

PHYSICS 017: Linear Algebra for Physics, Spring 2022

LEC: Prof. Flip Tanedo (flip.tanedo@ucr.edu)

TA: Ian Chaffey (ichaf001@ucr.edu)

CRN: 69513 (Course Reference Number)

MEET: TR 12:30–1:50pm PHYS 2104

DIS: none

UNITS: 4

Critical Information

WEB PAGE: sites.google.com/ucr.edu/physics017

CANVAS: elearn.ucr.edu/courses/37232

Lecture notes, homework and our course calendar will be linked from the course web page. We will post some course readings (e.g. selections from textbooks) on the Canvas page. The professor and TA office hours will be posted on the course webpage.

This document was last updated: March 28, 2022

Course Materials

Unfortunately there is no perfect textbook for this course.¹ Rather than forcing you to purchase an expensive book that does not align with our focus, we will post lecture notes online and supplement them with selections from other textbooks on Canvas.

Primary: Course notes are posted to our website and will be our primary reference. We also post selected readings on our course Canvas page as additional references.

Suggested: The first chapter (“Mathematical Introduction”) of *Principles of Quantum Mechanics* (2nd ed.) by R. Shankar covers all of the main ideas in our course. Selections from this chapter posted to Canvas.

Suggested: The appendix of *Introduction to Quantum Mechanics* (2nd ed.) by D. Griffiths has a similar introduction to these key ideas at a slightly more accessible level. Selections from this chapter posted to Canvas.

Suggested: Course notes, “*The Mathematics of Quantum Mechanics*” by M. LaForest covers a broad set of ideas in a similar style. Selections from this chapter posted to Canvas.

Optional: *Linear Algebra Done Right*, Axler. [Digital version available free through UCR library.] This is a more formal linear algebra textbook from a more mathematical perspective. If you are especially mathematical you may want to follow along with this book.

Course Description

Physics 17 covers the essential mathematics for quantum mechanics for undergraduate physics majors. It introduces real and complex linear algebra of finite and infinite-dimensional vector spaces. Examples are drawn from simple quantum mechanical systems. **Topics may include:** matrices, linear equations, bases, eigenvectors and eigenvalues, complex vector spaces, functions as

¹On the other hand, this means we have the freedom to teach the course according to how physicists actually think about linear algebra, tensors, and all that.

infinite-dimensional vectors, differential operators as matrices, Fourier transforms, eigenfunctions of common differential operators, and basics of the representation theory of Lie groups.

Course Prerequisites

There are no strict prerequisites. We expect students to have taken the equivalent of:

- single variable calculus (Math 9)
- the first-year physics sequence (Physics 40 or 41) .

You should have an idea of matrix multiplication from precalculus. Note: the current course catalog lists Math 46 and 10B as prerequisites for this course. The instructor is willing to waive these requirements for students on a case-by-case basis.

Course Format

This course will be *in person*.

Course Expectations

I *strongly* encourage you to ask questions in class and to discuss with your classmates outside of class. There are two questions that you can *always* ask:

1. “*Is it obvious that...?*” This means: I don’t know if I fully understand something. Maybe I’m looking at it the wrong way, what is the best way to see that this is true?
2. “*Why are we doing this?*” You may understand the details, but have lost track of the big picture. What is the main point of this section?

These are good ways to clarify what we’re doing without worrying about “appearing dumb” for asking them.

Course Policies

- **Inclusion:** we are committed to creating an inclusive learning space where we respect one another regardless of race/ethnicity, gender identities, gender expressions, sexual orientation, socioeconomic status, age, disabilities, religion, regional background, veteran status, citizenship status, nationality and other diverse identities that we each bring to class.
- **No bullying:** this course requires students to share work with one another. We will treat each other with respect in our constructive criticism and we will not share each others’ materials outside our course without their explicit written permission. Do not be a troll or a bully; we are each offering some vulnerability to support this learning environment. The instructors reserve the right to punish misbehavior with zero credit on assignments or failure in the course. Be kind.
- **Attendance:** attendance is not part of your grade but is strongly encouraged. You are investing time and resources to be a UCR student and take this class; the goal of the instructors is for the class time to be valuable rather than simply being a recitation of something you could learn by reading a book. If the instructors are failing at this goal, please contact them to politely inform them of this shortcoming.

