DESIGN, ROBOTICS, AND MANUFACTURING (DROM) MAJOR FIELD SYLLABUS

Mechanical and Aerospace Engineering Department
University of California, Los Angeles

The program is developed around an integrated approach to design, robotics, and manufacturing. It includes research on manufacturing and design aspects of mechanical systems; material behavior and processing; robotics and manufacturing systems; CAD/CAM theory and applications; computational geometry and geometric modeling, composite materials and structures; automation and digital control systems, micro- and nano-devices, Radio Frequency Identification (RFID) and wireless systems.

Summary of Major Field Body of Knowledge:

Students should master the major field body of knowledge covered in six of the following courses: MAE 262, MAE 263A, MAE 263B, MAE 263C, MAE 277, MAE M280B, MAE 294A, MAE 295A, MAE C296A, MAE 296B, MAE C297A (*equivalent to MAE 298 on Rapid Prototyping and Manufacturing*), MAE C237, and MAE 297B (*equivalent to MAE 298 on Nanomanufacturing Science and Engineering*).

The written qualifying (preliminary) examination covers a subset of the major field body of knowledge, defined by any four of the following courses.

1. MAE C237
2. MAE 262
3. MAE 263A
4. MAE 263B
5. MAE 263C
6. MAE 277
7. MAE M280B
8. MAE 295A
9. MAE C296A
10. MAE 296B
11. MAE C297A or MAE 298 (Li) on “Rapid Prototyping and Manufacturing”
12. MAE 294A
13. MAE 297B or MAE 298 (Li) on “Nanomanufacturing Science and Engineering”

Minimum Requirements for Ph.D. Major Field Students:

The student must pass a written examination in the major field and satisfy other program requirements for the Ph.D. in the MAE Department besides completing all other formal University requirements.

Format of Written Qualifying Examination:

The exam consists of a 4-hour closed book part and a 4-hour open book part.

Timing of Written Qualifying Examination:

Offered towards the end of every spring quarter.

Link to old exams:

http://www.mae.ucla.edu/graduate-programs-and-preliminary-exams/

Ph.D. Minor Field Requirements:

Minor field requirements can be satisfied by completing three of the courses listed below with grades of B or better with at least one A. At least two of the courses must be graduate courses:

MAE 156A, 162A, 166C, 171B, 183A, 184, 185, C237, 262, 263C, M270A or 277, 294A, 295A, 296A, 296B, C297A, M297B.

Syllabus for the Major Field in Design, Robotics, and Manufacturing

Students majoring in Design, Robotics, and Manufacturing are required to have knowledge in six subject areas from the list below:

Intelligent Material Systems [MAE 262]

Constitutive relations for electro-magneto-mechanical materials. Fiber-optic sensor technology. Micro/macro analysis, including classical lamination theory, shear lag theory, concentric cylinder analysis, hexagonal models, and homogenization techniques as they apply to active materials. Active systems design, inch-worm, and bimorph.

Robotics [MAE 263A]

Kinematical models of serial robotic manipulators, including spatial descriptions and transformations (Euler angles, Denavit-Hartenberg/DH parameters, equivalent angle vector), frame assignment procedure, direct kinematics, inverse kinematics (geometric and algebraic approaches), mechanical design topics.

Robotics [MAE 263B]

Dynamics models of serial and parallel robotic manipulators, including review of spatial descriptions and transformations along with direct and inverse kinematics, linear and angular velocities, Jacobian matrix (velocity and force), velocity propagation method, force propagation method, explicit formulation of Jacobian matrix, manipulator dynamics (Newton/Euler formulation, Lagrangian formulation), trajectory generation, introduction to parallel manipulators.

Robotics [MAE 263C]

Sensors, actuators, and control schemes for robotic systems, including computed torque control, linear feedback control, impedance and force feedback control, and advanced control topics from nonlinear and adaptive control, hybrid control, nonholonomic systems, vision-based control, and perception.

Advanced Robotics [MAE 263D]

Current and advanced topics in robotics and control, including kinematics, dynamics, control, mechanical design, advanced sensors and actuators, flexible links, manipulability, redundant manipulators, human-robot interaction, teleoperation, haptics.

Mechatronics [MAE 277]

Digital signal processing and control analysis of mechatronic systems. System inversion based digital control algorithms and robustness properties, Youla parameterization of stabilizing controllers, previewed optimal feedfoward compensator, repetitive and learning control, and adaptive control. Applications to mechatronic systems.

Microelectromechanical Systems (MEMS) Fabrication [M280B]

Constitutive relations for electro-magneto-mechanical materials. Fiber-optic sensor technology. Micro/macro analysis, including classical lamination theory, shear lag theory, concentric cylinder analysis, hexagonal models, and homogenization techniques as they apply to active materials. Active systems design, inch-worm, and bimorph.

Compliant Mechanism Design [MAE294A]

Advanced compliant mechanism synthesis approaches, modeling techniques, and optimization tools. Fundamentals of flexible constraint theory, principles of constraint- based design, projective geometry, screw theory kinematics, and freedom and constraint topologies. Applications: precision motion stages, general purpose flexure bearings, microstructural architectures, MEMs, optical mounts, and nano-scale positioning systems. Hands-on exercises include build-your-own flexure kits, CAD and FEA simulations, and term project.

<u>RFID in Manufacturing and Supply Chain [MAE 295A]</u>
Examination of the emerging discipline of Radio Frequency Identification (RFID), including basics of RFID, how RFID systems function, design and analysis of RFID systems, and applications to fields such as supply chain, manufacturing, retail, and homeland security.

