Time: 01:30 PM-02:20 PM Monday, Wednesday, and Friday  
Location: Wang 2555

Instructor:  
Vikas Tomar  
3205 ARMS  
Phone: 4-3423 (765-494-3423 for offcampus)  
E-mail: tomar@purdue.edu (replace AT with @)

Teaching Assistant (TA):  
Chandra Prakash  
E-mail: cprakash@purdue.edu (replace AT with @)  
Phone: 765-496-1990

Office location for office hours:  
ARMS 3119 3:00-5:00 PM (Wed, Th, Fri)

Extra for Distance Students:  
Besides Office Hours Individual appointment with instructor using email OR cell: 317-294-3251 (if I don’t respond, leave me a message stating time when I should call back with number).

Office Hours Begin Wednesday, Sept 02

ALL STUDENTS: please set up an appointment with me based on your convenience. If you see me in hallway please feel free to stop me for a discussion.

We (TA and/OR I) will respond to emails at-most within a day. If you want to set up an appointment (phone talk or office visit) we can set that up on an individual basis. Just email us at least a day in advance to fix up an appointment. We will also use VideoEverywhere and Kaltura tools for video messaging about specific technical stuff.

Piazza for specific issues related to homework.

WHEN EMAILING PLEASE EMAIL BOTH TO THE TA AND ME TO ENSURE EARLIEST RESPONSE.

Mode of Contact, Announcement, and Information:
Most usually it will be Emails (except office hours and by appointment). Try to keep them short and to the point. If you have a lot to say then write it in a separate file and attach.

ACROBAT PDF IS THE ONLY ALLOWED FORMAT FOR EMAILS ATTACHMENTS FOR ANY COMMUNICATION INCLUDING ASSIGNMENT SUBMISSIONS DUE TO PROBLEMS WITH SPAM AND VIRUSES ETC...

Besides Emails, individual contact mode is phone.

In the case of announcements to the whole class the announcements will be made from:
(1) Email and
(2) Public website of the class at:
https://engineering.purdue.edu/~tomar/Teaching/AAE558/Index.htm

Pre-requisite: AAE 453 or consent of instructor (THE COURSE NEEDS HEAVY EXPERIENCE IN MATRIX ALGEBRA AND MATLAB PROGRAMMING. FIRST FEW ASSIGNMENTS REQUIRE HEAVY MATLAB PROGRAMMING)  
Co-requisite: None
Required text: A First Course in Finite Elements [Paperback] [Jacob Fish (Author), Ted Belytschko (Author)] Wiley; 978-0470035801. (PLEASE NOTE THAT THERE IS ONLY ONE EDITION. However, PLEASE BUY THE LATEST PRINT SINCE THE OLD PRINT HAS A LOT OF TYPOS. LATEST PRINT WAS DONE IN JANUARY 2012)

Necessary Background:
(1) Mechanics of Materials and Structural Analysis
   Review Websites:
   Undergraduate Mechanics
   http://web.mst.edu/~mecmovie/
   Graduate Mechanics
   http://solidmechanics.org/
(2) Linear Algebra:
   Review Website
   http://www.sosmath.com/matrix/matrix.html
(3) MATLAB Tutorial
   • http://www.mathworks.com/academia/student_center/tutorials/launchpad.html
   • http://www.mathworks.com/academia/student_center/tutorials/intropage.html

Goals:
The goal of AAE 558 is to introduce the theory behind finite element calculations of stress, strain, and deformation in structures and materials and describe the role of a commercial finite element package in structural analysis and design.

Objectives AND Envisioned Outcomes:
(1) Understand the relationship between the finite element shape functions and constitutive behavior and element stiffness matrices
(2) Develop the weak form of the equations of mechanics
(3) Relate mesh and loading to the assembled stiffness matrix
(4) Provide criteria for engineering judgment required to assess the appropriateness of the choice of a finite element model for a particular structure
(5) Provide training to understand the equations guiding black-box software such as ABAQUS.

