# The University Senate of Michigan Technological University

## Proposal 10-12

(Voting Units: Academic)

## "Proposal for a New Bachelor's Degree Program: Bachelor of Arts in Physics with a Concentration in Secondary Education"

**Department of Physics**
**Michigan Technological University**

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1. General description and characteristics of program.

The Bachelor of Arts in Physics with a Concentration in Secondary Education is a liberal arts degree that is intended to provide students with a solid foundation in physics and to prepare them for a career teaching in high school by earning State of Michigan provisional certification in physics secondary education. Graduates will be well-informed of the methods of scientific inquiry in general, and be well-equipped for lifelong learning. In particular, graduates will understand core physics principles, and be trained in physics education pedagogies based on experience and current physics education research. More detailed outcomes are summarized in the Appendix.

With fewer major requirements as compared to the complimentary B.S. degree in physics with a Concentration in Secondary Education, students can more easily complete the requirements for a teaching minor (required for certification), or also pursue other scholarly interests in the arts, humanities, social sciences, business, law, etc. This degree program will also be more flexible for students who either do not matriculate able to enroll immediately in calculus, or who change to this major within the first few years of enrollment.

Provisional certification in secondary education takes place through a process that is separate from the awarding of university B.A. or B.S. degrees, and is coordinated through the Michigan Tech department of Cognitive and Learning Sciences' Division of Teacher Education following the rules and policies set forth by the State of Michigan Department of Education.

2. Rationale.

Michigan Technological University currently offers three undergraduate degrees in physics:

- Bachelor of Science in Physics
- Bachelor of Science in Applied Physics
- Bachelor of Science in Physics with a concentration in Secondary Education

These first two of these degrees provide students with a rigorous foundation and advanced studies in physics and are primarily designed to give students excellent preparation for graduate studies in physics or closely related fields, or for a technical career with physics as its primary focus. The B.S. in Physics with Secondary Education concentration is designed for students seeking to become certified to teach physics in high school, and is also quite demanding.

The number of students completing the B.S. in Physics with a Concentration in Secondary Education has been approximately one to two per year over the past decade. While Michigan Tech has the capacity to graduate more students with secondary education certification in physics, our experience advising students suggests that our current B.S. program in physics may not be optimal to meet the needs and interests of all of our students who are interested in becoming high school physics teachers. A Bachelor of Arts in Physics with a Concentration in Secondary Education would allow us to better meet the needs of these students through a more flexible degree program, and thereby also contribute to the national need of more well-trained high school physics teachers (see below).

In addition to the requirements for their teaching major, students seeking State of Michigan provisional certification in secondary education must also complete the requirements of a teaching minor. The demanding degree requirements of our B.S. in Physics with Secondary Education Concentration, along with the requirements for the teaching minor, make it quite challenging for students to be able to graduate in four years. The increased number of free electives in the proposed B.A. degree program will allow students more flexibility in their schedule, help to accommodate courses for their teaching minor, and facilitate graduation in four years.

As public and private schools in the US continue to work to bolster STEM education, high school student enrollment in physics courses has steadily been increasing since 1987.[1] Over the same period of time, access to physics courses in high school has steadily remained high (over 90% of students attend a high school offering physics). Nevertheless, according to Judy Franz, Executive Officer of the American Physical Society from 1994-2009, "a recent study has found less than one quarter of physics departments have teacher education programs with recent graduates, and the number of graduates from these programs is about 1/3 of the national need."[2] According to the American Institute of Physics report on *Who Teaches in High School Physics*[3], based on a 2008-2009 national survey, while "the number of teachers teaching physics has grown by more than 25% since 2001," the growth rate is and has been below the growth rate of students taking physics courses in high school since 1993. The report further notes that while over half of the teachers surveyed identified themselves as physics specialists, "less than half have a degree in physics or physics education." Although the report does qualify that "this does not necessarily imply that the teachers are not qualified to teach physics," we assert that increasing the number of high school teachers with a degree in physics will further increase the quality of physics education in high school, and help to maintain a high level of professional satisfaction among those teachers.

This new degree program supports the Michigan Technological University Strategic Plan most directly in the following points:

Goal 1: Attract, retain, and support a world-class and diverse faculty, staff, and student population.

1.1: Provide an outstanding professional and cultural environment for all members of the Michigan Tech community.

- recruit, enroll, support, and recognize bright, motivated, and adventurous students.

1.2 Cultivate a diverse, inclusive, and collegial environment.

- develop and implement campus and unit initiatives to increase diversity;

Goal 2: Deliver a distinctive and rigorous discovery-based learning experience grounded in science, engineering, technology, sustainability, the business of innovation, and an understanding of the social and cultural contexts of our contemporary world.

2.1 Provide dynamic discovery-based learning that integrates instruction, research, and innovation in undergraduate and graduate programs.

- incorporate and expand discovery-based programs in all curricula;
- strengthen existing programs and develop undergraduate and graduate programs in new and emerging interdisciplinary areas;

2.2 Cultivate intellectual diversity and a worldview adapted to the needs and challenges of the 21st century.

- develop graduates with strong leadership and team-building capabilities, critical thinking skills, and ethical awareness.

3. Discussion of related programs within the institution and at other institutions.

The first two years of study in the B.A. Physics program with Concentration in Secondary Education will be very similar to our existing B.S. Physics programs, thus allowing maximum flexibility should students wish to change major.

The primary difference between the B.A. and B.S. degrees in Physics with Secondary Education Concentration will be a decreased number of required physics courses for the B.A. degree. Along the same lines, a separate proposal is being submitted for a Bachelor of Arts in Physics, which will be particularly attractive to students seeking maximum versatility in their undergraduate studies with a physics core. Although the physics and astronomy credits are lower relative to our B.S. degree, they are still substantial in comparison with similar degree programs at other Michigan universities (see below) and should serve to satisfy State of Michigan secondary education provisional certification requirements for physics.

