<u>**Detailed Syllabus**</u>
Lecture-wise Breakup

Course Code	19M21PH211	**Semester:** Even	**Semester:** III **Session:** 2022-23 **from:** July 2022 to December 2022
Course Name	Nuclear and Particle Physics		
Credits	4	**Contact Hours**	3+1
Faculty (Names)	**Coordinator**	Dr. Manoj Tripathi	
	Teacher	Dr. Manoj Tripathi	

S. N.	COURSE OUTCOMES	COGNITIVE LEVELS
C211.1	Recall the basic nuclear properties and laws of nuclear and particle physics.	Remembering (C1)
C211.2	Understand different phenomenon and concepts of nuclear and particle physics along with their interpretation.	Understanding (C2)
C211.3	Apply the concept and principles to solve problems related to nuclear and particle physics.	Applying (C3)
C211.4	Analyze and examine the solutions of the problems of nuclear and particle physics using physical and mathematical tools involved.	Analyzing (C4)

Module No.	Title of the Module	Topics in the Module	No. of Lectures for the module
1.	**Nucleus properties and nuclear models**	Basic nuclear properties – size, shape and charge distribution, nuclear energy levels, nuclear angular momentum, parity, isospin, statistics, and nuclear magnetic dipole moment. Binding energy, semi-empirical formula, Liquid drop model, Magic Numbers, Shell model and collective nuclear model.	8
2.	**Nuclear decay and nuclear reaction**	Alpha decay, Gamow's theory of alpha decay, Beta decay, Fermi's theory of beta decay, Fermi-Kurie plot, decay rates,Fermi and Gamow Teller selection rules, Gamma decay,Angular correlation in successive gamma emissions. Fission and Fusion, Nuclear reactions, reaction mechanism, compound nuclei and direct	8

		reactions.	
3.	**Nuclear forces**	Classification of fundamental forces, Nature of nuclear force, form of nucleon-nucleon potential, charge independence and charge-symmetry of nuclear forces. Deuteron problem – properties of deuteron, ground state of deuteron, excited state, magnetic quadrupole moment of deuteron.	9
4.	**Elementary particles and relativistic kinematics**	Classification of elementary particles and their quantum numbers (charge, spin, parity, isospin, strangeness, etc.), Gellmann-Nishijima formula, Lepton & Hadrons, Classification of Hadron in baryons and mesons, Okubo mass formula for octet and decaplet Hadrons, Quark model,. C, P, and T invariance. Elementary particle symmetries, SU(2) and SU(3) groups, Their representations. Application of symmetry arguments to particle reactions. Parity non-conservation in weak interaction.	15
		Total number of Lectures	**40**

Evaluation Criteria	
Components	**Maximum Marks**
T1	20
T2	20
End Term Examination	35
TA	25 [Attendance (05 M), Class Test, Quizzes, *etc* (06 M), Assignments in PBL mode (10 M), and Internal assessment (04 M)
TOTAL	**100**

Project Based Learning	Students may be given to complete a task like identifying common applications to nuclear science, recent developments in nuclear science, etc. The students may be asked to make presentations on topics like nuclear reactions, nuclear models and their applications. Problems based upon Beta decay, Deutron problem, Particles interaction may also be included. Students may be taken to research lab where they can visualize the real applications of the subject. The students may also be asked to study the research articles relevant to the subject and present them.

Recommended Reading material: Author(s), Title, Edition, Publisher, Year of Publication etc. (Text books, Reference Books, Journals, Reports, Websites etc. in the IEEE format)

1.	K. S. Krane, Introducing nuclear physics, Wieley India (2008).
2.	D. C. Tayal, Nuclear Physics.Himalya Publication House, Bombay (2015).
3.	Irving Kaplan, Nuclear Physics, Narosa Publication (2002).
4.	D. Griffiths,Introduction to elementary particles, 2^{nd} Ed, Academic Press (2008).
5.	S. N. Ghoshal, Nuclear and Particle Physics, S. Chand Limited (2008).

