

REDUCIBLE SUBGROUPS OF EXCEPTIONAL ALGEBRAIC GROUPS

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ABSTRACT. Let G be a simple algebraic group over an algebraically closed field. A closed subgroup H of G is called G -completely reducible (G -cr) if, whenever H is contained in a parabolic subgroup P of G , it is contained in a Levi factor of P . In this paper we complete the classification of connected G -cr subgroups when G has exceptional type, by determining the L_0 -irreducible connected reductive subgroups for each simple classical factor L_0 of a Levi subgroup of G . As an illustration, we determine all reducible, G -cr semisimple subgroups when G has type F_4 and various properties thereof. This work complements results of Lawther, Liebeck, Seitz and Testerman, and is vital in classifying non- G -cr reductive subgroups, a project being undertaken by the authors elsewhere.

1. INTRODUCTION

The subgroup structure of linear algebraic groups is a theory with applications throughout algebra and beyond. When working over $\mathbb{R}$ or $\mathbb{C}$, close connections with compact Lie groups give direct applications in geometry and physics. Over local fields and global fields, important applications are found in number theory, for instance in the Langlands program. Over finite fields and their algebraic closures, the subgroup structure has direct applications to the study of finite simple groups, for instance the subgroup structure of exceptional simple algebraic groups has been heavily used in understanding maximal subgroups of the corresponding finite groups of Lie type [18, 9, 8, 16].

Reductive subgroups of reductive groups are an important special instance of this problem. On the one hand, a result of Borel and Tits [5] states that for a reductive group G , a connected subgroup of G is either itself reductive, or contained ‘canonically’ in a proper parabolic subgroup of G . Thus the problem reduces to understanding parabolic subgroups and reductive subgroups, for instance a maximal connected subgroup of G is either parabolic or reductive. On the other hand, understanding reductive subgroups is equivalent to understanding affine homogeneous spaces for G , since for a closed subgroup $H \leq G$, the coset space G/H is an affine variety precisely when H° is reductive [23].

Let G be a connected reductive algebraic group over an algebraically closed field. Following [25], a closed subgroup H of G is said to be G -completely reducible (G -cr) if whenever H is contained in a parabolic subgroup P of G , it is contained in a Levi factor of P , and non- G -cr otherwise. Similarly, H is called G -irreducible or just *irreducible* if H is not contained in any proper parabolic subgroup of G , and *reducible* otherwise. The G -cr subgroups of G are precisely the L -irreducible subgroups of L , as L ranges over the Levi subgroups of G [4, Corollary 3.5], allowing $L = G$ to account for G -irreducible subgroups.

In the present work we classify the L_0 -irreducible connected subgroups as L_0 varies over those simple algebraic groups of classical type which occur as factors of Levi subgroups of a simple algebraic group G of exceptional type. Together with work of the second author and many others [1, 13, 14, 16, 28, 27, 29, 30, 31], the results here effectively complete the classification of G -cr

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Reductive Subgroups Of Exceptional Algebraic Groups

Martin W. Liebeck, Gary M. Seitz



Reductive Subgroups Of Exceptional Algebraic Groups:

Reductive Subgroups of Exceptional Algebraic Groups Martin W. Liebeck, 1996 **Reductive Subgroups of Exceptional Algebraic Groups** Martin W. Liebeck, Gary M. Seitz, 1996 The theory of simple algebraic groups is important in many areas of mathematics The authors of this book investigate the subgroups of certain types of simple algebraic groups and obtain a complete description of all those subgroups which are themselves simple This description is particularly useful in understanding centralizers of subgroups and restrictions of representations **The Irreducible Subgroups of Exceptional Algebraic Groups** Adam R. Thomas, 2021-06-18 This paper is a contribution to the study of the subgroup structure of exceptional algebraic groups over algebraically closed fields of arbitrary characteristic Following Serre a closed subgroup of a semisimple algebraic group G is called irreducible if it lies in no proper parabolic subgroup of G In this paper we complete the classification of irreducible connected subgroups of exceptional algebraic groups providing an explicit set of representatives for the conjugacy classes of such subgroups Many consequences of this classification are also given These include results concerning the representations of such subgroups on various G modules for example the conjugacy classes of irreducible connected subgroups are determined by their composition factors on the adjoint module of G with one exception A result of Liebeck and Testerman shows that each irreducible connected subgroup X of G has only finitely many overgroups and hence the overgroups of X form a lattice We provide tables that give representatives of each conjugacy class of connected overgroups within this lattice structure We use this to prove results concerning the subgroup structure of G for example when the characteristic is 2 there exists a maximal connected subgroup of G containing a conjugate of every irreducible subgroup A_1 of G *On Non-Generic Finite Subgroups of Exceptional Algebraic Groups* Alastair J. Litterick, 2018-05-29 The study of finite subgroups of a simple algebraic group G reduces in a sense to those which are almost simple If an almost simple subgroup of G has a socle which is not isomorphic to a group of Lie type in the underlying characteristic of G then the subgroup is called non generic This paper considers non generic subgroups of simple algebraic groups of exceptional type in arbitrary characteristic **A_1 Subgroups of Exceptional Algebraic Groups** Ross Lawther, Donna M. Testerman, 1999 This book is intended for graduate students and research mathematicians interested in group theory and generalizations *Maximal Subgroups of Exceptional Algebraic Groups* Gary M. Seitz, 1991 Let G be a simple algebraic group of exceptional type over an algebraically closed field of characteristic p The subgroups of G maximal with respect to being closed and connected are determined although mild restrictions on p are required in dealing with certain simple subgroups of low rank For $p = 0$ we recover the results of Dynkin *Maximal Subgroups of Exceptional Groups of Lie Type* David A. Craven, 2022-04-08 View the abstract **The Reductive Subgroups of F_4** David I. Stewart, 2013-04-22 Let G/K be a simple algebraic group defined over an algebraically closed field K of characteristic $p \geq 0$ A subgroup X of G is said to be G completely reducible if whenever it is contained in a

