

Solutions to Joe Harris'
Algebraic Geometry: A First Course

Patrick Borse

ABSTRACT. This document contains solutions to the exercises of Joe Harris' *Algebraic Geometry: A First Course*.

Contents

Part I. Examples of Varieties and Maps	5
Lecture 1. Affine and Projective Varieties	6
Lecture 2. Regular Functions and Maps	7
Lecture 3. Cones, Projections, and More About Products	8
Lecture 4. Families and Parameter Spaces	9
Lecture 5. Ideals of Varieties, Irreducible Decomposition, and the Nullstellensatz	10
Lecture 6. Grassmannians and Related Varieties	11
Lecture 7. Rational Functions and Rational Maps	12
Lecture 8. More Examples	13
Lecture 9. Determinantal Varieties	14
Lecture 10. Algebraic Groups	15
Part II. Attributes of Varieties	16
Lecture 11. Definitions of Dimension and Elementary Examples	17
Lecture 12. More Dimension Computations	18
Lecture 13. Hilbert Polynomials	19
Lecture 14. Smoothness and Tangent Spaces	20
Lecture 15. Gauss Maps, Tangential and Dual Varieties	21
Lecture 16. Tangent Spaces to Grassmannians	22
Lecture 17. Further Topics Involving Smoothness and Tangent Spaces	23
Lecture 18. Degree	24
Lecture 19. Further Examples and Applications of Degree	25
Lecture 20. Singular Points and Tangent Cones	26

Lecture 21. Parameter Spaces and Moduli Spaces	27
Lecture 22. Quadrics	28

Part I

Examples of Varieties and Maps

LECTURE 1

Affine and Projective Varieties

Exercise 1.3.

Exercise 1.5.

Exercise 1.6.

Exercise 1.11.

Exercise 1.12. s

Exercise 1.13.

Exercise 1.15.

Exercise 1.19.

Exercise 1.21.

Exercise 1.23.

Exercise 1.24.

Exercise 1.25.

Exercise 1.27.

Exercise 1.28.

Exercise 1.29.

LECTURE 2

Regular Functions and Maps

Exercise 2.2.

Exercise 2.3.

Exercise 2.5.

Exercise 2.8.

Exercise 2.9.

Exercise 2.10.

Exercise 2.12.

Exercise 2.13.

Exercise 2.14.

Exercise 2.15.

Exercise 2.17.

Exercise 2.18.

Exercise 2.19.

Exercise 2.20.

Exercise 2.22.

Exercise 2.25.

Exercise 2.26.

Exercise 2.28.

Exercise 2.29.

LECTURE 3

Cones, Projections, and More About Products

Exercise 3.2.

Exercise 3.7.

Exercise 3.8.

Exercise 3.9.

LECTURE 4

Families and Parameter Spaces

Exercise 4.2.

Exercise 4.3.

Exercise 4.4.

Exercise 4.7.

Exercise 4.10.

Exercise 4.11.

Exercise 4.12.

Exercise 4.13.

Exercise 4.14.

Exercise 4.16.

Exercise 4.17.

LECTURE 5

Ideals of Varieties, Irreducible Decomposition, and the Nullstellensatz

Exercise 5.2.

Exercise 5.3.

Exercise 5.4.

Exercise 5.5.

Exercise 5.9.

Exercise 5.10.

Exercise 5.13.

Exercise 5.14.

LECTURE 6

Grassmannians and Related Varieties

Exercise 6.2.

Exercise 6.4.

Exercise 6.5.

Exercise 6.6.

Exercise 6.7.

Exercise 6.8.

Exercise 6.9.

Exercise 6.15.

Exercise 6.16.

Exercise 6.20.

LECTURE 7

Rational Functions and Rational Maps

Exercise 7.1.

Exercise 7.5.

Exercise 7.6.

Exercise 7.7.

Exercise 7.8.

Exercise 7.9.

Exercise 7.10.

Exercise 7.12.

Exercise 7.13.

Exercise 7.14.

Exercise 7.19.

Exercise 7.20.

Exercise 7.23.

Exercise 7.25.

Exercise 7.26.

Exercise 7.27.

Exercise 7.28.

Exercise 7.29.

LECTURE 8

More Examples

Exercise 8.2.

Exercise 8.4.

Exercise 8.6.

Exercise 8.7.

Exercise 8.8.

Exercise 8.10.

Exercise 8.11.

Exercise 8.12.

Exercise 8.13.

Exercise 8.15.

Exercise 8.16.

Exercise 8.18.

Exercise 8.19.

Exercise 8.21.

Exercise 8.22.

Exercise 8.23.

Exercise 8.24.

Exercise 8.25.

Exercise 8.27.

Exercise 8.28.

Exercise 8.31.

Exercise 8.32.

Exercise 8.33.

Exercise 8.37.

Exercise 8.38.

LECTURE 9

Determinantal Varieties

Exercise 9.5.

Exercise 9.9.

Exercise 9.11.

Exercise 9.13.

Exercise 9.14.

Exercise 9.16.

Exercise 9.17.

Exercise 9.18.

Exercise 9.19.

Exercise 9.20.

Exercise 9.23.

Exercise 9.24.

