MECH 4395/5390/6390 – Special Topics in Mechanical Engineering
Plasma Applications in Engineering

Instructor               Dr. Amelia Greig
Office                   A109 / Virtual through Microsoft Teams
Office Hours             By appointment. Please email to schedule.
E-mail                   adgreig@utep.edu
Class Times              MW 9:00am – 10:20am
Delivery Method          Online through Blackboard Collaborate *subject to change

This syllabus covers the three cross-listed classes of MECH 4395, MECH 5390, and MECH 6390. Course delivery methods and topics are the same for both courses. Differences in expected depth of knowledge between class levels will be clearly indicated in course materials. Assessment for each class level will be commensurate with expected knowledge level.

Course description:
Plasma applications in engineering are wide, varied, and developing fast. This course introduces the plasma state and plasma theory in the context of applied engineering applications. Applications studied will include manufacturing, propulsion, power (fusion), communications, space weather, plasma medicine, and aerodynamics.

The course structure consists of
1) Online classes to introduce plasma theory and analysis techniques with highlighted examples of plasma technologies applying the introduced theory
3) Case studies of plasma technologies used across various engineering fields
4) Short assessment items to cement fundamental plasma concepts and knowledge
5) Longer assessment items to showcase your new abilities in plasma in engineering

Prerequisites:
None. However, a fundamental understanding of linear algebra, partial differential equations, probability, fluid mechanics, and electromagnetism are assumed.

Course outcomes:
By the end of this course, you will be able to:
   1) Differentiate the plasma state from other states of matter using its unique properties
   2) Analyze the plasma state as applied to engineering technologies and processes
   3) Evaluate plasma-based engineering technologies for both performance and global impact
   4) Propose plasma based solutions for current engineering challenges

Course Topics:
See Attachment A of this syllabus
Textbooks and Other Useful References:
Complete course notes are available through the course Blackboard page. Please feel free to use these, or make your own.


There is no required textbook for this class, all required materials will be provided. However, you may find the below references useful for deeper understanding of the course material.
- Principles of Plasma Physics for Engineers and Scientists by Inan and Golkowski (Cambridge). An excellent introductory reference for plasma physics as applied to engineering. Recommended to supplement undergraduate level class content.
- Fundamentals of Plasma Physics by Bittencourt (Springer) - An advanced text on plasma physics with in depth mathematical descriptions and derivations. Recommended to supplement graduate level course content, or for those looking for a deeper understanding.
- Introduction to Electrodynamics by Griffith (Prentice Hall) - Excellent textbook for help with electromagnetism and electrodynamics

Recommendations for other resources for additional details on specific topics will be included at the relevant point in course materials.

Assessment and Grading:
Assessment for the course has been designed to both complement the learning process and enable you to showcase their new abilities in dealing with the plasma state and plasma technologies.

Assessment formats:
1) Regular short answer question sets to cement fundamental plasma concepts.
2) A report or white paper on plasma technology in engineering for a topic of your choice taken from the plasma roadmap.

Assessment submissions:
All assessment is distributed and submitted online through the assessment folder on Blackboard. Refer to Blackboard or the course schedule for exact due dates and times.

Extension Requests and Assessment Excusals
Extensions for assessable item due dates, and excusal for assessable activities or exams will only be granted for University approved reasons as outlined in the catalog. These include participation in University-recognized activities, Religious Holy days, and military leave. http://catalog.utep.edu/undergrad/academic-regulations/curriculum-and-classroom-policies/

Grade management:
Blackboard grade book will be used to distribute and manage all grades for the course.
Course grades:
Overall course grades will be awarded based on the following scale:
A = 100%-89%,  B= 88%-80%,  C = 79%-70%,  D=69%-60%,  F<60%.
At the end of the course, overall course percentage grade will be rounded up to the nearest integer in all cases.

<table>
<thead>
<tr>
<th>Grade Scale</th>
<th>Percentage</th>
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<tbody>
<tr>
<td>A</td>
<td>100-89%</td>
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<tr>
<td>B</td>
<td>88-80%</td>
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<tr>
<td>C</td>
<td>79-70%</td>
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<tr>
<td>D</td>
<td>69-60%</td>
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<tr>
<td>F</td>
<td>&lt;60%</td>
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</table>

Final grades will be calculated using the following distribution:
70%  Short answer question sets (7 sets worth 10% each)
30%  Report or white paper on the plasma roadmap

Extra credit opportunities:
There will be opportunities for extra credit throughout the course for all class levels. If you are interested in an extra credit opportunity, please email me.

