

# PROPOSED PHYSICS CURRICULUM CHANGES

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## Motivation

It goes without saying that we have a strong interest in strengthening our program and in serving our students by providing the best possible undergraduate physics education. In this document I have reimagined the Physics BS curriculum to try to address some of the areas in our curriculum that I would personally like us to try to improve, including:

- (i) There exists less-than-optimal coordination between physics and math coursework and, in particular, our students tend to exhibit weak *applied* mathematical skills even after taking the full set of mathematics courses.
- (ii) I feel that the physics major is overly burdensome in terms of the number of courses and credits our students have to take, which makes it challenging for students to pursue other majors/minors (mathematics, astrophysics, data science, computational science), go abroad, start the physics major in their sophomore year, pursue the 3/2 engineering program, engage in independent research, and so forth.
- (iii) And finally I feel that the current curriculum does not suitably prepare our students for graduate school and particularly for the GRE which takes place in the fall of their senior year.

Please note that this is a strawman proposal meant to engender discussion, not to create any hard feelings whatsoever! In particular, I have assumed that existing courses are not “owned” by anyone and have only approached this exercise from a high-level standpoint of what I think will best serve our students.

## Current Physics BS

Before presenting my specific proposal I thought it would be helpful to review the current curriculum. Table 1 summarizes the current suite of courses a “typical” BS student would take. For comparison across the various proposed programs, the table also shows the number of student **Credit Hours (CH)** and **Faculty Contact Hours (FCH)**.<sup>1</sup>

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<sup>1</sup>I have assumed three lecture sections and three lab sections of general physics (per semester) and one lecture and two lab sections (each) of Modern Physics and Electronics I.

Table 1:: Current Physics BS Curriculum

<b>Fall Year 1</b>	CH	FCH	<b>Spring Year 1</b>	CH	FCH
General Physics I	4	18	General Physics II	4	18
General Physics Review I	0	1	General Physics Review II	0	1
Calculus I	4	0	Calculus II	4	0
Software Tools for Physicists	3	3			
<i>Total:</i>	<i>11</i>	<i>22</i>	<i>Total:</i>	<i>8</i>	<i>19</i>
<b>Fall Year 2</b>	CH	FCH	<b>Spring Year 2</b>	CH	FCH
Modern Physics	4	9	Computational Physics	3	3
Electronics I	4	9	Thermal Physics	3	3
Calculus III	4	0	Differential Equations	3	0
<i>Total:</i>	<i>12</i>	<i>18</i>	<i>Total:</i>	<i>9</i>	<i>6</i>
<b>Fall Year 3</b>	CH	FCH	<b>Spring Year 3</b>	CH	FCH
Mechanics I	4	6	Electromagnetism I	4	6
Chemistry I	4	0	Experimental Techniques	2	5
Applied Math	3	0	Linear Algebra	3	0
<i>Total:</i>	<i>11</i>	<i>6</i>	<i>Total:</i>	<i>9</i>	<i>9</i>
<b>Fall Year 4</b>	CH	FCH	<b>Spring Year 4</b>	CH	FCH
Advanced Lab I	1	3	Advanced Lab II	1	3
Quantum Physics	3	3	Physics Elective	3	3
<i>Total:</i>	<i>4</i>	<i>6</i>	<i>Total:</i>	<i>4</i>	<i>6</i>
				CH	FCH
<b>Grand Total:</b>				<b>68</b>	<b>94</b>

## Proposed Physics BS

Table 2 and the exposition below summarize the new proposed Physics BS curriculum. Courses in **red** are new while courses in **blue** are existing courses which would be modified as described below.

