AUBURN UNIVERSITY

SAMUEL GINN
COLLEGE OF ENGINEERING

AEROSPACE

Special Topics: Perturbation Methods in Engineering

AERO 4970/7970 **Course Outline** **Fall Semester 2014**

Lecturer: Joseph Majdalani, P.E., Ph.D.

Lecture Times: TBD

Lecture Location: TBD

Office Hours: TBD

Contacts: (1) email: maji@auburn.edu; (2) office: 334-844-6800.

Homepage: http://majdalani.eng.auburn.edu/teaching.html

Teaching Assistant: TBD.

Textbook: Class notes and David C. Wilcox, Perturbation Methods in the Computer Age, DCW Industries, Inc., 1995.

References:

1. Milton Van Dyke, Perturbation Methods in Fluid Mechanics, Annotated Edition, Parabolic Press, Inc., Stanford, CA, 1975.
2. Bhimsen K. Shivamoggi, Perturbation Methods for Differential Equations, Birkhäuser, Boston, 2002.
3. Carl M. Bender, and Steven A. Orszag, Advanced Mathematical Methods for Scientists and Engineers, McGraw-Hill, Inc., 1978.
4. Shijun Liao, Beyond Perturbation: Introduction to the Homotopy Analysis Method, 1st ed., Chapman & Hall/CRC Press, Boca Raton, FL, 2003.
5. Ali Hassan Nayfeh, Introduction to Perturbation Techniques, Wiley Classics Library Edition, John Wiley & Sons, Inc., 1981.
6. Ali Hassan Nayfeh, Perturbation Methods, John Wiley & Sons, Inc., 1973.
7. James A. Murdock, Perturbation Theory and Methods, John Wiley & Sons, Inc., 1991.
8. Jerry Kevorkian, and Julian D. Cole, Multiple Scale and Singular Perturbation Methods, Springer-Verlag, Inc., 1996.

9. A. Aziz, and T. Y. Na, Perturbation Methods in Heat Transfer, Hemisphere Publishing Corp., 1984.

Prerequisites: Differential Equations.

Objectives: The purpose of this course is to introduce students to asymptotic methods used in the construction of analytical approximations to transcendental equations and differential equations. By the end of the course students will be able to:

- understand when and how perturbation methods can be applied;
- obtain regular perturbation solutions to algebraic equations involving small or large parameters;
- construct perturbation solutions to linear and nonlinear boundary value problems for ODEs;
- identify singular perturbation problems and apply one of the strained-coordinate methods;
- understand how solutions to initial value problems may depend on slow and fast scales and apply matched asymptotic and multiple scale methods to such problems.

Motivation: Many of the problems facing physicists, engineers, and applied mathematicians involve such difficulties as nonlinear governing equations, variable coefficients, and nonlinear boundary conditions at complex known or unknown boundaries that preclude solving them exactly. Consequently, solutions are approximated using numerical techniques, analytic techniques, and combinations of both. Foremost among the analytic techniques are the systematic methods of perturbations in terms of a small or large parameter or coordinate. This course is concerned with these perturbation techniques. The advantage of having an approximate formula to the solution of an equation, as opposed to having a computer program that generates numbers, is that it is more easily possible to see the role of the different variables and parameters in the solution. The key to solving modern problems is mathematical modeling. This process involves retaining certain elements, neglecting some, and approximating yet others. To accomplish these important steps, one needs to decide the order of magnitude of the different elements appearing in the system.

Catalog Data: Solution of nonlinear problems in solid and fluid mechanics and dynamics by use of asymptotic perturbation techniques. Asymptotic expansions, regular and singular perturbations and applications in dynamics, celestial mechanics, potential, viscous and compressible flows. Uniformly valid approximations in various physical problems. Generalized boundary-layer techniques. Coordinate straining techniques; Poincaré's method. Matched asymptotic expansions and multiple scales. Problems with several time or length scales. Examples taken from various fields of science.

Grading and Exams: The final grade is based on the best score earned under any one of the four options described below.

Option 1	**Option 2**	**Option 3**	**Option 4**
Homework: 20%.	Homework: 20%.	Notebook: 10%.	Notebook: 10%.
Exam I: 20%.	Best Exam: 20%.	Homework: 20%.	Homework: 20%.
Exam II: 20%.	Final: 60%.	2 Exams: 40%.	Best Exam: 20%.
Final: 40%.		Final: 30%.	Final: 50%.

Perturbation Methods in Engineering

Lecture		Date	Topics		
1	August	18	Introduction	*Week 1*	
			Examples		
			High-order polynomial		
2		23	High-order polynomial	*Week 2*	
3		25	Landau Orders		
			Gauge Functions		
4		30	Non-dimensionalizing Equations.	*Week 3*	
5	September	1	Regular Pert. –Von Karman's Eqn.		
			Regular Pert. –Heat Transfer Prob.		
		6	NO CLASS–Labor Day Holiday	*Week 4*	
6		8	Regular Pert. –Method of Ansatz.		
7		13	Regular Pert. –Laplace's Eq.	*Week 5*	
8		15	Regular Pert. –Flow Past Cylinder		
9		20	Singular Pert. –Nonlinear Spring	*Week 6*	
10		22	Singular Pert. –Nonlinear Spring		
11		27	Strained Coordinates –Lindstedt	*Week 7*	
12		29	Strained Coordinates –Lindstedt		
13	October	4	EXAM I	*Week 8*	Take Home
		6	NO CLASS–Fall Break		
14		11	Strained Coordinates –PLK BCs	*Week 9*	
15		13	Strained Coordinates –PLK		
16		18	Strained Coordinates –Pritulo	*Week 10*	
17		20	Boundary Layer Theory –Prandtl		
18		25	Inner Approximation –Erdelyi	*Week 11*	
19		27	Van Dyke's Matching Principle		
20	November	1	Matched-Asymptotic Expansions	*Week 12*	
21		3	Multiple Scales		
22		8	Multiple Scales	*Week 13*	
23		10	Multiple Scales		
24		15	Nonlinear Scales	*Week 14*	
		17	NO CLASS—Thanksgiving		
25		22	EXAM II	*Week 15*	Take Home
26		24	GST Method		
27		29	Other Topics and Review	*Week 16*	
	December	1	NO CLASS–Study Period		
28		6	FINAL EXAM (TBD)	*Week 17*	Take Home