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Niagara College Photonics Diploma & Laurier Bachelor of Science in Photonics

Photonics Engineering Diploma to Bachelor of Science – Photonics Pathway with Bridging Semester

FINAL REPORT:

CURRICULUM ANALYSIS AND PROGRAM PLAN

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Introduction

The purpose of this project is to create a pathway for student graduating from Niagara College's two and three year Photonics diploma programs into Wilfrid Laurier's Honours Bachelor of Science in Photonics degree program. The methodology proposed was to examine the program learning outcomes (PLOs) and curriculum maps of each of the programs and use that to determine where the Niagara college graduates would be prepared to enter the Photonics BSc curriculum. The goal of the pathway is to produce graduates who have the complementary skills and knowledge that come from meeting the learning outcomes for the Niagara Photonics Engineering Technology diploma and the Laurier Honours Bachelor of Science in Photonics. A further goal is to make completion of these two credentials efficient for students, by granting significant transfer credit to Niagara students entering the Laurier program. In five years of study, students will complete two credentials which would ordinarily require seven years of study. The curriculum analysis has been conducted with care and precision, so as to ensure that students undertaking the pathway are equipped to complete it successfully.

This report summarizes the process undertaken by both institutions to compare PLOs and curriculum maps, the challenges encountered when using such an approach, a detailed description of the curriculum analysis that took place, and the conclusions drawn about the entry point and proposed curriculum for students pursuing the Niagara-Laurier Photonics pathways.

Niagara College Photonics Engineering Technology Program Learning Outcomes

The use of Learning Outcomes at Ontario Colleges is part of well a well-established system. All college programs, including certificates, diplomas, advanced diplomas, graduate certificates and bachelor degrees have ministry approved program outcomes attached to each program of instruction. This ensures that similar programs at different colleges teach to the identical learning outcomes, creating a consistent and transparent system of post-secondary education. Often, programs will include provincial learning outcomes, validated through the Credential Validation Service (CVS) along with college specific outcomes, unique to the particular college offering the program. Often, these unique outcomes can be regionally focused.

The province follows a clearly defined cycle to update Program Learning Outcomes. Bringing together the colleges that offer the cluster of programs being updated, colleagues will work together with industry partners and the Ministry to ensure updated standards reflect the emerging needs of the programs being discussed.

The Learning outcomes for the three year Advanced Diploma in Photonics Engineering Technology were recently updated in 2013. As this program is only offered at Niagara College several accrediting bodies were consulted in the process. The new standards were designed in a manner that will allow the program to easily achieve accreditation with the Accreditation Board for Engineering and Technology (ABET), the Canadian Technology Accreditation Board (CTAB), and the International Society for Optics and Photonics should the program to choose to move towards accreditation.

Wilfrid Laurier University Bachelor of Science Photonics

Learning Outcomes

Using an outcomes-based approach to curriculum design and review is still relatively new in the Ontario university sector. Prior to the introduction of new Institutional Quality Assurance Procedures (IQAP) in 2011, there were no institutional requirements for programs to define learning outcomes at the program level. Since 2011, program level learning outcomes have been integrated into the new program development and cyclical review processes, but the uptake and interest in this approach has varied across the university, with many programs only creating learning outcomes when they are scheduled for cyclical reviews. This is the case for the Bachelor of Science in Photonics program, which created learning outcomes during its last cyclical review in 2012-2013. The learning outcomes for this program were derived initially from two sources: the Institute of Physics which accredits programs in the United Kingdom and Ireland, and the Australian Institute of Physics which accredits programs in Australia. The PLOs were assembled by the department chair for the Self-Study, but these outcomes have not yet informed the Photonics curriculum to a meaningful extent.

During the curriculum analysis process for this project, the PLOs created for the cyclical review were revisited and revised based on committee input. The PLOs are now more reflective of the program's goals but do not yet have widespread currency within the department or its curriculum.

As noted below, the PLOs of the Laurier Photonics program emphasize the acquisition and demonstration of advanced knowledge in areas related to Physics and Photonics. Students are expected to integrate their learning from a variety of courses and disciplines and apply this knowledge to solve complex problems. It is expected that they can communicate their ideas clearly and demonstrate the ability to complete work both independently and in team settings. Preparation for future employment is valued by the program, but more in a self-directed manner than taught and assessed directly in the curriculum.

