Straw Man Proposal for the Undergraduate Physics Curriculum

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1 Objectives

The current typical schedule of student coursework is shown in Table 1 for honors students. The schedule for transfer students that arrive at UC Davis for their Junior year is shown in Table 2. There are of course many students taking different trajectories through our program, but most are some variation on these two. This proposal aims to improve upon this course of study, to achieve the following aims:

- Physics majors that complete 9HD or 9D in the fall of their sophomore year have little to do for the rest of the year. The honors students have 9HE, but this is effectively an elective and does little to further prepare them for upper division course work. The recent addition of 40 and 80 helps somewhat, but not enough. The result of this stalling is that the junior and senior year are a race to complete the degree requirements, leaving very little flexibility or time for advanced electives.

- Transfer students that arrive at UC Davis for their Junior year face a wall of coursework that they have to handle in the first quarter: math methods, mechanics, and modern physics. Many also take Physics 102, which is nominally a one credit course, but generally nearly as much work as a four credit course. For many of the transfer students these courses are the first physics courses that require solving challenging homework problems, and they face effectively

Table 1: Typical schedule for undergraduate physics majors, taking the 9H series, in the fall quarter, omitting lab courses.

year	fall	winter	spring
Freshman	9HA	9HB	9HC
Sophomore	9HD	9HE	40
Junior	104A 105A	105B 110A	110B 115A
Senior	115B 110C 112		

Table 2: Typical schedule for undergraduate physics majors that transfer to UC Davis in their Junior year, omitting lab courses.

year	fall	winter	spring
Junior	9D		40
	104A	105B	110B
	105A	110A	115A
	102		
Senior	115B		
	112		

16 credits. We have two trains of students running through our program (transfers and honors students) and the fall of their junior year is the train wreck where they collide.

- The current curriculum does not include sufficient computing practice for our students. It's useful to consider what a physics degree would like if we taught calculus the same way we teach computing. Students would arrive their Freshman year and take an introductory calculus course. Then, they would take their physics courses, which would never mention calculus. At some point in their Junior or Senior year, they would take a one quarter course called "Calculus in Physics" that would attempt to show all the ways we use calculus in physics. Our students are experts at calculus because they learn how to use the tool, and then apply it, again and again, throughout their coursework. To remain relevant in the modern world (or even the world from 20 years ago, to be honest) our majors need more practice in the use of computing as a tool for solving physics problems.

- We are allowed to require a maximum of 110 credits from the college of Letters and Science, which is one half the maximum number of credits students are allowed to take. Fitting the canon of undergraduate physics into such a tight space is extremely challenging. Students complain that we waste time teaching some topics again and again (e.g. Special Relativity from scratch) while completely dropping other topics (e.g. Classical Hamiltonians). The problem is particularly acute for Applied Physics majors, where core material must be dropped to make space for coursework outside of Physics.

- The prerequisite structure of the upper division courses creates many tiers. As an extreme example, 122 requires 112, which requires 115A, which requires 104A and 105A, both of which require the 9 series. This, combined with the rapid paces, leaves very little flexibility for students once they start their Junior year. For example, missing a single quarter of the courses in the Junior year of Table 1 requires an exception to prerequisites or an extra year to graduate.

A proposal to improve on all of these issues is detailed in the next section followed by a discussion of non-lab coursework, computational lab work, and experimental lab work in turn, and pre-requisite structure.

Table 3: Preparatory Subject Matter

Credits: 49-50. *: recommended, C: concurrently.

Course		Credits	Offered	Pre-reqs	Name
PHY	9A	5	F,S		Classical Physics *(Class. Mech.)*
	9B	5	F,W		Classical Physics *(Waves, Thermo., Optics.)*
	9C	5	W,S		Classical Physics *(Elec. and Magn.)*
	9D	4	F,S		Modern Physics *(Rel. and Quant. Mech.)*
	or				
PHY	9HA	5	F		Honors Physics *(Class. Mech.)*
	9HB	5	W		Honors Physics *(Rel. and Stat. Mech.)*
	9HC	5	S		Honors Physics *(Waves and Quant. Mech.)*
	9HD	5	F		Honors Physics *(Elec. and Magn.)*
MAT	21A	4			
	21B	4			
	21C	4			
	21D	4			
	22A	3			
	22B	3			
PHY	40	4	S		Introduction to Physics Computation
	80	4	(F),W,S	40,9D	Experimental Techniques
PHY	185*	1	S		
	190*	1	F		

2 B.S. Requirements (Minimal)

The proposed B.S. Requirements are presented in Tables 3 and 4. Example schedules are presented in Tables 5 and 6.

