ENVE5703: Radiative Transfer and Remote Sensing
Department of Civil and Environmental Engineering
Course Syllabus, Fall 2020

Instructor: Dr. Thomas W. Walker
Email: thomas.walker@carleton.ca

Course Description (Calendar):

An exploration of interactions between light, Earth’s surface, and the atmosphere, applications to satellite remote sensing. Fundamentals of radiation and its interactions with matter, equation of radiative transfer, scattering and phase functions. Geometries of remote sensing, measurement methods including passive thermal, reflected solar, and active sensing. Applications to atmospheric science, hydrology, and land use.

Student Learning Outcomes:

At the end of this course, students will be able to:

- Explain fundamental properties of radiation and its interaction with matter, and describe the origin of features in both the solar and terrestrial emission spectra on the basis of these fundamentals;
- Perform calculations of radiation budgets and manipulate the equations that govern radiative transfer in the atmosphere;
- Analyze a satellite remote sensing instrument or technique and present the results in a succinct and cogent manner; and,
- Interpret atmospheric heating and cooling rates, and appreciate the fundamental importance of radiative transfer in the Earth system as it relates to the regulation of climate.

Course Week-by-Week Outline (subject to change):

Contents of the course or the length of time spent on a given topic may change based on interest in the class.

**Week 1: Fundamentals of Radiation**
- Posing the problem. Definition of terms and geometry.
- Fundamentals of radiation, including thermodynamic equilibrium, the Planck function, Wien’s displacement law, and the Stefan-Boltzmann law.

**Week 2: Radiation-Matter Interactions**
- Absorption and emission, scattering, Kirchoff’s law, Beer-Lambert law, classical and QM interpretations of emission, vibrorotational spectra, line shapes, pressure and Doppler broadening.

**Week 3: Radiative Transfer Equation**
- Schwarzschild’s equation, optical thickness, solution in plane-parallel atmosphere, multiple scattering and absorption, Legendre polynomials, atmospheric heating and cooling rates.
Week 4: Solar Radiation: The Sun as a source of radiation, geometry of Earth’s orbit, the solar constant.

Week 5: Earth’s Atmosphere: Atmospheric composition and temperature structure, ozone layer, greenhouse gases, the atmospheric emission spectrum, Rayleigh scattering and the colour of the sky.


Week 7: Inverse Problem and Retrievals: Introduction to inverse theory. Solutions to Fredholm integrals, Chahine’s method, matrix methods, optimal estimation, and minimum variance.


Weeks 10-11: Project Presentations: This time is reserved for students to present their project results to the class. Presentation length depends slightly on course enrollment.

Week 12: Applications to Climate: Role of radiation in the climate; clouds, aerosols, forcings, and feedbacks. Two-stream approximation, radiative transfer in climate models.

Textbook:

The following textbook will be followed in the course, although not always in order. The electronic version has been placed on reserve in the MacOdrum Library, and may be accessed through Ares (linked from the course cuLearn page).


Assessment:

Carleton University uses the twelve-point system for letter grades as follows:

<table>
<thead>
<tr>
<th>Percentage Range</th>
<th>Grade</th>
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<tbody>
<tr>
<td>90 – 100 %</td>
<td>A+</td>
</tr>
<tr>
<td>85 – 89 %</td>
<td>A</td>
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<tr>
<td>80 – 84 %</td>
<td>A-</td>
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<tr>
<td>77 – 79 %</td>
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<tr>
<td>60 – 62 %</td>
<td>C-</td>
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<tr>
<td>57 – 59 %</td>
<td>B-</td>
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<tr>
<td>53 – 56 %</td>
<td>C+</td>
</tr>
<tr>
<td>50 – 52 %</td>
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The final grade for the course will comprise take-home assignments, a project presentation to be given in class, an annotated bibliography outlining the intended presentation topic, and a final exam. Details on the individual graded components will be released at a later time. Weightings are as follows:

<table>
<thead>
<tr>
<th>Component</th>
<th>Weight</th>
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<tbody>
<tr>
<td>Assignments (best 3 of 4)</td>
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<tr>
<td>Annotated Bibliography</td>
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</tr>
<tr>
<td>Project Presentations</td>
<td>20</td>
</tr>
<tr>
<td>Final Exam</td>
<td>40</td>
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</tbody>
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Course Policies

Communications

Course materials will be distributed through the course's cuLearn page. Students are responsible for ensuring they are correctly registered through cuLearn, and for checking the cuLearn course management site regularly. Lecture slides will be made available before class; however, material will be presented in class that is not accessible through the slides alone.