The curriculum map included here as Appendix 3 indicates how the Photonics PLOs are addressed across the four year curriculum. At Laurier, a scale of "Introduce, Reinforce, Met" is traditionally used to map undergraduate curricula to more accurately demonstrate how students' knowledge and skills are developed progressively across courses. Prior to participating in this project, the Photonics program did not have a map for its curriculum.

Through the process of examining their PLOs and mapping the Photonics curriculum to these outcomes, the program has a better sense of how to communicate how students' knowledge and skills are developed across the curriculum.

Learning Outcomes Comparison Chart

In undertaking the curriculum analysis for the two programs, several options were considered with regard to comparing the learning outcomes across the Niagara and Laurier programs. Early attempts were made to map the Niagara courses to the Laurier outcomes and vice versa, but none of these attempts generated useful results for the committee. Part of the challenge in comparing the programs using a learning outcomes framework is the way in which the PLOs have been integrated into each program. At Niagara the PLOs govern the curriculum to a far greater extent than they do at Laurier, where they were created primarily for accountability purposes.

In trying to visualize how the goals and outcomes of each program were different, the PLOs of each program were compared across the OCAV Undergraduate Degree Level Expectations (UDLEs). The PLOs of each program were mapped to the six UDLE categories. This analysis proved fruitful because it illuminated the highly complementary character of the two programs' learning outcomes. As can be seen in Appendix 5 , the emphasis of the PLOs for the Niagara diploma are on students' ability to apply the knowledge that they are learning to do and construct devices, as well as to equip them with the skills necessary to succeed in related fields of employment. By contrast, the PLOs of the Laurier Photonics program are less heavily weighted on doing than knowing, with a stronger emphasis on advanced knowledge in Physics and Photonics and the ability to use this knowledge in combination with mathematical skills to solve defined and undefined problems. The two programs have different emphases that when combined, are quite complementary to one another.

Curriculum Analysis Process

The goal of the curriculum analysis was to arrive at program design that would enable students to efficiently meet the requirements of the two programs, while maximizing successful outcomes for students following the pathway.

The curriculum analysis was challenging for several reasons:

a. Knowledge acquisition in the physical sciences is highly cumulative, making appropriate course sequencing especially important.

b. As noted above, the learning outcomes of the two programs are complementary. As a result, there was very little straightforward transfer of learning from the Niagara programs to the Laurier program.

c. Furthermore, at the commencement of the process, the Laurier Photonics BSc PLOs had not yet achieved currency or undergone mapping. As part of the curriculum analysis, the PLOs were interrogated and revised and a map was prepared (see Appendices 3 and 4).

d. The Niagara College diploma programs recently underwent significant revisions. Because many of the courses in the revised program have yet to be taught, detailed teaching and learning plans (TLPs, analogous to Laurier's syllabi) were not available for all courses.

Given these circumstances, members of Laurier's Photonics program felt that the only way an accurate curriculum analysis could be conducted was by examining the content of each of the courses taught at both Niagara and Laurier. This was accomplished by looking closely at both the Niagara and Laurier course syllabi and consulting with faculty in both programs. By doing a course-by-course comparison, topics and courses considered key to achieving the Laurier PLOs were identified. Appendix 6 identifies the course-by-course analysis done by Laurier faculty members to determine which courses Niagara graduates would need to take in order to successfully meet the learning outcomes of the Laurier Photonics BSc program.

Identified Gaps and Bridging Program Plan

Appendix 7 outlines the sequencing of courses for students pursuing the pathway programs, including the courses identified as necessary pre-requisites for Niagara graduates to complete prior to entering the Photonics program.

The bridging program courses are both in mathematics, reflecting the fact that mathematics is an essential tool for understanding and solving problems in physics. Laurier's Math Assistance Centre offers several programs designed to address gaps in students' mathematics background. The Calculus Preparation Evaluation identifies the first-year calculus course for which a student is best prepared. Depending on the student's level of preparation and aptitude for mathematics, there are a number of potential courses through which students could attain the skills necessary to begin the Laurier Photonics program. The Math Assistance Centre also offers a series of pre-calculus modules to help students address gaps in their preparation.

