Rayat Shikshan Sanstha's

Yashavantrao Chavan Institute of Science, Satara

Lead College of Karmaveer Bhaurao Patil University, Satara

Syllabus for B.Sc. II Physics

As per

NEP 2020

w. e. f. 2024-25

1. Title: Physics

2. Year of Implementation: The syllabus will be implemented from June, 2024.

3. Duration: The course shall be a full time.

4. Pattern: Semester examination.

5. Medium of Instruction: English

6. Structure of Course:

B.Sc. II Semester III

Sr. No.	Course Title	Theory			Practical		
		Course Code	Lectures per week	Credit	Course Code	Lectures per week	Credit
1	**Heat and Thermal Physics**	**BPT 231**	2	2	**Practical BPP233**	4	2
2	**Waves, Oscillations and Sound**	**BPT 232**	2	2	**Practical BPP234**	4	2

B.Sc. II Semester IV

Sr. No.	Course Title	Theory			Practical		
		Course Code	Lectures per week	Credit	Course Code	Lectures per week	Credit
1	**Modern Physics and Electronics**	**BPT 241**	2	2	**Practical BPP243**	4	2
2	**Optics and Lasers**	**BPT 242**	2	2	**Practical BPP244**	4	2

B: B.Sc. P: Physics T: Theory, P: Practical

7. Titles of Courses of B.Sc.II:

B.Sc. II (Semester III)

Theory: 30 lectures, 30 hours (for each Course)

Course – V: BPT 231 HEAT AND THERMAL PHYSICS:

Course – VI: BPT 232 WAVES, OSCILLATIONS AND SOUND

Practical: 30 lectures: 30 hours (for each Course)

Practical Course: BPP233: HEAT AND THERMAL PHYSICS

BPP234: WAVES, OSCILLATIONS AND SOUND

B.Sc. II (Semester IV)

Theory: 30 lectures, 30 hours (for each Course)

Course – VII: BPT241: MODERN PHYSICS AND ELECTRONICS

Course – VIII: BPT242: OPTICS AND LASERS

Practical: 30 lectures: 30 hours (for each Course)

Practical Course: BPP243: THERMAL PHYSICS

BPP244: OPTICS AND LASERS

Physics Major

B.Sc. II

Semester – III

Course – V: BPT 231: Heat and Thermal Physics

Course Objectives: Student should be able to:

1. Understand kinetic interpretation of temperature, Andrew's Expt. and different types of thermometers.
2. Study kinetic theory of gasses and the concept of Transport phenomena.
3. Explain thermo-dynamical state, thermodynamic equilibrium, various thermodynamic processes and first law of thermodynamics.
4. Verify thermodynamic Potential, Maxwell's Relations and applications.

Credits (Total Credits 2)	**SEMESTER-III BPT231 Heat and Thermal Physics**	**No. of hours per unit/credits**
UNIT - I	**Ideal, Real Gas and Thermometry**	**(8)**
	• Kinetic Interpretation of temperature, Andrew's experiment and curve, critical constants, Relation between critical constants and Van der waal's constants, Reduced equation of state. • Principle of thermometry, types of thermometers, Scales of temperature (Celsius, Kelvin, Fahrenheit and Rankine), • Mercury thermometer, Thermoelectric thermometer, Platinum resistance thermometer, • Thermistor.	
UNIT - II	**Kinetic Theory of Gases and Transport Phenomena**	**(8)**
	• Review, Derivation of Maxwell's law of distribution of velocities and its experimental verification, • Mean free path, Transport phenomena-Transport of momentum(viscosity), Transport of thermal energy (conduction), Transport of mass (diffusion), • Degrees of freedom, Law of equipartition of energy (No derivation) and its application to specific heat of gases (mono and diatomic).	
UNIT - III	**Thermodynamics**	**(7)**

	• Second law of thermodynamics (Explanation and different statements), Carnot's ideal heat engine, • Carnot cycle (working and efficiency), Carnot's theorem, Entropy (concept and significance), • Entropy changes in reversible and irreversible processes, Entropy –Temperature diagram, • Third law of thermodynamics, Heat Engines in practice, Rankine cycle, • Steam Engine, • Internal Combustion Engine a) Otto Engine b) Diesel Engine.	
UNIT - IV	**Thermodynamic Potential**	**(7)**
	• Enthalpy, Gibbs function, Helmholtz and Internal Energy function, • Maxwell's Relations and applications, Joule –Thompson effect, Clausius- Clapeyron Equation, • Expressions for (Cp- Cv) and Cp/ Cv , TDS equation.	

Course Outcomes: Students will be able to:

1. Explain the concept of mean free path, Transport of momentum, thermal energy and mass
2. Evaluate Andrew's expt., Curve and different types of thermometers
3. Differentiate otto engine and diesel engine and apply the concept of entropy
4. Analyze Enthalpy and TDS equation

Reference Books :

1. J. P. Agrawal and Satya Prakash, Heat Thermodynamics and Statistical Physics, 2018,Pragati Prakashan.
2. M.W. Zemansky and R. Dittman, Heat and Thermodynamics, 2011, Tata McGraw-Hill Education Pvt. Ltd., 8th
3. J. B. Rajam and C. L. Arora, Text book of Heat and Thermodynamics, 2009, S. Chand and Company Ltd Publisher
4. D. S. Mathur, Heat and Thermodynamics, 2008, S. Chand and Sons Ltd. Publisher
5. .Brijlal and N. Subramanyam, , Heat and Thermodynamics, 2001, S.Chand and Company Ltd. Publisher.
6.
7. Meghnad Saha and B.N. Srivastava, A treatise on Heat, 1935, Indian Press Ltd., 2nd edition.

Course – VI: BPT 232; Waves, Oscillations and Sound

Course Objectives: Students should be able to:

1. Understand SHM and its solution, superposition principle and Lissajous figures and their uses.
2. Study travelling and standing waves on a string, plane waves and spherical waves.
3. Study transducers and their types, to understand concept of acoustics of buildings, Sabine's experimental work and reverberation time.
4. Understand the Piezo-electric effect, detection of Ultrasonic waves and applications of Ultrasonic waves.