Attendance and Participation:
To encompass all unique situations participants may find themselves in, a combination of synchronous and asynchronous delivery methods are used.
- Live classes will be held online at the times stated at the beginning of the syllabus
- Those attending live classes may ask and have questions answered in real time
- ALL classes will be recorded for those unable to make the scheduled live class time
- Forums on Blackboard will be made available for questions that arise outside of online class times

Attendance for live classes is not compulsory and records of attendance will not be kept.

Course Communication:
All course content, assessment details, announcements, and other course information will be available on the Blackboard course page. Please make Blackboard your first stop for all course information, and check it regularly for updates. Relevant course information may also be periodically sent to your UTEP email. Please be sure to check your email on a regular basis.

Blackboard Forums:
Please post questions regarding course material and assessment on the Blackboard forums. This way, all students can benefit from the interaction. I will do my best to answer your questions within one working day of the post. Questions about course content asked through email will not be answered, instead you will get a response asking you to put it on the forums.

DO NOT post questions about grading and/or personal issues on the forums. Use only in-person or email interactions for these questions. I will do my best to answer your questions within one working day of the email.

Inclusion:
My goal for the classroom is to have an engaging, intellectual, and safe learning environment. I aim to foster open communication and discussion. Due to the diversity of individual beliefs, backgrounds, and experiences, I expect every member of this class (myself included) to show
respect for every other member of this class. If you feel that you are not being respected in this course or our department in anyway, please come see me, another mechanical faculty/staff member you are comfortable approaching, or the Student Engagement and Leadership Center.

**University Support Services:**
The following services are just some of many offered by the department and UTEP. Please make use of them to improve your educational experience.

**ACES & Tutoring Center:**
Please note there are tutoring services available in the ACES center. Tutoring is provided free to you by the Department. If tutors are not used, the Department may stop funding them. Check the schedule of the tutors and make use of the services. For more details visit ME Advising Blackboard -> MECH Academic Advising -> Tutoring & Resources. At the link you can find tutor schedules, location of the ACES center and the list of tutors available. For more information send email to METutors@utep.edu

**Reasonable Accommodation Policy:**
If you have a disability and need classroom accommodations, please contact the Center for Accommodations and Support Services (CASS) at 747-5148, or by email to cass@utep.edu, or visit their office located in UTEP Union East, Room 106. For additional information, please visit the CASS website at www.sa.utep.edu/cass.

**Mental Health Concerns**
A recent American College Health Survey found stress, sleep problems, anxiety, depression, interpersonal concerns, death of a significant other and alcohol use are among the top ten health impediments to academic performance.

The University of Texas at El Paso (UTEP) offers students, including veterans and active duty, a wide range of mental-health related resources on and off campus. The on campus resources include counseling and treatment when there is a need, to support for recovery. For a list of all support services available visit [https://www.utep.edu/student-affairs/resources/Mental-Health-Resources-for-UTEP-Students.html](https://www.utep.edu/student-affairs/resources/Mental-Health-Resources-for-UTEP-Students.html)

**Course and University Policies:**
Complete University academic policies and regulations can be found In the UTEP catalog, [http://catalog.utep.edu/undergrad/academic-regulations/](http://catalog.utep.edu/undergrad/academic-regulations/)

**Academic Integrity**
The University of Texas at El Paso prides itself on its standards of academic excellence. In all matters of intellectual pursuit, UTEP faculty and students must strive to achieve excellence based on the quality of work produced by the individual. In the classroom and in all other academic activities, students are expected to uphold the highest standards of academic integrity. Any form of academic dishonesty is an affront to the pursuit of knowledge and jeopardizes the quality of the degree awarded to all graduates of UTEP. It is imperative,
therefore, that the members of this academic community understand the regulations pertaining
to academic integrity and that all faculty insist on adherence to these standards.

Any student who commits an act of academic dishonesty is subject to discipline. Academic
dishonesty includes, and is not limited to cheating, plagiarism, collusion, the submission for
credit of any work or materials that are attributable in whole or in part to another person, taking
an examination for another person, and any act designed to give unfair advantage to a student
or the attempt to commit such acts. Proven violations of the detailed regulations, as printed in
the Handbook of Operating Procedures (HOP), and available in the Office of Student Life and
on the homepage of the Office of Student Life at www.utep.edu/dos, can result in sanctions
ranging from disciplinary probation, to a failing grade on the work in question, to a failing
grade in the course, to suspension or dismissal, among others.