Calendar descriptions for bridging courses are provided in Appendix 8.

Appendices

Appendix 1: Niagara Photonics Engineering Technology Program Learning Outcomes

Appendix 2: Niagara College Photonics Engineering Technology Curriculum Map

Appendix 3: Laurier Bachelor of Science in Photonics Program Learning Outcomes

Appendix 4: Laurier Bachelor of Science in Photonics Curriculum Map

Appendix 5: Program Learning Outcomes Comparison Chart

Appendix 6: Course by Course Comparison

Appendix 7: Proposed NCC Photonics Engineering Technology – WLU Photonics Pathway (3+2)

Appendix 8: Course descriptions for bridging courses

APPENDIX 1: NIAGARA PHOTONICS ENGINEERING TECHNOLOGY PROGRAM LEARNING OUTCOMES

Vocational Learning Outcomes: Photonics Engineering Technology

Modified from the outcomes generated at the Photonics Advisory Committee meeting, June 14, 2012

The graduate has reliably demonstrated the ability to:	
1	Design, construct and test laser devices and systems.
2	Design, construct and test Photonic/optical components and systems
3	Design, construct and test electronic systems
4	Construct and test opto-mechanical components and systems
5	Apply health and safety practices to minimize exposure to unsafe conditions and ensure a safe working environment for oneself and co-workers.
6	Perform tasks in accordance with relevant law, policies, procedures, standards, regulations and ethical principles.
7	Apply the principles of mathematics and science to analyze and solve technical problems related to photonics technology.
8	Apply the principles of physical and natural science.
9	Communicate information effectively, credibly, and accurately for the installation, maintenance, repair and manufacture of components.
10	Manage, evaluate and document data.
11	Manage, lead and work in a team to meet target goals.
12	Evaluate and analyze systemic problems and produce troubleshooting techniques to address these problems.
13	Apply strategies for ongoing personal and professional development to enhance performance as a photonics professional.
14	Select for purchase equipment, components, and systems that fulfill job requirements and functional specifications.
15	Implement and conduct quality control and quality assurance procedures.
16	Apply business/management principles, ethics, sustainability, contracts, codes and standards.
17	Manage projects adhering to the standards of the Project Management Body of Knowledge (PMBOK).
18	Research, analyze, prepare, document, submit and defend a technology report.

APPENDIX 2: NIAGARA COLLEGE PHOTONICS ENGINEERING TECHNOLOGY CURRICULUM MAP

	The graduate has reliably demonstrated the ability to:	COMM1133	CAPT1011	MATH1131	PHTN1101	PHYS1220	MMFG1279	ELNC1220	MATH1231	COMM1430	CAPT1012	PHYS1215	NEWW1008	CAPT1013	ELNC1321	MATH1331	PHTN1300	PHTN1334	COMM1308	PHTN1304	PHTN1400	MATH1431	PHTN1431	PHTN1432	PHTN1305	TECH1100	ELNC1430	PHTN1306	PHTN1307	PHTN1531	COMM1522	PHYS1630	TECH1101	PHTN1310	PHTN1311	PHTN1631	PHTN1312	COMM1622	TECH1102
1	Design, construct and test laser devices and systems.																X			X	X							X											
2	Design, construct and test Photonic/optical components and systems				X								X					X		X				X	X				X					X		X			
3	Design, construct and test electronic systems		X				X	X					X		X												X			X									
4	Construct and test opto-mechanical components and systems		X								X			X									X									X							
5	Apply health and safety practices to minimize exposure to unsafe conditions and ensure a safe working environment for oneself and co-workers.				X															X	X																		
6	Perform tasks in accordance with relevant law, policies, procedures, standards, regulations and ethical principles.												X										X			X													
7	Apply the principles of mathematics and science to analyze and solve technical problems related to photonics technology.			X		X		X	X				X	X		X		X				X	X		X														
8	Apply the principles of physical and natural science.				X	X						X			X									X	X							X							
9	Communicate information effectively, credibly, and accurately for the installation, maintenance, repair and manufacture of components.									X	X			X																									
10	Manage, evaluate and document data.									X																											X		
11	Manage, lead and work in a team to meet target goals.																						X								X						X		
12	Evaluate and analyze systemic problems and produce troubleshooting techniques to address these problems.												X							X													X		X				
13	Apply strategies for ongoing personal and professional development to enhance performance as a photonics professional.																									X													
14	Select for purchase equipment, components, and systems that fulfill job requirements and functional specifications.																																		X				
15	Implement and conduct quality control and quality assurance procedures.																																X						
16	Apply business/management principles, ethics, sustainability, contracts, codes and standards.																														X				X		X	X	X
17	Manage projects adhering to the standards of the Project Management Body of Knowledge (PMBOK).																																						X
18	Research, analyze, prepare, document, submit and defend a technology report.																														X							X	

