Sindh Curriculum for

PHYSICS

GRADE IX - XII

2024

GOVERNMENT OF SINDH
SCHOOL EDUCATION & LITERACY DEPARTMENT
DIRECTORATE OF CURRICULUM, ASSESSMENT & RESEARCH SINDH JAMSHORO

Preface

The rapid advancement of knowledge necessitates a continuous evolution of curricula and textbooks to keep pace with contemporary developments. The previous update to the Sindh Physics Curriculum was conducted between 2018-19, highlighting the need for a comprehensive review and subsequent revision.

Moreover, the recent updates to the standards and domains within Pakistan's National Curriculum presented a timely opportunity to align the Sindh Physics Curriculum with these national benchmarks. This alignment ensures that our students are equipped with the requisite knowledge, skills and attitude to excel both nationally and internationally.

Consequently, a thorough review of the Sindh Physics Curriculum was undertaken. A significant departure from previous versions, this document amalgamates the Benchmarks 9-10 and 11-12 into a single unified framework. This consolidated approach enhances coherence and facilitates a smoother transition for students.

The revised curriculum is meticulously designed to be relevant, contextually appropriate, and user-friendly. It builds upon the foundational knowledge acquired in lower grades while seamlessly connecting to higher-level studies and university courses.

Key Improvements in the document can be indicated as its clarity, conciseness, better structure and the language used. The text is more direct and focused. The Information is presented in a logical flow. Academic and formal tone is maintained in the language.

Further improvements and suggestions for betterment and quality education will be welcomed by the Directorate of Curriculum, Assessment and Research Sindh.

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Introduction

Sindh Curriculum for Physics grades IX-XII is a comprehensive document that guides the teachers, students, authors and the school system to achieve specific learning outcomes in a systemic way.

The curriculum aims at preparing students for a successful life through understanding of the science for service of the society, environment and wellbeing of the fellow-people.

The Sindh Curriculum for Physics in addition encourages creative work, critical thinking, promotes problem solving skills and helps for shift from rote-memorization to conceptual understanding and application of learning.

The curriculum contains fundamental concepts, understanding and application of knowledge of physics. It includes practical use of these concepts, principles and laws in the real world through science, technology, engineering, arts and mathematics. Necessary skills related to practical work are included as separate domain that will become part of practical journal.

The updated version of curriculum extensively focused on acquisition of knowledge, necessary skills and understanding of concepts in a constructive, connected and coherent fashion. The learning domains and the standards are updated and aligned with the National Curriculum of Pakistan for Physics grades IX-XII, so as the students in can excel in the subject while continuing education in any region or under any examination board within Pakistan.

The secondary school physics grades IX-X and the higher secondary physics grades XI-XII are published in single document for convenient and visible progression across the grade levels. Now it comprised of the eleven (11) domains (a) Nature of Physics, (b) Measurement, (c)Mechanics, (d) Heat & Thermodynamics (e) Waves (f) Electricity & Magnetism (g) Electronics (h) Modern Physics (i) Earth & Space and (j) Medical Physics. The practical related learning outcomes are now covered up separately under domain (k) Experimental Skills.

The curriculum fosters innovative teaching and learning approaches, as well as study skills, to deepen students' comprehension of the natural world through physics. It aims to enhance understanding of concepts, procedures, and cosmic processes. To achieve this, students are encouraged to actively engage in scientific inquiry through observation, measurement, classification, prediction, experimentation, inference, and effective communication of findings in a scientific format.

Required cognitive level weightage is indicated in the curriculum document that helps students in learning, teachers in the planning the teaching sessions and the authors and material developers for required depth of the textbook and learning materials.

The curriculum suggests multiple ways of questioning and assessment. Each unit should contain self-assessment question related to each theme. further multiple-choice questions, extended response questions and construct response questions along with numerical problem must be given for assessment of learning at the end of each unit.

The guidelines for teachers' professional development, selection of material and the instructions for authors, textbook writers and the examiners are also given in addition to the scheme of assessment to achieve the entirely learning outcomes properly.

Cross Cutting Themes

Guidance for the Reader

The idea of Science, Technology, Engineering, The Arts and Mathematics (STEAM) is an overarching idea for how to break up the study of Physics into core disciplinary knowledge (that students need to learn in order to pass examination at each grade level) and cross-cutting themes (interdisciplinary connections and recurring ideas that are best reinforced in every chapter in order to promote student critical thinking and curiosity, but that is not expected to be assessed in standardized exams).

Cross-cutting themes must be appropriately included into every chapter of schools textbooks that are aligned with these standards. This does not mean that every subcomponent of every theme must be included in every chapter, rather that where connections are appropriate and would enhance the study of the core disciplinary knowledge these should be incorporated.

The themes presented below are adapted from the “Next Generation Science Standards”.

Science: theoretical understandings about science in general, experimental skills and their mutual overlaps in the methods of scientific inquiry.

Technology and Engineering: applications of science to create solutions that improve standards of living, along with the design thinking approach of engineering applied to scientific problems and vice versa.

Arts: What can be understood about the nature of science from the fine arts, performing arts and the humanities

Mathematics: the connections of mathematics with the natural world, and its interconnectedness with the methods of the natural sciences.

Theme	Components	Elaboration and Guidance
Science	**A) Scientific Knowledge (these themes are applied across the conceptual SLOs)** **1. Patterns** i) Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. ii) Classifications or explanations used at one scale may fail or need revision when information from smaller or larger scales is introduced; thus requiring improved investigations and experiments. iii) Patterns of performance of designed systems can be analyzed and interpreted to reengineer and improve the system. iv) Mathematical representations are needed to identify some patterns. v) Empirical evidence is needed to identify patterns **2. Cause and Effect: Mechanism and Prediction** i) Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. ii) Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. iii) Systems can be designed to cause a desired effect iv) Changes in systems may have various causes that may not have equal effects **3. Scale, Proportion, and Quantity** i) The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. ii) Some systems can only be studied indirectly as they are too small, too large, too fast, or too slow to observe directly. iii) Patterns observable at one scale may not be observable or exist at other scales. iv) Using the concept of orders of magnitude allows one to understand how a model at one scale relates to a model at another scale. v) Algebraic thinking is used to examine scientific data and predict the effect of a	**Elaborations on (A) Scientific Knowledge):** 1. **Patterns:** Observed patterns in nature guide organization and classification and prompt questions about relationships and causes underlying them. 2. **Cause and Effect:** Events have causes, sometimes simple, sometimes multifaceted. Deciphering causal relationships, and the mechanisms by which they are mediated, is a major activity of science and engineering. 3. **Scale, Proportion and Quantity:** In considering phenomena, it is critical to recognize what is relevant at different size, time, and energy scales, and to recognize proportional relationships between different quantities as scales change. 4. **Systems and System Models:** A system is an organized group of related objects or components; models can be used for understanding and predicting the behavior of systems. 5. **Energy and Matter:** Tracking energy and matter flows, into, out of, and within systems helps one understand their system's behavior 6. **Structure and Function:** The way an object is shaped or structured determines many of its properties and functions. 7. **Stability and Change:** For both designed and natural systems, conditions that affect stability and factors that control rates of change are critical elements to consider and understand. **Elaborations on (B) Scientific Practices:**

Theme	Components	Elaboration and Guidance
	change in one variable on another (e.g. linear growth vs. exponential growth). **4. Systems and System Models** i) Systems can be designed to do specific tasks. ii) When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models. iii) Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows-within and between systems at different scales. iv) Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models. **5. Energy and Matter: Flows, Cycles, and Conservation** i) The total amount of energy and matter in closed systems is conserved. ii) Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. iii) Energy cannot be created or destroyeE-only moves between one place and another place, between objects and/or fields, or between systems. iv) Energy drives the cycling of matter within and between systems v) In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved. **6. Structure and Function** i) Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem. ii) The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials.	**1. Asking Questions and Defining Problems:** A practice of science is to ask and refine questions that lead to descriptions and explanations of how the natural and designed world(s) works and which can be empirically tested. Engineering questions clarify problems to determine criteria for successful solutions and identify constraints to solve problems about the designed world. Both scientists and engineers also ask questions to clarify ideas. **2. Developing and Using Models:** A practice of both science and engineering is to use and construct models as helpful tools for representing ideas and explanations. These tools include diagrams, drawings, physical replicas, mathematical representations, analogies, and computer simulations. Modeling tools are used to develop questions, predictions and explanations; analyze and identify flaws in systems; and communicate ideas. Models are used to build and revise scientific explanations and proposed engineered systems. Measurements and observations are used to revise models and designs. **3. Planning and Carrying Out Investigations:** Scientists and engineers plan and carry out investigations in the field or laboratory, working collaboratively as well as individually. Their investigations are systematic and require clarifying what counts as data and identifying variables or parameters. Engineering investigations identify the effectiveness, efficiency, and durability of designs under different conditions.

Theme	Components	Elaboration and Guidance
	7. Stability and Change i) Much of science deals with constructing explanations of how things change and how they remain stable. ii) Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible. iii) Feedback (negative or positive) can stabilize or destabilize a system. iv) Systems can be designed for greater o lesser stability. **B) Scientific Practices** **1. Asking Questions and Defining Problems** i) Ask questions: - that arise from careful observation of phenomena, or unexpected results, to clarify and/or seek additional information - that arise from examining models or a theory, to clarify and/or seek additional information and relationships. - to determine relationships, including quantitative relationships, between independent and dependent variables. - to clarify and refine a model, an explanation, or an engineering problem. ii) Evaluate a question to determine if it is testable and relevant. iii) Ask questions that can be investigated within the scope of the school laboratory, research facilities, or field (e.g., outdoor environment) with available resources and, when appropriate, frame a hypothesis based on a model or theory. iv) Ask and/or evaluate questions that challenge the premise(s) of an argument, the interpretation of a data set, or the suitability of a design. v) Define a design problem that involves the development of a process or system with interacting components and criteria and constraints that may include social, technical and/or environmental considerations. **2. Developing and Using Models** i) Evaluate merits and limitations of two different models of the same proposed tool, process, mechanism, or system in order to select or revise a model that best fits the evidence or design criteria.	**4. Analyzing and Interpreting Data:** Scientific investigations produce data that must be analyzed in order to derive meaning. Because data patterns and trends are not always obvious, scientists use a range of tools including tabulation, graphical interpretation, visualization, and statistical analysis to identify the significant features and patterns in the data. Scientists identify sources of error in the investigations and calculate the degree of certainty in the results. Modern technology makes the collection of large data sets much easier, providing secondary sources for analysis. Engineering investigations include analysis of data collected in the tests of designs. This allows comparison of different solutions and determines how well each meets specific design criteria – that is, which design best solves the problem within given constraints. Like scientists, engineers require a range of tools to identify patterns within data and interpret the results. Advances in science make analysis of proposed solutions more efficient and effective. **5. Using Mathematics and Computational Thinking:** In both science and engineering, mathematics and computation are fundamental tools for representing physical variables and their relationships. They are used for a range of tasks such as constructing simulations; solving equations exactly or approximately; and recognizing, expressing, and applying quantitative relationships. Mathematical and computational approaches enable scientists and engineers to predict the behavior of systems and test the validity of such predictions.

Theme	Components	Elaboration and Guidance
	ii) Design a test of a model to ascertain its reliability. iii) Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system. iv) Develop and/or use multiple types of models to provide mechanistic accounts and/or predict phenomena, and move flexibly between model types based on merits and limitations. v) Develop a complex model that allows for manipulation and testing of a proposed process of system. vi) Develop and/or use a model (including mathematical and computational) to generate data to support explanations, predict phenomena, analyze systems, and/or solve problems **3. Planning and Carrying Out Investigations** i) Plan an investigation or test a design individually and collaboratively to produce data to serve as the basis for evidence as part of building and revising models, supporting explanations for phenomena, o testing solutions to problems. Consider possible confounding variables or effects and evaluate the investigation's design to ensure variables are controlled. ii) Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. iii) Plan and conduct an investigation or test a design solution in a safe and ethical manner including considerations of environmental, social, and personal impacts. iv) Select appropriate tools to collect, record, analyze, and evaluate data. v) Make directional hypotheses that specify what happens to a dependent variable when an independent variable is manipulated. vi) Manipulate variables and collect data about a complex model of a proposed process or system to identify failure points or improve performance relative to criteria for success or other variables.	**6. Constructing Explanations and Designing Solutions:** The goal of science is the construction of theories that provide explanatory accounts of the world. A theory becomes accepted when it has multiple lines of empirical evidence and greater explanatory power of phenomena than previous theories. The goal of engineering design is to find a systematic solution to problems that is based on scientific knowledge and models of the material world. Each proposed solution results from a process of balancing competing criteria of desired functions, technical feasibility, cost, safety, aesthetics, and compliance with legal requirements. The optimal choice depends on how well the proposed solutions meet criteria and constraints. **7. Engaging in Argument from Evidence:** In science and engineering, reasoning and argument based on evidence are essential to identifying the best explanation for a natural phenomenon or the best solution to a design problem. Scientists and engineers use argumentation to listen to, compare, and evaluate competing ideas and methods based on merits. Scientists and engineers engage in argumentation when investigating a phenomenon, testing a design solution, resolving questions about measurements, building data models, and using evidence to evaluate claims. **8. Obtaining, Evaluating and Communicating Information:** Scientists and engineers must be able to communicate clearly and persuasively the ideas and methods they generate. Critiquing and communicating ideas individually and in groups

Theme	Components	Elaboration and Guidance
	4. Analyzing and Interpreting Data i) Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution. ii) Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible. iii) Consider limitations of data analysis (e.g., measurement error, sample selection) when analyzing and interpreting data. iv) Compare and contrast various types of data sets (e.g., selH-generated, archival) to examine consistency of measurements and observations. v) Evaluate the impact of new data on a working explanation and/or model of a proposed process or system vi) Analyze data to identify design features or characteristics of the components of a proposed process or system to optimize it relative to criteria for success. **5. Using Mathematics and Computational Thinking** i) Create and/or revise a computational model or simulation of a phenomenon, designed device, process, or system. ii) Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations. iii) Apply techniques of algebra and functions to represent and solve scientific and engineering problems. iv) Use simple limit cases to test mathematical expressions, computer programs, algorithms, or simulations of a process or system to see if a model “makes sense” by comparing the outcomes with what is known about the real world. v) Apply ratios, rates, percentages, and unit conversions in the context of complicated measurement problems involving quantities with derived or compound units (such as mg/mL, kg/m3 , acrF-feet, etc.).	is a critical professional activity. Communicating information and ideas can be done in multiple ways: using tables, diagrams, graphs, models, and equations as well as orally, in writing, and through extended discussions. Scientists and engineers employ multiple sources to obtain information that is used to evaluate the merit and validity of claims, methods, and designs **9.** Illustrate, with examples of achievements made by scientists in both theoretical and experimental physics, that the 'scientific method' in practice is not a linear process that goes from hypothesis to theory to law.

Theme	Components	Elaboration and Guidance
	6. Constructing Explanations and Designing Solutions i) Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables. ii) Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. iii) Apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects. iv) Apply scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion. v) Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. **7. Engaging in Argument from Evidence** i) Compare and evaluate competing arguments or design solutions in light of currently accepted explanations, new evidence, limitations (e.g., tradF-offs), constraints, and ethical issues. ii) Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merits of arguments. iii) Respectfully provide and for receive critiques on scientific arguments by probing reasoning and evidence and challenging ideas and conclusions, responding thoughtfully to diverse perspectives, and determining what additional information is required to resolve contradictions. iv) Construct, use, and/or present an oral and written argument or counter-arguments based on data and evidence. v) Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge, and student-generated evidence. vi) Evaluate competing design solutions to a real-world problem based on scientific ideas	

Theme	Components	Elaboration and Guidance
	and principles, empirical evidence, and/or logical arguments regarding relevant factors (e.g., economic, societal, environmental, ethical considerations). **8. Obtaining, Evaluating and Communicating Information** i) Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions and/or to obtain scientific and/or technical information to summarize complex evidence, concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms. ii) Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem. iii) Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source. iv) Evaluate the validity and reliability of and/or synthesize multiple claims, methods, and/or designs that appear in scientific and technical texts or media reports, verifying the data when possible. v) Communicate scientific and/or technical information or ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically).	
Technology & Engineering	**1. Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.** i) Analyze complex real-world problems by specifying criteria and constraints for successful solutions. ii) Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. iii) Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global	The Engineering Design cycle can be considered to consist of the below three iterative steps in a global problem-solving context: Define: Attend to a broad range of considerations in criteria and constraints for problems of social and global significance. Develop solutions: Break a major problem into smaller problems that can be solved separately Optimize: Prioritize criteria, consider tradeoffs, and assess social and environmental impacts as a

Theme	Components	Elaboration and Guidance
	challenges also may have manifestations in local communities. iv) All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment. v) New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. **2. Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.** i) Design a solution to a complex real-world problem, based on scientific knowledge, student generated sources of evidence, prioritized criteria, and tradeoff considerations. ii) Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (tradF-offs) may be needed. **3. Evaluate a solution to a complex real-world problem based on prioritized criteria and tradF-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.** i) Evaluate a solution to a complex real-world problem, based on scientific knowledge, student generated sources of evidence, prioritized criteria, and tradeoff considerations. ii) When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. **4. Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.** i) Use mathematical models and/or computer simulations to predict the effects of a design solution on systems and/or the interactions between systems.	complex solution is tested and refined.

Theme	Components	Elaboration and Guidance
	ii) Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs. iii) Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows— within and between systems at different scales. **5.** Interdependence of Science, Engineering, and Technology i) Science and engineering complement each other in the cycle known as research and development (R&D). ii) Many R&D projects may involve scientists, engineers, and others with wide ranges of expertise. **6.** Influence of Engineering, Technology, and Science on Society and the Natural World i) Modern civilization depends on major technological systems, such as agriculture, health, water, energy, transportation, manufacturing, construction, and communications. ii) Engineers continuously modify these systems to increase benefits while decreasing costs and risks. iii) New technologies can have deep impacts on society and the environment, including some that were not anticipated. iv) Analysis of costs and benefits is a critical aspect of decisions about technology.	
The Arts and Mathematics	**A) Mathematical Knowledge in Science** (these are embedded int the conceptual SLOs, as well as s in the prerequisite mathematical knowledge requirements) **B) Nature of Science** **1. Scientific Investigations Use a Variety of Methods** i) Science investigations use diverse methods and do not always use the same set of procedures to obtain data. ii) New technologies advance scientific knowledge.	

Theme	Components	Elaboration and Guidance
	iii) Scientific inquiry is characterized by a common set of values that include: logical thinking, precision, open-mindedness, objectivity, skepticism, replicability of results, and honest and ethical reporting of findings. iv) The discourse practices of science are organized around disciplinary domains that share examples for making decisions regarding the values, instruments, methods, models, and evidence to adopt and use. v) Scientific investigations use a variety of methods, tools, and techniques to revise and produce new knowledge. **2. Science knowledge is based on empirical evidence.** i) Science disciplines share common rules of evidence used to evaluate explanations about natural systems. ii) Science includes the process of coordinating patterns of evidence with current theory. iii) Science arguments are strengthened by multiple lines of evidence supporting a single explanation. **3. Scientific Knowledge is Open to Revision in Light of New Evidence** i) Scientific explanations can be probabilistic. ii) Most scientific knowledge is quite durable but is, in principle, subject to change based on new evidence and/or reinterpretation of existing evidence. iii) Scientific argumentation is a mode of logical discourse used to clarify the strength of relationships between ideas and evidence that may result in revision of an explanation. **4. Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena** i) Theories and laws provide explanations in science, but theories do not with time become laws or facts. ii) A scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that has been repeatedly confirmed through observation and experiment, and the science community validates each theory before it is accepted. If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence.	

Theme	Components	Elaboration and Guidance
	iii) Models, mechanisms, and explanations collectively serve as tools in the development of a scientific theory. iv) Laws are statements or descriptions of the relationships among observable phenomena. v) Scientists often use hypotheses to develop and test theories and explanations. **5. Science is a Way of Knowing** i) Science is both a body of knowledge that represents a current understanding of natural systems and the processes used to refine, elaborate, revise, and extend this knowledge. ii) Science is a unique way of knowing and there are other ways of knowing. iii) Science distinguishes itself from other ways of knowing through use of empirical standards, logical arguments, and skeptical review. iv) Science knowledge has a history that includes the refinement of, and changes to, theories, ideas, and beliefs over time. **6. Scientific Knowledge Assumes an Order and Consistency in Natural Systems** i) Scientific knowledge is based on the assumption that natural laws operate today as they did in the past and they will continue to do so in the future. ii) Science assumes the universe is a vast single system in which basic laws are consistent. **7. Science is a Human Endeavor** i) Scientific knowledge is a result of human endeavor, imagination, and creativity. ii) Individuals and teams from many nations and cultures have contributed to science and to advances in engineering iii) Scientists' backgrounds, theoretical commitments, and fields of endeavor influence the nature of their findings. iv) Technological advances have influenced the progress of science and science has influenced advances in technology. v) Science and engineering are influenced by society and society is influenced by science and engineering **8. Science Addresses Questions About the Natural and Material World** i) Not all questions can be answered by science. ii) Science and technology may raise ethical issues for which science, by itself, does not provide answers and solutions.	

Theme	Components	Elaboration and Guidance
	iii) Science knowledge indicates what can happen in natural systems-not what should happen. The latter involves ethics, values, and human decisions about the use of knowledge. iv) Many decisions are not made using science alone, but rely on social and cultural contexts to resolve issues.	

Theoretical Concepts Progression Grid

Guidance for the Reader

Assumption of Prior Knowledge: It is assumed that students will already have knowledge (and be able to apply it as needed in their current class) of what they learned their previous grades, so SLOs from previous grades are not repeated in the higher grades. In practice, teachers may want to refresh concepts with their students as appropriate.

Organization of the SLOs in the Progression Grid: Inside a grade, teachers are free to teach the content in any order of preference. Textbook publishers are also free to organize the contents of their books in any manner that they consider most effective, as long as all the SLOs in the Progression Grid and Cross-Cutting themes are covered.
The SLOs inside a grade do not need to be taught in the order presented in a grade in this PG. The Nature of Science domain would, for example, be best taught by being integrated into the teaching of all the chapters of the curriculum.

Nature of Science Domain Guidance for the Reader: Nature of Science learning objectives have been added to the Progression Grid. The purpose of studying science at the high school level is not only to prepare students for further study in the sciences. Many students will in fact not go on to study further science or STEM fields. The science that they learn in school may well remain their understanding of the subject for the rest of their lives. Hence these curricula must consider what citizens in a democratic society ought to know about the nature of science. "Nature of Science" (NOS) means teaching about science's underlying assumptions, and its methodologies. This involves some integrated study of the history of science, and some of the broad concepts from the philosophy of science. It is important to study NOS because it helps students become critical thinkers about the scientific information they consume from the world around them. Teaching NOS in the study of Physics, Biology, Chemistry is a cutting-edge international trend.

In Nature of Science domain SLOs, unless explicitly stated, where the SLO begins with the phrase 'explain with examples' it is enough that students study 2-3 examples and can use them in their answers for examination questions.
There is no need to extensively or comprehensively study the history of science or its applications in other fields.
The purpose here is that students are able to develop an appreciation of these aspects of the field of physics with some rigor (hence these SLOs are expected to be assessed), but not to become so extensive that it take a lot of time out from building competence in rest of the domains on physics skills and knowledge.

Assessment Criterion for Domain A
Assessment of Nature of Science in standardized board exams will be kept to objective knowledge; students will not be expected to write argumentative essays or express subjective perspectives. Rather assessment in the standardized exams will occur through multiple choice questions and/or through short answer questions that require two-three sentence responses. Sample questions are provided in the Curriculum Guidelines. In their regular classroom study, teachers are encouraged to teach these topics through learner-centered activities that promote curiosity, inquiry, creativity, critical discussion and collaboration. Detailed section on assessment is on page 108.

Domain A: Nature of Science

This field studies science's underlying assumptions, and its methodologies. This involves some integrated study of the history, philosophy and sociology of science.

Note: In the Nature of Science domain SLOs, unless explicitly stated, where the SLO begins with the phrase 'explain with examples' it is enough that students study 2-3 examples and can use them in their answers for examination questions. There is no need to extensively or comprehensively study the history of science or its applications in other fields. The purpose here is that students are able to develop an appreciation of these aspects of the field of physics with some rigor (hence these SLOs are expected to be assessed), but not to become so extensive that it take a lot of time out from building competence in rest of the domains on physics skills and knowledge. Assessment of Nature of Science in standardized board exams will be kept to objective knowledge; students will not be expected to write argumentative essays or express subjective perspectives. Rather assessment in the standardized exams will occur through multiple choice questions and/or through short answer questions that require two-three sentence responses. Sample questions are provided in the Curriculum Guidelines. In their regular classroom study, teachers are encouraged to teach these topics through learner-centered activities that promote curiosity, inquiry, creativity, critical discussion and collaboration.

