

Physics 4343: Atomic, Molecular, and Optical Physics

MoWeFr 2:00-2:50pm Rm 127 Fall '24

Instructor:

Dr. Daniel Fischer
email: fischerda@mst.edu
phone: (573) 308-2782
office: 110 Physics
lab: G10 Physics

Office hours:

Tu 4:00pm-6:00pm (PLC in 207 Physics)
(See if I'm around at other times)

Texts:

There is no course textbook. Parts of the course will use "Atoms, Molecules and Optical Physics" by I. Hertel and C. Schulz. Another AMO textbook used in the course is "Atoms, molecules and photons: an introduction to atomic-, molecular-, and quantum-physics" by W. Demtroeder. Supplemental material and references will be provided on CANVAS.

Learning outcome:

This course will be on methods and applications of modern atomic and molecular physics. An introduction to the structure and dynamics of atomic and simple molecular systems as well as into their interaction with light is given. The most fundamental theoretical models (non-relativistic quantum mechanics) as well as relevant approximations will be discussed. The course will also include selected topics in recent atomic physics such as atomic clocks, laser cooling, and precision spectroscopy.

Assessment:

Course points:

3 hourly exams @ 100 pts	300 P
Comprehensive final exam	100 P
Homework (10 of 11)	300 P
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SUM	700 P

Grades:

A	≥ 90%
B	≥ 80%
C	≥ 70%
D	≥ 60%
F	< 60%

Homework:

One of the goals of this course is to develop your ability to solve basic problems in atomic molecular physics. A problem set will be assigned weekly on Wednesdays and will generally be due the Wednesday after class in the following week. I can assist in understanding the assignments during office hours. Your 10 highest scores will count towards your final grade. **Late homework will not be graded unless you contact me in advance to request and extension.**

Exam dates:

09/13/2024	Exam 1 (2pm-2:50pm)
10/09/2024	Exam 2 (2pm-2:50pm)
11/08/2024	Exam 3 (2pm-2:50pm)
12/10/2024	Final exam (3pm to 5pm)

Complaints:

If there are any complaints that cannot be resolved they can be taken to the department chair Dr. Vojta (102 Physics, vojta@mst.edu).

Physics 4343: Atomic Physics

Module 1: The “pre-history” of atomic physics

- Stoichiometry
- Kinetic theory of gases
- Spectroscopy (Balmer series, Lyman series, etc.)
- Scattering experiments (Rutherford)
- The classic atomic model (Bohr)

Module 2: A (very brief) introduction into quantum mechanics

- Schrodinger's wave mechanics (wave functions, wave packets, expectation values)
- Dirac notation (Bra- and Ket-vectors, Hermitian operators, eigenstates and eigenvalues)
- The "measurement problem"
- Commutators and the Heisenberg's uncertainty principle
- Angular momentum in quantum mechanics

Module 3: The hydrogen atom (basics)

- The Schrodinger equation for the Coulomb potential
- Eigenstate wave functions and eigenenergies of the hydrogen atom

Module 4: The hydrogen atom (details)

- Fine structure, magnetic moments, spin-orbit coupling, relativistic shifts, Dirac equation (Stern-Gerlach, Einstein-de-Haas, high precision spectroscopy)
- Lamb-shift and quantum electro dynamics (QED) (Lamb-Rutherford)
- Nuclear spin and Hyperfine structure
- Static external fields, Zeeman effect, Stark effect

Module 5: Emission and absorption of electromagnetic radiation

- emission and absorption processes, Einstein Coefficients
- electric dipole matrix elements
- selection rules

- line widths

Module 6: Atoms with more than one electron

- Exchange symmetry, fermions, and bosons
- The Helium atom
- Shell model, build-up of many electron atoms, and periodic table
- Angular momentum coupling and Hund's rules
- Theoretical approximations: Independent electron model, Hartree-Fock approximation, and configuration interaction
- Excited atomic states and autoionization processes

Module 7: Introduction into molecular physics

- "exact" solution of the H_2^+ molecular ion
- Variational principle and linear combination of atomic orbitals
- Orbitals of the H_2 molecule
- Covalent, ionic, and van-der-Waals bonds
- Born-Oppenheimer approximation
- Vibrations, rotations, ro-vibrational transitions

