

Anthony E. Clement, Stephen Majewicz, Marcos Zyman

The Theory of Nilpotent Groups

This monograph presents both classical and recent results in the theory of nilpotent groups and provides a self-contained, comprehensive reference on the topic. While the theorems and proofs included can be found throughout the existing literature, this is the first book to collect them in a single volume. Details omitted from the original sources, along with additional computations and explanations, have been added to foster a stronger understanding of the theory of nilpotent groups and the techniques commonly used to study them. Topics discussed include collection processes, normal forms and embeddings, isolators, extraction of roots, P -localization, dimension subgroups and Lie algebras, decision problems, and nilpotent groups of automorphisms. Requiring only a strong undergraduate or beginning graduate background in algebra, graduate students and researchers in mathematics will find *The Theory of Nilpotent Groups* to be a valuable resource.

ISBN 978-3-319-66211-4



9 783319 662114

► birkhauser-science.com



1	Commutator Calculus	1
1.1	The Center of a Group	1
1.1.1	Conjugates and Central Elements	1
1.1.2	Examples Involving the Center	3
1.1.3	Central Subgroups and the Centralizer	5
1.1.4	The Center of a p -Group	6
1.2	The Commutator of Group Elements	6
1.3	Commutator Subgroups	9
1.3.1	Properties of Commutator Subgroups	14
1.3.2	The Normal Closure	19
	References	21
2	Introduction to Nilpotent Groups	23
2.1	The Lower and Upper Central Series	23
2.1.1	Series of Subgroups	23
2.1.2	Definition of a Nilpotent Group	24
2.1.3	The Lower Central Series	26
2.1.4	The Upper Central Series	29
2.1.5	Comparing Central Series	32
2.2	Examples of Nilpotent Groups	34
2.2.1	Finite p -Groups	34
2.2.2	An Example Involving Rings	35
2.3	Elementary Properties of Nilpotent Groups	37
2.3.1	Establishing Nilpotency by Induction	38
2.3.2	A Theorem on Root Extraction	41
2.3.3	The Direct Product of Nilpotent Groups	44
2.3.4	Subnormal Subgroups	44
2.3.5	The Normalizer Condition	46
2.3.6	Products of Normal Nilpotent Subgroups	46
2.4	Finite Nilpotent Groups	47

2.5	The Tensor Product of the Abelianization	50
2.5.1	The Three Subgroup Lemma	50
2.5.2	The Epimorphism $\bigotimes_{\mathbb{Z}}^n Ab(G) \rightarrow \gamma_n G / \gamma_{n+1} G$	52
2.5.3	Property $\mathcal{P}$	58
2.5.4	The Hirsch-Plotkin Radical	59
2.5.5	An Extension Theorem for Nilpotent Groups	61
2.6	Finitely Generated Torsion Nilpotent Groups	64
2.6.1	The Torsion Subgroup of a Nilpotent Group	65
2.7	The Upper Central Subgroups and Their Factors	67
2.7.1	Intersection of the Center and a Normal Subgroup	67
2.7.2	Separating Points in a Group	69
	References	73
3	The Collection Process and Basic Commutators	75
3.1	The Collection Process	75
3.1.1	Weighted Commutators	76
3.1.2	The Collection Process for Weighted Commutators	77
3.1.3	Basic Commutators	78
3.1.4	The Collection Process For Arbitrary Group Elements	79
3.2	The Collection Formula	83
3.2.1	Preliminary Examples	83
3.2.2	The Collection Formula and Applications	85
3.3	A Basis Theorem	87
3.3.1	Groupoids and Basic Sequences	88
3.3.2	Basic Commutators Revisited	89
3.3.3	Lie Rings and Basic Lie Products	90
3.3.4	The Commutation Lie Ring	93
3.3.5	The Magnus Embedding	97
3.4	Proof of the Collection Formula	101
	References	106
4	Normal Forms and Embeddings	107
4.1	The Hall-Petresco Words	107
4.1.1	m -Fold Commutators	108
4.1.2	A Collection Process	108
4.1.3	The Hall-Petresco Words	110
4.2	Normal Forms and Mal'cev Bases	113
4.2.1	The Structure of a Finitely Generated Nilpotent Group	113
4.2.2	Mal'cev Bases	116
4.3	The R -Completion of a Finitely Generated Torsion-Free Nilpotent Group	124
4.3.1	R -Completions	124
4.3.2	Mal'cev Completions	128
4.4	Nilpotent R -Powered Groups	132
4.4.1	Definition of a Nilpotent R -Powered Group	132
4.4.2	Examples of Nilpotent R -Powered Groups	132
4.4.3	R -Subgroups and Factor R -Groups	133