Credits (Total Credits 2)	**SEMESTER-III BPT 232 Waves, Oscillations and Sound**	**No. of hours per unit/credits**
UNIT - I	**Oscillations**	**(8)**
	• Simple harmonic motion, Differential equation of SHM and its solutions, Kinetic and potential energy, • Kater's pendulum, Damped oscillations, Superposition of two collinear harmonic Oscillations: • Linearity and superposition principle • Oscillations having equal frequencies along the line and • Oscillations having different frequencies along the same straight line (beats), • Lissajous figures with equal and unequal frequencies and their uses.	
UNIT - II	**Wave Motion**	**(8)**
	• Transverse waves on a string, traveling and standing waves on a string, normal modes of a string, • Laws of vibration, Energy density and energy transport of transverse wave along a stretched string, • group velocity, phase velocity, plane waves and relation between them, • spherical waves, • intensity of a wave	
UNIT - III	**Sound**	**(7)**

	• Acoustics Transducers (Qualitative), pressure microphone, moving coil loudspeaker, Digital audio system. • **Acoustics of Buildings:** Reverberation time, factors affecting acoustics of buildings, • Sabine's experimental work and formula, • optimum reverberation time, • Requirements of good acoustics.	
UNIT - IV	**Ultrasonic Waves**	**(7)**
	• Piezo-electric effect, Magnetostriction effect, • production of ultrasonic waves- magnetostriction oscillator, Piezo-electric oscillator, • detection of ultrasonic waves :Kundt's tube. sensitive flame method, thermal detector, quartz crystal method, Magnetostrictive method, • Applications of ultrasonic waves	

Course Outcomes: Students will be able to:

1. Explain superposition principle, Lissajous figures and their uses
2. Understand plane waves, spherical waves
3. Differentiate concept of acoustics of buildings, Sabine's experiment and reverberation time.
4. Analyze detection of ultrasonic waves and their applications.

Reference Books:

1. Subrahmanyam and Brijlal, 2018, *A text book of Sound*, 2nd edition, S. Chand Publisher.
2. Satya Prakash, 2017, *Oscillations and Waves*, Pragati Prakashan.
3. D. Chattopadhyay, 2016, *A Treatise on oscillations, waves and acoustics*, Books and allied Pvt. Ltd. Publisher.
4. J. Walker, David Halliday and Robert Resnick, 2014, *Principles of Physics*,10thedition, Wiley Publisher.
5. Halliday and Resnick, 2011, *Fundamentals of Physics Volume 1*, 9thedition, Wiley Publisher.
6. D. S. Mathur, 2010, *Elements of properties of matter*, S. Chand and Co Ltd. Publisher.
7. D. R. Khanna and R. S. Bedi, 1971, Textbook *of Sound*, Atma Ram and Sons Publisher.

Practical Paper: BPP 233; Thermal Physics

BPP 234; Waves, Oscillations, Sound

Course Objectives: Student should be able to:

1. Learn measuring skills in practical.
2. understand the principles of Lee's method and Searle's apparatus for measuring thermal conductivity
3. Gain practical experience in studying the variation of thermo-electromotive force (emf) with temperature across thermocouple junctions.
4. learn practical experience in verifying laws of probability distribution through coin tossing experiments.
5. understand the principles of coupled oscillations and bifilar pendulum.
6. Gain practical experience in generating and observing Lissajous figures using oscilloscopes and signal generators.
7. Learn how log decrement measurements can be used to characterize damping in oscillatory systems.
8. Learn how microphone directionality affects sound capture and reproduction in various applications.

Credits: 02	**SEMESTER-III BPP 233** **Thermal Physics**	**No. of hours per unit** (60)
	1. To determine Coefficient of Thermal Conductivity of a bad conductor by Lee's method. 2. To determine Coefficient of Thermal Conductivity of copper by Searle's apparatus. 3. To study the variation of thermo-emf with temperature across two junctions of a thermocouple. 4. To determine the temperature coefficient of resistance of a given coil by P. O. box. 5. Temperature coefficient of resistance by Platinum resistance thermometer. 6. To determine the thermal conductivity of a metal rod by Forbe's method. 7. To determine Coefficient of Thermal Conductivity of glass in the form of a tube. 8. To determine the specific heat of a liquid (turpentine oil) by law of cooling. 9. To determine the ratio of specific heat of air by Clement and Desorme's method. 10. Determination of Stefan's constant/ Verification of Stefan's law. 11. Study of temperature coefficient of Thermistor. 12. To determine Mechanical Equivalent of Heat J by Callendar and Barne's constant flow method.	**03 Hrs / Practical**

	13. To verify the laws of Probability Distribution and to verify laws of probability of throwing one coin, two coins and then coins (or more). 14. The study of Statistical Distribution from the given data and to find most probable, average and rms values. 15. To compare heat transfer between different material surface and the black body surface by radiation and find the emissivity of different material surfaces. 16. To determine the mechanical equivalent of heat by Searle's method. 17. To verify Newton's law of cooling. 18. Calibration of thermocouple by potentiometer. 19. Computer Simulation of black body radiation -PHET sim. 20. Computer Simulation - isothermal, adiabatic, isobaric and isochoric processes - PHET sim.	
Credits: 02	**BPP 234 Waves, Oscillations & Sound**	**No. of hours per unit** (60)
	1. To investigate the motion of coupled oscillations. 2. To determine acceleration due to gravity by using Bifilar Pendulum. 3. To study Lissajous figures. 4. Measurement of velocity of sound by Kundt's tube method. 5. Measurement of Velocity of Sound by CRO. 6. Measurement of velocity of sound by Kundt's tube method. 7. Measurement of Velocity of Sound by Resonating Bottle. 8. Measurement of log decrement by Exponential Decay. 9. To determine velocity of transverse waves using a sonometer. 10. To study directional characteristics of the microphone. 11. To verify the laws of transverse vibration using Melde's apparatus. 12. To determine the frequency of A.C supply by Melde"s experiment. 13. Determination of the force constant of a helical spring by plotting a graph between mass and square of time period by the method of oscillation. 14. Study the factors affecting the period of a simple pendulum. 15. Study the damping effect on oscillations of the pendulum or spring-mass system. 16. To determine the coefficient of damping and relaxation time of a damped simple harmonic motion using a simple pendulum. 17. To determine the restoring force per unit extension of a spiral spring by statistical and dynamical methods. 18. Study of damped oscillation to calculate damping coefficient using torsional pendulum immersed in a liquid. 19. Computer Simulation of oscillating mass - measurement of temperature and energy - PHET sim. 20. Computer Simulation of normal modes of vibration - PHET sim.	**03 Hrs / Practical**

Course Outcomes: Students will be able to:

1. learn measuring skills in practical
2. demonstrate an understanding of various methods used to measure thermal conductivity, including Lee's method, Searle's apparatus, and Forbes' method.
3. develop an understanding of the thermal properties of various materials, including metals, insulators, and liquids, and their significance in practical applications.
4. learn to apply statistical methods to analyze data and evaluate uncertainties in experimental measurements.
5. acquire practical skills in setting up and conducting experiments to investigate the motion of coupled oscillations, determine acceleration due to gravity, generate Lissajous figures, and measure sound velocity using various methods.
6. develop the ability to analyze and interpret experimental data related to oscillatory systems, including log decrement measurements, Lissajous figures, and directional characteristics of microphones.
7. develop understanding of wave phenomena, including the propagation of sound waves and transverse waves, and their measurement using experimental setups.

