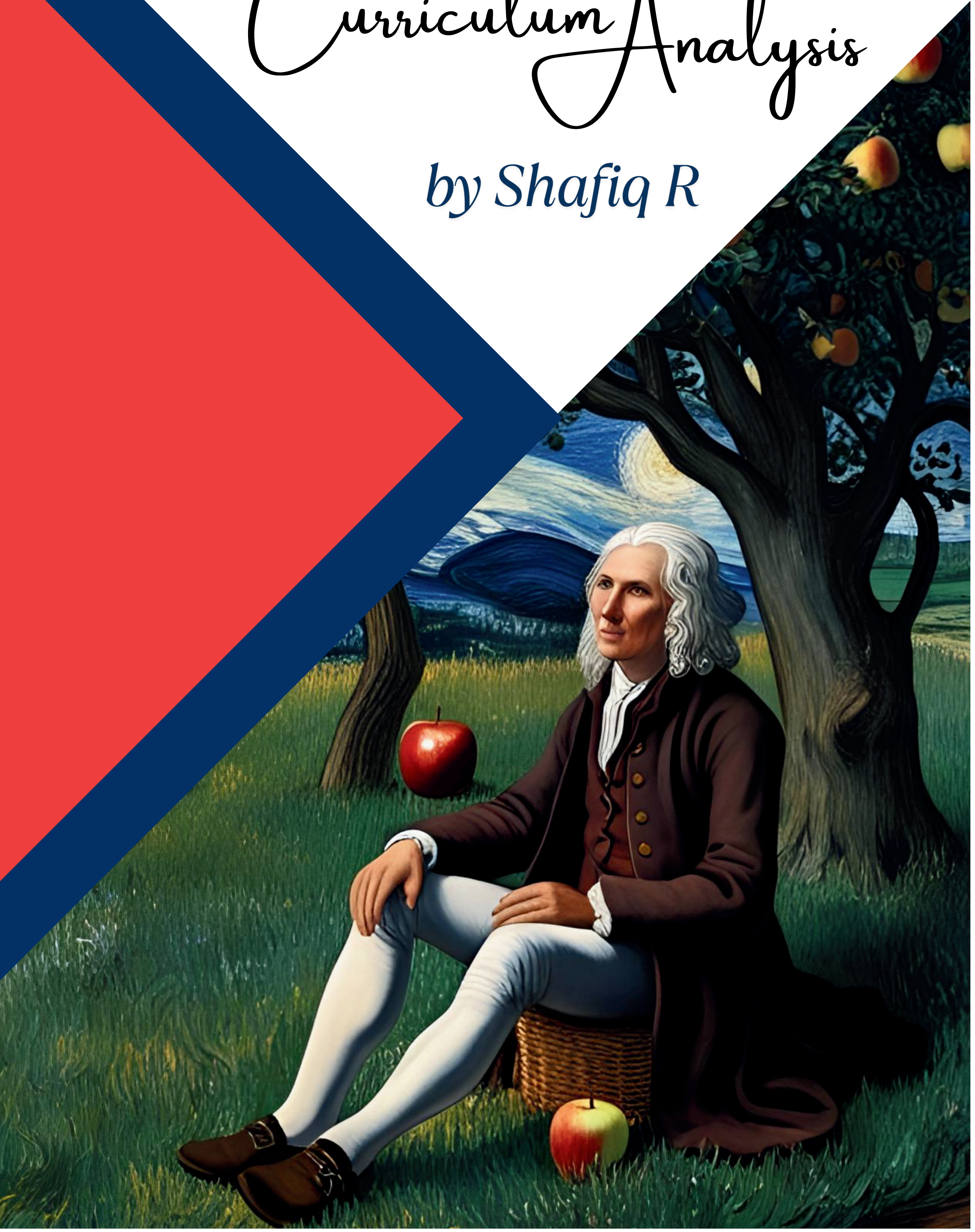
Curriculum Analysis

by Shafiq R



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SP015

Comprehensive Analysis of SP015 Learning Outcomes

SP015 introduces students to the foundational principles of physics through an algebra-based lens, covering mechanics, oscillations, wave behavior, and thermodynamic systems. Designed for college-level learners, this course emphasizes conceptual understanding, mathematical reasoning, and scientific inquiry to explore the fundamental laws that govern motion, force, energy, and matter.

Rooted in 21st-century learning principles, the SP015 curriculum empowers students to think critically, collaborate effectively, and connect physics to everyday experiences and technologies. Students are encouraged to engage with physics as a process — constructing models, analyzing patterns, interpreting data, and solving real-world problems using evidence-based reasoning.

Each chapter is built around explicitly stated learning outcomes, which have been analyzed using Bloom's Revised Taxonomy and aligned with NGSS-inspired scientific practices and Modeling Instruction strategies. Lessons are sequenced into modular 3-day instructional blocks, incorporating inquiry-driven activities, formative assessments, and opportunities for active learning.

By the end of SP015, students will not only develop proficiency in solving physics problems but also gain an appreciation for how physics principles underlie natural phenomena and engineered systems. This course provides a critical foundation for SP025 and other future scientific studies.

Chapter 1: Physical Quantities & Measurements

Learning Outcomes

1. Define dimension of physical quantities.
2. Determine the dimensions of derived quantities.
3. Verify the homogeneity of equations using dimensional analysis.
4. Define scalar and vector quantities.
5. Resolve vector into two perpendicular components (x and y axes).
6. Determine resultant of vectors, limited to three vectors only.

LO	Bloom's Revised Taxonomy	Three-Dimensional Learning	Modeling Instruction	Backward Design (UbD)
Define dimension of physical quantities	Remembering and Understanding	Core Idea: Physical quantities and measurement Scientific Practice: Constructing explanations	Introduce measurement tools and emphasize the role of dimensions in modeling physical phenomena.	Students must understand the foundational concept of physical dimensions, critical for all subsequent topics.
Determine the dimensions of derived quantities	Applying and Analyzing	Core Idea: Relationships among physical quantities Scientific Practice: Using mathematics and computational thinking	Derive dimensions within models to show interconnectedness of physical concepts.	Students should connect base quantities to more complex derived ones, reinforcing conceptual understanding.
Verify the homogeneity of equations using dimensional analysis	Analyzing and Evaluating	Core Idea: Mathematical relationships in physics Scientific Practice: Engaging in argument from evidence	Use dimensional analysis as a modeling validation tool, ensuring consistency within a physical model.	Students will check the validity of equations, crucial for problem-solving and real-world applications.
Define scalar and vector quantities	Remembering and Understanding	Core Idea: Quantities and their properties Scientific Practice: Developing and using models	Model physical situations emphasizing the scalar or vector nature of quantities.	Students must differentiate types of quantities to correctly approach physics problems.
Resolve vector into two perpendicular components (x and y axes)	Applying	Core Idea: Vector operations in two dimensions Scientific Practice: Using mathematics and computational thinking	Emphasize vector decomposition within dynamic and static models.	Students develop skills to handle vectors analytically, foundational for mechanics and other topics.
Determine resultant of vectors, limited to three vectors only	Applying and Analyzing	Core Idea: Force interactions and resultant forces Scientific Practice: Using mathematics and computational thinking	Build vector addition models in physical and graphical representations.	Students must find net effects of multiple vectors, key for understanding force and motion.

Summary Table

Learning Outcome	Bloom's Level	Relevant Physics Practice	Modeling Instruction Perspective
Define dimension of physical quantities	Remembering, Understanding	Constructing explanations	Measurement tools and conceptual models
Determine the dimensions of derived quantities	Applying, Analyzing	Mathematical thinking	Deriving dimensions within models
Verify homogeneity of equations	Analyzing, Evaluating	Argument from evidence	Validating models with dimensional analysis
Define scalar and vector quantities	Remembering, Understanding	Developing models	Modeling scalar and vector properties
Resolve vector into components	Applying	Mathematical thinking	Decomposing vectors in models
Determine resultant of vectors	Applying, Analyzing	Mathematical thinking	Vector addition in models

Unit Plan for Algebra-Based Physics (3 1-hour Lessons)

<table>
<tr>
<td>Lesson 1: Understanding Physical Dimensions

Focus Topic:
Define dimensions of physical quantities; determine dimensions of derived quantities.

Activity Ideas:
• Card-sorting
Match physical quantities to base units.
• Mini-lab: Use measuring tools to identify and record dimensions.

Formative Check
Exit ticket, Provide dimensions for three given physical expressions.</td>
<td>Lesson 2: Dimensional Analysis & Quantity Types

Focus Topic:
Verify homogeneity of equations; define scalar vs vector quantities.

Activity Ideas:
• Peer discussion: Evaluate the homogeneity of sample equations.
• Think-Pair-Share: Classify various quantities as scalar or vector.

Formative Check:
Short quiz, Homogeneity checks and scalar/vector identification.</td>
<td>Lesson 3: Vector Operations

Focus Topic:
Resolve vectors into components; determine resultant of up to three vectors.

Activity Ideas:
• Group whiteboard
Graphical vector decomposition exercises.
• Force-table demo or simulation:
Compute resultant vectors practically.

Formative Check:
Lab worksheet, calculate components and resultant for given vector sets.</td>
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<tr>
<td colspan="3">Active-Learning Techniques & Model-Based Language
• Think-Pair-Share: Encourage students to articulate model components and compare reasoning.
• Peer Instruction: Use clicker questions to probe understanding of model consistency and homogeneity.
• Whiteboarding: Have teams collaboratively build and revise conceptual models of vectors and dimensions.
• Mini-labs: Engage students in hands-on measurement and modeling activities.

Use model-based language such as:
- "Our model predicts that the dimensions must match on both sides of the equation."
- "This term in the model represents the vector component along the y-axis."
- "Let's validate our model by checking the unit consistency."
- "Adjust the model parameters to see how the resultant vector changes."</td>
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Chapter 2: Kinematics of Linear Motion

Learning Outcomes

1. Define instantaneous velocity (and acceleration), average velocity (and acceleration) and uniform velocity (and acceleration)
2. Interpret physical meaning of displacement-time, velocity-time and acceleration-time graphs
3. Determine distance travelled, displacement, velocity and acceleration from appropriate graphs.
4. Derive and apply equations of linear motion with uniform acceleration.
5. Describe projectile motion launched at a zero and non-zero angle.
6. Solve problems related to projectile motion.

LO	Bloom's Revised Taxonomy	Three-Dimensional Learning	Modeling Instruction	Backward Design (UbD)
Define instantaneous velocity (and acceleration), average velocity (and acceleration) and uniform velocity (and acceleration)	Remembering and Understanding.	Core Idea: Motion and Stability: Forces and Interactions. Science Practice: Constructing explanations and defining concepts.	Establishing a conceptual framework through operational definitions; anchoring future models of motion.	Students must first grasp clear definitions to distinguish between related motion concepts, forming a foundation for interpreting motion in later lessons.
Interpret physical meaning of displacement-time, velocity-time and acceleration-time graphs	Understanding and Analyzing.	Core Idea: Representing and interpreting motion. Science Practice: Analyzing and interpreting data.	Graphs are representations of models; use them to connect conceptual and mathematical models of motion.	Students must be able to extract real-world meaning from graphical information, crucial for problem solving and experimental design.
Determine distance travelled, displacement, velocity and acceleration from appropriate graphs.	Applying and Analyzing.	*Core Idea:* Quantitative relationships in kinematics. *Science Practice:* Using mathematics and computational thinking.	Extract quantitative information from graphical representations of physical models.	Students should develop skills in quantitative reasoning through graphical interpretation.
Derive and apply equations of linear motion with uniform acceleration.	Analyzing, Applying, and Creating.	*Core Idea:* Conservation laws and relationships among physical quantities. *Science Practice:* Using mathematics and computational thinking.	Develop motion models from experimental observations; derive equations to represent these models.	Students should not only memorize but derive and understand how equations model physical motion.
Describe projectile motion launched at a zero and non-zero angle.	Understanding and Analyzing.	*Core Idea:* Independence of perpendicular motion components.	Model projectile motion with graphical and mathematical representations emphasizing independence of vertical and horizontal motions.	Students must conceptualize two-dimensional motion by decomposing it into independent motions.

		Science Practice: Developing and using models.		
Solve problems related to projectile motion.	Applying and Evaluating.	*Core Idea:* Quantitative problem solving with vectors and motion. *Science Practice:* Using mathematics and computational thinking.	Solve real-world problems by applying models of two-dimensional motion.	Students apply conceptual understanding and mathematical models to real-world and theoretical scenarios.

