Physical Mechanics

2020 Fall Block C | Physics 339 | PEngel 167

Instructor:

Name: Dr. Tom Kirkman   General Office Hours: 7:30 A.M. – 5:00 P.M.
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Texts:

- *Classical Mechanics* by John R. Taylor (University Science Books 2005)
  Chapters: 1–11, 13
- `http://www.physics.csbsju.edu/339`

Grading:

Your grade will be determined by averaging five scores: total homework score, two exam scores, and the final exam score (which is double-counted). Assigned homework is due at class time on the following class day. I'll generally accept late homework but will perhaps apply a late penalty. Day-by-day homework assignments are recorded in the `assignments.txt` file at the class web site. I encourage you to work together on homework and to seek help/hints from me. The exams will consist of a few (∼4) problems. Currently I'm thinking the exams will be in-class, but the future is not clear. Approximate exam dates are: 2 November (Monday) and 10 November (Tuesday), but I can easily be swayed to move exam dates. The final exam will be a three hour comprehensive exam on the last class day. Note that handouts, exams and lecture notes from 2014 and 2017 are available from the class web site.

Questions:

There is no such thing as a dumb question. Questions asked during lecture do not "interrupt" the lecture, rather they indicate your interests or misunderstandings. I'd much rather clear up a misunderstanding or further develop a topic of interest than continue a dull lecture.

Remember: you are almost never alone in your interests, your misunderstandings, or your problems. Please help your classmates by asking any question vaguely related to physics. If you don't want to ask your question during class, that's fine too: I can be found almost any time in my office (132) or the nearby labs. Drop in or Zoom in any time!

Topics:

This course covers 'classical mechanics'. The word *classical* (in contrast to 'quantum' or 'relativistic') suggests we're mostly concerned with approximating the motion of 'normal' objects (e.g., the apples and planets considered by Newton). We'll begin with Newton's view of mechanics (PHILOSOPHIÆ NATURALIS PRINCIPIA MATHEMATICA—1687). Newton's fundamental equation: $\sum \mathbf{F}_i = m\mathbf{a}$, says that the total vector force determines/causes a particle's acceleration and then from the accelearation (and some calculus) the particle's path can be determined. We'll then develop the more powerful (but mathematically equivalent) methods discovered by Joseph-Louis Lagrange (*Mécanique analytique*—1788) and William Rowan Hamilton (1833). Either way the result of applying the physics will be a differential equation. While these FDP[1] were limited to pencil-and-paper solutions ('analytical' solutions) you'll be solving many differential equations using the computer program *Mathematica* ('computational' or 'numerical' solutions).

Many topics this fall should be familiar to you from 191: vectors, conservation laws, SHM, gravity. However the two additional years of mathematics you've completed since 191 will be put to use. Calculus (119 & 120) will be everywhere, Linear Algebra (239) will be the basis for vector and matrix operations (up through eigenvectors), the second order differential equations you studied in 337 *are* $F = ma$, and—as usual—we may be ahead of your Multivariable Calculus (305) class in our use of vector calculus. (Vector calculus will play the leading role in next semester's E&M.)

Some of the class will be devoted to reformulating dynamics. Newton thought of *forces* as the *cause* of motion: $\mathbf{F} = m\mathbf{a}$. Oddly enough we can produce identical results (i.e., identical differential equations of motion) from a very different point of view. (Think about that for a minute: different ideas of 'cause' produce the same predictions. . . how can science determine which is 'right'?) Instead of $\mathbf{F} = m\mathbf{a}$ we'll use minimization principles developed by Lagrange which will require some new mathematics: the *calculus of variations*. You're used to using calculus to find *where* (i.e., the x value) a known function, $f(x)$, has a maximum or minimum. Calculus of variations is used to find the *whole* function which minimizes (or maximizes) some integral property. For example, consider a twisted (non-planar) wire loop. If you dip the loop in soapy water and then remove it, a smooth surface of soap film forms. What determines the location (z) of the surface at various points inside the loop (i.e., the surface $z = f(x, y)$)? It turns out (to minimize energy) the film adjusts itself to minimize its surface area. So $f(x, y)$ defines the surface which on the boundary matches the actual wire position and has less total surface area than any other such surface. (Actually the calculus of variations just tells you what differential equation f should satisfy; you then have to solve that diffeq with the methods you learned in 337.)

Oddly enough the main reason we're spending time on these reformulated versions of classical mechanics is that they are needed to understand *quantum* mechanics. So this time next year expect to be seeing Hamiltonians again.

One final point: it is important to remember that the subject of our study is not in the book; it is any object in motion. Spin a penny on your desk any try to explain why it does what it does. Luckily my test questions will not be that hard!

References:

Classical Dynamics by Marion (QA845)

Classical Mechanics by Barger & Olsson (QA805)

Mechanics by Symon (QC125.2)

Analytical Mechanics by Grant Fowles & George Cassiday (QA807)

Principles of Mechanics by Synge & Griffith (QA807)

Newtonian Dynamics by Baierlein (QA845)

Classical Mechanics by Goldstein (QA805) — graduate text

[1] Famous Dead Physicists