CALIFORNIA STATE POLYTECHNIC UNIVERSITY, POMONA

ACADEMIC SENATE

ACADEMIC PROGRAMS COMMITTEE

REPORT TO

THE ACADEMIC SENATE

AP-033-156

Physics, B.S.—Integrated Science Option

General Education Committee	**Date: 04/03/2016**
Executive Committee **Received and Forwarded**	**Date: 05/18/16**
Academic Senate	**Date: <u>05/25/2016</u>** **<u>First Reading</u>** **<u>06/01/2016</u>** **<u>Second Reading</u>**

BACKGROUND: The Department of Physics and Astronomy is proposing a new Option in Integrated Science under its Bachelor of Science in Physics. This program balances a solid foundation in physics with courses in other areas of science in order to meet the requirements for a Single Subject Teaching Credential in Physics, as set forth by the California Commission on Teacher Credentialing. The rationale for offering such a specialized program is that California has a documented need for qualified physics teachers, but the standard physics program that Cal Poly Pomona had traditionally offered does not include the balance of coursework in other fields that aspiring teachers need under state rules (so that they can teach introductory general science courses as well as specialized high school physics courses). Consequently, aspiring physics teachers must first complete a four-year degree in physics and then take nearly a year of additional science courses (primarily in geology and biology) BEFORE they can begin a credential program. This program will streamline the path to a teaching credential, meeting an important workforce need of the state while reducing the cost of training teachers and the time that students must invest.

RESOURCES CONSULTED:
Faculty
Department Chairs
Associate Deans
Deans
Office of Academic Programs

DISCUSSION:
Before reaching the Academic Programs Committee, this program was reviewed by the College Curriculum Committee in the College of Science as well as the Dean of Science and the Office of Academic Programs. The Academic Programs Committee then conducted campus-wide consultation, as well as its own review of the program. No comments were received by the Academic Programs Committee.

RECOMMENDATION:

The Academic Programs Committee recommends approval of the Integrated Science Option under the Bachelor of Science in Physics.

BS in Physics
(Integrated Science Option)

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CURRICULUM SHEET

CURRICULUM SHEET

CURRICULUM SHEET FOR SEMESTER CONVERSION

	Program Name: Bachelor of Science in Physics—Integrated Science Option
	Total Units (Major [including option/emphasis]+GE-Double Count): 119
	Major Courses – Core – Units: 45

Course Number	**Title**	**Units (lec/lab)**	**GE Area Double Count**
CHM 1210/1210L	General Chemistry 1	3/1	B1, B3
MAT 1140	Calculus I	4	B4
MAT 1150	Calculus II	4	
MAT 2140	Calculus III	4	
MAT 2250	Linear Algebra with Applications to Differential Equations	4	
MAT 2010	Introduction to Computational Methods in Mathematics	4	
PHY 1510/1510L	Introduction to Newtonian Mechanics	3/1	
PHY 1520/1520L	Introduction to Electromagnetism and Circuits	3/1	
PHY 2530/2530L	Introduction to Electromagnetic Radiation and Special Relativity	3/1	
PHY 2540/2540L	Introduction to Thermal and Quantum Physics	3/1	
PHY 3600/3600A	Mathematical Methods of Physics 1	3/1	
PHY 4630	Senior seminar	1	

Major Courses – Core Electives – Units: None

Option Courses – Units: 26

Course Number	**Title**	**Units (lec/lab)**	**GE Area Double Count**
CHM 1220/L	General Chemistry II	3/1	
BIO 1210/L	Foundations of Biology: Energy, Matter, and Information	3/1	B2
BIO 1220/L	Foundations of Biology: Evolution, Ecology, and Biodiversity	3/1	
PHY 3210/A	Advanced Classical Mechanics	3/1	
STS 2010	Introduction to Science, Technology, and Society Studies	3	C2
GSC 1110	Principles of Geology	3	
GSC 1410L	Principles of Geology Laboratory	1	
GSC 1160	Introduction to Astronomy	3	

Option Electives: 16 units			
Course Number	**Title**	**Units (lec/lab)**	**GE Area Double Count**
3 units must be selected from the following list:			
PHY 3040/3040L	Electronics for Scientists	2/1	
AST 3240/3240A	Observational Astronomy	2/1	
PHY 4090/4090A	Computational Physics	2/1	
PHY 4170/4170L	Wave Optics	2/1	
PHY 4410	Internship in Physics	1 or 2	
PHY 4610/4620	Senior Project	1/2	
Another 4 units must be selected from the following list:			
PHY 4010/4010A	Quantum Mechanics 1	3/1	
PHY 4140/4140A	Electricity and Magnetism 1	3/1	
PHY 4330/4330A	Thermal and Statistical Physics	3/1	
Another 2 units must be selected from the following list:			
PHY 4510L	Advanced Laboratory Physics—Advanced Instrumentation	1/1	
PHY 4520L	Advanced Laboratory Physics—Contemporary Experiments	1/1	
1 unit of supervised teaching experience or pedagogy seminar, which may be obtained via courses that include PHY 2000, 2990, 4000, 4410, 4410, as well as other courses approved by the department.			
3 units chosen from PHY 3010, PHY 3020, PHY 3060, AST 3050, or AST 3420.		3	B5
An additional 3 units selected from any upper-division PHY or AST courses (except AST 3050, AST 3420, PHY 3010, and PHY 3020) or other upper-division math, science, and engineering courses approved by the department.			

GE units not double-counted: 33 (Areas A1, A2, A3, C1, C3, C4, D1, D2, D3, D4, E)

4-YEAR ROADMAP

Department: Physics and Astronomy
Physics Major-Integrated Science Option
Curriculum Year: 2018-2019

Your department has developed this road plan, taking into account prerequisites and schedule restrictions.
Students should pay attention to these concerns when deviating from this plan.

Total Units:	**120**
	Option Core
	Option Electives
	GE
	Major Core

Year 1: Fall

Course	Description	Units
MAT 1140	Calculus I (GE Area B4)	4
CHM 1210/L	General Chemistry I (GE Area B1&B3)	4
SCI 1010/A	Freshman Experience I (Partial GE Area E)	2
ENG ???	Composition Course (GE Area A1)	3
	Total	**13**

Year 1: Spring

Course	Description	Units
MAT 1150	Calculus II	4
PHY 1510/L	Introduction to Newtonian Mechanics	4
CHM 1220/L	General Chemistry II	4
SCI 1020	Freshman Experience II (Complete GE Area E)	1
LD GE 5	Any lower-division course in GE Area A, B2, C, or D	3
	Total	**16**

Year 2: Fall

Course	Description	Units
MAT 2140	Calculus III	4
PHY 1520/L	Introduction to Electromagnetism & Circuits	4
STS 2010	Science, Tech, & Society Studies (Also C2)	3
BIO 1210/L	Foundations of Biology: Energy, Matter, and Information (GE Area B2)	4
	Total	**15**

Year 2: Spring

Course	Description	Units
MAT 2250	Linear Algebra w/ Applications to Differential Equations	4
PHY 2530/L	Introduction to Electromagnetic Radiation and Special Relativity	4
MAT 2010	Introduction to Computational Methods in Mathematics	4
BIO 1220/L	Foundations of Biology: Evolution, Ecology, and Biodiversity	4
	Total	**16**

