The University Senate of Michigan Technological University

Proposal 13-15

(Voting Units: Academic)

Master of Science Degree Program in Applied Physics

Department of Physics
Michigan Technological University
Houghton, MI 49931

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I. Introduction

The Department of Physics is proposing a new Master of Science (M.S.) degree program in Applied Physics. The proposed program will meet the needs of scientists and engineers seeking training in contemporary areas that make connections between the traditional branches of physics and engineering. The new degree will distinguish itself from the existing M.S. degree in Physics by offering significant additional flexibility to faculty and students in tailoring the required coursework to prepare students for the interdisciplinary research. The proposed program will use the resources already available in the Department of Physics and at the University. The M.S. in Applied Physics is expected to attract domestic and international students to pursue graduate study in interdisciplinary areas of science, including nanotechnology, photonics, atmospheric science and biophysics.

II. Proposal

1. General description and characteristics of program

The study of physics has generally been focused on the foundational disciplinary areas including, high-energy physics, atomic and molecular physics, astrophysics, and nuclear physics. During the past two decades, new branches of physics have gained increasing attention, particularly in those interface areas where traditional physics intersects with other applied disciplines. These include biophysics, physics at the nanoscale condensed matters, materials physics, atmospheric physics, optics/photonics, optoelectronics, etc. In order to fill such a void in the interdisciplinary program in physics at the Master's level, we have proposed the Master of Science degree in Applied Physics (M.S. Appl. Phys.). It is to be noted here that our department offers the Ph.D. degree in Engineering Physics in collaboration with departments in the College of Engineering and is an active participant in the interdisciplinary program, Ph.D. in Atmospheric

Science. The M.S. Appl. Phys. program can be considered as extension of those two successful programs to the M.S. level.

2. Rationale

Much exciting research is now being done in new interdisciplinary branches of physics, including physics at nanoscale, photonics, and optoelectronics etc. Most of the faculty members of the department have established research programs in these "frontier" areas of applied physics. The current M.S. in Physics program at Michigan Tech does not allow M.S.-seeking graduate students adequate flexibility to meet the demands of such frontier areas. The proposed M.S. Appl. Phys. program will provide the necessary framework to allow faculty to tailor core courses for their students that are more closely aligned to their specialized research areas. The new program will also attract physics undergraduate students from more diverse backgrounds to pursue graduate-level study in applied physics at Michigan Tech, and will provide better job opportunities for our graduates in areas of contemporary technological interest.

The proposed M.S. Appl. Phys. degree will offer the following advantages:

- The required core courses will be tailored to meet the needs of student depending on their individual area of research. These core courses will be decided by the research advisor or the director of the Engineering Physics graduate program (prior to the identification of the research advisor), and can be selected from within the physics department as well as in cognate departments.

- The proposed M.S. Appl. Phys. degree program will attract students from diverse undergraduate backgrounds, including but not limited to physics. For example, students with undergraduate backgrounds/degrees in atmospheric science, materials science, electrical engineering, etc. may be interested in M.S. level study and research with a significant physics foundation.

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

3.1. Related programs within the institution

Michigan Tech offers a M.S. degree in Physics, Ph.D. degree in Physics, and a Ph.D. degree in Engineering Physics. Course requirements for these programs are summarized in the following table:

Degree	**Course Requirements Beyond Those of the Graduate School**
M.S. in Physics Thesis option Report option Coursework option	<u>Core Courses (15 credits):</u> PH5010 Journal Club (1 credit) PH5110 Classical Mechanics (2 credits) PH5210 Electrodynamics I (3 credits) PH5310 Statistical Mechanics (3 credits) PH5320 Mathematical Physics (3 credits)

	PH5410 Quantum Mechanics I (3 credits) Disciplinary Electives Two PH courses at the 4000-level and higher from a restricted list. Research PH5999 Master's Research (6 credits required for Plans A and D)
Ph.D. in Physics	Core Courses (15 credits): [Same as for M.S. in Physics above] Disciplinary Electives Two PH courses at the 4000-level and higher from a restricted list. Specific additional courses may be required by the student's advisory committee. Research PH6975 Full-Time Doctoral Research and PH6999 Doctoral Research as required to complete doctoral research and credit requirements
Ph.D. in Engineering Physics	Core Courses (15 credits): [Same as for M.S. in Physics above] Disciplinary Electives Three courses at the 4000-level and higher, including a minimum of one course at the 5000-level or higher); selected from a restricted list, and as approved by the student's advisory committee. Specific additional courses may be required by the student's advisory committee. Research PH6975 Full-Time Doctoral Research and PH6999 Doctoral Research as required to complete doctoral research and credit requirements