parabolic subgroup of G it is contained in a Levi subgroup of that parabolic. A subgroup X of G is said to be G irreducible if X is in no proper parabolic subgroup of G and G reducible if it is in some proper parabolic of G . In this paper the author considers the case that $G = F_4(K)$. The author finds all conjugacy classes of closed connected semisimple G reducible subgroups X of G . Thus he also finds all non G completely reducible closed connected semisimple subgroups of G . When X is closed connected and simple of rank at least two he finds all conjugacy classes of G irreducible subgroups X of G . Together with the work of Amende classifying irreducible subgroups of type A_1 this gives a complete classification of the simple subgroups of G . The author also uses this classification to find all subgroups of $G = F_4$ which are generated by short root elements of G by utilising and extending the results of Liebeck and Seitz.

Algebraic Groups and their Representations R.W. Carter, J. Saxl, 2012-12-06 This volume contains 19 articles written by speakers at the Advanced Study Institute on Modular representations and subgroup structure of algebraic groups and related finite groups held at the Isaac Newton Institute Cambridge from 23rd June to 4th July 1997. We acknowledge with gratitude the financial support given by the NATO Science Committee to enable this ASI to take place. Generous financial support was also provided by the European Union. We are also pleased to acknowledge funds given by EPSRC to the Newton Institute which were used to support the meeting. It is a pleasure to thank the Director of the Isaac Newton Institute Professor Keith Moffatt and the staff of the Institute for their dedicated work which did so much to further the success of the meeting. The editors wish to thank Dr Ross Lawther and Dr Nick Inglis most warmly for their help in the production of this volume. Dr Lawther in particular made an invaluable contribution in preparing the volume for submission to the publishers. Finally we wish to thank the distinguished speakers at the ASI who agreed to write articles for this volume based on their lectures at the meeting. We hope that the volume will stimulate further significant advances in the theory of algebraic groups.

The Maximal Subgroups of Positive Dimension in Exceptional Algebraic Groups Martin W. Liebeck, Gary M. Seitz, 2004. Intends to complete the determination of the maximal subgroups of positive dimension in simple algebraic groups of exceptional type over algebraically closed fields. This title follows work of Dynkin who solved the problem in characteristic zero and Seitz who did likewise over fields whose characteristic is not too small.

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Table of Contents Reductive Subgroups Of Exceptional Algebraic Groups

1. Understanding the eBook Reductive Subgroups Of Exceptional Algebraic Groups
 - The Rise of Digital Reading Reductive Subgroups Of Exceptional Algebraic Groups
 - Advantages of eBooks Over Traditional Books
2. Identifying Reductive Subgroups Of Exceptional Algebraic Groups
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
3. Choosing the Right eBook Platform
 - Popular eBook Platforms
 - Features to Look for in an Reductive Subgroups Of Exceptional Algebraic Groups
 - User-Friendly Interface

4. Exploring eBook Recommendations from Reductive Subgroups Of Exceptional Algebraic Groups
 - Personalized Recommendations
 - Reductive Subgroups Of Exceptional Algebraic Groups User Reviews and Ratings
 - Reductive Subgroups Of Exceptional Algebraic Groups and Bestseller Lists
5. Accessing Reductive Subgroups Of Exceptional Algebraic Groups Free and Paid eBooks
 - Reductive Subgroups Of Exceptional Algebraic Groups Public Domain eBooks
 - Reductive Subgroups Of Exceptional Algebraic Groups eBook Subscription Services
 - Reductive Subgroups Of Exceptional Algebraic Groups Budget-Friendly Options
6. Navigating Reductive Subgroups Of Exceptional Algebraic Groups eBook Formats
 - ePub, PDF, MOBI, and More
 - Reductive Subgroups Of Exceptional Algebraic Groups Compatibility with Devices
 - Reductive Subgroups Of Exceptional Algebraic Groups Enhanced eBook Features
7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of Reductive Subgroups Of Exceptional Algebraic Groups
 - Highlighting and Note-Taking Reductive Subgroups Of Exceptional Algebraic Groups
 - Interactive Elements Reductive Subgroups Of Exceptional Algebraic Groups
8. Staying Engaged with Reductive Subgroups Of Exceptional Algebraic Groups
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Reductive Subgroups Of Exceptional Algebraic Groups
9. Balancing eBooks and Physical Books Reductive Subgroups Of Exceptional Algebraic Groups
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection Reductive Subgroups Of Exceptional Algebraic Groups
10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
11. Cultivating a Reading Routine Reductive Subgroups Of Exceptional Algebraic Groups
 - Setting Reading Goals Reductive Subgroups Of Exceptional Algebraic Groups
 - Carving Out Dedicated Reading Time

12. Sourcing Reliable Information of Reductive Subgroups Of Exceptional Algebraic Groups
 - Fact-Checking eBook Content of Reductive Subgroups Of Exceptional Algebraic Groups
 - Distinguishing Credible Sources
13. Promoting Lifelong Learning
 - Utilizing eBooks for Skill Development
 - Exploring Educational eBooks
14. Embracing eBook Trends
 - Integration of Multimedia Elements
 - Interactive and Gamified eBooks

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