THE UNIVERSITY OF TEXAS AT AUSTIN
DEPARTMENT OF MECHANICAL ENGINEERING

# ME381Q.1 ENGINEERING ANALYSIS: ANALYTICAL METHODS
# SPRING 2015

Unique Numer #18243: Tuesdays and Thursdays (9:30-11am, ETC 5.148)

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**Office Hours:** Tuesdays 3:30-5:30pm and Wednesdays 3-5pm or by appointment

**Objective:**
Objective of this course is to enable students to understand and apply standard mathematical techniques used in mechanically-oriented engineering practice and research literature. More specifically, the students are expected to obtain understanding and mastery of key analytical and numerical methods for solving ordinary and partial differential equations, with strong application focus in mechanical engineering applications.

**Goals:**
- Learn key analytical techniques for solving various forms of ordinary differential equations
- Prove key theorems pertaining to ordinary differential equations most frequently encountered in mechanical engineering
- Learn most frequently used approximate methods for solving ordinary differential equations
- Demonstrate key theoretical concepts from the theory of ordinary differential equations using simulations of typical mechanical engineering systems
- Learn analytical methods for solving key partial differential equations encountered in mechanical engineering research and practice

**Prerequisites:**
At least one course in:
- Ordinary differential equations (this is not the first time you are having a course on ordinary differential equations)
- Advanced calculus (knowledge of derivatives, integrals, partial derivatives)
- Knowledge of key linear algebra concepts (you know matrix calculus, are able to find eigenvalues and eigenvectors of matrices, are aware of the concept of linear dependence/independence of vectors)

**Required text:**
Greenberg, M. D., 1998, *Advanced Engineering Mathematics,* 2nd Edition, Pearson (Englewood Cliffs, NJ), ISBN-10: 0133214311.

**Additional text (not required):**
Snider, A. D., 2006, *Partial Differential Equations: Sources and Solutions,* Dover Publications (Mineola, NY) ISBN-10: 0486453405.

**Recommended Math Programs (or Symbolic Manipulator):**
Matlab, Mathematica, or MathCad

**Exams:**

- **1st Midterm Exam (in class); March 12, 2015, 9:30-10:45am**
- **2nd Midterm Exam (in class); April 16, 2015, 9:30-10:45am**
- **Final Exam (comprehensive 3 hour exam); May 18, 2-5pm**

**Homeworks:**
Homeworks will be given approximately every week. Late homeworks will not be accepted. Lowest homework score will be dropped from the final grade calculations!

**Grading**

- Homeworks – 25%
- First and second midterm[1] – 45%
- Final exam – 30%

**Re-grading Policy:**
Re-grade requests for homeworks and exams will be honored up to 7 days after the corresponding assignment was returned to the students. After that, even justified requests will not be honored.

**Dean's Scholastic Dishonesty Policy**
Any plagiarism or cheating on exams, quizzes and homework will be reported according to The University's Policy on Scholastic Dishonesty and the Mechanical Engineering Department's Honor Code, http://registrar.utexas.edu/catalogs/gi09-10/ch01/.

**Students with Disabilities**
Students with disabilities may request appropriate academic accommodations from the Division of Diversity and Community Engagement, Services for Students with Disabilities, 471-6259, *http://www.utexas.edu/diversity/ddce/ssd/.*

**Religious Observances**
By UT Austin policy, you must notify the instructor of your pending absence at least fourteen days prior to the date of observance of a religious holyday. If you must miss a class, an examination, a work assignment, or a project in order to observe a religious holyday, you will be given an opportunity to complete the missed work within a reasonable time after the absence.

[1] Lower of the two scores will be weighed 20%, while the higher of the two scores will be weighed 25%.