Standard: Students should be able to:

Students should be able explain with examples that science operates in a historical context that affects its current practices and paradigms

Benchmark I:

Benchmark I: Critically analyze claims made about the relationship of physics with society

Grade IX	Grade X	Grade XI	Grade XII
Nature of Science and Physics **[SLO:P-09-A-01]** Describe physics as the study of matter, energy, space, time and their mutual connections and interactions **[SLO:P-09-A-02]** Explain with examples that physics has many such-fields, and in today's world involves interdisciplinary fields. (Students should be able to distinguish in terms of the broad subject matter that is studied between the fields: Biophysics Astronomy Astrophysics Cosmology Thermal Physics Optics Classical Mechanics Quantum Mechanics Relativistic Mechanics Nuclear Physics Particle			

Grade IX	Grade X	Grade XI	Grade XII
Physics, Electromagnetism Acoustics Computational Physics Geophysics Climate Physics **[SLO:P-09-A-03]** Explain with examples how Physics is a subset of the Physical Sciences and of the natural sciences **[SLO:P-09-A-04]** State that scientists who specialize in the research of physics are called Physicists **[SLO:P-09-A-05]** Brief with examples that science is a collaborative field that requires interdisciplinary researchers working together to share knowledge and critique ideas **[SLO:P-09-A-06]** Understand the terms 'hypothesis', theory' and 'law' in the context of research in the physics **[SLO:P-09-A-07]** Explain, with examples in Physics, falsifiability as the idea that a theory is scientific only if it makes assertions that can be disproven **[SLO:P-09-A-08]** Differentiate the terms 'science', 'technology' and 'engineering' with suitable examples			

Standard: Students should be able to: Standard: Students should be able to explain, with examples, what philosophical assumptions underpin the practice of science	
Benchmark I: Students should able to: - identify common sources of argumentative fallacies - explain the broad schools of thought about the relationship between physics and metaphysics - give examples of ethical dilemmas that emerge from research and practice of science - explain the broad schools of thought about how science is distinguished from other fields of inquiry	**Benchmark I: Students should be able to:** - explain the broad schools of thought in debates about the role of beauty in science - explain how paradoxes and thought experiments help physicists in scientific inquiry - explain the broad debates about whether it is ethical to continue research in outer space and of subatomic particles

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			NATURE OF SCIENCE AND PHYSICS **[SLO:P-12-A-01]** Explain, with examples, what do thinkers who hold the view that there is inherent mathematical beauty in the natural world mean by: (i) elegance of simplicity (ii)symmetry **[SLO:P-12-A-02]** Explain, with an example, a counter-argument to the claim that physical truths must be inherently mathematically elegant or display symmetry Debates: **[SLO:P-12-A-03]** Describe the main pros and cons in the debate about: (i) whether humans should research whether there are aliens somewhere in the universe (ii) whether research should continue on uncovering the secrets of subatomic particles, given the

Grade IX	Grade X	Grade XI	Grade XII
			advent of nuclear weapons Thought experiments **[SLO:P-11-A-04]** Explain how the below thought experiments helped convey important physics concepts that would have been impractical to investigate empirically the Newton's cannonball

Domain B: Measurement
Physics is the study of relationships between physical quantities. This involves quantifying them by developing units of measurement, taking readings with instruments to make measurements, and expressing how certain or uncertain one is about the soundness of the readings taken.

Standard: Students will be able to:

- Express mathematically and manipulate basic and derived physical quantities
- Identify and explain the reasons for common sources of human and systematic error in experiments
- Identify, explain and describe the utility of measurement instruments in terms of precision
- Quantify the uncertainty in reading taken and calculations made through those raw readings.

Benchmark: Describe those physical quantities as scalar and vector, it can be classified into basic and derived quantities. Physical quantities can be measured, but empirical measurements are accompanied by sources of error.	**Benchmark:** Describe that physical equations must be dimensionally consistent, and sources of error in measurements can be quantified. These errors can be compounded when measured quantities are used to calculate further derived quantities.

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PHYSICAL QUANTITIES AND MEASUREMENT **[SLO:P-09-B-01]** Differentiate between physical and nonphysical quantities **[SLO:P-09-B-02]** Explain with examples that physics is based on physical quantities [including that these consist of a magnitude and a unit] **[SLO:P-09-B-03]** Differentiate between base and derived physical quantities and units. **[SLO:P-09-B-04]** Apply the seven units of System International (SI) [along with their symbols and physical quantities (standard definitions of SI units are not required)]		**S. I Base, Supplementaryand derived units** **[SLO:P-11-B-01]** State SI base units, derive units, and supplementary units for various measurements. **[SLO:P-11-B-02]** Express derived units as products or quotients of the base units. **[SLO:P-11-B-03]** State the conventions for indicating units as set out in the SI units. **Dimensionality** **[SLO:P-11-B-04]** Check the homogeneity of physical equations by using dimensionality and base units. **[SLO:P-11-B-05]** Derive formulae in simple cases using dimensions.	

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[SLO:P-09-B-05] Make use of reasonable estimates of Physical quantities [of those that are discussed in the pi of this grade level] **Prefixes** **[SLO:P-09-B-06]** Inter convert the prefixes and their symbols to Indicate multiple and sub-multiple for both base and derived units] **Vector and Scalars** **[SLO:P-09-B-07]** Analyze and express numerical data using scientific notation [In measurements and calculations.] **SLO:P-09-B-08]** Differentiate between scalar and vector quantities [A scalar has magnitude (size) only and that a vector quantity has magnitude and direction. Students should be able to represent vectors graphically] **[SLO:P-09-B-09]** Justify that distance, speed, time, mass, energy, and temperatures are scalar quantities.		**Errors and Uncertainty** **[SLO:P-11-B-06]** Justify Why all measurements contain some uncertainty. **[SLO:P-11-B-07]** Distinguish between systematic errors (including zero errors) and random errors. **[SLO:P-11-B-08]** Assess the uncertainty in a derived quantity by simple addition of actual, fractional or percentage uncertainties	

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[SLO:P-09-B-10] Justify that displacement, force; weight, velocity, acceleration, momentum, electric field strength and gravitational field strength are vector quantities. **[SLO:P-09-B-11]** Determine, by calculation or graphically, the resultant of two vectors at right angles **Theory of measurement** **[SLO:P-09-B-12]** Choose a proper instrument (meter rule, Vernier calipers, screw gauge, physical balance stop watch, measuring cylinder) for the measurement of length, diameter, mass, time and volume in daily life activities. **[SLO:P-09-B-13]** Determine the least count of a data collection instrument (analog) from its scale **[SLO:P-09-B-14]** Determine an average value for an empirical reading [including small distance and for a short interval of time by measuring multiples (including the period of			

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oscillation of a pendulum)] **[SLO:P-09-B-15]** Round off and justify calculation estimates [Based on empirical data to an appropriate number of significant figures] **[SLO:P-09-B-16]** Critique and analyze experiments for sources of error [Including identifying sources of systematic and random error in measurements and suggesting steps to correct them] **[SLO:P-09-B-17]** Differentiate between precision and accuracy			

Domain C: Mechanics

Mechanics is the study of the motion of mechanical points, bodies and systems with or without consideration of their associated physical properties and the forces acting on them.

Standard: Students will be able to:

- Differentiate between scalar and vector quantities and manipulate mathematically
- Describe distance, displacement, speed, velocity, and acceleration and analyze analytically and graphically
- Differentiate between different kinds of forces and their effects
- Use Newton's laws to analyze motion and equilibrium
- Analyze circular and rotational motion in terms of forces and momentum
- Differentiate between work, energy and power
- Use the law of conservation of energy to analyze the viability and efficiency of systems
- Differentiate between kinetic and gravitational potential energy and analyze it mathematically

Benchmark I: Describe and analyze translatory motion in one dimension through analytical and graphical manipulation of scalar and vector. **Benchmark II:** Describe and analyze the effects of forces and momentum on the translational and rotational motion of bodies in one dimension. **Benchmark III:** Describe and analyze the dynamics of rotational motion quantitatively and circular motion qualitatively in terms of forces in one dimension **Benchmark IV:** Describe and analyze in one dimension, analytically and graphically, how forces can cause solids to stretch and compress **Benchmark V:** Describe and analyze the effects of energy transfers and energy transformations on a body, along with the advantages and disadvantages of harnessing energy from natural resources of harnessing energy from natural resources	**Benchmark I:** Describe and analyze translatory and rotational motion in a plane through analytical and graphical manipulation of scalar and vector quantities **Benchmark II:** Explain events in terms of Newton's laws, including the Law of Gravitation, and the law of conservation of momentum in up to two dimensions **Benchmark III:** Describe and analyze the dynamics of rotational and circular motion in terms of forces and momentum in one dimension **Benchmark IV:** Describe and analyze the deformation of solids, analytically and graphically, in terms of how forces and pressure can cause stretching, compression, stress and strain **Benchmark V:** Describe and analyze analytically and graphically the effects of energy transfers and energy transformations on a body

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KINEMATICS **Rest and Motion** **[SLO:P-09-C-01]** Describe using examples how objects can be at rest and in motion simultaneously. **Types of Motion** **[SLO:P-09-C-02]** Identify different types of motion i.e., translatory, (linear, random, and circular); rotatory and vibratory motions and distinguish among them.		**SCALAR AND VECTOR** **Vectors** **[SLO:P-11-C-01]** Describe a vector and its representation **[SLO:P-11-C-02]** Define and differentiate between scalar and vector quantities **Vector Product** **[SLO:P-11-C-03]** Describe the product of two vectors (dot and cross-product) along with their properties	**GRAVITATION** **Newton's law of gravitation** **[SLO:P-12-C-01]** State and explain Newton's law of gravitation **[SLO:P-12-C-02]** Define and calculate gravitational field strength [this will include more challenging problems than in Grade 9. It will involve use of $g = \frac{GM}{r^2}$]

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Describing motion **SLO:P-09-C-03]** Define and calculate speed [Using the equation speed = distance/time, $v = \triangle s/\triangle t$ (this should include an understanding of the term instantaneous speed)] **[SLO:P-09-C-04]** Define and calculate average speed [average speed = (total distance traveled)/(total time taken)] **[SLO:P-09-C-05]** Differentiate between average and instantaneous speed **[SLO:P-09-C-06]** Differentiate between uniform velocity and non-uniform velocity **[SLO:P-09-C-07]** Define and calculate acceleration [Includes deriving the units of acceleration as ms^{-2} from the formula $a = \triangle v/\triangle t$ and using the formula to solve problems. This also includes knowing that that deceleration is negative acceleration and using fact in calculations.] **[SLO:P-09-C-08]** Differentiate between uniform acceleration and non-uniform acceleration Differentiate with examples between distance and displacement, speed and velocity		**Displacement / Distance with graphical representation** **[SLO:P-11-C-04]** Describe vector nature of displacement. **[SLO:P-11-C-05]** Analyze and interpret patterns of motion of objects using displacement-time graph, velocity-time graph acceleration-time graph **Speed and velocity with graphical representation** **[SLO:P-11-C-06]** Determine the instantaneous velocity of an object moving along the same straight line by measuring the slope of displacement-time graph. **Acceleration, equations of uniformly accelerated motion** **[SLO:P-11-C-07]** Derive equation of uniformly accelerated motion **[SLO:P-11-C-08]** Derive the equations of motion [For uniform acceleration cases only. Derive from the definitions of velocity and acceleration as well as graphically] Solve the problems **Projectile Motion** **[SLO:P-11-C-09]** Understand projectile motion	**[SLO:P-12-C-03]** Analyse gravitational fields by means of field lines. [This includes knowing that for a point outside a uniform sphere, the mass of the sphere may be considered to be a point mass at its center.] **[SLO:P-12-C-04]** Apply Newton's law of gravitation to solve problems [F=G (m_1 m_2)/r^2 for the force between two-point masses to solve problems] **[SLO:P-12-C-05]** Analyze circular orbits in gravitational fields [By relating the gravitational force to the centripetal acceleration, it causes] **[SLO:P-12-C-06]** Analyze the motion of geostationary satellites [This includes knowing that a geostationary orbit remains at the same point above the Earth's surface, with an orbital period of 24hours, orbiting from west to east, directly above the Equator] **[SLO:P-12-C-07]** Derive the equation for gravitational field strength [From Newton's law of gravitation and the definition of gravitational field, the equation g = GM /r^2 for the gravitational

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Graphical Analysis of motion **[SLO:P-09-C-09]** Plot and interpret distance-time graph and speed-time graph **[SLO:P-09-C-10]** Determine and interpret the slope of distance-time and speed-time graph **[SLO:P-09-C-11]** Determine from the shape of the graph, the state of a body (i) at rest (ii)moving with constant speed (iii) moving with variable speed **[SLO:P-09-C-12]** Calculate the area under speed-time graph to determine the distance traveled by the moving body. **[SLO:P-09-C-13]** Solve problems related to uniformly accelerated motion using appropriate equations **[SLO:P-09-C-14]** Develop the equation of uniformly accelerated motion according to the requirement of the problem **[SLO:P-09-C-15]** Solve problems related to freely falling bodies using 9.8 m/s2 as the acceleration due to gravity. **Different types of forces** **[SLO:P-09-C-16]** Illustrate that mass is a measure of the quantity of matter in an object		**[SLO:P-11-C-10]** Calculate height, range and time of flight using equations of projectile motion. **[SLO:P-11-C-11]** Describe elastic and inelastic collision with examples **[SLO:P-11-C-12]** Justify why though the momentum of a closed system is always conserved, some change in kinetic energy may take place. **ROTATIONAL AND CIRCULAR MOTION** **Kinematics of Angular Motion** **[SLO:P-09-C-13]** Define angular displacement, angular velocity and angular acceleration and express angular displacement in radians. **[SLO:P-09-C-14]** Solve problems by using $S= r \theta$ and $v=r \omega$. **[SLO:P-09-C-15]** Define and calculate average orbital speed [from the equation $v=2\pi rT$ where r is the average radius of the orbit and T is the orbital period; apply this equation to solve numerical problems] **[SLO:P-09-C-16]** Interpret and compare given planetary data [about orbital distance, orbital period, density, surface temperature and	field strength due to a point mass] **[SLO:P-12-C-08]** Analyze, why g is approximately constant for small changes in height near the Earth's surface **[SLO:P-12-C-09]** Define and calculate gravitational potential [Use $\phi=-G M/r$ for the gravitational potential in the field due to a point mass] [At a point as the work done per unit mass in bringing a small test mass from infinity to the point] **[SLO:P-12-C-10]** Justify how the concept of gravitational potential leads to the gravitational potential energy of two point masses [Use of Ep = G Mm/r in problems is expected]

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[SLO:P-09-C-17] Explain that the mass of an objects its change from its state of rest or motion (inertia) **[SLO:P-09-C-18]** Explain contact and non-contact forces **[SLO:P-09-C-19]** Differentiate between different types of forces [including weight (gravitational force), friction, drag, air resistance, tension (elastic force), electrostatic force, magnetic force, thrust (driving force), and contact force] **[SLO:P-09-C-20]** State that there are three fundamental forces and describe them in terms of their relative strengths [these are the gravitational, strong and electroweak forces. Students should know that Pakistani Scientist won the Nobel Prize for ping prove that the weak force and the electromagnetic force are actually unified] **[SLO:P-09-C-21]** Define and calculate weight [Weight is the force exerted on an object with mass by a planet's gravity, and use W = mg] **[SLO:P-09-C-22]** Define and calculate gravitational field strength		uniform gravitational field strength at the planet's surface] **[SLO:P-11-C-17]** Use equations of angular motion to solve problems involving rotational motions. **Centripetal Force and Centripetal Acceleration** **[SLO:P-11-C-18]** Describe qualitatively motion in a curved path due to a perpendicular force. **[SLO:P-11-C-19]** Define and calculate centripetal force and centripetal acceleration [Use F=mrω^2, F=(mv^2)/r $a = r\omega^2$ **[SLO:P-11-C-20]** Justify how a centrifuge is used to separate materials using centripetal force **[SLO:P-11-C-21]** Describe situations in which the centripetal acceleration is caused by a tension force, a frictional force, a gravitational force, or a normal force. **Orbital velocity** **[SLO:P-11-C-22]** Define the term orbital velocity and derive relationship between orbital velocity, the gravitational constant, mass and the radius of the orbit.	

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[This includes being able to state that a gravitational field is a region in which a mass experiences a force due to gravitational attraction. Students should be able to define gravitational field strength (g) as force per unit mass use the equation gravitational field strength=weight/mass g=W/m (and know that this is equivalent to the acceleration of free fall)] **[SLO:P-09-C-23]** Justify and illustrate the use electronic balances to measure mass [understanding the internal workings of the electronic balance is not required; just how to practically use the instrument in appropriate situations] **[SLO:P-09-C-24]** Justify and illustrate the use of a force meter to measure weight **[SLO:P-09-C-25]** Represent the forces acting on a body using free body diagrams **Newton's Laws of motion** **[SLO:P-09-C-26]** State and apply Newton's 1st law **[SLO:P-09-C-27]** Identify the effect of force on velocity [It may change the velocity of an object by changing its direction of motion or its speed]		**[SLO:P-11-C-23]** Explain why the objects in orbiting satellites appear to be weightless. **[SLO:P-11-C-24]** Describe how artificial gravity is created to counter weightlessness **Moment of Inertia** **[SLO:P-11-C-25]** Define and calculate moment of inertia of a body **Angular Momentum** **[SLO:P-11-C-26]** Define and calculate angular momentum of a body **[SLO:P-11-C-27]** State and apply the law of conservation of angular momentum. Illustrate the applications of conservation of angular momentum in real life [such as by flywheels to store rotational energy, by gyroscopes in navigation systems, by ice skaters to adjust their angular velocity] **Torque** **[SLO:P-11-C-28]** Define torque as the cross product of force and moment arm **[SLO:P-11-C-29]** Derive and apply the relation between torque, moment of inertia and angular acceleration	

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[SLO:P-09-C-28] Determine the resultant of two or more forces acting along the same straight line **[SLO:P-09-C-29]** State and apply Newton's second law in terms of acceleration **[SLO:P-09-C-30]** State and apply Newton's third law **[SLO:P-09-C-31]** Explain with examples how Newton's third law describes pairs of forces of the same type acting on different objects. **[SLO:P-09-C-32]** State the limitations of Newton's laws of motion [That they are not exact but provide a good approximation, unless an object is moving close to the speed of light or small enough that quantum effects come significant (for example, In the se of high-speed bodies, the theory of relativistic mechanics is used. In the case of very small objects at the atomic level, quantum mechanics is used).] **[SLO:P-09-C-33]** Describe and identify states of equilibrium [This includes the types, conditions, and states of equilibrium and identifying examples of them daily life examples.]		**FLUID STATICS** **Pascal's Law** **[SLO:P-11-C-30]** Describe Pascal's Law **[SLO:P-11-C-31]** Describe applications of Pascal's law **Archimedes' Principal** **[SLO:P-11-C-32]** State Archimedes' principal Derive the equation of up thrust acting on a body in fluid **[SLO:P-11-C-33]** Justify how ships are engineered to float in the sea **Buoyancy and Law of Floatation** **[SLO:P-11-C-34]** Describe the basic concepts of buoyancy **[SLO:P-11-C-35]** State law of floatation **FLUID DYNAMICS** **Fluid Friction** **[SLO:P-11-C-36]** Describe those real fluids are viscous fluids. **[SLO:P-11-C-37]** Describe those viscous forces in a fluid cause a retarding force on an object moving through it. **[SLO:P-11-C-38]** Explain how does the magnitude of the viscous force on an object moving in fluid depend on the size and velocity of the object.	

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Friction **[SLO:P-09-C-34]** Analyse the dissipative effect of friction [This include identifying where dissipation may occur and giving examples such as rubbing hands together produces heat, asteroids that enter the Earth's atmosphere disintegrate due to high temperature generated from air resistance] **[SLO:P-09-C-35]** Analyse the dynamics of an object reaching terminal velocity **[SLO:P-09-C-36]** Differentiate qualitatively between rolling and sliding friction need for coefficients of friction] **[SLO:P-09-C-37]** Justify methods to reduce friction **Momentum** **[SLO:P-09-C-38]** Define and calculate momentum **[SLO:P-09-C-39]** Define and calculate impulse [Use the equation Impulse = $F\Delta t = m\Delta V$] **[SLO:P-09-C-40]** Apply the principle of the conservation of momentum to solve simple problems in one dimension **[SLO:P-09-C-41]** Define resultant force in terms of momentum		**Streamline and Turbulent Flow** **[SLO:P-11-C-39]** Define the terms: steady (streamline or laminar) flow, incompressible flow and non-viscous flow as applied to the motion of an ideal fluid. **[SLO:P-11-C-40]** Justify that the pressure differences an arise from different rates of flow of a fluid **[SLO:P-11-C-41]** Describe that the majority of practical examples of fluid flow and resistance to motion in fluids involve turbulent rather than laminar conditions. **Equation of Continuity** **[SLO:P-11-C-42]** Identify that the equation of continuity is a form of the principle of conservation of mass. **[SLO:P-11-C-43]** Solve problems by using the equation of continuity **Bernoulli's Equation and its Application** **[SLO:P-11-C-44]** Explain and apply Bernoulli's equation for horizontal and vertical fluid flow. **[SLO:P-11-C-45]** Explain why real fluids are viscous fluids.	

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[As the change in momentum per unit time; recall and use the equation resultant force = change in momentum/ time taken F=Δp/Δt] **DYNAMICS-II** **TURNING EFFECTS OF FORCES** **Force on bodies** **[SLO:P-09-C-42]** Define like and unlike parallel forces **Moment of Forces** **[SLO:P-09-C-43]** Define moment of force or torque as moment = force x perpendicular distance from pivot to the line of action of force. **[SLO:P-09-C-44]** Explain the turning effect of force by relating it to everyday life. **[SLO:P-09-C-45]** Illustrate by describing a practical application of moment of force in the working of bottle opener, spanner, door/windows handle etc. **Principle of moments** **[SLO:P-09-C-46]** State the principle of moments **[SLO:P-09-C-47]** Verify the principle of moments by using a meter rod balanced on a wedge		**[SLO:P-11-C-46]** Describe how viscous forces in a fluid cause a retarding force on an object moving through it. **[SLO:P-11-C-47]** Describe super fluidity [As the state in which a liquid will experience zero viscosity. Students should know the implications of this state e.g. this allows for super fluid's to creep over the walls of containers to 'empty' themselves. It also implies that if you stir a superfluid, the vortices will keep spinning indefinitely.] **[SLO:P-11-C-48]** Analyze the real-world applications of the Bernoulli effect [For example, atomizers in perfume bottles, the swinging trajectory of a spinning cricket ball and the lift of a spinning golf ball (the magnus effect), the use of Ventur ducts in filter pumps and car engineers to adjust the flow of fluid, etc.] **PHYSICS OF SOLIDS** **Elasticity** **[SLO:P-11-C-49]** Justify why and apply the fact that the area under the force-extension graph represents the work done	

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[SLO:P-09-C-48] Define couple as a pair of forces tending to produce rotation **[SLO:P-09-C-49]** Analyze objects in equilibrium using the principle of moments **[SLO:P-09-C-50]** Justify experiment to verify the principle of moments **Centre of mass & centre of Gravity** **[SLO:P-09-C-51]** Define the Centre of mass and Centre of gravity of a body **[SLO:P-09-C-52]** Determine the position of Centre of mass/gravity of regularly and irregularly shaped objects **[SLO:P-09-C-53]** Describe how to determine the position of the center of gravity of a plane lamina using a plumb line **[SLO:P-09-C-54]** Analyze, qualitatively, the effect of the position of the center of gravity on the stability of simple objects **[SLO:P-09-C-55]** Plane how the stability of an object can be improved [by lowering the center of mass and decreasing the base area of the object]		**[SLO:P-11-C-50]** Determine the elastic potential energy of a material [That is deformed within its limit of proportionality from the area under the force F-extension graph. Also] state and use $E_P = \frac{1}{2}\ FX = \frac{1}{2}$ kx^2 For a material deformed within its limit of proportionality] **[SLO:P-11-C-51]** Deduce the work done from force displacement graph **[SLO:P-11-C-52]** Differentiate between conservative and non-conservative forces **[SLO:P-11-C-53]** Utilize the work-energy theorem in a resistive medium to solve problems **Classification of Solids** **[SLO:P-11-C-54]** Distinguish between the structure of crystalline, glassy, amorphous and polymeric solids. **[SLO:P-11-C-55]** Describe that deformation in solids is caused by a force and that in one dimension; the deformation can be tensile or compressive. **Mechanical Properties of Solids** **[SLO:P-11-C-56]** Define and use the terms stress, strain and the young modulus	

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[SLO:P-09-C-56] Illustrate the applications of stability physics in real life [Such as this concept is central to engineering technology such as balancing toys and racing cars **[SLO:P-09-C-57]** Predict qualitatively the motion of rotating bodies [Describe qualitatively that, analogous to Newton's 1st law for translational motion, an object that is rotating will continue to do so at the same rate unless acted upon by a resultant moment (in which case it would begin, to accelerate or decelerate its rotational motion)] **Central Force** **[SLO:P-09-C-58]** Define Centripetal Force and centrifugal force **[SLO:P-09-C-59]** Describe qualitatively motion in a circular path due to a centripetal force, **[SLO:P-09-C-60]** Identify the sources of centripetal force real life examples [e.g. tension in a string for a stone being swirled around, gravity for the Moon orbiting the Earth] **[SLO:P-11-C-61]** Justify how a centrifuge is used to separate		**[SLO:P-11-C-57]** Define and use the terms Young's modulus, bulk modulus and shear modulus. **[SLO:P-11-C-58]** Explain that squeezing the end of a rubber pipe results in increase inflow velocity **[SLO:P-11-C-59]** Describe an experiment to determine the young modulus of a metal wire. **[SLO:P-11-C-60]** Describe and use the terms elastic deformation, plastic deformation and elastic limit **[SLO:P-11-C-61]** Demonstrate the force F-extension graphs for typical ductile, brittle and polymeric materials. Become familiar ultimate tensile stress, elastic deformation and plastic deformation of a material.	

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materials using centripetal force **FORCES AND MATTER** **Forces acting on solids** **[SLO:P-11-C-62]** Illustrate that forces may change the shape and size of the body **Hook's law** **[SLO:P-11-C-63]** Define Hook's law Calculate extension in spring and spring constant using formula $F = kx$ **[SLO:P-09-C-64]** Sketch, plot and interpret load-extension graphs for an elastic solid **[SLO:P-09-C-65]** Define and use the term 'limit of proportionality' for a load-extension graph [Including identifying this point on the graph (an understanding of the elastic limit is not required)] **[SLO:P-09-C-66]** Illustrate the applications of Hooke's Law [Such as that it is the fundamental graph represents the work done principle behind engineering many measurement instruments such as the spring scale, the galvanometer, and the balance wheel of the mechanical clock.]			

