FOUR-YEAR UNDER GRADUATE PROGRAMME (FYUGP)

BSc PHYSICS HONOURS

<table>
<tr><td>Programme</td><td colspan="5">B.Sc. Physics Honours</td></tr>
<tr><td>Course Title</td><td colspan="5">ELECTRONICS I</td></tr>
<tr><td>Type of Course</td><td colspan="5">Core in Major</td></tr>
<tr><td>Semester</td><td colspan="5">II</td></tr>
<tr><td>Academic Level</td><td colspan="5">100 –199</td></tr>
<tr><td rowspan="2">Course Details</td><td>Credit</td><td>Lecture per week</td><td>Tutorial per week</td><td>Practical per week</td><td>Total Hours</td></tr>
<tr><td>4</td><td>3</td><td>-</td><td>2</td><td>75</td></tr>
<tr><td>Pre-requisites</td><td colspan="5">The course usually encompasses proficiency in mathematics, physics, and basic circuit theory, alongside computer literacy and potentially some laboratory experience, ensuring students have the foundational knowledge needed for the course material.</td></tr>
<tr><td>Course Summary</td><td colspan="5">The course provides students with a comprehensive introduction to fundamental concepts in electronics, including circuit analysis, semiconductor devices and digital logic, equipping them with the essential skills and knowledge needed to understand and work with electronic systems.</td></tr>
</table>

Course Outcomes (CO):

CO	CO Statement	Cognitive Level*	Knowledge Category#	Evaluation Tools used
CO1	Define the basic concepts of semiconductor physics, including energy bands, charge carriers, and doping.	Remember	Definitions and basic concepts	Quizzes
CO2	Explain the operating principles of semiconductor diodes, including forward and reverse bias conditions.	Understand	Laws and theories of semiconductor physics	Problem sets, concept maps
CO3	Analyse the applications of semiconductor diodes in rectification, clipping, and clamping circuits.	Analyse	Semiconductor device applications	Research papers, case studies
CO4	Explain the principles of operation of bipolar junction transistors (BJTs) and field-effect transistors (FETs), including their modes of operation and characteristics.	Understand	Laws and theories of semiconductor physics	Problem sets, concept maps
CO5	Apply diode and transistor models to analyse electronic circuits.	Apply	Application of principles	Laboratory experiments, simulations
CO6	Define the basic concepts of digital electronics, including binary number systems, hexadecimal number systems	Remember	Definitions and basic concepts	Quizzes
* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C) # - Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)				

Mapping of COs with PSOs and POs :

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	3	1	0	0	3	0	1	0	0	1	0	0	0
CO2	3	1	0	0	3	0	1	0	0	1	0	0	0
CO3	3	2	3	0	3	0	1	0	1	1	2	0	0
CO4	3	1	3	0	3	0	1	0	0	1	0	0	0
CO5	3	1	0	0	2	1	1	0	0	1	0	0	0
CO6	3	2	3	1	2	1	1	0	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
- Internal Theory / 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	✓	✓		✓

Detailed Syllabus:

Module	Unit	Content	Hrs (45 +30)	Marks (70)
I		SEMICONDUCTOR PHYSICS	10	15
	1	Semiconductor	3	
	2	P N Junction	2	
	3	Break down and Knee Voltage	2	
	4	Special Purpose diodes: LED and Photodiode	3	
	Sections : 5.1 – 5.19, 7.2 – 7.10 of Book 1			
II		SEMICONDUCTOR DIODE APPLICATIONS	10	20
	5	Rectifier	2	
	6	Half Wave and Full Wave Rectifiers	2	
	7	Filter Circuits	2	
	8	Voltage Multipliers	2	
	9	Zener Diode as Voltage Stabiliser	2	
	Sections : 6.8 – 6.28, Book 1			
III		TRANSISTORS	15	25
	10	Transistor	2	
	11	Transistor Connections	3	
	12	Transistor as an amplifier	3	
	13	Faithful Amplification and transistor biasing	3	

