Text: *Engineering Mechanics: Dynamics, 9th Edition* (9th Edition); James L. Meriam, L. Glenn Kraige, and Jeffrey N. Bolton; John Wiley & Sons; 2018; ISBN: 9781119390985 (enhanced epub); 9781119390985 (ePub); $69/term (available from WileyPLUS via single sign-on through Blackboard.

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Grading policies: *Homework*

- There will be weekly problem assignments delivered through WileyPLUS, the online content and learning platform associated with the text.
- The number of problems and associated points may vary from week to week, but all assignments will be equally weighted.
- You are encouraged to work together (which is admittedly difficult in the current environment) and teach one together. Piazza has been enabled for this course so you may discuss problems and share ideas asynchronously.
- Helping one another does not extend to copying someone else's work, allowing someone else to copy your work, doing assigned work for someone else, or allowing someone else to do the assigned work for you.
- Late homework loses 50% of the original value per day that it is late which means homework submitted within 24 hours of the due date/time can receive no more than 50% of the maximum score and homework submitted more than 24 hours late earns a score of 0.

Discussion

- There will be weekly deliverables associated with the discussion section.
- The discussion deliverables will be provided at the start of the discussion period and will be due at the end of class on Friday.
- The Friday class will usually be a continuation of the Thursday discussion section.
- The deliverables will be "graded" on a CR/NC basis and the overall discussion grade will be determined by the number of CRs divided by the number of deliverables.
- If you miss a discussion for a valid reason (e.g., illness, University-sponsored travel, etc.), you be excused from any deliverable due that week and the deliverable grade will appear in Blackboard as an EX which will be treated as equivalent to a CR.

Exams

- There will be four equally weighted exams given at roughly equal intervals. The last exam will be given on the day scheduled for the final exam. The first two exams will focus on particles and the last two exams will focus on rigid bodies.

Final grade calculation

- Your homework average will provide 10% of your grade.
- Your discussion average will provide 10% of your grade.
- Your exam average will provide 80% of your grade.

Background

Many students consider the study of dynamics to be one of the most challenging subjects in the entire engineering curriculum because it combines many topics that are typically studied in isolation and brings them together in one arena in which all of the topics are important. Think of the things you must know... You have real objects with real shapes and sizes so you must be ready to apply the principles of geometry and trigonometry. As the objects move through the space-time continuum, differential equations are used to describe how the parameters of motion vary with time. Since these objects move in 3-dimensional space, vectors are needed to talk about the various components. Finally, these equations need to be manipulated and solved simultaneously which requires a knowledge of algebra and linear algebra. Entire branches of mathematics have been developed specifically to talk about dynamic systems.

If you are looking for someone to blame for this course, look no further than Isaac Newton (1643-1727) and his seminal work, *Philosophiæ Naturalis Principia Mathematica* (often referred to simply as *The Principia*). This entire course is predicated upon Newton's observation that the force applied to a particle is proportional to the change in the linear momentum of the particle. Simple mathematical operations (like vector arithmetic), basic geometry, some algebra, and straight-forward applications of differential and integral calculus lead directly to everything else covered in the course. Not coincidentally, Newton is also responsible (along with Gottfried Wilhelm von Leibniz) for the branch of mathematics known as calculus.

If you want more people to fault, you can attribute geometry to Archimedes (287-211 BC) and his colleagues in Ancient Greece; algebra to Muhammad ibn-Musa al-Khwarizmi (780-850 AD); most modern mathematical notation, calculus texts, and the extension of Newton's work to rigid bodies to Leonhard Euler (1707-1783); the principle of dimensional homogeneity and the importance of the equal sign to Joseph Fourier (1768-1830); and vector analysis to Josiah Willard Gibbs (1839-1903).

Learning objectives and outcomes

This course covers elementary particle and rigid body dynamics — the study of how particles and rigid bodies respond to applied forces and/or torques. Although you should have some background in this subject from an earlier course in physics, this course provides a framework for the application of the principles of dynamics to much more complex systems than those you encounter in typical entry-level physics courses. Despite providing a framework for approaching more complex problems, this course is still limited in scope because we will deal almost entirely with greatly simplified systems using idealized elements and we will restrict ourselves to systems for which the resulting differential equations can be easily solved.