Practical reference Books:

1. H. Singh and P. S. Hemne, 2011, *B.Sc. Practical Physics*, 4thed , S. Chand Publication.
2. S. L. Gupta and V. Kumar, 2010,*Practical Physics, 27thed, Pragati Prakashan*
3. *D. Chattopadhyay* ,P. C. Rakshit,2005,An Advanced course in Practical Physics, New Central Book Agency Pvt. Ltd. ition.
4. C. L Arora, 1957, *B.Sc. Practical Physics,* S. Chand Publication
5. Marsh W. White , Kenneth V. Manning ,1954, *Experimental College Physics* , 3rd ed, McGraw Hill Higher Education.
6. B.L. Worsnop ,H.T. Flint,1951, *Advanced Practical Physics for Students* , 9th ed., Littlehampton Book Services Ltd.

SEMESTER- IV

Course VII: BPT 241 Modern Physics and Electronics

Course Objectives: Students should be able to:

1. Understand special theory of relativity
2. Study wave particle duality
3. Study various characteristics of transistor
4. Study various types of oscillators

Credits (Total Credits 2)	**SEMESTER-IV BPT241 Modern Physics and Electronics**	**No. of hours per unit/credits**
UNIT - I	**Special theory of Relativity**	**(8)**
	• Inertial and Non-Inertial frame of references, • Galilean transformation equations, • Michelson- Morley experiment, Ether hypothesis, • Postulates of special theory of relativity, • Lorentz transformation equations, • Relativistic addition of velocities, Length contraction, Time dilation, variation of mass with velocity, mass energy relation.	
UNIT - II	**Matter Waves**	**(8)**
	• Wave particle duality, De-Broglie hypothesis of matter waves, Derivation of wavelength of matter wave, • Concept of wave packet, • Davisson and Germer experiment, Uncertainty principle (statement only): position–momentum and energy- time, • Application of uncertainty principle non existence of free electrons in the nucleus.	
UNIT - III	**Transistor**	**(7)**
•	• Revision of Bipolar Junction Transistor (BJT), • Single stage common emitter transistor amplifier, • Frequency response curve of an amplifier, • negative and positive feedback, • Effect of negative feedback on the gain response curve, • Problems.	
UNIT - IV	**Oscillator**	**(7)**

	• Introduction, Types of waves, Oscillations from tank circuit, • Barkhausen's criterion for sustained oscillations, • Phase shift oscillator, • Colpitt's oscillator, • Problems.	

Course Outcomes: Students will be able to:

1. Explain postulates of special theory of relativity
2. Understand concept of wave packet and Uncertainty principle
3. Differentiate negative and positive feedbacks in transistor
4. Analyze oscillators and oscillations

Reference Books:

1. Albert Einstein, Relativity: The Special and the General Theory (Fingerprint Publishing, 2017) 2-62.
2. NouredineZettili, Quantum Mechanics Concept and Applications (A John Wiley and Sons Ltd Publisher, 2nd edition, 2009) 10-222.
3. G. Aruldas, Quantum Mechanics (Prentice Hall India Learning Private Limited Publisher, 2nd edition, 2008) 4-48.
4. Robert Resnick, Introduction to Special Relativity (Wiley; 1st edition, 2007) 1-188.
5. V.K. Mehta, Rohit Mehta, Principles of Electronics (S Chand; 10th Rev. Edn. 2006 edition, 2005) 33-541.

Course VIII: BPT242 Optics and Lasers

Course Objectives: student should be able to:

1. Understand the concept of cardinal points, working of Searle's goniometer, optical magnifications, difference between resolving and magnifying powers.
2. Study division of amplitude, division of wavefront, formation of interference in various films, Fresnel diffraction, Fraunhofer diffraction and a convex lens.
3. Understand structure and types of optical fibers, principle and working of fiber optic communication system, working of some lasers and idea of Holography.
4. Understand polarization principle, construction and working of polarimeter.

Credits: 2	**SEMESTER-IV** **BPT 242** **Optics and Lasers**	**No. of hours per unit/credits**
UNIT - I	**Geometrical optics**	**(8)**
	• Definition and properties of cardinal points of a lens system, coincidence of principal points and nodal points, • Image formation by cardinal points, Newton's formula, relation between focal lengths of an optical system, • axial, lateral and angular magnifications; Abbe's sine condition.	

	• **Resolving power** Resolving power, Rayleigh's criterion for the limit of resolution, • comparison between magnifying power and resolving power, • resolving power of plane diffraction grating, resolving power of prism.	
UNIT - II	**Interference of light**	**(8)**
	• Principle of superposition of waves, Division of amplitude, division of wavefront, • interference in thin parallel films due to reflected light, • wedge shaped films, • Newton's rings, its applications for ndetermination of wavelength of light and R.I. of liquid.	
UNIT - III	**Diffraction and Polarization of light**	**(7)**
	• Introduction and types of diffraction, • Fraunhofer diffraction and Fresnel diffraction: • plane diffraction grating, theory of plane diffraction grating, its application to determine wavelength of monochromatic light. • **Polarization** : Introduction, Types of polarization, Polarization by double refraction, • Huygens explanation of double refraction through uniaxial crystals, • optical rotation laws of rotation of the plane of polarization, polarimeter.	
UNIT - IV	**Laser system**	**(7)**
	• Absorption, spontaneous and stimulated emission, • Einstein coefficients (only definitions), • population inversion, optical and electrical pumping, properties of lasers, • Ruby laser, • Helium-Neon laser, • uses of laser, idea of holography(qualitative treatment only).	

Course Outcomes: Students will be able to:

1. Explain cardinal points, working of Searle's goniometer and optical magnifications
2. Understand Fresnel diffraction, Fraunhofer diffraction, half period zones, zone plates and difference between zone plate and a convex lens.
3. Differentiate structure and types of optical fibers, principle and working of fiber optic communication system.
4. Analyze principle, construction and working of polarimeter.