Topics:
1. Introduction—Background and Applications of Finite Elements (Chapter 1-Text Book)
2. Direct Approach for Discrete Systems—One Dimensional Problems (Chapter 2)
3. Direct Approach for Discrete Systems—Two Dimensional and Three Dimensional Problems (Chapter 2)
4. Finite element formulation for beams (Chapter 5-Text Book) [PLEASE note change in sequence from book]
5. Formulation: Strong and Weak Forms in one dimensional problems (Chapter 3-Text Book)
6. Introduction to ABAQUS (Chapter 11-Text Book) [THIS is done earlier than book sequence to get you started on the final project]
7. Approximation of Trial Solutions, Weight Functions and Gauss Quadrature (Chapter 4-Text Book)
8. Finite Element Formulation for One-Dimensional Problems and Error Analyses (Chapter 5-Text Book)
9. Formulation: Strong and Weak Forms in two dimensional problems (Chapter 6, 7-Text Book)
10. Finite Element Formulation for two dimensional Problems: Linear Elasticity (Chapter 11-Text
Book
11. Error, estimation, and convergence (Chapter 8-Text Book)
12. Three dimensional Finite element analyses (Chapter 7,9-Text Book)
13. Plate and shell bending problems (Class lecture-no text book coverage)
14. Dynamics using the finite element method (If time permits: class lecture-no text book coverage)
15. Special Topics: Fracture, Bending (plates and shells), dynamics, non-linear material models (If time permits: class lecture-no text book coverage)

ADDITIONS, AMENDMENTS, OR CORRECTIONS TO THIS SYLLABUS MAY BE MADE THROUGHOUT THE SEMESTER VIA IN CLASS ANNOUNCEMENTS, HANDOUTS, OR E-MAIL.

Assessment:
Your performance in this course will be measured by homework assignments, exams, and a Final Project. Each student will complete a final project.

Grading:
- Homework: 19%
- exam-1: 20%
- exam-2: 20%
- exam-3: 20%
- exam-4 (class project): 20%
- Class Survey: 1% (please email me your email proof of having performed this survey in order to get this credit)

Grades scale. I will be aiming for a distribution that looks like this:
- 100-90 A
- 80-89 B
- 65-79 C
- 50-64 D
- 49-0 F

The above scale may be adjusted down but not up. For example, 95 is a guaranteed A while 89 may possibly be an A depending upon the curve of grading.

Exams and Homeworks:
Homeworks will have roughly a frequency of one per week. Please see homework submission timeline with the schedule table at the end of this handout. Your homeworks will be graded and solutions will be posted on the Blackboard Vista website. Homeworks will be returned in class for in-class students and will be scanned and posted on blackboard vista for off-campus students. The homework submission deadline time is 1:30 PM before the lecture on the day homework is due. The schedule for grading and posting homework solutions is given at the end of this handout. For distance students the submission is at the end of the day (11:59 PM) on which homework is due by email to instructor and copied to both TA and grader. ALL SUBMISSIONS MUST BE IN PDF FORMAT.

Late homeworks will not be accepted and zero grades will be given. Depending upon the personal grievance/problem individual exception may be given depending upon the gravity of situation (contact instructor at least one lecture in advance).
FINAL EXAM IS IN THE FORM OF A PROJECT. THE GUIDELINE FOR PROJECT REPORT EVALUATION IS GIVEN IN THE END OF THIS HANDOUT.

Choice of final project report due in class, Friday, November, 13-2014: by 1:30 PM (by the end of day for distance students)
Choice of Problem and problem stages description (please ask me if you are not clear what this means. I’ll also mention this in class) - a **2 PAGE PDF REPORT** THAT HAS AN INFORMAL DESCRIPTION OF PROBLEM INCLUDING FIGURE, LOADING, BOUNDARY CONDICTION, AND ISSUE AT HAND. PLEASE USE FINAL PROJECT REPORT FORMAT GIVEN AT THE END OF THIS HANDOUT AS A GUIDELINE. This will not be graded. This part is just to make sure you are clear about your project in time. I will go through each report and will contact you if I see something wrong. If I don’t contact you in a week after submission that means you can proceed with your work.