Year 3: Fall

Course	Description	Units
PHY 2540/L	Introduction to Thermal & Quantum Physics	4
PHY 3600/A	Mathematical Methods of Physics 1	4
PHY 2990, 4410, etc.	Supervised Physics Teaching Experience or Physics Pedagogy Seminar	1
LD GE 8	Any lower-division course in GE Area A, B2, C, or D	3
LD GE 9	Any lower-division course in GE Area A, B2, C, or D	3
	Total	**15**

Year 3: Spring

Course	Description	Units
PHY 3210/A	Advanced Classical Mechanics	4
GSC 1110/1410L	Principles of Geology	4
PHY 4510L/A or 4520L/A	Advanced Laboratory Physics	2
LD GE 10	Any lower-division course in GE Area A, B2, C, or D	3
LD GE 11	Any lower-division course in GE Area A, B2, C, or D	3
	Total	**16**

Year 4: Fall

Course	Description	Units
PHY ???	PHY Restricted Elective	3
PHY ???	UD PHY elective	3
GSC 1160	Introduction to Astronomy	3
LD GE 12	Any lower-division course in GE Area A, B2, C, or D	3
LD GE 13	Any lower-division course in GE Area A, B2, C, or D	3
	Total	**15**

Year 4: Spring

Course	Description	Units
PHY 4630	Senior Seminar	1
PHY ???	Physics theory elective	4
PHY ??? Or AST ???	B5 Synthesis course from AST or PHY	3
Synthesis 2	Any upper-division course in GE Area C4 or D4	3
Synthesis 3	Any upper-division course in GE Area C4 or D4	3
	Total	**14**

TWO-YEAR COURSE SCHEDULE

Physics and Astronomy Projected Two-Year Course Schedule

Please refer to BroncoDirect for the current academic quarter course schedule

(x=offered, a=as needed, o=occasional)

Prefix	Number	Title	Units	2018 Fall	2019 Spring	2019 Fall	2020 Spring
AST	1010	Stars, Galaxies, and the Universe	3	x	x	x	x
AST	2000	Special Study for Lower-Division Students	1-2	a	a	a	a
AST	2990/2990A/2990L	Special Topics for Lower-Division Students	1-3	o	o	o	o
AST	3050	Archaeoastronomy	3				x
AST	3240	Observational Astronomy	2		x		x
AST	3240A	Observational Astronomy Computer Activity	1		x		x
AST	3420	Life, the Universe, and Everything	3	x	x	x	x
AST	4000	Special Study for Upper-Division Students	1-2	a	a	a	a
AST	4240	Astrophysics I: Stars and Planetary Systems	3	x		x	
AST	4240A	Astrophysics I Recitation	1	x		x	
AST	4250	Astrophysics II: Galaxies and the Universe	3		x		x
AST	4250A	Astrophysics II Recitation	1		x		x
AST	4610	Senior Project 1	1	a	a	a	a
AST	4620	Senior Project 2	2	a	a	a	a
AST	4990/4990A/4990L	Special Topics for Upper-Division Students	1-3	o	o	o	o
PHY	1020	Fundamentals of Physics	3	x		x	
PHY	1050	The Physics of Musical Sound	2		x		x
PHY	1050L	Physics of Musical Sound Laboratory	1				x
PHY	1210	Physics of Motion, Fluids, and Heat	3	x	x	x	x
PHY	1210L	Laboratory on Motion, Fluids, and Heat	1	x	x	x	x
PHY	1220	Physics of Electromagnetism, Circuits, and Light	3	x	x	x	x
PHY	1220L	Laboratory on Electromagnetism, Circuits, and Light	1	x	x	x	x
PHY	1510	Introduction to Newtonian Mechanics	3	x	x	x	x

PHY	1510A	Newtonian Mechanics Recitation	1	x	x	x	x
PHY	1510L	Newtonian Mechanics Laboratory	1	x	x	x	x
PHY	1520	Introduction to Electromagnetism and Circuits	3	x	x	x	x
PHY	1520A	Electromagnetism and Circuits Recitation	1	x	x	x	x
PHY	1520L	Introductory Laboratory on Electromagnetism and Circuits	1	x	x	x	x
PHY	2000	Special Study for Lower-Division Students	1-2	a	a	a	a
PHY	2120	Physics for Elementary Educators	2	x	x	x	x
PHY	2120L	Physics for Elementary Educators Lab	1	x	x	x	x
PHY	2530	Introduction to Electromagnetic Radiation and Special Relativity	3	x	x	x	x
PHY	2530A	Electromagnetic Radiation and Special Relativity Recitation	1	x	x	x	x
PHY	2530L	Introductory Laboratory on Electromagnetic Radiation and Special Relativity	1	x	x	x	x
PHY	2540	Introduction to Thermal and Quantum Physics	3	x	x	x	x
PHY	2540A	Thermal and Quantum Physics Recitation	1	x	x	x	x
PHY	2540L	Introductory Laboratory on Thermal and Quantum Physics	1	x	x	x	x
PHY	2990/2990A/2990L	Special Topics for Lower-Division Students	1-3	o	o	o	o
PHY	3010	Energy and Society	3		x		x
PHY	3020	Physics for Future Presidents	3	x		x	
PHY	3040	Electronics for Scientists	2		x		x
PHY	3040L	Electronics for Scientists Laboratory	1		x		x
PHY	3060	History of Physics	3	x		x	
PHY	3210	Advanced Classical Mechanics	3		x		x
PHY	3210A	Advanced Classical Mechanics Recitation	1		x		x
PHY	3440	Applied Optics	2	x		x	
PHY	3440A	Computational Activities in Applied Optics	1	x		x	
PHY	3600	Mathematical Methods of Physics 1	3	x	x	x	x
PHY	3600A	Mathematical Methods of Physics Recitation	1	x	x	x	x
PHY	3610	Mathematical Methods of Physics 2	3		x		x
PHY	4000	Special Study for Upper-Division Students	1-2	a	a	a	a
PHY	4010	Quantum Mechanics 1	3	x		x	

PHY	4010	Biophysics	3		x		x
PHY	4010A	Quantum Mechanics 1 Recitation	1	x		x	
PHY	4020	Quantum Mechanics 2	3				x
PHY	4040	Introduction to High Energy Physics	3		x		
PHY	4060	Introduction to Condensed Matter Physics	3	x			
PHY	4090	Computational Physics	2		x		x
PHY	4090A	Computational Physics Activity	1		x		x
PHY	4140	Electricity and Magnetism 1	3		x		x
PHY	4140A	Electricity and Magnetism 1 Recitation	1		x		x
PHY	4150	Electricity and Magnetism 2	3	x		x	
PHY	4170	Wave Optics	2		x		x
PHY	4170L	Wave Optics Laboratory	1		x		x
PHY	4220	Plasma Physics	3			x	
PHY	4330	Thermal and Statistical Physics	3	x		x	
PHY	4330A	Thermal and Statistical Physics Recitation	1	x		x	
PHY	4410	Internship in Physics	1-2	a	a	a	a
PHY	4510A	Advanced Laboratory Physics - Advanced Instrumentation Recitation	1	x	x	x	x
PHY	4510L	Advanced Laboratory Physics - Advanced Instrumentation	1	x	x	x	x
PHY	4520A	Advanced Laboratory Physics - Contemporary Experiments Recitation	1	x	x	x	x
PHY	4520L	Advanced Laboratory Physics - Contemporary Experiments	1	x	x	x	x
PHY	4610	Senior Project 1	1	a	a	a	a
PHY	4620	Senior Project 2	2	a	a	a	a
PHY	4630	Senior Seminar	1		x		x
PHY	4990/4990A/4990L	Special Topics for Upper-Division Students	1-3	o	o	o	o

MISSION, OUTCOMES, AND ASSESSMENT PLAN

MISSION STATEMENT, OUTCOMES, AND ASSESSMENT PLAN FOR THE PHYSICS MAJOR: INTEGRATED SCIENCE OPTION

Mission:
The mission of the Integrated Science Option is to provide students with a balance of in-depth physics knowledge and quantitative skills alongside a broad education in the other branches of natural science, the history and nature of science, and strong communication skills for a wide variety of careers in education and education policies including secondary math and science teaching.

