DEPARTMENT OF GEOSCIENCE
COURSE OUTLINE
WINTER 2016

1. **Course:** GOPH 699.09, Selected Topics in Geophysics: Computational Methods for Geophysicists

   Lecture/Tutorial: L02: W 17:00-19:45, SA 125 (1 per week, 165 mins)
   Labs: B02: M 17:00-18:50, ES 254 (1 per week, 110 mins)

2. **Instructional Team**

   Instructor: Dr. Brandon Karchewski, ES 108, T: 403-220-6678, E: brandon.karchewski@ucalgary.ca
   Office hours by appointment

   Geoscience Department: ES 118, T: 403-220-5841, W: geoscience.ucalgary.ca, E: geoscience@ucalgary.ca

3. **Prerequisites:** Permission of the instructor and department is required to register in this course. Appropriate background is given by MATH 211 (Linear Methods I) and one of the following:

   a. MATH 331 (Multivariate Calculus)
   b. MATH 367 (University Calculus III) and AMAT 311 (Differential Equations I)
   c. MATH 375 (Differential Equations for Eng and Sci) and MATH 377 (Vector Calculus for Eng and Sci)

   and one of the following:

   a. CPSC 217 (Introduction to Computer Science for Multidisciplinary Studies I)
   b. CPSC 231 (Introduction to Computer Science for Computer Science Majors I)
   c. CPSC 235 (Advanced Introduction to Computer Science)

   or equivalent courses in *linear algebra*, *vector calculus*, *differential equations* and *introductory computer science*.

   Antirequisites: Credit in GOPH 699.09 will not be given to those who have completed one of the following:

   a. AMAT 491 (Numerical Analysis I) and AMAT 493 (Numerical Analysis II)
   b. PHYS 381 (Computational Physics I) and PHYS 481 (Computational Physics II)

   or an equivalent set of courses with substantial overlap with the content of this course.

4. **Description:**
   Topics in numerical analysis emphasizing geophysics applications. Topics will include error analysis, Taylor series, root finding algorithms, linear system solver algorithms, LU decomposition, curve fitting, discrete Fourier transforms, numerical differentiation and integration, numerical solution of ODEs, introduction to PDE solvers.

3. **Learning Objectives:**

   By the end of this course, students should be able to:

   1. ***Explain*** and ***implement*** numerical solution algorithms to a selection of fundamental problems in applied mathematics, within a geophysics context.
   2. ***Perform*** error analyses of approximate numerical solutions and ***discuss*** whether the solutions are acceptable.
   3. ***Explain*** the advantages and limitations of the numerical techniques examined in the course.
   4. ***Distinguish*** between and ***select*** the most applicable of available numerical techniques for an analysis task in geophysics.
   5. ***Use*** software packages (spreadsheet tools such as MS Excel and programming languages such as Matlab) to compute numerical solutions.
   6. ***Communicate*** the results of numerical analysis to peers in the scientific community and ***critically evaluate*** the work of peers.

5. **Course Materials:**

   Suggested Course Texts: S. Chapra. (2012). *Applied Numerical Methods W/MATLAB for Engineers and Scientists, 3rd Edition*. New York: McGraw-Hill, ISBN: 9780073401102.
   S. Chapra, R. Canale. (2015). *Numerical Methods for Engineers, 7th Edition*. New York: McGraw-Hill, ISBN: 9780073397924.

G.R. Lindfield, J.E.T. Penny. (2012). *Numerical Methods, 3rd Edition*. New York: Elsevier Academic Press, ISBN: 9780123869425.

Any of the above texts (or previous editions of same) will provide a good reference for most of the course content. These are just three suggestions, and none are absolutely required to succeed in the course. There are many other texts on numerical methods and you are encouraged to consult with the instructor if you are unsure about whether the text that you are considering is appropriate. Much of the course theory is also available on websites such as Wolfram MathWorld (http://mathworld.wolfram.com/) or Wikipedia (e.g. https://en.wikipedia.org/wiki/Fourier_transform). The brevity and quality of the information may vary by source, so treat any source with the critical eye that all scientists and engineers cultivate (this applies to Wikipedia, textbooks and journal articles alike). For course content that is not covered in detail in the texts above, the instructor will post supplemental notes or links to other sources on D2L (https://d2l.ucalgary.ca/login.asp). You will be expected to stay up-to-date with the online content of the course on a weekly basis.

For in-class quizzes and term tests, you will need a non-programmable scientific calculator such as the Casio FX-991 or one with similar functionality.

6. Grading: The University policy on grading and related matters is described in sections F.1 and F.2 of the online University Calendar.

