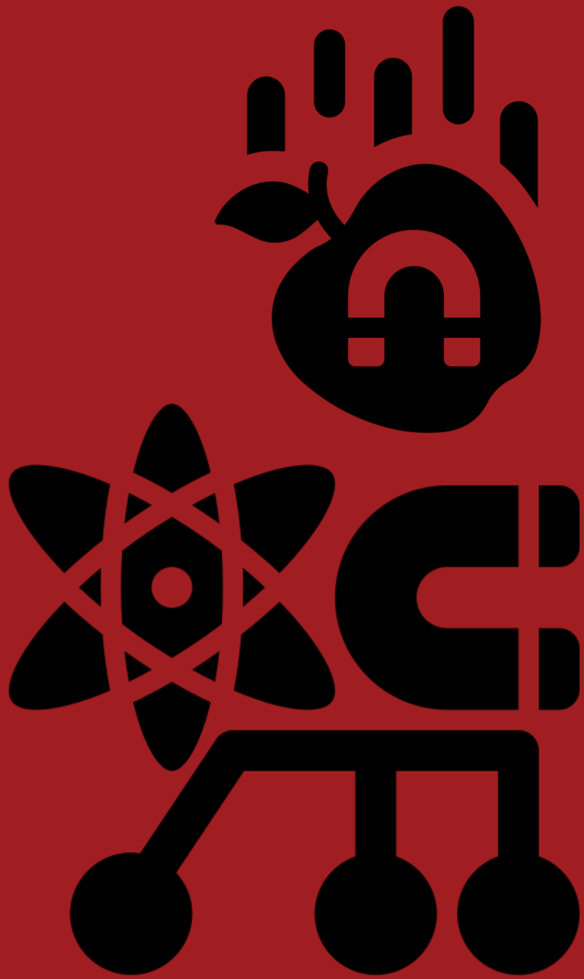
Draft

Learning Framework

Physics

Classes 11-12



CO-CREATED BY CBSE- CENTRE FOR EXCELLENCE IN ASSESSMENT
IN COLLABORATION WITH EDUCATIONAL INITIATIVES

FOREWORD

The vision of the National Education Policy (NEP) 2020 released by the Government of India, directs that children not only learn, but more importantly learn how to learn. Education, must move towards less content, and more towards learning about how to think critically and solve problems, how to be creative and multidisciplinary, and how to innovate, adapt, and absorb new material in novel and changing fields. Pedagogy must evolve to make education more experiential, holistic, integrated, inquiry-driven, discovery-oriented, learner-centred, discussion-based, flexible, and, of course, enjoyable. The policy has a clear mandate for competency-based education (CBE) to enhance acquisition of critical 21st century skills by the learners. The first determinant for implementing CBE is a curriculum which is aligned to defined learning outcomes and that clearly states the indicators to be achieved.

The Central Board of Secondary Education (CBSE) has collaborated with Educational Initiatives, to develop the Learning Framework for English, Hindi, Mathematics, Physics, Chemistry, Biology, History, Geography, Economics, Accountancy, Business Studies and Computer Science in Grade 11 and 12. The Learning Frameworks comprise explicitly stated knowledge, skills and dispositions that an education system should try to achieve. These frameworks would help develop a common shared understanding among teachers, students and other stakeholders and would serve as a common benchmark for teaching, learning and assessment across the country.

These frameworks present indicators that are aligned to the CBSE curriculum and the NCERT learning outcomes. They further outline samples of pedagogical processes and assessment strategies to encourage curiosity, objectivity, creativity with a view to nurture scientific temper. This framework would be a key resource for teachers as they execute the curriculum. They have been developed to ensure that teachers align the learning to meet the set quality standards and also use it to track learning levels of students. The effort has been to synchronize focus on quality education with uniformity in quality of standards across CBSE schools.

We hope, these frameworks would not only become a reference point for competency-based education across the country but also facilitate planning and design of teaching-learning processes and assessment strategies by teachers and other stakeholders.

Any feedback regarding the framework is welcomed.

CBSE Academic Unit

PREFACE

The National Education Policy 2020 has outlined the importance of competency-focused education in classrooms, leading to curricular and pedagogical reforms in the school systems. The policy emphasizes on the development of higher order skills such as analysis, critical thinking and problem solving through classroom instructions and aligned assessments. These skills are important indicators which will further the dissemination of pedagogy and learning outcomes across schools and boards.

In order to propagate indicator-based learning through 'Learning Frameworks', the Central Board of Secondary Education has collaborated with Educational Initiatives (Ei). Learning frameworks are a comprehensive package which provides learning outcomes, indicators, assessment frameworks, samples of pedagogical processes, tools and techniques for formative assessment, blueprint, assessment items and rubrics. 12 such frameworks have been developed for English, Hindi, Mathematics, Physics, Chemistry, Biology, History, Geography, Economics, Accountancy, Business Studies and Computer Science in Grade 11 and 12.

The frameworks are adopted from the learning outcomes outlined in the NCERT which are mapped to key concepts of the content. These content domain specific learning outcomes are broken down into indicators which defines the specific skills a learner needs to attain. A clear understanding of these LOs will be immensely helpful for teachers and students to learn better. This document will help teachers to focus on skills of the subject in addition to concepts.

"As per the National Focus group Position Paper on Teaching of Science, *"At the higher secondary stage science should be introduced as separate disciplines with emphasis on experiments/technology and problem solving. The content should not be information laden, and not aim to widely cover all aspects of the subject. Considering the vast breadth of knowledge in any subject, the exigencies of time and the student's capacity, some delimitation, or rather, identification of core areas has to be done. At this stage, core topics of a discipline, considering recent advances, should be carefully identified and treated with appropriate rigour and depth"*

As per NCERT Learning Outcomes for Higher Secondary Stage *"Physics is basic to the understanding of almost all the branches of science and technology. The intricate concepts of physics must be understood, comprehended and appreciated. Students must learn to ask questions like 'why', 'how', 'how do we know it'. They will find almost always that the question 'why' has no answer within the domain of physics and science in general. In the learning of physics, there should be stress upon the learner acquiring inquiry and process skills of science. This is necessary since the inquiry and process* *skills are more enduring and enable the learner to cope with the ever changing and expanding field of science and technology. Inquiry skills should be supported and strengthened by investigative, reasoning and quantitative skills. The theoretical component of higher secondary physics should strongly emphasize problem solving, awareness of conceptual pitfalls, linkages among various concepts and critical interrogation of different topics. Narratives giving insights on the historical development of key concepts of physics should be integrated into the content judiciously. The teaching of the theoretical aspects and the experiments based on them should be closely integrated and dealt together."*

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CONTENTS

1. NATURE OF THE SUBJECT

. Physics is said to be the most basic of all sciences, concerning itself with energy, matter, space and time, and their interactions. Its laws and theories express the general truths of nature. Physicists have asked questions about the deeper structure of matter and the universe, from the level of sub-atomic particles to galaxies and black holes, and the answers they have found have led to more exciting questions and experiments. One can even say that discoveries in the last century in the areas of quantum physics and relativistic physics have pushed our understanding of nature beyond human imagination. While clear logical thinking is definitely required in pursuing questions in physics like any other scientific discipline, there is a lot of scope for creative imagination and problem-solving for making important breakthroughs which sometimes may even require a complete paradigm shift.Another key driver for development of scientific knowledge has been the motivation to improve the welfare of humanity by using the knowledge to create innovative and useful technologies. Here too the discoveries made in physics over the last century has given humanity technologies which even a century back would have been considered more marvelous than any magic. The advances in nuclear and solar energy technology, the satellite communication and GPS technology, semiconductor devices and optical data transfer have all shaped the modern world at an unimaginable scale and rate.

Students who choose to study physics at higher secondary stage in India often do so keeping in mind the requirements of professional courses which require application of physics. There are others too who are interested and curious to know and understand deeply the concepts and principles, and these students may be wishing to study physics further in college and beyond. Therefore, the higher secondary curriculum of physics needs to cater to both *deeper conceptual understanding as well as problem-solving and applications in real-life and technological contexts*. The curriculum also needs to keep in mind the steep gradient from the secondary school science curriculum and therefore needs to help students start from basic concepts in each domain in physics. The focus of the physics curriculum at this stage should be on understanding of core concepts and application of the same in authentic contexts instead of rote learning and superficial covering of topics. It is also important that through the study of physics, students also get to appreciate the nature of science as a dynamic process which is ever expanding, deepening and if required, revising a vast body of knowledge which provides us with the best possible model of the reality of the physical and natural world.
Active learning, through which students become active participants in the learning process, is an important means for development of student’s scientific skills. In the process of active learning, students move from being passive recipients of knowledge to being participants in activities that encompass analysis, synthesis and evaluation besides developing skills, values and attitudes. Active learning not only emphasizes the development of students’ scientific skills but also their exploration of their own scientific aptitude and values.

The basic elements of active learning are speaking, listening, reading, writing and reflecting. These basic elements involve cognitive activities that allow students to clarify the question, consolidate and appropriate the new knowledge. The second factor of active learning is the learning strategies that incorporate the above basic elements. These are small groups, cooperative work, case studies, simulation, discussion, problem solving and journal writing. Third factor of active learning is teaching resources that the teacher uses to encourage students to interact and participate actively in the activities.

Active learning techniques and pedagogical approaches enable effective increase in attitudes and successes of the students. For the concepts and subjects about physics or science that are not understood by students and lead some confusion, it is possible to make them clear by teaching these concepts more concretely and through research, observation and experiments. Students should be encouraged with giving responsibilities and helping them to develop their creativeness.

Following are the desirable scientific teaching practices. These practices are often closely associated with student success.
Learner centered classroom environments -- identifying, confronting, and resolving preconceptions, and beginning instruction with what students know.

- Knowledge centered -- focus on how something is known as much as what is known, and provide examples of what mastery looks like.
- Assessment centered -- make frequent attempts to make students' thinking and learning visible as a guide for further instruction.
- Community centered -- encourages a culture of questioning, including a bit of risk taking and respect for others
- Regularly employ active learning strategies
- Provide meaningful, engaged learning for all students.
- Provide an active approach to learning that includes a strong emphasis on student interaction with phenomena.
- Clear and explicit linkage between representations and phenomena represented.
- Engage students in challenging, authentic, interdisciplinary tasks.
- Provide opportunities for students to observe, explore, and test hypotheses.
- Encourage the students' imagination, logic, and open-mindedness.
- Incorporate the content and processes of science giving due regard to science teaching standards.
- Link scientific concepts and processes with prior learning in science and other disciplines.

- Depth and breadth of coverage are reasonably balanced.
- Engage all learners in meaningful scientific tasks involving high-order thinking skills.
- Providing and receiving feedback
- Accommodating student learning styles
- Teaching in a way that is consistent with student development
- Including real-world applications in the learning process
- Moving from concrete to abstract
- Requiring practice of learned skills
- Employing learning cycles - observation, generalization, verification, application
- Making use of multiple intelligences
- Eliciting and addressing misconceptions
- Promoting critical thinking
- Creating, sharing, and using scoring rubrics
- Aligning objectives, instruction, and assessment
- Focusing on depth in addition to breadth of coverage
- Placing strong emphasis on interaction with phenomena
- Making clear and explicit linkage of representations to phenomena
- Using multiple representations of physical phenomena

2. STAGE SPECIFIC CURRICULAR EXPECTATIONS

Learning Outcomes at Higher Secondary stage developed by National Council for Educational Research and Training (NCERT) mentions the following curricular expectations for physics.

CE1. develop interest to study Physics as a discipline

CE2. strengthen the concepts developed at the secondary stage to acquire firm ground work and foundation for further learning of Physics more effectively and learning the relationship with real life situations

CE3. apply reasoning to develop conceptual understanding of Physics concepts

CE4. realize and appreciate the interface of Physics with other disciplines

CE5. get exposure to different processes used in Physics-related industrial and technological applications

CE6. develop process-skills and experimental, observational, manipulative, decision-making and investigatory skills

CE7. synthesize various science/physics concepts to solve problems and thinking critically in the process of learning Physics

CE8. understand the relationship between nature and matter on scientific basis, develop positive scientific attitude, and appreciate the contribution of Physics towards the improvement of quality of life and human welfare

CE9. comprehend the contemporary knowledge and develop aesthetic sensibilities

CE10. appreciate the role and impact of Physics and technology, and their linkages with overall national development

The focus of the curriculum must therefore be on developing conceptual understanding, and on understanding the relationship of the disciplinary knowledge with real life situations, with technology and with other disciplines. The curriculum should also aim at developing both discipline-specific process skills, e.g. scientific inquiry, observation, etc. and general thinking skills, e.g. problem solving, critical thinking, etc. in the context of learning physics.

3. CONTENT DOMAINS

The content in CBSE curriculum has been organized around broad content units. Class 11 content covers mechanics, thermodynamics and wave motion, and this is covered in the first year. Class 12 content covers electromagnetism, optics and atomic physics, and this is covered in the second year. The content units for the two classes, with the chapters from the NCERT textbooks and the recommended number of 40-minute teaching periods are mentioned in the tables below.

Class 11 Content units and textbook chapters

Content units	NCERT textbook chapters	Number of teaching periods
I. Physical world and measurement	1. Units and measurements	10
II. Kinematics	2. Motion in a straight line 3. Motion in a plane	24
III. Laws of motion	4. Laws of motion	14
IV. Work, energy and power	5. Work, energy and power	12
V. Motion of system of particles and rigid body	6. System of particles and rotational motion	18
VI. Gravitation	7. Gravitation	12
VII. Properties of bulk matter	8. Mechanical properties of solids 9. Mechanical properties of fluids 10. Thermal properties of matter	24
VIII. Thermodynamics	11. Thermodynamics	12
IX. Behaviour of perfect gases and kinetic theory of gases	12. Kinetic theory	8
X. Oscillations and waves	13. Oscillations 14. Waves	26

Class 12 Content units and textbook chapters

Content units	NCERT textbook chapters	Number of teaching periods
I. Electrostatics	1. Electric charges and fields 2. Electrostatic potential and capacitance	26
II. Current electricity	3. Current electricity	18
III. Magnetic effects of current and magnetism	4. Moving charges and magnetism 5. Magnetism and matter	25
IV. Electromagnetic induction and alternating currents	6. Electromagnetic induction 7. Alternating current	24
V. Electromagnetic waves	8. Electromagnetic waves	4
VI. Optics	9. Ray optics and optical instruments 10. Waves optics	30
VII. Dual nature of radiation and matter	11. Dual nature of radiation and matter	8
VIII. Atoms and nuclei	12. Atoms 13. Nuclei	15
IX. Electronic devices	14. Semiconductor electronics: materials, devices and simple	10

4. SUBJECT SPECIFIC COGNITIVE DOMAINS

"As the Board is progressively allowing more space to 'learning outcome based' assessment in place of textbook driven assessment, question papers of Board examinations will have more questions based on real-life situations requiring students to apply, analyse, evaluate and synthesize information as per the stipulated outcomes. The core-indicators to be assessed in all questions, however, will be from the prescribed syllabus and textbooks recommended therein. This will eliminate predictability and rote learning to a large extent." [CBSE Curriculum}

A statement of a learning objective contains a verb (an action) and an object (usually a noun).

- The verb generally refers to the actions associated with the intended cognitive process.
- The object generally describes the knowledge the students are expected to acquire or construct.

CATEGORIES OF COGNITIVE DOMAINS

Revised Bloom's taxonomy (Anderson and Krathwohl, 2001) of cognitive process dimension has six categories, each associated with a set of specific cognitive processes. CBSE curriculum intends to have a balance of these categories of intellectual tasks in the teaching-learning and assessment of learning of a subject. These six categories as described in the revised Bloom's taxonomy, with their specific cognitive processes, are mentioned below.

COGNITIVE DOMAIN – **REMEMBER**

'Remember' involves retrieving relevant knowledge from long-term memory. **Recognising** and **recalling** are the specific cognitive skills associated with this cognitive domain. Asking students to provide definition of a concept, e.g. of nuclear binding energy, or to label the schematic diagram of an instrument or a device are examples of assessment tasks that cover this cognitive domain.

COGNITIVE DOMAIN – **UNDERSTAND**

'Understand' involves 'constructing meaning from instructional messages, including oral, written and graphic communication'. **Interpreting**, **exemplifying**, **classifying**, **summarizing**, **inferring**, **comparing**, **explaining** are the specific cognitive skills associated with this cognitive domain. Asking students to explain a phenomenon in terms of physical concepts/principles, e.g. how a charged object pulls bits of paper, or to compare two physical situations, e.g. magnetic field produced by a permanent magnet and by a current carrying solenoid are examples of assessment tasks covering this cognitive domain.

COGNITIVE DOMAIN – **APPLY**

'Apply' involves carrying out or using a procedure in a given situation. **Executing** and **implementing** are the specific cognitive skills associated with this cognitive domain. Assessment tasks wherein students have to use the knowledge and/or procedures to solve a problem or to arrive at a decision in a given real-life situation cover this cognitive domain. Solving numerical problems based on formulae and mathematical relationships is a common example of such a task. However, problems demanding an application of qualitative understanding and application of concepts would also fall in this domain.

COGNITIVE DOMAIN – **ANALYSE**

'Analyse' involves breaking material into constituent parts and determining how parts relate to one another and to an overall structure and purpose. **Differentiating**, **organising** and **attributing** are the specific cognitive skills associated with this cognitive domain. Asking students to compare and explain the relationship between two physical quantities from the same content domain, e.g. electric potential and electric potential energy or asking them to identify relevant factors in a given situation, e.g. identifying factors which would affect the final velocity of an object thrown from a height are examples of some tasks from this cognitive domain.

COGNITIVE DOMAIN – **EVALUATE**

'Evaluate' involves making judgments based on criteria and standards. **Checking** and **critiquing** are the specific cognitive skills associated with this cognitive domain. Assessment tasks that require a deeper level of understanding wherein students are required to provide justification for their choice, e.g. explaining if given data support a conclusion, can be used for this cognitive domain.

COGNITIVE DOMAIN – **CREATE**

'Create' involves putting elements together to form a coherent or functional whole; or reorganising elements into a new pattern or structure. **Generating**, **planning** and **producing** are the specific cognitive skills associated with this cognitive domain. Tasks that require students to produce new artefacts based on what they have learnt, e.g. developing a model or writing a response to an open-ended question or coming up with hypotheses that can explain an observed phenomenon can assess students' proficiency in this cognitive domain.

CATEGORIES OF KNOWLEDGE DOMAINS

The knowledge dimension represents a range from concrete (factual) to abstract (metacognitive). Representation of the knowledge dimension as a number of discrete steps can be a bit misleading. For example, all procedural knowledge may not be more abstract than all conceptual knowledge. And metacognitive knowledge is a special case. In this model, "metacognitive knowledge" is knowledge of one's own cognition and about oneself in relation to various subject matters.

KNOWLEDGE DOMAIN – FACTUAL

Factual Knowledge – The basic elements students must know to be acquainted with a discipline or solve problems. This dimension refers to essential facts, terminology, details or elements students must know or be familiar with in order to understand a discipline or solve a problem in it. For example, the definition of non-uniform motion before introduction of what results in an acceleration in a body; the knowledge of Cartesian sign conventions before using lens and mirror formula; etc

KNOWLEDGE DOMAIN – CONCEPTUAL

Conceptual Knowledge – The inter-relationships among the basic elements within a larger structure that enable them to function together. It is the knowledge of classifications, principles, generalizations, theories, models, or structures pertinent to a particular disciplinary area. For example: a charged particle moving with velocity perpendicular to magnetic field, experiences centripetal force that is provided by the magnetic force.

KNOWLEDGE DOMAIN –PROCEDURAL

Procedural Knowledge – How to do something, methods of inquiry, and criteria for using skills, algorithms, techniques, and methods. It refers to information or knowledge that helps students to do something specific to a discipline, subject, or area of study. It also refers to methods of inquiry, very specific or finite skills, algorithms, techniques, and particular methodologies. For example, for resistors in series, the voltage always divides and current is the same through each one of them while its vice versa in case of resistors in parallel. Hence while finding equivalent resistance of multiple networks, this knowledge becomes the basis of identifying whether the given adjacent resistors in a given network are in series or parallel.

KNOWLEDGE DOMAIN –METACOGNITIVE

Metacognitive Knowledge – Knowledge of cognition in general, as well as awareness and knowledge of one's own cognition. It is the awareness of one's own cognition and particular cognitive processes. It is strategic or reflective knowledge about how to go about solving problems, cognitive tasks, to include contextual and conditional knowledge and knowledge of self. For example, while taking a turn while driving a car, it is out of self-experience that the driver slows down the car in order to take a turn of small radius of curvature. From the physics problem solving point of view, for a given frictional force between the car tyres and the road, larger speed ensures larger radius of the turn and smaller speed corresponds to smaller radius of turn, to avoid overturning of the car.

KINDS OF ASSESSMENT TASKS FOR DIFFERENT COGNITIVE DOMAINS

Some more examples of kinds of assessment tasks that can be associated with the different cognitive domains are given below. The following list should be taken as an indicative not an exhaustive one.

Cognitive domain	Assessment tasks
Remember	Identify, state or define facts, relationships, formulae or concepts.

• recognising • recalling	Identify or describe properties of physical concepts, materials or objects. Recognize and correctly use scientific vocabulary, symbols, abbreviations, units, and scales. Identify the appropriate use for scientific equipment and procedures.
Understand • interpreting • exemplifying • classifying • summarizing • inferring • comparing • explaining	Interpret information in the form of texts, graphs or images in terms of physical concepts and their relationships. Provide examples of physical concepts or physical phenomena related to specific concepts. Classify or compare situations, processes or objects using physical concepts or principles. Provide a summary of development of a physical concept, model or a principle. Derive a mathematical relationship representing relationship between different physical quantities. Infer relationships between physical concepts from given data or graphs. Provide or identify an explanation for an observation or a natural phenomenon using physical concepts or principles.
Apply • executing • implementing	Use knowledge of physical concepts and their relationships to solve problems set in a variety of situations. Use a known procedure to measure a physical quantity or to find the relationship between physical quantities. Relate knowledge of an underlying concept to an observed or inferred property, behaviour or use of objects, or materials.
Analyse • differentiating • organising • attributing	Describe relationships between physical concepts or principles from within the same or across different content domains. Differentiate between physical concepts, principles or phenomena from within the same content domain. Use evidence and conceptual understanding to predict the effects of changes in conditions on a physical system. Identify or formulate questions that can be answered by a given experiment or scientific investigation. Identify characteristics of scientific investigations in terms of dependent/independent or controlled/measured variables.
Evaluate	Evaluate alternative explanations for an observed phenomenon.

• checking • critiquing	Compare different approaches to a given problem. Evaluate conclusions drawn from a scientific investigation.
Create • generating • planning • producing	Answer questions or make decisions which involve considering a number of different or related concepts and principles. Plan an experiment with clear steps to investigate a question/problem or to test a hypothesis. Make a model to illustrate a physical concept or principle.

These are learning objectives – not learning activities. It may be useful to think of preceding each objective with something like, "students will be able to…:"

	The Knowledge Dimension **Factual** The basic elements a student must know to be acquainted with a discipline or solve problems in it.	The Knowledge Dimension **Conceptual** The interrelationships among the basic elements within a larger structure that enable them to function together.	The Knowledge Dimension **Procedural** How to do something, methods of inquiry, and criteria for using skills, algorithms, techniques, and methods.	The Knowledge Dimension **Metacognitive** Knowledge of cognition in general as well as awareness and knowledge of one's own cognition
The Cognitive Process Dimension **Remember** Retrieve relevant knowledge from long-term memory.	**Remember + Factual** List the Cartesian sign conventions for mirror formulae	**Remember + Conceptual** Recognize the reasons for heating up of an oscillating pendulum in the presence of magnetic field	**Remember + Procedural** Recall how to connect resistors in series or parallel to an external power source	**Remember + Metacognition** Identify the strategies to remember the image formations in lens and mirrors for different positions of the objects
The Cognitive Process Dimension	**Understand + Factual**	**Understand + Conceptual**	**Understand + Procedural**	**Understand + Metacognition**

Understand Construct meaning from instructional messages, including oral, written and graphic communication.	Summarise the factors on which magnetic force on a moving charge particle depends upon	Classify materials as para-, dia- and ferro- basis their magnetic properties	Clarify steps to assemble resistors to form a Wheatstone or bridge	Predict the galvanometer deflection while a magnet is moved towards the coil connected to it, after noticing the direction of deflection while the magnet moved away from the coil
The Cognitive Process Dimension **Apply** Carry out or use a procedure in a given situation.	**Apply + Factual** Respond to recurring activity of moving an object towards or away from the mirror	**Apply + Conceptual** Provide suggestion to form circuits providing maximum illumination for a given input power source	**Apply + Procedural** Carry out tests to determine terminal velocities of a given object in liquids of different viscosities	**Apply + Metacognition** Use techniques that match with one's strengths. For ex., if a student is good with mechanics and force law, the student may undertake a task to prove that a ball thrown through a tunnel passing through the center of Earth undergoes SHM
The Cognitive Process Dimension **Analyze** Break material into foundational parts and determine how parts relate to one another and the overall structure or purpose	**Analyse + Factual** Select a material that is most suitable for induction cookware	**Analyse + Conceptual** Differentiate between two mirrors without touching them	**Analyse + Procedural** Integrate the working of cyclotron with the principles of magnetic force of accelerating charge	**Analyse + Metacognition** Deconstruct the non- inertial reference frames and the presence of pseudo forces

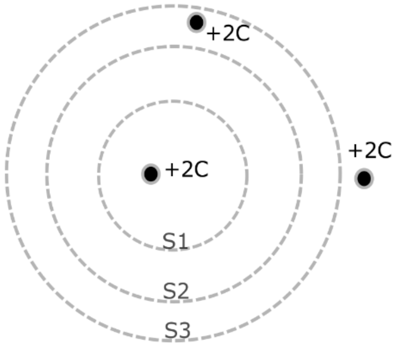
The Cognitive Process Dimension **Evaluate** Make judgments based on criteria and standards.	**Evaluate + Factual** Check for illustrations that constitute non inertial reference frames	**Evaluate + Conceptual** Determine the relevance of beat formation while tuning a wired musical instrument like a violin	**Evaluate + Procedural** Judge the efficiency of a heat engine in comparison to a perfect Carnot engine	**Evaluate + Metacognition** Reflect on the understanding of image formation in lens while reproducing the ray diagrams in telescope and microscope
The Cognitive Process Dimension **Create** Put elements together to form a coherent whole; reorganize into a new pattern or structure.	**Create + Factual** Generate a list of object positions in ray diagrams (lens and mirrors) that produce images with positive magnifications	**Create + Conceptual** Assemble a given set of resistors into a suitable network that results in minimum (or maximum) equivalent resistance	**Create + Procedural** Design a transformer that produces a desired voltage output for a given input voltage	**Create + Metacognition** Create a flow diagram that outlines the effect on charges as they are at rest or move with varying velocities, with or without the presence of external magnetic or electric fields in their vicinity

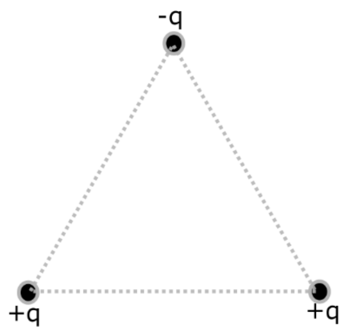
SUGGESTED SAMPLE TASKS FROM DIFFERENT COGNITIVE DOMAINS SPECIFIC TO A CONTENT UNIT

Some specific examples of tasks from different cognitive domains are described below for two content chapters from classes 11 and 12 NCERT physics textbooks. A chapter may not always cover all six cognitive domains. The following list of tasks should be taken as an indicative list not a comprehensive one.

CHAPTER 1. ELECTRIC CHARGES AND FIELDS – CLASS 12

Cognitive domain	Suggested sample tasks
Remember	• Define electric flux. • How does the electric field of a dipole vary with respect to the distance from its centre?
Understand	• Explain how a charged plastic comb attracts small bits of paper. • Explain why the magnitude of electric field drops off more rapidly away from an electric dipole as compared to from a point charge. • Derive the expression for the electric field at a point on the equatorial plane of an electric dipole.
Apply	• The electric field in the atmosphere near the surface of the Earth is about 100 N/C. Estimate the amount of net electric charge in a cuboid of air of height 2 m and a square base of side 50 cm, standing on the ground on its square base. • The diagram below shows three point charges and three Gaussian surfaces (spherical) – S1, S2 and S3. Compare the electric flux through S1, S2 and S3.

	 • A metal sphere S1 suspended from an insulating thread has a total positive charge of +(Q1+q) and a total negative charge of (-Q1). (i) What is the net charge on the sphere S1? (ii) Another metal sphere S2 of the same size and carrying a positive charge of +Q and a negative charge of -Q is brought in contact with the suspended metal sphere, and is then separated from it. What is the total positive charge on the suspended metal sphere S1 now? (iii) What is the total negative charge on sphere S2 now?
Analyse	• Explain the effect of increasing the distance between the two point charges in an electric dipole on the electric field measured at a point (i) on the axis of the dipole, and (ii) on the equatorial plane of the dipole. • Explain how the magnitude of electric field inside and outside a uniformly charged spherical shell will change if the radius of the shell is increased without changing the net charge on its surface? (Imagine a balloon with a conductive coating carrying a net charge on its surface being inflated.) • Differentiate between 'charging by contact' and 'charging by induction'. • Use mathematical form of Coulomb's law to show that the force applied by two point charges on each other is equal in magnitude and opposite in direction in accordance to Newton's third law.

Evaluate	• Evaluate the role of the following forces on the oil drops in Millikan's oil drop experiment and identify the ones that can be ignored for the purpose of the experiment. (Description of the experiment with values of physical quantities involved is provided.) electrostatic force, gravitational force, drag force, buoyant force • Electric field in the vicinity of a continuous charge distribution can be computed using one of the following approaches: (i) Compute the electric field due to an infinitesimally small element of the charge distribution, and integrate it over the whole charge distribution. (ii) Draw a suitable Gaussian surface and compute the electric field using Gauss's law. Compare the two approaches and illustrate through an example each where you would prefer one approach to another.
Create	• Draw the electric field lines for the following configuration of point charges.  • Here is a basic description of an activity that can be done to verify Coulomb's law: Two small pith balls with a conducting coating are charged equally. They are suspended from insulating threads and the separation between them is measured. The charge on the pith balls is reduced to half of the original and the separation between them is again measured. Describe in detail the following:

	(i) How can the two pith balls be charged equally? (ii) How can the charge on the pith balls be reduced to half? (iii) How can the measurements of the separation between the pith balls be used to verify Coulomb's law? *[Hint: A component of the tension in the suspending threads will balance the repulsive force between the pith balls.]*

5. LEARNING OUTCOMES

> "Indicator based Learning focuses on the student's demonstration of desired learning outcomes as central to the learning process. Learning outcomes are statements of abilities that are expected students will gain as a result of learning the activity. Learning outcomes are, thus, statements of what a learner is expected to know, understand and/or be able to demonstrate after completion of a process of learning. Therefore, the focus is on measuring learning through attainment of prescribed learning outcomes, rather than on measuring time." [Senior School Curriculum, CBSE]

Following learning outcomes for senior secondary stage developed by National Council for Educational Research and Training (NCERT) state important knowledge, skills and dispositions students need to attain at the end of an academic year in classes 11 and 12 in the context of learning physics.