	14	Methods of Transistor Biasing – Base resistor method, Voltage Divider method, Design of transistor biasing circuits	4	
	Sections: 8.1 – 8.14, 8.16 – 8.23, 9.1 – 9.16, 9.18, Book 1			
IV	**DIGITAL FUNDAMENTALS**		**10**	
	18	Analog and Digital Signals	2	**10**
	19	Binary Number System	2	
	20	Decimal to Binary Conversion	2	
	21	Hexadecimal Number System	2	
	22	Binary-Coded Decimal Code	2	
	Sections: 26.1 – 26.6, 26.8 – 26.9, 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.			
	1	**Study the V-I characteristics of diodes.** • Characteristics of Ge, Si diodes, LEDs and photodiode. • Reverse characteristics - Germanium diode; AO79 may give better results. • ExpEYES may be used. https://expeyes.in/experiments/electronics/diodeIV.html • Optional: Plot and fit the experimental data with the diode equation in GeoGebra or any other application and calculate the value of the ideality factor of the PN junction.		
	2	**Study the characteristics of Zener diode and construct a voltage regulator.** • Study the V-I characteristics of zener diode and hence determine the breakdown voltage. • https://expeyes.in/experiments/electronics/zenerIV.html • Construct a voltage regulator using a zener diode and determine the percentage of voltage regulation.		

	3	**Study the V-I characteristics of solar cell and find the open circuit voltage, short circuit current and maximum power point.** • Plot the V-I characteristics of solar cell under dark and illuminated conditions and get the open circuit voltage and short circuit current. • Plot voltage-power graph and get the maximum output power point. • Optional: find the efficiency of the solar cell, if a standardized light source is available. • ExpEYES may be used. Solar cell of voltage rating 3V and current rating of the order of 100mA is desirable for the study. • https://expeyes.in/experiments/electronics/diodeIV.html		
	4	**Construction of the Half Wave Rectifier.** • Construct a half wave rectifier. Breadboard may be used for the easy replacement of the filters. • Observe the waveforms without filter and with filter capacitors of four different values (4.7uF, 10uF, 47uF, 100uF) using CRO/ExpEYES. Measure the voltages and calculate the ripple factor. • Observe the variation of the ripple factor when filters of different values are used, by maintaining a low value of the load resistance.		
	5	**Construction of the center tapped full wave rectifier and regulated power supply.** • Construct a center tapped full wave rectifier without filter and with a filter. • Connections may be realized through soldering, to get an experience of soldering. • Measure the AC and DC voltages using a multimeter and calculate the ripple factor without and with a filter. • Observe the variation of the ripple factor with load resistance, when filter is used. • Construct 5V/12V regulated power supply using 78XX IC.		
	6	**Construction of the Bridge rectifier.** • Construct a bridge rectifier. Breadboard may be used for the easy replacement of the filters. • Observe the waveforms without filter and with filter capacitors of four different values (4.7uF, 10uF, 47uF, 100uF) using CRO. Measure the voltages and calculate the ripple factor. • Observe the variation of the ripple factor when filters of different values are used, by maintaining a low value of the load resistance.		
	7	**Realize clipping and clamping circuits using diodes and observe the waveforms.**		

		• Construct circuits using ordinary and zener diodes to clip the top, or bottom, or both of a waveform at a particular dc level. • Construct positive and negative clamper circuits and analyse the waveforms using CRO/ExpEYES. • https://expeyes.in/experiments/electronics/clipping.html https://expeyes.in/experiments/electronics/clamping.html		
	8	**Transistor input, output & transfer characteristics in CE configuration.** • Draw the static characteristics of the transistor in common emitter configuration and calculate input/output resistance and the current gain. • ExpEYES may be used https://expeyes.in/experiments/electronics/npn.html		
	9	**Construction of voltage multiplier (Doubler and Tripler).** • Construct the voltage doubler and tripler using diodes and capacitors and study the variation of ripple factor with respect to the capacitance values.		
	10	**Study the characteristics of LDR.** • Measure the dark resistance of LDR • Place LDR at different distances from an electric lamp and measure its resistance. Plot light intensity ($E\alpha\frac{1}{r^2}$) vs LDR resistance. • Optional: Construct a dark sensor using LDR and transistor. In order to turn on the LED in the desired light intensity, an adjustable resistor can be used in the circuit.		

