NATIONAL SCHOOL OF SCIENCES

Roadmap to the International Physics Olympiad

A Comprehensive Syllabus and Preparation Guide for NEB Grade 11–12 Students

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Document Approval & Preface

This comprehensive roadmap has been meticulously prepared by Divya Darsheel Sharma and formally approved by the Physics Department of the National School of Sciences. It is designed to serve as the definitive guide for students under the National Examination Board (NEB) curriculum in Nepal who aspire to transition from standard board examinations to the rigorous demands of the National Physics Olympiad (NPhO) and ultimately the International Physics Olympiad (IPhO).

> *Approved by: The Physics Department, National School of Sciences. Prepared by: Divya Darsheel Sharma. Date: September 2026.*

The transition from NEB Physics to IPhO Physics requires a fundamental paradigm shift. While the NEB curriculum emphasizes standard formula application and basic numerical problem-solving, the Olympiad demands deep conceptual synthesis, advanced mathematical modeling, and the ability to derive physical laws from first principles. This document bridges that gap through a heavily detailed, three-tiered progression system: Beginning, Medium, and Absolute Tough.

Executive Summary

This document provides a structured, rigorous, and exhaustive syllabus breakdown for NEB Grade 11–12 students. The curriculum is deliberately divided into three progressive tiers. This phased approach ensures a solid foundation in NEB-aligned concepts before advancing to the complex calculus-based reasoning and abstract theoretical frameworks required at the international level. Mastery of the mathematical toolkit is treated as a prerequisite to all physical domains.

1. The Mathematical Toolkit

Before engaging with advanced physics, mastery of the underlying mathematics is non-negotiable. The IPhO expects fluency in the following areas, which extend significantly beyond the standard NEB mathematics curriculum.

1.1 Calculus & Differential Equations

- Multivariable Calculus: Partial derivatives, gradients, line integrals, and surface integrals.
- Taylor & Maclaurin Series: Small-angle approximations, binomial expansions, and potential energy minima analysis.
- Differential Equations: First-order separable, second-order linear homogeneous (SHM), and damped/driven oscillators.
- Integration Techniques: Integration by parts, substitution, and Gaussian integrals for statistical mechanics.

1.2 Linear Algebra & Complex Analysis

- Matrices & Eigenvalues: Crucial for coupled oscillations, normal modes, and quantum mechanics.
- Complex Numbers: Euler's formula, phasor representation for AC circuits, and complex impedance.
- Vector Calculus: Dot/cross products, coordinate transformations (Cartesian, polar, spherical, cylindrical).

1.3 Dimensional Analysis & Approximations

- Buckingham Pi Theorem and order-of-magnitude estimations.
- Limiting case analysis to verify the physical validity of derived equations.

2. Beginning Level: NEB Foundation & NPhO Entry

This tier focuses on mastering the core NEB Grade 11–12 physics syllabus with an emphasis on deep conceptual understanding and multi-step problem solving, moving away from rote memorization.

Domain	Core NEB Concepts	Olympiad Extensions & IPhO Ceiling
Classical Mechanics	Kinematics (1D/2D), Newton's Laws, Work-Energy Theorem, Basic Momentum, Uniform Circular Motion, Gravitation.	Calculus-based kinematics, variable mass systems, center of mass integration, non-inertial reference frames, advanced rotational dynamics, central force motion.
Thermodynamics	Temperature, Calorimetry, Ideal Gas Law, Kinetic Theory, 1st Law, Specific Heats, Heat Transfer.	2nd Law, Entropy, Carnot Cycle, Thermodynamic Potentials, Clausius-Clapeyron Equation, Phase Transitions, Fourier's Law.
Waves & Oscillations	SHM (springs, pendulums), Wave Equation, Superposition, Standing Waves, Doppler Effect (Sound).	Coupled oscillators, normal modes, wave packets, group vs. phase velocity, electromagnetic Doppler effect.
Electromagnetism	Coulomb's Law, Gauss's Law, Capacitance, Kirchhoff's Rules, RC Circuits, Biot-Savart, Faraday's Law.	Method of Images, Multipole Expansion, Dielectrics, Maxwell's Equations, EM Waves, Poynting Vector, AC Resonance.
Optics & Modern	Geometrical Optics, Young's Double Slit, Photoelectric Effect, Bohr Model, Radioactivity.	Matrix Optics, Interferometers, Diffraction Gratings, Special Relativity (4-Vectors), 1D Schrödinger Equation.

