

Topics in Numerical Computing “Machine Learning for Physicists”
PHYC4250/5250 Syllabus Winter 2025/26
Department of Physics and Atmospheric Science

Instructor: Andrew Rutenberg adr@dal.ca Dunn223
Lectures: MWF 8:35-9:25am LSC C334
Office Hours: drop-in (Dunn223) + RutenHour
Zoom (as needed): <https://us02web.zoom.us/j/6908945246> **Shared [Dropbox](#)**
TA: Gavin Kerr (one-on-one help by request) Gavin.Kerr@dal.ca

Course Description We will learn Machine Learning techniques assuming a physics background. This will include (at the end) deep-learning approaches for spatial (image, CNN) and temporal data (RNN). Programming skills are required but no specific physics. A computer with Python installed is required (Anaconda installation recommended).

Course Prerequisites PHYC1290, MATH 1010, PHYC2050 (or equivalent)

Course Objectives/Learning Outcomes

To understand the basis of standard machine learning techniques, and how to effectively navigate and implement them. With these techniques data analysis can be done without starting from a particular analytic model (theory).

Required books:

Acquaviva, "[Machine Learning for Physics and Astronomy](#)" (available on Amazon)
Prince, "[Understanding Deep Learning](#)" deep-learning (free PDF)

Also helpful:

Chollet, "[Deep Learning with Python](#)" (2nd ed) Keras focused (free PDF)
Deisenroth "[Mathematics for Machine Learning](#)" background (free PDF)
online background: [StatQuest](#) youtube ML
review by Mehta et al (2019) <https://doi.org/10.1016/j.physrep.2019.03.001> (basis of old course)

Conversion of numerical grades to Final Letter Grades for 4250 follows the [Dalhousie Grade Scale](#)

A+ (90-100)	B+ (77-79)	C+ (65-69)	D	(50-54)
A (85-89)	B (73-76)	C (60-64)	F	(<50)
A- (80-84)	B- (70-72)	C- (55-59)		

Course Policies: *Late assignments may be penalized by one mark and may not be accepted after material is taken up. You are encouraged to collaborate and help each other but not to blindly copy. Reuse of class/notebook code is encouraged (if helpful). Any material that is not yours (including ChatGPT or similar) should be attributed. Assignments should be done with Jupyter-notebooks or equivalent and any required packages should be documented.*

10 assignments (10x4%) **required**
participation (10x2%) **4250 only**
questions (10x1%)
0-4 technique reports (4x10%) **max 1/month**
0-2 projects (2x20%) **max 1/month**

everyone does assignments (40%) and selects the other 60% by their preference.

Course Assessment

assignments (typically 4% each, total of 40%). Assigned approximately weekly. A typical assignment will be:

- a) [1 mark] Topical Jupyter notebook will be provided to introduce a method. You run, modify, and discuss.
- b) [2 marks] You write code to use a topical method. Document, modify, plot, discuss. An explicit plan for the code should be provided before any LLM coding assistance. How do you know it works?
- c) [1 mark] You debug/confront/discuss/run someone else's code from (b). You then discuss what you learned/taught/found. At first this will be done in class on Friday with random partners.

Each assignment should be emailed as a unified PDF for ease of marking, but code should be separately provided. Any LLM (Claude, chat-GPT, Gemini, etc.) use should be documented (key prompts, platform, key contributions). Use of GitHub, Google collab, etc.. are welcome.

participation (4250 only, 1% each, max 2/week, max 20%) If you show up to class you get a participation mark. Some of these will be based on classroom engagement (i.e. show up body and soul).

questions (1% each, max 1/week, max 10%) You provided a written question about the material or course up to that time as an anonymized PDF. You can include your sense of what the answer is (from Google or LLM or reading). I'll try to answer, and will share with class. Note that if you have no question, then you should either skip a week or you can read more deeply/extensively until you come up with something. How/what/why/when are good suggestions to start with, but what you are curious about (and that you can't solve immediately with a Google search) is best.

Technique reports (10% each, max 1/month): from the literature or the reading list, make a 1-2 page pdf summary (with links to background and/or applications), make a jupyter-notebook example with tips, *and* do a class presentation (10min+5minQ&A) on a machine learning technique that wasn't covered in class. The paper pdf, summary pdf, and jupyter-notebook should be shared with class. (The notebook code can be based on code from the web, with attribution and with modification.). You should use LaTeX with Overleaf, using a prltex style file that will be provided. A suggested outline will be provided, but can be improved on.