While I encourage collaboration between students in order to understand the course material,
assignments submitted for grading MUST be done by each student independently.
Inappropriate collaboration (also known as cheating) includes:
• Using all or parts of assignments, exams, or projects from this year or any previous
  year that were not created by you personally;
• Talking, passing information, or using inappropriate materials during an in-class exam

Anyone found to be participating in inappropriate collaboration may be immediately failed
from the course and subject to disciplinary action.

You must show your working for all problems submitted for grading. The instructor may
require you to explain how you solved a problem on an assessable item at any time after
submission. If you refuse or cannot explain your work you may be subject to disciplinary
action.

If you are suspected of scholastic dishonesty you may or may not be directly confronted
about your conduct by the instructor or proctor. You will however, be reported to the Office of
Student Conduct and Conflict Resolution (OSCCR). Your grade in the class may not be
available until OSCCR makes a final ruling, this may adversely impact your ability to enroll in
other classes.

Harassment Policy
The University (see Handbook of Operating Procedures 1.2.2.4) has a zero-tolerance policy
for harassment. Engagement in any behavior considered harassment will be reported to the
proper authorities. In addition to generally understood forms of harassment, the department
also treats the following behavior as harassment:
• Repeated emails and/or calls regarding subjects that have already been addressed. Once
  a decision has been made or a question answered, a student who continues to ask the
  same question will be given a warning by the recipient of the email/call. If the student
  continues, the behavior will be reported. Questions that seek understanding of course
material are not harassment; but repeated questions about a grade or an administrative decision are.

- Grades are NOT negotiable, ever. If you believe a grading mistake has been made, you must follow the process described in the UTEP catalog. Any request for a grade elevation that is NOT based on a mistake is considered harassment and will be reported immediately.
- Remaining in an office after the occupant requests you leave is considered harassment and potentially threatening. You will be reported immediately without warning and depending on the severity, may be reported to law enforcement.
- Similar behavior towards department staff, and student advisors will also be treated as harassment, including persistent phone calls, emails, and badgering. Department staff and student advisors are there to help students, and should be treated with due respect.

Student Conduct
While enrolled at the University, a student neither loses the rights nor escapes the responsibilities of citizenship. Any student who engages in conduct that is prohibited by the Board of Regents' Rules and Regulations or University rules or by federal, state, or local law is subject to discipline whether such conduct takes place on or off campus or whether civil or criminal penalties are also imposed for such conduct. All students are expected and required to obey the law, to show respect for properly constituted authority, and to observe correct standards of conduct.

The University of Texas at El Paso administers student discipline according to established procedures of due process. Procedures are defined and described in the Rules and Regulations of the Board of Regents, Rule 50101, and in the Handbook of Operating Procedures (HOP). Students should check with appropriate departments whose policy or regulation is of concern. If necessary, students need to refer to the rules in the Regents' Rules and Regulations (http://www.utsystem.edu/bor/rules) and the HOP. The Office of Student Life can assist on this matter. This set of rules is available at https://www.utep.edu/vpba/hoop/.

Family Educational Rights and Privacy Act (FERPA)
The Family Educational Rights and Privacy Act (FERPA), 20 U.S.C. §1232g and the Texas Public Information Act, Texas Government Code, § 552.001, et seq., are federal and state laws that provide students the following rights with respect to their student educational records. The University of Texas System and The University of Texas at El Paso have implemented a student records policy that adheres to these laws. For more information regarding the University’s implementation of these laws, please review the Handbook of Operating Procedures.
**Syllabus Attachment A: Course Topics**