LECTURE 10

Algebraic Groups

Exercise 10.5.

Exercise 10.6.

Exercise 10.7.

Exercise 10.10.

Exercise 10.11.

Exercise 10.13.

Exercise 10.14.

Exercise 10.20.

Exercise 10.22.

Exercise 10.24.

Exercise 10.25.

Exercise 10.26.

Exercise 10.28.

Exercise 10.29.

Exercise 10.30.

Exercise 10.31.

Part II

Attributes of Varieties

LECTURE 11

Definitions of Dimension and Elementary Examples

Exercise 11.6.

Exercise 11.9.

Exercise 11.10.

Exercise 11.11.

Exercise 11.15.

Exercise 11.16.

Exercise 11.19.

Exercise 11.20.

Exercise 11.21.

Exercise 11.23.

Exercise 11.25.

Exercise 11.26.

Exercise 11.27.

Exercise 11.28.

Exercise 11.29.

Exercise 11.31.

Exercise 11.33.

Exercise 11.39.

Exercise 11.41.

Exercise 11.43.

Exercise 11.44.

Exercise 11.45.

LECTURE 12

More Dimension Computations

Exercise 12.3.

Exercise 12.4.

Exercise 12.6.

Exercise 12.7.

Exercise 12.10.

Exercise 12.11.

Exercise 12.13.

Exercise 12.16.

Exercise 12.17.

Exercise 12.19.

Exercise 12.20.

Exercise 12.21.

Exercise 12.23.

Exercise 12.25.

Exercise 12.26.

Exercise 12.27.

LECTURE 13

Hilbert Polynomials

Exercise 13.1.

Exercise 13.5.

Exercise 13.6.

Exercise 13.8.

Exercise 13.9.

Exercise 13.13.

Exercise 13.14.

Exercise 13.15.

Exercise 13.17.

Exercise 13.18.

LECTURE 14

Smoothness and Tangent Spaces

Exercise 14.1.

Exercise 14.2.

Exercise 14.3.

Exercise 14.5.

Exercise 14.6.

Exercise 14.7.

Exercise 14.11.

Exercise 14.12.

Exercise 14.13.

Exercise 14.14.

Exercise 14.15.

LECTURE 15

Gauss Maps, Tangential and Dual Varieties

Exercise 15.5.

Exercise 15.6.

Exercise 15.8.

Exercise 15.9.

Exercise 15.11.

Exercise 15.12.

Exercise 15.15.

Exercise 15.16.

Exercise 15.18.

Exercise 15.19.

Exercise 15.23.

Exercise 15.25.

LECTURE 16

Tangent Spaces to Grassmannians

Exercise 16.3.

Exercise 16.4.

Exercise 16.5.

Exercise 16.7.

Exercise 16.9.

Exercise 16.11.

Exercise 16.14.

Exercise 16.15.

Exercise 16.16.

Exercise 16.17.

Exercise 16.19.

Exercise 16.22.

Exercise 16.23.

LECTURE 17

Further Topics Involving Smoothness and Tangent Spaces

Exercise 17.3.

Exercise 17.4.

Exercise 17.6.

Exercise 17.7.

Exercise 17.9.

Exercise 17.10.

Exercise 17.12.

Exercise 17.13.

Exercise 17.15.

Exercise 17.17.

Exercise 17.19.

Exercise 17.20.

Exercise 17.21.

LECTURE 18

Degree

Exercise 18.2.

Exercise 18.7.

Exercise 18.11.

Exercise 18.14.

Exercise 18.18.

Exercise 18.21.

Exercise 18.22.

Exercise 18.23.

LECTURE 19

Further Examples and Applications of Degree

Exercise 19.2.

Exercise 19.3.

Exercise 19.6.

Exercise 19.7.

Exercise 19.12.

Exercise 19.13.

Exercise 19.15.

Exercise 19.16.

Exercise 19.19.

LECTURE 20

Singular Points and Tangent Cones

Exercise 20.3.

Exercise 20.4.

Exercise 20.6.

Exercise 20.7.

Exercise 20.8.

Exercise 20.9.

Exercise 20.10.

Exercise 20.11.

Exercise 20.12.

Exercise 20.13.

Exercise 20.14.

Exercise 20.15.

Exercise 20.16.

Exercise 20.17.

LECTURE 21

Parameter Spaces and Moduli Spaces

Exercise 21.3.

Exercise 21.4.

Exercise 21.5.

Exercise 21.6.

Exercise 21.9.

Exercise 21.10.

Exercise 21.11.

Exercise 21.12.

LECTURE 22

Quadrics

Exercise 22.1.

Exercise 22.2.

Exercise 22.3.

Exercise 22.4.

Exercise 22.6.

Exercise 22.9.

Exercise 22.10.

Exercise 22.11.

Exercise 22.15.

Exercise 22.16.

Exercise 22.17.

Exercise 22.18.

Exercise 22.19.

Exercise 22.20.

Exercise 22.23.

Exercise 22.24.

Exercise 22.25.

Exercise 22.26.

Exercise 22.29.

Exercise 22.30.

Exercise 22.35.

Exercise 22.36.

Exercise 22.37.

Exercise 22.39.

Exercise 22.40.