

Group theory and quantum mechanics

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1. General Information

- Course objectives: To deliver the subset of group theory known to have important applications in physics. Formal proofs will be minimized, emphasized only when straightforward or essential to understanding.
- Pre-requisites: Students must be comfortable with quantum mechanics.
- Class time & location
 - Tuesday & Thursday 14:00-15:15, Howey S106.
 - No regular office hours. If there are questions, you can catch me after classes, email me at zhuxi_luo@gatech.edu or schedule a meeting with me.
- TA and TA office hours: To be determined.

2. Course requirements, grading, and guidelines

- Grading: 100 points in total
 - Biweekly homework, 60 points
 - Presentation, 40 points
 - Attendance is not required, but success requires mastering the lectures' materials.
- Letter grading: Final score will be rounded to the next integer.
 - A: 90 points or more
 - B: 80-89 points
 - C: 70-79 points
 - D: 60-69 points
 - F: 59 or less
- Homework: A couple of problems for each set.
 - 10 points each. Submit on canvas. Typically due two weeks after the homework is announced..

- Students can skip one set of homework of their choice. It's recommended to save this for sickness or emergencies etc. If all 7 sets of homeworks are completed, the 6 sets with the highest scores will be kept.
- Recommended: First think independently; then discuss with classmates or other people/robots if needed. However, after discussions, students are expected to write down their own solutions independently.
- Copying solutions from any source without understanding them is plagiarism. If discovered, the whole homework set will receive zero points and the academic misconduct will be reported.
- Penalty for late submissions: 2 points within one day, 3 points between 1-2 days, 5 points between 2 days and 2 weeks, 10 points after 2 weeks (no points left).
- Oral presentation
 - 20 minutes oral presentation plus 5 minutes Q & A on selected topics.
 - Inform me your choice of topic in advance.
 - Presentations can happen any time during the semester. Whenever you feel ready, schedule with me. All presentations must be completed before Dec. 16th.
 - Presentations can be either in class (with extra credits) or in private.
 - Examples of presentation topics:
 - Wigner's theorem
 - Projective representation
 - Mermin-Wagner theorem
 - Goldstone's theorem
 - Lieb-Shultz-Mattis theorem
 - Coleman-Mandula theorem
 - Non-invertible symmetry
 - Landau's theory of phase transitions
 - Fun groups such as monster group
 - Racah algebra
 - Solving the quintic equation
 - Applications of group theory in your field!
 - ...
- Academic integrity: <https://catalog.gatech.edu/rules/18/>
- Students with disabilities: Contact me and the office of disability services as soon as

possible <https://disabilityservices.gatech.edu/>

- AI policy: <https://oit.gatech.edu/ai/guidance>

3. Course content and materials

- Lecture notes and other supplementary readings: Will be posted on canvas after each class.
- Textbook: Not required, as lecture notes will be self-contained. But in case students are interested, here is a list:
 - Group theory in physics: an introduction, by J. F. Cornwell.
 - Group theory in a nutshell for physicists, by A. Zee.
 - Group theory and quantum mechanics, by M. Tinkham.
 - Lie algebras in particle physics - from isospin to unified theories, by H. Georgi.
 - Applications of finite groups, by J. S. Lomont.
 - Group theory, by P. Cvitanović.
 - Physics 220: Symmetries in Physics, by J. McGreevy.
 - Lecture notes on Group theory in physics, by D. Arovas.
 - Introduction to group theory for physicists, by M. von Steinkirch.
- Plan of the course (subject to changes)
 - **Why** group theory?
 - **Basic framework**: Definition and examples, presentations, homomorphism and isomorphism, subgroup, class, invariant subgroup, cosets, factor groups, (semi)-direct product.
 - **Discrete groups**: Lagrange's theorem, multiplication table, re-arrangement theorem. Permutation group, dihedral group, quaternionic group.
 - **Representation theory**: Definition, examples, equivalent, unitary, irreducible representations, Schur's lemma, orthogonality theorem, character, character table, projectors, direct product representation, representations of direct product groups, induced representations.
 - **Lie groups**: Coordinate transformations and Lie's idea, Lie algebra, structure constants, tensor methods, $SO(N)$, $SU(N)$, $Sp(2N)$, Casimirs, Cartan-Weyl method,

Dykin diagrams, simple lie algebras, regular subalgebras, spinor representations, Clebsch-Gordan coefficients, Wigner Eckard theorem.

- **Applications in quantum mechanics:** Schrodinger's equation revisited, degeneracy, transition probabilities and selection rules, time-independent perturbations,
- **Crystals:** point groups and irreps, Bloch's theorem, Brillouin zones, space groups, crystal-field splitting of atomic energy levels
- **Selected important symmetries:** CPT, Lorentz group, Poincaré group, conformal group, isometry of AdS, grand unification.
- **Beyond** group theory

Enjoy groups!