Detailed Syllabus

Lecture-wise Breakup

Course Code	19M21PH212	**Semester: Odd**	**Semester: III Session** 2022 -2023 Month from: July-December
Course Name	Advanced Quantum Mechanics		
Credits	4	**Contact Hours**	3+1
Faculty (Names)	**Coordinator**	Prof. S P Purohit	
	Teacher	Prof. S P Purohit	

COURSE OUTCOMES		**COGNITIVE LEVELS**
C212.1	Recall basic ideas of advanced quantum mechanics	Remembering (C1)
C212.2	Explain various physical phenomena which can be explained only using advanced quantum mechanics	Understanding (C2)
C212.3	Apply time-independent perturbation methods, time-dependent perturbation methods, quantum collision theory, quantum statistics and relativistic quantum mechanics for quantum mechanical systems.	Applying (C3)
C212.4	Analyze advanced quantum mechanical problems.	Analyzing (C4)

Module No.	**Title of the Module**	**Topics in the Module**	**No. of Lectures for the module**
1.	**Approximation methods for time-dependent problems**	Time-dependent perturbation theory, General features, Fermi's golden rule, periodic perturbation, the adiabatic approximation and application to some atomic systems.	8
2.	**Quantum collision theory**	Scattering experiments and cross-sections, non-relativistic scattering theory, scattering by central potential, phase shift analysis, optical theorem, method of partial waves, scattering by a square well potential, the Born approximation, some applications of quantum collision theory.	8
3.	**Quantum statistics**	The density matrix, the density matrix for a spin-1/2 system, polarisation, the equation of motion of the density matrix, quantum mechanical ensembeles, applications to single-particle systems, systems of non-interacting particles, consequences of particle statistics, ideal quantum gases, Bose-Einstein condensation in atomic gases.	6

4.	**Relativistic quantum mechanics**	The Klein-Gordon equation, the Dirac equation, physical implementation and applications, covariant formulation of the Dirac theory, plane wave solutions of the Dirac equation.	6
5.	**Quantization of Wave Fields**	Classical and quantum field equations, coordinates of the field, time derivatives, classical Lagrangian and Hamiltonian equations, quantum equations for the field, fields with more than one components, quantisation of the non-relativistic Schrodinger equation, creation, destruction and number operators, anticommutation relations and operators, electromagnetic field in vacuum, interaction between charged particles and electromagnetic field.	8
6.	**Some applications of quantum mechanics (only qualitative discussion)**	The van der Waals interaction, electrons in solids, the decay of K-mesons, semiconductor quantum devices, quantum communication	4
		Total number of Lectures	**40**

Evaluation Criteria

Components	**Maximum Marks**
T1	20
T2	20
End Semester Examination	35
TA	25 [PBL (10 M); 2 Quizzes (3 M+3 M); Attendance (05 M) and Class performance (4 M)]
Total	**100**

Recommended Reading material: Author(s), Title, Edition, Publisher, Year of Publication etc. (Text books, Reference Books, Journals, Reports, Websites etc. in the IEEE format)

1.	Leonard I. Schiff, Quantum Mechanics, McGraw-Hill, Singapore, 1985
2.	B. H. Bransden and C. J. Joachain, Quantum Mechanics, Pearson Education Ltd., 2000
3.	J. J. Sakurai, Advanced Quantum Mechanics
4.	J. D. Bjorken& S. D. Drell, Relativistic Quantum Fields

Project Based Learning: The TA components of evaluation criteria involve the PBL component of MM: 06. The PBL exercise is given to each student in areas where the quantum mechanics plays a central role. The objective of the PBL exercises is chosen to enhance the employability of students in the areas of quantum technologies.

Detailed Syllabus

Lecture-wise Breakup

Course Code	19M21PH213	**Semester:** Odd	**Semester: III Session** 2022 -2023 **Month from:** July-December
Course Name	Numerical Techniques and Computer Programming		
Credits	03	**Contact Hours**	03

Faculty (Names)	**Coordinator(s)**	**Dr. Ravi Gupta**
	Teacher(s) (Alphabetically)	**Dr. Ravi Gupta**

