UNIVERSITY OF CALIFORNIA
UCMERCED

Syllabus for ME280 "Fractional Order Mechanics"

Fall 2017

(Last offering: Fall 2014; Next offering: Fall 2020, 2023)

Instructor: YangQuan Chen
(ychen53@ucmerced.edu)

Designation:	**ME280 "Fractional Order Mechanics" (4 credits)**
Catalog Description:	This course prepares students with fractional calculus (differentiation or integration of non-integer order) and fractional dynamic modeling of complex mechanical systems such as porous medias, particulate systems, soft matters etc. that have inherent nature of memory, heredity, or long-range dependence (LRD), or long range interactions at or across various scales.
Text Books and Other Required Materials:	**Textbooks:** • Richard Magin (2006). "*Fractional Calculus in Bioengineering*" Begell House Publishers. ISBN-13: 978-1567002157 • Igor Podlubny (1999). "*Fractional Differential Equations. An Introduction to Fractional Derivatives, Fractional Differential Equations, Some Methods of Their Solution and Some of Their Applications*", Academic Press, San Diego - New York – London. ISBN-13: 978-0125588409 • Bruce J West. "*Fractional Calculus View of Complexity: Tomorrow's Science*." CRC Press; 1 edition (October 9, 2015) Hardcover: 303 pages; ISBN-10: 1498738001; ISBN-13: 978-1498738002 **Reference Textbooks:** • Concepción A. Monje, YangQuan Chen, Blas Vinagre, Dingyu Xue and Vicente Feliu (2010). "*Fractional Order Systems and Controls - Fundamentals and Applications.*" Advanced Industrial Control Series, Springer-Verlag. ISBN-13: 978-1849963343. (free pdf access from UC Merced). • Francesco Mainardi (2010). "*Fractional Calculus and Waves in Linear Viscoelasticity: An Introduction to Mathematical Models*". ISBN-13: 978-1848163294. Imperial College Press. • Zhuang Jiao, YangQuan Chen and Igor Podlubny. (2012) "*Distributed-Order Dynamic Systems: Stability, Simulation, Applications and Perspectives*" SpringerBrief, Springer-Verlag, Feb. 2012, 103 pages, ISBN-13: 978-1447128519 (free pdf access from UC Merced).

Course Objectives/ Student Learning Outcomes:	**Course Goal:** ME280 is to prepare graduate students, not necessarily in the field of mechanical engineering, with the basic knowledge of fractional calculus (FC: differentiation or integration of noninteger order) and working ability in using FC in modeling their respective (complex) systems related to their research topics, where, as exploring into micro and nano world, more and more "anomalous" behaviors are being observed in materials such as porous medias, particulate systems, soft matters etc. The students are expected to recognize and deal with the inherent nature of memory, or hereditary, or long range dependence, or long range interactions in the mechanic systems at smaller and smaller scales. **Course Learning Outcomes:** Upon completion of ME280, students should be able to 1. Perform basic fractional calculus math derivations; 2. Do fractional order modeling of relaxation processes from complex systems using both numerical simulation as well as lab experiments on complex system components such as super-capacitor charging process; 3. Do numerical solution of fractional order differential equations; 4. Perform simple fractional order damping control analysis; 5. Understand the fractional mechanics in classical sense (Bagley-Torvik's stress-strain relationships etc.) 6. Appreciate the new tool of fractional order calculus of variation and its role in fractional order Euler-Lagrange mechanics 7. Acquire distributed-order thinking in fractional order mechanics. 8. Use the theory and techniques in "fractional order mechanics" to address the modeling of non-mechanical systems in their respective domain such as thermal/fluid systems, bioengineering system, cognitive science, material science, biological systems, physiological systems, networked systems, human-centric man-made systems etc. 9. Agree that "being anomalous is normal" when FC is used as the modeling tool and fractional calculus view of complexity has many fundamental advantages. **Relationship to Program Learning Outcomes and Program Requirements:** ME280 is an instrumental course that could help the graduates in almost all graduate programs to perform potentially transformative research using "fractional order thinking" to deal with the complex systems in their research.
Prerequisites by Topic:	1. College calculus 2. Ordinary differential equations 3. Integral transforms (Laplace and Fourier) **4.** Basic knowledge of signals and systems related to selected domain knowledge such as mechanical systems, thermal/fluid systems, bioengineering system, cognitive science, material science,

