

DEPARTMENT OF MATHEMATICS, UNIVERSITY OF UTAH  
**Numerical Solutions of Partial Differential Equations**  
**Math 6630 – Section 001 – Spring 2023**  
**Course Information and Syllabus**  
Updated January 23, 2023

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**Instructor:** Akil Narayan  
**Email:** [akil@sci.utah.edu](mailto:akil@sci.utah.edu)  
**Phone:** 801-581-8984  
**Office:** WEB 4666, LCB 116

**Office hours:** Mondays 1:30-2:30pm, LCB 116  
Thursdays 1pm-2pm, WEB 4666

**Class type:** In Person

**Class time and location:** MW, 11:50am-1:10pm, AEB 360  
Virtual: Zoom, by request only, see Canvas for link

**Attendance policy:** Attendance during lectures is *not* a part of your grade. However, I strongly recommend that you attend the lectures; attendance is an essential ingredient for success in this course.

**Section webpage:** <http://www.sci.utah.edu/~akil/math6630>

**Note:** Scores for graded assignments and any recorded videos will be posted on Canvas.

**Course Information:** This is a 3-credit course.

**Learning objectives:** The course will serve as a theoretical and computational overview for algorithms that approximate solutions to partial differential equations (PDEs). We will review basic functional analysis, linear algebra, and PDE theory. The bulk of the course will be devoted to finite difference, spectral, and finite volume/element-based discretizations for PDEs. We will discuss theory behind stability and convergence of these methods along with computational and algorithmic considerations. Students will gain experience in implementation for some of these methods.

**Prerequisites:** Math 6610 and 6620 or equivalent. This course requires graduate-level knowledge of numerical analysis (in particular, numerical methods for ordinary and partial differential equations) and some programming experience.

**Course description:** Analysis and implementation of numerical methods for solving partial differential equations. Issues of stability and accuracy. Linear and nonlinear problems.

**Text:** There are no required textbooks, with class notes serving as the primary source of material. However, the following books are useful as supplementary texts as they are authoritative on certain topics:

- Finite volume methods and conservation laws
  - *Numerical Methods for Conservation Laws: From Analysis to Algorithms*, Jan. S. Hesthaven, SIAM, 2018, ISBN 978-1-61197-509-3.
  - *Numerical Methods for Conservation Laws*, Randall J. LeVeque, Springer, 1992, ISBN 978-0-8176-2723-2.
  - *Finite Volume Methods for Hyperbolic Problems*, Randall J. LeVeque, Cambridge University Press, 2002, ISBN 978-1-139-43418-8.
- Finite difference methods

- *Title: Finite Difference Methods for Ordinary and Partial Differential Equations: Steady-State and Time-Dependent Problems*, Randall J. LeVeque, SIAM, 2007, ISBN 978-0-89871-783-9.
  - *Finite Difference Computing with PDEs: A Modern Software Approach*, Hans Petter Langtangen & Svein Linge, Springer, 2017, ISBN 978-3-319-55456-3.
  - *Time-Dependent Problems and Difference Methods*, Heinz-Otto Kreiss, Joseph Oliger, & Bertil Gustafsson, John Wiley & Sons, 2013, ISBN 978-1-118-54852-3.
- Spectral Methods
    - *Spectral Methods: Fundamentals in Single Domains*, Claudio Canuto, M. Youssuf Hussaini, Alfio Quarteroni, & Thomas A. Zang, Springer, 2011, ISBN 978-3-540-30725-9.
    - *Spectral Methods: Algorithms, Analysis and Applications*, Jie Shen, Tao Tang, & Li-Lian Wang, Springer Science and Business Media, 2011, ISBN 978-3-540-71041-7.
    - *Time-Dependent Problems and Difference Methods*, Heinz-Otto Kreiss, Joseph Oliger, & Bertil Gustafsson, John Wiley & Sons, 2013, ISBN 978-1-118-54852-3.
    - *Spectral Methods for Time-Dependent Problems*, Jan. S. Hesthaven, Sigal Gottlieb, & David Gottlieb, Cambridge University Press, 2007, ISBN 978-1-139-45952-5.
  - Finite element methods
    - *The Finite Element Method: Linear Static and Dynamic Finite Element Analysis*, Thomas J. R. Hughes, Dover, 2000, ISBN 978-0-486-41181-1.
    - *The Mathematical Theory of Finite Element Methods*, Susanne Brenner & Ridgway Scott, Springer, 2007, ISBN 978-0-387-75933-3.
    - *Nodal Discontinuous Galerkin Methods: Algorithms, Analysis, and Applications*, Jan S. Hesthaven & Tim Warburton, Springer Science and Business Media, 2007, ISBN 978-0-387-72065-4.