4.4.4	<i>R</i> -Morphisms	135
4.4.5	Direct Products	136
4.4.6	Abelian <i>R</i> -Groups	137
4.4.7	Upper and Lower Central Series	137
4.4.8	Tensor Product of the Abelianization	139
4.4.9	Condition Max- <i>R</i>	141
4.4.10	An <i>R</i> -Series of a Finitely <i>R</i> -Generated Nilpotent <i>R</i> -Powered Group	142
4.4.11	Free Nilpotent <i>R</i> -Powered Groups	143
4.4.12	ω -Torsion and <i>R</i> -Torsion	143
4.4.13	Finite ω -Type and Finite Type	148
4.4.14	Order, Exponent, and Power-Commutativity	149
	References	152
5	Isolators, Extraction of Roots, and <i>P</i>-Localization	155
5.1	The Theory of Isolators	155
5.1.1	Basic Properties of <i>P</i> -Isolated Subgroups	155
5.1.2	The <i>P</i> -Isolator	157
5.1.3	<i>P</i> -Equivalency	160
5.1.4	<i>P</i> -Isolators and Transfinite Ordinals	166
5.2	Extraction of Roots	168
5.2.1	$\mathcal{U}_P$ -Groups	169
5.2.2	$\mathcal{U}_P$ -Groups and Quotients	171
5.2.3	<i>P</i> -Torsion-Free Locally Nilpotent Groups	172
5.2.4	Upper Central Subgroups of $\mathcal{U}_P$ -Groups	172
5.2.5	Extensions of $\mathcal{U}_P$ -Groups	174
5.2.6	<i>P</i> -Radicable and Semi- <i>P</i> -Radicable Groups	175
5.2.7	Extensions of <i>P</i> -Radicable Groups	176
5.2.8	Divisible Groups	177
5.2.9	Nilpotent <i>P</i> -Radicable Groups	178
5.2.10	The Structure of a Radicable Nilpotent Group	185
5.2.11	The Maximal <i>P</i> -Radicable Subgroup	186
5.2.12	Residual Properties	190
5.2.13	$\mathcal{D}_P$ -Groups	199
5.2.14	Extensions of $\mathcal{D}_P$ -Groups	201
5.2.15	Some Embedding Theorems	203
5.3	The <i>P</i> -Localization of Nilpotent Groups	206
5.3.1	<i>P</i> -Local Groups	206
5.3.2	Fundamental Theorem of <i>P</i> -Localization of Nilpotent Groups	209
5.3.3	<i>P</i> -Morphisms	212
	References	216
6	"The Group Ring of a Class of Infinite Nilpotent Groups" by S. A. Jennings	219
6.1	The Group Ring of a Torsion-Free Nilpotent Group	219
6.1.1	Group Rings and the Augmentation Ideal	219

6.1.2	Residually Nilpotent Augmentation Ideals	222
6.1.3	E. Formanek's Generalization	228
6.2	The Dimension Subgroups	232
6.2.1	Definition and Properties of Dimension Subgroups	232
6.2.2	Faithful Representations	243
6.3	The Lie Algebra of a Finitely Generated Torsion-Free Nilpotent Group	251
6.3.1	Lie Algebras	252
6.3.2	The A -Adic Topology on FG	253
6.3.3	The Group $1 + \bar{A}$	254
6.3.4	The Maps $\exp$ and $\log$	255
6.3.5	The Lie Algebra $\bar{A}$	256
6.3.6	The Baker-Campbell-Hausdorff Formula	258
6.3.7	The Lie Algebra of a Nilpotent Group	258
6.3.8	The Group $(\bar{A}, *)$	262
6.3.9	A Theorem on Automorphism Groups	265
6.3.10	The Mal'cev Correspondence	267
	References	268
7	Additional Topics	269
7.1	Decision Problems	269
7.1.1	The Word Problem	270
7.1.2	The Conjugacy Problem	272
7.2	The Hopfian Property	274
7.3	The (Upper) Unitriangular Groups	276
7.4	Nilpotent Groups of Automorphisms	281
7.4.1	The Stability Group	282
7.4.2	The IA-Group of a Nilpotent Group	286
7.5	The Frattini and Fitting Subgroups	291
7.5.1	The Frattini Subgroup	291
7.5.2	The Fitting Subgroup	297
	References	299
	Index	301