

**Time:** TBD

**Location:** TBD

**Instructor:**

Prof. Vikas Tomar, Ph.D.  
2033 ARMS

**Phone:** 4-3423 (765-494-3423 for off-campus)

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**Teaching Assistant (TA):** TBD

**Office hours:**

TBD

USE PIAZZA for Homework and Exam Discussions (all exams are in the form of a take-home project and require project report submission. Besides office hours online consulting sessions will be provided for exams as well)

**VERY IMPORTANT: All E-Mail Attachments must be in PDF format.**

**Try to Keep Emails short and to the point. If you need to say or explain something in extreme details then use attachments.**

**EMERGENCY**

**Public announcement from Purdue**

(Please enroll at: <http://www.purdue.edu/emergency/>)

**PLEASE NOTE THAT** Purdue's home page ([www.purdue.edu](http://www.purdue.edu)) is the official source of emergency information.

**Pre-requisite/Needed Qualifications: 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 (especially important if you are using a second hand version). LATEST PRINT WAS DONE IN JANUARY 2012. IF YOU ARE CONFUSED THEN JUST GET THE LATEST NEW VERSION SOLD AT AMAZON.COM). Please go through erratum and posted on book companion site (<http://bcs.wiley.com/he-bcs/Books?action=index&itemId=0470035803&bcsId=3625>). Also, download all code packages available at this site.

**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/launchpad.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. Please note that it's a 5-level course (senior elective and graduate introductory)

**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. Formulation: Strong and Weak Forms in one dimensional problems (**Chapter 3-Text Book**)
5. Approximation of Trial Solutions, Weight Functions and Gauss Quadrature (**Chapter 4-Text Book**)
6. Introduction to ABAQUS (**Chapter 11-Text Book**)
7. Finite Element Formulation for One-Dimensional Problems and Error Analyses (**Chapter 5-Text Book**)
8. Finite element formulation for beams (**Chapter 10-Text Book**)
9. Multi-dimensional scalar field problems (**Chapters 6, 7-Text Book**)
10. Multi-dimensional vector field problems (**Chapter 8, 9-Text Book**)
11. Plate and shell bending problems (**Class lecture-no textbook coverage**)
12. 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. Final project is your final exam.

**Grading:**

Homework	24%
exam-1 (take-home)	25%
exam-2 (take-home)	25%
preliminary report (take home)	2%
exam-3 (in the form of take home final class project)	23%
Class Survey	1% (please upload your email proof of having performed this survey on Brightspace in order to get this credit. You will get invitation for survey towards end of semester around thanksgiving holidays)

**Grades scale.**

$$\begin{bmatrix} A + & A & A - \\ B + & B & B - \\ C + & C & C - \\ D + & D & D - \end{bmatrix} = \begin{bmatrix} 97\% & 93\% & 90\% \\ 87\% & 83\% & 80\% \\ 77\% & 73\% & 70\% \\ 67\% & 63\% & 60\% \end{bmatrix}$$

Please confirm your scores (i.e., homework assignments and exams) in Brightspace throughout the semester. Students' final letter grades will be based on their scores in Brightspace.

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.

### Homeworks:

Your homeworks will be graded and solutions will be posted on the Brightspace

Homeworks will be returned through Brightspace.

**Homework return time is 11:59 PM the day it is due on Brightspace.**

**The schedule for grading and posting homework solutions is given at the end of this handout.** 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 of the submission date).

### (New!) Academic Guidance in the Event a Student is Quarantined/Isolated

Special exception will be given to quarantined/isolated students if they cannot submit homework/exams. The corresponding exams/homeworks will not be counted in overall grades and corresponding score will be weighted based on remaining submissions.

If you become quarantined or isolated at any point in time during the semester, in addition to support from the Protect Purdue Health Center, you will also have access to an Academic Case Manager who can provide you academic support during this time. Your Academic Case Manager can be reached at [acmq@purdue.edu](mailto:acmq@purdue.edu) and will provide you with general guidelines/resources around communicating with your instructors, be available for academic support, and offer suggestions for how to be successful when learning remotely. Importantly, if you find yourself too sick to progress in the course, notify your academic case manager and notify me via email or Brightspace. We will make arrangements based on your particular situation. The Office of the Dean of Students ([odos@purdue.edu](mailto:odos@purdue.edu)) is also available to support you should this situation occur.

### Final Exam:

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, Monday, NOVEMBER, 16 ON Brightspace:**  
(by the end of day 11:59 pm for every student)-

✓ You can just scribble on a page. But draw a picture, explain boundary conditions, and explain what is the outcome you are expecting.