Summary Table

Learning Outcome	Bloom's Level	Relevant Physics Practice	Modeling Instruction Perspective
Define instantaneous, average, and uniform velocity/acceleration	Remembering, Understanding	Constructing explanations	Defining operational concepts
Interpret displacement-time, velocity-time, and acceleration-time graphs	Understanding, Analyzing	Analyzing and interpreting data	Graphs as representations of models
Determine distance, displacement, velocity, and acceleration from graphs	Applying, Analyzing	Using mathematics and computational thinking	Extracting quantitative information
Derive and apply equations of motion	Analyzing, Applying, Creating	Using mathematics and computational thinking	Building mathematical models from observations
Describe projectile motion at zero and non-zero angles	Understanding, Analyzing	Developing and using models	Modeling 2D motion components
Solve projectile motion problems	Applying, Evaluating	Using mathematics and computational thinking	Applying 2D motion models to real-world problems

Unit Plan for Algebra-Based Physics (3 1-hour Lessons)

Lesson 1: Introduction to Motion and Graphical Interpretation **Focus Topic:** Definitions of velocity and acceleration; Graphical representations of motion. **Activity Ideas:** Quick think-pair-share: define terms in your own words. Analyze example displacement-time and velocity-time graphs in small groups. **Formative Check:** Exit ticket with 3 questions: 1 definition, 1 graph interpretation, 1 application. **Active-Learning Techniques:** Think-Pair-Share, Concept Sketching.	**Lesson 2: Quantitative Analysis and Equations of Motion** **Focus Topic:** Determining quantities from graphs; Deriving equations of motion. **Activity Ideas:** Derivation walk-through with guided student input (whiteboarding step-by-step). Solve simple problems based on derived equations. **Formative Check:** Quiz with graphical analysis and equation application. **Active-Learning Techniques:** Whiteboarding, Group Problem Solving.	**Lesson 3: Projectile Motion** **Focus Topic:** Understanding and solving projectile motion problems. **Activity Ideas:** Demonstration: launch a projectile horizontally and at an angle. Group work: Predict, then measure, projectile range. Solve projectile motion word problems collaboratively. **Formative Check:** Lab worksheet: prediction, data collection, and comparison. **Active-Learning Techniques:** Predict-Observe-Explain, Peer Instruction.

Model-Based Language: "What does the graph model about the object's motion?"	**Model-Based Language:** "How do the equations emerge from the graphical patterns?"	**Model-Based Language:** "How can we model the horizontal and vertical motions separately?"

Chapter 3: Momentum & Newton's Laws of Motion

Learning Outcomes

1. Define momentum and impulse
2. Solve problems related to impulse and impulse momentum theorem in 1 dimension
3. Use F-t graph to determine impulse
4. State the principle of conservation of linear momentum
5. Apply the principle of conservation of momentum in elastic and inelastic collisions in 2D collisions
6. Differentiate elastic and inelastic collisions
7. Identify forces (Weight, Tension, Normal force, friction, and external force) acting on a body in different situations
8. Sketch free body diagram
9. Determine static and kinetic friction
10. State Newton's laws of motion
11. Apply Newton's laws of motion involving forces (Weight, Tension, Normal force, friction, and external force)

LO	Bloom's Revised Taxonomy	Three-Dimensional Learning	Modeling Instruction	Backward Design (UbD)
Define momentum and impulse	Remembering, Understanding	Core Idea: Forces and Motion relationships. Science Practice: Constructing explanations and defining concepts.	Introducing momentum and impulse as foundational concepts.	Students must first understand the basic definitions of momentum and impulse before applying them in problem solving.
Solve problems related to impulse and impulse momentum theorem in 1 dimension	Applying, Analyzing	Core Idea: Cause and effect relationships. Science Practice: Using mathematics and computational thinking.	Building models connecting force, time, and momentum change.	Students apply the impulse-momentum theorem to real-world linear motion scenarios.
Use F-t graph to determine impulse	Analyzing	Core Idea: Quantitative graphical interpretation. Science Practice: Analyzing and interpreting data.	Modeling impulse as the area under a force-time curve.	Students interpret force-time graphs to calculate physical quantities.
State the principle of conservation of linear momentum	Remembering, Understanding	Core Idea: Conservation laws in physics. Science Practice: Constructing explanations.	Stating and explaining conservation principles within collision models.	Students must recognize when and how momentum is conserved in isolated systems.
Apply the principle of conservation of momentum in elastic and inelastic collisions in 2D collisions	Applying, Analyzing	Core Idea: Interaction of objects. Science Practice: Using mathematics and computational thinking.	Applying momentum conservation laws in two-dimensional settings.	Students use models to solve 2D collision problems analytically and graphically.

Differentiate elastic and inelastic collisions	Understanding, Analyzing	Core Idea: Types of collisions and energy conservation. Science Practice: Constructing explanations.	Modeling differences based on kinetic energy conservation.	Students describe and distinguish collision types based on modeling results.
Identify forces (Weight, Tension, Normal force, friction, and external force) acting on a body in different situations	Understanding	Core Idea: Forces and motion. Science Practice: Developing and using models.	Identifying all forces acting in everyday scenarios.	Students build free-body models by identifying forces correctly.
Sketch free body diagram	Applying	Core Idea: Forces acting at a point. Science Practice: Developing and using models.	Using diagrams to model forces acting on objects.	Students create free-body diagrams to represent physical scenarios.
Determine static and kinetic friction	Applying, Analyzing	Core Idea: Friction and surfaces. Science Practice: Using mathematics and computational thinking.	Modeling frictional forces under different conditions.	Students calculate and distinguish between static and kinetic friction forces.
State Newton's laws of motion	Remembering, Understanding	Core Idea: Laws of motion. Science Practice: Constructing explanations.	Stating fundamental laws that govern motion.	Students articulate Newton's laws clearly to form a basis for deeper understanding.
Apply Newton's laws of motion involving forces (Weight, Tension, Normal force, friction, and external force)	Applying, Analyzing	Core Idea: Cause and effect of forces. Science Practice: Using mathematics and computational thinking.	Using Newton's laws to model forces in real-world situations.	Students apply Newton's laws to solve problems involving forces like tension, normal force, and friction.

Summary Table

Learning Outcome	Bloom's Level	Relevant Physics Practice	Modeling Instruction Perspective
Define momentum and impulse	Remembering, Understanding	Constructing explanations and defining concepts.	Introducing momentum and impulse as foundational concepts.
Solve problems related to impulse and impulse momentum theorem in 1D	Applying, Analyzing	Using mathematics and computational thinking.	Building models connecting force, time, and momentum change.

Use F-t graph to determine impulse	Analyzing	Analyzing and interpreting data.	Modeling impulse as the area under a force-time curve.
State the principle of conservation of linear momentum	Remembering, Understanding	Constructing explanations.	Stating and explaining conservation principles within collision models.
Apply the principle of conservation of momentum in elastic and inelastic collisions in 2D	Applying, Analyzing	Using mathematics and computational thinking.	Applying momentum conservation laws in two-dimensional settings.
Differentiate elastic and inelastic collisions	Understanding, Analyzing	Constructing explanations.	Modeling differences based on kinetic energy conservation.
Identify forces acting on a body in different situations	Understanding	Developing and using models.	Identifying all forces acting in everyday scenarios.
Sketch free body diagram	Applying	Developing and using models.	Using diagrams to model forces acting on objects.
Determine static and kinetic friction	Applying, Analyzing	Using mathematics and computational thinking.	Modeling frictional forces under different conditions.
State Newton's laws of motion	Remembering, Understanding	Constructing explanations.	Stating fundamental laws that govern motion.
Apply Newton's laws of motion involving forces	Applying, Analyzing	Using mathematics and computational thinking.	Using Newton's laws to model forces in real-world situations.

Unit Plan for Algebra-Based Physics (3 1-hour Lessons)

Lesson 1: Momentum and Impulse	**Lesson 2: Conservation of Momentum and Collisions**	**Lesson 3: Newton’s Laws, Forces, and Free-Body Diagrams**
Focus Topic: Define momentum and impulse; solve 1D impulse-momentum problems; interpret F-t graphs. **Activity Ideas:** - Quick definition and discussion of momentum and impulse. - Analyze simple F-t graphs to find impulse. - Small group problem solving using impulse-momentum theorem. **Formative Check:** Exit ticket with definition + graph interpretation question. **Active-Learning Techniques:** Think-Pair-Share, Graph interpretation, Mini whiteboarding. **Model-Based Language:** "How does the area under the curve represent a change in momentum?"	**Focus Topic:** State and apply the conservation of momentum in 1D and 2D collisions; differentiate elastic vs inelastic collisions. **Activity Ideas:** - Class demonstration of collisions (low-friction carts). - Group activity: predict outcomes for elastic and inelastic collisions. - Problem-solving practice with 2D collision diagrams. **Formative Check:** Quick quiz: conservation principle and collision types. **Active-Learning Techniques:** Predict-Observe-Explain, Group problem-solving. **Model-Based Language:**	**Focus Topic:** State Newton’s laws; identify forces; draw free-body diagrams; apply Newton’s laws. **Activity Ideas:** - Identify forces in various real-world situations. - Sketch and discuss free-body diagrams in pairs. - Solve friction-related force problems. **Formative Check:** Lab worksheet: force identification and FBD sketching. **Active-Learning Techniques:** Whiteboarding, Peer instruction. **Model-Based Language:** "How does Newton’s 2nd law model the net force causing acceleration?"

	"What does the model predict about the momentum of the system after collision?"	

Chapter 4: Work, Energy & Power

Learning Outcomes

1. State the physical meaning of scalar product for work by constant force
2. Define and apply work done by a constant force
3. Determine work done from a force-displacement graph
4. Define and use equations for gravitational potential energy, elastic potential energy for spring, and kinetic energy
5. State and apply the principle of conservation of mechanical energy
6. State and apply work-energy theorem
7. Define and use average power as function of work done and time and instantaneous power as a scalar product of constant force and velocity

LO	Bloom's Revised Taxonomy	Three-Dimensional Learning	Modeling Instruction	Backward Design (UbD)
State the physical meaning of scalar product for work by constant force	Remembering, Understanding	Core Idea: Work as a scalar product of force and displacement. Science Practice: Constructing explanations.	Understanding scalar product physically to connect force and motion.	Students must grasp scalar product interpretation to apply work calculations meaningfully.
Define and apply work done by a constant force	Understanding, Applying	Core Idea: Work-energy interaction. Science Practice: Using mathematics and computational thinking.	Building models to represent energy transfer via force application.	Students need to use the formula to connect force, displacement, and work.
Determine work done from a force-displacement graph	Applying, Analyzing	Core Idea: Area under curve interpretation. Science Practice: Analyzing and interpreting data.	Work modeled as area under a force-displacement curve.	Students interpret graphical information to compute work.
Define and use equations for gravitational potential energy, elastic potential energy for spring, and kinetic energy	Remembering, Applying	Core Idea: Energy forms and relationships. Science Practice: Constructing explanations and using mathematics.	Defining key energy concepts and applying energy equations.	Students build conceptual and mathematical models linking forms of mechanical energy.
State and apply the principle of conservation of mechanical energy	Understanding, Applying	Core Idea: Energy conservation. Science Practice: Constructing explanations.	Applying conservation principles to closed systems.	Students identify energy transformations and apply conservation models.
State and apply work-energy theorem	Understanding, Applying	Core Idea: Connection between work and energy change. Science Practice: Using	Modeling energy changes as work performed by forces.	Students connect net work to changes in kinetic energy.

		mathematics and computational thinking.		
Define and use average power as function of work done and time and instantaneous power as a scalar product of constant force and velocity	Applying, Analyzing	Core Idea: Power as work/time ratio and force-velocity product. Science Practice: Using mathematics and computational thinking.	Modeling rates of energy transfer.	Students calculate average and instantaneous power using correct physical models.

Summary Table

Learning Outcome	Bloom's Level	Relevant Physics Practice	Modeling Instruction Perspective
State the physical meaning of scalar product for work by constant force	Remembering, Understanding	Constructing explanations.	Understanding scalar product physically to connect force and motion.
Define and apply work done by a constant force	Understanding, Applying	Using mathematics and computational thinking.	Building models to represent energy transfer via force application.
Determine work done from a force-displacement graph	Applying, Analyzing	Analyzing and interpreting data.	Work modeled as area under a force-displacement curve.
Define and use equations for gravitational potential energy, elastic potential energy for spring, and kinetic energy	Remembering, Applying	Constructing explanations and using mathematics.	Defining key energy concepts and applying energy equations.
State and apply the principle of conservation of mechanical energy	Understanding, Applying	Constructing explanations.	Applying conservation principles to closed systems.
State and apply work-energy theorem	Understanding, Applying	Using mathematics and computational thinking.	Modeling energy changes as work performed by forces.
Define and use average power as function of work done and time and instantaneous power as a scalar product of constant force and velocity	Applying, Analyzing	Using mathematics and computational thinking.	Modeling rates of energy transfer.

