Course Number: *PHY4706*	***Course Name: Quantum Matter & Technologies (QM&T)***	BML MUNJAL UNIVERSITY FROM HERE TO THE WORLD
Credits: *3 (1-1-1)*	***Contact hours per week* = 3** Hours	
Instructor-in-charge: Dr. Abhimanyu Singh Rana	***TA (s):*** Anamika, Anchal	

Aim of the course: The aim of the course is to introduce basic concepts of quantum physics and related principles of quantum computing. For hands-on learning, students will receive opportunities to write a program for IBM quantum experience platform and perform experiments, projects and group activities .

Course Overview and Context: Recently, many advances in quantum technologies (based on some interesting concepts of quantum physics and matter) have emerged where big companies like Google, Microsoft, IBM and Facebook are taking interest due to the impact of these technologies beyond the imagination of a layman. In quantum physics, it is quite evident that whether it makes sense or not, but it "works". Some concepts still look far sighted now where the quantum physics proposes that it is possible to have a communication far beyond using conventional technologies (in a very robust manner without losing the information) or the state can't be just defined as 0 and 1 (used in current computation) but the infinite states between 0 and 1 (giving extremely fast and accurate calculations). However, all these discoveries will depend on the progress made in the manipulation and development of quantum matter at atomic scales.

In this course, I will take this journey from this fascinating physics to some serious applications in quantum information processing devices and computing. As the course is UG, there will be less use to rigorous mathematics and wherever it appears it will be explained at simpler level. Many activities such programming a real quantum computer through remote IBM Quantum Experience (https://quantum-computing.ibm.com/) and experiments will be performed in class itself. The difficult concepts will be explained with help of videos and animations. The practice and focus on problems will be done through take-home assignments (which will be major component of internal marks).

Topics of the Course

- **Fundamentals of Quantum Mechanics**
  Particles and Waves, Uncertainty Principle, Wavefunctions, Superposition Principle, Schrodinger Equation, Quantum Tunneling, Quantum Entanglement

- **Quantum Matter, Devices and Measurement Technologies**
  Quantum Dots, Nanostructures, 2-D Materials, Quantum Hall Effect, Superconductors, Tunneling Devices (Josephson junctions, STM, SQUID etc.) Ion-traps

  Quantum Information Processing and Computing Technologies
  Qubits, Bloch Sphere, Quatum Logic Gates (X, Y, Z, H, CNOTetc), Basic architecture of quantum computing and examples of Quantum Algorithms (Bernstein–Vazirani, Shor's Algorithm etc)
- **Programming a Quantum Computer, Lab Projects**

Week wise Schedule:

Week 1-2: Particles and Waves, Uncertainty Principle, Wavefunction,

Week 3-4: Superposition principle, Schrodinger Equation, Quantum Tunneling

Week 5-6: EPR Paradox, Quantum Entanglement, Quantum Decoherance

Week 7-8: Quantum Dots, Nanostructures, 2-D Materials, Quantum Hall Effect Week 9-10: Superconductors, Josephson junctions

Week 11-12: STM, SQUID, Ion-traps,

Week 13-14: Qubits, Bloch Sphere, Quantum Logic Gates (X, Y, Z, H, CNOT etc)

Week 15-16: Basic architecture of quantum computing and examples of Quantum Algorithms (Bernstein– Vazirani, Shor's Algorithm etc)

Course Outcomes

On the completion of the course the students will

CO1: Understand the principles of quantum mechanics, quantum matter and get familiar with the new research areas in the field of quantum computing
CO2: Apply these concepts in solving the problems in quantum information and quantum computation.
CO3: Analyze and compare the results and data of different quantum materials and device technologies

CO-PO Mapping (CSE/ME/ECOM)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3														
CO2	3						2		2	3					
CO3	3						2		1	2					

*The mapping criteria from 3 to 1 indicates the strongest to weakest

Course Competencies: (Course Outcomes further elaborated) and Instruction schedule:

	Competency	**CO**	**CL**	**No of sessions**
C1	Understanding the basic concepts of quantum mechanics such as particles and waves, uncertainty principle, wavefunctions, superposition of wavefunctions, quantum tunneling	CO1	U	7 sessions
C2	Understanding the quantum phases of matter, quantum dots,Two-dimensional (2D) electro systems, graphene, superconductors, topological insulators	CO1	U	8 sessions
C3	Apply the fundamental principle and various phase of quantum matter in the understanding the working of various quantum devices, Josephson junctions, Ion-trap, STM, SQUID.	CO2	AP	8 sessions
C4	Analyze the results and compare the suitable materialsdifferent quantum devices & technologies	CO3	AP	6 Session
	Apply the fundamental knowledge to understanding	CO2	AP	8 sessions

