NATIONAL SCHOOL OF SCIENCES

Roadmap to the International Mathematical 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 Mathematics 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 Mathematics Olympiad (NMO) and ultimately the International Mathematical Olympiad (IMO).

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Mathematics is the subject where the District to International progression matters the most. Upper levels stop being about knowing more chapters and become almost entirely about problem-solving technique and mathematical maturity. The Mathematical Association of Nepal (MAN) structures the District Mathematics Olympiad (DMO) around Grade 12 mathematics and logical reasoning, while later selection rounds become substantially more competition-oriented. There is no finite IMO syllabus in the school-textbook sense; the IMO is fundamentally a problem-solving competition. This document is a mastery map of the mathematical concepts and techniques that repeatedly form the basis of Olympiad problems.

Executive Summary

This document provides a structured, rigorous, and exhaustive syllabus breakdown for NEB Grade 11–12 students. The curriculum is divided into progressive levels, from Level 0 (Mathematical Foundations) to Level 8 (Advanced Olympiad Techniques), followed by a strategic breakdown of the District, Province, National, and International competition tiers. A central tenet of this roadmap is that mathematical Olympiad performance is much less correlated with simply finishing the curriculum and much more correlated with deep problem-solving maturity.

Level 0 — Mathematical Foundations

Before Olympiad mathematics, students must eliminate weaknesses in basic mathematical manipulation. Arithmetic and algebraic fluency must become completely automatic. You should not lose a problem because you spent five minutes fighting basic algebra.

Arithmetic & Algebraic Fluency (Priority: Maximum)

- Fractions, ratios, percentages, powers, roots, and scientific notation.
- Absolute value, basic inequalities, and algebraic manipulation.
- Factorization, expansion, simplification, and modular arithmetic basics.
- Estimation and bounding techniques.

Level 1 — Algebra

Algebra is one of the four major pillars of Olympiad mathematics. It requires moving beyond mechanical solving to exploiting symmetry, substitutions, factorization, bounds, and parity.

Polynomials & Equations (Priority: Maximum)

- Polynomial identities, remainder/factor theorems, Vieta's relations, and symmetric polynomials.
- Root-location arguments, polynomial divisibility, and interpolation.
- Linear, quadratic, systems, radical, exponential, and logarithmic equations.
- Equations involving parameters and functional identities.

Inequalities (Priority: Maximum)

This deserves major priority. At District level, basic inequalities are enough. At National/International levels, inequality problems become extremely sophisticated.

- AM-GM, Cauchy-Schwarz, triangle inequality, and rearrangement ideas.
- Jensen's inequality, uvw-type methods, and equality conditions.
- Bounding, homogenization, normalization, and smoothing.

Sequences, Functional Equations & Complex Numbers

- Sequences: AP, GP, HP, telescoping, nonlinear recurrences, and generating functions.
- Functional Equations: Injectivity/surjectivity, symmetry, periodicity, Cauchy-type equations.

- Complex Numbers: Polar form, De Moivre's theorem, geometric interpretation, and locus problems.

Level 2 — Number Theory

Number Theory is the second core pillar of Olympiad mathematics. It relies heavily on logical deduction and structural properties of integers.

Divisibility, Primes & Modular Arithmetic (Priority: Maximum)

- Divisibility rules, GCD/LCM, Euclidean algorithm, Bézout identity, and the fundamental theorem of arithmetic.
- Prime factorization, prime distributions, and infinitude of primes.
- Congruences, modular inverses, Fermat's little theorem, Euler's theorem, and the Chinese remainder theorem.
- Orders modulo n, quadratic residues, and Legendre-symbol concepts.

Diophantine Equations & Valuations (Priority: Maximum)

- Integer solutions, linear Diophantine equations, factoring techniques, and bounding.
- Infinite descent, Pell-type equations, and Vieta jumping.
- Floor/ceiling functions, divisor-counting, Euler's phi function, and Möbius-function concepts.
- p-adic valuation, Legendre-type valuation formulas, and divisibility via valuations.

Level 3 — Geometry

Geometry is the second giant pillar and the area where proof-writing maturity matters most. Coordinate geometry is a tool, not the end goal.

Euclidean & Triangle Geometry (Priority: Maximum)

- Congruence, similarity, Pythagorean theorem, and basic angle properties.
- Triangle centers: Centroid, orthocenter, circumcenter, incenter, excenters, and the Euler line.
- Major theorems: Ceva, Menelaus, angle bisector theorem, Stewart's theorem, and Apollonius theorem.

Circle & Advanced Euclidean Geometry

- Chords, tangents, cyclic quadrilaterals, power of a point, and radical axis/centers.
- Directed angles, homothety, spiral similarity, isogonal lines, and symmedians.
- Inversion, projective methods, and advanced transformations.

Coordinate & Trigonometric Geometry

- Strategic coordinate placement, vector coordinates, and analytic proofs.
- Sine/cosine rules, area formulas, half-angle identities, and trigonometric inequalities.

Level 4 — Combinatorics

Combinatorics is the third giant pillar. It relies on clever counting, structural invariants, and extremal arguments.