**FINAL PROJECT REPORT DUE MONDAY, DECEMBER 07 ON Brightspace in PDF FORMAT BY THE END OF DAY (11:59 PM)**

**PLEASE SEE BRIGHTSPACE CLASS FOLDER FOR MODEL REPORTS. There will be a discussion lecture focusing on this.**

**FORMAT FOR FINAL EXAM PROJECT REPORT (see posted sample reports on Brightspace):**

- Turn in a 10 page maximum **excluding** the title page and table of contents.
- The **10 page limit also excludes 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.
- At most 4 figures (figures also means plots with at most two parts e.g. (a) (b) of each figure) are allowed in 10 pages (extra plots in appendix ok).
- At the end of this handout more details regarding the report grading are provided.
- **Information put in appendix is for your own mental satisfaction. I don't look in appendix.**

**The report should have:**

1. Cover page with title, student name (**not counted in the 10 page limit**)
2. Table of contents page (**not counted in the 10 page limit**)
3. An abstract page (counted in 10 page limit are bullets 3 to 8)
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**). Information put in appendix is for your own mental satisfaction. I don't look in appendix.

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.

**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.** (Validation needs experiments and therefore not covered in this class).

### 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. Problems come when people access teaching version over network. Unfortunately we cannot provide a lot of help here if such things happen. In that case, please use student version.

### 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 (see COVID-19 discussion on page-3). 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.

### Attendance

**I will try giving video link to lectures. All homework and exam submissions are online. All exams are take-home exams.**

**Students should stay home and contact the Protect Purdue Health Center (496-INFO) if they feel ill, have any symptoms associated with COVID-19, or suspect they have been exposed to the virus. In the current context of COVID-19, in-person attendance will not be a factor in the final grades, but the student still needs to inform the instructor of any conflict that can be anticipated and will affect the submission of an assignment or the ability to take an exam. Only the instructor can excuse a student from a course requirement or responsibility. When conflicts can be anticipated, such as for many University-sponsored activities and religious observations, the student should inform the instructor of the situation as far in advance as possible. For unanticipated or emergency conflict, when advance notification to an instructor is not possible, the student should contact the instructor as soon as possible by email, through Brightspace, or by phone. When the student is unable to make direct contact with the instructor and is unable to leave word with the instructor's department because of circumstances beyond the student's control, and in cases of bereavement, quarantine, or isolation, the student or the student's representative should contact the Office of the Dean of Students via [email](#) or phone at 765-494-1747. Our course Brightspace includes a link on Attendance and Grief Absence policies under the University Policies menu.**

**Classroom Guidance Regarding Protect Purdue**

The **Protect Purdue Plan**, which includes the **Protect Purdue Pledge**, is campus policy and as such all members of the Purdue community must comply with the required health and safety guidelines. Required behaviors in this class include: staying home and contacting the Protect Purdue Health Center (496-INFO) if you feel ill or know you have been exposed to the virus, properly wearing a mask **in classrooms and campus building**, at all times (e.g., mask covers nose and mouth, no eating/drinking in the classroom), disinfecting desk/workspace prior to and after use, maintaining appropriate social distancing with peers and instructors (including when entering/exiting classrooms), refraining from moving furniture, avoiding shared use of personal items, maintaining robust hygiene (e.g., handwashing, disposal of tissues) prior to, during and after class, and following all safety directions from the instructor.

Students who are not engaging in these behaviors (e.g., wearing a mask) will be offered the opportunity to comply. If non-compliance continues, possible results include instructors asking the student to leave class and instructors dismissing the whole class. Students who do not comply with the required health behaviors are violating the University Code of Conduct and will be reported to the Dean of Students Office with sanctions ranging from educational requirements to dismissal from the university.

Any student who has substantial reason to believe that another person in a campus room (e.g., classroom) is threatening the safety of others by not complying (e.g., not wearing a mask) may leave the room without consequence. The student is encouraged to report the behavior to and discuss next steps with their instructor. Students also have the option of reporting the behavior to the **Office of the Student Rights and Responsibilities**. See also **Purdue University Bill of Student Rights**.

**Related Considerations:**

- 1. A listing of recommended safe practices for the specific class or laboratory setting (other PPE or safety behavior) can be found at the links below.*
  - **[Overarching SOP for Classrooms, Instructional Laboratories, and Experiential Courses](#)**
- 2. References Supporting Protect Purdue Compliance:*
  - **Office of the Dean of Students [Protect Purdue Compliance Plan: Ask, Offer, Leave, Report](#)**
  - **Office of the Dean of Students [Managing Classroom Behavior and Expectations](#)**

**Academic Integrity.** <http://www.purdue.edu/odos/osrr/academic-integrity/index.html>

- **Syllabus statement.** “Academic integrity is one of the highest values that Purdue University holds. Individuals are encouraged to alert university officials to potential breaches of this value by either emailing [integrity@purdue.edu](mailto:integrity@purdue.edu) or by calling 765-494-8778. While information may be submitted anonymously, the more information that is submitted provides the greatest opportunity for the university to investigate the concern.”
- **Purdue Honors Pledge.** “As a boilermaker pursuing academic excellence, I pledge to be honest and true in all that I do. Accountable together - we are Purdue.”

