MatSE 540 COURSE SYLLABUS
CRYSTAL ANISOTROPY
Fall 2022, Pennsylvania State University
In Class Lectures, EE West 203, 10.35-11.50am Tuesdays and Thursdays.

Instructors: Prof. Venkatraman Gopalan
N-212 Millennium Science Complex
gopalan@psu.edu
Office Hours by Appointment anytime with Gopalan. Just contact.

Teaching Assistant: Sankalpa Hazra
Email: sqh6014@psu.edu
N-213 Millennium Science Complex
Office Hours From 4-6pm Tuesdays
on Zoom at: https://psu.zoom.us/my/sankalpah
Password: 061331

Missed Classes: None currently but will let you know if any.

Extra classes: Mathematica training class, August 31, 5-6.00pm, Steidle 116

Grades:

<table>
<thead>
<tr>
<th>HWs:</th>
<th>50% (~Weekly)</th>
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<tbody>
<tr>
<td>Mid-semester</td>
<td>25% (October 11, in class)</td>
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<tr>
<td>Finals:</td>
<td>25% (Dec 12-16, TBD)</td>
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</tbody>
</table>

HW policy: 20% loss of grades per day of delay (after 5pm).
No homeworks accepted after solutions are posted on CANVAS.

Prerequisites: NONE for graduate students. Undergraduates, please contact the instructor.

Textbooks (recommended):


F. Albert Cotton, Chemical applications of group theory, (John Wiley and Sons).

Internet materials and links:

Online material on CANVAS

Self-study undergraduate Linear Algebra (from notes by Prof. Y. Vorobets, A&M on CANVAS; http://www.math.tamu.edu/~yvorobet/MATH304-504/).

Assistance with Textbooks
The instructor will make available necessary materials on Canvas. The above listed books are worth owning if you are a graduate student and can afford it.

Penn State honors and values the socioeconomic diversity of our students. If you require assistance with the costs of textbooks for this course, contact the Office of Student Care and Advocacy (120 Boucke Building, 863-4926, http://studentaffairs.psu.edu/studentcare). For additional need related to socioeconomic status please visit http://sites.psu.edu/projectcahir.

Course Description (from LionPath):
Symmetry aspects of crystals and physical properties. Matrix and tensor methods. MATSE 540 Crystal Anisotropy (3) In this course symmetry and tensors are used to describe the physical properties of materials as a function of direction, i.e., how a material will respond to different types of stimuli as a function of direction. A variety of thermal, mechanical, electric, magnetic, and optical properties are covered, including pyroelectricity, pyromagnetism, thermal expansion, dielectric constant, magnetic susceptibility, piezoelectricity, piezomagnetism, elastic stiffness and compliance, electrostriction, magnetostriction, index of refraction, and non-linear optical effects. At first the response of single crystals are considered, but this is later extended to polycrystalline samples with various types of texture. As the course makes extensive use of symmetry, several weeks are dedicated to the development of the 32 crystallographic point groups using group theory. Symmetry operations are described using coordinate transformation matrices and stereographic projections. Both tensor quantities and tensor properties are described as a function of increasing tensor rank (up to fourth rank) for a multitude of polar tensors followed by axial tensors. For magnetic materials, the 90 magnetic point groups are introduced. For polycrystalline materials, the 7 Curie groups are utilized. A variety of practical examples illustrating the use of tensors to describe the properties of materials are covered in class and in in-depth homework sets involving both matrix and tensor form. The computer program Mathematica is used extensively in class and in the homework sets to visualize the physical properties of materials in three dimensions as well as to rapidly apply symmetry and tensor methods to high-rank tensor properties of low symmetry materials.

Course Content: See CANVAS.

Course Goals and Objectives: Contact MatSE office (Hayley Colyer, hjc24@psu.edu) for ABET accreditation goals and objectives for this course.

Assessment Policy:
- Required written/oral assignments: See above for HWs, Midterm, Finals, attendance and participation points.
- Examination Policy: See above for midterm and finals details. Make up exams can be administered as needed; please contact the instructor before the exam if you believe you need this.
- Grading Policy: See late HW policy and exam policy above. Grading scale is out of 100. There is no curving of the grades. Typically, below 60% is a failing grade in this course.
MatSE 540: Fall 2022 (Tuesdays and Thursdays, 10.35am -11.50 am, In class, EE West 203) (Tentative lecture schedule below; Changes are possible).