**Class meetings:** This class meets in person twice per week. Class meetings will primarily be lecture-based, which will include a discussion of theory and practice examples. I encourage you to participate in class, in particular with questions and related discussions.

**Homework/projects:** This course will have 3 projects involving theory and implementation of schemes. Projects form half of the graded portion of this class, and are equally weighted. Since this is an advanced class in numerical methods, I will expect a L<sup>A</sup>T<sub>E</sub>X-typeset report with your solution/discussion, along with computer code that reproduces plots in your submission. Both the report source and the code will be submitted through the version control system Git. Logistics and a more detailed description of expectations for report submission will be provided at a later date during class. Due dates for the projects are TBA and will be discussed during the semester. *Note:* Since I expect electronic submission of reports, students will need access to an internet-connected computer with appropriate programming and typesetting software. If this is an issue, please talk to me about your situation.

One of the 3 projects is a preliminary assignment (“project 0”) that will focus on training students in the logistics of submission with Git. This assignment will not exercise any course-related technical content, and instead will ensure that students are able to use the requisite version control and typesetting tools for submitting the two main projects.

**Presentation:** At the end of the semester, students are responsible for 1 in-class presentation on a relevant paper or topic of their choosing. Toward the middle of the semester, more detailed logistics (including a list of potential papers) will be provided and discussed in class.

**Grading:** Your course grade will be computed as follows.

- Homeworks/Projects .....50%
- Presentation ..... 50%

Final letter grades will be assigned based on the following scheme:

- 92% - 100% — A
- 90% - 91% — A–
- 88% - 89% — B+
- 82% - 87% — B
- 80% - 81% — B–
- 78% - 79% — C+
- 72% - 77% — C
- 70% - 71% — C–
- 68% - 69% — D+
- 62% - 67% — D
- 60% - 61% — D–
- 0% - 59% — E

**Important dates:**

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<b>Jan 20</b>	Last day to add, drop, elect CR/NC or audit classes
<b>Mar 3</b>	Last day to withdraw from classes
<b>Apr 21</b>	Last day to reverse CR/NC option
<b>Apr 26</b>	Reading Day

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**Class communication:** An email list is set up with which I shall send out information not communicated during class. This email list will also be used to communicate class information in the case of unusual circumstances affecting the the logistics of the class. If you are not officially registered for the class but wish to be on the roster, please discuss it with me.

*If you are registered for the course, but do not receive the course email announcements to your University of Utah email address, please notify me immediately. You can forward your Utah emails to other email addresses. (Navigate to <http://www.cis.utah.edu>, login, and change your UMail settings.)*

The section website will be used to communicate more technical matter of the class (e.g. assignments, lecture summaries, etc.).

In the event of a major campus emergency, course requirements, deadlines and grading percentages are subject to change that may be necessitated by a revised semester calendar or other circumstances. The above two methods, in addition to the coursewide website, are reliable means of getting information about changes to the course.

**Communication with the instructor:** The most reliable and preferred means of contacting me is via email, and I typically respond in less than 24 hours. Communication through the messaging system in Canvas will also work, but possibly with a slightly longer response time.

One-on-one meetings can also be set up with me outside of office hours; please set up such meetings with me via email.

