Sample Syllabus

Course Syllabus

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Penn State University

Department of Mechanical & Nuclear Engineering

ME 452 – Vehicle Dynamics

Spring 2019

Syllabus revision: -

Instructor: Gary Neal

323 Leonhard Bldg.

Telephone: 863-5468

Email: gln103@psu.edu (mailto:gln103@psu.edu)

Office hours: by Appt.

Location: Section meeting M, W, F 12:20PM-1:10PM 102 Leonhard Building

Course TA: N/A

Course Description: This course conducts investigations of one-dimensional, two-dimensional, and three-dimensional dynamics, kinematics and design integrated into the study of vehicle dynamics. Topics include body kinematics, steady state body dynamics, transient stability, tire forces, suspension, automatic control, and driver interaction. The emphasis is on the analysis of a vehicle as a complex system, recognizing how to abstract observed behaviors into appropriate mathematical models, how to decompose behaviors into subsystems, how to construct and perform numerical simulations, and how to design and analyze experiments to test models and simulations to gain insights into design goals and tradeoffs.

Pre-requisites: ME 370, **Concurrent:** ME 450

I'm expecting each student to walk in the door with a basic familiarity with typical tools used for systems and signals analysis including Laplace Transforms, eigenvalues, bode plots, etc. If I say "differential equation", you shouldn't hyperventilate too much. Students should have a firm understanding of mass-spring-damper systems along with detailed knowledge of characteristic responses of these systems in under-damped, critically damped, and over-damped conditions. We will be analyzing the differential equations for systems in transfer-function, state-space, and frequency domains and will often switch representations quite abruptly. This analysis will strongly complement ME450, hence why this class is listed as a co-requisite.

Nearly all assignments will require the use of MATLAB, so knowledge of this software is beneficial. For students who are not familiar with this software, a memory of structured programming as well as some willingness to learn this material is expected.

And one final note on prerequisites: you are NOT expected to be a “gearhead” to enjoy this course and be very successful academically! In fact, I’ve found that gear-head types sometimes have trouble “unlearning” material that is incorrect or that is only valid for race cars, not passenger vehicles.

Course Objectives: Upon completing this course, students should be able to:

1. Associate observed vehicle behavior with the vehicle dynamic model causing the motion.
2. Identify and mathematically characterize linear and nonlinear behavior in a vehicle or vehicle subsystem including characteristics of the dynamic models, experimental responses, and simulation outcomes.
3. Code, implement, and critically analyze the results of numerical simulations and other computational models of vehicle system behavior specifically focusing on lumped-parameter models and methods of decomposing behaviors into simpler interconnected subsystems and error-checking subsystems and their interactions.
4. Predict the influence of subsystem behavior on entire vehicle system performance using a variety of tools including, but not limited to, simulation models, steady-state analysis of equations of motion, solving differential equations, graphical analysis, and frequency-domain analysis.
5. Evaluate the primary design constraints that govern vehicle and subsystem design. Using these principles, should be able to evaluate and justify existing vehicle system designs and formulate improved designs for new vehicle subsystems.
6. Calculate the limits of vehicle designs including acceleration and braking, cornering ability, suspension and ride handling, roll stability, etc.
7. Explain how common changes in vehicle setup – weight distribution, wheel usage, etc. – affects vehicle stability and braking performance in both low and high-speed driving, in both steady-state and transient maneuvers.
8. Justify existing tradeoffs in model simplicity or complexity in representing an actual system. By examination of the vehicle system behavior, students are expected to form and justify mathematical model representations of suitable complexity, even extending this to new systems and situations.
9. Understand and characterize how automated subsystems such as ABS, rear-wheel steering, and active suspension will change vehicle performance and vehicle/roadway interaction.

Grading Table: Final grade will be based on:

Item	**Final Grade**
Exams	60%
Homework	26%
Final Project	7%

Quizzes	7%

Textbook: (required) MATLAB Student Edition… You can find this software at all campus bookstores, any campus computer labs, etc. The price is about $25 for software that engineers have to pay about $30k for when they graduate. Due to the low price, convenience, and frequency with which you will use this software, you will see a high return on investment by purchasing this software.

Other Good References:

Gillespie, T. (1992) *Fundamentals of Vehicle Dynamics*. Warrendale, PA: Society of Automotive Engineers. This is a good starter book for anyone new to vehicle dynamics, but for those really interested in vehicle dynamics, will leave you asking for more depth. It was the class text from 2004-2007.