The overall grade in the course will be based on the following grading scheme:

Grade Component	***Weight***	***Notes***
Lab assignments/reports (4)	10%	See course schedule herein and details posted on D2L
Term Project**	15%	See course schedule herein and details posted on D2L
Midterm Exam	20%	***During lab period week of Feb 22-26, room TBA***
Final Exam**	25%	***During final exam period, scheduled by Registrar***

**Students must achieve a minimum of 50% on the term project and the final exam to obtain a passing grade.

Individual elements of the course (i.e. labs, exams) will be assigned a percentage score. Final percentage grades for the overall course will be calculated based on the grade weighting scheme indicated above and will be converted to letter grade as follows:

Letter Grade	**Percent**	**Letter Grade**	**Percent**
A+	95-100	C+	65-69
A	90-94	C	60-64
A-	85-89	C-	58-59
B+	80-84	D+	55-59
B	75-79	D	50-54
B-	70-74	F	<50

7. Format of the Course:

Lecture: The course will involve one (1) weekly lecture period (165 minutes), where the instructor will lead the students through a discussion of the topic for that week. The first part of the period will typically involve some explanation of the theory topic for that week, with ample time for questions and discussion of concepts. The second part of the period will include some example(s) illustrating the theoretical concepts applied to simple problems, with demonstrations of implementations in Excel and/or Matlab. The course schedule provides relevant chapter references in Chapra (2012) and the instructor may post additional material for that week at least one week prior. Students are expected to review this content prior to the lectures.

Labs: There will be one (1) weekly lab period (110 minutes). In the computer labs, you will complete assignments in which you will implement a numerical solution to a geophysics application problem in Matlab. There will be a total of four (4) lab assignments and you will have at least two lab periods to work on each assignment, though it is expected that you may also need to spend some time outside of the scheduled lab periods to complete the assignments. Your submission of these assignments will include both the code that you used to generate your solution and a brief scientific report summarizing the background theory, methods, results and conclusions of the assignment. The reports will be reviewed by two of your peers for technical merit and clarity of presentation, and your grade will be based on a rubric grade assigned by the peer reviewers. You will also receive constructive feedback from the reviewers to promote improvement in scientific communication skills. The instructor will review the feedback and grades assigned by the reviewers for consistency and accuracy. The details of the rubric and format of the feedback will be posted on D2L.

Term Project: The term will culminate with a term project that will draw on your knowledge of the entire course content to solve a substantial problem in computational geophysics and present your results in a scientific report and oral presentation. You will be provided with a list of potential topics on D2L, or you can propose an alternative topic based on your interests, subject to instructor approval. You are also encouraged to discuss the topic with your graduate

advisor, as it is likely possible to align this project with the research goals of your thesis. The project will be due at the end of the term, but you will have the opportunity to discuss your progress with the instructor throughout the term. The format of the report will be posted on D2L.

8. **Missed Components of Term Work:** The regulations of the Faculty of Science pertaining to this matter are found in the Faculty of Science area of the Calendar in Section 3.6. It is the student's responsibility to familiarize himself/herself with these regulations. See also Section E.6 of the University Calendar.

9. **Scheduled out-of-class activities:** There will be a 2-hour midterm exam the week of Feb 22-26 during the scheduled computer lab time. This room will be posted on D2L at least one week prior. **REGULARLY SCHEDULED CLASSES HAVE PRECEDENCE OVER ANY OUT-OF-CLASS-TIME-ACTIVITY.** If you have a conflict with this out-of-class activity, please inform your instructor as soon as possible so that alternative arrangements may be made for you.

10. **Examination Policy**: The midterm and final exams will be closed book, but you will be allowed to prepare a reference equation sheet to bring with you to the exam. The allowed format of the equation sheet will be posted on D2L at least one week prior to the exams. Non-programmable calculators are allowed in both exams. Students should also read the Calendar, Section G, on Examinations.

11. **Writing across the curriculum statement** In this course, the quality of the student's writing in laboratory reports will be a factor in the evaluation of those reports. See also Section E.2 of the University Calendar.

12. **OTHER IMPORTANT INFORMATION FOR STUDENTS:**

    (a) Misconduct: Academic misconduct (cheating, plagiarism, or any other form) is a very serious offence that will be dealt with rigorously in all cases. A single offence may lead to disciplinary probation or suspension or expulsion. The Faculty of Science follows a zero tolerance policy regarding dishonesty. Please read the sections of the University Calendar under Section K. Student Misconduct to inform yourself of definitions, processes and penalties

    (b) Assembly Points: In case of emergency during class time, be sure to FAMILIARIZE YOURSELF with the information on assembly points.

    (c) Student Accommodations: Students needing an Accommodation because of a Disability or medical condition should contact Student Accessibility Services in accordance with the Procedure for Accommodations for Students with Disabilities available at http://www.ucalgary.ca/policies/files/policies/procedure-for-accommodations-for-students-with-disabilities_0.pdf. Students needing an Accommodation in relation to their coursework or to fulfil requirements for a graduate degree, based on a Protected Ground other than Disability, should communicate this need, preferably in writing, to the Associate Head of Geoscience, Dr. E.S. Krebes by email krebes@ucalgary.ca or phone 403-220-5850.

    (d) Safewalk: Campus Security will escort individuals day or night (http://www.ucalgary.ca/security/safewalk/). Call 220-5333 for assistance. Use any campus phone, emergency phone or the yellow phones located at most parking lot pay booths.

