Department of Civil Engineering
The University of Texas Arlington

CE 5310 - PLASTIC ANALYSIS AND DESIGN OF STRUCTURES

Summer 2016

Prerequisite: CE 4348 Steel Design or Equivalent

Instructor: Dr. Shih-Ho (Simon) Chao, Ph.D., P.E.

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Office Telephone Number: 817-272-2550

Email Address: shchao@uta.edu

Faculty Profile: https://www.uta.edu/profiles/shih-ho-chao

Office Hours:

- Mondays and Wednesdays, 12:30 PM-2:30PM
- Questions via e-mail
- Or by appointment

Section Information: CE 5310-001; CE 5310-002

Time and Place of Class Meetings: Jun 6 to August 10; Mondays and Wednesdays, 10:30 AM-12:20 PM, NH 109

Course Content:

- Elastic Design versus Plastic Design; Earthquake-Resistance Design; Related Information in AISC Seismic Provisions;
- Overview of Inelastic Behavior of Steel Structural Members; Ductile and Non-Ductile Failure Modes;
- Stress-Strain Response of Steel under Monotonic and Cyclic Loadings; Plastic Properties; Strain Rate Effect; Hysteretic Loops; Bauschinger Effect; Isotropic and Kinematic Hardening and Models; Brace Buckling;
- Mechanism of Plastic Deformation and Strain-Hardening of Steel; Dislocation; Fracture; Low-Cycle Fatigue; Fatigue Mechanisms and Microscopic Features;
- Inelastic Moment-Curvature Relations of Typical Structural Steel; Plastic Hinges; Plastic Hinge Rotations; Load-Deflection of Inelastic Members; Methods of Plastic Analysis to Determine the Ultimate Load-Carrying Capacity of Steel Members; Upper Bound Theorem; Lower Bound Theorem; Uniqueness Theorem; Stepwise Incremental Methods for Studying

the Behavior of Steel Structures Beyond the Elastic Range up to Collapse; Mechanism Method;

- Factors Influencing the Plastic Moment Capacity of Steel Members; Residual Stresses; Local Buckling; Lateral-Torsional Buckling; Shear; Shear Hinges; Multi-Axial States of Stress; von Mises Criterion; Axial Loads;

- Plastic Design for Seismic-Resistant Structures; structural analysis and design include moment frames (MFs), concentrically-braced frames (CBFs), eccentrically-braced frames (EBFs), buckling-restrained braced frames (BRBFs), special truss moment frames (STMFs), as well as some other framing systems will be discussed;

- Computer Software: XTRACT and PERFORM-2D/3D computer programs will be introduced. The former is used for obtaining moment-curvature curves of sections with any material and geometric shapes; and the latter is used to perform inelastic pushover and dynamic analyses for structures subjected to extreme events such as earthquake loadings.

Student Learning Outcomes:

After completion of the course, the student should be able to:

- ✓ Understand the micromechanical behavior of plasticity and fracture mechanism of steel.
- ✓ Recognize the difference between elastic and plastic behavior of structural members.
- ✓ Determine the yield mechanisms and ultimate strength of structures.
- ✓ Use computer programs to perform nonlinear static (pushover) and dynamic analyses of structures.
- ✓ Design structures by plastic method.
- ✓ Perform seismic design and analysis of steel structures by plastic methodology.

Attendance: required.

Make-up Classes:

Will be announced later.

Major assignments and examinations:

Homework:

- ➢ Homework problems will be assigned each Monday (or Wednesday) and are generally due on the following Monday (or Wednesday). All homework will be counted towards the final grade.
- ➢ Homework will be collected at the beginning of class on the due date. A late homework loses 30% per day.
- ➢ Students are encouraged to talk to the instructor about those assigned problems the student is having trouble with.
- ➢ Students are also encouraged to work in small groups to develop solutions to the problems but each student must write up his/her own homework. No credit will be given for homework copied or if your homework has been copied.

Term Project:

Project details will be announced sometime in mid-July. Final presentation of the term project is on Wednesday August 10 during lecture and the report (both hardcopy and electronic copy, as well as the PowerPoint presentation) is due on the same date.