C5	the advance concepts of qubits, quantum computation, decoherence, quantum superposition, quantum entanglement and quantum encryption			
C6	Apply these principles to the problems in quantum computation	CO2	AP	5 sessions
C7	Analyze the compare the results of the simulations producedby simple programming through IBM Quantum Experience(online virtual platform by IBM)	CO3	AP	6 sessions

Learning Resources:

Textbook(s):

1. David J. Griffiths, Introduction to Quantum Mechanics, Cambridge University Press, 2017
2. Eleanor G. Rieffel and Wolfgang H. Polak, Quantum Computing: A Gentle Introduction, Cambridge, Mass.: The MIT Press\
3. Jack D. Hidary, Quantum Computing: An Applied Approach, Springer

Reference Book(s):

4. Richard Phillips Feynman, The Feynman Lectures on Physics (Volume 3), Pearson P T R; 1st Edition
5. Chris Bernhardt, Quantum Computing for Everyone, Cambridge, Mass.: The MIT Press
6. Michael A. Nielsen &Isaac L. Chuang, Quantum Computation and Quantum Information, Cambridge University Press

Online Resources:

1. https://www.coursera.org/learn/physical-basis-quantum-computing
2. https://www.coursera.org/learn/quantum-computing-algorithms
3. https://www.edx.org/course/applications-of-quantum-mechanics
4. https://www.edx.org/course/hardware-of-quantum-computer

Assessment Pattern: The final grade will be based on the marks/ grades obtained in the mid-semester andend-semester evaluation along with other assessments defined in the assessment table. Relative grading method defined in the academic regulations of the university will be followed to grade the students. Studentmust secure minimum 40% of marks after completing all the assessments in the following table to becomeeligible for grading.

Evaluation Component	Duration	Weightage (%)	Due Date	Remark
Assignment I	Week	10	23 Aug 2024	
Assignment II	Week	20	20 Sept 2024	
Assignment III	Week	20	11 Oct 2024	
Quiz/Viva-Voce	One	10	15 Nov 2024	Close Book
Make Up Internal Exam	Week	NA	22 Nov 2024	
End term presentation	Throughout the course	20	5 Dec 2024	
End term project report	Throughout the course	30	9 Dec 2024	

Project or Assignments: There will be project(s) and assignments. The details of the project guidelines will be provided in a separate document by the instructor.

Experiential Learning components:

- Programming a Quantum Computer through IBM Quantum Experience
- The students will be doing experiments in CAMD labs. These need to be documented and written in report form.
- Various online tools and visualization software to enhance the imagination, knowledge, giving real- time feedback, interesting polls, quizzes and brainstorming sessions during classes.
- Group projects will be given where students will apply the theoretical knowledge learned during class session in online, face-to-face, flip class and blended mode of delivery. This will allow students to have a strong grip on concepts and strengthen their knowledge in the subject.

Student Responsibilities:

- Attend lectures to obtain all the course material that you are responsible for.
- Check announcements at LMS and emails on a regular basis.
- Submit assignments/projects on time.
- Regularly, check your marks on the LMS and make sure they are up to date.

Attendance Policy: Students are expected to attend the classes regularly. Failure to attend the classes regularly and adhere to the expected attendance percentage will result in a reduction of the grade or awarding ‘R’ grade as per the University’s grading policy.

Evaluation procedures for tests and assignments: The final grade will be based on the marks / grades obtained in the mid-semester and end-semester evaluation which would be done based on the correct answer to the question as well as correct explanation for the right answer opted for.

Late assignment submission policy: 5% of the total marks would be deducted for late submission.

Make-up examination/work policy: As per University norms. Please collect details from program office.

Behavior expectations: Mobile phones and other distractive elements/gadgets are not permitted in the class.
Other Policies or Procedures:

a) Academic Honesty
You must abide by BMU’s academic honesty policy. For example, an excerpt is provided for your guidance as follows:
” Students who compromise the integrity of the classroom are subject to disciplinary action on the part of the University. Violations of classroom standard include:
1. Cheating in any form, whether in formal examinations or elsewhere
2. Plagiarism, using the work of others as your own without assigning proper credit to the source
3. Misrepresentation of any work done in the classroom or in preparation for class
4. Falsification, forgery, or alteration of any documents pertaining to academic records
5. Disruptive behaviour in a course of study or abusiveness toward faculty or fellow students.”

b) Teaching Improvement
Please feel free to make suggestions to improve the content of the class and my instruction skills. You can share these suggestions directly to me or by email or anonymously leave your comments by sliding them under my office door.