# Manav Batavia

Curriculum Vitae

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## EDUCATION

**Purdue University**                                                                                    Indiana, USA
*Ph.D. in Mathematics*                                                                              *Aug 2022 - Present*

**Indian Institue of Technology Bombay**                                                            Mumbai, India
*Integrated Master's of Science (B.S.+M.Sc.) in Mathematics*                          *July 2017 – June 2022*

- Awarded the Institute Silver medal.
- Cumulative Performance Index (CPI) : 9.82/10.
- Minor in Computer Science and Engineering, Minor CPI: 9.60/10.

## PUBLICATIONS, PREPRINTS AND WORKING PAPERS

3. H. Ananthnarayan, **M. Batavia**, O. Javadekar, ***Associated graded modules over Noetherian local rings***, in preparation.

2. A. Agarwal, **M. Batavia**, Z. Lihn, H. Lu, A. Maithani, A. Pradhan, S. Rath, A. Seceleanu, ***Betti Numbers of Quadratic Ideals of Low Embedding Dimension***, in preparation.

1. S. Banerjee, **M. Batavia**, B. Kane, M. Kyranbay, D. Park, S. Saha, H. C. So, P. Varyani, ***Fermat's Polygonal Number Theorem for Repeated Generalised Polygonal Numbers***, Journal of Number Theory, Volume 220, 2021, Pages 163-181. [doi]

## RESEARCH EXPERIENCE

**Master's Thesis: Homological Algebra**                                                   July 2021 – May 2022
*Guide: Prof. Ananthnarayan Hariharan, Department of Mathematics*                          *IIT Bombay*

- Explored Schreyer's algorithm for computing the projective resolution of a finitely generated module over a polynomial ring in finitely many variables.
- Learned about the relation between the Betti numbers of an ideal and those of its initial ideal, elegantly proved using a homogenization technique, the Tor functor and Farkas's lemma.
- Explored the theory of Stanley-Reisner ideals and Fröberg's work on Stanley-Reisner rings.
- Studied the Eliahou-Kervaire resolution and Peeva's work on consecutive cancellations in Betti numbers.
- Studied Avramov and Eisenbud's work on the regularity of modules over a Koszul algebra.
- Explored Herzog and Kühl's work on Cohen-Macaulay modules having pure resolution
- Explored Puthenpurakal's work on associated graded modules having a pure resolution, and successfully generalised the results to modules over Noetherian local rings.
- Independently proved the Auslander-Buchsbaum-Serre equivalences, and studied Burch's work on constructing ideals with arbitrarily large projective dimension, generated by three or fewer elements.

**Betti Tables of Quadratic Ideals in Characteristic Two**                             June - August 2021
*Guide: Prof. Alexandra Seceleanu, Department of Mathematics*                    *University of Nebraska-Lincoln*

This research was done as part of the Polymath Jr. 2021 program.

- Succeeded in resolving all quadratic ideals with three generators in a polynomial ring in three variables over a field of characteristic two. The results attained are easily applicable to larger ideals and larger polynomial rings.
- The approach involved classification of all such ideals into certain categories and subcategories, followed by suitable application of results on Koszul complexes and mapping cones, among others.
- In particular, application of mapping cone theory, coupled with degree comparisons, enabled us to resolve ideals with higher number of generators using well known results on ideals with fewer generators.
- Acquainted myself with the computer algebra system Macaulay2, critical for the computational aspect of the project.
- Presented our results at the Young Mathematicians Conference 2021, organised by the Ohio State University.
- Currently compiling the work done in this project for publication.

## Drinfeld Modular Forms

- Versed myself with the theory of additive polynomials over a finite field, and Carlitz and Drinfeld modules from David Goss's text "Basic Structures of Function Field Arithmetic".
- Proceeded to read Richard Pink's trifecta of papers on the Galois representations associated to a Drinfeld module in special characteristic.