Final Project Report Due Monday, December 14 BY EMAIL in PDF FORMAT BY THE END OF DAY (11:59 PM) **PLEASE SEE BLACKBOARD FOR MODEL REPORTS** Turn in a 10 page maximum (you could choose to write less pages but there will be a deduction of 5 points per page for running over 10 pages in report excluding the title page and table of contents. **10 page limit excludes table of contents, title, and appendix**. Please submit in acrobat pdf format. No other format is acceptable. Please put extraneous information such as codes, long data tables, and data execution etc. in appendix. The report should only have plots and text. At most 4 plots are allowed. See at the end of this handout for more details regarding the report grading.

IMPORTANT INFORMATION REGARDING EXAM AND CHOICE OF PROBLEMS:

The apparent difficulty of the task that you undertake is of course strongly dependent on your choice of problem. The amount of credit given will depend upon the problem difficulty, but the grade will also strongly depend on you convincing me that your analysis is proper. Thus the supporting documentation might include a convergence study and perhaps some simpler related problems in which you have compared the finite element solution to solutions available in the literature or to a solution derived analytically. Else, you might choose a problem that has been solved previously and compare your FEM solution to the previous solution. **Convince me that you have verified your solution.**

Students attending this class have a fair experience in writing the report. However for uniformity, the following layout must be followed in report outline. Suggested format is US-Letter sized page with 1” margin on all side, Times New Roman 12 sized font with single spacing. The report should have:

1. Cover page with title, student name (not counted in 10 page limit)
2. Table of contents page (not counted in 10 page limit)
3. An abstract page (counted in 10 page limit)
4. Objective or introduction: Describe briefly what the reader will see in your report.
5. Setup or procedure: Describe briefly how you create your FEM model.
6. Describe the model. The number elements, type of elements, material properties, type of structural member approximation (such as a tapered cross-section being approximated by uniform cross-sections), section properties, boundary conditions, and the load values (you may create table to present data, take screen snapshots from software..its upto you.)
7. Results and Discussions: Use Figure numbers, Table numbers, and equation numbers in your report to discuss your results. Discuss all the checks (MANDATORY) such as a convergence check made to ensure your results are fine (all research papers on using FEM are outright
rejected without convergence checks). Bring relevant observation to the attention of the reader rather than expecting the reader to wade through the information in your report.

8. Conclusion: Brief synopsis of what you have one in previous steps with most focus on your findings.

9. Appendix: (Can be handwritten) Information needed: mechanics of materials equations, formulae, calculations, values of variables in your computations, assumption etc. (not counted in 10 page limit)

Software:
You can use any software of your choice, but class presentations and training documents will focus on ABAQUS. I encourage using ABAQUS. Student version of ABAQUS is available with book. We will also work on MATLAB software available with book on companion site. In that case they can use any of the available free FEM software. An example of software available is at: http://www.freebyte.com/cad/fea.htm

The School of Aeronautics and Astronautics has agreed to provide access to Abaqus on-campus. I'll give those details separately when I provide training.

Policies:
The University Regulations Handbook reads: "Students are expected to be present for every meeting of the classes in which they are enrolled." Regular attendance will not be taken, but if you must miss a class, you are responsible for the lecture material, assignments and / or announcements made.

Late homework will generally not be accepted except in the case of illness or serious emergency. Contact the instructor before the due date (if possible) to arrange an acceptable due date.

Illnesses and emergencies should be documented with an appropriate authority (such as a doctor etc.)

Grading corrections:
Any disputes over grading should be brought to the instructor.

Campus Emergencies
In the event of a major campus emergency, course requirements, deadlines, and grading percentages are subject to changes that may be necessitated by a revised semester calendar or other circumstances beyond the instructor’s control. Information about these changes will be available from the Blackboard Vista web page, via my e-mail (tomar(at) purdue.edu) or my office phone (765-494-3423).

PLEASE NOTE THAT Purdue’s home page (www.purdue.edu) is the official source of emergency information.