Books and References:

1. Principles of Electronics by V K Mehtha and Rohith Mehtha (Book 1)
2. Electronics lab manual by K A Navas (vol 1 & 2)
3. Electronic Devices and Circuit Theory by Robert L. Boylestad and Louis Nashelsky
4. Electronic Principles by Albert Malvino and David J. Bates
5. Analog Electronics: Devices, Circuits, and Techniques by Chitralekha Mahanta
6. Basic Electrical and Electronics Engineering by R.K. Rajput
7. Semiconductor Devices: Physics and Technology by S. M. Sze

PHY2MN104 - Optics and Lasers

Programme	**B.Sc. Physics Honours**				
Course Title	**OPTICS AND LASERS**				
Type of Course	**Minor (SET IV: OPTICAL 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. Basics of Physics and Chemistry (Plus Two Level)				
Course Summary	This course explores light's properties, reflection, refraction, and applications in phenomena like interference, diffraction, polarization, and lasers.				

			PSO 1	PSO 2	PSO 3	PSO 4	PSO 5	PS O6	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	Explain the fundamentals properties of light, including reflection, refraction, and the electromagnetic spectrum.	Understand	2	1	0	0	1	1	2	1	0	1	0	1	0
CO 2	Apply the laws of reflection and refraction to solve problems involving mirrors and lenses.	Apply	2	2	1	0	1	1	2	1	0	1	0	1	0
CO 3	Analyse the behaviour of light waves using concepts like interference and diffraction, recognize different types of polarization and explain methods for producing and manipulating polarized light.	Analyze	2	2	2	0	2	2	2	1	0	1	1	1	0

CO 4	Apply the knowledge of optics and lasers to understand real-world applications in different fields.	Analyze	2	1	1	0	1	1	2	1	0	1	1	1	0
CO 5	Analyse the light waves and different phenomena's that can be used to study the behaviour of light waves.	Understand	2	1	1	0	2	2	2	1	0	1	1	1	0
CO 6	Through practical experiments and theoretical analysis, students will explore applications of the laws of reflection, refraction, interference, diffraction, polarization and determining the wavelength of light using laser applications.	Evaluate	2	2	1	0	3	2	2	1	1	1	1	1	0

Detailed Syllabus:

Module	Unit	Content	Hrs (45 +30)	Marks (70)
I	**Introduction**		**7**	**15**
	1	Properties of light, Laws of reflection, laws of refraction	2	
	2	Refractive index, Optical path, Electromagnetic spectrum and visible light	3	
	3	Photons, Dual nature of light	2	
	Sections 1.5 – 1.12, Book 1			
II	**Ray optics**		**10**	**15**
	4	Reflection at plane Mirrors	1	
	5	Reflection at spherical mirror: Basic terms and sign convention, spherical mirror equation (No derivation) , Focal point and focal length	2	
	6	spherical mirror equation Applied to concave mirror convex mirror and plane mirror	3	
	7	Refraction at spherical surfaces, Gaussian relation	2	
	8	Lens equation, Lens maker's equation.	2	
	Sections 3.3, 3.4, 3.12, 4.8 - 4.10, Book 1			
III	**Wave optics**		**20**	**25**