Table 2:: Proposed Physics BS Curriculum

<b>Fall Year 1</b>	CH	FCH	<b>Spring Year 1</b>	CH	FCH
General Physics I	4	18	General Physics II	4	18
Math for Physicists/Engineers I	1	1	Math for Physicists/Engineers II	1	1
Calculus I	4	0	Calculus II	4	0
Software Tools for Physicists	3	3			
<i>Total:</i>	<i>12</i>	<i>22</i>	<i>Total:</i>	<i>9</i>	<i>19</i>
<b>Fall Year 2</b>	CH	FCH	<b>Spring Year 2</b>	CH	FCH
Electromagnetism I	4	6	Mechanics I	4	6
Math for Physicists/Engineers III	1	1	Math for Physicists/Engineers IV	1	1
Calculus III	4	0	Differential Equations	3	0
Chemistry I	4	0			
<i>Total:</i>	<i>13</i>	<i>7</i>	<i>Total:</i>	<i>8</i>	<i>7</i>
<b>Fall Year 3</b>	CH	FCH	<b>Spring Year 3</b>	CH	FCH
Advanced Lab Techniques I	1	1	Advanced Lab Techniques II	1	1
Quantum Physics	3	3	Thermal Physics	3	3
Electronics I	4	9	Experimental Techniques	2	5
<i>Total:</i>	<i>8</i>	<i>13</i>	<i>Total:</i>	<i>6</i>	<i>9</i>
<b>Fall Year 4</b>	CH	FCH	<b>Spring Year 4</b>	CH	FCH
Physics Elective	3	3	Physics Elective	3	3
Honors Thesis			Honors Thesis		
<i>Total:</i>	<i>3</i>	<i>3</i>	<i>Total:</i>	<i>3</i>	<i>3</i>
				CH	FCH
<b>Grand Total:</b>				<b>62</b>	<b>83</b>

### Description of Proposed Courses and Course Changes

- **Math for Physicists & Engineers I, II, III, IV**
  - *Summary:* A perennial problem in our physics courses, especially our calculus-based general physics sequence, is the fact that students do not learn the basic

mathematical tools they need until well into their sophomore and junior year. Meanwhile, teaching math in our courses leaves less time for teaching physics! The goal of the *Math for Physicists & Engineers* four-course sequence—which would be taught in close coordination with the concomitant physics courses—is to provide students with the mathematical tools from calculus, linear algebra, and differential equations they need to solve a wide range of elementary physics problems. These courses will also serve our applied physics majors.

- *Approximate Topics (unordered)*: vectors; matrices; coordinate systems (1D, 2D, 3D); differentiation; integration (1D); line integrals; circular motion; cross/scalar product; linear equations; matrix diagonalization; Taylor series expansions; div; grad; curl; Fourier analysis; special functions.
- *Issues to Consider*: We could consider enabling students to test out of one or more of these courses depending on their math background (or ability to learn the material on their own!). Also note that these courses would be taught by physics faculty.
- General Physics I
  - *Summary*: Not having to teach vectors, differentiation, and circular motion in general physics will allow for more time for all topics, but especially rigid-body statics and dynamics, as well as gravity (which are typically rushed at the end of the semester or not taught at all). It's also possible that a chapter on basic fluids could also be taught here.
  - *Approximate topics*: kinematics, forces, energy, work, momentum, rigid-body statics and dynamics, gravity, and fluids.
- General Physics II
  - *Summary*: Students frequently struggle with electromagnetism because they don't have the requisite mathematical background. Moreover, the fact that we don't teach (general physics level) thermodynamics means that time has to be spent in *Thermal Physics* on these topics. Therefore, I propose we push electromagnetism (with the exception of the charge model and basic circuits) to students' sophomore year, freeing up considerable time for thermodynamics and fluids (if not taught in General Physics I). In addition, some basic topics from *Modern Physics* like the Bohr model of the atom and the Schrödinger equation could be introduced at the end of the semester.
  - *Example topics (unordered)*: fluids, thermodynamics, waves, optics, charge model, basic circuits, basic atomic/modern physics.

- Issues to Consider: How will not teaching electromagnetism impact non-physics majors who only take General Physics I & II? Perhaps they can take General Physics I & II
- Electromagnetism I
  - Summary: I propose that Electromagnetism I becomes a sophomore-level course which introduces electromagnetism to our students for the first time, as well as special relativity. With the mathematical foundations of general physics and the Math for Physicists & Engineers courses completed, students should be able to tackle Maxwell's equations and electrodynamics at a reasonably rigorous level.
  - Example topics (unordered): electrostatics; electric potential; current; magnetic field; induction; Maxwell's equations; light; electrodynamics; special relativity; mathematical methods.
  - Issues to Consider: This course is currently a 400-level course in the catalog...
- Mechanics I
  - Summary: I propose that Mechanics I becomes a sophomore-level course centered around the Lagrangian mechanics formalism, supplemented with additional advanced topics not covered in general physics. Hamiltonian mechanics would *not* be introduced here.
  - Example topics (unordered): particle dynamics; energy/work; conservative forces; rigid-body statics/dynamics; orbital mechanics and gravity; oscillators; rotating reference frames; Lagrangian mechanics.
  - Issues to Consider: This course perhaps more naturally belongs in the fall of the sophomore year but after a year of general physics students should really see electromagnetism then. Note that this course is currently a 300-level course in the catalog...
- Advanced Lab Techniques I & II
  - Summary: I have not fully fleshed out this idea yet, but my thinking is that we reimagine the senior-level *Advanced Lab I & II* sequence as a junior-level hands-on course which covers a wide range of laboratory techniques and methods not previously taught. Some possible topics could include advanced statistical methods, 3D printing, machine shop methods, scientific writing, experimental design, etc. Students could also start to lay out their *Honors Thesis* research proposal.
- Honors Thesis
  - Summary: My thinking here is that we allow students the option of carrying out an *independent* research project in their senior year which would culminate in a

