

## Chapter 73 – Speed of Sound

$S_{SND}$  = constant over the short periods during one of our calculations. The speed of sound changes over longer periods. The speed of sound is affected by the air pressure, the air temperature, and the chemical composition.

The table below shows the results of a detailed spreadsheet calculation of the speed of sound at two different temperatures. You can see that the speed of sound increases as the temperature increases. It also increases as the pressure decreases. This spreadsheet can be used to calculate the changes in the speed of sound with altitude if pressure and temperature are known.

Speed of Sound Calculations			
$v = \sqrt{B/\rho}$	Where $B$ is the bulk Modulus and $\rho$ is the density of the gas,		
$B = \gamma p$	where $\gamma = 1.40$ for diatomic gases and $p$ is the pressure. Therefore,		
Assuming:	$\gamma =$	<b>1.4</b>	for a diatomic ideal gas
	$\rho_0 =$	<b>1.2929</b> kg/m <sup>3</sup>	for dry air at 0°C and one atmosphere
	$\rho_t =$	<b>1.2047</b> kg/m <sup>3</sup>	$= 273.16 \cdot \rho_0 \cdot P / (t + 273.16) / 101300$
	$P =$	<b>101300</b> Pa	atmospheric pressure
	$v = \sqrt{\gamma P / \rho} =$	$\sqrt{1.40 \cdot 101300 / 1.294439} =$	
	$v(0^\circ\text{C}, 101,300\text{ Pa}) =$	<b>331.20</b> m/s	at 0°C and one atm pressure in air
The velocity in a mixture of ideal diatomic gases is slightly more complex to calculate, but for air (a mixture of O <sub>2</sub> and N <sub>2</sub> ) it gives a nearly identical result.			
	$v(0^\circ\text{C}, 101,300\text{ Pa}) =$	<b>333.77</b> m/s	at 0°C and one atm pressure (O <sub>2</sub> , N <sub>2</sub> mix)
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$V$ is proportional to the $\sqrt{T/T_0}$ K	Therefore, the speed of sound at $t =$		<b>20</b> °C
$v(20^\circ\text{C}, 101,300\text{ Pa}) =$	<b>343.11</b>	m/s for an ideal diatomic gas at 1 atm.	
$v(20^\circ\text{C}, 101,300\text{ Pa}) =$	<b>345.77</b>	m/s for a 20:80 mixture of O <sub>2</sub> & N <sub>2</sub> at 1 atm	

Normal fluctuations in temperature and pressure at ground level also change the speed of sound. Around normal room temperature, say 20 °C, the calculation above suggests that a value around 340 m/s should be a good value to use. In a given problem we should not be surprised to see values between 330 and 350 m/s. Any value in this range could be correct on any given day, given the right set of atmospheric conditions.

The formula in the Formula Sheet for Physics lists 343 primarily to avoid introducing an extra parameter into the complexities of the Doppler Shift calculation. But if you ever need to solve a problem that requires a different speed of sound, simply replace the 343 m/s in the equation with the number given in the problem.