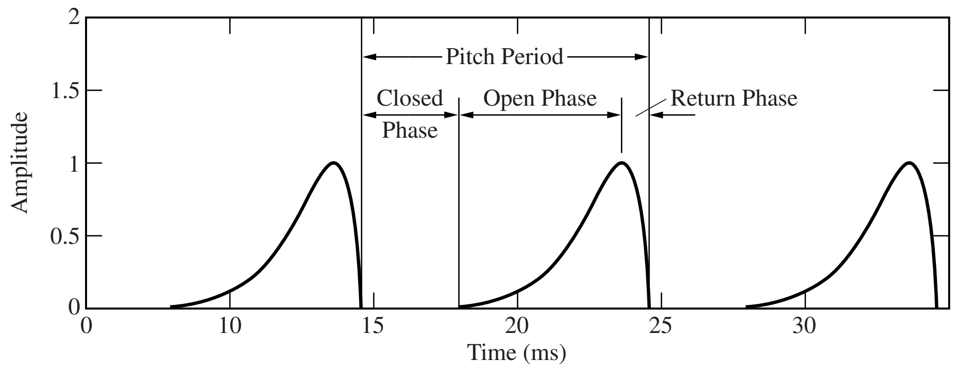

Figure 3.6 Illustration of periodic glottal airflow velocity.

might see typically one to four pitch periods over the duration of the sound, although, as we will see in the discussion of prosodics, the number of pitch periods changes with numerous factors such as stress and speaking rate. The rate at which the vocal folds oscillate through a closed, open, and return cycle is influenced by many factors. These include vocal fold muscle tension (as the tension increases, so does the pitch), the vocal fold mass (as the mass increases, the pitch decreases because the folds are more sluggish), and the air pressure behind the glottis in the lungs and trachea, which might increase in a stressed sound or in a more excited state of speaking (as the pressure below the glottis increases, so does the pitch). The pitch range is about 60 Hz to 400 Hz. Typically, males have lower pitch than females because their vocal folds are longer and more massive.

A simple mathematical model of the glottal flow is given by the convolution of a periodic impulse train with the glottal flow over one cycle. The following example shows glottal flow waveforms with different shapes and pitch periods, as well as how the simple convolutional model lends insight into the spectral nature of the glottal airflow.

EXAMPLE 3.1 Consider a glottal flow waveform model of the form

$$u[n] = g[n] * p[n] \tag{3.1}$$

where $g[n]$ is the glottal flow waveform over a single cycle and $p[n] = \sum_{k=-\infty}^{\infty} \delta[n - kP]$ is an impulse train with spacing P. Because the waveform is infinitely long, we extract a segment by multiplying $u[n]$ by a short sequence called an *analysis window* or simply a *window*. The window, denoted by $w[n, \tau]$, is centered at time τ, as illustrated in Figure 3.7, and the resulting waveform segment is written as

$$u[n, \tau] = w[n, \tau](g[n] * p[n]).$$

Using the Multiplication and Convolution Theorems of Chapter 2, we obtain in the frequency domain

$$U(\omega, \tau) = \frac{1}{P} W(\omega, \tau) \circledast \left[\sum_{k=-\infty}^{\infty} G(\omega)\delta(\omega - \omega_k) \right]$$