**COVID-19 considerations:** All class activities will take place in person. University leadership continues to monitor the COVID-19 pandemic, and will follow guidance from the CDC. University leadership has urged all faculty, students, and staff to model the vaccination, masking, testing and self-reporting behaviors we want to see in our campus community. These include:

**Vaccination:** Get a COVID-19 vaccination if you have not already done so; see <https://alert.utah.edu/covid/vaccine/>.

**Masking:** Masks are no longer required outside of Health Sciences facilities. Indoor masking recommendations are based on current conditions and health department recommendations.

**Testing:** Self-reporting positive COVID-19 test results. Regardless of your status regarding COVID-19, I **strongly urge** you to take advantage of university COVID-19 testing services at <https://alert.utah.edu/covid/testing>, including free asymptomatic testing.

**Student responsibilities and integrity:** All students are expected to maintain professional behavior in the classroom setting, according to the Student Code, spelled out in the Student Handbook. Students have specific rights in the classroom as detailed in Article III of the Code. The Code also specifies proscribed conduct (Article XI) that involves cheating on tests, plagiarism, and/or collusion, as well as fraud, theft, etc. Students should read the Code carefully and know they are responsible for the content. According to Faculty Rules and Regulations, it is the faculty responsibility to enforce responsible classroom behaviors, and I will do so, beginning with verbal warnings and progressing to dismissal from and class and a failing grade. Students have the right to appeal such action to the Student Behavior Committee.

<http://regulations.utah.edu/academics/6-400.php>

**Inclusivity:** It is my intent that students from all diverse backgrounds and perspectives be well served by this course, that students' learning needs be addressed both in and out of class, and that the diversity that students bring to this class be viewed as a resource, strength and benefit. It is my intent to present materials and activities that are respectful of diversity: gender, sexuality, disability, age, socioeconomic status, ethnicity, race, and culture. Your suggestions are encouraged and appreciated. Please let me know ways to improve the effectiveness of the course for you personally or for other students or student groups. In addition, if any of our class meetings conflict with your religious events, please let me know so that we can make arrangements for you.

**Discrimination and Harassment:** If you or someone you know has been harassed or assaulted, you are encouraged to report it to the Title IX Coordinator in the Office of Equal Opportunity and Affirmative Action, 135 Park Building, 801-581-8365, or Office of the Dean of Students, 270 Union Building, 801-581-7066. To report to the police, contact the Department of Public Safety, 801-585-2677(COPS). Please see Student Bill of Rights, section E <http://regulations.utah.edu/academics/6-400.php>. I will listen and believe you if someone is threatening you.

**Classroom Social Equity:** Canvas allows students to change the name that is displayed AND allows them to add their pronouns to their Canvas name. Class rosters are provided to the instructor with the student's legal name as well as "Preferred first name" (if previously entered by you in the Student Profile section of your CIS account, which managed can be managed at any time). While CIS refers to this as merely a preference, I will honor you by referring to you with the name and pronoun that feels best for you in class or on assignments. Please advise me of any name or pronoun changes so I can help create a learning environment in which you, your name, and your pronoun are respected. If you need any assistance or support, please reach out

to the LGBT Resource Center: [https://lgbt.utah.edu/campus/faculty\\_resources.php](https://lgbt.utah.edu/campus/faculty_resources.php)

**English Language Learners:** If you are an English language learner, please be aware of several resources on campus that will support you with your language and writing development. These resources include: the Writing Center (<http://writingcenter.utah.edu/>); the Writing Program (<http://writing-program.utah.edu/>); the English Language Institute (<http://continue.utah.edu/eli/>). Please let me know if there is any additional support you would like to discuss for this class.