All electronic communications with the instructor must be through official Carleton email accounts. Effort will be made to respond to inquiries as quickly as possible, but please expect delays of up to 48 hours for a response. Complex technical questions should be addressed during office hours or by appointment.

Lateness

A geometrically-scaled penalty will be deducted from assignments and reports passed in after the deadline. The first day will deduct 10% of the possible grade for that assignment, the second will deduct 20%, the third 40%, and so on. Accommodation may be made for valid reasons, requirements for which are outlined below.

Final Exam

The final exam is for evaluation purposes only and exam papers will not be returned to the student. A minimum mark of 40% on the final exam is required to pass the course.

Appeals

All grade appeals in this course must be made within one week of the posting date.

Course Material Copyright

Classroom teaching and learning activities, including lectures, discussions, presentations are copy protected and remain the intellectual property of the instructor. All course materials, including Powerpoint presentations, outlines, videos, and other materials are also protected by copyright and remain the intellectual property of the instructor. Students registered in the course may take notes and make copies of course material for their own educational use only. Students are not permitted to reproduce or distribute lecture notes and course materials publicly for commercial or non-commercial purposes without express written consent from the copyright holder(s). Students are not permitted to upload these copyrighted materials to any online repositories.

Academic Integrity:

Academic integrity is essential to the pursuit of learning and scholarship in a university, and to ensure that a degree from Carleton University is a strong signal of each student's individual academic achievement. As a result, the University treats cases of cheating and plagiarism very seriously. Carleton University's Policy on Academic Integrity (http://www.carleton.ca/Registrar/academic-integrity) outlines the behaviours that constitute academic dishonesty and the processes for addressing academic offences. It is your responsibility to be familiar with these policies. Any students who do not act with academic integrity will face severe consequences including immediate referral to Associate Dean of Student Affairs.
Academic Accommodation:

Students with diverse learning styles and needs are welcome in this course. You may need special arrangements to meet your academic obligations during the term. For an accommodation request, the processes are as follows. For more information, please consult: http://students.carleton.ca/course-outline

Pregnancy Obligation

Please contact the instructor with any requests for academic accommodation during the first two weeks of class, or as soon as possible after the need for accommodation is known to exist. For more details, please consult: http://students.carleton.ca/course-outline

Religious Obligation

Please contact the instructor with any requests for academic accommodation during the first two weeks of class, or as soon as possible after the need for accommodation is known to exist. For more details, please consult: http://students.carleton.ca/course-outline

Accommodations for Students with Disabilities

The Paul Menton Centre for Students with Disabilities (PMC) provides services to students with Learning Disabilities (LD), psychiatric/mental health disabilities, Attention Deficit Hyperactivity Disorder (ADHD), Autism Spectrum Disorders (ASD), chronic medical conditions, and impairments in mobility, hearing, and vision. If you have a disability requiring academic accommodations in this course, please contact PMC at 613-520-6608 or pmc@carleton.ca for a formal evaluation. If you are already registered with the PMC, contact your PMC coordinator to send me your Letter of Accommodation at the beginning of the term, and no later than two weeks before the first in-class scheduled test or exam requiring accommodation (if applicable). Requests made within two weeks will be reviewed on a case-by-case basis. After requesting accommodation from PMC, meet with me to ensure accommodation arrangements are made. Please consult the PMC website (http://www.carleton.ca/pmc) for the deadline to request accommodations for the formally-scheduled exam (if applicable).

Survivors of Sexual Violence

As a community, Carleton University is committed to maintaining a positive learning, working, and living environment where sexual violence will not be tolerated, and survivors are supported through academic accommodations as per Carleton’s Sexual Violence Policy. For more information about the services available and to obtain information about sexual violence and/or support, please visit: http://www.carleton.ca/sexual-violence-support

Accommodation for Student Activities

Carleton University recognizes the substantial benefits, both to the individual student and for the university, that result from a student participating in activities beyond the classroom experience. Reasonable accommodation must be provided to students who compete or perform at the national or international level. Please contact the instructor with any requests for academic accommodation during the first two weeks of class, or as soon as possible after the need for accommodation is known to exist. For more information, please consult: http://students.carleton.ca/course-outline