**ME 581 Simulation of Multibody Dynamics - Spring 2022 – 316 Leonhard - 12:20-1:10 MWF**

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Text: *Computer-Aided Kinematics and Dynamics of Mechanical Systems*, E.J. Haug (see link on course web page)

Grading: 5 homeworks (50pts), 5 computer programs (100pts), semester project (50pts)

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| Wk | Lect | Date | Chap | On-line notes | Topic | Assign  Due |
| 1 | 1 | Jan 10 | 1.1-1.2 | 01\_01 | administration, 2D mobility, topology | H1 |
|  | 2 | Jan 12 | 1.3-1.4 | 01\_02 | 3D mobility, topology |  |
|  | 3 | Jan 14 |  | 03\_01 | geometric kinematics |  |
| 2 | 4 | Jan 17 |  |  | no class - MLK Day |  |
|  | 5 | Jan 19 | 4.5 | 03\_02 | complex number kinematics | H2/H1 |
|  | 6 | Jan 21 |  | 03\_03 | Newton-Raphson solution |  |
| 3 | 7 | Jan 24 |  | 05\_01, 05\_02 | experimental kinematics |  |
|  | 8 | Jan 26 |  | 08\_02 | Newtonian mechanics, inverse dynamics | H3/H2 |
|  | 9 | Jan 28 |  | 09\_02 | Lagrangian mechanics |  |
| 4 | 10 | Jan 31 |  | 08\_13 | DAE versus reduced DOF dynamics |  |
|  | 11 | Feb 2 |  |  | no class |  |
|  | 12 | Feb 4 | 2.1-2.6 | 04\_01,04\_02, 04\_03 | matrix notation, velocity, acceleration |  |
| 5 | 13 | Feb 7 | 3.1 | 04\_03, 04\_04 | generalized coordinates, constraint equations | C1/H3 |
|  | 14 | Feb 9 | 3.2-3.3.2 | 04\_04, 04\_05 | revolute, double revolute, prismatic, pin-in-slot |  |
|  | 15 | Feb 11 | 3.3.3-3.5 | 04\_04, 04\_05 | gears, driving constraints |  |
| 6 | 16 | Feb 14 | 3.6, 3.7, 4.2 | 04\_05, 04\_06 | position, velocity, acceleration, singularities |  |
|  | 17 | Feb 16 | 6.1.1-6.1.3 | 07\_01, 07\_02 | centroidal polar moment of inertia | C2/C1 |
|  | 18 | Feb 18 | 6.1.4-6.1.5 | 07\_03 | centroidal polar moment of inertia |  |
| 7 | 19 | Feb 21 | 6.2 | 08\_10 | generalized forces |  |
|  | 20 | Feb 23 | 6.3.1 | 08\_11 | 2D dynamic equations of motion |  |
|  | 21 | Feb 25 | 6.3.2-6.3.3 | 08\_12 | Lagrange multipliers, constraint reaction forces | C3/C2 |
| 8 | 22 | Feb 28 | 6.4-6.5 | 08\_13 | forward/inverse dynamics, DAE |  |
|  | 23 | Mar 2 |  |  | no class |  |
|  | 24 | Mar 4 | 6.6 | 02\_01, 02\_02 | Working Model demo |  |
| 9 | 25 | Mar 14 | 7.1-7.5 | 10\_01, 10\_02 | numerical integration | prospectus |
|  | 26 | Mar 16 | 7.1-7.5 | 10\_01, 10\_02 | numerical integration | C4/C3 |
|  | 27 | Mar 18 | 7.3 | 10\_3 | coordinate partitioning, constraint stabilization |  |
| 10 | 28 | Mar 21 |  | 11\_11 | RSUR geometric |  |
|  | 29 | Mar 23 | 9.1, 9.2 | 11\_01, 11\_02 | 3D matrix kinematics, rotation matrix | proposal |
|  | 30 | Mar 25 | 9.3 | 11\_02 | Chasles angle, Euler angles, Euler parameters | H4/C4 |
| 11 | 31 | Mar 28 | 9.4 | 11\_03 | partial derivative, pi prime directions |  |
|  | 32 | Mar 30 |  |  | no class |  |
|  | 33 | Apr 1 | 9.4.4 | 11\_04 | basic constraints |  |
| 12 | 34 | Apr 4 | 9.5,9.6 | 11\_04 | mechanical/driver constraints | H4/H5 |
|  | 35 | Apr 6 | 9.6 | 11\_12 | RSUR, Jacobians |  |
|  | 36 | Apr 8 | 9.6 | 11\_12 | McPherson strut |  |
| 13 | 37 | Apr 11 | 9.6 | 11\_05 | position, velocity, acceleration analysis | C5 |
|  | 38 | Apr 13 | 11.2 | 11\_06, 11\_07 | moments and products of inertia |  |
|  | 39 | Apr 15 | 11.4 | 11\_07 | actuator forces | H5 |
| 14 | 40 | Apr 18 | 11.3, 11.6 | 11\_05, 11\_08 | 3D dynamic equations of motion |  |
|  | 41 | Apr 20 |  | 03\_05, 03\_06 | instant centers, instant screws |  |
|  | 42 | Apr 22 |  | 10\_04 | collision |  |
| 15 | 43 | Apr 25 |  | 10\_04 | collision |  |
|  | 44 | Apr 27 |  |  | no class |  |
|  | 45 | Apr 29 |  | 10\_04 | collision | C5 |
|  |  | May 4 |  | send by email | 15 slides x 20 sec timed presentations |  |