The Concentration requirements for Secondary Education (see table under Part 6 below), which are used in part to satisfy provisional certification requirements of the State of Michigan, would be essentially the same for the B.A. program as it is for our current B.S. program with Concentration in Secondary Education. In addition, we propose requiring PH 4710 Methods of Teaching Physics, which has recently been developed and was offered for the first time in Spring Semester 2011 with five students enrolled. (PH4710 is not currently required for the B.S. degree but the department is moving toward also requiring it for the B.S. degree, commensurate with the new B.A. degree being approved). In this course, students will gain hands-on experience using physics-education-research-based pedagogies for physics instruction, including designing, setting up and implementing physics laboratories. The physics-related provisional certification requirements of State of Michigan for the proposed B.A. program will largely be met by the same courses as meet these requirements in our B.S. Physics with Concentration in Secondary Education. The Appendix presents a matrix from the certification evaluation conducted in 2004 for the B.S. in Physics with Concentration in Secondary Education. The matrix includes the narrative explaining how the required courses and/or experiences in the B.S. program fulfilled the standards program certification, along with comments regarding relevant changes that have taken place in the curriculum since 2004, and narrative about how proposed B.A. in Physics with Secondary Education Concentration would similarly fulfill the program standards. This information is provided as evidence that should this B.A. program be approved, it is reasonable to expect that certification of the program by the State of Michigan Department of Education will also be approved.

A summary of the credit requirements for our current B.S. programs and our proposed B.A. programs in physics are given in Table 1 below. The B.A. in Physics with Secondary Education Concentration requires 35-36 credits in physics courses. Of these required physics credits, 9 credits are physics electives subject to the restriction that 6 credits be at the 3000-level or higher. The proposed physics and astronomy credit requirement for the B.A. in Physics with Secondary Education Concentration is comparable to that required for B.A. programs at other universities, which typically range from 27 credits (e.g. Michigan State University[4]) to 36 credits (e.g. Case Western Reserve University[5]), many of which also have options for secondary education certification. In terms of courses in physics and astronomy, B.A. in Physics programs across the country vary from being relatively unstructured beyond the core introductory physics courses, to more highly regulated in terms of the types and level of courses taken beyond the introductory courses. Since our B.S. programs are already highly structured, the proposed B.A. in Physics is designed to be relatively less structured beyond the core introductory physics courses up to and including modern physics in order to maximize the flexibility of the program for students.

**Table 1.** Summary of Credit Requirements for B.S. and B.A. Degrees in Physics at Michigan Tech

| | | | |
|---|---|---|---|

| Degree Program | Required Physics & Astronomy Credits | Free-Elective Credits | Total Credits for Graduation |
|---|---|---|---|
| B.S. in Physics | 69 | 9 | 128 |
| B.S. in Physics with Secondary Education Concentration | 46 | 3-4‡ | 126 |
| B.S. in Applied Physics | 57 | 8 | 128 |
| B.A. in Physics* | 37-38 | 34-37 | 124 |
| B.A. in Physics with Secondary Education Concentration* | 37 | 11-13‡ | 126 |

*Proposed

‡ Free electives for students seeking concentration in secondary education use all or part of these free elective credits to fulfill the provisional certification requirement of completing a teaching minor. Additional credits may be required as the actual credits required for a teaching minor will depend on the selected teaching minor.

The B.A. in Physics with Secondary Education Concentration has approximately 11 to 14 free-elective credits (depending on allowed variations in the major requirements). In practice, students will typically use these credits to fulfill their teaching minor requirements for provisional secondary education certification. In comparison, the B.S. in Physics with Concentration in Secondary Education has only 3 to 4 free-elective credits available. More than this is typically needed satisfy the requirement for a teaching minor necessary for provisional secondary education certification, making it difficult to complete this degree and concentration in four years. For example, the most popular teaching minor selected by physics majors is in mathematics, which typically requires a minimum of 11 additional credits in mathematics for most of our physics majors.

Table 2 compares undergraduate-level secondary education certification programs in physics at Michigan's public universities.

**Table 2. Undergraduate-Level Secondary Education Certification Programs in Physics at Michigan's Public Universities**

| | Degree | Physics & Astronomy Credits Required | Education Program |
|---|---|---|---|
| **Central Michigan University** | B.S. | 38 | B.S. in Education (Physics Major) |
| **Eastern Michigan University** | B.A./B.S. | 38 | Secondary Teacher Certification |
| **Grand Valley State University** | B.S. | 42 | Certification for Secondary Teaching |
| **Michigan State University** | B.A.<br>B.S. | 27-32<br>37-41 | Teacher Certificate Option<br>Teacher Certificate Option |
| **Michigan Technological University** | B.A.*<br>B.S. | 37<br>46 | Secondary Education Concentration<br>Secondary Education Concentration |
| **Northern Michigan University** | B.A. | 32 | Secondary Education Physics Major |

*Proposed

4. Projected enrollment.
   We expect to have up to two new students join the program per year. As the program gains some visibility and prominence, we anticipate eventually reaching eight to ten students enrolled per year. Although this is a relatively small number of students, it is very significant in terms of the size our programs in physics and the rate of certification of high school physics teachers nationwide.
5. Scheduling plans (Extension, Evening, Regular).
   Regular
6. Curriculum design (refer to format of degree audit form). Indicate subject areas to be used for Departmental GPA calculation.

Subject areas to be used for Departmental GPA calculation have a "›" mark before the Course Number; the 9 credits of physics electives are also to be included.
All course descriptions, including prerequisites, can be viewed online at
http://www.mtu.edu/catalog/undergraduate/course-descriptions/pdf/undergraduate.pdf

| **Major Requirements** | | |
|---|---|---|
| **Course Number** | **Course Name** | **Credits** |
| CH 1150 | University Chemistry I | 3 |
| CH 1151 | University Chemistry Lab | 1 |
| CH 1153 | University Chem Recitation I | 1 |
| | | |
| MA 1160/ 1161 | Calculus with Technology I/ Calculus Plus w/ Technology I | 4-5 |
| MA 2160 | Calculus with Technology II | 4 |
| MA 2320/ 2330 | Elementary Linear Algebra/ Introduction to Linear Algebra | 2-3 |
| MA 3160 | Multivariable Calculus with Technology | 4 |
| MA 3530 | Introduction to Differential Equations | 3 |
| | | |
| ›PH 1600 | Introductory Astronomy | 2 |
| ›PH 1610 | Introductory Astronomy Lab | 1 |
| ›PH 1160 | Honors Physics I- Mechanics | 4 |
| ›PH 1161 | Introduction to Experimental Physics I | 1 |
| ›PH 1360 | Honors Physics II- Rotation and Vibration | 2 |
| ›PH 1361 | Introductory Experimental Physics II | 1 |
| ›PH 2020 | Introduction to Error Analysis and Scientific Programming | 1 |
| ›PH 2260 | Honors Physics III- Electricity and Magnetism | 4 |
| ›PH 2261 | Introductory Experimental Physics III | 1 |
| ›PH 2300 | University Physics III- Fluids and Thermodynamics | 2 |
| ›PH 2400 | University Physics IV- Waves and Modern Physics | 3 |
| ›PH 3210 | Optics | 3 |
| ›PH 4010 | Senior Colloquium I | 1 |
| | | |
| ›Physics Electives *(minimum 6 credits at the 3000-level or higher, excluding PH4011, PH 4050, PH4080, and no more than 3 credits of PH 4999)*** | | 9 |
| Major Requirements sub total | | (57-59) |

