Resonance Tube

Objective

The objective of this activity is to give an understanding of how resonance occurs and identify what properties determine when resonance takes place.

Materials

1. Digital thermometer (in the room)
2. Resonance tube
3. Right-angle clamp
4. Tuning fork striker
5. Tuning forks

Background

All objects will vibrate with a "characteristic" or "natural" frequency. When an object is acted upon by a periodic force with a frequency precisely the natural frequency of that object, the amplitude of the object's vibration increases greatly. This phenomenon is called resonance.

When a periodic sound source (like a tuning fork) is situated at one end of a tube of air, sound waves travel down the tube and are reflected back at the end of the tube. (A sound wave will be reflected from either an open end or a closed end.) The reflected waves travel back and are re-reflected from the end where the source is situated. If this re-reflected wave coincides exactly with a newly formed wave from the source, they reinforce one another and the amplitude becomes very large, as with waves moving on a string. At this condition the system becomes a much more efficient radiator of sound waves and a distinct increase in the intensity of the sound can be heard for several feet. Resonance!

It turns out that when standing waves occur in a tube, reflection must occur at a displacement node at the closed end and at an antinode near to but not exactly at the open end.

Procedure

In this experiment a tuning fork will be mounted over the open end of a vertical tube with water forming a closed bottom end. The water level can be varied, thus varying the length of the tube in which the wave may travel. (***Caution***: Never strike a tuning fork with a metal object, because dents change the fork's shape and thus its frequency of vibration.) With the tuning fork vibrating, the water level can be varied and the precise length for resonance should be noted for several standing wave patterns. Strike the fork, then change the water level until you hear a distinct increase in the volume of the forks sound. Watch the water level, as too much water in the tube will lead to spillage. The distance between two successive water levels that give resonance will be the distance between two standing wave nodes. (The end of the tube next to the fork should not be taken as an antinode because of a slight end effect, thus the distance from the fork to the first resonance is not equal to half of a wavelength.) The distance between two successive nodes is half the wavelength of the sound wave. From wavelength and frequency compute the speed of sound in air. The velocity of the sound wave will be the product of the wavelength, λ, and the frequency, f (or $v = \lambda f$).

The speed of sound in air increases with the square root of absolute temperature. An approximate expression for computing the speed of sound (that is adequate for this experiment) is $v = 331 + 0.6T$ (in m/s), where T is the temperature in degrees Celsius (notice that the speed of sound is 331 m/s at 0°C (273 K)). How does this theoretical value compare with the speed you measured above?

The experiment should be repeated with a tuning fork of a different frequency. A moment's thought should indicate that 3/4 of the wavelength should be shorter than the maximum length of the tube in order to perform the experiment as described above. It should also be mentioned that sometimes a fork will vibrate in more than the fundamental mode and the overtones can be troublesome. The overtones, if present, will have a higher frequency than the fundamental frequency. (The fundamental frequency is stamped on the fork.)