	9	Interference, Young double slit experiment	2	
	10	Coherence and conditions for interference	1	
	11	Interference in thin parallel films	2	
	12	Interference in wedge shaped film, Angle of wedge and thickness of spacer, Colour of thin films	2	
	13	Newton's rings: determination of wavelength of light	2	
	14	Diffraction: Difference between diffraction and interference, Fresnel and Fraunhoffer type diffraction	1	
	15	Fraunhoffer diffraction at a single slit, double slit (Calculus method is excluded), Plane diffraction grating.	3	
	16	Polarization: Types of polarization, Brewster's law	2	
	17	Production of plane polarized light	1	
	18	Polarizer and analyser, Malu's law, Double refraction	2	
	19	Optical activity and specific rotation	2	
	Section 14.4 – 14.7,15.2, 15.5, 15.6, 17.6 - 17.7, 18.1, 18.2, 18.4, 18.7, 20.1, 20.2, 20.5, 20.6, 20.8 - 20.11, 20.27 - 20.29, Book 1			
IV	**Quantum optics**		**8**	**15**
	20	Lasers, Thermal equilibrium, Absorption of a Photon, Spontaneous emission, Stimulated emission, Population inversion	3	
	21	Components of Laser and lasing action	2	
	22	Ruby laser, Nd-YAG laser, Helium Neon laser, Carbon dioxide laser, semiconductor laser.	3	
	Sections 22.1, 22.3, 22.4, 22.7, 22.8, 22.9, 22.14, 22.15, 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	**Determine the refractive index of (a) given liquid and (b)the material of a lens, by forming a liquid lens.** • Through this experiment the students are expected to get the concepts of image formation, combination of lenses and radius of curvature of the surface of lens. • Determine the radius of curvature of the lens by Boy's method and hence calculate the refractive indices.		
	2	**Determine the focal length of the combination of two lenses separated by a distance.** • Determine the focal lengths, f1 and f2 of the two lenses using an illuminated cross-slit screen holder, nodal slide(for placing the lenses) and plane mirror arrangement. • Place the two lenses separated by a distance d, determine the focal length, F of the combination and verify the relation • $\frac{1}{F} = \frac{1}{f1} + \frac{1}{f2} - \frac{d}{f1f2}$. • The combination of the lenses in the eyepiece of the spectrometer/ travelling microscope may be used for the study. • https://www.youtube.com/watch?v=IO1EEtyNPBg • https://www.youtube.com/watch?v=tNo4Ipk74SU		
	3	**Determination of the dispersive power of a solid prism using a spectrometer.** • Find the angle of the prism and the angle of minimum deviation for prominent lines of the mercury spectrum using a spectrometer. • Calculate the refractive indices corresponding to the colors and find the dispersive power of the material of the prism for two pairs of wavelengths.		
	4	**Refractive indices of quartz prism using spectrometer.** • Determine the refractive indices of quartz for the ordinary and extraordinary rays of a sodium vapour lamp by arranging the quartz prism at minimum deviation position in the spectrometer. • Verify the polarizations of the ordinary and extraordinary rays using a polaroid.		
	5	**Determination of wavelengths of mercury spectrum using diffraction grating and spectrometer.** • Arrange the grating at normal incidence. • Standardize the grating using the green line of mercury and then find the wavelengths of other prominent lines of the spectrum.		
	6	**Newton's rings-determination of the wavelength of sodium light** • Form of Newton's rings in the air-film in between a plano-convex lens and a glass plate using sodium-source.		

