FOUR-YEAR UNDER GRADUATE PROGRAMME (FYUGP)

BSc APPLIED PHYSICS HONOURS

Programme	**B.Sc. Applied Physics Honours**				
Course Title	**MODERN PHYSICS AND NUCLEAR PHYSICS**				
Type of Course	**Minor (SET II: MATERIALS PHYSICS)**				
Semester	**II**				
Academic Level	**100 - 199**				
Course Details	Credit	Lecture per week	Tutorial per week	Practical per week	Total Hours
	4	3	-	2	75
Pre-requisites	1.Foundational understanding of classical physics, particularly in mechanics and electromagnetism. 2. Proficiency in algebra, calculus and trigonometry.				
Course Summary	This course explores the dual nature of particles and waves, as well as the structure and behavior of atomic and nuclear systems. Through theoretical discussions and practical applications, students will investigate electromagnetic waves, particle-wave duality phenomena, atomic structure, nuclear composition, and nuclear transformations.				

Course Outcomes (CO):

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools used
CO1	Understand the duality of particles and waves, Describe experimental evidence supporting the wave-particle duality, including the photoelectric effect and Compton effect.	U	C	Instructor-created exams / Quiz
CO2	Define pair production and its significance in quantum mechanics, Understand the concept of matter waves proposed by Louis de Broglie.	U, Ap	P	Seminar Presentation / Group Tutorial Work
CO3	Explain the structure of the atom according to the nuclear model, Understand Energy Levels and Spectra	Ap	P	Practical Assignment / Observation of Practical Skills

CO4	Investigate Nuclear Structure Understand stable nuclei, binding energy, and models such as the liquid drop model and shell model	U	C	Instructor-created exams / Home Assignments
CO5	Understand radioactive decay processes and their implications for nuclear stability,	Ap	P	One Minute Reflection Writing assignments
CO6	Analyse nuclear reactions, including fission and fusion, and their relevance in energy production and stellar evolution.	Ap	P	Writing assignments /Viva Voce
* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C) # - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)				

Detailed Syllabus:

Module	Unit	Content	Hrs (45 +30)	Marks (70)
I		**Particle properties of waves & Wave properties of particles**	**12**	**15**
	1	Electromagnetic Waves, Black body Radiation	3	
	2	Photoelectric Effect	2	
	3	Compton Effect	2	
	4	Pair Production	3	
	5.	De Broglie Waves	2	
	Sections from References: 2.1, 2.2, 2.3, 2.7,2.8, 3.1, Book 1			
II		**Atomic Structure**	**10**	**22**
	6	The Nuclear Atom	2	
	7	Electron Orbits	2	
	8	Atomic Spectra	2	
	9	The Bohr Atom	2	
	10	Energy Levels and Spectra	2	
	Sections from References:4.1, 4.2, 4.3, 4.4, 4.5, Book 1			
III		**Nuclear Structure**	**13**	**20**
	11	Nuclear composition	2	
	12	Nuclear properties	2	
	13	Stable nuclei	2	
	14	Binding energy	2	
	15	Liquid drop model, Shell model	2	
	16	Magic numbers	1	
	17	Meson theory of nuclear forces.	2	
	Sections from References:11.1, 11.2, 11.3, 11.4, 11.5, 11.6, 11.7, Book 1			
IV		**Nuclear Transformations**	**10**	**13**
	18	Radioactive decay, radioactivity and the Earth	1	