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Properties of fluids **[SLO:P-09-C-67]** Define and calculate pressure **[SLO:P-09-C-68]** Demonstrate the factors that affects the pressure **[SLO:P-09-C-69]** Calculate the pressure using formula $P = \frac{F}{A}$ **[SLO:P-09-C-70]** Analyze in situations how pressure at a surface produces a force in a direction at right angles to the surface [can make reference to experiments to verify this principle] **[SLO:P-09-C-71]** Justify that the atmosphere exerts a pressure. **[SLO:P-09-C-72]** describe that atmospheric pressure decreases with the increase in height above the Earth's surface. **[SLO:P-09-C-73]** explain that changes in atmospheric pressure in a region may indicate a change in the weather. **[SLO:P-09-C-74]** Analyze the workings and applications of a liquid barometer **[SLO:P-09-C-75]** Justify why and analyze quantitatively how pressure varies with depth in liquid.			

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[SLO:P-09-C-76] Analyze the workings and applications of a manometer **[SLO:P-09-C-77]** Define and apply Pascal's law [Apply Pascal's law to systems such as the transmission of pressure in hydraulic systems with particular reference to the hydraulic press and hydraulic brakes on vehicles.] **WORK, ENERGY AND POWER** **Work** **[SLO:P-09-C-78]** Define work and its SI unit. **[SLO:P-09-C-79]** Calculate work done using equation $Work = force \times distance$ moved in the direction of force **Energy forms** **[SLO:P-09-C-80]** Define kinetic energy and potential energy **[SLO:P-09-C-81]** Prove that kinetic energy $E_k = \frac{1}{2}mv^2$ and formula for gravitational potential energy [Such as in gravitational potential, chemical, elastic (strain), nuclear, electrostatic, and internal (thermal) energies]			

Grade IX	Grade X	Grade XI	Grade XII
[SLO:P-09-C-82] Use Kinetic Energy $E_k = \frac{1}{2} mv^2$ and potential energy $E_p = mgh$ to solve problems. **Conversion of energy** **[SLO:P-09-C-83]** Explain that energy may be stored **[SLO:P-09-C-84]** Describe how energy is transferred and stored during events and processes [e.g. work done during transfer by mechanical work done, electrical work done, and heat] **[SLO:P-09-C-85]** State and apply the principle of the conservation of energy **[SLO:P-09-C-86]** Justify why perpetual energy machines do not work **Renewable and Non renewable energy sources** **[SLO:P-09-C-87]** Differentiate energy sources as non-renewable and renewable energy sources with examples of each. **[SLO:P-09-C-88]** Describe how useful energy may be obtained from natural resources [including the cases of (a) chemical energy stored in fossil fuels,			

Grade IX	Grade X	Grade XI	Grade XII
(b) chemical energy stored in biofuels, (c) hydroelectric resources, (d) solar radiation, (e) nuclear fuel, (f) geothermal resources (g) Wind, (h) Tides, (i) Waves in the sea while including references to a boiler, turbine and generator where they are used] **[SLO:P-09-C-89]** Describe advantages and disadvantages of methods of energy generation [limited to whether it is renewable, when and whether it is available, and Its impact on the environment] **Efficiency** **[SLO:P-09-C-90]** Define and calculate power [as work done per unit time and also as energy transferred per unit time. This also includes applying the equations: $power = \frac{workdone}{time}$ taken $P = \frac{w}{t}$ $Power = \frac{energy\ transferred}{time}$ taken $P = \frac{w}{t}$ to solve simple problems] **[SLO:P-09-C-91]** Define and calculate efficiency [including: (%) efficiency = (useful energy output)/ (total energy input) (× 100%)			

Grade IX	Grade X	Grade XI	Grade XII
(%) efficiency = (useful power output)/ (total power input) (×100%)] **[SLO:P-09-C-92]** Apply the concept of efficiency to simple problems involving energy transfer **[SLO:P-09-C-93]** Explain why a system cannot have an efficiency of 100%.			

Domain D: Heat and Thermodynamics
In this field students study Heat as a form of energy and its co related with thermodynamics.

Standard: Students should be able to describe and analyze:

- describe and analyze the effects of heat on the physical properties of matter by making reference to the Kinetic theory of matter
- how heat can be transferred through different modes

Benchmark I: Use the kinetic theory of matter to explain the physical properties of matter and how these transforms upon changes in state **Benchmark II:** Explain how heat can be transferred through convection, conduction and radiation and the effects and applications of these modes of transfer	**Benchmark I:** Benchmark I: Use the kinetic theory of matter to account for the properties of an ideal gas

Grade IX	Grade X	Grade XI	Grade XII
DENSITY AND TEMPERATURE **Density:** **[SLO:P-09-D-01]** Define and calculate density **[SLO:P-09-D-02]** Justify and illustrate how to determine the density of a substance [Including for a liquid, of a regularly shaped solid and of an irregularly shaped solid which sinks in a liquid (volume by displacement), including appropriate calculations] **Particle Theory of Matter:** **[SLO:P-09-D-03]** Describe, qualitatively, the particle structure of solids, liquids and gasses [Including relating their properties to the forces and distances between particles and to the motion of the particles (atoms, molecules, ions and electrons)	**Thermal Properties of Mater:** **[SLO:P-10-D-01]** Define the terms heat capacity and specific heat capacity with SI unit **[SLO:P-10-D-02]** Organize experiments to measure the specific heat capacity [of a solid and of a liquid] **[SLO:P-10-D-03]** Describe the effect of large specific heat capacity of water in our everyday life, **Thermal Expansion and Kinetic Theory of Matter:** **[SLO:P-10-D-04]** Define thermal Expansion **[SLO:P-10-D-05]** Explain thermal expansion in terms of kinetic theory [For solids, liquids and gasses. This includes stating the relative order of magnitudes of the expansion of solids, liquids and gasses.]	**Thermal Equilibrium** **[SLO:P-11-D-01]** State that regions of equal temperature is in thermal equilibrium **Gas Laws** **[SLO:P-11-D-02]** **[**Derive gas laws (Boyle's law, Charle's law and Avogadro's law) **[SLO:P-11-D-03]** Apply the equation of state for an ideal gas [expressed as pV = nRT, where n = amount of substance (number of moles) and as pV = NkT, where N = number of molecules] **[SLO:P-11-D-04]** state that the Boltzmann constant k is given by $k = \frac{R}{N_A}$ **[SLO:P-11-D-05]** Use the equation, including a graphical representation of the relationship between pressure and volume for a gas at constant temperature.	**IDEAL GASES AND STATISTICAL METHODS** **Kinetic Molecular theory** **[SLO:P-12-D-01]** explain how molecular movement causes the pressure exerted by a gas **[SLO:P-12-D-02]** Derive and use the relationship $pV = \frac{1}{2} Nm < c^2 >$ [where $< c^2 >$ is the mean-square speed (a simple model considering one-dimensional collisions and then extending to three dimensions using $\frac{1}{3} < c^2 \geq < c_{x^2} >$ is sufficient)] **[SLO:P-12-D-03]** Calculate the root-mean-square speed of an ideal gas **[SLO:P-12-D-04]** Derive and use the formula for the average translational kinetic energy of agas

Grade IX	Grade X	Grade XI	Grade XII
[SLO:P-09-D-04] Describe plasma as a fourth state of matter [in which a significant portion of the material is made up of ions or electrons e.g. in stars, neon lights and lighting streamers] **Temperature:** **[SLO:P-09-D-05]** Describe the relationship between the motion of particles and temperature [including the idea that there is a lowest possible temperature (approx. -273°C), known as absolute zero, where the particles have least kinetic energy] **[SLO:P-09-D-06]** State that an increase in the temperature of an object increases its internal energy **[SLO:P-09-D-07]** Explain, with examples, how a physical property which varies with temperature may be used for the measurement of temperature **[SLO:P-09-D-08]** Justify the need for fixed points in the point and steam point.] **[SLO:P-09-D-09]** Illustrate what is meant by the sensitivity, range and linearity of thermometers.	**[SLO:P-10-D-06]** Analyze the applications and consequences of thermal expansion in real life **[SLO:P-10-D-07]** Describe qualitatively the thermal expansion of solids (linear and volumetric expansion) **[SLO:P-10-D-08]** Explain the thermal expansion of liquids (real and apparent expansion) **[SLO:P-10-D-09]** Analyze the pressure and the changes in pressure of a gas in terms of particles [the forces exerted by particles colliding with surfaces, creating a force per unit area.] **Changes in State:** **[SLO:P-10-D-10]** Explain the process of evaporation and the difference between boiling and evaporation **[SLO:P-10-D-11]** Define the terms for the changes in state between solids, liquids, and gases. **[SLO:P-10-D-12]** Analyze how temperature, humidity, surface area and air movement over a surface affect evaporation. **[SLO:P-10-D-13]** Describe the use of cooling caused by evaporation in the	**Kinetic Theory of Gases** **[SLO:P-11-D-06]** Describe the basic assumptions of the kinetic theory of gasses. [Including understanding the temperature, pressure and density conditions under which an ideal gas is a good approximation of a real gas.] **First Law of Thermodynamics** **Heat and Work** **[SLO:P-11-D-07]** Describe that heat flow and work are two forms of energy transfer between systems and calculate heat being transferred. **Internal Energy** **[SLO:P-11-D-08]** Relate rise in temperature of a system increases its internal energy. **Second Law of Thermodynamics** **[SLO:P-11-D-09]** State and explain second law of thermodynamics. **[SLO:P-11-D-10]** State the working principle of heat engine [Specifically, the below **[SLO:P-11-D-11]** Describe the concept of reversible and irreversible processes.	**[SLO:P-12-D-05]** Illustrate that the model of ideal gasses is used a base from which the field of statistical mechanics emerged [and has helped explain the behavior of 'non-ideal' gasses through modifications to the model e.g. the behavior of stars] **[SLO:P-12-D-06]** State that under extreme physical conditions, atoms can break down into sub-atomic particles that can form unusual states of matter [Such as degenerate matter. Usually made of any one kind of subatomic particle such as neutron degenerate matter in neutron stars under strong gravity and heat) a Bose-Einstein condensates (created when certain materials are taken to very low temperatures a then exhibit remarkable properties like superconductivity and superfluidity)]

Grade IX	Grade X	Grade XI	Grade XII
[SLO:P-09-D-10] Analyze how the structure of a liquid in-glass thermometer affects its sensitivity, range and linearity **[SLO:P-09-D-11]** Differentiate between the structure and function of liquid-in-glass and of thermocouple thermometers	refrigeration process without using harmful CFCs. **[SLO:P-10-D-14]** Define latent heat [as the energy required to change the state of a substance and explain it in terms of particle behavior and the forces between particles.] **[SLO:P-10-D-15]** Demonstrate experiments to determine heat of fusion and heat of vaporization of ice and water respectively by sketching temperature-time graph on heating ice. **[SLO:P-10-D-16]** Explain that certain materials, when cooled to near absolute zero, can exhibit superconductivity **[SLO:P-10-D-17]** Describe superconductivity [as when atoms are in this state, their kinetic energy is low, so there is little (or no) resistance to the flow of electrons.] **Transfer of Heat:** **[SLO:P-10-D-18]** Justify experiments to distinguish between good and bad thermal conductors **[SLO:P-10-D-19]** Explain thermal conduction in all solids [in terms of atomic or molecular lattice	**[SLO:P-11-D-12]** Describe the working of petrol engine and diesel engine. **Carnot Cycle** **[SLO:P-11-D-13]** Explain the working principle of Carnot'sengine **[SLO:P-11-D-14]** State that the Carnot cycle sets a limit for the efficiency of a heat engine at the temperatures of its heat reservoirs given by $Efficiency = 1 - \frac{T_{cold\ reservoir}}{T_{hot\ reservoir}}$ [the efficiency is independent of the nature of the working substance] **[SLO:P-11-D-15]** Solve problems to find out the efficiency of heat engine **Refrigerator** **[SLO:P-11-D-16]** Describe that refrigerator is a heat engine operating in reverse as that of an ideal heat engine and find its efficiency **[SLO:P-11-D-17]** Solve problems to find out the efficiency of a refrigerator	

Grade IX	Grade X	Grade XI	Grade XII
	vibrations and also in terms of the movement of free (delocalized) electrons in metallic conductors] **[SLO:P-10-D-20]** Explain convection in liquids and gasses [in terms of density changes] Justify experiments to illustrate convection **[SLO:P-10-D-21]** Explain convection in seawater to support marine life **[SLO:P-10-D-22]** Describe the role of land breezes and sea breezes in maintaining moderate coastal climates **[SLO:P-10-D-23]** Explain how birds are able to fly for hours without flapping their wings and gliders are able to rise by riding on thermal currents **[SLO:P-10-D-24]** Describe the process of thermal energy transfer by radiation [and know that it does not require a medium] **[SLO:P-10-D-25]** Describe the effect of surface color and texture on the emission, absorption and reflection of infrared radiation	**Entropy** **[SLO:P-11-D-18]** Define term "system" and explain that an increase in temperature increases the disorder of the system. **[SLO:P-11-D-19]** Describe that change in entropy is positive when heat is added and negative when heat is removed from the system. **[SLO:P-11-D-20]** Explain that increase in entropy means degradation of energy. **[SLO:P-11-D-21]** Explain that energy is degraded during all-natural processes. **[SLO:P-11-D-22]** Identify that system tend to become less orderly over time. **[SLO:P-11-D-23]** Explain that Entropy, S, is a thermodynamic quantity that relates to the degree of disorder of the particles in a system. **[SLO:P-11-D-24]** Solve problems using the equation of entropy	

Grade IX	Grade X	Grade XI	Grade XII
	[SLO:P-10-D-26] Justify qualitatively how the rate of emission of radiation depends on the surface temperature and surface area of an object **[SLO:P-10-D-27]** Justify Experiments to distinguish between good and bad emitters and absorbers of infrared radiation **[SLO:P-10-D-28]** Analyze the consequence of heat radiation in the greenhouse effect and its effect in global warming. **[SLO:P-10-D-29]** Analyze everyday applications of conduction, convection and radiation [Including: (a) heating objects such as kitchen pans (b) heating a room by convection (c) measuring temperature using an infrared thermometer (d) using thermal insulation to maintain the temperature of a liquid and to reduce thermal energy transfer in buildings (e) the mechanism of a household hot-water system]		

Domain E: Waves
In this field students study the physical nature of waves and how the propagate, with a special look at the cases of sound and light.

Standard: Students should be able to:
- mathematically describe how waves propagate and the general properties of reflection, refraction and diffraction
- explain how the wave theory of light can help explain various optical phenomena

Benchmark I: Explain wave motion in terms of oscillations and energy and apply the basic principles of wave reflection, refraction and diffraction to solve problems **Benchmark II:** Use the principles of reflection and refraction from the wave model of light to create and analyze ray diagrams that help explain images generated by simple mirrors, lenses and total internal reflection	**Benchmark I:** Analytically and graphically explain the nature and effects of simple harmonic motion, the doppler effect, and attenuation of sound wave intensity in media **Benchmark II:** Use wave theory to analyze diffraction patterns, interference and polarization in the context of light and sound and other waves

Grade IX	Grade X	Grade XI	Grade XII
	GENERAL WAVES PROPERTIES **Wave and Nature of Waves:** **[SLO:P-10-E-01]** Describe wave motion as illustrated by vibrations in rope, slinky spring and by experiments with water waves **[SLO:P-10-E-02]** Illustrate that for a transverse wave, the direction of vibration is at right angles to the direction of the energy transfer [including giving examples such as electromagnetic radiation, waves on the surface of water, and seismic S-waves (secondary)] **[SLO:P-10-E-03]** Illustrate that for a longitudinal wave, the direction of vibration is parallel to the direction of the energy transfer	**Superposition of Waves** **[SLO:P-11-E-01]** Use the principle of superposition of waves to solve problems **[SLO:P-11-E-02]** Differentiate between constructive and destructive interference. **[SLO:P-11-E-03]** Apply the principle of superposition to explain the working of noise canceling headphones. **[SLO:P-11-E-04]** Illustrate experiments that demonstrate stationary waves [using microwaves, stretched strings and air columns (it will be assumed that end corrections are negligible; knowledge of the concept of end corrections is not required)]	**OSCILLATIONS** **Simple Harmonic Motion:** **[SLO:P-12-E-01]** Use the terms displacement, amplitude, period, frequency, angular frequency and phase difference in the context of oscillations **[SLO:P-12-E-02]** Express the period of simple harmonic motion in terms of both frequency and angular frequency **[SLO:P-12-E-03]** Explain that simple harmonic motion occurs when acceleration I proportional to displacement from fixed point and in the opposite direction **[SLO:P-12-E-04]** use $a = \omega^2 x$ to solve problems

Grade IX	Grade X	Grade XI	Grade XII
	[including give examples such as sound waves and seismic P-waves (primary)] **[SLO:P-10-E-04]** Explain that waves are means of energy transfer without transfer of matter **[SLO:P-10-E-05]** Distinguish between mechanical and electromagnetic waves **Properties of Waves** **[SLO:P-10-E-06]** Describe properties of waves such as reflection, refraction and diffraction with the help of ripple tank [Describe how wavelength gap size affects diffraction at an edge and diffraction through a gap size] **[SLO:P-10-E-07]** Analyze the phenomenon of tsunamis generated under the surface of water [in terms of underwater earthquakes/volcanic activity generating waves that increase in frequency and amplitude as they encounter increasingly shallow water] **[SLO:P-10-E-08]** Define the terms speed (v), frequency (f), wavelength (λ), time period (T), amplitude, crest, trough, cycle, wave front, compression	**[SLO:P-11-E-05]** Explain the formation of a stationary wave using graphical representation **[SLO:P-11-E-06]** Explain the formation of harmonics in stationary waves. **[SLO:P-11-E-07]** Explain the observed change in frequency of a mechanical wave coming from a moving object as it approaches and moves away [describing of the Doppler effect for a stationary source and a moving observer is not required] **[SLO:P-11-E-08]** Use the expression $f_0 = \frac{f_s \cdot v}{v \pm v_s}$ for the observed frequency when a source of sound waves moves relative to a stationary observer. **[SLO:P-11-E-09]** Explain the applications of the Doppler effect [such as radar, sonar, astronomy, satellite, radar speed traps and studying cardiac problems in humans] **Polarization** **[SLO:P-11-E-10]** Explain that polarization is a phenomenon associated with transverse waves. **[SLO:P-11-E-11]** Define and apply Malus's law [$I = I_0 cos^2\theta$ to calculate the intensity of	**[SLO:P-12-E-05]** use the equations $v = v_0 \cos(\omega t)$ and $v = \pm\omega\sqrt{(x_{0^2} - x^2)}$ to solve problems **Energy Conservation in SHM** **[SLO:P-12-E-06]** Analyze graphical representations of the variations of displacement, velocity and acceleration for simple harmonic motion **[SLO:P-12-E-07]** Analyze the interchange between kinetic and potential energy during simple harmonic motion **[SLO:P-12-E-08]** Apply $\frac{1}{2}m\omega^2 x_{0^2}$ for the total energy of a system undergoing simple harmonic motion **Resonance** **[SLO:P-12-E-09]** State that resonance involves a maximum amplitude of oscillations and that this occurs when an oscillating system is forced to oscillate at its natural frequency. **[SLO:P-12-E-10]** Describe qualitatively the factors which determine the frequency response and sharpness of the resonance.

Grade IX	Grade X	Grade XI	Grade XII
	and rarefaction Solve problems by applying the relation f = 1/T and v = f λ **SOUND** **Sound Waves** **SLO:P-10-E-09]** Illustrate a method involving a measurement of distance and time for determining the speed of sound in air **[SLO:P-10-E-10]** Define that the speed of sound in air is approximately 330-350m/s **[SLO:P-10-E-11]** Explain that, in general, sound travels faster in solids than in liquids and faster in liquids than in gasses. **[SLO:P-10-E-12]** Illustrate the factors which affects the speed of sound (temperature, humidity etc.) **Timbre** **[SLO:P-10-E-13]** Describe how different sound sources produce sound waves with different timbres [including making reference to the shape of the traces on an oscilloscope] **Noise Pollution** **[SLO:P-10-E-14]** Analyze the effects of noise pollution on the environment	a plane-polarized electromagnetic wave after transmission through a polarizing filter or a series of polarizing filters. (calculation of the effect of a polarizing filter on the intensity of an unpolarized wave is not required).] **[SLO:P-11-E-12]** Explain the use of polaroids in sky photography and stress analysis of materials **Diffraction** **[SLO:P-11-E-13]** Analyze experiments that demonstrate diffraction [including the qualitative effect of the gap width relative to the wavelength of the wave; for example, diffraction of water waves in a ripple tank] **[SLO:P-11-E-14]** Explain the term coherence. **[SLO:P-11-E-15]** Explain beats [as the pulsation caused by two waves of slightly different frequencies interfering with each other] **[SLO:P-11-E-16]** Illustrate examples of how beats are generated in musical instruments **Gravitational waves** **[SLO:P-11-E-17]** Describe qualitatively gravitational waves	**[SLO:P-12-E-11]** identify the use of standing waves and resonance in applications [such as Rubens tubes, Chladni plates and acoustic levitation (knowledge of wave harmonic modes is not required)] **[SLO:P-12-E-12]** Justify that there are some circumstances in which resonance is useful [such as tuning a radio, microwave oven and other circumstances in which resonance should be avoided such as airplane's wing or a suspension bridge] **Damped Harmonic Oscillations** **SLO:P-12-E-13]** describe that a resistive force acting on an oscillating system causes damping **[SLO:P-12-E-14]** use the terms light, critical and heavy damping **[SLO:P-12-E-15]** sketch displacement-time graph to illustrate light, critical and heavy damping **[SLO:P-12-E-16]** Describe practical examples of damped oscillations with particular reference to the efforts of the degree of damping and the importance of critical

Grade IX	Grade X	Grade XI	Grade XII
	[SLO:P-10-E-15] Define ultrasound. **[SLO:P-10-E-16]** Describe how the reflection of sound may produce an echo. [simple experiments to show the reflection of sound waves] **[SLO:P-10-E-17]** Illustrate and analyze the uses of ultrasound [in cleaning, prenatal and other medical scanning, and in sonar (including calculation of depth or distance from time and wave speed)] **[SLO:P-10-E-18]** Illustrate the use of infrasound [e.g. by elephants in communication, and in the study of seismic activity] **Acoustics** **[SLO:P-10-E-19]** Justify the importance of acoustic protection **[SLO:P-10-E-20]** Describe how knowledge of the properties of sound waves is applied in the design of buildings with respect to acoustics **[SLO:P-10-E-21]** Explain the use of soft materials to reduce echo sounding [such as in classroom studies, and other public gathering buildings]	[as waves of the intensity of gravity generated by the accelerated masses of an orbital binary system that propagate as waves outward from their source at the speed of light] **[SLO:P-11-E-18]** State that as a gravitational wave passes a body with mass the distortion in spacetime can cause the body to stretch and compress periodically **[SLO:P-11-E-19]** State that gravitational waves pass through the Earth due to far off celestial events, but they are very minute amplitude **[SLO:P-11-E-20]** Describe the use of interferometers in detecting gravitational waves [Interferometers are very sensitive detection devices that make use of the interference of laser beams (working and set up details are not required) and were used to first detect the existence of gravitational waves]	damping in cases such as a car suspension system. **INTERFERENCE AND DIFFRACTION** **Describe Youngs' double slit** **[SLO:P-12-E-17]** Use $\Delta y = \frac{\lambda L}{d}$ for double-slit interference using light to solve problems **[SLO:P-12-E-18]** use $d \sin(\theta) = n\lambda$ to solve problems **[SLO:P-12-E-19]** describe the use of a diffraction grating to determine the wavelength of light [the structure and use of the spectrometer are not included] **[SLO:P-12-E-20]** with the context of the electron diffraction double slit experiment, explain the below two of the many interpretations of quantum mechanics: i) Copenhagen interpretation ii) many worlds interpretation

Grade IX	Grade X	Grade XI	Grade XII
	Ear Drum **[SLO:P-10-E-22]** Explain how sound is converted by the eardrum and nerves into electrical signals that are then interpreted by the brain **ELECTROMAGNETIC SPECTRUM** **Description of Light** **[SLO:P-10-E-23]** Explain the dispersion of light by a prism [including the detection of nonvisible spectra by a thermometer] **[SLO:P-10-E-24]** State the colours of the visible spectrum and explain how the colours are related to frequency/ wavelength. **[SLO:P-10-E-25]** Describe the behavior of light when passing through water droplets. **[SLO:P-10-E-26]** State that all electromagnetic waves travel with the same high speed in air and state the magnitude of that speed. **Reflection of Light** **[SLO:P-10-E-27]** Describe the terms used in reflection including normal, angle of incidence, angle of reflection and state laws of reflection		

Grade IX	Grade X	Grade XI	Grade XII
	[SLO:P-10-E-28] Use the law of reflection to solve simple optical problems **Plane Mirror** **[SLO:P-10-E-29]** Organize an experiment to find the position and characteristics of an optical image formed by a plane mirror. [same size, same distance from mirror as object and virtual] **Refraction of light** **SLO:P-10-E-30]** Apply the qualitative principle that a wave refracts towards the normal when it slows down while entering a medium, and that it refracts away from the normal if it speeds up when it enters a new medium [in the case the angle of incidence is zero, then the waves continue parallel to the normal] **[SLO:P-10-E-31]** Define and use the refractive index from a vacuum to a medium for Light as $\frac{c}{v}$ **[SLO:P-10-E-32]** Define refractive index n as $n = \frac{\sin(i)}{\sin(r)}$ Apply Snell's law, $n_i \sin(i) = n_r$ sin (r) to solve simple problems.		