Program Objectives:

1. Students will be able to explain and apply basic principles of foundational theories of physical, earth, and life science to fundamental phenomena and technologically relevant processes in the real world.
2. Students will be able to use common mathematical and computational techniques to obtain quantitative predictions from physical models.
3. Students will be able to work with experimental apparatus to make accurate physical measurements, will be able to identify the limitations of various measuring devices, and will be able to quantify the systematic and statistical uncertainties in their experimental results.
4. Students will be able to communicate an understanding of basic principles from the physical, earth, and life sciences, as well as problem solving strategies and of analyses of experimental data, in both written and oral forms, for both expert and non-expert audiences.
5. Students, upon graduation, will be prepared for careers in teaching, research, industry, or public service, as well as advanced study in physics and related fields.

Student Learning Outcomes:
We have designed the student learning outcomes to be closely aligned with the program objectives:

Area 1: Scientific Principles

LO 1a: Students will be able to identify the appropriate physical quantities to solve for when given information on a physical system and asked to predict its behavior.

LO 1b: Students will be able to identify the appropriate equations to apply for modeling a system, and will be able to state the reasons why those equations are necessary and others are not.

LO 1c: Students will be able to use physics models to obtain quantitative predictions for real-world technologies and problems. Examples may include energy issues, medical devices, and information technology.

LO 1d: In developing these models, students will be able to draw upon key foundational theories of physics, including Newtonian mechanics, the theory of relativity, electromagnetism, quantum mechanics, thermodynamics, and statistical mechanics.

LO 1e: Students will be able to describe foundational principles of biology, geology, and chemistry, and explain examples in which these principles are technologically and/or socially relevant.

Area 2: Theoretical and mathematical skills:

LO 2a: Students will be able to use estimation techniques and dimensional analysis to obtain quantitative predictions from simple models of a physical system, with the goal of getting estimates that are accurate to within an order of magnitude.

LO 2b: Students will be able to apply standard analytical techniques for the solution of ordinary and partial differential equations to solve common physics equations in situations that are relevant to the real world.

LO 2c: Students will be able to use proportional reasoning and dimensional analysis to check analytical solutions, and to predict the qualitative behavior of physical systems.

LO 2d: Students will be able to use computer tools to solve physically relevant problems that are not amenable to exact solutions.

Area 3: Experimental and technological skills

LO 3a: Students will be able to set up and troubleshoot components of experimental and/or computational tools in order to perform a measurement or simulation of a physically relevant quantity or phenomenon.

LO 3b: Students will be able to quantitatively describe the limitations of their experimental apparatus or algorithm, and use information on those limitations to determine uncertainties in measured quantities or precision of computed quantities.

LO 3c: Students will be able to analyze experimental or simulation data and compare the results of the data analysis with basic theories of biology, chemistry, and geology.

Area 4: Professional Communication Skills

LO 4a: Students will be able to write professional-quality reports that describe the methods, results, and interpretation of experimental or computational investigations of physics problems.

LO 4b: Students will be able to give verbal presentations on scientific principles, applications of scientific principles principles, and the results of scientific investigations, at a level understandable by an audience of novices. These presentations may include visual aids.

Area 5: pedagogical content knowledge

LO 5a: Students will be able to integrate content and pedagogy as effectively as potential future educators.

LO 5b: students will be able the observe phenomena, look for patterns, and develop explanations for these patterns.

LO 5c: Students will be able to use these explanations to make predictions about the outcomes of experiments,

LO 5d: Students will be able to evaluate the outcomes of the experiments and decide if they are consistent with the predictions, and revise the explanations if necessary

LO 5e: students will be able to represent physical processes in multiple ways.

Curriculum Matrix: We will collect evidence for assessment of learning outcomes from (1) courses required of all students in this program and (2) relevant electives taken by a large portion of the students in the program. Courses required of all students in the option are listed in **bold red**, and elective courses are listed in *gray italics*. We are leaving out activity courses that are designed primarily to reinforce concepts from lecture, but are including selected activity courses that include significant hands-on projects.

Learning outcomes

Classes	1a: Identify physical quantities	1b: Identify appropriate equations	1c: Obtain real-world predictions from models	1d: Use foundational theories of physics	1e: Describe foundational principles of biology, chemistry, & geology	2a: Estimation	2b: Analytical techniques	2c: Proportional reasoning	2d: Computation	3a: Set up experiments or computations	3b: Uncertainty	3c: Data analysis	4a: Written communication	4b: Spoken communication	5a: Integrate content and pedagogy	5b: Observe phenomena & develop explanations	5c: Use explanations to make predictions	5d: Evaluate experimental outcomes	5e: Represent physical processes multiple ways
PHY 2530: EM waves & relativity	X	X		X		X	X	X											X
PHY 2530L: EM waves & relativity lab						X		X		X	X	X	X	X *		X	X	X	
PHY 2540: Thermo & QM	X	X		X		X	X	X											X
PHY 2540L: Thermo & QM lab						X		X		X	X	X	X	X *		X	X	X	
PHY 3040: Electronics	X	X		X		X	X	X											X
PHY 3040L: Electronics lab						X		X		X	X	X	X	X *		X	X	X	
PHY 3210: Mechanics	X	X	X	X		X	X	X	X										X
AST 3240: Observational Astronomy	X	X		X		X	X	X								X	X	X	X
AST 3240A: Observational Astronomy Computer Activity						X		X		X	X	X	X	X *		X	X	X	X
PHY 3440: Applied Optics	X	X	X	X		X	X	X											X
PHY 3440A: Applied optics computational activity						X			X			X	X	X *					X
PHY 3600: Math methods	X	X		X		X	X	X											
PHY 4090: Computational	X	X		X		X		X	X	X	X	X	X	X *					X

PHY 4100: Biophysics	x	x	x	x		x	x	x	x *			x	x	x *					x
PHY 4170: Wave optics	x	x		x		x	x	x											x
PHY 4170L: Wave optics lab						x		x		x	x	x	x	x *		x	x	x	
Physics theory electives	x	x		x		x	x	x											x
PHY 4510 A/L and/or PHY 4520 A/L:						x		x		x	x	x	x	x *		x	x	x	
PHY 4610/4620: Senior project (for relevant project topics)	x *	x *	x	x *	x *	x	x *	x	x *	x	x	x	x		x *				x
PHY 4630: Seminar			x *	x	x	x		x				x	x	x					x
Teaching Experience														x	x				x
BIO 1210					x														
BIO 1210L					x					x	x	x	x	x *		x	x	x	
BIO 1220					x														
BIO 1220L					x					x	x	x	x	x *		x	x	x	
CHM 1210	x	x	x		x	x		x											x
CHM 1210L					x					x	x	x	x	x *		x	x	x	
CHM 1220	x	x	x		x														x
CHM 1220L					x					x	x	x	x	x *		x	x	x	
GSC 1110: Principles of Geology					x														x
GSC 1140: Principles of Geology Laboratory					x					x	x	x	x	x *		x	x	x	
GSC 1160: Astronomy					x														x

Methods of Assessment:

The committee responsible for assessment will request the following from instructors of relevant courses:

1) Copies of questions, problems, and assignments that are particularly useful for assessing the program's learning outcomes.
2) A summary (including scores, grades, or other quantitative results) of class performance on those assignments, problems, etc. in the past year (including both the average and the range).