Unit Plan for Algebra-Based Physics (3 1-hour Lessons)

Lesson 1: Work, Scalar Product, and Force-Displacement Graphs	Lesson 2: Energy Forms and Conservation Principles	Lesson 3: Work-Energy Theorem and Power
Focus Topic: State physical meaning of scalar product; define work; determine work from F-x graphs. **Activity Ideas:** • Concept discussion: scalar product interpretation. • Analyze force-displacement graphs to calculate work. • Quick problems on work by constant forces. **Formative Check:** Exit ticket: brief scalar product explanation + work calculation from graph. **Active-Learning Techniques:** Think-Pair-Share, Graph Interpretation. **Model-Based Language:** "What does the model of the graph tell us about the work done?"	**Focus Topic:** Define gravitational, elastic potential, and kinetic energy; apply conservation of mechanical energy. **Activity Ideas:** Explore scenarios involving different mechanical energy types. Solve problems involving conservation of mechanical energy. Energy bar charts activity to visualize transformations. **Formative Check:** Quiz: mechanical energy forms and conservation application. **Active-Learning Techniques:** Whiteboarding, Bar Chart Modeling. **Model-Based Language:** "Where in the model does potential energy convert to kinetic energy?"	Focus Topic: State and apply work-energy theorem; define and use average and instantaneous power. **Activity Ideas:** • Demonstration: work-energy changes with motion. • Calculate work done and changes in kinetic energy. • Group problems on average and instantaneous power. **Formative Check:** Lab worksheet on work-energy calculations and power analysis. **Active-Learning Techniques:** Predict-Observe-Explain, Problem Solving. **Model-Based Language:** "How does the model connect force and velocity in calculating instantaneous power?"

Chapter 5: Circular Motion

Learning Outcomes

1. Define and use angular displacement, period of circular path, frequency of circular path and angular velocity
2. Describe uniform circular motion
3. Convert units between degrees, radians, revolution and rotation
4. Explain centripetal acceleration and centripetal force
5. Solve problems related to centripetal force for uniform circular motion cases (horizontal, vertical and conical pendulum, excludes banked curve)

LO	Bloom's Revised Taxonomy	Three-Dimensional Learning	Modeling Instruction	Backward Design (UbD)
Define and use angular displacement, period of circular path, frequency of circular path and angular velocity	Remembering, Applying	Core Idea: Descriptions of motion in a circle. Science Practice: Using mathematics and computational thinking.	Defining circular motion quantities and linking them mathematically.	Students must understand and use circular motion variables to model movement along a circular path.
Describe uniform circular motion	Understanding, Analyzing	Core Idea: Uniform motion along a curved path. Science Practice: Constructing explanations.	Modeling constant-speed circular motion behavior.	Students describe qualitative and quantitative aspects of uniform circular motion.
Convert units between degrees, radians, revolution and rotation	Applying	Core Idea: Measurement and unit conversions. Science Practice: Using mathematics and computational thinking.	Translating measurements across different angular units.	Students become proficient in working across various angular measurement systems.
Explain centripetal acceleration and centripetal force	Understanding, Analyzing	Core Idea: Force and acceleration in circular paths. Science Practice: Constructing explanations.	Modeling inward force requirement for maintaining circular motion.	Students articulate why an inward force is needed for circular motion.
Solve problems related to centripetal force for uniform circular motion cases (horizontal, vertical and conical pendulum, excludes banked curve)	Applying, Analyzing	Core Idea: Dynamics of circular motion. Science Practice: Using mathematics and computational thinking.	Applying centripetal force relationships to physical cases (horizontal, vertical, conical pendulum).	Students solve problems by applying models of circular motion without needing advanced banking curve cases.

Summary Table

Learning Outcome	Bloom's Level	Relevant Physics Practice	Modeling Instruction Perspective
Define and use angular displacement, period of circular path, frequency of circular path and angular velocity	Remembering, Applying	Using mathematics and computational thinking.	Defining circular motion quantities and linking them mathematically.
Describe uniform circular motion	Understanding, Analyzing	Constructing explanations.	Modeling constant-speed circular motion behavior.
Convert units between degrees, radians, revolution and rotation	Applying	Using mathematics and computational thinking.	Translating measurements across different angular units.
Explain centripetal acceleration and centripetal force	Understanding, Analyzing	Constructing explanations.	Modeling inward force requirement for maintaining circular motion.
Solve problems related to centripetal force for uniform circular motion cases (horizontal, vertical and conical pendulum, excludes banked curve)	Applying, Analyzing	Using mathematics and computational thinking.	Applying centripetal force relationships to physical cases (horizontal, vertical, conical pendulum).

Unit Plan for Algebra-Based Physics (3 1-hour Lessons)

Lesson 1: Describing Circular Motion	Lesson 2: Forces and Acceleration in Circular Motion	Lesson 3: Solving Centripetal Force Problems
Focus Topic: Define and use angular displacement, period, frequency, and angular velocity; convert units. **Activity Ideas:** • Define key circular motion terms with examples. • Practice converting between degrees, radians, revolutions, and rotations. • Solve short problems calculating angular quantities. **Formative Check:** Exit ticket: unit conversion and basic angular calculation. **Active-Learning Techniques:** Think-Pair-Share, Quick Practice Sets. **Model-Based Language:** "How does angular displacement relate to the distance travelled in a circle?"	**Focus Topic:** Describe uniform circular motion; explain centripetal acceleration and centripetal force. **Activity Ideas:** • Demonstration: rotating object with visible inward force. • Small group discussion: why does acceleration point inward? • Sketching diagrams showing velocity and acceleration vectors. **Formative Check:** Short quiz: explaining the direction of forces and accelerations. **Active-Learning Techniques:** Demonstrations, Concept Sketching. **Model-Based Language:** "How does the model explain the constant inward acceleration?"	**Focus Topic:** Solve problems related to centripetal force in horizontal, vertical, and conical pendulum cases. **Activity Ideas:** • Solve structured problems for circular motion in horizontal and vertical planes. • Small group work: set up and solve conical pendulum problems. • Peer teaching: groups explain different motion cases to each other. **Formative Check:** Problem set covering different circular motion scenarios. **Active-Learning Techniques:** Group Problem Solving, Peer Instruction. **Model-Based Language:** "Which forces in your model provide the necessary centripetal acceleration?"

Chapter 6: Rotation of Rigid Body

Learning Outcomes

1. Define and use angular displacement, average angular velocity (and acceleration), instantaneous angular velocity (and acceleration)
2. Analyse parameters in rotational motion with their corresponding quantities in linear motion
3. Solve problems relating to rotational motion with constant angular acceleration
4. State physical meaning of vector product for torque
5. Define and apply torque
6. State conditions for equilibrium of rigid body
7. Solve problems related to equilibrium of uniform rigid body, limited to 5 forces
8. Define and use moment of inertia
9. Use equations of moments of inertia of uniform rigid body
10. State and use net torque
11. Explain and use angular momentum
12. State and use principle of conservation of angular momentum

Learning Outcome	Bloom's Level	Three-Dimensional Learning (Science Practice / Core Idea)	Modeling Instruction Perspective	Backward Design (UbD)
Define and use angular displacement, average and instantaneous angular velocity and acceleration	Remembering, Applying	Using mathematics and computational thinking / Rotational motion quantities	Define and calculate angular quantities; connect with linear analogs	Students develop fluency in angular kinematics to analyze motion patterns
Analyse parameters in rotational motion with their corresponding quantities in linear motion	Analyzing, Understanding	Constructing explanations / Analogies between linear and rotational motion	Match rotational variables with translational equivalents	Students recognize conceptual parallels across motion types
Solve problems relating to rotational motion with constant angular acceleration	Applying, Analyzing	Using mathematics and computational thinking / Dynamics of rotation	Apply angular kinematic equations to motion scenarios	Students solve angular acceleration problems to predict rotational behavior
State physical meaning of vector product for torque	Remembering, Understanding	Constructing explanations / Torque as a vector product	Explain torque as cross product of force and lever arm	Students grasp the role of direction and leverage in generating torque
Define and apply torque	Understanding, Applying	Using mathematics and computational thinking / Rotational effects of force	Calculate torque using defined models in real-world contexts	Students relate force magnitude, angle, and position to rotational influence
State conditions for equilibrium of rigid body	Remembering, Understanding	Constructing explanations / Rotational and translational equilibrium	Define static equilibrium conditions: net force = 0, net torque = 0	Students identify equilibrium in static rigid bodies
Solve problems related to equilibrium of	Applying, Analyzing	Using mathematics and computational thinking / Force and torque balance	Apply equilibrium conditions to analyze force systems	Students determine unknowns in multi-force systems ensuring balance

uniform rigid body, limited to 5 forces				
Define and use moment of inertia	Remembering, Applying	Constructing explanations / Resistance to angular acceleration	Define moment of inertia conceptually and computationally	Students interpret and use rotational mass distribution effectively
Use equations of moments of inertia of uniform rigid body	Applying	Using mathematics and computational thinking / Rotational inertia of simple objects	Use standard equations for moment of inertia of known shapes	Students compute I values in modeling of rotational dynamics
State and use net torque	Understanding, Applying	Using mathematics and computational thinking / Net torque and angular acceleration	Relate net torque to rotational motion via Newton's second law analog	Students apply $\Sigma\tau = I\alpha$ to determine angular responses
Explain and use angular momentum	Understanding, Applying	Constructing explanations / Angular analog of momentum	Define and use angular momentum ($L = I\omega$) in rotational systems	Students analyze rotational dynamics using angular momentum
State and use principle of conservation of angular momentum	Applying, Evaluating	Using mathematics and computational thinking / Angular momentum conservation	Apply conservation to systems with no external torque	Students predict changes in angular velocity with shifting mass distribution

Summary Table

Learning Outcome	Bloom's Level	Relevant Physics Practice	Modeling Instruction Perspective
Define and use angular displacement, average and instantaneous angular velocity and acceleration	Remembering, Applying	Using mathematics and computational thinking	Define and calculate angular quantities; connect with linear analogs
Analyse parameters in rotational motion with their corresponding quantities in linear motion	Analyzing, Understanding	Constructing explanations	Match rotational variables with translational equivalents
Solve problems relating to rotational motion with constant angular acceleration	Applying, Analyzing	Using mathematics and computational thinking	Apply angular kinematic equations to motion scenarios
State physical meaning of vector product for torque	Remembering, Understanding	Constructing explanations	Explain torque as cross product of force and lever arm
Define and apply torque	Understanding, Applying	Using mathematics and computational thinking	Calculate torque using defined models in real-world contexts
State conditions for equilibrium of rigid body	Remembering, Understanding	Constructing explanations	Define static equilibrium conditions: net force = 0, net torque = 0
Solve problems related to equilibrium of uniform rigid body, limited to 5 forces	Applying, Analyzing	Using mathematics and computational thinking	Apply equilibrium conditions to analyze force systems
Define and use moment of inertia	Remembering, Applying	Constructing explanations	Define moment of inertia conceptually and computationally
Use equations of moments of inertia of uniform rigid body	Applying	Using mathematics and computational thinking	Use standard equations for moment of inertia of known shapes

State and use net torque	Understanding, Applying	Using mathematics and computational thinking	Relate net torque to rotational motion via Newton's second law analog
Explain and use angular momentum	Understanding, Applying	Constructing explanations	Define and use angular momentum (L = Iω) in rotational systems
State and use principle of conservation of angular momentum	Applying, Evaluating	Using mathematics and computational thinking	Apply conservation to systems with no external torque

Unit Plan for Algebra-Based Physics (3 1-hour Lessons)

Lesson 1: Angular Quantities and Rotational Motion	Lesson 2: Torque, Equilibrium, and Moment of Inertia	Lesson 3: Angular Momentum and Conservation
Focus Topic: Define angular variables and compare to linear motion **Activity Ideas:** • Concept introduction: angular displacement, velocity, acceleration • Analogies: angular vs linear variables table • Practice angular motion calculations **Formative Check:** Exit ticket comparing angular and linear quantities **Active-Learning Techniques:** Think-Pair-Share, Graphic Organizers **Model-Based Language:** "What's the angular counterpart of linear acceleration in this motion model?"	**Focus Topic:** Model torque and equilibrium conditions **Activity Ideas:** • Torque demo (wrench/door lever) and guided derivation • Free-body diagrams for static equilibrium • Inertia of rods, discs, and ring systems **Formative Check:** Mini-quiz: torque calculation and moment of inertia **Active-Learning Techniques:** Peer Instruction, Diagram Solving **Model-Based Language:** "Which part of your model shows the torque-generating force?"	**Focus Topic:** Apply angular momentum and conservation principle **Activity Ideas:** • Demo: spinning chair and arm contraction • Conservation problems (before-after scenarios) • Group presentations: everyday rotational examples **Formative Check:** Short written scenario-based conservation explanation **Active-Learning Techniques:** Predict-Observe-Explain, Peer Teaching **Model-Based Language:** "What stays constant in your rotational model and why?"