Grade IX	Grade X	Grade XI	Grade XII
	Total internal reflection **[SLO:P-10-E-33]** Define the terms critical angle and total internal reflection [conditions for total internal reflection] **[SLO:P-10-E-34]** Derive the equation $n = \frac{1}{\sin(c)}$ **[SLO:P-10-E-35]** Apply the equation $n = \frac{1}{\sin(c)}$ to solve simple problems **[SLO:P-10-E-36]** Describe experiments to show internal reflection and total internal reflection **[SLO:P-10-E-37]** Describe how total internal reflection is used in light propagation through optical-fibers **[SLO:P-10-E-38]** Describe the use of optical fibers in telecommunications and medical field and state the advantages of their use. **Refraction through different shapes** **[SLO:P-10-E-39]** Develop an experiment to show refraction of light by transparent blocks of different shapes.		

Grade IX	Grade X	Grade XI	Grade XII
	GEOMETRICAL OPTICS **Lenses** **[SLO:P-10-E-40]** Analyze the action of thin converging and thin diverging lenses on a parallel beam of light **[SLO:P-10-E-41]** Draw ray diagrams to illustrate the formation of real and virtual images of an object by a converging lens **[SLO:P-10-E-42]** Differentiate between real and virtual images **[SLO:P-10-E-43]** Define power of a lens and its unit. **[SLO:P-10-E-44]** Explain the terms focal length, principal axis and principal focus (focal point) **[SLO:P-10-E-45]** Solve problems of image location by lenses using lens formula. **[SLO:P-10-E-46]** Identify the use of a single lens as a magnifying glass and in a camera, projector and photographic enlarger and draw ray diagrams to show how each forms an image. **[SLO:P-10-E-47]** Illustrate with examples how the biological eye processes color in various organisms		

Grade IX	Grade X	Grade XI	Grade XII
	[**a.** role of rods and cones in the eye, along with the brain, in detecting light and discerning color in combinations of 3 channels (red, yellow, blue) **b.** know that different living organisms may see more and less colors e.g. the mantis shrimp has 12 channels of color and view ultraviolet light.] **[SLO:P-10-E-48]** State that extreme gravity from interstellar objects like blackholes can cause light to bend (from the perspective of the observer) in a way that is analogous to a simple lens [This is called 'gravitational lensing'.] **[SLO:P-10-E-49]** State that 'acoustic lenses' are made of materials and shapes that work to focus or diverge sound		
	Magnification **[SLO:P-10-E-50]** Define and calculate linear magnification [as the ratio of image length to object length; state and use the equation linear magnification = image length/object length] **[SLO:P-10-E-51]** Describe the use of a single lens as a magnifying glass		

Grade IX	Grade X	Grade XI	Grade XII
	Eye and Vision **[SLO:P-10-E-52]** Draw ray diagrams to show the formation of images in the normal eye, a short- sighted eye and a long-sighted eye **[SLO:P-10-E-53]** Describe the use of lenses/ contact lenses for rectifying vision defects of the human eye.		

Domain F: Electricity and Magnetism
This is the filed that Studies the physical properties of electric and magnetic phenomenon, along with the nature of electromagnetism.

Standard: Students should be able to:

- describe mathematically the nature of static magnetic and electric fields
- analyze and account for the distribution of current, voltage and resistance in simple DC circuits
- explain how power can be generated through electromagnetic induction
- account for how motors make use of electromagnetism to generate kinetic energy
- analyses AC circuits in terms of current, resistance, reactance, voltage, and impedance

Benchmark I: Explain qualitatively the origin, properties, phenomena and magnetic domain theory and electric charges. **Benchmark II:** Apply knowledge of the relationships between electric current, voltage, resistance and power in simple circuits to describe their applications (in technology and in nature) and the need for safety measures in electric appliances	**Benchmark I:** Analyze quantitatively the interactions of electric fields in applications of static magnetic and electric fields in terms of electric force, field strength, potential and potential energy. **Benchmark II:** Derive and use Kirchhoff's laws to describe the design and application of simple circuits **Benchmark III:** Apply quantitatively the principles of magnetic flux, electromagnetic forces, induction and radiation to describe: (1) how electricity can be generated (2) how alternating current in circuits can be regulated the applications of electromagnetic radiation in medical technology

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MAGNETISM **Magnetic Properties** **[SLO:P-09-F-01]** Describe the forces between magnetic poles and between magnets and magnetic materials [Including the use of the term's north pole (N pole), south pole (S pole), attraction and repulsion, magnetized and unmagnetized] **[SLO:P-09-F-02]** Describe induced magnetism **[SLO:P-09-F-03]** State the difference between magnetic and non-magnetic materials	**Electro-statistics** **[SLO:P-10-F-01]** Define the existence of different kind of charges. **[SLO:P-10-F-02]** State that unlike charges attract and like charges repel. **[SLO:P-10-F-03]** Explain that charging of solids by friction involves only a transfer of negative charge (electrons). **Electrostatic Induction** **[SLO:P-10-F-04]** Describe experiments to show electrostatic charging by friction and induction.	**ELECTRIC FIELDS** **Force between two Charges** **[SLO:P-11-F-01]** Define Electrostatic force **[SLO:P-11-F-02]** Explain Coulomb's law **[SLO:P-11-F-03]** Describe the coulombs force in different mediums Solve problems using Columbus Law **Electric Field** **[SLO:P-11-F-04]** Describe the concept of an electric field as anexample of a field of force. **[SLO:P-11-F-05]** Derive the expression	**ELECTRIC POTENTIAL & CAPACITORS** **Electric Potential** **[SLO:P-12-F-01]** Define absolute electric potential and the unit of electric potential. **[SLO:P-12-F-02]** Define potential difference and emf **[SLO:P-12-F-03]** Solve problems by using the expression $V = \frac{W}{q}$ **[SLO:P-12-F-04]** Calculate the potential in the field of a point charge using the equation $V = \frac{l}{4\pi\varepsilon o}\frac{q}{r}$

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[SLO:P-09-F-04] Differentiate between temporary and permanent magnets **[SLO:P-09-F-05]** Describe magnetic fields **[SLO:P-09-F-06]** Illustrate the plotting of magnetic field line with a compass or iron filings **[SLO:P-09-F-07]** Draw the pattern and direction of the magnetic field lines around a bar Magnet **[SLO:P-09-F-08]** State that the direction of the magnetic field at a point is the direction of the force on the N pole of a magnet at that point **[SLO:P-09-F-09]** state that the relative strength of a magnetic field is represented by the spacing of the magnetic field lines **[SLO:P-09-F-10]** Describe uses of permanent magnets and electromagnets **[SLO:P-09-F-11]** Explain qualitatively in items of the domain theory of magnetism how demagnetized [stroking methods, heating, orienting in north-south direction and striking, use of a solenoid] **[SLO:P-09-F-12]** Differentiate between ferromagnetic,	**Electrical conductors & Insulators** **[SLO:P-10-F-05]** State examples of electrical conductors and insulators **[SLO:P-10-F-06]** Describe an experiment to distinguish between electrical conductors and insulators **[SLO:P-10-F-07]** state and use a simple electron model to explain the difference between electrical conductors and insulators **[SLO:P-10-F-08]** Explain how a lightning rod can protect humans **[SLO:P-10-F-09]** Explain electrical breakdown [it occurs when a strong electric field passes through a gas and causes its atoms to ionize] **[SLO:P-10-F-10]** State that Corona discharge and Lichtenberg figures are visible examples of electrical breakdown. **[SLO:P-10-F-11]** Explain how lightning is generated (including the below steps of formation: - through friction between the water molecules suspended in clouds in the case of thunderstorms, and from between smoke	**[SLO:P-11-F-06]** Define electric field strength as force per unitpositive charge. **[SLO:P-11-F-07]** Solve problems and analyze information using $E = \frac{F}{q}$ **[SLO:P-11-F-08]** Solve problems involving the use of the expression. $E = \frac{l}{4\pi\varepsilon o} \frac{q}{r2}$ **Electric Field** **[SLO:P-11-F-09]** Sketch the electric field lines for two-point charges of equal magnitude with same or opposite signs. **[SLO:P-11-F-10]** describe the effect of a uniform electric field on the motion of charged particles **[SLO:P-11-F-11]** state that, for a point outside a spherical conductor, the charge on the sphere may be considered to be a point charge at its center **[SLO:P-11-F-12]** Explain how a Faraday cage works [by inducing internal electric fields that work to shield the inside from the influence of external electric fields]	**[SLO:P-12-F-05]** Show that the electric field at a point is given by the negative of potential gradient at that point. **[SLO:P-12-F-06]** Solve problems by using the expression $E = -\frac{V}{d}$ Define electron volt. **Capacitor** **[SLO:P-12-F-07]** Explain capacitors as Charge storing Devices **[SLO:P-12-F-08]** Identify types of capacitors used in different field **[SLO:P-12-F-09]** Identify factors affecting the capacitance of a parallel plate capacitor and use equations $\varepsilon r = \frac{C}{Co}$ $C = \varepsilon o \varepsilon r \frac{A}{d}$ Calculate combined capacitance of capacitors in series and in parallel. **[SLO:P-12-F-10]** Demonstrate charging and discharging of a capacitor through a resistance. **[SLO:P-12-F-11]** Prove that energy stored in a capacitor is $W = {}^{1} QV$ and hence $E = \frac{1}{2} CV^{2}2$ **[SLO:P-12-F-12]** analyze graphs of the variation with time of potential difference, charge and current for a

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paramagnetic and diamagnetic materials [by making reference to the domain theory of magnetism and the effects of external magnetic fields on these material] **[SLO:P-09-F-13]** Describe the nature of the Earth's magnetic field [specifically, that: - is opposite to its geographical north south orientation - protects life on the planet from cosmic radiation - allows animals that make use of biomagnetism (e.g. many birds and turtles) to navigate during migration)] **[SLO:P-09-F-14]** Analyze applications of magnets in recording technology [and illustrate how electronic devices need to be kept safe from strong magnetic fields] **[SLO:P-09-F-15]** State that soft magnetic material (such as soft iron) can be used to provide shielding from magnetic fields)	particles in the case of volcanic lightning - lightning streamers are created through the process of electrical breakdown and this provided a path for the electric current from one charged object to the other - in the case of cloud-ground lightning a strong electric field from the clouds induces an opposite net charge in the conducting material present in the ground, and when this field becomes strong enough it generates lightning streams that provide the path for cloud to ground and ground-to-cloud discharge) **[SLO:P-10-F-12]** State that there are many kinds of atmospheric lightning [e.g. sprites, jets, elves, trolls, pixies, ghosts, ball lightning) that are still being researched]	**Electric Flux** **[SLO:P-11-F-13]** Describe electric flux. Explain electric flux through a surface enclosing a charge.	capacitor discharging through a resistor [use $\tau = RC$ for the time constant for a capacitor discharging through a resistor] **[SLO:P-12-F-13]** Use equations of the form $x = x_0\left(exp\ \left(\frac{-t}{RC}\right)\right)$ where x could represent current, charge or potential difference for a capacitor discharging through a resistor] **[SLO:P-12-F-14]** list the use of capacitors in various household appliances [such as in flash guns, refrigerators, electric fans, rectification circuits, etc.] Bioelectricity: **Bioelectricity** **[SLO:P-12-F-15]** Illustrate how bioelectricity is generated in animals [- cells control the flow of specific charged elements across the membrane with proteins that sit on the cell surface and create an opening for certain ions to pass through. These proteins are called ion channels. - When a cell is stimulated, it allows positive charges to enter the cell through open ion channels. The inside of the cell then becomes more positively charged,

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			which triggers further electrical currents that can turn into electrical pulses, called action potentials. - The bodies of many organisms use certain patterns of action potentials to initiate the correct movements, thoughts and behaviors.] **[SLO:P-12-F-16]** State that there are several species of aquatic life, such as Electrophorus Electricus, that can naturally generate external electric shocks through internal biological mechanisms that act as batteries **[SLO:P-12-F-17]** Explain, with examples of animal with this ability, that electroreception is the ability to detect weak naturally occurring electrostatic fields in the environment
	Electric field and its intensity **[SLO:P-10-F-13]** Define electric field and electric field intensity. **[SLO:P-10-F-14]** Sketch the electric field lines for an isolated +ve and –ve point charges. **[SLO:P-10-F-15]** Analyze and illustrate simple electric field patterns [including the direction of the field:	**DC CIRCUITS** **Resistors and its Types** **[SLO:P-11-F-14]** Recall concept of resistance **[SLO:P-11-F-15]** Indicate the value of resistance by reading color code on it. **Resistivity, and its Dependence upon Temperature** **[SLO:P-11-F-16]** Define resistivity and explain its dependence	**ELECTROMAGNETIC INDUCTION** **Faraday's Law** **[SLO:P-12-F-18]** use the concept of magnetic flux linkage **[SLO:P-12-F-19]** Describe the production of electricity by magnetism. **[SLO:P-12-F-20]** Explain that induced emf's can be generated in two ways. (i)by relative movement (the generator effect).

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	(a) around a point charge (b) around a charged conducting sphere (c) between two oppositely charged parallel conducting plates (end effects will not be examined)] Solve problems using equation $E=F/q^0$ **Electrostatic potential** **[SLO:P-10-F-16]** Describe the concept of electrostatic potential. **[SLO:P-10-F-17]** Define the unit "volt". **[SLO:P-10-F-18]** Describe potential difference as energy transfer per unit charge. Describe one situation in which static electricity is dangerous and the precautions taken to ensure that static electricity is discharged safely **CURRENT ELECTRICITY** **Electric current** **[SLO:P-10-F-19]** Define and calculate electric current. **[SLO:P-10-F-20]** Differentiate between conventional and actual current **[SLO:P-10-F-21]** Explain electrical conduction [in metals in terms of the movement of free electrons]	upon temperature and alsoderive the mathematical relationship between them **[SLO:P-11-F-17]** state and use $R = \frac{pL}{A}$ Define conductance and conductivity of conductor. **[SLO:P-11-F-18]** State that the resistance of a light dependent resistor (LDR) decreases as the light intensity increases **Internal Resistance** **[SLO:P-11-F-19]** Understand the effects of the internal resistance of a source of e.m.f. on the terminal potential difference **[SLO:P-11-F-20]** Distinguish between e.m.f. and p.d. using the energy considerations. **[SLO:P-11-F-21]** Explain the internal resistance of sources and its consequences for external circuits. Describe some sources of e.m.f. Describe the conditions for maximum power transfer **Power Dissipationin Resistors** **[SLO:P-11-F-22]** state and use $P = IV$, $P = I^2$ Rand $P = \frac{V^2}{R}$	(ii)by changing a magnetic field (the transformer effect). **[SLO:P-12-F-21]** Infer the factors affecting the magnitude of the induced emf. **[SLO:P-12-F-22]** State Faraday's law of electromagnetic induction. **[SLO:P-12-F-23]** Account for Lenz's law to predict the direction of an induced current and relate to the principle of conservation of energy. Apply Faraday's law of electromagnetic induction and Lenz's law to solve problems **Self- Induction** **[SLO:P-12-F-24]** Define Self Induction and its unit **[SLO:P-12-F-25]** How an inductor is used to store electric potential energy? Derive energy produced in Self Induction is $E = \frac{1}{2} Li2$ **Mutual Inductance** **[SLO:P-12-F-26]** Explain Mutual Inductance (M) and its unit henry. **[SLO:P-12-F-27]** Describe the construction of a transformer and explain how it works.

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	[SLO:P-10-F-22] state that current is measured in amps (amperes) and that the amp is given by coulomb per second (C/s) **[SLO:P-10-F-23]** Differentiate between direct current (DC) and alternating current (AC) **Potential difference and emf** **[SLO:P-10-F-24]** Understand the potential difference and emf across a circuit component and name its unit. **[SLO:P-10-F-25]** State that e.m.f. and p.d. are measured in volts and that the volt is given by joule per coulomb (J/C) **[SLO:P-10-F-26]** Calculate the total e.m.f. where several sources are arranged in series **[SLO:P-10-F-27]** State that the e.m.f of identical sources connected in parallel is equal to the e.m.f. of one of the sources **Ohm's Law** **[SLO:P-10-F-28]** Describe Ohm's law and its limitations. **Resistance** **[SLO:P-10-F-29]** Define resistance and its unit.	**Kirchhoff's Laws** **[SLO:P-11-F-23]** State Kirchhoff's first law and appropriate the link to conservation of charge **[SLO:P-11-F-24]** State Kirchhoff's second law and appropriate the link to conservation of energy **[SLO:P-11-F-25]** Derive equations by using Kirchhoff's laws, a formula for the combined resistance of two or more resistors connected in series and parallel **[SLO:P-11-F-26]** Solve problems by using Kirchhoff's laws for the combined resistance of two or more resistors in series and parallel **[SLO:P-11-F-27]** Describe the function of potentiometer to measure and compare potentials without drawing any current from the circuit. **Balanced Potential** Describe the construction and working of Galvanometer and Its conversion into Voltmeter, Ammeter and Avometer **[SLO:P-11-F-28]** Solve problems using $R_x = (V - I_g R_g)$ $R_s = (I - I_g) R_g$	**[SLO:P-12-F-28]** Identify the relationship between the ratio of the number of turns in the primary and secondary coils and the ratio of primary to secondary voltages. **[SLO:P-12-F-29]** Recall that how step up and step-down transformers can be used to ensure efficient transfer of electricity along cables. **[SLO:P-12-F-30]** Describe the use of step-down and step-up transformers for the electric supply from power station to houses and electric appliances at home. **[SLO:P-12-F-31]** Solve problems using $\frac{N_s}{N_p} = \frac{V_s}{V_p}$ **Motional emf and A.C generator** **[SLO:P-12-F-32]** Define motional emf **[SLO:P-12-F-33]** Compute the potential difference across ends of a given rod or wire moving through a magnetic field **[SLO:P-12-F-34]** Explain construction and working of an AC generator **[SLO:P-12-F-35]** Identify the factors affecting induced EMF of an AC generator

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	Series and parallel combinations **[SLO:P-10-F-30]** Calculate the effective resistance of a number of resistances connected in series and also in parallel. **The I-V characteristics for ohmic and non ohmic conductors** **[SLO:P-10-F-31]** Describe the factors affecting the resistances of a metallic conductor Sketch and interpret the V-I characteristics graph for a metallic conductor, a filament lamp and a thermistor **Circuit Diagrams:** **[SLO:P-10-F-32]** Draw circuit diagrams [with cells, batteries, power supplies, generators, potential dividers, switches, resistors (fixed and variable), heaters, thermistors (NTC only), light-dependent resistors (LDRs), lamps, motors, ammeters, voltmeters, transformers, fuses, relays, diodes and light-emitting diodes (LEDs)] **[SLO:P-10-F-33]** Calculate current, voltage and resistance in parts of a circuit or in the whole circuit **[SLO:P-10-F-34]** Describe the action of negative temperature coefficient (NTC) thermistors and light-dependent resistors	**[SLO:P-11-F-29]** explain the internal resistance of sources and its consequences for external circuits	**[SLO:P-12-F-36]** Solve problems using $\xi = \xi 0\ Sin2\pi ft$ **A.C. Motor and Back emf** **[SLO:P-12-F-37]** Describe the main features of an A.C motor and the role of each feature. **[SLO:P-12-F-38]** Explain the production of back emf in electric motors.

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	[including explaining their use as input sensors] **[SLO:P-10-F-35]** Analyze the function of variable potential dividers in circuits [including using the equation for two resistors used as a potential divider $\frac{R1}{R2} = \frac{V1}{V2}$] **[SLO:P-10-F-36]** Describe and explain the action of relays in switching circuits. **Electric power and Joule's law:** **[SLO:P-10-F-37]** Describe how energy is dissipated in a resistance and explain Joule's law. **[SLO:P-10-F-38]** Use the equation, power = current × voltage P = IV to solve simple problems **[SLO:P-10-F-39]** Apply the equation E=I.Vt = I2Rt = V2 t/R to solve numerical problem. Calculate the cost of energy when given the cost per kWh. **Use of Circuit Components** **[SLO:P-10-F-40]** Identify circuit components such as switches, resistors batteries transducers, LDRs, Thermistors and capacitors, Relays and diodes, LEDs.		

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	[SLO:P-10-F-41] Identify the symbols of circuit components and colour codes on resistors **[SLO:P-10-F-42]** Construct simple series (single path) and parallel circuits (multiple paths). **[SLO:P-10-F-43]** State the functions of the live, neutral and earth wires in the domestic main supply. **[SLO:P-10-F-44]** Predict the behavior of light bulbs in series and parallel circuit such as for celebration lights. **Measuring instruments (voltmeter, galvanometer, ammeter)** **[SLO:P-10-F-45]** Describe the use of electrical measuring devices like galvanometer, ammeter and voltmeter (construction and working principles not required). **Safety Measures** **[SLO:P-10-F-46]** Describe hazards of electricity (damage insulation, overheating of cables, damp conditions). **[SLO:P-10-F-47]** Explain the use of safety measures in household electricity, (fuse, circuit breaker, earth wire).		

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	[SLO:P-10-F-48] Describe the damages of an electric shock from appliances on the human body. **[SLO:P-10-F-49]** Explain what happens when a live wire touches a metal case that is earthed **[SLO:P-10-F-50]** Explain why the outer casing of an electrical appliance must be either **[SLO:P-10-F-51]** Non-conducting (doublF-insulated) or earthed **[SLO:P-10-F-52]** state that a mains circuit consists of a live wire (line wire), a neutral wire and an earth wire. **[SLO:P-10-F-53]** Explain why fuses and circuit breakers are connected into the live **[SLO:P-10-F-54]** Wire for the circuit to be switched off safely. **[SLO:P-10-F-55]** Explain why domestic supplies are connected in parallel. **[SLO:P-10-F-56]** Explain the damage that electric shock could do to a human being [in terms of burns, cardiorespiratory failure and seizures]		

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	ELECTROMAGNETISM **Magnetic effect of a steady current** **[SLO:P-10-F-57]** Explain by describing an experiment that an electric current in a conductor produces a magnetic field around it. **[SLO:P-10-F-58]** Define Magnetic field **[SLO:P-10-F-59]** Sketch the lines of magnetic force **[SLO:P-10-F-60]** Describe the pattern and direction of the magnetic field due to currents in straight wires and in solenoids. **[SLO:P-10-F-61]** State the effect on the magnetic field of changing the magnitude and direction of the current **[SLO:P-10-F-62]** Describe how the magnetic effect of a current is used in relays and loudspeakers [including giving examples of their application] **Force on a current carrying conductor in a magnetic field** **[SLO:P-10-F-63]** Describe an experiment to show that a force acts on a current carrying conductor in a magnetic field [including the effect of reversing: (a) the current	**MAGNETIC FIELDS** **Magnetic Field** **[SLO:P-11-F-30]** Define and explain magnetic field **[SLO:P-11-F-31]** Describe and sketch field lines pattern due to a long current carrying straight wire **[SLO:P-11-F-32]** Describe that a magnetic field is an example of a field of force produced either by current-carrying conductors or by permanent magnets **Magnetic Flux & Flux Density** **[SLO:P-11-F-33]** Describe the concept of magnetic flux (Ø) as scalar product of magnetic field (B) and area (A) using the relation ØB = B.A **[SLO:P-11-F-34]** define magnetic flux [as the product of the magnetic flux density and the cross-sectional area perpendicular to the direction of the magnetic flux density] **[SLO:P-11-F-35]** Solve the problems using $\text{ØB} = \text{B.A}$ **[SLO:P-11-F-36]** Define magnetic flux density and the Tesla	**AC CIRCUITS:** **Alternating Current** **[SLO:P-12-F-39]** Define the terms time period, frequency, instantaneous peak value and root mean square value of an alternating current and voltage. **[SLO:P-12-F-40]** Represent a sinusoidal alternating current or voltage by an equation of the form $x = xo \sin \omega t$ **[SLO:P-12-F-41]** Describe the phase of A.C and how phase lags and leads in A.C Circuits. **[SLO:P-12-F-42]** use the fact that the mean power in a resistive load is half the maximum power for a sinusoidal alternating current **[SLO:P-12-F-43]** distinguish between root-mean square (r.m.s.) and peak values [including stating and using $I_{rms} = \frac{I_0}{\sqrt{2}}$ and $V_{rms} = \frac{V_0}{\sqrt{2}}$ for a sinusoidal alternating current] **AC through Resistor** **[SLO:P-12-F-44]** Explain the flow of A.C through Resistors **[SLO:P-12-F-45]** Calculate the resistance of resistors

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	(b)the direction of the field] **[SLO:P-10-F-64]** state and use the relative directions of force, magnetic field and current **[SLO:P-10-F-65]** Describe the magnetic field patterns between currents in parallel conductors and relate these to the forces on the conductors [excluding the Earth's field] **[SLO:P-10-F-66]** state that a current-carrying coil in a magnetic field may experience a turning effect and that the turning effect is increased by increasing: (a) the number of turns on the coil (b)the current (c) the strength of the magnetic field **Turning effect on a current carrying coil in a magnetic field** **[SLO:P-10-F-67]** State that a current carrying coil in a magnetic field experiences a torque. **Electric motor** **[SLO:P-10-F-68]** Describe the operation of an electric motor, including the action of a split-ring commutator and brushes	**Force on a Moving Charged Particle in a Uniform Magnetic Field** **[SLO:P-11-F-40]** Explain that a force acts on a charged particle in a uniform magnetic field. **[SLO:P-11-F-41]** Solve problems using $F = qvB\sin\theta$ **[SLO:P-11-F-42]** describe the motion of a charged particle moving in a uniform magnetic field perpendicular to the direction of motion of the particle **[SLO:P-11-F-43]** Describe a method to measure the e/m of an electron by applying magnetic field and electric field on a beam of electrons. **[SLO:P-11-F-44]** Describe the motion of electrons in an electric field and magnetic field using a Cathode Ray tube. **[SLO:P-11-F-45]** Solve problems using related equations **Force on a Current carrying straight wire in a Uniform Magnetic Field** **[SLO: P-11-F-46]** state that a force act on a current-carrying conductor placed in a magnetic field	**[SLO:P-12-F-46]** Construct phasor diagrams and carry out calculations on circuits including resistive Components **AC through Capacitor** **[SLO:P-12-F-47]** Explain the flow of A.C through capacitors **[SLO:P-12-F-48]** Calculate the reactance of capacitors **[SLO:P-12-F-49]** Construct phasor diagrams and carry out calculations on circuits including reactive components **AC through Inductor** **[SLO:P-12-F-50]** Explain Ac through inductors. **[SLO:P-12-F-51]** Identify inductors as important components of A.C circuits termed as chokes **[SLO:P-12-F-52]** Construct phasor diagrams and carry out calculations on circuits including inductive Components **[SLO:P-12-F-53]** describe impedance as vector summation of resistances and reactances. **RLC Circuit** **[SLO:P-12-F-54]** Describe impedance as vector summation of resistances and reactance

