

# Final Assessment Report for Physics and Astronomy Programs (BSc)

## **Program goal**

The Department of Physics and Astronomy started in 1957 and currently hosts one of the largest physics programs at both the undergraduate and graduate levels in Canada. The departmental program goal is to be an internationally renowned department, demonstrating both excellence in undergraduate education experience and world-class research by its graduate students and post-doctoral fellows. The Department currently has four Distinguished Teacher Award recipients, pointing clearly, as the external reviewers wrote, to a “healthy culture embedded in the Department that recognizes the importance of good teaching”. The Department and its programs are well regarded within the university, in terms of its core research and teaching mission, and also in many aspects that fully follow the University’s current Strategic Plan.

## **Process Used to Prepare the Self Study / Details of Site Visit**

This is the Department of Physics and Astronomy’s third review of its undergraduate programs, the first two occurring in 1998 and 2005. The Chair, assisted by the Associate Chair and Undergraduate Officers prepared the self-study report. Faculty, graduate students and undergraduate students were consulted. Data were provided by IAP and Co-operative Education, and compiled from departmental records.

The site visit by two external reviewers (Dr. Doug Bonn, University of British Columbia; Dr. Peter Martin, University of Toronto) accompanied by a UW faculty member (Dr. Marios Ionnidis, Chemical Engineering) took place on February 11-12, 2013. The review team met with departmental and institutional administrators, faculty and lecturers. Undergraduate and graduate students also met with the review team.

The reviewers’ report was received on May 30, 2013 and the Department’s and Dean’s response and implementation plan were received on October 2, 2013 . This final assessment report compiles information from the self-study, the external reviewer report and the program response.

## Response to comments in the previous review

As it relates to undergraduate labs – undergraduate student involvement in providing input into curriculum and teaching issues now occurs annually where third and fourth year students meet with the departmental Chair, Associate Chair and Undergraduate Advisors. Lab content and lab equipment have been improved, and faculty are more involved in senior year labs.

Concerning recruitment and retention, a mentoring program at the junior level was developed and tutorials were introduced at all levels of the program. Increased outreach efforts to high school students has occurred and the Department is currently discussing joint outreach efforts with the Perimeter Institute. A variety of initiatives have been put in place to assist struggling students, including a Faculty-level Student Success Officer position, remedial sessions for students who performed poorly in a preparatory test taken at the beginning of their first fall term, and better scheduling of help sessions.

## Undergraduate programs offered

Undergraduate Physics programs are many and varied.

- Honours Physics (regular and co-operative – each also has three specializations: Applied Physics, Astrophysics and Biophysics Specialization)
- Honours Mathematical Physics (regular and co-operative – each also has two specializations: Astrophysics and Biophysics)
- Honours Chemical Physics (regular and co-operative ; joint with the Department of Chemistry – reviewed in the 2008/09 year by Department of Chemistry).
- Joint Honours “X” with Physics (Admission into this plan requires an overall average of 65% in the student's home academic plan)

Several new plans started in September 2012 but are not part of this cyclical review.

These plans are:

- Honours Life Physics (regular and co-operative – a non-specialized version and two specializations – Biophysics, which is joint with the Department of Biology, and Medical Physics)
- Honours Physics and Astronomy (regular and co-operative)
- Honours Materials and Nanosciences (regular and co-operative; joint with the Department of Chemistry)
- Biophysics Minor

In the last four years the entire undergraduate program has been reorganized, with an overall reduction of teaching requirements, despite some new courses being added. Emphasis has been placed on the quality of the undergraduate program, over the quantity of course offerings. Reductions were achieved through elimination of some advanced but poorly enrolled courses. To ensure breadth in the more specialized upper-year course offerings, some courses are taught every other year. The department has recently undergone a curriculum mapping exercise, mapping program learning objectives to core, elective and service courses. The department also mapped its program learning outcomes to OCAV's Undergraduate Degree Level Expectations (UDLEs). The external reviewers concluded "Overall, there is a deliberate, well-motivated, and well-planned policy to ensure both a program with clear learning objectives and effective assessment of the students' learning outcomes." The Department has four undergraduate officers; all first year undergraduate students have an opportunity to meet with one of the undergraduate officers at the start of their programs. In addition, there are a number of program specialists who advise for the various programs offered.

### **Innovation in undergraduate programs**

The Physics program employs a number of contemporary approaches to its pedagogy, including use of 'Clickers', concept mapping and teaching retreats for its instructors. The seminar course PHYS 10 focuses on the new first year cohort and their career development and allows these new students to identify with their Department and program from the outset.