Reference Books:

1. J. P. Agarwal, 2017. *Physical optics and lasers,* 13th edition,Pragati Prakashan.
2. Brij Lal, M. N. Avadhanulu and N. Subrahmanyam. 2012. A *Textbook of Optics.* 25th edition. S. Chand Publisher,
3. Thyagarajan, K., and AjoyGhatak. 2011. *Lasers Fundamentals and Applications*, 2nd edition, Springer Science and Business Media Publisher.
4. Laud, B. B. 2011. *Lasers and non-linear optics*. New Delhi: New Age International Publishers.
5. Longhurst, R. S. 1967. *Geometrical and physical optics*. 2ndedition, New York: Wiley.
6. AjoyGhatak, 2008. *Optics*. 4th edition, McGraw Hill Education India Pvt Ltd.
7. R. Murugeshan and K. Sivaprasath, 1997. *Optics and Spectroscopy*, 10th edition, S. Chand Publisher.
8. Mathur, B. K. 1964. *Principles of optics*. Kanpur: Gopala Printing.

Practical Paper: BPP 243: Modern Physics & Electronics
BPP 244: Optics and Lasers

Course Objectives: Students should be able to:

1. Develop practical skills.
2. Understand the principles of CE (Common Emitter) amplifier configuration.
3. Learn methods for determining the frequency of oscillation.
4. Gain practical skills in constructing and testing the oscillator using BJT.
5. Gain practical experience in measuring and analyzing gain variation.
6. Understand the concept of cardinal points in optics.
7. Gain practical experience in using a goniometer to measure the equivalent focal length of compound optical systems.
8. Learn how Cauchy's constants relate to the optical properties of materials.
9. Understand the principles of interference and its application in determining wavelengths.

Credits: 02	**SEMESTER-IV** **BPP 243** **Modern Physics & Electronics**	**No. of hours per unit/credits** (60)
	1. Measurement of Planck's constant using black body radiation 2. To design a single stage CE amplifier of given gain using voltage divider bias. 3. Frequency response of single stage RC coupled amplifier. 4. To study the variation of gain of CE amplifier with frequency at a fixed load. 5. Effect of negative feedback on frequency response of RC coupled amplifier. 6. To determine the frequency of the Crystal oscillator. 7. To build and test Colpitts oscillator using BJT. 8. To build and test Phase shift oscillator using BJT. 9. To build and test Hartley oscillator using BJT. 10. UJT as Relaxation oscillator. 11. To study divergence of a laser beam.	**03 Hrs / Practical**

	12. Determination of Wavelength of He-Ne Laser using grating. 13. Photoresponse of a solar cell 14. I-V Characteristics of a solar cell 15. Determination of refractive index of a thin film using Michelson interferometer. 16. To study CB and CE characteristics of a transistor and calculate transistor parameters. 17. The polar intensity distribution of an electric bulb using a photoelectric cell. 18. Computer Simulation- Michelson Morley experiment- PHET sim. 19. Computer Simulation - Wave Packet - PHET sim. 20. Computer Simulation - Davisson nd Germer Electron diffraction experiment - PHET sim.	
Credits: 02	**BPP 244 Optics and Lasers**	(60)
	1. Study of cardinal points using Goniometer. 2. Determination of equivalent focal length of a system of lenses by using Goniometer. 3. Determination of R.I. of given liquid by Liquid Lens. 4. Determination of dispersive power of material of prism. 5. Determination of Cauchy's Constants. 6. Determination of Resolving Power of plane diffraction grating. 7. Determination of Resolving Power of prism. 8. Obtaining Biprism fringes without lateral shift. 9. Measurement of distance between two coherent sources in biprism. 10. Determination of Wavelength of sodium source by Newton's rings. 11. Determination of radius of curvature of a given plano convex lens by Newton's rings. 12. Determination of specific rotation of sugar solution using Polarimeter. 13. Study of cardinal points by Newton's Method. 14. Determination of Thickness of air film by interference. 15. Double refraction. 16. Diffraction due to a single slit. 17. Zone plate experiment. 18. Study of polarization of light by simple reflection. 19. Computer Simulation of interference of waves - PHET sim. 20. Computer Simulation of image formation in mirror and lenses - PHET sim.	**03 Hrs / Practical**

Course Outcomes: Students will be able to:

1. learn measuring skills in practical
2. capable of building and testing of Colpitts, Phase shift, and Hartley oscillators employing BJT transistors.
3. design CE amplifiers with specified gains using voltage divider biasing techniques.
4. determine the radius of curvature of convex mirrors, enhancing their understanding of

geometric optics principles.

5. Gain insights into the phenomenon of diffraction through practical experimentation, enabling them to analyze diffraction patterns.
6. demonstrate an understanding of the concept of cardinal points and their significance in optical systems.
7. understand the concept of resolving power and be able to determine the resolving power of optical elements such as diffraction gratings and prisms.
8. gain knowledge of dispersive power and Cauchy's dispersion equation, and they will be able to determine dispersive power and Cauchy's constants experimentally.
9. acquire practical skills in determining wavelengths using various experimental setups including Fresnel's bi-prism, Newton's rings, and diffraction gratings.

Reference Books:

1. H. Singh and P.S. Hemne, 4th edition, 2011 B.Sc. Practical Physics.S. Chand Publisher,
2. S. L. Gupta and V. Kumar, 27th edition, 2010 Practical Physics, Pragati Prakashan.
3. D. Chattopadhyay and P. C. Rakshit, 7th edition, 2005 An Advanced Course in Practical Physics, New Central Book Agency Pvt. Ltd., .
4. B. L. Worsnop and H. T. Flint, 9th edition 1961 Advanced Practical Physics for Students, Asia Pub. House.
5. C. L. Arora,1957, B.Sc. Practical Physics, S. Chand Publisher, .
6. White and Manning, 3rd edition 1954, Experimental College Physics, McGraw-Hill Book Company,.

(MINOR PHYSICS)

B.Sc. Part-II Semester-IV

BPT 235: Thermal Physics, Waves and Oscillations (Credits: 02)

Course Objectives: Students should be able to:

1. study thermodynamic system, thermodynamic laws, and variables in thermodynamics
2. evaluate the significance of different thermodynamic potentials in describing the equilibrium and stability of systems.
3. Define transverse waves, and describe the concept of normal modes of vibration in a string and forming standing wave patterns.
4. Derive the differential equation of SHM and solve it to obtain equations of motion, analyze kinetic and potential energy, their interconversion during oscillatory motion.

