The document is a proposal for a new course, GEOS 607 Applied Seismology, submitted by Geology and Geophysics. The proposal details the course's objectives, prerequisites, and requirements. The course is described as a graduate-level science class with GEOS 609 (proposed Foundations of Geophysics) as a prerequisite. It is offered in Spring, Even-numbered Years and requires 3 credits. The course format includes lecture, including in-class computational examples, and short in-class discussions. It is designed to cover modeling techniques for earthquakes and Earth structure using wave propagation algorithms and real seismic data. The prerequisites include GEOS F431 or GEOS F631, or permission of instructor.
11. COURSE CLASSIFICATIONS: Undergraduate courses only. Consult with CLA Curriculum Council to apply S or H classification appropriately; otherwise leave fields blank.

H = Humanities  
S = Social Sciences

Will this course be used to fulfill a requirement for the baccalaureate core? If YES, attach form.

YES:  
NO:  
X

IF YES, check which core requirements it could be used to fulfill:

O = Oral Intensive, Format 6
W = Writing Intensive, Format 7
Natural Science, Format 8

19. COURSE REPEATABILITY:

Is this course repeatable for credit? YES  
NO  
X

Justification: Indicate why the course can be repeated (for example, the course follows a different theme each time).

How many times may the course be repeated for credit?

TIMES

If the course can be repeated for credit, what is the maximum number of credit hours that may be earned for this course?

CREDITS

If the course can be repeated with variable credit, what is the maximum number of credit hours that may be earned for this course?

CREDITS

13. GRADING SYSTEM: Specify only one. Note: Later changing the grading system for a course constitutes a Major Course Change.

LETTER: X  
PASS/FAIL: 

14. PREREQUISITES

GEOS 699; or permission of instructor

These will be required before the student is allowed to enroll in the course.

16. SPECIAL RESTRICTIONS, CONDITIONS

16. PROPOSED COURSE FEES

Has a memo been submitted through your dean to the Provost for fee approval?

Yes/No

17. PREVIOUS HISTORY

Has the course been offered as special topics or trial course previously?

Yes/No

If yes, give semester, year, course #, etc.: Spring 2012, GEOS F694
18. **ESTIMATED IMPACT**

**WHAT IMPACT, IF ANY, WILL THIS HAVE ON BUDGET, FACILITIES/SPACE, FACULTY, ETC.**

This graduate-level will fulfill part of the teaching workload for new Geology & Geophysics faculty member Tape. Anticipated enrollment is 5-10 students; a small classroom in Elvey or Reichardt will be required.

19. **LIBRARY COLLECTIONS**

Have you contacted the library collection development officer (kljensen@alaska.edu, 474-6695) with regard to the adequacy of library/media collections, equipment, and services available for the proposed course? If so, give date of contact and resolution. If not, explain why not.

No [ ] Yes [X] [ ]

20. **IMPACTS ON PROGRAMS/DEPTS**

What programs/departments will be affected by this proposed action?

Include information on the Programs/Departments contacted (e.g., email, memo)

The Department of Geology and Geophysics will be affected by this proposal action in the sense that Applied Seismology will fulfill credit requirements for M.S. or Ph.D. geophysics students. In the revised geophysics curriculum, Applied Seismology is an elective course.

21. **POSITIVE AND NEGATIVE IMPACTS**

Please specify positive and negative impacts on other courses, programs and departments resulting from the proposed action.

The course will have a positive impact on the MS/PhD geophysics program (see “Justification” below).

The applied nature of the proposed course will provide valuable research training for students. The computational training would allow students to excel in several other courses with computational applications, such as the STAT 4XX and MATH 6XX courses listed in the proposed revisions to the geophysics curriculum.

The addition of a new graduate-level geophysics course could potentially diminish enrollment in other geophysics courses; however, students tend to take several more courses than the minimum requirements in geophysics MS/PhD. If a student decides to take only one seismology course, then Applied Seismology could diminish enrollment in Intermediate Seismology. C. Tape and D. Christensen have discussed how to make the two seismology courses complementary. We note that neither course is a prerequisite for the other.

**JUSTIFICATION FOR ACTION REQUESTED**

The purpose of the department and campus-wide curriculum committees is to scrutinize course change and new course applications to make sure that the quality of UAF education is not lowered as a result of the proposed change. Please address this in your response. This section needs to be self-explanatory. Use as much space as needed to fully justify the proposed course.

