

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

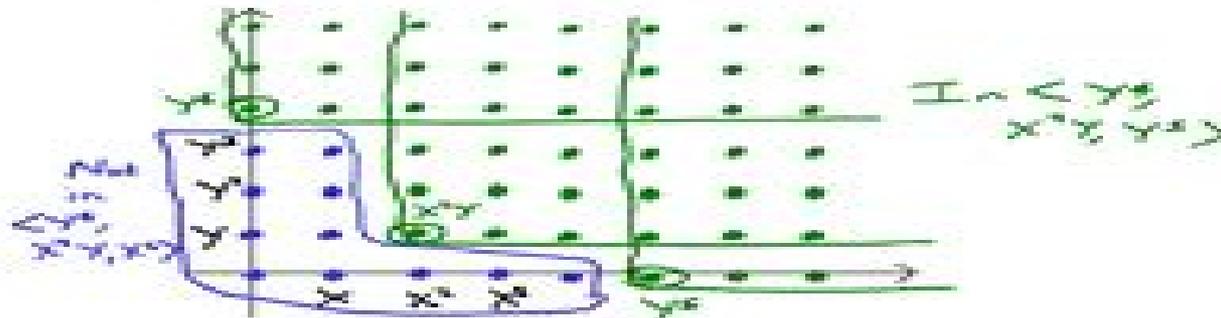
$X^2Y$  is in  $I$  if and only if  $X^2Y \mid X^2Y^m$  (or  $Y^4 \mid X^2Y^m$ , but that is implied by  $X^2Y \mid X^2Y^m$ ), so the following are not in  $I$ :  $X^2$

For  $X^2Y^m$  and  $X^2Y^3$ , 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  $I$ :  $X^3, X^4$

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  $I$ :

- $1, Y, Y^2, Y^3, X, XY, XY^2, XY^3, X^2, X^3, X^4$



(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  $m \geq 3$ . Thus the following are not in  $J$ :  $X^2, X^2Y, X^2Y^2$

Similarly,  $X^3Y^2$  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  $X^2Y^3$  because  $X^2Y^2 \in \langle X^2Y^3 \rangle$  so omitting  $X^2Y^3$  from our generating set wouldn't change anything). Thus the following are not in  $J$ :  $X^3, X^3Y, X^3Y^2, X^4, X^4Y, X^4Y^2$

# Commutative Algebra Exercises Solutions

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