CLASS 11 LEARNING OUTCOMES FOR PHYSICS

(1) **recognises the concepts of Physics related to various natural phenomena**; such as, force, momentum, mechanical properties of solids and fluids, simple harmonic motion, greenhouse effect, variation in speed of sound in different media

(2) **differentiates between certain physical quantities**; such as, between distance and displacement; speed and velocity; rectilinear and curvilinear motions; average, relative, and instantaneous velocity and speed; stress and strain; Young's modulus, shear modulus and bulk modulus

(3) **uses International system of units (SI Units), symbols, nomenclature of physical quantities and formulations, conventions**; such as, common SI prefixes and symbols for multiples and sub-multiples; important constants; conversion factors; mathematical formulae; SI derived units (expressed in SI base units); SI derived units with special names; guidelines for using symbols for physical quantities, chemical elements and nuclides; guidelines for using symbols for SI units e.g. newton, pascal, joule, watt, hertz, kelvin, dimensional formulae of physical quantities

(4) **explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis**; such as, need of accuracy, precision, errors and uncertainties in measurement; fundamental forces in nature – gravitational, electromagnetic, strong and

weak nuclear forces; and unification of forces; various laws such as laws of motion, friction, lubrication, conservation laws, change in velocity due to acceleration, acceleration due to gravity of earth, why a seasoned cricketer draws in her/his hands during a catch; isothermal, isobaric, isochoric and adiabatic processes; formation of beats due to interference of sound waves

(5) **derives formulae and equations**, such as, dimensional formulae and dimensional equation; kinematic equations for uniformly accelerated motion; equation of path of a projectile; equation of motion of an object in a plane with constant acceleration, potential energy of a spring, proof of work-energy theorem for a variable force, work done by a torque, efficiency of Carnot engine, different harmonics in stretched strings/pipes; Bernoulli's equation, Equation for pressure of an ideal gas, equations for velocity, acceleration, energy of a particle executing SHM

(6) **analyses and interprets data, graphs, and figures, and draws conclusion**; such as, motion in a plane; analysis of the function of time to identify periodic and non-periodic motion; behavior of a material from its stress-strain curve; isothermal and adiabatic processes from P-V curves; variation of resonance peak with damping from the graph of amplitude versus angular frequency

(7) **handles tools and laboratory apparatus properly; measures physical quantities using appropriate apparatus, instruments, and devices**; such as, scales, vernier calipers, screw gauge, spherometer, beam balance, stop clock/watch, inclined plane, sonometer, resonance tube, an arrangement for determining Young's modulus of the material of a wire

(8) **plans and conducts investigations and experiments to arrive at and verify the facts, principles, phenomena, relationship between physical quantities, or to seek answers to queries on their own**; such as, study the effect of detergent on surface tension of water; determine terminal velocity of a spherical body; study the effect of changing the mass of bob or length of pendulum, on its time period; study the factors affecting the rate of loss of heat of a liquid; find the coefficient of friction between surface of a moving block and that of a horizontal surface

(9) **communicates the findings and conclusions** in oral/written/ICT form that shows critical thinking, such of plotting a suitable graph between load and extension for finding force constant of a helical spring

(10) **exhibits creativity and out-of–the-box thinking in solving challenging physics problems**; such as, minimum speed required by a motorcyclist at the uppermost position to perform a vertical loop in a death well in a circus; a pillar with distributed shape at the end support more load.

(11) **applies concepts of physics in daily life with reasoning while decision-making and solving problems**; such as, maximum possible speed of a car on a banked road; in which direction to hold the umbrella if rain is falling vertically and wind is blowing in certain direction; during blood transfusion the height at which the blood container be placed so that blood may just enter the vein through the needle inserted in vein; a spinning ball deviates from its parabolic trajectory; changing the tension in the wire of sitar for changing frequency of sound emitted by it

(12) **takes initiative to learn about the newer researches, discoveries and inventions in physics**; such as, about space programme of India and other countries; research to increase the strength of a material, increase the efficiency of engines

(13) **recognises different processes used in Physics-related industrial and technological applications**; such as, knowledge of strength of materials used for structural design of columns, beams and supports while designing a building; hydraulic machine for lifting heavy objects; knowledge about beats for tuning musical instruments

(14) **realises and appreciates the interface of Physics with other disciplines**; such as, application of Doppler effect in medical science to study heart beats and blood flow in different parts of body; mechanism of conversion of heat into work for different heat engines; properties of materials in different branches of engineering

(15) **develops positive scientific attitude, and appreciates the role and impact of Physics and technology towards the improvement of quality of life and human welfare**, such as, nuclear radiation techniques for diagnosis and treatment, nuclear power.

(16) **exhibits values of honesty, objectivity, respect for life, rational thinking, and freedom from myth and superstitious beliefs while taking decisions, etc.**

CLASS 12 LEARNING OUTCOMES FOR PHYSICS

(1) **recognises the concepts of Physics related to various natural phenomena**; such as, electrostatic force; electric and magnetic fields and flux; electrostatic potential; drift of electrons; electric current; resistance of materials; magnetic properties of materials; electromagnetic induction; reflection, refraction, interference, diffraction of light; formation of rainbow; nuclear fusion and nuclear fission.

(2) **differentiates between certain physical quantities**; such as, between electric field and electric potential; electrical resistance and resistivity; potential difference and emf of a cell; interference and diffraction; wave and particle nature of light; e Nuclear fusion and nuclear fission; conductors and bad conductors or dielectrics

(3) **uses International system of units (SI Units), symbols, nomenclature of physical quantities and formulations, conventions**; such as, coulomb (C), farad (F), ampere (A), ohm (Ω), tesla (T), degree (°);

(4) **explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis**; such as, force between charges, electric field and potential due to charges; force on charges in an electric field; forces on moving charges in a magnetic field, torque on a rectangular current loop in an uniform magnetic field; eddy currents; formation of secondary rainbow;; energy produced due to fusion, generation of emf by solar radiation.

(5) **derives formulae and equations**, such as, electrostatic forces and fields due to charge distributions; potential energy of system of charges; torque on a dipole in uniform electric field; effective capacitance of combination of capacitors in series and in parallel; energy stored in a capacitor; magnetic field on the axis of a circular current loop; resonant frequency in series LCR circuit; thin lens formula, de Broglie wavelength; equations for nuclear fission and fusion, mass defect; fringe width in Young's double slit experiment

(6) **analyses and interprets data, graphs, and figures, and draws conclusion**; such as, field due to a uniformly charged thin spherical shell is zero at all points inside the shell; hysteresis loop; direction of induced current in the figure; position of image in ray diagrams; fringe pattern due to diffraction at single slit; V-I characteristics of a p-n junction diode; effect of potential on photoelectric current and effect of frequency of incident radiation on stopping potential for a given photosensitive material; plot of binding energy per nucleon versus mass number;

(7) **handles tools and laboratory apparatus properly; measures physical quantities using appropriate apparatus, instruments, and devices**; such as, an electroscope to detect charge on a body; power supplies; voltmeter; ammeter; multimeter; rheostat; galvanometer; meter bridge;; sonometer; travelling microscope; concave and convex lens, prism, glass slab

(8) **plans and conducts investigations and experiments to arrive at and verify the facts, principles, phenomena, relationship between physical quantities, or to seek answers to queries on their own**; such as, verification of Ohm’s law; determining specific resistance of a material; finding frequency of ac mains;; study the image formation by concave and convex lens;; determine refractive index of a liquid using a convex lens and a plane mirror; draw I-V characteristics curves of a p-n junction diode

(9) **communicates the findings and conclusions** in oral/written/ICT form that shows critical thinking, such as, appropriately conveying the critical angle in internal reflection by drawing ray diagrams to describe it

(10) **exhibits creativity and out-of–the-box thinking in solving challenging physics problems**; such as, calculating the required range of variable capacitor of LC circuit of a radio for the radio to be able to tune over a given frequency range of broadcast band; assessing the depth of a pond in clear water using the knowledge of refractive index of water; calculating the energy released in fission or fusion process.

(11) **applies concepts of physics in daily life with reasoning while decision-making and solving problems**; such as, if a certain capacitance is required in a circuit across a certain potential difference then suggesting a possible arrangement using minimum number of capacitors of given capacity which can withstand a given potential difference; selecting the appropriate wire for doing wiring at home keeping in view all considerations;,

(12) **takes initiative to learn about the newer research, discoveries and inventions in Physics**; such as, accelerators, thermistors, electrical properties of materials, India’s atomic energy programme; research on the possibility of static electricity charging electronic devices; improving magnetic bottles to keep high energy plasma in fusion under control, newer designs of nuclear reactors

(13) **recognises different processes used in Physics-related industrial and technological applications**; such as, using electrostatic shielding in protecting sensitive instruments from outside electrical influences; use of superconducting magnets for running magnetically levitated superfast trains; applications of optical fibers for transmission of optical signals; use of controlled chain reaction in nuclear

(14) **realises and appreciates the interface of Physics with other disciplines**; such as, with Chemistry as various materials give rise to interesting properties in the presence or absence of electric field, making light sensitive cells using the applications of photoelectric effect; use of atomic and nuclear physics in medicine, use of electromagnetic radiations in communication, use of optical phenomenon in entertainment.

(15) **develops positive scientific attitude, and appreciates the role and impact of Physics and technology towards the improvement of quality of life and human welfare**

(16) **exhibits values of honesty, objectivity, respect for life, rational thinking, and freedom from myth and superstitious beliefs while taking decisions, etc.**

CLASSES 11-12 COMMON LEARNING OUTCOMES FOR PHYSICS

As can be seen from the two lists of learning outcomes above, the basic LOs are the same for both the classes and the differences lie in the specific instances that have been taken from the content domain for illustrative purposes. In this document from here onwards, the following list of LOs will be referred to for both the classes. *It is important to note that LOs 7, 8 and 9 are specifically relevant to practical work prescribed in the physics curriculum.*

LO1. Recognizes the concepts of Physics related to various natural phenomena

LO2. Differentiates between certain physical quantities

LO3. Uses International system of units (SI Units), symbols, nomenclature of physical quantities and formulations, conventions

LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis

LO5. Derives formulae and equations

LO6. Analyses and interprets data, graphs, and figures, and draws conclusion

LO7. Handles tools and laboratory apparatus properly; measures physical quantities using appropriate apparatus, instruments, and devices

LO8. Plans and conducts investigations and experiments to arrive at and verify the facts, principles, phenomena, relationship between physical quantities, or to seek answers to queries on their own

LO9. Communicates the findings and conclusions in oral/written/ICT form that shows critical thinking

LO10. Exhibits creativity and out-of–the-box thinking in solving challenging physics problems

LO11. Applies concepts of physics in daily life with reasoning while decision-making and solving problems

LO12. Takes initiative to learn about the newer research, discoveries and inventions in Physics

LO13. Recognises different processes used in Physics-related industrial and technological applications

LO14. Realises and appreciates the interface of Physics with other disciplines

LO15. Develops positive scientific attitude, and appreciates the role and impact of Physics and technology towards the improvement of quality of life and human welfare

LO16. Exhibits values of honesty, objectivity, respect for life, rational thinking, and freedom from myth and superstitious beliefs while taking decisions, etc.

6. CONTENT DOMAIN SPECIFIC LEARNING OUTCOMES AND INDICATORS

The learning outcomes defined by NCERT are generic and broadly defined for the content defined in the curriculum. They articulate the discipline-specific skills that students need to attain through learning different concepts in the syllabus. A clear understanding of the scope of these learning outcomes for each concept in the NCERT textbook chapters will be very helpful for both teachers and students in planning teaching and learning better. The following process has been followed to list out the content domain specific learning outcomes (CLOs) and indicators for all the content units and textbook chapters.

- Concepts discussed in the textbook chapters were mapped to key concepts under each content domain in the CBSE syllabus.
- Relevant NCERT learning outcomes were identified for each key concept in the chapter.
- Content domain specific learning outcomes (CLO) were defined for the NCERT learning outcomes relevant for the chapter. The cognitive process in the NCERT learning outcome and the CLO is the same.
- Each CLO was broken down into specific learning indicators called as 'indicator' which defines the specific skill or knowledge that a student needs to attain. The cognitive process addressed in indicators may be same or lower than the cognitive process addressed in CLO.

CLASS 11 CONTENT DOMAIN SPECIFIC LEARNING OUTCOMES AND INDICATORS

Unit and Chapter	Key concept	NCERT Learning Outcomes	Content domain specific Learning Outcomes	Indicators
I. Physical world and measurement 2. Units and measurement	International system of units	LO3. Uses International system of units (SI Units), symbols, nomenclature of physical quantities and formulations, conventions	CLO01.Enumerates the International system of base and supplementary units	C1.Lists and defines international standards of units of measurements used for measurement of 7 base and 2 supplementary physical quantities
I. Physical world and measurement 2. Units and measurement	Significant figures	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO02.Estimates precise experimental results using significant figures and rounding off the final results	C2.Defines and states the rules for writing significant figures in a result of a measurement
I. Physical world and measurement 2. Units and measurement	Significant figures	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis		C3.States the rules for rounding off uncertain digits of significant figures and for determining uncertainties in the results of calculations
I. Physical world and measurement 2. Units and measurement	Dimensions of physical quantities	LO3. Uses International system of units (SI Units), symbols, nomenclature of physical quantities and formulations, conventions	CLO03.Identifies and applies the concept of dimensions, dimensional formulae and dimensional analysis techniques to write, validate and derive correct physical equations	C4.Defines dimensions of a physical quantity in terms of the exponents of fundamental units and expresses dimensions of common physical quantities used in the mechanics and heat
I. Physical world and measurement 2. Units and measurement	Dimensional formulae of physical quantities	LO3. Uses International system of units (SI Units), symbols, nomenclature of physical quantities and formulations, conventions		C5.Defines dimensional formulae of a physical quantity in terms of fundamental units and explains how to write a dimensional equation if the dimensional formula of a physical quantity is known

Unit and Chapter	Key concept	NCERT Learning Outcomes	Content domain specific Learning Outcomes	Indicators
I. Physical world and measurement 2. Units and measurement	Applications of Dimensional analysis	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO04.Identifies and applies the concept of dimensions, dimensional formulae and dimensional analysis techniques to write, validate and derive correct physical equations	C6.Defines principle of homogeneity for dimensional equations and applies dimensional analysis technique to check the correctness of physical equations
II. Kinematics 3. Motion in a straight line	Kinematics as field of study of describing motion in physics	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO05.Describes position, distance and displacement of a body in motion	C7.Defines path length or distance travelled by a body in reference to x-coordinate axis
II. Kinematics 3. Motion in a straight line	Kinematics as field of study of describing motion in physics	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis		C8.Defines displacement of a body moving along a straight line
II. Kinematics 3. Motion in a straight line	Kinematics as field of study of describing motion in physics	LO6. Analyses and interprets data, graphs, and figures, and draws conclusion		C9.Plots graph between position and time of a body in motion and infers the nature of motion of a body from the shapes of position time graphs
II. Kinematics 3. Motion in a straight line	Position, path length and displacement	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO06.Explains average and instantaneous velocity	C10.Defines average velocity of a body and identifies average velocity as a slope of a tangent to position-time graph of a body in motion
II. Kinematics 3. Motion in a straight line	Position, path length and displacement	LO6. Analyses and interprets data, graphs, and figures, and draws conclusion		C11.Plots and explains position-time graphs for a moving body depicting positive, zero and negative average velocity
II. Kinematics 3. Motion in a straight line	Position, path length and displacement	LO2. Differentiates between certain physical quantities		C12.Defines and differentiates average speed from average velocity and solves numerical problems based on them

Unit and Chapter	Key concept	NCERT Learning Outcomes	Content domain specific Learning Outcomes	Indicators
II. Kinematics 3. Motion in a straight line	Position, path length and displacement	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis		C13.Defines instantaneous velocity of a body and recognises the slope of tangent to position-time graph at any instant of a body in motion as instantaneous velocity
II. Kinematics 3. Motion in a straight line	Position, path length and displacement	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO07.Explains the concept of acceleration of a body in non uniform motion	C14.Defines average acceleration in terms of rate of change in instantaneous velocities
II. Kinematics 3. Motion in a straight line	Position, path length and displacement	LO6. Analyses and interprets data, graphs, and figures, and draws conclusion		C15.Plots and interprets position-time and velocity-time graphs to determine displacement, nature of acceleration and direction of motion of a body
II. Kinematics 3. Motion in a straight line	Position, path length and displacement	LO5. Derives formulae and equations	CLO08.Derives and explains kinematic equations of linearly accelerated motion	C16.Derives kinematic equations of motion using velocity-time graph method and calculus method for a body moving along straight line with uniform acceleration
II. Kinematics 3. Motion in a straight line	Position, path length and displacement	LO11. Applies concepts of physics in daily life with reasoning while decision-making and solving problems	CLO09.Derives and explains kinematic equations of linearly accelerated motion	C17.Solves numerical problems involving motion of body along straight line in uniform acceleration
II. Kinematics 3. Motion in a straight line	Position, path length and displacement	LO11. Applies concepts of physics in daily life with reasoning while decision-making and solving problems	CLO10.Appreciates the application of kinematic equations of linear motion to freely falling bodies	C18.Applies equations of straight line motion for a freely falling bodies with appropriate cartesian coordinate sign conventions and solves numerical problems based on real life situations
II. Kinematics 3. Motion in a straight line	Position, path length and displacement	LO6. Analyses and interprets data, graphs, and figures, and draws conclusion		C19.Plots position-time; velocity-time and acceleration-time graphs for a body under free fall

Unit and Chapter	Key concept	NCERT Learning Outcomes	Content domain specific Learning Outcomes	Indicators
II. Kinematics 3. Motion in a straight line	Average velocity and average speed	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO11.Defines and explains relative velocity of one body with respect to another moving along straight lines	C20.Defines relative velocity of one body with respect to second body with second body being considered as reference point of coordinate axes
II. Kinematics 3. Motion in a straight line	Average velocity and average speed	LO11. Applies concepts of physics in daily life with reasoning while decision-making and solving problems	CLO12.Defines and explains relative velocity of one body with respect to another moving along straight lines	C21.Solves numerical problems based on relative velocities to determine the time taken to overtake, distance travelled before the overtake and instant when the two oppositely moving bodies crossover
II. Kinematics 4. Motion in a plane	Scalars and vectors	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO13.Explains scalar and vector quantities and their mathematical operations	C22.Defines scalar and vector physical quantities with examples and explains the various vector operations
II. Kinematics 4. Motion in a plane	Scalars and vectors	LO6. Analyses and interprets data, graphs, and figures, and draws conclusion		C23.Defines and represents graphically the position and displacement vectors for a given set of position vectors at different times of a body moving in a plane
II. Kinematics 4. Motion in a plane	Vector operations	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis		C24.States triangle law and parallelogram law of vector addition for adding two or more vectors
II. Kinematics 4. Motion in a plane	Resolution of vectors	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis		C25.Explains the resolution of vectors in a plane and in space in terms of two or more unit vectors

Unit and Chapter	Key concept	NCERT Learning Outcomes	Content domain specific Learning Outcomes	Indicators
II. Kinematics 4. Motion in a plane	Motion in a plane	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO14.States and derives the equations of a uniformly accelerated motion of a body in a plane using vectoral notations	C26.Defines average and instantaneous velocity of a body in motion in a plane in terms of unit vectors
II. Kinematics 4. Motion in a plane	Motion in a plane	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis		C27.Defines average and instantaneous acceleration of the ratio of change in velocity vectors to time where velocity vectors are expressed in terms of unit vectors
II. Kinematics 4. Motion in a plane	Motion in a plane	LO11. Applies concepts of physics in daily life with reasoning while decision-making and solving problems		C28.Applies differential calculus to determine velocity and acceleration vectors from a given position vector expressed as a function of time
II. Kinematics 4. Motion in a plane	Motion in a plane with uniform acceleration	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis		C29.Recognises that a motion in two dimensions can be treated as two simultaneous one-dimensional motions with constant accelerations along perpendicular directions
II. Kinematics 4. Motion in a plane	Projectile motion	LO5. Derives formulae and equations	CLO15.Describes projectile motion and derives all equations related to projectile motion	C30.Derives the equations of motion for displacement and velocity along horizontal and vertical motions of the projectile motion
II. Kinematics 4. Motion in a plane	Projectile motion	LO5. Derives formulae and equations		C31.Derives the equations for total time of flight, maximum vertical height and horizontal range of the projectile
II. Kinematics 4. Motion in a plane	Projectile motion	LO11. Applies concepts of physics in daily life with reasoning while decision-making and solving problems		C32.Solves problems based on real life projectiles like jet of water projecting out of fire engine pipe, food packets being dropped by a moving airplane,

Unit and Chapter	Key concept	NCERT Learning Outcomes	Content domain specific Learning Outcomes	Indicators
				canon firing canon ball and a player kicking the football
II. Kinematics 4. Motion in a plane	Uniform circular motion	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO16.Applies the concepts of vectors to explain motion of a body along a circular path	C33.Defines and describes uniform circular motion in terms of angular displacement and angular velocity of a body
II. Kinematics 4. Motion in a plane	Uniform circular motion	LO5. Derives formulae and equations		C34.Derives a formula for centripetal acceleration in terms of angular velocity, radius and linear speed of a uniform circular motion
III. Laws of motion 5. Laws of motion	Newton's first law of motion	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO17.States Newton first law of motion and identifies the role of inertia in common day to day experiences	C35.States Newton first law of motion
III. Laws of motion 5. Laws of motion	Inertia	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis		C36.Describes the concept of inertia in a body and its role in getting a body to move and the factors on which it depends upon
III. Laws of motion 5. Laws of motion	Momentum	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO18.States Newton first law of motion and identifies the role of inertia in common day to day experiences	C37.Defines linear momentum of a body in motion and recognises the role of force in the change in momentum
III. Laws of motion 5. Laws of motion	Newton's second law of motion	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO19.Explains Newton second law of motion; discovers its mathematical differential formulation	C38.States Newton second law of motion in terms of relation between net external force acting on the body and rate of change in momentum produced in the body

Unit and Chapter	Key concept	NCERT Learning Outcomes	Content domain specific Learning Outcomes	Indicators
III. Laws of motion 5. Laws of motion	Reference frames	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis		C39.Defines inertial and non inertial reference frames basis the applicability of Newton laws of motion in them
III. Laws of motion 5. Laws of motion	Impulse	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis		C40.Defines impulse in terms of a large variable force acting on system for a very short time interval and establishes its relation with change in momentum using Newton second law of motion
III. Laws of motion 5. Laws of motion	Newton’s third law of motion	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO20.States Newton’s third law of motion and infers the Law of conservation of momentum from Newton second and third laws	C41.Defines Newton's third law of motion and identifies the forces occurring in pairs as action-reaction forces using common examples
III. Laws of motion 5. Laws of motion	Law of conservation of linear momentum	LO5. Derives formulae and equations		C42.States law of conservation of linear momentum and validates the law of conservation of momentum using Newton second law of mathematical equation
III. Laws of motion 5. Laws of motion	Applications of Law of conservation of linear momentum	LO11. Applies concepts of physics in daily life with reasoning while decision-making and solving problems	CLO21.Applies Law of conservation of momentum to the collisions of bodies in 1- and 2- dimensional motion	C43.Applies law of conservation of linear momentum to study the forces and transfer of momentum during the collisions between two elastic balls moving along straight line and when moving in a plane (2 dimensions)
III. Laws of motion 5. Laws of motion	Equilibrium of bodies	LO11. Applies concepts of physics in daily life with reasoning while decision-making and solving problems		C44.Defines translational equilibrium of a body and applies the rules of resolution of vectors to write equations of forces acting in a plane on a body in equilibrium

Unit and Chapter	Key concept	NCERT Learning Outcomes	Content domain specific Learning Outcomes	Indicators
III. Laws of motion 5. Laws of motion	Types of mechanical forces	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO22.Identifies common mechanical forces that act on a body at rest or motion	C45.Identifies forces like normal reaction, friction, buoyant forces and spring force as contact forces that act on two bodies in contact with each other
III. Laws of motion 5. Laws of motion	Friction	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis		C46.Explains different types of friction and their formulations in terms of normal reaction and coefficient of friction
III. Laws of motion 5. Laws of motion	Dynamics of Circular motion	LO11. Applies concepts of physics in daily life with reasoning while decision-making and solving problems	CLO23.Describes the dynamics of motion of a car along a circular track	C47.Defines centripetal force on a body moving in a circular path and identifies the importance of friction acting on a body during a circular motion
III. Laws of motion 5. Laws of motion	Banking of roads	LO11. Applies concepts of physics in daily life with reasoning while decision-making and solving problems		C48.Applies rules of resolution of vectors to identify, resolve forces acting on a car moving along a level and banked circular track and constructs the equations using Newton laws
III. Laws of motion 5. Laws of motion	Free body diagrams and equations	LO11. Applies concepts of physics in daily life with reasoning while decision-making and solving problems	CLO24.Writes and solves free body equations in mechanics	C49.Solves problems involving body in equilibrium or in motion under the action of multiple forces using free body diagrams and equations using Newton laws
IV. Work, energy and power 6. Work, energy and power	Scalar product of vector	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO25.Explains the multiplication of vectors using scalar product method	C50.Defines scalar product or dot product between two vector physical quantities, represents it graphically and states its properties

Unit and Chapter	Key concept	NCERT Learning Outcomes	Content domain specific Learning Outcomes	Indicators
IV. Work, energy and power 6. Work, energy and power	Work energy theorem for constant force	LO5. Derives formulae and equations	CLO26.Derives and explains work-energy theorem	C51.Derives the equation of work-energy theorem from the equation of a uniformly accelerated motion and applies the theorem of work-energy to solve numerical problems
IV. Work, energy and power 6. Work, energy and power	Kinetic energy	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO27.Defines kinetic energy of body in motion	C52.Defines kinetic energy in terms of scalar product between velocities, states its units, dimensions and solves numerical problems based on it
IV. Work, energy and power 6. Work, energy and power	Work energy theorem for a variable force	LO5. Derives formulae and equations		C53.States and derives work-energy theorem for variable force and applies the theorem to solve numerical questions
IV. Work, energy and power 6. Work, energy and power	Potential energy	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO28.Describes the concept of potential energy of a body in relation to conservative forces acting on a body	C54.Explains the meaning of conservative forces and recognises that potential energy is energy stored in a body when the work is done against a conservative force
IV. Work, energy and power 6. Work, energy and power	Potential energy of a spring	LO5. Derives formulae and equations	CLO29.Identifies spring force as a conservative force and derives an expression for potential energy stored in a spring	C55.Derives an expression for work done by the conservative force of the spring due to its extension or compression
IV. Work, energy and power 6. Work, energy and power	Potential energy of a spring	LO6. Analyses and interprets data, graphs, and figures, and draws conclusion		C56.Explains and represents graphically the variation of potential energy and kinetic energy of the spring-block system as it moves back and forth.

Unit and Chapter	Key concept	NCERT Learning Outcomes	Content domain specific Learning Outcomes	Indicators
IV. Work, energy and power 6. Work, energy and power	Energy forms	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO30.Identifies various forms of energies and states the law of conservation of energy	C57.Explains various energy forms like heat, electrical, chemical and nuclear energy and states the principle of conservation of energy in systems under the effect of both conservative and non-conservative forces
IV. Work, energy and power 6. Work, energy and power	Power	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO31.Defines instantaneous mechanical power of a body	C58.Defines instantaneous power of a body as a limiting value of average power and solves numerical problems based on power consumed or dissipated by a body
IV. Work, energy and power 6. Work, energy and power	Collisions	LO5. Derives formulae and equations	CLO32.Explains collisions between two bodies moving along a straight line or in a plane	C59.Applies law of conservation of linear momentum to a collision process using Newton second and third laws and derives formulae for final velocities of the bodies after an elastic collision between two bodies moving along a straight line and along a plane
V. Motion of system of particles and rigid body 7. Systems of particles and rotational motion	Center of mass	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO33.Defines and describes center of mass of a rigid body and derives formula for linear momentum of a system of particles	C60.Defines center of mass of a system of particles distributed in a 2 and 3-dimensional plane and explains the motion of center of mass in relation to change in position coordinates, velocity and acceleration of center of mass
V. Motion of system of particles and rigid body 7. Systems of particles	Vector product of two vectors	LO11. Applies concepts of physics in daily life with reasoning while decision-making and solving problems	CLO34.Explains vector product of two vector quantities	C61.Defines vector product between two vector quantities giving the result as a vector and solves problems based on vector product between two vectors expressed using unit vectors

Unit and Chapter	Key concept	NCERT Learning Outcomes	Content domain specific Learning Outcomes	Indicators
and rotational motion				
V. Motion of system of particles and rigid body 7. Systems of particles and rotational motion	Angular variables	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO35.Defines the various angular variables associated with a rigid body in rotational motion around a fixed axis	C62.Defines angular displacement, angular velocity, angular acceleration for a rigid body in rotational motion about a fixed axis
V. Motion of system of particles and rigid body 7. Systems of particles and rotational motion	Torque and angular momentum	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis		C63.Defines torque as a moment of force acting on the body and angular momentum as the moment of linear momentum of the particle about a fixed axis rotating about a fixed point and establishes the relation between them
V. Motion of system of particles and rigid body 7. Systems of particles and rotational motion	Law of conservation of angular momentum	LO5. Derives formulae and equations		C64.Validates the law of conservation of angular momentum using the relation between angular momentum of a system of particles and total torque about a fixed point
V. Motion of system of particles and rigid body 7. Systems of particles and rotational motion	Equilibrium of rigid bodies	LO1. Recognises the concepts of Physics related to various natural phenomena	CLO36.Recognises the conditions of mechanical equilibrium in a rigid body	C65.Recognises the essential conditions of equilibrium of rigid body as a constant linear momentum and angular momentum for translational and rotational equilibrium

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V. Motion of system of particles and rigid body 7. Systems of particles and rotational motion	Center of gravity	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO37.Explains centre of gravity of a rigid body in terms of torques due to gravitational forces	C66.Defines center of gravity of rigid body and solves problems based on rigid body in equilibrium condition under the effect of gravitational forces by applying principle of moments and concept of center of gravity
V. Motion of system of particles and rigid body 7. Systems of particles and rotational motion	Kinetic energy of a body in rotational motion	LO5. Derives formulae and equations	CLO38.Defines moment of inertia as an analogue of mass of a rigid body in rotational motion and proves the two theorems related to moment of inertia of a rigid body about a fixed axis	C67.Derives an expression for kinetic energy of a system of particles rotating around a fixed axis with a constant angular velocity
V. Motion of system of particles and rigid body 7. Systems of particles and rotational motion	Moment of inertia	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis		C68.Defines moment of inertia as a rotational analogy of mass of a body in linear motion and states the formulae of moment of inertias of some commonly used rigid bodies about a fixed axis of rotation
V. Motion of system of particles and rigid body 7. Systems of particles and rotational motion	Kinematics of rotational motion of a rigid body	LO5. Derives formulae and equations	CLO39.States and derives kinematic equations of a rigid body and explains dynamics of rotational motion of a rigid body in terms of torque, work done and angular momentum about a fixed axis of rotation	C69.Writes the rotational analogous equations of motion to linear equations for a body in uniform rotational motion and applies them to solve problems

Unit and Chapter	Key concept	NCERT Learning Outcomes	Content domain specific Learning Outcomes	Indicators
V. Motion of system of particles and rigid body 7. Systems of particles and rotational motion	Work done in rotational motion	LO5. Derives formulae and equations		C70.Derives formula for the work done in terms of the net torque causing angular displacement in rigid body and defines instantaneous power in terms of net torque and angular velocity of the rotating rigid body
V. Motion of system of particles and rigid body 7. Systems of particles and rotational motion	Angular momentum in case of rotation about a fixed axis	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO40.Describes and differentiates angular momentum vector for a symmetric and asymmetric rigid bodies rotating about a fixed axis	C71.Identifies the two components of angular momentum for a particle rotating about a fixed axis: one component parallel and another component perpendicular to fixed axis for symmetric and asymmetric bodies
V. Motion of system of particles and rigid body 7. Systems of particles and rotational motion	Law of conservation of angular momentum	LO5. Derives formulae and equations		C72.States the law of conservation of angular momentum in terms of moment of inertia and angular velocity of the rigid body moving around a fixed axis
V. Motion of system of particles and rigid body 7. Systems of particles and rotational motion	Rolling motion	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO41.Defines and explains rolling motion of a rigid body	C73.Defines rolling motion and derives the condition of rolling without slipping
VI. Gravitation 8. Gravitation	Kepler's Laws	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO42.States and explains Kepler's laws of planetary motion	C74.Explains Kepler's law of orbits and defines foci, semi major and semi minor axes for the elliptical planetary orbits around the Sun