Michigan Tech does not have an existing M.S. degree program that specifically meets the areas of atmospheric physics, biophysics, photonics, optoelectronics, and physics at nanoscale etc. (http://www.mtu.edu/gradschool/programs/degrees/). Students graduating from the M.S. in Appl. Phys. program may opt to enroll in our Engineering Physics Ph.D. program.

3.2. Related programs at other institutions

There are several universities offering M.S. and Ph.D. level graduate programs in applied physics including:

University of Michigan (http://www-applied.physics.lsa.umich.edu/)
Columbia University (http://apam.columbia.edu/applied-physics#Programs),
Caltech (http://www.aph.caltech.edu/),
Stanford University (http://www.stanford.edu/dept/app-physics/cgi-bin/), and
Cornell University (http://www.aep.cornell.edu/).

All these universities emphasize new emerging areas of study, including:

- nanoscience/condensed matter/solid-state physics,
- laser/photonics/plasma physics,
- biophysics/medical physics,

with the intent to better prepare their students in these fields. As quoted from the website of the program at the University of Michigan, "Applied Physics is an interdisciplinary Ph.D. program that bridges physics with emerging technologies." According to the program at Stanford University, "The purpose of the master's program is to further develop knowledge and skills in applied physics and to prepare students for a professional career or doctoral studies." From the program description on the Caltech website, "The Applied Physics option at Caltech offers a multidisciplinary graduate program spanning engineering and physics in which fundamental physical principles are used to address research issues of technological importance at the frontiers of engineering and science." Based on these web sites on February 27, 2014, the number of graduate students enrolled in these programs pursuing both M.S. and Ph.D. degrees are about 69 at the University of Michigan, 95 at Columbia, 118 at Caltech, and 75 at Cornell (data from Stanford is not available on their website).

In addition to these institutions, there are many other universities that offer the Master degree in Applied Physics or Engineering Physics, for example,

- Oregon State University (http://www.physics.orst.edu/MSApplied)
- John Hopkins University (http://ep.jhu.edu/graduate-programs/applied-physics)
- University of Massachusetts Boston (http://www.umb.edu/academics/csm/physics/grad/applied_physics_ms)
- George Mason University (http://spacs.gmu.edu/category/academics/graduate-programs/ms-applied-engineering-physics/)
- New Jersey Institute of technology (http://spacs.gmu.edu/category/academics/graduate-programs/ms-applied-engineering-physics/)
- University of North Caroline Charlotte (https://physics.uncc.edu/graduate-programs/ms-applied-physics)

3.3 Projected enrollment and economic impact

The projected enrollment in the proposed M.S. Appl. Phys. program would be about 5 students. We anticipate the majority of the students being 5th year M.S. students, thus completing within one year with the course work option. As the program gains some visibility and prominence, we anticipate eventually reaching 10-12 students enrolled per year.

The demands for the new M.S. Appl. Phys. program is well justified as highlighted as follows. According to a recent report from the American Institute of Physics[1]:

a) The total number of exiting Master's degree has increased from 672-716 (between 2002 to 2004) to 735-801 (between 2009 and 2012).
b) The most frequently cited research specialty of these exiting Masters (classes of 2009, 2010, and 2011) are condensed matter (13%), applied physics (11%), materials science (8%), optics

[1] P. J. Mulvey and S. Nicholson (2014) Trends in Exiting Physics Master's. *AIP focus on*, March 2014, http://www.aip.org/statistics/reports/trends-exiting-physics-masters.

(6%), and medical science (6%), with a total of 44%. These are among the research areas of the new M.S. Appl. Phys. Program. [It is noted that in this report, a large number of citations (35%) are categorized as "other", and astronomy is cited at 9%].