<table>
<thead>
<tr>
<th>L #</th>
<th>Date</th>
<th>Content</th>
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<tbody>
<tr>
<td>1</td>
<td>August 23</td>
<td>All properties as tensors; tensor notation</td>
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<tr>
<td>2</td>
<td>August 25</td>
<td>Coordinate Transformation and Symmetry Elements</td>
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<td>3</td>
<td>August 30</td>
<td>Point group symmetries</td>
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<td>3a</td>
<td>August 31</td>
<td>Mathematica introduction in Steidle 116, 5-6 pm</td>
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<tr>
<td>4</td>
<td>September 1</td>
<td>Point group symmetry continued; group theory formalism</td>
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<td>5</td>
<td>September 6</td>
<td>Group theory continued</td>
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<td>6</td>
<td>September 8</td>
<td>Space groups and translations</td>
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<tr>
<td>7</td>
<td>September 13</td>
<td>Definition of a Tensor and Neumann’s law</td>
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<td>8</td>
<td>September 15</td>
<td>First rank tensors: Pyroelectricity</td>
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<tr>
<td>9</td>
<td>September 20</td>
<td>Second rank tensor: Dielectric constant</td>
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<td>10</td>
<td>September 22</td>
<td>Geometric representation of 2nd rank tensors</td>
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<td>11</td>
<td>September 27</td>
<td>Second rank tensors: Stress</td>
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<tr>
<td>12</td>
<td>September 29</td>
<td>Second rank tensors: Strain</td>
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<tr>
<td>13</td>
<td>October 4</td>
<td>Thermodynamics of tensor properties</td>
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<tr>
<td>14</td>
<td>October 6</td>
<td>Third rank-tensors: Piezoelectricity</td>
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<tr>
<td>15</td>
<td>October 11</td>
<td>Midterm</td>
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<tr>
<td>16</td>
<td>October 13</td>
<td>Fourth-rank tensors: Elasticity</td>
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<td>17</td>
<td>October 18</td>
<td>Compliance, Compressibility etc</td>
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<td>18</td>
<td>October 20</td>
<td>Axial vectors</td>
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<td>19</td>
<td>October 25</td>
<td>Magnetic point groups</td>
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<tr>
<td>20</td>
<td>October 27</td>
<td>Magnetic space groups</td>
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<td>21</td>
<td>November 1</td>
<td>Thermodynamics of magnetic tensors</td>
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<td>22</td>
<td>November 3</td>
<td>First rank tensors: Pyromagnetism, Ferromagnetism, Antiferromagnetism</td>
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<td>23</td>
<td>November 8</td>
<td>Second rank tensors: Magnetic susceptibility and Magnetolectric effect</td>
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<td>24</td>
<td>November 10</td>
<td>3rd and 4th-rank tensors: Piezomagnetism and Magnetostriction</td>
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<td>25</td>
<td>November 15</td>
<td>Electromagnetism and Refractive Index</td>
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<td>26</td>
<td>November 17</td>
<td>Nonlinear optics</td>
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<tr>
<td></td>
<td>November 22</td>
<td>Thanksgiving Break</td>
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<td></td>
<td>November 24</td>
<td>Thanksgiving Break</td>
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<tr>
<td>27</td>
<td>November 29</td>
<td>Group theory</td>
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<tr>
<td>28</td>
<td>December 1</td>
<td>Character Tables</td>
</tr>
<tr>
<td>29</td>
<td>December 6</td>
<td>Molecular Vibrations, Spectroscopy</td>
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<tr>
<td>30</td>
<td>December 8</td>
<td>Electronic Structure</td>
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</tbody>
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Academic Integrity

Two Sample statements are given below; please edit to fit your class.

Students in this class are expected to write up their problem sets individually, to work the exams on their own, and to write their papers in their own words using proper citations. Class members may work on the problem sets in groups, but then each student must write up the answers separately. Students are not to copy problem or exam answers from another person's paper and present them as their own; students may not plagiarize text from papers or websites written by others. Students who present other people's work as their own will receive at least a 0 on the assignment and may well receive an F or XF in the course. Please see: Earth and Mineral Sciences Academic Integrity Policy: http://www.ems.psu.edu/undergraduate/academic-advising/forms-and-procedures/academic-integrity, which this course adopts. To learn more, see Penn State's "Plagiarism Tutorial for Students."

Course Copyright

All course materials students receive or to which students have online access are protected by copyright laws. Students may use course materials and make copies for their own use as needed, but unauthorized distribution and/or uploading of materials without the instructor’s express permission is strictly prohibited. University Policy AD 40, the University Policy Recording of Classroom Activities and Note Taking Services addresses this issue. Students who engage in the unauthorized distribution of copyrighted materials may be held in violation of the University’s Code of Conduct, and/or liable under Federal and State laws.