written Honors Thesis. The department could then award the “best” thesis at the end of the year or at graduation.

- Physics Electives

- *Summary:* In addition to the required courses tabulated above students would also have to complete two additional upper-level physics electives. Some possibilities include: astrophysics, computational physics, optics, nuclear and particle physics, simulation and modeling, nanoscience, solid state physics, strength of materials, etc.

### *Additional Notes and Thoughts*

- It goes without saying that modern physics and computational physics are missing from Table 2 and that there has been a significant reshuffling of the order in which existing courses would be taught. *Although my proposed curriculum isn't necessarily optimal, every change was made for very specific reasons that I look forward to debating!*
- In this proposal the “automatic” math minor is no longer part of the major. However, students interested in graduate school should be strongly encouraged to take linear algebra, applied math, complex analysis, and other upper-level math electives. Alternatively, students can pursue a minor in data science, astrophysics, chemistry, etc.
- In the interest of maximizing allocation of departmental and College resources, I propose we remove general physics review as a “free” course. One possibility would be to have the students attend one mandatory hour of office hours. The “freebie” Advanced Lab contact hours have also been removed.
- There should be a very strong computational thread connecting *all* the courses—and especially the labs. To be specific, we should write down the precise learning goals we want our courses to be able to accomplish (in terms of what we want our students to be able to *do* computationally), and then implement those goals.

## **Proposed Applied Physics BS**

The redesigned physics curriculum makes it straightforward to implement an *applied physics* BS, as summarized in Table 3. Moreover, a slight variation in this curriculum will much more easily allow our students to transfer to RPI/Clarkson to pursue either aeronautical or mechanical engineering as part of the 3/2 program, and should also allow our students to pursue the masters in mechanical engineering at Clarkson as part of the 4/1 program.

To avoid double-counting, in this table I have only highlighted the *additional* faculty contact hours (above and beyond the regular BS) that the new major would require.

Table 3:: Proposed Applied Physics BS Curriculum

<b>Fall Year 1</b>	CH	FCH	<b>Spring Year 1</b>	CH	FCH
General Physics I	4	-	General Physics II	4	-
Math for Physicists/Engineers I	1	-	Math for Physicists/Engineers II	1	-
Calculus I	4	0	Calculus II	4	0
Software Tools for Physicists	3	-	<b>Solidworks / CAD</b>	1	1
<i>Total:</i>	<i>12</i>	<i>-</i>	<i>Total:</i>	<i>10</i>	<i>1</i>
<b>Fall Year 2</b>	CH	FCH	<b>Spring Year 2</b>	CH	FCH
Electromagnetism I	4	-	Mechanics I	4	-
Math for Physicists/Engineers III	1	-	Math for Physicists/Engineers IV	1	-
Calculus III	4	0	Differential Equations	3	0
Chemistry I	4	0			
<i>Total:</i>	<i>13</i>	<i>-</i>	<i>Total:</i>	<i>8</i>	<i>-</i>
<b>Fall Year 3</b>	CH	FCH	<b>Spring Year 3</b>	CH	FCH
Advanced Lab Techniques I	1	-	Advanced Lab Techniques II	1	-
<b>Mechanics II</b>	3	3	Thermal Physics	3	-
Electronics I	4	-	<b>Solid State Physics / Material Science</b>	3	3
<i>Total:</i>	<i>8</i>	<i>3</i>	<i>Total:</i>	<i>7</i>	<i>3</i>
<b>Fall Year 4</b>	CH	FCH	<b>Spring Year 4</b>	CH	FCH
<b>Strength of Materials</b>	3	3	Physics Elective	3	-
Honors Thesis			Experimental Techniques	2	-
			Honors Thesis		
<i>Total:</i>	<i>3</i>	<i>3</i>	<i>Total:</i>	<i>5</i>	<i>-</i>
				CH	FCH
<b>Grand Total:</b>				<b>66</b>	<b>10</b>