

Solutions to exercises – week 6

1. For each of the following ideals of  $\mathbb{Q}[X, Y]$ , list all monomials in  $\mathcal{M}(X, Y)$  which do not belong to the given ideal. (Use the solution of the membership problem for monomial ideals, Proposition 6.5.)

- (a)  $\langle Y^4, X^2Y, X^2 \rangle$
- (b)  $\langle X^3Y^2, X^2Y^3, X^2Y^4 \rangle$

Q1 Solution:

(a) Let  $I = \langle Y^4, X^2Y, X^2 \rangle$ .

$Y^4$  is in  $I$  if and only if  $Y^4 \mid Y^a$  i.e.  $a \geq 4$ , so the following are not in  $I$ :  $1, Y, Y^2, Y^3$

$X^2Y$  is in  $I$  if and only if  $Y^a \mid X^2Y$  i.e.  $a \geq 1$  (note that  $X^2Y$  or  $X^2$  never divide  $X^2Y$ ), so the following are not in  $I$ :  $X, XY, XY^2, XY^3$

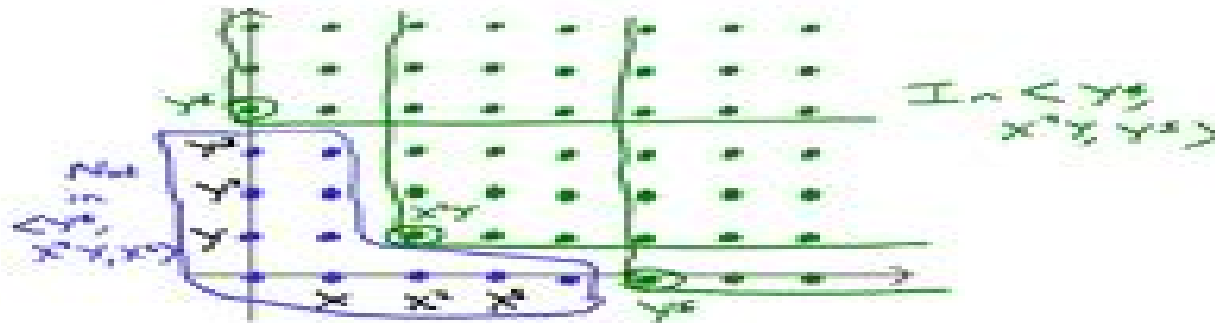
$X^2Y$  is in  $I$  if and only if  $X^2Y \mid X^2Y^a$  (or  $Y^a \mid X^2Y^a$ , but that is implied by  $X^2Y \mid X^2Y^a$ ), so the following are not in  $I$ :  $X^2$

For  $X^2Y^a$  and  $X^2Y^b$ , again these are in  $I$  if and only if they are divisible by  $X^2Y$  i.e. when  $a \geq 1$ . We are left with the following not in  $I$ :  $X^2, X^2$

If  $m \geq 3$ , then  $X^mY^m$  is always divisible by  $X^2$  so always in  $I$ .

In conclusion, there are 11 monomials which are not in  $I$ :

- $1, Y, Y^2, Y^3, X, XY, XY^2, XY^3, X^2, X^2, X^2, X^2$



(b) Let  $J = \langle X^3Y^2, X^2Y^3, X^2Y^4 \rangle$ .

$Y^4$  or  $X^2Y^3$  are never divisible by any of  $X^3Y^2, X^2Y^3$  or  $X^2Y^4$ , so they are never in  $J$ .

$X^2Y^4$  is in  $J$  if and only if  $X^3Y^2 \mid X^2Y^4$  i.e. if and only if  $a \geq 3$ . Thus the following are not in  $J$ :  $X^2, X^2Y, X^2Y^2$

Similarly,  $X^2Y^3$  or  $X^2Y^4$  are in  $J$  if and only if they are divisible by  $X^2Y^3$  i.e. if and only if  $m \geq 3$  (note that we don't need to consider divisibility by  $X^3Y^2$  because  $X^3Y^2 \nmid (X^2Y^3)$  so omitting  $X^3Y^2$  from our generating set wouldn't change anything). Thus the following are not in  $J$ :  $X^2, X^2Y, X^2Y^2, X^3, X^3Y, X^3Y^2$

# Commutative Algebra Exercises Solutions

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## **Table of Contents Commutative Algebra Exercises Solutions**

1. Understanding the eBook Commutative Algebra Exercises Solutions
  - The Rise of Digital Reading Commutative Algebra Exercises Solutions
  - Advantages of eBooks Over Traditional Books
2. Identifying Commutative Algebra Exercises Solutions
  - 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 Commutative Algebra Exercises Solutions
  - User-Friendly Interface
4. Exploring eBook Recommendations from Commutative Algebra Exercises Solutions
  - Personalized Recommendations
  - Commutative Algebra Exercises Solutions User Reviews and Ratings
  - Commutative Algebra Exercises Solutions and Bestseller Lists
5. Accessing Commutative Algebra Exercises Solutions Free and Paid eBooks
  - Commutative Algebra Exercises Solutions Public Domain eBooks
  - Commutative Algebra Exercises Solutions eBook Subscription Services
  - Commutative Algebra Exercises Solutions Budget-Friendly Options

6. Navigating Commutative Algebra Exercises Solutions eBook Formats
  - ePub, PDF, MOBI, and More
  - Commutative Algebra Exercises Solutions Compatibility with Devices
  - Commutative Algebra Exercises Solutions Enhanced eBook Features
7. Enhancing Your Reading Experience
  - Adjustable Fonts and Text Sizes of Commutative Algebra Exercises Solutions
  - Highlighting and Note-Taking Commutative Algebra Exercises Solutions
  - Interactive Elements Commutative Algebra Exercises Solutions
8. Staying Engaged with Commutative Algebra Exercises Solutions
  - Joining Online Reading Communities
  - Participating in Virtual Book Clubs
  - Following Authors and Publishers Commutative Algebra Exercises Solutions
9. Balancing eBooks and Physical Books Commutative Algebra Exercises Solutions
  - Benefits of a Digital Library
  - Creating a Diverse Reading Collection Commutative Algebra Exercises Solutions
10. Overcoming Reading Challenges
  - Dealing with Digital Eye Strain
  - Minimizing Distractions
  - Managing Screen Time
11. Cultivating a Reading Routine Commutative Algebra Exercises Solutions
  - Setting Reading Goals Commutative Algebra Exercises Solutions
  - Carving Out Dedicated Reading Time
12. Sourcing Reliable Information of Commutative Algebra Exercises Solutions
  - Fact-Checking eBook Content of Commutative Algebra Exercises Solutions
  - 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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