COURSE OUTCOMES		**COGNITIVE LEVELS**
C213.1	Define key concepts used in programming, data structures, Numerical methods.	Remember Level (C1)
C213.2	Explain basics of programming, data structures, numerical analysis, parallel programming.	Understand Level (C2)
C213.3	Create programs using C to implement various problems in numerical analysis.	Apply Level (C3)
C213.4	Create programs using Mathematica and MATLAB to solve various problems in numerical physics.	Apply level (C3)

Module No.	**Title of the Module**	**Topics in the Module**	**No. of Lectures for the module**
1.	**Introduction to Programming**	Fundamentals of Programming, high/low level languages, compilation and linking, Basic data types, Arithmetic operators, Elementary introduction to header files, print f, scan f and control functions of Turbo C/C++, Looping	10
2.	**Data Structures**	Oneand two dimensional arrays of various data types, Operations involving matrices and vectors, String of characters and related library functions, Functions and arrays, Structures, array of structures, unions and enumerations, Command line arguments. Dynamical memory	10

		allocation, Plotting simple geometric figures	
3.	**Numerical Techniques**	Simple C programs covering some elementary topics in numerical analysis such as root finding, interpolation, numerical differentiation and integration, numerical linear algebra, Euler and Runga-Kutta methods.	15
4.	**Approximation methods**	Basic ideas of parallel computing and introduction to the software popularly used in Physics such as Mathematica and MATLAB	05
		Total number of Lectures	**40**

Evaluation Criteria

Components	**Maximum Marks**
T1	20
T2	20
End Semester Examination	35
TA	25 [Attendance (05 M), Class Test, Quiz, *etc* (6 M), PBL (10 M) Internal assessment (04 M)]
Total	**100**

Recommended Reading material: Author(s), Title, Edition, Publisher, Year of Publication etc. (Text books, Reference Books, Journals, Reports, Websites etc. in the IEEE format)

1.	Greg Perry and Dean Miller, C Programming Absolute Beginner's Guide, Paperback, 2013.
2	Bjarne Stroustrup , C++ Programming Language, Paperback, 2013.
3	K. E. Atkinson, Numerical Analysis, John Wiley (Asia), 2004.
4	S. C. Chapra and R. P. Canale, Numerical Methods for Engineers, Tata McGraw Hill, 2002.
5	Stephen Wolfram ,The Mathematica Book, Fifth Edition , Wolfram Media, Inc., 2012.
6	A. Gilat, MATLAB An Introduction With Applications 4th Edition, John Wiley, 2013.
7.	YashavantKanetkar, Let Us C, 16th Edition, BPB Publications, 2018
8.	B. S. Grewal, Numerical Methods in Engineering and Science with Programs in C, C++, and MATLAB, Khanna Publishers, 2013

Project Based Learning: Students are required to write programming code individually using any of the tools or programs; and do a presentation in the end. This knowledge of coding can be utilized in different software organizations/firms/ industries.

Detailed Syllabus
Lecture-wise Breakup

Course Code	19M21PH214	**Semester:** Odd	**Semester: III Session** 2022 -2023 **Month from:** July-December
Course Name	Advanced Condensed Matter Physics-1		
Credits	03	**Contact Hours**	03

Faculty (Names) **Coordinator(s)** Dr Manoj Kumar

Teacher(s) (Alphabetically) NA

COURSE OUTCOMES		COGNITIVE LEVELS
C214.1	Recall basic concepts related to magnetism, transport phenomena, phase transition and super conductivity	Remember Level (C1)
C214.2	Explain the significance and value of condensed matter physics, both scientifically and in the wider community	Understand Level (C2)
C214.3	Develop knowledge of conception or notion involved in various theories and models studied in this course	Apply Level (C3)
C214.4	Make use of various methods and solve problems related to studied theories.	Apply level (C3)