**Course Objectives**

1) Diagram topology and detemine mobility of 2D and 3D mechanisms

2) Compute kinematics and dynamics of 2D mechanisms using generalized coordinates, constraint vectors and differential-algebraic equations

3) Measure mass moment of inertia

4) Compute kinematics and dynamics of 3D mechanisms using Euler parameters, constraint vectors and differential-algebraic equations

5) Describe 2D and 3D kinematics using finite and instantaneous screw axes

6) Communicate well using verbal, written and electronic methods

**Course Policy**

1) All students must attend class or view all posted video lectures.

2) Homework and computer assignments must be **individual** work.

3) Students should know and understand these course policies in regard to College of Engineering policy on academic integrity available at <http://www.engr.psu.edu/CurrentStudents/acadinteg.aspx>.

**Homework/Computer Project Policy**

1) Homework and computer projects are due by 5:00pm Eastern Time on dates posted in the syllabus. No late submissions will be accepted unless prior approval has been granted.

2) Students should submit PDF copy for all homework/projects via Canvas. **Combine all files into a single PDF.** Use filename convention "Lastname\_Hxx.pdf" or "Lastname\_Cxx.pdf" where xx = 01, 02, 03, etc.

**Final Project Information**

You will formulate, complete and demonstrate a project utilizing the concepts learned in this course. Project topics are your choice and may be drawn from your research/teaching interests, industrial experience, hobbies or intriguing devices. ***Be creative.*** Your mechanisms may be planar or 3D, open loop or closed loop, static or moving. The projects may range from design of novel mechanisms, to analysis of existing devices, to exemplar use of analysis packages (e.g. Working Model, ADAMS), to modeling of biological motion, to construction of working prototypes (passive, motorized or instrumented), to literature review and a written report on theoretical kinematics or dynamics (e.g. screw theory, Kane’s equations).

### Final Project Deliverables

1) A brief three sentence prospectus for your project concept

2) A short, one page proposal detailing your project concept and project team. The proposal should contain WHO comprises your project team, WHAT you wish to accomplish, WHY this topic is pertinent or interesting or valuable, and HOW you plan to complete this project (e.g. time plan, requisite resources).

3) A self-explanatory, high quality final report as PDF in conference paper format

<http://www.me.psu.edu/sommer/me581/report_format.docx>

<https://www.asme.org/getmedia/d509f565-d314-485c-9209-1e257f051d12/asme_org_template.docx>

4) A five minute PPTX with voice-over

a) modified Pecha Kucha format, 15 slides by 20 seconds each, automatically timed

b) limit size to be able to send by email

c) filename convention = lastname.PPTX

**Notice of Video Recording**

Video and audio recordings of class lectures will be part of the classroom activity. The video and audio recording is used for educational use/purposes and may be made available to all students presently enrolled in the class. For purposes where the recordings will be used in future class session/lectures, the videos will adequately remove any type of student identifying information.

**World Campus technical support** [wdtechsupport@outreach.psu.edu](mailto:wdtechsupport@outreach.psu.edu)

**Academic Integrity -** [**http://www.engr.psu.edu/faculty-staff/academic-integrity.aspx**](http://www.engr.psu.edu/faculty-staff/academic-integrity.aspx)

The University defines academic integrity as the pursuit of scholarly activity in an open, honest and responsible manner. All students should act with personal integrity, respect other students' dignity, rights and property, and help create and maintain an environment in which all can succeed through the fruits of their efforts (refer to [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)).

**Disability -** [**http://equity.psu.edu/ods/faculty-handbook/syllabus-statement**](http://equity.psu.edu/ods/faculty-handbook/syllabus-statement)

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> . For further information, please visit the Student Disability Resources Web site: <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> . If the documentation supports your request for reasonable accommodations, your campus's disability services office 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.