Examinations:

There will be one mid-term exam (in class: including Distance Learning students) and a final examination (comprehensive exam). Open book, notes, and homework.

Scheduled exam dates are: Mid-term: July 18 (Monday), 10:30AM to 12:20PM
Final exam: August 15 (Monday), 10:30AM to 12:30PM

For online students, if you decide to take another class at the same time or overlapping with this class, you need to make a plan for your another class. You need to take the exam at the same time with all the other students.

Make-up Exam Policy:

Makeup exams are given only in extreme circumstances; examples of extreme circumstances are serious illness of the student (doctor's note required) or death in the family. I must be contacted before the exam if such a circumstance applies to you.

Grading: The course grade will be based on:

20% - Homework
20% - Term Project
30% - Mid-term exam
30% - Final exam

100%

Final exam will not be returned, but may be reviewed by students.

The grade assigned to the student's numerical average will be as follows:

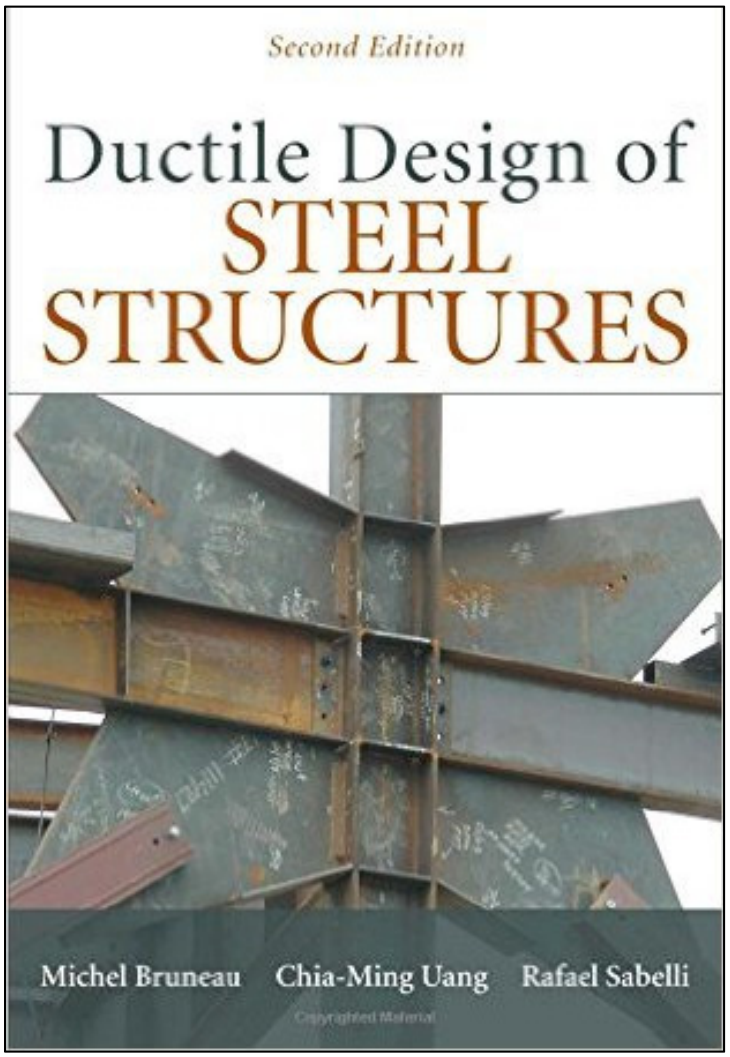
(a)	90 to 100 average	=	A
(b)	80 to 89.9 average	=	B
(c)	70 to 79.9 average	=	C
(d)	60 to 69.9 average	=	D
(e)	< 60 average	=	F