#### Parameterized Verification under Sequential Consistency
*Guide: Prof. Roland Meyer, Institute of Theoretical Computer Science*      March – June 2020     *Technische Universität Braunschweig*
- Worked on proving that the paremeterized reachability problem under sequential consistency is EXPTIME-complete.
- The approach involved reduction of Boolean pushdown to parameterized program under sequential consistency and vice versa, drawing on techniques used by Farzan and Vandikas in their paper on automated hypersafety verification.

#### Generalization of Fermat's Polygonal Number Theorem
*Guide: Prof. Ben Kane, Department of Mathematics*     May – July 2019     *The University of Hong Kong*
- Acquired minimal number of terms for which certain weighted sums of generalized polygonal numbers are universal.
- The approach involved using Siegel and Weil's work on local representations to conclude a special universality of the sum of five generalised polygonal numbers, and consequently treating the smaller cases using a variety of methods.
- The work done resulted in the aforementioned publication in the Journal of Number Theory.

## READING PROJECTS

#### Decoding Cyclic Codes: The Cooper Philosophy
*Course Project, MA5105: Coding Theory*     October 2021     *IIT Bombay*
- Learned about Cooper's ideas on decoding BCH cyclic codes using the theory of Gröbner bases.
- Read and presented the ideas outlined by Chen, Reed, Helleseth and Truong in their work on the use of Gröbner bases to decode binary cyclic codes up to the true minimum distance.

#### Lie Groups and Lie Algebras
*Guide: Prof. Dipendra Prasad, Department of Mathematics*     January – May 2021     *IIT Bombay*
- Read and presented sections of the book "Symmetries, Representations and Invariants" (Goodman, Wallach).
- In addition to acclimatisation with Lie groups and Lie algebras, the primary objective was to explore the regular representations of classical connected groups and their Lie algebras.

#### Combinatorial Algorithm for Computing Determinants
*Course Project, CS711: Computational Ring Theory*     November 2020     *IIT Bombay*
- Read and presented the purely combinatorial algorithm proposed by Mahajan and Vinay to compute the determinant over arbitrary commutative rings. In the same paper, they also proved that the complexity class GapL characterizes the complexity of computing the determinant of matrices over the integers.

#### Automata Theory
*Guide: Prof. Krishna S., Department of Computer Science and Engineering*     January – May 2020     *IIT Bombay*
- Explored a number of references and research papers related to automata theory, such as Dexter Kozen's "Automata and Computability" and the research papers Automated Hypersafety Verification (by Farzan and Vandikas) and Analysis of Boolean Programs (by Godefroid and Yannakakis).
- Studied the concepts of pushdown automata, context free grammar, Boolean programs, looping tree automata and reductions, among others.

## ACADEMIC ACHIEVEMENTS

- Department Rank 1 in mathematics at IIT Bombay.
- Awarded Advanced Performance (AP) grade in Group and Ring Theory (MA419), Complex Analysis (MA412), Introduction to Numerical Analysis (MA214) and Logic for CS and Automata Theory (CS228) at IIT Bombay (awarded to exceptional performers).
- All India rank of 174 in IIT JEE Advanced (out of 0.17 million candidates).
- All India rank of 8 in the B.Math entrance exam for Indian Statistical Institute (ISI).
- Acquired a score in the 99.89th percentile in JEE Mains (out of 1.19 million candidates).
- All India rank of 349 in Kishore Vaigyanik Protsahan Yojana (KVPY), organised by the Department of Science and Technology, Government of India (out of 0.1 million candidates).
- Awarded the Mitacs Globalink scholarship for a research internship in Canada.
- Awarded by Jamnabai Narsee School for highest in ICSE examination.