** These courses can count toward the total credit hours of Physics Electives, but not toward the 6 minimum credits at the 3000-level or higher.

| **Concentration Requirements**† | | |
|---|---|---|
| **Course Number** | **Course Name** | **Credits** |
| ED 3100 | Instructional Technology | 2 |
| ED 3110†† | Psychological Foundations of Learning | 3 |
| ED 3210 | Foundations of Education | 2 |
| ED 3410 | Clinical Experience | 1 |
| ED/HU 4150 | Literacy in Content Areas | 4 |
| ED 4700 | Fundamentals of Instruction | 3 |
| ED 4720 | Methods of Teaching Science | 2 |

| | | |
|---|---|---|
| ›PH 4710 | Methods of Teaching Physics | 2 |
| ED 4910 | Directed Teaching | 12 |
| | Concentration Requirements Sub Total | (31) |

†For Michigan Teaching Certification, students must also complete a secondary teacher certification minor. Additional credits depend on the minor chosen. In addition, students must be certified in First Aid and CPR for child and adult, either by completing EH 3985 or Red Cross or American Heart Association training. Consult Michigan Tech Department of Cognitive and Learning Sciences for appropriate course selection.

††From HASS Distribution Course Lists: ED 3110 satisfies 3 credits of this requirement.

| **General Education Requirements** | | |
|---|---|---|
| **Course Number** | **Course Name** | **Credits** |
| UN 1001 | Perspectives on Inquiry | 3 |
| UN 1002*** | World Cultures | 4 |
| UN 2001 | Composition: Oral, Written and Visual | 3 |
| UN 2002 | Institutions | 3 |
| | | |
| **HASS Distribution Courses: 15 total credits required.**<br>**Six credits must be at the 3000- or 4000-level.**<br>• No more than 3 credits from the HASS Creative Endeavors List may be used to satisfy the HASS Distribution List requirements.<br>• No more than 3 credits from the HASS Supplemental List may be used to satisfy the HASS Distribution List requirements.<br>• ED3110 counts 3 credits toward this 15-credit requirement. | | |
| General Education Requirement Sub Total | | (25)† |
| | | |
| **Co-Curricular Activities** (3 units)<br>Required for graduation, but not included in the calculation of the GPA, or in the overall credits required for the degree. | | |
| | | |
| **Free Electives**<br>Many of these credits will typically be fulfilled by the Secondary Teaching Certification Minor credits. The actual number of credits needed will vary depending on the teaching minor selected. | | **11-13** |
| | | |
| **Total Credits Required for Degree** | | **126** |

***Two semesters of a single modern language (6 cr) in addition to UN1003 World Cultures Activities (1 cr) can substitute for UN1002 + 3 credits of distribution course requirements.

†Three credits for ED 3110 is counted in the Concentration Requirements section.

An alternate route for students to enter the program who may be changing from an non-engineering major, or, who may be entering the physics program without being ready for calculus would be to allow the following substitutions:

| **Substitute this course** | **In place of this course** |
|---|---|
| PH 2100 University Physics I: Mechanics | PH 1160 Honors Physics I- Mechanics |
| PH 1100 Physics by Inquiry I | PH 1161 Introduction to Experimental Physics I |
| PH 2200 University Physics II: Electricity & Magnetism | PH 2260 Honors Physics II- Electricity & Magnetism |
| PH 1200 Physics by Inquiry II | PH 2261 Introduction to Experimental Physics III |

PH 2100, PH 1100, PH 2200, and PH 1200 are offered every semester, including the summer, unlike the honors physics sequence above, which is only offered once per year each fall. Students in the alternate route would still take PH 1360 Honors Physics II and PH 1361 Introduction to Experimental Physics II as their schedules permit.

7. New course descriptions. (New Course Add Forms are needed for each course and will be processed upon final approval of program.)
   No new courses are necessary and none are proposed.
   PH4710 is a relatively new course, however, and its catalog description is therefore given here for convenience of the reader:

   **PH 4710 - Methods of Teaching Physics**
   Hands-on exploration of physics education methods in classroom, laboratory, and tutoring environments. Students study highlights of physics education research and explore use of several tools and pedagogical techniques, including web-based homework systems, simulations, classroom feedback systems, and equipment for laboratories and lecture demonstrations.
   **Credits:** 2.0 **Lec-Rec-Lab:** (0-1-2)
   **Semesters Offered:** Spring - Offered alternate years beginning with the 2010-2011 academic year
   **Restrictions:** May not be enrolled in one of the following Class(es): Freshman
   **Pre-Requisite(s):** PH 1210 or PH 2200 or PH 2260
8. Library and other learning resources.
   No additional library or learning resources are required.
9. Computing Access Fee.
   No longer assessed by the university.

10. Faculty resumes (a web site link is sufficient).
    www.phy.mtu.edu/BA/facultyvitae.pdf

11. Description of available/needed equipment.
    The Physics Department at Michigan Technological University is well equipped with modern teaching laboratories for introductory as well as advanced physics laboratories. The department also maintains a staffed and well-equipped facility for laboratory experiments and lecture demonstrations. The resources and staff for this facility, under the supervision of Senior Lecturer Michael Meyer, are invaluable to students seeking secondary education certification in physics and will further support this new program.
    Since Michigan Tech already offers three B.S. degrees in physics, and enrollment increases are expected to be modest, no additional equipment is required.

