Physics 2820: Computational Mechanics Fall 2025

Instructor: Lev Tarasov

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best to reach me by MUN (not brightspace) email: lev@mun.ca
Office hours: will be set if/when there is a desire in the class for set hours that can accommodate all students. Otherwise, see me after class or send me an email with your available times for the next 36 hours and I should be able to slot you in (at least on a Monday, Wednesday, and Friday).

Prerequisites: PHYS1051, Co-req: MATH 2000

Course server: 134.153.142.78 (only accessible within MUN firewall).

Course web page: on BrightSpace for some secondary material

Lectures: Tu,Th 2:00 - 3:20 in C2039

Labs:

Sec003 Tuesday 3:30-5:00 pm, C-2039

Laboratories (6 graded in total) form a component of the course. If you anticipate missing a lab, please contact Prof. Tarasov via MUN email. Jupyter notebooks from labs will be collected electronically Wednesday mornings.

Text: None required as the internet has many free and useful resources. For those keen on scientific computing, a recommended text, and one previously used as the main textbook, is Computational Physics, Second Edition, by Nicholas J. Giordano and Hisao Nakanishi (Pearson, 2006). Another useful resource (and good source for project ideas) is the freely available "An Introduction to Computer Simulation Methods Third Edition" by Gould et al., available at : `https://www.compadre.org/osp/document/ServeFile.cfm?ID=7375&DocID=527`. Other relevant material will be made available on the course server.

Evaluation:
project 20%
3-4 Assignments 25%
6 graded Labs 15%
1 Mid-term test 15%, Oct 28 including Lab period
Final Exam 25%
Note: no supplementary tests or exam are available
The Mid-term is "no gain, no pain": if you do better on the final exam, then the midterm grade will be replaced with the final grade.
Note: given budget cuts to MUN, there may not be a TA for this course. If that is the case, then the assignment and lab grading will be severely diminished (balanced with peer-grading) and more of the grade will be assigned to the Mid-term and Final Exam.

misc: Instructor to whole class communications will be in class and via Brightspace email. Individual online communication will be via MUN email (NOT Brightspace).

Lab and assignment scheduling: The course will start with weekly Labs to get everyone up to speed. Assignments will be interspersed with remaining Labs across October and November. Students will be given at least 2 weeks for assignment completion. A free Lab period will generally be made available for help with each assignment.

Required Software: In this course, we will write code in Python3 within Jupyter notebooks. Everything needed for this course is on the course server:
134.153.142.78

The Python and Jupyter notebooks software can also be obtained by downloading the Anaconda package for free:
https://www.anaconda.com/products/individual. The package is available for the Linux operating system (free open source and runs most of the internet) as well as non-free corporate operating systems: MacOS and bloated Windows.

Course Approach: Learning requires engagement (R.I.P. sponge pseudo-theory of learning), doing, and making mistakes. The course is structured with some initial "hand-holding", progressing quickly to an expectation of growing proficiency by mid-course. This will entail effort and sweating through debugging, experimenting, and not relying on google nor ChatGPT for answers (though both will be useful tools for debugging and refining your own coding strategies).

Note on use of generative AI (eg ChatGPT): This has become another coding tool for many, and as such, the intelligent use of generative AI will be allowed for parts of this course.

Synopsis: Most of the physical phenomena around us is not amenable to the analytical solutions you worked through in first year physics. Instead approximate numerical solutions of the set of governing equations are required. Computers have therefore become a critical tool for most of physics. Solutions of complex systems (such as the Earth's climate system) can also easily generate terabytes (Tb) of data, well beyond what any individual could parse number by number. Computers are therefore often necessary for data analysis and data visualization.

Phys 2820 introduces the student to the world of computational physics. From plotting functions and finding roots of algebraic equations, to solving a differential equation, to carrying out operations on sets of data to find relationships between measured variables, the skills learned will be useful anywhere computers are used to solve problems. In order to make use of a computer, one must be able to precisely translate the method of solving the problem into instructions that the computer can blindly follow. Thus, students will gain hands-on experience in programming (in Python, which continues to grow various packages for visualization, statistics, AI, numerical solutions,..). Students will learn some of the numerical techniques used to differentiate and integrate functions and to solve ordinary differential equations, and gain an appreciation of the limits of numerical solutions. The context of computation will be primarily classical mechanics.

