The Doppler Formula for Sound

The frequency that is perceived by a listener when the listener and/or source move through the medium that carries the sound is given by the general expression:

$$f_{new} = f_{orig}\left(\frac{v \pm v_{observer}}{v \mp v_{source}}\right)$$

where f_{orig} is the original frequency emitted by the source, v is the speed of sound in that medium (for example, air at room temperature: v = 340 m/s), $v_{observer}$ is the speed of the observer with respect to the medium, and v_{source} is the speed of the source with respect to the medium.

While this equation may look complicated, it is really just a compact way of dealing with all the possible ways (in a one-dimensional situation) the source and listener can move relative to each other and through the medium. To use the formula, just note that if either the source or the listener approaches the other, then f_{new} increases and if the source and listener move away from each other, f_{new} decreases. Several examples follow:

Source at rest (v_{source} = 0) and listener moving toward source results in a higher pitch heard by the listener. Therefore choose the '+' sign in the numerator:

$$f_{new} = f_{orig}\left(\frac{v + v_{observer}}{v}\right) \qquad \text{(Listener moves toward stationary source.)}$$

Source at rest (v_{source} = 0) and listener moving away from source results in a lower pitch heard by the listener. Therefore choose the '–' sign in the numerator:

$$f_{new} = f_{orig}\left(\frac{v - v_{observer}}{v}\right) \qquad \text{(Listener moves away from stationary source.)}$$

Listener at rest ($v_{observer}$ = 0) and source moving toward listener results in a higher pitch heard by the listener. Therefore choose the '–' sign in the denominator:

$$f_{new} = f_{orig}\left(\frac{v}{v - v_{source}}\right) \qquad \text{(Source moves toward stationary listener.)}$$

Listener at rest ($v_{observer}$ = 0) and source moving away from the listener results in a lower pitch heard by the listener. Therefore choose the '+' sign in the denominator:

$$f_{new} = f_{orig}\left(\frac{v}{v + v_{source}}\right) \qquad \text{(Source moves away from stationary listener.)}$$

In summary, choose the upper sign if when either object (source or listener) is moving toward the other and the lower sign if either object is moving away from the other.

As another example, what if BOTH the source moves toward the listener and listener moves toward the source simultaneously? You simply choose the appropriate sign that would produce an increase in perceived frequency for each object. In this case, since the listener moves toward the source, choose the '+' sign in the numerator. At the same time, since the source moves toward the listener, choose the '–' sign in the denominator:

$$f_{new} = f_{orig}\left(\frac{v + v_{observer}}{v - v_{source}}\right)$$ (Source and listener move toward each other.)

Finally, the other three possibilities are as follows:

$$f_{new} = f_{orig}\left(\frac{v - v_{observer}}{v + v_{source}}\right)$$ (Source and listener move away from each other.)

$$f_{new} = f_{orig}\left(\frac{v - v_{observer}}{v - v_{source}}\right)$$ (Source chasing listener.)

$$f_{new} = f_{orig}\left(\frac{v + v_{observer}}{v + v_{source}}\right)$$ (Listener chasing source.)