CEE 201L. Uncertainty, Design, and Optimization

Instructor: Henri Gavin, 162 Hudson Annex, henri.gavin@duke.edu
T.A.: Matthew Brune, matthew.brune@duke.edu
Lecture: Mo, We, Fr, 12:00 - 12:50, 216 Hudson
Recitation: Th, 5:15 - 6:30, 115A Hudson
zoom: Meeting ID: 952 2731 0393 Passcode: UDO
Office Hours: H.G.: Mo 4:30 - 5:30, and by appointment, 162 Hudson
M.B.: We 5:00 - 6:00, and by appointment, 115 Hudson (?)

Textbook: Notes and assignments are available through the course website.
Website: http://www.duke.edu/~hpgavin/cee201/
Prerequisite: EGR 201L. Mechanics of Solids.

Academic Integrity: The Duke Community Standard applies.
Grading: 4 projects (40%); 6 homeworks (35%); 1 final (20%); ∞ participation: (5%)

BULLETIN DESCRIPTION


COURSE OBJECTIVES AND MEASURABLE OUTCOMES

Students successfully completing CEE 201L will be able to:

1. Identify, formulate, and solve engineering problems by:
   (a) formulating constrained optimization problems from broad design goals,
   (b) interpreting and assessing designs provided by solutions to constrained optimization problems, and
   (c) identifying possible obstacles to practical and successful implementations.

2. Design systems, components, and processes to meet desired needs within realistic constraints, (including economic, environmental, social, and safety constraints) by:
   (a) mathematically modeling the system to be designed,
   (b) defining design attributes to parameterize the design, and
   (c) intelligently iterating on the design to meet the desired objectives without violating constraints.

This course measures the students' progress in meeting the above objectives by requiring students to:

1. understand procedures for numerical optimization and to apply these methods to diverse problems (homework and projects);
2. interpret constrained optimization as method for structural analysis using energy methods (homework and midterm exam);
3. model uncertainties involved in system design and to propagate these uncertainties through optimized designs (homework and projects);
4. work in groups to design feasible and cost-effective systems to meet specific design goals (projects);
5. write programs (using Matlab) to analyze candidate systems and to utilize optimization-solvers in order to efficiently converge on optimal designs (projects); and
6. present methods and communicate findings in written project reports (projects).
GENERAL REQUIREMENTS

- **The Duke Community Standard** [http://www.integrity.duke.edu/standard.html]: Duke University is a community dedicated to scholarship, leadership, and service and to the principles of honesty, fairness, respect, and accountability. Citizens of this community commit to reflect upon and uphold these principles in all academic and non-academic endeavors, and to protect and promote a culture of integrity.

To uphold the Duke Community Standard:

- I will not lie, cheat, or steal in my academic endeavors;
- I will conduct myself honorably in all my endeavors; and
- I will act if the Standard is compromised.

- **Attendance**: There is no textbook; your lecture notes will be your only reference for many parts of the course. Please be on time. Please keep your cell phones off. Your participation will make this course much more fun!

- **Communication**: We will use e-mail for out-of-class communications related to the course. Start the subject line of any/all email to me with CEE 201:

- **Extra-curricular and co-curricular activities**: In most cases extra-curricular and co-curricular activities conflicting with course commitments can be resolved easily. Just let me know beforehand.

- **Grading**: The TAs will grade your solutions to homework assignments. I will grade the projects and the take-home exams. See me (not the TA) about any grading issues before the last day of class.

HOMEWORK AND PROJECT REQUIREMENTS

- **Collaboration and Academic Integrity**: Collaboration with other students enrolled in the course is encouraged on homeworks and is required on projects. Present your own solutions in a way that makes sense to you. Copying will be considered a violation of the Duke Community Standard. The TAs may not solve homework problems for you. On each assignment, write and sign the reaffirmation, "I have adhered to the Duke Community Standard in completing this assignment."