In the 1980s there were three seismology courses are UAF: Beginning Seismology, Intermediate Seismology, and Advanced Seismology. At present, only Intermediate Seismology is offered (taught by Doug Christensen). C. Tape was hired in 2010 in part to teach an advanced-level, applied seismology course, which is lacking from the current curriculum. The addition of the applied seismology course will strengthen training for seismology graduate students and also strengthen the MS/PhD concentration in Solid Earth Geophysics. Applied Seismology will directly build upon geophysics and computational training that students will receive in the (proposed and) required Foundations of Geophysics (GEOS F609). Furthermore, in spring 2010, geophysics graduate students met multiple times to suggest changes to the MS/PhD geophysics program; an applied seismology course was one of their concrete recommendations.
### Approvals

**Signature, Chair,**
**Program/Department of:**

<table>
<thead>
<tr>
<th>Signature</th>
<th>Date</th>
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<tbody>
<tr>
<td>[Signature]</td>
<td>9/8/11</td>
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</table>

Signature, Chair, College/School Curriculum Council for:

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<th>Signature</th>
<th>Date</th>
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<tr>
<td>[Signature]</td>
<td>9/28/11</td>
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</table>

Signature, Dean, College/School of:

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<tr>
<th>Signature</th>
<th>Date</th>
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<tbody>
<tr>
<td>[Signature]</td>
<td>Oct 2, 2011</td>
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</tbody>
</table>

Signature of Provost (if applicable)

Offerings above the level of approved programs must be approved in advance by the Provost.

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### All Signatures Must Be Obtained Prior to Submission to the Governance Office

<table>
<thead>
<tr>
<th>Signature, Chair</th>
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</thead>
<tbody>
<tr>
<td>Date</td>
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</table>

Faculty Senate Review Committee:
- Curriculum Review
- GAAC
- Core Review
- SADAC

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### Additional Signatures: (As needed for cross-listing and/or stacking)

<table>
<thead>
<tr>
<th>Signature, Chair, Program/Department of:</th>
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<th>Signature, Chair, College/School Curriculum Council for:</th>
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<tr>
<th>Signature, Dean, College/School of:</th>
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<tr>
<td>Date</td>
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</table>
ATTACH COMPLETE SYLLABUS (as part of this application). Note: The guidelines are online: http://www.uaf.edu/uafgov/faculty-senate/curriculum/course-degree-procedures-/uaf-syllabus-requirements/
The Faculty Senate curriculum committees will review the syllabus to ensure that each of the items listed below are included. If items are missing or unclear, the proposed course (or changes to it) may be denied.

SYLLABUS CHECKLIST FOR ALL UAF COURSES
During the first week of class, instructors will distribute a course syllabus. Although modifications may be made throughout the semester, this document will contain the following information (as applicable to the discipline):

1. Course information:
   - Title, number, credits, prerequisites, location, meeting time
   - (make sure that contact hours are in line with credits).

2. Instructor (and if applicable, Teaching Assistant) information:
   - Name, office location, office hours, telephone, email address.

3. Course readings/materials:
   - Course textbook title, author, edition/publisher.
   - Supplementary readings (indicate whether required or recommended) and any supplies required.

4. Course description:
   - Content of the course and how it fits into the broader curriculum;
   - Expected proficiencies required to undertake the course, if applicable.
   - Inclusion of catalog description is strongly recommended, and
   - Description in syllabus must be consistent with catalog course description.

5. Course Goals (general), and (see #6)

6. Student Learning Outcomes (more specific)

7. Instructional methods:
   - Describe the teaching techniques (eg: lecture, case study, small group discussion, private instruction, studio instruction, values clarification, games, journal writing, use of Blackboard, audio/video conferencing, etc.).

8. Course calendar:
   - A schedule of course topics and assignments must be included. Be specific so that it is clear that the instructor has thought this through and will not be making it up on the fly (e.g. it is not adequate to say “lab”. Instead, give each lab a title that describes its content). You may call the outline Tentative or Work in Progress to allow for modifications during the semester.

9. Course policies:
   - Specify course rules, including your policies on attendance, tardiness, class participation, make-up exams, and plagiarism/academic integrity.

10. Evaluation:
    - Specify how students will be evaluated, what factors will be included, their relative value, and how they will be tabulated into grades (on a curve, absolute scores, etc.)
    - Publicize UAF regulations with regard to the grades of "C" and below as applicable to this course. (Not required in the syllabus, but may be a convenient way to publicize this.) Faculty Senate Meeting #171:
      http://www.uaf.edu/uafgov/faculty-senate/meetings/2010-2011-meetings/#171

11. Support Services:
    - Describe the student support services such as tutoring (local and/or regional) appropriate for the course.

