TAM 412: Intermediate Dynamics – Spring 2025

MW 3-4:50pm, 3100 LuMEB

Instructor: Prof. Kathryn Matlack, kmatlack@illinois.edu

Office hours: Thursdays 3-4pm, LUMEB 3046

TA: Taojun Wang, taojunw2@illinois.edu

Office hours: *Time and location TBD*

Course Description

The main goal of this course is to provide graduate students and upper-level undergraduates with a foundation in analytical dynamics and vibrations of mechanical systems. The course combines theoretical treatment of concepts and techniques with applications in mechanics and engineering. The first half of the course will focus on vectorial and analytical mechanics, where students will analyze and mathematically describe the motion of bodies and systems under the action of forces. The second half of the course will focus on analyzing vibrations of multi-degree-of-freedom systems, where students will analyze and predict the response of mechanical systems undergoing small oscillations.

Course Logistics

Textbook. L. Meirovitch, 2001, Fundamentals of Vibrations, Waveland Press *(required)*.

Course resources in Grainger Library:

- J. H. Ginsberg, 2007, Engineering Dynamics, Cambridge University Press.
- D. Greenwood, 1988, Principles of Dynamics, 2nd edition, Prentice Hall.
- D. A. Wells, 1967, Schaum's Outline of Theory and Problems of Lagrangian Dynamics, With a Treatment of Euler's Equations of Motion, Hamilton's Equations and Hamilton's Principle, New York, Schaum Pub. Co.
- M. D. Ardema, 2005, Analytical Dynamics: Theory and Applications, Springer-Verlag.

Additional reading material, handouts and notes will be provided by the Instructor.

Pre-Requisites. TAM 212; MATH 225 or MATH 415; and MATH 285

Class Credits. 4 undergraduate or graduate hours.

Course Website. All course announcements, homework postings, and homework submissions will be done through *Canvas*. Lecture notes will be posted on Box – the link will be posted as an announcement on Canvas.

Course Expectations

Classes. During class time, the instructor will introduce and discuss new concepts, present and solve example problems. While solving example problems, the instructor will solicit input from students, such that students are actively involved in these portions of the lectures. The idea is that students will first gainß knowledge of a new concept, see how to apply the concept to a problem, and then apply the concept with guidance from the instructor. In this way, you will build a knowledge base that will enable you to succeed on homework, exams, and later in approaching similar problems later in your careers.

Student Expectations.

- Attend all class sessions, arrive on time, complete homework assignments on time.

- Participate in class by asking and answering questions, and actively participating in solving example problems presented in lectures.
- Refrain from using cellphones, tablets, and laptops for reasons unrelated to the course.
- Show respect for your peers and instructor.

Instructor Expectations.

- Arrive on time to class prepared with an agenda for the day.
- Support student learning by communicating expectations to students, clearly explaining concepts and example problems, and being available to students through email and office hours.
- Show respect for students by grading fairly and consistently, and accepting feedback from students with an open mind.

Equity and Diversity. This is an equal opportunity classroom environment. We value the diversity represented by the participants in this course. Our diversity is a primary source of ideas and perspectives. As you work through the course, practice using this diversity to your advantage.

Assessments and Evaluation

Grade breakdown. Midterm: 30%, Final Exam: 30%, Homework: 30%, In-class problem solving sessions: 10%

The total score *s* corresponds to final grades as follows:

$97\% \le s < 100\%$	A+	$93\% \le s < 97\%$	A	$90\% \le s < 93\%$	A-
$87\% \le s < 90\%$	B+	$83\% \le s < 87\%$	B	$80\% \le s < 83\%$	B-
$77\% \le s < 80\%$	C+	$73\% \le s < 77\%$	C	$70\% \le s < 73\%$	C-
$67\% \le s < 70\%$	D+	$63\% \le s < 67\%$	D	$60\% \le s < 63\%$	D-
$s < 60\%$	F				

Homework. There will be a series of homework assignments, roughly every week, which will be posted on Canvas. Homework will be due roughly one week after it is assigned. Homework submissions must be uploaded to Canvas and will be due on the specified dates/times. No hard copies of homework will be accepted. *Your lowest homework grade will not be counted toward your final grade.*

Homework problems will be graded on completeness and correctness. Some homework problems will be graded for correctness, while some homework problems will be graded credit/no credit, where credit is given if the problem is attempted. It is the student's responsibility to check their graded homework against the posted solutions to ensure they know how to solve all assigned problems.