<u>Mechanical Design-I [MAE 296A]</u>
Material selection in mechanical design. Load and stress Analysis. Deflection and stiffness. Failure due to static loading. Fatigue failure. Design for safety factors, and design for reliability. Statistical considerations in design. Applications of failure prevention in the design of power transmission shafting. Design project involving CAD
& FEM modeling.

<u>Thermochemical Processing of Materials [MAE 296B]</u>
Thermodynamics, heat and mass transfer, principles of material processing: phase equilibria and transitions, transport mechanisms of heat and mass, moving interfaces and heat sources, natural convection, nucleation and growth of microstructure, manufacturing defects, materials instabilities. Applications in Chemical Vapor Deposition (CVD), Infiltration, Solidification, Welding, Consolidation, Coatings and Thin Films.

<u>Rapid Prototyping and Manufacturing [MAE C297A or MAE 298]</u>
Rapid prototyping (RP), also named solid free-form fabrication or additive manufacturing, has emerged as a popular manufacturing technology to accelerate product creation in the last two decades. A machine for layered manufacturing builds parts directly from CAD models. This novel manufacturing technology enables the building of parts that have traditionally been impossible to fabricate because of their complex shapes or variety in materials. In analogy to the speed and flexibility of desktop pub- lishing, rapid prototyping is also called desktop manufacturing or 3-D printing, with actual 3-D solid objects instead of mere 2-D images. The methodology of rapid proto- typing has also been extended into meso-/micro-/nano-scale to produce 3D functional miniature components.

<u>Smart Grids [MAE C237]</u>
Demand response; transactive/price-based load control; home-area network, smart energy profile; advanced metering infrastructure; renewable energy integration; so- lar and wind generation intermittency and correction; microgrids; grid stability; energystorage and electric vehicles-simulation; monitoring; distribution and transmission grids; consumer-centric technologies; sensors, communications, and computing; wireless, wireline, and powerline communications for smart grids; grid modeling, stability, and control; frequency and voltage regulation; ancillary services; wide-area situational

awareness, phasor measurements; analytical methods and tools for monitoring and control. Concurrently scheduled with course MAE C237.

<u>Nanomanufacturing Science and Engineering [MAE 298 or MAE 297B]</u>

Nano-Products (i.e. products containing nanoscale components to offer novel properties) are to be manufactured from a variety of nanomaterials to meet emerging product specifications. Emerging nanomanufacturing methodologies for novel nanomaterials and nanocomponents are essential to develop new nanoproducts, to manufacture next-generation nanomachines, to improve nanoproduct performance, to reduce cost, and to minimize environmental impact. It is essential to understand the fundamental principles that serve as the foundation for nanomanufacturing. This course will discuss about science and engineering aspects of nanomanufaturing. It will especially discusses about the implications of intermolecular and surface forces for nanoscience and nanoengineering.

References:

1. J. E. Shigley, Mechanical Engineering Design, McGraw-Hill, New York, 5th Ed. 1989.
2. Collins, Jack A., Failure of Materials in Mechanical Design - Analysis, Prediction, and Prevention, 2nd Ed, John Wiley & Sons, Inc. 1993.
3. A.C. Ugural and S. K. Fenster, Advanced Strength and Applied Elasticity, Elsevier, 1987
4. Nasr M Ghoniem, Failure Analysis in Mechanical Design, Lecture Notes, ASUCLA, 2007.
5. Nasr M Ghoniem and Adrienne Lavine, Thermochemical Processing of Materials, Lecture Notes, ASUCLA, 2008.
6. C. Liu, Foundations of MEMS, Pearson Education, 2006.
7. Marc J. Madou, Fundamentals of Microfabrication and Nanotechnology, 3rd Ed., Vol. II., CRC Press 2011 [CM280A]
8. R. Wolf and R. Tauber, Silicon Processing for the VLSI Era, Vol. 1, Process Technology, 2nd ed., Lattice Press, 1999.
9. S. D. Senturia, Microsystem Design, Kluwer Academic, 2001.
10. John J. Craig, Introduction to Robotics - Mechanics & Control, Addison Wesley, the latest edition.
11. Lung-Wen Tsai, Robot Analysis - The Mechanics of Serial and Parallel Manipulators, the latest edition.
12. I.D. Faux and M.J. Pratt, Ellis Horwood, Computational Geometry for Design and Manufacture, the latest edition.
13. Michael E. Mortenson, Geometric Modeling, John Wiley & Sons, Inc., the latest edition.
14. V.Z Parton, Electromagnetoelasticity.
15. Lagoudas, D, Shape Memory Alloys: Modeling and Engineering Applications.
16. Engdahl, G, Handbook of Giant Magnetostrictive Materials.
17. HF Tiersten, Linear Piezoelectric Plate Vibrations: Plate theory and piezoelectrics
18. Chen, C. T., Linear Systems Theory, HRW.

19. Desoer, C. A, Notes for a Second Course on Linear Systems, Van Nostrand Reinhold, New York, 1970.

20. Noble, B. and J. W. Daniel, Applied Linear Algebra, Second Edition, Prentice-Hall, Englewood Cliffs, New Jersey, 1977.

21. Gene F. Franklin, J. David Powell, and Michael Workman, Digital Control of Dynamic Systems 3rd Edition.

22. Klaus Finkenzeller, RFID Handbook: Fundamentals and Applications in Contactless Smart Cards and Identification, 2 edition, Publisher: John Wiley & Sons, Inc., May 2003.