Exercises

Exercise 23.1 **Diffusion for odd integer Λ.** *Show that when the slope $\Lambda = 2k-1$ in (23.9) is an odd integer, the diffusion constant is given by $D = (\Lambda^2-1)/24$, as stated in (23.21).*

Exercise 23.2 **Fourth-order transport coefficient.** *Verify (23.24). You will need the identity*

$$\sum_{k=1}^{n} k^4 = \frac{1}{30} n(n+1)(2n+1)(3n^2+3n-1)\,.$$

Exercise 23.3 **Finite Markov partitions.** *Verify (23.28).*

Exercise 23.4 **Maps with variable peak shape:**
Consider the following piecewise linear map

$$f_\delta(x) = \begin{cases} \frac{3x}{1-\delta} & \text{for } x \in \left[0, \frac{1}{3}(1-\delta)\right] \\ \frac{3}{2} - \left(\frac{2}{\delta}\left|\frac{4-\delta}{12} - x\right|\right) & \text{for } x \in \left[\frac{1}{3}(1-\delta), \frac{1}{6}(2+\delta)\right] \\ 1 - \frac{3}{1-\delta}\left(x - \frac{1}{6}(2+\delta)\right) & \text{for } x \in \left[\frac{1}{6}(2+\delta), \frac{1}{2}\right] \end{cases} \tag{23.38}$$

and the map in $[1/2, 1]$ is obtained by antisymmetry with respect to $x = 1/2$, $y = 1/2$. Write the corresponding dynamical zeta function relevant to diffusion and then show that

$$D = \frac{\delta(2+\delta)}{4(1-\delta)}$$

See refs. [23.17, 23.18] for further details.

Exercise 23.5 **Two-symbol cycles for the Lorentz gas.** *Write down all cycles labeled by two symbols, such as* (0 6), (1 7), (1 5) *and* (0 5).

Appendix T contains several project-length deterministic diffusion exercises.

Exercise 23.6 **Accelerated diffusion.** *Consider a map h, such that $\hat{h} = \hat{f}$ of figure 23.6 (b), but now running branches are turner into standing branches and vice versa, so that $1, 2, 3, 4$ are standing while 0 leads to both positive and negative jumps. Build the corresponding dynamical zeta function and show that*

$$\sigma^2(t) \sim \begin{cases} t & \text{for } \alpha > 2 \\ t \ln t & \text{for } \alpha = 2 \\ t^{3-\alpha} & \text{for } \alpha \in (1,2) \\ t^2/\ln t & \text{for } \alpha = 1 \\ t^2 & \text{for } \alpha \in (0,1) \end{cases}$$

Exercise 23.7 **Recurrence times for Lorentz gas with infinite horizon.** *Consider the Lorentz gas with unbounded horizon with a square lattice geometry, with disk radius R and unit lattice spacing. Label disks according to the (integer) coordinates of their center: the sequence of recurrence times $\{t_j\}$ is given by the set of collision times. Consider orbits that leave the disk sitting at the origin and hit a disk far away after a free flight (along the horizontal corridor). Initial conditions are characterized by coordinates (ϕ, α) (ϕ determines the initial position along the disk, while α gives the angle of the initial velocity with respect to the outward normal: the appropriate measure is then $d\phi\, \cos\alpha\, d\alpha$ ($\phi \in [0, 2\pi)$, $\alpha \in [-\pi/2, \pi/2]$. Find how $\psi(T)$ scales for large values of T: this is equivalent to investigating the scaling of portions of the state space that lead to a first collision with disk $(n, 1)$, for large values of n (as $n \mapsto \infty$ $n \simeq T$).*