3) Examples of student work that highlight areas of particularly common strengths and weaknesses.

For courses in which Integrated Science students are a small portion of the enrollment, the committee will work with instructors of sections that have multiple Integrated Science students enrolled.

Timeline of Assessment:

In order to align our assessment efforts with the five year planning and program review cycle, and to synchronize assessment of courses with similar learning outcomes, we plan to collect and analyze evidence relating to each learning objective twice in a five year cycle. All courses mentioned below are those listed on the Curriculum Matrix above. We will alternate between assessing more theoretical and mathematical outcomes (which are largely common between all of our contemplated options) and assessing more option-specific skills.

Year	Data Collection	Key Learning Outcomes	Action/Plans
1	Lecture/discussion courses without accompanying labs	LO 1a-1d, 2a-2c (Concepts, principles, and theories)	• Presentation to department. • Evaluation in light of previous 5 year review. • Plans for near-term improvements.
2	Lab and activity classes, senior seminar, supervised teaching, and biology, chemistry, and geology classes	LO 1e, 2d, 3a-3c, 4a-4b (Laboratory, technological, and professional skills)	• Presentation to department. • Evaluation in light of previous 5 year review. • Plans for near-term improvements.
3	Lecture/discussion courses without accompanying labs	LO 1a-1d, 2a-2c (Concepts, principles, and theories)	• Presentation to department. • Evaluation in light of year 1 plans. • Begin planning more substantial changes and improvements.
4	Lab and activity classes, senior seminar, supervised teaching, and biology, chemistry, and geology classes	LO 1e, 2d, 3a-3c, 4a-4b (Laboratory, technological, and professional skills)	• Presentation to department. • Evaluation in light of year 1 plans. • Begin planning more substantial changes and improvements.
5	Summary of years 1-4, and additional data for areas identified as needing further analysis.		• Evaluation of past years of effort. • Evaluate effectiveness of attempts to improve. • Reconsider program objectives. • Plan changes for future.

Learning outcomes

Classes	1a: Identify physical quantities	1b: Identify appropriate equations	1c: Use symmetry	1d: Obtain real-world predictions from models	1e: Use foundational theories	2a: Estimation	2b: Analytical techniques	2c: Proportional reasoning	2d: Computation	3a: Set up experiments or computations	3b: Uncertainty	3c: Data analysis	4a: Written communication	4b: Spoken communication
PHY 1510: Newtonian Mechanics	I	I	I	I	I	I	I	I						
PHY 1510L: Newtonian Mechanics Lab						I		I		I	I	I	I	I
PHY 1520: E&M	I	I	I	I	I	I	I	I						
PHY 1520L: E&M Lab						I		I		I	I	I	I	I
PHY 2530: EM waves & relativity	D	D	D	D	D	D	D	D						
PHY 2530L: EM waves & relativity lab						D		D		D	D	D	D	D*
PHY 2540: Thermo & QM	D	D	D	D	D	D	D	D						
PHY 2540L: Thermo & QM lab						D		D		D	D	D	D	D*
MAT 2010: Numerical Methods									I					
PHY 3040: Electronics	D	D	D	D	D	D	D	D						
PHY 3040L: Electronics lab						D		D		D	D	D	D	D*
AST 3240: Observational Astronomy	D	D		D	D	D	D	D						
AST 3240A: Observational Astronomy Computer Activity						D		D		D	D	D	D	D*
PHY 3210: Mechanics	D	D	D	D	D	D	D	D	D					
PHY 3440: Applied Optics	D	D	D	D	D	D	D	D						
PHY 3440A: Applied optics computational activity						D			D			D	D	D*
PHY 3600: Math methods	D	D	D	D	D	D	D	D						
PHY 4010: Quantum	M	M	M	M	M	M	M	M						
PHY 4090: Computational	M	M	M	M	M	M		M	M	M	M	M	M	M*
PHY 4140: E&M	M	M	M	M	M	M	M	M						
PHY 4170: Wave optics	M	M	M	M	M	M	M	M						
PHY 4170L: Wave optics lab						M		M		M	M	M	M	M*
PHY 4330: Thermo	M	M	M	M	M	M	M	M						
PHY 4510 A/L: Adv. Lab 1						M		M		M	M	M	M	M*
PHY 4520 A/L: Adv. Lab 2						M		M		M	M	M	M	M*
PHY 4630: Seminar				M		M		M				M	M	M*

*When applicable; instructor-dependent

Learning outcomes

Classes	1a: Identify physical quantities	1b: Identify appropriate equations	1c: Use Biological Principles	1d: Obtain real-world predictions from models	1e: Use foundational theories	2a: Estimation	2b: Analytical techniques	2c: Proportional reasoning	2d: Computation	3a: Set up experiments or computations	3b: Uncertainty	3c: Data analysis	3d: Biology and biochemistry lab proficiency	4a: Written communication	4b: Spoken communication
PHY 1510: Newtonian Mechanics	I	I		I	I	I	I	I							
PHY 1510L: Newtonian Mechanics Lab						I		I		I	I	I		I	I
PHY 1520: E&M	I	I		I	I	I	I	I							
PHY 1520L: E&M Lab						I		I		I	I	I		I	I
PHY 2530: EM waves & relativity	D	D		D	D	D	D	D							
PHY 2530L: EM waves & relativity lab						D		D		D	D	D		D	D*
PHY 2540: Thermo & QM	D	D		D	D	D	D	D							
PHY 2540L: Thermo & QM lab						D		D		x	x	x		x	D*
BIO 1210, 1220: Intro bio principles			I												
BIO 1210l, 1220L: Intro bio labs													I		
MAT 2010: Numerical Methods									I						
PHY 3040: Electronics	D	D		D	D	D	D	D							
PHY 3040L: Electronics lab						D		D		D	D	D		x	D*
PHY 3440: Applied Optics	D	D		D	D	D	D	D							
PHY 3440A: Applied optics computational activity						D			D			D		D	D*
PHY 3600: Math methods	D	D		D	D	D	D	D							
PHY 4090: Computational	M	M		M	M	M		M	M	M	M	M		M	M*
PHY 4100: Biophysics	M	M	D	M	M	M	M	M	D*			M		M	M*
PHY 4170: Wave optics	M	M		M	M	M	M	M							
PHY 4170L: Wave optics lab						M		M		M	M	M		M	M*
PHY 4330: Thermo	M	M		M	M	M	M	M							
Physics theory electives	M	M		M	M	M	M	M							
PHY 4510 A/L and/or PHY 4520 A/L:						M		M		M	M	M		M	M*
PHY 4610/4620: Senior project (if project topic is biophysical)	M*	M*	M	M*	M*	M	M	M	M*	M	M	M	M*	M	
PHY 4630: Seminar			M*	M		M		M				M		M	M*

Advanced bio/chem lectures			D			M		M							
Advanced bio/chem labs			D			D		D	D*	D	D	D	D	D	D*