	19	Half-life, Radiometric dating	2	
	20	Alpha decay, Beta decay, Gamma decay	3	
	21	Nuclear reactions, Nuclear fission	3	
	22	Nuclear fusion in stars	1	
	Sections from References: 12.1, 12.2, 12.4 (Tunnel theory concept only), 12.5, 12.6, 12.8, 12.9, 12.10, 12.11, Book 1			
V	**PRACTICALS**		**30**	
	Conduct any 6 experiments from the given list and 1 additional experiment, decided by the teacher-in-charge, related to the content of the course. The 7th experiment may also be selected from the given list. Other experiments listed here may be used as demonstrations of the concepts taught in the course. Necessary theory of experiments can be given as Assignment/ Seminar.			
	1	**Determination of Plank's constant using LEDs** ● Observe the turn-on voltage, V_0 of LEDs and calculate the value of h. Use at least 4 different colors of LED (with transparent casing) ● Plot $\frac{1}{\lambda} - V_0$ graph using Python, fit a straight line to get the slope and estimate the value of h. ● Calculate the %error. ● Programmable voltage source of ExpEYES may be used to find the turn-on voltage.		
	2	**Continuous and line spectra- Determination of the wavelengths and photon energy.** ● Familiarize the initial adjustments and measurements in the spectrometer. ● Mount the grating at normal incidence on the spectrometer. ● Determine the wavelengths of the sodium vapor lamp and calculate the associated photon energy. ● Determine the approximate range of the wavelengths of the continuous spectrum of incandescent/white LED lamp or any one coloured LED and calculate the associated photon energy. ● The readings of the first order spectrum will be enough. Number of lines/m of the grating can be given.		
	3	**Mercury spectrum- Determination of wavelength and photon energy.** ● Determine wavelength of any four prominent lines and associated photon energy of the mercury spectrum using a spectrometer with grating at normal incidence. ● The readings of the first order spectrum will be enough. Number of lines/m of the grating may be given.		
	4	**Hydrogen spectrum - Determination of wavelengths and calculation of the Rydberg's constant.**		

		• Determine the wavelengths and photon energy in eV of the prominent lines of the Balmer series of the Hydrogen spectrum using a spectrometer with grating at normal incidence. • Calculate the Rydberg's constant and estimate the % error. • The readings of the first order spectrum will be enough. Number of lines/m of the grating may be given.		
	5	**Wave Packets - Analysis of beats in sound.** • The experiment is intended to understand the concept of wave packet, phase and group velocities. • Generate sounds waves of two near frequencies using smartphone/ExpEYES/Function generator and the superimposed wave can be recorded and analysed using smartphone/ExpEYES/CRO • Change the separation between the frequencies and compare the results with the theoretical values. • https://expeyes.in/experiments/sound/beats.html • Multi Tone generator and Audio scope tools of Phyphox may be used https://phyphox.org/experiment/tone-generator/		
	6	**7. Analysis of Hydrogen spectra using the Tracker Video Analysis tool**. • Calibrate the video of the Hydrogen spectra in the Tracker tool using two laser wavelengths/lines of mercury spectra. • Plot the intensity profile, find the prominent wavelengths of the Balmer series and calculate the Rydberg's constant. • Estimate the %error. • Pre recorded video of the Hydrogen spectra can be used. • https://physlets.org/tracker/. • https://www.youtube.com/watch?v=UCCPkJpUQEw		
	7	**Black body spectrum of Sun -Estimation of surface temperature using the Tracker Video Analysis tool.** • Calibrate the video of the solar spectra in the Tracker tool using two laser wavelengths/lines of mercury spectra. • Plot wavelength vs intensity, get λ_{max} and using Wein's law calculate the surface temperature. • Pre recorded video of the solar spectra can be used.		
	8	**Verification of Wein's displacement law and Stefan's law using incandescent bulb.** • Calibrate the video of the spectra of the incandescent bulb in the Tracker tool using two laser wavelengths/lines of mercury spectra. • Plot wavelength vs intensity and note λ_{max} . • Repeat the experiment by increasing the operating voltage of the incandescent bulb(hence increasing the temperature of the source) • From the plots, verify the Wein's displacement law and Stefan's law.		
	9	**Study the specific rotation of the sugar solution using a polarimeter.**		