Chapter 7: Oscillations & Waves – SHM

Learning Outcomes

1. Explain SHM
2. Apply SHM displacement equation (sine function)
3. Derive and use SHM equations for velocity as a function of time, velocity as a function of displacement, acceleration as a function of time, acceleration as a function of displacement, kinetic as function of displacement and potential energy as function of displacement.
4. Emphasise the relationship between total SHM energy and amplitude
5. Apply equations of velocity, acceleration, kinetic energy and potential energy for SHM.
6. Analyse the displacement-time, velocity-time, acceleration-time and energy displacement graphs.
7. Use expressions for period of SHM for simple pendulum and mass-spring system.

Learning Outcome	Bloom's Level	Three-Dimensional Learning (Science Practice / Core Idea)	Modeling Instruction Perspective	Backward Design (UbD)
Explain SHM	Understanding	Constructing explanations / Periodic motion characteristics	Define SHM using conceptual models of oscillatory motion	Students articulate SHM as a restoring force-based motion pattern
Apply SHM displacement equation (sine function)	Applying	Using mathematics and computational thinking / Displacement-time relationships	Apply the sine model to represent displacement	Students relate the mathematical sine model to physical motion
Derive and use SHM velocity/acceleration/energy equations	Creating, Applying, Analyzing	Developing and using models / Energy and motion in oscillating systems	Derive relationships from displacement and energy models	Students connect changes in energy and motion across time and space
Emphasise relationship between total SHM energy and amplitude	Understanding, Evaluating	Constructing explanations / Energy-amplitude relationship	Highlight amplitude's role in determining mechanical energy	Students link system energy to the square of amplitude conceptually
Apply velocity, acceleration, kinetic energy, and potential energy equations	Applying, Analyzing	Using mathematics and computational thinking / SHM energy dynamics	Solve problems using dynamic energy and motion formulas	Students determine system behavior at various positions and times
Analyse displacement-time, velocity-time, acceleration-time, and energy-displacement graphs	Analyzing	Analyzing and interpreting data / Oscillatory behavior over time	Interpret graphical representations of periodic motion	Students extract physical meaning from graph shape and symmetry
Use expressions for period of SHM (pendulum and spring)	Applying	Using mathematics and computational thinking / System-specific periodic motion	Apply known formulas for different SHM systems	Students compute oscillation periods for physical systems

Summary Table

Learning Outcome	Bloom's Level	Relevant Physics Practice	Modeling Instruction Perspective
Explain SHM	Understanding	Constructing explanations	Define SHM using restoring force-based models
Apply SHM displacement equation (sine function)	Applying	Using mathematics and computational thinking	Use mathematical functions to describe motion
Derive and use SHM motion and energy equations	Creating, Applying, Analyzing	Developing and using models	Derive motion-energy relationships using graphs and math
Emphasise total SHM energy–amplitude link	Understanding, Evaluating	Constructing explanations	Interpret total energy as proportional to amplitude squared
Apply equations for velocity, acceleration, KE and PE	Applying, Analyzing	Using mathematics and computational thinking	Use expressions to analyze and predict SHM behavior
Analyse SHM motion and energy graphs	Analyzing	Analyzing and interpreting data	Connect graphical features to oscillation patterns
Use period equations for pendulum and spring	Applying	Using mathematics and computational thinking	Apply system-specific models to predict periods

Unit Plan for Algebra-Based Physics (3 1-hour Lessons)

<table>
<tr>
<td>Lesson 1: Understanding SHM and Mathematical Models
Focus Topic:
Definition of SHM and displacement equation using sine function
Activity Ideas:
Pendulum demonstration to introduce SHM
Sketch restoring force vectors and displacement relationships
Derive and explore the sine function for displacement
Formative Check:
Exit ticket: Identify amplitude, frequency, and phase in SHM equation
Active-Learning Techniques:
Think-Pair-Share, Interactive Whiteboarding
Model-Based Language:
“What is the restoring force doing when the object is farthest from equilibrium?”</td>
<td>Lesson 2: SHM Velocity, Acceleration, and Energy
Focus Topic:
Derive velocity, acceleration, kinetic and potential energy in SHM
Activity Ideas:
Guided derivations: v(t), a(t), KE(x), PE(x)
Group practice: find velocity and energy at given displacements
Energy bar charts to visualize total energy and amplitude
Formative Check:
Worksheet with derivation steps and application problems
Active-Learning Techniques:
Guided Derivation, Visual Representations, Peer Collaboration
Model-Based Language:
“How does the energy model explain why kinetic energy is max at equilibrium?”</td>
<td>Lesson 3: Graphs, Energy-Amplitude Relation, and Period
Focus Topic:
Interpret SHM graphs and apply period equations for spring and pendulum
Activity Ideas:
Analyze motion and energy graphs (d-t, v-t, a-t, KE/PE-x)
Emphasize amplitude’s link to energy using visual patterns
Lab or simulation to explore period of spring and pendulum systems
Formative Check:
Short quiz: read and interpret SHM graphs, compute periods
Active-Learning Techniques:
Graph Matching, Simulation-Based Lab, Exit Slips
Model-Based Language:
“What does the graph’s curvature tell you about the object’s acceleration?”</td>
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Chapter 7: Oscillations & Waves – Progressive Waves

Learning Outcomes

1. Define wavelength
2. Define and use wavenumber as a function of wavelength
3. Solve problems related to equation of progressive wave (sine wave)
4. Distinguish between particle vibrational velocity and wave propagation velocity.
5. Use particle vibrational velocity equation
6. Use wave propagation velocity equation
7. Analyse graphs of displacement-time and displacement-distance
8. State the principle of wave superposition for constructive and destructive interferences.
9. Use standing wave equation
10. Compare between progressive waves and standing waves.
11. Solve problems related to the fundamental and overtone frequencies for stretch string, open ended air columns and air columns with one end closed.
12. State Doppler effect for sound waves.
13. Apply Doppler effect equation for relative motion between source and observer. Limited to stationary observer and moving source and vice versa.

Learning Outcome	Bloom's Level	Three-Dimensional Learning (Science Practice / Core Idea)	Modeling Instruction Perspective	Backward Design (UbD)
Define wavelength	Remembering	Constructing explanations / Characteristics of waves	Describe periodic wave properties conceptually	Students build foundational understanding of spatial wave structure
Define and use wavenumber	Remembering, Applying	Using mathematics and computational thinking / Wave measurement	Apply spatial wave frequency ($2\pi/\lambda$)	Students link spatial frequency to real-world wave analysis
Solve progressive wave equation problems	Applying, Analyzing	Using mathematics and computational thinking / Wave modeling	Use sinusoidal wave equation to describe motion	Students compute displacement at given time and position
Distinguish between vibrational velocity and propagation velocity	Understanding, Analyzing	Constructing explanations / Particle vs wave motion	Separate conceptual models for vibration vs propagation	Students understand velocity of individual particle vs wave front
Use particle vibrational velocity equation	Applying	Using mathematics and computational thinking / SHM wave analysis	Apply derivative of displacement for particle speed	Students calculate oscillatory velocity using time-based function
Use wave propagation velocity equation	Applying	Using mathematics and computational thinking / Wave transport	Use $v = f\lambda$ or $v = \omega/k$ to describe wave travel	Students link wave speed to wave parameters
Analyse displacement-time and displacement-distance graphs	Analyzing	Analyzing and interpreting data / Wave representation	Extract features like amplitude, wavelength, phase	Students interpret graphical data to describe wave motion
State superposition principle	Remembering	Constructing explanations / Interference patterns	Articulate behavior of overlapping waveforms	Students describe and predict constructive vs destructive effects
Use standing wave equation	Applying	Using mathematics and computational thinking / Wave resonance	Apply $y = 2A \sin(kx)\cos(\omega t)$ to describe standing waves	Students model standing wave patterns mathematically

Compare progressive and standing waves	Understanding, Analyzing	Constructing explanations / Types of wave behavior	Compare spatial and temporal characteristics	Students recognize defining traits of each wave type
Solve problems for frequencies in strings and air columns	Applying, Analyzing	Using mathematics and computational thinking / Wave resonance in media	Apply formulas for harmonic frequencies	Students compute resonant frequencies in bounded systems
State Doppler effect for sound	Remembering	Constructing explanations / Sound wave motion	Describe frequency change due to motion	Students articulate cause of perceived pitch shift
Apply Doppler equation (limited scope)	Applying	Using mathematics and computational thinking / Relative motion of waves	Use simplified Doppler equations	Students apply correct formulas based on motion of source or observer

Summary Table

Learning Outcome	Bloom's Level	Relevant Physics Practice	Modeling Instruction Perspective
Define wavelength	Remembering	Constructing explanations	Define key spatial wave properties
Define and use wavenumber	Remembering, Applying	Using mathematics and computational thinking	Link wavelength to spatial frequency
Solve progressive wave problems	Applying, Analyzing	Using mathematics and computational thinking	Model wave motion using sinusoidal functions
Distinguish between vibrational and propagation velocity	Understanding, Analyzing	Constructing explanations	Compare wave front movement with local particle oscillations
Use particle vibrational velocity equation	Applying	Using mathematics and computational thinking	Derive velocity of oscillating point
Use wave propagation velocity equation	Applying	Using mathematics and computational thinking	Relate speed to wavelength and frequency
Analyse displacement-time and displacement-distance graphs	Analyzing	Analyzing and interpreting data	Interpret graphical representation of wave motion
State superposition principle	Remembering	Constructing explanations	Describe additive nature of wave interaction
Use standing wave equation	Applying	Using mathematics and computational thinking	Apply model for stationary wave pattern
Compare progressive and standing waves	Understanding, Analyzing	Constructing explanations	Contrast motion and energy distribution
Solve resonance problems in strings/air columns	Applying, Analyzing	Using mathematics and computational thinking	Apply harmonic models to physical systems
State Doppler effect	Remembering	Constructing explanations	Define source/observer frequency shift
Apply Doppler effect equations	Applying	Using mathematics and computational thinking	Solve frequency shift based on relative motion

Unit Plan for Algebra-Based Physics (3 1-hour Lessons)

Lesson 1: Fundamentals of Wave Motion	Lesson 2: Progressive and Standing Wave Models	Lesson 3: Resonance and Doppler Effect Applications
Focus Topic: Define wave properties and distinguish between particle and wave motion	**Focus Topic:** Apply progressive wave and standing wave equations; analyze superposition **Activity Ideas:**	**Focus Topic:** Model resonant frequencies and explain Doppler shift **Activity Ideas:**

Activity Ideas: • Spring wave demo: particle vs wave front • Guided labeling of wave diagrams • Graphical analysis of displacement-time and displacement-distance **Formative Check:** Exit ticket: Identify and distinguish v_particle and v_wave **Active-Learning Techniques:** Think-Pair-Share, Diagram Analysis **Model-Based Language:** “Where in your model do particles vibrate and where does the wave travel?”	• Simulation: two waves overlapping (interference) • Derive standing wave equation collaboratively • Practice problems: $y = A \sin(kx - \omega t)$, $y = 2A \sin(kx)\cos(\omega t)$ **Formative Check:** Worksheet: progressive vs standing wave comparison and graph reading **Active-Learning Techniques:** Predict-Observe-Explain, Equation Matching **Model-Based Language:** “What changes when two waves of equal amplitude meet at a point?”	• Demo: tuning fork with tube (resonance) • Practice: frequency calculation for strings and air columns • Guided explanation and application of Doppler equations **Formative Check:** Short quiz on resonant systems and Doppler scenarios **Active-Learning Techniques:** Hands-On Demonstration, Scenario Problem Solving **Model-Based Language:** “What does your model predict about frequency when the source moves toward the observer?”

Chapter 8: Physics of Matter

Learning Outcomes

1. Distinguish between stress and strain for tensile and compression force.
2. Analyse the graph of stress-strain for a metal under tension.
3. Explain elastic and plastic deformations.
4. Analyse graph of force elongation for brittle and ductile materials.
5. Define and use Young's Modulus
6. Apply strain energy equation from force-elongation graph.
7. Apply strain energy per unit volume from the stress-strain graph.
8. Define heat conduction
9. Solve problems related to rate of heat transfer through a cross sectional area with a maximum of two insulated objects in series.
10. Analyse graph of temperature-distance for heat conduction through insulated and non-insulated rods for a maximum of two rods in series.
11. Define coefficient of linear heat expansion, coefficient of area heat expansion and coefficient of volume heat expansion.
12. Solve problems related to thermal expansion of linear, area and volume, including the expansion of liquid in a container.