3. Medium Level: National Competitiveness & APhO Standard

At this stage, students must integrate multiple concepts and apply calculus-based reasoning. This tier aligns with the difficulty of national-level olympiad examinations and the Asian Physics Olympiad (APhO).

3.1 Advanced Mechanics

- Non-inertial reference frames: Pseudo-forces, Coriolis effect, and centrifugal potential.
- Variable mass systems: Derivation and application of the Rocket Equation.
- Advanced Rotational Dynamics: Rolling without slipping, gyroscopic precession, and torque-induced angular momentum changes.
- Central Force Motion: Effective potential, orbit equations, and Keplerian mechanics derived from energy conservation.

3.2 Advanced Electromagnetism

- Electrostatics: Method of images, multipole expansion, and energy density of electric fields.
- Magnetostatics: Magnetic materials (paramagnetism, diamagnetism, ferromagnetism) and boundary conditions.
- Electrodynamics: Maxwell's equations in differential form, displacement current, and EM wave propagation in dielectric media.
- AC Circuit Analysis: Complex impedance, phasor diagrams, RLC resonance, and power factor calculations.

3.3 Advanced Thermodynamics & Statistical Mechanics

- Thermodynamic Cycles: Otto, Diesel, and Stirling engines; calculating efficiency and entropy generation.
- Phase Transitions: Clausius-Clapeyron equation and latent heat derivations.
- Introductory Statistical Mechanics: Boltzmann distribution, equipartition theorem, and macroscopic properties from microscopic states.

4. Absolute Tough Level: IPhO Status

This tier represents the ceiling of pre-university physics. Problems at this level require creative insight, advanced mathematical formalism, and the ability to model non-ideal, real-world experimental scenarios.

4.1 Analytical Mechanics

- Calculus of Variations: Euler-Lagrange equations and the principle of least action.
- Lagrangian Mechanics: Generalized coordinates, constraints, and conservation laws via Noether's theorem.
- Small Oscillations: Eigenfrequencies, normal modes via matrix diagonalization.
- Rigid Body Dynamics: Inertia tensor, principal axes, and Euler's equations of motion.

4.2 Quantum & Relativistic Physics

- Special Relativity: Lorentz transformations, relativistic kinematics, 4-vectors, and invariant mass.
- Quantum Mechanics: 3D Schrödinger equation, angular momentum operators, spin, and perturbation theory.
- Quantum Statistics: Fermi-Dirac and Bose-Einstein distributions, blackbody radiation, and Planck's law.

4.3 Advanced Electrodynamics

- Retarded Potentials: Liénard-Wiechert potentials and dipole radiation.
- Radiation: Larmor formula, scattering cross-sections, and waveguides.

5. Experimental Physics & Data Analysis

The IPhO practical examination is as rigorous as the theoretical one. Students must master the following experimental competencies:

- Error Propagation: Covariance, partial derivatives, and standard deviation analysis.
- Data Linearization: Logarithmic plotting for exponential decay, power laws, and extracting physical constants from slopes/intercepts.
- Statistical Analysis: Least-squares linear regression, chi-square goodness of fit, and identification of systematic vs. random errors.
- Instrumentation: Oscilloscopes, lock-in amplifiers, optics bench alignments, and designing an experiment from first principles.

6. Strategic Preparation & Resource Guide

Transitioning from the NEB curriculum to IPhO readiness requires a fundamental shift in study methodology. Students must prioritize derivation over memorization and utilize the following canonical literature:

- Classical Mechanics: Introduction to Classical Mechanics by David Morin.
- Electrodynamics: Introduction to Electrodynamics by David J. Griffiths.
- General Problem Solving: Problems in General Physics by I.E. Irodov; Aptitude Test Problems in Physics by S.S. Krotov.
- Conceptual Depth: The Feynman Lectures on Physics (Volumes I–III).

References and Recommended Literature

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[3] Morin, D. Introduction to Classical Mechanics: With Problems and Solutions. Cambridge University Press, 2008.

[4] Griffiths, D. J. Introduction to Electrodynamics. Cambridge University Press, 2017.

[5] Feynman, R. P., Leighton, R. B., & Sands, M. The Feynman Lectures on Physics. Basic Books, 2011.

[6] National Examination Board (NEB), Nepal. Physics Curriculum for Grades 11 and 12. Government of Nepal, 2023.

[7] Zheltkov, A. et al. Experimental Physics Olympiad: Data Analysis and Uncertainty Guide. IPhO Secretariat, 2020.