By the end of this course, you will be able to:

1. draw the Free Body Diagrams (FBD) of particles acting under the influence of applied forces;
2. recognize a non-rotating or rotating frame of reference in which the path of a particle is simple to describe;
3. select a coordinate system in which the position, velocity, acceleration, and jerk of a particle are easy to express;
4. recognize constraints on the motion of a particle;
5. combine the equations of motion and constraints into a set of equations sufficient to solve for all of the unknown quantities;
6. apply the separation-of-variables method to solve simple differential equations involving the motion of single particles;
7. predict the motion that results from a particular set of forces applied to a particle;
8. determine the forces required to cause a particle to follow a specified path;
9. extend items 1-8 above to systems of particles;
10. determine the position, velocity, acceleration, and jerk of one location on a rigid body in terms of another location on the same or another rigid body, the angular velocity of the body, and the angular acceleration of the body; and
11. extend items 1-8 above to one or more rigid bodies.

Although the following quote comes from a text in a completely different field, it is worth including here because it addresses a truth that is applicable to all branches of engineering. Applied to the field of dynamics, you must repeatedly apply the theoretical concepts to practical problems. Assuming your goal is to really learn about the field of dynamics as opposed to simply clearing another hurdle on your way to graduation, there isn't a choice between reading the text or doing exercises—you must do both. Reading the text is essential to understanding both the theory and the limits beyond which it does not apply. Exercises then help you to discover how that theory enables you to solve real-world problems. As you encounter problems in the text that can be solved in multiple ways (some of which you may remember from previous courses), you are encouraged to apply the concepts from the sections that immediately precede the problems so you learn new ways to solve similar problems.

> It is difficult, if not impossible, for anyone to learn a subject purely by reading about it, without applying the information to specific problems and thereby being encouraged to think about what has been read. Furthermore, we all learn best the things that we have discovered for ourselves. Therefore the exercises form a major part of this work; a definite attempt has been made to keep them as informative as possible and to select problems that are enjoyable as well as instructive.[1].

[1]Donald C. Knuth, *The Art of Computer Programming*, Volume 4A, Fascicle 5, Addison-Wesley, 2019, ISBN 978-0-13-467179-6, in Notes on the Exercises

What do grades mean?

Unlike some classes, the average weighted score is not set to some specific letter grade with your letter grade assigned depending on how far your score falls from the mean. Instead, final course grades are determined based on your demonstrated mastery of the content and your ability to apply the theories and the ideas presented in lectures and readings to real-world problems. Accordingly, the following aspirational rubric is used to guide the assignment of course grades:

- A Performs to the highest standards; demonstrates a mastery of all course material and an ability to apply all aspects of the course content, theories and the ideas presented in lectures and readings to real-world problems; actively engages in class by paying attention and/or participation. Assignments are complete and on-time; grades on all assignments, exams, and discussion activities are consistently excellent.
- B Performs to high standards; demonstrates mastery of most course material and a frequent ability to apply aspects of the course content, theories and the ideas presented in lectures and readings to real-world problems; usually engaged in class. Assignments rarely incomplete and/or late; grades on assignments, exams, and discussion activities are normally good, but not excellent.
- C Performs to moderate standards; demonstrates incomplete mastery of most course material and only a partial ability to apply aspects of the course content, theories and the ideas presented in lectures and readings to real-world problems; sometimes engaged in class. Assignments may occasionally be incomplete and/or late; grades on assignments, exams, and discussion activities are typically only fair.
- D Performs to low standards; demonstrates mastery of only a small fraction of the course material and an ability to apply only a few aspects of the course content, theories and the ideas presented in lectures and readings to real-world problems; rarely engaged in class. Assignments may often be incomplete and/or late; grades on assignments, exams, and discussion activities are often poor.
- F Performs to very low standards; fails to demonstrate mastery of any course material and shows almost no ability to apply aspects of the course content, theories and the ideas presented in lectures and readings to real-world problems; almost never engaged in class. Assignments frequently incomplete and/or late; grades on assignments, exams, and discussion activities are routinely poor.

With such a rubric, there is no reason that you—along with everyone else—can't receive an A in the course. Obviously, there is another side to this coin as well. The outcome is in your hands.