Module No.	Title of the Module	Topics in the Module	No. of Lectures for the module
1.	Dielectrics and Ferroelectrics	Dielectrics, Maxwell Boltzmann equations, Polarization and macroscopic electric field, Local electric field of an atom, Lorentz field, Polarizabilty, Classius-Mossoti relation, Type of polarization and polarizabilities, Frequency dependence of polarizabilities. Ferroelectric crystals and structural phase transitions, Order-disorder phase transition, Displacive and soft mode transition, LST relation, Landau Theory of Phase transition, First order and second order phase transition, Anti-ferroelectricity, Ferroelectric domains (90^o and 180^o), Piezoelectricity and piezoelectric relations	12
2.	Magnetism	Magnetiztion and magnetic susceptibilty, Langevin theory of diamagnetism and Van Vleckparamagnetism, Quantum theory of Paramagnetism, Curie Brillouin law. Curie-Weiss ferromagnets, Magnons, Curie temperature and susceptibility of Ferrimagnets, Néeltemperature and Anti-ferromagnetic order, Brags-Willium theory, Heisenberg model,Ising model; Elements of magnetic properties of metals, Landau diamagnetism, Pauli paramagnetism, Stoner ferromagnetism;	12

		Magnetic resonance; NMR and EPR.	
3.	Transport Properties	Boltzmann equation; Relaxation time approximation; General transport coefficients; Electronic conduction in metals; Thermoelectric effects; Transport phenomena in magnetic field; Magnetoresistance; Hall effect and Quantum Hall effect.	10
4.	Superconductivi ty	Cooper pairing and BCS theory; Ginzburg Landau theory; Flux quantization; Supercurrent tunneling; DC and AC Josephson effects; High-Tc superconductors.	6
		Total number of Lectures	**40**

Evaluation Criteria

Components	**Maximum Marks**
T1	20
T2	20
End Semester Examination	35
TA	25 [Attendance (5), 2 Quiz/class tests (6), PBL in Assignments (10), Student's performance (4)]
Total	**100**

Recommended Reading material: Author(s), Title, Edition, Publisher, Year of Publication etc. (Text books, Reference Books, Journals, Reports, Websites etc. in the IEEE format)

1.	Kittel C, "Introduction to Solid State Physics", 8th Ed. Wiley eastern Ltd
2	Ashcroft N W and Mermin N D, "Solid State Physics", Holt-Saunders
3	Chaikin P M and Lubensky T C, "Principles of Condensed Matter Physics", Cambridge University Press
4	Harrison P, "Quantum Wells, Wires and Dots", Wiley & Sons Ltd.
5	B. D. Cullity and C. D. Graham, "Introduction to magnetic materials" John Wily & Sons, Inc, 2011
6	K. H. J. Buschow and F. R. de Boer, "Physics of Magnetism and Magnetic Materials" Kluwer Academic Publishers, 2003
7	Stephen Blundell, "Magnetism in Condensed Matter" Oxford University Press (2001)
8	M. Tinkham, "Introduction to superconductivity" McGrawHill, New York. (1996); Dover Books (2004)
9	P. G. de Gennes, "Superconductivity of metals and alloys" W. A. Benjamin, New York (1966); Perseus Books (1999)
10	A. A. Abrikosov, "Fundamentals of the theory of metals" North Holland, Amsterdam (1998)

Project Based Learning: This course contains the materials which are widely used in high tech industry. As a Physics course, students are trained to understand the properties of materials and to do assignment/project based on the theoretical and experimental fundamental they have learned. The project based on these studies to be evaluated.

<u>**Detailed Syllabus**</u>
Lecture-wise Breakup

Course Code	19M21PH215	**Semester:** Odd	**Semester:** III **Session:** 2022-2023 **Month from:** July to December
Course Name	Optoelectronics		
Credits	3	**Contact Hours**	3

Faculty (Names)	**Coordinator**	Navneet Kumar Sharma
	Teacher	Navneet Kumar Sharma

COURSE OUTCOMES		**COGNITIVE LEVELS**
C215.1	Recall the fundamentals of semiconductor physics, LEDs, Injection laser diodes	Remembering (C1)
C215.2	Explain basic principle of optoelectronic detection: photodiodes, photoconducting detectors; modulators	Understanding (C2)
C215.3	Apply concepts of fibers: step index, graded index, numerical aperture; modes: single mode and multimode; V parameter; evanescent modes; losses in fibers; dispersion in fibers; Fiber bragg grating	Applying (C3)
C215.4	Analyze semiconductor optical amplifiers; Erbium-doped fiber amplifiers; Fiber Raman amplifiers	Analyzing (C4)