Projects (20% each, max 1/month) explore a **new dataset** of your interest using deep learning techniques. A template will be provided as the course progresses. **5250 students must do at least one project, while 4250 students can do a project.** The first project should include a vanilla deep-

learning. A second project should also include more specialized (e.g. CNN or RNN) deep-learning architectures. The writeup should be aimed at classmates (i.e. should be sharable and useful for them to learn/understand your methods, data, and results), and useable code should be shared from e.g. GitHub. **You should start by proposing a topic (and data) with the instructor.** You should aim towards a physics application (with "physics" data, broadly construed).

University Policies, Statements, and Resources:

Recognition of Mi'kmaq Territory

Dalhousie University acknowledges that we are in Mi'kma'ki, the ancestral and unceded territory of the Mi'kmaq People and pays respect to the Indigenous knowledges held by the Mi'kmaq People, and to the wisdom of their Elders past and present. The Mi'kmaq People signed Peace and Friendship Treaties with the Crown, and section 35 of the Constitution Act, 1982 recognizes and affirms Aboriginal and Treaty rights. We are all Treaty people. Dalhousie University also acknowledges the histories, contributions, and legacies of African Nova Scotians, who have been here for over 400 years.

Dalhousie University would like to acknowledge that the University is on Traditional Mi'kmaq Territory. The Elders in Residence program provides students with access to First Nations elders for guidance, counsel, and support. Visit or e-mail the Indigenous Student Centre at 1321 Edward St or elders@dal.ca. Additional information regarding the Indigenous Student Centre can be found at: https://www.dal.ca/campus_life/communities/indigenous.html

Internationalization

At Dalhousie, 'thinking and acting globally' enhances the quality and impact of education, supporting learning that is "interdisciplinary, cross-cultural, global in reach, and orientated toward solving problems that extend across national borders." Additional internationalization information can be found at: <https://www.dal.ca/about-dal/internationalization.html>

Academic Integrity

At Dalhousie University, we are guided in all our work by the values of academic integrity: honesty, trust, fairness, responsibility, and respect. As a student, you are required to demonstrate these values in all the work you do. The University provides policies and procedures that every member of the university community is required to follow to ensure academic integrity. Additional academic integrity information can be found at: https://www.dal.ca/dept/university_secretariat/academic-integrity.html

Accessibility

The Student Accessibility Centre is Dalhousie's centre of expertise for matters related to student accessibility and accommodation. If there are aspects of the design, instruction, and/or experiences within this course (online or in-person) that result in barriers to your inclusion, please contact the Student Accessibility Centre (https://www.dal.ca/campus_life/academic-support/accessibility.html) for all courses offered by Dalhousie with the exception of Truro. For courses offered by the Faculty of Agriculture, please contact the Student Success Centre in Truro (<https://www.dal.ca/about-dal/agricultural-campus/student-success-centre.html>)

Conduct in the Classroom – Culture of Respect

Substantial and constructive dialogue on challenging issues is an important part of academic inquiry and exchange. It requires willingness to listen and tolerance of opposing points of view. Consideration of individual differences and alternative viewpoints is required of all class members, towards each other, towards instructors, and towards guest speakers. While expressions of differing perspectives are welcome and encouraged, the words and language used should remain within acceptable bounds of civility and respect.

Diversity and Inclusion – Culture of Respect

Every person at Dalhousie has a right to be respected and safe. We believe inclusiveness is fundamental to education. We stand for equality. Dalhousie is strengthened in our diversity. We are a respectful and inclusive community. We are committed to being a place where everyone feels welcome and supported, which is why our Strategic Direction prioritizes fostering a culture of diversity and inclusiveness (Strategic Priority 5.2). Additional diversity and inclusion information can be found at: <http://www.dal.ca/cultureofrespect.html>

Student Code of Conduct

Everyone at Dalhousie is expected to treat others with dignity and respect. The Code of Student Conduct allows Dalhousie to take disciplinary action if students don't follow this community expectation. When appropriate, violations of the code can be resolved in a reasonable and informal manner - perhaps through a restorative justice process. If an informal resolution can't be reached, or would be inappropriate, procedures exist for formal dispute resolution. The full Code of Student Conduct can be found at: https://www.dal.ca/dept/university_secretariat/policies/student-life/code-of-student-conduct.html

Fair Dealing Policy

The Dalhousie University Fair Dealing Policy provides guidance for the limited use of copyright protected material without the risk of infringement and without having to seek the permission of copyright owners. It is intended to provide a balance between the rights of creators and the rights of users at Dalhousie. Additional information regarding the Fair Dealing Policy can be found at: https://www.dal.ca/dept/university_secretariat/policies/academic/fair-dealing-policy.html