Counting & Pigeonhole Principle (Priority: Maximum)

- Addition/multiplication principles, permutations, combinations, and inclusion-exclusion.
- Pigeonhole principle: Basic, generalized, extremal, and combined with number theory or geometry.
- Double counting: Counting the same object two ways, incidence counting, and combinatorial identities.

Graph Theory, Invariants & Extremal Principle

- Graphs, paths, cycles, trees, bipartite graphs, coloring, and Eulerian/Hamiltonian concepts.
- Invariants: Parity, modular, geometric, and coloring invariants.
- Extremal principle: Minimal counterexample, maximal element, and extremal configurations.

Levels 5, 6 & 7 — Probability, Vectors & Calculus

These areas serve as supporting toolkits rather than primary pillars for classical IMO preparation.

Probability

- Conditional probability, independence, and combinatorial probability.
- Expected value, linearity of expectation, random variables, and random walks.

Vectors & Linear Methods

- Vector operations, dot products, collinearity, and geometric interpretations.
- Matrices, determinants, and systems of linear equations (supporting toolkit).

Calculus

Classical IMO problems rarely require advanced calculus. Do not spend 40% of your Olympiad preparation on board-exam integration techniques just because calculus is huge in NEB.

- Limits, continuity, derivatives, and optimization.
- Olympiad calculus: Inequality proofs, monotonicity, convexity/concavity, and tangency arguments.

Level 8 — Advanced Olympiad Techniques

This is where the real transformation happens. The focus shifts from learning topics to mastering meta-techniques and proof structures.

Proof Techniques (Priority: Maximum)

- Direct proof, contradiction, contrapositive, and mathematical induction (including strong induction).
- Case analysis, construction, extremal arguments, and infinite descent.

Mathematical Experimentation

Before proving, strong Olympiad mathematicians test small cases, calculate examples, search for patterns, identify invariants, and formulate conjectures. The workflow is: Experiment → conjecture → simplify → identify structure → choose a technique → prove.

The Four Olympiad Pillars

After stripping away the school curriculum, the mathematical Olympiad core becomes four distinct pillars. Everything else supports these four.

Pillar	Core Domains
Algebra	Polynomials, equations, inequalities, sequences, functional equations, complex numbers
Number Theory	Divisibility, primes, modular arithmetic, Diophantine equations, valuations
Geometry	Euclidean, triangle, circle, transformations, coordinate, trigonometric, inversion
Combinatorics	Counting, pigeonhole, double counting, graph theory, invariants, extremal methods

The Four Olympiad Levels

The MAN selection pipeline becomes progressively more problem-solving oriented. Preparation must scale according to the competition tier.

District Level — Breadth + Speed

Objective: Fast recognition, accurate execution, and logical reasoning based on Grade 12 mathematics. Master equations, quadratics, basic inequalities, divisibility, primes, basic geometry, and basic counting. Do not over-specialize yet.

Province Level — Competition Mathematics

Knowing the NEB syllabus is no longer enough. Focus shifts to standard Olympiad techniques: inequalities, recurrences, congruences, Diophantine equations, Ceva/Menelaus, power of a point, pigeonhole, and double counting.

National Level — Problem Solving

The distinction gets serious. Subjective exams span the four pillars with multi-hour solving time. The biggest skill is writing a complete proof: Claim → reasoning → lemma → proof → conclusion.

International (IMO) Level

The syllabus essentially becomes infinite. The target is not to learn more mathematics, but to become capable of solving deep, unfamiliar mathematical problems.

Final Priority Map

S-Tier — The Real Core (Non-Negotiable)

- Algebra: Polynomials, inequalities, functional equations, sequences/recurrences.
- Number Theory: Divisibility, modular arithmetic, Diophantine equations, valuations.
- Geometry: Triangle/circle geometry, Ceva/Menelaus, similarity, power of a point.
- Combinatorics: Pigeonhole, double counting, invariants, extremal principle.
- Universal: Proof writing, induction, contradiction, construction, logical reasoning.

A-Tier & B-Tier

A-Tier includes complex numbers, coordinate geometry, graph theory, transformations, inversion, and Vieta jumping. B-Tier (Supporting Toolkit) includes vectors, matrices, calculus, and statistics. These matter for NEB and overall mathematical maturity, but should not consume the same preparation time as the four pillars.

Strategic Differences & Conclusion

For Chemistry, the path is: learn the syllabus → strengthen concepts → solve Olympiad problems. For Biology: learn the syllabus → understand mechanisms → interpret data → solve unfamiliar problems.

For Mathematics, the path is fundamentally different: Learn the foundations → learn techniques → solve hundreds of unfamiliar problems → learn from failed attempts → repeat.

If the entire roadmap must be reduced to one sentence: For District, master Grade 12 mathematics. For Province, learn Olympiad techniques. For National, master Algebra, Number Theory, Geometry, and Combinatorics. For IMO, become an exceptional mathematical problem solver. By systematically mastering this roadmap, a dedicated NEB student can develop the analytical depth required to excel on the global stage.

References and Recommended Literature

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