Module No.	**Title of the Module**	**Topics in the Module**	**No. of Lectures for the module**
1.	Optoelectronic Sources	Fundamental aspects of semiconductor physics: p-n junction, heterojunction; LEDs; Types of LEDs: surface and edge emitting; Injection laser diodes.	8
2.	Optoelectronic Detectors	Basic principle of optoelectronic detection: Types of photodiodes; photoconducting detectors.	6
3.	Optoelectronic Modulators	Review of basic principles of modulators; electro-optic, acousto-optic, magneto-optic modulators.	8
4.	Optical Fiber-Theory	Classification of fibers: step index and graded index; numerical aperture; modes in optical fiber: single mode and multimode; V parameter; evanescent modes; losses in fibers: bending and coupling; dispersion in fibers: dispersion compensated, dispersion flattened and dispersion shifted; Fiber bragg grating.	12
5.	Optical Amplifiers	Semiconductor optical amplifiers; Erbium-doped fiber amplifiers; Fiber Raman amplifiers.	6
		Total number of Lectures	**40**

Evaluation Criteria

Components	**Maximum Marks**
T1	20
T2	20
End Semester Examination	35
TA	25 [Attendance (05 M), Class Test, Quizzes, etc (06 M), Assignments in PBL mode (10 M), and Internal assessment (04 M)]

Total	**100**

Recommended Reading material: Author(s), Title, Edition, Publisher, Year of Publication etc. (Text books, Reference Books, Journals, Reports, Websites etc. in the IEEE format)	
1.	Fundamentals of Photonics – B. E. A. Saleh and M. C. Teich, wiley, 2nd edition.
2.	Principles of Optics - M. Born and E. Wolf , Cambridge university press, 7th edition.
3.	Optical Electronics - A.Ghatak and K.Thyagarajan, Cambridge university press.
4.	Optical Fiber Communications: principles and practice – John M.Senior, Pearson Education, 3rd edition.
5.	Electronic Communications – D. Roddy and J. Coolen, Pearson Education, 4th edition.

Project based learning: Each student will opt a topic and will do the theoretical study in detail. The students will submit their report. The students analyze the fiber bragg gratings, semiconductor optical amplifiers, erbium-doped fiber amplifiers and fiber Raman amplifiers. This shall improve the skills and employability of the students in photonic industries.

Course Name: Laboratory-1 (19M25PH111)
COURSE OUTCOMES: Upon the completion of this subject, students will be able to

S.No.	DESCRIPTION	COGNITIVE LEVEL (BLOOMS TAXONOMY)
C170.1	Recall optics, solid state physics and modern physics principles behind the experiments.	Remembering (C1)
C170.2	Explain the experimental setup and the principles involved behind the experiments performed.	Understanding (C2)
C170.3	Plan the experiment and set the apparatus and take measurements.	Applying (C3)
C170.4	Analyze the data obtained and calculate the error.	Analyzing (C4)
C170.5	Interpret and justify the results.	Evaluating (C5)

CO-PO MAPPING:

COs	PO1	PO2	PO3	PSO1
C170.1	1	1		1
C170.2	2	2		1
C170.3	3	3	1	1
C170.4	3	3	1	2
C170.5	3	3	1	2

3: Strongly Related   2: Moderately Related   1: Weakly related   Left Blank: Not related

Detailed Syllabus

Lab-wise Breakup

Course Code	**19M25PH111**	**Semester: ODD**	**Semester: 1st Session:** 2022 -2023 **Month from: July to December**
Course Name	**Laboratory-1**		
Credits	4	**Contact Hours**	8

Faculty (Names)	**Coordinator(s)**	Navendu Goswami
	Teacher(s) (Alphabetically)	Navendu Goswami, N. K. Sharma, R. K. Dwivedi, S. P. Purohit,

COURSE OUTCOMES		**COGNITIVE LEVELS**
C170.1	Recall optics, solid state physics and modern physics principles behind the experiments.	Remembering (C1)
C170.2	Explain the experimental setup and the principles involved behind the experiments performed.	Understanding (C2)
C170.3	Plan the experiment and set the apparatus and take measurements.	Applying (C3)
C170.4	Analyze the data obtained and calculate the error.	Analyzing (C4)
C170.5	Interpret and justify the results.	Evaluating (C5)