Honor code:
Collaboration with other students on assessments and homework is acceptable - even encouraged - because learning from peers is a valuable addition to the educational experience. However, each student is responsible for completing his/her own work. All submitted assignments must be demonstrably independent from that of other students.
Wang Hall Emergency Procedures

A comprehensive listing of all Armstrong Hall emergency procedures and other information is available in the Building Emergency Plan (BEP). Click the link below to access the ARMS BEP.

- [WANG Building Emergency Plan (Draft Version)]

The two most common emergency situations encountered at Purdue are fire alarms and severe weather alerts. The evacuation/shelter-in-place locations for these two types of emergencies are below (as described in the BEP):

**Fire Alarm:** The evacuation location for the ENE spaces in WANG is the grassy area to the north of the rear parking lot (shown in the photo below). Use the nearest stairwell to exit the building. **Do not use the elevator.**

![Fire Alarm Evacuation Location](image)

**Severe Weather Shelter-In-Place:** The severe weather shelter-in-place location for WANG is any space on the first floor that is away from windows and other glass. Ideally, the first floor stairwell, restrooms, and janitor area are to be used. An alternate shelter-in-place location is the tunnel underneath the Northwestern Parking Garage. This location should only be used if it is safe to briefly travel outdoors.

An ENE emergency response plan for WANG will be developed in the coming months.
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<thead>
<tr>
<th>Date</th>
<th>Topic</th>
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<tr>
<td>8/24</td>
<td>Introduction-Background And Applications of FEM</td>
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<tr>
<td>8/26, 8/28, 8/31, 9/2, 9/4, 9/9, 9/11, 9/14</td>
<td>Direct Approach for Discrete Systems</td>
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<tr>
<td>9/09</td>
<td>Homework 1 is due</td>
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<td>9/14</td>
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<tr>
<td>09/16, 9/18, 9/21, 9/23, 9/25, 9/30</td>
<td>Finite Element Formulation for Beams, Formulation: Strong and Weak Forms in 1-D</td>
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<tr>
<td>EXAM 1 ON SEPTEMBER 28 IN CLASS (SEPARATE ARRANGEMENT FOR DISTANCE STUDENTS TO BE NOTIFIED BY EMAIL)</td>
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<tr>
<td>9/21</td>
<td>Homework 3 is due</td>
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<tr>
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<tr>
<td>10/02, 10/05, 10/07, 10/09, 10/14</td>
<td>Approximation of Trial Solutions, Weight Functions and Gauss Quadrature, Finite Element Formulation for One Dimensional Problems</td>
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<td>10/14</td>
<td>Homework 5 is due</td>
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<td>10/19</td>
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<td>EXAM 2 ON OCTOBER 26 IN CLASS (SEPARATE ARRANGEMENT FOR DISTANCE STUDENTS TO BE NOTIFIED BY EMAIL)</td>
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<tr>
<td>10/16, 10/19, 10/21, 10/23, 10/26, 10/28, 10/30, 11/2</td>
<td>ABAQUS Training-Part 1, Strong and Weak Forms in Multidimensional Problems</td>
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<td>11/4, 11/6</td>
<td>ABAQUS training</td>
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<td>11/9, 11/11, 11/13</td>
<td>Finite Element Formulation for Multidimensional Scalar Field Problems Including Linear Elasticity</td>
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<td>11/2</td>
<td>Homework 7 is due</td>
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<td>11/9</td>
<td>Homework 8 is Due</td>
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<td>11/16</td>
<td>preliminary report is due</td>
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<tr>
<td>11/23</td>
<td>EXAM 3 TAKE HOME IS DUE (PROBLEM TO BE POSTED BY END OF DAY 11/16)</td>
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<tr>
<td>11/13, 11/18, 11/20</td>
<td>Error Estimation Convergence</td>
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<td>11/30</td>
<td>Homework 9 is due</td>
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<tr>
<td>11/23, 11/30, 12/02, 12/04, 12/07, 12/09, 12/11</td>
<td>Three Dimensional Finite Element Analyses, Beam and plate bending problems, Modeling Considerations and Software Use, Special situations such as fracture mechanics</td>
</tr>
<tr>
<td>Guest lectures 12/7-12/11</td>
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</tbody>
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**FINAL REPORT AND PRESENTATION IS DUE: 12/14 USING EMAIL TO INSTRUCTOR**

