Prof. Dr. Catharina Stroppel
Dr. Pieter Belmans

# Sheet 10

Solutions to be handed in before class on Friday December 20.

**Problem 43.** In this problem we consider the Chow ring of $\mathbb{P}^2$ and $\mathbb{P}^3$.

1. Compute explicitly $\mathrm{A}(\mathbb{P}^2)$ (resp. $\mathrm{A}(\mathbb{P}^3)$) by expressing the products of Schubert classes $[\Omega_w]$ for $w \in \{e, s_1, s_2s_1\}$ (resp. $w \in \{e, s_1, s_2s_1, s_3s_2s_1\}$) in terms of Schubert classes.

2. Use the labelling of Schubert varieties $\Omega_\lambda$ via partitions $\lambda$ for

$$\lambda \in \left\{\emptyset, \square, \begin{smallmatrix}\square\\\square\end{smallmatrix}\right\}, \text{resp. } \lambda \in \left\{\emptyset, \square, \begin{smallmatrix}\square\\\square\end{smallmatrix}, \begin{smallmatrix}\square\\\square\\\square\end{smallmatrix}\right\} \tag{24}$$

and consider the Littlewood–Richardson coefficients

$$[\Omega_\lambda][\Omega_\mu] = \sum_\nu \mathrm{c}^\nu_{\lambda,\mu}[\Omega_\nu]. \tag{25}$$

Show that

$$\mathrm{c}^\nu_{\lambda,\mu} = \#\{\text{semistandard (skew) tableaux of shape } \nu/\lambda \text{ of weight } \mu\}. \tag{26}$$

3. Show that if $|\lambda| + |\mu| = |\nu|$ that

$$\mathrm{c}^\nu_{\lambda,\mu} = [S(\nu) : S(\lambda) \otimes S(\mu)] \tag{27}$$

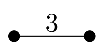
where $S(\lambda)$ for $\lambda$ a partition of $n$ denotes the corresponding irreducible $\mathrm{S}_n$-module.

(5 points)

**Problem 44.** Calculate or describe via a picture the geometric representation for the Coxeter group $(W, S)$ attached to



and

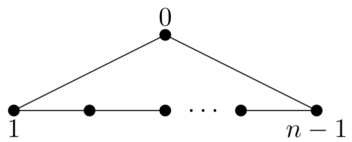



(2 points)

**Problem 45.** Consider the following set of periodic permutations of the integers

$$\left\{ f\colon \mathbb{Z} \to \mathbb{Z} \mid f(i+n) = f(i) + n, \sum_{i=1}^n f(i) = \sum_{i=1}^n i, f \text{ is bijective} \right\}. \tag{28}$$

Show that this defines (via composition of maps) a group which is isomorphic to the Coxeter group with Coxeter diagram




(3 points)

**Problem 46.** Consider the Coxeter group $(W, S)$ associated to


with $S = \{s, t\}$.

1. Describe all the elements of $W$.
2. Show that $W \cong S_2 \ltimes \mathbb{Z}$ as abstract groups.
3. Realise $W$ as an affine reflection group. For this, consider the subspace $U = \mathbb{R}\alpha_s$ of the geometric representation and the affine hyperplanes for $\alpha = \alpha_s$

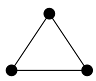
$$H_{\alpha,r} := \{\lambda \in U \mid 2(\lambda, \alpha) = r\}. \tag{29}$$

Show that $W$ is isomorphic to the affine reflection group generated by $s_\alpha = s_{\alpha,0}$ and $s_{\alpha,1}$, where

$$s_{\alpha,r} \colon \lambda \mapsto \lambda - (2(\lambda, \alpha) - r)\alpha \tag{30}$$

is the affine reflection in the hyperplane $H_{\alpha,r}$.

4. Give an analogous description for the Coxeter group $(W, S)$ associated to



(6 points)

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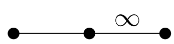
**Optional problem 3.** Show that the Coxeter group attached to the Coxeter diagram




is isomorphic to $\mathrm{PGL}_2(\mathbb{Z}) := \mathrm{GL}_2(\mathbb{Z})/\{\pm 1\}$.

Here you can use that

1. $\mathrm{PGL}_2(\mathbb{Z})$ is generated by the order two elements

$$\begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix}, \begin{pmatrix} -1 & 1 \\ 0 & 1 \end{pmatrix}, \begin{pmatrix} -1 & 0 \\ 0 & 1 \end{pmatrix} \tag{31}$$

which gives a morphism $\varphi \colon W \to \mathrm{PGL}_2(\mathbb{Z})$;

2. the subgroup $\mathrm{PSL}_2(\mathbb{Z})$ of index 2 is the free product of the groups of order 2 and 3 generated by $\varphi(s_1 s_2)$ and $\varphi(s_2 s_3)$.

(4 points)