Some course topics (more may be added as per student interest) Computer simulations in physics, how computers work, writing numerical programs and general structure thereof, real world mechanics (eg air friction, spinning balls), harmonic motion, Chaos (Lorentz model), numerical differentiation and integration, numerical solution of ODEs, basic data analysis, 3 body problem,...

Project This is a chance to work in a group (of 3 to 4) on a scaled down realistic computational project that is of interest to you. The main improvement requested from last year's class was an earlier start and stronger pushing from the instructor to stay on time. As such, here is the nearly written in stone schedule for this:

Sept 20	electronically submit project proposal to instructor (docx or latex or google docs). Students are strongly encouraged to discuss potential topics with instructor before hand
Oct 1	submit final (as needed) revised project proposal with at least 3 peer-reviewed article references
Oct 17	submit numerical plan for project to include equations and discretization (if required) along with testing, validation, and analysis plans.
Nov 18	submit project
Nov 18:Dec 2	5 to 10 minute presentations to class of project by each group

project grade scheme 20% proposal

10% presentation

30% code, grading includes: numerical stability, code organization/elegance, clarity (eg thoughtful naming of variables), and quality of documentation

40% experiments, analysis, and results presentation (do experiments and results presentation meaningfully answer research questions? Are plots/tables clearly labelled and easy to interpret? Are sources of uncertainty not addressed in the model and experiments qualitatively evaluated? Are next steps (eg if this were an undergraduate research project) thoughtfully described?)

NOTE: plagiarism is an academic offence. If code is plagiarized, it may result in 0 value for the code part of the grade (it should result in 0 value, but MUN bureaucratic policies may leave other options open..). Plagiarism is uncited use of someone else's creation (text or code or..). If you used code from somewhere else, cite the source and state what you did to modify it.

4) proposal components: topic, detailed specification of system to be modelled including equations to be coded, inputs, outputs, list of parameters including values/ranges, list of key references (must include at least three peer-reviewed scientific journal articles), draft set of experiments and results analysis plan, and statement of why this interests you.

5) some topic ideas: critical: something that you are very curious about or deeply interested in, preferably within the context of classical mechanics:
- ice sheet or ice shelf model
- 3 or more body planetary motion perhaps with a rocket trajectory
- landslide model
- earth quake model
- billiards simulator
- molecular level model of diffusion
- bicycle simulator

If you really want to do something beyond classical mechanics, some possible ideas are:
- 1 or 2D simplified climate model
- traffic flow model (eg freeway with on/off ramps and/or grid of city streets with traffic lights)
- pandemic model (eg Covid-19)

- population ecology model involving at least 3 species/roles
- electricity grid model including base (eg hydro or nuclear) and intermittent (eg wind/solar) supply components
- heat flow model including conduction and advection, multiple conductances
- forest fire spreading model (with wind, mix of vegetation, temperature and humidity dependence)
- or any other context that involves modelling of a physical (including biological) system
(if uncertain, run the idea by me)

proposal grade scheme /10 total

/2 complexity of problem/model (accounting for # of team members)

/4 completeness: Detailed specification of system to be modelled including equations to be coded, inputs, outputs, list of parameters including values/ranges, and tuning/testing plan.

/1 refs: List of key references (must include at least one peer-reviewed scientific journal).

/2 Draft set of experiments and results analysis plan

/1 Statement of why this interests you and why its worth doing

template for P2820 project proposal

0) title and group members' names

1) abstract (@ 1/4 page, brief summary of proposal)

2) intro: topic, brief description of system to be modelled, why are you interested in this, and motivation of research questions.