Requirements for plotting data for homework: use engineering software, save the plot as an image/pdf, and add this to your pdf submission. Photos of laptop screens of plots will NOT be accepted and will receive a 0. Make sure all axes are labeled, text is legible, and the orientation of the plot is the same as the rest of the homework pages.

Homework will be submitted electronically on Canvas. You may type your homework or handwrite it and scan/photograph it. Some suggestions for apps include:

Multi-platform: CamScanner

Android: Clear Scan, Adobe Scan

iOS: Prizmo, Scanbot Pro

Due to logistical constraints fairness to your fellow students, *late homework will not be accepted*. You are encouraged to collaborate and cooperate with your peers on these assignments; however, you should only hand in your own original homework. Evidence of plagiarism will be dealt with seriously.

In-Class Problem Solving Sessions. There will be about 4 group "in class problem solving sessions" during class time during the semester that will be graded on effort, attendance, and participation. These will occur during 1-2 hours of lecture time. The tentative dates for these sessions are listed in the calendar below, and will be announced during lecture at least 1 week prior. You must attend class; if you are sick or have any other university-approved excused absence, please let me know ASAP and we will work out an alternative solution/assignment.

Exams. Two closed-book exams, a mid-term and a final exam, will evaluate your understanding of the course material. Please mark your calendars and plan accordingly, since due to logistical constraints and reasons of fairness to your fellow students, ***no conflict or make-up exams will be given***. The only exceptions will be for medical reasons or extreme circumstances, provided necessary documentation provided to the dean of students and an official excused absence letter is provided to the instructor.

- *Midterm Exam:* Wednesday March 8, 2023, 3-4:50pm, LuMEB 3100
- *Final Exam*: Monday May 8, 2023, 8-11am

Course Policies

1. The Instructor and TA will be available during posted office hours, and by appointment when requested. Students can reach us through email and can expect a response within 24 hours during the school week.
2. An exam or homework regrade request may be made, but it must be within 1 week of when the assignment was returned to students. A regrade request must consist of a clear written explanation justifying why it was graded incorrectly. Note that in the case of a regrade request, the entire assignment or exam can be regraded at the discretion of the instructor.
3. Make-up exams will not be given. If there are extenuating circumstances (e.g. death in the family, hospitalization), please contact me as soon as possible.
4. Laptops, tablets, and cell phones are discouraged from class, unless using them to take notes or complete in-class work. Students using them in a disruptive manner will be asked to leave the class.
5. Collaboration on homework is encouraged and recommended. Collaboration on exams is not allowed.

Topics to Be Covered

Vectorial and Analytical Mechanics. Newton's laws, work and energy, dynamics of systems of particles, dynamics of rigid bodies, dynamics in moving frames, generalized coordinates, the principle of virtual work, holonomic and non-holonomic constraints, D'Alembert's principle, Lagrange's equations, a brief introduction to variational methods in Mechanics, Hamilton's generalized principle, derivation of Lagrange's equations of systems with or without constraints, applications in mechanics and engineering.

Vibrations of Single-Degree-of-Freedom Systems. The undamped harmonic oscillator, effect of viscous damping and Hamiltonian formulation, effect of dry friction, response to harmonic and periodic excitations, resonance, base excitation, vibration measurement equipment, structural damping and non-causality effects.

Vibrations of Multi-Degree-of-Freedom Systems. Linearization of Lagrange's equations, Betti-Maxwell's reciprocity theorem, vibrations of natural and non-natural systems, the eigenvalue problem and normal modes, orthogonality of vibration modes and modal analysis for systems with distinct or repeated eigenvalues, bi-orthogonality conditions for non-symmetric matrices and the bi-expansion theorem, solution of the initial value (Cauchy) problem, perturbation theory for eigenvalue problems with distinct, close or repeated eigenvalues, damped systems.

Special Topics in Dynamics. Experimental methods in vibrations and dynamics, applications to periodic systems and metamaterials, Introduction to nonlinear perturbation theory, nonlinear forced and internal resonances.

Accommodations for Disabilities

To obtain disability-related academic adjustments and/or auxiliary aids, students with disabilities must contact the course instructor as soon as possible. To ensure that disability-related concerns are properly addressed from the beginning, students with disabilities who require assistance to participate in this class should contact Disability Resources and Educational Services (DRES) and see the instructor as soon as possible. If you need accommodations for any sort of disability, please speak to me after class, or make an appointment to see me, or see me during my office hours. DRES provides students with academic accommodations, access, and support services. To contact DRES you may visit 1207 S. Oak St., Champaign, call 333-4603 (V/TDD), or e-mail a message to disability@uiuc.edu. http://www.disability.illinois.edu/.