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	Electromagnetic induction **[SLO:P-10-F-69]** Describe an experiment to show that a changing magnetic field can induce e.m.f. in a circuit. **[SLO:P-10-F-70]** List factors affecting the magnitude of an induced e.m.f. **[SLO:P-10-F-71]** Explain that the direction of an induced e.m.f opposes the change causing it and relate this phenomenon to conservation of energy **A.C Generator** **[SLO:P-10-F-72]** Describe a simple form of A.C generator. **Mutual Induction** **[SLO:P-10-F-73]** Describe mutual induction and state its units **Transformer** **[SLO:P-10-F-74]** Identify that a transformer works on the principle of mutual induction between two coils **[SLO:P-10-F-75]** Describe the purpose of transformers in A.C circuits **[SLO:P-10-F-76]** Identify the role of transformers in power	**[SLO:P-11-F-47]** explain the origin of the forces between current-carrying conductors and determine the direction of the forces. **[SLO:P-11-F-48]** Describe the factors affecting the force on a current carrying conductor in a magnetic field. **[SLO:P-11-F-49]** Solve problems using the equation $F = BIL\ sin\theta$, with directions as interpreted by Fleming's left-hand rule **[SLO:P-11-F-50]** Define magnetic flux density [as the force acting per unit current per unit length on a wire placed at right angles to the magnetic field] **[SLO:P-11-F-51]** Understand how the force on a current-carrying conductor can be used to measure the flux density of a magnetic field using a current balance **Torque on a Current Carrying Coil** **[SLO:P-11-F-52]** Understand the turning effect on a current carrying coil in a magnetic field Derivation and use of $T = BANI$ **Ampere's Law and its Applications** **[SLO:P-11-F-53]** State and explain Amperes law	**[SLO:P-12-F-55]** Construct phasor diagrams and carry out calculations on circuits including resistive reactive and inductive components in series and parallel. **[SLO:P-12-F-56]** Solve the problems using the formulae of A.C Power. **[SLO:P-12-F-57]** Explain resonance in an A.C circuit and carry out calculations using the resonant frequency formulae. **[SLO:P-12-F-58]** Describe that maximum power is transferred when the impedances of source and load match to each other. **[SLO:P-12-F-59]** Illustrate the principle of metal detectors used for security checks. **[SLO:P-12-F-60]** State the principle of electro-cardiograph in medical diagnostic. **[SLO:P-12-F-61]** Describe the importance of oscillator circuit as broadcaster of radio waves. **[SLO:P-12-F-62]** Describe the principle of resonance in tuning circuits of a radio. **[SLO:P-12-F-63]** Solve problems using Equations of RC, RL, LC, RLC circuits in series and parallel

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	transmission from power station to your house. **[SLO:P-10-F-77]** List the use of transformer (step-up and step-down) for various purposes in your home. **[SLO:P-10-F-78]** Use the equation $\frac{V_p}{V_d} = \frac{N_p}{N_s}$ [where P and S refer to primary and secondary, to solve problems] **[SLO:P-10-F-79]** Justify the advantages of high voltage transmission [including explaining why power losses in cables are smaller when the voltage is greater]	**[SLO:P-11-F-54]** Explain solenoid and toroid Solve problems to obtain Magnetic flux density of solenoid and toroid by amperes law $B = \frac{\mu o I}{2\pi r}$ and B = μoNI **[SLO:P-11-F-55]** explain how electric and magnetic fields can be used in velocity selection **[SLO:P-11-F-56]** sketch magnetic field patterns due to the currents in a long straight wire, a flat circular coil and a long solenoid **[SLO:P-11-F-57]** state that the magnetic field due to the current in a solenoid is increased by a ferrous core. **Faraday's Law of EM Induction:** **[SLO:P-11-F-58]** use the concept of magnetic flux linkage **[SLO:P-11-F-59]** explain experiments that demonstrate Faraday's and Lenz's laws [(a) that a changing magnetic flux can induce an e.m.f. in a circuit, (b)that the induced e.m.f. is in such a direction as to oppose the change producing it, (c) the factors affecting	

Grade IX	Grade X	Grade XI	Grade XII
		the magnitude of the induced e.m.f.] **[SLO:P-11-F-60]** Use Faraday's and Lenz's laws of electromagnetic induction to solve problems **[SLO:P-11-F-61]** explain how seismometers make use of electromagnetic induction to the earthquake detection [specifically in terms of: (i) any movement or vibration of the rock on which the seismometer rests (buried in a protective case) results in relative motion between the magnet and the coil (Suspended by a spring from the frame.) (ii) the emf induced in the coil is directly proportional to the displacement associated]	

Domain G: Digital Electronics
This domain is the branch of electronics that deals with the study of discrete-valued inputs and outputs, digital signals and the components that use or create them.

Standard: Students should be able to:
- Understand the world of digital electronics
- Learn digital logic design
- Enhance design and analysis skills
- Work with problem-solving skills

Benchmark I: Digital Circuits knowledge provides students with a fundamental understanding of the design and operation of. (1) Integrated Circuits (ICs) (2) Logical Gates (3) Components of Information Technology (4) Tools of AI	**N/A**

Grade IX	Grade X	Grade XI	Grade XII
	Digital Electronics **[SLO:P-10-G-01]** Identify that the modern world is the world of digital electronics. [examples touch screen, biometric devices, face recognition, noise cancellation in mobile phones, home appliances, AC/DC inverters, communication, e-business, online education & shopping] **Electronic Components** **[SLO:P-10-G-02]** Identify the basic electronic components, resistors, condensers, diodes including LEDs, transistors and Integrated circuits ICs **[SLO:P-10-G-03]** Describe the action of a bipolar npn transistor as a switch. **[SLO:P-10-G-04]** Show diode working as a rectifier. [Half-wave rectifier and full-wave rectifier bridge]		

Grade IX	Grade X	Grade XI	Grade XII
	Analogue and digital electronics **[SLO:P-10-G-05]** State the basic operations of digital electronics. **[SLO:P-10-G-06]** Explain that electronic devices can act as switches that can convert incoming voltage into binary electrical pulses of high and low voltage (or 1 and 0)] **Logical Gates** **[SLO:P-10-G-07]** State in words and in truth table form the action of logic gates (AND, OR, NAND, NOR and NOT). **Thermionic Emission** **[SLO:P-10-G-08]** Explain the process of thermionic emission emitted from a filament. **Electron gun and cathode rays** **[SLO:P-10-G-09]** Describe the simple construction and use of an electron gun as a source of electron beam. **Deflection of electron by electric field** **[SLO:P-10-G-10]** Describe the effect of electric field on an electron beam.		

Grade IX	Grade X	Grade XI	Grade XII
	Deflection of electron by magnetic field **[SLO:P-10-G-11]** Describe the effect of magnetic field on an electron beam. **Cathode Rays Oscilloscope (CRO)** **[SLO:P-10-G-12]** Describe the basic principle of CRO and make a list of its uses. **Information and Communication Technologies (ICTs)** **Components of ICT** **[SLO:P-10-G-13]** Describe the components of information technology. **Flow of Information** **[SLO:P-10-G-14]** Explain briefly the transmission of electric signals through wires, radio waves through air and light signals through optical fibers. [Wi-Fi, Bluetooth, cellular data, etc.] **Communication Technology** **[SLO:P-10-G-15]** Describe the use of, cell phones and computers in text, audio & video communication. Realize that there will be use of quantum computers in future **[SLO:P-10-G-16]** Make a list of the use of modern means of		

Grade IX	Grade X	Grade XI	Grade XII
	communication, social media platforms, Vlogs, personal channels, E-mail and internet. **Storing information** **[SLO:P-10-G-17]** Describe the use of information storage devices such as, hard discs, floppy, compact Discs, flash-drive and Sky-drive, one-drive, google-drive etc. **Handling Information and information processing,** **[SLO:P-10-G-18]** Identify the functions of word processing, data managing, monitoring and controlling (practice basic data analysis tools) excel, **Artificial Intelligence** **[SLO:P-10-G-19]** Use AI tools to get academic support, writing, drawing, planning, etc. **[SLO:P-10-G-20]** Draft proper prompts to get specific tasks done through AI tools, Google Gemini, Meta, etc. **[SLO:P-10-G-21]** Compare the variation in output as results of different prompts and commands.		

Domain H: Modern Physics
This domain focuses on new fields of physics that were developed in the 19th and 20th centuries. These include nuclear physics, relativity and quantum physics.

Standard: Students should be able to:
- Describe the standard model of particle physics
- Analyze radioactive decay processes
- Explain the processes of nuclear fusion and fission
- Explain the postulates and implications of special relativity
- Use the quantum mechanical model of photons to explain phenomena

Benchmark I: Describe and explain, with reference to broad qualitative ideas from relativity, quantum mechanics and particle physics: (1) the structure of atoms and atomic nuclei (2) the origin of radioactivity and its uses and hazards.	**Benchmark I:** Explain and apply knowledge of the basic inter-related postulates of and discoveries from: (1) the special theory of relativity (2) the standard model of particle physics (3) quantum theory **Benchmark II:** Describe and explain, with reference to broad qualitative ideas from relativity, quantum mechanics and particle physics: (1) the structure of atoms and atomic nuclei (2) the origin of radioactivity and its uses and hazards.

Grade IX	Grade X	Grade XI	Grade XII
	Nuclear Physics **[SLO:P-10-H-01]** Describe the structure of an atom in terms of a nucleus and electrons **[SLO:P-10-H-02]** Justify the findings of the alpha particle scattering experiments [Specifically, that it provides evidence for: (a) a very small nucleus surrounded by mostly empty space (b) a nucleus containing most of the mass of the atom (c) a nucleus that is positively charged] **Protons, Neutrons** **[SLO:P-10-H-03]** Describe the composition of the nucleus in terms protons and neutrons **[SLO:P-10-H-04]** Explain that number of protons in a nucleus	**RELATIVITY:** **Frame of Reference** **[SLO:P-11-H-01]** Describe Relative Motion with suitable examples (same and opposite direction) **[SLO:P-11-H-02]** Distinguish between inertial and non-inertial frames of reference **Special Theory of Relativity** **[SLO:P-11-H-03]** describe the significance of Einstein's assumption of the constancy of the speed of light. **[SLO:P-11-H-04]** Identify that if c is constant then space and time become relative. **[SLO:P-11-H-05]** State the postulates of Special relativity	**QUANTUM PHYSICS:** **Atomic Spectra** **[SLO:P-12-H-01]** State that there are discrete electron energy levels in isolated atoms (e.g. atomic hydrogen) **[SLO:P-12-H-02]** explain the appearance and formation of emission and absorption line spectra **[SLO:P-12-H-03]** Explain how the uniqueness of the spectra of elements can be used to identify an element. **Quantum Theory of Light** **[SLO:P-12-H-04]** state that electromagnetic radiation has a particulate nature

Grade IX	Grade X	Grade XI	Grade XII
	distinguishes one element from the other and represent various nuclides by using the symbol of proton number Z and nucleon number A notion zX^A **Elements and isotopes** **[SLO:P-10-H-05]** Explain what is meant by an isotope and state that an element may have more than one isotope **[SLO:P-10-H-06]** Explain that some nuclei are unstable, give out radiation to get rid of excess energy and are said to be radioactive. [emission of radiation from a nucleus as spontaneous and random] **Natural Radioactivity** **[SLO:P-10-H-07]** Describe the deflection of α-particles β -particles and γ-radiation in electric fields and magnetic fields **[SLO:P-10-H-08]** Describe that the three types of radiation are α, β &γ. [Justify qualitatively the order of strength for α-particles, β -particles and γ-radiation in terms of their relative: ionizing effects penetrating powers] [there are other kinds of decay as well but students are not required to study those at this level), in the	**[SLO:P-11-H-06]** Explain qualitatively and quantitatively the consequences of special relativity [Specifically in the case of: a. the relativity of simultaneity. b. the equivalence between mass and energy. c. length contraction. d. time dilation. e. mass increase] **General Relativity** **[SLO:P-11-H-07]** State that spacetime is a mathematical model in relativity that treats time as a fourth dimension of the traditional three dimensions of space (It can be thought of as a metaphorical sheet of paper that can bend, and when it bends it can cause effects such as stretching and compression seen when gravitational waves pass through objects.) **PARTICLE PHYSICS:** **Quark Theory** **[SLO:P-11-H-08]** Describe quarks and antiquarks (as a fundamental [including that there are six flavors (types) of quark: up, down, strange, charm, top and bottom] **[SLO:P-11-H-09]** describe protons and neutrons in terms of their quark composition	**[SLO:P-12-H-05]** Explain and apply the photonic model of light to solve problems [use $E = hf$ to solve problems, and use the electron volt (eV) as a unit of energy] **[SLO:P-12-H-06]** Explain that a photon has Momentum [including that the momentum is given by $p = \frac{E}{C}$ (connect with the idea that light can exert a force)] **Photoelectric Effect** **[SLO:P-12-H-07]** Describe the phenomenon of photoelectric effect **[SLO:P-12-H-08]** Explain Photoelectric Effect on the basis of quantum theory **[SLO:P-12-H-09]** state and apply $hf = \emptyset + \frac{1}{2} mv_{max^2}$ **[SLO:P-12-H-10]** explain why the maximum kinetic energy of photoelectrons is independent of intensity, whereas the photoelectric current is proportional to intensity **Compton Effect** **[SLO:P-12-H-11]** Explain the particle model of light in terms of photons with particular energy and frequency.

Grade IX	Grade X	Grade XI	Grade XII
	emission of C-particles or -particles and/or y-radiation] **Natural Transmutations** **[SLO:P-10-H-09]** Explain that an element may change into another element when radioactivity occurs. **[SLO:P-10-H-10]** Explain that how does the nucleus change during alpha beta and gamma decay? **Background Radiation** **[SLO:P-10-H-11]** Describe sources of background radiations and artificial radiations. [including: (a) radon gas (in the air) (b) rocks and buildings (c) food and drink (d) cosmic rays] **Radioactivity and Half-life** **[SLO:P-10-H-12]** Describe the activity of a radioactive material in terms of counts per unit time **[SLO:P-10-H-13]** Explain the meaning of half-life of a radioactive material. **[SLO:P-10-H-14]** Make calculation based on half-life which might involve information in tables or shown by decay curves. **[SLO:P-10-H-15]** Determine the half-life of a sample of radioactive material by using a graph of number	**[SLO:P-11-H-10]** Define meson, baryon and hadrons and state that a hadron may be either a baryon (consisting of three quarks) or a meson (consisting of one quark and an antiquark) **[SLO:P-11-H-11]** describe the changes to quark composition that take place during C-and B+ decay **Fundamental particles of standard Model of Particles** **[SLO:P-11-H-12]** Define Leptons and state that electrons and neutrinos are fundamental particles called leptons **[SLO:P-11-H-13]** State, W, Z, gluon, and photons as fundamental particles called exchange particles or force carriers **[SLO:P-11-H-14]** State the Higgs Boson as a fundamental particle which is responsible for the particle's mass. **[SLO:P-11-H-15]** Explain that every subatomic particle has a corresponding antiparticle [that has the same mass as a given particle but opposite electric or magnetic properties according to the Standard Model of Particle Physics)]	**[SLO:P-12-H-12]** Describe Compton effect qualitatively Solve problems using $\Delta\lambda=h(1-\cos\theta)m0c$ **[SLO:P-12-H-13]** Explain how electron microscopes achieve very high resolution. **Pair Production** **[SLO:P-12-H-14]** Explain the process of pair production on the basis of conservation Laws **Annihilation of Matter** **[SLO:P-12-H-15]** Describe conservation laws in the annihilation of matter. **Wave Nature of particles** **[SLO:P-12-H-16]** Juxtapose the evidence for light as a wave and as a particle [Explain that the photoelectric effect provides evidence for a particulate nature of electromagnetic radiation while phenomena such as interference and diffraction provide evidence for a wave nature] **[SLO:P-12-H-17]** Analyze qualitatively the evidence provided by electron diffraction for the wave nature of particles **[SLO:P-12-H-18]** Explain and apply the de Broglie wavelength

Grade IX	Grade X	Grade XI	Grade XII
	of radioactive nuclei or activity versus time. **[SLO:P-10-H-16]** State the effects of ionizing nuclear radiations on living things, including cell death, mutations and cancer **[SLO:P-10-H-17]** Make estimation of age of ancient objects by the process of carbon dating. **Radioisotopes** **[SLO:P-10-H-18]** Explain how the type of radiation emitted and the half-life of the isotope determine which isotope is used for applications [including: household fire (smoke) alarms irradiating food to kill bacteria sterilization of equipment using gamma rays measuring and controlling thicknesses of materials with the choice of radiations used linked to penetration and absorption diagnosis and treatment of cancer using gamma rays] **Fission and Fusion** **[SLO:P-10-H-19]** Describe briefly the process of fission and fusion with examples [fusion as the formation of a larger nucleus by combining two smaller nuclei with the release of energy, and recognize	**String Theory** **[SLO:P-11-H-16]** State quantum fields and string theory. Explain that there are various contending theories about what 'mass' and 'force' are generated from [e.g. that these are generated from quantum fields when they are energized, or from multidimensional 'strings' that vibrate in higher dimensions to give rise to particles (no further technical knowledge beyond these simple descriptions is expected at this level)] **Particle Accelerator** **[SLO:P-11-H-17]** Explain the working principle of particle accelerators and also their uses. **[SLO:P-11-H-18]** Explain that antimatter is the counterpart of matter [e.g. a positron is the antimatter counterpart to an electron] **[SLO:P-11-H-19]** Illustrate that antiparticles usually have the same weight, but opposite charge, compared to their matter counterparts **Dark Matter** **[SLO:P-11-H-20]** State that most of the matter in the observable universe is matter	to solve problems [use $\lambda = h/p$ to solve problems] **Uncertainty Principle** **[SLO:P-12-H-19]** State and explain Heisenberg's uncertainty principle qualitatively, **[SLO:P-12-H-20]** Use the uncertainty principle to explain why empirical measurements must necessarily have uncertainty in them Particle Physics: **NUCLEAR PHYSICS** **Laws of Radioactivity** **[SLO:P-12-H-21]** Explain that fluctuations in count rate provide evidence for the random nature of radioactive decay **[SLO:P-12-H-22]** Identify the spontaneous and random nature of nuclear decay. **[SLO:P-12-H-23]** Define the terms activity and decay constant and recall and Solve problems using A=λN **[SLO:P-12-H-24]** State law of radioactive decay **[SLO:P-12-H-25]** Infer and sketch the exponential nature of radioactive decay **[SLO:P-12-H-26]** use the relationship $x = x_{0}e^{\lambda t}$ [where x could represent activity, number of

Grade IX	Grade X	Grade XI	Grade XII
	fusion as the energy source for stars] **[SLO:P-09-H-20]** Define and calculate average orbital speed [from the equation $v = \frac{2\pi r}{T}$ where r is the average radius of the orbit and T is the orbital period; apply this equation to solve numerical problems] **[SLO:P-09-H-21]** Interpret and compare given planetary data [about orbital distance, orbital period, density, surface temperature and uniform gravitational field strength at the planet's surface] **[SLO:P-10-H-22]** Explain the nature of the Sun [as a star of medium size, it consists mostly of hydrogen and helium, and that it radiates most of its energy in the infrared, visible and ultraviolet regions of the electromagnetic spectrum] **[SLO:P-10-H-23]** Describe that it is hypothesized that most of the matter in the universe is made up of dark matter **Hazards and Safety Measures** **[SLO:P-10-H-24]** State the effects of ionizing nuclear radiations on living things, including cell	**[SLO:P-11-H-21]** Describe the asymmetry of matter and antimatter in the universe as an unsolved mystery **[SLO:P-11-H-22]** Describe annihilation reactions [a particle meets its corresponding antiparticle; they undergo annihilation reactions in which either all the mass is converted to heat and light energy, or some mass is left over in the form of new subatomic particles.]	undecayed nuclei or received count rate) to solve problems analytically and graphically] **[SLO:P-12-H-27]** Describe the term half life and solve problems using the equation $\lambda = \frac{\frac{0.693}{T_1}}{2}$ **Mass Defect and Binding Energy** **[SLO:P-12-H-28]** Define the terms unified mass scale, mass defect and calculate binding energy using Einstein's equation **[SLO:P-12-H-29]** Illustrate graphically the variation of binding energy per nucleon with the mass number. **Nuclear Reactions/ Conservation of Mass and Energy** **[SLO:P-12-H-30]** Determine the release of energy from different nuclear reactions. **[SLO:P-12-H-31]** Explain that atomic number and mass number conserve in nuclear reactions. **[SLO:P-12-H-32]** Describe energy and mass conservation in simple reactions and in radioactive decay. **[SLO:P-12-H-33]** Describe the phenomena of nuclear fission and fusion. **[SLO:P-09-H-34]**

Grade IX	Grade X	Grade XI	Grade XII
	death, mutations and cancer **[SLO:P-10-H-25]** Explain how radioactive materials are moved, used and stored in a safe way [(with reference to: reducing exposure time increasing distance between source and living tissue use of shielding to absorb radiation]		Explain how the neutrons produced in fission create a chain reaction and that this is controlled in a nuclear reactor [including the action of coolant, moderators and control rods] **[SLO:P-12-H-35]** calculate the energy released in nuclear reactions using $E = \Delta mc^2$ **[SLO:P-12-H-36]** describe the function of the principal components of a water moderated power reactor [core, fuel, rods, moderator, control rods, heat exchange, safety rods and shielding] **[SLO:P-12-H-37]** explain why uranium fuel needs to be enriched before use **[SLO:P-12-H-38]** compare the amount of energy released in a fission reaction with the (given) energy released in a chemical reaction.

Domain I: Earth Space Science
This is a field of wide range of disciplines that study various aspects of the Earth Space and its processes for climate systems as well as our solar system and other planetary system.

Standard: Students should be able to:

- Explain how cyclones are formed
- Explain how global warming contributes to extreme weather events
- Explain the phenomena of geothermal activities
- Describe Earth's climate system
- Explain how climate science is a example of a chaotic system
- Determine the distances of galaxies
- Explain Big Bang Theory

Benchmark I: Explain and apply knowledge based on the scientific evidence (1) of convection to explain cyclones (2) for global warming contributes to extreme weather (3) that how magma flows beneath the Earth	**Benchmark I:** Explain and apply knowledge based on the scientific evidence (1) of convection to explain cyclones (2) for global warming contributes to extreme weather (3) that how magma flows beneath the Earth **Benchmark II:** Describe and explain with reference to broad qualitative ideas (1) of climate systems (2) for ocean currents and wind patterns (3) for stabilization of greenhouse (4) that how the thermohaline circulation transports heat from the tropics to the polar regions (5) to apply inverse square law for radiant flux intensity (6) to estimate the radius of a star

Grade IX	Grade X	Grade XI	Grade XII
	CLIMATE PHYSICS **Weather and Climate change** **[SLO:P-10-I-01]** Use ideas of convection to explain how cyclones are formed **[SLO:P-10-I-02]** Explain how global warming contributes to extreme weather events [specifically in the case of • hurricanes • heat waves • Flooding • Rainfall • Wildfires • droughts • winter storms]		**CLIMATE PHYSICS** **Climate systems** **[SLO:P-12-I-01]** Describe Earth's climate system as a complex system having five interacting components [the atmosphere (air), the hydrosphere (water), the cryosphere (ice and permafrost), the lithosphere (earth's upper rock: layer) and the biosphere (living things).] **[SLO:P-12-I-02]** Relate ocean currents and wind patterns to the climate system [as the statistical characterization of the climate system, representing the average weather, typically over a period of 30 years, and

Grade IX	Grade X	Grade XI	Grade XII
	Geothermal activity **[SLO:P-10-I-03]** Explain the phenomena of geothermal activity on the basis of • Conduction • convection and • radiation **[SLO:P-10-I-04]** Explain [how magma flows beneath the Earth, why it causes tectonic plate movement, volcanic eruptions and how the center of the Earth remains hot since being formed over 4 billion years ago]		is determined by a combination of processes in the climate system, such as ocean currents and wind patterns.] Analysis **[SLO:P-12-I-03]** Explain climate inertia [as the phenomenon by which climate systems show resistance or slowness to changes in significant factors e.g. stabilization of greenhouse emissions might show a slow response due to the action of complex feedback systems] **[SLO:P-12-I-04]** Explain that climate change can be categorized into internal variations and external forcing: **[SLO:P-12-I-05]** Explain how global climate is determined by energy transfer from the Sun [with specific reference to the below factors and terms: - state and use the term Earth energy budget - Explain how the energy imbalance between the poles and the equator can affect atmospheric circulation] **[SLO:P-12-I-06]** Explain that momentum, the Earth's rotation diverts the air to the right in the Northern Hemisphere and to the left in the Southern hemisphere, thus forming distinct atmospheric cells.