- **Neatness**: 15 of 100 points on each assignment are allocated to neatness.
  - Use pencil, preferably a mechanical pencil.
  - Write neatly and clearly.
  - Write your first and last name, the course number, the assignment number and the due-date in the upper right corner of the first page. Write the page number on each page (e.g., 3/6, means page 3 of 6)
  - Write out each problem statement. (i.e., Given=. . . , Find=. . . , Collaborators=. . . ) For “Collaborators:” list the people with whom you worked on the problem. If there are no collaborators just write “none”.
  - Use a straight edge (your Duke ID card, a ruler, or a triangle) to draw straight lines.
  - Present solutions to problems in the same order as listed in the assignment.
    Begin every problem on a new page that it can fit on the same page.
  - Describes your thinking in words to be eligible for partial credit.
  - Draw a box around your final answer. Give the units for numerical answers.
  - Staple your solution set. If you scan, use: PDF, b&w, 300 dpi, and high contrast settings.
• **Programming:** Some homework assignments and all projects involve MATLAB programming. Help with MATLAB can be provided by the TA and by HPG. Include your code and any plots to your homework and project PDFs prior to submitting your work.

• **Submission of work:** Upload your homework assignments and project reports to the CEE 201L Gradescope page by 5:00 pm on the due date. For everyone's efficiency, please set that your scan settings result in reasonably sized files ... less than 10MB, please. Low quality scans will be penalized 5 neatness points.

• **Short-term illness:** If illness or injury prevents you from attending class or meeting a deadline, read the new university policy on short-term and long-term health issues, complete this secure on-line incapacitation form, and meet with or contact me within 48 hours to figure out a plan for your support and accommodation.

• **Extensions:** Every student can get one automatic one-work-day homework extension. To obtain the extension, simply send me an e-mail stating your extension request, with Cc to yourself, and with the subject line: CEE 201: <your name> extension request at least 24 hours before the deadline. Automatic extensions are not available on projects or the final.

• **Late work:** Except for cases of an extension, grades for late work will be penalized ten points for each weekday late; Assignments submitted after the the solution is posted get no credit.

• **Group Project Peer Evaluation (optional):** For each project each student has the option to anonymously indicate the percent effort of each member of their group, including themselves, by submitting a Project Cross Evaluation Form. The project grade for group member $i$, $(g_i)$ will be apportioned according to the team project grade, $g$, and the contributions $c_i$ of team member $i$ to the project, as reported by any members of the group,

$$ g_i = g - (100 - g) \left( 1 - \frac{n}{m} \frac{1}{100} \sum_{i=1}^{m} c_i \right) $$

where the group has $n$ members and $m$ group members submit project cross-evaluation forms. For example, if a group earns a “B” (a grade $g$ of 85) and two of three group members anonymously submit a project cross-evaluation form, grades for members of the group will be assigned as follows:

<table>
<thead>
<tr>
<th>evaluated student</th>
<th>evaluating student</th>
<th>adjusted grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bob</td>
<td>“X”</td>
<td>81.25</td>
</tr>
<tr>
<td>Sue</td>
<td>“Y”</td>
<td>83.50</td>
</tr>
<tr>
<td>Tim</td>
<td>40 30</td>
<td>90.25</td>
</tr>
</tbody>
</table>

so the individual student grades would be 81 for Bob, 84 for Sue, and 90 for Tim.

• **Homework answer keys:** will be posted on Sakai after homeworks are graded and returned.
## COURSE SCHEDULE