Learning Outcome	Bloom's Level	Three-Dimensional Learning (Science Practice / Core Idea)	Modeling Instruction Perspective	Backward Design (UbD)
Distinguish between stress and strain	Understanding, Analyzing	Constructing explanations / Mechanical response of solids	Define and compare response parameters	Students identify how force and deformation relate under tension/compression
Analyse stress-strain graph for metal	Analyzing	Analyzing and interpreting data / Elastic-plastic transition	Identify key points (elastic limit, yield, fracture)	Students interpret real material behavior under increasing load
Explain elastic and plastic deformation	Understanding	Constructing explanations / Material deformation	Model internal behavior of materials	Students distinguish between recoverable and permanent deformations
Analyse force-elongation graph for brittle/ductile	Analyzing	Analyzing and interpreting data / Fracture mechanics	Contrast mechanical profiles graphically	Students describe material characteristics from graphical features
Define and use Young's Modulus	Remembering, Applying	Using mathematics and computational thinking / Material stiffness	Quantify stiffness as stress/strain ratio	Students calculate and compare material rigidity
Apply strain energy equation from force-elongation graph	Applying	Using mathematics and computational thinking / Mechanical energy in materials	Use area under F-x curve	Students compute work done on materials
Apply strain energy per unit volume from stress-strain graph	Applying	Using mathematics and computational thinking / Energy density in solids	Use area under σ-ε curve	Students compare energy stored across different materials
Define heat conduction	Remembering	Constructing explanations / Thermal energy transfer	Introduce conduction concept with molecular model	Students describe microscopic mechanism of conduction

Solve heat transfer problems (two objects in series)	Applying	Using mathematics and computational thinking / Steady-state heat flow	Apply conduction equations in series systems	Students compute rate of heat flow in layered materials
Analyse temperature-distance graphs for conduction	Analyzing	Analyzing and interpreting data / Heat gradient	Relate slope to temperature gradient and material type	Students interpret insulating and non-insulating material performance
Define coefficients of thermal expansion	Remembering	Constructing explanations / Thermal response of materials	Define α (linear), β (area), γ (volume)	Students understand expansion tendencies under heat
Solve expansion problems (solid and liquid)	Applying, Analyzing	Using mathematics and computational thinking / Thermal expansion modeling	Apply $\Delta L = \alpha L \Delta T$, and similar for A, V	Students determine how structures or containers respond to heating

Summary Table

Learning Outcome	**Bloom's Level**	**Relevant Physics Practice**	**Modeling Instruction Perspective**
Distinguish stress and strain	Understanding, Analyzing	Constructing explanations	Compare force and deformation responses
Analyse stress-strain graph	Analyzing	Analyzing and interpreting data	Identify elastic, yield, and fracture points
Explain elastic and plastic deformation	Understanding	Constructing explanations	Describe recoverable vs permanent deformation
Analyse brittle vs ductile graphs	Analyzing	Analyzing and interpreting data	Contrast mechanical behavior visually
Define and use Young's Modulus	Remembering, Applying	Using mathematics and computational thinking	Quantify material stiffness
Apply strain energy equation (F-x graph)	Applying	Using mathematics and computational thinking	Use area under force-elongation curve
Apply energy per volume (σ-ε graph)	Applying	Using mathematics and computational thinking	Use area under stress-strain graph
Define heat conduction	Remembering	Constructing explanations	Describe thermal transport at molecular level
Solve heat transfer problems (in series)	Applying	Using mathematics and computational thinking	Model steady heat transfer through layers
Analyse temperature-distance graphs	Analyzing	Analyzing and interpreting data	Interpret gradients for material conductivity
Define thermal expansion coefficients	Remembering	Constructing explanations	Introduce α, β, γ as expansion constants
Solve expansion problems	Applying, Analyzing	Using mathematics and computational thinking	Apply ΔL, ΔA, ΔV formulas to solids/liquids

Unit Plan for Algebra-Based Physics (3 1-hour Lessons)

Lesson 1: Mechanical Properties of Solids	**Lesson 2: Energy in Deforming Solids and Heat Transfer Basics**	**Lesson 3: Heat Conduction and Expansion**
Focus Topic: Stress, strain, elasticity, and mechanical graphs **Activity Ideas:**	**Focus Topic:** Strain energy + Intro to heat conduction **Activity Ideas:**	**Focus Topic:** Thermal conductivity and expansion effects **Activity Ideas:**

• Tension test video / force-elongation simulation • Label stress-strain and force-elongation graphs • Match graphs to brittle/ductile materials **Formative Check:** Exit ticket: Identify yield point and describe ductile vs brittle **Active-Learning Techniques:** Interactive graph analysis, Concept sorting **Model-Based Language:** “What does this slope and curve tell us about the material’s response to force?”	• Calculate energy from area under graphs • Derive strain energy and energy density expressions • Discuss conduction at molecular level (animation) **Formative Check:** Mini-quiz on strain energy + short paragraph on how heat transfers **Active-Learning Techniques:** Whiteboarding, Think-Pair-Share, Energy modeling **Model-Based Language:** “Where in the graph is the energy stored — and how do we calculate it?”	• Analyze temperature vs distance graphs • Practice problems on two-conductor systems • Solve ΔL, ΔA, ΔV problems for metal rods, liquid in container **Formative Check:** Exit quiz: conduction graph + thermal expansion example **Active-Learning Techniques:** Data interpretation, Guided practice **Model-Based Language:** “How does your model explain expansion when both the container and liquid are heated?”

Chapter 9: Kinetic Theory of Gases & Thermodynamics

Learning Outcomes

1) State the assumptions of kinetic theory of gases.
2) Describe root mean square speed of gas molecules
3) Solve problems related to rms speed of gas molecules as functions of mass of gas molecules and molar mass of gas molecules
4) Solve problems related to ideal gas equations as functions of rms speed and density
5) Explain and use translational kinetic energy of a molecule
6) Define degree of freedom
7) Identify number of degrees of freedom for monoatomic, diatomic and polyatomic gas molecules.
8) State the principle of equipartition of energy
9) Discuss internal energy of gas.
10) Solve problems related to total internal energy of gas as a function of degrees of freedom.
11) State the first law of thermodynamics for energy work done by gas.
12) Solve problems related to the first law of thermodynamics.
13) Define thermodynamic processes - isothermal, isochoric, isobaric and adiabatic.
14) Analyse pressure-volume gaphs for all thermodynamic processes.
15) Derive equation of work done in isothermal, isochoric and isobaric processes from pressure-volume graph.
16) Solve problems related to work done in isothermal, isochoric and isobaric processes.

Learning Outcome	Bloom's Level	Three-Dimensional Learning (Science Practice / Core Idea)	Modeling Instruction Perspective	Backward Design (UbD)
State the assumptions of kinetic theory of gases	Remembering	Constructing explanations / Molecular theory of matter	Define microscopic basis for macroscopic properties	Students understand gas pressure and temperature as particle behavior effects
Describe root mean square speed of gas molecules	Understanding	Constructing explanations / Particle speed distribution	Relate individual molecular motion to average system behavior	Students connect temperature to microscopic particle speed
Solve problems related to rms speed of gas molecules	Applying, Analyzing	Using mathematics and computational thinking / Kinetic theory application	Model rms as a function of mass and temperature	Students solve speed problems using derived expressions
Solve problems related to ideal gas equations in terms of rms speed and density	Applying	Using mathematics and computational thinking / Ideal gas relationships	Use derived equations linking macroscopic and microscopic variables	Students explore the connection between gas laws and kinetic theory
Explain and use translational kinetic energy of a molecule	Understanding, Applying	Constructing explanations / Energy of motion in gases	Link molecular speed to kinetic energy	Students calculate KE as a function of temperature
Define degree of freedom	Remembering	Constructing explanations / Molecular motion types	Introduce motion axes for molecules	Students categorize motion types across molecules
Identify degrees of freedom of monoatomic, diatomic, and polyatomic gases	Understanding, Applying	Constructing explanations / Degrees of freedom and motion	Classify molecules by shape and motion	Students determine energy modes of different gases

State the principle of equipartition of energy	Remembering	Constructing explanations / Energy distribution in gases	Link internal energy to degrees of freedom	Students understand equal energy sharing per freedom
Discuss internal energy of gas	Understanding	Constructing explanations / Total energy concept	Relate temperature to internal energy	Students interpret thermal energy as microscopic motion
Solve problems on internal energy of gas	Applying, Analyzing	Using mathematics and computational thinking / Gas energy model	Apply internal energy formulas with specific heat capacity	Students quantify gas energy based on freedom count
State the first law of thermodynamics	Remembering	Constructing explanations / Energy conservation in thermal systems	Define $Q = \Delta U + W$	Students articulate how energy flows through a gas system
Solve problems on the first law of thermodynamics	Applying	Using mathematics and computational thinking / Heat, work, and energy	Apply signs and formulas for ΔU, Q, and W	Students compute heat flow in gas systems
Define thermodynamic processes	Remembering	Constructing explanations / Types of thermal change	Identify constant-variable processes	Students define and compare P-V-T behaviors
Analyse pressure-volume graphs	Analyzing	Analyzing and interpreting data / Thermal system representation	Relate work to area under curve	Students extract work and heat trends from graphs
Derive work done from P-V graphs	Creating, Applying	Using mathematics and computational thinking / Thermodynamic work	Use integrals/geometry to extract work	Students explain derivations using graphical approach
Solve problems on work done in thermodynamic processes	Applying, Analyzing	Using mathematics and computational thinking / Work-energy analysis	Apply appropriate equations by process	Students determine gas work in each thermodynamic path

Summary Table

Learning Outcome	**Bloom's Level**	**Relevant Physics Practice**	**Modeling Instruction Perspective**
State assumptions of kinetic theory	Remembering	Constructing explanations	Define microscopic basis for macroscopic properties
Describe rms speed	Understanding	Constructing explanations	Link temperature to particle motion
Solve rms speed problems	Applying, Analyzing	Using mathematics and computational thinking	Calculate speed from mass/temp relationships
Use ideal gas equation with rms speed/density	Applying	Using mathematics and computational thinking	Connect micro/macro gas variables
Use translational KE	Understanding, Applying	Constructing explanations	KE from rms speed or temp
Define degree of freedom	Remembering	Constructing explanations	Motion categories per particle
Identify degrees of freedom	Understanding, Applying	Constructing explanations	Classify molecules and modes of motion
State equipartition principle	Remembering	Constructing explanations	Distribute energy per DOF
Discuss internal energy	Understanding	Constructing explanations	Link internal energy to temperature
Solve internal energy problems	Applying, Analyzing	Using mathematics and computational thinking	Quantify energy using DOF

State 1st law of thermodynamics	Remembering	Constructing explanations	Define conservation of energy
Solve 1st law problems	Applying	Using mathematics and computational thinking	Solve for Q, U, or W
Define thermodynamic processes	Remembering	Constructing explanations	Define process by variable constancy
Analyse P-V graphs	Analyzing	Analyzing and interpreting data	Relate graph to energy transfers
Derive work done equations	Creating, Applying	Using mathematics and computational thinking	Area under P-V graph = work
Solve work problems	Applying, Analyzing	Using mathematics and computational thinking	Calculate work by process type

Unit Plan for Algebra-Based Physics (3 1-hour Lessons)

Lesson 1: Kinetic Theory and Molecular Motion **Focus Topic:** Assumptions of kinetic theory, root-mean-square speed, kinetic energy, and ideal gas equations **Activity Ideas:** • Use particle animation to visualize assumptions • Practice calculating rms speed from molecular and molar mass • Diagram comparison: vibrational velocity vs propagation velocity **Formative Check:** Exit ticket: Calculate rms speed and explain pressure-mass-temp relationship **Active-Learning Techniques:** Think-Pair-Share, Guided Calculation **Model-Based Language:** "What does your model predict about gas pressure if particles move faster?"	**Lesson 2: Internal Energy and Energy Distribution** **Focus Topic:** Equipartition of energy, degrees of freedom, internal energy, and total energy problems **Activity Ideas:** • Categorize gases (mono, di, polyatomic) and their degrees of freedom • Use KE = (f/2)kT and U = n(f/2)RT to explore energy distribution • Discuss energy per degree of freedom (equipartition) **Formative Check:** Mini-quiz: Equipartition and U = n(f/2)RT calculation **Active-Learning Techniques:** Whiteboarding, Energy Diagrams, Peer Explanation **Model-Based Language:** "How much energy is stored per degree of freedom — and why?"	**Lesson 3: Thermodynamic Processes and Work** **Focus Topic:** Thermodynamic processes and graphical work derivation **Activity Ideas:** • Classify isothermal, isobaric, isochoric, adiabatic on P-V graphs • Derive work equations from geometry/integration • Solve practice problems using real-world examples (engines, balloons) **Formative Check:** Problem set: process recognition + work calculations **Active-Learning Techniques:** Graph Analysis, Equation Derivation, Predict-Observe-Explain **Model-Based Language:** "What does the shape of the P-V curve tell you about the work done by the gas?"