There is modest participation of the Department in international exchanges for undergraduates; this needs to be improved. Notable, however, is the significant involvement in the "China 2+2" program, with 22 students in physics and mathematical physics. In this program students from Chinese Universities come to UW for their 3rd and 4th years of study and obtain degrees from both their Chinese University and UW. The number of Chinese Universities participating in the program has grown to 22.

The Department is involved in online delivery of its courses (mostly 100-level) and is also enhancing these resources by developing online assignments. Life Physics and Materials and Nanosciences are attractive new interdisciplinary programs, joining Chemical Physics in providing novel opportunities for students. They are very much in keeping with contemporary trends to link physics to its application in other fields.

## Students

The physics program has one of the largest undergraduate physics enrollments in the country and attracts high quality undergraduate students. Physics students are admitted through the Physical Sciences entry point. From 2004 to 2010, Physics programs have averaged 433 applicants and 160 applicants for co-op and regular programs, respectively. Numbers of registered first year students averaged 39 (co-op) and 11 (regular) students. Numbers generally increase in latter years. The highest number of registered co-op students occurred in Fall 2009 with 67 students – the lowest was in the Fall of 2004 and 2005, each with 10 co-op students. The highest number of registered regular students occurred in Fall 2006 with 16 students – the lowest was in the Fall of 2004 with 4 regular students.

Student quality is high. From 2004 to 2010, median entrance grades for both co-op and regular programs were in the 85-90% range. Thirty three percent of first year co-op students had entrance averages of at least 90%, compared to 27% of first regular students. During this same time period, 20 out of the 345 Physics first-year registrations were international students, with the United States (7), China (3) and United Arab Emirates (3) being the top 3 sources of students. Female students over the same time period ranged from a low of 5% FTE of first year enrollments in 2005/2006 to a high of 20% FTE in 2008/2009, averaging 16%.

From 1998 to 2005, overall retention over this seven year window in Physics co-op programs has varied from 66-92% and for regular programs 50-75%, suggesting a higher caliber of students overall in the co-op program. Attrition between year 1 and year 2 averaged 10%.

Only a very small minority (~3%) of Physics students pursue their study on a part-time basis. The number of degrees granted from 2005 to 2011 has averaged 29 degrees per year. On average, 43% of Physics co-op students and 33% of Physics regular students graduate in 6 terms or less. An average of 40% of those students graduating with a BSc in Physics graduate on the Dean's Honours List, which means they graduated with a cumulative average of at least 80%.

## Co-operative Education

Most first-year Physics students select the co-op program. Physics co-op students generally have high levels of co-op employment. Over the past five years, Physics has had an average of 27 co-op students scheduled out to work per term. Unemployment has averaged 3.25% with no more than two students unemployed at any one time. Winter term typically has the largest number of students scheduled out to work,

whereas the Spring term always has the fewest. Co-op employment may be found almost anywhere, in virtually any industry and is available to Physics students at all levels of their program.

During their discussion with students, the external reviewers noted that “Although there was some disappointment in subsequent years, the <co-op> program is not broken. Reasons given for leaving the co-op cohort were (1) to accelerate graduation (looking to graduate school); (2) no job (there is not a huge selection of physics jobs and job descriptions could be better) coupled with the \$600 fee; (3) access to other experiences in research within the program or over summers, where soft skills can also be developed.” Other reasons include: “failure to meet academic requirements, and flow to other co-op programs in science (biology)”.

Physics students are ranked highly by their employers – with 93% of students ranked Outstanding/Excellent/Very Good, and the highest percentage of students ranked Excellent (47%). Twenty-five percent of Physics students received an Outstanding rating from employers compared to 18% of UW students. The majority of students rank their employment experiences very high (10 being the highest ranking). 96% of students ranked their employers within the 7-10 range, with the majority of students ranking their employers an 8-9.

No substantive data is included in the self-study on post-graduation activity of graduates, whether employment or further study. There is, however, a single statement that Physics students go on to top tier graduate schools, or work at high tech industries, hospitals and education sectors. The external reviewers commented that “during our visit we met with graduate students who had been Waterloo undergraduates and in our own universities we have had successful graduate students who were Waterloo undergraduates.”

## Faculty

The Department currently has a faculty complement of 42 FTEs (up from 29.5 in the last review) and has two Tier 1 Canada Research Chairs (CRC) and two Tier 2 CRCs starting in 2013. The complement consists of 9 Assistant Professors, 18 Associate Professors and 15 Full Professors. It also has 3 lecturers, 3 full-time definite term appointments and 3 part-time appointments. With the significant increase in compliment, and enhanced ties with the Institute for Quantum Computing (IQC) and the Perimeter Institute (PI), graduate student numbers have increased to 250, making the Department one of the largest (if not the largest) graduate physics program in the country.