APPENDIX 3: LAURIER BACHELOR OF SCIENCE IN PHOTONICS PROGRAM LEARNING OUTCOMES

Honours Bachelor of Science in Photonics Program Learning Outcomes

1. Demonstrate a basic knowledge of the physics core areas: mechanics, thermodynamics, waves, electricity and magnetism, electronics, optics, and modern physics.

2. Demonstrate knowledge of advanced physics concepts in classical mechanics, statistical mechanics, quantum mechanics, electromagnetic theory, and condensed matter physics.

3. Demonstrate advanced knowledge in fibre optics, lasers, photonic devices, and electro-optics.

4. Use appropriate knowledge and skills to solve physics problems with well-defined solutions as well as tackle open-ended problems.

5. Interpret a physics problem into a mathematical form for description, analysis and solution using appropriate problem solving skills in calculus to the level of differential equations and vector field calculus, linear algebra, transforms, complex numbers, series, trigonometry, complex analysis, special functions, and probability and statistics.

6. Expand knowledge and range of perspectives through non-science electives.

7. Demonstrate computational skills for algorithm development using programming languages to the level of scientific programming.

8. Competently and safely use a range of measurement and data analysis tools to collect data with appropriate precision and carry out the subsequent analysis with due regard to the uncertainties.

9. Conduct independent investigations by methods that include experimentation, analysis, and synthesis of information.

10. Communicate complex information effectively and concisely by means of written documents, presentations or discussion.

