

Solutions to exercises – week 6

1. For each of the following ideals of $\mathbb{Q}[X, Y]$, list all monomials in $k[X, Y]$ 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 $Y^4 \mid Y^m$ i.e. $m \geq 4$, so the following are not in I : $1, Y, Y^2, Y^3$

X^2Y is in I if and only if $Y^4 \mid XY^m$ i.e. $m \geq 4$ (note that X^2Y or X^2 never divide XY^m), so the following are not in I : X, XY, XY^2, XY^3

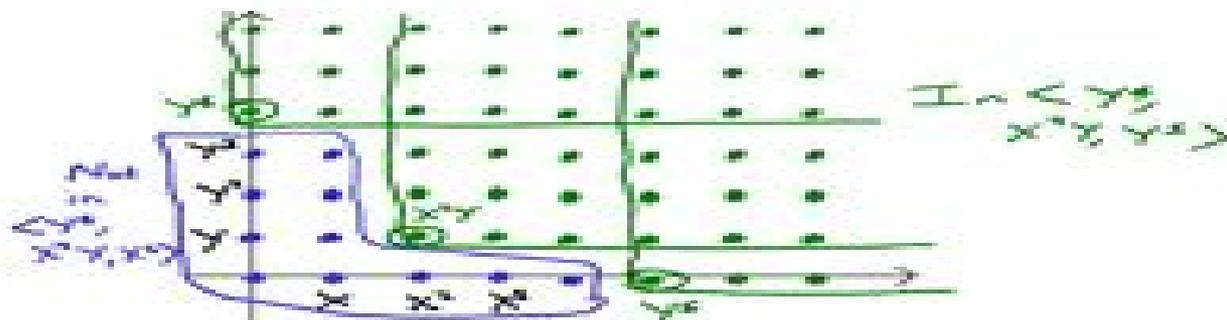
X^2Y is in I if and only if $X^2Y \mid X^2Y^m$ (or $Y^4 \mid X^2Y^m$, but that is implied by $X^2Y \mid X^2Y^m$), so the following are not in I : X^2

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

If $m \geq 5$, then X^2Y^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 XY^4 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 $m \geq 3$. Thus the following are not in J : X^2, X^2Y, X^2Y^2

Similarly, X^2Y^3 or X^2Y^3 are in J if and only if they are divisible by X^2Y^2 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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