<table>
<thead>
<tr>
<th>Week</th>
<th>Dates</th>
<th>Topic</th>
<th>Reading</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>1/5 -1/7</td>
<td>Design: innovation, analysis, evaluation, iteration, and optimization;</td>
<td>[3] Ch.1</td>
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<td></td>
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<td>design parameters, cost functions, safety constraints, and failure probability</td>
<td>[3] Ch.2</td>
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<td>safety factors, uncertainty, and risk. Matlab</td>
<td>[43]</td>
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<tr>
<td></td>
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<td>due 1/14 HW 1: Matlab skills</td>
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<tr>
<td>2</td>
<td>1/10-1/14</td>
<td>Constrained Optimization: direct search and quadratic programming methods, equality and inequality constraints</td>
<td>[42] [16] [19]</td>
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<td>due 1/21 HW 2: Constrained Optimization: search methods</td>
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<tr>
<td>3</td>
<td>1/17</td>
<td>Martin Luther King Day</td>
<td>M.L.K.: 1963, 1964</td>
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<td></td>
<td>1/19-1/21</td>
<td>Hessian matrix, gradient, and Lagrange multipliers,</td>
<td>[17] [18] [19] [20]</td>
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<td>sensitivity of cost to constraint relaxation and parameter variation</td>
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<td>due 1/28 HW 3: Constrained Optimization: gradient methods</td>
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<td>4</td>
<td>1/24-1/28</td>
<td>Uncertainty: random variables, histograms, and empirical distributions.</td>
<td>[1] Ch.1,3,5</td>
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<td></td>
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<td>sets, mutually exclusive, collectively exhaustive, independence, union, intersection</td>
<td>[24]</td>
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<td>uniform, triangular, normal, log-normal, Poisson, exponential, Rayleigh, Laplace</td>
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<td>Monte-Carlo simulation</td>
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<td>due 2/4 HW 4: Uncertainty: analysis and simulation</td>
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<td>— ENGINEERING DESIGN VIA OPTIMIZATION WITH UNCERTAINTY —</td>
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<tr>
<td>5</td>
<td>1/31-2/4</td>
<td>Design based analysis of networks: trusses, pipelines, power grids</td>
<td>[40] [41]</td>
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<td></td>
<td>2/11</td>
<td>due 1/14 HW 5: Computer Aided Network Analysis</td>
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<td>6</td>
<td>2/7-2/11</td>
<td>Design-based analysis and optimization of electrical power networks, LP as a SQP</td>
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<td></td>
<td>2/18</td>
<td>due 2/18 Project 1: Generate and distribute enough electrical power to meet uncertain demand</td>
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<td>7</td>
<td>2/14-2/18</td>
<td>Design-based analysis and optimization of structures</td>
<td>[40] [41]</td>
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<td>2/28</td>
<td>due 2/28 Project 2.1: Optimize a nonlinear truss.</td>
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<td>8</td>
<td>2/21-2/25</td>
<td>Failure Analysis and Constraint-Parameter correlation</td>
<td>Project 2.2: Truss failure and correlation analysis.</td>
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<td>3/4</td>
<td>due 3/4 Project 2.2: Truss failure and correlation analysis.</td>
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<td>9</td>
<td>2/28-3/4</td>
<td>Minimum total potential energy and in-class project work</td>
<td>[21] [22]</td>
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<td>10</td>
<td>3/7-3/11</td>
<td>Spring Break</td>
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<tr>
<td>11</td>
<td>3/14-3/18</td>
<td>Review Projects 1 and 2</td>
<td>course notes</td>
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<tr>
<td>12</td>
<td>3/21-3/25</td>
<td>Rainfall, streamflow, aquifer and reservoir storage, transpiration, evaporation</td>
<td>course notes</td>
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<td>due 4/1 Project 3.1: Provide enough clean drinking water.</td>
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<tr>
<td>13</td>
<td>3/28-4/1</td>
<td>In-class project work</td>
<td>Project 3.2: Water supply ailure and correlation analysis.</td>
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<td>4/8</td>
<td>due 4/8 Project 3.2: Water supply ailure and correlation analysis.</td>
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<td>14</td>
<td>4/4-4/8</td>
<td>Vibration of single degree of freedom systems</td>
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<td>Free response, forced response, resonance, frequency response function</td>
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<td>4/15</td>
<td>due 4/15 HW 6: Structural dynamics</td>
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<td>Effect of viscous damping and inelastic energy dissipation</td>
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<td>Seismic isolation</td>
<td>[26]</td>
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<tr>
<td>16</td>
<td>4/18-4/20</td>
<td>In-class project work</td>
<td>Project 4: Protect fragile objects from earthquake hazards.</td>
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<tr>
<td></td>
<td>due 4/20</td>
<td>Project 4: Protect fragile objects from earthquake hazards.</td>
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<td>due 4/29 TAKE HOME FINAL due at 5:00 pm</td>
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</tbody>
</table>
References

[37] Petroski, Henry, *Design Paradigms, Case Histories of Error and Judgment in Engineering*, Cambridge Univ. Press,