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VI. Gravitation 8. Gravitation	Kepler's Laws	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis		C75.Explains Kepler's law of areas and recognises that this law was based on the observation that speed of the planet lowers as it moves away from the Sun during its revolution around the Sun
VI. Gravitation 8. Gravitation	Kepler's Laws	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis		C76.States Kepler's law of periods and proves that Kepler's law of periods is a consequence of law of conservation of angular momentum
VI. Gravitation 8. Gravitation	Universal law of gravitation	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO43.States and explains Newton's Universal law of gravitation	C77.States Newtons law of gravitation, writes its vectoral notation and solves problems based on law of gravitation and the calculation of resultant gravitational force due to system of mass particles
VI. Gravitation 8. Gravitation	Universal law of gravitation	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis		C78.Recognises that gravitational force due to a spherical shell on a mass particle nearby is just as if the entire mass of the shell is concentrated at its centre and that gravitational force due to a spherical shell at any point inside it is zero
VI. Gravitation 8. Gravitation	Acceleration due to gravity	LO5. Derives formulae and equations	CLO44.Describes and explains acceleration due to gravity and the factors on which it depends upon	C79.Defines acceleration due to gravity and derives its formula using Newtons law of gravitation

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VI. Gravitation 8. Gravitation	Acceleration due to gravity	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis		C80.Derives formulae expressing acceleration due to gravity as a function of height from the surface of planet and the depth inside Earth
VI. Gravitation 8. Gravitation	Gravitational potential energy	LO5. Derives formulae and equations	CLO45.Explains gravitational potential energy in relation to the conservative force of gravitation	C81.Derives the formula for gravitational potential energy as a work done in moving a mass particle from one position to another against gravitational force and recognises that its value rises to maximum value of zero at infinity location from Earth surface and is negative at all points closer to Earth
VI. Gravitation 8. Gravitation	Gravitational potential energy	LO11. Applies concepts of physics in daily life with reasoning while decision-making and solving problems		C82.Solves problems based on the calculation of gravitational potential energy due to a system of mass particles
VI. Gravitation 8. Gravitation	Escape speed	LO5. Derives formulae and equations	CLO46.Explains escape speed and derives it from the principle of conservation of energy	C83.Defines escape speed of a body and derives its formula for escape speed as a function of acceleration due to gravity and radius of the planet
VI. Gravitation 8. Gravitation	Earth's satellites	LO5. Derives formulae and equations	CLO47.Describes the dynamics of the motion of Earth satellites by applying Kepler's laws	C84.Defines orbital speed of a satellite and derives formulae for orbital speed, its time period and its total energy by using Kepler's laws
VII. Properties of bulk matter 9. Mechanical properties of solids	Elastic and plastic bodies	LO2. Differentiates between certain physical quantities	CLO48.Differentiates between rigid, elastic and plastic bodies	C85.Defines and differentiates between rigid, elastic and plastic bodies

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VII. Properties of bulk matter 9. Mechanical properties of solids	Elastic behaviour of solids	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO49.Explains elastic behaviour in solids	C86.Defines deforming and restoring forces that occur in an elastic body and describes the effect of restoring forces on rigid bodies that enable the body to regain original shape and size
VII. Properties of bulk matter 9. Mechanical properties of solids	Stress and strain	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO50.Describes and explains different types of stresses and corresponding strains produced in a body	C87.Defines and states formulae and units for each of three types of stresses and strains produced in a body under the effect of deforming force
VII. Properties of bulk matter 9. Mechanical properties of solids	Elastic behaviour of solids	LO6. Analyses and interprets data, graphs, and figures, and draws conclusion		C88.States Hooke's law and identifies the condition under which it is applicable and explains the stress vs strain graph in terms of elastic behaviour of the solid under the effect of deforming force
VII. Properties of bulk matter 9. Mechanical properties of solids	Elastic moduli	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO51.Describes elastic moduli of various bodies with different materials, elastic behaviours and shapes	C89.Defines Young's modulus of elasticity, Shear modulus of elasticity and Bulk modulus of elasticity and states units and dimensions of each of the elasticity moduli
VII. Properties of bulk matter 9. Mechanical properties of solids	Elastic potential energy	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO52.Explains and derives elastic potential energy stored in a stretched wire	C90.Defines elastic potential energy in terms of work done against the deforming force in increasing the length of a wire through unit value and derives formula for elastic potential energy stored in a stretched wire

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VII. Properties of bulk matter 9. Mechanical properties of solids	Applications of elastic behaviour of materials	LO15. Develops positive scientific attitude, and appreciates the role and impact of Physics and technology towards the improvement of quality of life and human welfare	CLO53.Appreciates the applications of Elastic behaviour of materials	C91.Takes initiative to understand the reason for the use I-shaped pillars in the construction of bridges; suitable specifications of rope used in the cranes to life heavy loads; designs of the cross sectional shapes of the load bearing beams and columns used in the constructions of bridges and buildings and why the pillars and columns with distributed shapes are better in load distribution than round shaped pillars using the principle of elasticity
VII. Properties of bulk matter 10. Mechanical properties of fluids	Pressure	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO54.Defines fluids and explains pressure experienced in fluids	C92.Defines average pressure exerted by fluid on a surface and states its units and dimensions
VII. Properties of bulk matter 10. Mechanical properties of fluids	Pascal's Law	LO5. Derives formulae and equations		C93.States Pascals law and proves it qualitatively
VII. Properties of bulk matter 10. Mechanical properties of fluids	Fluid pressure	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO55.Explains the effect of gravity on fluid pressure	C94.Identifies that pressure of a liquid column depends upon height of column, density of fluid and acceleration due to gravity
VII. Properties of bulk matter 10. Mechanical properties of fluids	Atmospheric pressure	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis		C95.Defines gauge pressure at a point inside the liquid and atmospheric pressure and describes the working of a barometer and manometers

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VII. Properties of bulk matter 10. Mechanical properties of fluids	Hydraulic machines	LO11. Applies concepts of physics in daily life with reasoning while decision-making and solving problems	CLO56.Describes and explains hydraulic machines based on Pascal's law	C96.Explains the working of hydraulic lift and brakes by applying Pascal's law
VII. Properties of bulk matter 10. Mechanical properties of fluids	Streamlines	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO57.Explains the properties, laws and mathematical equations followed during fluid flow	C97.Describes the characteristics of streamlines during a fluid flow and states equation of continuity for incompressible fluids in flow
VII. Properties of bulk matter 10. Mechanical properties of fluids	Bernoulli's Theorem	LO5. Derives formulae and equations		C98.States Bernoulli's theorem and derives Bernoulli's theorem using work energy theorem for the flow of incompressible and steady flow of fluids
VII. Properties of bulk matter 10. Mechanical properties of fluids	Torricelli's law	LO11. Applies concepts of physics in daily life with reasoning while decision-making and solving problems		C99.States Torricelli's law to define the speed of efflux of fluid from an open tank and derives Torricelli's Law using Bernoulli's theorem and describes the applications like venturimeter
VII. Properties of bulk matter 10. Mechanical properties of fluids	Applications of Bernoulli's Theorem	LO11. Applies concepts of physics in daily life with reasoning while decision-making and solving problems		C100.Solves problems based on Bernoulli's theorem and its applications
VII. Properties of bulk matter 10. Mechanical properties of fluids	Viscosity	LO3. Uses International system of units (SI Units), symbols, nomenclature of physical quantities and formulations, conventions	CLO58.Explains the viscosity of fluids in terms of fluid friction	C101.Defines coefficient of viscosity as the ratio of shear stress and strain rate and states the units, formula and dimensions of coefficient of viscosity

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VII. Properties of bulk matter 10. Mechanical properties of fluids	Stoke's law	LO5. Derives formulae and equations		C102.States the viscous force experienced by a body moving through a fluid in the form of Stoke's law and derives a formula for terminal velocity of a raindrop falling through air using Stokes law and force of gravity
VII. Properties of bulk matter 10. Mechanical properties of fluids	Surface tension	LO5. Derives formulae and equations	CLO59.Explains surface tension as surface property of liquids only	C103.Defines surface tension as the property of liquid in terms of surface energy per unit area and surface force per unit length and derives its formula basis qualitative principles of Energy conservation
VII. Properties of bulk matter 10. Mechanical properties of fluids	Angle of contact	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis		C104.Defines angle of contact between a liquid and a solid surface and recognises the dependency of angle of contact on the surface tension for a given pair of liquid and solid surfaces in contact
VII. Properties of bulk matter 10. Mechanical properties of fluids	Surface energy	LO5. Derives formulae and equations		C105.Proves mathematically using the principles of surface tension and surface energy that pressure inside a liquid drop and a bubble is always more than pressure outside them
VII. Properties of bulk matter 10. Mechanical properties of fluids	Capillarity	LO5. Derives formulae and equations		C106.Defines capillarity and derives an expression for the height of rise of a liquid through a capillary tube due to surface tension

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VII. Properties of bulk matter 11. Thermal properties of matter	Temperature and heat	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO60.Explains and differentiates between heat and temperature of a body	C107.Defines heat and temperature and states the various units for the measurements of temperature
VII. Properties of bulk matter 11. Thermal properties of matter	Ideal gas equation	LO5. Derives formulae and equations		C108.States Boyle's law and Charles' law for ideal gases and combines them to derive ideal gas equation for ideal gases
VII. Properties of bulk matter 11. Thermal properties of matter	Thermal expansion	LO3. Uses International system of units (SI Units), symbols, nomenclature of physical quantities and formulations, conventions	CLO61.Explains thermal expansion in substances and identifies linear, superficial and cubical expansions	C109.Defines linear expansion, superficial expansion and cubical expansion as change in corresponding configurations of the body due to heat exchanges
VII. Properties of bulk matter 11. Thermal properties of matter	Thermal expansion	LO5. Derives formulae and equations		C110.Defines and derives a mathematical relation between coefficients of linear, superficial and volume expansion and solves problems based on coefficient of expansivity and thermal stress
VII. Properties of bulk matter 11. Thermal properties of matter	Specific heat capacity	LO3. Uses International system of units (SI Units), symbols, nomenclature of physical quantities and formulations, conventions	CLO62.Defines heat capacity and specific heat capacity of a substance and states its importance in amount of heat exchanged by a body to change its temperature	C111.Defines specific heat capacity, heat capacity and molar specific heat capacity of a substance and states their units, dimensions and formulae
VII. Properties of bulk matter 11. Thermal properties of matter	Calorimetry	LO11. Applies concepts of physics in daily life with reasoning while decision-making and solving problems		C112.States the principle of calorimetry and solves problems based on heat exchanges and principle of calorimetry

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VII. Properties of bulk matter 11. Thermal properties of matter	Change of state	LO6. Analyses and interprets data, graphs, and figures, and draws conclusion	CLO63.Explains the process of change of state and describes the heat exchanges during the process	C113.Describes the process of change of state from ice to water to steam as heat is absorbed, using graph between temperature versus time and defines melting, vaporisation, freezing and condensation
VII. Properties of bulk matter 11. Thermal properties of matter	Latent heat	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis		C114.Defines latent heat of fusion and vaporisation, states the units, dimensions and formula of latent heat and solves problems based on them
VII. Properties of bulk matter 11. Thermal properties of matter	Heat transfer	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO64.Explains the mechanisms of heat transfers from one body to another through conduction, convection and radiation	C115.Describes the three modes of heat transfer as conduction, convection and radiation
VII. Properties of bulk matter 11. Thermal properties of matter	Black body radiation	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis		C116.Explains that black bodies are good absorbers and good radiators of heat and describes blackbody radiation as a function of wavelength of radiation emitted at different temperatures of the blackbody using a graphical plot
VII. Properties of bulk matter 11. Thermal properties of matter	Heat radiation	LO6. Analyses and interprets data, graphs, and figures, and draws conclusion		C117.States and explains the importance of Wien's displacement law, the Stefan Boltzmann’s law and recognises the relation between rate of heat energy emitted to temperature of the body and Newtons law of cooling

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VIII. Thermodynamics 12. Thermodynamics	Concept of heat and Thermal equilibrium	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO65.Describes the history of concept of heat	C118.Defines thermodynamics as a branch of physics that deals with concept of heat and conversion of heat into other forms of energy involving macroscopic variables of system
VIII. Thermodynamics 12. Thermodynamics	Zeroth law of thermodynamics	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO66.States and explains Zeroth law of thermodynamics	C119.States and explains Zeroth law of thermodynamics and illustrates thermal equilibrium attained by two systems separated by adiabatic wall or a diathermic wall
VIII. Thermodynamics 12. Thermodynamics	Heat, Internal energy and work	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO67.Describes and explains the three important thermodynamic variables as heat, internal energy and work done	C120.Defines internal energy as macroscopic thermodynamic variable in terms of molecular kinetic and potential energy of the system
VIII. Thermodynamics 12. Thermodynamics	Heat, Internal energy and work	LO1. Recognises the concepts of Physics related to various natural phenomena		C121.Identifies pressure, volume, internal energy and temperature as state variables of a thermodynamic system whereas heat and work done are not state variables
VIII. Thermodynamics 12. Thermodynamics	First law of thermodynamics	LO6. Analyses and interprets data, graphs, and figures, and draws conclusion	CLO68.States and explains first law of thermodynamics	C122.States first law of thermodynamics and explains that while heat exchanges and work done on the system is path dependent, the difference between the amount of heat exchanged and work done is path independent

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VIII. Thermodynamics 12. Thermodynamics	Specific heat capacity	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO69.Describes and explains specific heat capacity and molar specific heat of matter	C123.Defines heat capacity, specific heat capacity and molar specific heat capacity of a solid, states their units and dimensions and derives the relation between molar specific heat capacity and 3R
VIII. Thermodynamics 12. Thermodynamics	Specific heat capacity	LO5. Derives formulae and equations		C124.Defines specific heat capacity at constant volume and specific heat capacity at constant pressure and derives the expression for the difference between specific heat capacity at constant pressure and specific heat capacity at constant volume as equal to universal gas constant R
VIII. Thermodynamics 12. Thermodynamics	Second law of thermodynamics	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO70.States and explains second law of thermodynamics	C124.States Kelvin Planck statement and Clausius statement of second law of thermodynamics
VIII. Thermodynamics 12. Thermodynamics	Reversible and irreversible processes	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO71.Explains working principle of an ideal carnot engine	C125.Defines reversible and irreversible thermodynamic processes
IX. Behaviour of perfect gases and kinetic theory of gases 13. Kinetic theory	Molecular nature of matter	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO72.Explains Dalton's atomic theory of matter, lists its postulates and describes the properties of different states of matter	C126.States the main features of Dalton's atomic theory of matter, explains Gay Lussac's Law and the atomic nature of solids, liquids and gases

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IX. Behaviour of perfect gases and kinetic theory of gases 13. Kinetic theory	Behaviour of gases	LO6. Analyses and interprets data, graphs, and figures, and draws conclusion	CLO73.Describes and explains behaviour of gases basis the gas laws	C127.States the ideal gas equation in terms of pressure, volume, absolute temperature and Boltzmann constant and plots the graphical representations of gas equations as a function of pressure for ideal gases and real gases
IX. Behaviour of perfect gases and kinetic theory of gases 13. Kinetic theory	Gas Laws	LO6. Analyses and interprets data, graphs, and figures, and draws conclusion		C128.States Boyle's law and Charles's law for ideal gases and plots P versus V and V versus T for real gases
IX. Behaviour of perfect gases and kinetic theory of gases 13. Kinetic theory	Gas Laws	LO5. Derives formulae and equations		C129.Derives Dalton's law of particle pressures for a mixture of non reacting gases from ideal gas equations and solves problems based on gas equations and gas laws
IX. Behaviour of perfect gases and kinetic theory of gases 13. Kinetic theory	Kinetic theory of gases	LO5. Derives formulae and equations	CLO74.States kinetic theory of gases and uses the theory to explain the pressure exerted by gas molecules and its temperature	C130.States the postulates of kinetic theory of gases and derives an expression for pressure exerted by gas enclosed in a container in terms of number density, mean squared velocity and mass of the gas molecules
IX. Behaviour of perfect gases and kinetic theory of gases 13. Kinetic theory	Kinetic theory of gases	LO5. Derives formulae and equations		C131.Derives the expression relating pressure, volume and internal energy of the gas; kinetic energy of the gas molecules and Dalton's law of particle pressures for a mixture of non reacting gases using kinetic theory

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IX. Behaviour of perfect gases and kinetic theory of gases 13. Kinetic theory	Law of equipartition of energy	LO5. Derives formulae and equations	CLO75.States and explains the law of equipartition of energies for gas molecules with varying degrees of freedom	C132.Expresses the average energy of monoatomic and diatomic gas molecules, using all the components of kinetic energies, one each for its degrees of freedom
IX. Behaviour of perfect gases and kinetic theory of gases 13. Kinetic theory	Law of equipartition of energy	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis		C133.States law of equipartition of energy for ideal gases and recognises that as per Law of equipartition of energy, each energy mode contributes equal amounts to the average energy of gas molecule
IX. Behaviour of perfect gases and kinetic theory of gases 13. Kinetic theory	Specific heat capacity	LO5. Derives formulae and equations	CLO76.Describes specific heat capacities of gases, solids and water and states their values in terms of universal gas constant	C134.Derives the value of molar specific heat capacity at constant volume and pressure and their ratio for monoatomic, diatomic and polyatomic gases
IX. Behaviour of perfect gases and kinetic theory of gases 13. Kinetic theory	Specific heat capacity	LO5. Derives formulae and equations		C135.Uses law of equipartition of energies to determine specific heat capacities of solids and derives the value of specific heat capacity of water by using law of equipartition of energy
IX. Behaviour of perfect gases and kinetic theory of gases 13. Kinetic theory	Mean free path	LO5. Derives formulae and equations	CLO77.Defines mean free path of gas molecules based on kinetic theory of gases	C136.Defines and derives formula for mean free path for free gas molecules using kinetic theory of gases

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X. Oscillations and waves 14. Oscillations	Periodic and oscillatory motions	LO1. Recognises the concepts of Physics related to various natural phenomena	CLO78.Describes periodic and oscillatory motion using common examples and states suitable equations of motion	C137.Defines periodic and oscillatory motion and defines their time periods and frequencies and their relationship
X. Oscillations and waves 14. Oscillations	Periodic and oscillatory motions	LO5. Derives formulae and equations		C138.Proves qualitatively that a sum of sine and cosine functions represent a periodic motion whereas an exponential and a log function represent a non-periodic motion
X. Oscillations and waves 14. Oscillations	Simple harmonic motion	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO79.States the equations governing the displacement, velocity and acceleration of a body in simple harmonic motion	C139.Defines phase constant, time period, amplitude and angular frequency for a body in simple harmonic motion and compares the graphical plots of motion of two bodies in simple harmonic motion with different amplitudes, phase difference and time periods
X. Oscillations and waves 14. Oscillations	Simple harmonic motion and Uniform circular motion	LO5. Derives formulae and equations		C140.Writes the equations of motion for the perpendicular projection on diameter of uniform circular motion and recognises their motions as simple harmonic motion
X. Oscillations and waves 14. Oscillations	Velocity and acceleration in SHM	LO5. Derives formulae and equations		C141.Derives the equations for displacement, velocity and acceleration of the body in SHM and plots their graphs with respect to time

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X. Oscillations and waves 14. Oscillations	Force law and Energy in SHM	LO5. Derives formulae and equations	CLO80.Explains the energy and the force law of the body in SHM	C142.Derives the expression for the restoring force acting on the body, kinetic energy, potential energy and total energy of the body in SHM and represents graphically the variation of kinetic and potential energy of simple harmonic oscillator as a function of time and position
X. Oscillations and waves 14. Oscillations	Illustrative examples of bodies in SHM	LO5. Derives formulae and equations		C143.Proves that the motion of a two springs attached on the either side of a block and fixed supports in horizontal plane execute SHM
X. Oscillations and waves 14. Oscillations	Illustrative examples of bodies in SHM	LO5. Derives formulae and equations	CLO81.Identifies few examples of bodies in SHM and derives their equations of motion and time periods	C144.Proves that loaded spring in horizontal plane and a simple pendulum oscillates in simple harmonic motion and derives expressions for their time periods
X. Oscillations and waves 15. Waves	Wave motion	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO82.Describes the concept of wave motion with examples	C145.Defines wave motion as a mode of energy transfer, defines mechanical, electromagnetic and matter waves and explains the propagation of disturbance through a mechanical medium in terms of changes in densities and pressures in small increments layer by layer
X. Oscillations and waves 15. Waves	Transverse and longitudinal waves	LO2. Differentiates between certain physical quantities	CLO83.Explains the characteristics of transverse and longitudinal wave motions with examples	C146.Defines transverse and longitudinal wave motion and explains the propagation of disturbances through a medium as a series of crests

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				and trough or compressions and rarefactions
X. Oscillations and waves 15. Waves	Displacement equation for progressive waves	LO6. Analyses and interprets data, graphs, and figures, and draws conclusion	CLO84.Writes and explains the displacement equations for progressive waves	C147.Defines progressive wave motion, writes its displacement equation using a sinusoidal function and plots a sinusoidal graph to depict the travelling progressive wave
X. Oscillations and waves 15. Waves	Displacement equation for progressive waves	LO5. Derives formulae and equations		C148.Identifies and defines amplitude, phase and the wave number using the progressive wave equation and derives the expressions of time period and angular frequency using the displacement equation of progressive wave
X. Oscillations and waves 15. Waves	Velocity of progressive waves	LO5. Derives formulae and equations	CLO85.Derives the expressions for velocity of travelling progressive waves	C149.Derives the expression for velocity of a progressive wave and the the formula for speed of wave
X. Oscillations and waves 15. Waves	Velocity of progressive waves	LO5. Derives formulae and equations		C150.Derives a formula for speed of sound through gases and solid medium in terms of elasticity modulus
X. Oscillations and waves 15. Waves	Velocity of progressive waves	LO5. Derives formulae and equations		C151.Derives the Newton formula for speed of sound in air and applies Laplace's correction
X. Oscillations and waves 15. Waves	Superposition of progressive waves	LO5. Derives formulae and equations	CLO86.States the principle of superposition of mechanical waves and derives the equations of resultant wave	C152.States the principle of superposition of waves and derives a mathematical equation describing the

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				resultant wave due to superposition of two harmonic progressive waves
X. Oscillations and waves 15. Waves	Reflection of waves	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO87.Describes the reflection of progressive waves from rigid and non rigid boundaries	C153.Explains why the amplitude of resultant wave at position of rigid boundary is zero and that due to reflection from a non rigid boundary, the superimposed wave has double the amplitude at the position of the boundary and writes the mathematical equations for the reflected waves at rigid and non rigid boundaries
X. Oscillations and waves 15. Waves	Standing waves	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO88.Defines and explains standing waves produced due to reflection of waves by two boundaries	C154.Defines standing or stationery waves that are formed due to reflection by two boundaries and derives mathematical equations to represent standing waves
X. Oscillations and waves 15. Waves	Standing waves	LO5. Derives formulae and equations		C155.Derives the formulae of normal modes for standing waves produced in stretched strings and for normal modes for standing waves produced in air column in a Closed pipe
X. Oscillations and waves 15. Waves	Formation of beats	LO5. Derives formulae and equations	CLO89.Demonstrates and explains the formation of beats due to superposition of sound waves of slightly different frequencies	C156.Defines beats and beat frequency and proves mathematically using superposition principle that beat frequency is the difference in frequencies of the constituent superimposing progressive waves

CLASS 12 CONTENT DOMAIN SPECIFIC LEARNING OUTCOMES AND INDICATORS

Unit and Chapter	Key Concept	NCERT Learning Outcomes	Content domain specific Learning Outcomes	Indicators
I. Electrostatics 1. Electric Fields	Electric charges	LO1. Recognises the concepts of Physics related to various natural phenomena	CLO1.explain origin, types and properties of electric charges	C1.Recognises two types of charges based on frictional electrostatic phenomena and infer the properties of charges
I. Electrostatics 1. Electric Fields	Electric charges	LO13. Recognises different processes used in Physics-related industrial and technological applications		C2.Explains earthing and its importance in the household circuits
I. Electrostatics 1. Electric Fields	Electric charges	LO2. Differentiates between certain physical quantities		C3.Differentiates between conductors and insulators based on the movement of charges
I. Electrostatics 1. Electric Fields	Electric charges	LO1. Recognises the concepts of Physics related to various natural phenomena		C4. Elaborates quantization, additivity and conservation of charge

Unit and Chapter	Key Concept	NCERT Learning Outcomes	Content domain specific Learning Outcomes	Indicators
I. Electrostatics 1. Electric Fields	Coulomb’s Law	LO1. Recognises the concepts of Physics related to various natural phenomena	CLO2.derive and apply Coulomb’s law to calculate forces due to one/multiple charges	C5.Derives and states Coulomb’s law in vector form
I. Electrostatics 1. Electric Fields	Coulomb's Law	LO10. Exhibits creativity and out-of–the-box thinking in solving challenging physics problems		C6.Applies Coulombs law of electrostatics and newton's law of gravitation to compare the forces acting between a proton and an electron
I. Electrostatics 1. Electric Fields	Coulomb's Law	LO10. Exhibits creativity and out-of–the-box thinking in solving challenging physics problems		C7. Appreciates superposition principle of electrostatics force and apply Coulomb's law to calculate forces due to multiple charges
I. Electrostatics 1. Electric Fields	Electric field	LO5. Derives formulae and equations	CL03.deduce electric field using electrostatic force and explain the properties of field lines	C8.Infers the inter-relation between electric field and electrostatic force and explain electric field as a special case of force using mathematical formula
I. Electrostatics 1. Electric Fields	Electric field	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis		C9.Draws and explains the significance of electric field lines in terms of intensity and direction of electric field

Unit and Chapter	Key Concept	NCERT Learning Outcomes	Content domain specific Learning Outcomes	Indicators
I. Electrostatics 1. Electric Fields	Electric field	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis		C10.Appreciates the properties of electric field lines in terms of its direction, etc
I. Electrostatics 1. Electric Fields	Electric dipole	LO5. Derives formulae and equations	CLO4. understand electric dipole and apply Coulombs law to calculate electric field and torque due to electric dipole	C11.Explains the formation of an electric dipole and derive a general vector formula for a dipole moment.
I. Electrostatics 1. Electric Fields	Electric dipole	LO5. Derives formulae and equations		C12.Derives electric field of a dipole in its equatorial plane and axial plane at a distance r from the dipole center
I. Electrostatics 1. Electric Fields	Electric dipole	LO5. Derives formulae and equations		C13.Derives the equation for torque experienced by a dipole in an uniform electric field
I. Electrostatics 1. Electric Fields	Electric flux	LO5. Derives formulae and equations	CLO5.explain and apply electric flux using a simple charge placed inside a surface	C14.Elaborates electric flux using a surface diagram and derive the relation between flux and electric field

Unit and Chapter	Key Concept	NCERT Learning Outcomes	Content domain specific Learning Outcomes	Indicators
I. Electrostatics 1. Electric Fields	Electric flux	LO5. Derives formulae and equations		C15.Explains Gauss law and derive a general equation for Gauss law
I. Electrostatics 1. Electric Fields	Gauss law	LO11. Applies concepts of physics in daily life with reasoning while decision-making and solving problems	CLO6. apply Gauss law to calculate electric filed when the source distribution has simple symmetry	C16.Applies gauss law to calculate electric field due to thin infinitely long straight wire, plane sheet and spherical shell of a particular density
I. Electrostatics 2. Electrostatic potential and capacitance	Electric potential energy	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CL07.Describes the concept of electric potential energy and electric potential	C17.Describes electric potential energy as a difference between two points and as negative of work done by electric field and identifies the path independence of the work done by electrostatic field
I. Electrostatics 2. Electrostatic potential and capacitance	Electric potential	LO5. Derives formulae and equations		C18.Describes the concept of electric potential as derived from electric potential energy for a unit positive charge and derives the expression for the electric potential at a point due to the electrostatic field of a point charge
I. Electrostatics 2. Electrostatic potential and capacitance	Electric potential	LO2. Differentiates between certain physical quantities		C19.Compares the variation of electric field and electric potential due to a point charge with the distance from the charge and solves problems related to electric potential and electric potential energy

Unit and Chapter	Key Concept	NCERT Learning Outcomes	Content domain specific Learning Outcomes	Indicators
I. Electrostatics 2. Electrostatic potential and capacitance	Electric potential due to a dipole	LO5. Derives formulae and equations	CLO8.Derives the expression for the electric potential due to an electric dipole, system of charges, charged spherical shell and a sphere	C20.Derives the expression for the electric potential due to an electric dipole along axial and equatorial line
I. Electrostatics 2. Electrostatic potential and capacitance	Electric potential due to continuous bodies	LO5. Derives formulae and equations		C21.Explains how to derive the electric potential due to a system of discrete point charges and a continuous charge distribution and derives the expression for the electric potential within, on the surface of and outside a uniformly charged thin spherical shell and solid sphere
I. Electrostatics 2. Electrostatic potential and capacitance	Equipotential surface	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO9.Describes the concept of equipotential surfaces	C22.Describes the concept of an equipotential surfaces and explains the relationship between electric field and rate of change of electric potential
I. Electrostatics 2. Electrostatic potential and capacitance	Electric potential energy	LO5. Derives formulae and equations	CLO10.Derives the expression for the electric potential energy of a system of point charges	C23.Derives the expression for the electric potential energy of a system of point charges and a dipole in an external electric field

Unit and Chapter	Key Concept	NCERT Learning Outcomes	Content domain specific Learning Outcomes	Indicators
I. Electrostatics 2. Electrostatic potential and capacitance	Electrostatics of solid conductors	LO5. Derives formulae and equations	CLO11.Explains electrostatic properties of solid conductors and a dielectric	C24.Explains and derives for an expressions of electrostatic field and electric potential inside a conductor, on its surface and outside the charged conductor and explains the principle behind electrostatic shielding
I. Electrostatics 2. Electrostatic potential and capacitance	Electrostatics of solid conductors	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis		C25.Explains how a net dipole moment is developed due to an external electric field in the materials made of polar molecules and non-polar molecules
I. Electrostatics 2. Electrostatic potential and capacitance	Capacitors and capacitance	LO5. Derives formulae and equations	CLO12.Defines a capacitor and derives expressions for capacitance for parallel plate capacitor and related terms for dielectrics	C26.Defines capacitance for a system of two conductors charged with equal and opposite charges and derives the expression for capacitance of a parallel plate capacitor with vacuum and a dielectric between the plates
I. Electrostatics 2. Electrostatic potential and capacitance	Parallel plate capacitor	LO5. Derives formulae and equations		C27.Derives the expression for equivalent capacitance for capacitors connected in series and in parallel
I. Electrostatics 2. Electrostatic potential and capacitance	Potential energy in a capacitor	LO5. Derives formulae and equations		C28.Derives the expression for energy stored in a capacitor and energy density for the electric field inside a parallel plate capacitor

Unit and Chapter	Key Concept	NCERT Learning Outcomes	Content domain specific Learning Outcomes	Indicators
II. Current electricity 3. Current electricity	Ohms Law	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO13.States and explains Ohms law in conductors	C29.States Ohms law and gives its formula in terms of current, resistance, voltage, current density and electric field
II. Current electricity 3. Current electricity	Ohms Law	LO5. Derives formulae and equations		C30.Derives formula for drift velocity, recognises conductivity and mobility of the charge carriers and identifies the limitations of Ohms law
II. Current electricity 3. Current electricity	Resistivity	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO14.Defines resistivities of various materials	C31.Defines resistivity of materials, states its formula and identifies its dependence on temperature of the material
II. Current electricity 3. Current electricity	Electrical energy and power	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO15.Describes the power loss in a conductor carrying current	C32.Defines energy dissipated and power consumed through a conductor of resistance R and carrying current I