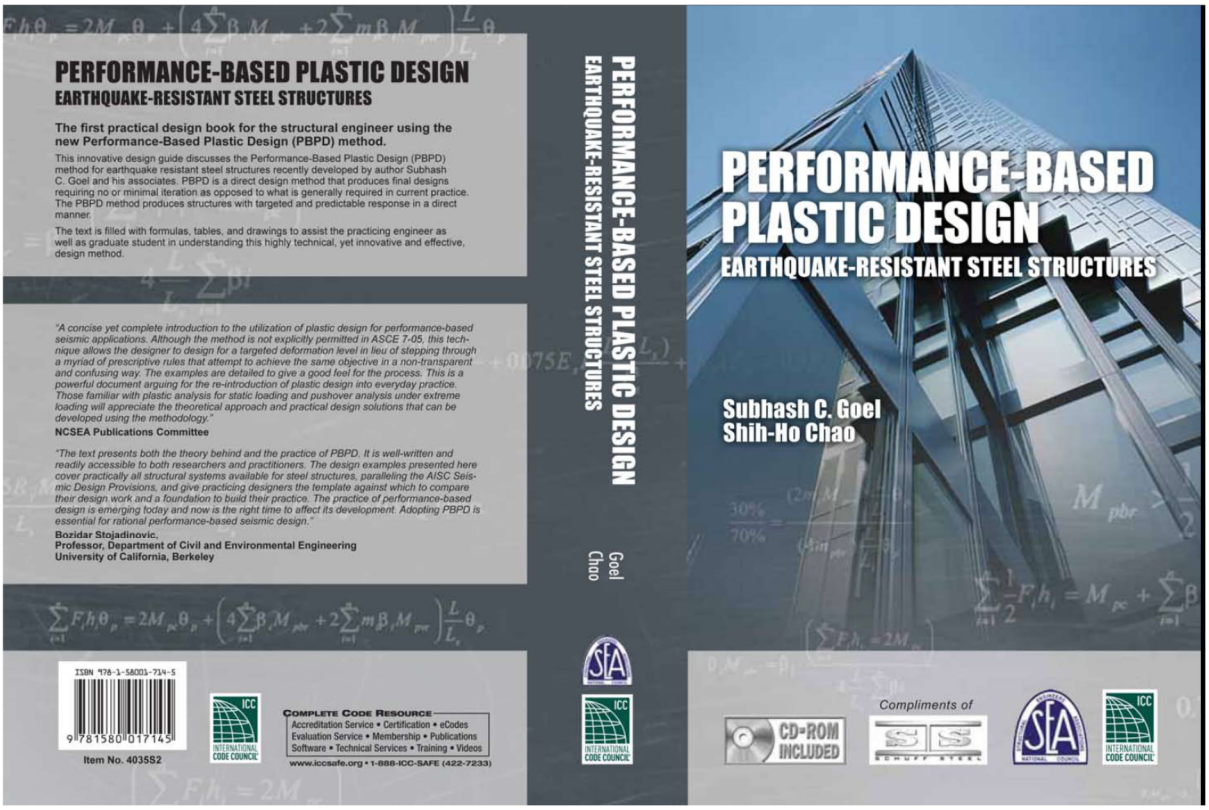
Required Textbooks and Other Course Materials:

Textbook is not required.

Major References:

- "Ductile Design of Steel Structures" by Michel Bruneau, Chia-Ming Uang, and Rafael Sabelli. Second Edition, McGraw-Hill, 2011.
- AISC. (2010). Specification for Structural Steel Buildings. ANSI/AISC Standard 360-10, American Institute of Steel Construction, Chicago, Illinois.
- AISC. (2010). Seismic Provisions for Structural Steel Buildings. ANSI/AISC Standard 341-10, American Institute of Steel Construction, Chicago, Illinois.
- Goel, Subhash. C., and Chao, Shih-Ho. (2008). Performance-Based Plastic Design: Earthquake Resistant Steel Structures. International Code Council (ICC), 261 pp.




