Appendix C

NATIONAL INSTITUTE OF PHYSICS
College of Science
University of the Philippines, Diliman, Quezon City

COURSE SYLLABUS
Physics 305: Special Topics in Theoretical Physics

A. Course Catalogue Description

1. **Course Number:** Physics 305
2. **Course Title:** Special Topics in Theoretical Physics (Quantum Computation and Quantum Information)
3. **Course Description:** This graduate course provides a rigorous, mathematically grounded introduction to the principles and techniques of quantum computation and quantum information
4. **Prerequisite: Physics 117, Physics 142**
5. **Semester Offered: 1st Semester**
6. **Course Credit: 3 units**
7. **Number of Hours: 1.5 hours**
8. **Meeting Type: Classroom**
9. **Course Stipulation (if applicable):**
10. **Course Goals:**

Equip graduate students with the rigorous mathematical foundations in quantum computation and information in preparation for advanced research and responsible innovation.

B. Rationale

Quantum computation and information is a pillar of modern physical science and emerging technological industries (secure communications, advanced cryptography , quantum-enhanced sensing, simulation, optimization). A rigorous grounding in the course enables graduates to critically assess claims of quantum advantage, design resource-aware algorithms for noisy intermediate-scale devices and contribute theoretical advances that reduce hardware overhead.

C. Course Outline

1. Course Outcomes (CO)

Upon completing the course, students must be able to:

CO 1. Explain and rigorously manipulate the mathematical framework of qubits, multi-qubit systems, tensor products, density operators, and quantum measurement postulates

CO 2. Construct and analyze quantum circuits implementing universal gate sets and key algorithms (Deutsch–Jozsa, Simon, Grover, Phase Estimation, Shor

CO 3. Quantify information quantities (entropy, mutual information) and characterize entanglement, mixed states, and typical quantum channels.

CO 4. Model decoherence and quantum noise; design elementary quantum error-correcting codes; explain stabilizer formalism and thresholds.

CO 5. Explain principles of quantum key distribution (e.g., BB84, E91) and analyze security assumptions and vulnerabilities.

CO 6. Critically read, present, and propose extensions to recent quantum computation and information research papers.

1.1 Program Objectives Met by the Course

Course Outcomes	Program Learning Objectives*				
	A	B	C	D	E
CO 1	*		*		
CO 2	*		*		
CO 3	*		*		
CO 4	*		*		
CO 5	*		*		
CO 6				*	*

A. To demonstrate breadth and depth in the knowledge of the core areas in physics.
B. To communicate scientific ideas and research results in written and oral formats.
C. To utilize advanced theoretical, computational, or empirical methods in physics.
D. To evaluate new developments in physics.
E. To create new knowledge through original and independent research in theoretical, computational or empirical physics.

2. Course Content (at least 2 levels)

Course Topics	No. of Hours
I. Quantum computation	27
Quantum circuits, the quantum Fourier transform and applications, quantum search algorithms, quantum computer realizations	
II. Quantum information	27
Quantum noise and quantum operations, distance measures for quantum operations, quantum error correction, entropy and information, quantum information theory	

3. Course Coverage

Appendix C

Week	Course outcome/s	Course Topic	Essential or Key Questions	Suggested Teaching and Learning Activities	Suggested Assessment Tools/ Activities	Core Readings/ Learning Resources
1,2	**CO 1**	Quantum mechanics in finite-dimensional Hilbert spaces				Chapter 2
3,4	CO 1	Quantum circuits				Chapter 4
5,6	CO 1, CO 2	The quantum Fourier transform				Chapter 5
6,7	CO 2	Quantum search algorithms				Chapter 6
8,9	CO 2, CO 6	Quantum computers and their physical realizations				Chapter 7
10,11	CO 3, CO 4	Quantum noise and quantum operations				Chapter 8
11,12	CO 3	Distance measures for quantum information				Chapter 9
13,14	CO 3, CO 4	Quantum error correction				Chapter 10
15,16	CO 3	Entropy and information				Chapter 11
17,18	CO 3, CO 6	Quantum information theory				Chapter 12

4. Course Requirements

1. Midterm exam (35%)
2. Final exam (35%)
3. Problem sets (20%)
4. Attendance (10%)

D. References

Text book: Quantum Computation and Quantum Information: 10th Anniversary Edition Nielsen and Chuang

Mathematics of Quantum Computation, Sherer

E. List of Faculty who will handle the course