Instructor
Amir Hakami (amir_hakami@carleton.ca)
Office hours: by appointment

Teaching Assistants:
TBD

Course components
Lectures (3 hours a week)
Tutorial (1 hour a week)
Discussion sessions (3 hours, alternate weeks)

Mode of delivery
All the components of the course (including written evaluations) will be conducted in-person. The lectures will not be recorded. If an instructor or TA is symptomatic, that lecture, discussion session, or tutorial may be held online as a real-time session at the same time as the cancelled in-person session. If a substitute session is delivered online, every effort will be made to record the session and make it available for asynchronous learning. If the instructor or TA is not able to attend the session, an offline recording of the session will be provided as soon as possible.

If you are symptomatic, please follow the University and Public Health guidelines about class attendance. In lectures, I do not use slides or pre-distributed notes. Lectures will only loosely follow the supplementary textbooks. Your best source for the material taught in this course are your notes; therefore, detailed note-taking is highly recommended. I recognize that in a pandemic, this may cause difficulty and inconvenience due to missed classes. I encourage that you form support groups for note-sharing, group work, and collaborative learning. I would also be happy to post notes, if a volunteer is willing to share theirs. Finally, please take advantage of the office hours of the instructor and TAs to stay current with the material that you may miss or have difficulty with.

Evaluation
ENVE 4003 students would require a minimum overall course grade of D- (50%) and a minimum mark of 40% in the final exam (overall, written and oral – see below) to pass the course. ENVE 5101 students would require a minimum overall course grade of B- (70%) and final exam grade of 50% to successfully complete the course.

ENVE 4003
10% Assignments
15% Discussion sessions
20% Midterm
25% Oral final exam (see below)
30% Written final exam (see below)
10% Active and engaged participation (see below)

ENVE 5101
10% Assignments
20% Discussion papers
25% Midterm
45% Written final exam
10% Active and engaged participation (see below)

Midterm – ENVE 4003/5101
October 19, in-person.

Oral Final Exam – ENVE 4003
The ENVE 4003 final exams consists of oral and written tests. Oral final exams will take place in the last 2 weeks of the semester, and the written final test will be at the scheduled examination time. Oral examinations will be one-on-one, 15-minute tests, consisting of questions on the material covered in the course. The oral exams will be conducted online and will be recorded for documentation purposes.
Written Final Exam – ENVE 4003/5101

The final exam for both ENVE 4003 and ENVE 5101 will be conducted in-person at the centrally scheduled examination time. The final exam covers all the course material with more focus on the post-midterm components.

Topical discussions
Throughout the semester we will read and discuss 4-5 scientific articles. These articles are related to the subjects covered in the course and are meant to demonstrate how the theoretical topics discussed throughout the semester have real-world implications. Additionally, and just as importantly, the discussion articles are chosen such that they have direct societal relevance, i.e., topics that are at the interface of air pollution engineering and non-engineering disciplines such as public policy, economics, public health, or environmental/social justice. In preparing for these discussions, students (and in particular graduate students) are expected to conduct further reading and individual research on the topics as necessary.

ENVE 4003 students are required to attend the discussion sessions, and they are evaluated based on their contribution to the discussion. ENVE 5101 students are welcome to attend the discussion sessions; however, their evaluation will be based on written discussion papers (1000 words for each discussion paper). Details about the discussion topics and articles, as well as guidelines for discussion papers will be provided during the semester.

Class participation and engagement
This course aspires to be as interactive as possible. Students who actively and significantly contribute to exchanges and interactions during the lectures and general discussion periods (e.g., by asking and/or answering questions, bringing relevant topics for discussion, etc) can receive bonus marks (up to 10%) for their help in creating an engaging learning environment. Note that the expectation of contribution for this bonus mark goes beyond simple attendance and participation, and that the judgement on what constitutes significant contribution lies solely with the instructor.

General guidelines

Communications
All course materials will be posted on Brightspace. Electronic communications with us must be carried out through your official Carleton email.

Assignment submissions
All assignments/reports should be submitted by the due date and time. Penalties for late submissions are 20% within an hour, and 50% between 1 and 24 hours. Submissions after 24 hours receive no credit. If solutions are posted within 24 hours of the due date, late submissions will not be accepted. Students can discuss assignments with each other, but the submitted material must be your individual work.

Academic integrity and plagiarism
It is your responsibility to ensure that the work you submit for any form of evaluation (assignment, exam, test, written discussion or review, term paper, etc) is your work (and only your work) performed for the sole purpose of this course. If you find this requirement ambiguous please take the time to familiarize yourself with Carleton’s academic integrity policy (https://carleton.ca/secretariat/wp-content/uploads/Academic-Integrity-Policy.pdf). This course follows a zero-tolerance policy and all suspected/alleged cases of violation of academic integrity, including plagiarism, will be forwarded to the Dean’s Office for formal investigation.

Office hours and meetings
Students should feel comfortable to contact the instructor by email to schedule a meeting for any reason. I have not set scheduled office hours, so that you can schedule meetings throughout the week. Information about TA office hours will be communicated by the TAs.