Credits (Total Credits 2)	**Semester III BPT235: Thermal Physics Waves and Oscillations**	**No. of hours per unit/credit**
Unit I	**Thermodynamics**	**8**
	• Thermodynamic systems, Macroscopic and Microscopic Variables, • Thermodynamical Equilibrium and Thermodynamical state, • Zeroth law of thermodynamics and concept of Temperature, • Heat and Work and their path-dependence, Thermal processes, First law of thermodynamics and internal energy, • Second law of thermodynamics (Explanation and different statements), • Entropy (concept and significance), Entropy changes in reversible and irreversible processes.	
Unit II	**Thermodynamic Potentials**	**07**
	• Internal Energy; Enthalpy; Helmholtz free energy; Gibbs free energy and their significance; • Maxwell's thermodynamic relations (using thermodynamic potentials) and their significance; • TdS relations; Energy equations and Heat Capacity equations; • Third law of thermodynamics (Nernst Heat theorem)	
Unit III	**Wave Motion**	**08**

	• Transverse waves on a string, travelling and standing waves on a string, normal modes of a string, Laws of vibration, • Energy density and energy transport of transverse wave along a stretched string, • Group velocity, phase velocity, plane waves and relation between them, • Spherical waves, intensity of a wave.	
Unit IV	**Oscillations**	**07**
	• Simple harmonic motion, Differential equation of SHM and its solutions, • Kinetic and potential energy, Damped oscillations, • Superposition of two collinear harmonic Oscillations: Linearity and superposition principle 1) Oscillations having equal frequencies along the line. 2) Oscillations having different frequencies along the same straight line (beats), Lissajous figures with equal and unequal frequencies and their uses.	

Course Outcomes: Students will be able to:

1. Define temperature, heat, and work in thermodynamics and understand their path-dependence in different thermodynamic processes, describe various types of thermal processes.
2. Apply Maxwell's thermodynamic relations using thermodynamic potentials to derive relationships between various thermodynamic properties.
3. Differentiate between traveling and standing waves on a string and identify their characteristics.
4. Define simple harmonic motion, and apply the principles of superposition to analyze the behavior of two collinear harmonic oscillations and their resultant motion,

Reference Books:

1. J. P. Agrawal and Satya Prakash, 2018, Heat Thermodynamics and Statistical Physics, Pragati Prakashan.
2. Satya Prakash, 2017, Oscillations and Waves, Pragati Prakashan.
3. D. Chattopadhyay, 2016, A Treatise on oscillations, waves and acoustics, Books and allied Pvt. Ltd. Publisher.
4. Halliday and Resnick, 2011, Fundamentals of Physics Volume 1, 9th edition, Wiley Publisher.
5. D. S. Mathur, 2008, Heat and Thermodynamics, S. Chand and Sons Ltd. Publisher.
6. Brijlal and N. Subramanyam, 2001, Heat and Thermodynamics, S.Chand and Company Ltd. Publisher.

Practical Paper : BPP236: Thermal Physics, Waves, and Oscillations (Credits:2)

Course Objectives: Students should be able to:

1. understanding of heat transfer mechanism while determining the coefficient of thermal conductivity of a bad conductor using Lee's method.
2. Study the electrical properties and temperature dependence of resistance,to measure the temperature coefficient of resistance of a given coil using a P. O. box.
3. investigate Stefan's constant and verify Stefan's law, applying principles of black body radiation and thermal radiation.
4. Study the motion of coupled oscillations, providing insight into the behavior of coupled harmonic oscillators.
5. Learn to measure the velocity of sound using a resonating bottle, a CRO, Kundt's tube method, and a sonometer, providing practical experience with different methods of sound velocity measurement.

Credits (Total Credits 2)	**Semester IV BPP 236 Thermal Physics, Waves, and Oscillations**	**No. of hours per Unit(60)**
	1. To determine Coefficient of Thermal Conductivity of a bad conductor by Lee's method. 2. To determine the temperature coefficient of resistance of a given coil by P. O. box. 3. To determine the specific heat of a liquid (turpentine oil) by law of cooling. 4. To determine Coefficient of Thermal Conductivity of glass in the form of a tube. 5. To determine the ratio of specific heat of air by Clement and Desorme's method. 6. Determination of Stefan's constant/ Verification of Stefan's law. 7. Study of temperature coefficient of Thermistor. 8. To investigate the motion of coupled oscillations. 9. To determine acceleration due to gravity by using Bifilar Pendulum. 10. Measurement of Velocity of Sound by Resonating Bottle. 11. Measurement of Velocity of Sound by CRO. 12. Measurement of velocity of sound by Kundt's tube method. 13. Measurement of Velocity of Sound by Sonometer. 14. Measurement of log decrement by Exponential Decay. 15. To determine velocity of transverse waves using sonometer. 16. Determination of mechanical equivalent of heat by Searle's method. 17. To study the variation of T with L for a compound pendulum.	**03 Hrs / Practical**

	18. Computer simulation of an oscillating mass - Measurement of T and energy - PHET sim. 19. Computer simulation for normal modes of vibration - PHET sim. 20. Computer simulation of isothermal, adiabatic, isobaric and isochoric processes - PHET sim.	

Students should be able to:

1. learn measuring skills in practical
2. apply knowledge of electrical properties and temperature dependence of resistance to accurately measure the temperature coefficient of resistance using a P. O. box setup.
3. Perform experiments to measure the coefficient of thermal conductivity of glass in different forms, and analyze the results to conclude about material properties.
4. Verify Stefan's law and determine Stefan's constant through experimental investigation of thermal radiation phenomena, enhancing understanding of black body radiation.
5. Measure the acceleration due to gravity accurately using a bifilar pendulum, and interpret the results to understand gravitational forces and their effects.
6. Measure the velocity of sound using various experimental setups such as resonating bottles, CROs, Kundt's tube method, and sonometers, and analyze the data to understand the propagation of sound waves.

Practical Reference Books

1. H. Singh and P. S. Hemne, 2011, B.Sc. Practical Physics, 4th edition, S. Chand Publication.
2. S. L. Gupta and V. Kumar, 2010,Practical Physics, 27th edition, Pragati Prakashan.
3. D. Chattopadhyay ,P. C. Rakshit,2005,An Advanced course in Practical Physics,New Central Book Agency Pvt. Ltd. edition.
4. C. L Arora, 1957, B.Sc. Practical Physics, S. Chand Publication
5. Marsh W. White , Kenneth V. Manning ,1954, Experimental College Physics , 3rd edition, McGraw Hill Higher Education
6. B.L. Worsnop ,H.T. Flint,1951, Advanced Practical Physics for Students , 9th ed.,Little hampton Book Services Ltd.