Furthermore, the employment rate of physics and astronomy Master recipients are quite strong, at 95% for U.S. citizens, and 93% for non-U.S. citizens, according to a latest available report[2] from the American Institute of Physics. This report also pointed out that some of the applied physics areas are among the most frequently cited research specialties of these Masters recipients (classes of 2006, 2007, 2008). For example, condensed matter (17%), optics (10%), applied physics (9%), and materials science (9%), make up a total of 45%. [It is noted that in this report, a large number of citations (40%) are categorized as "other", and astronomy is cited for 15%].

4. Scheduling plans (Extension, Evening, Regular)

Regular only.

5. Curriculum design

The curriculum structure of the proposed M.S. Appl. Phys. program is similar to our current M.S. Physics program, but as noted above, offers students additional flexibility through tailoring their respective core courses as a foundation for work in a more specialized applied physics program. For example, students in biophysics could be better prepared with a core course on molecular biology, and students in physics at nanoscale may need core courses in advanced solid state theory (e.g. quantum tunneling, quantum confinement phenomena) and device engineering. The proposed program will therefore provide a framework for realistic curricula to prepare future members of the workforce who will be successful in the frontier areas of science and engineering that have built upon the latest advancements in physics.

The next table lists the course requirements for the proposed program. These requirements are in addition to those of the Graduate School. A minimum of 30 credits are required for the program.

Degree	Course Requirements Beyond Those of the Graduate School
M.S. in Applied Physics Thesis option Report option Coursework option	<u>Core Courses:</u> *Minimum of 10 PH credits at the 4000-level or higher including a minimum of 6 credits from the following list:* PH5010 Journal Club (1 credit; required) PH5110 Classical Mechanics (2 credits) PH5210 Electrodynamics I (3 credits) PH5310 Statistical Mechanics (3 credits) PH5320 Mathematical Physics (3 credits) PH5410 Quantum Mechanics I (3 credits) <u>Application Electives</u>

[2] P. Mulvey and B. Shindel (2011) Physics & Astronomy Master's Initial Employment. *AIP focus on,*, April 2011, http://www.aip.org/statistics/reports/physics-astronomy-master%E2%80%99s-initial-employment).

	Minimum 10 credits at the 4000-level and higher (including at least one course at the 5000-level or higher) from an Application Elective list; with approval of advisor. *Additional courses may be required by the student's advisory committee under plans A and B.* Research *PH5999 Master's Research* Minimum 6 credits for thesis degree (Thesis option) Minimum 3 credits for report degree (Report option) No research for coursework degree (Coursework option)

Application Elective course lists, shown below, will be updated annually. New lists may be created by the Engineering Physics Graduate Studies Committee, depending on faculty interests and available course offerings.

Application Elective Lists

(I) Atmospheric Physics:

PH 5640 - Atmospheric Physics
PH 5680 - Atmospheric Fluid Dynamics
PH 5320 - Mathematical Physics
ATM 5010 - Research Methods in Atmospheric Science
ATM 5519 - Atmospheric Biogeochemistry
ATM 5515/CE5515/CH5515 - Atmospheric Chemistry
ATM 5512 - Applied Boundary Layer Meteorology
CE 5800/GE 5800 - Mathematical Modeling of Earth Systems
ENVE 4501 - Environmental Engineering Chemical Processes
ENVE 4504 - Air Quality Engineering and Science
EE 5540 - Statistical Optics
FW 5340 - Advanced Topics in Climate Change
GE 4250 - Fundamentals of Remote Sensing
GE 5030 - Earth Systems Science II

(II) Physics at Nanoscale

PH 5410 - Quantum Mechanics I,
PH 5520 - Materials Physics,
PH 5530 - Selected Topics in Nanotech,
PH 4510 - Introduction to Solid State Physics,
EE 5471 - Microfabrication Laboratory,
EE 5460 - Solid State Devices,
MEEM 5130 - Nanoscale Science and Technology,
MY 6200 - Advanced Topics in Materials Characterization,
PH 4510 - Introduction to Solid State Physics
PH 5530 - Selected Topics in Nanotech (theory and experiment both)
PH 4390 - Computational Methods in Physics
PH 5510 - Theory of Solids