*When applicable; instructor-dependent

Learning outcomes

Classes	1a: Identify physical quantities	1b: Identify appropriate equations	1c: Obtain real-world predictions from models	1d: Use foundational theories of physics	1e: Describe foundational principles of biology, chemistry, & geology	2a: Estimation	2b: Analytical techniques	2c: Proportional reasoning	2d: Computation	3a: Set up experiments or computations	3b: Uncertainty	3c: Data analysis	4a: Written communication	4b: Spoken communication	5a: Integrate content and pedagogy	5b: Observe phenomena & develop explanations	5c: Use explanations to make predictions	5d: Evaluate experimental outcomes	5e: Represent physical processes multiple ways
PHY 1510: Newtonian Mechanics	I	I	I	I		I	I	I									I		I
PHY 1510L: Newtonian Mechanics Lab						I		I		I	I	I	I	I		I	I	I	I
PHY 1520: E&M	I	I	I	I		I	I	I									I		I
PHY 1520L: E&M Lab						I		I		I	I	I	I	I		I	I	I	I
PHY 2530: EM waves & relativity	D	D		D		D	D	D									D		D
PHY 2530L: EM waves & relativity lab						D		D		D	D	D	D	D*		D	D	D	D
PHY 2540: Thermo & QM	D	D		D		D	D	D									D		D
PHY 2540L: Thermo & QM lab						D		D		D	D	D	D	D*		D	D	D	D
MAT 2010: Numerical Methods									I										
PHY 3040: Electronics	D	D		D		D	D	D											D
PHY 3040L: Electronics lab						D		D		D	D	D	D	D*		D	D	D	
PHY 3210: Mechanics	D	D	D	D		D	D	D	D										D
AST 3240: Observational Astronomy	D	D		D		D	D	D								D	D	D	D
AST 3240A: Observational Astronomy Computer Activity						D		D		D	D	D	D	D*		D	D	D	D
PHY 3440: Applied Optics	D	D	D	D		D	D	D											D
PHY 3440A: Applied optics computational activity						D			M			D	D	D*		D	D		D
PHY 3600: Math methods	D	D		D		D	D	D											
PHY 4090: Computational	M	M		M		M		M	M	M	M	M	M	M*					M
PHY 4100: Biophysics	M	M	M	M	D	M	M	M	D*			M	M	M*		M	M	M	M
PHY 4170: Wave optics	M	M		M		M	M	M											M
PHY 4170L: Wave optics lab						M		M		M	M	M	M	M*		M	M	M	M
Physics theory electives	M	M		M		M	M	M											M
PHY 4510 A/L and/or PHY 4520 A/L:						M		M		M	M	M	M	M*		M	M	M	

PHY 4610/4620: Senior project (for relevant project topics)	M*	M*	M	M*	M*	M	M*	M	M*	M	M	M	M	M	M	M			M
PHY 4630: Seminar					M										D				
Teaching Experience															I, D				
BIO 1210					I														
BIO 1210L					I														
BIO 1220					I														
BIO 1220L					I														
CHM 1210					I														
CHM 1210L					I														
CHM 1220					I														
CHM 1220L					I														
GSC 1110: Principles of Geology					I														
GSC 1140: Principles of Geology Laboratory					I														
GSC 1160: Astronomy					I														

*When applicable; instructor-dependent

Curriculum Proposal: Option in Integrated Science

Prepared by Alex Small, Associate Professor, Department of Physics and Astronomy

Key information

The Department of Physics and Astronomy is submitting this request to create an **option** in Integrated Science under the existing Bachelor of Science program in Physics.

There are currently no options under the existing Bachelor of Science program in Physics. This option will include ***only existing courses*** from the departments of Physics and Astronomy, Biological Sciences, Chemistry and Biochemistry, Geological Sciences, and Mathematics and Statistics and ***will not require any new courses***, while also helping to ***serve a vital need for graduates qualified to enter single-subject teaching credential programs for high school physics***.

Aims of the program

This program combines advanced coursework in physics with strong mathematical foundations and year-long sequences in biology, chemistry, and geology, as well as courses on social and historical issues in science and technology and also interdisciplinary coursework that integrates multiple sciences. ***This varied set of courses was chosen to fulfill the requirements set forth by the state's Commission on Teacher Credentialing (CTC)*** for students seeking to demonstrate subject matter competence before entering a Single Subject Credential Program in physics. The primary design goal for this program is to increase the number of well-qualified high school physics teachers. However, this is not a narrowly-focused vocational degree aimed at one specific job. ***The breadth of science coursework in this degree program is also suitable for students interested in careers in science journalism, science policy and regulatory affairs, public outreach, and other career paths*** that require a mix of in-depth scientific training, broad knowledge of the sciences, and facility in communicating science to people.

Consistent with this aim, we have the following Mission Statement for the Integrated Science Option:

> *The mission of the Integrated Science Option is to provide students with a balance of in-depth physics knowledge and quantitative skills alongside a broad education in the other branches of natural science, the history and nature of science, and strong communication skills for a wide variety of careers in education and education policies including secondary math and science teaching.*

In pursuit of that mission, the curriculum for this degree option (described below) will require a mix of introductory and advanced physics courses (both laboratory and theoretical) at the same level as those taken by other physics majors, the same introductory biology courses as biology majors, a full year each of chemistry and earth science, and then a mix of electives that include laboratory courses, theoretical courses, project-oriented courses that combine theory and experiment, and classes that integrate physics with other sciences in the context of social and historical questions. Additionally, this degree option requires a supervised teaching experience or pedagogy seminar. While we recognize that not all of the students in this program will pursue teaching careers, ***practice in explaining science to novices is a valuable experience for anyone in a career that will require significant interaction with non-scientists or scientists in other specialties***.

Consistent with a curriculum that balances depth in physics with breadth across the natural sciences, we have the following Program Objectives:

1. Students will be able to explain and apply basic principles of foundational theories of physical, earth, and life science to fundamental phenomena and technologically relevant processes in the real world.
2. Students will be able to use common mathematical and computational techniques to obtain quantitative predictions from physical models.
3. Students will be able to work with experimental apparatus to make accurate physical measurements, will be able to identify the limitations of various measuring devices, and will be able to quantify the systematic and statistical uncertainties in their experimental results.
4. Students will be able to communicate an understanding of basic principles from the physical, earth, and life sciences, as well as problem solving strategies and of analyses of experimental data, in both written and oral forms, for both expert and non-expert audiences.
5. Students, upon graduation, will be prepared for careers in teaching, research, industry, or public service, as well as advanced study in physics and related fields.

To achieve those objectives, we have the following Learning Outcomes, which are closely aligned with the Program Objectives:

Area 1: Scientific Principles
LO 1a: Students will be able to identify the appropriate physical quantities to solve for when given information on a physical system and asked to predict its behavior.

LO 1b: Students will be able to identify the appropriate equations to apply for modeling a system, and will be able to state the reasons why those equations are necessary and others are not.

LO 1c: Students will be able to use physics models to obtain quantitative predictions for real-world technologies and problems. Examples may include energy issues, medical devices, and information technology.

LO 1d: In developing these models, students will be able to draw upon key foundational theories of physics, including Newtonian mechanics, the theory of relativity, electromagnetism, quantum mechanics, thermodynamics, and statistical mechanics.

LO 1e: Students will be able to describe foundational principles of biology, geology, and chemistry, and explain examples in which these principles are technologically and/or socially relevant.

Area 2: Theoretical and mathematical skills:
LO 2a: Students will be able to use estimation techniques and dimensional analysis to obtain quantitative predictions from simple models of a physical system, with the goal of getting estimates that are accurate to within an order of magnitude.

LO 2b: Students will be able to apply standard analytical techniques for the solution of ordinary and partial differential equations to solve common physics equations in situations that are relevant to the real world.