12. Disabilities Services:
The Office of Disability Services implements the Americans with Disabilities Act (ADA), and insures that UAF students have equal access to the campus and course materials.
    - State that you will work with the Office of Disabilities Services (208 WHITAKER BLDG, 474-5655) to provide reasonable accommodation to students with disabilities.

6/30/2011
QUICK REFERENCE: Section 8 contains the calendar of topics and deadlines.

1. Course information. Course number is F626 (2/21/2012, JH).
   GEOS F626 Applied Seismology, 3 credits, Spring 2014
   Meeting times: Tuesday and Thursday, 9:45–11:15
   Meeting location: TBA
   Prerequisites: GEOS F626 (Foundations of Geophysics)
                 GEOS F431 or F631, or permission of instructor.

2. Instructor information.
   Instructor: Carl Tape
   Office: 413D Elvey (Geophysical Institute)
   Email: carltape@gi.alaska.edu
   Phone: (907) 474-5456
   Office hours: Wednesday, 10:00–11:00, or by appointment

3. Course materials.
   (a) Textbooks. All textbooks are available at the UAF library. The required textbooks are:
       One copy of [1] and [2] will be on reserve in Mather Library (within the IARC building); [1] is
       also available to be checked out from the UAF library as an e-book.

       I recommend the following textbooks for supplemental and more detailed information:
       seismology: [3, 4, 5, 6, 7] (2009 paperback printing if available)
       continuum mechanics: [8, 5]
       One copy of each of these books is on reserve at Mather library.

   (b) Journal articles assigned as reading will be available as PDFs through the course website on
       UAF Blackboard.

   (c) Students will need computers for their homework. General-use computers in UAF labs will be
       made available to students if needed.

   (d) Matlab will be the primary computational program for the course. Matlab is available via a
       UAF-wide license.

4. Course description.
   Seismology combines observational data (seismograms) with numerical modeling methods to obtain
   powerful inferences about earthquake sources and the three-dimensional structure of Earth’s interior.
   Applied Seismology will provide essential training for students’ interested in academic, industrial, or
   governmental careers in seismology.

   Catalog description: Presentation of modeling techniques for earthquakes and Earth structure using
   wave propagation algorithms and real seismic data. Covers several essential theories and algorithms
   for applications in seismology, as well as the basic tools needed for processing and using recorded
   seismograms. Topics include the seismic wavefield (body waves and surface waves), earthquake
   moment tensors, earthquake location, and seismic tomography. Assignments require familiarity with
   linear algebra and computational tools such as Matlab.

5. Course goals.
   We will explore the study of earthquakes and Earth’s interior structure using seismological theories
   and algorithms. The underlying physical phenomenon we will examine is the seismic wavefield: the
time-dependent, space-dependent elastic waves that originate at an earthquake source (for example, a fault slips) and propagate through the heterogeneous Earth structure, then are finally recorded as time series at seismometers on Earth's surface. Students will examine real seismic data and use computational models to estimate properties about earthquake source and Earth structure. Students will acquire practical, advanced seismological training that will prepare them for seismological investigations in the future, whether in academic, industry, or government jobs.

6. Student learning outcomes.

Upon completion of this course, students should be able to:

(a) Understand the relevant temporal, spatial, and magnitude scales in the field of seismology.
(b) Describe the physical quantities that govern seismic wave propagation.
(c) Describe the seismic phases that arise in a regional or global layered Earth model.
(d) Describe the seismic moment tensor, the fundamental model of an earthquake source.
(e) Understand the basic framework of inverse problems within the context of seismology.
(f) Describe several different seismological tools that can be used to investigate an individual earthquake.
(g) Understand the connection between earthquakes, continental deformation, and plate tectonics.
(h) Understand the distinction between one-dimensional and three-dimensional Earth structure, and how this affects theory and algorithms in seismology.
(i) Read seismological journal articles and summarize the content efficiently.
(j) Write, improve, and run simple computational algorithms in Matlab.
(k) Plot and manipulate recorded seismograms.

7. Instructional methods.

(a) Assignments and grades (along with general course information and handouts) will be posted on Blackboard: classes.uaf.edu.
(b) Lectures will be the primary mode of instruction. Some lectures will be supplemented with computational examples to prepare students for homework problems.
(c) Each student is expected to lead one brief discussion and review of an assigned journal article.
8. Course calendar (tentative).