**Holidays:** September 07 (Labor Day), October 12-13 (Fall Break), November 25-27 (Thanksgiving)

**Note:** Dates FOR EXAMS, HOMEWORK DUES, AND REPORTS can be changed by in-class announcements
REPORT WRITING GUIDELINES

GENERAL COMMENTS
• FOLLOW THE REPORT WRITING GUIDELINES WHICH ARE IN THE SYLLABUS

IMPORTANT ITEMS TO BE INCLUDED IN EXAMS:
• FORM FE EQUATIONS AND SOLVE
• EXPERIMENT WITH DIFFERENT NUMBER OF ELEMENTS TO MAKE SURE SOLUTION IS CORRECT (CONVERGENCE STUDY)
• COMPARE WITH ANALYTICAL SOLUTION
• ASSESS ERROR (DIFFERENCE BETWEEN FE SOLUTION WITH DIFFERENT SUBDIVISIONS VS. ANALYTICAL SOLUTION)

POINT DIVISION DURING REPORT GRADING (OUT OF 100)

FORMATTING HAS 10 POINTS DIVIDED AS:
IS NUMBER OF PAGE GUIDELINES FOLLOWED PROPERLY: 3 POINTS
AT MOST 5 PLOTS WITH PROPER ILLUSTRATION: 3 POINTS
ARE ALL REQUIRED REPORT SECTIONS PRESENT: 4 POINTS

TECHNICAL CONTENT CARRIES 90 POINTS DIVIDED AS:
1. FE MODEL: 20 POINTS
   1.A. IS PROBLEM MATHEMATICALLY AND FIGUATIVELY SPECIFIED WITH BOUNDARY CONDITIONS PROPERLY? AND ELEMENT PLACEMENT DESCRIBED (10 POINTS)
   1.B. IS PROBLEM OBJECTIVE SPECIFIED MATHEMATICALLY IN A WAY AS DISCUSED IN CLASS (5 POINTS)
   1.C. ARE LIMITATIONS OF SOLVING THE PROBLEM WITH GIVEN ELEMENT SIZE AND TYPE DISCUSSED (5 POINTS)
2. RESULTS: (15 POINTS)
   2.A DO RESULTS SUPPLY QUANTITATIVE DATA TO SUPPORT OBJECTIVE ACHIEVEMENT (7.5 POINTS)
   2.B HOW WELL IS DATA REPRESENTED USING ANALYSES AND PLOTS (7.5 POINTS)
3. FE EQUATIONS: (20 POINTS)
   3.A IS WEAK FORM AT ELEMENT LEVEL GIVEN? (10 POINTS) (NEEDS TO BE PROBLEM SPECIFIC)
   3.B IS A DESCRIPTION OF HOW GLOBAL FE EQUATIONS RELATED TO LOCAL FE EQUATIONS PROVIDED? (10 POINTS)
4. CONVERGENCE ANALYSES: (20 POINTS)
   4.A HOW IS THE STUDY PERFORMED (SYMMETRIC VS. RANDOM; ASPECT RATIO USE, ELEMENT SHAPES DISCUSSION) (10 POINTS)
   4.B ARE ELEMENT SHAPES DISCUSSED AND ANALYSES CORRECTNESS JUSTIFIED? DID ONE USE RIGHT PARAMETERS TO JUSTIFY CONVERGENCE? (10 POINTS)
5. ANALYTICAL SOLUTION COMPARISON (15 POINTS)
   5.A WHAT PART OF FE CHOSNE TO COMPARE WITH ANALYTICAL SOLUTION..HOW THE CHOICE IS JUSTIFIED? HOW WELL IS THE COMPARISON POSED (10 POINTS)
   5.B IS THERE A DIRECT CORRESPONDENCE BETWEEN ANALYTICAL MODEL AND MODEL SOLVED? (5 POINTS)