- **Late homework will not be accepted.** The peer critique aspect of this course is only fair if your peers have access to your work in a timely manner.
- **Communication policy:** When emailing the instructors, please include [P017] in the subject line. For example, “[P017] Possible typo on the homework assignment”. This ensures that the email will be routed properly. The professor anticipates checking course email twice a week on the day of lecture. Physics questions should be asked *in class* where everyone can benefit from the discussion.

COVID-19 Policies

We will follow the UCR COVID return protocols². Please note that we will not be recording lectures. If you have to miss lectures, please confer with your classmates and the posted course notes.

Course Requirements and Assessment

This course is 4 units. One course unit corresponds to approximately three hours of student time per week. Thus 4 units = 12 hours/week, which roughly translates into 3 hours/week of lecture time and 9 hours/week of out-of-class reading, writing, discussing, and recording.

Assignments. All assignments are submitted electronically by an online form. Please typeset or scan your work (e.g. via phone).

- **Short homework:** assigned every Tuesday, due on Thursday before the start of class. These are *brief* exercises to review earlier material.
- **Long homework:** assigned on Tuesday of odd-numbered weeks and due in two weeks. You will have a total of four assignments.
- **Explainer video:** assigned on Tuesday of odd-numbered weeks and due in two weeks. For each long homework, you will be semi-randomly assigned one problem to prepare a 5-minute video explaining the solution to your classmates.
- **Peer review:** assigned on Thursday of odd-numbered weeks and due in one week. You will review some of your classmates explainer videos and provide feedback.

Grading. There will be no final exam and we will not use the final exam slot.

- 20% Short homework
- 30% Long homework
- 30% Explainer video
- 20% Peer review

Occasional extra credit opportunities may come up in class and in the assignments.

Learning Objectives

By the end of this course, you are expected to be able to do the the following learning outcomes:

²campusreturn.ucr.edu

1. Write a system of linear equations as a matrix equation.
2. Apply the Gram-Schmidt procedure to produce an orthonormal basis.
3. Interpret tensors as multilinear maps and perform index-based tensor manipulations on metric spaces.
4. Interpret Lorentz transformations as rotations in Minkowski space.
5. Systematically diagonalize a matrix into a basis of eigenvectors and identify the eigenvalues.
6. Write vectors and matrices using bra-ket notation.
7. Connect the eigenvectors and eigenvalues of a quantum mechanical system to physical observables and states.
8. Interpret differential operators as matrices on an infinite dimensional vector space.
9. Perform Fourier transformations to momentum space to derive the eigenfunctions and eigenvalues of differential operators.
10. Identify whether an operator may be a physical observable based on hermiticity.
11. Confirm the orthonormality of the eigenfunctions of a differential operator.
12. Relate mathematical properties of operators to physical properties in quantum mechanics.

By the end of this course, students will be mathematically prepared for upper-division quantum mechanics and electrodynamics.

Syllabus/Agenda

The weekly agenda is as follows. We reserve the right to adapt the topics and pacing as needed for our class. Please see the course webpage for the most updated information.

1. Matrices, index notation, basis vectors. Review of ‘high school’ vectors and matrices. All sorts of notation for vector spaces.
Reading: Laforest 2.1–2.5, Shankar 1.1.
2. Metrics: raising and lowering indices. Changing basis.
Reading: Laforest 2.5–2.6, Shankar 1.2.
3. Linear algebra and (multi-)linear maps.
Reading: Axler Ch. 3, Shankar 1.3.
4. Rotations and boosts. A hint of complex linear algebra. Special relativity.
Reading: to be determined, e.g. Ch. 1 from *Spacetime and Geometry* by S. Carroll. Shankar 1.4–1.7
5. Eigenvalues and Eigenvectors.
Reading: Shankar 1.8. Griffiths A.5.
6. Complex vector spaces. Spinors, a hint of quantum mechanics.
Reading: Shankar 1.4–1.7
7. Eigenvalue/eigenvector problems in quantum mechanics. Commutators.
Reading: to be determined, e.g. Griffiths appendix.
8. Infinite dimensional vector spaces. Function spaces, differential operators. Differential equations as linear algebra with very large matrices. Fourier transforms.
Reading: to be determined, e.g. Shankar 1.9.
9. Representation theory of Lie groups. Clebsch–Gordan coefficients. Tensor products.
Reading: to be determined.