Course outline

This section contains a weekly plan for the semester. While not fixed in stone, this schedule roughly illustrates what we'll be discussing each week and the work you'll be expected to complete. We may not follow the exact sequence of topics in the text — depending on class progress, we might jump ahead at some points during the term or return to earlier material at other points — but this is the outline we will try to follow. We will start with single particles and examine their kinematics, their motion as described by Newton's Laws, and how Newton's Laws lead to relationships between impulse and momentum and between work and energy. We will then introduce multiple particles and see how Newton's Laws and the relationships between impulse and momentum and between work and energy change when multiple particles are involved. Finally, we'll introduce the concept of a rigid body and see what happens to those same Newton's Laws and the relationships between impulse and momentum and between work and energy change when rigid bodies are involved.

Week-by-week schedule

You should note that the number of class meetings per week is not constant due to various holidays. This term, we only have to compensate for Labor Day since there isn't a Fall Recess and Thanksgiving occurs after the end of final exams. Since the week of Labor Day loses one lecture, that loss may affect what we can cover that week—if so, we'll make appropriate adjustments as we go.

In the table that follows: Column 1 contains the week of the term; Column 2 contains the reading material for the week; Column 3 briefly describes the topics that will be discussed in class that week; and Column 4 identifies the problem assignment for the week. *You are expected to have completed the reading assignment before the lectures on those topics start.*

Week	Reading assignment	Lecture topics	Problem set
1	*Text: Ch. 1* *Bb: Vector review handout* *Bb: Separation of Variables handout*	*Nomenclature; ideal systems; problems solvable by SoV* [$\ddot{s} = \ddot{s}(t)$, $\ddot{s}(s)$, *or* $\ddot{s}(\dot{s})$]; *rectilinear motion*	
2	*Text: Ch. 2 (§2.1-7)* *Bb: Coordinate systems handout*	*Rectilinear and curvilinear motion; Cartesian, cylindric, spherical, and intrinsic coordinate systems*	*Problem set #1*
3	*Text: Ch. 2 (§2.8-9)*	*Relative and constrained motion*	*Problem set #2*
4	*Text: Ch. 3 (§3.1-5)* *Bb: Systems of particles handout (§1-2)*	$\boldsymbol{F} = m\boldsymbol{a}$ *for single particles*	*Problem set #3*
5	*Text: Ch. 3 (§3.8-14)* *Bb: Particle collision handout*	*Linear impulse/momentum; particle impacts; Angular impulse/momentum; central force motion*	*Problem set #4*
6	*Text: Ch. 3 (§3.6-7)* *Bb: Conservative forces handout*	*Work/energy; power; conservative forces; potential energy*	*Problem set #5*
7	*Text: Ch. 4 (§4.1-7)* *Bb: Systems of particles handout (§3)*	*Closed systems of particles; force, energy, and momentum*	*Problem set #6*
8	*Text: Ch. 5 (§5.1-5)*	*Rigid body planar kinematics; abs. and rel. vel./acc.; Joints/contact conditions*	*Problem set #7*
9	*Text: Ch. 5 (§5.6-7)*	*Rotating frames*	*Problem set #8*
10	*Text: Ch. 6 (§6.1-4)* *Bb: Rigid body motion handout (§1-3)*	$\boldsymbol{F} = \dot{\mathbf{L}}$ *and* $\boldsymbol{M}_O = \dot{\mathbf{H}}_O$ *for rigid bodies in planar motion;*	*Problem set #9*
11	*Text: Ch. 6 (§6.5)* *Bb: Rigid body motion handout (§1-3)*	$\boldsymbol{F} = \dot{\mathbf{L}}$ *and* $\boldsymbol{M}_O = \dot{\mathbf{H}}_O$ *2-D constrained motion*	*Problem set #10*
12	*Text: Ch. 6 (§6.8)* *Bb: Rigid body motion handout (§4)*	*Impulse/Momentum for rigid bodies in planar motion; Rigid body impact*	*Problem set #11*
13	*Text: Ch. 6 (§6.6-7)* *Bb: Rigid body work/energy handout*	*Work/Energy for rigid bodies in planar motion*	*Problem set #12*
14	*Study days and* *Final exam*		