11. Understand and interpret complex concepts and information precisely in order to construct logical arguments.

12. Demonstrate an ability to work effectively both independently and in groups.

13. Demonstrate ethical scientific behaviour.

14. Use practical knowledge and skills to identify and secure future career opportunities.

APPENDIX 4: LAURIER BACHELOR OF SCIENCE IN PHOTONICS CURRICULUM MAP

Honours Photonics Program Learning Outcomes Legend: **I = Introduce R = Reinforce M = Met**	Required Courses																														
	CP104	MA110	MA122	PC131	CP114	MA110	MA121	PC120	PC132	MA201	MA205	PC200	PC212	MA255	PC221	PC235	PC237	PC242	PC300	PC321	PC344	PC364	PC481	PC315	PC331	PC360	PC454	PC482	PC421	PC474	PC481	ELECTIVES
1. Demonstrate a basic knowledge of the physics core areas: mechanics, thermodynamics, waves, electricity and magnetism, electronics, optics, and modern physics.		I	I	R		I	I	I/R	R	I	I	R	R	R	R	R	R	M	M													
2. Demonstrate knowledge of advanced physics concepts in classical mechanics, statistical mechanics, quantum mechanics, electromagnetic theory, and condensed matter physics.		I	I	I		I	I	I	I	I	I	I	R	R	R	R	R	R	R	R	R	R	R	R	R	R	M					
3. Demonstrate advanced knowledge in fibre optics, lasers, photonic devices, and electro-optics.		I	I	I		I	I	I	I	I	I	I	I	I	I	I	R	R	R	R	R	R	R	R	R	R	R	R	R	M	M	
4. Use appropriate knowledge and skills to solve physics problems with well-defined solutions as well as tackle open-ended problems.		I	I	I		R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	M	M	M	M	M	
5. Interpret a physics problem into a mathematical form for description, analysis and solution using appropriate problem solving skills in calculus to the level of differential equations and vector field calculus, linear algebra, transforms, complex numbers, series, trigonometry, complex analysis, special functions, and probability and statistics.		I	I	I		I	I	I	I	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R/M	M	M	M			
6. Expand knowledge and range of perspectives through non-science electives.																																I, R, M
7. Demonstrate computational skills for algorithm development using programming languages to the level of scientific programming.	I	I	I	I	I	I	I	I	I	I	R	R		R	R		R		R			R	R	M					M	M	M	
8. Competently and safely use a range of measurement and data analysis tools to collect data with appropriate precision and carry out the subsequent analysis with due regard to the uncertainties.		I	I	R	I	I	I	I	R	I	I	R		I	R		R		R				R	R		R	R	R	R	M	M	
9. Conduct independent investigations by methods that include experimentation, analysis, and synthesis of information.		I	I	R	I	I	I	R	R	I	I	R		R	R		R		R				R	R		R	R	R	R	M	M	
10. Communicate complex information effectively and concisely by means of written documents, presentations or discussion.		I	I	R	I	I	I	R	R	I	I	R		I	R		R		R	R	R	R	R	R	R	R	M	M	M	M	M	
11. Understand and interpret complex concepts and information precisely in order to construct logical arguments.		I	I	I	I	I	I	I	I	I	I	I	R			R	R	R	R	R	R		R	R	R	R	M	M	M	R	M	
12. Demonstrate and ability to work effectively both independently and in groups.	I	I	I	I	I	I	I	I	I	I	R	R	R	R	R	R	R	R	R	R/M	R/M	R/M	R	R/M	R/M	R/M	M	M	M	M		
13. Demonstrate ethical scientific behavior.	I	I	I	I	I	I	I	I	I	I	R	R	R	R	R	R	R	R	R	R/M	R/M	R/M	R				M		M	M		
14. Use practical knowledge and skills to identify and secure future career opportunities.																							I	I	I	R	R	R	R	M		

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APPENDIX 5: PROGRAM LEARNING OUTCOMES COMPARISON CHART

Undergraduate Degree Level Expectations	Niagara College Photonics Engineering Technology Program Learning Outcomes	Wilfrid Laurier Photonics BSc Learning Outcomes
Depth and Breadth of Knowledge		• Demonstrate a basic knowledge of the physics core areas: mechanics, thermodynamics, waves, electricity and magnetism, electronics, optics, and modern physics. • Demonstrate knowledge of advanced physics concepts in classical mechanics, statistical mechanics, quantum mechanics, electromagnetic theory, and condensed matter physics. • Demonstrate advanced knowledge in fibre optics, lasers, photonic devices, and electro-optics.
Knowledge of Methodologies	• Manage, evaluate and document data. • Research, analyze, prepare, document, submit and defend a technology report.	• Competently and safely use a range of measurement and data analysis tools to collect data with appropriate precision and carry out the subsequent analysis with due regard to the uncertainties. • Conduct independent investigations by methods that include experimentation, analysis, and synthesis of information.

Undergraduate Degree Level Expectations	Niagara College Photonics Engineering Technology Program Learning Outcomes	Wilfrid Laurier Photonics BSc Learning Outcomes
Application of Knowledge	• Design, construct and test laser devices and systems • Design, construct and test Photonic/optical components and systems • Design, construct and test electronic systems • Construct and test opto-mechanical components and systems • Apply health and safety practices to minimize exposure to unsafe conditions and ensure a safe working environment for oneself and co-workers. • Apply the principles of mathematics and science to analyze and solve technical problems related to photonics technology. • Apply the principles of physical and natural science. • Evaluate and analyze systemic problems and produce troubleshooting techniques to address these problems. • Implement and conduct quality control and quality assurance procedures.	• Use appropriate knowledge and skills to solve physics problems with well-defined solutions as well as tackle open-ended problems. • Interpret a physics problem into a mathematical form for description, analysis and solution using appropriate problem solving skills in calculus to the level of differential equations and vector field calculus, linear algebra, transforms, complex numbers, series, trigonometry, complex analysis, special functions, and probability and statistics. • Demonstrate computational skills for algorithm development using programming languages to the level of scientific programming.
Communication Skills	• Communicate information effectively, credibly, and accurately for the installation, maintenance, repair and manufacture of components.	• Communicate complex information effectively and concisely by means of written documents, presentations or discussion. • Understand and interpret complex concepts and information precisely in order to construct logical arguments.
Awareness of Limits of Knowledge		• Expand knowledge and range of perspectives through non-science electives.

