YSC2203 Classical Mechanics (AY2021/2022 Sem 2)

Instructor: Ng Hui Khoon

Course Information

Class schedule: 1×60-min section and 2×90-min lectures per week; consult Registry for schedule.
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Classical Mechanics

What is it? Classical Mechanics is about the physics of massive bodies moving under the influence of mechanical forces. We discuss motion of objects of everyday size—in contrast with particles of atomic scale in quantum mechanics; we talk about effects from forces in general—in contrast with electrodynamics that treat specifically electric and magnetic forces and associated phenomena; we examine deterministic motion of a single system—in contrast with statistical physics where ensemble/average behavior is studied.

Why now? Classical Mechanics is traditionally used as the "gateway" into the formal Physics curriculum. It is the first course where you will meet the full rigor of mathematics used to describe our physical world, using a subject matter that is already familiar and tangible: the motion of objects you see around you. Yet, as you will see, the treatment is very different from that in high-school mechanics/physics classes. This rigorous mathematical approach forms the basis of all physical theory, and the techniques and concepts you meet in this course will be employed in your subsequent study of physics.

Workload

5 modular credits = 12.5 hours per week:
4hr class time + 8.5hr for reviewing lecture notes & textbook, and attempting the problem set.

There will be weekly problem sets, a mid-semester exam, a test in the second half of the semester, and a final exam at the end.

Lectures

Lectures will be white-board based (or digital equivalent, if Covid-19 restrictions set in). You are expected to take notes during the lecture. Scans of my notes will be provided after each lecture, but you would do well to take down also what I say during the lecture. Lectures will be fast paced, as we have a lot of material to cover.

Sections

In Section, we will review the material covered in the previous week, including going over the graded assignment, as well as attempting new problems/activities related to the week's content. You should expect to go up to the board to present and discuss your solutions to the problems.

Textbook

The nominal textbook for the class is Thornton & Marion, Classical Dynamics of Particles and Systems, by Thornton and Marion (5th edition). The course is pitched at a level most closely resembling the content of this textbook. We will not follow the textbook very closely, and I will provide my own lecture notes throughout the course, but you may find it helpful to have a separate book to refer to.

Two other books that you can consider (optional) are 1) Classical Mechanics, by Golstein; 2) Classical Mechanics, by Kibble and Berkshire.The Goldstein book is a classic, pitched at a level higher than is needed for our class; the Kibble and Berkshire is pitched at a level lower than for our class. Nevertheless, you may still find both books useful. There are also many other classical mechanics textbooks available in the bookstore or library.

Assessment breakdown
35% assignments; 20% Test 1 (Week 7); 15% Test 2 (Week 11); 30% Final exam.
In addition, I reserve the right to adjust your final grade by up to one tier in the grade scale (e.g., a B to a B+, or an A to an A-), depending on your in-class participation (= attendance + contribution to class discussion).

Tentative schedule of topics

PART 1 (Weeks 1-6). Simple systems of point masses

Week 1: Math preparation.

Week 2: Math preparation; Newton's equation of motion.

Week 3: Newton's equation of motion - more on simple harmonic motion; Conservative forces.

Week 4: Conservative forces and conservation laws.

Week 5: Central force motion.

Week 6: Central force motion.

Recess Week

Part 2 (Weeks 7-13). Complex systems

Week 7: Test 1 (Wks 1-6); Gravity and extended mass distributions.

Week 8: Lagrange formalism.

Week 9: Lagrange formalism; Small-amplitude oscillations.

Week 10: Small-amplitude oscillations; Rigid bodies.

Week 11: Rigid bodies; Test 2.

Week 12: Rigid bodies.

Week 13: Rigid bodies and optional topics.

Reading Week

Final exam

Pre-course Math background

The following lists topics you are expected to know well BEFORE starting on the course. The depth of knowledge expected is at the level taught in YSC1213 General Physics and YSC1216 Calculus (pre-requisites for this course); some may be topics you have seen before in high school.

- Vectors:
  - Concept of vectors in 3D space: objects with a direction and a magnitude; what is a unit vector?
  - Scalar (dot) product of vectors; cross product of vectors—how to compute, and what they mean
  - Coordinate systems: Cartesian coordintes (2D and 3D); Polar coordinates (2D)
  - Multiplying matrices with each other; multiplying/applying matrices to vectors
- Elementary functions: (know what they are)
  - Polynomials (also, remind yourself how to solve a quadratic equation)

  - Exponential and logarithm functions
  - Trigonometric functions and basic trigonometric identities
  - Hyperbolic functions: cosh, sinh, tanh— at least know what they are. How are these related to the trigonometric functions and the exponential functions?
- One-variable calculus:
  - Basics of differentiation: differentiation of elementary functions, the product rule, chain rule, etc.
  - Concept of differentiation: What does the derivative of a function mean conceptually?
  - Basics of integration: integration by parts, integration by substitution, integrals of elementary functions (polynomials, exponentials, cosines, sines, hyperbolic cosines and sines, etc.), definite and indefinite integrals, etc.
  - Concept of integration: What does the integral of a function mean conceptually?
  - Concept of a differential equation: e.g., $\frac{\mathrm{d}F}{\mathrm{d}x} = -kx$—what does such an equation mean? (You are likely not familiar with how to solve a differential equation, but at least know what it means.)
- Functions of more than 1 variable: e.g., $F(x, y)$. (Rudimentary conceptual knowledge only)
  - What does such a multi-variable function mean conceptually?
  - Concept of "multi-variable" derivative, i.e., partial derivative, e.g., $\frac{\partial F}{\partial x}$: What does this mean?
  - Concept of multi-variable integration: What does it mean to have a double integral of a function $f(x, y)$? (You are likely not familiar with how to evaluate multi-variable integrals, but at least know what they mean.)
- Basic curve sketching: e.g., what does the graph of $1/x$ look like? $\sin x$? $\cosh x$? what are asymptotes?
- Understand the symbol: Summation notation, e.g., $\Sigma_{i=1}^{n} x_i$.
- Complex numbers (know what they are only): what is a complex number, what is its modulus, its argument, its complex conjugate?
- Taylor expansion: What is it? You may not have seen this before, but it is easy to read up on. Just knowing what it is suffices – we will go through this in class (and will use it repeatedly) but it'll be easier if you have at least an inkling of what it is. Note that the binomial expansion, something you have probably seen before, is a special case of this.