12. Program costs, years 1, 2, and 3. (Additional information may be requested by the Senate Finance Committee.)
    Because this degree program is a subset of our existing B.S. program in physics with a concentration in secondary education, because no new courses are necessary, and because the anticipated number of students expected to enroll is small, no additional costs are anticipated for this new degree program.
13. Space.
    No additional space is required to accommodate the new degree program.
14. Policies, regulations and rules.
    Students applying to and enrolled in this program are subject to the programs rules and policies of Michigan Tech's Division of Teacher Education, which can be found at http://www.ed.mtu.edu/stu/progress.html. For convenience of reviewers, the current policies are provided here:

## Admission

Admission to Michigan Tech does not automatically grant a student admission to the teacher education program. **Students must apply separately to the Division of Teacher Education.** Typically, students apply to the program no earlier than their sophomore year. Requirements for admission include:

- Prior experience working with children or adolescents. Teacher candidates will document their experience in their portfolio.
- A 2.5 GPA is required in your major for Math, Science and English or a 2.75 GPA for Social Studies, and Economics majors. A 2.5 GPA is also required for your education courses and certification minor.
- Recommendation from the Dean of Students, or if a post graduate, two letters of references.
- Completion of the Conviction Statement form authorizing release of all records and information pertaining to any convictions for criminal offenses or penalties for violation of University regulations to the Division of Teacher Education. This information may be on file either at the Dean of Students' Affairs office of the University, the Michigan State Police, or any other criminal justice agency. Through this form, students consent to the use and communication of such information by the faculty and administration of teacher education in assessing compliance with admission requirements. Teacher education reserves the right to refuse admission based on any criminal record that indicates the student might have an adverse affect on the teaching profession. Any misrepresentation by a student concerning a matter governed by teacher education requirements shall itself constitute a failure to comply.
- Students not meeting these criteria may appeal in writing citing reason(s) for the appeal and supporting documentation to the Division of Teacher Education Admission Appeal Committee.
- Departmental approval is required prior to registration for all Education courses.

## Portfolio

All teacher education students must maintain a portfolio. This portfolio will consist of a multidimensional collection of educational work and life experiences and will provide evidence of satisfactory professional progress in the teacher education program. Students are encouraged to begin their portfolio upon admission to teacher education and maintain all relevant material to their preparation as a teacher in their portfolio.

## Progress in the Program

Admission to the Methods phase of the program enables students to enroll in ED 4700, Fundamentals of Instruction, which is a prerequisite for all subject matter methods courses and student teaching. The Education faculty committee evaluates all candidates prior to their enrollment in ED 4700. The committee is interested in determining if the applicant possesses the characteristics necessary for effective teaching. They wish to identify students who need opportunities for remediation, further academic preparation, or special assistance or consideration. Interviews, portfolios, and other materials may be required as part of this evaluation process. Candidates may be required to correct specific deficiencies through remedial courses or other interventions before being permitted to enroll in ED 4700. The committee will inform candidates as to whether or not they have been approved to enroll in the methods phase, typically by the end of week 8 of the early block.

## Dismissal

A student will be dismissed from the teacher education program if one or more of the following conditions occur:

- Any misrepresentation by a student concerning a matter governed by teacher education admission requirements.
- Any violation of University regulations which indicates that the student might have an adverse affect on the teaching profession.

- Lack of professionalism including, but not limited to withdrawing from student teaching, behavior in schools not consistent with the policies and practices of that school; and public behavior not consistent with professional teacher norms.
- A failing grade in any education/methods course required for certification.

**Certification**

In order to be recommended by the University for State of Michigan Certification you must:

- Successfully complete the secondary school teacher certification program.
- Must be certified in First Aid and CPR.
- Passed the MTTC Basic Skills & subject area tests.
- Received a baccalaureate degree in appropriate field with a GPA Major and Minor of 2.5 for Math, Science & English or a 2.75 GPA for Social Studies.

The candidate will be recommended for a Michigan Secondary Provisional Certificate valid in grades 6 through 12 for a period of six (6) years. (During that six-year period, each holder of the secondary provisional certificate must qualify for a Professional Certificate by earning 18 semester credits in a *planned program* at a university and by presenting evidence of three years of successful teaching experience at the secondary level.) Candidates must consult with advisors in the Division of Teacher Education as early as possible in order to schedule the necessary courses.

15. Accreditation requirements.
    Not applicable.
16. Internal status of the proposal.
    8/30/2011 - the physics undergraduate studies committee approved the proposal and recommended it to the physics department faculty for its consideration.
    9/12/2011- Physics faculty unanimously approve the proposal.
    9/15/2011- Submit proposal to Dean, College of Sciences and Arts; cc. Provost office.
    9/20/2011- Presentation to Sciences and Arts College Council.
    9/27/2011- Approved by the College Council, College of Sciences and Arts
    10/4/2011- Distributed for university Administrative Review
    10/12/2011- Approved by the Deans' Council and Provost; forwarded to the University Senate
17. Planned implementation date.
    Fall semester ~~2013~~ 2012

**APPENDIX: Standards for the Preparation of Teachers of Physics (DE Endorsement)**

The State of Michigan Department of Education conducts periodic reviews/program evaluations of the secondary education certification programs. The secondary education certification program for Physics through the B.S. in Physics with Secondary Education Concentration was last completed in 2004 based on state standards from 2002. Documents submitted for this evaluation may be found at http://www.ed.mtu.edu/PeriodicReview/Physics/index.html

Provisional Certification for secondary education in physics through the proposed B.A. in Physics with Concentration in Secondary Education should follow largely in parallel with the B.S. program; however, several changes in the physics curriculum have taken place since 2004. The entire matrix from the 2004 evaluation is included below for the secondary teaching major, along with comments relevant to changes in the curriculum and the proposed B.A. in Physics with Concentration in Secondary Education. This is presented as a reasonable case that the proposed program can lead to certification in the State of Michigan; however, this will be a separate process. Depending on possible new rules and guidelines, changes to the curriculum may become necessary in the future.

The following three levels of proficiency are used in the matrix below:

**A – Awareness**

The physics teacher recognizes/recalls the existence of different aspects of the science of physics and related teaching strategies.

**B – Basic Understanding**
The physics teacher articulates knowledge about the science of physics and related instructional and assessment strategies. The physics teacher demonstrates proficiency in using the knowledge at a fundamental level of competence acceptable for teaching.