LO 2c: Students will be able to use proportional reasoning and dimensional analysis to check analytical solutions, and to predict the qualitative behavior of physical systems.

LO 2d: Students will be able to use computer tools to solve physically relevant problems that are not amenable to exact solutions.

<u>Area 3: Experimental and technological skills</u>

LO 3a: Students will be able to set up and troubleshoot components of experimental and/or computational tools in order to perform a measurement or simulation of a physically relevant quantity or phenomenon.

LO 3b: Students will be able to quantitatively describe the limitations of their experimental apparatus or algorithm, and use information on those limitations to determine uncertainties in measured quantities or precision of computed quantities.

LO 3c: Students will be able to analyze experimental or simulation data and compare the results of the data analysis with basic theories of the physical, life, and earth sciences.

<u>Area 4: Professional Communication Skills</u>

LO 4a: Students will be able to write professional-quality reports that describe the methods, results, and interpretation of experimental or computational investigations of physics problems.

LO 4b: Students will be able to give verbal presentations on scientific principles, applications of scientific principles principles, and the results of scientific investigations, at a level understandable by an audience of novices. These presentations may include visual aids.

<u>Area 5: pedagogical content knowledge</u>[1]

LO 5a: Students will be able to integrate content and pedagogy as effectively as potential future educators.

LO 5b: Students will be able the observe phenomena, look for patterns, and develop explanations for these patterns.

LO 5c: Students will be able to use these explanations to make predictions about the outcomes of experiments.

LO 5d: Students will be able to evaluate the outcomes of the experiments and decide if they are consistent with the predictions, and revise the explanations if necessary

LO 5e: students will be able to represent physical processes in multiple ways.

A separate document describes the methods by which these learning outcomes will be assessed.

<u>Justification of need for this program</u>

I. The persistent shortage of fully prepared Physics high school teachers

The recruitment and retention of skilled, knowledgeable, and well-prepared high school math and science teachers is a critical and recognized national priority[2]. The situation in the state of California is

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[1] Shulman, L. (1987). Knowledge and teaching: Foundations of the new reform. Harvard Educational Review, 57(1).

no different. According to a report by the California Council on Science and Technology (CCST) and the Center for the Future of Teaching and Learning, California faces a persistent and critical shortage of fully prepared math and science teachers and lacks the capacity to produce enough of them to meet future needs.[3]

With regard to high school physics teachers specifically, the problem is even more acute. Estimates vary, but ***somewhere between 50% and 65% of high school physics teachers do not have a degree in physics***, with the American institute of Physics putting the number at 68%[4] while the National Center for Education Statistics puts the number at 50%.[5] The disagreement is likely due to differences in sampling methods[6], but either figure indicates ***a substantial deficit of preparation in the high school physics teaching workforce***. Additionally, the American Institute of Physics finds that among the large number of high school physics teachers without a physics degree, ***25% of high school physics teachers lack any university-level physics coursework beyond the introductory level***, calling into question their ability to teach advanced-placement (AP) courses and keep abreast of societally and technologically relevant developments in physics.[7] Even more worryingly, the National Center for Education Statistics finds that these under-prepared teachers have a disproportionate impact, with ***60% of all high school physics classes[8] and students[9] being taught by people who lack a physics degree***. This can be contrasted with strikingly different scenarios in many other fields of high school teaching, even among some other STEM disciplines. For example, the National Center for Education Statistics finds that the proportions of Social Science, English, Biology, and Mathematics courses taught by teachers with degrees in these disciplines are, respectively, 79%, 79%, 74%, and 70%.[10] Clearly, high school physics teaching is in a unique crisis situation that is not shared by most other disciplines.

The shortage of well-prepared high school physics teachers has decisively negative effects at the college and university level. A substantial body of research has demonstrated that high-quality, in-depth ***high school physics courses taught by teachers with strong backgrounds in physics are excellent predictors of success in student performance not only in college physics but in other science coursework as well***.[11]

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[2] National Academy of Sciences, National Academy of Engineering, & Institute of Medicine, *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future*. (The National Academies Press, 2007).

[3] http://www.ccst.us/news/2007/20070305TCPA.php

[4] Susan White and John Tyler, "Who Teaches High School Physics? Results from the 2012-13 Nationwide Survey of High School Physics Teachers" (American Institute of Physics, 2015), available at https://www.aip.org/sites/default/files/statistics/highschool/hs-whoteaches-13.pdf

[5] Jason Hill, Christina Stearns, Chelsea Owens, "Education and Certification Qualifications of Departmentalized Public High School-Level Teachers of Selected Subjects: Evidence From the 2011–12 Schools and Staffing Survey", (National Center for Education Statistics, US Department of Education, 2015), page 19. Available at http://nces.ed.gov/pubs2015/2015814.pdf

[6] Physics Teacher Education Coalition (PhysTEC), http://www.phystec.org/webdocs/shortage.cfm

[7] Susan White and John Tyler, "High School Physics Teacher Preparation: Results from the 2012–13 Nationwide Survey of High School Physics Teachers" (American Institute of Physics, 2015). Available at https://www.aip.org/sites/default/files/statistics/highschool/hs-teacherprep-12.pdf

[8] Hill, Stearns, and Owens, page 26

[9] Hill, Stearns, and Owens, page 29

[10] Hill, Stearns, and Owens, page 19

[11] Sadler, P. M. & Tai, R. H. Success in introductory college physics: The role of high school preparation. *Science Education* **85**, 111-136 (2001).

,[12] Because undergraduate physics courses are taken by virtually all undergraduate science and engineering majors in this country, along with a substantial number of students from other disciplines seeking to fulfill General Education requirements, a deficiency in the competence of the physics high school teacher workforce also has a direct and negative impact on retention and graduation rates in a wide range of disciplines at the college and university level. Indeed, a focus on student success at Cal Poly Pomona requires recognition that student success is heavily dependent on factors in place well before setting foot on campus, and so it is incumbent upon us to address this problem in the high school teaching workforce.

a) Problems with the current CPP high school physics teacher preparation pathway

Like most traditional undergraduate programs in Physics, the Bachelor of Science program at CPP provides substantial intellectual depth with a focus on preparing students for industry and graduate study. While these are important career paths for many students, our BS program has historically fallen short on coursework required specifically for high school science teaching credentials in the state of California. Consequently, students who wish to obtain teaching credentials must take nearly a year of additional courses (particularly in the earth and life sciences) before entering the credential program. These additional course requirements invariably slow their progress and may even impose a heavy financial burden.

b) How the new Integrated Science Option will fit with the department's strengths

For many years, but especially recently, our department has been exceeding the national average number of graduates (10 per department in 2013-2014, with a wide variance[13]) by a factor of 2-3 (with more than 30 expected in Spring of 2016), largely through energetic pursuits of strategic activities informed by research on successful physics departments. (The research on these successful departments was summarized in a report called "SPIN UP."[14]) Moreover, the statistical report cited in footnote 12 shows that only 2 CSU campuses produced more physics graduates than Cal Poly Pomona, and both of those campuses are involved in the Physics Teacher Education Coalition (PhysTEC[15]), as is Cal Poly Pomona. <u>***If the CSU is to play a role in providing California with well-trained high school physics teachers, the numbers show that this can only happen with the participation of Cal Poly Pomona!***</u> The large cohorts that we are graduating put us in a favorable position to make substantial contributions to the resolution of the current national problem of the shortage of well-prepared high school Physics teachers.