	biological systems, physiological systems, networked systems, human-centric man-made systems etc.
Course Policies:	• Prerequisites are based on instructor approval. • The approval is based on email or face-to-face interview. • Send email request for enrollment first via yqchen@ieee.org
Academic Dishonesty Statement:	1. Each student in this course is expected to abide by the University of California, Merced's Academic Honesty Policy. Any work submitted by a student in this course for academic credit will be the student's own work. 2. You are encouraged to study together and to discuss information and concepts covered in lecture and the sections with other students. You can give "consulting" help to or receive "consulting" help from such students. However, this permissible cooperation should never involve one student having possession of a copy of all or part of work done by someone else, in the form of an e mail, an e mail attachment file, a diskette, or a hard copy. Should copying occur, both the student who copied work from another student and the student who gave material to be copied will both automatically receive a zero for the assignment. Penalty for violation of this Policy can also be extended to include failure of the course and University disciplinary action. **3.** During examinations, you must do your own work. Talking or discussion is not permitted during the examinations, nor may you compare papers, copy from others, or collaborate in any way. Any collaborative behavior during the examinations will result in failure of the exam, and may lead to failure of the course and University disciplinary action.
Disability Statement:	**Accommodations for Students with Disabilities**: The University of California Merced is committed to ensuring equal academic opportunities and inclusion for students with disabilities based on the principles of independent living, accessible universal design and diversity. I am available to discuss appropriate academic accommodations that may be required for student with disabilities. Requests for academic accommodations are to be made during the first three weeks of the semester, except for unusual circumstances. Students are encouraged to register with Disability Services Center to verify their eligibility for appropriate accommodations.
Topics:	1) Motivations and real world needs; (2 weeks) 2) Mathematical foundations of fractional calculus; (2 weeks) 3) Fractional order system modeling; (2 weeks) 4) Fractional mechanics in classical sense (Bagley-Torvik) (4) 5) Fractional order damping control (1 week) 6) Fractional Euler-Lagrange mechanics and fractional variational principle. (2 weeks) 7) Distributed-order mechanics (1 week) 8) Focused Independent Study and Presentation (FISP) (2 weeks, max. 12 talks with 25 min. each)
Class/laboratory Schedule:	**Class:** Tu and Th 4:30-5:45 @ COB1-264 First class: 8/24/2017 **Lab:** (SE1-172, Tue. 9:00-11:50AM) One per two weeks with computer simulation labs and/or one or two mechatronics labs on fractional order component modeling and fractional order closed loop control (subject to

	changes). Equivalent minimum 3 hours lab/project work per week is expected. Meeting in Lab (SE1-172, Tue. 9:00-11:50AM) weekly is encouraged.
Midterm/Final Exam Schedule:	One take-home midterm exam on Week-09. No final exam. But on Week-16 and -17, course term paper presentation will be open to public. All talks will be recorded. Tu 8:00-11:00am CLSSRM 264 12-DEC-2017 and 07-DEC-2017
Course Calendar:	1) Motivations and real world needs; (2 weeks) (recorded lectures) 2) Mathematical foundations of fractional calculus; (2 weeks) 3) Fractional order system modeling; (3 weeks) 4) Fractional mechanics in classical sense (Bagley-Torvik) (3 weeks) 5) Fractional order damping control (1 week) 6) Fractional Euler-Lagrange mechanics and fractional variational principle. (2 weeks) 7) Distributed-order mechanics (1 week) Focused Independent Study and Presentation (FISP) (2 weeks, max. 12 talks with 25 min. each)
Professional Component:	Engineering Science: 50%; Engineering Methods: 50%
Assessment/Grading Policy:	• Course attendance and discussion participation and every in-class quiz (10%) • Labs (8 lab projects) (25%) • Focused Independent Study and Presentation (FISP) (20%) • Take home mid-term exam (15%) • Homework (Weekly, ~ 15 times) 30%
Coordinator:	YangQuan Chen
Contact Information:	YangQuan Chen, ychen53@ucmerced.edu, tel. 209-228-4672. Office SE2-273.
Office Hours:	Tu 9:00-11:50pm Location: SE1-172 or SE2-273 **(Dr. YangQuan Chen's office at campus)**