PERFORMANCE-BASED PLASTIC DESIGN
EARTHQUAKE-RESISTANT STEEL STRUCTURES
The first practical design book for the structural engineer using the new Performance-Based Plastic Design (PBPD) method.
This innovative design guide discusses the Performance-Based Plastic Design (PBPD) method for earthquake resistant steel structures recently developed by author Subhash C. Goel and his associates. PBPD is a direct design method that produces final designs requiring no or minimal iteration as opposed to what is generally required in current practice. The PBPD method produces structures with targeted and predictable response in a direct manner.
The text is filled with formulas, tables, and drawings to assist the practicing engineer as well as graduate student in understanding this highly technical, yet innovative and effective, design method.
"A concise yet complete introduction to the utilization of plastic design for performance-based seismic applications. Although the method is not explicitly permitted in ASCE 7-05, this technique allows the designer to design for a targeted deformation level in lieu of stepping through a myriad of prescriptive rules that attempt to achieve the same objective in a non-transparent and confusing way. The examples are detailed to give a good feel for the process. This is a powerful document arguing for the re-introduction of plastic design into everyday practice. Those familiar with plastic analysis for static loading and pushover analysis under extreme loading will appreciate the theoretical approach and practical design solutions that can be developed using the methodology."
NCSEA Publications Committee
"The text presents both the theory behind and the practice of PBPD. It is well-written and readily accessible to both researchers and practitioners. The design examples presented here cover practically all structural systems available for steel structures, paralleling the AISC Seismic Design Provisions, and give practicing designers the template against which to compare their design work and a foundation to build their practice. The practice of performance-based design is emerging today and now is the right time to affect its development. Adopting PBPD is essential for rational performance-based seismic design."
Bozidar Stojadinovic,
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University of California, Berkeley
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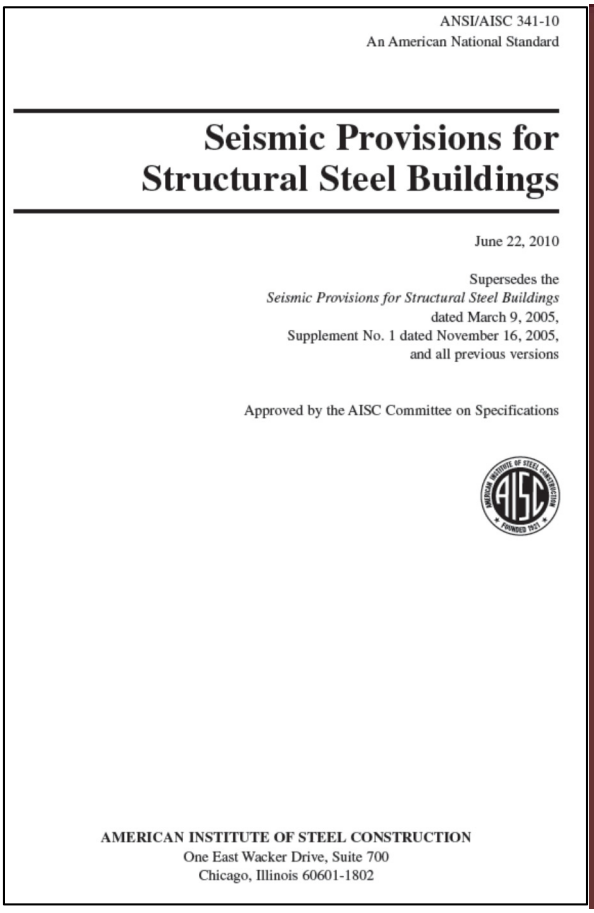
ANSI/AISC 341-10
An American National Standard
Seismic Provisions for Structural Steel Buildings
June 22, 2010
Supersedes the
Seismic Provisions for Structural Steel Buildings
dated March 9, 2005,
Supplement No. 1 dated November 16, 2005,
and all previous versions
Approved by the AISC Committee on Specifications
AMERICAN INSTITUTE OF STEEL CONSTRUCTION
One East Wacker Drive, Suite 700
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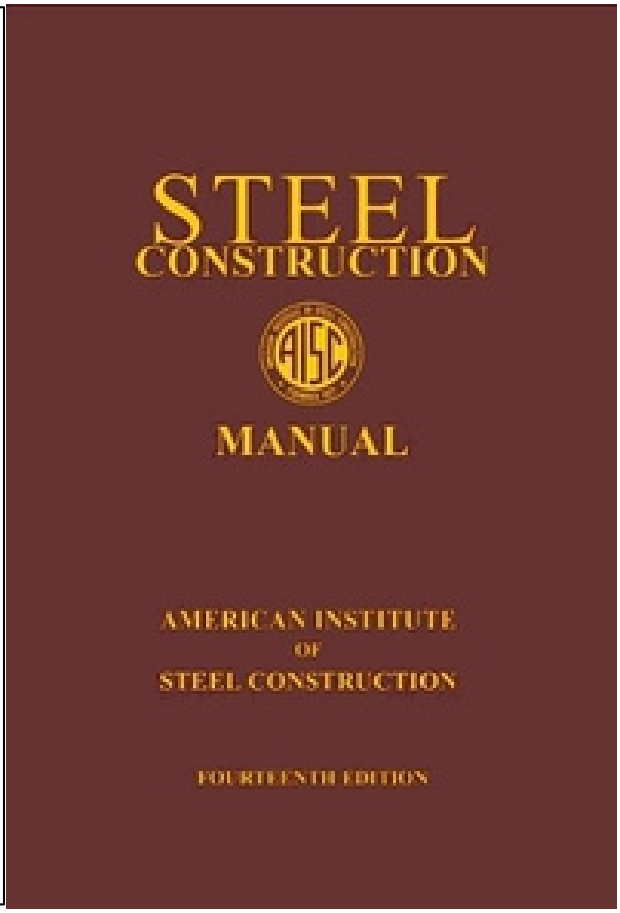
STEEL
CONSTRUCTION
MANUAL
AMERICAN INSTITUTE
OF
STEEL CONSTRUCTION
FOURTEENTH EDITION