The Department has strong research programs in astrophysics and gravitation, biophysics and soft matter physics, condensed matter physics, photonics, and quantum computing. The research excellence of its faculty has been recognized by the research awards that have been received such as: Early Research Awards, Canada Research Chairs, Sloan Fellowships, Herzberg Medal, CIHR new investigator award, Killam Fellowship, and Fellow of the Royal Society of Canada. Over the period of the self study, the department brought in an average of \$11M/year of research funding to the University. This figure includes funds derived from federal, provincial, industry and other sources. The figure also represents one of the highest research-funded departments in the University.

Although this funding is used for research purposes, Physics undergraduate students benefit directly from undergraduate research assistantships provided by individual faculty members, and benefit indirectly by access to many types of sophisticated research equipment in research labs. For example, fourth year project courses (PHYS 437A and 437B) offer students an opportunity to do research projects with a professor, therefore undergraduates can experience the day-to-day research activities of that professor and his or her graduate students, and contribute while learning about a specialized area of Physics. Many undergraduate Physics students also get their names on their first publication through this type of experience.

The normal teaching load of 3 courses per year is heavier than in other research-intensive Physics departments in Canada. This is caused by the additional teaching requirements due to the co-op structure of various programs. To be competitive in research activity, there is a desire in the department to reduce the teaching load to 2 courses per year as in most other Physics departments in Canada; however, currently this cannot be achieved.

Teaching evaluation scores are reported as professor evaluations on a 10 point scale. The overall departmental average includes teaching evaluations from regular faculty members, sessionals, lecturers, adjunct faculty and external faculty to the department. The term-averaged scores range from 7.32 to 8.31. This reported data were not compared to Faculty of Science data.

In addition to teaching their own students, Physics faculty carry out considerable service teaching, both within Science (mainly Chemistry, Biology and Earth and Environmental Sciences) and in other Faculties (Engineering, Applied Health Sciences, and Mathematics). On an annual basis, the department teaches approximately 850 non-physics Science as well as Mathematics students and approximately 1100 Engineering students.

## External reviewers' report and program response

The external reviewers' report was generally positive. They concluded that the "department clearly delivers high quality undergraduate teaching in a wide range of program offerings and also in courses offered to students pursuing other specializations. All of the essential ingredients are in place in terms of talented faculty members, both senior and a significant cohort of new recruits, plus dedicated instructors and others involved in the delivery of these programs. This success has been achieved in a challenging funding environment through an impressively systematic and well-organized approach to curriculum development and change."

The external reviewers provided the following comments and suggestions for program improvement:

1. Referred to by the reviewers as an area of tension, they noted the contrast between infrastructure development for IQC and QNC versus the poor quality and inadequate quantity of space housing Physics and Astronomy. The distribution of the Department among several buildings was also noted as a problem.

**Program response:** A partial solution to the problem is moving a few teaching laboratories to the new Science-1 building. These will be showcase for undergraduate labs that can service Physics (and other) students and can be used for outreach purposes. A mid-term solution will be to move some faculty laboratories to the proposed Science-2 building, which will be ready in ~4 years. The Physics Building itself, however, remains a challenge to maintain. The Department has started to plan proactive renovation and maintenance of the Physics building, to take advantage of the building maintenance and renovation funds at the University.

2. Diversity of faculty is an important goal, but women presently comprise only 10% of the complement, which is well below the number looking at current graduate populations in physics and astronomy in North America. This impacts the experience of undergraduates, where diversity is also a goal. Presently, the first-year class is only about 14% female.

**Program response:** A confidential paper trail provides explanations for decisions that were made during the hiring process. In future new faculty searches, the Department will continue to pay attention to the possibility of increasing the female/male faculty ratio in Physics and Astronomy during searches for new faculty members.

3. The reviewers noted that there is a lack of employment data of our undergraduate students, six months to two years after graduation.

**Program response:** The Department confirmed that it has poor data collection in this area and plans to liaise with the Faculty Alumni Officer more closely but anticipates that collecting this data will remain a challenge.

4. The reviewers noted that there were severe budget cuts to the Department.

**Program response:** The Department is currently functioning with an operating deficit and expects further budget cuts in the next few years to exacerbate the situation. Some steps have been taken to increase funding by expanding undergraduate programs and course offerings. It remains to be seen if this activity will be sufficient to generate enough funding to balance the incremental budget cuts incurring in future years and to reduce the existing deficit in the Department. The Dean has promised that in the next few years, some funding consideration will be made in areas where basic operation of the Department is jeopardized.