<table>
<thead>
<tr>
<th>Day</th>
<th>Date</th>
<th>Topic</th>
<th>Reading Due</th>
<th>Homework Due</th>
<th>Assigned</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Thurs Jan-19</td>
<td>Seismology in 1911, 2011, and 2111</td>
<td>SW1</td>
<td>—</td>
<td>PS-1</td>
</tr>
<tr>
<td>2</td>
<td>Tues Jan-24</td>
<td>Seismograms, signal, noise, measurements</td>
<td>S11, SW6.6</td>
<td>PS-1</td>
<td>PS-2</td>
</tr>
<tr>
<td>3</td>
<td>Thurs Jan-26</td>
<td>Basic analysis and processing of seismograms</td>
<td>DT2.6</td>
<td>PS-2</td>
<td>PS-3</td>
</tr>
<tr>
<td>4</td>
<td>Tues Jan-31</td>
<td>Continuum mechanics</td>
<td>DT3, SW2, S2</td>
<td>PS-2</td>
<td>PS-3</td>
</tr>
<tr>
<td>5</td>
<td>Thurs Feb-02</td>
<td>Equations of motion</td>
<td>DT2</td>
<td>PS-3</td>
<td>PS-4</td>
</tr>
<tr>
<td>6</td>
<td>Tues Feb-07</td>
<td>Solving the wave equation (3D)</td>
<td>SW2, S3</td>
<td>PS-4</td>
<td>PS-5</td>
</tr>
<tr>
<td>7</td>
<td>Thurs Feb-09</td>
<td>Solving the wave equation (1D and 2D)</td>
<td>SW2.9, S8.6, DT10.5</td>
<td>PS-5</td>
<td>PS-6</td>
</tr>
<tr>
<td>8</td>
<td>Tues Feb-14</td>
<td>Normal modes: theory and observations</td>
<td>SW2.7-2.8, S8</td>
<td>PS-5</td>
<td>PS-5</td>
</tr>
<tr>
<td>9</td>
<td>Thurs Feb-16</td>
<td>Surface waves: theory and observations</td>
<td>[9, 10, 11]</td>
<td>PS-6</td>
<td>PS-7</td>
</tr>
<tr>
<td>10</td>
<td>Tues Feb-21</td>
<td>Body waves, reflection, and transmission</td>
<td>S4, SW3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Thurs Feb-23</td>
<td>Waveform modeling</td>
<td>SW4.3</td>
<td>PS-5</td>
<td>PS-6</td>
</tr>
<tr>
<td>12</td>
<td>Tues Feb-28</td>
<td>Wavefield modeling</td>
<td>[12, 13]</td>
<td>PS-6</td>
<td>PS-7</td>
</tr>
<tr>
<td>13</td>
<td>Thurs Mar-01</td>
<td>Finite-frequency sensitivity kernels</td>
<td>[14, 15]</td>
<td>final project</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Tues Mar-06</td>
<td>Ambient-noise tomography</td>
<td>[16], DT8.2</td>
<td>PS-7</td>
<td>PS-8</td>
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<tr>
<td>15</td>
<td>Thurs Mar-08</td>
<td>Preliminary Reference Earth Model</td>
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<tr>
<td>16</td>
<td>Tues Mar-13</td>
<td>SPRING BREAK</td>
<td></td>
<td></td>
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<tr>
<td>17</td>
<td>Thurs Mar-15</td>
<td>SPRING BREAK</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>18</td>
<td>Tues Mar-20</td>
<td>Forward problems and inverse problems</td>
<td>[16]</td>
<td>PS-8</td>
<td>PS-9</td>
</tr>
<tr>
<td>19</td>
<td>Thurs Mar-22</td>
<td>Earthquake location</td>
<td>SW4, S9</td>
<td>PS-8</td>
<td>PS-9</td>
</tr>
<tr>
<td>20</td>
<td>Tues Mar-27</td>
<td>Seismic moment tensor</td>
<td>SW4.4, S9</td>
<td>PS-9</td>
<td>PS-10</td>
</tr>
<tr>
<td>21</td>
<td>Thurs Mar-29</td>
<td>Finite source models</td>
<td>S9.8, WS4.5</td>
<td>PS-9</td>
<td>PS-10</td>
</tr>
<tr>
<td>22</td>
<td>Tues Apr-03</td>
<td>Seismic tomography: global</td>
<td>S5, SW7.3</td>
<td>PS-10</td>
<td>PS-11</td>
</tr>
<tr>
<td>23</td>
<td>Thurs Apr-05</td>
<td>Seismic tomography: crustal</td>
<td>SW3.2-3.3</td>
<td>PS-10</td>
<td>PS-11</td>
</tr>
<tr>
<td>24</td>
<td>Tues Apr-10</td>
<td>Anisotropy and attenuation</td>
<td>SW3.6-3.7, S6.6,11.3</td>
<td>PS-11</td>
<td>final project</td>
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<tr>
<td>25</td>
<td>Thurs Apr-12</td>
<td>Adjoint methods in seismology</td>
<td>[17, 18]</td>
<td>PS-11</td>
<td>final project</td>
</tr>
<tr>
<td>26</td>
<td>Tues Apr-17</td>
<td>Finite source inversion</td>
<td>S9.8, SW4.5</td>
<td>final project</td>
<td>final project</td>
</tr>
<tr>
<td>27</td>
<td>Thurs Apr-19</td>
<td>Seismology, geodesy, and deformation</td>
<td>WS5</td>
<td>final project</td>
<td>final project</td>
</tr>
<tr>
<td>28</td>
<td>Tues Apr-24</td>
<td>Seismology of volcanoes</td>
<td>[19]</td>
<td>final project</td>
<td>final project</td>
</tr>
<tr>
<td>29</td>
<td>Thurs Apr-26</td>
<td>Seismology of glaciers</td>
<td>[20, 21]</td>
<td>final project</td>
<td>final project</td>
</tr>
<tr>
<td>30</td>
<td>May-01</td>
<td>Seismology in the oil industry</td>
<td>S7, WS3.3</td>
<td></td>
<td>final project</td>
</tr>
<tr>
<td>31</td>
<td>Thurs May-03</td>
<td>Seismic monitoring for nuclear activity</td>
<td>[22]</td>
<td>REPORT</td>
<td></td>
</tr>
</tbody>
</table>

