Hints for Some Exercises

Chapter 1

1.5 Consider $A(H_n)^2$ and use Exercise 3.

1.6 (a) First count the number of sequences $V_{i_0}, V_{i_1}, \ldots, V_{i_\ell}$ for which there exists a closed walk with vertices $v_0, v_1, \ldots, v_\ell = v_0$ (in that order) such that $v_j \in V_{i_j}$.

1.11 Consider the rank of $A(\Gamma)$ and also consider $A(\Gamma)^2$. The answer is very simple and does not involve irrational numbers.

1.12 (b) Consider $A(G)^2$.

Chapter 2

2.2 See Exercise 9 in Chap. 9.

2.5 (c) Mimic the proof for the graph C_n, using the definition

$$\langle \chi_u, \chi_v \rangle = \sum_{w \in \mathbb{Z}_n} \chi_u(w) \overline{\chi_v(w)},$$

where an overhead bar denotes complex conjugation.

Chapter 3

3.4 You may find Example 3.1 useful.

3.7 It is easier *not* to use linear algebra.

3.8 See previous hint.

3.10 First show (easy) that if we start at a vertex v and take n steps (using our random walk model), then the probability that we traverse a fixed closed walk W is equal to the probability that we traverse W in reverse order.

3.12 See hint for Exercise 7.

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Undergraduate Texts in Mathematics, DOI 10.1007/978-1-4614-6998-8,

Chapter 4

4.4 (b) One way to do this is to count in two ways the number of k-tuples $(v_1, \ldots, v_k)$ of linearly independent elements from $\mathbb{F}_q^n$: (1) first choose v_1, then v_2, etc., and (2) first choose the subspace W spanned by $v_1, \ldots, v_k$, and then choose v_1, v_2, etc.

4.4 (c) The easiest way is to use (b).

Chapter 5

5.5 (a) Show that $N_n \cong B_n/G$ for a suitable group G.

5.9 (a) Use Corollary 2.4 with $n = \binom{p}{2}$.

5.13 Use Exercise 12.

Chapter 6

6.2 (b) Not really a hint, but the result is equivalent [why?] to the case $r = m$, $s = n$, $t = 2$, and $x = 1$ of Exercise 34 in Chap. 8.

6.3 Consider $\mu = (8, 8, 4, 4)$.

6.5 First consider the case where S has ζ elements equal to 0 (so $\zeta = 0$ or 1), ν elements that are negative, and π elements that are positive, so $\nu + \zeta + \pi = 2m + 1$.

Chapter 7

7.16 (a) Use Pólya's theorem.

Chapter 8

8.3 Encode a maximal chain by an object that we already know how to enumerate.

8.7 Partially order by diagram inclusion the set of all partitions whose diagrams can be covered by nonoverlapping dominos, thereby obtaining a subposet Y_2 of Young's lattice Y. Show that $Y_2 \cong Y \times Y$.

8.14 Use induction on n.

8.17 (a) One way to do this is to use the generating function $\sum_{n \geq 0} Z_{\mathfrak{S}_n}(z_1, z_2, \ldots)\, x^n$ for the cycle indicator of $\mathfrak{S}_n$ (Theorem 7.13). Another method is to find a recurrence for $B(n+1)$ in terms of $B(0), \ldots, B(n)$ and then convert this recurrence into a generating function

8.18 Consider the generating function

$$G(q, t) = \sum_{k,n \geq 0} \kappa(n \to n + k \to n) \frac{t^k q^n}{(k!)^2}$$

and use (8.25).

8.20 (b) Consider the square of the adjacency matrix of $Y_{j-1,j}$.

8.24 Use Exercise 14.

Chapter 9

9.1 There is a simple proof based on the formula $\kappa(K_p) = p^{p-2}$, avoiding the Matrix-Tree Theorem.

9.2 (c) Use the fact that the rows of $\boldsymbol{L}$ sum to 0 and compute the trace of $\boldsymbol{L}$.

9.5 (b) Use Exercise 3 in Chap. 1.

9.6 (a) For the most elegant proof, use the fact that commuting $p \times p$ matrices A and B can be simultaneously triangularized, i.e., there exists an invertible matrix X such that both XAX^{-1} and XBX^{-1} are upper triangular.

9.6 (d) Use Exercise 8(a).

9.7 Let G^* be the full dual graph of G, i.e., the vertices of G^* are the faces of G, including the outside face. For every edge e of G separating two faces R and S of G, there is an edge e^* of G^* connecting the vertices R and S. Thus G^* will have some multiple edges and $\#E(G) = \#E(G^*)$. First show combinatorially that $\kappa(G) = \kappa(G^*)$. (See Corollary 11.19.)

9.10 (a) The laplacian matrix$\boldsymbol{L} = \boldsymbol{L}(G)$ acts on the space $\mathbb{R}V(G)$, the real vector space with basis $V(G)$. Consider the subspace W of $\mathbb{R}V(G)$ spanned by the elements $v + \varphi(v)$, $v \in V(G)$.

9.11 (a) Let $s(n,q,r)$ be the numberof $n \times n$ symmetric matrices of rank r over $\mathbb{F}_q$. Find a recurrence satisfied by $s(n,q,r)$ and verify that this recurrence is satisfied by

$$s(n,q,r) = \begin{cases} \prod_{i=1}^{t} \dfrac{q^{2i}}{q^{2i}-1} \cdot \prod_{i=0}^{2t-1} (q^{n-i}-1), \; 0 \le r = 2t \le n, \\ \prod_{i=1}^{t} \dfrac{q^{2i}}{q^{2i}-1} \cdot \prod_{i=0}^{2t} (q^{n-i}-1), \;\; 0 \le r = 2t+1 \le n. \end{cases}$$

9.12 Any of the three proofs of the Appendix to Chap. 9 can be carried over to the present exercise.

Chapter 10

10.3 (b) Use the Perron–Frobenius theorem (Theorem 3.3).

10.6 (a) Consider A^ℓ.

10.6 (f) There is an example with nine vertices that is not a de Bruijn graph.

10.6 (c) Let E be the (column) eigenvector of $\boldsymbol{A}(D)$ corresponding to the largest eigenvalue. Consider $\boldsymbol{A}E$ and $\boldsymbol{A}^{\mathrm{t}}E$, where t denotes transpose.

Chapter 11

11.4 Use the unimodularity of the basis matrices $\boldsymbol{C}_T$ and $\boldsymbol{B}_T$.

11.6 (a) Mimic the proof of Theorem 9.8 (the Matrix-Tree Theorem).

11.6 (b) Consider ZZ^t.

Chapter 12

12.4 The best strategy involves the concept of odd and even permutations.

12.5 For the easiest solution, don't use linear algebra but rather use the original Oddtown theorem.

12.12 What are the eigenvalues of skew-symmetric matrices?

12.15 Consider the incidence matrix M of the sets and their elements. Consider two cases: $\det M = 0$ and $\det M \neq 0$.

12.18 Consider the first three rows of H. Another method is to use row operations to factor a large power of 2 from the determinant.

12.21 It is easiest to proceed directly and not use the proof of Theorem 12.18.

12.23 First find a simple explicit formula for the generating function $\sum_{n\geq 0} f(n)x^n$.

12.26 Differentiate with respect to x (12.10) satisfied by y.

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R.P. Stanley, *Algebraic Combinatorics: Walks, Trees, Tableaux, and More*,
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