

# Finite group schemes

Lecture course in WS 2004/05

by Richard Pink, ETH Zürich

[pink@math.ethz.ch](mailto:pink@math.ethz.ch)

# Contents

<b>Outline</b>	<b>iii</b>
<b>Acknowledgements</b>	<b>iii</b>
<b>Lecture 1</b>	<b>1</b>
§1 Motivation . . . . .	1
§2 Group objects in a category . . . . .	3
<b>Lecture 2</b>	<b>6</b>
§3 Affine group schemes . . . . .	6
§4 Cartier duality . . . . .	8
§5 Constant group schemes . . . . .	9
<b>Lecture 3</b>	<b>12</b>
§6 Actions and quotients in a category . . . . .	12
§7 Quotients of schemes by finite group schemes, part I . . . . .	14
<b>Lecture 4</b>	<b>17</b>
§8 Quotients of schemes by finite group schemes, part II . . . . .	17
§9 Abelian categories . . . . .	19
§10 The category of finite commutative group schemes . . . . .	20
<b>Lecture 5</b>	<b>24</b>
§11 Galois descent . . . . .	24
§12 Étale group schemes . . . . .	26
§13 The tangent space . . . . .	26
<b>Lecture 6</b>	<b>28</b>
§14 Frobenius and Verschiebung . . . . .	28
§15 The canonical decomposition . . . . .	32
§16 Split local-local group schemes . . . . .	34
<b>Lecture 7</b>	<b>36</b>
§17 Group orders . . . . .	36
§18 Motivation for Witt vectors . . . . .	37
§19 The Artin-Hasse exponential . . . . .	38
<b>Lecture 8</b>	<b>42</b>
§20 The ring of Witt vectors over $\mathbb{Z}$ . . . . .	42
§21 Witt vectors in characteristic $p$ . . . . .	45

<b>Lecture 9</b>	<b>48</b>
§22 Finite Witt group schemes . . . . .	48
<b>Lecture 10</b>	<b>54</b>
§23 The Dieudonné functor in the local-local case . . . . .	54
<b>Lecture 11</b>	<b>59</b>
§24 Pairings and Cartier duality . . . . .	59
§25 Cartier duality of finite Witt group schemes . . . . .	61
<b>Lecture 12</b>	<b>64</b>
§26 Duality and the Dieudonné functor . . . . .	64
<b>Lecture 13</b>	<b>69</b>
§27 The Dieudonné functor in the étale case . . . . .	69
§28 The Dieudonné functor in the general case . . . . .	72
<b>References</b>	<b>74</b>

# Outline

The aim of the lecture course is the classification of finite commutative group schemes over a perfect field of characteristic  $p$ , using the classical approach by contravariant Dieudonné theory. The theory is developed from scratch; emphasis is placed on complete proofs. No prerequisites other than a good knowledge of algebra and the basic properties of categories and schemes are required. The original plan included  $p$ -divisible groups, but there was no time for this.

# Acknowledgements

It is my great pleasure to thank the participants of the course for their active and lively interest. In particular I would like to thank Alexander Caspar, Ivo Dell’Ambrogio, Stefan Gille, Egon Rütsche, Nicolas Stalder, Cory Edwards, and Charles Mitchell for their efforts in preparing these notes.

Zürich, February 10, 2005

Richard Pink