May-XX  | FINAL PROJECT PRESENTATION

1SW = Ref. [1]; S = Ref. [2]; DT = Ref. [5]

Some Important Dates:

- First class: Thursday January 19
- Last day to add class: Friday January 27
- Last day to drop class: Friday Feb 3
- Last day for student- or faculty-initiated withdraw: Friday March 23
- Last class: Thursday May 3
- Final project report due: Thursday May 3
- Final project presentation: TBD (May 7-10)
9. Course policies.

(a) **Attendance:** All students are expected to attend and participate in all classes.

(b) **Tardiness:** Students are expected to arrive in class prior to the start of each class. If a student does arrive late, they are expected to do so quietly and inform the instructor without disturbing the class.

(c) **Participation and Preparation:** Students are expected to come to class with assigned reading and other assignments completed as noted in the syllabus.

(d) **Assignments:**

i. All assignments are due at the start of class on the due date noted in the Syllabus.

ii. Late assignments will be accepted with a 20% penalty per day late; an assignment that is ≥ 5 days late will receive a zero.

iii. The lowest homework assignment will be dropped when computing the course grade.

**Homework Tips:** Please type or write neatly, keep the solutions in the order assigned and staple pages together. Include only relevant computer output in your solutions (a good approach is to cut and paste the relevant output for each problem into an editor such as MS Word or Latex). Also clearly circle or highlight important numbers in the output, and label them with the question number. I also suggest that you to include your Matlab code in your answers, both so that you can refer back to it for future assignments and so that I can identify where a mistake may have occurred. Display numerical answers with a reasonable number of significant figures and with units if the quantity is not dimensionless.

Homework scores are based on clarity of work, logical progression toward the solution, completeness of interpretation and summaries, and whether a correct solution was obtained. I encourage you to discuss homework problems with other students, however the work you turn in must be your own.

(e) **Graded Assignments:** Assignments will be graded for students within seven days of their receipt and returned at the end of the next class.

(f) **Reporting Grades:** All student grades, transcripts and tuition information are available online at [www.uanolive.alaska.edu](http://www.uanolive.alaska.edu).

(g) **Consulting fellow students:** Students are welcome to discuss with each other general strategies for particular homework problems. However, the write-up that is handed in—including any computer codes—must be individual work.

(h) **Plagiarism:** Students must acknowledge any sources of information—including fellow students—that influenced their homework assignments or final project. Any occurrence of plagiarism will result in a maximal penalty of forfeiture of all points for the particular homework assignment. If the plagiarism is between two students, then both students will potentially receive the penalty.

(i) **All UA student academics and regulations are adhered to in this course. You may find these in the UAF Catalog.**


(a) For students in the M.S. or Ph.D. program, you must receive a C or higher for this course for it to count toward your degree requirements.

