



## 8. Groups of Permutations

1.  $\begin{pmatrix} 1 & 2 & 3 & 4 & 5 & 6 \\ 1 & 2 & 3 & 6 & 5 & 4 \end{pmatrix}$     2.  $\begin{pmatrix} 1 & 2 & 3 & 4 & 5 & 6 \\ 2 & 4 & 1 & 5 & 6 & 3 \end{pmatrix}$     3.  $\begin{pmatrix} 1 & 2 & 3 & 4 & 5 & 6 \\ 3 & 4 & 1 & 6 & 2 & 5 \end{pmatrix}$
4.  $\begin{pmatrix} 1 & 2 & 3 & 4 & 5 & 6 \\ 5 & 1 & 6 & 2 & 4 & 3 \end{pmatrix}$     5.  $\begin{pmatrix} 1 & 2 & 3 & 4 & 5 & 6 \\ 2 & 6 & 1 & 5 & 4 & 3 \end{pmatrix}$

6. Starting with 1 and applying  $\sigma$  repeatedly, we see that  $\sigma$  takes 1 to 3 to 4 to 5 to 6 to 2 to 1, so  $\sigma^6$  is the smallest possible power of  $\sigma$  that is the identity permutation. It is easily checked that  $\sigma^6$  carries 2, 3, 4, 5 and 6 to themselves also, so  $\sigma^6$  is indeed the identity and  $|\langle\sigma\rangle| = 6$ .

7.  $\tau^2 = \begin{pmatrix} 1 & 2 & 3 & 4 & 5 & 6 \\ 4 & 3 & 2 & 1 & 5 & 6 \end{pmatrix}$  and it is clear that  $(\tau^2)^2$  is the identity. Thus we have  $|\langle\tau^2\rangle| = 2$ .

8. Because  $\sigma^6$  is the identity permutation (see Exercise 6), we have

$$\sigma^{100} = (\sigma^6)^{16}\sigma^4 = \sigma^4 = \begin{pmatrix} 1 & 2 & 3 & 4 & 5 & 6 \\ 6 & 5 & 2 & 1 & 3 & 4 \end{pmatrix}.$$

9. We find that  $\mu^2$  is the identity permutation, so  $\mu^{100} = (\mu^2)^{50}$  is also the identity permutation.

10.  $\{\mathbb{Z}, 17\mathbb{Z}, 3\mathbb{Z}, \langle\pi\rangle\}$  is a subcollection of isomorphic groups, as are  $\{\mathbb{Z}_6, G\}$ ,  $\{\mathbb{Z}_2, S_2\}$ ,  $\{S_6\}$ ,  $\{\mathbb{Q}\}$ ,  $\{\mathbb{R}, \mathbb{R}^+\}$ ,  $\{\mathbb{R}^*\}$ ,  $\{\mathbb{Q}^*\}$ , and  $\{\mathbb{C}^*\}$ .

11.  $\{1, 2, 3, 4, 5, 6\}$     12.  $\{1, 2, 3, 4\}$     13.  $\{1, 5\}$

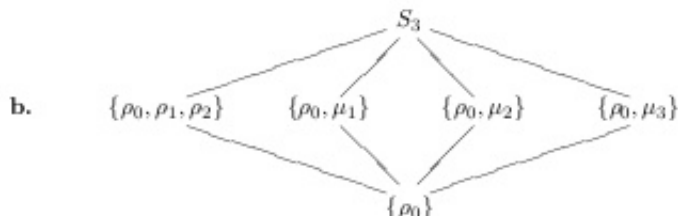
14. We see that  $\epsilon, \rho$ , and  $\rho^2$  give the three positions of the triangle in Fig. 8.9 obtained by rotations. The permutations  $\phi, \rho\phi$ , and  $\rho^2\phi$  amount geometrically to turning the triangle over ( $\phi$ ) and then rotating it to obtain the other three positions.

15. A similar labeling for  $D_4$  is  $\epsilon, \rho, \rho^2, \rho^3, \phi, \rho\phi, \rho^2\phi, \rho^3\phi$  where their  $\phi$  is our  $\mu_1$ . They correspond to our elements in the order  $\rho_0, \rho_1, \rho_2, \rho_3, \mu_1, \delta_1, \mu_2, \delta_2$ .

16.  $\sigma$  may have the action of any of the six possible permutations of the set  $\{1, 2, 4\}$ , so there are six possibilities for  $\sigma$ .

17. There are 4 possibilities for  $\sigma(1)$ , then 3 possibilities for  $\sigma(3)$ , then 2 possibilities for  $\sigma(4)$ , and then 1 possibility for  $\sigma(5)$ , for  $4 \cdot 3 \cdot 2 \cdot 1 = 24$  possibilities in all.

18. a.  $\langle\rho_1\rangle = \langle\rho_2\rangle = \{\rho_0, \rho_1, \rho_2\}$  and  $\langle\mu_1\rangle = \{\rho_0, \mu_1\}$ .



19. (See the answer in the text.)

20. This group is not isomorphic to  $S_3$  because it is abelian and  $S_3$  is nonabelian. It is isomorphic to  $\mathbb{Z}_6$ .

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532 MATHEMATICS Since the coins are fair, we can assign the probability  $\frac{1}{8}$  to each sample point. Let E be the event at least two heads appear and F be the event first coin shows tail.

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