(III) Photonics

BE 5250 - Biomedical Optics,
EET 5261 - Optical System Design and Testing
EE 5410 - Engineering Electromagnetics,
EE 5526 - Microwave Engineering
EE 5528 - Antenna Engineering,
EE 5490 - Solar Photovoltaic Science and Engineering,
PH 5410 - Quantum Mechanics I,
PH 5320 - Mathematical Physics,
PH 5510 - Theory of Solids,

(IV) Biophysics

PH 4999 - Molecular Biology for Physicists and Engineers
BE 5250 - Biomedical Optics
BE 5550 - Biostatistics for Health Science Research
BE 5880 - Principles and Analysis of Cellular Processes
BL 5010 - Cellular Imaging and Confocal Microscope
BL 5035 - Bioimaging
BL 5370 - Special Topics in Microbiology
BL 5360 - Special Topics in Biochemistry
BMB 6020 - Theoretical Molecular Biology

Degree Options:

Students may earn the degree of M.S. in Appl. Phys. according to the following options, which highlight program-specific requirements that are in addition to any University and Graduate School requirements.

Thesis Option

In addition to the coursework requirements described above, a minimum of 6 credits in PH5999 (research) is required. Remaining credits of the 30 total required by the Graduate School may include additional course or research credits (up to a maximum of 10 research credits) as approved by the director of the Engineering Physics graduate program and the student's advisory committee. A minimum of 12 credits must be at the 5000-6000 level and a maximum of 12 credits can be at the 3000-4000 level. Requirements of this option also include a written Master's thesis and a final oral examination based on the student's thesis.

Report Option.

In addition to the coursework requirements described above, a minimum of 3 credits in PH5999 (research) is required. Remaining credits of the 30 total required by the Graduate School may include additional course or research credits (up to a maximum of 6 research credits) as approved by the Engineering Physics graduate program director and the student's advisory committee. A minimum of 12 credits must be at the 5000-6000 level and a maximum of 12 credits can be at the 3000-4000 level. A student following the project option is expected to: present written and oral project reports at the conclusion of the project.

Coursework Option

Students will be required to take 30 course credits including the core course and disciplinary elective requirements listed above, and as approved by the Engineering Physics graduate program director. A minimum of 18 credits must be at the 5000-6000 level and a maximum of 12 credits can be at the 3000-4000 level.

Students may initially be advised by the Engineering Physics graduate program director for their degree program. Students pursuing the Thesis option or Report option should choose a research advisor prior to the end of the second academic-year semester in residence. The Engineering Physics graduate program director will remain the advisor for students pursing the Coursework option.

6. New course descriptions

Since the department already offers graduate degrees in physics, no new courses are necessary and none are proposed.

7. Library and other learning resources

No additional library or learning resources are required.

8. Computing Access Fee

Not applicable.

9. Faculty resumes

The curriculum vitae of the faculty members are given at:
http://www.mtu.edu/physics/department/faculty/

Graduate Faculty serving this program will be the same as the existing M.S. and Ph.D. degrees in the department of Physics. The Faculty members are:

Don Beck, Professor
Jacek Borysow, Professor
Will Cantrell, Associate Professor
Ramy El-Ganainy, Assistant Professor
Brian Fick, Professor
Petra Huentemeyer, Associate Professor
John Jaszczak, Professor
Alex Kostinski, Professor
Miguel Levy, Professor
Claudio Mazzoleni, Associate Professor
Peter Moran, Associate Professor
Robert Nemiroff, Professor
Dave Nitz, Professor
Ravindra Pandey, Professor
Ranjit Pati, Professor

Warren Perger, Professor
Max Seel, Professor
Raymond Shaw, Professor
Bryan Suits, Professor
Yoke Khin Yap, Professor

10. Description of available/needed equipment

The Physics Department at Michigan Technological University is well equipped with modern research laboratories: http://www.mtu.edu/physics/facilities/research/

Since the department already offers M.S. degrees in physics, and enrollment increases are expected to be modest, no additional equipment is required.

11. Additional Resources Required

No additional costs are anticipated for this new graduate degree program.

12. Space

No additional space is required to accommodate the new graduate degree program.

13. Policies, regulations and rules

None besides curricular requirements outlined above.

14. Accreditation requirements

Not applicable.

15. Internal status of the proposal

Feb 20, 2014: The physics and engineering physics graduate studies committee approved the proposal and recommended it to the physics department faculty for its consideration.