Unit and Chapter	Key Concept	NCERT Learning Outcomes	Content domain specific Learning Outcomes	Indicators
II. Current electricity 3. Current electricity	Cells, emf and potential difference	LO5. Derives formulae and equations	CLO16.Defines and differentiates between emf and potential difference across a cell	C33.Defines electromotive force across a cell in open circuit and differentiates it from potential difference across a cell in closed circuit and derives the relation between them when a current I is drawn by an external resistor connected across a cell
II. Current electricity 3. Current electricity	Combination of cells	LO5. Derives formulae and equations	CLO17.Derives and describes the equivalent emf across a combination of cells connected in series and parallel	C34.Recognises the cells connected in series and in parallel combination and derives equivalent emf across multiple cells connected in series and in parallel
II. Current electricity 3. Current electricity	Combination of cells	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis		C35.Identifies the equivalent internal resistances across a combination of multiple cells connected in series and in parallel in an electric circuit
II. Current electricity 3. Current electricity	Kirchhoff's rules	LO11. Applies concepts of physics in daily life with reasoning while decision-making and solving problems	CLO18.States and explains Kirchhoff's rules across electric circuits	C36.States the two Kirchhoff's rules: Junction rule and Loop rule for electric circuits and applies the rules for solving electric circuit problems
II. Current electricity 3. Current electricity	Wheatstone's bridge	LO7. Handles tools and laboratory apparatus properly; measures physical quantities using appropriate apparatus, instruments, and devices	CLO19.Describes the principle and working of each of applications of Kirchhoff's rules, that is, Wheatstone bridge	C37.Describes the working principle of Wheatstone bridge and using Kirchhoff's rules derives the balanced condition of the bridge

Unit and Chapter	Key Concept	NCERT Learning Outcomes	Content domain specific Learning Outcomes	Indicators
III. Magnetic effects of current and magnetism 4. Moving charges and magnetism	Magnetic force of moving charges and current carrying conductor	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO20.Explains magnetic Lorentz force on a charge moving in magnetic field	C38.Defines magnetic Lorentz force on a charge moving with velocity v in magnetic field B and identifies its direction using Fleming's left hand rule and extrapolates the definition to identify the magnetic force on current-carrying element in magnetic field
III. Magnetic effects of current and magnetism 4. Moving charges and magnetism	Motion in combined electric and magnetic fields	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO21.Describes the path followed by charged particle projected in the region under combined effect of electric and magnetic fields	C39.Explains the nature of path followed by charged particle projected with a velocity v in magnetic field and recognises how the shape of the path followed by the moving charge depends upon its angle of projection into the magnetic field
III. Magnetic effects of current and magnetism 4. Moving charges and magnetism	Motion in combined electric and magnetic fields	LO11. Applies concepts of physics in daily life with reasoning while decision-making and solving problems		C40.Identifies the two applications of motion of charged particles under the combined effect of electric and magnetic fields as velocity selector and the cyclotron and describes their working principle and derives the related equations
III. Magnetic effects of current and magnetism 4. Moving charges and magnetism	Biot Savart Law	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO22.States Biot Savart's law and describes the magnetic field produced by current element and a current carrying loop	C41.Identifies the current-carrying element as a vector source of magnetic field and states Biot savart's law to describe the nature of magnetic field produced by a current-carrying element

Unit and Chapter	Key Concept	NCERT Learning Outcomes	Content domain specific Learning Outcomes	Indicators
III. Magnetic effects of current and magnetism 4. Moving charges and magnetism	Biot Savart Law	LO11. Applies concepts of physics in daily life with reasoning while decision-making and solving problems		C42.Applies Biot savart's law to current-carrying loop to determine the magnetic field produced along its axis and at the center of the loop and identifies the factors on which it depends upon
III. Magnetic effects of current and magnetism 4. Moving charges and magnetism	Ampere's circuital law	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO23.States Ampere's circuital law and applies it to determine the magnetic field due to an infinitely long current-carrying conductor	C43.States Ampere's circuital law and recognises it as an alternative to Biot savart law to determine magnetic field due to current carrying sources
III. Magnetic effects of current and magnetism 4. Moving charges and magnetism	Ampere's circuital law	LO11. Applies concepts of physics in daily life with reasoning while decision-making and solving problems	CLO23.States Ampere's circuital law and applies it to determine the magnetic field due to an infinitely long current-carrying conductor	C44.Applies Ampere's circuital law to determine magnetic field due to infinitely long current carrying wire and lists the various features of this magnetic field
III. Magnetic effects of current and magnetism 4. Moving charges and magnetism	The solenoid and toroid	LO5. Derives formulae and equations	CLO24.Describes the current-carrying solenoid and toroid and derives magnetic fields produced due to them	C45.Defines a current-carrying solenoid and applies Ampere's circuital law to derive magnetic field along its axis, outside it and at its end

Unit and Chapter	Key Concept	NCERT Learning Outcomes	Content domain specific Learning Outcomes	Indicators
III. Magnetic effects of current and magnetism 4. Moving charges and magnetism	The solenoid and toroid	LO5. Derives formulae and equations		C46.Defines a current-carrying toroid and applies Ampere's circuital law to derive magnetic field along its axis and outside it
III. Magnetic effects of current and magnetism 4. Moving charges and magnetism	Force between two parallel current carrying conductors	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO25.Explains the forces exerted by a pair of parallel current-carrying wires on each other and defines one ampere of current	C47.Explains the reason why forces of interaction exist between a pair of parallel or antiparallel current-carrying wires placed nearby and identifies these forces as action-reaction pair
III. Magnetic effects of current and magnetism 4. Moving charges and magnetism	Force between two parallel current carrying conductors	LO5. Derives formulae and equations		C48.Derives the formula for forces between a pair of parallel current-carrying wires and recognises that parallel current-carrying wires attract whereas anti-parallel current-carrying wires repel each other and uses this formula to define the magnitude of one Ampere of current
III. Magnetic effects of current and magnetism 4. Moving charges and magnetism	Torque on current carrying loop	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO26.Describes the torque acting on a current-carrying loop placed in a magnetic field and identifies it as equivalent to a magnetic dipole placed in an external magnetic field	C49.Explains why a current-carrying loop placed in an external magnetic field experiences a net zero force but a non-zero net torque and derives the formula for the net torque and identifies its direction

Unit and Chapter	Key Concept	NCERT Learning Outcomes	Content domain specific Learning Outcomes	Indicators
III. Magnetic effects of current and magnetism 4. Moving charges and magnetism	Torque on current carrying loop	LO1. Recognises the concepts of Physics related to various natural phenomena		C50.Recognises a current-carrying loop as a magnetic dipole, compares its nature and behaviour with an electric dipole (a pair of equal and opposite charges) and defines magnetic dipole moment of the current-carrying loop as well as that due to a revolving charge
III. Magnetic effects of current and magnetism 4. Moving charges and magnetism	The moving coil galvanometer	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO27.Describes the construction and working principle of moving coil galvanometer and takes initiative to convert a MCG into a voltmeter and an ammeter and use it appropriately for the measurements of voltages and currents in an electric circuit	C51.Describes the construction and working principle of a moving coil galvanometer, derives the formulae for deflection produced due to flow of current I through it and states the current and voltage sensitivities of the MCG

Unit and Chapter	Key Concept	NCERT Learning Outcomes	Content domain specific Learning Outcomes	Indicators
III. Magnetic effects of current and magnetism 4. Moving charges and magnetism	The moving coil galvanometer	LO7.Handles tools and laboratory apparatus properly; measures physical quantities using appropriate apparatus, instruments, and devices		C52.Modifies a moving coil galvanometer into an ammeter and a voltmeter so as to use it for the measurement of currents and voltages in an electric circuit
III. Magnetic effects of current and magnetism 5. Magnetism and matter	Bar magnet and its magnetic field	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO28.Describes a bar magnet and identifies the features of magnetic field due to the bar magnet	C53.Identifies a bar magnet and describes the nature of magnetic field around it in terms of magnetic field lines and lists its various features
III. Magnetic effects of current and magnetism 5. Magnetism and matter	Bar magnet and its magnetic field	LO2. Differentiates between certain physical quantities		C54.Compares the nature of magnetic field lines patterns due to a bar magnet and a current carrying solenoid with electric field lines pattern due to an electric dipole and draws the points of similarities and differences between the patterns and the field sources

Unit and Chapter	Key Concept	NCERT Learning Outcomes	Content domain specific Learning Outcomes	Indicators
III. Magnetic effects of current and magnetism 5. Magnetism and matter	Bar magnet and its magnetic field	LO5. Derives formulae and equations		C55.Derives the formula of magnetic field due to a bar magnet and identifies pole strength of each of the two poles of a bar magnet
III. Magnetic effects of current and magnetism 5. Magnetism and matter	Magnetic dipole and its interaction with external magnetic field	LO5. Derives formulae and equations	CLO29.Defines a magnetic dipole and describes its interaction with the external magnetic field when placed parallel, anti-parallel or any other angle	C56.Proves that a magnetic dipole executes a simple harmonic motion when placed parallel to external magnetic field and disturbed slightly and derives the formulae for its time period, angular frequency and potential energy
III. Magnetic effects of current and magnetism 5. Magnetism and matter	Magnetic dipole and its interaction with external magnetic field	LO2. Differentiates between certain physical quantities		C57.Compares magnetic dipole with an electric dipole as an electrostatic analogue and derives the formula for magnetic field due to magnetic dipole along its axial line and equatorial line
III. Magnetic effects of current and magnetism 5. Magnetism and matter	Magnetism and Gauss's law	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO30.States and explains Gauss's law of magnetism	C58.States Gauss's law for magnetism along with its formula for magnetic flux through a closed surface and compares with Gauss's law of electrostatics

Unit and Chapter	Key Concept	NCERT Learning Outcomes	Content domain specific Learning Outcomes	Indicators
III. Magnetic effects of current and magnetism 5. Magnetism and matter	Magnetisation, magnetic intensities and magnetic properties of materials	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO31.Defines magnetisation, magnetic intensity and magnetic susceptibility and differentiates different types of magnetic materials basis these properties	C59.Defines magnetisation, magnetic intensity and magnetisation susceptibility due to magnetic materials and states each of the formulae, dimensions and their units
III. Magnetic effects of current and magnetism 5. Magnetism and matter	Magnetisation, magnetic intensities and magnetic properties of materials	LO2. Differentiates between certain physical quantities	CLO31.Defines magnetisation, magnetic intensity and magnetic susceptibility and differentiates different types of magnetic materials basis these properties	C60.Defines and differentiates the three types of magnetic materials: paramagnetic, ferromagnetic and diamagnetic basis their behaviour when placed in external magnetic field and their values of each of magnetisations, magnetic intensities and magnetic susceptibility
IV. Electromagnetic induction and alternating currents 6. Electromagnetic induction	Faraday's laws of induction	LO12. Takes initiative to learn about the newer research, discoveries and inventions in Physics	CLO32.Takes initiative to explore historical experiments of Faraday and Henry and states Faraday's two laws of induction	C61.Describes the historical experiments of Faraday and Henry, states Faraday's two laws of induction, defines magnetic flux in terms of magnetic field and area and states equation of induced emf in a coil in terms of rate of change in magnetic flux linked with it
IV. Electromagnetic induction and alternating currents 6. Electromagnetic induction	Faraday's laws of induction	LO6. Analyses and interprets data, graphs, and figures, and draws conclusion	CLO32.Takes initiative to explore historical experiments of Faraday and Henry and states Faraday's two laws of induction	C62.Recognises the importance of Lenz's law in identifying the direction of induced emf across a coil due to the change in magnetic flux linked with it and appreciates the Lenz's law as a subsequence of the law of conservation of energy

Unit and Chapter	Key Concept	NCERT Learning Outcomes	Content domain specific Learning Outcomes	Indicators
IV. Electromagnetic induction and alternating currents 6. Electromagnetic induction	Motional emf	LO5. Derives formulae and equations	CLO33.Explains the concept of motional emf induced across a conductor moving through a magnetic field with a velocity and undergoes change in the magnetic flux linked with it as a function of time	C63.Derives an equation for motional emf induced across a conductor moving with a velocity v by applying the definition of magnetic flux and Faraday's law of induction
IV. Electromagnetic induction and alternating currents 6. Electromagnetic induction	Motional emf	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis		C64.Explains that the induction of motional emf through a moving conductor in the magnetic field is consistent with the law of conservation of energy and derives the formulae for induced current in the conductor, force acting on the conductor due to magnetic field and power dissipated in order to produce the motional emf
IV. Electromagnetic induction and alternating currents 6. Electromagnetic induction	Motional emf	LO11. Applies concepts of physics in daily life with reasoning while decision-making and solving problems		C65.Apply the concept of motional emf and Faraday's laws to understand the formation of eddy currents in the metal plates moving through a magnetic field and identifies advantages, disadvantages of eddy currents and methods to reduce them

Unit and Chapter	Key Concept	NCERT Learning Outcomes	Content domain specific Learning Outcomes	Indicators
IV. Electromagnetic induction and alternating currents 6. Electromagnetic induction	Inductance	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO34.Explains inductance as property of the coil undergoing change in magnetic flux linked with it	C66.Defines inductance as property of coil that depends upon its geometry and material properties and states its formula, dimensions and units
IV. Electromagnetic induction and alternating currents 6. Electromagnetic induction	Inductance	LO5. Derives formulae and equations		C67.Defines mutual inductance of one solenoid with respect to another solenoid such that change in flux linked with one changes the flux in another and an emf is induced as per Faraday's laws of induction and derives the formula for mutual inductance and identifies the factors on which it depends upon
IV. Electromagnetic induction and alternating currents 6. Electromagnetic induction	Inductance	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis		C68.Identifies the induction of self induced emf due to change in flux linked with the coil itself and defines self inductance, its formula and dimensions and explains how the property of self inductance of a coil plays the role of inertia in electricity

Unit and Chapter	Key Concept	NCERT Learning Outcomes	Content domain specific Learning Outcomes	Indicators
IV. Electromagnetic induction and alternating currents 6. Electromagnetic induction	AC generator	LO7. Handles tools and laboratory apparatus properly; measures physical quantities using appropriate apparatus, instruments, and devices	CLO35.Describes the construction and working principle of AC generator	C69.Describes the construction and working principle of AC generator using the Faraday's laws of induction, derives the equations of induced motional emf and identifies the induced motional emf as a sinusoidal function of time and angle of rotation of the coil in the magnetic field
IV. Electromagnetic induction and alternating currents 7. Alternating current	AC Voltage applied to a resistor	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO36.Defines alternating current and voltage and describes the behaviour of current, voltage and power dissipated across a resistor when an alternating voltage is applied	C70.Defines alternating voltage and current and expresses them in terms of time varying sinusoidal functions of time and angular frequency
IV. Electromagnetic induction and alternating currents 7. Alternating current	AC Voltage applied to a resistor	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis		C71.Explains the variation of current through a circuit with resistor upon applying the alternating voltage and writes the equations of applied AC voltage, time varying current produced, and instantaneous power dissipated through the AC circuit
IV. Electromagnetic induction and alternating currents 7. Alternating current	AC Voltage applied to a resistor	LO6. Analyses and interprets data, graphs, and figures, and draws conclusion		C72.Defines rms voltage, rms current, peak values of alternating voltages and currents and represents the alternating current and voltage through an AC circuit with resistor using phasors

Unit and Chapter	Key Concept	NCERT Learning Outcomes	Content domain specific Learning Outcomes	Indicators
IV. Electromagnetic induction and alternating currents 7. Alternating current	AC voltage applied to an inductor	LO11. Applies concepts of physics in daily life with reasoning while decision-making and solving problems	CLO37.Describes the behaviour of current, voltage and power dissipated through an AC circuit containing inductor only	C73.Applies Kirchhoff's loop rule to obtain equations of varying current and voltage in an AC circuit containing an inductor and writes the equations using sinusoidal functions and identifies the maximum values of current and voltage
IV. Electromagnetic induction and alternating currents 7. Alternating current	AC voltage applied to an inductor	LO5. Derives formulae and equations		C74.Defines inductive reactance of an inductor, derives formula for instantaneous power dissipated through an inductor and draws the phasor diagrams using voltage and current phasors for an AC circuit containing inductor
IV. Electromagnetic induction and alternating currents 7. Alternating current	AC voltage applied to a capacitor	LO11. Applies concepts of physics in daily life with reasoning while decision-making and solving problems	CLO38.Describes the behaviour of current, voltage and power dissipated through an AC circuit containing capacitor only	C75.Applies Kirchhoff's loop rule to obtain equations of varying current and voltage in an AC circuit containing a capacitor and writes the equations using sinusoidal functions and identifies the maximum values of current and voltage

Unit and Chapter	Key Concept	NCERT Learning Outcomes	Content domain specific Learning Outcomes	Indicators
IV. Electromagnetic induction and alternating currents 7. Alternating current	AC voltage applied to a capacitor	LO5. Derives formulae and equations		C76.Defines capacitive reactance of a capacitor, derives formula for instantaneous power dissipated through a capacitor, draws the phasor diagrams using voltage and current phasors for an AC circuit containing capacitor and describes the charging and discharging of the capacitor during one AC cycle of current flowing through the circuit
IV. Electromagnetic induction and alternating currents 7. Alternating current	AC voltage applied across LCR series circuit	LO11. Applies concepts of physics in daily life with reasoning while decision-making and solving problems	CLO39.Describes the AC circuit containing inductor, capacitor and resistor in series and explains the variation of current, voltage and power dissipation in the series LCR circuit	C78.Applies Kirchhoff's loop rule to obtain equations of varying current and voltage in an AC circuit containing an inductor, a capacitor and a resistor connected in series and derives the equations for instantaneous current and its phase relationship to the applied voltage using phasor diagrams and analytical methods
IV. Electromagnetic induction and alternating currents 7. Alternating current	AC voltage applied across LCR series circuit	LO6. Analyses and interprets data, graphs, and figures, and draws conclusion		C79.Defines impedance and phase angle in a series LCR circuit and represents the phasor diagram for LCR series circuit using time varying current and voltage phasors

Unit and Chapter	Key Concept	NCERT Learning Outcomes	Content domain specific Learning Outcomes	Indicators
IV. Electromagnetic induction and alternating currents 7. Alternating current	AC voltage applied across LCR series circuit	LO6. Analyses and interprets data, graphs, and figures, and draws conclusion		C80.Defines natural frequency, resonant frequency, the condition for attaining resonance of a series LCR circuit and describes the resonance graph (current versus angular frequency of the applied voltage), identifies the factor defining the sharpness of the resonance curve, its bandwidth and the quality factor of the series LCR circuit in resonance
IV. Electromagnetic induction and alternating currents 7. Alternating current	The power factor	LO5. Derives formulae and equations	CLO40.Defines instantaneous power dissipated in a series LCR circuit and identifies the power factor	C81.Defines and derives an expression for the instantaneous and the average power dissipated through a series LCR circuit, identifies the power factor in the expression and recognises the nature of the AC circuit depending upon the values of the power factor
IV. Electromagnetic induction and alternating currents 7. Alternating current	Transformer s	LO12. Takes initiative to learn about the newer research, discoveries and inventions in Physics	CLO41.Describes the construction, working principle and derives the related equations of a transformer	C82.Describes the construction of a transformer, identifies its working principle based on the mutual induction, derives the equation for transformer ratio and classifies the transformers as two types: step up and step down transformers

Unit and Chapter	Key Concept	NCERT Learning Outcomes	Content domain specific Learning Outcomes	Indicators
V. Electromagnetic waves 8. Electromagnetic waves	Displacement and conduction current	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO42.Explains the concept of displacement current produced between two charged plates and compares it with conduction current	C83.Defines displacement current as current through a space due to the time varying electric fields and compares it with the conduction current which is due to the flow of actual charge carriers
V. Electromagnetic waves 8. Electromagnetic waves	Displacement and conduction current	LO5. Derives formulae and equations		C84.Derives the Ampere's Maxwell law and concludes upon a symmetrical form of electromagnetic induction wherein time varying magnetic field and electric field give rise to each other
V. Electromagnetic waves 8. Electromagnetic waves	Electromagnetic waves	LO12. Takes initiative to learn about the newer research, discoveries and inventions in Physics	CLO43.Takes initiative to understand the historical experiments conducted by Hertz, Maxwell and Bose to produce electromagnetic waves and describes the nature of the em waves	C85.Takes initiative to describe the various experiments performed by Hertz, Maxwell and Bose to generate electromagnetic waves in the lab and how these experiments lead Marconi to generate and transmit electromagnetic waves over large distances
V. Electromagnetic waves 8. Electromagnetic waves	Electromagnetic waves	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO44.Describes the nature of electromagnetic waves in terms of time varying electric and magnetic fields	C86.Identifies and describes the nature of progressive electromagnetic waves as a stream of continuously changing electric and magnetic fields

Unit and Chapter	Key Concept	NCERT Learning Outcomes	Content domain specific Learning Outcomes	Indicators
V. Electromagnetic waves 8. Electromagnetic waves	Electromagnetic waves	LO5. Derives formulae and equations		C87.Derives the formulae relating the peak values of electric and magnetic field values for a given em wave and derives the relation between the speed of the em waves and the electric and magnetic properties of the medium
V. Electromagnetic waves 8. Electromagnetic waves	Electromagnetic spectrum	LO6. Analyses and interprets data, graphs, and figures, and draws conclusion	CLO45.Describes the electromagnetic spectrum, the different em waves, the order of their distribution in the em spectrum, the frequency ranges and states the applications of each of the type of em wave	C88.Describes the features of an electromagnetic spectrum, the various types of electromagnetic waves, their frequency ranges, their placement in the spectrum and applications of each of the electromagnetic waves
VI. Optics 9. Ray optics and optical instruments	Reflection of light by spherical mirrors	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO46.Recalls all the technical terms defined for spherical mirrors and identifies the correct sign conventions for mirrors and lenses	C89.Recalls and defines the terms pole, centre of curvature, principal axis, focus and radius of curvature for spherical mirrors and derives the relationship between focal length and radius of curvature
VI. Optics 9. Ray optics and optical instruments	Reflection of light by spherical mirrors	LO3. Uses International system of units (SI Units), symbols, nomenclature of physical quantities and formulations, conventions		C90.Uses the Cartesian sign convention for spherical mirrors and lenses based on the direction of incident light

Unit and Chapter	Key Concept	NCERT Learning Outcomes	Content domain specific Learning Outcomes	Indicators
VI. Optics 9. Ray optics and optical instruments	Reflection of light by spherical mirrors	LO5. Derives formulae and equations	CLO47.Draws ray diagram to determine the position of the image of an object and derives all the equations related to spherical mirrors	C91.Draws the ray diagrams to determine the position of the image of an object and derives the mirror equation and the magnification formula for spherical mirrors
VI. Optics 9. Ray optics and optical instruments	Laws of refraction of light	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO48.Knows Snell's laws of refraction and obtains the relationship among relative refractive indices of different materials	C92.Knows Snell's laws of refraction and obtains the relationship between refractive indices of two materials with respect to each other
VI. Optics 9. Ray optics and optical instruments	Refractive index	LO5. Derives formulae and equations	CLO49.Explains various phenomena related to refraction and the phenomenon of total internal reflection	C93.Derives the formula for apparent depth of a surface due to refraction when viewed normally from above and explains natural phenomena like difference in actual and real sunset/sunrise, oval shape of the sun during sunrise/sunset, etc. due to atmospheric refraction
VI. Optics 9. Ray optics and optical instruments	Total internal reflection	LO1. Recognises the concepts of Physics related to various natural phenomena		C94.Explains the phenomenon of total internal reflection, derives the expression for critical angle for total internal reflection for any two optical media

Unit and Chapter	Key Concept	NCERT Learning Outcomes	Content domain specific Learning Outcomes	Indicators
VI. Optics 9. Ray optics and optical instruments	Refraction at spherical surfaces	LO5. Derives formulae and equations	CLO50.Derives the relationship between object and image distances and derives lens maker's and thin lens formula	C95.Derives the relationship between object and image distances for the image formed of a point object due to refraction between two optical media
VI. Optics 9. Ray optics and optical instruments	Refraction at spherical surfaces	LO5. Derives formulae and equations		C96.Derives lensmaker's formula for thin lenses and thin lens formula (relationship among focal length, object distance and image distance)
VI. Optics 9. Ray optics and optical instruments	Refraction by thin lenses	LO5. Derives formulae and equations		C97.Defines power of a lens and derives the expression for the power of a thin lens
VI. Optics 9. Ray optics and optical instruments	Refraction by thin lenses	LO5. Derives formulae and equations		C98.Derives the expression for the focal length and magnification produced by a combination of thin lenses
VI. Optics 9. Ray optics and optical instruments	Refraction through a prism	LO5. Derives formulae and equations	CLO51.Derives various relationships for a light ray passing through a prism	C99.Derives the expression for the refractive index of a prism in terms of minimum angle of deviation and factors on which it depends upon

Unit and Chapter	Key Concept	NCERT Learning Outcomes	Content domain specific Learning Outcomes	Indicators
VI. Optics 9. Ray optics and optical instruments	Dispersion of light	LO1. Recognises the concepts of Physics related to various natural phenomena	CLO52.Explains the formation of rainbows and colours due to scattering of light	C100.Explains the formation of primary and secondary rainbows in terms of total internal reflection and dispersion of light and explains natural phenomena related to scattering of light, e.g. blue or reddish colours of the sky or white colour of clouds
VI. Optics 9. Ray optics and optical instruments	Microscope	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO53.Explains the magnification by a microscope	C101.Explains the magnification by a single lens microscope using appropriate ray diagrams and derives the expression of magnification for a single lens microscope when image is at (a) near point and (b) infinity
VI. Optics 9. Ray optics and optical instruments	Microscope	LO5. Derives formulae and equations		C102.Derives the expression of magnification for a compound microscope and explains the magnification by a compound microscope using appropriate ray diagrams
VI. Optics 9. Ray optics and optical instruments	Telescope	LO5. Derives formulae and equations	CLO54.Derives the expression for the magnification by a telescope	C103.Derives the expression for the magnification by a refracting telescope with two convex lenses and explains the magnification using appropriate ray diagrams

Unit and Chapter	Key Concept	NCERT Learning Outcomes	Content domain specific Learning Outcomes	Indicators
VI. Optics 10. Waves optics	Wave theory of light	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO55.Compares wave theory with corpuscular theory and explains geometrical optics in terms of wave optics	C104.Compares the corpuscular theory and wave theory of light with the differences in their predictions about speed of light and explains geometrical optics as approximation of wave optics when wavelength can be considered to be negligibly small
VI. Optics 10. Waves optics	Huygens principle	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO56.States Huygens principle, explains Snell's law of refraction, law of reflection and total internal reflection using the principle	C105.States Huygens principle and uses the principle to determine new wave front for a given wave front
VI. Optics 10. Waves optics	Huygens principle	LO5. Derives formulae and equations		C106.Derives Snell's law of refraction and laws of reflection and explains total internal reflection using Huygens principle
VI. Optics 10. Waves optics	Superposition of light waves	LO5. Derives formulae and equations	CLO57.States the superposition principle of waves and derives the expressions for intensity of light for interference from coherent and incoherent light sources	C107.States the superposition principle of waves and derives the condition for constructive and destructive interference at a point away from two coherent sources of light

Unit and Chapter	Key Concept	NCERT Learning Outcomes	Content domain specific Learning Outcomes	Indicators
VI. Optics 10. Waves optics	Superposition of light waves	LO5. Derives formulae and equations		C108.Derives the expression for the intensity of light at a point of due to interference from two coherent or two incoherent sources of light
VI. Optics 10. Waves optics	Young's double slit interference experiment	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO58.Explains the Young's double slit experiment and derives the expression for fringe width in Young's experiment	C109.Explains and derives the expression for points where constructive or destructive interference takes place in Young's experiment
VI. Optics 10. Waves optics	Young's double slit interference experiment	LO5. Derives formulae and equations		C110.Derives the expression for fringe width, explains the shapes of the fringes and draws the graph to represent intensity variation in the fringes in Young's experiment
VI. Optics 10. Waves optics	Diffraction of light	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO59.Explains what is diffraction of light waves and the pattern observed for diffraction from a single slit	C111.Explains the locations of maxima (intensity) and minima (intensity) in a single-slit diffraction pattern and distinguishes them from the intensity patterns observed for double slit interference

Unit and Chapter	Key Concept	NCERT Learning Outcomes	Content domain specific Learning Outcomes	Indicators
VII. Dual nature of radiation and matter 11. Dual nature of radiation and matter	Electron emission	LO7. Handles tools and laboratory apparatus properly; measures physical quantities using appropriate apparatus, instruments, and devices	CLO60.Describes the three significant historical experiments that lead to the discovery of electrons and recognises that valence electrons can be emitted from the metal surfaces under certain conditions	C112.Takes initiative to understand the experiments performed by William crookes that lead to observation of cathode rays, experiment to determine specific charge of electron by JJ Thomson and Millikan's oil drop experiment to determine the charge on electron
VII. Dual nature of radiation and matter 11. Dual nature of radiation and matter	Electron emission	LO9. Communicates the findings and conclusions		C113.Identifies three physical processes that can result in emission of electrons from a metal surface : thermionic emission, field emission and photoelectric emission
VII. Dual nature of radiation and matter 11. Dual nature of radiation and matter	Photoelectri c effect	LO7. Handles tools and laboratory apparatus properly; measures physical quantities using appropriate apparatus, instruments, and devices	CLO61.Describes how photoelectric effect was first observed historically and identify the factors that leads to photoelectric emission in metals	C114.Describes Hertz's experiment that lead to the first ever observation of emission of electrons by the metallic emitter plate under the effect of incident ultra violet rays and explains the process of how an electron is emitted due to incident radiations

Unit and Chapter	Key Concept	NCERT Learning Outcomes	Content domain specific Learning Outcomes	Indicators
VII. Dual nature of radiation and matter 11. Dual nature of radiation and matter	Photoelectric effect	LO9. Communicates the findings and conclusions		C115.Describes Hallwach's and Lenard's experiment to explain the dependency of photoelectric current on collector plate potential, frequency and intensity of the incident radiation
VII. Dual nature of radiation and matter 11. Dual nature of radiation and matter	Experimental study of Photoelectric effect	LO7. Handles tools and laboratory apparatus properly; measures physical quantities using appropriate apparatus, instruments, and devices	CLO62.Describes the experimental set up used for the study of photoelectric effect	C116.Describes the details of the experimental set up of photoelectric effect and its operation
VII. Dual nature of radiation and matter 11. Dual nature of radiation and matter	Experimental study of Photoelectric effect	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO63.Explains the variation of photoelectric current as a function of intensity of incident radiation & potential difference and describes the variation of stopping potential with frequency of the incident radiation	C117.States that photoelectric current varies linearly with the intensity of incident radiation and plots the graph between photoelectric current as a function of intensity of incident radiation

Unit and Chapter	Key Concept	NCERT Learning Outcomes	Content domain specific Learning Outcomes	Indicators
VII. Dual nature of radiation and matter 11. Dual nature of radiation and matter	Experimental study of Photoelectric effect	LO6. Analyses and interprets data, graphs, and figures, and draws conclusion		C118.Describes the variation of photoelectric current with the increase in the applied potential difference between the two electrode plates and plots the graph between the two
VII. Dual nature of radiation and matter 11. Dual nature of radiation and matter	Experimental study of Photoelectric effect	LO6. Analyses and interprets data, graphs, and figures, and draws conclusion		C119.Defines stopping potential and plots the graph between photoelectric current and the potential difference applied across the plates
VII. Dual nature of radiation and matter 11. Dual nature of radiation and matter	Experimental study of Photoelectric effect	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis		C120.Recalls the wave nature of light as electromagnetic waves with energy spread in continuum across the spread of the wave and explains how wave theory fails to explain the important experimental results of photoelectric effect