Module 8: Light-matter interaction II / coupled two-level systems

- Two-level quantum systems
- Rotating wave approximation
- Solution of the Schroedinger equation in the rotating wave approximation (Rabi oscillations)
- Density matrix formalism
- Applications: Laser cooling, Ramsey spectroscopy and atomic clocks

Module 9: Quantum Computing

- Principles of quantum computing
- Optical trap as Q-bits
- Realizing quantum gates with optical traps

Missouri S&T Campus & UM System Policies

Statement about Copyright, FERPA, and Use of Video

It is vitally important that our classroom environment promotes the respectful exchange of ideas. This entails being sensitive to the views and beliefs expressed during discussions whether in class or online. Please obtain instructor permission before recording any class activity. It is a violation of University of Missouri policy to distribute such recordings without authorization and the permission of all who are recorded. More information is provided [online](#).

Accessibility and Accommodations

It is the university's goal that learning experiences be as accessible as possible. If you anticipate or experience physical or academic barriers based on a disability, please contact Student Accessibility and Testing at (573) 341-6655, email dss@mst.edu, or visit <https://saat.mst.edu/> for information.

Student Honor Code and Academic Integrity

- All students are expected to follow the [Honor Code](#).
- Student Academic Regulations describes the student standard of conduct relative to the University of Missouri System's Collected Rules and Regulations section 200.010, and offers descriptions of academic dishonesty including cheating, plagiarism, and sabotage, any of which will be reported to the Vice Provost for Undergraduate Education.
- Other resources for students regarding academic integrity can be found [online](#).

Student Well-Being (<https://wellbeing.mst.edu/>)

Student Well-Being provides counseling services, health promotion initiatives, and prevention programs to empower the S&T community to thrive and enhance personal, academic, and professional success. Department office hours are Monday-Friday, 8am-5pm. On the website, you can find information related to individual and group counseling, wellness consultations and training, resources for many health and wellness topics, and help for mental health crisis situations.

UCARE

UCARE is the central point of contact to connect a student who may be experiencing a personal, academic, financial, wellbeing, and/or other concern to support and resources. Sharing your concern with UCARE helps connect a student with solution focused assistance to support their holistic well-being, success, and academic progress. A referral can be submitted at <https://go.mst.edu/ucare-refer> or by emailing <mailto:mucare@mst.edu>.

Health and Well-Being Canvas Cours

(<https://umssystem.instructure.com/enroll/G3LY3G>) The Health and Well-Being Canvas Course features training, presentations, and other health and well-being resources for students. One feature of the course is the Miner Well-Being Certification Program, a semester-long certification where participants can engage with campus-wide services and initiatives and develop skills that contribute to personal well-being and student success. Students can enroll in the free, non-credit course at any time.

Nondiscrimination, Equity, and Title IX

Missouri S&T is committed to the safety and well-being of our campus community, and to creating an environment free from discrimination and harassment.

The University does not discriminate on the basis of race, color, national origin, ancestry, religion, sex, pregnancy, sexual orientation, gender identity, gender expression, age, disability, protected veteran status, and any other status protected by applicable state or federal law. As used in this policy, the word “sex” is also inclusive of the term “gender.”

Additionally, US Federal Law Title IX states that no member of the university community shall, on the basis of sex, be excluded from participation in, or be denied benefits of, or be subjected to discrimination under any education program or activity. Violations of this law include sexual harassment, sexual assault, dating/domestic violence, and stalking.

In accordance with the University of Missouri’s Collected Rules and Regulations, all faculty and staff are required to report any information concerning discrimination disclosed through communication including, but not limited to, direct conversation, email, social media, classroom papers and homework exercises to the Equity Officer/Title IX Coordinator.

Office of Equity and Title IX

Equity Officer and Title IX Coordinator: Dr. Paul Hirtz

Phone: (573) 341-7734

Location: 900 Technology Drive, Suite 500

E-mail: equity@mst.edu

Classroom Egress Maps

For all in-person instruction, faculty should explain where the classroom emergency exits are located. Classroom egress maps are posted at <http://designconstruction.mst.edu/floorplan/>.