Undergraduate Degree Level Expectations	Niagara College Photonics Engineering Technology Program Learning Outcomes	Wilfrid Laurier Photonics BSc Learning Outcomes
Autonomy and Professional Capacity	• Apply health and safety practices to minimize exposure to unsafe conditions and ensure a safe working environment for oneself and co-workers. • Perform tasks in accordance with relevant law, policies, procedures, standards, regulations and ethical principles. • Manage, lead and work in a team to meet target goals. • Apply strategies for ongoing personal and professional development to enhance performance as a photonics professional. • Select for purchase equipment, components, and systems that fulfill job requirements and functional specifications. • Apply business/management principles, ethics, sustainability, contracts, codes and standards. • Manage projects adhering to the standards of the Project Management Body of Knowledge (PMBOK).	• Demonstrate an ability to work effectively both independently and in groups. • Demonstrate ethical scientific behaviour. • Use practical knowledge and skills to identify and secure future career opportunities.

APPENDIX 6: COURSE BY COURSE COMPARISON

The following table provides an overview of the process undertaken at Laurier to match courses completed by students in the Niagara Photonics Engineering Technology program with those that comprise the Laurier Bachelor of Science in Photonics. To undertake this analysis, Laurier faculty examined the syllabi and Teaching and Learning Plans for each of the Niagara course in order to confirm which topics were taught within a course and which were missing. If the Niagara courses met the threshold of approximately 80%, they were considered to be a match for an existing Laurier course and therefore not required of students in the pathway.

Year/Term	WLU Course	NCC Course	Missing Topics	Comments
Year 1 F	CP104	CTEC1544 (ends in 2015)	1. Numbers 2. Variables 3. Expressions 4. Functions 5. Loops 6. Statements 7. Nested Loops 8. Arrays 9. Lists 10. Text Processing 11. Recursion	NCC makes change to cover these missing topics in CAPZT1011 starting 2015.
	MA110 (or MA103)	MATH1331 MATH1431	1. Multivariable calculus 2. Missing labs	**Match** (Multivariable calculus offered as separate course MA212)
	MA122	No match		
	PC131/PC132	PHYS1220+PHYS1630	1. Rotation 2. Rolling Torque and Angular Momentum 3. Fluids 4. Equilibrium and Elasticity 5. Entropy 6. Gravitation (part)	No Match for PC131

Year/Term	WLU Course	NCC Course	Missing Topics	Comments
	Elective			
Year 1 W	CP114	No match		
	MA121	No match		
	PC120	ELNC1430		**Match**
Year 2 F	MA201	No match		
	MA205	No match		
	PC200	ELNC1220		
	PC212	ELNC1320	1. Electric Field 2. Gauss' Law 3. Electric Potential 4. Magnetic Fields 5. Magnetic Fields due to currents	**Match**
	Elective			
Year 2 W	MA255	No match		

Year/Term	WLU Course	NCC Course	Missing Topics	Comments
	PC221	ELNC1220, ELNC1320, ELEC1532		
	PC235	No match		
	PC237	PHTN1100, 1215, 1220, 1530		
	PC242	Match	1. Special Relativity 2. Schroedinger Eq. and Applications 3. Atomic Structure 4. Molecular Structure	**Match**
Year 3 F	PC300			**Match**
	PC321	No match		
	PC344	No match		
	PC364	CTEC1339 PHTN1334	1. Multiplexing 2. Switching 3. Digital to Analog Conversion	No Match
	PC481	PHTN1220, 1334, 1531	1. Theory on Planar Waveguide Structures, and Cylindrical Fiber 2. Signal Degradation in Optical Fibers; 3. Labs	No Match
	Elective			
Year 3 W	PC315	No match		