Originality Checking Software

The course instructor may use Dalhousie's approved originality checking software and Google to check the originality of any work submitted for credit, in accordance with the Student Submission of Assignments and Use of Originality Checking Software Policy. Students are free, without penalty of grade, to choose an alternative method of attesting to the authenticity of their work and must inform the instructor no later than the last day to add/drop classes of their intent to choose an alternate method. Additional information regarding Originality Checking Software can be found at: <https://www.dal.ca/about/leadership-governance/academic-integrity/faculty-resources/original-plagiarism-detection.html>

Student Use of Course Materials

Course materials are designed for use as part of this course at Dalhousie University and are the property of the instructor unless otherwise stated. Third party copyrighted materials (such as books, journal articles, music, videos, etc.) have either been licensed for use in this course or fall under an exception or limitation in Canadian Copyright law. Copying this course material for distribution (e.g. uploading to a commercial third-party website) may lead to a violation of Copyright law.

University Policies and Programs

Important Dates in the Academic Year (including add/drop dates): http://www.dal.ca/academics/important_dates.html
Classroom Recording Protocol: https://www.dal.ca/dept/university_secretariat/policies/academic/classroom-recording-protocol.html
Dalhousie Grading Practices Policies: https://www.dal.ca/dept/university_secretariat/policies/academic/grading-practices-policy.html
Grade Appeal Process: https://www.dal.ca/campus_life/academic-support/grades-and-student-records/appealing-a-grade.html
Sexualized Violence Policy: https://www.dal.ca/dept/university_secretariat/policies/health-and-safety/sexualized-violence-policy.html
Scent-Free Program: <https://www.dal.ca/dept/safety/programs-services/occupational-safety/scent-free.html>

Learning and Support Resources

General Academic Support – Advising (Halifax): https://www.dal.ca/campus_life/academic-support/advising.html
General Academic Support – Advising (Truro): <https://www.dal.ca/about-dal/agricultural-campus/ssc/academic-support/advising.html>
Student Health & Wellness Centre: https://www.dal.ca/campus_life/health-and-wellness.html
On Track (helps you transition into university, and supports you through your first year at Dalhousie and beyond): https://www.dal.ca/campus_life/academic-support/On-track.html
Indigenous Student Centre: https://www.dal.ca/campus_life/communities/indigenous.html
Indigenous Connection: <https://www.dal.ca/about-dal/indigenous-connection.html>
Elders-in-Residence (The Elders in Residence program provides students with access to First Nations elders for guidance, counsel, and support. Visit the office in the Indigenous Student Centre or contact the program at elders@dal.ca or 902-494-6803: <https://cdn.dal.ca/content/dam/dalhousie/pdf/academics/IJG/indigenous-studies/Elder-Protocol-July2018.pdf>)
Black Student Advising Centre: https://www.dal.ca/campus_life/communities/black-student-advising.html
International Centre: https://www.dal.ca/campus_life/international-centre.html
LGBTQ2SIA+ Collaborative: <https://www.dal.ca/dept/vpei/edia/education/community-specific-spaces/LGBTQ2SIA-collaborative.html>
Dalhousie Libraries: <http://libraries.dal.ca/>
Copyright Office: <https://libraries.dal.ca/services/copyright-office.html>
Dalhousie Student Advocacy Services: <https://www.dsu.ca/dsas?rq=student%20advocacy>
Dalhousie Ombudsperson: https://www.dal.ca/campus_life/safety-respect/student-rights-and-responsibilities/where-to-get-help/ombudsperson.html
Human Rights and Equity Services: <https://www.dal.ca/dept/hres.html>
Writing Centre: https://www.dal.ca/campus_life/academic-support/writing-and-study-skills.html
Study Skills/Tutoring: http://www.dal.ca/campus_life/academic-support/study-skills-and-tutoring.html
Faculty of Science Advising Support: <https://www.dal.ca/faculty/science/current-students/undergrad-students/degree-planning.html>

Safety

Biosafety: <http://www.dal.ca/dept/safety/programs-services/biosafety.html>
Chemical Safety: <https://www.dal.ca/dept/safety/programs-services/chemical-safety.html>

Radiation Safety: <http://www.dal.ca/dept/safety/programs-services/radiation-safety.html>

Laser Safety: <https://www.dal.ca/dept/safety/programs-services/radiation-safety/laser-safety.html>