**C – Comprehensive Understanding**
The physics teacher is able to apply broad, in-depth knowledge of the different aspects of the science of physics in a variety of settings. (This level is not intended to reflect mastery; all teachers are expected to be lifelong learners.)

| Standard/Guideline | | Narrative Explaining how Required Courses and/or Experiences Fulfill the Standards for Program | |
|---|---|---|---|
| | | **Secondary Major** | **New Comments Relevant to This Proposal** |
| | **Submit a narrative that explains how this program:** | | |
| A. | uses the Michigan Curriculum Framework K-12 Science Content Standards and Benchmarks as the critical foundation for teacher preparation, ensuring that physics teachers have the content knowledge and the ability to teach this curriculum; and | Major certification for secondary physics education is only offered to students seeking B.S. degrees in physics. The curriculum is comprehensive in introductory and advanced content knowledge for all areas required by the Michigan Curriculum Framework K-12 Science Content Standards and Benchmarks. Details are described below. | Still applicable except for adding the B.A. in physics, as well as the B.S. in physics degree. |

| Standard/Guideline | | Narrative Explaining how Required Courses and/or Experiences Fulfill the Standards for Program | |
|---|---|---|---|
| | | **Secondary Major** | **New Comments Relevant to This Proposal** |
| B. | develops an understanding of the interconnectedness of all science, including biology, chemistry, and the earth/space sciences, and relates this understanding to the teaching of physics. | The sophomore seminar (PH2010) course offers discussion of connections to other disciplines such as biology and earth science (remote sensing). ). Topics in introductory physics classes are explicitly motivated by connections with other sciences and especially to engineering disciplines. The topics in PH2400 illustrate the connection between physics and chemistry. Specific connection to earth/space science is also shown in the course in astronomy (PH1600). | Sophomore Seminar (PH2010) is no longer being offered. PH2020 Scientific Programming and Error Analysis has been substituted in its place. The methods and techniques of PH2020 are broadly applicable.<br><br>Topics in the introductory physics sequence (PH1160, PH1161, PH1360, PH1361, PH2260, PH2261, PH2300, PH2400) have significant motivational connections with other sciences and engineering disciplines. Topics in Waves and Modern Physics (PH2400) illustrate explicit and foundational connections between physics and chemistry. Specific connections to earth/space science is also explored in PH1600 Introductory Astronomy and PH1610 Introductory Astronomy Lab. |

| No. | Standard/Guideline | Level of Proficiency | Narrative Explaining how Required Courses and/or Experiences Fulfill the Standards for Program | |
|---|---|---|---|---|
| | | | **Secondary Major** | **New Comments Relevant to This Proposal** |
| | **The preparation of physics teachers will enable them to:** | | | |
| 1.0 | understand and develop the major concepts and principles of physics as the study of matter and energy and of the interaction between the two and including mechanics, electricity, magnetism, thermodynamics, waves, optics, solid-state physics, atomic and nuclear physics, radioactivity, relativity, and quantum mechanics and shall include such topics as: | | | |

| No. | Standard/Guideline | Level of Proficiency | Narrative Explaining how Required Courses and/or Experiences Fulfill the Standards for Program | |
|---|---|---|---|---|
| | | | Secondary Major | New Comments Relevant to This Proposal |
| 1.1 | Matter and Energy | | | |
| 1.1.1 | mechanics | C | Relationships between matter, motion, energy, forces and potentials are introduced and explored in detail through concepts and problems in PH1160 and through hands-on experience in PH1161. Relativistic mechanics is explored in PH2400. Explored at a more advanced level in PH3221. | Still applicable. Also introduced in PH1600/PH1610. PH3221 should read PH3110. PH3110 will be an elective in the B.A. program. Students not taking PH3110 will still have "C" proficiency in this area. |
| 1.1.1.2 | conservation of energy, momentum, angular momentum | C | Introduced and explored in detail through concepts and problems in PH1360 and through hands-on experience in PH1161. Relativistic energy and momentum are explored in PH2400. Explored at a more advanced level in PH3221. | Still applicable. Also introduced in PH1600/PH1610. PH3221 should read PH3110. PH3110 will be an elective in the B.A. program. Students not taking PH3110 will still have "C" proficiency in this area. |
| 1.1.1.3 | inertia | C | Introduced and explored in detail through concepts and problems in PH1160 and through hands-on experience in PH1161. Explored at a more advanced level in PH3221. | Still applicable. PH3221 should read PH3110. PH3110 will be an elective in the B.A. program. Students not taking PH3110 will still have "C" proficiency in this area. |
| 1.1.1.4 | oscillatory motion | C | Introduced and explored in detail through concepts and problems in PH1360 and through hands-on experience in PH1161. Explored at a more advanced level in PH3221. | Still applicable. PH1161 should read PH1361. PH2400 is also relevant. PH3221 should read PH3110. PH3110 will be an elective in the B.A. program. Students not taking PH3110 will still have "C" proficiency in this area. |

| No. | Standard/Guideline | Level of Proficiency | Narrative Explaining how Required Courses and/or Experiences Fulfill the Standards for Program | |
|---|---|---|---|---|
| | | | Secondary Major | New Comments Relevant to This Proposal |
| 1.1.1.5 | law of gravity | C | Introduced and explored in detail through concepts and problems in PH1160. Explored at a more advanced level in PH3221. | Still applicable. Also introduced in PH1600/PH1610. PH3221 should read PH3110. PH3110 will be an elective in the B.A. program. Students not taking PH3110 will still have "C" proficiency in this area. |
| 1.1.2 | Electricity and Magnetism | | | |
| 1.1.2.1 | electro-statics – Coulomb's law | C | Introduced and explored in detail through concepts and problems in PH2260 and through hands-on experience in PH2261. Explored at a more advanced and in-depth level in PH4210. | Still applicable. PH4210 will be an elective in the B.A. program. Students not taking PH4210 will still have "C" proficiency in this area. |
| 1.1.2.2 | electro-static field and potential | C | Introduced and explored in detail through concepts and problems in PH2260 and through hands-on experience in PH2261. Explored at a more advanced and in-depth level in PH4210. | Still applicable. PH4210 will be an elective in the B.A. program. Students not taking PH4210 will still have "C" proficiency in this area. |
| 1.1.2.3 | electric dipoles | C | Introduced and explored in detail through concepts and problems in PH2260 and through hands-on experience in PH2261. Explored at a more advanced and in-depth level in PH4210. | Still applicable. PH4210 will be an elective in the B.A. program. Students not taking PH4210 will still have "C" proficiency in this area. |
| 1.1.2.4 | electro-static energy and force | C | Introduced and explored in detail through concepts and problems in PH2260 and through hands-on experience in PH2261. Explored at a more advanced and in-depth level in PH4210. | Still applicable. PH4210 will be an elective in the B.A. program. Students not taking PH4210 will still have "C" proficiency in this area. |