**Undocumented Student Support:** Immigration is a complex phenomenon with broad impact—those who are directly affected by it, as well as those who are indirectly affected by their relationships with family members, friends, and loved ones. If your immigration status presents obstacles to engaging in specific activities or fulfilling specific course criteria, confidential arrangements may be requested from the Dream Center. Arrangements with the Dream Center will not jeopardize your student status, your financial aid, or any other part of your residence. The Dream Center offers a wide range of resources to support undocumented students (with and without DACA) as well as students from mixed-status families. To learn more, please contact the Dream Center at 801-213-3697 or visit [dream.utah.edu](http://dream.utah.edu).

**Veterans:** If you are a student veteran, the University of Utah has a Veterans Support Center located in Room 161 in the Olpin Union Building. Hours: M-F 8-5pm. Please visit their website for more information about what support they offer, a list of ongoing events and links to outside resources: <http://veteranscenter.utah.edu/>.

**The Americans with Disabilities Act:** The University of Utah seeks to provide equal access to its programs, services and activities for people with disabilities. If you will need accommodations in the class, reasonable prior notice needs to be given to the Center for Disability & Access, 162 Olpin Union Building, 801-581-5020, <https://disability.utah.edu>. CDA will work with you and the instructor to make arrangements for accommodations. All written information in this course can be made available in alternative format with prior notification to the Center for Disability & Access.

**Student wellness:** Personal concerns such as stress, anxiety, relationship difficulties, depression, cross-cultural differences, etc., can interfere with a student's ability to succeed and thrive at the University of Utah. For helpful resources contact the Center for Student Wellness at [www.wellness.utah.edu](http://www.wellness.utah.edu) or 801-581-7776.

**University Counseling Center (UCC):** The UCC staff is committed to supporting the mental health needs of our campus community. Their phone number is 801-581-6826. Their hours are Monday-Friday, 8:00am-5:00pm. For after-hours emergencies, contact the 24/7 Crisis Line: 801-587-3000 . More information is at <https://counselingcenter.utah.edu/>. **Student Success Advocates:** The mission of Student Success Advocates is to support students in making the most of their University of Utah experience ([ssa.utah.edu](http://ssa.utah.edu)). They can assist with mentoring, resources, etc. Any student who faces challenges securing their food or housing and believes this may affect their performance in the course is urged to contact a Student Success Advocate for support (<https://asuu.utah.edu/displaced-students>).

**Addressing Sexual Misconduct:** Title IX makes it clear that violence and harassment based on sex and gender (which includes sexual orientation and gender identity/expression) is a Civil Rights offense subject to the same kinds of accountability and the same kinds of support applied to offenses against other protected categories such as race, national origin, color, religion, age, status as a person with a disability, veteran's status or genetic information. If you or someone you know has been harassed or assaulted on the basis of your sex, office for equal

opportunity and affirmative action including sexual orientation or gender identity/expression, you are encouraged to report it to the University's Title IX Coordinator; Director, Office of Equal Opportunity and Affirmative Action, 135 Park Building, 801-581-8365, <https://oeo.utah.edu/contact-us/index.php> or to the Office of the Dean of Students, 270 Union Building, 801-581-7066, <https://deanofstudents.utah.edu>. For support and confidential consultation, contact the Center for Student Wellness, 426 SSB, 801-581-7776. To report to police, contact the Department of Public Safety, 801-585-2677(COPS), <https://police.utah.edu>.

**Campus Safety:** The University of Utah values the safety of all campus community members. To report suspicious activity or to request a courtesy escort, call campus police at 801-585-COPS (801-585-2677). You will receive important emergency alerts and safety messages regarding campus safety via text message. For more information regarding safety and to view available training resources, including helpful videos, visit [safeu.utah.edu](http://safeu.utah.edu).

**Office of the Dean of Students:** The Office of the Dean of Students is dedicated to being a resource to students through support, advocacy, involvement, and accountability. It serves as a support for students facing challenges to their success as students, and assists with the interpretation of University policy and regulations. To contact the Office of the Dean of Students, please email [deanofstudents@utah.edu](mailto:deanofstudents@utah.edu) or call 801-581-7066. There is more information at <https://deanofstudents.utah.edu>.