2026-27

Course Code		:	1BPHS102C/202C	QUANTUM PHYSICS AND QUANTUM COMPUTING (CS, IS, AIML & BT) (Integrated)	Semester	:	I/II
L : T : P		:	3:0 :2		Course Type	:	IPCC
Hours / Sem	Teaching	:	42+26Hrs		CIE Marks	:	50
	Learning (TW+SL)	:	44Hrs		SEE Marks	:	50
	Exam	:	08Hrs		Total Marks	:	100
	Total Hrs	:	120Hrs		Credits	:	04

Professional Competency:

Apply quantum mechanics principles to conductors, superconductors, laser and quantum computing.

Course Outcomes:

After completion of the course, student will be able to:

CO1: Apply the quantum mechanics principles and properties of conductors for engineering applications.
CO2: Apply appropriate properties of superconductors and semiconductors for engineering applications.
CO3: Apply appropriate properties of laser and type of optical fiber for engineering applications.
CO4: Apply basic principles of quantum computing for engineering applications.

Unit – I (11 Hrs)

Quantum mechanics:

Introduction, de Broglie hypothesis and its derivation, matter waves and its properties, quantization of energy levels, Phase velocity and group velocity, relation between group velocity and particle velocity. Heisenberg's uncertainty principle and its physical significance (no derivation), Application of uncertainty principle (nonexistence of electron in the nucleus-relativistic), Principle of complementarity, Wave function and its properties, Derivation of one dimensional time independent Schrodinger’s wave equation. Physical significance of a wave function and Born interpretation, Expectation value and its physical significance. Eigen functions and eigen values. Applications of Schrodinger’s wave equation - eigen functions and energy eigen values of a particle in a one dimensional potential well of infinite height, role of higher dimensions, waveforms and probabilities. Numerical problems.

Electrical properties of metals :

Introduction, failures of classical free electron theory, Matthiessen’s rule, assumptions of quantum free electron theory, Fermi energy, Fermi-Dirac statistics, density of states (qualitative), Fermi factor, variation of Fermi factor with temperature and energy, success of quantum free electron theory. Numerical problems.

Unit – II (10 Hrs)

Superconductivity:

Introduction to superconductors, temperature dependence of resistivity in conductors and superconductors, Meissner’s effect, critical magnetic field, temperature dependence of critical magnetic field, Silsbee effect. Formation of cooper pairs, Two-fluid model, BCS theory and its limitations, Type-I and Type-II superconductors, high temperature superconductors, quantum tunneling, Josephson junction. Applications of superconductors: DC and AC (RF) SQUIDs. In quantum computing - charge, phase and flux qbits. Numerical problems.

Semiconductors :

Introduction, Fermi level in intrinsic and extrinsic semiconductor, expression for concentration of electrons in conduction band and holes concentration in valance band (no derivation), relation between Fermi energy and energy gap in intrinsic semiconductors (derivation), law of mass action, electrical conductivity of a semiconductor (derivation), Hall effect, expression for Hall voltage and Hall coefficient (derivation) and its applications. Numerical problems.

Unit – III	10 Hrs

Photonics:

Laser:

Introduction, interaction of radiation with matter (absorption, spontaneous emission and stimulated emission), Einstein's coefficients (derivation for energy density), conditions for laser action, requisites of a laser system, working mechanism, characteristics of a laser, classification of lasers. Construction and working of Nd:YAG and semiconductor diode lasers. Applications of lasers- laser bar code scanner, laser printer and laser cooling, Mach-Zehnder interferometer. Numerical problems.

Optical fibers:

Introduction, principle and structure, propagation mechanism in optical fibers, angle of acceptance, numerical aperture and its derivation. Modes of propagation (qualitative), V number and number of modes, types of optical fibers, attenuation and fiber losses. Applications-optical fiber communication system and fiber optic networking. Numerical problems.

Unit – IV	11 Hrs

Quantum Computing:

Introduction to quantum computing, Moore's law and its limitations, classical vs quantum computation. Quantum system as a qubit and its properties. Representation of qubit on Bloch sphere, two and multi qubit systems. Dirac representation and matrix operations: Dirac's bra-ket representation of quantum states $|0\rangle$ and $|1\rangle$, their matrix forms. Inner product- proof of orthonormality of quantum states using matrix notation and basis. Outer product- density matrix representation of single and two qubit systems. Unitary matrices- Pauli matrices and their operation on single and two qubit systems. Hermitian operator. Numerical problems

Quantum gates:

Single qubit gates: quantum NOT gate, Pauli –X,Y and Z gates, Hadamard gate, phase gate - S and T gates. Multiqubit gates: control and target qubit, CNOT gate (discussion for 4 different input states), swap gate, controlled Pauli –X,Y and Z gates, Toffoli gate and Fredkin gate