| No. | Standard/Guideline | Level of Proficiency | Narrative Explaining how Required Courses and/or Experiences Fulfill the Standards for Program | |
|---|---|---|---|---|
| | | | Secondary Major | New Comments Relevant to This Proposal |
| 1.1.2.5 | Ohm's law | C | Introduced and explored in detail through concepts and problems in PH2260 and through hands-on experience in PH2261. Explored at a more advanced and in-depth level theoretically in PH4210 and practically in PH2230. | Still applicable. PH4210 and PH2230 will be an elective in the B.A. program. Students not taking PH4210 and/or PH2230 will still have "C" proficiency in this area. |
| 1.1.2.6 | magnetic induction field | C | Introduced and explored in detail through concepts and problems in PH2260 and through hands-on experience in PH2261. Explored at a more advanced and in-depth level in PH4210. | Still applicable. PH4210 will be an elective in the B.A. program. Students not taking PH4210 will still have "C" proficiency in this area. |
| 1.1.2.7 | Biot-Savart law | B | Introduced and explored in detail through concepts and problems in PH2260 and through hands-on experience in PH2261. Explored at a more advanced and in-depth level in PH4210. | Still applicable. PH4210 will be an elective in the B.A. program. Students not taking PH4210 will still have "C" proficiency in this area. |
| 1.1.2.8 | Ampere's law | B | Introduced and explored in detail through concepts and problems in PH2260 and through hands-on experience in PH2261 | Still applicable. |
| 1.1.2.9 | magnetic energy, force, and torque | C | Introduced and explored in detail through concepts and problems in PH2260 and through hands-on experience in PH2261 | Still applicable. |
| 1.1.2.10 | Maxwell's equations | A | Introduced and explored through concepts and problems in PH2200. | Introduced and explored through concepts and problems in PH2260. |
| 1.1.2.11 | relativistic electro-dynamics | A | Introduced in PH2400 with special relativity, and PH4210. | Still applicable. Also mentioned in electives PH3110 and PH4210. |
| 1.1.3 | Thermodynamics | | | |

| No. | Standard/Guideline | Level of Proficiency | Narrative Explaining how Required Courses and/or Experiences Fulfill the Standards for Program | |
|---|---|---|---|---|
| | | | Secondary Major | New Comments Relevant to This Proposal |
| 1.1.3.1 | Temperature | C | Introduced and explored in detail through concepts and problems in PH2300. Explored at a more advanced level in PH3300. | Still applicable. |
| 1.1.3.2 | Work | C | Introduced and explored in detail through concepts and problems in PH1160 and PH2300. Explored at a more advanced level in PH3300. | Still applicable in the whole introductory physics sequence and in elective PH3300. Students not taking PH3300 will still have "C" proficiency in this area. |
| 1.1.3.3 | specific heat | C | Introduced and explored in detail through concepts and problems in PH1160 and PH2300. Explored at a more advanced level in PH3300. | Introduced and explored in detail through concepts and problems in PH2300. Explored at a more advanced level in elective PH3300. Students not taking PH3300 will still have "C" proficiency in this area. |
| 1.1.3.4 | Compressibility | A | Introduced and explored in detail through concepts and problems in PH1160 and PH2300. Explored at a more advanced level in PH3300. | Introduced and explored in detail through concepts and problems in PH2300. Explored at a more advanced level in elective PH3300. Students not taking PH3300 will still have "C" proficiency in this area. |
| 1.1.3.5 | Entropy | A | Introduced and explored in detail through concepts and problems in PH1160 and PH2300. Explored at a more advanced level in PH3300. | Introduced and explored in detail through concepts and problems in PH2300. Explored at a more advanced level in elective PH3300. Students not taking PH3300 will still have "C" proficiency in this area. |
| 1.1.3.6 | laws of thermodynamics | B | Introduced and explored in detail through concepts and problems in PH1160 and PH2300. Explored at a more advanced level in PH3300. | Introduced and explored in detail through concepts and problems in PH2300. Explored at a more advanced level in elective PH3300. Students not taking PH3300 will still have "B" proficiency in this area. |

| No. | Standard/Guideline | Level of Proficiency | Narrative Explaining how Required Courses and/or Experiences Fulfill the Standards for Program | |
|---|---|---|---|---|
| | | | Secondary Major | New Comments Relevant to This Proposal |
| 1.1.3.7 | internal energy | B | Introduced and explored in detail through concepts and problems in PH1160 and PH2300. Explored at a more advanced level in PH3300. | Introduced and explored in detail through concepts and problems in PH1160 and PH2300. Explored at a more advanced level in elective PH3300. Students not taking PH3300 will still have "B" proficiency in this area. |
| 1.1.3.8 | Enthalpy | B | Introduced and explored in detail through concepts and problems in PH1160 and PH2300. Explored at a more advanced level in PH3300. | Introduced and explored in detail through concepts and problems in PH2300. Explored at a more advanced level in elective PH3300. Students not taking PH3300 will still have "B" proficiency in this area. |
| 1.1.3.9 | Maxwell – Boltzmann theory | B | Introduced and explored in detail through concepts and problems in PH1160 and PH2300. Explored at a more advanced level in PH3300. | Introduced in PH2300. Explored at a more advanced level in elective PH3300. Students not taking PH3300 will still have "B" proficiency in this area. |
| 1.1.3.10 | cryogenics – properties of materials at low temperatures and safe handling of liquid nitrogen | A | Introduced in PH2300 and PH3300. | Exposure during freshmen orientation. Introduced in PH2300 and elective PH3300. Additional experience is gained in PH4710 and through optimal departmental teaching assistant opportunities if so chosen to warrant “A” proficiency. |
| 1.1.4 | Optics | | | |
| 1.1.4.1 | simple optical systems | C | Introduced and explored in some detail PH2400. Explored at a more advanced level in PH3210. | PH2400 should be removed from this section. Explored at an advanced level in PH3210. Covered through guided construction in three laboratories in PH2261. |

| No. | Standard/Guideline | Level of Proficiency | Narrative Explaining how Required Courses and/or Experiences Fulfill the Standards for Program | |
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| | | | Secondary Major | New Comments Relevant to This Proposal |
| 1.1.4.2 | interference and interferometers | B | Introduced and explored through concepts, demonstrations and problems in PH2400. Explored at a more advanced level in PH3210. | Still applicable. Also covered through guided construction in three laboratories in PH2261. |
| 1.1.4.3 | diffraction | C | Introduced and explored through concepts, demonstrations and problems in PH2400. Explored at a more advanced level in PH3210. | Still applicable. Also introduced in PH1600. |
| 1.1.4.4 | double-slit | C | Introduced and explored through concepts, demonstrations and problems in PH2400. Explored at a more advanced level in PH3210. | Still applicable. |
| 1.1.4.5 | Grating | C | Introduced and explored through concepts, demonstrations and problems in PH2400. Explored at a more advanced level in PH3210. | Still applicable. |
| 1.1.4.6 | limit resolution | B | Introduced and explored in PH2400. Explored at a more advanced level in PH3210. | Still applicable. Also introduced in PH1600. |
| 1.1.4.7 | polarization and reflection | C | Introduced and explored in PH2400. Explored at a more advanced level in PH3210 and PH4210. | Still applicable, except PH4210 is an elective in the B.A. program. Students not taking PH4210 will still have "C" proficiency. |
| 1.1.4.8 | spectroscopy | C | Introduced and explored through concepts and problems in PH2400. Explored in more detail in PH3410. | Still applicable. Also introduced in PH1600/PH1610. PH3410 is an elective in the B.A. program but students not taking PH3410 will still have "C" proficiency. |
| 1.1.4.9 | radiometry | A | Introduced in PH2200 and PH2400. | Still applicable. |