<table>
<thead>
<tr>
<th>Topic</th>
<th>Topics</th>
</tr>
</thead>
<tbody>
<tr>
<td>01: Introduction to the Plasma State</td>
<td>Plasma; Fourth state; Natural plasma; Artificial plasma; Plasma temperature; Plasma density; Electron Volt (eV); Thermal plasma; Non-thermal plasma;</td>
</tr>
<tr>
<td>02: Creating Plasma</td>
<td>Breakdown; Ionization potential; Free electron; Lorentz Force; Drift; Townsend avalanche; Self-sustaining condition; pressure-distance (pd); Paschen law; Paschen curve; Glow discharge; Arc plasma; <strong>Examples: Lightning; Crooke’s Tube; Neon Sign</strong></td>
</tr>
<tr>
<td>03: Plasma Oscillations</td>
<td>Quasineutrality; Debye shielding; Debye length; Debye sphere; Plasma parameter; Boltzmann relation; Plasma frequency; Four Criteria for Plasma</td>
</tr>
<tr>
<td>04: Single Particle Motion</td>
<td>Lorentz Force; Cyclotron frequency; Larmor radius; Guiding center; Magnetic moment; Drift; Magnetic mirror; Electron cyclotron resonance (ECR); <strong>Examples: Hall thruster; Aurora; ECR ion source</strong></td>
</tr>
<tr>
<td>05: Kinetic Theory</td>
<td>Ideal gas law (Boltzmann form); Phase space; Phase space diagrams; Distribution functions; Boltzmann equation;</td>
</tr>
<tr>
<td>06: Plasma Equilibrium</td>
<td>Steady-state plasma; Maxwell-Boltzmann distribution; Most probable speed; Thermal speed; Root-Mean-Square (RMS) speed; High-energy tail; Saha equation; Shifted Maxwellian; Bi-Maxwellian; Vlasov equation; <strong>Examples: Ion thruster; Hypersonic communication blackout</strong></td>
</tr>
<tr>
<td>07: Molecular Collisions</td>
<td>Collisional cross-sections; Mean free path; Collision Frequency; Coulomb collisions; Knudsen number; Rarefied flow; Random particle walk; Conductivity; Mobility; Diffusion; Drift-Diffusion; Ambipolar Diffusion</td>
</tr>
<tr>
<td>08: Surface Processes</td>
<td>Reaction rates; Work function; Secondary electrons; Physisorption; Chemisorption; Sticking Coefficient; Sputtering</td>
</tr>
<tr>
<td>09: Plasma Sheaths</td>
<td>Plasma Potential; Bohm velocity; Pre-sheath; Child-Langmuir law; <strong>Example: Langmuir Probe</strong></td>
</tr>
<tr>
<td>10: Plasma Manufacturing and Processing</td>
<td>Plasma etching; Plasma ashing; Plasma-enhanced chemical vapor deposition (CVD); Thin-film deposition; Plasma-immersion ion implantation (PIII)</td>
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<tr>
<td><strong>Case Studies:</strong> Integrated circuit reactor; Fuel cell; Artificial hip; Plasma torch</td>
<td></td>
</tr>
<tr>
<td>11: Fluid-based Plasma Analysis</td>
<td>Collisionless plasma; Collisonal plasma; Moments of the Boltzmann equation; Continuity equation; Momentum equation; Energy equation; Maxwell’s equations; Two-fluid model; <strong>Examples: Over-the-Horizon Radar; Fluorescent Tube; Diamagnetic Drift</strong>;</td>
</tr>
<tr>
<td>12: Magneto-hydrodynamics</td>
<td>Charge conservation; Mass conservation; Equation of Motion; Generalized Ohm’s law; Magnetic viscosity; Magnetic Reynolds number; <strong>Example: Parker Spiral (Solar Wind)</strong>;</td>
</tr>
<tr>
<td>Section</td>
<td>Description</td>
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</tbody>
</table>
| 13: Magnetic Plasma Confinement | Magnetic pressure; Plasma kinetic pressure; Beta parameter; Pinch; Bennett relation; Bennett distribution;  
**Example: Tokomak; Compact Fusion;** |
| 14: Plasma Fusion | Lawson Criteria; Magnetic Confinement Fusion (MCF); Inertial Confinement Fusion (ICF); Magnetized Target Fusion (MTF);  
**Case Studies: ITER; KSTAR; Wendelstein 7-X; NIF; General Fusion;** |
| 15: Atmospheric Plasma | Dielectric Barrier Discharge; Filamentary discharge; Streamer; Ionic wind;  
**Case Study: MIT Electric Aircraft** |
| 16: Flow Control Applications | Vortex generator; Active noise control; Separation control; Film cooling; Hypersonic flow control;  
**Case Study: Wind Turbine; Plasma Stream; Plasmeron** |
| 17: Biomedicine and Environment | Free radicals; Reactive oxygen and nitrogen species (RONS); Ozone generation; Electrostatic precipitation;  
**Case Studies: Plasma scalpel; CAP treatment; Root canal disinfection; Water purification; Surface sterilization** |
| 18: Plasma Assisted Combustion | Plasma chemical conversion (PCC); Plasma remediation; Plasma assisted ignition (PAI); Plasma assisted combustion (PAC);  
**Case Studies: Remediation of CO2; Plasma hydrogen generation; Scramjet; Pulse Detonation Engine** |
| 19: Plasma Modeling | Global Models; Power Balance; Particle Balance; Computational Fluid Dynamics (CFD); Direct Solve Monte Carlo (DSMC); Particle-In-Cell (PIC);  
**Example: Electrothermal plasma thruster** |
| 20: Advanced Plasma Applications | Plasma windows; Plasma valve;  
**Case Study: Electron Beam Welding** |
**Syllabus Attachment B: Course Schedule (subject to change)**