Grade IX	Grade X	Grade XI	Grade XII
			[SLO:P-12-I-07] Explain that ocean water that has more salt has a higher density and differences in density play an important role in ocean circulation. **[SLO:P-12-I-08]** Explain how the thermohaline circulation transports heat from the tropics to the polar regions. **[SLO:P-12-I-09]** Explain how climate science is a example of a chaotic system, [using the metaphor of a butterfly" wing flaps may cause hurricanes I another part of the world, due to the conservation of angular mathematics of chaos theory are not required; just the idea that with very complex systems it is very difficult to predict outcomes and they are very sensitive to initial conditions] **ASTRONOMY AND COSMOLOGY/ ASTROPHYSICS/ SPACE SCIENCE** **Luminosity** **[SLO:P-12-I-10]** Explain the term luminosity [as the total power of radiation emitted by a star] **[SLO:P-12-I-11]** Apply the inverse square law for radiant flux intensity [F in terms of the luminosity L of the source $F = \frac{L}{4\pi d2}$]

Grade IX	Grade X	Grade XI	Grade XII
			[SLO:P-12-I-12] Define and apply standard candles [Explain the use of standard candles to determine distances to galaxies] **Blackbody Radiation** **[SLO:P-12-I-13]** Explain blackbody radiation and apply Wien's displacement law to solve problems [$\lambda maxT$ = constant to estimate the peak surface temperature of a star] **[SLO:P-12-I-14]** Apply the Stefan Boltzmann law to solve problems [$L = 4\pi r2 \times \sigma T2$ to solve problems] **[SLO:P-12-I-15]** Estimate the radius of a star [applying Wien's displacement law. and the Stefan-Boltzmann law] **Red Shift** **[SLO:P-12-I-16]** Explain that the lines in the emission and absorption spectra from distant objects show an increase in wavelength from their known values **[SLO:P-12-I-17]** Explain why red-shift leads to the idea that the Universe is expanding [include using $\Delta\lambda/\lambda \approx \Delta f/f \approx v/c$ for the red-shift of electromagnetic radiation from a source moving relative to an observer to solve problems relating to the expanding universe]

Grade IX	Grade X	Grade XI	Grade XII
			Big Bang Theory **[SLO:P-12-I-18]** State and explain Hubble's law and how it leads to the Big Bang theory

Domain J: Medical Physics
Medical physics is an interdisciplinary field deals with the application and methods of physics to the diagnosis and treatment of human diseases with a detailed goal of improving human health and well-being.

Standard: Students should be able to:
- Explain what is a medical tracer
- Explain that piezo-electric effect and its application
- Explain the use of X-rays in medical imaging

N/A	**Benchmark I: Benchmark II**: Apply their knowledge of physics to the production and apply for (1) PET scan (2) ultrasound (3) CT scan

Grade IX	Grade X	Grade XI	Grade XII
			MEDICAL IMAGING **Pet Scanning** **[SLO:P-12-J-01]** Explain what is a medical tracer [a substance containing radioactive nuclei that can be introduced into the body and is then absorbed by the tissue being studied] **[SLO:P-12-J-02]** Explain annihilation reactions [they occur when a particle interacts with its antiparticle and that mass energy and momentum are conserved in the process] **[SLO:P-12-J-03]** Illustrate how PET scanning works [positrons emitted by the decay of the tracer annihilate when they interact with electrons in the tissue, producing a pair of gamma-ray photons traveling in opposite directions]

Grade IX	Grade X	Grade XI	Grade XII
			[SLO:P-12-J-04] Calculate the energy of the gamma ray photons emitted during the annihilation of an electron-positron pair **[SLO:P-12-J-05]** Explain that the gamma ray photons from an annihilation event travel outside the body and can be detected [including that an image of the tracer concentration in the tissue can be created by processing the arrival times of the gamma-ray photons] **Piezo- Electric Effect Ultrasound** **[SLO:P-12-J-06]** Explain that piezo-electric effect and its application in medical science [ultrasound waves are generated and detected by a piezoelectric transducer] **[SLO:P-12-J-07]** Explain how ultrasound can be used to obtain diagnostic information about internal body structures **X-Rays and CT scan** **[SLO:P-12-J-08]** Explain that X-rays are produced by electron bombardment of a metal target and calculate the minimum wavelength of X-rays produced from the accelerating p.d.

Grade IX	Grade X	Grade XI	Grade XII
			[SLO:P-12-J-09] Explain the use of X-rays in imaging internal body structures [including and describing of the term contrast in X-ray imaging] **[SLO:P-12-J-10]** Explain how computed tomography (CT) scanning works [it produces a 3D image of an internal structure by first combining multiple X-ray images taken in the same section from different angles to obtain a 2D image of the section, then repeating this process along an axis and combining 2D images of multiple sections]

Experimentation Skills Progression Grid

Guidance for the Reader

Guidance on Practical Work Expectations: For the sciences, there is no compulsory list of practical experiments that students have to conduct during their studies.
Students are still expected to do extensive practical work (ideally two lessons in the lab per week), but the purpose of the lab work is to build their critical thinking, experiment designing, data collection and analysis skills. In their board exams, they will not be expected to reproduce a memorized practical that they have already studied in their classes. In Grade 10 board exams they are expected to conduct experiments (with apparatus and on broad topics that they have studied) as per the instructions they will be provided, and then analyze the data collected and then critique the experimental methodology followed. A more advanced version of this practical exam is also expected to be conducted in Grade 11 board exams. In Grade 12 they are expected to be able to rigorously design experiments of their own to test provided hypotheses (on broad topics that they have studied).

Guidance for Assessing Projects
In Grade 12, the model projects will be designed and prescribed. However, institutions may propose, identify and assign projects to group of Students in accordance with the available, low-cost, no-cost, local resources, web resources and interest of the students.
Each student is expected to design, run and demonstrate atleast two projects in small groups.
Student will be required to demonstrate and explain one project in final examination for evaluation and award of marks.

Grade-wise Progression of Skills: This progression grid is about building skills. Grades 9-10 have the same skills listed, because the idea is to reinforce them through the practical work, they will do associated with the topics they are studying. For example, in Grade 9 students may learn about kinematics and to conduct practical work to investigate the acceleration of a ball down an inclined plane. In this experiment they would learn experimental design, data collection and analysis skills. Similarly in Grade 10 they may learn about thermodynamics and investigate the heat capacity of materials. Here again they would be building experimental design, data collection and analysis skills; just with a different topic. In contrast, Grade 11 and 12 have their skills learning outcomes separately listed. This is because in Grade 11, compared with Grade 10, the empirical research skills expected are more advanced. In Grade 12, there is a much stronger emphasis on learning how to design experiments to investigate given hypotheses, and these skills are hence listed in more detail at this level. Further guidance for educators on how to conduct lab classes keeping in mind this vision is provided in the Curriculum Guidelines.

Organization of the SLOs in the Progression Grid: Inside a grade, teachers are free to teach the content in any order of preference. Textbook publishers are also free to organize the contents of their books in any manner that they consider most effective, as long as all the SLOs in the Progression Grid and Cross-Cutting themes are covered. The SLOs inside a grade do not need to be taught in the order presented in a grade in this progression grid.

Domain X: Experimentation Skills
These cover the skills that are necessary for describing how to design and practically conduct physics experiments. These skills are not meant to be applied not only in the science lab, but as skills of critical analysis for describing empirical data as well.

SAFETY MEASUREMENTS
Standard: Students should be able to:
Demonstrate knowledge of how to select and safely use techniques, apparatus and materials

Benchmark I: Students should be able to follow provided safety instructions and take general precautions in a lab setting	**Benchmark I:** Students should be able to identify and take the safety measures required to conduct experiments	**Benchmark I:** Students should be able to design safe experiments
Grade IX-X	**Grade XI**	**Grade XII**
[SLO:P-09-10-X-01] explain, with examples, how hazards in a science lab can be classified into: ((i) physical hazards, (ii) chemical hazards, (iii) biological hazards, (v) safety hazards) **[SLO:P-09-10-X-02]** identify for a given experimental procedure what would be the most appropriate personal Protective equipment to wear before setting up the apparatus **[SLO:P-09-10-X-03]** Identify the meaning of common hazard signs in the laboratory **[SLO:P-09-10-X-04]** call emergency services in case of an accident in the lab	**[SLO:P-11-X-01]** test that the lab equipment is functioning properly, without any potential risk of injury, before conducting an experiment **[SLO:P-11-X-02]** ensure that work space for conducting the experiment is not too crowded with apparatus as to be hazardous **[SLO:P-11-X-03]** ensure that safe distance is kept at all times from other investigators who may be handling lab apparatus **[SLO:P-11-X-04]** suggest broadly what potential bodily harm could occur from physical, chemical, biological and safety hazards in the context of the experiment being conducted **[SLO:P-11-X-05]** State that it is always better to ask for help from the lab instructor when unsure of how to use new apparatus	**[SLO:P-12-X-01]** develop and justify safety guidelines for a proposed procedure, that also outline the overall risks of the experiment, keeping in mind: ((i) the apparatus, (ii) the surrounding environment, (iii) need for personal protective equipment)

EXPERIMENT PLANNING AND MEASUREMENT
Standard: Students should be able to:
Plan experiments and investigations

Benchmark I: Create an outline of how to conduct an experiment to compare a given dependent variable and independent variable	**N/A**	**Benchmark I:** Create an outline of a complete experimental design for a formulated hypothesis
Grade IX-X	**Grade XI**	**Grade XII**
[SLO:P-09-10-X-05] Define and use the below terms:		**[SLO:P-12-X-02]** Formulate a testable hypothesis by:

Grade IX-X	Grade XI	Grade XII
- True value: the value that would be obtained in an ideal measurement - Measurement error: the difference between a measured value and the true value of a quantity - Accuracy: a measurement result is described as accurate if it is close to the true value - Precision: how close the measured values of a quantity are to each other - Repeatability: a measurement is repeatable if the same or similar result is obtained when the measurement is repeated under the same conditions, using the same method, within the same experiment - Reproducibility: a measurement is reproducible if the same or similar result is obtained when the measurement is made under either different conditions or by a different method or in a different experiment - Validity of experimental design: an experiment is valid if the experiment tests what it says it will test. The experiment must be a fair test where only the independent variable and dependent variable may change, and controlled variables are kept constant - Range: the maximum and minimum value of the independent or dependent variables - Anomaly: an anomaly is a value in a set of results that appears to be outside the general pattern of the results, i.e. an extreme value that is either very high or very low in comparison to others - Independent variables: independent variables are the variables that are changed in a scientific experiment by the scientist. Changing an independent variable may		identifying the independent variable in the experiment identifying the dependent variable in the experiment identifying the variables that are to be kept constant. **[SLO:P-12-X-03]** Explain the methods of data collection by: a. describing the method to be used to vary the independent variable b. describing how the independent and dependent variables are to be measured c. describing how other variables are to be kept constant de describing, with the aid of a clear labeled diagram, the arrangement of apparatus for the experiment and the procedures to be followed. **[SLO:P-12-X-04]** Explain the methods of data analysis by: a. describing how the data should be used in order to reach a conclusion, including details of derived quantities to be calculated from graphs. **[SLO:P-12-X-05]** Suggest how technology can be used to digitize data collection by describing as appropriate: a. the use of an oscilloscope (or storage oscilloscope) to measure voltage, current, time and frequency be how to use light gates connected to a data logger to determine time, velocity and acceleration b. how other sensors can be used with a data logger, e.g. motion sensor.

Grade IX-X	Grade XI	Grade XII
cause a change in the dependent variable - Dependent variables: dependent variables are the variables that are observed or measured in a scientific experiment. - Dependent variables may change based on changes made to the independent variables **[SLO:P-09-10-X-06]** identify appropriate apparatus for collecting the data **[SLO:P-09-10-X-07]** visualize how the collected data would be tabulated or graphed **[SLO:P-09-10-X-08]** explain step by step the methodology for analyzing the data (e.g. gradient of line of best fit, plugging average value of dependent variable into a formula etc.) **[SLO:P-09-10-X-09]** suggest how sources of human and systematic error could be mitigated		
OBSERVATIONS, MEASUREMENT AND ESTIMATES **Standard: Students should be able to:** Make and record observations, measurements and estimates.		
Benchmark I: Collect data under instructor supervision while minimizing sources of random and systematic error	**Benchmark I:** Collect data without supervision while minimizing sources of random and systematic error	**N/A**
Grade IX-X	**Grade XI**	**Grade XII**
[SLO:P-09-10-X-10] set up experimental apparatus under supervision from an instructor **[SLO:P-09-10-X-11]** take steps to avoid parallax error **[SLO:P-09-10-X-12]** identify and correct for potential zero error **[SLO:P-09-10-X-13]** take an appropriate number of readings to average out errors	**[SLO:P-11-X-06]** Set up apparatus correctly without assistance from a supervisor **[SLO:P-11-X-07]** follow instructions given in the form of written instructions and diagrams (including circuit diagrams) **[SLO:P-11-X-08]** use apparatus to collect an appropriate quantity of data	

Grade IX-X	Grade XI	Grade XII
[SLO:P-09-10-X-14] take correct meniscus readings **[SLO:P-09-10-X-15]** record sources of potential error (e.g. lack of lighting due to power outage) **[SLO:P-09-10-X-16]** take steps to avoid systematic error in specific context of the experiment e.g. ensuring that the table the set-up in on is level **[SLO:P-09-10-X-17]** make measurements using common laboratory apparatus, such as millimeter scales, protractors, top-pan balances, newton meters, analogue or digital electrical meters, measuring cylinders, vernier calipers, micrometer screw gauges and thermometers **[SLO:P-09-10-X-18]** use a stop-watch to measure intervals of time, including the period of an oscillating system by timing an appropriate number of consecutive oscillations **[SLO:P-09-10-X-19]** use both analogue scales and digital displays. Be familiar with the following experimental contexts: **[SLO:P-09-10-X-20]** measurement of physical quantities such as length, volume or force **[SLO:P-09-10-X-21]** measurement of small distances or short intervals of time **[SLO:P-09-10-X-22]** determining a derived quantity such as the extension per unit load for a spring, the value of a known resistance or the acceleration of an object	**[SLO:P-11-X-09]** repeat readings where appropriate **[SLO:P-11-X-10]** make measurements that span the largest possible range of values within the limits either of the equipment provided or of the instructions given.	

Grade IX-X	Grade XI	Grade XII
[SLO:P-09-10-X-23] Testing and identifying the relationship between two variables such as between the potential difference across a wire and its length **[SLO:P-09-10-X-24]** Comparing measured quantities such as angles of reflection **[SLO:P-09-10-X-25]** Comparing derived quantities such as density **[SLO:P-09-10-X-26]** cooling and heating, including measurement temperature **[SLO:P-09-10-X-27]** experiments using springs and balances **[SLO:P-09-10-X-28]** timing motion or oscillations **[SLO:P-09-10-X-29]** electric circuits, including the connection and reconnection of these circuits, and the measurement of current and potential difference **[SLO:P-09-10-X-30]** optics experiments using equipment such as optics pins, mirrors, prisms, lenses, glass or Perspex blocks (both rectangular and semicircular), including the use of transparent, translucent and opaque substances to investigate the transmission of light **[SLO:P-09-10-X-31]** procedures using simple apparatus, in situations where the method may not be familiar to the candidate.		
DATA COLLECTION **Standard: Student should be able to:** Collect data while minimizing errors and uncertainty estimates.		
Benchmark II: Collect data under instructor supervision while minimizing sources of random and systematic error	**Benchmark II:** Collect data without supervision while minimizing sources of random and systematic error	**Benchmark II:** Tabulate and graph data appropriately, including use of false origins and tabulating uncertainty estimates

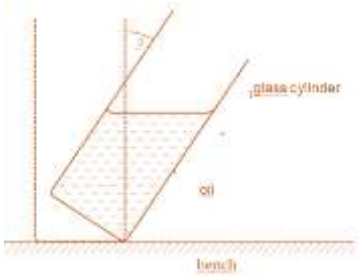
Grade IX-X	Grade XI	Grade XII
Use the below good practices in tabulating data: **[SLO:P-09-10-X-32]** Record measured and calculated quantities with correct units accompanying them **[SLO:P-09-10-X-33]** Organize tabulated results with the following elements present: the heading of each column, the name or symbol of the measured or calculated quantity, together with the use the below good practices in drawing graphs: **[SLO:P-09-10-X-34]** Label axes with quantities and units **[SLO:P-09-10-X-35]** Use scales for the axes that allow the majority of the graph paper to be used in both directions, and be based on sensible ratios, e.g. 2cm on the graph paper representing 1, 2 or 5 units of the variable (or 10, 20 or 50, etc.). **[SLO:P-09-10-N-36]** Plot data points to an accuracy of better than one half of one of the smallest squares on the grid. **[SLO:P-09-10-N-37]** Plot data points using small crosses or fine dots with a circle drawn around them.	**[SLO:P-11-X-11]** use a false origin where appropriate while plotting graphs	**[SLO:P-12-X-06]** show uncertainty estimates, in absolute terms, beside every value in a table of results
ESTIMATION WITH APPROPRIATE SIGNIFICANT FIGURES **Standard: Student should be able to:** Estimate data collect to an appropriate number of significant figures, decimal points and uncertainties		
Benchmark III: Estimate data collected to an appropriate number of significant figures and decimal points	**Benchmark III:** Estimate data collected to an appropriate number of significant figures and with the uncertainty quoted	**Benchmark III:** Estimate data collected to an appropriate number of significant figures, with the uncertainty quoted and express graphically with error bars and lines of best and worst fit

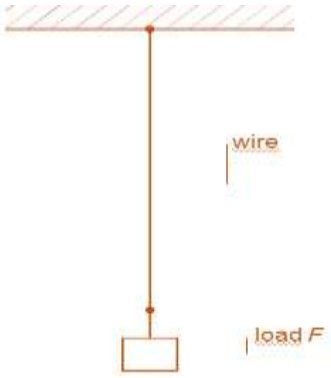
Grade IX-X	Grade XI	Grade XII
[SLO:P-09-10-X-38] Use measuring instruments to their full precision	**[SLO:P-11-X-12]** estimate the absolute uncertainty in measurements	**[SLO:P-12-X-07]** show error bars, in both directions where appropriate, for each point on the graph

Grade IX-X	Grade XI	Grade XII
[SLO:P-09-10-X-39] Estimate the number of significant figures for calculated quantities as being the same as the least number of significant figures in the raw data used.	**[SLO:P-11-X-13]** express the uncertainty in a measurement as an absolute or percentage uncertainty, and translate between these forms **[SLO:P-11-X-14]** express the absolute uncertainty in a repeated measurement as half the range of the repeated readings, where this is appropriate.	**[SLO:P-12-X-08]** draw a straight line of best fit and a worst acceptable straight line through the points on the graph.
INTERPRETATION AND EVALUATION **Standard: Students should be able to:** Interpret and evaluate experimental observations and data		
Benchmark I: Analyze plotted linear graphs and tables	**Benchmark I:** Analyze tabular data, plotted linear and polynomial graphs for how well they fit with the hypothesized theoretical relationship the studied variables by considering the calculated values obtained and their corresponding percentage uncertainty	**Benchmark I:** Analyze tabular data, plotted linear, polynomial, exponential and logarithmic graphs for how well they fit with the hypothesized theoretical relationship the studied variables by considering the calculated values obtained and their corresponding percentage and absolute uncertainty
Grade IX-X	**Grade XI**	**Grade XII**
[SLO:P-09-10-X-40] Show clear working in calculations, and key steps in reasoning **[SLO:P-09-10-X-41]** Express calculated ratios as decimal numbers, of two or three significant figures. **[SLO:P-09-10-X-42]** Sketch lines of best fit with an equal number of points on either side of the line over its entire length (the points should not be seen to lie all above the line at one end, and all below the line at the other end) **[SLO:P-09-10-X-43]** Convey the calculations for the gradient of a straight line by using a triangle whose hypotenuse extends over at least half the length of the plotted graph line.	**[SLO:P-11-X15]** draw straight lines of best fit or curves to show the trend of a graph **[SLO:P-11-X16]** draw tangents to curved trend lines and determine the gradient of a straight-line graph or of a tangent to a curve **[SLO:P-11-X-17]** relate straight-line graphs to equations of the form y = *mx* +c, and derive expressions that equate to the gradient and/or the y-intercept of their graphs **[SLO:P-110-X-18]** read the coordinates of points on the trend line of a graph **[SLO:P-11-X-19]** **[SLO:P-11-X-20]** determine the y-intercept of a straight-line graph or of a tangent to a curve, including where these are on graphs with a false origin.	**[SLO:P-12-X-09]** rearrange expressions into the forms $y = mx + c$, $y = axn$ *and* $y = aekx$ **[SLO:P-12-X-10]** describe how a graph of y against x is used to find the constants m and c in an equation of the form $y=mx+c$ **[SLO:P-12-X-11]** describe how a graph of log y against log *x* is used to find the constants a and *n* in an equation of the form $y = ax^n$ **[SLO:P-12-X-12]** describe how a graph of in *y* against *x* is used to find the constants a and k in an equation of the form $y = ae^{kx}$ **[SLO:P-12-X-13]** decide what derived quantities to calculate from raw data in order to enable an appropriate graph to be plotted.

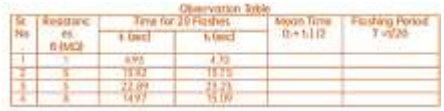
Grade IX-X	Grade XI	Grade XII
[SLO:P-09-10-N-44] Determine the intercept of a straight-line graph **[SLO:P-09-10-N-45]** Take readings from graphs by extrapolation or interpolation	**[SLO:P-11-N-21]** draw conclusions from an experiment, including determining the values of constants **[SLO:P-11-N-22]** explain whether experimental data supports a given hypothesis and make predictions based on the data **[SLO:P-11-N-23]** determine whether a relationship containing a constant is supported by experimental data **[SLO:P-11-N-24]** for results of an experiment: (i) calculate the percentage difference between values of the constant (ii) compare this percentage difference with a prF-given percentage uncertainty (iii) give a conclusion based on this comparison.	**[SLO:P-12-X-14]** convert absolute uncertainty estimates into fractional or percentage uncertainty estimates and vice versa **[SLO:P-12-X-15]** calculate uncertainty estimates in derived quantities **[SLO:P-12-X-16]** estimate the absolute uncertainty in the gradient of a graph by stating that absolute uncertainty = gradient of line of best fit-gradient of worst acceptable line **[SLO:P-12-X-17]** estimate the absolute uncertainty in the y-intercept of a graph by stating that absolute uncertainty = y-intercept of line of best fit-y intercept of worst acceptable line **[SLO:P-12-X-18]** express a quantity as a value, an uncertainty estimate and a unit.
SOURCES OF ERRORS AND POSSIBLE IMPROVEMENTS **Standard: Students should be able to:** To evaluate methods and suggest possible improvements		
Benchmark I: Evaluate and suggest improvements regarding whether and experimental design: - is valid and reliable - has source of error that could be better mitigated - is safe to conduct	**Benchmark I:** Evaluate and suggest improvements regrading whether an experimental design could improve on the uncertainty in its conclusions	**N/A**
Grade IX-X	**Grade XI**	**Grade XII**
[SLO:P-09-10-X-46] Identify whether an experimental procedure has validity (whether the results really do represent what they are supposed to measure) regarding the hypothesis being tested, and suggest changes to ensure validity as appropriate **[SLO:P-09-10-X-47]** identify whether an experimental procedure is reliable (whether the results can be reproduced under	**[SLO:P-11-X-25]** identify and describe the limitations in an experimental procedure **[SLO:P-11-X-26]** identify the most significant sources of uncertainty in an experiment suggest modifications: **[SLO:P-11-X-27]**	

Grade IX-X	Grade XI	Grade XII
the same conditions), and suggest changes to ensure reliability as propriate **[SLO:P-09-10-X-48]** recommend how to mitigate sources of random and systematic error inherent in the given experimental design **[SLO:P-09-10-X-49]** identify unsafe procedure in an experimental design and suggest ways to mitigate any hazards	an experimental arrangement that will improve the accuracy of the experiment or to extend the investigation to answer a new question **[SLO:P-11-X-28]** describe these modifications clearly in words or diagrams.	