Semester-IV

BPT245: Optics and Modern Physics (Credits:2)

Course Objectives: Students should be able to:

1. Define the concept of interference. analyze the formation of Newton's rings and their characteristics,
2. understand the theory of diffraction and plane diffraction grating.
3. state the postulates of the special theory of relativity, and understand their fundamental importance.
4. Describe the fundamental properties of lasers, and analyze various applications of lasers

Credits (Total Credits 2)	Semester IV BPT245: Optics and Modern Physics	No. of hours per unit/credit
Unit I	**Interference of light**	**09**
	• Principle of superposition of waves, Division of amplitude, division of wavefront, • Interference in thin parallel films due to reflected light, • Wedge shaped films, Newton's rings, its applications for determination of wavelength of light and R.I. of liquid.	
Unit II	**Diffraction of light:**	**06**
	• Diffraction and its types , • Fraunhofer diffraction, • plane diffraction grating, theory of plane diffraction grating, its application to determine wavelength of monochromatic light,	
Unit III	**Special theory of Relativity**	**09**
	• Inertial and Non-Inertial frame of references, • Galilean transformation equations, • Michelson- Morley experiment, Ether hypothesis, • Postulates of special theory of relativity, • Lorentz transformation equations, • Relativistic addition of velocities, • Length contraction, Time dilation, variation of mass with velocity, • Mass energy relation.	

Unit IV	**Laser system**	**06**
	• Absorption, spontaneous and stimulated emission, Einstein coefficients (only definitions), • Population inversion, optical and electrical pumping, • Properties of lasers, • Ruby laser, Helium-Neon laser, uses of laser, • Idea of holography (qualitative treatment only).	

Course Outcomes: After completion of the unit, Student will be **able to:**

1. Understand the principle of wave superposition and its application to interference phenomena, describe the formation and properties of Newton's rings and its application.
2. Explain the principles and types of diffraction in optics, describe the theory and operation of plane diffraction grating.
3. Define and differentiate between inertial and non-inertial frames of reference, and describe the Michelson-Morley experiment.
4. Define laser, and explain the significance of population inversion in laser operation, understand the properties of lasers and their implications for various applications.

Reference Books:

1. Albert Einstein, Relativity: The Special and the General Theory (Fingerprint Publishing, 2017) 2-62.
2. Brij Lal, M. N. Avadhanulu and N. Subrahmanyam. 2012. A Textbook of Optics. 25th edition. S. Chand Publisher.
3. Ajoy Ghatak, 2008. Optics. 4th edition, McGraw Hill Education India Pvt Ltd.
4. Robert Resnick, Introduction to Special Relativity (Wiley; 1st edition, 2007) 1-188.
5. Longhurst, R. S. 1967. Geometrical and physical optics. 2nd edition, New York: Wiley.
6. Mathur, B. K. 1964. Principles of optics. Kanpur: Gopala Printing.

Practical Paper : BPP246: Optics and Modern Physics (Credits:2)

Course Objectives: Students should be able to:

1. understand and apply the principles of black body radiation for the measurement of Planck's constant.
2. study cardinal points using a goniometer
3. measure the refractive index of a given liquid using a liquid lens, providing hands-on experience with optical measurement techniques.
4. applying interference and diffraction principles to measure optical wavelengths.
5. understanding of interference patterns and optical configurations by obtaining biprism fringes without lateral shift.

Credits (Total Credits 2)	**Semester IV** **BPT246: Optics and Modern Physics**	**No. of hours per unit (60)**
	1. Measurement of Planck's constant using black body radiation.	**03 Hrs / Practical**

	2. Determination of dispersive power of material of prism. 3. Determination of Cauchy's Constants. 4. Study of cardinal points using Goniometer. 5. Determination of Thickness of air film by interference. 6. Determination of R.I. of given liquid by Liquid Lens. 7. Determination of divergence of laser beam. 8. Determination of Resolving Power of plane diffraction grating. 9. Determination of Resolving Power of a prism. 10. Determination of Wavelength of sodium source by Newton's rings. 11. Determination of radius of curvature of a plano convex lens by Newton's ring apparatus. 12. Determination of Wavelength of He-Ne Laser using grating. 13. Study of cardinal points by Newton's Method. 14. Obtaining Biprism fringes without lateral shift. 15. Measurement of distance between two coherent sources in biprism. 16. Diffraction due to a single slit. 17. Verification of Stefan's law. 18. Computer simulation of interference of waves - PHET sim. 19. Computer simulation of image formation by mirror and lenses- PHET sim. 20. Computer simulation of Michelson Morley experiment- PHET sim.	

Course Outcomes: Students will be able to…

1. Demonstrate the understanding of black body radiation principle by accurately measuring Planck's constant.
2. Use a goniometer to identify and understand the cardinal points in optical systems.
3. Perform accurate measurements of specific rotation using a polarimeter, and interpret the results to draw conclusions about the composition and properties of optically active substances.
4. Utilize a liquid lens to measure the refractive index of a given liquid.
5. Determine the wavelength of a given source using Newton's rings experiment, He-Ne Laser experiment etc. to understand interference phenomena and optical wavelength measurement techniques.
6. Obtain biprism fringes without lateral shift, and analyze the interference patterns to understand the behavior of coherent light sources.

Reference Books:

1. S. L. Gupta and V. Kumar, 2010,Practical Physics, 27th ed, Pragati Prakashan
2. H. Singh and P. S. Hemne, 2011, B.Sc. Practical Physics, 4th ed , S. Chand Publication.
3. D. Chattopadhyay ,P. C. Rakshit,2005,An Advanced course in Practical Physics, New Central Book Agency Pvt. Ltd. ition.

4. Marsh W. White , Kenneth V. Manning ,1954, Experimental College Physics , 3rd ed, McGraw Hill Higher Education.
5. C. L Arora, 1957, B.Sc. Practical Physics, S. Chand Publication.
6. B.L. Worsnop ,H.T. Flint,1951, Advanced Practical Physics for Students , 9th ed., Littlehampton Book Services Ltd.