10. Room for special topics according to interest. Possible topics include the basics of quantum computing and quantum information, Green's functions in field theory, a hint of general relativity based on symmetry principles.

UC Riverside Policies

The information below is fairly standard and you may have already read much of it several times in different courses.³ Please be aware of topics where this course differs from others, for example, academic integrity policies with respect to solutions sites.

Course-specific norms

Titles. We ask that you refer to the professor as *Dr. Tanedo* or *Professor Tanedo*. The purpose of this norm is to encourage uniform honorifics and avoid gender-based and ethnicity-based stereotyping that can affect early career academics.

Academic Misconduct and Plagiarism

It is the *responsibility of each student* to be familiar with the definitions, policies, and procedures concerning academic misconduct. Please revisit our Academic Integrity Policies and Procedures⁴ for more information. This site also defines misconduct, provides examples of prohibited conduct, and explains the sanctions available for those found guilty of misconduct.

Plagiarism is the appropriation of another person's ideas, processes, results, or words without giving appropriate credit. This includes the copying of language, structure, or ideas of another and attributing (explicitly or implicitly) the work to one's own efforts. Issues of significant academic integrity will be reported to the Student Conduct & Academic Integrity Programs office⁵ for mediation. The SCAIP office adjudicates these cases independently of the instructor.

A rough guideline for *this course* is:

- You are *encouraged* to work with other students. You should ask each other questions and learn from one another. Your submitted work should draw on your collaborations, but should be prepared by yourself independently.
- You are *encouraged* to use reputable outside resources. Anything that is not explicitly part of our course materials should be *cited*. A citation contains enough information for any reader to access the same resource. Even after citing other work, your submitted work should be prepared by yourself independently.
- You are *welcome* to have others give you feedback on your independently prepared work and to incorporate that feedback into revisions of your work. All revisions should reflect your own independent work based on that feedback.
- *What about Chegg (and similar sites)?* The course materials contain several worked examples that are the best practice problems for our class. Given that we encourage outside research, we will *not* restrict what resources you may use—however, we do discourage lazy use of solutions sites like Chegg. If you do use any external resources—whether Chegg, Wikipedia, other

³Much of the following text is adapted from templates from the UCR XCITE team. Yes, this is a citation.

⁴conduct.ucr.edu/policies/academic-integrity-policies-and-procedures

⁵conduct.ucr.edu

textbooks, or an academic journal—you are *required* to cite those sources in your submitted assignment.

For example: while researching a particular problem, you may find a part of the problem solved in a clever way on some solutions site. You are allowed to learn from this and think carefully for how it applies to the specific problem on your assignment. You should prepare your assignment *without* the site in front of you, and in your solution you should provide a citation to the webpage along the lines of: “*the technique to use a Fourier transform to integrate this distribution comes from Person McPersonson via <https://...>*” You are responsible for the intellectual merit of anything you submit—so if your solution draws from a garbage source, you can expect a garbage grade.

Motivation for this academic integrity policy. Part of your training as an academic is to effectively use existing literature to solve new problems. 100 years ago ‘existing literature’ meant printed material in a library. In modern times this includes everything accessible on the web. Rather than trying to artificially regulate permissible sources, we will strive for meaningful assessment and responsible engagement with the breadth of possible sources. Proper citation is not only honesty about sources of inspiration; it also highlights your individual contributions to your finished product. Ultimately, your submitted assignments are for your benefit. Careful citations to outside literature will make it easy for you to refer back to useful resources in the future.