Table 4: Core Subject Matter

Credits: 46-50. *: recommended, C: concurrently.

Course		Credits	Offered	Pre-reqs	Name
PHY	102	4	W	40, 9D	Computational Physics
	104A	4	F	C:9D	Mathematical Physics
	105A	4	W	104A, 9D	Classical Mechanics I
	105B	4	S	105A, 102	Classical Mechanics II
	110A	4	W	104A, 9D	Electricity and Magnetism I
	110B	4	S	110A, 102	Electricity and Magnetism II
	115A	4	F	104A, 9D	Quantum Mechanics I
	115B	4	W	115A, 102	Quantum Mechanics II
	115C	4	S	115B	Applications of Quantum Mechanics
	112	4	F	104A, 9D	Thermodynamics and Statistical Mechanics
PHY	116A	4	W	80	Instrumentation with Discrete Electronics
	116B	4	S	116B	Instrumentation with Integrated Electronics
	or				
PHY	122A or B	4	(F),W,S		Advanced Physics Laboratory
	Any two of				(all three recommended):
PHY	105L	1	S	102,C:105B	Computational Lab in Mechanics
	112L	1	F	102,C:112	Computational Lab in Statistical Mechanics
	115L	1	W	102,C:115B	Computational Lab in Quantum Mechanics

Electives: an additional 15 credits of electives is required, 12 credits from advanced (capstone) topics.
Total Units: 110-115

Table 5: Example schedule for undergraduate physics majors taking the 9H series and opting for the 116 lab sequence. E is an elective course. Rate is 5-9 credits per quarter.

year	fall	winter	spring
Freshman	9HA(5)	9HB(5)	9HC(5) 40(4)
Sophomore	9HD(5) 104A(4)	105A(4) 102(4)	105B(4) 105L(1) 80(4)
Junior	115A(4) 112(4) 112L(1)	115B(4) 110A(4) 115L(1)	115C(4) 110B(4)
Senior	E(4) E(4)	116A(4) E(4)	116B(4) E(4)

Table 6: Example schedule for for an undergraduate physics majors that transfered to UC Davis in their Junior year without Physics D or 40 equivalents. Rate is 12-13 credits per quarter.

year	fall	winter	spring
Junior	9D(4) 40(4) 104A(4)	105A(4) 110A(4) 102(4)	105B(4) 105L(1) 110B(4) 80(4)
Senior	115A(4) 112(4) 112L(1) E(4)	115B(4) 122A(4) E(4) 115L(1)	115C(4) E(4) E(4)

3 Discussion of Regular Coursework

The typical schedule of courses for the proposed new curriculum is shown in Table 5 for honors physics and Table 6 for Junior transfer students. The primary feature is that incoming transfer students now overlap mostly with sophomore honors physics students. This eliminates the stalling of our honors students while relieving some of the intense academic pressure on incoming transfer students. Our experience has been that the best of the transfer students perform as well as our four-year students once they have sufficient time to adjust, and this proposal gives them that time. Accelerating the honors students also provides tremendous additional flexibility to their schedule. Transfer students that wish to complete their degree in two-years are still highly constrained, but instead of facing a 13 credit brick wall, they start with only eight credits of required coursework in their first fall quarter at UCD.

Several new classes have been added and others require changes to their content or will no longer be required:

- 9A-D and 9HA-D These courses are largely unchanged, however, some fine adjustments may be needed to ensure that the 9 series plus 104A are sufficient preparation for 115A and 112.

- 9HE is no longer offered: This course is effectively an elective, with content that varies from instructor to instructor. By removing it, we allow the Honors students to start toward the core material sooner, leaving more time for advanced electives. With more relaxed schedule in their senior year, it seems highly plausible that physics majors will take more electives.

- The 115 sequence will be substantially revised. The addition of 115C as a third quarter is intended to achieve a number of effects to the entire sequence. 115A will be an introduction to QM that relies only on 9 series and 104B, and it should function well as a standalone course for applied physics majors who will not be required to take 115B and 115C. The next two quarters, 115B and 115C, have 102 as prerequisites and can therefore integrate significant computational work into the curriculum. The extra time should also allow coverage of new topics (e.g. QIT).

- 102: This course will be renamed "Computational Physics" and will be closer in content to the 104B as taught by some instructors. This course will play a more integral role in this revised curriculum and so the content and tools will need to be more consistently covered

than in 104B. The decision to use 102 as the course number is for clarity, as 104A will not be a prerequisite.

- 110C is no longer offered: A third quarter of E+M is too much to allocate to this topic, given the other needs of the curriculum and limited number of required credits. 110A and B will need some adjustment to make certain that the vector potential and special relativity are covered.