- **Commercial Websites.**

- In general, notes are “considered to be ‘derivative works’ of the instructor's presentations and materials, and they are thus subject to the instructor's copyright in such presentations and materials.” As such, they cannot be sold or bartered without your express written permission. See the policy with regard to commercial note taking in classes that you may wish to include in your syllabus ([see part J of the Purdue student misc. conduct regulations](#)).
- Course materials may NOT BE posted anywhere due to copyright issues.

**Diversity & Inclusion**

- Purdue University is committed to maintaining a community which recognizes and values the inherent worth and dignity of every person; fosters tolerance, sensitivity, understanding, and mutual respect among its members; and encourages each individual to strive to reach his or her own potential. In pursuit of its goal of academic excellence, the University seeks to develop and nurture diversity. The University believes that diversity among its many members strengthens the institution, stimulates creativity, promotes the exchange of ideas, and enriches campus life. Purdue's nondiscrimination policy can be found at: [http://www.purdue.edu/purdue/ea\\_eou\\_statement.html](http://www.purdue.edu/purdue/ea_eou_statement.html).

- **When interacting with colleagues (on campus or off-campus), please conduct yourself in a professional, respectful manner**

- Please help to ensure that we have a positive working environment
- We want to have fun, but not at the expense of others
- No jokes or comments that are insensitive with regards to gender, race, religion, sexual orientation, etc.
- No wall art or white board graffiti that may be considered insensitive
- No social media posting that portrays anyone associated with AAE in a less than positive manner

**Mental Health Syllabus Statement**

**CAPS Information:** Purdue University is committed to advancing the mental health and well-being of its students. If you or someone you know is feeling overwhelmed, depressed, and/or in need of support, services are available. For help, such individuals should contact Counseling and Psychological Services (CAPS) at (765)494-6995 and <http://www.purdue.edu/caps/> during and after hours, on weekends and holidays, or through its counselors physically located in the Purdue University Student Health Center (PUSH) during business hours

**Students with Disabilities**

- **The Disability Resource Center (DRC)** is a resource for students and instructors. Students may present a “Letter of Accommodation” to you at any point in the semester. Should you have questions about accommodations, please contact the DRC at: 494-1247 or [drc@purdue.edu](mailto:drc@purdue.edu). In many cases the DRC can partner with you to develop inclusive teaching strategies that benefit all students in your class.
- **Accessibility and Accommodations Syllabus Statement:** Purdue University strives to make learning experiences as accessible as possible. If you anticipate or experience physical or academic barriers based on disability, you are welcome to let me know so that we can discuss options. You are also encouraged to contact the Disability Resource Center at: [drc@purdue.edu](mailto:drc@purdue.edu) or by phone: 765-494-1247.” <http://www.purdue.edu/drc/faculty/syllabus.html>

**Emergency Procedures**

- Emergency notification is vital! .
  - Keep your cell phone on to receive a Purdue ALERT text message. (in this case our common text system)
  - Log into a Purdue computer connected to the network...will receive any Desktop Popup Alerts.
  - If you have a “no cell phone” in class policy allow one or two students who have signed up for Purdue ALERT to keep their phones on to receive any alerts.

**EMERGENCY PREPAREDNESS – A MESSAGE FROM PURDUE**

To report an emergency, **call 911**. To obtain updates regarding an ongoing emergency, sign up for Purdue Alert text messages, view [www.purdue.edu/ea](http://www.purdue.edu/ea).

There are nearly 300 **Emergency Telephones** outdoors across campus and in parking garages that connect directly to the PUPD. If you feel threatened or need help, push the button and you will be connected immediately.

If we hear a **fire alarm** during class we will immediately suspend class, evacuate the building, and proceed outdoors. Do not use the elevator.

If we are notified during class of a **Shelter in Place requirement for a tornado** warning, we will suspend class and shelter in [the basement].

If we are notified during class of a **Shelter in Place requirement for a hazardous materials release, or a civil disturbance**, including a shooting or other use of weapons, we will suspend class and shelter in the classroom, shutting the door and turning off the lights.

Please review the Emergency Preparedness website for additional information. [http://www.purdue.edu/ehps/emergency\\_preparedness/index.html](http://www.purdue.edu/ehps/emergency_preparedness/index.html)

***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](#)

**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)****FORMATING 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 MATHMATICALLY IN A WAY AS DISCUSSED 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 CHOSEN 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)