Module No.	Title of the Module	List of Experiments	CO
1.	Optics	1. Wavelength measurement of Na-source using Michelson interferometer. 2. Determination of coherence & width of spectral lines using Michelson interferometer 3.To determine the wavelengths of Balmer series in the visible region from hydrogen emission and to determine the Rydberg constant	1-5
2.	Modern Physics	4. Measurement of critical potential using Franck-Hertz tube. 5. To observe the Zeeman spitting of the green mercury line using Fabry-Perot etalon for normal transverse and longitudinal configuration.	1-5
3.	Solid State Physics	6. Determination of band gap of semiconductor from temperature dependence of Resistivity using Four Probe	1-5

		Method 7. To study B-H loop for a given sample by CRO 8. Study of Dielectric constant and determination of Curie temperature of ferroelectric ceramics 9. Study of Hall Effect and determination of allied coefficients 10. Study of magneto resistance of given semiconductor material 11. Study of Magnetostriction using Michelson Interferometer 12. Study of electron spin resonance and determination of line width, electron spin, magnetic moment of an electron and electron g factor.	

Evaluation Criteria

Components	**Maximum Marks**
Mid Term Viva (V1)	20
End Term Viva (V2)	20
D2D	60 [Attendance (10), PBL (10), Record File/Auxiliary Copy (10) & Continuous Assessment (30)]
Total	**100**

Recommended Reading material: Author(s), Title, Edition, Publisher, Year of Publication etc. (Text books, Reference Books, Journals, Reports, Websites etc. in the IEEE format)

1.	Experiment hand-outs.

Project based learning: Each student in a group of 3-4 or individually will develop a mini project with the help of various concepts of optics, solid state physics and modern physics. Individually or in a team they will learn how to apply the concepts for problem solving in a meaningful way.

Detailed Syllabus

Course Code	19M25PH212	**Semester: Odd**	**Semester** III **Session** 2022 - 2023 **Month: July to Dec**
Course Name	Laboratory-3 (Applied Optics)		
Credits	4	**Contact Hours**	8
Faculty (Names)	**Coordinator(s)**	Manoj Kumar	
	Teacher(s)	Amit Verma, Anirban Pathak, Manoj Kumar	

COURSE OUTCOMES		**COGNITIVE LEVELS**
C217.1	Recall the principles of Optical Spectroscopy, optical fibers, optoelectronics and Lasers behind the experiments.	Remembering (C1)
C217.2	Explain the experimental setup and the principles involved behind the experiments performed.	Understanding (C2)
C217.3	Plan the experiment and set the apparatus and take measurements.	Applying (C3)
C217.4	Analyze the data obtained and calculate the error.	Analyzing (C4)
C217.5	Interpret and justify the results.	Evaluating (C5)

Module No.	**Title of the Module**	**Topics in the Module**	**CO**
1.	**Optical Spectroscopy**	**1.**Determination of size of Nano materials by uv-vis absorption spectrophotometer. **2.** Determination of optical band gap (Δ∑) of materials by uv-vis emission spectrophotometer. **3.** Determination of optical band gap (Δ∑) of materials by uv-vis absorption spectrophotometer. **4.** Determination of various nonlinear optical coefficients (first and second order hyperpolarizabilities) by FTIR spectrometry.	*1-5*
2.	**Optical Fibers**	**5.**To measure the power loss at a splice between two multimode fibers and study the variation of splice loss with transverse and longitudinal offsets. **6.**To couple the light from an optical source into the optical fiber and to measure its Numerical aperture (NA). **7.**To determine the mode field diameter (MFD) of the fundamental mode in given single mode fiber (SMF) by a measurement of its far field.	1-5
3.	**Laser and Applications**	**8.**Measurement of laser parameters using He-Ne laser. **9.**Determination of optical absorption coefficient and determination of refractive index of the liquids using He-Ne laser. **10.** Biasing characteristics of a Laser diode and spectral characterization using an Optical Spectrum Analyzer.	**1-5**

Evaluation Criteria

Components	Maximum Marks
Mid Term Viva (V1)	20
End Term Viva (V2)	20
Day To Day Evaluation	60 [Attendance (10), PBL (10), Record File/Auxiliary Copy (10) & Continuous Assessment (30)]
Total	**100**

Recommended Reading material: Author(s), Title, Edition, Publisher, Year of Publication etc. (Text books, Reference Books, Journals, Reports, Websites etc. in the IEEE format)

Project based learning: The students will do small projects in groups for better understanding of this laboratory course. Mainly, the students will do the projects based on laser and optical fiber. This will help the students to understand the concept of photons generation and their propagation in a better way.