Unit and Chapter	Key Concept	NCERT Learning Outcomes	Content domain specific Learning Outcomes	Indicators
VII. Dual nature of radiation and matter 11. Dual nature of radiation and matter	Einstein's theory of Photoelectri c effect	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO64.Describes the basic features of Einstein's explanation for photoelectric effect	C121.States the Einstein's photoelectric equation and explains all the observations of photoelectric effect using Einstein's photoelectric equation
VII. Dual nature of radiation and matter 11. Dual nature of radiation and matter	Energy quantum of radiation	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO65.Describes the particle nature of light basis the evidence provided by photoelectric phenomenon	C122.Defines photon as discrete quanta of energy and recognises that each photon carries energy and possesses momentum
VII. Dual nature of radiation and matter 11. Dual nature of radiation and matter	de-Broglie hypothesis	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO66.Explains the outcomes of de-Broglie's equation and describes the incorporation of Heisenberg uncertainty principle into matter-wave picture of particle	C123.States de-Broglie hypothesis of wave nature of particles and states de-Broglie equation giving the formula for wavelength of wave associated with a mass particle
VII. Dual nature of radiation and matter 11. Dual nature of radiation and matter	de-Broglie hypothesis	LO5. Derives formulae and equations		C124.Defines matter waves and derives the mathematical expression for wavelength of the wave associated with a mass particle in terms of applied accelerating potential

Unit and Chapter	Key Concept	NCERT Learning Outcomes	Content domain specific Learning Outcomes	Indicators
VII. Dual nature of radiation and matter 11. Dual nature of radiation and matter	de-Broglie hypothesis	LO6. Analyses and interprets data, graphs, and figures, and draws conclusion		C125.States the Heisenberg uncertainty principle and interprets the principle using de-Broglie hypothesis and Born's probability interpretation of matter waves of mass particle
VIII. Atoms and nuclei 12. Atoms	Models of atom	LO12. Takes initiative to learn about the newer research, discoveries and inventions in Physics	CLO67.Takes initiative to understand historical experiments related to the atomic models	C126.Describes JJ Thomson's plum pudding model of an atom and states basic features of Rutherford model of an atom as proposed by Rutherford
VIII. Atoms and nuclei 12. Atoms	Models of atom	LO7. Handles tools and laboratory apparatus properly; measures physical quantities using appropriate apparatus, instruments, and devices		C127.Studies the alpha particle scattering experiment and plots the graph between the number of scattered alpha particles versus their scattering angles
VIII. Atoms and nuclei 12. Atoms	Electron orbits	LO12. Takes initiative to learn about the newer research, discoveries and inventions in Physics	CLO68.Explains the nature of electron orbits basis Rutherford model of atom	C128.Recognises the basic features of Rutherford scattering experiment that lead to Rutherford's model of atom and derives the expression for radii of electron orbits and total energy of electrons around the nucleus of an atom

Unit and Chapter	Key Concept	NCERT Learning Outcomes	Content domain specific Learning Outcomes	Indicators
VIII. Atoms and nuclei 12. Atoms	Atomic spectra	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO69.Explains the characteristics of atomic spectra of hydrogen atom	C129.Identifies the conditions under which an atom can get excited and emit radiations of specific wavelengths and defines emission and absorption spectrum of hydrogen atom containing single electron
VIII. Atoms and nuclei 12. Atoms	Spectral series of hydrogen atom	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO70.Takes initiative to study the details of simplest atomic spectra of hydrogen atom	C130.Defines spectral lines as sets of definite wavelengths of radiations emitted by an excited atom
VIII. Atoms and nuclei 12. Atoms	Spectral series of hydrogen atom	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis		C131.Defines Balmer series for hydrogen atom and identifies specific wavelengths of the spectral lines that constitute Balmer series and states their empirical formula
VIII. Atoms and nuclei 12. Atoms	Spectral series of hydrogen atom	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis		C132.Defines Lyman series, Lyman formula and recognises that Lyman series of spectrum lies in UV region

Unit and Chapter	Key Concept	NCERT Learning Outcomes	Content domain specific Learning Outcomes	Indicators
VIII. Atoms and nuclei 12. Atoms	Spectral series of hydrogen atom	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis		C133.Defines Pfund series, Pfund formula and recognises that Pfund series of spectrum lies in infra red region
VIII. Atoms and nuclei 12. Atoms	Spectral series of hydrogen atom	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis		C134.Defines Brackett series, Brackett formula and recognises that Brackett series of spectrum lies in infra red region
VIII. Atoms and nuclei 12. Atoms	Bohr model of atom	LO6. Analyses and interprets data, graphs, and figures, and draws conclusion	CLO71.States and explains why Rutherford nuclear model failed and how Bohr model was a better model of atom	C135.Recognises the reason for the failure of Rutherford model of atom that was based on classical theory of electromagnetism
VIII. Atoms and nuclei 12. Atoms	Bohr model of atom	LO5. Derives formulae and equations		C136.States the postulates of Bohr's model of atom and derives the formula for angular momentum of electron in an nth orbit, the radius of orbiting electron and total energy of an electron in stable energy states in an atom basis the Bohr's atomic model

Unit and Chapter	Key Concept	NCERT Learning Outcomes	Content domain specific Learning Outcomes	Indicators
VIII. Atoms and nuclei 12. Atoms	Energy levels	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO72.Identifies the energy levels of single electron in the hydrogen atom as per Bohr model	C137.Defines and derives the various possible energy states of hydrogen atoms as per Bohr model of atom and defines ionisation energy of hydrogen atom
VIII. Atoms and nuclei 12. Atoms	Line spectra of Hydrogen atom	LO5. Derives formulae and equations	CLO73.Explains line spectra of hydrogen atom basis Bohr's postulates	C138.Derives the Rydberg formula for the spectral lines of hydrogen atom and depicts the spectral series of hydrogen atom using an energy level diagram
VIII. Atoms and nuclei 12. Atoms	De-Broglie Explanation of quantisation condition of Bohr model	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO74.Takes initiative to understand de-Broglie explanation of Bohr postulate of quantisation of angular momentum	C139.Explains the stability of electron in its discrete orbit due to the formation of resonant standing wave of definite frequency and applies the de Broglie equation to prove the validity of the quantisation of angular momentum as proposed by Bohr's second postulate
VIII. Atoms and nuclei 12. Atoms	De-Broglie Explanation of quantisation condition of Bohr model	LO6. Analyses and interprets data, graphs, and figures, and draws conclusion		C140.Recognises the failure of Bohr model to explain the atomic structure of multi electron atoms like that of helium and relative intensities of various frequencies in the spectrum

Unit and Chapter	Key Concept	NCERT Learning Outcomes	Content domain specific Learning Outcomes	Indicators
VIII. Atoms and nuclei 13. Nuclei	Atomic masses and Discovery of neutron	LO3. Uses International system of units (SI Units), symbols, nomenclature of physical quantities and formulations, conventions	CLO75.States the units for measurements of masses of sub atomic particles and takes initiative to study the historical experimental approaches undertaken to identify and discover neutron	C141.Defines the atomic mass unit, atomic number and states the weighted average of atomic masses of the isotopes of chlorine and hydrogen atoms
VIII. Atoms and nuclei 13. Nuclei	Atomic masses and Discovery of neutron	LO3. Uses International system of units (SI Units), symbols, nomenclature of physical quantities and formulations, conventions		C142.Takes initiative to understand the historical experiment conducted by Chadwick that lead to the discovery of neutrons and states the mass of neutron in terms of atomic mass units and the formula for the radius of the nucleus
VIII. Atoms and nuclei 13. Nuclei	Mass energy equivalence	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO76.Explains the nature and type of energy that binds the nucleons inside the nucleus	C143.Defines mass defect in terms of difference in masses between nucleons and nucleus and applies the Einstein's mass-energy equivalence equation to calculate the energy associated with a nucleus
VIII. Atoms and nuclei 13. Nuclei	Mass energy equivalence	LO6. Analyses and interprets data, graphs, and figures, and draws conclusion		C144.Defines binding energy of a nucleus and binding energy per nucleon and plots the graph between binding energy per nucleon as a function of mass numbers of various atomic nuclei

Unit and Chapter	Key Concept	NCERT Learning Outcomes	Content domain specific Learning Outcomes	Indicators
VIII. Atoms and nuclei 13. Nuclei	Nuclear forces	LO6. Analyses and interprets data, graphs, and figures, and draws conclusion	CLO77.Describes the important characteristics of nuclear forces	C145.States the important characteristics of nuclear forces and plots and analyses the graph between potential energy of a pair of nucleons versus their distance of separation
VIII. Atoms and nuclei 13. Nuclei	Nuclear fission	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO78.Describes nuclear fission as breaking up of large nucleus into smaller nuclei	C146.Defines nuclear fission reaction with examples of Uranium-235 nucleus triggered by slow moving neutron and derives the Q value of nuclear fission reaction of U235 as ~200 MeV per fissioning nucleus
VIII. Atoms and nuclei 13. Nuclei	Nuclear fission	LO7. Handles tools and laboratory apparatus properly; measures physical quantities using appropriate apparatus, instruments, and devices		C147.Describes the construction and principle of working of nuclear reactor
VIII. Atoms and nuclei 13. Nuclei	Nuclear fusion	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis		C148.Defines nuclear fusion reaction with examples of fusion reactions between protons, deuterium and tritium and defines thermonuclear fusion reactions

Unit and Chapter	Key Concept	NCERT Learning Outcomes	Content domain specific Learning Outcomes	Indicators
IX. Electronic devices 14. Semiconductor electronics: materials, devices and simple circuits	Vacuum tubes and semiconductor devices	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO79.Takes initiative to understand the history of development of semiconductor electronics	C149.States the working of vacuum tubes and states how solid state semiconductor devices allow the controlled flow of electrons
IX. Electronic devices 14. Semiconductor electronics: materials, devices and simple circuits	Conductors, semiconductors and insulators	LO2. Differentiates between certain physical quantities	CLO80.Classifies solids as conductors, semiconductors and insulators on the basis of resistivities and energy bands	C150.Classifies solids as conductors, semiconductors and insulators basis the relative values of resistivity and on the basis the energy bands and energy level diagrams
IX. Electronic devices 14. Semiconductor electronics: materials, devices and simple circuits	Conductors, semiconductors and insulators	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis		C151.Defines and differentiates between valence and conduction energy bands of the valence electrons of the solids and explains the band theory of solids using the concept of energy gap between valence band and conduction band
IX. Electronic devices 14. Semiconductor electronics: materials, devices and simple circuits	Intrinsic semiconductors	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO81.Explains the lattice structure and behaviour of intrinsic semiconductors	C152.Recognises purest form of semiconductor solids as intrinsic semiconductors, defines intrinsic carrier concentration and recognises the total electric current through intrinsic semiconductors as the sum of electron and hole current

Unit and Chapter	Key Concept	NCERT Learning Outcomes	Content domain specific Learning Outcomes	Indicators
IX. Electronic devices 14. Semiconductor electronics: materials, devices and simple circuits	Extrinsic semiconductors	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO82.Explains how intrinsic semiconductors can be converted into extrinsic semiconductors	C153.Explains how doping of an intrinsic semiconductor results in an extrinsic semiconductor and identifies two types of extrinsic semiconductors as n-type and p-type
IX. Electronic devices 14. Semiconductor electronics: materials, devices and simple circuits	Extrinsic semiconductors	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis		C154.Identifies and defines the new energy levels created due to doping in semiconductors as donor energy levels and acceptor energy levels and explains the energy band diagrams of n-type and p-type semiconductors using schematic diagrams
IX. Electronic devices 14. Semiconductor electronics: materials, devices and simple circuits	pn junction	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis	CLO83.Defines and describes pn junction as the basic building block of semiconductor devices	C155.Explains how a pn junction is produced, states how a depletion region is formed across the pn junction and explains how a potential barrier is produced across the pn junction due to diffusion of majority carriers and drifting of minority carriers across the junction
IX. Electronic devices 14. Semiconductor electronics: materials, devices and simple circuits	Forward and reverse biased pn junction	LO6. Analyses and interprets data, graphs, and figures, and draws conclusion	CLO84.Extrapolates the understanding of pn junction to create a pn diode and describes its behaviour under the effect of forward and reverse external bias	C156.Describes the behaviour of pn junction diode under the application of an external forward bias and reverse bias

Unit and Chapter	Key Concept	NCERT Learning Outcomes	Content domain specific Learning Outcomes	Indicators
IX. Electronic devices 14. Semiconductor electronics: materials, devices and simple circuits	Forward and reverse biased pn junction	LO7. Handles tools and laboratory apparatus properly; measures physical quantities using appropriate apparatus, instruments, and devices		C157.Takes initiative to perform the experiment to study and plot the VI characteristics of pn junction diode and defines threshold voltage, reverse saturation current and dynamic resistance using VI characteristic graph of pn junction diode
IX. Electronic devices 14. Semiconductor electronics: materials, devices and simple circuits	Rectifiers	LO6. Analyses and interprets data, graphs, and figures, and draws conclusion	CLO85.Explains the working of pn junction diode as a rectifier in electronic circuits	C158.States the role of pn junction diode in a rectifier, describes the circuit used and plots the graphs of input and output waveforms of half wave rectifier
IX. Electronic devices 14. Semiconductor electronics: materials, devices and simple circuits	Rectifiers	LO4. Explains processes, phenomena and laws with the understanding of the relationship between nature and matter on scientific basis		C159.Describes the circuit used as full wave rectifier and plots the graphs of input and output waveforms of full wave rectifier

7. SAMPLE PEDAGOGICAL PROCESSES AND ASSESSMENT STRATEGIES

> "The pedagogical practices should be learner centric. It is expected of a teacher to ensure an atmosphere for students to feel free to ask questions. They would promote active learning among students with a focus on reflections, connecting with the world around them, creating and constructing knowledge. The role of a teacher should be that of a facilitator who would encourage collaborative learning and development of multiple skills through the generous use of resources via diverse approaches for transacting the curriculum." [CBSE Curriculum for classes 11-12]

NCERT higher secondary stage learning outcomes document provides a common set of pedagogical processes for each subject. Keeping these as guidelines, specific pedagogical processes and assessment strategies for a topic from one chapter each from classes 11 and 12 have been developed as suggestions and are shared in this section. These instances of pedagogical process and assessment strategies should enable teachers to derive principles for making the alignment between learning outcomes, pedagogical practices and assessment in their classrooms and to use these for creating their lesson plans. The key principles considered while designing the pedagogical processes and assessment strategies are the following:

1. Keeping learner at the centre
    - Since new knowledge is built over existing knowledge, both pedagogy and assessment should focus on students' pre-requisite knowledge, skills, attitudes, and beliefs that they bring in classroom setting.
    - Constructivist approaches to learning with the student being at the centre of the learning process as an active constructor of knowledge must be emphasized.
    - Since students effectively learn by doing, classroom processes should involve activities, analysis and discussions. Systematic experimentation as a tool to discover/verify theoretical principles must be included.
2. Focusing on learning outcomes
    - Learning outcomes indicate what a student will be able to do at the end of an instruction unit by precisely breaking down broad goals of physics education (apply reasoning to develop conceptual understanding, develop process skills and experimental, observational, manipulative, decision-making and investigatory skills, etc.) to more measurable and observable behavior for each class.

- Students learn better when the method of teaching, learning activities and assessment strategies are all aligned well to the learning outcomes. Pedagogical processes and assessment strategies should be aligned to both content domains and cognitive skills as mentioned in this document earlier.

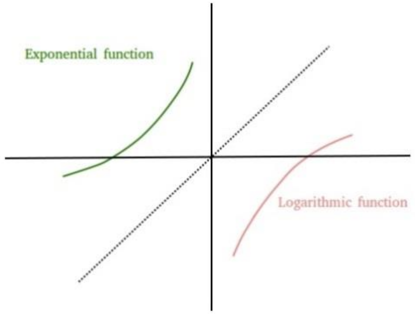
3. Making effective use of assessments
   - Assessment should be viewed as an integral part of pedagogy and it should focus on giving timely individualized feedback to students. Quality formative assessment should be designed as it helps to modulate students' understanding of their own learning and helps teachers adapt their pedagogy based on students' actual learning.
   - Multiple modes of assessment including portfolios, project work, presentations, written and oral assignments should be used to reflect individual capacities of a student.
4. Creating a social and inclusive learning environment
   - Cooperative and peer-supported teaching learning activities should be used to empower students to take charge of their own learning.
   - Peer assessment involving students assessing work of their peers against set assessment criteria should be used.
   - Specific pedagogical processes should be used in the classroom that would help those students who may face learning difficulties including language, visual-spatial, or mixed processing problems.

SUGGESTED PEDAGOGICAL PROCESSES AND ASSESSMENT STRATEGIES FOR CLASS 11

Content unit: 14. Oscillations **Chapter:** Simple harmonic motion **Topic:** Kinematics of Simple harmonic motion

Suggested pedagogical processes and assessment strategies for Class 11

Learning outcomes	Indicators	Pedagogical processes	Assessment strategies
CLO124. Explains the complete kinematics and dynamics of simple harmonic motion	C737 Recognizes the condition that classifies an oscillatory motion as simple harmonic motion	Graphs like a sine wave or a cosine wave should be used to illustrate the periodic nature of the motion of a body. Teacher can conclude that any periodic	Given below are two graphs representing a logarithmic and an exponential function.

	C738 Identifies the displacement function of simple harmonic motion as sinusoidal	functions like a sine, a cosine function, and their linear combinations can be used to represent a periodic motion. The teacher identifies SHM as a special case of periodic motion, where the displacement of the body in a periodic motion is a continuous and sinusoidal function of time.	State reasons why neither of these functions and graphs can represent a body moving in simple harmonic motion. 
	C739 Defines phase constant, time period, amplitude and angular frequency for a body in simple harmonic motion	With a help of simple demonstration of a simple pendulum (a small metal ball tied to a long string) the variations in the displacement and velocity of the bob at extreme and mean positions can be illustrated. As a classroom activity, let the students can record the data of displacement (in terms of the amplitude) versus time (in terms of fraction of the time-period, that is at 0, T/4, T/2, 3T/3 and T). The students can be encouraged to plot a graph (displacement versus time) to depict the nature of motion executed by an oscillating pendulum.	What is the phase difference between two oscillating bodies in SHM, with object 1 starting its motion from the mean position versus object 2 starting its motion from the extreme position?

		From the graph, identify and correlate with the various parameters associated with the oscillating pendulum, that is, time period, frequency, phase angle and amplitude.	
CLO124. Explains the complete kinematics and dynamics of simple harmonic motion	C740 States the equation for displacement of a body in simple harmonic motion in terms of phase and angular frequency C741 Plots the position-time graph of body in simple harmonic motion	From the graphs that are plotted by the students, let the students identify the suitable sinusoidal function/equation that can be used to represent the oscillatory motion of the bob. The teacher can state the most suitable sinusoidal function to represent the simple harmonic motion of a body. From the equation of the SHM, identify different components, like amplitude, angular frequency and time period of the body in SHM. Students can be encouraged to write all the possible sinusoidal functions and their combinations that can be used to denote the simple harmonic functions.	Students can be asked to reduce the different functions in the form that is similar to equation of simple harmonic motion and identify the various parameters of SHM. **Question**: From given equations below, identify time period, frequency, phase angle and amplitude of the body in SHM. 1. $x = 4\cos(1.33t+\pi/5)$ 2. $x = A \sin \omega t + B \cos \omega t$
CLO124. Explains the complete kinematics and dynamics of simple harmonic motion	C742 Compares the graphical plots of motion of two bodies in simple harmonic motion with different amplitudes C743 Compares the graphical plots of motion of two bodies in	In order to understand the correlation between the graphical representation and the actual SHM of an oscillating body, the students can be encouraged to plot multiple graphs (displacement versus time) on the common scale to represent different SHMs for the comparison sake:	The students can be asked to depict the following two SHMs using sinusoidal graphs on a common scale, on a single graph. a. Amplitude A, frequency ω, time period T b. Amplitude 2A, frequency 2ω, time period T/2

	simple harmonic motion with a phase difference C744 Compares the graphical plots of motion of two bodies in simple harmonic motion with different time periods	a. SHM 1 with amplitude A. SHM 2 with amplitude 2A. b. SHM 1 with amplitude A. SHM 2 with amplitude A but begins its oscillatory motion after T/4 time interval. c. SHM 1 with amplitude A and time period T. SHM 2 with amplitude A and time period 2T (it oscillates slower and takes double time to complete one oscillation). For each of the above cases, the teacher can do the demonstration of the oscillatory motion using the simple pendulum. It is important for the students to be able to associate the actual motion with the graphical representations.	
CLO124. Explains the complete kinematics and dynamics of simple harmonic motion	C745 Proves mathematically that a displacement equation with combination of sine and cosine functions represent the simple harmonic motion	The teacher can take examples like the ones given below and using Trigonometric identities, express these functions in the standard format of simple harmonic function, that is, $A\sin(\omega t+\varphi)$. 1. $\sin\omega t + \cos \omega t$ 2. $\sin\omega t - \cos\omega t$ The students should be encouraged to estimate the time period, amplitude and phase angle in each of the above instances.	As an assessment strategy, the students can be asked to categorize the following functions as Periodic only **OR** both periodic and simple harmonic **OR** Non periodic motion. a. $\sin^3\omega t$ b. $e^{(-\omega t)}$ c. $\cos\omega t + \cos2\omega t$ d. $A \sin \omega t + B \cos2\omega t$ e. $\sin2\omega t$

		The teacher can take another example of a function like: 3. $\sin^2\omega t$ Using the approach similar as previous, the students can be encouraged to conclude that functions like the above do represent periodic motion but NOT a simple harmonic function.	

SUGGESTED PEDAGOGICAL PROCESSES AND ASSESSMENT STRATEGIES FOR CLASS 12

Content unit: VI. Optics **Chapter:** 9. Ray optics and optical instruments **Topic:** Reflection of light by spherical mirrors

Table 7.2. Suggested pedagogical processes and assessment strategies for Class 12

Learning outcomes	Indicators	Pedagogical processes	Assessment strategies
CLO92. Recalls the technical terms defined for spherical mirrors CLO93. Uses the correct sign convention for mirrors and lenses	C133. Recalls and defines the terms pole, centre of curvature, principal axis, normal for spherical mirrors C134. Uses the Cartesian sign convention for spherical mirrors and lenses based on the direction of incident light	The terms related to the geometry of the spherical mirrors should be illustrated by cutting a hollow ball (plastic/rubber) along a plane. This would help the students visualize the terms like pole, centre and radius of curvature.	The teacher can ask students to mark these terms in a diagram for a concave mirror after defining these for a convex mirror. Teacher can ask the students deduce from the ball activity mentioned. Will the aperture of a spherical mirror be greater, equal or smaller than twice the radius of curvature of the mirror?

CLO94. Defines focus for spherical mirrors CLO95. Derives the relationship between focal length and radius of curvature for spherical mirrors	C135. Defines principal focus, focal plane and focal length for paraxial rays for spherical mirrors C136. Derives the relationship between focal length and radius of curvature for spherical mirrors	Students should be asked to work in small groups and make a cross-section of a spherical mirror by bending aluminum sheet along cylindrical surface. They should use a parallel beam of bright light (obtained using a convex lens and bright lamp or using sunlight) to see how the metal foil focuses the light beam. They should be encouraged to change the radius of curvature of the foil and notice how the pattern of the reflected light changes. This would help them understand the need for the approximation of paraxial rays better for defining a focal point for spherical mirrors. The teacher should derive the relationship between focal length and radius of curvature for a convex mirror.	The discussion based on the observations from the activity with the curved aluminum sheet can start with students answering some of the following questions: *Does the parallel beam of light get focused to a point?* *How does the pattern of the reflected light change on changing the radius of curvature of the foil?* *How does the pattern change if the incident light beam is narrowed?* *How does the location of the focused light changes on changing the radius of curvature of the foil?* The students should be asked to derive the relationship between focal length and radius of curvature for a concave mirror immediately after the teacher had shown them the derivation for the convex mirror.
CLO96. Explains the concept of an image in ray optics CLO97. Distinguishes between real and virtual images	C137. Explains an optical image as a point-to-point correspondence with the object through reflection or refraction C138. Distinguishes between real and virtual images	The students should be asked to use convex and concave lenses to look at objects through them, to try obtaining images on a wall or a sheet of paper. They should be asked to put down their observations and questions arising out of this activity.	After the discussion in the class, the students can be asked to write a note on ‘how we can see virtual images even if these are not formed on a screen’.

		The whole group should discuss the observations and the questions together with the teacher. This discussion can be used by the teacher to clarify the distinction between real and virtual images, and also to explain how we see virtual images.	
CLO98. Draws ray diagram to determine the position of the image of an object	C139. Draws the convenient incident and reflected rays to determine the position of the image of an object	The teacher should show how to draw the ray diagrams for one object position each for a convex and a concave mirror. Students should then be asked to draw the images for objects at other positions for both kinds of mirrors. The students should be asked to verify each of their recordings about images from the ray diagrams using actual convex and concave mirrors, and a pencil as an object.	1. Students should record their observations from their ray diagrams in the following format: <object position>: beyond C, at C, between C and F, at F, between F and mirror <distance of the image, relative size of the image and nature of the image for all above object positions> 2. What happens if you use three construction rays to draw the ray diagram for image formation in a perfectly spherical concave mirror – do they meet at a single point?
CLO99. Derives the mirror equation for spherical mirrors CLO100. Derives the magnification formula for spherical mirrors	C140. Derives the mirror equation for spherical mirrors C141. Derives the magnification formula for spherical mirrors	The derivation of the mirror equation should first be attempted by the students in small groups before the teacher explaining the whole derivation. This would enable students to apply their prior understanding of ray diagrams and their knowledge of high school geometry to solve a new problem.	The students should be asked to verify for themselves (as homework) if the mirror equation for concave mirrors is the same as that derived by the teacher for the convex mirrors.

CLO101. Solves problems related to image formation by spherical mirrors algebraically	C142. Uses mirror equation and magnification formula to solve problems related to image formation by spherical mirrors	The students should be asked to solve problems set in real-life contexts, e.g. checking the variation in apparent speed of an approaching vehicle as seen in the rear view mirror of a car, or the magnification obtained by the use of a concave mirror by a dentist. In such problems, the values of focal lengths or distances should be close to as found in authentic situations. Students can even be asked to choose these values in small groups for themselves and solve the problems.	The students should be asked to obtain image distance and image size for 3-4 cases using both (a) mirror equation and magnification formula, and (b) scaled ray diagrams. They should compare the accuracy of the results from ray diagrams to the ones obtained algebraically.

8. TEST PAPER DESIGN

TEST PAPER BLUEPRINTS FOR CLASS 12 FINAL EXAMINATION

The test papers for the final examination for class 12 should be balanced in terms of its coverage of content domains, cognitive domains and types of questions. However, the blueprint governing the design of the test papers should not be very rigid and should provide sufficient latitude to the paper setter so that the focus while setting the paper remains on the quality of questions and the overall balance of the test paper. Keeping this in mind, the following blueprint tables have provided ranges of numbers instead of absolute numbers for some of the criteria of the test paper design.

Table 8.1. Distribution of marks across content domains

Content domain	Marks distribution
Electrostatics	16-20
Current electricity	
Magnetic effects of current and magnetism	16-20
Electromagnetic induction and alternating currents	
Electromagnetic waves	16-20
Optics	
Dual nature of radiation and matter	16-20
Atoms and nuclei	
Electronic devices	
Total	**70**

Table 8.2. Distribution of marks across cognitive domains

Cognitive domain	Marks distribution
Remember	15-20
Understand	20-25
Apply	15-20
Analyse, Evaluate and Create	10-15
Total	**70**

Table 8.3. Distribution of marks across types of questions

Question type	Marks distribution
MCQs with single option or multiple options as correct answer	12-15
Very short answer questions with 1 mark	8-10
Short answer questions with 2 or 3 marks	25-30
Long answer questions (including structured questions with sub-questions) with 4 or 5 marks	20-25
Total	**70**

Other details of the test paper

Maximum marks: 70

Duration of the test (writing time): 3 hours

Time given for reading the test paper: 15 minutes

Total word count of the questions: 1600-2200 words

9. ASSESSMENT OF PRACTICAL WORK

A key component of the physics curriculum for classes 11-12 is practical work related to the concepts and principles covered in the content domains. Along with discovering or verifying results covered in the curriculum, students are also expected to acquire and practice process skills related to science. The learning outcomes for the curriculum as listed in chapter 5, include the following 3 learning outcomes which are especially relevant for practical work in physics.

LO7. Handles tools and laboratory apparatus properly; measures physical quantities using appropriate apparatus, instruments, and devices

LO8. Plans and conducts investigations and experiments to arrive at and verify the facts, principles, phenomena, relationship between physical quantities, or to seek answers to queries on their own

LO9. Communicates the findings and conclusions in oral/written/ICT form that shows critical thinking

DESIGN OF THE PRACTICAL EXAMINATION

Students are expected to conduct experiments, do practical activities and investigative projects throughout the course of 2 years, and are also required to take a practical examination at the end of each year.

Table 9.1. Distribution of marks for the practical examination

Activity	Distribution of marks
Two experiments, one from each section	7+7
Practical record [experiments and activities]	5
One activity from any section	3
Investigatory project	3
Viva on experiments, activities and project	5
Total	**30**

The practical record to be submitted by the students at the time of final examination has to include:

- Record of at least 12 experiments [with 6 from each section], to be performed by the student
- Record of at least 6 Activities [with 3 each from section A and section B], to be performed by the student
- Report of the project to be carried out by the student

The lists of suggested experiments, practical activities and investigative projects that students are expected to work on throughout the course are given below for both classes 11 and 12.