## TEACHING EXPERIENCE

**Teaching Assistant: Calculus II** | *MA16200, Purdue University*     Aug 2022 – Present

**Teaching Assistant: Linear Algebra** | *MA106, IIT Bombay*     Mar – May 2022

**Teaching Assistant: Calculus I** | *MA109, IIT Bombay*     Nov 2021 – Jan 2022

**Teaching Assistant: Introduction to Calculus** | *MA105, IIT Bombay*     July – Nov 2019

## Public Talks

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|---|---|
| M.Sc. Thesis Stage 2 \| *IIT Bombay* | May 2022 |
| Operad Theory \| *Homotopy Theory Course Seminar, IIT Bombay* | Apr 2022 |
| M.Sc. Thesis Stage 1 \| *IIT Bombay* | Nov 2021 |
| Decoding Cyclic Codes: The Cooper Philosophy \| *Coding Theory Course Seminar, IIT Bombay* | Oct 2021 |
| Betti Tables of Quadratic Ideals in Characteristic Two \| *Young Mathematicians Conference* | Aug 2021 |
| Explicit Factorisation over a Dedekind Domain \| *Algebraic Number Theory, IIT Bombay* | Apr 2021 |
| Length of Finite Free Resolutions \| *Advanced Commutative Algebra Course Seminar, IIT Bombay* | Feb 2021 |
| Combinatorial Computation of the Determinant \| *Computational Ring Theory Course Seminar, IIT Bombay* | Nov 2020 |
| Discrete Valuation Rings \| *Ring and Module Theory Course Seminar, IIT Bombay* | Nov 2019 |

## Relevant Coursework

**Advanced Instructional Course in Commutative Algebra**  Jan – May 2021
*Instructors: Prof. Dilip Patil, Prof. Indranath Sengupta, Prof. Jugal Verma*  *National Centre for Mathematics*

- Flat and faithfully flat modules, faithfully flat descent, Tor and Ext functors, injective, projective and global dimension, regular local rings, flat extensions of regular local rings, Serre's normality criterion.
- Krull dimension, Noether's normalization lemma, Hilbert-Samuel functions and polynomials, normal rings, finiteness of integral closure, complete local rings, formal smoothness, Cohen's structure theorem for complete local rings.
- Regular sequences, quasi-regular sequences, depth and grade, Cohen-Macaulay rings and modules, homological characterization of injective dimension, Gorenstein rings, injective modules, Matlis duality.

**Graduate Courses in Mathematics**: Algebra 1, Combinatorics 1, Advanced Commutative Algebra, Topics in Algebra, Algebraic Topology, Topics in Topology.

**Other Courses in Mathematics**: Algebraic Number Theory, Analytic Number Theory, Coding Theory, Representation Theory of Finite Groups, Commutative Algebra, Ring and Module Theory, Algebraic Topology, Functional Analysis, Partial Differential Equations, Measure Theory, Applied Stochastic Processes, Probability, Topology, Complex Analysis.

**Computer Science**: Computational Ring Theory, Logic for CS and Automata Theory, Data Structures and Algorithms, Design and Analysis of Algorithms, Introduction to Machine Learning, Digital Image Processing.

## Technical Skills

**Programming Languages**: C++, Python, MATLAB.
**Software**: Macaulay2, LaTeX, SolidWorks, AutoCAD, XCircuit.

## Positions of Responsibility

**Department Academic Mentor** \| *IIT Bombay*  April 2019 – Present

- Delivered multiple seminars aimed at freshmen and sophomore students in the mathematics department, advising them on their academic choices and future avenues.
- Responsible for mentoring 12 sophomore students to ensure their academic and holistic development.
- Co-founded the Mathematics D-AMP blog, intended to be a one-stop destination for academic resources, course reviews, internship experiences and other resources for undergraduate math students at IIT Bombay.

**National Service Scheme (NSS) Volunteer** \| *IIT Bombay*  July 2017 – May 2018

- Dedicated over 80 hours towards various activities directed toward sustaining the environment, including creating awareness and recycling plastic waste, among other ventures.
- Visited government schools and imparted environmental education to underprivileged children.

## Extra-Curricular Activities

- Mentored 12 students as part of the Summer of Science program at IIT Bombay, providing them with necessary guidance in group and ring theory, topology and real analysis.
- Finished 3rd in Math Bazinga 2018 - an annual mathematics competition open to all students in IIT Bombay.
- Developed an autonomous Arduino robot which navigates through mazes, as part of a competition at IIT Bombay.
- Finished in the top 5 (out of 400+ participants) in a cricket trivia competition at EnB Buzz, IIT Bombay.