D etailed Syllabus
Course description file

Course Code	20M22PH212	**Semester: Odd**		**Semester: 3rd, Session 2022-23** **Month from: July to December**	
Course Name	Quantum Optics				
Credits	**3**		**Contact Hours**	**3**	
Faculty (Names)	**Coordinator**	Dr Amit Verma			
	Teacher	Dr Amit Verma			

COURSE OUTCOMES		**COGNITIVE LEVELS**
CO1	Recall basics of field quantization	Remembering (C1)
CO2	Explain various physical phenomena which fall under the domain of quantum optics	Understanding (C2)
CO3	Apply the witnesses of quantum ness of light on various quantum states to determine their non classical properties and applicability	Applying (C3)
CO4	Analyze complex problems related to matter field interaction using quantum treatment	Analyzing (C4)

Module No.	**Title of the Module**	**Topics in the Module**	**No. of Lectures for the module**
1.	**Introduction to quantum optics**	Classification of optics as classical, semi-classical and quantum optics; establish the need of field quantisation for the understanding of various optical phenomena; quantization of electromagnetic field (second quantization), normal ordering and field operators.	5
2.	**Coherent state and the notion of nonclassicality**	Coherent state as an eigen ket of annihilation operator and other definitions of coherent state; properties of coherent state; notion of pure and mixed state; Glauber-Sudarshan P- representation and the notion of nonclassical states.	5
3.	**Quantum (nonclassical) states of light their properties, witnesses and nonclassicality inducing operations**	Notion of squeezed state, antibunched state, entangled states, states with sub-Poissonian photon statistics, etc, and their properties; Displacement operator, squeezing operator, and photon addition and subtraction operators, their roles in inducing nonclassicality. Operational criteria for witnessing nonclassicality with emphasis on correlation functions and quasi probability distributions like Wigner function and Q function.	8
4.	**Generation, evolution and**	Various physical process used to generate quantum (nonclassical) light e.g., SPDC and other nonlinear optical	14

	detection of quantum (nonclassical) state of light	processes; mathematical methods and models used in quantum optics: Jayne-Cummings model, Rabi models, rotating wave approximation, Fokker-Planck equation and elementary idea of Master equation and open quantum system; Detection of quantum light by coincidence-counting and methods of phase-sensitive detection; Landmark experiments in quantum optics.	
5.	**Applications of Quantum Optics**	Precise measurement (with example of LIGO), laser cooling and BEC, ion trapping, CPT, EIT, slow light, applications in quantum communication, quantum computation and in quantum metrology with specific mention of quantum radar.	8
		Total number of Lectures	**40**

Evaluation Criteria

Components	**Maximum Marks**
T1	20
T2	20
End Semester Examination	35
TA	25 [2 Quiz (6 M), Attendance (5 M) and A mini-project (PBL) (10M) and class performance (4M)]
Total	**100**

Recommended Reading material: Author(s), Title, Edition, Publisher, Year of Publication etc. (Text books, Reference Books, Journals, Reports, Websites etc. in the IEEE format)

1.	M Fox, Quantum optics: An introduction, Oxford University Press, Oxford 2006
2.	Z Ficek and M R Wahiddin, Quantum Optics for Beginners , CRC Press, London2014
3.	G S Agarwal, Quantum Optics, Cambridge University Press, Cambridge, 2012

Project Based Learning (PBL): The students will be given small projects (in groups) on various topics Gravitational wave detection, Nonclassical states, Phase space distribution and Mathematica programs on different nonclassical properties, to explore their applications in fundamental science and computational technology to understand the role of Quantum Optics. This will help the students to connect the concept studied in the class with their application in quantum technologies and will enhance their analytical skills.