LIST OF PRACTICAL Standard Experiments		
Grade IX-X	**Grade XI**	**Grade XII**
NOTE: 1. At least 30 standard practical along with exercises are required to be performed during the two years of course of studies of grades IX-X. 2. Use of centimeter graph paper is made compulsory.	**NOTE:** 1. At least 20 standard practicals along with exercises are required to be performed during the course of studies of class XI. 2. Use of centimeter graph paper be made compulsory	**NOTE:** Examples related to Planning Analysis and Evaluation (Sample questions taken as example from Cambridge A level examination)
1. To measure the area of cross section by measuring diameter of a solid cylinder with vernier calipers. 2. To measure the volume of a solid cylinder by measuring length and diameter of a solid cylinder with vernier calipers. 3. To measure the thickness of a metal strip or a wire by using a screw gauges. 4. To find the acceleration of a ball rolling down an angle iron by drawing a graph between 2S and T^2. 5. To find the value of "g" by free fall method. 6. Investigate the relationship between force of limiting friction and normal reaction to find the co-efficient of sliding friction between a wooden block and horizontal surface. 7. Measure the force of limiting friction by rolling a roller on a horizontal plane. 8. To determine the value of "g" by the Atwood's machine. 9. To determine the resultant of two forces graphically using a Horizontal force table. 10. To verify the principle of moments by using a meter rod balanced on a wedge. 11. To find the tension in the strings by balancing a meter rod on the stands.	1. To measure the area of cross section by measuring diameter of a solid cylinder with vernier calipers. 2. Measure the diameters of a few ball bearings of different sizes using Screw Gauge and estimate their volumes. Mention the uncertainty in each result. 3. Determine the radius of curvature of convex lens and a concave lens using a spherometer. 4. Determine the weight of a body by vector addition of forces. 5. Investigate the value of 'g' by free fall method using electronic timer. 6. Determine the moment of inertia of a fly wheel. 7. Investigate the fall of spherical steel balls through a viscous medium and determine. (i) terminal velocity (ii) coefficient of viscosity of the fluid 8. Verify that the time period of the simple pendulum is directly proportional to the square root of its length and hence find the value of 'g' from the graph. 9. Determine the acceleration due to gravity by oscillating mass-spring system. 10. Determine the value of 'g' by vibrating a metal lamina suspending from different points.	**Example-1:** A student is investigating the angle at which a glass cylinder containing oil topples, as shown in Fig.  A cylinder containing a mass m of oil can be tilted through a maximum angle ø from the vertical before it topples. It is suggested that the relationship between *m* and *ø* is $1/\tan ø = am/\rho d^3 + b$ where d is the diameter of the cylinder, ρ is the density of the oil and a and b are constants. Design a laboratory experiment to test the relationship between *ø* and *m*. Explain how your results could be used to determine values for *a* and *b*. You should draw a diagram, on page 3, showing the arrangement of your equipment. In your account you should pay particular attention to; • the procedure to be followed, • the measurements to be taken, • the control of variables, • the analysis of the data, • the safety precautions to be taken. **Example -2**

Grade IX-X	Grade XI	Grade XII
12. To find the weight of an unknown object by using vector addition of forces. 13. To find the weight of an unknown object by using principle of moments. 14. To study the effect of the length of simple pendulum on time and hence find "g" by calculation. 15. To prove that time period of a simple pendulum is independent of (i) mass of the pendulum (ii) amplitude of the vibration. 16. To study the relationship between load and extension (Helical Spring) by drawing a graph. 17. To find the density of a body heavier than water by Archimedes principle. 18. To find the density of a liquid using 5 ml syringe (instead of density bottle). 19. To find the specific heat by the method of mixture using polystyrene cups (used as container of negligible heat capacity). 20. To draw a graph between temperature and time when ice is converted into water and then to steam by slow heating. 21. To measure the specific heat of fusion of ice. 22. To verify the laws of refraction by using a glass slab. 23. To find the refractive index of water by using concave mirror. 24. To determine the critical angle of glass using a semicircular slab and a light ray box/or by prism. 25. To trace the path of a ray of light through glass prism and measure the angle of deviation. 26. To find the focal length of a convex lens by parallax method.	11. Determination of frequency of A.C by Melde's apparatus / electric sonometer. 12. Investigation of the laws of vibration of stretched strings by sonometer or electromagnetic method. 13. Determine the wavelength of sound in air using stationary waves and to calculate the speed of sound using resonance tube. 14. Determine the wavelength of light by using a diffraction grating and spectrometer. 15. Determine the slit separation of a diffraction grating by using laser light of unknown wavelength. 16. Determine time constant by charging and discharging a capacitor through a resistor. (XII) 17. Determine resistance of wire by slide Wire Bridge. 18. Determine resistance of voltmeter by drawing graph between R and I/V. 19. Determine resistance of voltmeter by discharging a capacitor through it. 20. Analyze the variation of resistance of thermistor with temperature. 21. Determine internal resistance of a cell using potentiometer. 22. Determine emf of a cell using potentiometer. 23. Determine the emf and internal resistance of a cell by plotting V against I graph. 24. Investigate the relationship between current passing through a tungsten filament lamp and the potential applied across it. 25. Convert a galvanometer into voltmeter of range 0 – 3 V. 26. Determine the relation between current and capacitance when different capacitors are used in AC	A student is investigating how the extension of a loaded wire depends on the diameter of the wire. The apparatus is set up as shown in Fig.  A load F is applied to the wire and the extension e is measured. The experiment is repeated for wires of the same material and same initial length L but different diameter d. It is suggested that e and d are related by the equation $e = 4LF/\pi Ed^2$ where E is a constant. (a)A graph is plotted of e on the y-axis against $\frac{1}{d^2}$ on the x-axis. Determine an expression for the gradient. (b)Values of d and e are given in Table d^2 Calculate and record values of $\frac{1}{d^2}$ $10^6 m^{-2}$ Calculate and record values of

d / 10^{-3} m	e / 10^{-3} m	
0.28 ± 0.02	11.3	
0.32 ± 0.02	8.6	
0.38 ± 0.02	6.0	
0.46 ± 0.02	4.1	
0.56 ± 0.02	2.7	
0.72 ± 0.02	1.7	

Grade IX-X	Grade XI	Grade XII
27. To set up a microscope and telescope. 28. Verify Ohm's law (using wire as conductor). 29. To study resistors in series circuit. 30. To study resistors in parallel circuit. 31. To find the resistance of galvanometer by half deflection method. 32. To trace the magnetic field using a bar magnet. 33. To trace the magnetic field due to a current carrying circular coil. 34. To verify the truth table of OR, AND, NOT, NOR and NAND gates. 35. To make a burglar alarm/fire alarm using an appropriate gate.	circuit using different series and parallel combinations of capacitors. 27. Determine Young's modulus of the material of a given wire using Searle's apparatus. 28. Draw characteristics of semiconductor diode and calculate forward and reverse current resistances. 29. Study the half and full wave rectification by semiconductor diodes by displaying on CRO 30. Study of the variation of electric current with intensity of light using a photocell. 31. Determine Planck's constant using internal potential barrier of different light emitting diodes. 32. Observe the line spectrum of mercury with diffraction grating and spectrometer to determine the wavelength of several different lines, and hence, draw a conclusion about the width of visible spectrum. 33. Using a set of at least 100 dice, simulate the radioactive decay of nuclei and measure the simulated half-life of the nuclei	$\frac{1}{d^2}$ include the absolute uncertainties in $\frac{1}{d^2}$ **a.** (i) Plot a graph of $\frac{e}{10^{-3}}$ m against $\frac{1}{d^2}\,10^6 m^{-2}$ include error bars for $\frac{1}{d^2}$ (ii) Draw the straight line of best fit and a worst acceptable straight line on your graph. Both lines should be clearly labeled. (iii) Determine the gradient of the line of best fit. Include the absolute uncertainty in your answer. **b.** (i) Using your answers to (a) (iii) determine the value of E. Include an appropriate unit. Data: L= 2.50±0.01 m and F=19.0±0.5 N. **Example -3** **Measurement of Unknown Resistance by Using a Neon Flash Lamp and a Capacitor** A group of students performed an experiment to determine the unknown resistance of a resistor by using a neon flash lamp and a capacitor Q.01. Draw a Circuit Diagram and label each component The experimental result is tabulated and given below:  Q.02. By using the given table (i) Estimate the least count of stop-watch used (ii). Complete the table Q.03. (i) Plot the points on the graph, using suitable scale for resistance on X-axis and flashing period on Y-axis with proper labelling.

Grade IX-X	Grade XI	Grade XII
		(ii). Draw a line of best fit through the pointed points. (iii). Estimate the unknown resistance X From the graph. 

COMPREHENSIVE LIST OF REQUIRED APPARATUS FOR A STANDARD PHYSICS LABORATORY		
Grade IX-X	**Grade XI**	**Grade XII**
Experiment No. Apparatus /Equipment 1. Vernier calipers, solid cylinder. 2. Vernier calipers, solid cylinder. 3. Screw gauge, metal strip or small solid sphere or a piece of wire. 4. Angle iron 2m long, 2 wooden stands having V-shaped top, steel ball, stopwatch, meter rod. 5. Free-fall apparatus, a metal bob, stopwatch. 6. Horizontal plane, weight box, pulley, wooden block, pan, thread, spring balance, meter rod. 7. Horizontal plane, weight box, pulley, pan, thread, ruler. 8. Atwood's machine, stopwatch, meter rod. 9. Horizontal board fixed with three pulleys, plane mirror strip, 3 sets of slotted masses of 50 g with hangers, thread, meter scale, protractor. 10. Meter rod, wooden wedge, thread, weight box. 11. Two stands, two spring balances, meter rod, thread. 12. Horizontal board fixed with three pulleys, plane mirror strip, 3 sets of slotted masses of 50 g with hangers, thread, meter scale, protractor. 13. Wedge, meter rod, slotted weights, thread, object of unknown weight. 14. Metallic bob, vernier calipers, meter scale, stopwatch, splatted cork, stand with clamp. 15. Metallic bob, vernier calipers, meter scale, stopwatch, splatted cork, stand with clamp. 16. Helical spring, iron stand, half meter rod, set of masses with hanger. 17. Physical balance, weight box, solid body (glass stopper),	**Experiment No. Apparatus/Equipment** 1. Vernier Calipers, solid cylinder. 2. Micrometer screw gauge, ball bearings of different sizes. 3. Spherometer, a convex lens and a concave lens 4. Meter rod, wedge, two stands, set of slotted weights, two spring balances. 5. Free fall apparatus, steel ball, electronic timer with power supply, plumb line and meter rod. 6. Flywheel, stopwatch, string, pan, different weights, meter rod, piece of chalk and a Vernier calipers. 7. A long glass plastic tube about 1 m long, glycerin, steel ball bearings of five or six different diameters, dilute caustic soda, tweezers, meter rod, paper collars, and rubber bands 8. Simple pendulum, stopwatch, stand, thread, cork, Vernier calipers. 9. Resonance apparatus, two tuning forks of known frequency, thermometer, plumb line, Vernier calipers, cork or rubber pad, two set squares, beaker and water. 10. Helical spring, heavy iron stand, hanger, slotted weights, stopwatch. 11. AC vibrator, step-down transformer (6V-A.C), connecting wire, stout cotton thread, pulley, and scale plan. 12. Sonometer, tuning forks of different frequencies, hanger, set of ½ kilogram weights, wires of different diameters, scissors, sensitive balance, weight box and meter rod. 13. Resonance apparatus, two tuning forks of known frequency, thermometer, plumb line, Vernier calipers,	

Grade IX-X	Grade XI	Grade XII
beaker, thread, small wooden bench, water, thermometer. 18. 5 ml disposable syringe, liquid, water, beaker, weight box, physical balance. 19. Polystyrene cup, two thermometers, heating arrangement, metallic bob, physical balance, weight box. 20. Gas burner or spirit lamp, thermometer (-10oC to 110oC), iron stand, beaker, stopwatch, tripod stand, stirrer. 21. Copper calorimeter with lagging, thermometer, ice chips. 22. Rectangular glass slab, common pins, drawing pins, drawing board, geometry box, white sheet of paper. 23. Concave mirror, stand with a clamp, cork with a pin. 24. Semicircular glass block, ray box, drawing board, white paper and pins, protractor, half meter rule, pair of compasses or prism. 25. Glass prism, drawing board, white paper and drawing pins, common pins, geometry box. 26. Convex lens, two needles, three uprights, knitting needle and a meter rod. 27. Convex lens of different focal length and meter rod. 28. Voltmeter, ammeter, a piece of resistance wire, rheostat, battery, connecting wires, key. 29. Two standard resistances, voltmeter, ammeter, connecting wires, key, battery, rheostat. 30. Two standard resistances, voltmeter, ammeter, connecting wires, key, battery, rheostat. 31. Galvanometer, dry cell with box, high resistance box, low resistance box, two keys. 32. Bar magnet, drawing board, white paper and pins, magnetic compass, needle, pencil.	cork or rubber pad, two set squares, beaker and water. 14. Spectrometer, diffraction grating, sodium lamp. 15. 1mW He-Ne laser source, diffraction grating, drawing board, a white screen, meter rod. 16. Galvanometer, power supply or battery, large value capacitor, key, stopwatch. 17. Slide wire bridge, resistance box, unknown resistance, galvanometer, rheostat, cell, tapping key, connecting wires and sand paper. 18. Voltmeter, resistance box, two keys, sand paper, connecting wires and graph paper. 19. Voltmeter, power supply or battery, large value capacitor, key, stopwatch and slide wire bridge 20. Thermistor, beaker, water, thermometer, slide wire bridge, resistance box, battery, galvanometer, rheostat, cell, tapping key, connecting wires, power supply or battery, large value capacitor, key, stop watch and slide wire bridge. 21. Potentiometer, battery, ammeter, resistance box, rheostat, two keys, galvanometer, given cell, shunt wire, sand paper and connecting wires. 22. Potentiometer, battery, ammeter, resistance box, rheostat, two keys, galvanometer, given cell, shunt wire, sand paper and connecting wires. 23. Power supply or battery, voltmeter, ammeter, rheostat or resistance box or assorted resistors. 24. 36W, 12 volt car bulb, bulb holder, 12 volt battery, high resistance rheostat, voltmeter, ammeter, key, sand paper and connecting wires. 25. Galvanometer, ammeter, standard voltmeter, accumulator, resistance box,	

Grade IX-X	Grade XI	Grade XII
33. Circular coil fitted on a wooden board, compass needle, ammeter, battery, key. 34. OR gate, AND gate, NOT gate, NOR gate and NAND gate modules, power supply, LED indicator module. 35. NOT gate module, thermistor or smoke sensor, alarm system, power pack.	plug key, rheostat, sand paper and connecting wires. 26. AC milliammeter, AC voltmeter, capacitors of different capacitances 0.1 µF,0.2 µF, 0.3 µF, 0.4 µF, 0.5 µF, step-down transformer with tapings of 6, 12, volts or a variac, sand paper and connecting wires. 27. Searle's apparatus, half kg slotted weights and meter rod. 28. A suitable semi conductor diode such as (IN 60), voltmeter (0 to 3V), voltmeter (0 to 50 V), milliammeter, micro ammeter, 500 ohms rheostat, 1 kilo ohm resistor, 3 volt battery, 0-250 volts continuously variable power supply, sand paper and connecting wires. 29. AC power supply or step-down transformer, semiconductors diodes, circuit board, connecting wires and CRO. 30. Photocell, sensitive galvanometer, battery, rheostat, key, electric bulb preferably point-o-type lamp, suitable case for the bulb and photocell and connecting wires. 31. Spectrometer, L.E.D's fitted on board, power supply, diffraction grating. 32. Mercury lamp, spectrometer, diffraction grating. 33. 100 dice	

COMPREHENSIVE LIST OF REQUIRED APPARATUS FOR A STANDARD PHYSICS LABORATORY FOR GRADES IX-X (FOR A GROUP OF 40 STUDENTS)

Grade IX-X

S.#	Apparatus/ Equipment	Qty.
1.	Vernier Calipers	12
2.	Screw gauge	12
3.	Solid cylinder	12
4.	Metallic wire	1 kg
5.	Small metallic sphere	12
6.	Angle iron 2m long with steel ball	10
7.	Wooden stands having V-shaped top	10
8.	Atwood's machine	10
9.	Stopwatch	10
10.	Free fall apparatus	10
11.	Metallic bob	10
12.	Wooden block	10
13.	Weight box with fractional weights	2
14.	Pulley	20
15.	Spring balance	20
16.	Horizontal Board fixed with three pulleys	10
17.	Pan	20
18.	Slotted weights with hangers set of 50g weights	20
19.	Slotted weights with hangers set of 20g weights	20
20.	Meter rod	20
21.	Wedge	12
22.	Plane mirror strip	24
23.	Protractor	24
24.	Inclined plane	10
25.	Steel roller with suspended pan	10
26.	Helical spring	24
27.	Iron stands with clamps	20
28.	Physical balance	02
29.	Beaker (Assorted 250 cc, 500 cc, 1000 cc)	24
30.	Small wooden bench	10
31.	5 ml disposable syringes	20
32.	Polystyrene cups	24
33.	Thermometer – 10C° to 110C° with half degree mark	24
34.	Gas burner or spirit lamp	10
35.	Solid lead shots	1 kg

Grade XI

S.#	Apparatus/ Equipment	Qty.
1.	Gravesend's Apparatus or Vector Table	10
2.	Hanger	10
3.	Slotted Weights	10
4.	Solid Cylinder	10
5.	Plane Mirror Strip	24
6.	Meter rod	20
7.	Protractor	20
8.	Metallic bob	10
9.	Set square	10
10.	Ticker tape	5
11.	Power supply (AC & DC)	10
12.	Electric stop clock	5
13.	Frequency meter	5
14.	Electromagnet	5
15.	Two-way switch	5
16.	Vernier Calipers	10
17.	Cork	1 pkt
18.	Stand with clamp	10
19.	Stopwatch	10
20.	Thread	5 spools
21.	Helical spring	20
22.	Slotted weights with hanger	20 sets
23.	Trolley	10
24.	Smooth plane wooden surface with adjustable screws	5
25.	Trolley weight (1 kg) set	10
26.	Ticker-timer	5
27.	Plasticine	5 pkt
28.	Resonance tube	10
29.	Glycerin	5 liter
30.	Steel ball bearings of different sizes	1 pkt
31.	Bar magnet	10
32.	Half kg. Slotted masses	5 sets
33.	Fly wheel	5 sets
34.	Meld's apparatus	5
35.	Rubber pad	10
36.	Tuning forks (480 & 512 Hz)	10
37.	Electric oscillator	10 each
38.	Sonometer	5
39.	Tubes (one sliding into other)	10
40.	Thermometer	10
41.	Iron stand with clamp	10

Grade XII

36.	Tripod stand	10
37.	Stirrer	10
38.	Thread	5 spools
39.	Splinted cork	1 pkt
40.	Rubber pad	12
41.	Concave mirror with stand	12
42.	Needles with stands (Uprights)	24
43.	Kitting needle	12
44.	Rectangular glass slab	12
45.	Common pins	2 pkt
46.	Drawing board pins	2 pkt
47.	White paper	1 pkt
48.	Semi-circular glass slab	10
49.	Light ray box	10
50.	Drawing board	15
51.	Compass	15
52.	Glass prism	12
53.	Convex lens (f= 10 cm to 20 cm)	20
54.	Voltmeter (0 - 5V)	10
55.	Ammeter (0 – 3A)	10
56.	Resistance wire	1 spool
57.	Rheostat	10
58.	Connecting wires	2 kg
59.	Keys	20
60.	Standard resistances (1Ω, 2Ω, 5Ω, 10Ω)	10 each
61.	Galvanometer	10
62.	Dry cell with box	24
63.	High resistance box	12
64.	Low resistance box	12
65.	Bar magnet	12 set
66.	Circular coil (fitted on wooden board)	10
67.	Power supply	10
68.	OR gate module	10
69.	AND gate module	10
70.	NOR gate module	10
71.	NAND gate module	10
72.	NOT gate module	10
73.	LED indicator module	10
74.	Alarm system	5
75.	Smoke sensor	5
76.	Thermistor	5

42.	Spectrometer	20
43.	He-Ne- gas laser	10
44.	CRO	5
45.	Microphone	5
46.	Diffraction grating	10
47.	Measuring tape	5
48.	Electric calorimeter	10
49.	Rheostat (low resistance)	10
50.	Rheostat (high resistance)	10
51.	Ammeter – (0-3A)	10
52.	Voltmeter (0-15V)	10
53.	Half degree thermometer	10
54.	Physical balance	4
55.	Weight box	4
56.	Meter bridge	10
57.	Galvanometer	10
58.	Dry cell	5 pkt
59.	Resistance box (high resistance)	10
60.	Resistance box (low resistance)	10
61.	Resistance box (fractional)	10
62.	Jockey	10
63.	Keys	10
64.	Thermistor	10
65.	Beaker (250, 500 cc)	10 each
66.	Screw gauge	10
67.	Potentiometer	10
68.	Car bulb with holder	10
69.	12 Volts Battery	2
70.	Plotting compass	12
71.	Capacitors (1 μ F - 8 μ F)	10 sets
72.	Two-way key	10
73.	Auto transformer	10
74.	Semiconductor diode	20
75.	Milli ammeter	10
76.	Micro ammeter	10
77.	NPN transistor	20
78.	Photo cell	10
79.	Wooden box	10
80.	Lamp	10
81.	Step-down transformer	10
82.	AC voltmeter	6
83.	Multimeter (digital)	6
84.	GM tube	2
85.	Scaler Unit	2
86.	Inclined plane with changeable inclination	6
87.	Steel Roller	6
88.	Metal Lamina	10
89.	Printing Screen Pieces (Used)	10
90.	Dice	150
91.	GM Point Tube	5

92.	Set of LEDs of different colours fitted on board	5
93.	Mercury Lamp	5
94.	Spherometer	10

Assessment

The rapid advancement of knowledge necessitates a continuous evolution of curricula and textbooks to keep Assessments are an important part of the teaching and learning cycle. However, usually assessments are only focused on measuring student achievement, instead of also acting as a means of feedback to improve teaching and learning. Assessments should serve the following aspects in the classrooms:

1. Providing opportunities for open-ended discussions and the refinement of newly acquired knowledge.
2. Embracing diverse perspectives by encouraging students with different levels of understanding and emphasizing the idea that there is no singular "correct answer."
3. Presented through various modes, not restricted to conventional paper-and-pencil responses to restrictive questions.
4. Structured to encourage analysis, comparison, generalization, prediction, and adaptation based on developmental levels.
5. Capable of promoting collaboration and teamwork in demonstration of competency.
6. Assess student performance to summarize and report on their understanding at a specific point in time.
7. Continuous and cumulative, demonstrating progress and development over time.

Thus, assessment should be conducted regularly using a variety of methods such as oral questionnaires, surveys and practical observations, project-based learning, and written tests. Conducting regular surveys provides the necessary information to plan the teacher's daily instruction.

Based on the findings of the assessment, a teacher may decide to move on to the next teaching lesson/topic, develop remedial teaching, write a refreshing exercise/exercise or modify the teaching method.
Access to progressive feedback should reflect the way teachers teach and explain what students need to learn. The primary purpose of classroom assessment for this grade is not only to evaluate and categorize student performance, but also to inform and improve learning, and to track student achievement in end-of-year academic achievement.

Types of Assessments

Assessments can be divided into three categories: Formative Assessment (Assessment for Learning) and Summative Assessment (Assessment of Learning) and Performance Assessment (Assessment as learning).

Formative Assessment: The ongoing evaluation of student learning and progress during the learning process. The primary purpose of formative assessment is to provide feedback to both students and teachers to enhance ongoing instruction and improve student learning. Formative assessments are typically informal, conducted in class, and not applicable for grading, this is for remarks. They are used to identify students' strengths and weaknesses, adjust instruction accordingly, and set future learning goals.

Summative Assessment: This refers to the evaluation of student learning and achievement at the end of a unit, term, or course. The main goal of summative assessment is to determine the extent to which students have met specified learning objectives and to provide a final grade or overall score. Summative assessments are formal, often taking the form of tests and exams. They provide evidence of learning and student achievement over a set period and are typically the basis for final grades, influencing decisions about student promotion, placement, and graduation.

Both formative and summative assessments should include a range of questions that test students on multiple levels. Emphasis should be placed on open-ended questions that allow for multiple strategies and solutions and do not have a specific right or wrong answer. These types of questions provide students with the opportunity to demonstrate conceptual understanding, and encourage critical thinking,

creativity, and problem-solving skills. Conversely, closed-ended questions have a specific set of answers with only one correct answer.

Performance-based Assessments

Performance-based assessments are evaluation methods that measure students abilities to apply their knowledge and skills in practical, real-world scenarios. Unlike traditional assessments that rely on standardized tests and multiple-choice questions, performance-based assessments require students to actively demonstrate what they have learned through various tasks and activities. These assessments emphasize the application of knowledge rather than rote memorization, providing a more authentic measure of a student's understanding and competence.

One key characteristic of performance-based assessments is the emphasis on higher-order thinking skills, such as critical thinking, problem-solving, creativity and effective communication. These assessments not only evaluate what students know but also how well they can apply that knowledge to solve practical problems.

Performance-based assessments offer a more comprehensive and authentic way to evaluate students' abilities by focusing on practical application and higher-order thinking skills. It provides accurate representation of a student's understanding but also contribute to the development of critical skills necessary for success in various aspects of life.

Classroom Assessment Strategies

Assessment is an integral and continuous part of classroom activities. It entails observing students active working, listening and their contributions. Additionally, it involves analyzing student work based on specific criteria, emphasizing an understanding of their thought processes and addressing both their reasoning and areas of confusion. Effective assessment engages students as active participants in all kind of activities.

The classroom assessment strategies play very important role in providing ongoing feedback to both learners and teachers. They illuminate what concepts are clear and what learners find challenging. It offers valuable insights for teachers to adjust and modify courses or learning plans accordingly.
Teachers come to know about the student progress not solely through formal tests but also through continuous, moment-by-moment observation of students in action during instructional activities. In order to assess student knowledge, skills and attitudes, teachers employ various tools and approaches. The following section outlines some of the classroom assessment strategies.

A. **Observation**
   The observation in the classroom is a dynamic and versatile strategy that supports effective teaching by providing real-time insights into student learning, engagement and behavior. It enhances the overall assessment process and contributes in creating a student-centered learning environment.

B. **Classroom Discussions:** Encourage students to participate in regular class discussions, either in small groups or as a whole class. Ask questions, listen to students' responses, and provide feedback on their understanding. These discussions provide an opportunity to check for understanding, encourage critical thinking, and identify areas where students need further clarification.

C. **Quizzes:** Give quizzes or short assessments on the material covered in class. These can be conducted within a unit to assess individual student's understanding of the ideas across units. These quizzes should consist of different types of questions that assess different levels of cognitive demand to push students to think, create, connect, and analyze.

D. **Group project**: Occasionally, at the end of a unit, students can be given group projects that require them to apply their knowledge, understanding and skills together to create some things. Provide the students a rubric before assigning each project and make sure they understand it. During the project, ensure that the students use the rubric to check their progress.

E. **Performance Tasks**
   Performance includes activities such as skill demonstrations, games, routines, drawings, projects and presentations. With the help of these tasks, students actively perform, create, construct, produce and engage in specific activities. It also helps in the development of deep understanding and higher-order

thinking skills. The nature of performance tasks involves substantial work, often spanning days to weeks for completion and necessitates students to describe their work. The performance is directly observable and it allows for a clear evaluation of students' abilities. Moreover, the criteria for assessment are explicitly specified and communicated to students for detailed explanation of the task.