For example, uploading completed labs, homework, or other assignments to any study site constitutes a violation of this policy.

Accommodations for Students with Disabilities

Penn State welcomes students with disabilities into the University's educational programs. Every Penn State campus has an office for students with disabilities. The Student Disability Resources (SDR) website provides contact information for every Penn State campus: (http://equity.psu.edu/student-disability-resources/disability-coordinator). For further information, please visit the Student Disability Resources website (http://equity.psu.edu/student-disability-resources).

In order to receive consideration for reasonable accommodations, you must contact the appropriate disability services office at the campus where you are officially enrolled, participate in an intake interview, and provide documentation: http://equity.psu.edu/student-disability-resources/applying-for-services. If the documentation supports your request for reasonable accommodations, your campus’s disability services office will provide you with an accommodation letter. Please share this letter with your instructors and discuss the accommodations with them as early in your courses as possible. You must follow this process for every semester that you request accommodations.

Attendance

See attendance and participation grades listed above. Regular attendance is critical for building on the skills and knowledge developed throughout the class. Students who participate have a more complete understanding of the material presented and are more likely to succeed in the class. This is true whether your attendance is face-to-face or remote. This course abides by the Penn State Attendance Policy E-11: http://undergrad.psu.edu/aappm/E-11-class-attendance.html, and Conflict Exam Policy 44-35: http://senate.psu.edu/policies-and-rules-for-undergraduate-students/44-00-examinations/#44-35. Please also see Illness Verification Policy: https://studentaffairs.psu.edu/health-wellness/medical-services/policies-patient-resources, and Religious Observance Policy: http://undergrad.psu.edu/aappm/R-4-religious-observances.html. Students who miss class for legitimate reasons will be given a reasonable opportunity to make up missed work, including exams and quizzes. In all cases, you should inform me in advance, when possible. Missing class, even for a legitimate purpose, may mean
there is work that cannot be made up, hurting your grade in this class. In addition to illness, legitimate reasons for missing class include religious observance, military service, family emergencies, regularly scheduled university-approved curricular or extracurricular activities, and post-graduate, career-related interviews when there is no opportunity for students to re-schedule these opportunities (such as employment and graduate school final interviews). Students who encounter serious family, health, or personal situations that result in extended absences should contact the Office of the Assistant Vice President for Student Affairs (AVPSA) and Student Care and Advocacy for help: http://studentaffairs.psu.edu/studentcare. Whenever possible, students participating in University-approved activities should submit to the instructor a Class Absence Form: http://undergrad.psu.edu/aappm/classabs.pdf, at least one week prior to the activity.

**Reporting Bias-Motivated Incidents**
Penn State takes great pride to foster a diverse and inclusive environment for students, faculty, and staff. Acts of intolerance, discrimination, or harassment due to age, ancestry, color, disability, gender, gender identity, national origin, race, religious belief, sexual orientation, or veteran status are not tolerated (https://policy.psu.edu/policies/ad29) and can be reported through Educational Equity via the Report Bias webpage.

**Counseling and Psychological Services**
Many students at Penn State face personal challenges or have psychological needs that may interfere with their academic progress, social development, or emotional wellbeing. The university offers a variety of confidential services to help you through difficult times, including individual and group counseling, crisis intervention, consultations, online chats, and mental health screenings. These services are provided by staff who welcome all students and embrace a philosophy respectful of clients’ cultural and religious backgrounds, and sensitive to differences in race, ability, gender identity and sexual orientation. Services include the following:

- Counseling and Psychological Services at University Park (CAPS): 814-863-0395
- Counseling and Psychological Services at Commonwealth Campuses
- Penn State Crisis Line (24 hours/7 days/week): 877-229-6400
- Crisis Text Line (24 hours/7 days/week): Text LIONS to 741741

**Webcam Requirements**
This course may require you to have a webcam for class assessments. Classes and assessments may be conducted using Zoom or other technology selected by your instructor which may use your computer’s webcam or other technologies to communicate, monitor, and/or record classes, class activities, and assessments. Assessments may also be conducted using proctoring software, which may listen to you, monitor your computer screen, view you and your surroundings, and record (including visual and audio recordings) all activity during the proctoring process. Please contact your instructor if you are unable to comply or have any questions or concerns.

**Syllabus and Paper Acknowledgement Forms:**
It is the recommendation of the college that all students sign and return the Syllabus Acknowledgement Form (http://facdev.e-education.psu.edu/sites/default/files/files/Syllabus acknowledgement form.doc) during the first week of the semester. In addition, The College also recommends the Paper Submission Form (http://facdev.e-education.psu.edu/sites/default/files/files/Paper submission form.docx) as a way to have students take responsibility for papers/labs/homework done as part of group work.

