ME542/AUTO542 VEHICLE DYNAMICS AND AUTOMATION W 2022

Instructors:

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Lectures: Tu 1:30pm - 3:00pm
Th 1:30pm - 3:00pm

Recitation: Fr 1:30pm - 3:00pm

Office hours: M 10:00am - 11:00am
Tu 5:00pm - 6:00pm
We 10:00am - 11:00am
We 4:00pm - 6:00pm

Prerequisites: You are expected to have knowledge of vector calculus, matrices algebra, differential equations, and rigid body dynamics.

Reading:
K. Popp and W. Schiehlen, *Ground Vehicle Dynamics*, Springer, 2010
http://link.springer.com/book/10.1007/978-3-540-68553-1
D. Schramm, M. Hiller, R. Bardini, *Vehicle Dynamics: Modeling and Simulation*, Springer, 2014
http://link.springer.com/book/10.1007/978-3-540-36045-2
R. Rajamani, *Vehicle Dynamics and Control*, 2nd edition, Springer, 2012
http://link.springer.com/book/10.1007/978-1-4614-1433-9
A. G. Ulsoy, H. Peng, M. Çakmakci, Automotive Control Systems, Cambridge Univ. Press 2012
http://www.cambridge.org/us/academic/subjects/engineering/control-systems-and-optimization/automotive-control-systems
T. D. Gillespie, *Fundamentals of Vehicle Dynamics*, SAE International, 1992

Course description: This course focuses on the dynamics and control of road vehicles. Dynamical models of automobiles and trucks are constructed and analyzed. Controllers are designed for driver assistance and vehicle automation. Topics include: longitudinal vehicle dynamics; cruise control and adaptive cruise control; ride dynamics; passive and active suspension design; nonholonomic dynamics of rolling; kinematic and dynamic bicycle models of automobile steering; lane-keeping control; motion planning for automated vehicles, longitudinal and lateral tire models; vehicle handing with tires.

Website: We will maintain a course website on which we will post material (assignments, solutions, handouts, etc.) as well as announcements. You can access our course website at canvas https://umich.instructure.com

The Engineering Honor Code: https://elc.engin.umich.edu/honor-council/
No member of the community shall take unfair advantage of any other member of the community.

Diversity Equity and Inclusion: https://docs.asee.org/public/LGBTQ/Syllabus_Inclusion_Statement.pdf

Assignments: Eleven homework assignments will be set during the term that will be posted on the course's website. Homework sets are **due at 11:59pm Thursdays on canvas**. The lowest homework score for the term will be dropped. Homework solutions will be available through the course web site.

You are encouraged to discuss and work on homework together but the final document must represent your own understanding of the material.

If you find errors in your graded homework (e.g. scores do not add up, the grader missed a page etc.) you may ask for re-grade. You need to attach a sheet where you write up the issue and resubmit the homework to the professor within one week after receiving the graded homework.

Examinations: Midterm Exam: March 9 (Wed)
Final Exam: April 27 (Tu)

The exams will be closed book. One sheet of notes (8.5" by 11") will be permitted for the exams (one-sided for the midterm and double-sided for the final).

Grading:	Homework	30%
	Midterm Exam	30%
	Project	10%
	Final Exam	30%

Additional rules: no laptops, cell phones, iPods, iPads, etc. during the class

Course Outline:

1. Longitudinal vehicle dynamics
1.1 Review of the Newton-Euler approach of modelling rigid body dynamics
1.2 Modeling longitudinal vehicle dynamics
1.3 Adaptive cruise control design

2. Ride dynamics
2.1 Lagrange equations and their application to multi-body systems
2.2 Random processes
2.3 Quarter car model and suspension design
2.4 Half car model (bounce, pitch)
2.5 Passive and active suspension design

3. Vehicle handing
3.1 Nonholonomic systems and Appell equations
3.2 Bicycle model of vehicle steering
3.3 Lane keeping control
3.4 Lateral + roll dynamics

4. Tire models
4.1 Longitudinal and lateral and brush model
4.2 Stretched-string model
4.3 Magic formula

5. Vehicle handing with tires
5.1 Bicycle model with elastic tires
5.2 Steady state handling (oversteer, understeer)
5.3 Transient handling and lane keeping control
5.4 Lateral + roll dynamics