SP025

Comprehensive Analysis of SP025 Learning Outcomes

The SP025 course is designed to provide algebra-based college students with a comprehensive foundation in the core topics of electromagnetism, circuitry, optics, and nuclear physics. Grounded in the principles of 21st-century learning, this course aims to foster deep conceptual understanding, develop scientific reasoning, and promote active engagement with real-world applications of physics.

The curriculum is structured around clearly defined learning outcomes for each chapter, systematically mapped to Bloom's Revised Taxonomy, key scientific practices, and research-based instructional strategies rooted in the Modeling Instruction framework. Each unit is supported by a 3-day instructional sequence featuring focus topics, collaborative learning activities, and formative assessment tools to monitor student progress.

Through inquiry-based exploration, hands-on modeling, and reflective problem solving, students will investigate the invisible forces that govern electric and magnetic interactions, analyze wave phenomena through ray and wavefront models, and examine the structure and behavior of subatomic particles using the lens of modern physics.

This document serves both as a teaching guide and a curriculum reference, ensuring pedagogical alignment while empowering instructors to create engaging, student-centered learning environments that emphasize reasoning over rote memorization and application over abstraction.

Chapter 1: Electrostatics

Learning Outcomes

1. State Coulomb's Law
2. Sketch the electric force diagram
3. Apply Coulomb's Law for a system of point charges for simple configuration of charges with a maximum of four charges in 2D.
4. Define and use electric field strength
5. Use equation for electric field strength from point charges
6. Sketch the electric field strength diagram for simple configuration of charges with a maximum of four charges in 2D.
7. Determine the electric field strength for a system of charges for simple configuration of charges with a maximum of four charges in 2D.
8. Define electric potential
9. Define and sketch equipotential lines and surfaces of an isolated charge and a uniform electric field.
10. Use electric potential equation for a point charge and a system of charges for simple configuration of charges with a maximum of four charges in 2D.
11. Apply potential difference between two points and its relationship with energy
12. Apply the change in electric potential energy between two point in electric field of different electrical potential.
13. Apply potential energy of a system of point charges up to a maximum of three charges.
14. Analyse the motion of a charge qualitatively and quantitatively in a uniform electric field for a stationary charge, charge moving perpendicularly to the field, charge moving parallel to the field and charge in dynamic equilibrium.
15. Use equation for electric field strength and potential difference in parallel plate uniform electric field.

Learning Outcome	Bloom's Level	Physics Practice	Modeling Perspective	21st Century Teaching Strategy/Tool
State Coulomb's Law	Remembering	Constructing explanations	Define interaction law between particles	Interactive digital notes + flashcards
Sketch the electric force diagram	Understanding, Applying	Developing and using models	Represent vector forces and symmetry	Whiteboarding + peer critique
Apply Coulomb's Law for a system of point charges for simple configuration of charges with a maximum of four charges in 2D	Applying, Analyzing	Using mathematics and computational thinking	Use superposition to construct net force model	Group problem-solving + simulation
Define and use electric field strength	Remembering, Applying	Constructing explanations	Introduce force per unit charge	Socratic questioning + guided notes
Use equation for electric field strength from point charges	Applying	Using mathematics and computational thinking	Apply $E = kQ/r^2$ to point charge scenarios	Simulation-based practice + homework drills
Sketch the electric field strength diagram for simple configuration of charges with a maximum of four charges in 2D	Applying	Developing and using models	Use field line rules and vector addition	Peer whiteboarding + feedback gallery walk
Determine the electric field strength for a system of charges for simple configuration of charges with a maximum of four charges in 2D	Applying, Analyzing	Using mathematics and computational thinking	Superposition of vector fields	Scaffolded worksheet + paired work
Define electric potential	Remembering	Constructing explanations	Introduce energy per unit charge	Interactive lecture + visual concept map
Define and sketch equipotential lines and surfaces of an isolated charge and a uniform electric field	Understanding, Applying	Developing and using models	Relate geometry to constant potential energy	Simulation sketching + concept peer check
Use electric potential equation for a point charge and a system of charges for simple configuration of charges with a maximum of four charges in 2D	Applying	Using mathematics and computational thinking	Scalar summation model	Group challenge problems + whiteboard walk
Apply potential difference between two points and its relationship with energy	Applying	Constructing explanations	Link ΔV with work done on charge	Clicker questions + energy reasoning tasks

Apply the change in electric potential energy between two points in electric field of different electrical potential	Applying	Using mathematics and computational thinking	Energy conservation in electric context	Problem sets + group discussions
Apply potential energy of a system of point charges up to a maximum of three charges	Applying, Analyzing	Using mathematics and computational thinking	Energy of system via pairwise potentials	POGIL-style worksheet
Analyze the motion of a charge qualitatively and quantitatively in a uniform electric field for various orientations	Analyzing	Analyzing and interpreting data	Predict and model trajectory under field forces	Lab simulation + motion tracking or video analysis
Use equation for electric field strength and potential difference in parallel plate uniform electric field	Applying	Using mathematics and computational thinking	Model parallel plates as uniform field setup	Interactive simulation + problem stations

Unit Plan for Algebra-Based Physics (3 1-hour Lessons)

Lesson 1: Electric Forces and Field Diagrams	Lesson 2: Electric Fields and Equipotentials	Lesson 3: Electric Potential Energy and Charge Motion
Focus Topics: • Coulomb's Law • Electric force diagrams • Superposition in simple 2D configurations **Activity Ideas:** • *Quick review* of Coulomb's Law using an interactive animation or demo • *Think-Pair-Share*: Predict forces on a test charge from surrounding point charges • *Whiteboard Activity*: Draw electric force vectors and resultant forces for 2–4 charge systems • *Use PhET simulation*: Visualize forces acting on multiple charges **Formative Check:** • Exit ticket: Short problem using Coulomb's Law + sketch of net force diagram for 3 charges • Peer-reviewed whiteboard solution gallery	**Focus Topics:** • Electric field strength • Electric field and equipotential diagrams • Field from point charges and in uniform configurations **Activity Ideas:** • *Guided derivation*: $E = kQ/r^2$ and vector addition for E-field • *Sketch and critique*: Field line and equipotential diagrams for single, dipole, and 4-charge layouts • *Simulations*: Explore electric field and equipotential overlays • *Card match activity*: Match diagrams to equations and physical setups **Formative Check:** • Concept sketch quiz: Identify valid/invalid electric field diagrams and explain reasoning • Paired challenge: Calculate E-field at a point in a 3-charge system	**Focus Topics:** • Electric potential and potential difference • Electric potential energy • Charge motion in uniform fields **Activity Ideas:** • *Demo*: Charged object in a parallel plate field — predict and observe motion • *Problem solving stations*: Energy conservation problems ($\Delta U = q\Delta V$) • *Group mini-lab*: Map motion paths for different field/charge configurations • *Socratic discussion*: Energy ideas behind charge in equilibrium vs acceleration **Formative Check:** • Exit quiz: Use potential difference to find ΔU and predict charge motion • Group problem: Charge entering uniform field at angle — determine path and energy change

Chapter 2: Capacitors & Dielectrics

Learning Outcomes

1. Define and use capacitance
2. Determine the effective capacitance of capacitors in series and in parallel
3. Apply energy stored equation for a capacitor.
4. State physical meaning of time constant of a capacitor and use the equation
5. Sketch and explain the characteristics of charge-time and current-time graph for charging and discharging of a capacitor.
6. Use current equations for capacitor charging and discharging.
7. Define and use dielectric constant
8. Describe the effects of dielectric on a parallel plate capacitor
9. Apply equation of capacitance of air-filled parallel plate capacitor
10. Determine capacitance with dielectric

Learning Outcome	Bloom's Level	Physics Practice	Modeling Perspective	21st Century Teaching Strategy/Tool
Define and use capacitance	Remembering, Applying	Constructing explanations	Introduce charge-storage concept	Guided notes + peer questioning
Determine the effective capacitance of capacitors in series and in parallel	Applying	Using mathematics and computational thinking	Use analogies to resistors for model development	Problem-solving carousel
Apply energy stored equation for a capacitor	Applying	Using mathematics and computational thinking	Represent stored energy as area under Q-V graph	Graph interpretation + application problems
State physical meaning of time constant of a capacitor and use the equation	Understanding, Applying	Constructing explanations	Interpret time constant from exponential behavior	Simulation + concept sketching
Sketch and explain charge-time and current-time graphs for charging/discharging	Understanding, Analyzing	Analyzing and interpreting data	Match physical process to graph shape	Whiteboarding + graph gallery walk
Use current equations for capacitor charging and discharging	Applying	Using mathematics and computational thinking	Use exponential models	Worksheet practice + peer tutoring
Define and use dielectric constant	Remembering, Applying	Constructing explanations	Link material property to field reduction	Interactive concept mapping
Describe the effects of dielectric on a parallel plate capacitor	Understanding	Constructing explanations	Model dielectric as polarization mechanism	Simulation exploration + concept sketches
Apply equation of capacitance of air-filled parallel plate capacitor	Applying	Using mathematics and computational thinking	Connect physical dimensions to charge storage	Hands-on demo + problem practice
Determine capacitance with dielectric	Applying	Using mathematics and computational thinking	Modify vacuum model with dielectric factor	Worked examples + group quiz

Unit Plan for Algebra-Based Physics (3 1-hour Lessons)

Day	Focus Topic	Activity Ideas	Formative Check
Day 1	Capacitance, Series/Parallel Combinations, Energy Stored	- Use real capacitors to explore series/parallel behavior - Group derivation of equivalent capacitance - Energy calculation problems and Q-V area analysis	Exit ticket: calculate Ceq + energy for a mixed network
Day 2	Capacitor Charging/Discharging, Time Constant, Graphs	- Use a simulation to observe Q and I vs time - Sketch and explain graphs with peers - Group derivation of time constant concept	Mini-quiz: sketch + interpret Q-t and I-t graphs
Day 3	Dielectrics, Capacitance with Dielectric	- Use visual simulation of dielectric slab insertion - Discuss effect on E, V, Q, C - Problem solving for C with dielectric constant	Peer assessment: dielectric effects + C calculation

Chapter 3: Electric Current & Direct Current Circuits

Learning Outcomes

1. Describe microscopic model of current with an emphasis on the flow of free electrons in a metal, including the concept of drift velocity
2. Define electric current
3. Use electric current equation
4. State and use Ohm's law
5. Define and use resistivity
6. Explain the effect of temperature on electrical resistance in metals.
7. Use equation of resistance variation with temperature
8. Define electromotive force and internal resistance of a battery
9. State factors that influence the internal resistance
10. Explain the relationship between emf of a battery and potential difference across the battery terminals.
11. Use terminal voltage
12. Determine the effective resistance of resistors in series and parallel
13. State and apply Kirchhoff's Rules.
14. Use equations for electrical power.
15. Use equation for electrical energy
16. Explain principle of potential divider
17. Use equation of potential divider
18. Explain principles of potentiometer and its applications
19. Use related equations for potentiometer

Learning Outcome	**Bloom's Level**	**Physics Practice**	**Modeling Perspective**	**21st Century Teaching Strategy/Tool**
Describe microscopic model of current with drift velocity	Understanding	Constructing explanations	Model free electron motion and net drift	Simulation with narration + analogies
Define electric current	Remembering	Constructing explanations	Define charge flow per unit time	Guided notes + peer explanation
Use electric current equation	Applying	Using mathematics and computational thinking	Quantify current using $I = Q/t$	Worked problems + instant feedback quiz
State and use Ohm's law	Remembering, Applying	Using mathematics and computational thinking	Relate $V = IR$ as linear resistance model	Lab with resistors + linear graphing
Define and use resistivity	Remembering, Applying	Constructing explanations	Link material, geometry, and resistance	Resistivity experiment + calculations
Explain temperature's effect on resistance	Understanding	Constructing explanations	Model lattice vibration and scattering	Concept animation + real metal wire demo
Use equation of resistance variation with temperature	Applying	Using mathematics and computational thinking	Apply $R = R_0(1+\alpha\Delta T)$	Guided worksheet + graph matching
Define emf and internal resistance	Remembering	Constructing explanations	Describe energy supply and internal loss	Socratic questioning + labeled diagrams