| No. | Standard/Guideline | Level of Proficiency | Narrative Explaining how Required Courses and/or Experiences Fulfill the Standards for Program | |
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| | | | Secondary Major | New Comments Relevant to This Proposal |
| 1.1.4.10 | photometry | A | Introduced in PH2200 and PH2400. | Still applicable. |
| 1.1.4.11 | lasers, holography, fiber optics | B | Introduced and explored in PH2400. Explored at a more advanced level in PH3210. | Still applicable. |
| 1.1.5 | Quantum Physics | | | |
| 1.1.5.1 | blackbody radiation | B | Introduced and explored through concepts and problems in PH2400. Explored in more detail in PH3410. | Still applicable. Also introduced in PH1600/PH1610. PH3410 is an elective in the B.A. program, but students not taking PH3410 will still have "B" proficiency. |
| 1.1.5.2 | Schrodinger's equation | A | Introduced and explored in some detail PH2400 and at a more advanced level in PH3410. | Still applicable. PH3410 is an elective in the B.A. program, but students not taking PH3410 will still have more than "A" proficiency. |
| 1.1.5.3 | multiple wave functions | A | Introduced and explored in some detail PH2400 and at a more advanced level in PH3410. | Still applicable. PH3410 is an elective in the B.A. program, but students not taking PH3410 will still have "A" proficiency. |
| 1.1.5.4 | shell model of the atom | B | Introduced and explored in some detail PH2400 and at a more advanced level in PH3410. | Still applicable. PH3410 is an elective in the B.A. program, but students not taking PH3410 will still have "B" proficiency. |
| 1.1.5.5 | theory of solids | A | Introduced and explored in some detail PH2400. | Still applicable. |
| 1.1.5.6 | Fermi-Dirac statistics | A | Introduced in PH3300. | Introduced in PH2300 and elective PH3300. Students not taking PH3300 will still have "A" proficiency. |
| 1.1.5.7 | Bose-Einstein statistics | A | Introduced in PH3300. | Introduced in PH2300 and elective PH3300. Students not taking PH3300 will still have "A" proficiency. |
| 1.1.6 | Acoustics | | | |

| No. | Standard/Guideline | Level of Proficiency | Narrative Explaining how Required Courses and/or Experiences Fulfill the Standards for Program | |
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| | | | Secondary Major | New Comments Relevant to This Proposal |
| 1.1.6.1 | wave motion | C | Introduced and explored in detail through concepts, demonstrations, and problems in PH1360. | Introduced and explored in detail through concepts, demonstrations, and problems in PH1360 and PH2400. Waves are explored through guided construction in PH1361. |
| 1.1.6.2 | sound waves | C | Introduced and explored in detail through concepts, demonstrations, and problems in PH1360. | Still applicable. Also explored through guided construction in PH1361. |
| 1.1.6.3 | doppler effect | C | Introduced and explored in detail through concepts, demonstrations, and problems in PH1360. | Still applicable. Also introduces for light in PH1610/PH1610. |
| 1.1.6.4 | standing waves | C | Introduced and explored in detail through concepts, demonstrations, and problems in PH1360. | Also explored through guided construction in PH1361. |
| 1.1.6.5 | resonance | C | Introduced and explored in detail through concepts, demonstrations, and problems in PH1360. | Still applicable. Also explored through guided construction in PH1361. More advanced treatment is covered in PH2400, and elective PH3110. |
| 1.1.7 | Nuclear Physics | | | |
| 1.1.7.1 | properties of nuclei | C | Introduced and explored in some detail PH2400. | Still applicable. |
| 1.1.7.2 | nuclear models | C | Introduced and explored in some detail PH2400. | Still applicable. |
| 1.1.7.3 | nuclear magnetic resonance | A | Introduced PH2400. | Still applicable. |
| 1.1.7.4 | radioactivity | C | Introduced and explored in some detail through concepts and problems PH2400. | Still applicable. |
| 1.1.7.5 | Fission | C | Introduced and explored in some detail through concepts and problems PH2400. | Still applicable. |
| 1.1.7.6 | Fusion | C | Introduced and explored in some detail through concepts and problems PH2400. | Still applicable. |

| No. | Standard/Guideline | Level of Proficiency | Narrative Explaining how Required Courses and/or Experiences Fulfill the Standards for Program | |
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| | | | Secondary Major | New Comments Relevant to This Proposal |
| 1.1.7.7 | elementary quark model | B | Introduced and explored in PH2400. | Introduced in PH2400. |
| 1.1.7.8 | standard model of elementary particle physics | B | Introduced and explored in PH2400. | Still applicable. |

| No. | Standard/Guideline | Narrative Explaining how Required Courses and/or Experiences Fulfill the Standards for Program | |
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| | | Secondary Major | New Comments Relevant to this Proposal |
| | **The preparation of physics teachers will enable them to:** | | |
| 2.0. | apply mathematics, including statistics and calculus and introductory differential equations, to investigations in physics and the analysis of data; | These mathematical tools are foundational to the study of physics and are utilized in all courses, from introductory to advanced. Graphical and statistical analysis of data is introduced and used in all physics laboratory courses. | Still applicable.<br>Students comprehensively cover differential and integral calculus, linear algebra, multivariable calculus and differential equations in the required mathematics courses (MA1160, MA2160, MA2320/2330, MA3160, MA3530)<br>PH2020 also covers statistics and analysis of data.<br>Statistics is also covered in elective PH3300. |