		• Determine the radius of curvature by Boy's method and determine the wavelength of the source. • Optional: In experiment 5 and 6, record a short video of the interference pattern, calibrate the video using scale marked on the glass plate, analyse the video using Tracker tool. From the intensity profile get the locations of the dark rings and calculate the wavelength of the source/thickness of the sample https://physlets.org/tracker/. https://www.youtube.com/watch?v=UCCPkJpUQEw		
	7	**Air wedge-determination of the radius of a thin wire/human hair/thin foil.** • Form interference fringes using sodium-source, in the air-film in between wedge formed by placing the given sample between the glass plates. • Measure the positions of the successive dark bands using a travelling microscope and determine the angle of the wedge and thickness of the sample given.		
	8	**Wavelength of laser using grating** • The laser light diffracted from the transmission grating is allowed to fall on a screen and record the maxima points in a paper and calculate the wavelength of the laser. • Determine the number of lines/ meter of the grating using the green line of the mercury		
	9	**Single slit diffraction using laser - Determination of slit width.** • The laser light diffracted from the narrow slit is allowed to fall on a screen and record the maxima or minima points in a paper. • From the width of the central maxima or the position of minimum intensity points, calculate the slit width. • Verify the slit width using a traveling microscope. • Wavelength of laser can be found using diffraction grating of known N.		
	10	**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.		
	11	**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		
	12	**Spectrometer-Determination of the Cauchy's constants of the given prism** • Find the angle of the prism, the minimum deviation angles of the prominent lines of the mercury spectrum and hence calculate the refractive indices for the colors. • Determine A and B from the • $\mu - \frac{1}{\lambda^2}$ graph.		
	13	**Determine the numerical aperture (NA) of an optical fiber using a laser** • Couple the light from the laser source onto one of the fiber ends and the light coming from the other end is allowed to fall on a screen(sheet having circular markings) placed perpendicular to the axis of the fiber. • Measure the diameter of the laser beam on the screen and the distance between the screen and fiber output end and hence calculate the NA.		
	14	**Determination of the Velocity of Sound in Air.** • Sound wave of known frequency is generated using a wave generator(WG) and piezo buzzer and are recorded using a microphone(MIC). • Phase differences between the WG and MIC waveforms were analyzed in a CRO and the distance between them were adjusted to make both of them in phase and hence calculate velocity of sound. • Phase difference can be analyzed from the Lissajous figure obtained by X-Y plotting of WG and MIC waves. • ExpEYES may be used. • https://expeyes.in/experiments/sound/velocity.html • https://expeyes.in/experiments/electrical/xyplot.html		
	15	**Transformation of Energy from One Form to Another.** • Roll a hollow cylinder from a height, in an inclined plane, without pushing. • Measure radius of the cylinder and record the velocity of the cylinder using the gyroscope of the phone inserted into the cylinder.		

		• Calculate the total energy before the cylinder starts to roll (Potential Energy, mgh) • Calculate the total energy (Translational KE + Rotational KE) when the cylinder reaches the bottom of the plane. • Estimate the energy lost as heat and sound. Repeat the experiment for different heights. • Experiment 23 for Book 4 • https://phyphox.org/experiment/roll/#more-509		

Books and References:

1) A Textbook of Optics by N. Subramanyam, Brij Lal, M N Avadhanulu (25TH EDITION) (Book 1)
2) Optics by Ajoy Ghatak, Tata McGrow-Hill (Book 2)
3) Optics by Eugene Hecht, Addison-Wesley (Book 3)
4) Smartphones as Mobile Minilabs in Physics(Edn. 1) by Jochen Kuhn & Patrik Vogt, Springer, (Book 4)
5) https://phyphox.org/
6) https://physlets.org/tracker/

MDC - DEPARTMENT OF PHYSICS

ASTRONOMY AND STARGAZING

PHY2F M 106

CO	CO Statement	Cognitive level	Knowledge category	Evaluation tools used
CO1	Introduction to Astronomy and an overview of ancient models to the modern astronomical theories.	U	C	Instructor-created exams / Quiz
CO2	Apply observational techniques and methods to effectively navigate the night sky. Understanding the milky way galaxy, planets and phases of the moon	Ap	P	Instructor-created exams / Quiz
CO3	Understanding the solar system and Its formation. Understanding how seasons happen. Overview about solar eclipse.	U	C	Observational Home Assignment / Viva Voce
CO4	Overview of constellations and stars, Seasonal sky gazing	Ap	P	Demonstration Skills / Viva Voce
CO5	Foster an interest in science. Develop a scientific temper, curiosity and a sense of wonder about the universe.	Ap	P	Instructor-created Home Assignments

* - Remember (R), Understand (U), Apply (Ap), Analyse (An), Evaluate (E), Create (C)

- Factual Knowledge(F) Conceptual Knowledge (C) Procedural Knowledge (P) Metacognitive Knowledge (M)