SUGGESTED EXPERIMENTS, PRACTICAL ACTIVITIES AND INVESTIGATIVE PROJECTS – CLASS 11

EXPERIMENTS

SECTION A

1. To measure diameter of a small spherical/cylindrical body and to measure internal diameter and depth of a given beaker/calorimeter using Vernier Callipers and hence find its volume
2. To measure diameter of a given wire and thickness of a given sheet using screw gauge
3. To determine volume of an irregular lamina using screw gauge
4. To determine radius of curvature of a given spherical surface by a spherometer
5. To determine the mass of two different objects using a beam balance
6. To find the weight of a given body using parallelogram law of vectors
7. Using a simple pendulum, plot its L-T^2 graph and use it to find the effective length of second's pendulum
8. To study variation of time period of a simple pendulum of a given length by taking bobs of same size but different masses and interpret the result

9. To study the relationship between force of limiting friction and normal reaction and to find the co- efficient of friction between a block and a horizontal surface
10. To find the downward force, along an inclined plane, acting on a roller due to gravitational pull of the earth and study its relationship with the angle of inclination θ by plotting graph between force and sin θ

SECTION B

1. To determine Young's modulus of elasticity of the material of a given wire
2. To find the force constant of a helical spring by plotting a graph between load and extension
3. To study the variation in volume with pressure for a sample of air at constant temperature by plotting graphs between P and V, and between P and 1/V
4. To determine the surface tension of water by capillary rise method
5. To determine the coefficient of viscosity of a given viscous liquid by measuring terminal velocity of a given spherical body
6. To study the relationship between the temperature of a hot body and time by plotting a cooling curve
7. To determine specific heat capacity of a given solid by method of mixtures
8. To study the relation between frequency and length of a given wire under constant tension using sonometer
9. To study the relation between the length of a given wire and tension for constant frequency using sonometer
10. To find the speed of sound in air at room temperature using a resonance tube by two resonance positions

PRACTICAL ACTIVITIES

SECTION A

1. To make a paper scale of given least count, e.g., 0.2 cm, 0.5 cm
2. To determine mass of a given body using a metre scale by principle of moments
3. To plot a graph for a given set of data, with proper choice of scales and error bars
4. To measure the force of limiting friction for rolling of a roller on a horizontal plane

5. To study the variation in range of a projectile with angle of projection
6. To study the conservation of energy of a ball rolling down on an inclined plane (using a double inclined plane)
7. To study dissipation of energy of a simple pendulum by plotting a graph between square of amplitude and time

SECTION B

1. To observe change of state and plot a cooling curve for molten wax
2. To observe and explain the effect of heating on a bi-metallic strip
3. To note the change in level of liquid in a container on heating and interpret the observations
4. To study the effect of detergent on surface tension of water by observing capillary rise
5. To study the factors affecting the rate of loss of heat of a liquid
6. To study the effect of load on depression of a suitably clamped metre scale loaded at (i) its end (ii) in the middle
7. To observe the decrease in pressure with increase in velocity of a fluid

SUGGESTED EXPERIMENTS, PRACTICAL ACTIVITIES AND INVESTIGATIVE PROJECTS – CLASS 12

EXPERIMENTS

SECTION A

1. To determine resistivity of two / three wires by plotting a graph for potential difference versus current
2. To find resistance of a given wire / standard resistor using metre bridge
3. To verify the laws of combination (series) of resistances using a metre bridge OR
   To verify the laws of combination (parallel) of resistances using a metre bridge
4. To determine resistance of a galvanometer by half-deflection method and to find its figure of merit
5. To convert the given galvanometer (of known resistance and figure of merit) into a voltmeter of desired range and to verify the same OR
   To convert the given galvanometer (of known resistance and figure of merit) into an ammeter of desired range and to verify the same

6. To find the frequency of AC mains with a sonometer

SECTION B

1. To find the value of v for different values of u in case of a concave mirror and to find the focal length
2. To find the focal length of a convex mirror, using a convex lens
3. To find the focal length of a convex lens by plotting graphs between u and v or between 1/u and 1/v
4. To find the focal length of a concave lens, using a convex lens
5. To determine angle of minimum deviation for a given prism by plotting a graph between angle of incidence and angle of deviation
6. To determine refractive index of a glass slab using a travelling microscope
7. To find refractive index of a liquid by using convex lens and plane mirror
8. To draw the I-V characteristic curve for a p-n junction diode in forward bias and reverse bias

PRACTICAL ACTIVITIES

SECTION A

1. To measure the resistance and impedance of an inductor with or without iron core
2. To measure resistance, voltage (AC/DC), current (AC) and check continuity of a given circuit using multimeter
3. To assemble a household circuit comprising three bulbs, three (on/off) switches, a fuse and a power source
4. To assemble the components of a given electrical circuit
5. To study the variation in potential drop with length of a wire for a steady current
6. To draw the diagram of a given open circuit comprising at least a battery, resistor/rheostat, key, ammeter and voltmeter. Mark the components that are not connected in proper order and correct the circuit and also the circuit diagram

SECTION B

1. To identify a diode, a resistor and a capacitor from a mixed collection of such items

2. Use of multimeter to see the unidirectional flow of current in case of a diode and check whether a given electronic component (e.g., diode) is in working order
3. To study effect of intensity of light (by varying distance of the source) on an LDR
4. To observe refraction and lateral deviation of a beam of light incident obliquely on a glass slab
5. To observe diffraction of light due to a thin slit
6. To study the nature and size of the image formed by a (i) convex lens, (ii) concave mirror, on a screen by using a candle and a screen (for different distances of the candle from the lens/mirror)
7. To obtain a lens combination with the specified focal length by using two lenses from the given set of lenses

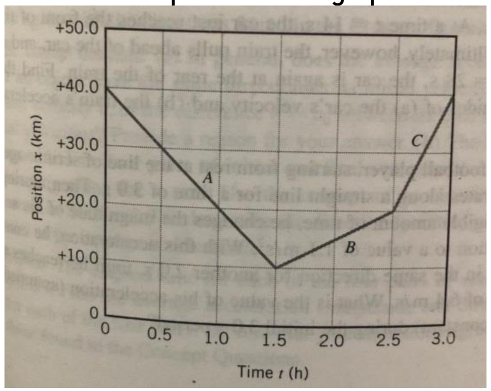
INVESTIGATIVE PROJECTS

1. To study various factors on which the internal resistance/EMF of a cell depends
2. To study the variations in current flowing in a circuit containing an LDR because of a variation in (a) the power of the incandescent lamp, used to 'illuminate' the LDR (keeping all the lamps at a fixed distance) (b) the distance of a incandescent lamp (of fixed power) used to 'illuminate' the LDR
3. To find the refractive indices of (a) water (b) oil (transparent) using a plane mirror, an equiconvex lens (made from a glass of known refractive index) and an adjustable object needle
4. To investigate the relation between the ratio of (i) output and input voltage and (ii) number of turns in the secondary coil and primary coil of a self-designed transformer
5. To investigate the dependence of the angle of deviation on the angle of incidence using a hollow prism filled one by one, with different transparent fluids
6. To estimate the charge induced on each one of the two identical Styrofoam (or pith) balls suspended in a vertical plane by making use of Coulomb's law
7. To study the factor on which the self-inductance of a coil depends by observing the effect of this coil, when put in series with a resistor/(bulb) in a circuit fed up by an A.C. source of adjustable frequency

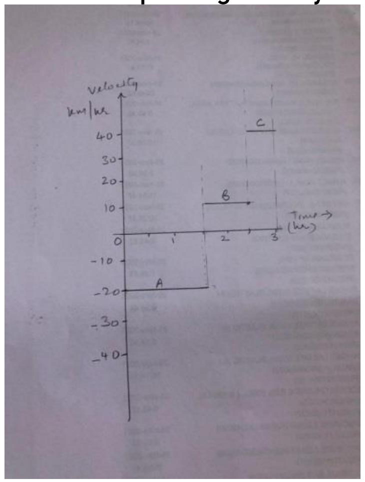
10. ESSENTIAL IDEAS WITH SAMPLE QUESTIONS – GRADE 11

Chapter name	1.Units and measurement	
Marking Rubric		
Essential Idea	Dimensional analysis can be employed for checking the dimensional consistency of the physical equations and realising that dimensionally incorrect equation are definitely incorrect whereas on the other hand a dimensionally correct equation may not be exact or accurate.	
Item Stem	Given dimensional formulae of $\frac{e^2}{4\pi\epsilon_o}$ = $[M^1L^3T^{-2}]$; G = $[M^{-1}L^3T^{-2}]$ and c = $[M^0L^1T^{-1}]$, identify the dimensionally correct equations using these constants amongst the following.	
Correct answer	$l \propto \frac{1}{c^2}\sqrt{\frac{Ge^2}{4\pi\epsilon_o}}$	LHS, dimensional formula of l = $[M^0L^1T^0]$ RHS, substituting the dimensional formulae of c, G and $\frac{e^2}{4\pi\epsilon_o}$, gives [L]. So LHS = RHS Dimensionally consistent equation.
Distractor 1	$l \propto c^2\sqrt{\frac{Ge^2}{4\pi\epsilon_o}}$	On substituting the dimensions on RHS, and solving for the dimensions, RHS = $[M^0L^5T^{-4}]$ LHS $\neq$ RHS, so incorrect option
Distractor 2	$l \propto \frac{1}{c^2}\sqrt{\frac{e^2}{4\pi\epsilon_o G}}$	On substituting the dimensions on RHS, and solving for the dimensions, RHS = $[M^1L^{-2}T^2]$ LHS $\neq$ RHS, so incorrect option
Distractor 3	$l \propto \frac{G}{c^2}\sqrt{\frac{e^2}{4\pi\epsilon_o}}$	On substituting the dimensions on RHS, and solving for the dimensions, RHS = $[M^{-1/2}L^{5/2}T^{-1}]$ LHS $\neq$ RHS, so incorrect option

<table>
<tr><td>Chapter name</td><td colspan="2">2. Motion in a straight line</td></tr>
<tr><td>Essential Idea 1</td><td colspan="2">Uniform and non-uniformly accelerated motion of a body along a straight-line are represented using displacement-time and velocity-time graphs. On the other hand, the shapes of the motion graphs are interpreted to deduce the nature of the motion and thereby know the various kinematic variables associated with the motion.</td></tr>
<tr><td>Item stem</td><td colspan="2">A to & fro trip made by a tourist bus are recorded in the form of position-time graph as shown here.



a. What is the average velocity (magnitude and direction) during each of the segments A, B and C as marked here?
b. Sketch a corresponding velocity-time graph of the tourist bus.</td></tr>
<tr><td colspan="3">Marking Rubric</td></tr>
<tr><td>Part</td><td>Description</td><td>Marks</td></tr>
</table>

A possible complete answer:	a. Average velocity along A: (10-40)/1.5 = - 30/1.5 = - 20 km/hr The negative sign indicates the Bus is moving opposite to reference direction. Average velocity along B: (20-10)/1 = 10 km/hr. The bus is moving along the reference direction. Average velocity along C: (40-20)/0.5 = 20/0.5 = 40 km/hr. The bus is moving along the reference direction. b. The corresponding velocity-time graph of the bus: 	3
Stepwise break up	a. The calculation of the average velocity for each segment using the formula: Average velocity = total distance travelled/total time taken. Significance of + and – sign in the average velocity value. Average velocity along segment A = -20 km/h Average velocity along segment B = 10 km/h Average velocity along segment C = 40 km/h	0.5 mark for each calculation along with the mention of correct direction of motion
	b. Sketch of the velocity time graph for three segments of the motion of the bus.	0.5 mark for each segment of velocity time graph

Essential Idea 2	Linear equations of motion of a uniformly accelerated body relate the 5 kinematic variables associated with the linear motion of the body, that is., displacement S, time t, initial velocity u, final velocity v and uniform acceleration, a.	
Item Stem	Suri begins to ride his car from rest, with velocity increasing linearly with time as v = kt, where k = 2. What is the distance covered by Suri in metres within first 5 seconds of his ride?	
Correct answer	25	k here corresponds to acceleration of Suri's car. So use $S = ut + ½ at^2$
Distractor 1	2	Incorrect comparison of equation v = kt, with v = d/t
Distractor 2	10	Incorrect use of equation v = kt, here v represents velocity and not distance.
Distractor 3	50	Incorrect calculation using the equation $v^2-u^2 = 2aS$

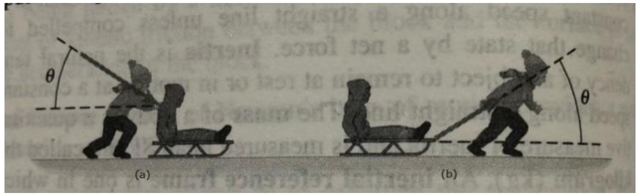
Chapter name	4.Motion in a plane
Essential Idea 1	Motion in a plane is considered as a combination of two separate simultaneous one-dimensional motions along two perpendicular directions. Equations of linear accelerated or uniform motion, apply to each of the individual motions.
Item stem	An airplane in its ascending flight has initial components of speed and accelerations along x- and y- axis as given here: (table below) Take the directions of upwards and to the right as positive. a. Determine the final velocities along x- and y- axis after 5 seconds of the flight. b. What is the magnitude and direction of the final velocity of the airplane after 5 seconds?

u_x	a_x	u_y	a_y
10 m/s	20 m/s^2	8 m/s	10 m/s^2

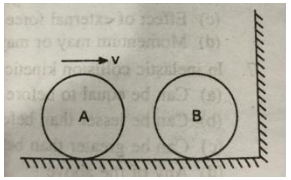
Marking Rubric		
Part	Description	Marks
A possible complete answer:	a. Final velocity along x- axis: $v_x = u_x + a_x t$ $v_x = 10 + 20.5 = 110$ m/s Final velocity along y- axis: $v_y = u_y + a_y t$ $v_y = 8 + 10.5 = 58$ m/s b. Net final velocity after 5 seconds: v = $\sqrt{v_x^2 + v_y^2}$ = $\sqrt{110^2 + 58^2}$ ~ 124 m/s Direction of final velocity: $\tan\theta = v_y/v_x = 58/110 = 0.52$ $\theta = \tan^{-1} 0.52$	4
Stepwise break up	a. Calculation of final velocity along x- axis using equation of motion: $v_x = u_x + a_x t$	1
	a. Calculation of final velocity along y- axis using equation of motion: $v_y = u_y + a_y t$	1
	b. Calculation of final net velocity: Magnitude of final velocity: using the formula: v = $\sqrt{v_x^2 + v_y^2}$	1

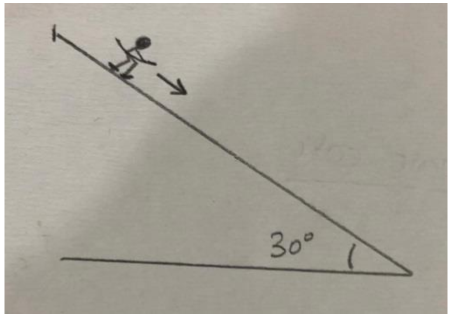
	b. Direction of final velocity using the formula: $\tan\theta = v_y/v_x$	1

Essential Idea 2	A projectile is a body that is either dropped from a height or projected with an initial velocity. Thereon the projectile moves freely under the effect of gravity. The path followed by the projectile is parabolic and the various quantities like maximum height attained, horizontal range covered and the time of flight are obtained by considering its flight as a motion in two dimensions.	
Item Stem	A diver dives from a cliff that is 50 m high. Rocks extend horizontally to about 20 m from the foot of the cliff. What should be the minimum horizontal speed with which the diver should take off the cliff while diving to just miss hitting the rocks at the bottom? Take g = 10 m/s^2	
Correct answer	$20/\sqrt{10}$ m/s	Find the time of flight in vertical direction. $t = \sqrt{10}$ s In the same time, use $v = x/t$ for horizontal motion, where x is 10 m and t is time of flight. $v = 20/\sqrt{10}$ m/s
Distractor 1	$\sqrt{10}/20$ m/s	Incorrect transposition of the values while calculating horizontal uniform speed.
Distractor 2	$\sqrt{1000}$	This is final velocity along the vertical direction.
Distractor 3	$10\sqrt{10}$	This is the speed obtained if the horizontal motion is considered accelerated under the effect of g.

Chapter name	5.Laws of motion	
Essential Idea 1	Newton second law gives a quantitative expression to the force and its effect on the body. When multiple forces act on the body, the net resultant force is the vector sum of these concurrent forces acting on the body. The body moves in the direction of the net force with an acceleration, governed by the equation, F = ma.	
Item stem	Tim has to pull his injured little brother John on the ice sledge. Considering that there is unavoidable friction between the sledge and the icy surface, what should we recommend Tim to do for the easy run home:  Should Tim pull the sledge or push the sledge?	
Marking Rubric		
Part	Description	Marks
A possible complete answer:	In (a) Tim pushes the sledge with a force F. Resolving the forces, F$\cos\theta$ acts to the right. F$\sin\theta$ acts downwards. Total force pressing the sledge to the icy surface = Normal reaction on the sledge = W + F$\sin\theta$ Friction force f opposing forward force F$\cos\theta$ is μ x Normal reaction = μ(W + F$\sin\theta$) The net force that moves the sledge forward is = F$\cos\theta$ – μ(W + F$\sin\theta$) ...(1) In (b) Tim pulls the sledge with a force F. Resolving the forces, F$\cos\theta$ acts to the right.	3

	$F\sin\theta$ acts upwards. Total force pressing the sledge to the icy surface = Normal reaction on the sledge = $W - F\sin\theta$ Friction force f opposing forward force $F\cos\theta$ is μ x Normal reaction = $\mu(W - F\sin\theta)$ The net force that moves the sledge forward is = $F\cos\theta - \mu(W - F\sin\theta)$....(2) Comparing eqn (1) and (2), we see that for the same force F applied by Tim, it's the pull that will result in greater effective force acting on sledge and hence the make it an easier run home!	
Stepwise break up	In case of the push: Calculation of friction opposing the motion of the sledge and the net force that moves the sledge forward. Friction force = $\mu(W + F\sin\theta)$ Net forward force on the sledge = $F\cos\theta - \mu(W + F\sin\theta)$	1
	In case of the pull: Calculation of friction opposing the motion of the sledge and the net force that moves the sledge forward. Friction force = $\mu(W - F\sin\theta)$ Net forward force on the sledge = $F\cos\theta - \mu(W - F\sin\theta)$	1
	Compare the two net forces and arrive at the final conclusion: Its easier to pull than to push.	1

Essential Idea 2	When net external force acting on a system of bodies is zero, the total momentum of the system is always conserved. In case of collision, in the absence of external forces, , the internal forces that act on the colliding bodies bring about changes in the individual momenta of the colliding bodies, with net total change in momentum of the colliding bodies being zero.	
Item Stem	A and B are two identical balls. Initially, ball A is moving to the right with velocity v and ball B is at rest. Assume all the collisions that would occur in this illustration as elastic.  Identify the correct statements from the following: i. A total of three collisions take place ii. The kinetic energy of the ball A and B gets interchanged after all of the collisions have taken place iii. The speeds of A and B remain unchanged after all the collisions have taken place iv. Ball A and B stick and move together after all the collisions have taken place	
Correct answer	Only i and iii	Ball A collides with B and B collides with wall, rebounds and collides with A again. With each collision being elastic and the balls being identical, the KE is conserved and speeds are exchanged. So only i and iii are correct.
Distractor 1	Only iii and iv	Statement iv cannot be true as the sticking together of the balls occurs in perfectly inelastic collision. That's incorrect.
Distractor 2	Only i and ii	Since the collisions are elastic, KE of ball A is regained as at the start whereas KE of ball B becomes 0, as at the start. So statement ii is incorrect.
Distractor 3	Only iii and iv	Statement iii is true due to the all the collisions being elastic. Statement iv can be true if all the collisions are perfectly inelastic. Hence statement iv becomes invalid in the given case here.

Chapter name	6. Work energy and power	
Essential Idea 1	Work energy theorem states that the total work done by an external force acting on the body is equal to total change produced in the kinetic energy of the body.	
Item stem	A 40 kg skier moving at a speed of 2 m/s begins his 50 m downward slide along an inclined slope. If the friction force of 50 N opposed his motion downwards, determine the speed of the skier at the bottom of the slope. You may take g = $10 m/s^2$  	
Marking Rubric		
Part	Description	Marks

A possible complete answer:	As per Work energy theorem: Work done along the slope = Change in KE = $K_f - K_i$ $K_i = ½\ mu^2 = ½ \times 40 \times 2^2 = 80$ J W = net force down the slope x displacement along the slope $= (mg\sin 30 - f_r) \times 50 = (40 \times 10/2 - 50) \times 50 = 7500$ J $K_f = W - K_i = 7500 - 80 = 7420$ J The speed with which the skier will reach the base of the slope: $7420 = ½\ mv^2$ $v^2 = 7420 \times 2/40 = \sqrt{371}$ m/s = 19.2 m/s	3
Stepwise break up	Calculation of initial kinetic energy = 80J	0.5
	Calculation of total work done on the skier = 7500 J	1
	Applying Work energy theorem to determine the final kinetic energy, $K_f = 7420$ J	0.5
	Calculating of the final speed from final kinetic energy, $v = \sqrt{371}$ m/s	1

Essential Idea 2	Forces like gravitational and electric forces are conservative; forces like friction and air resistance are non-conservative. A force is conservative when the work done by it is independent of the path chosen by the moving body and it is zero in case of a closed path. Non-conservative forces follow the rules to the contrary.	
Item Stem	Identify a correct statement that illustrates work done by a conservative or a non-conservative forces.	
Correct answer	Work done by gravitational force on the satellite moving along a circular path around Earth is zero	Gravitational force is a conservative force. Gravitational force acts perpendicular to the motion satellite along its circular orbit. So work done is zero as the angle between force and displacement is 90. This is correct statement.
Distractor 1	Work done by air resistance on the body can be positive or negative depending upon whether the body is slowing or speeding.	Air resistance always acts opposite to the motion of the body. It is a non-conservative force. Work done by air resistance is always negative irrespective whether the body is slowing or speeding. This statement is incorrect.
Distractor 2	Same work is done by kinetic frictional force on the body irrespective of the lengths of the path chosen between initial and final positions	Kinetic frictional force is non-conservative, so work done depends upon the length of the path chosen. Longer the path more is the work done. This statement is incorrect.
Distractor 3	Gravitational force does negative work on the roller coaster moving down and positive work on the roller coaster when moving up	Gravitational force is conservative force and always acts vertically downwards. So work done by it is negative if the roller coaster is moving up and positive if it is moving down. This statement is incorrect.

Chapter name	7. Systems of particles and rotational motion	
Essential Idea 1	Angular momentum associated with a particle rotating about a fixed point is defined as moment of linear momentum. Considering a rigid body rotating about a fixed axis, angular momentum is defined in terms of its angular velocity and moment of inertia about the axis of rotation. In the absence of any external torque acting on the rotating body, angular momentum of the rigid body moving about a fixed axis is always conserved.	
Item stem	A disc of radius R and mass M is rotating about vertical axis passing through its centre and perpendicular to its plane with angular velocity ω. A ring of same dimension but mass 2M is placed very gently on the rotating disc coaxially. What will be the angular velocity of the system now?	
Marking Rubric		
Part	Description	Marks
A possible complete answer:	Moment of inertia of disc about an axis as given here: $I = ½ MR^2$ Angular momentum of the disc = $I\omega = ½ MR^2\omega$ When the ring is placed on the rotating disc, the total MI of the system becomes: $I' = ½ MR^2 + MR^2 = (3/2) MR^2$ Since there is no external torque acting on the system, angular momentum of the system is conserved, So $I'\omega' = I\omega$ $(3/2) MR^2 \omega' = ½ MR^2\omega$ So $\omega' = \omega/3$	2
Stepwise break up	Determine MI and angular momentum of the disc: $L = ½ MR^2\omega$	0.5

	After the ring is placed on the disc, the MI of the system: $I' = (3/2)\ MR^2$	0.5
	Applying the law of conservation of angular momentum and finding the final value of angular velocity $\omega' = \omega/3$	1

Essential Idea 2	The total kinetic energy of the rigid body in rolling motion is attributed to two components: kinetic energy due to linear motion and kinetic energy due to rotation about its axis. So the law of conservation of energy in the case when the body is both moving with linear speed and rotating about its axis includes the sum of potential energy of the body, kinetic energy due to translational motion and kinetic energy due to rotational motion.	
Item Stem	A body of mass m, starting from rest, slides down the frictionless inclined slope and attains a speed v at the bottom of the slope. Another body of same mass m, but in the shape of a disc rolls down the same slope. The linear speed of the disc at the bottom of the slope will be :	
Correct answer	$v\sqrt{\frac{2}{3}}$	Apply conservation of mechanical energy for the sliding body: PE = KE (linear) $h = v^2/2g$ Apply conservation of mechanical energy for the rolling disc: PE = KE (linear) + KE (rotational) $mgh = \frac{1}{2} mv_1^2 + \frac{1}{2} I\omega^2$ Substituting for h, I of disc and $v_1 = r\omega$ $v_1 = v\sqrt{\frac{2}{3}}$
Distractor 1	$v\sqrt{\frac{3}{2}}$	Incorrect transposition while solving the last equation
Distractor 2	$v/\sqrt{2}$	Using incorrect value of MI of the disc

Distractor 3	v	Not considering the rotational kinetic energy of the disc while applying the conservation of mechanical energy for disc

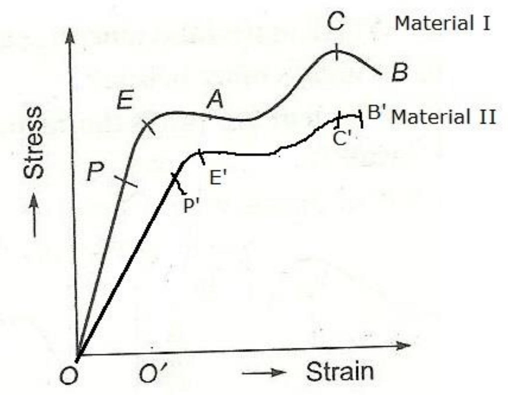
Chapter name	8. Gravitation

Essential Idea 1	Taking Earth's surface as reference point of gravitational potential energy, when a body is thrown from the surface of Earth, the law of conservation of energy implies that its kinetic energy keeps getting converted to potential energy as it rises up. If the height to which the body rises above the surface of Earth is comparable to radius (h ~ R) of Earth, then variation of g with height must be considered. The value of g no longer stays constant over such great heights (h >> R) from the surface of the Earth.	
Item stem	If a body of mass m is projected vertically upwards from the surface of Earth with a speed $v = 0.5v_e$, where v_e is the escape velocity of Earth, show that the maximum height to which the body may rise from the surface of Earth is R/3. Here R is radius of Earth.	
Marking Rubric		
Part	Description	Marks
A possible complete answer:	Conservation of energy: $\frac{1}{2} mv^2 = \frac{mgh}{1+\frac{h}{R}}$, here g has been taken as a function of h Here $v = 0.5v_e$ and $v_e = \sqrt{2gR}$ Substituting and transposing h = R/3	2
Stepwise break up	Applying conservation of energy to the body thrown from the surface and considering the variation of g with height $\frac{1}{2} mv^2 = \frac{mgh}{1+\frac{h}{R}}$,	1
	Substituting for the value of escape speed in terms of R and calculating the height h h = R/3	1

Essential Idea 2	Kepler's law of periods states that square the time period of planet revolving around the Sun is directly proportional to cube of average radius of its orbit. This relationship is derived from the fact that gravitational force of attraction between any two bodies follows inverse square law and it provides for the required centripetal force for the planet to revolve around the sun.

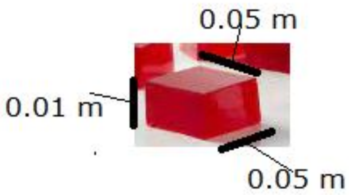
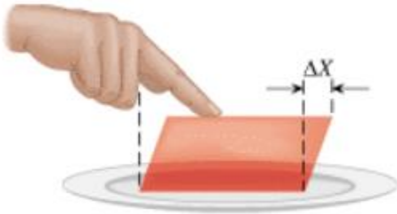
Item Stem	A planet revolves around an imaginary star under the effect of gravitational force that is proportional to $r^{-5/2}$ instead of the usual inverse square law. If the planet follows a circular orbit of radius r and its time period of revolution around the star is T, then how does Kepler's law of periods modify, if it does, for such an imaginary planet-star system?	
Correct answer	$T^2 \propto r^{7/2}$	Gravitational force provides for centripetal force, $\frac{mv^2}{r} = \frac{K}{r^{5/2}}$ $v^2 = \frac{K}{r^{3/2}}$ As Time period $T = \frac{2\pi r}{v}$, substituting for v, $T^2 \propto r^{7/2}$
Distractor 1	$T^2 \propto r^3$	Kepler's law of period is independent of gravitational force being an inverse square law. This is incorrect statement.
Distractor 2	$T^2 \propto r^{-5/2}$	As per Kepler's law of periods, the nature of dependence of gravitational force is same as that of T^2. This is incorrect statement.
Distractor 3	$T^2 \propto r^{3/2}$	An error while transposing the power across the equations of centripetal and gravitational force. This is incorrect statement.

Chapter name	9. Mechanical properties of solids

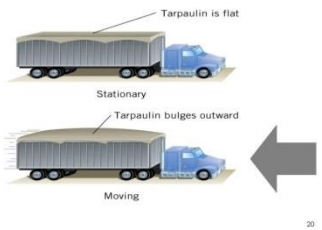
Essential Idea 1	The relation between stress and strain for a given material can be studied experimentally and represented graphically. The nature of this graph is of great advantage in understanding the mechanical properties of the material like its strength, stiffness and hardness.
Item stem	Stress-strain graphs of two materials 1 and 2 is given below.  a. If the 2 materials I and II with the same length and cross-section are subjected to change the dimensions in equal measure, which one will require greater force? Give reason. b. Identify the part of the graph I wherein the proportionality of stress to strain is lost, the property of elasticity isn't, and on the removal of load, the metal will still return to its original dimensions. c. Identify the point on the graph I such that from this point on, it doesn't matter if you release the tensile force or apply a force in the opposite direction, the material will not return to its original dimensions. d. Ultimate tensile strength is the maximum stress on a material's stress-strain curve. Identify the Ultimate tensile strength points in the two materials I and II from the graphs. e. Toughness of a material is its ability to absorb energy before it is fractured and energy absorbed is given by area enclosed by the part CB (Or C'B') and the strain axis. Identify the material that will absorb more energy before failing. Which one of the two materials is brittle and ductile? Give one example each.

Marking Rubric		
Part	Description	Marks
A possible complete answer:	a. Material I had greater modulus of elasticity. Hence it will require greater force to bring about the change in dimensions of same measure as in II. b. PE part of the graph: Between the proportionality limit and elastic limit c. Elastic limit of yield point E d. C and C' e. Material I Material I is ductile. Example. Steel wire (any metal) Material II is brittle. Example: Ceramic	5
Stepwise break up	a. Material I had greater modulus of elasticity. Hence it will require greater force to bring about the change in dimensions of same measure as in II.	1
	b. PE part of the graph: Between the proportionality limit and elastic limit	0.5
	c. Elastic limit of yield point E	0.5
	d. C and C'	0.5
	e. Material I Material I is ductile. Example. Steel wire (any metal) Material II is brittle. Example: Ceramic	0.5 mark each point

Essential Idea 2	As per Hooke's law, stress is directly proportional to strain, considering small deformations. The constant of proportionality in this ratio is defined as elastic modulus of the material that is subjected to the deforming stress. The three types of elastic moduli: Young modulus, bulk

	modulus and shear modulus. The definition of elastic modulus depends upon the nature of the applied deforming force and type of strain it produces in the body.	
Item Stem	A rectangular block of rose jelly of dimensions as shown is acted upon by a tangential force of 0.5 N producing a relative shift of top layer through 0.005 m with respect to bottom layer.    The shear modulus of rigidity of the rose jelly is	
Correct answer	400 N/m^2	Shear modulus = 0.5 x 0.01/[0.05 x 0.05 x 0.005] = 400 N/m^2
Distractor 1	100 N/m^2	Incorrect substitution of perpendicular distance between top and bottom layers and shear shift. This is an incorrect answer

Distractor 2	25×10^{-2} m^2/N	Incorrect definition of shear modulus as strain/stress. This is an incorrect answer
Distractor 3	0	Since shear modulus of fluids is taken as zero, considering jelly as almost a fluid. This is incorrect answer

Chapter name	10. Mechanical properties of fluids
Essential Idea 1	Bernoulli's equation states that in a steady flow of a non-viscous and incompressible fluid of density ρ, the pressure P, the fluid speed v and the elevation y at two points are related by $P_1 + ½ \rho v_1^2 + \rho g y_1 = P_2 + ½ \rho v_2^2 + \rho g y_2$ Points 1 and 2 are selected randomly, so as per the equation, it's the sum, $P + ½ \rho v^2 + \rho g y$, that stays constant at all the points of the fluid flow.
Item stem	Tarpaulin covers the cargo that is pulled by the truck. In a stationary truck, the tarpaulin stays flat whereas it bulges out when the truck is in motion. This is primarily due to the pressure difference between the inside and outside the tarpaulin.  If the truck is travelling with a speed of 30 m/s and density of air is 1.3 kg/m^3, how much is the pressure difference between the inside and outside the tarpaulin ?
Marking Rubric	

Part	Description	Marks
A possible complete answer:	Applying Bernoulli's equation, $P_1 + ½ \rho v_1^2 = P_2 + ½ \rho v_2^2$ Here P_1 and P_2 is the pressure inside and outside the tarpaulin respectively and v_1 and v_2 is the speed of the air inside and outside the tarpaulin respectively $v_1 = 0$ $P_1 - P_2 = ½ \rho v_2^2 = ½ \times 1.3 \times 30^2 = 585$ Pa	2
Stepwise break up	For correct equation statement: Applying Bernoulli's equation, $P_1 + ½ \rho v_1^2 = P_2 + ½ \rho v_2^2$ Here P_1 and P_2 is the pressure inside and outside the tarpaulin respectively and v_1 and v_2 is the speed of the air inside and outside the tarpaulin respectively	1
	For correct calculations and final result: $v_1 = 0$ $P_1 - P_2 = ½ \rho v_2^2 = ½ \times 1.3 \times 30^2 = 585$ Pa	1

Essential Idea 2	Capillarity is a phenomenon of liquids due to which if a tube of narrow bore is immersed in it, the liquid either ascends or descends relative to surrounding liquid due to the property of surface tension. The height to which the liquid rises or falls in the capillary tube is such that force due to surface tension is balanced by the pressure difference.
Item Stem	A liquid rises to a height of 16 cm in a capillary tube of length 20 cm. If a tube of height 12 cm is placed in the same liquid as above, which one of the following will occur?