F. Questioning/Interviews

Questioning and interviews serve as dynamic and insightful classroom assessment strategies, contributing to a comprehensive understanding of students' knowledge, skills as well as critical thinking abilities. In the Physics Curriculum, these approaches transcend the traditional recall of facts with purpose aiming to foster in-depth understanding and practical application of concepts. This assessment technique not only measures students' knowledge but also serves as a platform for enhancing verbal presentation skills as well. Interviews offer students an opportunity to showcase their ability to articulate their understanding and clarify concepts. Overall, questioning and interviews play a pivotal role in promoting critical thinking, enhancing communication skills and providing valuable insights into student learning within the classroom.

G. Journals/Learning Logs/Reflections:

Engaging in journal writing, learning log entries and reflections offers students a valuable avenue to document their personal record (thoughts, choices, feelings, progress and participation).
With the help of words and pictures students can describe their understanding. These recorded entries identify most effective learning styles of the students. Additionally, journal entries provide indicators of developing attitudes toward concepts, processes, skills and their potential applications in societal contexts. Embracing self-assessment through journaling allows students to reflect on strengths, weaknesses, attitudes, interests and new ideas, fostering a deeper understanding of their own learning journey.

H. Portfolios:

Portfolios present an alternative and comprehensive method for assessing students' progress in meeting Curriculum Outcomes over an extended period. This form of assessment places the student at the center of the process. It allows collaborative decision-making between the student and teacher regarding the portfolio's content. Portfolios can encompass a diverse range of items such as artifacts which student collect for strengthening his learning capabilities. Portfolios also facilitate individual reflection and self-assessment. Moreover, sharing portfolios with others, particularly for younger students, becomes an exciting opportunity to review and witness their developmental journey over time.

I. Homework:

Occasionally, give students homework to allow them to practice what they learnt during class. The homework questions will also be tasks that allow a deeper level of thinking instead of closed questions that have only one accurate answer. Students can choose a homework buddy to ask for help with homework assignments and they will be encouraged to identify concepts they are struggling with. Homework might only be given a couple of times in a unit to not overburden students, but it will help students self-assess themselves and revisit the concepts discussed in class. At the beginning of the class following a class where a homework was assigned, have a brief discussion that draws connections across homework problems, talks about the challenges students faced, or asks students the justification behind their solving techniques.

J. Paper and Pencil Tasks:

Paper and pencil tasks include different ways teachers check what you know, like answering questions (which can be multiple-choice, constructed Response Questions, Elaborated Response Questions with Numerical where applicable).

These tasks can serve both formative and summative assessment purposes and may take the form of written assignments or tests. It is crucial for students to be aware of the expectations and the rubric by which their work will be assessed. While these tasks are effective in assessing knowledge, understanding, application and higher abilities of concepts.

Assessment Tools

Assessment tools are instrument for measurement or making judgments, based on the interpretation of evidence for determining how well the student is performing or learning. Such tools include the performance criteria to determine the level of students' progress and achievement. Examples of assessment tools are checklists, rating scales, scoring rubrics, frequency indexes, inventories and anecdotal notes.

A. Checklist:

A checklist is a tool used to keep track of specific things students should know or be able to do. It lists clear criteria (like guidelines) for behaviors and performance related to what students are supposed to learn. The criteria in checklists should be easy to understand and observable by students. Students can even help make the checklist or add new items for different assessments.

B. Rating Scales:

Rating scales are lists of criteria that help judge how well students are performing along a scale. These scales can use words like "always," "frequently," "rarely," or numbers like 5, 4, 3, 2, 1 (where 5 is the best and 1 is the lowest).

C. Rubrics and Grading

An important measurement tool for both formative and summative assessment is rubrics. They allow for a structured way to gauge student performance and score their work instead of grading haphazardly, which helps minimize subjectivity in grading as well. If multiple graders are grading the same assignment, having a rubric also helps maintain consistency across the student grading. It further helps teachers plan ahead and know what they expect from their students. And although creating a rubric takes time, once it is created, general rubrics can be used for multiple tasks and specific rubrics can be used to grade the same tasks again, so in the longer run, they can help save time. Rubrics are also beneficial for the students as they outline what is expected from them. Knowing beforehand what they are being assessed on can help students strive for that goal. It also helps them self-assess themselves as they can monitor their progress and see where they fall according to the rubric and what is needed for them to reach the higher levels of the rubric. Moreover, having a rubric sends out the message to the students that they are not just being graded on a correct answer, but instead it is the quality of their work which includes their understanding of the concept that matters too.

Rubrics can take many forms, depending on the task and objective. You can break down a student's performance into separate criteria and assign a score to each or evaluate the task given as a whole. There can even be task-specific rubrics or general rubrics that can be used for multiple tasks.

Scheme of Assessments

Grade-IX

S. #	Domain	Cognitive level of SLOs						Total
		Remembering	Understanding	Applying	Analyzing	Evaluating	Creating	
1.	Nature of Science	02	05	-	01			08
2.	Measurement	-	03	06	04	04		17
3.	Mechanics	23	17	35	08	09		92
4.	Heat and Thermodynamics	04	03	01	01	02		11
5.	Electricity and Magnetism	10	04		01			15
Total		**39**	**32**	**42**	**15**	**15**		**143**
Percentage		**27%**	**22%**	**29%**	**11%**	**11%**		**100%**

Grade-X

S.#	Domain	Cognitive level of SLOs						Total
		Remembering	Understanding	Applying	Analyzing	Evaluating	Creating	
1.	Nature of Science	-	01	-	-	-	-	01
2.	Heat and Thermodynamics	06	13	01	05	04	-	29
3.	Waves	10	23	14	05	01	-	53
4.	Electricity and Magnetism	24	25	18	09	01	-	77
5.	Electronics	03	10	05	03	-	-	21
6.	Modern Physics	08	10	06	-	01	-	25
Total		**51**	**82**	**44**	**22**	**07**	**-**	**206**
Percentage		**25%**	**40%**	**21%**	**11%**	**03%**	**-**	**100%**

Grade-XI

S. #	Domain	No. of Unit	Cognitive level of SLOs						Total
			Remembering	Understanding	Applying	Analyzing	Evaluating	Creating	
1.	Measurement	-	1	2	1	1	3	0	08
2.	Mechanics	-	1	20	13	6	15	6	61
3.	Heat and thermodynamics	-	0	11	8	0	3	2	24
4.	Waves	-	0	10	3	2	4	1	20
5.	Electricity and Magnetism	-	5	24	14	5	3	7	58
6.	Modern Physics	-	4	11	3	3	1	0	22
Total			**11**	**78**	**42**	**17**	**29**	**16**	**193**
Percentage (%)			**5**	**40.4**	**21.7**	**8.8**	**15**	**8.2**	**100%**

Grade-XII

S.#	Domain	No. of Unit	Cognitive Level of SLOs						Total
			Remembering	Understanding	Applying	Analyzing	Evaluating	Creating	
1.	Nature of Science	-	0	4	0	0	0	0	**04**
2.	Mechanics	-	1	2	5	2	0	0	**10**
3.	Heat and thermodynamics	-	0	2	4	0	0	0	**06**
4.	Waves	-	2	10	5	2	1	0	**20**
5.	Electricity and Magnetism	-	11	24	24	3	1	0	**63**
6.	Modern Physics	-	4	21	12	1	0	0	**38**
7.	Earth and Space Science	-	1	11	6	0	0	0	**18**
8.	Medical Physics	-	0	9	1	0	0	0	**10**
Total			**19**	**83**	**57**	**8**	**2**	**0**	**169**
Percentage (%)			**11.24**	**49.11**	**33.72**	**4.7**	**1.18**	**0**	**100**

Unit wise weightage for Grade-IX

S. No.	Title of Unit	Number of SLOs	Percentage
1.	Nature of Science and Physics	08	6%
2.	Physical Quantities and Measurement	17	12%
3.	Kinematics	15	10%
4.	Dynamics-I	27	19%
5.	Dynamics-II	20	14%
6.	Force and Matter	16	11%
7.	Work Energy and Power	16	11%
8.	Density and Temperature	11	8%
9.	Magnetism	15	10%
	Total	**145**	**100%**

Unit wise weightage for Grade-X

S. No.	Title of Unit	Number of SLOs	Percentage
1.	Thermal Properties of Matter	17	8%
2.	Transfer of Heat	12	6%
3.	General Waves Properties	08	4%
4.	Sound	14	7%
5.	Electromagnetic Spectrum	17	8%
6.	Geometrical Optics	14	7%
7.	Electrostatics	18	9%
8.	Current Electricity	26	12%
9.	Measuring Instruments	12	6%
10.	Electromagnetism	23	11%
11.	Digital Electronics	12	6%
12.	Information and Communication Technologies (ICTs)	09	4%
13.	Nuclear Physics	25	12%
14.	Climate Physics	04	2%
Total		**211**	**100%**

Unit wise weightage for Grade-XI

S. No	Title of Unit	Number of SLOs	Percentage
1	Measurement	08	4.1 %
2	Vectors and Scalars	08	4.1 %
3	2-Dimensional Motion	07	3.6 %
4	Rotational and Circular Motion	17	8.8 %
5	Fluid Properties • Fluid Statics • Fluid Dynamics	19	9.8 %
6	Physics of Solids	09	4.6 %
7	Gas Law	06	03 %
8	Thermodynamics	18	9.3 %
9	Waves	20	10.3 %
10	Electrostatics	15	7.8 %
11	DC Circuits	17	8.8 %
12	Electromagnetism	28	14.4 %
13	Relativity	07	3.6 %
14	Particle Physics	15	7.8 %
	Total	194	100%

Unit wise weightage for Grade-XII

S. No.	Title of Unit	Number of SLOs	Percentage
1.	Nature of Science and Physics	04	2%
2.	Gravitation	10	6%
3.	Ideal Gases and Statistical Methods	06	4%
4.	Oscillations	16	9%
5.	Interference and Diffraction	04	2%
6.	Electric Potential and Capacitors	17	10%
7.	Electromagnetic Inductions	21	12%
8.	AC Circuits	25	15%
9.	Modern Physics	20	12%
10.	Nuclear Physics	18	11%
11.	Climate Physics	09	5%
12.	Astrophysics	09	5%
13.	Medical Physics	10	6%
	Total	**169**	**100%**

Teaching Leaning Approaches and Strategies

Teaching and learning approaches are the methods and techniques used by educators to facilitate the acquisition of knowledge and skills by students. Various approaches and strategies are utilized in teaching. Commonly used ones are:

Lecture: The instructor delivers a presentation or speech to the students, providing information and explanations on a particular topic or new concepts and theories.

Inquiry-Based Learning: Actively engage students in learning processes by asking questions, investigating problems, and exploring solutions. This approach promotes critical thinking, problem-solving skills, and independent learning.

Cooperative Learning: Allow students to work in groups to accomplish a common goal. This approach encourages collaboration, communication, and teamwork among students.
Problem-Based Learning: Engage students to solve real-world problems or case studies, applying their knowledge and skills to find solutions. This approach fosters critical thinking, analytical skills, and practical application of knowledge.

Technology-Enhanced Learning: Integrating technology tools and resources into teaching and learning activities. This can include online platforms, multimedia resources, educational apps, and virtual simulations.

Experiential Learning: Allow students to explore through direct experience and reflection. This exploration can involve field trips, hands-on activities, simulations, and role-playing. Experiential learning enhances understanding, retention, and application of concepts.

Flipped Classroom: Students prepare for class by independently reviewing instructional materials (e.g., videos, readings) before attending class.

Differentiated Instruction: An instructor must recognize that a few students have diverse learning needs, this approach involves tailoring instruction to accommodate various learning styles, abilities, and interests. It may include using different instructional materials, flexible grouping, and individual assessments.

Reflective Practice: An instructor has to encourage students to reflect on their learning experiences, identify strengths and areas for improvement, and set goals for future learning. Reflection promotes metacognition and self-directed learning.

Guidelines for Writing a Textbook

An important dimension of curriculum is the translation of learning experiences or contents at the proper cognitive level of the target students. It is highly technical and delicate task to assist both teachers and students in learning and transmission of the life experiences. The concept to be introduced be explained informally before providing the formal definition or statement along with tangible examples from real life situation. The solved examples and the exercises should cover the whole range of variety of questions and their applications in the everyday life. Keeping this strategy in view, the author should observe the following guidelines while writing the textbooks.

1. Student learning outcomes (SLOs) expected to be achieved in each chapter should be prominently stated at the beginning of the chapter.
2. Cover all SLOs addressed in Curriculum with their Cognitive levels without any significant gaps.
3. Headings and sub headings should be clearly indicated.
4. Key words, terms and definitions should be highlighted in the text.
5. Concepts, application and relationships should be developed from concrete to abstract or simple to complex.
6. Ensure all information is accurate, up-to-date and authentic.
7. Illustration are relevant and clear to enhance the text.
8. Use clear and organized layout to enhance readability.
9. Organized text logically with progression of ideas.
10. Include text/content which provoking the critical thinking and problem-solving skills of students.
    a. Provide transition from previous information covered and new information presented. This should be achieved by providing review of the linked topics using text boxes on the right margin of the page.
11. A summary of every chapter should be included before the concept map.
12. Concept map for each chapter should be developed by author. A sample of concept map of the chapter to be provided to the author even though he/she wants to create a novel concept map then it is allowed but it is subject to the approval of review committee.
13. Assessment questions at the end of each section should be included. These questions must be in 4 categories, Multiple choice questions, Constructed Response Questions, Extended Response Questions and Numerical. All question will be thought provoking and questions will develop according to the SLOs and weightage of topics in chapter.
14. In Assessment, variety of question like, single select, multi-select, graph-based, reasoning based MCQs, CRQs and ERQs may be added to develop critical analysis skill in students.
    a. Author will also provide solutions of end of the section and end of the chapter questions that will be included in the teacher's guide.
15. The amount of information to be covered by the chapter must match the number of hours of instructional time.
16. The intended level and scope of treatment of each content/concept is defined by the desired learning outcomes identifying learning abilities, Investigation Skills/ Laboratory work and relevance with science, technology and society (STS). The intended learning outcomes mentioned under STS should preferably be developed through novel questions or numerical problems on real life situations.
17. The text should be free from material repugnant to Islamic and Pakistani Ideology.
18. Examples and applications from local environment should be preferred.

19. SI units and terminology should be used all over in the text. However, conversion tables with other units can be given as additional information. Uniformity be maintained in symbolic representation of physical quantities and values of constants throughout in the text and in numerical problems.
20. Answers to the numerical problems should be quoted in scientific notation with correct number of significant figures and units.
21. Solved numerical examples and end of chapter numerical problems should be based on variety of situations in novel manner and be related to local environment, culture and real-life situations.
22. Boxed "Tid bits", "interesting information", "do you know", and "point of ponder" may be given to highlight additional information along with the description of concepts particularly related to STS connection through inquiry process.
23. Interesting sidelights such as case studies, discoveries, related technologies etc. may be given in the form of "boxed essays".
24. Tables, flow charts/diagrams and concept maps may be given wherever appropriate.
25. Reference of the experiments given in the practical manual should be made with the related topics given in the text.
26. Coherent and precise summary should be given at the end of each chapter.
27. MCQS and Structured Questions should be given at the end of each Unit. They should test not only knowledge but particularly the higher abilities such as understanding, handling information, analyzing, application of ideas and solving problems and relevant Investigation Skills/ Laboratory work and processes.
28. Self-Assessment Questions should be given at the end of each content of chapter.
29. A comprehensive glossary of terms and index should be given at the end of the book.
30. The teachers guide and workbooks should also be developed along with textbook which should include suitable strategies that a teacher can adopt for teaching a particular topic and should contain instructions how to explain a topic and how to show relevant demonstration.
31. Do not plagiarize content, follow copyright laws.
32. Reviewed your manuscript with peers.
33. A practical manual for the students should also be written to support practical work.

General Guidelines for Writing a Chapter

- Introduction: Start each chapter with a captivating title, colorful images, trigger questions, and Specific Learning Outcomes (SLOs).
- Clear Objectives: Define learning outcomes at the chapter's outset.
- Emphasis on Key Terms: Highlight important words and their definitions.
- Structured Presentation: Use color-coded headings for clarity.
- Fascinating Tidbits: Include interesting science snippets throughout.
- Visual Engagement: Incorporate vibrant illustrations and student-drawn diagrams.
- Interactive Questions: Pose "Do You Know?" questions for recall and application.
- Relatable Context: Integrate everyday experiences for relevance.
- Hands-On Exploration: Include activities for student inquiry.
- Real-Life Connections: Demonstrate practical applications of scientific principles.
- Values and Ethics: Infuse lessons with ethical considerations.
- Technology Integration: Encourage internet resource use with IT-related activities.

Specific Guidelines for Writing a Chapter

- The authors should adhere to the learning outcomes of each concept or chapter as mentioned with the contents in the curricula.
- The continuity of the concepts with the earlier classes, their integration and logical development should be ensured.
- Horizontal and vertical overlapping of the concepts should be avoided.
- The textbook should be informative and interactive with questions to be put at suitable intervals to provoke the students to think.
- The details of the treatment of the concept should be properly classified into headings and subheadings.
- The language used should be simple, clear, straight forward, unambiguous and easily comprehensible by the students of the particular level.
- Simple questions may be asked within the chapter, which requires students to recall, think, and apply what they have just learnt as well as to reinforce the learning of the concepts and principle.
- The new advancements and development in the subjects should be incorporated where appropriate.
- The examples and applications should be from everyday life and be supportive of our cultural values.
- SI units should be used throughout the text and the numerical values used for various constants should be same.
- Photographs and illustrations should be clear, labeled and supportive of the text. Tables, flow charts and graphs may be given wherever needed.
- Key points at the end of each chapter should provide a summary of the important concepts and principles discussed in the chapter.
- Review questions should be given at the end of each chapter requiring students to recall, think and apply what they have learnt in this chapter. This should start from simple questions increasing the complexity gradually and should test knowledge, understanding and skills of the students. The last few questions should encourage the student to apply the concepts studied in this chapter.
- Each chapter should be accompanied with its precise and coherent summary to be given at the end of this chapter
- Solved numerical examples within the chapter and review questions at the end of the chapter should be based on variety of situations and should be related to local environment and culture

Guidelines for Choosing a Textbook

There may be many textbooks published by different publishers in the market. Head of institutions and Teachers need to make a choice of the text from among them. Following key questions may help in choosing the textbook.

Sr. #	Keys Questions	Yes / No
1.	Is the textbook attractive and appealing with quality paper, images and double-binding?	
2.	Is the guidelines for utilizing a textbook provided in the beginning of the textbook?	
3.	Is the sample lesson plan for teachers provided?	
4.	Is the content accurate, up to date and age appropriate?	
5.	Does it focus important knowledge, skills and aptitudes?	
6.	Do the illustrations (maps, pictures, drawings, graphs) help us understand the content better?	
7.	Do the end-of-the-chapter exercises encourage students to think creatively and critically, to develop their skills and imagination?	
8.	Are activities suitable for the needs of the learner?	
9.	Do activities include students participation in addressing real life issues?	
10.	Do activities promote required skills (collaboration, critical thinking, problem solving, inter-personal, adaptability, flexibility, leadership, ethos/pathos etc.)?	
11.	Is a variety of assessment strategies suggested? (e.g., binary, selected response questions, multiple-choice items, completing picture/map items, project work, exhibitions, interpretive exercises, Constructed response question (CRQs) and Extended response question (ERQs) etc.)	
12.	Are there any biases in the textbook? e.g. religion, race, caste, gender, occupation, class etc.	
13.	Do the textbook present issues from many perspectives?	
14.	Does it include current issues, problems, and happenings?	
15.	Is it aligned with student learning outcomes (SLOs) of the Sindh Curriculum?	
16.	Is a teacher's guide/notes included (such as instructed activities, icebreaker, brainstorming, formative assessment)?	
17.	Are the contents relevant to the needs, age, and level of understanding of the students?	
18.	Does the textbook contain appropriate headings and subheadings including introduction, subthemes, summary etc?	
19.	Does it have an introduction explaining its organization, table of contents etc.?	
20.	Are there suggestions for further reading in the area or websites for further information?	

Guidelines for Teachers Training & Professional Development

Teacher is the most important variable for ensuring effective teaching and learning environment at classroom and school. Teachers are expected to use and apply different strategies of teaching and learning according to situations, age appropriateness, and students' prior knowledge.

Curriculum and textbook are the supporting resources for creating a conducive learning environment. In order to make a meaningful contribution towards the national development, it is important to initiate and implement out-come oriented teaching and learning activities. To do so, it is expected that the teachers are knowledgeable, life-long leaners, skilled with pedagogical practices, understand child psychology and able to create and sustain positive learning and nurturing environment. In order to achieve these expectations, the teachers need continuous professional develop and Teacher must develop managerial skills regarding new and existing resources. Teachers need to develop activities that enhance concepts of students and match with the level and interest of a learner. Following are some of the opportunities for teachers' professional development.

Teacher Training Institutions: Various public and private sector universities and institutions offering various pre-service and in-service professional development programmes for the teachers. For example, PITE, STEDA, RSU, SIBAU, AKU-IED, TRC, etc.

In this digital age online learning is the greatest source of professional development. Some of the online opportunities include: Coursera, EdeX, Khan Academy, Mobile applications, Knowledge Platform, Sabaq Foundation, etc.

Besides, professional development opportunities include, reading books and articles on teaching methods, watching educational movies, writing reflective loge/diary, microteaching sessions, workshops, meetings, conferences, etc.

Also, teachers need to learn how to develop age-appropriate outcome-oriented activities, which is not easy. Therefore, teacher learning is not a one-day task, but a continuous learning process. Teachers are requested to keep on learning and facilitating the students for their better future.

Teacher training programmes therefore need to be critically analyzed and restructured to provide for experiences, which will help develop these competencies. The effort of reforming teaching and learning strategies in the interest of promoting students' understanding must be long-term, must explore teachers' prior knowledge and experience, must utilize collaborative problem-solving teams, and must work toward the redefinition of student's and teacher's roles in the classroom.

Comprehensive understanding of teaching methods

Teacher should have full command over different methods of teaching. For example, they are taught to promote inquiry by participating in "inquiry experiences" similar to those they will eventually provide for their students. They must have understanding of elements of constructive teaching practices, and various inquiry approaches. Still, knowledge of methods is not enough, but a person who teaches must have full understanding about the philosophy of each teaching method.

Experienced and effective teachers know that their method and style has to be adapted and transformed to fit the local situation and external factors that may impinge on a lesson.

Time Management

Time management is essential for implementation of teaching and learning practices.

Teacher should have command on time management with small and large groups, for inquiry/investigative activities, role-plays as well as for assessing and evaluating students' learning and its documentation.

Teachers' ought to evaluate their own teaching practices and subject knowledge in the light of information about the Content Standards and Students' Learning Outcomes. They improve their teaching practices by soliciting feedback and engaging in cycles of planning, teaching, reflecting, discerning problems, and applying new trends and strategies. Teachers use reflection and feedback to formulate and prioritize goals for increasing their subject knowledge and teaching effectiveness.

Educational Resource

Technology and Digital Resources: There are an increasing variety of resources such as videos, animations, computer software, projector, online learning platforms, YouTube, TEDx, Khan academy, etc., offer simulations and models of real-life situations that permit the investigation of phenomena that are not easily available because of cost, safety, or accessibility. Computers and related technologies such as laptop, tablet, smartphones, offer students a very important resource for learning the concepts and processes of science through simulations, graphics, sound, data manipulation, and model building.

Educational Tours (visits): Keeping in view that students link their learning experiences with real-life situations pertaining to environment, community, resources and local expertise, explorative activities. All such activities are characterized by active student involvement in attempting to find answers to questions about the natural and constructed world. For this, teacher has to plan a tour and identify and contact appropriate authorities to seek written permission from parents, principal at school, and management at place of visit). Explain them about the purpose of the tour. Develop a task sheet to be completed by students. Evaluate and record the students' outcomes.

Guest Speakers: Guest speakers from laboratories/factories or some community personnel (**Enhance Gender Equality)** as scientist, astronauts, researcher, teacher educators) from NCP, PIEAS, SUPARCO, NUST etc can be invited/ Video interview or online motivational session to the school/college that could help students develop interest in learning of Physics.

Libraries: Great reads make great writers and leaders; great writers make great communicators and persuaders. Libraries are great sources for promoting reasoning, critical thinking skills among students to become great readers and writers. The schools and teachers must provide leisure reading resources and time to the students. Reading should be encouraging through variety of ways like Book Reviews, Stories etc.

PROVINCIAL REVIEW COMMITTEE (PRC) FOR PHYSICS CURRICULUM

S.#	Name of Member		Signature
1.	Dr. Mazhar Ali Abbassi, Professor, Institute of Physics, University of Sindh, Jamshoro	Chairman	
2.	Dr, Barkat Ali Laghari, Assistant Professor, GCU Hyderabad	Member	
3.	Mr. Noor Ahmed Khoso, Associate Professor, PIET Sindh Nawabshah	Member	
4.	Mr. Abdul Majeed Tanwari, Associate Professor, DJ Sindh Govt. Science College Karachi	Member	
5.	Mr. Sarwaruddin Jamali, Assistant Professor, GECE (Men) Hyderabad	Member	
6.	Mr. Zaheer Hussain Abbasi, Subject Specialist, DCAR Sindh, Jamshoro	Member	
7.	Dr. Susheel Kumar, Lecturer, Govt. Muslim Science College Hyderabad	Member	
8.	Mr. Attaullah Shar, Govt. Boys Degree College, Qasimabad	Member	
9.	Abdul Rehman Indhar, Assistant, Sindh Text Book Board	Member	
10.	Mr. Muhammad Yousif Chana, Subject Specialist, DCAR, Jamshoro	Member	
11.	Ms. Rozina Channar, Subject Specialist, PEACe, Jamshoro	Member/ Secretary	