Module	Unit	Content	Hrs (36+9)	Marks (50)
I		**Astronomy- an overview**	**10**	**15**
	1	Ancient Astronomy- Astronomy around the World, Early Greek and Roman Cosmology, Ptolemy's Model of the Solar System, Astrology and Astronomy- The Beginnings of Astrology, The Horoscope, Astrology Today	2	
	2	The Celestial Sphere, Celestial Poles and Celestial Equator, Rising and Setting of the Sun, Fixed and Wandering Stars, Constellations	2	
	3	The Birth of Modern Astronomy-Copernicus, The Heliocentric Model, Galileo and the Beginning of Modern Science, Galileo's Astronomical Observations, Kepler's Laws of Planetary Motion, Orbits in the Solar System	3	
	4	Telescopes, How Telescopes Work, Formation of an Image by a Lens or a Mirror	1	
	5	The Nature of Astronomy, The Nature of Science, The Laws of Nature, Numbers in Astronomy, A Tour of the Universe, The Universe on the Large Scale, The Universe of the Very Small, A Conclusion and a Beginning	2	
	Sections 1.1-1.4, 1.6-1.9, 2.1-2.4, 3.1,3.4, 6.1 of Book 1			
II		**Step into the Sky**	**6**	**10**
	6	Darkness and Light, Finding Your Way around the Sky, Cosmic Protractor, Special Effects, Night Vision, The Milky Way	2	
	7	Moon: Phases of Moon, Characteristics, Moonrise, Moonset, Moon Illusion	1	
	8	Sightseeing on the moon, Lunar topography, Formation	2	
	9	Lunar Eclipse	1	
	Chapter 1 & 2 of Book 2			
III		**Sun and Planets**	**10**	**12**
	10	Sun, How seasons happen, Sun paths, Telling time by the Sun	1	
	11	A visit to the sun, Power house, Storms on Sun, How the Sun formed, Our sun is born	2	

	12	Solar Eclipse, How Are Eclipse of the Sun and Moon the Same-and Different? Why Can't We Look at the Sun? What to take eclipse-watching?	1	
	13	Planets: Earth's siblings in the sky, Star or Planet? Sky Wanderer, Roaming around Solar system	2	
	14	Terrestrial & Jovian Planets, Small solar system Bodies, Meet the eight planets	2	
	15	How the Solar System Formed, Comets, Other suns and their Solar Systems	2	
	Chapter 3 & 4 of Book 2			
IV	**Stars, constellations & stellar evolution**		**10**	**13**
	16	Stars and Constellations: How stars move during the night, North star	2	
	17	North & South Using the Stars, The Zodiac and the Ecliptic, Rasis & Nakshatras	2	
	18	Seasonal Sky gazing Northern Hemisphere - November, December & January Stars. (Constellations Orion, Canis Major, Lepus, Taurus, Gemini, Auriga)	3	
	19	How Stars Are Born, Live, and Die, Meteor Shower. Deep Sky Objects.	3	
	Chapter 5 of Book 2 and Chapter 3 & 10 of Book 3			
V	**Open Ended Module: Hands-on Astronomy**		**9**	
	1	• Demonstrations using Stellarium or any other sky guide apps – constellations, eclipses, planetary alignment etc. https://va-iitk.vlabs.ac.in/?page=exp1 • Citizen science projects like Galaxy-zoo • Smartphone Astrophotography		
	References 4-7			

Books and References:

1. Astronomy 2e by Andrew Fraknoi, David Morrison, and Sidney C. Wolff, OpenStax CNX (Book 1) https://open.umn.edu/opentextbooks/textbooks/390
2. Sky Gazing- A Guide to the Moon, Sun, Planets, Stars, Eclipses, and Constellations by Meg Thacher, Storey Publishing. (Book 2)
3. The Joy of Skywatching by Biman Bose, National Book Trust , India. (Book 3)
4. https://stellarium.org/
5. https://va-iitk.vlabs.ac.in/?page=exp1
6. https://www.zooniverse.org/projects/zookeeper/galaxy-zoo/
7. A Guide to Smartphone Astrophotography by Dr. Sten Odenwald, a free e-book from NASA https://spacemath.gsfc.nasa.gov/SMBooks/AstrophotographyV1.pdf