Summary: When in doubt about academic integrity in this course, you may contact the professor.

Academic Support Services

Undergraduates: UCR Academic Resource Center⁶ offers peer-to-peer as well as staff supported mentoring and workshops. You may find it helpful to access their writing center⁷.

Graduates: refer to the UCR Graduate Student Resource Center⁸ and Graduate Writing Center⁹.

Student Needs: The following UCR resources are available to support students:

- Student Health Services¹⁰
- Counseling & Psychological Services¹¹ (CAPS)
- Residential Life and Dining: Basic Needs¹², including R’Pantry and Emergency Housing

Equity and Access

Reasonable Accommodation for Disabilities

Students with disabilities who require accommodations in this course must be registered with Student Disability Resource Center (SDRC).¹³ The SDRC directly contacts the professor to handle

⁶arc.ucr.edu

⁷arc.ucr.edu/writing

⁸gsrc.ucr.edu

⁹gwc.ucr.edu

¹⁰studenthealth.ucr.edu

¹¹counseling.ucr.edu

¹²basicneeds.ucr.edu

¹³sdrc.ucr.edu

all disability-related accommodations. If you have a disability and you would like to make a request for reasonable accommodation, please contact the Student Disability Resource Center directly.

Adjustments for Pregnancy/Childbirth

Should you need modifications or adjustments to your course requirements because of documented pregnancy-related or childbirth-related issues, please contact the instructor. Generally, modifications will be made where medically necessary and similar in scope to accommodations based on temporary disability. Learn more about the rights of pregnant and parenting students by consulting the Office of Diversity, Equity, and Inclusion.¹⁴

Title IX Resources

For any concerns regarding gender-based discrimination, sexual harassment, sexual misconduct, stalking, or intimate partner violence, the University offers a variety of resources, including advocates on-call 24/7, counseling services, mutual no contact orders, scheduling adjustments, and disciplinary sanctions against the perpetrator. Please see the Title IX website¹⁵ for more information or to file a report. They can be reached at (951)827-7070.

Please note that faculty and staff at UCR who receive information regarding sexual violence and sexual harassment are required to share that information with the Title IX office, for example by making their own report. If you are need a confidential source of support, please reach out to the ucr care office.¹⁶

Religious Absences

It is the policy of the University to excuse absences of students that result from religious observances and to provide for the rescheduling of examinations and additional required classwork that may fall on religious holidays without penalty. It is the responsibility of *the student* to make alternate arrangements with the instructor at least one week prior to the actual date of the religious holiday.

Library And Technical Support

Access digital materials and other resources at the UCR Library¹⁷. It may be especially helpful to be able to connect to the campus network through the UCR VPN¹⁸.

ITS Student Technology Services¹⁹ supports 9 student computer labs, including 7 public labs and 2 nonpublic labs, with approximately 293 public lab hours per week available for academic use by all UCR students. UCR students can use the ITS STS website to submit a ServiceLink ticket or may directly contact BearHelp@ucr.edu. They provide assistance with computer and specialized software access, R'Mail and Canvas accounts, network connectivity, or any other services used by UCR students.

¹⁴diversity.ucr.edu

¹⁵titleix.ucr.edu

¹⁶care.ucr.edu

¹⁷library.ucr.edu

¹⁸library.ucr.edu/using-the-library/technology-equipment/connect-from-off-campus

¹⁹its.ucr.edu/sts

Recognition of reading the syllabus

In recognition of anyone who actually skimmed through the syllabus (it was a pain to write) and made it this far, please email the professor with the following subject title: “[P017] Capybara Parade” and attach your favorite photo of a capybara (for good practice, please include a citation to the source). Students who do this before Week 2 will receive a small extra credit on their course grade.

Registration and Withdrawal

If you choose to withdraw from this course, you must complete the appropriate forms from the Office of the Registrar.²⁰

²⁰registrar.ucr.edu/calendar