		• Determine the specific rotation corresponding to different concentrations of the sugar dissolved in water. • Draw a graph between rotation and concentrations and verify the linear relationship.		
	10	**Verification of Malus's law using polarizer, analyzer and photo detector** • Unpolarized light is allowed to pass through a polarizer and is observed through an analyzer. • Vary the angle between the axes of polarizer and analyzer and measure the intensity of the light (current output of the photodetector). • Plot $\theta - I$ and $cos^2\theta - I$ graphs and verify the Malus's law. • A flat computer monitor (or LCD TV screen) in plain white color can be used as the source of linear polarized light. • The ambient light sensor of the smartphone and the orientation sensor of the smartphone can be used to measure the illuminance and the angles respectively. • A small piece of polarizer (a square of about 1 cm side) from an old calculator's display was placed over the ambient light sensor as analyser. • https://arxiv.org/pdf/1607.02659		
	11	**Brewster's law experiment, determination of angle of polarisation and refractive index.** • Experimental arrangement- Sodium vapour lamp, Spectrometer, Polarizer (Graduated on 360° rotating) coupled in front of the spectrometer telescope, prism or glass plate. • Get the angle of incidence corresponding to the minimum intensity of light and hence calculate the refractive index of the material. • https://www.youtube.com/watch?v=f2A8sM1xhbQ		
	12	**Mapping of the magnetic field lines of a bar magnet.** • Fix a paper on a drawing board kept on a table and place the bar magnet at the center along the magnetic meridian. • Using a small compass needle, map the magnetic field lines of the magnet placed with north pole pointing south • Mark the null points (where the horizontal component of Earth's magnetic field, Bh cancels the field due to magnet) along the axial/equatorial line and measure the distance, 2d, between them. • Calculate the moment of the magnet. $m = \frac{4\pi}{\mu_0}\frac{(d^2-l^2)^2}{2d}B_h$		
	13	**Circular coil- Verification of Biot Savart's law and determination of Bh.** • Move a compass through a platform along the axis of the coil carrying a study current. Note the deflection of the needle and plot magnetic flux density ($B = B_h tan\theta$) as a function of distance.		

		• Optional: Smartphone magnetometer may be used to measure the strength of the magnetic field along the axial line and plot the data. https://phyphox.org/experiment/magnetic-field/ • Experiment 62 of Book 2 • By varying current and (or) distance of the compass box along the axial line of the coil, note the deflection and hence determine the value of Bh.		
	14	**Calibrate the ammeter using potentiometer** • Standardize the potentiometer using a Danial cell or any other standard voltage source. • Determine the current for at least 8 trials and draw the calibration graph.		
	15	**Parallel plate capacitor. (a) verify the relationship between capacitance and the area of the plates (b) determination of dielectric constant of thin dielectric sheet.** • Form a parallel plate capacitor with dielectric material filled between the plates. • Multimeter/ ExpEYES can be used to measure the capacitance. (For a significantly measurable value of the capacitance, use plates of dimension 10cmx10cm, or greater) • Change the area of the capacitor plates and verify the relationship of the capacitance on the area (Using the same set of plates, the area can be changed by varying the overlapping region of the plates) • By measuring the capacitance for different areas of the capacitor plates and (or) thickness of the dielectric material,determine the dielectric constant of the given material/liquid. http://www.indosawedu.com/dielectric-constant.php https://www.youtube.com/watch?app=desktop&v=sx0tzAj-Dm4 https://www.youtube.com/watch?v=lKfIkUuFT-U		

Books and References:

1. Concepts of Modern Physics, Arthur Beiser 6th Edition (Book 1)
2. Smartphones as Mobile Minilabs in Physics(Edn. 1) by Jochen Kuhn & Patrik Vogt, Springer, (Book 2)
3. Modern Physics for Scientists and Engineers" by John Morrison
4. Modern Physics by Raymond A. Serway
5. Introduction to Nuclear and Particle Physics - V K Mittal, R C Verma and S C Gupta
6. Introductory Nuclear Physics by Kenneth S. Krane
7. Principles of Nuclear Physics by A. B. Migdal
8. https://phyphox.org/
9. https://physlets.org/tracker/
10. https://expeyes.in/

Mapping of COs with PSOs and POs :

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	3	2	2	1	1	0	3	2	1	1	2	0	0
CO 2	2	3	2	1	1	1	3	3	1	0	2	0	0
CO 3	1	2	3	3	1	1	2	2	2	2	2	0	0
CO 4	1	1	1	3	2	2	2	1	2	2	3	0	0
CO 5	1	2	1	1	3	1	2	2	2	2	3	0	0
CO 6	1	2	1	1	3	2	2	1	2	2	3	0	0

Correlation Levels:

Level	Correlation
0	Nil
1	Slightly / Low
2	Moderate / Medium
3	Substantial / High

Assessment Rubrics:

- Quiz / Discussion / Seminar
- InternalTheory/Practical Exam
- Assignments /Viva
- End Semester Exam (70%)

Mapping of COs to Assessment Rubrics

	Internal Theory/ Practical Exam	Assignment /Viva	Practical Skill Evaluation	End Semester Examinations
CO 1	✓	✓		✓
CO 2	✓	✓		✓
CO 3	✓	✓		✓
CO 4	✓	✓		✓
CO 5	✓	✓		✓
CO 6		✓	✓	