| No. | Standard/Guideline | Narrative Explaining how Required Courses and/or Experiences Fulfill the Standards for Program | |
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| | | **Secondary Major** | **New Comments Relevant to this Proposal** |
| 3.0 | relate the concepts of physics to contemporary, historical, technological, and societal issues; in particular, relate concepts of physics to current controversies and other issues; | Students study a wide variety of current research topics and make oral presentations in PH2010. Students hear about cutting-edge research through outside visitors in PH4010. Historical perspectives are generally given with the introduction to new topics in both introductory and advanced courses. Technological applications are stressed, particularly in the introductory courses. Applications of much of the physics covered in the curriculum have had major implications for almost all aspects of modern civilization from communications, to medical diagnosis and imaging, to travel and computing. | PH2010 is no longer offered. The rest is still applicable. |
| 4.0 | locate resources, design and conduct inquiry-based open-ended investigations in physics, interpret findings, communicate results, and make judgments based on evidence; | Guided discovery-based, computer interfaced experiments are foundational to the introductory laboratories PH1161 and PH2261. Students have opportunity to explore phenomena according to their own inquiry, during each laboratory. More advanced experiments and data analysis, with more freedom of investigation is offered in PH3480. | Guided discovery-based, computer interfaced experiments are foundational to the introductory laboratories PH1161, 1361 and PH2261. Students have opportunity to explore phenomena according to their own inquiry, during each laboratory. More advanced experiments and data analysis, with more freedom of investigation is offered in PH3480, which is an elective. Students will gain further experience in these areas with an explicit eye toward instruction in PH 4710 Methods of Teaching Physics. |

| No. | Standard/Guideline | Narrative Explaining how Required Courses and/or Experiences Fulfill the Standards for Program | |
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| | | **Secondary Major** | **New Comments Relevant to this Proposal** |
| 5.0 | construct new knowledge for themselves through research, reading and discussion, and reflect in an informed way on the role of science in human affairs; | Students study a wide variety of current research topics and make oral presentations in PH2010. Construction of new knowledge for students takes place extensively through problem solving, which progressively gets more difficult and mathematically challenging (and rewarding) as the curriculum advances. | Still applicable, except that PH2010 is no longer offered. Additional construction of new knowledge will also take place through PH4010, PH4710 and ED4720. |
| 6.0 | understand and promote the maintenance of a safe science classroom as identified by the Council of State Science Supervisors, including the appropriate use and storage of scientific equipment, and safe storage, use, and disposal of materials; | ED 4910 Supervising teachers role-model safe science classroom practices.<br><br>ED4830 Methods of Teaching Science, Math & Computer Science Negligence, liability, OSHA, and specific issues of safety in all science classrooms and labs | Still applicable.<br><br>ED4830 is now ED4720 Methods of Teaching Science.<br><br>PH4710 Methods of Teaching Physics also covers these topics. |

| No. | Standard/Guideline | Narrative Explaining how Required Courses and/or Experiences Fulfill the Standards for Program | |
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| | | **Secondary Major** | **New Comments Relevant to this Proposal** |
| 7.0 | demonstrate competence in the practice of teaching as defined within the Entry-Level Standards for Michigan Teachers; | ED4830/31 Methods of Teaching Science, Math & Computer Science. Lesson plans are developed using fundamental instructional techniques. Emphasis is on application of basic skills in a real world, hands-on context. Objectives, plans, tests, and materials for 4-5 class periods are prepared and taught in front of peers for evaluation and subsequent modification. All teaching is video-taped and critiqued.<br><br>General: All core courses and clinical experiences offered by the Education Department to Pre-Service teachers are structured about the Michigan Entry Level Standards. The Intended Learning Outcomes of these courses and experiences have been keyed to the MELS. | Still appropriate.<br><br>ED4830/31 is replaced by ED4720.<br><br>Additional experience is gained in PH4710 Methods of Teaching Physics. |

| No. | Standard/Guideline | Narrative Explaining how Required Courses and/or Experiences Fulfill the Standards for Program | |
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| | | **Secondary Major** | **New Comments Relevant to this Proposal** |
| 8.0 | create and maintain an educational environment in which conceptual understanding will occur for all science students; | ED4830/31 Methods of Teaching Science, Math & Computer Science. Course is structured around Science for All Americans and the Michigan Frameworks. Lesson planning exercises are performed using input from current research on learning, as well as data concerning which instructional techniques are optimal given the content and the students, and employing assessment methods for timely detection of learning problems.<br><br>ED3110 Psychological Foundations. Application of principles of psychology to create meaningful and effective learning. There is a special focus on learners of diverse aptitudes and backgrounds | Still appropriate.<br><br>ED4830/31 is replaced by ED4720.<br><br>Additional experience is gained in PH4710 Methods of Teaching Physics. |
| 9.0 | demonstrate competence in the practice of teaching through investigative experiences and by demonstrating the application of the scientific processes and in assessing student learning through multiple processes; and | ED4830/31 Methods of Teaching Science, Math & Computer Science: Inductive labs are designed and contrasted with recipe/traditional designs Summative and formative assessment techniques are illustrated and practiced through plans prepared to model specific lessons, activities, and labs.<br><br>ED3110 Psychological Foundations<br>Focus on psychological theories that inform dominant assessment procedures. The psychological bases of new trends in the assessment of learning | Still appropriate.<br><br>ED4830/31 is replaced by ED4720.<br><br>Additional experience is gained in PH4710 Methods of Teaching Physics. |

| No. | Standard/Guideline | Narrative Explaining how Required Courses and/or Experiences Fulfill the Standards for Program | |
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| | | Secondary Major | New Comments Relevant to this Proposal |
| 10.0 | develop an understanding and appreciation for the nature of scientific inquiry. | PH1161, PH2261 laboratory courses emphasize understanding physical concepts through inquiry and the scientific method. | PH1161, PH1361, and PH2261 laboratory courses emphasize understanding physical concepts through inquiry and the scientific method. More advanced appreciation for scientific inquiry in the laboratory is developed in elective courses PH3210, PH3480. |

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[1] Feder, T. "The state of physics in US high schools." *Physics Today* (2010) 30.

[2] Franz, J. "Improving K-12 science education." *APS News* **19**(7), (2010) 8.

[3] White, S. and Tesfaye, C. L. Who teaches physics in high school physics? Results from the 2008-09 Nationwide Survey of High School Teachers. *Focus on*. November, 2010. Available at http://www.aip.org/ statistics/trends/reports/hsteachers.pdf [last accessed 7/25/2011].

[4] http://www.reg.msu.edu/academicprograms/ProgramDetail.asp?Program=3839 [last accessed July 26, 2011].

[5] http://www.phys.cwru.edu/undergrad/programs/ba_phys.php and http://www.phys.cwru.edu/undergrad/programs/ba_teach.php [last accessed July 28, 2011].

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