Dixon, J.C. (1996) *Tires, Suspension, and Handling 2nd Edition.* Warrendale, PA: Society of Automotive Engineers, ISBN 1-56091-831-4. This is not a comprehensive book covering every aspect of vehicle dynamics, but it has good material on transient handling response and suspension design, which seems to be a primary interest are of students in the course. I've used it as the class text from 2007-2010. It's a solid book.

Pacejka, H.B. (2002) *Tire and Vehicle Dynamics.* Warrendale, PA: Society of Automotive Engineers. This is the definitive book on tire modeling with a solid, but terse treatment of vehicle dynamics. Because this book obtains its depth too quickly, it is not appropriate for beginners or as a first book on vehicle dynamics. But it has good nuggets for those familiar with the material, and is a great text for graduate students working in tire dynamics and tire modeling.

Wong, J.Y. (1997) *Theory of Ground Vehicles 2nd or 3rd Edition*, John Wiley. Another good "beginner book" that I sometimes suggest in lieu of Gillespie. Its treatment of ground forces and tracked vehicles is a good complement to those applying vehicle dynamics to ground robots or tanks. It is probably the best textbook on non-traditional vehicles (such as tanks) that is presently available.

Bosch R. GmbH (2011) *Bosch Automotive Handbook 8th edition*, BOSCH GmbH, ISBN: 978-0837616865. It remains a great reference for all types of automotive systems, components, and engineering principles. Unfortunately, it is not very quantitative.

Karnopp, D. (2004) *Vehicle Stability*, CRC Press, ISBN 9780203913567. This is a great book on vehicle stability analysis, and is one of the few books on vehicle dynamics that I would consider graduate-level. However, like the title says, the focus is on stability and little else. I like this book as it chooses what to focus on, and does that very well.

Milliken W. and Milliken D. (1994) *Race Car Vehicle Dynamics,* Warrendale, PA: Society of Automotive Engineers, ISBN of 978-1-56091-526-3. This book provides great coverage of vehicle setup, especially for racing and transient handling and is considered one of the "must read" books for those working in vehicle dynamics. However, for a semester-long course, the material is far too detailed for a beginning student, as it takes a good chunk of time to navigate through the tremendous amount of material they provide. This is a book that you almost have to be an expert in vehicle dynamics first to understand the nuances within. It is very easy with this book to confuse a minor detail with a primary effect, and I do not encourage students to start with this book.

Ellis J.R. (1993) *Vehicle Handling Dynamics*, Mechanical Engineering Publication Limited, London, 1993.

Stone R. and Ball J. (2004) *Automotive Engineering Fundamentals,* Warrendale, PA: Society of Automotive Engineers, ISBN of 978-0-7680-0987-3. This is a great "all around" book, covering everything from chassis to powertrain to aerodynamics. It doesn't get into enough depth into any one area to be the key reference for any topic, but this is a book that I reach for (with Gillespie) to train someone to understand vehicle design generally in just one book. This is one of the books to buy if you want to have an introduction to most everything in a way that is accessible to undergrad engineers.

Adams H. (1992) *Chassis Engineering: Chassis Design, Building, & Tuning for High Performance Handling*, HP Books, ISBN: 978-1557880550. This is a great book for those students in the class that are tuning vehicles for high performance in a garage somewhere (Formula SAE). The content is high-school level at best, but the insights and explanations give a practical insight that's generally better than almost any other vehicle textbook I've seen. And the book is inexpensive!

Hei Ing, B and Ersoy, M. (2010) *Chassis Handbook: Fundamentals, Driving Dynamics, Components, Mechatronics, Perspectives (ATZ/MTZ-Fachbuch), Vieweg+teubner Verlagm,* ISBN: 978-3663205197. This book is written with a very strong industry focus, and is meant to be the "book to read" for interns that are joining European OEMs. The material is written very directly with little interpretation or flourish, but as a result the book is DENSE in content. If one understands everything in this book, they will unquestionably be an expert on vehicle design. This is meant to be one of the books on the shelf of an automotive engineer, but the material is so thick that I doubt that many engineers will dig through it.

Jazar, R. (2014) *Vehicle Dynamics*, Springer, ISBN: 978-1-4614-8543-8. This is quite a heft of a book (a back-breaking 1000+ pages!) for the price ($75 the last I checked) and especially comprehensive. Unlike the Racecar Vehicle Dynamics, the primary focus is on passenger vehicles as is this class. Unfortunately, I feel that the 2nd edition is actually much worse than the 1st, adding lots of fluff rather than paring the material down to core design issues. As you can imagine in a text this large, there is a lot of detail. In fact, the book is presented in a format that is mostly bulleted insights on details rather than a careful mathematical development of core ideas. There are lots of examples within, but I personally feel that the material wanders too much to fit well within an undergraduate course.