Course and lecture layout (subject to modification):
This course will prepare students to answer the following questions:

- What are the processes that contribute to formation, transport, and transformation of air pollution at local, regional, and global scales?
- What are the current local, regional, and global air pollution problems facing us?
- What are the main scientific/engineering challenges that exist in air quality policy-making?
- What are the main engineering control approaches for air pollution control?
General course layout:

Local/Regional Air Pollution

- **Sources**: 10
- **Physics**: 4-8
- **Chemistry**: 11-14
- **Policy**: 9-10
- **Controls**: 15-23
- **Pollution**: 9-10
- **Impact**: 2-4, 9-10, 24

Global Air Pollution

- Global Warming**: 2-4
- **Ozone Depletion**: 24

Nonlinear (topical) schedule of lecture sessions (subject to modification)

1. **General overview**: temporal and spatial scales of air pollution, system approach to atmospheric pollution.

Global Air Pollution

2-4. **Global warming**: interaction of pollutants with radiative budget of the atmosphere.

24. **Stratospheric ozone depletion**: Chapman mechanism, ozone depletion and ozone depleting substances.

Local/Regional Air Pollution

4-8. **Atmospheric physics**: general circulation, horizontal and vertical transport of pollution, stability and lapse rate (review), turbulence and Reynolds decomposition (review), characteristic times in the atmosphere.

9-10. **Air pollution policy**: regulation of air pollution, air pollution decision-making, regulatory and economic instruments.

11-14. **Ozone chemistry and pollution**: atmospheric kinetics, major precursor sources and budgets, NOx chemistry, CO and Hydrocarbon oxidation, urban smog formation, ozone isopleth, chemical regimes and control options.

Pollution Control

15-17. **Aerosol dynamics and pollution**: aerosol characteristics, major sources and budgets, size distribution and distribution modes, formation and removal processes, single particle dynamics.

18-21. **Aerosol control**: particle removal mechanisms; settling chambers design and efficiency, cyclone performance and design, electrostatic precipitators (ESP), filters and baghouse design.

22-23. **Control of gas-phase species**: combustion and thermodynamics of pollutant formation, NOx formation and Zeldovich mechanism, post-combustion NOx control, combustion modification techniques, Low-NOx burners, Flue Gas Recirculation (FGR), Selective Catalytic and Noncatalytic Reduction (SCR & SNCR).

Reference material and textbooks

Your main source of content for the course should be your class notes. Note that there will be additional material in the lectures that are not available in the references given below, and conversely, only a fraction of the material discussed in these references are covered in the course. Main references are chosen such that they are available electronically, but please note that there might be limitations in the number of simultaneous access points.

**Main reference materials**


3- Schnelle, K. B.; Brown, C. A, Air pollution control technology handbook, CRC Press, 2002. [Available electronically through the library]

**Other recommended books**


2- De Nevers, Noel, Air pollution control engineering by, McGraw-Hill, 2000 (2nd ed).
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<tr>
<th>Week</th>
<th>Topics</th>
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<tr>
<td>Week 1 (Sep 7, 9)</td>
<td>Definitions and general concepts; classification of pollutants. Radiation and Earth’s energy balance; effective temperature.</td>
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<td>Week 2 (Sep 14, 16)</td>
<td>Greenhouse effect; Simple radiative model; climate sensitivity; global warming potential.</td>
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<td>Week 3 (Sep 21, 23)</td>
<td>Atmospheric structure; barometric law; general circulation model, weather systems and air pollution.</td>
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<td>Week 4 (Sep 28, 30)</td>
<td>Concentrations; sources and sinks; simple models and mass balance; atmospheric lifetime; pollutant transport in the atmosphere and characteristic times.</td>
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<td>Week 5 (Oct 5, 7)</td>
<td>Air pollution policy; taxation and cap-and-trade systems; air pollution health effects; benefit-cost analysis; criteria air contaminants; standards.</td>
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<td>Week 6 (Oct 12, 14)</td>
<td>Atmospheric chemistry; photochemical reactions and mechanisms; NOx cycle; photochemical production of ozone; ozone isopleth.</td>
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<td>Week 7 (Oct 21)</td>
<td>Nonlinearity, ozone control policy</td>
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<td>Week 8 (Nov 2, 4)</td>
<td>Atmospheric aerosols, health, and climate; particle modes; aerosol size distribution; aerosol dynamics and processes.</td>
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<td>Week 9 (Nov 9, 11)</td>
<td>Particle settling and Stokes velocity; aerodynamic diameter; stopping distance.</td>
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<td>Week 10 (Nov 16, 18)</td>
<td>Particle removal concepts; removal efficiency; settlers; cyclones; devices in series or in parallel.</td>
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<td>Week 11 (Nov 23, 25)</td>
<td>Electrostatic precipitators; Baghouses; other particles removal devices.</td>
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<td>Week 12 (Nov 30, Dec 2)</td>
<td>Combustion, air-to-fuel ratio; Zeldovich mechanism; combustion modification; selective catalytic and non-catalytic reductions.</td>
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<td>Week 13 (Dec 7)</td>
<td>Stratospheric ozone depletion.</td>
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**Academic Accommodation**
You may need special arrangements to meet your academic goals and objectives during the term. For an accommodation request the processes are as follows:

*Pregnancy obligation*
Write to me 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 see the [Student Guide](http://carleton.ca/equity/wp-content/uploads/Student-Guide-to-Academic-Accommodation.pdf)

*Religious obligation*
Write to me 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 see the [Student Guide](http://carleton.ca/equity/wp-content/uploads/Student-Guide-to-Academic-Accommodation.pdf)

**Academic 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](mailto: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). After requesting accommodation from PMC, please let me know to ensure accommodation arrangements are made. Please consult the [PMC website](http://carleton.ca/equity/) for the deadline to request accommodations for the formally-scheduled exam (if applicable).