(b) **Grading is based on:**

<table>
<thead>
<tr>
<th>%</th>
<th>Description</th>
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<tbody>
<tr>
<td>10</td>
<td>Attendance and participation</td>
</tr>
<tr>
<td>60</td>
<td>Homework Assignments</td>
</tr>
<tr>
<td>30</td>
<td>Individual Final Project</td>
</tr>
</tbody>
</table>
(c) Overall course grades are based on the following criteria:

<table>
<thead>
<tr>
<th>Grade</th>
<th>Range of Scores</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>$x \geq 93$</td>
<td>Excellent performance: student demonstrates deep understanding of the subject</td>
</tr>
<tr>
<td>A−</td>
<td>$90 \leq x &lt; 93$</td>
<td>Strong performance: student demonstrates strong understanding of the subject, but the work lacks the depth and quality needed for an 'A'</td>
</tr>
<tr>
<td>B+</td>
<td>$87 \leq x &lt; 90$</td>
<td>Average performance: student comprehends the essential material</td>
</tr>
<tr>
<td>B</td>
<td>$83 \leq x &lt; 87$</td>
<td>As reflected by the average quality of assignments</td>
</tr>
<tr>
<td>B−</td>
<td>$80 \leq x &lt; 83$</td>
<td>Below average performance: student demonstrates comprehension of some concepts</td>
</tr>
<tr>
<td>C+</td>
<td>$77 \leq x &lt; 80$</td>
<td>Failure to complete work with 60% quality</td>
</tr>
<tr>
<td>C</td>
<td>$73 \leq x &lt; 77$</td>
<td></td>
</tr>
<tr>
<td>C−</td>
<td>$70 \leq x &lt; 73$</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>$60 \leq x &lt; 70$</td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>$x &lt; 60$</td>
<td></td>
</tr>
</tbody>
</table>

(d) Final Project. The final project will constitute 30% of the course grade. The project will involve independent research into one aspect of seismology. It will require some computation and will be presented in the form of a written report, due on the last lecture class of the semester, and a short in-class presentation during the scheduled final exam. The report will be written in manuscript-submission style and format, using the guidelines for Geophysical Research Letters. Additional details, including project suggestions, will be provided by the instructor midway through the course.


The instructor is available by appointment for additional assistance outside session hours. UAF has many student support programs, including the Math Hotline (1-866-UAF-MATH; 1-866-6284) and the Math and Stat Lab in Chapman building (see www.uaf.edu/dms/mathlab/ for hours and details).


The Office of Disability Services implements the Americans with Disabilities Act (ADA), and it ensures that UAF students have equal access to the campus and course materials. The Geophysics Program will work with the Office of Disability Services (203 WHIT, 474-7043) to provide reasonable accommodation to students with disabilities.

13. References listed in syllabus.


Problem 1. Forward problem: PREM

The Preliminary Reference Earth Model, established in 1980, is a seminal work in seismology (Dziewonski and Anderson, 1981). It is a spherically symmetric model of Earth structure, a type of model described as “one dimensional,” since variations are only present in the radial dimension. A PDF of Dziewonski and Anderson (1981) is available on the course website on Blackboard.

1. (X points) Read Dziewonski and Anderson (1981, Table 1) and the associated text. List and describe the material properties in PREM; list what units PREM assumes for each variable.

   How many geometrical parameters are needed to describe PREM? How many parameters are needed to describe \( Q_\mu \)? Ignoring anisotropy, how many additional parameters are needed to describe \( V_S(r) \) in PREM?

2. (X points) Write a Matlab function that inputs a vector of radial (or depth) values and outputs a vector of \( V_S \) values. Compute \( V_S \) for depths of 1.5 km, 10 km, and 50 km. Do the values seem reasonable?

   Hint: Use the command polyval to save some time.

3. (X points) Plot a figure showing \( V_S(r) \) for \( r \) ranging from the center of Earth to the surface of Earth. Make sure that axes are labeled with units.

Problem 2. Forward problem: Generating an ellipse described by \( m \)

In class we discussed the least-squares method and showed how to construct a solution for fitting a line to scattered data, which required a two-parameter model (\( y \)-intercept and slope). Here the assignment is to compute a best-fitting ellipse for a set of data.

An equation for an ellipse centered at \((0,0)\) is given by

\[
bx^2 + cxy + dy^2 = 1, \tag{1}
\]

where \( b, c, \) and \( d \) are the unknowns that we want to determine by using a least-squares method.