State factors influencing internal resistance	Remembering	Constructing explanations	Relate material, size, temp to resistance	List-sort activity + group discussion
Explain emf vs terminal voltage	Understanding	Constructing explanations	Link open/closed circuit behavior	Battery + bulb demo + peer reasoning
Use terminal voltage equation	Applying	Using mathematics and computational thinking	$V = \varepsilon - Ir$	Problem solving with real circuits
Determine effective resistance in series/parallel	Applying	Using mathematics and computational thinking	Model current and potential in network	Circuit building with resistors + testing
State and apply Kirchhoff's Rules	Understanding, Applying	Using mathematics and computational thinking	Use conservation of charge and energy	Loop rule + node rule board work
Use equations for electrical power	Applying	Using mathematics and computational thinking	Model energy transfer per time	Real appliance label analysis + $P = IV$ practice
Use equation for electrical energy	Applying	Using mathematics and computational thinking	$E = Pt$, $E = VIt$	Energy cost calculation task
Explain principle of potential divider	Understanding	Constructing explanations	Describe voltage splitting in series	Demo with variable resistor + explanation
Use equation of potential divider	Applying	Using mathematics and computational thinking	$V_{out} = V_{in}(R_2/(R_1+R_2))$	Problem pairs + verification
Explain potentiometer principle and applications	Understanding	Constructing explanations	Model long-wire comparison setup	Explore use in sensors + demos
Use potentiometer equations	Applying	Using mathematics and computational thinking	Proportional length-voltage mapping	Calculation task + concept check

Unit Plan for Algebra-Based Physics (3 1-hour Lessons)

Day	Focus Topic	Activity Ideas	Formative Check
Day 1	Current, Ohm’s Law, Resistance & Temperature Effects	- Microscopic current model animation - Ohm's Law resistor lab (graphing V-I) - Discussion: how temperature affects resistance	Exit ticket: define current + identify resistance behavior on V-I graph
Day 2	EMF, Internal Resistance, Terminal Voltage & Power	- Battery + bulb demo with open/closed circuit - Use $\varepsilon = V + Ir$ and compare emf and terminal voltage - Electrical power and energy problem solving	Mini-quiz: match circuit diagram to correct emf and terminal voltage
Day 3	Circuit Laws, Potential Divider, Potentiometer	- Kirchhoff’s rule board practice (loop & node) - Build/test potential divider circuits - Explore potentiometer applications and practice equations	Group task: solve a circuit using Kirchhoff + find Vout from divider

Chapter 4: Magnetism

Learning Outcomes

1. Define magnetic field
2. Identify magnetic field sources
3. Sketch magnetic field lines for bar magnet, current carrying conductor (straight wire, circular coil and solenoid) and the Earth magnetic field.
4. Sketch and determine resultant magnetic field diagram at a point, limited to two current carrying straight wires and in 2D
5. Determine direction of magnetic field by using right hand rule.
6. Determine the magnitude of magnetic field by using equations for magnetic field for long straight wire, at the centre of a circular coil, at the centre of a solenoid and at the end of solenoid.
7. Explain and use equation for magnetic force on a moving charge particle in a uniform magnetic field
8. Determine the direction of magnetic force on a moving charge particle in a uniform magnetic field
9. Describe circular motion of a charge in a uniform magnetic field
10. Use relationship between magnetic force and centripetal force on a moving charge particle in a uniform magnetic field
11. Explain and use magnetic force on a current carrying conductor in a uniform magnetic field.
12. Determine direction of magnetic force on a current carrying conductor in a uniform magnetic field.
13. Explain magnetic force per unit length of two parallel current-carrying conductors.
14. Applying equation for magnetic force per unit length for two parallel current-carrying conductors.
15. Explain the motion of a moving charged particle in a region of magnetic and electric field.
16. Use equation for velocity in velocity selector in a Bainbridge mass spectrometer.

Learning Outcome	**Bloom's Level**	**Physics Practice**	**Modeling Perspective**	**21st Century Teaching Strategy/Tool**
Define magnetic field	Remembering	Constructing explanations	Describe magnetic influence as vector field	Concept-based interactive notes
Identify magnetic field sources	Understanding	Constructing explanations	Relate moving charges to field generation	Video exploration + cause-effect matching
Sketch magnetic field lines for various configurations	Applying	Developing and using models	Visualize field lines and direction	Whiteboarding + simulation overlay
Sketch and determine resultant magnetic field diagram at a point	Analyzing	Analyzing and interpreting data	Use vector addition of fields	Paired sketch + peer feedback
Determine direction of magnetic field using right hand rule	Applying	Using mathematics and computational thinking	Connect geometry and current to field direction	Hands-on gestures + diagram prediction
Determine magnetic field magnitude (wire, coil, solenoid)	Applying	Using mathematics and computational thinking	Model B from geometry and current	Equation-based practice + live demos
Explain and use magnetic force on moving charge	Understanding, Applying	Constructing explanations	Model force as vector cross product	Group derivation + example solving
Determine direction of magnetic force on moving charge	Applying	Using mathematics and computational thinking	Use right-hand rule for velocity and B	Peer quiz + interactive simulation

Describe circular motion in magnetic field	Understanding	Constructing explanations	Use uniform circular motion + Lorentz force	PhET sim + qualitative predictions
Use $F = qvB = mv^2/r$	Applying	Using mathematics and computational thinking	Link motion with force balance	Graph + calculation problems
Explain and use magnetic force on conductor	Understanding, Applying	Constructing explanations	Relate current, length, and field	Lab: wire + magnetic field interaction
Determine direction of force on conductor	Applying	Using mathematics and computational thinking	Vector reasoning + right-hand rule	Whiteboard quiz + physical model
Explain force per unit length on wires	Understanding	Constructing explanations	Model action-reaction between wires	Discussion + animation analysis
Apply equation for force per unit length	Applying	Using mathematics and computational thinking	Quantify interaction force	Calculation pairs + class polling
Explain motion in electric and magnetic fields	Understanding	Constructing explanations	Describe vector balance and net force	Interactive overlay diagramming
Use equation for velocity selector	Applying	Using mathematics and computational thinking	Balance electric and magnetic forces	Numerical problems + mass spectrometer context

Unit Plan for Algebra-Based Physics (3 1-hour Lessons)

Day	Focus Topic	Activity Ideas	Formative Check
Day 1	Magnetic Fields: Sources, Diagrams, and Right-Hand Rule	- Video demo: magnetic field patterns (iron filings + sim) - Sketch magnetic fields for bar magnet, wire, coil - Practice RH rule: field direction from current	Exit ticket: determine field direction for given configurations
Day 2	Magnetic Forces on Charges and Conductors	- Use PhET simulation to explore charge path in B field - Derive and apply $F = qvB = mv^2/r$ - Practice RH rule for force direction on moving charges & wires	Mini quiz: match force diagrams to motion and field
Day 3	Applications: Parallel Wires, Velocity Selector, E+B Field Motion	- Explore force between wires (demo/sim) - Mass spectrometer example using velocity selector equation - Group diagramming of charge in E+B regions	Group task: analyze unknown particle in velocity selector

Chapter 5: Electromagnetic Induction

Learning Outcomes

1. Define and use magnetic flux
2. Use magnetic flux linkage usage
3. Explain induced emf by using Faraday's experiment
4. State and use Faraday's Law
5. State and use Lenz's law to determine the direction of induced current
6. Apply induced emf in a straight conductor, a coil and a rotating coil.
7. Define self inductance
8. Apply equations of self inductance for coil and solenoid.
9. Apply the energy stored in an inductor
10. Define mutual inductance.
11. Use mutual inductance between two coaxial solenoids.

Learning Outcome	**Bloom's Level**	**Physics Practice**	**Modeling Perspective**	**21st Century Teaching Strategy/Tool**
Define and use magnetic flux	Remembering, Applying	Constructing explanations	Model magnetic field area product	Field diagram sketches + equation practice
Use magnetic flux linkage	Applying	Using mathematics and computational thinking	Multiply flux with number of turns	Coil simulations + step-by-step breakdown
Explain induced emf using Faraday's experiment	Understanding	Constructing explanations	Relate changing flux to emf generation	Interactive animation + group explanation
State and use Faraday's Law	Remembering, Applying	Using mathematics and computational thinking	Use emf = $-d\Phi/dt$	Equation application problems
State and use Lenz's law for induced current direction	Remembering, Applying	Constructing explanations	Opposition modeling in system behavior	Simulation + right-hand rule extension
Apply induced emf in straight conductor, coil, rotating coil	Applying	Using mathematics and computational thinking	Model flux change across geometries	Scenario-based calculation tasks
Define self inductance	Remembering	Constructing explanations	Describe inductor opposing its own current change	Guided notes + concept linking
Apply self inductance equations (coil & solenoid)	Applying	Using mathematics and computational thinking	$L = N\Phi/I$ or geometric model	Worked example problems
Apply energy stored in inductor	Applying	Using mathematics and computational thinking	Model energy storage as $\frac{1}{2}LI^2$	Energy comparison tasks + graph analysis
Define mutual inductance	Remembering	Constructing explanations	Describe flux linkage between coils	Coil interaction demo + analogy activity

Unit Plan for Algebra-Based Physics (3 1-hour Lessons)

Day	Focus Topic	Activity Ideas	Formative Check
Day 1	Magnetic Flux, Faraday's & Lenz's Law	- Coil-magnet simulation: visualize flux changes - Derive and apply Faraday's Law - Use Lenz's Law to predict current direction	Exit quiz: use Faraday and Lenz on new flux scenario
Day 2	Induced EMF in Conductors, Coils, and Rotation	- Apply emf = Blv and emf for rotating coil - Diagram current paths in rotating loops - Real-world device analysis (bike dynamos)	Problem set: calculate emf for straight and rotating coils
Day 3	Inductance, Mutual Inductance, and Energy in Inductors	- Define and compute L and M - Demonstrate linked coils with LEDs - Compare energy in inductors vs capacitors	Task: compute L, M and energy stored in inductor

Chapter 6: AC Circuits

Learning Outcomes

1. Define alternating current
2. Sketch and interpret sinusoidal AC waveform.
3. Use equations of sinusoidal voltage and current.
4. Define rms current and voltage for AC source.
5. Use equations relating to rms current to peak current and rms voltage to peak voltage.
6. Sketch and use phasor diagram and sinusoidal waveform to show the phase relationship between current and voltage for a single component circuit of resistor, capacitor and inductor.
7. use phasor diagram to analyse voltage, current and impedance of series circuit of RL, RC and RLC.
8. Define and use equations of capacitive reactance, inductive reactance, impedance and phase angle.
9. Explain graphically the dependence of variables and its relations to resonance.
10. Apply equations of average power, power loss, instantaneous power and power factor to AC circuit with components in series.

Learning Outcome	**Bloom's Level**	**Physics Practice**	**Modeling Perspective**	**21st Century Teaching Strategy/Tool**
Define alternating current	Remembering	Constructing explanations	Introduce AC as time-varying signal	Animated concept visual + terminology drill
Sketch and interpret sinusoidal AC waveform	Understanding, Applying	Developing and using models	Visualize AC variation over time	Graph matching activity + whiteboard sketching
Use equations of sinusoidal voltage and current	Applying	Using mathematics and computational thinking	Apply $V = V_0\sin(\omega t)$, $I = I_0\sin(\omega t)$	Equation modeling + peer tutoring
Define rms current and voltage	Remembering	Constructing explanations	Relate average energy contribution	Discussion + root-square-mean breakdown
Use rms-peak relations	Applying	Using mathematics and computational thinking	$V_{rms} = V_0/\sqrt{2}$, $I_{rms} = I_0/\sqrt{2}$	Calculation drills + clicker questions
Sketch and use phasor diagrams for single component AC circuits	Understanding, Applying	Developing and using models	Represent phase difference visually	Rotation sim + phasor sketch gallery
Use phasor diagram for voltage/current in RL, RC, RLC circuits	Analyzing	Analyzing and interpreting data	Use vector addition for total impedance	Step-by-step diagram construction + comparison
Define and use capacitive/inductive reactance, impedance, phase angle	Remembering, Applying	Using mathematics and computational thinking	Quantify opposition to current flow	Guided notes + practice tasks
Explain graphically variable dependence and resonance	Understanding	Analyzing and interpreting data	Use amplitude vs frequency graphs	Simulated resonance tuning + reasoning discussion

Apply power equations to AC circuit	Applying	Using mathematics and computational thinking	Use Pavg = VrmsIrmscosθ and others	Real-world appliance data + task sheet

Unit Plan for Algebra-Based Physics (3 1-hour Lessons)

Day	Focus Topic	Activity Ideas	Formative Check
Day 1	AC Waveforms, RMS Values, and Peak Relationships	- Sketch AC waveforms from animation - Derive and use $V = V_0\sin(\omega t)$ - Calculate rms values from peak data	Exit quiz: identify waveform features and compute rms from peak
Day 2	Phasors and Reactance in R, L, C Circuits	- Use phasor diagrams for resistor, capacitor, inductor - Model RL, RC, RLC circuits with vector addition - Practice calculating X_L, X_C, Z	Group problem: build phasor diagram for mixed circuit
Day 3	Power in AC Circuits and Resonance	- Derive and apply Pavg, instantaneous power, power factor - Explore resonance graph with simulation - Match frequency to amplitude graphs for RLC	Mini-quiz: resonance condition + power factor application

Chapter 7: Optics – Part 1

Learning Outcomes

1. State radius of curvature relation to focal length for a spherical mirror.
2. Sketch ray diagrams with a minimum of two rays to determine the characteristics of image formed by spherical mirror.
3. Use mirror equation for real objects with positive focal length for concave mirror.
4. Use equation for magnification for spherical mirror.
5. Use equation for refractive at spherical surface with positive radius for convex surface.
6. Use thin lens equation for real objects with positive focal length for convex lens.
7. Use lensmaker's equation
8. Apply magnification
9. Use thin lens formula for a combination of two convex lenses.