Other useful References:

- AISC. (2012). Seismic Design Manual. 2nd Edition, American Institute of Steel Construction, Chicago, Illinois.
- AISC., ANSI/AISC 358-10, Prequalified Connections for Special and Intermediate Steel Moment Frames for Seismic Applications, American Institute of Steel Construction, Chicago, Illinois., 2010.
- Beedle, L. S., Plastic Design of Steel Frames, John Wiley and Sons, New York, 1966.
- Chao, S.-H. and Goel, S. C., Performance-Based Seismic Design of EBF Using Target Drift and Yield Mechanism as Performance Criteria, Report No. UMCEE 05-05, Department of Civil and Environmental Engineering, University of Michigan, Ann Arbor, MI., 2005.
- Chao, S.-H. and Goel, S. C., Performance-Based Plastic Design of Seismic Resistant Special Truss Moment Frames, Report No. UMCEE 06-03, Department of Civil and Environmental Engineering, University of Michigan, Ann Arbor, MI., 2006.
- Chao, S.-H. and Goel, S. C., "Performance-Based Design of Eccentrically Braced Frames Using Target Drift and Yield Mechanism," AISC Engineering Journal, 3rd Quarter, 2006, pp. 173-200.
- Chao, S.-H. and Goel, S. C., "A Seismic Design Method for Steel Concentric Braced Frames for Enhanced Performance," Proceedings, Fourth International Conference on Earthquake Engineering, Taipei, Taiwan., 2006.
- Chao, S.-H., and Goel, S. C., "Performance-Based Plastic Design of Special Truss Moment Frames," AISC Engineering Journal, 2nd Quarter, 2008, pp. 127-150.
- Chao, S.-H. Goel, S. C, and Lee, S.-S., "A Seismic Design Lateral Force Distribution Based on Inelastic State of Structures," Earthquake Spectra, Earthquake Engineering Research Institute, Vol. 23, No.3, 2007, pp. 547-569.
- Chen, W. F. and Sohal, I., Plastic Design and Second-Order Analysis of Steel Frames, Springer-Verlag, 1995.
- Chen. W. F. and Han, D. J., Plasticity for Structural Engineers, Gau Lih Book Co., LTD., 1995, 606 pages.
- Disque, R. O., Applied Plastic Design in Steel, Van Nostrand Reinhold, 1983.
- Galambos, T. V. and Surovek, A. E., Structural Stability of Steel—Concepts and Applications for Structural Engineers, John Wiley & Sons, Inc., 2008, 373 pp.
- Goel, S. C. and Leelataviwat, S., "Seismic Design by Plastic Method," Engineering Structures, Vol. 20, No. 4-6, April-Jun, 1998, pp. 465-471.
- Goel, S. C., Liao, W.-C., Bayat, M. R., and Chao, S.-H. (2010), "Performance-Based Plastic Design (PBPD) Method for Earthquake-Resistant Structures: An Overview" The Structural Design of Tall and Special Buildings, Vol. 19, pp. 115-137.