Year/Term	WLU Course	NCC Course	Missing Topics	Comments
	PC331	No match		
	PC360	No match		
	PC454	No match		
	Elective			
Year 4 F	PC482	PHTN1100,1300, 1400, 1500, 1531		**Match**
	Electives			
Year 4 W	PC421	PHTN1531, PHTN1500		No Match
	PC474	PHTN1334, PHTN1220	1. Optical network examples –SUNET and Ethernet 2. Wavelength-Division-Multiplexing (WDM)	No Match
	Electives			

APPENDIX 7: PROPOSED NCC PHOTONICS ENGINEERING TECHNOLOGY – WLU PHOTONICS PATHWAY (3+2)

Honours Photonics (BSc)

(Pathway for NCC 3 year Photonics Engineering Technology diploma students)

The aim of the pathway of BSc program is to develop a strong understanding of the theory and application of photonics, with specific emphasis on data communications and networks, and with practical hands-on exposure to optics, fibre optics, and lasers giving the pathway students to graduate with a valuable mix of skills and knowledge. Given the potential importance of photonics to future technological developments in many areas, students with this combination of practical, theoretical, and research skills would be very well-positioned to meet the needs of emerging technology fields.

The program consists of 20 full-credit courses (or equivalent).

This schedule serves as a guide to the order that the courses may be taken. Students may follow a different schedule of their choice, subject to academic regulations, including course pre-requisites.

Bridging Gap Courses[1]	1.MA201 Multivariable calculus and 2.MA122 Introductory Linear Algebra	
	Fall Term	**Winter Term**
Year 3	PC131 Mechanics MA121 Introduction to Mathematical Proofs MA205 Differential Equations I *1.0 elective credits*	CP114 Data Structure MA255 Continuous and Discrete Transforms PC235 Classical Mechanics PC315 Intro to Scientific Computation PC360 Electromagnetic Theory
Year 4	PC321 Quantum Mechanics I PC344 Thermodynamics & Statistical Physics PC364 Data Communications and Networks PC481 Fibre Optics *0.5 elective credits*	PC331 Quantum Mechanics II PC454 Solid State Physics PC474 Optical Networks PC421 Photonic Devices *0.5 elective credits*

Regulations

1. Program must include at least 9 and no more than 11 senior Physics credits.

[1] The courses listed for the bridging gap are the recommended courses to ensure that students have the mathematics skills necessary to complete the required courses. However, each student's level of preparation will be assessed through the Math Assistance Centre's Calculus Preparation Evaluation. On the basis of this assessment, a suitable suite of bridging courses will be recommended.

2. The electives must include at least 0.5 senior credit in Physics.
3. For progression into the next year, and for graduation, the requirement will be a minimum cumulative GPA of 5.00 (C) calculated on the Physics courses and a minimum overall GPA of 5.00 (C).
4. Candidates who have passed all courses of the final year, but have failed to obtain the requisite average for an honours degree, may elect to receive a general degree in Physics.
5. Maximum of 7 100-level credits are allowed.

Notes

All courses listed are one-half credit, except for courses denoted as follows:
* 1 credit course
° 0.25 credit course

APPENDIX 8: COURSE DESCRIPTIONS FOR BRIDGING COURSES

MA122
Introductory Linear Algebra

0.5 Credit

Systems of linear equations; algebra of complex numbers; algebra of matrices with real and complex entries; determinants and their applications; vector geometry in $\mathbf{R}^2$ and $\mathbf{R}^3$; spanning, linear independence and linear transformations in $\mathbf{R}^n$ and $\mathbf{C}^n$; introduction to eigenvalues and eigenvectors; applications of linear algebra.

MA201
Multivariable Calculus

0.5 Credit

Vector functions; differential and integral calculus of functions of several variables, including vector fields; line and surface integrals including Green's Theorem, Stokes' Theorem and the Divergence Theorem.

Other potential bridging courses:

MA110
Introduction to Differential and Integral Calculus

1.0 Credit

A thorough introduction to limits of functions. Continuity and its consequences. Rational, algebraic and transcendental functions and geometric relationships. Theory and applications of differential and integral calculus of functions of a single variable. The Fundamental Theorem of Calculus and techniques of integration. Introduction to multivariable calculus and applications.