Rayat Shikshan Sanstha

Yashwantrao Chavan Institute of Science, Satara

Vocational skill course (VSC)

B.Sc II Semester III

BPP-VSC-I- Vocational skill course in Basic Electronic circuits

Course Objectives: Students should be able to:

1. understanding of Assembling electronic components
2. Study the Fabrication of Series and parallel resistive circuits.
3. Study of CRO and its applications
4. design PCB of Half wave rectifier
5. Learn about soldering tools and Safety precautions while Soldering & De soldering

Credits 2	**Vocational skill course in Physics-IV**	**No. of hours per unit (60)**
	1. Calibration of single phase energy meter with the help of standard wattmeter and stopwatch. 2. To build a given circuit on a breadboard.. 3. Testing and Polarity test of wiring installation. 4. Designing of a 7 segment display using LED and Breadboard. 5. Study of parallel resistive circuits. 6. Study of Series resistive circuits. 7. Study of CRO and its Application. 8. Testing of active and passive components. 9. To Design regulated power Supply using transistor 10. To study and design PCB of Half wave rectifier using Diptrace software 11. To study Electronic behavior of a diode in a circuit. 12. 12.To Design regulated power Supply for 5V output 13. 13.To Design and develop variable voltage regulator using LM317/347 14. To Build and test half wave rectifier circuit on PCB 15. Study of PO Box for resistance measurement . 16. Design of 7 segment display using LED and bread board. 17. Measurement of resistance by ammeter and voltmeter method and Ohm meter. 18. To simulate half wave rectifier circuit using Psim/pspice software 19. Study of soldering guns and related soldering material.. 20. 20. Study of Errors in measurements.	

Course Outcomes: Student will be able to

1. demonstrate the understanding Electronic circuit fabrication
2. simulate half wave rectifier circuit using Psim/pspice software
3. demonstrate the understanding of using matlab
4. design and develop regulated power Supply

Reference Books:

1. S. L. Gupta and V. Kumar, 2010,Practical Physics, 27th ed, Pragati Prakashan
2. H. Singh and P. S. Hemne, 2011, B.Sc. Practical Physics, 4th ed , S. Chand Publication.
3. D. Chattopadhyay ,P. C. Rakshit,2005,An Advanced course in Practical Physics, New Central Book Agency Pvt. Ltd. ition.
4. Marsh W. White , Kenneth V. Manning ,1954, Experimental College Physics , 3rd ed, McGraw Hill Higher Education.
5. C. L Arora, 1957, B.Sc. Practical Physics, S. Chand Publication
6. B.L. Worsnop ,H.T. Flint,1951, Advanced Practical Physics for Students , 9th ed., Littlehampton Book Services Ltd.

Rayat Shikshan Sanstha

Yashwantrao Chavan Institute of Science, Satara

Vocational skill course (VSC)

B.Sc II Semester IV

BPP-VSC-II- Vocational skill course in Applied Physics

Course Objectives: Students should be able to:

1. understand Error analysis
2. Study the types of Error
3. study the determination of resistance by four probe method
4. Study the Newton's law of cooling
5. Learn to measure the radius of curvature of lens

Credits 2	**Vocational skill course in Physics-IV**	**No. of hours per unit/credit**
	1. Graphical error analysis and Types of error (examples of from any of the experiments) 2. Analysis of random error (Gaussian Distribution Length/distance) 3. Study of oscillation of oscillating disc 4. Construction of a simple millimeter. 5. Equations of motion for a simple pendulum using the Euler method (Matlab). 6. Transient Response of LR circuit using Expeyes 17 kit 7. Conversion of galvanometer to Ammeter. 8. Conversion of galvanometer to voltmeter. 9. Graphs plotting in Matlab 10. Study of housing electricity. 11. Numerical Computation and Data Analysis In Python 12. Solving matrices by using matlab 13. Study of repairing home appliances. 14. Desing and Generate & measure voltages using Expeyes 17 kit 15. Desing and Observation of voltage waveforms using Expeyes 17 kit 16. Verification of Kepler's law by using matlab 17. Measurement of temperature using thermocouple. 18. Measurement of resistance using Expeyes 17 kit 19. RC Integrator and Differentiator using Expeyes 17 kit 20. Measurement Dielectric constant using Expeyes 17 kit	**03 Hrs / Practical**

Course Outcomes: Students will be able to:

1. Explain of Analysis of Error.
2. Demonstrate the understanding of Expeyes 17 kit
3. Determine dielectric constant using Expeyes 17 kit
4. Measurement of temperature using thermocouple
5. Explain of dielectric constant determination

Reference Books:

1. H. Singh and P. S. Hemne, 2011, B.Sc. Practical Physics, 4th ed , S. Chand Publication.
2. S. L. Gupta and V. Kumar, 2010,Practical Physics, 27th ed, Pragati Prakashan
3. Dr. Alok Kumar Gupta , Physics laboratory manual (312) , National Institute of open Schooling.
4. Nicholas J. Girodano and Hisan Nakanishi,Computational Physics using MATLAB, 2nd. ed,
5. C. L Arora, 1957, B.Sc. Practical Physics, S. Chand Publication
6. Marsh W. White , Kenneth V. Manning ,1954, Experimental College Physics , 3rd ed,

Skill Enhancement Course (Credit: 02)

BPP-SEC 02: MECHANICAL AND ELECTRICAL SKILLS

Total teaching Hours: 60; Credits: 2

Course Objectives: Students should be able to…

1. enable the students to become familiar with various mechanical and electrical tools.
2. enable the students to take experience with various mechanical and electrical tools through hands-on mode.
3. improve the abilities of the students to frame and tackle the problems.

Credits : 02	**BPP-SEC II: MECHANICAL AND ELECTRICAL SKILLS**	**No. of hours per unit** (60)
	1. Measuring units, Conversion to SI and CGS. 2. Measure the dimension of a solid block, volume of cylindrical beaker, diameter of a thin wire and thickness of metal sheet. 3. Use of Sextant to measure height of buildings, mountains, etc. 4. Introduction of Common materials used for manufacturing like steel, copper, iron, metal sheets, composites and alloy, wood. 5. Use of Cutting tools, lubricating oils. 6. Drilling holes of different diameter in a wooden block. 7. Soldering of electrical circuits having discrete components (R, L, C, and diode) and ICs. 8. To study Plumbing and various plumbing tools. 9. To study Brazing and Soldering processes. 10. To study the constructional details and working of centrifugal pumps. 11. To study the refrigerator and its components. 12. Study of air conditioner and its components. 13. To observe the loading effect of a multi-meter while measuring voltage across a low resistance and high resistance. 14. observe the limitations of a multi-meter for measuring high frequency voltage and currents. 15. Measurement of R, L and C using a LCR bridge/ universal bridge. 16. Measurement of temperature using thermocouple. 17. Measurement of resistance using Expeyes 17 kit 18. Measurement of resistance by ammeter and voltmeter method and Ohm meter. 19. To simulate half wave rectifier circuit using Psim/pspice software 20. Study of soldering guns and related soldering material..	**03 Hrs / Practical**

Outcomes: After completion of this course, students will be able to…

1. Measure the dimensions of any type of objects.
2. Differentiate between various cutting and drilling tools and techniques.
3. Differentiate the different types of material.
4. Perform soldering of electric connection.
5. Identify the comments of AC and Refrigerators.