- Hodge, P. G., Plastic Analysis of Structures, McGraw-Hill, Book Co., New York, 1981.
- Lee, S.-S. and Goel, S. C., Performance-Based Design of Steel Moment Frames Using Target Drift and Yield Mechanism, Report No. UMCEE 01-17, Department of Civil and Environmental Engineering, University of Michigan, Ann Arbor, MI., 2001.
- Lee, S.-S., Goel, S. C., and Chao, S.-H., "Performance-Based Design of Steel Moment Frames Using Target Drift and Yield Mechanism," Proceedings, 13th World Conference on Earthquake Engineering, Paper No. 266, Vancouver, B. C., Canada., 2004.
- Leelataviwat, S., Goel, S. C., and Stojadinović, B., "Toward Performance-Based Seismic Design of Structures," Earthquake Spectra, Vol. 15, No. 3, 1999, pp. 435-461.
- Massonnet, C. E. and Save, M. A., Plastic Analysis and Design; Volume One—Beams and Frames, Blaisdell, New York, 1965.
- Moy, S. S. J., Plastic Methods for Steel and Concrete Structures, Second Edition, Macmillan Press Ltd., 1996.
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- Park. R. and Paulay, T., Reinforced Concrete Structures, John Wiley and Sons, New York, 1975.
- Powell, G. H. (2010). Modeling for Structural Analysis – Behavior and Basics. Computers and Structures, Inc., 365 pp.
- Sahoo, D. R. and Chao, S.-H. (2010), "Performance-Based Plastic Design Method for Buckling-Restrained Braced Frames," Engineering Structures, Vol. 32, pp. 2950-2958.
- Salmon, C. G., Johnson, J. E., and Malhas, F. A. Steel Structures - Design and Behavior, Fifth Edition, HarperCollins, New York, 2009.

Drop Policy:

Students may drop or swap (adding and dropping a class concurrently) classes through self-service in MyMav from the beginning of the registration period through the late registration period. After the late registration period, students must see their academic advisor to drop a class or withdraw. Undeclared students must see an advisor in the University Advising Center. Drops can continue through a point two-thirds of the way through the term or session. It is the student's responsibility to officially withdraw if they do not plan to attend after registering. **Students will not be automatically dropped for non-attendance**. Repayment of certain types of financial aid administered through the University may be required as the result of dropping classes or withdrawing. For more information, contact the Office of Financial Aid and Scholarships (http://wweb.uta.edu/aao/fao/).

Americans with Disabilities Act:

The University of Texas at Arlington is on record as being committed to both the spirit and letter of all federal equal opportunity legislation, including the *Americans with Disabilities Act (ADA)*. All instructors at UT Arlington are required by law to provide "reasonable accommodations" to students

with disabilities, so as not to discriminate on the basis of that disability. Any student requiring an accommodation for this course must provide the instructor with official documentation in the form of a letter certified by the staff in the Office for Students with Disabilities, University Hall 102. Only those students who have officially documented a need for an accommodation will have their request honored. Information regarding diagnostic criteria and policies for obtaining disability-based academic accommodations can be found at www.uta.edu/disability or by calling the Office for Students with Disabilities at (817) 272-3364.

Title IX:

The University of Texas at Arlington is committed to upholding U.S. Federal Law "Title IX" such that no member of the UT Arlington community shall, on the basis of sex, be excluded from participation in, be denied the benefits of, or be subjected to discrimination under any education program or activity. For more information, visit www.uta.edu/titleIX.