CarSim Educational UMTRI – The University of Michigan Transportation Institute and MSC – Mechanical Simulation Corporation, July 1997. This software is sometimes installed in the MNE computer labs, and might be used for some of the homework assignments. This software is VERY expensive (in my opinion) and so I strongly encourage students to master the dynamics of vehicles using their own codes up to a level where they appreciate the nuance and additional details added by this professional software. I feel that jumping into this software without this understanding can cause students to misinterpret vehicle results and confuse primary dynamics with secondary effects.

Homework: Short homework assignments will be given over the entire semester, roughly one assignment corresponding to each lecture. Homework problems will be due one week after the completion of the lecture topic, since I sometimes present the solutions in class. To make the due dates very clear, the due dates will be listed in Canvas. Neatness counts – illegible and otherwise unprofessional solutions will be penalized at the discretion of the grader.

Questions: Please feel free to ask questions before, during, or after class, since this saves E-mail exchanges, scheduled meetings, etc. Email works as well, and if the question is good, I'll always CC the entire class. One key request: include a hypothesis. In other words, don't simply ask "What do I do here?" or "What do you mean?" or "I don't understand…". Instead, write, "I think you mean X here, is this correct?" or, "I think I should do Y, right?" A good question is one where we can reply with a yes or no answer (or a number), since this shows that you have a good understanding of both the material and what type of answer you want. Finally, the homework is meant to challenge you, but don't bang your head against a wall, especially on a software issue. If you aren't getting anywhere after a reasonable effort (20-30 minutes is a reasonable amount of time to work on a problem section), please just ask!

Quizzes: Short quizzes (5 minutes each) will be given over the semester based on assigned reading from the text or other supplemental material provided in class. Each quiz will be given unannounced in class. Because the purpose of this quiz is to ensure that students arrive to class on time, no makeup quizzes will be allowed. In the case a cell phone, etc. goes off in class, there will be an automatic, on-the-spot pop quiz.

Exams: Closed-book, closed-notes exams will be based on material from the assigned reading, lecture notes, and homework, with particular focus on lecture topics. Makeup exams will only be arranged for students with valid excuses provided at least one class period before the scheduled exam. If you have a valid conflict, please let me know as soon as possible. Exams will be held roughly after Lessons 12, 24, and 36 and correspond to first, middle, and final thirds of the class. Example exams are posted on Canvas.

Academic Integrity: Academic integrity is the pursuit of scholarly activity in an open, honest, and responsible manner. Academic integrity is a basic guiding principle for all academic activity at The Pennsylvania State University, and all members of the University community are expected to act in accordance with this principle (**Senate Policy 49-20** **(http://senate.psu.edu/policies-and-rules-for-undergraduate-students/47-00-48-00-and-49-00-grades/#49-20)**). Dishonesty of any kind will not be tolerated in this course. Dishonesty includes, but is not limited to, cheating, plagiarizing, fabricating information or citations, facilitating acts of academic dishonesty by others, having unauthorized possession of examinations, submitting work of another person or work previously used without informing the instructor, or tampering with the academic work of other students. Students who are found to be dishonest will receive academic sanctions and will be reported to the University's Office of Student Conduct for possible further disciplinary sanctions (refer to **Senate Policy G-9** **(http://undergrad.psu.edu/aappm/G-9-academic-integrity.html)**).

Students are encouraged to work together on homework assignments; however, original solutions are required. So how do I expect you to balance "working together" with "original solutions"? For homework, the threshold of cheating is defined as follows: If the person grading the assignments is able to identify which students have worked together by their solutions or specific aspects of their solution approach, and their interaction is NOT clearly documented on the solutions ("I obtained the following equation from Mary"), then these students are working too closely together.

If cheating or copying is suspected, all students involved will receive a warning if the violation is minor and if this is their first such warning. For obvious and major violations, e.g. major portions of the assignment are copied (such as simulations), then no credit will be given for the assignment to all students involved. After the first warning, any subsequent cheating – minor or major – will result in a zero for the entire assignment and

the student will be referred to the college for an academic integrity violation. Three cheating events will result in failing the class.

Again, note that I'm generally very forgiving of issues if teamwork is documented, e.g. "Mary helped me with my simulation block representing the coordinate transforms." Vague documentation such as "Mary helped me" is better than nothing but may still result in a zero for you (but not Mary) if that help is not specifically documented, and it seems like you didn't do anything but use Mary's simulation.

