which, after manipulation, yields the geometric sum formula.

###### Solution to Exercise 5.6.3

If the sampling frequency exceeds the Nyquist frequency, the spectrum of the samples equals the analog spectrum, but over the normalized analog frequency *fT* . Thus, the energy in the sampled signal equals the original signal's energy multiplied by *T*.

###### Solution to Exercise 5.7.1

This situation amounts to aliasing in the time-domain.

###### Solution to Exercise 5.8.1

When the signal is real-valued, we may only need half the spectral values, but the complexity remains unchanged. If the data are complex-valued, which demands retaining all frequency values, the complexity is again the same. When only

*K* frequencies are needed, the complexity is *O (KN)*.

###### Solution to Exercise 5.9.1

If a DFT required 1ms to compute, and signal having ten times the duration would require 100ms to compute. Using the FFT, a 1ms computing time would increase by a factor of about 10log210 = 33 , a factor of 3 less than the DFT would have needed.

###### Solution to Exercise 5.9.2

The upper panel has not used the FFT algorithm to compute the length-4 DFTs while the lower one has. The ordering is determined by the algorithm.

###### Solution to Exercise 5.9.3

The transform can have **any** greater than or equal to the actual duration of the signal. We simply "pad" the signal with zero-valued samples until a computationally advantageous signal length results. Recall that the FFT is an **algorithm** to compute the DFT (Section 5.7). Extending the length of the signal this way merely means we are sampling the frequency axis more fnely than required. To use the Cooley-Tukey algorithm, the length of the resulting zero-padded signal can be 512, 1024, etc. samples long.

###### Solution to Exercise 5.10.1

Number of samples equals 1.2 × 11025 = 13230. The datarate is 11025 × 16 = 176.4 kbps. The storage required would be 26460 bytes.

###### Solution to Exercise 5.10.2

The oscillations are due to the boxcar window's Fourier transform, which equals the sinc function.

###### Solution to Exercise 5.10.3

These numbers are powers-of-two, and the FFT algorithm can be exploited with these lengths. To compute a longer transform than the input signal's duration, we simply zero-pad the signal.