Course Schedule (tentative 11/15/21): **PS** = Popp-Schiehlen; **SHB** = Schramm-Hiller-Bardini, **R** = Rajamani, **UPC** = Ulsoy-Peng-Çakmakci)

LECTURE	DATE	TOPICS	READING	HW DUE DATES
1	Th 1/6	Introduction, Review of particle dynamics		
2	Tu 1/11	Review of particle and rigid body dynamics	**PS** 2.2-2.3 **SHB** 2	
3	Th 1/13	Review of rigid body dynamics	**PS** 8.2-8.5	HW#01
4	Tu 1/18	3D dynamics of the vehicle	**PS** 8.2-8.5	
5	Th 1/20	Longitudinal dynamics	**PS** 8.2-8.5 **R** 5.3-5.4	HW#02
6	Tu 1/25	Longitudinal dynamics, Cruise control	**PS** 8.2-8.5 **R** 5.3-5.4	
7	Th 1/27	Adaptive cruise control		
8	Tu 2/1	Constraints and Lagrange equations	**SHB** 4.1-4.5 **PS** 2.3	
9	Th 2/3	Quarter car model (1DOF)	**R** 10 **PS** 7.1-7.2.2	HW#03
10	Tu 2/8	Quarter car model (2DOF)	**R** 10 **PS** 7.1-7.2.2	
11	Th 2/10	Half-car model	**UPC** 4.4, 16 **PS** 7.2.3.1-7.3	HW#04
12	Tu 2/15	Suspension design and active suspension	**UPC** 4.4, 16 **PS** 7.2.3.1-7.3	
13	Th 2/17	Nonholonomic systems and Lagrange equations	Wang-Pao 2003 Flannery 2004	HW#05
14	Tu 2/22	Kinematic bicycle model	Astrom-Murray pp 51-53	
15	Th 2/24	Dynamic bicycle model		HW#06
	2/28-3/4	**WINTER RECESS**		
16	Tu 3/8	Nonholonomic systems and Appell equations	Wang-Pao 2003 Flannery 2004	
	We 3/9	**MIDTERM EXAM**		
17	Th 3/10	Dynamic bicycle model		
18	Tu 3/15	Steering control, Ackermann steering, Off tracking		
19	Th 3/17	Articulated vehicles, Handbrake on, Roll dynamics		HW#07
20	Tu 3/22	Tire models, Rolling resistance, Longitudinal brush model	**PS** 3.4.1, 3.4.4.1-3.4.4.3 **SHB** 7.3.1-7.3.4	
21	Th 3/24	Longitudinal brush model, Lateral brush model	**PS** 3.4.1, 3.4.4.1-3.4.4.3 **SHB** 7.3.1-7.3.4	HW#08

22	Tu 3/29	Lateral brush model, Stretched string model	Takacs-Orosz-Stepan 2009 Takacs-Stepan 2012	
23	Th 3/31	Magic formula, Combined slip model, Bicycle model(s) of automotive steering with brush tire	**PS** 9.1, **SHB** 10.1	HW#09
24	Tu 4/5	Steady state handling, Neutralsteer, Understeer, Oversteer	**PS** 9.1, **SHB** 10.1	
25	Th 4/7	Transient handling and steering control, Steering compliance	**PS** 9.1, **SHB** 10.1	HW#10
26	Tu 4/12	Banking, Differential braking, Rear wheel steering and four wheel steering		
27	Th 4/14	Roll dynamics		HW#11
28	Tu 4/19	Review and Project Presentation		
	Tu 4/27	**FINAL EXAM**		

HW#01 – Linear algebra and differential equations
HW#02 – Rigid body dynamics
HW#03 – Longitudinal dynamics
HW#04 – Lagrangian dynamics
HW#05 – Ride dynamics – Modeling and frequency response
HW#06 – Ride dynamics – Active Suspension Design
HW#07 – Steering and handling – Lagrangian and Appellian models
HW#08 – Steering and handling – Stability, control, sliding and rolling
HW#09 – Tire models – Longitudinal and lateral brush models
HW#10 – Tire models – Stretched string model and combined slip
HW#11 – Handling with tires