Student Code & Academic Integrity

The University of Illinois at Urbana-Champaign *Student Code* should also be considered as a part of this syllabus. Students should pay particular attention to Article 1, Part 4: Academic Integrity. Read the Code at the following URL: http://studentcode.illinois.edu/.

Academic dishonesty may result in a failing grade. Every student is expected to review and abide by the Academic Integrity Policy: http://studentcode.illinois.edu/. Ignorance is not an excuse for any academic dishonesty. It is your responsibility to read this policy to avoid any misunderstanding. Do not hesitate to ask the instructor(s) if you are ever in doubt about what constitutes plagiarism, cheating, or any other breach of academic integrity.

All students are responsible to refrain from infractions of academic integrity, conduct that may lead to suspicion of such infractions, and conduct that aids others in such infractions. "I did not know" is not an excuse.

The following are academic integrity infractions:

- Cheating - using or attempting to use unauthorized materials
- Plagiarism - representing the words, work, or ideas of another as your own
- Fabrication - falsification or invention of any information, including citations
- Facilitating infractions of academic integrity - helping or attempting to help another commit infraction
- Bribes, Favors, and Threats - actions intended to affect a grade or evaluation
- Academic Interference - tampering, altering or destroying educational material or depriving someone else of access to that material

(source http://www.provost.illinois.edu/academicintegrity/students.html)

Violators will be caught – we check. You can easily fail course or worse! All infractions are documented in campus-wide FAIR database.

Family Educational Rights and Privacy Act (FERPA)

Any student who has suppressed their directory information pursuant to *Family Educational Rights and Privacy Act* (FERPA) should self-identify to the instructor to ensure protection of the privacy of their attendance in this course. See http://registrar.illinois.edu/ferpa for more information on FERPA.

Note

This syllabus is subject to change based on student progress and feedback throughout the semester.

TAM 412 Schedule – Spring 2025
Note this schedule reflects the topics to be discussed and the general flow of the class, however the dates are approximate and may shift as we progress through the semester.

Date	Topic
W 1/22	Introduction, review of Newtonian dynamics
M 1/27	Work-energy principle (HW 1 posted)
W 1/29	Dynamics of systems of particles, rigid bodies
M 2/3	Rigid body dynamics, kinematics in moving frames
W 2/5	Dynamics in moving frames (HW 1 due)
M 2/10	Planar motion
W 2/12	Planar motion, equilibrium; ***In class problem solving session 1*** (HW 2 due)
M 2/17	Discrete models; notion of equivalent springs, Intro analytical mechanics
W 2/19	Generalized coordinates, Principle of virtual work
M 2/24	Constraints, Principle of D'Alembert (HW 3 due)
W 2/26	Hamilton's extended principle, ***In class problem solving session 2***
M 3/3	Lagrange's equations, Examples using analytical mechanics (HW 4 due)
W 3/5	Examples using analytical mechanics, constrained systems
M 3/10	Review, constrained systems (HW 5 due)
W 3/12	Midterm Exam
M 3/24	Constrained systems, Introduction to vibrations
W 3/26	SDOF systems, Intro to Multi-degree of freedom (MDOF) systems
M 3/31	Linearized Lagrange's equations for natural systems
W 4/2	Linearized Lagrange's equations for non-natural systems (HW 6 due)
M 4/7	Free vibrations of MDOF systems, Orthogonality
W 4/9	Example 2-DOF systems ***In class problem solving session 3***
M 4/14	Modal analysis for MDOF systems (HW 7 due)
W 4/16	Initial value problems; Examples of MDOF systems
M 4/21	Damping, Forced response from harmonic excitation in MDOF systems (HW8 due)
W 4/23	Examples on damping and forced harmonic response
M 4/28	Response to arbitrary forcing, examples of forced response (HW9 due)
W 4/30	Laboratory session and ***In class problem solving session 4***
M 5/5	Applications to vibration isolation and vibration absorbers
W 5/7	TBD (HW 10 due)
TBA	**Final Exam** (during scheduled exam time, May 9-15, 2025)

Updated 1/17/2025