March 25, 2014: The proposal was approved by the physics department faculty.

May 28, 2014: The proposal was discussed in the council meeting of the College of Science and Arts. Supportive suggestions were received.

July 7, 2014: The revised proposal was approved by the Dean of the College of Science and Arts.

September 2, 2014: Introduced to the Graduate Faculty Council.

September 10, 2014: Approved by the Deans Council.

October 7, 2014: Approved to the Graduate Faculty Council.

16. Planned implementation date

Fall semester 2015.

Appendix: Financial documentation for Mater of Science in Applied Physics

I. Relation to university strategic plan

a. Relation of program to the university's educational and research goals: This new Master program supports Goal 2.1 of the university strategic plan *(Integration of research, instruction, and innovation that achieves the University Student Learning Goals).* Specifically, "*strengthen existing programs and develop new offerings in emerging interdisciplinary areas."*

b. Consistency with the university's resource allocation criteria: The proposed program intended to attract new graduate students to the university based on existing instruction and research resources.

II. Impact on university enrollment

a. Projected number of students in the program: Projected enrollment is about 5 graduates at the initial phase.

b. Source of new students; in particular, will the students be drawn from existing programs, or will they be students who would otherwise not have come to MTU? Based on the recent reports from the American Institute of Physics (see details in the proposal), it is expected that the program will attract some new graduate students to the university.

c. What is the likely correlation between demand for the new program and existing enrollment patterns at MTU? This program emphasize on preparing students to meet the demands of interdisciplinary expertise in the job market. This will likely attract students from non-physic background into the department of physics and thus diversify the existing enrollment patterns at the departmental level.

d. What is the current enrollment in the unit? Fall 2013: 40 graduate students.

III. Impact on resources required by department in which the program is housed

a. Faculty lines: This program will be supported by existing faculty line.

b. Faculty and student labs, including ongoing maintenance: Existing research labs are adequate to support this program.

c. Advising: This will be supported by existing faculty line.

d. Assessment: The Engineering Physics graduate study committee will monitor and evaluate the enrollment and student performance of the new program in an annual basis.

IV. Impact on resources required by other units within the university

a. Other academic (e.g., Gen Ed) units with regard to faculty, labs and assessment. We do not expect any significant impact to other units although some of the existing classes may occasionally see an increase of enrollment by one or two students.

b. Information Technology, the Library, central administration and career planning with respect to the impact on the need for computing services, library resources, advising, record keeping, development of employer relations etc. There should be no significant impact on other units.

V. Assessment of the ability to obtain the necessary resources assuming requested funds are obtained. For high demand fields (e.g., business fields, etc.), will it be possible to fill allocated lines? Not applicable as we do not need addition resources.

VI. Past proposals

The Department of Physics has not initiated any new Master degree programs for about sixty years. Our Master program in Physics was announced in 1954. Our Physics PhD program was approved in 1987, and the PhD in Engineering Physics was started in 2011.

VII. Departmental budget contribution

All figures are for 2013-14.

a. **What is the department's total general fund budget?** The general fund base budget was $2.1 million.
b. **How much tuition does the department generate? This information should be provided for both the credit hours taught by the department and the number of credit hours taken by the department's majors.**

For courses taught by the department: Undergraduate tuition was $4,992,000 (~9600 SCH times $520 per credit hour) and graduate tuition was $431,520 (~580 SCH times $744 per credit hour). Total tuition was $5,423,520.

For courses taken by our majors and taught by other departments (estimated): 70 majors (primary majors only) times 32 credits per year times 0.6 (60% of credits taken outside the department) times $520 per credit equals $698,880.

VIII. How do the benefits from this program compare to other alternatives that are currently under consideration or development?

The proposed M.S. Appl. Phys. degree will offer the following benefits:

1. The required core courses will be tailored to meet the needs of student depending on their individual area of research. These core courses will be decided by the research advisor or the Engineering Physics graduate program director (prior to the identification of the research advisor), and can be selected from within the physics department as well as in cognate departments.
2. The proposed M.S. Appl. Phys. degree program will attract students from diverse undergraduate backgrounds, including but not limited to physics. For example, students with undergraduate backgrounds/degrees in atmospheric science, materials science, electrical engineering, etc. may be interested in M.S. level study and research with a significant physics foundation.