3) statement of research questions that will be answered by experiments with your model (key is to have specific/precise questions that you can actually answer)

4) specification of system to be modelled: including inputs, key parameters and their values or ranges, key outputs, equations describing system, and tentative code summary, eg:

```
# ####################
program myEarthClimodel
# myEarthClimodel computes the monthly mean 2 meter air temperature field for the Earth
# has 5% chance of monthly large fire boosting pCO2
# and 0.1% chance of nuclear war causing nuclear winter
# Model resolution is 10 degrees longitude by 10 degrees latitude with 3 atmospheric layers
# Input list is given in first subroutine call

readParmsInputs(time0,timef,LandMask[1:Nx,1:Ny],landAlbedo,oceanAlbedo,snowAlbedo,iceAlbedo,cl

init(time0,LandMask,landAlbedo,oceanAlbedo,snowAlbedo,iceAlbedo,cloudFractionCoef,PCO2[time0])
# initialize model

for t=time0 to timef
```

```
newEarthState=StepEarth(t,EarthState,pCO2[t])
if randGen>0.95 :
pCO2[t+1]=LargeFire(pCO2,newEarthState)
else if randGen < 0.001 :
newEarthState=NukeWinter(newEarthState)
outstep=outputstepSummary(newEarthState,EarthState)
plotStep(outstep)
EarthState=newEarthState

outputFinal(newEarthState)

end
# ##########################
```

5) experiments to be conducted and analysis plan, including tentative list of what will be plotted

6) reference list, including at least 1 article from a peer-reviewed scientific journal

NOTE, the model you build must not have an analytical solution.

Accommodations The mid-term test and final exam are both designed for at least 1 hour of extra time to avoid time pressure. If there is anything else that can be reasonably done to help you learn and excel in this course please speak to the instructor.

Academic Integrity, and missed labs/tests/exams Students are responsible for following regulations concerning academic integrity: http://www.mun.ca/regoff/calendar/sectionNo=REGS-0748
As labs are online, there should be no reason to miss a lab. Under exceptional circumstances a one day delay on the lab submission deadline may be offered. Missed midterm will be replaced with final exam grade. A missed final exam for a medical or family emergency will require contacting the physics undergraduate program officer (physicsAPO@mun.ca) for accommodation, otherwise a 0 grade for the final exam will be assigned.

Most importantly, communicate with your instructor if any issues arise or are about to arise.

Covid-19 (still kicking around) and any new epidemic or pandemic precautions and contingencies If you are feeling sick, please stay home. We will also keep some windows open to improve ventilation. If we have a Covid campus shutdown, we will transition to online learning. The only problem is that MUN ITS doesn't currently allow the course web-server to be accessed off-campus. So if this contingency happens, it will be a mess.

all other stuff that you will see repeated in course outlines:

Statement of Memorial University of Newfoundland's commitment to accommodation of students with disabilities (see also https://www.mun.ca/student/faculty-and-staff- resources/accessible-education/syllabus-statement-for-instructors/). e.g., Memorial University of Newfoundland is committed to fostering equitable and accessible learning environments for all students. Accommodations for students with disabilities are provided in accordance with the Accommodations for Students with Disabilities Policy (www.mun.ca/policy/site/policy.php?id=239) and its related procedures. Students who feel that they may require formal academic accommodations to address barriers or challenges they are experiencing related to their learning are encouraged to contact Accessibility Services (the Blundon Centre) at the earliest opportunity to ensure any required academic accommodations are provided in a timely manner. You can contact Accessibility Services (Blundon Centre) by emailing blundon@mun.ca.

Statement regarding academic integrity, including a reference to the entry on Academic Misconduct (University Regulation 6.12). Students are expected to adhere to those principles which constitute proper academic conduct. A student has the responsibility to know which actions, as described under Academic Offences in the University Regulations, could be construed as dishonest or improper. Students found guilty of an academic offence may be subject to a number of penalties commensurate with the offence including reprimand, reduction of grade, probation, suspension or expulsion from the University. For more information regarding this policy, students should refer to the University Regulations for Academic Misconduct (Section 6.12) in the University Calendar.