1. (X points) In symbolic form, write down a “forward function” for a model \( m = (b, c, d) \) that inputs a polar angle \( \theta_i \) and outputs the point \((x_i, y_i)\) on the ellipse described by \( m \) (Eq. 1). This function can be thought of as

\[
f(m, \theta_i) = (x_i, y_i). \tag{2}\]

2. (X points) Now assume an input set of \( N \) polar angles, \( \theta = (\theta_1, \theta_2, \ldots, \theta_N) \), and you want to determine the corresponding output \((x, y)\)-points describing the ellipse.
Write a function in Matlab \([x, y] = \text{getellipse}(m, \theta)\) that generates the proper output, and plot the result in Matlab for the model \(m = (0.1, 0.3, 0.5)\) using input angles \(\theta = (0, \ldots, 2\pi)\).

(Hint: For \(N\) linearly spaced angles, use \(\theta = \text{linspace}(0, 2\pi, N)\).

Problem 3. Inverse problem: Using least squares to fit an ellipse to a set of data

From Problem 2, you should now have a plotting tool for an arbitrary ellipse model \(m\). For this problem, you do not need the parameter \(\theta\).

1. (X points) Write down in matrix form the least-squares problem \(Gm = d\) whose unknown vector is \(m = [b\ c\ d]^T\), and show the dimensions of each array. Solve for \(m\) in symbolic form.

2. (X points) Using Matlab, implement your result in (a) and solve for \(m\) using the data

\((x_i, y_i) : (3, 3), (1, -2), (0, 3), (-1, 2), (-2, -2), (0, -4), (-2, 0), (2, 0)\).

Check that the result is the same as if you simply use the "\(\setminus\)" command: \(m = G \setminus d\).

(Hint: The design matrix \(G\) should be \(8 \times 3\).)

3. (X points) Here are a few lines of code to let you pick points interactively with the mouse. Try it for some data points of your own choosing. (You can copy these lines of code directly from the PDF, then paste them into Matlab.) Then generate a plot containing your points and the best-fitting ellipse.

```matlab
figure; sd = 3; hold off, axis equal, axis([-sd sd -sd sd]), axis manual, hold on, grid on x = []; y = []; button = 1; disp('Now we get another best-fitting ellipse centered at (0,0).'); disp('Click on your input points using the mouse.'); disp('Hit any key after the final point is entered.'); plot([-sd sd], [0 0], 'k', [0 0], [-sd sd], 'k'); while button==1
    [xx,yy,button] = ginput(1); disp(sprintf('%6.2f %6.2f',xx,yy)); x = [x; xx]; y = [y; yy]; plot(xx,yy,'x') end
```

Problem 4

(0 points) Approximately how many hours did you spend on this problem set? Feel free to suggest improvements here.
References

Problem Set 10: Fault parameters and moment tensors
GEOS 607: Applied Seismology, Carl Tape
Assigned: March 29, 2012 — Due: April 5, 2012

$\kappa = 40^\circ$, $\delta = 70^\circ$, $\lambda = -120^\circ$

Figure 1: Diagram showing notation for vectors and angles for Problem 2. The strike angle is $\kappa = 40^\circ$, the dip angle is $\delta = 70^\circ$, and the rake angle is $\lambda = -120^\circ$. Note that the map view of the beachballs shows the upper hemisphere, which differs from the seismological convention of plotting the lower hemisphere.
Problem 1. Rotations in 2D and 3D

This problem should prepare you for Problem 2. Please note: The full expressions for the equations below are messy, containing dozens of terms of \( \cos \alpha, \sin \phi \), etc. I am not asking for the full expressions; if you find yourself writing out long, messy equations, please stop!

1. (X points) Write down the 2 \times 2 rotation matrix \( R = R(\alpha) \) that rotates \( r = (x, y) \) by angle \( \alpha \) in the positive (counter-clockwise) direction. What is the relationship between \( R(\alpha) \) and \( R(-\alpha) \)? Show that for \( \alpha = 90^\circ \) your matrix will rotate \( r = (1, 0) \) to \( r' = (0, 1) \). If \( \alpha = 60^\circ \) and \( r = (1, 2) \), compute \( r' \); express your answer in exact (non-decimal) form.

2. (X points) Write down the 3 \times 3 rotation matrix \( R_z = R_z(\alpha) \) that rotates \( r = (x, y, z) \) by angle \( \alpha \) in the positive (counter-clockwise) direction about the z-axis, \( \hat{z} = (0, 0, 1) \). Repeat for \( R_x(\alpha) \) and \( R_y(\alpha) \).

