Guide to: moving wave emitters and receivers

Applications: wavelength and frequency shifts; echo-based speed measurements.

Basic idea: sound wave propagates in medium (air, fluid, solid): longitudinal compressions and rarefications; if source and/or observer move relative to medium there will be a wavelength change. the perceived frequency is in accord with this wavelength.

Derivations: 1) moving source: draw circles corresponding to emitted wave crests (time interval: $T = 1/f$); construct wavelengths $\lambda_a,\ \lambda_t$ observed by person source moves away from or towards it respectively; convert to frequencies $f_a,\ f_t$.

2) moving observer: construct position vs time graphs for crests emitted by source in intervals separated by $T = 1/f$ (slope = c_w); draw position-time graph for observer (slope $v_{\rm obs}$); watch time interval of intercepts $T_{\rm obs} = 1/f_{\rm obs}$.

3) formula for observed frequency can be combined to look at moving source and observer.

Equations: wavelength-frequency-propagation speed relation: $\lambda f = c_w$

moving source, stat. obs: $f_{\rm obs} = \dfrac{f_{\rm src}}{1 - v_{\rm src}/c_w}$; use $v_{\rm src} > 0$ in case of source moving towards.

stat. source, moving observer: $f_{\rm obs} = (1 + v_{\rm obs}/c_w) f_{\rm src}$; use $v_{\rm obs} > 0$ for obs. moving towards.

both obs and src moving: $f_{\rm obs} = \dfrac{1 + v_{\rm obs}/c_w}{1 - v_{\rm src}/c_w} f_{\rm src}$

Taylor series: to first order in $v_{\rm src}/c_w$ the moving-source formula yields the same as the moving-obs formula, which also agrees with the first-order expanded result for electromagnetic waves.

Problems: 13.51-59; 13.69. EM waves in vacuum/air no medium is required for propagation; there is only one formula which depends on the relative speed EQ. (23.19) in Giordano. Problems 23.43-48; 58, 59.
Using Radar to determine airplane speed, or police radar: note that object being monitored is moving with respect to the source (first Doppler shift), it re-emits (reflects) these waves as a moving source, so the shift appears twice (when the return signal is observed).
Given that airplane/car speeds are tiny compared to the speed of light, the simplest (lowest-order) Taylor expansion of Eq.(23.19) is sufficient, and it agrees with the moving-observer formula.
Also note that the shifts will be small, and therefore it is prudent to quote the shift, and calculate it directly from the lowest-order formula (otherwise one subtracts two nearly-equal numbers, and this can become meaningless on a calculator with limited number of digits).