**Penn State E-mail Accounts**
All official communications from Penn State are sent to students' Penn State e-mail accounts. Be sure to check your Penn State account regularly, or forward your Penn State e-mail (see https://pennstate.service-now.com/sp?id=kb_article_view&sys_kb_id=90160f4db9ed0949cede83aa1396199b) to your preferred e-mail account, so you don't miss any important information.

**Deferred Grades**
If you are prevented from completing this course within the prescribed amount of time for reasons that are beyond your control, it is possible to have the grade deferred with the concurrence of the instructor, following Penn State
Deferred Grade Policy 48-40 (http://senate.psu.edu/policies-and-rules-for-undergraduate-students/47-00-48-00-and-49-00-grades/#48-40). To seek a deferred grade, you must submit a written request (by e-mail or U.S. post) to the instructor describing the reason(s) for the request. Non-emergency permission for filing a deferred grade must be requested before the beginning of the final examination period. It is up to the instructor to determine whether or not you will be permitted to receive a deferred grade. If permission is granted, you will work with the instructor to establish a communication plan and a clear schedule for completion. If, for any reason, the course work for the deferred grade is not complete by the assigned time, a grade of "F" will be automatically entered on your transcript.

Military Personnel
Veterans and currently serving military personnel and/or spouses with unique circumstances (e.g., upcoming deployments, drill/duty requirements, disabilities, VA appointments, etc.) are welcome and encouraged to communicate these, in advance if possible, to the instructor in the case that special arrangements need to be made.

Technical Requirements
For this course, we recommend the minimum technical requirements outlined on the Dutton Institute Technical Requirements page (https://www.e-education.psu.edu/techspecs), including the requirements listed for same-time, synchronous communications. If you need technical assistance at any point during the course, please contact the ITS Help Desk (http://itservicedesk.psu.edu).

Netiquette
The term "Netiquette" refers to the etiquette guidelines for electronic communications, such as e-mail and bulletin board postings. Netiquette covers not only rules to maintain civility in discussions, but also special guidelines unique to the electronic nature of forum messages. Please review some general Netiquette guidelines that should be followed when communicating in this course.

Disruptive Behavior
Behavior that disrupts normal classroom activities will not be tolerated, in accordance with Items 9 and 14 in the Student Code of Conduct.

Mandated Reporting Statement
Penn State’s policies require me, as a faculty member, to share information about incidents of sex-based discrimination and harassment (discrimination, harassment, sexual harassment, sexual misconduct, dating violence, domestic violence, stalking, and retaliation) with Penn State’s Title IX coordinator or deputy coordinators, regardless of whether the incidents are stated to me in person or shared by students as part of their coursework. For more information regarding the University's policies and procedures for responding to reports of sexual or gender-based harassment or misconduct, please visit Penn State's Office of Sexual Misconduct Prevention & Response website.

Additionally, I am required to make a report on any reasonable suspicion of child abuse in accordance with the Pennsylvania Child Protective Services Law.

Diversity, Inclusion, and Respect
Penn State is “committed to creating an educational environment which is free from intolerance directed toward individuals or groups and strives to create and maintain an environment that fosters respect for others” as stated in Policy AD29 Statement on Intolerance. All members of this class are expected to contribute to a respectful, welcoming and inclusive environment and to interact with civility.

For additional information, see:
- Penn State Affirmative Action non-discrimination statement
- Policy AD 85 Sexual and gender-based harassment and misconduct, Title IX
- Policy AD91 Discrimination and Harassment, and Related inappropriate Conduct
- Penn State Statement on Diversity, Equity, and Inclusive Excellence
- Penn State Values
- Penn State Principles
- All In at Penn State: A Commitment to Diversity and Inclusion
**Accessible Syllabus**

Notes: Any syllabus posted online (e.g. a Word/PDF file or an online syllabus) should make destinations clickable links such as is done throughout this page. Also, in order to comply with [Penn State Policy AD69](http://policy.psu.edu/policies/ad69) (Accessibility of Penn State Web Pages), PDF documents cannot be the sole source of presenting online information. Such documents include syllabi, homework assignments, and scanned notes.

**Disclaimer Statement**

Please note that the specifics of this Course Syllabus can be changed at any time, and you will be responsible for abiding by any such changes. Changes to the syllabus shall also be given to the student in written (paper or electronic) form.