Correct answer	Liquid will stay at a height of 12 cm in the capillary tube	Liquid rise to the maximum height possible so as to keep the product $hr = Lr' = 2T/\rho g$, where L is insufficient length of the capillary tube, r and r' is the radius of the meniscus to which the liquid gets adjusted to at the top.
Distractor 1	Liquid will emerge out as a fountain	This is not possible. This will defy the conservation of energy principle.
Distractor 2	Liquid will flow down the sides of the capillary tube	This is not possible. Flowing down the sides will increase the exposed surface area of the liquid.
Distractor 3	Liquid will rise to a height of 8 cm only	Liquid rises to a height in a capillary tube such that the surface tension force is balanced by the force due to pressure difference. Hence for a given radius of the capillary tube, the liquid will rise to definite height as given by $h = 2T/\rho gr$. Due to incufficient length of capillary tube, the meniscus at the edge adjusts its radius such that $hr = Lr' = 2T/\rho g$.

Chapter name	11. Thermal properties of gases
Essential Idea 1	A perfect heat radiator, radiates heat at a rate as given by Stefan's law: $H = eA\sigma T^4$ where e is the emissivity and σ is Stefan-Boltzmann constant. Emissivity is equal to 1 for a perfect black body radiator. For rest all bodies, the value of e is less than 1.
Item stem	a. Two copper spheres of radii R_1 and R_2 are at temperatures T_1 and T_2 respectively such that $R_1 = 4R_2$ and $2T_1 = T_2$. Show that heat radiated per second by sphere 1 is same as that by sphere 2.

	b. Consider two copper spheres at same temperatures such that sphere 1 is solid and sphere 2 is hollow with inner radius r and outer radius same as that of solid sphere. When placed in similar environment, one of the two spheres is observed to cool faster. Identify the sphere that cools faster.	
Marking Rubric		
Part	Description	Marks
A possible complete answer:	a. From Stefan's law, heat radiated per second by a body, $H_1 = eA\sigma T^4 = e\pi\ R_1^2\sigma T_1^4$ $H_2 = eA\sigma T^4 = e\pi\ R_2^2\sigma T_2^4$ $\frac{H_1}{H_2} = \frac{R_1^2 T_1^4}{R_2^2 T_2^4} = \frac{1}{16} . \frac{2^4}{1} = 1$ $H = H_2$ Hence heat radiated per second by sphere 1 is same as that by sphere	2
	b. From Stefan's law for rate of loss of heat per second, $H_1 = eA\sigma(T^4 - T_o^4)$ $\frac{mc\Delta T}{\Delta t} = eA\sigma(\mathrm{T}^4 - T_o^4)$ $\frac{\Delta T}{\Delta t} = \frac{eA\sigma}{mc}(\mathrm{T}^4 - T_o^4)$ $\frac{\Delta T/_{\Delta t\ (s)}}{\Delta T/_{\Delta t\ (h)}} = \frac{m_h}{m_s}$ For same outer radius and same material of the spheres, $m_h < m_s$ so $\Delta T/_{\Delta t\ (s)} < \Delta T/_{\Delta t\ (h)}$	2

	So the hollow sphere will cool faster.	
Stepwise break up	a. For correct formulae and the ratio: From Stefan's law, heat radiated per second by a body, $H_1 = eA\sigma T^4 = e\pi R_1^2\sigma T_1^4$ $H_2 = eA\sigma T^4 = e\pi R_2^2\sigma T_2^4$ For correct calculations and final result : $\frac{H_1}{H_2} = \frac{R_1^2 T_1^4}{R_2^2 T_2^4} = \frac{1}{16} . \frac{2^4}{1} = 1$ $H = H_2$ Hence heat radiated per second by sphere 1 is same as that by sphere	1 1
	b. For correct modification of the Stefan formula by including the heat exchanges due to specific heat capacity: From Stefan's law for rate of loss of heat per second, $H_1 = eA\sigma(T^4 - T_o^4)$ $\frac{mc\Delta T}{\Delta t} = eA\sigma(\mathrm{T}^4 - T_o^4)$ $\frac{\Delta T}{\Delta t} = \frac{eA\sigma}{mc}(\mathrm{T}^4 - T_o^4)$ $\frac{\Delta T / \Delta t\ (s)}{\Delta T / \Delta t\ (h)} = \frac{m_h}{m_s}$ For substituting and final result:	1 1

	For same outer radius and same material of the spheres, $m_h < m_s$ so $\Delta T/_{\Delta t\ (s)} < \Delta T/_{\Delta t\ (h)}$ So the hollow sphere will cool faster.	

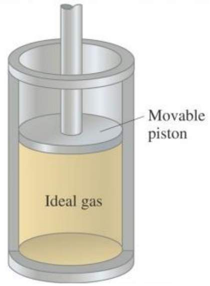
Essential Idea 2	Heat is exchanged when two substances at different temperatures are mixed. Calorimetry is the study of heat exchanges between any two substances in contact with each other. Principle of calorimetry states that heat lost by a body at higher temperature is equal to heat gained by the body at lower temperature. Heat exchanged by a body is directly proportional to the mass of the body, its specific heat capacity and the temperature difference.	
Item Stem	Three liquids of equal masses, L_1, L_2 and L_3 are at temperatures 10 °C, 20 °C and 50 °C. When L_1 and L_2 are mixed, the final temperature is 16 °C and when L_2 and L_3 are mixed, the final temperature is 35 °C . What will be the final temperature when L_1 and L_3 are mixed?	
Correct answer	34 °C	Equate heat exchanged by L_1 to heat exchanged by L_2 $S_1(16-10) = S_2(20-16)$ Equate heat exchanged by L_2 to heat exchanged by L_3 $S_2(35-20) = S_3(50-35)$ Equate heat exchanged by L_1 to heat exchanged by L_3 $S_1(\theta-10) = S_3(50-\theta)$ Solving, we get $\theta = 34$ °C

Distractor 1	30 °C	Average of temperatures of L_1 and L_3. This is incorrect concept.
Distractor 2	21.4 °C	Incorrect substitution of temperature differences for each heat exchange. This is incorrect answer.
Distractor 3	25 °C	Incorrect relation between specific heat capacities across the liquids while transposing the equations. This is incorrect answer.

Chapter name	12. Thermodynamics	
Essential Idea 1	First law of thermodynamics states that heat exchanged by a system is used for two purposes: change the internal energy of the system and to perform work. It is stated as, $\Delta Q = \Delta U + W$	
Item stem	For a lab experiment, a gas mixture needs to be heated to as high a temperature as possible. Is it advisable to heat the gas under constant pressure or constant volume? Give reason for your answer.	
Marking Rubric		
Part	Description	Marks
A possible complete answer:	Gas should be heated under constant volume. As per the first law of thermodynamics: $\Delta U = \Delta Q - W$ If W = 0, whatever heat ΔQ is used to heat the gas, it is absorbed by the gas to raise its internal energy ΔU. More is the rise in internal energy of the body, higher is the rise in its temperature.	2

	Since W = pΔV, at constant volume, ΔV = 0, so W =0.	
Stepwise break up	Statement of the first law of thermodynamics and the reason why W =0 so that heat absorbed by the gas is used completely for the rise in internal energy.	1
	Conclusion statement, that the gas should be heated under constant volume.	1

Chapter name	13. Kinetic theory of gases
Essential Idea 1	A gas that satisfies the equation, PV = nRT, is identified as an ideal gas. Real gases almost follow the ideal gas equation at low pressures and high temperatures. Ideal gas equation is used to arrive at Boyle's law and Charles law by fixing temperatures and volumes respectively.
Item stem	An ideal gas is enclosed in a cylinder with a movable piston as shown. The gas occupies a volume of 9 x 10^{-4} m^3 at temperature of 300 K and pressure of 5 x 10^5 Pa. (Take R = 8.314 J/mol-K)

	 a. How many moles of the gas are contained in the cylinder? b. Under what pressure can the gas be compressed isothermally to a volume of 2×10^{-4} m^3 ? c. Thereon the gas is heated to a temperature of 400 K at a constant volume. What will be the pressure on the gas?

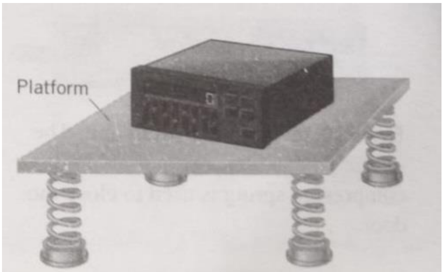
Marking Rubric		
Part	Description	Marks
A possible complete answer:	a. The number of moles of the gas contained in the cylinder: PV = nRT $n = PV/RT = 5 \times 10^5 \times 9 \times 10^{-4} / (8.314 \times 300) = 0.1804$ moles b. The pressure to which the gas is compressed isothermally to a volume of 2×10^{-4} m^3 : At constant temperature, $P_1 V_1 = P_2 V_2$ $5 \times 10^5 \times 9 \times 10^{-4} = P_2 \times 2 \times 10^{-4}$ $P_2 = 22.5 \times 10^5$ m^3 c. Thereon the gas is heated to a temperature of 400 K at a constant volume, such that the pressure on the gas is: At a constant volume, $P_2/T_2 = P_3/T_3$ $22.5 \times 10^5 / 300 = P_3/400$	3

	$P_3 = 30 \times 10^5$ Pa	
Stepwise break up	a. Use of ideal gas equation. Correct equation and the final result. PV = nRT $n = PV/RT = 5 \times 10^5 \times 9 \times 10^{-4} / (8.314 \times 300) = 0.1804$ moles	0.5 0.5
	b. Boyle's law to be applied. Correct equations and the final result. At constant temperature $P_1 V_1 = P_2 V_2$ $5 \times 10^5 \times 9 \times 10^{-4} = P_2 \times 2 \times 10^{-4}$ $P_2 = 22.5 \times 10^5\ m^3$	 0.5 0.5
	c. Chares law to be applied. Correct equation and the final result. At a constant volume, $P_2/T_2 = P_3/T_3$ $22.5 \times 10^5 / 300 = P_3/400$ $P_3 = 30 \times 10^5$ Pa	 0.5 0.5

Essential Idea 2	The average kinetic energy of the molecules of an ideal gas is proportional to the absolute temperature of the gas. $E = 3kT/2 = ½\ m\bar{v}^2$

	The mean square speed of the molecules is directly proportional to the absolute temperature of the gas. This equation relates the macroscopic variable, temperature of the gas with the microscopic variable, that mean square speed of the molecules.	
Item Stem	By what factor does the Kelvin temperature of the ideal gas change if the translational speed of each molecule of the gas becomes 4 times?	
Correct answer	16	Average KE per molecule of a gas E = ½ $m\bar{v}^2$ = 3kT/2 Here if v becomes 4 times, upon transposing we see that T becomes 16 times. It's the mean square of the speed of the molecules that is directly proportional to Kelvin temperature of the gas.
Distractor 1	4	The speed of the molecules is directly proportional to Kelvin temperature of the gas. This is incorrect concept.
Distractor 2	8	It's the mean square of the speed of the molecules and not 2 times the average speed that is directly proportional to Kelvin temperature of the gas. This is incorrect answer.
Distractor 3	1	The average speed of the molecules has no dependence on the kelvin temperature. This is incorrect statement.

Chapter name	14. Oscillations
Essential Idea 1	A loaded spring in vertical direction undergoes simple harmonic motion with angular frequency, $\omega = \sqrt{\frac{k}{m}}$, where $\omega = 2\pi f$

Item stem	An electronic equipment is placed on a platform supported by 4 identical vertical springs each of spring constant 1000 N/m as shown.  If the platform weighs 3 kg and the equipment weighs 5 kg, what is the frequency of vibration of the system of the springs?	
Marking Rubric		
Part	Description	Marks
A possible complete answer:	Mass supported by each spring = (3+5)/4 = 2 kg Frequency of vibration of each spring: $f = \frac{1}{2\pi}\sqrt{\frac{k}{m}} = \frac{1}{2\pi}\sqrt{\frac{1000}{2}}$ f = $5\sqrt{5}/\pi$ Hz	2
Stepwise break up	The weight gets divided equally across the 4 identical springs. Mass supported by each spring = (3+5)/4 = 2 kg Correct formula and final result.	1 1

	$f = \frac{1}{2\pi}\sqrt{\frac{k}{m}} = \frac{1}{2\pi}\sqrt{\frac{1000}{2}}$ f = 5√5/π Hz	

Essential Idea 2	The displacement of the object in simple harmonic motion is given as y = A sin (ωt+φ), where y is the displacement of the particle at time t, A is the amplitude, ω is the angular frequency of the particle in SHM. The augment (ωt+φ) represents phase angle of a particle in SHM with respect to mean position.	
Item Stem	Given two objects in SHM along the same straight line with same amplitude A and angular frequency ω. What is the phase difference between these two objects if they cross each other every time their displacement is half the amplitudes, while moving in opposite directions?	
Correct answer	120	In SHM, y = A sin (ωt+φ) = A/2 (ωt+φ) = $\sin^{-1}$ ½ (ωt+φ) is the phase angle is either 30 or 150 So if one object has a phase angle of 30, the second object has a phase angle of 150. The phase difference between the two objects is 120
Distractor 1	30	This is phase angle of first object. Phase difference is the difference in phase angle of the two objects in motion. This is incorrect.
Distractor 2	150	This is phase angle of second object. Phase difference is the difference in phase angle of the two objects in motion. This is incorrect.
Distractor 3	0	Since they cross each other, they are at same angular displacement with respect to mean position. This is incorrect.

Chapter name	15. Waves	
Essential Idea 1	Standing waves are produced in closed pipes due to reflection and superposition of the waves. Only odd harmonics or frequencies are possible in case of closed pipes, $f = n\ \frac{v}{4L}$, with n = 1, 3, 5,...	
Item stem	A tuning fork of frequency 170 Hz is vibrated just above a closed cylindrical tube of length 200 cm. Water is slowly poured into the tube. What is the minimum height of the water column in the tube at which the resonance is heard in the tube? Take v = 340 m/s at room temperature.	
Marking Rubric		
Part	Description	Marks
A possible complete answer:	For resonance with closed pipe, $f = n\ \frac{v}{4L}$, with n = 1, 3, 5,... L = $n\ \frac{v}{4f}$ = 50n cm So the possible lengths of the air column for resonance = 50 cm, 150 cm, 250 cm, etc Length of the air column = Length of tube – Height of the water column For the height of the water column to be minimum, the maximum possible length of the air column possible within the closed tube, that is 150 cm. So 150 = 200 – h h = 200 – 150 = 50 cm	3

Stepwise break up	Correct formula and calculation of possible length of the air column at which resonance is produced. For resonance with closed pipe, $f = n\ \frac{v}{4L}$, with n = 1, 3, 5,... L = $n\ \frac{v}{4f}$ = 50n cm So possible lengths of the air columns for resonance = 50 cm, 150 cm, 250 cm, etc	1
	State the relation between Tube length, air column and the water column. Identify the correct minimum condition. Length of the air column = Length of tube – Height of the water column For the height of the water column to be minimum, the maximum possible length of the air column possible within the closed tube, that is 150 cm.	0.5 0.5
	Final result, So 150 = 200 – h h = 200 – 150 = 50 cm	1

Essential Idea 2	A general wave equation for a progressive wave along a stretched string is given as: y = A sin 2π $\left[\frac{t}{T} - \frac{x}{\lambda}\right]$ where A is the amplitude of the wave T is the time period of the wave λ is the wavelength of the wave along the stretched string.
Item Stem	A vibrating stretched string is denoted by wave equation, y = 2 sin 2π $\left[\frac{t}{0.01} - \frac{x}{100}\right]$, here y and x are in cm and t in seconds. Identify the incorrect statement.

Correct answer	Wave is propagating along negative x-axis	This is incorrect statement. Since there is minus sign between t and x term, the wave is progressing along + x- axis. This is the correct option.
Distractor 1	The time period of the wave is 1/100 s	Comparing with equation of general wave motion, y = A sin $2\pi\left[\frac{t}{T}-\frac{x}{\lambda}\right]$ T = 0.01 s = 1/100 s So this is correct statement. This is incorrect option.
Distractor 2	Wavelength of the wave is 1 m	Comparing with equation of general wave motion, y = A sin $2\pi\left[\frac{t}{T}-\frac{x}{\lambda}\right]$ λ = 100 cm = 1 m So this is correct statement. This is incorrect option.
Distractor 3	Velocity of the wave is 100 m/s	Velocity of the wave, v = vλ = λ/T = 1/0.01 = 100 m/s So this is correct statement. This is incorrect option.

10. ESSENTIAL IDEAS WITH SAMPLE QUESTIONS – GRADE 12

Essential ideas and Sample questions

Chapter name	1. Electric charges and fields

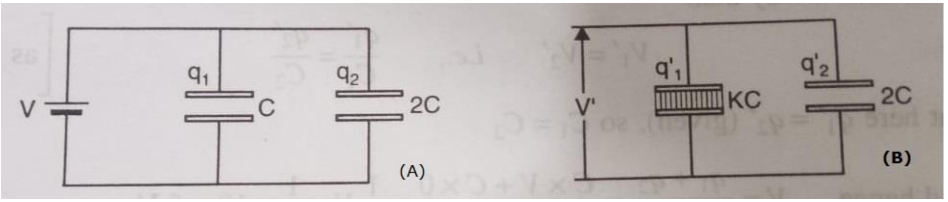
<table>
<tr><td>Essential Idea 1</td><td colspan="2">Gauss' law states that electric flux through a closed surface is $1/\varepsilon_o$ times the charge enclosed by that surface. This law is useful in determining the electric field due to symmetric and continuous charge distributions like a infinite line of charge or charged spherical shell, etc..</td></tr>
<tr><td>Item stem</td><td colspan="2">A long charged wire of radius a and linear charge density λ is placed coaxially inside a hollow cylinder of radius b and length L.


What is electric field in the space around the wire within the cylinder?</td></tr>
<tr><td colspan="3">Marking Rubric</td></tr>
<tr><td>Part</td><td>Description</td><td>Marks</td></tr>
<tr><td>A possible complete answer:</td><td>Applying Gauss' Law to a cylindrical surface of radius r, such that
a < r < b, the line of charge lying along its axis,
$\oint E.\Delta S = \frac{q}{\epsilon_o}$
E. 2πrL = $\frac{\lambda L}{\epsilon_o}$
E = $\frac{\lambda}{2\pi r \epsilon_o}$
which is same as that due to a wire and is independent of the presence of the cylinder around the wire.</td><td>2</td></tr>
<tr><td>Stepwise break up</td><td>Identifying Gaussian surface and applying Gauss law:</td><td>1</td></tr>
</table>

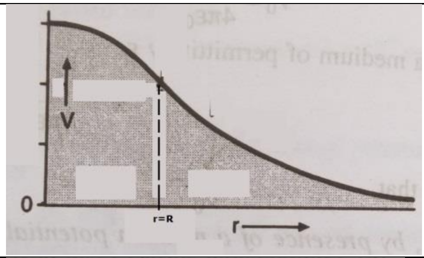
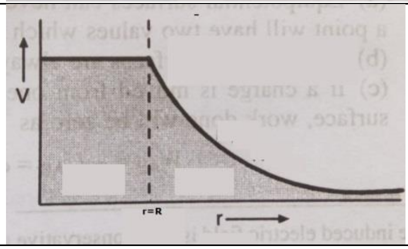
	$\oint E.\Delta S = \frac{q}{\epsilon_o}$	
	Substituting and getting the final result.. E. 2πrL = $\frac{\lambda L}{\epsilon_o}$ E = $\frac{\lambda}{2\pi r\epsilon_o}$ which is same as that due to a wire and is independent of the cylinder present around the wire.	1

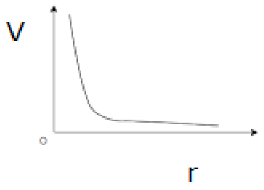
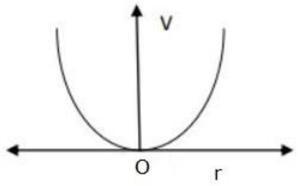
Essential Idea 2	The mutual electrostatic force between a pair of charges is directly proportional to product of charges and inversely proportional to square of the distance between them. This is Coulomb's law. If multiple Coloumb's forces due to multiple charges present around it act upon a charge, then the net force on the charge is the vector sum of the individual forces. This is as per the Superposition principle of electrostatic forces.	
Item Stem	Five corners of a regular hexagon of each side *a* has a static charge *q*. There is no charge located at the 6th corner of the hexagon. The net force on a single charge $-q$ placed at the geometric centre of the hexagon is	
Correct answer	$\frac{1}{4\pi\epsilon_o}\frac{q^2}{L^2}$	Since only 5 corners of hexagon have charges, 4 of these diametrically opposite placed charges balance their forces, The charge –q at the center experiences a net force due to only one charge placed at the 5th corner. $\frac{1}{4\pi\epsilon_o}\frac{q^2}{L^2}$ [Note that in a regular hexagon, side of each side is also same as distance between the center and corner/edge.]
Distractor 1	Zero	Forces get cancelled out due to the 5 charges placed along the 5 corners of the hexagon. This is incorrect, as the not all 5 charges are diametrically opposite to each other. Force due to one charge remains non-cancelled. This is incorrect option.

Distractor 2	$5x\frac{1}{4\pi\epsilon_o}\frac{q^2}{L^2}$	Force on charge at the center is 5 times the force due to each charge. This is incorrect as due to superposition principle on the Coulomb's forces, the vector addition results in only one non-cancelled force. This is incorrect option.
Distractor 3	$\frac{1}{4\pi\epsilon_o}\frac{q^2}{(\frac{L}{2})^2}$	The distance between the center of the hexagon and the corner is taken as L/2. This is incorrect as the distance is L. This is incorrect option.

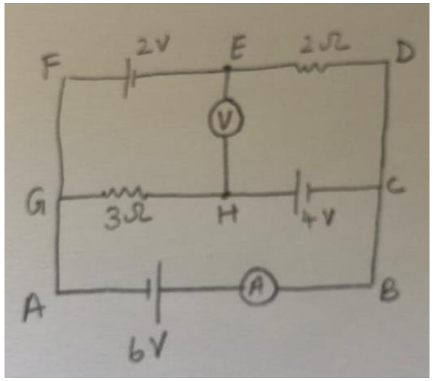
Chapter name	2. Electrostatic potential and capacitance	
Essential Idea 1	The capacitors when connected in parallel have same potential difference and the charge on each gets distributed in inverse proportion to their capacitances. Introduction of a dielectric of dielectric constant K into a capacitor increases its capacitance K times.	
Item stem	Fig (A) represents two capacitors C and 2C connected in parallel when connected to an external battery V. Fig (B) represents two capacitors C and 2C after they are disconnected from the external battery and a dielectric of dielectric constant K introduced in capacitor C.  What is the potential difference V' across the capacitors C and 2C in fig (B)?	
Marking Rubric		
Part	Description	Marks

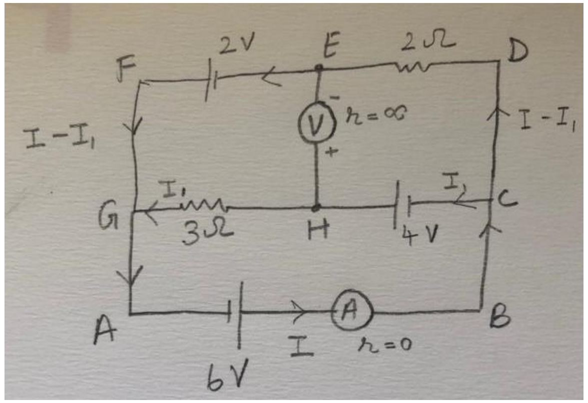
A possible complete answer:	When connected to V, Total charge on capacitors connected in parallel, $q = q_1 + q_2 = CV + 2CV = 3CV$ When disconnected from V and a dielectric introduced in C, Total charge $q' = q$ Total capacitance of the two capacitors in parallel, $C' = KC + 2C = (K+2)C$ Final potential across the combination $V' = \frac{q'}{C'} = \frac{3CV}{(K+2)C} = \frac{3V}{(K+2)}$	3
Stepwise break up	Find the total charge in combination when connected to external battery. Total charge on capacitors in parallel, $q = q_1 + q_2 = CV + 2CV = 3CV$	1
	Find the total charge and capacitance in combination when connected to external battery and with a dielectric in C. Total charge $q' = q$ Total capacitance $C' = KC + 2C = (K+2)C$	0.5 0.5
	Find the final potential difference across the new combination: $V' = \frac{q'}{C'} = \frac{3CV}{(K+2)C} = \frac{3V}{(K+2)}$	1

Essential Idea 2	Electric potential, V(r) at a point is the work done in order to bring a point charge from infinity to that point in the presence of an electric field. Electrostatic potential at infinity with respect to a source charge is taken as zero. The potential at a point with position vector r from the source charge Q is V(r) = $\frac{1}{4\pi\epsilon_0}\frac{q}{r^2}$ The variation of V(r) with respect to position r depends upon whether the source charge is a point charge, a dipole, a charged conducting solid sphere, a charged insulated solid sphere, etc.	
Item Stem	Each of the graphs below represents the variation of electrostatic potential with distance in the region around a source charge, that is, either a point charge or a continuous charge distribution. Identify the most relevant V(r) *vs.* r graph due to a uniform charged insulated sphere.	
Correct answer		This is V(r) *vs.* r graph due to a charged insulated sphere of radius R. For points r < R, V(r) depends inversely on radius of sphere and also on charge distribution across the radial distance of the sphere. V(r) falls as 1/r for points beyond r > R. This is the correct option.
Distractor 1		This is V(r) vs r graph due to a charged conducting sphere of radius R. V(r) is constant inside a conducting sphere (till r= R) and beyond r > R, the potential V(r) falls as 1/r. This is incorrect option.

Distractor 2		This graph represents V(r) falls as 1/r..that is true for a point charge. This is incorrect option.
Distractor 3		This is V(r) graph for an electric dipole, where r is the perpendicular distance from the center of the dipole. This is incorrect option.

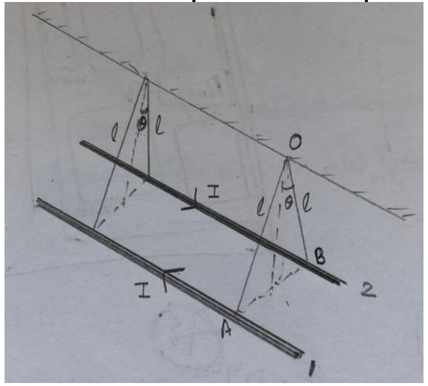
Chapter name	3. Current Electricity
Essential Idea 1	Kirchhoff's rules help analyse electric circuits. The junction rule is based on the fact that charge cannot accumulate at any point along the circuit or a junction.

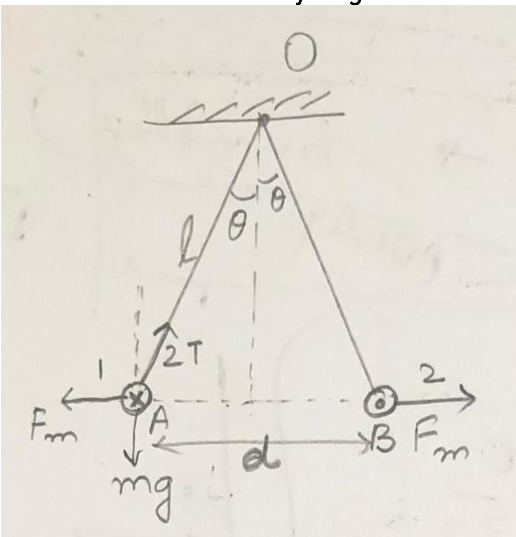
<table>
<tr><td></td><td colspan="2">The voltage loop rule is based on the fact that electric potential depends upon the location in the circuit. So in a closed loop, if the start and the end of the loop is the same, the total change in potential through the loop is zero.</td></tr>
<tr><td>Item stem</td><td colspan="2">The voltmeter and the ammeter connected in the given circuit are ideal. What will be their readings in this circuit?
</td></tr>
<tr><td colspan="3">Marking Rubric</td></tr>
<tr><td>Part</td><td>Description</td><td>Marks</td></tr>
<tr><td>A possible complete answer:</td><td>The current flow through the circuit :</td><td>3</td></tr>
</table>

	 Ideal voltmeter has infinite resistance. Ideal ammeter has zero resistance. Applying Kirchhoff's rule to loop ABCHGA: $6+4-3I_1 = 0$ Solving, $I_1 = 10/3$ A This is the ammeter reading. Applying Kirchhoff's rule to loop FEHGF: $-2 + V - 3I_1 = 0$ V = 12 volt. This is voltmeter reading.	
Stepwise break up	Representing correct directions of currents and taking correct resistances and voltage across an ideal voltmeter and an ideal ammeter.	1

	Applying Kirchhoff's voltage rule to the loop and finding current through the ammeter.	1
	Applying Kirchhoff's voltage rule to the loop and finding voltage across the voltmeter.	1

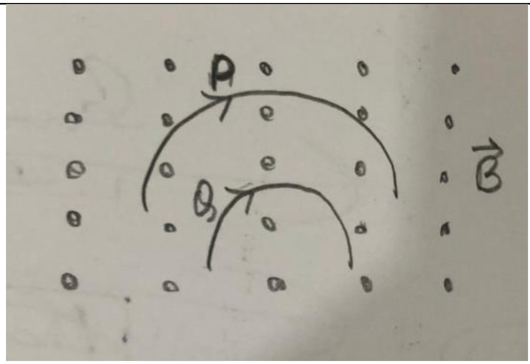
Essential Idea 2	Power dissipated by a battery source V through an external resistor R is given as V^2/R. Power dissipated through a resistor depends upon how much current is drawn from the power source. If a current I flows through a resistor, the power dissipated is also given as I^2R.	
Item Stem	Power P_s is dissipated through a series combination and power P_p is dissipated through the parallel combination of 3 equal resistors. The ratio of P_p to P_s is	
Correct answer	9	Equivalent $R_s = 3r$ Power dissipated by battery of Voltage V in series combination is $P_s = V^2/3r$ Equivalent $R_p = r/3$ Power dissipated by battery of Voltage V in parallel combination is $P_p = V^2/(r/3)$ $P_p/P_s = 9$ This is correct option.
Distractor 1	1/9	If Power in each combination is taken as I^2R_{eq}, the ratio of $P_p/P_s = 1/9$. This is incorrect as the current through the combination is different. Hence cannot use $P = I^2R_{eq}$ This is incorrect option.
Distractor 2	1	Power dissipation does not depend upon the nature of combination of resistors. This is incorrect option.
Distractor 3	6	Calculation mistake while transposing or taking the ratio. This is incorrect option.