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[12] Schwartz, M. S., Sadler, P. M., Sonnert, G. & Tai, R. H. Depth versus breadth: How content coverage in high school science courses relates to later success in college science coursework. *Science Education* **93**, 798-826 (2009).

[13] Starr Nicholson and Patrick J. Mulvey , "Roster of Physics Departments with Enrollment and Degree Data: Results from the 2014 Survey of Enrollments and Degrees" (American Institute of Physics, 2014). Available at https://www.aip.org/sites/default/files/statistics/rosters/physrost14.pdf

[14] Hilborn, R. C., Howes, R. H. & Krane, K. S., "Strategic Programs for Innovations in Undergraduate Physics Project Report" (American Association of Physics Teachers, 2003). Available at https://www.aapt.org/Programs/projects/spinup/upload/SPIN-UP-Final-Report.pdf

[15] http://www.phystec.org/

Three years ago (April 2012), Cal Poly Pomona was selected, through a highly competitive process, by PhysTEC as one of a small number of national PhysTEC institutions. The PhysTEC project (led by American Physical Society (APS) and the American Association of Physics Teachers (AAPT), with funding from the National Science Foundation (NSF)), has as its main goal the improvement and promotion of excellence in the education of future physics teachers, and provides funding and support for institutions in developing their physics teacher preparation programs into national models. Prominent among the elements of our PhysTEC participation is that we have recruited talented physics and engineering majors who have completed the introductory physics series to serve as Learning Assistants (LAs) in those same courses, and in our K-8 physical science teacher education course as well. The integration of LAs into CPP physics courses is a promising mechanism for motivating our stronger physics majors toward high school teaching as a career. The early teaching experience will also help students attain a deeper understanding of physics content knowledge and alert them to both the real-life rewards and challenges of teaching. In recognition of this fact, the Integrated Science Option requires students to complete either a pedagogy seminar or a supervised teaching experience.

The proposed Integrated Science option is also expected to complement our department's ongoing efforts to improve the retention and success of Physics majors and minors. Starting in 2009, a group of junior and mid-career Physics and Astronomy faculty, calling itself the "SPIN UP Group" (a name inspired by the previously-mentioned national report on successful physics programs), began meeting on a regular basis to implement strategies for recruiting and retaining students. ***A key recommendation of the SPIN UP report is to implement a wider, more flexible range of physics major and minor programs, and to offer more diversified career paths for students.*** While the department has made strides in facilitating networking between undergraduate physics majors and physicists in industry (e.g. alumni career panels and participation in local professional organizations), the path into teaching demands a more formal credentialing approach, because of the state's requirements for teacher preparation. The proposed Integrated Science option, being designed around the requirements of the Commission on Teacher Credentialing, aligns exactly with that recommendation.

Together with the overall growth of our major program, our continuing Learning Assistant Program, and the department's activity in Physics Education Research (PER) (including two hires in the past several years, Dr. Homeyra Sadaghiani and Dr. Qing Ryan) and the American Association of Physics Teachers (including 2015-2016 AAPT President and CPP Professor Emerita Dr. Mary Mogge, as well as 2007-2008 AAPT President and CPP Professor Emeritus Dr. Harvey Leff), the new Integrated Science Option will bring us closer to realizing ***the goal of a nationally recognized program that is a major facilitator for a high school physics teaching career***.

II. Anticipated Student Demand

According to the most recent available data from the American Institute of Physics Statistical Research Center, only 3.4% of students graduating with Physics degrees in 2011-2012 pursued careers in high school teaching.[16] Although we have only begun tracking the data in recent years, we have found that we tend to do somewhat better than this national average, with typically 1-2 students per year (out of a class of 20 or more) subsequently pursuing a teaching credential after graduation. Moreover, we have

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[16] Patrick Mulvey and Jack Pold, "Physics Bachelor's Initial Employment: Data from the degree recipient follow-up survey for the classes of 2011 and 2012" (American Institute of Physics, 2015). Available at https://www.aip.org/sites/default/files/statistics/employment/bachinitemp-p-12.1.pdf

strong reasons to believe that, at least within our department, the desire of students to pursue a high school physics teaching career and the demand for academic programs accommodating such a desire are currently stronger than what is indicated by the above-mentioned statistics. The Physics & Astronomy department administered a comprehensive survey in April and May 2012 to elicit physics student feedback regarding their interest in teaching physics and a proposed teacher preparation program. Based on sample size of 26 respondents:

- Over 80% of the students express some interest in teaching physics.
- Only 15% of the students seem knowledgeable about the coursework and requirements for entering the teaching credential program in physics at Cal Poly Pomona. The remaining 85% agree that there is no clear and coherent pathway presented in the course catalog for physics teaching credentialing.
- Approximately 90% of the students state that a teacher preparation program would positively affect their decision to become physics teachers, and 73% believe it would increase their interest in acquiring physics teaching credentials
- Approximately 77% state that a program that reduces the number of years of coursework required before entering the workforce as a teacher would increase their interest in entering the physics teaching credential program.

While we cannot assume that all of this potential interest would translate into action with a degree path in place, we can say that students would give serious consideration to a degree path that lowered the barriers to pursuing a high school teaching career.

III. Purpose and Characteristics of the Proposed Integrated Science Option

This new option aims to provide a strong foundation in Physics, albeit with fewer upper-division theory-oriented courses than the General Physics option. Compared to the General Physics option, the new program is more broadly based in the sciences, in keeping with the requirement of the Commission on Teacher Credentialing (CTC) that high school physics teachers have enough knowledge of chemistry, biology, and earth science to complement their physics teaching with introductory "general science" courses as needed.[17] However, ***our proposed Integrated Science Option does require students to cross a meaningful threshold of theoretical and experimental preparation***, while providing a much more flexible and significantly faster route towards teacher credentialing. Additionally, required courses from outside of physics are the same courses required of students majoring in those disciplines. The proposed program is offered through state support, and none of the courses in the proposed curriculum are online courses.

The current Physics Teacher Preparation Program at Cal Poly Pomona is a post-baccalaureate program in which students are expected to demonstrate both subject matter and pedagogy knowledge. After obtaining a BS or BA, and before entering the credential program, future high school physics teachers need to either satisfy 41 quarter units of additional coursework in the other three areas of science (or

[17] California Commission on Teacher Credentialing, "Science Teacher Preparation in California: Standards of Quality and Effectiveness for Subject Matter Programs"(2010). Available at http://www.ctc.ca.gov/educator-prep/standards/SSMP-Handbook-Science.pdf.

pass the California Subject Examination for Teachers (CSET), a test on advanced content in physics and introductory content across the four areas of science. In addition, they have to complete 4 education prerequisite courses (16 quarter units). Even though students can enroll in these prerequisite courses as undergraduates, most of the teacher preparation coursework for credentialing is typically done after they graduate. As a result, a student with a Cal Poly Physics BS degree often needs at least two more years towards credentialing beyond the Physics BS degree in the current arrangement.

The proposed Integrated Science option will shorten the post-baccalaureate period substantially, by including all of the required coursework in earth science, life science, and chemistry. It has been designed specifically to expedite the physics teaching credentialing requirements by enabling students to complete most of the CSET (Science Competency) and Education prerequisite requirements while obtaining their BS in Physics. As a consequence, those completing the BS in Physics—Integrated Science option will then spend just one additional year as a post-baccalaureate student to complete the core requirements of the credential program. The proposed degree program is very much in line with a national trend. Spurred by recommendations from the 2007 Gender Equity report released by the American Physical Society (APS)[18] in collaboration with the Department of Energy and the National Science Foundation, and in response to shortages of physics teachers nationwide, many universities across the country are starting up similar physics programs aimed at preparing students for high school teaching credentials.