3. (X points) Write a function in Matlab that inputs a rotation angle \( \alpha \) and an index for the axis \( (k = 1, 2, 3 \text{ for } x, y, z) \), and then outputs the \( R_k(\alpha) \).

4. (X points) Using the matrix functions \( R_x(\alpha), R_y(\alpha), R_z(\alpha) \), derive an expression for the matrix, \( U(w, \gamma) \), that rotates a vector \( r \) about the input vector \( w \) by angle \( \gamma \). Let \( \theta \) be the polar angle for \( w \) and \( \phi \) be the azimuthal angle.
   
   Hint: What operations should be applied to \( w \)?

5. (X points) Use your Matlab function for \( R_k(\alpha) \) to compute \( U(w, \gamma) \) for input values of \( w = (X, X, X) \) and \( \gamma = X^\circ \). Check that \( U(-w, -\gamma) \) gives the same result, and explain why this is the case.

Problem 2. From fault parameters to moment tensors

Figure 1 shows the basics of the problem: given measurements of the angles strike, dip, and slip, compute the 3 \times 3 symmetric moment tensor. This requires a choice of an orthonormal basis for expressing vectors and tensors; we will choose the Global Centroid Moment Tensor (GCMT) convention of up-south-east, or \( \hat{r}-\hat{\theta}-\hat{\phi} \).

You will utilize the function \( U(w, \gamma) \) that you obtained in Problem 1. Please note: The full expressions for the equations below are messy, containing dozens of terms of \( \cos \kappa, \sin \lambda \), etc. I am not asking for the full expressions; if you find yourself writing out long, messy equations, please stop!

1. (X points) Referring to Figure 1, write the expression for the strike vector, \( K \), in terms of \( U(w, \gamma) \). Hint: What should \( w \) and \( \gamma \) be? What angles does \( K \) depend on?

2. (X points) Write the expression for the normal vector, \( N \), in terms of \( U(w, \gamma) \). Hint: What should \( w \) and \( \gamma \) be? What angles does \( N \) depend on?

3. (X points) Write the expression for the normal vector, \( D \), in terms of \( U(w, \gamma) \). Hint: What should \( w \) and \( \gamma \) be? What angles does \( D \) depend on?
4. (X points) Using your matlab function for $U(w, \gamma)$, compute the vectors $K$, $N$, and $D$ for this example.

5. (X points) There are many choices for computing the eigenvectors associated with a moment tensor. For this example, compute them using the following formulas:

\[
\begin{align*}
    p_1 &= \frac{D + N}{|D + N|} \\
    p_3 &= \frac{D - N}{|D - N|} \\
    p_2 &= -p_1 \times p_3
\end{align*}
\]

Check that your computed eigenvectors are indeed unit vectors. Sketch the eigenvectors on the upper right diagram.

The columns of the eigenbasis, $U$, are $p_1$, $p_2$, and $p_3$. Compute the determinant to check that the eigenbasis is also a rotation matrix.

6. (X points) What are the (unsorted) eigenvalues of any double-couple moment tensor?

7. (X points) Our convention for eigenbasis $U$ is tied to eigenvalues ordered as $\lambda_1 = 1$, $\lambda_2 = 0$, $\lambda_3 = -1$. Thus, our "base" diagonal moment tensor is $M'$ with diagonal $[1, 0, -1]$. Write the expression for $M$, obtained from $M'$ via transformation by $U$. Check that the following operations are true for this example:

\[
\begin{align*}
    Mp_1 &= \lambda_1 p_1 = p_1 \\
    Mp_2 &= \lambda_2 p_2 = 0 \\
   Mp_3 &= \lambda_3 p_3 = -p_3
\end{align*}
\]

What is the physical meaning of these three operations? (Be careful: The moment tensor is associated with the P-wave motion only.)

8. (X points) Go to www.globalcmt.org/CMTsearch.html and enter the following search parameters:

- Starting Date: 2002/11/03
- Ending Date: Number of days = 1
- Moment Magnitude between 7 and 10
- OUTPUT Type: CMTSOLUTION format

Compute $M$ for $\kappa = 296$, $\delta = 71$, $\lambda = 29$; then compute $M$ for $\kappa = 29$, $\delta = 82$, $\lambda = 19$. Verify that the two moment tensors are the same (to two significant figures or so), and that they match the GCMT solution.

Discuss one seismic data set for which a point-source model of this earthquake is appropriate. Discuss one seismic data set for which a point-source model of this earthquake is not appropriate.
Problem 3

(0 points) Approximately how many hours did you spend on this problem set? Feel free to suggest improvements here.