fluxes) scales. Your model should have at least the degree of sophistication of our homework assignments but should include real device operation parameters.

Your final project should be a written report - limit on length is 25 pages, though 25 pages are not required. (Fewer pages of higher quality are preferred.) Please include a description of the discharge/plasma system or configuration, how you have analyzed it, the scaling laws you developed, and a discussion of what you have learned or the scientific conclusion you have obtained. Generously use plots to display parametric results. Essentially, prepare your report as if you are submitting it for journal publication (e.g. Physics of Plasmas, IEEE Transaction on Plasma Sciences).

Due Date: Thursday, April 25, 2019, 5:00 PM
Paper copy to: Prof. Zhang office
PDF copy to: pz@egr.msu.edu