Finally, we should emphasize that while this option has been designed to meet the requirements of the CTC and address an urgent need of the state of California, ***students who enter this option will not be locked into only one career path if their interests change***. This option will still provide a thorough grounding in the quantitative reasoning, laboratory, and computational skills that make so many physics majors successful in industry. In addition, the breadth of natural science coursework and teaching experience included in this option would be useful for a student considering a career in science policy or science journalism, where communicating outside one's specialty is central to the work. It is also noteworthy that physics majors have some of the highest LSAT scores of any college major[19] and are often sought after in patent law because of their technical expertise; the breadth of this option and the emphasis on thinking and communicating across disciplines could serve students well on that path.

Courses required for the program

This program requires 120 units, divided as follows:

1) 45 units of courses taken by all students in the Bachelor of Science program in Physics, including both Integrated Science students and students in other options:

CHM 1210/1210L	General Chemistry 1*	3/1
MAT 1140	Calculus I**	4
MAT 1150	Calculus II	4

[18] "Gender Equity: Strengthening the Physics Enterprise in Universities and National Laboratories" (American Physical Society, 2007). Available at http://www.aps.org/programs/women/workshops/gender-equity/upload/genderequity.pdf.

[19] Casey Langer Tesfaye and Patrick Mulvey, "MCAT, LSAT, and Physics Bachelor's" (American Institute of Physics, 2013). Available at https://www.aip.org/sites/default/files/statistics/undergrad/mcat-lsat1.pdf.

MAT 2140	Calculus III	4
MAT 2250	Linear Algebra with Applications to Differential Equations	4
MAT 2010	Introduction to Computational Methods in Mathematics	4
PHY 1510/1510L	Introduction to Newtonian Mechanics	3/1
PHY 1520/1520L	Introduction to Electromagnetism and Circuits	3/1
PHY 2530/2530L	Introduction to Electromagnetic Radiation and Special Relativity	3/1
PHY 2540/2540L	Introduction to Thermal and Quantum Physics	3/1
PHY 3600/3600A	Mathematical Methods of Physics 1	3/1
PHY 4630	Senior seminar	1

*Double-counts for GE Areas B1 and B3

**Double-counts for GE Area B4.

2) 26 units of courses required for the Option in Integrated Science:

CHM 1220/L	General Chemistry II	3/1
BIO 1210/L	Foundations of Biology: Energy, Matter, and Information*	3/1
BIO 1220/L	Foundations of Biology: Evolution, Ecology, and Biodiversity	3/1
PHY 3210/A	Advanced Classical Mechanics	3/1
STS 2010	Introduction to Science, Technology, and Society Studies**	3
GSC 1110	Principles of Geology	3
GSC 1410L	Principles of Geology Laboratory	1
GSC 1160	Introduction to Astronomy	3

*Double-counts for GE Area B2

**Double-counts for GE Area C2

3) 16 units of electives for the Option in Integrated Science:

At least 3 units selected from:		
PHY 3040/3040L	Electronics for Scientists	2/1
PHY 4090/4090A	Computational Physics	2/1
PHY 4170/4170L	Wave Optics	2/1
PHY 4410	Internship in Physics	1 or 2
PHY 4610/4620	Senior Project	1/2
At least 4 units selected from:		
PHY 4010/4010A	Quantum Mechanics 1	3/1
PHY 4140/4140A	Electricity and Magnetism 1	3/1
PHY 4330/4330A	Thermal and Statistical Physics	3/1
At least 2 units selected from		
PHY 4510L	Advanced Laboratory Physics—Advanced Instrumentation	1/1
PHY 4520L	Advanced Laboratory Physics—Contemporary Experiments	1/1
3 units chosen from PHY 3010, PHY 3020, PHY 3060, AST 3050, or AST 3240.*		3
1 unit of supervised teaching experience or pedagogy seminar, which may be obtained via courses that include PHY 2000, 2990, 4000, 4410, 4410, as well as other courses approved by the department.		
An additional 3 units selected from any upper-division PHY or AST courses (except AST 3050, AST 3420, PHY 3010, and PHY 3020) or other upper-division math, science, and engineering courses approved by the department.		

*Double-count for GE Area B5.

4) 33 units of GE courses (in addition to the double-counted courses listed above).

Separate from this document, we have developed a curriculum sheet and also a list of student learning outcomes that includes an assessment plan.

New courses to be developed
None!

This program is designed to make effective use of existing courses. The purpose of this program is not to bring a new field of knowledge to our campus, but rather to have a program that combines courses available in existing disciplines, and in a manner that helps satisfy the state's need for qualified teachers.

Faculty teaching in the proposed program
Lower-division courses for this program are foundational, and may be taught by any of the faculty in Physics and Astronomy, Biological Sciences, Chemistry and Biochemistry, Geological Sciences, Mathematics and Statistics, and Science and Technology Studies. The upper-division courses in this program will primarily be taught by the Physics and Astronomy faculty listed below. In particular, students preparing for teaching careers will typically be mentored by those faculty engaged in science education research.

- Dr. Nina Abramzon, Professor (with tenure), PhD in Physics (1999). Research experience in plasma physics and spectroscopy, including biomedical applications of plasmas.
- Dr. Steven McCauley, Professor (with tenure), PhD in Physics (1982). Research experience in photosynthesis.
- Dr. Hector Mireles, Professor (with tenure), PhD in Physics (2000). Research experience in magnetism, microscopy, and physics of "soft" materials.
- Dr. Jorge Moreno, Assistant Professor (probationary), PhD in Physics (2010). Research experience in computational astrophysics.
- Dr. Matthew Povich, Assistant Professor (probationary), PhD in Astronomy (2009). Research experience in observational astronomy.
- Dr. Alexander Rudolph, Professor (with tenure), PhD in Physics (1988). Research experience in observational astronomy and ***physics and astronomy education***.
- Dr. Qing Ryan, Assistant Professor (probationary), PhD in Physics (2014). ***Research experience in physics education.***
- Dr. Homeyra Sadaghiani, Associate Professor (with tenure), PhD in Physics (2005). ***Research experience in physics education.***
- Dr. Ertan Salik, Associate Professor (with tenure), PhD in Physics (2001). Research experience in fiber optics and biosensors.
- Dr. Alex Small, Associate Professor (with tenure), PhD in Physics (2005). Research experience in biophotonics, mathematical models in biology, statistical physics, and soft materials.
- Dr. Kurt Vandervoort, Professor (with tenure), PhD in Physics (1990). Research experience in superconductivity, atomic force microscopy, and biofilms.

Additional Resources Required
None. This program is designed to give students the opportunity to pursue an interdisciplinary path that draws on existing resources on campus. We anticipate that many of the students pursuing this option will be giving strong consideration to teaching careers. These students will be able to find particularly strong mentoring from faculty engaged in educational research, including Associate Professor Homeyra

Sadaghiani (Physics Education Research), Professor Alex Rudolph (Astronomy Education Research), and our newest hire Assistant Professor Qing Ryan (Physics Education Research, joint appointment with CEMaST). Additionally, the Department of Physics and Astronomy has for several years been running a very successful Learning Assistant Program, in which undergraduate students work alongside faculty to interact with students in class activities. The Learning Assistants also take a seminar course on pedagogical methods and issues, and we anticipate that most students with an interest in teaching careers would participate in this program.