Cheating of any kind on exams will not be tolerated and will be immediately processed as an academic integrity violation. Throughout all of your work in this class, please do not be a cheater. If you encounter others operating in an unethical manner and would like to bring this to my attention, please discuss this with me in person or send me an email. If you would like to do this anonymously, there are several online tools from which you can send anonymous emails. I will do my best to investigate the situation and determine a proper course of action.

Deadlines: Unless otherwise specified in the assignment form, assignments are due BEFORE 5pm the day they are due (I will always accept your submission early!). Why 5pm? In the professional world, 5pm is considered close of business (COB) and is when the majority of people leave work for the day. Late submissions will NOT be accepted.

Grading Scale & Grading Disputes: If a student feels that a report or homework was graded unfairly or in error, bring it to the instructor's attention within one week after the graded material was handed back. Scores will not be reconsidered after this time. End of semester average grading scale is as follows: A >93, A- >90-93, B+ >87-90, B >84-87, B- >81-84, C+ >78-81, C >72-78, D 63-72, F <63.

Attendance: Attendance is expected at the start of each class. Inform the instructor in writing prior to any anticipated legitimate absences. **Two absences** w/o a reasonable excuse is one letter grade reduction. Illness or a job interview is a reasonable basis. Also, see the Faculty Senate Policy on Class Attendance (42-27).

Cell Phones: As a professional courtesy turn cell phones off upon entering classroom. Texting during class is not acceptable and is non-professional.

Disabled Students: Penn State welcomes students with disabilities into the University's educational programs. Every Penn State campus has an office for students with disabilities. The Student Disability Resources Web site provides **contact information for every Penn State campus (http://equity.psu.edu/student-disability-resources/disability-coordinator)** : **http://equity.psu.edu/student-disability-resources/disability-coordinator (http://equity.psu.edu/student-disability-resources/disability-coordinator)** . For further information, please visit the **Student Disability Resources Web site (http://equity.psu.edu/student-disability-resources)** : **http://equity.psu.edu/student-disability-resources (http://equity.psu.edu/student-disability-resources)** .

In order to receive consideration for reasonable accommodations, you must contact the appropriate disability services office at the campus where you are officially enrolled, **participate in an intake interview, and provide documentation (http://equity.psu.edu/student-disability-resources/applying-for-services)** : **http://equity.psu.edu/student-disability-resources/applying-for-services (http://equity.psu.edu/student-disability-resources/applying-for-services)** . If the documentation supports your request for reasonable

accommodations, your **campus's disability services office** (http://equity.psu.edu/student-disability-resources/disability-coordinator) will provide you with an accommodation letter. Please share this letter with your instructors and discuss the accommodations with them as early in your courses as possible. You must follow this process for every semester that you request accommodations.

Counseling & Psychological Services (CAPS): CAPS can help students resolve personal concerns that may interfere with their academic progress, social development, and satisfaction at Penn State. Some of the more common concerns include anxiety, depression, difficulties in relationships (friends, roommates, or family); sexual identity; lack of motivation or difficulty relaxing, concentrating or studying; eating disorders; sexual assault and sexual abuse recovery; and uncertainties about personal values and beliefs. You can contact CAPS by calling the Main CAPS number/Appointment Scheduling: 814-863-0395 (Please call between the hours of 8am and 5pm, Monday-Friday to schedule an appointment) or visit us at our office location, 5th Floor Student Health Center.

Online Resources for Relaxation: It's important to take care of yourself. There are a number of valuable online resources that you can use for relaxation and stress reduction. Learn how stress impacts your health and life, as well as some self-help strategies for managing it through the **PSU Student Affairs EDGE online workshop** (http://edge.psu.edu/workshops/StressMgmt/) . Check out other stress management resources available, including a guided program called **Stress Recess** (http://cmhc.utexas.edu/stressrecess/index.html) . There are also a number of relaxation, visualization, and mindfulness resources at the **Mind Body Spa** (http://www.counseling.iastate.edu/relaxation-and-self-help-exercises/mind-body-spa) . You can also download **mindfulness meditations** (http://marc.ucla.edu/body.cfm?id=22) here.

Sexual Assault and Relationship Violence Hotline: A hotline has been established for victims and observers of sexual assault and relationship violence. Trained counselors on the hotline will help students access appropriate resources. Penn State students from any campus can call 1 (800) 560-1637 to access the 24 hour a day, seven days a week hotline.