5. The reviewers commented on the possibility of launching a quantum information science undergraduate program.

**Program response:** As a first step, the Department, in collaboration with the Institute for Quantum Computing, will actively consider creating a quantum information specialization, within the existing Honours Physics program.

6. The reviewers commented on the possibility of developing a new program in Computational Physics with Computer Science.

**Program response:** The recently deactivated Computational Science program in the Faculty of Science had weak enrollment and therefore the idea of re-developing a similar program needs to be carefully considered. Instead, the Department will consider creating a computational physics specialization within the existing Honours Physics program, which is a more promising proposition.

7. The reviewers suggested the possibility of cross-listing certain graduate courses with undergraduate courses.

**Program response:** The Department considers this to be an excellent idea which allows undergraduates to have access to graduate courses, which are at an advanced level. The Department will start considering the suggestion.

8. The reviewers commented that there is modest participation of the Department in international exchanges for undergraduates.



**Program response:** Currently, approximately 15% of third year and four year Physics students are visa students. The Department is comfortable with its current participation in international exchanges but recognizes that Canadian students do not actively participate. The Department will take measures to further promote existing exchange opportunities for its students, in addition to the 2+2 program.

9. The reviewers commented on the current “Islanding” of department members, in particular, groups of faculty members are assigned spaces in different buildings.

**Program response:** The Department has not noticed any negative consequences from the faculty members residing in different buildings. In fact, in the past few years, there has been active participation of its IQC members in all aspects of departmental life, including taking on major departmental service tasks. No follow-up is planned.

10. The reviewers commented: “Colloquia are often specialized and do not draw the interest of people outside a given sub-discipline”.

**Program response:** Moderate colloquium attendance has been a long standing problem. Among a few possible reasons, the idea that the talks are too specialized is the easiest to identify. The Department has initiated discussion of this topic at its regular monthly meetings.

11. The reviewers commented on the extensive use of teaching relief for select faculty (e.g., Canada Research Chairs, a number of IQC faculty) and believed that this has a negative impact on departmental morale as well as reduced opportunity for its undergraduates to be exposed to some of the Department’s most prominent researchers.

**Program response:** Teaching relief is normally given to faculty members who have an award (e.g., Steacie, etc.) that directly requires it, to CRCs according to UW’s usual practice, and to IQC/Perimeter joint hires where multiple positions were leveraged from original Waterloo FTEs. Except for one instance where the individual self-declared as research-inactive, no research-active members have been asked to teach more than 3 courses per year. Faculty members with lower teaching loads are expected to perform more in other areas; this is taken into account in their annual performance reviews. No follow-up is planned.

<b>Timeline</b>	<b>Aspect of the program</b>	<b>Reviewers' Comment</b>	<b>Response</b>	<b>Responsibility for Action</b>	<b>Resources Required</b>
2015	Infrastructure	1. Aging facilities in the Department	(i) Some undergrad teaching labs transferring to Science Teaching Complex, (ii) Acquire new research space in Science Research Complex, (iii) Proactive maintenance plan	(i) Assoc. Chair/Dean, (ii) Chair/Dean, (iii) Assoc. Chair/Chair/Dean	(i) Funding for lab equipment, (ii) Space allocation in Science Research Complex, (iii) University building maintenance/renovation funds and additional funding from the Dean
Ongoing	Staffing	2. Low fraction of female faculty	Continue to encourage strong female applicants	Chair	none
2013-2014		3. Lack of employment data on undergrads	Work with Faculty of Science Alumni Officer	Chair	none
2015	Financial	4. Severe budget cuts	New programs were introduced which will increase budget through enrolment	Chair/Dean	Increase Physics and Astronomy operating budget by \$200k/per year to cover teaching and other basic operational expenses.
2013-2014	Curriculum	5. Consider Quantum Information science undergraduate program	Initiate QI specialization and liaise with other units on program	Chair/Curriculum Committee	Minimum
2013-2014	Curriculum	6. Consider Computational Physics undergraduate program	Initiate Computational Physics specialization	Chair/Curriculum Committee	Minimum
2013-2014	Curriculum	7. Cross-list grad and undergraduate courses	Initiate review of feasibility	Chair/Curriculum Committee/Graduate Officer	Minimum

2013-2014		8. Participation in international exchanges	Encourage participation	Chair/Undergraduate Advisors	Minimum
Immediate		9. Issue of "islanding" in department	Not an issue	Chair	none
2013-2014		10. Colloquium participation	Address issue within the Department	Chair	Minimum
2013-2014		11. Impact of teaching relief on morale	The current assignment is reasonable	Chair	none