<table>
<thead>
<tr>
<th>Week</th>
<th>Day</th>
<th>Topic</th>
<th>Assessment Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>19-Jan</td>
<td>1</td>
<td>T</td>
<td>No Class</td>
</tr>
<tr>
<td>21-Jan</td>
<td>Th</td>
<td>01 Introduction to Plasma State / Course</td>
<td>Syllabus and expectations</td>
</tr>
<tr>
<td>26-Jan</td>
<td>2</td>
<td>T</td>
<td>02: Creating Plasma</td>
</tr>
<tr>
<td>28-Jan</td>
<td>Th</td>
<td>03: Plasma Oscillations</td>
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</tr>
<tr>
<td>2-Feb</td>
<td>3</td>
<td>T</td>
<td>04: Single Particle Motion</td>
</tr>
<tr>
<td>4-Feb</td>
<td>Th</td>
<td>04: Single Particle Motion</td>
<td>Quiz 1 due - before class (9am)</td>
</tr>
<tr>
<td>9-Feb</td>
<td>4</td>
<td>T</td>
<td>05: Kinetic Theory</td>
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<tr>
<td>11-Feb</td>
<td>Th</td>
<td>05: Kinetic Theory</td>
<td></td>
</tr>
<tr>
<td>16-Feb</td>
<td>5</td>
<td>T</td>
<td>06: Plasma Equilibrium</td>
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<tr>
<td>18-Feb</td>
<td>Th</td>
<td>06: Plasma Equilibrium</td>
<td>Quiz 2 due - before class (9am)</td>
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<tr>
<td>23-Feb</td>
<td>6</td>
<td>T</td>
<td>07: Molecular Collisions</td>
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<tr>
<td>25-Feb</td>
<td>Th</td>
<td></td>
<td>08: Surface Processes</td>
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<tr>
<td>2-Mar</td>
<td>7</td>
<td>T</td>
<td>09: Plasma Sheaths</td>
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<tr>
<td>4-Mar</td>
<td>Th</td>
<td></td>
<td>10: Plasma Manufacturing and Processing</td>
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<tr>
<td>9-Mar</td>
<td>8</td>
<td>T</td>
<td>10: Plasma Manufacturing and Processing</td>
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<tr>
<td>11-Mar</td>
<td>Th</td>
<td></td>
<td>No Class / Spare</td>
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<tr>
<td>16-Mar</td>
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<td>T</td>
<td>Spring Break</td>
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<tr>
<td>18-Mar</td>
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<td>Th</td>
<td>Spring Break</td>
</tr>
<tr>
<td>23-Mar</td>
<td>9</td>
<td>T</td>
<td>11: Fluid-based Plasma Analysis</td>
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<tr>
<td>25-Mar</td>
<td>Th</td>
<td></td>
<td>11: Fluid-based Plasma Analysis</td>
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<tr>
<td>30-Mar</td>
<td>10</td>
<td>T</td>
<td>12: Magneto-hydrodynamics</td>
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<td>1-Apr</td>
<td>Th</td>
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<td>12: Magneto-hydrodynamics</td>
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<tr>
<td>6-Apr</td>
<td>11</td>
<td>T</td>
<td>13: Magnetic Plasma Confinement</td>
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<td>8-Apr</td>
<td>Th</td>
<td></td>
<td>14: Plasma Fusion</td>
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<tr>
<td>13-Apr</td>
<td>12</td>
<td>T</td>
<td>15: Atmospheric Plasma</td>
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<td>15-Apr</td>
<td>Th</td>
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<td>16: Aerodynamics</td>
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<tr>
<td>20-Apr</td>
<td>13</td>
<td>T</td>
<td>17: Plasma Assisted Combustion</td>
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<tr>
<td>22-Apr</td>
<td>Th</td>
<td></td>
<td>18: Biomedicine and Environments</td>
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<tr>
<td>27-Apr</td>
<td>14</td>
<td>T</td>
<td>19: Plasma Modeling</td>
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<tr>
<td>29-Apr</td>
<td>Th</td>
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<td>19: Plasma Modeling</td>
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<tr>
<td>4-May</td>
<td>15</td>
<td>T</td>
<td>20: Advanced Plasma Concepts</td>
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<tr>
<td>6-May</td>
<td>Th</td>
<td></td>
<td>No Class / Spare</td>
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<tr>
<td>11-May</td>
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<td>T</td>
<td>Finals 10:00am - 12:45 pm Tuesday 11 May</td>
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<td>Report due - end of finals timeslot (12:45pm)</td>
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