Learning Outcome	**Bloom's Level**	**Physics Practice**	**Modeling Perspective**	**21st Century Teaching Strategy/Tool**
State radius of curvature relation to focal length for a spherical mirror	Remembering	Constructing explanations	Introduce R=2frelation	Guided notes + peer teaching
Sketch ray diagrams to determine image characteristics for spherical mirror	Applying	Developing and using models	Use geometric rays to analyze reflection	Whiteboarding + ray-tracing worksheet
Use mirror equation for real objects and concave mirror	Applying	Using mathematics and computational thinking	Apply $\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$	Problem-solving rotations
Use magnification equation for spherical mirror	Applying	Using mathematics and computational thinking	Relate image and object height/distances	Mini-lab with measured mirrors
Use equation for refraction at convex spherical surface	Applying	Using mathematics and computational thinking	Apply curved surface refraction formula	Step-by-step example analysis
Use thin lens equation for convex lens	Applying	Using mathematics and computational thinking	Apply $\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$	Lens bench simulation + calculation drills
Use lensmaker's equation	Applying	Using mathematics and computational thinking	Model lens geometry to find focal length	Interactive lens shape modeling
Apply magnification	Applying	Using mathematics and computational thinking	Combine equations for object-image systems	Visual magnification matching activity
Use thin lens formula for combination of two convex lenses	Analyzing	Using mathematics and computational thinking	Model two-lens systems step by step	Group diagram + problem walk-through

Unit Plan for Algebra-Based Physics (3 1-hour Lessons)

Day	Focus Topic	Activity Ideas	Formative Check
Day 1	Spherical Mirrors: Ray Diagrams and Equations	- Sketch ray diagrams for concave mirror- Derive and apply mirror & magnification equations- Demo: Show R=2f with spherical object	Exit quiz: sketch ray diagram + apply mirror equation
Day 2	Refraction and Convex Lens	- Apply convex surface refraction equation- Practice with thin lens equation in simulation- Derive & use lensmaker's equation	Worksheet: solve for image position and focal length
Day 3	Lens Systems and Magnification	- Analyze two-lens combinations- Step-by-step ray diagrams and calculations- Combine magnifications for total system	Group task: calculate and sketch ray diagram for 2-lens system

Chapter 7: Optics – Part 2

Learning Outcomes

1. State Huygens' Principle, using spherical and plane wave fronts as examples
2. Sketch and explain the wavefront of light after passing through a single slit and obstacle using Huygens' Principle.
3. Define coherence
4. State the conditions for interference of light
5. State the conditions of constructive and destructive interference for in phase and antiphase sources, with emphasis on the path difference and its equivalence to phase difference.
6. Use equations for bright fringes and dark fringes for interference of transmitted light through double slits.
7. Use equation of separation between two consecutive dark or bright fringes for interference of transmitted light through double slits.
8. Identify the occurence of phase change upon reflection
9. Describe the interference of light in thin films at normal incidence with the aid of a diagram, limited to three media
10. Use constructive and destructive interference equations for reflected light with no phase difference (non-reflective coating).
11. Use constructive and destructive interference equations for reflected light with \pi phase difference (reflective coating).
12. Explain the application of thin films
13. Define diffraction
14. Explain the diffraction of single slit with the aid of a diagram.
15. Use equations for dark fringes and bright fringes for diffraction by a single slit.
16. Explain the formation of diffraction by diffraction grating with the aid of a diagram
17. Apply bright fringe equation for diffraction grating

Learning Outcome	Bloom's Level	Physics Practice	Modeling Perspective	21st Century Teaching Strategy/Tool
State Huygens' Principle with examples	Remembering	Constructing explanations	Model light as wavefronts from point sources	Diagram analysis + visual simulation
Sketch and explain wavefronts after single slit and obstacle	Understanding, Applying	Developing and using models	Apply Huygens' wavelet construction	Whiteboard sketching + video support
Define coherence	Remembering	Constructing explanations	Introduce stable phase relation	Peer instruction + visual analogy
State conditions for interference	Remembering	Constructing explanations	Identify coherent source requirement	Think-pair-share + mini poster
State constructive/destructive conditions with phase/path difference	Understanding	Constructing explanations	Link path difference to phase relationship	Simulation with phase sliders
Use equations for double-slit interference (bright/dark fringes)	Applying	Using mathematics and computational thinking	Predict pattern based on geometry	Practice problems + laser demo
Use equation for fringe separation	Applying	Using mathematics and computational thinking	Relate geometry and wavelength	Measurement lab or virtual lab

Identify phase change on reflection	Understanding	Analyzing and interpreting data	Recognize phase shifts at boundary	Concept discussion with annotated diagrams
Describe thin film interference (3 media)	Understanding	Developing and using models	Visualize reflection with path differences	Diagram completion + guided example
Use interference equations (no phase shift)	Applying	Using mathematics and computational thinking	Calculate conditions for reflection minima/maxima	Practice exercises with diagrams
Use interference equations (π phase shift)	Applying	Using mathematics and computational thinking	Include phase shift in calculations	Application to real coatings
Explain thin film applications	Understanding	Constructing explanations	Connect model to real-life tools	Group poster or concept map
Define diffraction	Remembering	Constructing explanations	Define spreading and edge effects	Video example + think-aloud definitions
Explain single-slit diffraction with diagram	Understanding	Developing and using models	Model envelope pattern using interference of edges	Whiteboard sketching + animation
Use equations for diffraction minima/maxima	Applying	Using mathematics and computational thinking	Link geometry to angle spacing	Graphical + calculation task
Explain diffraction grating formation	Understanding	Developing and using models	Use multiple slit interference model	Ray diagram sketch + explanation
Apply bright fringe equation for diffraction grating	Applying	Using mathematics and computational thinking	Use dsinθ=nλd\sin\theta = n\lambda	Real-world application with spectrum demo

Unit Plan for Algebra-Based Physics (3 1-hour Lessons)

Day	Focus Topic	Activity Ideas	Formative Check
Day 1	Interference & Huygens' Principle	- Huygens’ principle animation & sketching- Explore double-slit with laser & ruler- Derive and apply fringe spacing formula	Quick worksheet: label fringes and compute spacing
Day 2	Thin Film Interference	- Diagram light rays in 3-medium system- Use equations for film with and without π shift- Apply to anti-reflective coatings	Exit ticket: identify thin film type + calculate thickness
Day 3	Diffraction (Single-Slit & Grating)	- Sketch envelope for single-slit pattern- Analyze patterns with simulation- Use grating equation for color separation	Challenge task: match angle to diffraction order & color

Chapter 8: Wave Properties of Particles

Learning Outcomes

1. State wave-particle duality
2. Use de Broglie wavelength
3. Describe the observation of electron diffraction in Davisson-Germer experiment.
4. Explain the wave behaviour of electron in an electron microscope with an emphasis on the relation between the de Broglie wavelength with the resolving power of the microscope
5. State the advantages of electron microscope compared to optical microscope

Learning Outcome	Bloom's Level	Physics Practice	Modeling Perspective	21st Century Teaching Strategy/Tool
State wave-particle duality	Remembering	Constructing explanations	Introduce dual nature of matter	Video intro + discussion prompt
Use de Broglie wavelength	Applying	Using mathematics and computational thinking	Model matter waves with $\lambda = h/p$	Calculation tasks + analogy with photons
Describe electron diffraction in Davisson-Germer experiment	Understanding	Analyzing and interpreting data	Use diffraction model for electrons	Virtual lab walkthrough + annotated diagram
Explain electron wave behavior in microscope context	Understanding	Constructing explanations	Relate λ to resolution in imaging	Comparison case study + simulation
State advantages of electron microscope	Remembering	Constructing explanations	Contrast optical vs electron imaging	Think-pair-share + summary table

Unit Plan for Algebra-Based Physics (3 1-hour Lessons)

Day	Focus Topic	Activity Ideas	Formative Check
Day 1	Wave-Particle Duality and de Broglie Hypothesis	- Introduce concept using photon and electron examples- Calculate de Broglie wavelength for various particles- Compare with real object scales	Exit ticket: calculate λ and interpret meaning
Day 2	Electron Diffraction and Davisson-Germer Experiment	- Watch virtual simulation of Davisson-Germer- Annotate diagram and explain pattern- Relate diffraction to wave model	Mini-quiz: identify components and result of experiment
Day 3	Electron Microscopy and Imaging Power	- Simulation comparing electron vs optical microscopes- Link λ to resolution and discuss implications- Identify real-world applications	Task: explain resolution benefit + summarize application in 1 paragraph

Chapter 9: Nuclear & Particle Physics

Learning Outcomes

1. Define and use mass defect equation
2. Define and use binding energy equation
3. Determine binding energy per nucleon
4. Sketch and describe graph of binding energy per nucleon against nucleon number
5. Explain alpha, beta plus, beta minus and gamma decays.
6. State and use decay law
7. Define and determine activity and decay constant with consideration to decay curve.
8. Use equations of decay for number of radioactive particles and activity
9. Define and use half-life equations
10. State the thermionic emission
11. Explain the acceleration of particles by electric and magnetic field.
12. State the role of electric and magnetic field in particle accelerators (LINAC and cyclotron) and detectors (general principles of ionization and deflection only)
13. State the need of high energies required to investigate the structure of nucleon.
14. Explain the standard quark-lepton model particles.
15. Explain the corresponding antiparticle for every particle.

Learning Outcome	**Bloom's Level**	**Physics Practice**	**Modeling Perspective**	**21st Century Teaching Strategy/Tool**
Define and use mass defect equation	Remembering, Applying	Using mathematics and computational thinking	Mass-energy conversion model	Guided examples + visual mass-energy balance
Define and use binding energy equation	Remembering, Applying	Using mathematics and computational thinking	Relate nuclear mass to energy content	Problem-solving worksheet
Determine binding energy per nucleon	Applying	Using mathematics and computational thinking	Normalize energy across nucleon count	Table analysis + group comparisons
Sketch and describe binding energy graph	Understanding, Analysing	Analyzing and interpreting data	Visualize nuclear stability pattern	Graph activity + sticky note plotting
Explain alpha, beta, and gamma decays	Understanding	Constructing explanations	Describe decay with particle conservation	Particle animation + sorting activity
State and use decay law	Remembering, Applying	Using mathematics and computational thinking	Model exponential change in N(t)	Graph + decay simulation
Define and determine activity and decay constant	Understanding, Applying	Using mathematics and computational thinking	Relate slope and decay rate	Graph analysis from real data
Use equations for decay and activity	Applying	Using mathematics and computational thinking	Apply $N(t) = N_0e^{-\lambda t}$ and $A = \lambda N$	Equation card sort + practice
Define and use half-life equations	Remembering, Applying	Using mathematics and computational thinking	Connect time constants to exponential decay	Half-life lab/sim + decay curve analysis

State thermionic emission	Remembering	Constructing explanations	Describe charge escape from heated metal	Demo + diagram annotation
Explain acceleration by electric/magnetic fields	Understanding	Constructing explanations	Model particle motion from Lorentz force	Diagram tracing + force mapping
State roles of fields in accelerators/detectors	Remembering	Constructing explanations	Explain ionization + deflection basics	Accelerator diagram analysis
State need for high energy in nucleon studies	Remembering	Constructing explanations	Link resolution to wavelength/energy	Analogy: camera resolution + wavelength chart
Explain standard model particles	Understanding	Constructing explanations	Classify quarks and leptons	Particle family tree activity
Explain particle-antiparticle pairs	Understanding	Constructing explanations	Match particles with opposites	Card-matching challenge

Unit Plan for Algebra-Based Physics (3 1-hour Lessons)

Day	Focus Topic	Activity Ideas	Formative Check
Day 1	Nuclear Mass, Binding Energy, and Decay Law	- Solve mass defect and BE questions- Sketch and analyze BE/nucleon graph- Introduce decay law + simulate decay graph	Exit quiz: binding energy & exponential decay
Day 2	Radioactivity, Half-life, and Particle Acceleration	- Half-life lab or sim- Use decay equations to model isotope samples- Diagram force on particles in fields	Worksheet: decay curve + force direction
Day 3	Standard Model & Subatomic Interactions	- Particle card sorting activity- Match particles and antiparticles- Group diagram of accelerators/detectors	Group quiz: model diagram + match terms to roles

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