# Course Timeline and Texts

**Week 1 (Jan 20 & 22, 2015)**

- Course intro
- Linear 1st order Ordinary Differential Equations (ODEs) (Sec. 2.2)
- Lagrange's method of undetermined coefficients, applications (Sec. 2.3)

**Week 2 (Jan 27 & 29, 2015)**

- First order nonlinear ODEs (Sec. 2.3, 2.4 and 2.5)
    - Bernoulli
    - Riccati
    - Separable equations
    - Exact coefficients and integrating factors

**Week 3 (Feb 3 & 5, 2015)**

- Higher order ODEs (Chapter 3)
    - Linear dependence, independence, Wronskians, general and particular solutions (Sec. 3.2)
    - Homogeneous linear ODEs (Sec. 3.3)
        - Existence and uniqueness theorem

**Week 4 (Feb. 10 & 12, 2015)**

- Homogeneous linear ODEs (Sec. 3.3)
    - General solution theorem
- Homogeneous linear ODEs with **constant** coefficients (Sec. 3.4)
    - Methods
    - Reduction of order
    - Examples (3.5)

**Week 5 (Feb. 17 & 19, 2015)**

- Homogeneous linear ODEs with **non-constant** coefficients – special cases that can be solved analytically (Sec. 3.6)
    - Cauchy-Euler Eqn.
    - Legendre's Eqn.
    - Examples

**Week 6 (Feb. 24 & 26, 2015)**

- Non-homogeneous linear ODEs (Sec. 3.7)
    - Homogeneous and particular solutions
    - Method of undetermined coefficients
    - Method of variation of parameters
    - Examples

**Week 7 (Mar. 3 & 5, 2015)**

- Non-homogeneous linear ODEs – application to harmonic oscillations (Sec. 3.8)
  - Free oscillations
  - Forced oscillations
  - Asymptotic behavior

**End of material for midterm 1**

**Week 8 (Mar. 10 & 12, 2015)**

- Solving systems of linear ODEs with constant coefficients using method of elimination (Sec 3.9)
- Review for the first midterm

- **First midterm – March 12, 2012 (weeks 1-7)**

**Week 9 (Mar 17 & 19, 2015)**
**No lectures**
Spring-break

**Week 10 (Mar. 24 & 26, 2015)**

- Solving systems of equations using matrix eigenvalue approaches (Chapter 11)
  - Review of e-value/e-vector theorems (11.2)
  - E-values/e-vectors for symmetric matrices (11.3)
  - Matrix diagonalization (11.4)

**Week 11 (Mar. 31 & Apr. 2, 2015)**

- Solving systems of equations using matrix eigenvalue approaches – Theory of Oscillations (Chapter 11)
  - Solving systems of linear ODEs with constant coefficients using matrix approaches (11.5)
  - Harmonic oscillators (unforced, forced)
- Laplace transforms (Chapter 5)
  - Introduction, basic properties, Laplace transforms of key functions (Sec. 5.1 – Sec. 5.3, Sec. 5.5, 5.6)

**Week 12 (Apr. 7 & 9, 2015)**

- Laplace transforms (Chapter 5 and course material)
  - Partial fraction expansion, using Laplace transforms to solve ODEs with constant coefficients (Sec. 5.4)
  - Asymptotic behavior with harmonic oscillations (Sec. 5.7)

**End of material for midterm 2**

**Beginning of approximate methods for solving ODEs**

**Week 13 (Apr. 14 & 16, 2015)**

- Linearization (course notes)
- **Second midterm – April 16, 2015.**

**Week 14 (Apr. 21 & 23, 2015)**

- Power-series based methods (Chapter 4)
  - Functional series, fundamental convergence theorems (Sec. 4.1 – 4.2)
  - Method of Frobenius (Sec. 4.3)
- Iterative numerical methods (Chapter 6)
  - Euler's method, Heun's method, solving systems of equations using iterative numerical methods (Sec. 6.1 – 6.3)

**Beginning of PDE related lectures**

**Week 15 (Apr. 28 & 30, 2015)**

- Fourier Analysis (Chapter 17)
  - Fourier series of periodic functions (Sec. 17.1-17.3)
  - Manipulations of Fourier Series (Sec. 17.4-17.5)

**Week 16 (May 5 & 7, 2015)**

- Vibrating string (Chapter 19)
  - Deriving equations (19.1)
  - Solution by separation of variables (19.2)
- **Time-permitting** - diffusion equation (Chapter 18)
  - Basic concepts (Sec. 18.2)
  - Solution by separation of variables (Sec. 18.3)

**Final Exam: Monday, May 18, 2:00-5:00 pm (location TBD)**