Academic Integrity:

Students enrolled in this course are expected to adhere to the UT Arlington Honor Code:

> *I pledge, on my honor, to uphold UT Arlington's tradition of academic integrity, a tradition that values hard work and honest effort in the pursuit of academic excellence.*
>
> *I promise that I will submit only work that I personally create or contribute to group collaborations, and I will appropriately reference any work from other sources. I will follow the highest standards of integrity and uphold the spirit of the Honor Code.*

UT Arlington faculty members may employ the Honor Code as they see fit in their courses, including (but not limited to) having students acknowledge the honor code as part of an examination or requiring students to incorporate the honor code into any work submitted. Per UT System *Regents' Rule* 50101, §2.2, suspected violations of university's standards for academic integrity (including the Honor Code) will be referred to the Office of Student Conduct. Violators will be disciplined in accordance with University policy, which may result in the student's suspension or expulsion from the University.

Student Support Services:

UT Arlington provides a variety of resources and programs designed to help students develop academic skills, deal with personal situations, and better understand concepts and information related to their courses. Resources include tutoring, major-based learning centers, developmental education, advising and mentoring, personal counseling, and federally funded programs. For individualized referrals, students may visit the reception desk at University College (Ransom Hall), call the Maverick Resource Hotline at 817-272-6107, send a message to resources@uta.edu, or view the information at www.uta.edu/resources.

Lab Safety Training:

[Required for laboratory courses in the Colleges of Engineering and Science] Students registered for this course must complete all required lab safety training prior to entering the lab and undertaking any activities. Once completed, Lab Safety Training is valid for the remainder of the same academic year (i.e., through the following August) and must be completed anew in

subsequent years. There are no exceptions to this University policy. Failure to complete the required training will preclude participation in any lab activities, including those for which a grade is assigned. [As necessary, continue with specific course-based information regarding the module(s) required, etc.]

Electronic Communication:

UT Arlington has adopted MavMail as its official means to communicate with students about important deadlines and events, as well as to transact university-related business regarding financial aid, tuition, grades, graduation, etc. All students are assigned a MavMail account and are responsible for checking the inbox regularly. There is no additional charge to students for using this account, which remains active even after graduation. Information about activating and using MavMail is available at http://www.uta.edu/oit/cs/email/mavmail.php.

Student Feedback Survey:

At the end of each term, students enrolled in classes categorized as "lecture," "seminar," or "laboratory" shall be directed to complete an online Student Feedback Survey (SFS). Instructions on how to access the SFS for this course will be sent directly to each student through MavMail approximately 10 days before the end of the term. Each student's feedback enters the SFS database anonymously and is aggregated with that of other students enrolled in the course. UT Arlington's effort to solicit, gather, tabulate, and publish student feedback is required by state law; students are strongly urged to participate. For more information, visit http://www.uta.edu/sfs.

Final Review Week:

A period of five class days prior to the first day of final examinations in the long sessions shall be designated as Final Review Week. The purpose of this week is to allow students sufficient time to prepare for final examinations. During this week, there shall be no scheduled activities such as required field trips or performances; and no instructor shall assign any themes, research problems or exercises of similar scope that have a completion date during or following this week *unless specified in the class syllabus*. During Final Review Week, an instructor shall not give any examinations constituting 10% or more of the final grade, except makeup tests and laboratory examinations. In addition, no instructor shall give any portion of the final examination during Final Review Week. During this week, classes are held as scheduled. In addition, instructors are not required to limit content to topics that have been previously covered; they may introduce new concepts as appropriate.

Emergency Exit Procedures:

Should we experience an emergency event that requires us to vacate the building, students should exit the room and move toward the nearest exit, which is located at the end of the hallway. When exiting the building during an emergency, one should never take an elevator but should use the stairwells. Faculty members and instructional staff will assist students in selecting the safest route for evacuation and will make arrangements to assist handicapped individuals.

Librarian to Contact:

Sylvia George-williams (Sylvia@uta.edu), Science & Engineering Librarian.

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