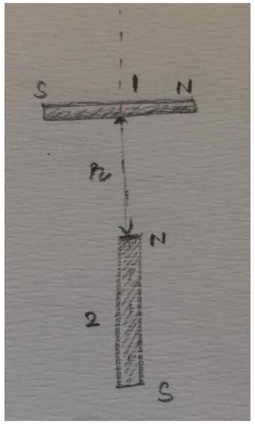
Chapter name	4. Moving charges and magnetism	
Essential Idea 1	Current flowing through a pair of parallel wires exert magnetic forces on each other. If the currents are in same direction, the two wires attract each other. If the currents are in opposite directions, the two wires repel each other. The force per unit length of the wire is given as: F = $\frac{\mu_o}{2\pi}\frac{I^2}{d}$, where d is the perpendicular distance of separation between the two current carrying wires.	
Item stem	Two long wires 1 & 2, each of linear mass density of λ, carry same current I in opposite directions. They lie in the same horizontal plane and each wire is suspended from a parallel support by means of a pair of non-stretchable strings of equal lengths l as shown.  Due to the magnetic force of repulsion between the two current carrying wires, they are oriented at a small angle θ of separation with respect to each other as shown in the figure. Find the angle θ.	
Marking Rubric		
Part	Description	Marks

A possible complete answer:	Consider length of each wire l and distance of separation as d when the angular separation is θ. T is the tension along each string. We can draw the free body diagram of the two wires as:  Balancing the forces on each wire in vertical and horizontal directions, $2T\cos\theta = mg = \lambda lg$ $2T\sin\theta = F_m = \frac{\mu_o}{2\pi}\frac{I^2 l}{d}$ $\tan\theta = \frac{\mu_o}{2\pi}\frac{I^2}{\lambda dg} = \frac{\mu_o}{2\pi}\frac{I^2}{\lambda g.2l\sin\theta}$ since θ is small, $\tan\theta \sim \sin\theta \sim \theta$ so $\theta^2 = \frac{\mu_o}{4\pi}\frac{I^2}{\lambda lg}$	3

	$\theta = \sqrt{\frac{\mu_o}{4\pi}\frac{I^2}{\lambda lg}} = I\sqrt{\frac{\mu_o}{4\pi\lambda lg}}$	
Stepwise break up	Breaking up the problem into a free body problem, drawing the free body diagram and representing the forces and angles.	1
	Writing the balancing force equations in horizontal and vertical directions: $2T\cos\theta = mg = \lambda lg$ $2T\sin\theta = F_m = \frac{\mu_o}{2\pi}\frac{I^2 l}{d}$	1
	Assuming small angle and simplifying to get the final equation in terms of l, λ and I.	1

Essential Idea 2	A particle of mass *m* carrying a charge *q* when enters a magnetic field *B* with speed *v*, executes a circular motion under the effect of magnetic force that acts perpendicular to its velocity. The magnetic force provides for the necessary centripetal force and hence its trajectory is circular in nature. The radius of this path is given as $r = mv/qB$.
Item Stem	Two charged particles each carrying same charge q, but of different masses m_p and m_q enter the magnetic field B with speed v_p and v_q respectively.

	 For the trajectories followed by P and Q as shown, which of the following condition is true?	
Correct answer	$m_p v_p > m_q v_q$	Radius of the trajectory followed by a moving charged particle in a magnetic field is *r = mv/qB*; that is, the radius of the path followed is directly proportional to the momentum (*mv*) of the charged particle. So more the momentum of the charged particle, greater is the radius of the path followed. This is correct option.
Distractor 1	$m_p v_p < m_q v_q$	Greater momentum implies shorter radius of curvature. This is incorrect option.
Distractor 2	$m_p v_p = m_q v_q$	The radius of the path followed is independent of the momentum of the moving charged particle. This is incorrect option.
Distractor 3	$m_p = m_q$ and $v_p = v_q$	Identical charged particles moving with same speeds, follow different trajectories depending upon their points of entry into the magnetic fields. This is incorrect.

Chapter name	5. Magnetism and matter	
Essential Idea 1	The strength of magnetic field along the equatorial line due to a magnetic dipole at a distance of the point that is much larger than the length of the dipole is twice the strength of magnetic field at an axial point at the same distance. Magnetic field at a point due to multiple sources is added vectorially using parallelogram law of vector addition.	
Item stem	Two identical magnetic dipoles each of magnetic dipole moment 2 Am^2 are placed with their axes perpendicular to each other with a distance of separation being r = 2 m between them.  Find the magnetic field at the point that is midway along the distance of separation between the two dipoles.	
Marking Rubric		
Part	Description	Marks

A possible complete answer:	Magnetic field due to magnetic dipole 1 at point O (midway along r) (along the equatorial line) = $B_1 = \frac{\mu_o}{4\pi}\frac{2m}{(r/2)^2}$ Magnetic field due to magnetic dipole 2 at point O (midway along r) (along the axial line) = $B_2 = \frac{\mu_o}{4\pi}\frac{m}{(r/2)^2}$ Net magnetic field at the point: (B_1 and B_2 are perpendicular to each other) $B = \sqrt{B_1^2 + B_2^2} = \frac{\mu_o}{4\pi} m\sqrt{5} = 2\sqrt{5}\ x\ 10^{-7}$ T	3
Stepwise break up	Writing correct formula for magnetic field due to dipole along equatorial line and substituting the correct values	1
	Writing correct formula for magnetic field due to dipole along axial line and substituting the correct values	1
	Finding the resultant magnetic field at a point by applying vector addition rule	1

Chapter name	6. Electromagnetic induction
Essential Idea 1	In case of a translatory motion of a conductor causing the cutting through steady magnetic field lines, results in an induced emf across the ends of the conductor. This emf generated due to motion of conductor in a steady field is known as motional emf, e = Blv
Item stem	A conductor of length l moves with a constant velocity v through Earth's magnetic field. In each of the following cases, identify the component of Earth's magnetic field (B_H or B_V) that it will cut through and determine the induced emf generated across the conductor. a. Conductor ends point along east-west and it moves vertically downwards

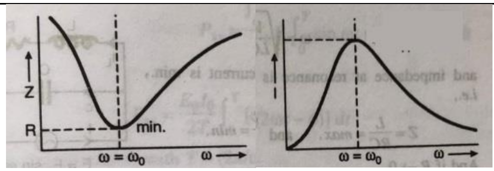
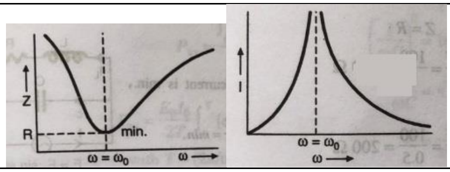
	b. Conductor ends point along north-south and it moves vertically downwards c. Conductor moves in horizontal plane in any direction	
Marking Rubric		
Part	Description	Marks
A possible complete answer:	a. Conductor pointing along east-west cuts through horizontal component of Earth's magnetic field. Flux linked with conductor as it moves through a vertical distance y, $\varphi_H = B_H l y$ Induced emf $e = \frac{d\varphi_H}{dt} = B_H l v$ b. Conductor pointing along north-south will be parallel to both B_H and B_V, hence it will not cut through any flux lines. Flux linked with conductor as it moves through a vertical distance y, $\varphi = 0$ Induced emf $e = \frac{d\varphi}{dt} = 0$ c. Conductor moving in horizontal direction and moving along any direction will cut through B_V only. Flux linked with conductor as it moves through a vertical distance y, $\varphi_V = B_V l y$ Induced emf $e = \frac{d\varphi_v}{dt} = B_V l v$	3

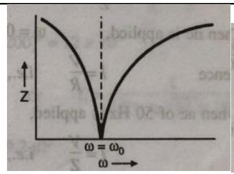
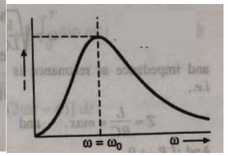
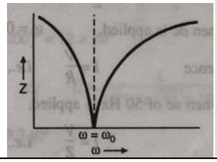
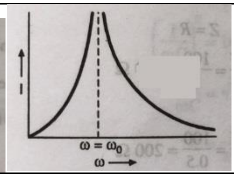
Stepwise break up	Correct identification of the component of Earth's field that the codnuctor cuts through in each case.	0.5 each
	Calculation and final expression for induced emf in each case.	0.5 each

Essential Idea 2	The changing current in coil 2 induces an emf in coil 1 that is nearby, such that the mutual inductance between this pair of coils is defined as: $e = M_{12}\, dI/dt$ The mutual inductance is the function of the dimensions and other physical parameters of the pair of coils and the rate at which the current changes in one of the them.	
Item Stem	The coefficient of mutual inductance between a pair of coils is equal to the induced emf produced in one coil. This is possible in case,	
Correct answer	the rate of change in current in the second coil is 1 A/s	As $e = M_{12}\, dI/dt$ If dI/dt = 1 A/s in the second coil, the mutual inductance between the two coils is equal to induced emf in the first coil. This is correct option
Distractor 1	the current in the second coil is 1 A	A steady current cannot induce emf in the neighbouring coil. This is incorrect option.
Distractor 2	the current in the second coil changes from 1 A to 2 A in 1 minute	The rate of change in current in the coil 2 = 1A/60 s = 1/60 The induced emf in coil 1 is not equal to M_{12}. This is incorrect option
Distractor 3	the currents in both the coils is 1 A	The current in one of the coils has to change, Or else there will be no induced emf. This is incorrect option.

Chapter name	7. Alternating current	
Essential Idea 1	For an AC circuit with a resistor and a capacitor, the total reactance offered to the current is given by Z = $\sqrt{R^2 + \frac{1}{(C\omega)^2}}$. where $1/C\omega$ is the capacitive reactance X_c offered by the capacitor. The current in the circuit leads the voltage by $\pi/2$.	
Item stem	A 100W, 100V bulb is to be connected to AC mains supply of 200 V, 50 Hz. Suggest a suitable capacitor that should be connected in series with the bulb so that the bulb lights up without burning out.	
Marking Rubric		
Part	Description	Marks
A possible complete answer:	For the bulb of the given rating, Resistance R of the bulb = V^2/P = 100 x 100 / 100 = 100 ohm Maximum current that can flow through this bulb, I = P/V = 100/100 = 1 A In the RC series circuit, Total reactance offered by the RC circuit to 1 A of the current is Z = V/I = 200 / 1 = 200 ohm Also Z = $\sqrt{R^2 + \frac{1}{(C\omega)^2}}$ Substituting for Z and R and ω = 50, solving for C, we get, C = $100/\pi$ F	3
Stepwise break up	Solving for the resistance and maximum current that can flow through the bulb.	0.5 mark each

	Finding the total impedance in the RC circuit, Z = 200 ohm	0.5 mark
	Substituting for Z and finding C using the formula, $Z = \sqrt{R^2 + \frac{1}{(C\omega)^2}}$ Calculating and finding the final result	0.5 mark 1 mark

Essential Idea 2	In the LC circuit, at resonance, the net impedance is zero and the current is infinite. In LCR series circuit connected to AC supply, the impedance at resonance is minimum and equal to resistance of the circuit and the current in the circuit is maximum and is equal to V_o/R.	
Item Stem	In case of series LCR circuit connected to AC supply, under the resonance condition at frequency $\omega = \omega_o$, the inductive reactance equals capacitive reactance thereby resulting in the minimum of the net impedance and the maximum of the current in the circuit. Identify the correct pair of graphs of impedance and current as a function of frequency in the LCR series AC circuit.	
Correct answer		The impedance of the circuit is minimum at resonance condition and is equal to resistance in the circuit. The current in the circuit is maximum as the impedance is minimum. Current I_o = V_o/Z = V_o/R = Maximum. So the second graph for current is correct. This option is correct.
Distractor 1		The impedance graph is correct. The current graph is incorrect as it depicts the current through LCR circuit to be infinite to resonance. That's not possible in LCR series AC circuit. This is an incorrect option.

Distractor 2		The impedance graph shows the value of Z = 0 at resonance in series LCR cicruit. That's incorrect. The current graph is correct. This is an incorrect option.
Distractor 3		Both the impedance and current graphs are incorrect. At resonance, Z = 0 and current is infinite. These values are incorrect. This option is incorrect.

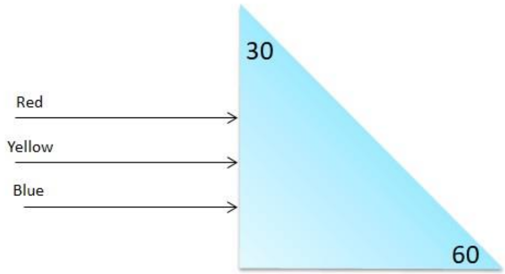
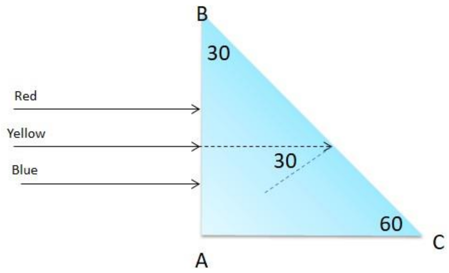
Chapter name	8. Electromagnetic waves
Essential Idea 1	The equation of each of the time varying electric and magnetic fields in a progressive electromagnetic wave are given by the equations: E = $E_o \cos [\frac{2\pi}{\lambda}(x - ct)]$ B = $B_o \cos [\frac{2\pi}{\lambda}(x - ct)]$ If the em wave is travelling along x axis, and electric field vector is along y axis, and the magnetic field vector is aligned perpendicular to both x axis and y axis.
Item stem	A certain electromagnetic wave travels through an empty space at a frequency of 1 GHz. The oscillating electric field attains peak value E_o = 50 V/m at a certain point O. a. What is the wavelength of the wave? b. What is B_o at point O? c. Write the equations for the electric and magnetic fields as a function of x and t near point O. Considering the direction of the wave along x-axis and electric field vector is along y axis, include the directions in the respective wave equations of E and B.
Marking Rubric	

Part	Description	Marks
A possible complete answer:	a. Wavelength, $\lambda = c/v = 3 \times 10^8 / 10^9 = 0.3$ m b. Peak value of magnetic field $B_o = E_o/c = 50/3 \times 10^8 = 16.6 \times 10^{-8}$ T c. The wave equations for E and B: $E = E_o \cos [\frac{2\pi}{\lambda}(x - ct)]$ $\vec{E} = 50 \cos [\frac{2\pi}{0.3}(x - 3\ x\ 10^8 t)]\ \hat{j}$ $\vec{B} = 16.6 \times 10^{-8} \cos [\frac{2\pi}{0.3}(x - 3 \times 10^8 t)]\hat{k}$	3
Stepwise break up	a. Calculation of wavelength using $\lambda = c/v$	0.5
	b. Calculation of the peak value of magnetic field	0.5
	c. Writing the wave equation of E with correct unit vector Writing the wave equation of B with correct unit vector	1 1

Essential Idea 2	Electromagnetic waves transport both energy U and momentum p. Electric and magnetic fields carry equal amounts of energy in an em wave. When em waves strike a surface they exert pressure on it, thereby transferring momentum to the surface upon which the em waves strike. Momentum transferred to the surface is given as, $p = U/c$.
Item Stem	A 70 kg astronaut stranded in space chooses to use his flashlight to move himself. If his flashlight can flash a 12 W light beam in space in a fixed direction so that he acquires momentum in the opposite direction, how much time do you think will he take to attain a speed of 2 m/s ?

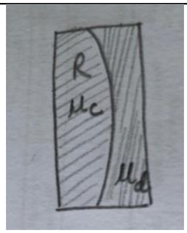
Correct answer	3.5×10^9 s	Energy radiated by flashlight in 1 second = 12 joule Momentum generated, p = U/c = 12/3 x 10^8 = 4 x 10^{-8} kgm/s Force exerted on his body every one second = p/t = 4 x 10^{-8} /1 = 4 x 10^{-8} N Using F = m(v-0)/t t = 70 x 2 / 4 x 10^{-8} = 35 x 10^8 s t = 3.5 x 10^9 s This is the correct option
Distractor 1	11.6 s	Equating, gain in KE to Power x time This is incorrect concept for relativistic speeds. This is incorrect option
Distractor 2	3.8×10^{-8} s	Taking incorrect equation: p = Uc This is incorrect option
Distractor 3	Infinite	Considering the low power of flashlight, the astronaut will take infinite time to gain the speed of 2m/s This is incorrect option

Chapter name	9. Ray optics and optical instruments
Essential Idea 1	Critical angle θ_c is the angle of incidence in the denser medium for which the angle of refraction in the rarer medium is 90°. For angle of incidence greater than θ_c, the light ray is total internally reflected back into the denser medium. This is the principle that is used by reflecting prisms.

Item stem	Red, yellow and blue lights travel together as a beam and fall on right-angled prism. Given the refractive indices of these colours with respect to the glass of the prism as 1.41, 1.72, 2.12 respectively. Which of the colours pass through the prism and which ones get reflected back?  	
Marking Rubric		
Part	Description	Marks
A possible complete answer:	If incident ray is normal to side AB, then the angle of incidence on the emergent side BC as per geometry is 30°.  The side BC will not transmit the ray if angle i > critical angle $i > \theta_c$	3

	sin i > sin θ_c sin 30 > 1/μ 0.5 > 1/μ μ > 2 The red light has μ = 1.41 < 2, So it will pass through BC surface. The yellow light has μ = 1.72 < 2, So it will pass through BC surface. The blue light has μ = 2.12 > 2, So it will get total internally reflected back from the surface BC.	
Stepwise break up	Identify the condition of total internal reflection for the given prism	0.5
	Find the limiting value of refractive index of colour of light that will get total internally reflected	1
	Compare the limiting value of refractive index with each of refractive indices of the three colours and identify the colour that will pass and the colour of light that will get total internally reflected	0.5 mark each

Essential Idea 2	Any pair of lens when placed together makes a lens combination. The reciprocal of focal length of such a combination is given as sum of reciprocals of respective focal lengths. $\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2}$ Lens maker formula is applied to each component lens independently. $\frac{1}{f} = (\mu - 1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$
Item Stem	A plano-convex lens of refractive index μ_c = 1.7 and a plano-concave lens of refractive index μ_d = 1.5, are combined as shown so as to construct a plane glass plate.

	 If the radius of curvature of the curved side of both the lens is same, which of the following system will the glass plate function as?	
Correct answer	Convergent system with positive focal length	Lens maker formula to each lens: $\frac{1}{f_c} = (\mu_c - 1)\left[\frac{1}{\infty} - \frac{1}{-R}\right] = \frac{\mu_c - 1}{R}$ $\frac{1}{f_d} = (\mu_d - 1)\left[\frac{1}{-R} - \frac{1}{\infty}\right] = \frac{-(\mu_d - 1)}{R}$ For a lens combination $\frac{1}{F} = \frac{1}{f_c} + \frac{1}{f_d}$ $F = \frac{R}{\mu_c - \mu_d}$ Since $\mu_c > \mu_d$, F is positive. So the system behaves convergent. This is correct option.
Distractor 1	Divergent system with negative focal length	Since the plano-concave lens comes as the second lens, the refracting rays out of the system diverge, hence the system behaves as divergent with negative focal length. This is incorrect option.
Distractor 2	Plane glass slab with zero focal length	Plano-convex and a plano-concave lens combine to form plane glass slab with zero focal length. This is incorrect option.
Distractor 3	Plane glass slab with infinite focal length	Plano-convex and a plano-concave lens combine to form plane glass slab with infinite focal length. This is incorrect option.

Chapter name	10. Wave optics	
Essential Idea 1	Fringe width of each of the fringes produced in Young's double slit experiment is written as $\beta = \frac{D\lambda}{d}$ Fringe width is directly proportional to the distance D between the slits and the screen and inversely proportional to the distance d between the slits.	
Item stem	In Young's double slit experiment, if the screen is moved towards the slits through 2 x 10^{-2} m the fringes become narrower by 2 x 10^{-5} m. If the distance between the slits is 10^{-3} m, find the wavelength of the light used in this experiment.	
Marking Rubric		
Part	Description	Marks
A possible complete answer:	As fringe width is given as $\beta = \frac{D\lambda}{d}$ The changes in fringe width and distance between slits and screen can be written as: $\Delta\beta = \frac{\Delta D\ \lambda}{d}$ $2 \times 10^{-5} = 2 \times 10^{-2} \times \lambda/10^{-3}$ $\lambda = 10^{-6}$ m = 10000 $\dot{A}$	2
Stepwise break up	Formula of fringe width and its correct form in terms of changes in D and β	1
	Substitution and calculation of final result	1

Essential Idea 2	In a single slit diffraction, the direction of central maxima is given by $d\sin\theta = n\lambda$ For the single slit diffraction, a central maxima followed by alternate dark and bright bands of equal widths on its either side on the screen, and the most suitable condition is $\lambda < d$	
Item Stem	In which of the following cases will the diffraction due to a single slit of width d due to light of wavelength λ, result in a general illumination of the screen and no distinction between dark and bright fringes are observed on the screen? (i) $\lambda \ll d$ (ii) $\lambda < d$ (iii) $\lambda = d$	
Correct answer	In (iii) only	When $\lambda = d$, the central maxima extends from $-\pi/2$ to $\pi/2$. So neither dark or bright bands are seen. Instead a general illumination of the screen is observed. This is correct option.
Distractor 1	In both (i) and (ii)	For $\lambda \ll d$, there is no diffraction as $\sin\theta \rightarrow \theta \rightarrow 0$, a bright image of slit is seen on the screen. For $\lambda < d$, a diffraction pattern of central maxima with alternate dark and bright bands are seen on the screen. This is incorrect option.
Distractor 2	In (ii) only	For $\lambda < d$, a diffraction pattern of central maxima with alternate dark and bright bands are seen on the screen. This is incorrect option.
Distractor 3	In both (ii) and (iii)	For $\lambda < d$, a diffraction pattern of central maxima with alternate dark and bright bands are seen on the screen. For $\lambda = d$, a general illumination of the screen is seen. This is incorrect option.

Chapter name	11. Dual nature of radiation and matter	
Essential Idea 1	Work function of the metal surface is the minimum energy required for the electron to escape the surface. If the electron absorbs energy greater than the minimum quantum required to escape, it means that the incident photon carries energy greater than the work function of the metal and, the excess energy is retained by the emitted photoelectron as its kinetic energy. This relation is expressed as Einstein photoelectric equation: $KE_{max} = hv - \varphi_o$ $\frac{hc}{\lambda} = \emptyset_o + \frac{1}{2}mv^2$	
Item stem	Lights of wavelengths 3000 $\dot{A}$ and 6000 A fall on a metallic surface and release photoelectrons with maximum speeds that are in ratio 3 : 1 respectively. What is the work function of the metal surface? Take h = 6.6 x 10^{-34} J.s	
Marking Rubric		
Part	Description	Marks
A possible complete answer:	From Einstein's photoelectric equation, $\frac{hc}{\lambda} = \emptyset_o + \frac{1}{2}mv^2$ For $\lambda_1 = 3000\dot{A}$, $\frac{hc}{\lambda_1} = \emptyset_o + \frac{1}{2}m(3v)^2 = \emptyset_o + \frac{9}{2}mv^2$ ...(1) For $\lambda_2 = 6000\dot{A}$, $\frac{hc}{\lambda_2} = \emptyset_o + \frac{1}{2}mv^2$ .....(2)	2

	Simplifying and transposing the two equations, $\varphi_o = 2.8 \times 10^{-19}$ J	
Stepwise break up	Writing the Einstein equation and substituting the values of λ_1 and λ_2	1
	Simplifying and solving the two equations to find the value of the work function	1

Essential Idea 2	Matter waves are associated with all mass particles, both microscopic and macroscopic. The wavelength associated with the matter particles was given by de Broglie as $\lambda = \frac{h}{mv}$, The de Broglie wavelength associated with matter particles is inversely proportional to the mass and the speed of the particle.	
Item Stem	Matter has dual nature, that is, it has both particle and wave properties. The wave properties of macroscopic objects are not generally observed. This is because:	
Correct answer	The speeds are too small	As de Broglie wavelength associated with a particle, $\lambda = \frac{h}{mv}$, For small speeds and large masses, the value of wavelength associated with macroscopic objects is very small. Hence, not observable. This is correct option.

Distractor 1	The dual nature applies only at atomic scale	Matter waves are associated with all mass particles in motion, both at microscopic and macroscopic level. This is incorrect option.
Distractor 2	The wavelengths are too large	The de Broglie wavelengths associated with macroscopic objects are extremely small and almost non measurable. This is incorrect option.
Distractor 3	The momenta are too small	The momentum associated with macroscopic objects is actually large compared to microscopic sub atomic particles due to their large masses. So as the de Broglie wavelength $\propto 1/p$, it is very small and non-measurable. So this option is incorrect.

Chapter name	12. Atoms	
Essential Idea 1	As per Bohr model of atom, the radius and speed of the electron revolving around the electron orbits depend upon the principal quantum numbers. Considering the Bohr electron orbits to be almost circular, the time period of revolution of electrons in the electron orbits can be written as $T = 2\pi r/v = 4h^3\varepsilon_o^2 n^3/me^4$. This relation implies that time period of revolution of an electron in the electron orbits is directly proportional to n^3.	
Item stem	Considering the Bohr model of atom to be valid, if the time period of revolution of an electron in the state n_1 is 8 times the time period of revolution of the electron in the state n_2 to which it is transitioned to, find the possible values of n_1 and n_2. Here n_1 and n_2 are the principal quantum numbers as per Bohr model of atom.	
Marking Rubric		
Part	Description	Marks

A possible complete answer:	Speed of the electron revolving in an orbit is $\propto 1/n$ Radius of the orbit $\propto n^2$ Time period of the revolving electron in any orbit of Bohr model of atom = T = $2\pi r/v$ This implies that $T \propto n^3$ So $T_{n1} / T_{n2} = \frac{n_1^3}{n_2^3}$ = 8 (as given) So $n_1/n_2 = 2$ $n_1 = 2\ n_2$ The possible values of n_1 and n_2 are: $n_2 = 1$, $n_1 = 2$; $n_2 = 2$, $n_1 = 4$; $n_2 = 3$, $n_1 = 6$ and so on.	3
Stepwise break up	Finding the relation for time period of revolution of the electron in electron orbits as a function of principal quantum number	1
	Substituting and finding the relation between n_1 and n_2	1
	Suggesting the suitable values of n_1 and n_2	1

Essential Idea 2	De Broglie hypothesised that electrons revolving in Bohr orbits are associated with circular standing waves of wavelength, $\lambda = h/mv$ De Broglie hypothesis was extended to all particles in motion. Matter waves are associated with all particles that are in the state of motion and the wavelength of the se matter waves is inversely proportional to mass and speed of the particle.
Item Stem	Read the following statements carefully. a. only charged particles at rest are accompanied by matter waves b. any particle in motion, whether charged or uncharged, is accompanied by matter waves c. the associated wavelength with proton is shorter than that of electron, both moving with same speed d. de Broglie wavelength associated with the matter wave of a charged particle is directly proportional to the potential difference through which it is accelerated

	Identify the correct statements.	
Correct answer	b and c only	Matter waves are associated with any mass particle in motion. Hence statement b is correct. The wavelength of the matter wave is inversely proportional to mass of the particle. Since $m_p > m_e$, So $\lambda_p < \lambda_e$. Hence the statement c is correct. This is correct option.
Distractor 1	a and b only	Not just the charged particle, but any particle that has mass and is in motion is associated with matter waves. So statement a is incorrect. This option is incorrect.
Distractor 2	a, b and d only	de Broglie wavelength associated with a charged particle is inversely proportional to the square root of the potential difference through it is accelerated. So statement d is incorrect. Statement a is also incorrect. This is incorrect option.
Distractor 3	only b is correct	Statement c is also correct as the wavelength of the matter wave is inversely proportional to mass of the particle. Since $m_p > m_e$, So $\lambda_p < \lambda_e$ This is incorrect option.

Chapter name	13. Nuclei	
Essential Idea 1	In a nuclear fusion reaction, two lighter nuclei of mass number A ≤ 10 combine to form heavier nuclei. The binding energy per nucleon of each of the fusing nuclei is lesser than the binding energy per nucleon of the product nucleus formed. More is the binding energy per nucleon greater is the stability of the nucleus, the products formed in the nuclear fusion reactions are more stable than the reactants. The energy is released in nuclear fusion reactions and hence they are exothermic reactions.	
Item stem	In the nuclear fusion reaction, two deuteron nuclei combine to form one alpha particle. ${}_{1}^{2}H + {}_{1}^{2}H \rightarrow {}_{2}^{4}He$ If the binding energy of deuteron is 1.15 MeV per nucleon and binding energy of the alpha particle is 7.1 MeV per nucleon, determine the energy released in the above reaction.	
Marking Rubric		
Part	Description	Marks
A possible complete answer:	Total binding energy of each deuteron nuclei = 1.15 x 2 = 2.3 MeV Total binding energy of the two fusing deuteron nuclei = 2.3 x 2 = 4.6 MeV Total binding energy of the product Helium nuclei formed = 7.1 x 4 = 28.4 MeV The energy released in this fusion reaction: 28.4 – 4.6 = 23.8 MeV	2
Stepwise break up	Calculation of the total binding energy of fusing nuclei and product nuclei	1
	Calculation of energy released in the reaction : BE of the product – BE of reactants	1

Essential Idea 2	The radius of the atomic nucleus is a function of the mass number A of the nucleus as $R = R_o A^{1/3}$ R_o is a constant and A is a mass number This implies that volume of the nucleus is proportional to R^3, where R is a function of A. This also implies that the density of nucleus is independent of the mass number and is constant for all the nuclei of any size.	
Item Stem	Given two atomic nuclei ${}^{27}_{13}Al$ and ${}^{125}_{52}Te$ and the mass of proton M_p = 1.007u and mass of neutron M_n = 1.008u. What is the ratio of the radii of the nuclei ${}^{27}_{13}Al$ to that of ${}^{125}_{52}Te$?	
Correct answer	0.6	Radius of any atomic nucleus, $R \propto A^{1/3}$ So $R_{Al} : R_{Te}$ = $27^{1/3}/125^{1/3}$ $R_{Al} : R_{Te}$ = 3/5 = 6/10 = 0.6 This is the correct option
Distractor 1	0.215	Radius of nucleus $\propto$ Sum of mass of nucleons $R_{Al} : R_{Te}$ = [13 x 1.007 + 14 x 1.008]/[52 x 1.007 + 73 x 1.008] = 0.215 This is incorrect concept. This is incorrect option.
Distractor 2	1.66	Incorrect calculation of the ratio $R_{Al} : R_{Te}$ using the formula $R \propto A^{1/3}$ This is incorrect option
Distractor 3	0.216	If $R \propto A$, $R_{Al} : R_{Te}$ = 27/125 = 0.216 This is incorrect concept. This is incorrect option.

Chapter name	14. Semiconductor electronics: Materials, devices and simple circuits	
Essential Idea 1	A pn junction connected under forward bias condition has a total forward current as a sum of hole current and the conventional current due to electron carriers. The forward bias current is almost negligible for initial forward bias till it reaches a threshold value. Forward bias current rises steeply as soon as the forward bias exceeds the applied threshold voltage.	
Item stem	A forward biased PN junction has a potential drop of 0.4 V across it, that is independent of the current. It can withstand a maximum current of 8 mA, beyond which it will burn out. If this diode is in series with 150 ohm of resistance, find the maximum battery voltage that should be applied when in forward bias.	
Marking Rubric		
Part	Description	Marks
A possible complete answer:	Resistance offered by the diode: R = 0.4 / 8 x 10^{-3} = 50 ohm So total resistance in the circuit = 50 + 150 = 200 ohm The maximum battery voltage allowed: V = 8 x 10^{-3} x 200 = 1.6 volt	2
Stepwise break up	Calculation of the resistance of the diode in forward bias	0.5
	Calculation of total resistance in circuit	0.5
	Finding the maximum battery voltage that can be applied across a forward biased diode	1

13. REFERENCE DOCUMENTS

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3. NCERT textbooks https://ncert.nic.in/textbook.php?keip1=0-8

4. IB Past papers https://ibresources.org/ib-past-papers/

5. HKDSE Past papers https://www.hkeaa.edu.hk/en/hkdse/hkdse_subj.html?A1&1&4_25

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