Practical Module	26 Hrs

01	Determination of wavelength of LASER using diffraction grating.
02	Determination of numerical aperture and acceptance angle of the given optical fiber.
03	Study the characteristics of a photodiode and to determine the power responsivity.
04	Determination of Planck's constant using LEDs.
05	Determination of Fermi energy of copper.
06	Determination of energy gap of the given semiconductor diode.
07	Black-box experiment (Identification of basic electronic components)
08	Resonance in LCR circuit.
09	Determination of resistivity of a semiconductor by four probe method.
10	Determination of dielectric constant of the material in a capacitor by charging and discharging method.
11	Characteristics of a bipolar junction transistor.
12	Interference by the division of amplitude(Air wedge/Newton's rings)
13	Predicting the outputs of various combinations of single and two qubit gates using QUIRK quantum simulator.
14	Predicting the outputs of various combinations of single and two qubit gates using QISKIT.
15	Data analysis using spread sheets.
16	PhET simulations.

Note: i) Introduction lab
ii) Any ten experiments are to be conducted from the above list.
iii) Two Virtual/simulation labs

Text Books:

01	Avadhanulu M.N. and Kshirsagar P. G. and Arun Murthy T.V.S, “ A Textbook of Engineering Physics”, S. Chand, New Delhi, 11th edition, 2019.
02	Kakani S.L. Shubra Kakani, “Engineering Physics” CBS Publishers and Distributers Pvt. Ltd, 3rd edition, 2020.
03	Satyendra Sharma and Jyotsna Sharma, “Engineering Physics”, Pearson, 2018.

Reference Books:

01	Pillai S. O, “Solid State Physics”, New Age International Private limited, 8th Edition, 2018.
02	Lala Parag K, “Quantum Computing”, McGraw Hill, 2020.
03	Beiser A, “Concepts of Modern Physics", McGraw-Hill Education, 6th edition, 2002.
04	Griffiths D. J, “Introduction to Quantum Mechanics” Pearson, 2nd edition, 2018.
05	Tinkham M, “Introduction to Superconductivity”, Dover Publications, 2nd edition, 2004.
06	Mishra P. K, “Superconductivity – Basics and Applications”, Ane Books, 2009.
07	Loud B. B, “LASERS and Non-Linear Optics”, New Age International, 2nd edition, 2002.
08	Saleh B. E. A. and Teich M. C, “Fundamentals of Photonics”, Wiley, 3rd edition, 2019.
09	Nielsen M. A. and Chuang I. L, “Quantum Computation and Quantum Information Cambridge”, University Press, 10th Anniversary edition, 2010.
10	Vishal Sahani, “Quantum Computing”, McGraw Hill, Education, 2007.
11	Anirban Pathak, “Elements of quantum computation and quantum communications”, CRC Press, 2013.
12	Kenneth Krane.S, “Modern Physics”, John Wiley and sons, 3 rd edition, 2012.

Web Links and Video Lectures:

01	NPTEL – Quantum Mechanics I (IIT Madras): https://nptel.ac.in/courses/115106066
02	NPTEL – Physics: Introductory Quantum Mechanics (NOC): https://archive.nptel.ac.in/courses/115/104/115104096
03	Solid State Physics – NPTEL (IIT Madras) https://nptel.ac.in/courses/115106127
04	A Brief Course on Superconductivity – NPTEL IIT Guwahati (Prof. Saurabh Basu) Playlist Introduction Video: https://www.youtube.com/watch?v=SHoGV-sezNI Full playlist available via the YouTube channel description or archive link.
05	Concepts in Magnetism and Superconductivity – NOC (IIT Kharagpur)Series start (Lecture 1): https://digimat.in/nptel/courses/video/115105131/L01.html
06	Introduction to Photonics – NPTEL (IIT Madras, Prof. Balaji Srinivasan) Lecture 03 to Lecture 12 cover: Direct video link (start Lecture 03): https://nptel.ac.in/courses/108106135/03
07	Semiconductor Optoelectronics – NPTEL (IIT Delhi, Prof. M. R. Shenoy)Direct video link (start relevant lecture): https://nptel.ac.in/courses/108108174/05
08	Lecture 04 – Quantum Computing Basics: https://www.youtube.com/watch?v=-fttE1SzpD8
09	Lecture 08 – Quantum Gates and Circuits Part 1: https://www.youtube.com/watch?v=nGPr1QM_XrY

Course Outcomes (Cos)	Program Outcomes and (WKs)										
	1	2	3	4	5	6	7	8	9	10	11
CO1	**3 (WK1, WK2,and WK3)**	**2 (WK1, WK2,and WK3)**						1			1
CO2	**3 (WK1, WK2, and WK3)**	**2 (WK1, WK2, and WK3)**						1			1
CO3	**3 (WK1, WK2, and WK3)**	**2 (WK1, WK2, and WK3)**						1			1
CO4	**3 (WK1, WK2, and WK3)**	**2 (WK1, WK2, and WK3)**			2 **(WK1, WK2, and WK3)**			1			1