Reference Books:

1. K.C. John, Mechanical workshop practice, 2010, PHI Learning Pvt. Ltd.
2. Bruce J Black 2005, Workshop Processes, Practices and Materials, 3 rd Edn., Editor Newnes [ISBN: 0750660732]
3. B L Theraja; A text book in Electrical Technology – S. Chand and Company.
4. M.G. Say, Performance and design of AC machines –ELBS Edn.
5. Lawrence Smyth/Liam Hennessy, New Engineering Technology, The Educational Company of Ireland [ISBN: 0861674480]

Skill Enhancement Course (Credit: 02)

BPP-SEC 03: COMPUTATIONAL SKILLS IN PHYSICS

Total teaching Hours: 60; Credits: 2

Course Objectives: Students should be able to…

1. study the students to understand various Computational tools.
2. understand the students to perform various Computations.
3. study to solve various problems through Computational methods.

Credits: 02	**BPP-SEC III: Computational Skills in physics**	**No. of hours per unit (60)**
	1. To compile a frequency distribution and evaluate mean, standard deviation etc. 2. To evaluate sum of finite series and the area under a curve. 3. To find the product of two matrices. 4. To find a set of prime numbers and Fibonacci series. 5. To write a program to open a file and generate data for plotting using Gnuplot. 6. Plotting trajectory of a projectile projected horizontally. 7. Plotting trajectory of a projectile projected making an angle horizontally.	**03 Hrs / Practical**

	8. Creating an input Gnuplot file for plotting data and saving the output for seeing on the screen. Saving it as an eps file and as a pdf file. 9. To find the roots of a quadratic equation. 10. Motion of a projectile using simulation and plot the output for visualization. 11. Numerical solution of equation of motion of simple harmonic oscillator and plot the outputs for visualization. 12. Motion of particle in a central force field and plot the output for visualization. 13. Use of basic MS-EXCEL for Data analysis-I. 14. Use of Advance-MS-EXCEL for Data analysis-II. 15. Use of Origin software. 16. Computer simulation of interference of waves - PHET sim. 17. Computer simulation of image formation by mirror and lenses- PHET sim. 18. Computer simulation of Michelson Morley experiment-PHET sim. 19. Computer Simulation of black body radiation -PHET sim. 20. Computer Simulation - isothermal, adiabatic, isobaric and isochoric processes - PHET sim.	

Outcomes: After completing this course, students will be able to,

1 solve the problem by compational methods

2. Use MS - EXCEL efficiently.

3. Plot and save various graph by using origin software.

Reference Books:

1. S.S. Sastry, Introduction to Numerical Analysis, 5 th Edn., 2012, PHI Learning Pvt. Ltd.
2. U.M. Ascher and C. Greif, A first course in Numerical Methods, 2012, PHI
3. Philip K Janert, Gnuplot in action: understanding data with graphs, (Manning 2010)
4. K.E. Atkinson, Learning Elementary Numerical Analysis, 3 r d E d n . , 2 0 0 7 , Wiley India Edition.
5. V. Rajaraman Computer Programming in Fortran 77". (Publisher: PHI).
6. R. C. Verma et al. Computational Physics: An Introduction, New Age International Publishers, New Delhi(1999)
7. Leslie Lamppost, LaTeX–A Document Preparation System", (Second Edition, Addison Wesley, 1994).
8. S Lipsdutz and A Poe, Schaum's Outline of Theory and Problems of Programming with Fortran, 1986Mc-Graw Hill Book Co.

Value Education Course (VEC)

Credits 2

BPT-VEC-II : Environmental Awareness for Physics

Course Objective: - Students should be able to…

1. Understand the major environmental issues facing the world today.
2. Identify personal and societal responsibilities towards the environment.
3. Understand the concept of sustainable development and its significance in addressing global challenges.
4. Explore the application of physics principles and technologies in renewable energy, climate change mitigation

Unit No.		No. of Lectures
1	**Environmental Issues**	**8**
	Pollution (air water and land), freshwater overuse, natural disasters, fuel and energy, Shortage due to overuse, increase in wasteland, biodiversity loss, global warming and climate change (causes an intensity of the problem) role of physics in creation of environmental issues	
2	**Environmental Laws and Ethics**	**8**
	Environmental Protection Act Wildlife Protection Act Forest Conservation Act Prevention and control of Pollution Act (air water and land) From unsustainable to sustainable development responsibilities of an environmentally aware citizen.	
3	**Sustainable Development Goals**	**7**
	Introduction to sustainable development, United Nations Sustainable Development Goals (SDGs), Economical, Technological and Industrial development in the context of sustainable development. Case studies and examples of sustainable development initiatives.	
4	**Role of Physics in meeting the Sustainable Development Goals**	**7**
	Introduction to the role of physics in sustainable development, Renewable energy technologies and sustainable development, Physics based approaches to tackle climate change, Environmental monitoring and pollution control technologies.	

Course Outcomes: Students will be able to

1. Explain the causes and consequences of environmental degradation.
2. Discuss ethical considerations in environmental decision-making.
3. Define sustainable development and explain its principles.
4. Describe how physics concepts and technologies contribute to addressing environmental challenges.

Reference Books:

1. Sorensen, Bent. *Renewable energy: physics, engineering, environmental impacts, economics and planning*. Academic Press, 2017.
2. Theis, Tom, and Jonathan Tomkin. "Sustainability: A comprehensive foundation." (2015).
3. Tester, Jefferson W., Elisabeth M. Drake, Michael J. Driscoll, Michael W. Golay, and William A. Peters. *Sustainable energy: choosing among options*. MIT press, 2012.
4. Findley, Roger W., and Daniel A. Farber. "Environmental law: cases and materials." *(No Title)* (1985).
5. Wright, Richard T. *Environmental science*. Galgotia Publications, 1974.
6. "The Sustainable Development Goals Report" published annually by the United Nations