    (e) Freedom of Information and Privacy: This course is conducted in accordance with the Freedom of Information and Protection of Privacy Act (FOIPP). As one consequence, students should identify themselves on all written work by placing their name on the front page and their ID number on each subsequent page. For more information see also http://www.ucalgary.ca/secretariat/privacy.

    (f) Student Union Information: VP Academic Phone: 403 220-3911 Email: suvpaca@ucalgary.ca SU Faculty Rep. Phone: 403 220-3913 Email: science1@su.ucalgary.ca, science2@su.ucalgary.ca and science3@su.ucalgary.ca; Student Ombuds Office: 403-220-6420 Email: ombuds@ucalgary.ca; http://ucalgary.ca/provost/students/ombuds

    (g) Internet and Electronic Device Information: You can assume that in all classes that you attend, your cell phone should be turned off unless instructed otherwise. Also, communication with other individuals, via laptop computers, Blackberries or other devices connectable to the Internet is not allowed in class time unless specifically permitted by the instructor. If you violate this policy you may be asked to leave the classroom. Repeated abuse may result in a charge of misconduct.

    (h) U.S.R.I.: At the University of Calgary, feedback provided by students through the Universal Student Ratings of Instruction (USRI) survey provides valuable information to help with evaluating instruction, enhancing learning and teaching, and selecting courses (www.ucalgary.ca/usri). Your responses make a difference – please participate in USRI Surveys.

Department Approval: ORIGINAL SIGNED Date: December 15, 2015

Associate Dean's Approval for
out of regular class-time activity: ORIGINAL SIGNED Date: December 16, 2015

Tentative Course Schedule for GOPH 699.09 – Winter 2016				
Week	**Dates**	**Lecture Topic(s)**	**Lab/Tutorial**	**Text Sections (Chapra 2012)**
1	Jan 11-15	***Error Analysis*** o Significant figures o Accuracy and precision o Error definitions and propagation o Taylor series	***Lab #0 – Basic Operations and Functions:*** Matlab and Excel	4.1-4.5
2	Jan 18-22	***Root Finding Algorithms*** o Bracketing methods (Bisection, False Position) o Open methods (Newton-Raphson)		5.1, 5.3-5.5, 6.2
3	Jan 25-29	***Linear Systems I*** o Gaussian elimination o Gauss-Jordan o LU Decomposition	***Lab #1 – Root Finding:*** Love Waves in Layered Media (due Tue Jan 26)	8.1-8.2, 9.1-9.3, 10.1-10.2
4	Feb 1-5	***Linear Systems II*** o Gauss-Seidel o Error analysis and system condition o Special systems (sparse, banded, symmetric) o Cholesky Decomposition		9.4, 10.3, 11.1-11.2, 12.1
5	Feb 8-12	***Curve Fitting I (Regression)*** o Linear regression o Polynomial regression o General Linear Least Squares (GLLS) o Linearization of nonlinear models		14.1, 14.3-14.5, 15.1-15.3
6	Feb 15-19*	***READING WEEK (NO CLASSES)***	***Lab #2 – Linear Systems and Regression:*** Seismic *a* and *b* Parameters (due Tue Feb 16)	
7	Feb 22-26	***Curve Fitting II (Fourier Transforms)*** o Discrete Fourier transform (DFT) o Discrete Inverse Fourier transform o Fast Fourier transforms (fft, ifft)	***Midterm Exam:*** During lab period this week, room ***TBA***	16.1-16.6
8	Feb 29-Mar 4	***Curve Fitting III (Interpolation)*** o Newton's divided differences o Lagrange interpolation o Spline interpolation		17.1-17.3, 18.1-18.4
9	Mar 7-11	***Numerical Integration*** o Newton-Cotes integration rules (trapezoidal rule, Simpson's rules) o Romberg integration o Gaussian quadrature	***Lab #3 – Fourier Transforms:*** Filtering Noise from Seismic Data (due Tue Mar 8)	19.1-19.4, 19.6, 20.1-20.3
10	Mar 14-18	***ODE Solvers I*** o Numerical derivative formulae o Euler's Method o Improvements to Euler's Method		21.1-21.2, 22.1-22.3
11	Mar 21-25**	***ODE Solvers II*** o Runge-Kutta Methods o Adaptive step size correction o Stiff systems	***Lab #4 – Numerical Integration:*** Gravity Effect of Arbitrary Mass (due Tue Mar 22)	21.3, 22.4-22.5, 23.1-23.3
12	Mar 28-Apr 1	***PDE Solvers I*** o Introduction to finite differences o Numerical partial derivatives o Boundary conditions		21.6, 24.1, 24.3
13	Apr 4-8	***PDE Solvers II*** o Introduction to finite elements o Interpolation (shape) functions o Boundary conditions		See notes on D2L
14	Apr 11-13	***Term Project Presentations***	***Term Project – ODE and PDE Solvers:*** Suggested Topics on D2L or discuss with instructor (due Wed Apr 13)	
	Apr 16-27	***Final Exam (scheduled by Registrar)***		

*No class Feb 15-19 (Reading Week)

**University closed (except libraries) on Mar. 25 (Good Friday)

Note: The course schedule is tentative and subject to changes