4 Discussion of Computational Physics

One of the major objectives of this curriculum overhaul is to better integrate computational physics throughout the curriculum, and this is accomplished in a number of ways:

- The one credit PHY 102 course is eliminated. Now every major takes PHY 40 and a new 4 credit PHY 102 for a total of eight credits of introductory programming and computational physics.
- Physics 80 is required for all majors and includes extensive use of scientific python for data analysis and presentation.
- There are three new one-credit computational lab courses (105L, 112L, and 115L) designed to be taken concurrently with 105B, 112, and 115B. They are computational problem solving labs related to mechanics, E+M, and quantum mechanics. The instructor will present a technique and problem during a single one hour lecture, and the students will have the rest of the week to complete their assignment. It is expected that one instructor will teach all three in a single year, which will count as one course. These are each offered in a different quarters, so students get three credits of computational problem-solving spread across an entire year. Due to credit limits, we only require two of these courses, but all three are recommended.
- PHY 105B, 110B, and 115B now have 102 (computational physics) as a pre-requisite. Computational problems can therefore be fully integrated into these courses.

5 Discussion of Labs

Physics 80 was introduced in 2018, and is currently a pre-req for 122A and 122B. It is anticipated that this will relieve some of the time pressure in this one quarter course.

In this proposal, Physics 80 is a pre-requisite for the 116 (Instrumentation) sequence. Physics 80 covers some of the content in 116A (passive analog electronics) and some of the content in 116C (computation with scientific python and statistical analysis). Therefore, the three quarter 116 sequence (A,B, and C) can become a two quarter sequence, 116A covers discrete electronics (analog and digital), and 116B can cover integrated electronics (microprocessors and FPGAs).

6 Discussion of Prerequisites

An overview of the prerequisite structure is shown in Fig. 1. Classes within a tier can require only earlier classes from within the sequence (e.g. B requires A) or classes from an earlier tier. One exception is that 104A requires 9D (which may be taken concurrently). Reducing the number of

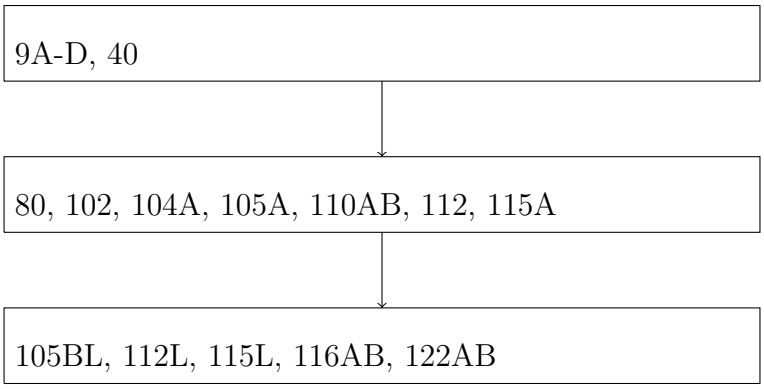

Figure 1: The prerequisite structure of required courses. At each tier, course prerequisites can only be earlier courses in the same sequence or courses from a previous tier. Courses from the lowest tier should not be prerequisites for any other courses outside their own sequence, including capstone courses.

tiers in our program to three affords significantly more flexibility for students to work through each tier in whatever order works best for their schedule. Because 102 requires 40 and the 9 series, but is needed for 115B and 105B, it remains a potential bottleneck, along with 104B. The limited number of offerings for most courses will also limit flexibility in practice.

The most notable changes are that:

- 115A does not require 105A anymore, 9A-D must suffice instead
- 112 does not require 115A anymore, 104A and 9A-D must suffice instead
- The new four-credit 102 course (which replaces both 104B and the current version of 102) does not require 104A, and instead requires 40.
- 105B and 115B require 102, which allows for computing to be integrated with the course.

Some classes can be globally substituted as prerequisites, which we note here:

- 9HD can replace 9D or 9C. Note that 9HC does not replace 9C due to different ordering of the Honors sequence.
- Any ECS introductory programming course can replace 40.

7 Other Goals

There are some other goals not included in this proposal that I would like to keep track of:

- It would be nice if e.g. 105A, 110A-B, 115A worked as complete set of core courses for e.g. Astro and Applied physics majors.
- I would like to offer some sort of lower division 3 credit elective for the transfer students (PHY 19?) to take in Fall of their Junior year, that focuses on solving problems from material in 9A-C. We could also recommend this to students that didn't did so well in 9 and can use a bit of brushing up before the upper division course work. Currently, 105A is filling this role.