

SPH3U 8.5 Properties of Sound Waves

1. Categories of sound waves

Audible sound waves:	we can hear f between 20 Hz - 20 kHz.
infrasonic	below our hearing, $f < 20 \text{ Hz}$. earthquakes.
ultrasonic	above our hearing, $f > 20 \text{ kHz}$.

2. The speed of sound through air

Equation:	$v_s = 331.4 \text{ m/s} + (0.606 \frac{\text{m}}{\text{s}^\circ\text{C}}) T$
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The temperature outside is 23 °C. What is the speed of sound in air at this temperature?

$$v_s = 331.4 + 0.606(23) = \underline{345 \text{ m/s.}}$$

If the speed of sound is measured to be 318 m/s, what is the current air temperature?

$$v_s = 331.4 + 0.606 T \quad T = \frac{v - 331.4}{0.606} = \frac{318 - 331.4}{0.606} = \underline{-22.1^\circ\text{C.}}$$

3. Mach number

Mach number:	ratio of airspeed to the local speed of sound.
equation	$M = \frac{v}{v_s}$ ($M = \frac{\text{airspeed of object}}{\text{speed of sound}}$)

An aircraft is flying at 905 km/h in air at the temperature -50.0 °C. Calculate the Mach number associated with this speed.

$$M = \frac{v}{v_s} \quad v_s = 331.4 + 0.606(-50)$$

$$= \underline{301.1 \text{ m/s.}}$$

$$v = 905 \frac{\text{km}}{\text{h}} \times \frac{1000 \text{ m}}{1 \text{ km}} \times \frac{1 \text{ h}}{3600 \text{ s}} = \underline{251.4 \text{ m/s.}}$$

$$M = \frac{251.4}{301.1} = 0.835 \quad \therefore \text{the Mach number is } 0.835.$$

4. Sound intensity

I	Sound intensity:	amount of sound energy transferred per unit area.
B	sound level	perceptual loudness of sound, in dB.

Type of sound	Typical sound intensity (W/m^2)	Sound level (dB)	Type of sound	Typical sound intensity (W/m^2)	Sound level (dB)
threshold of human hearing	1×10^{-12}	0	jet flyover (at 300 m)	1×10^{-2}	100
normal breathing (at 1 m)	1×10^{-11}	10	rock band	0.1	110
typical whisper (at 1 m)	1×10^{-10}	20	jet aircraft engine (at 80 m), power saw	1.0	120
empty classroom	1×10^{-9}	30	threshold of pain	10	130
computer (at 1 m)	1×10^{-8}	40	military jet taking off	100	140
library	1×10^{-7}	50	space shuttle (at 180 m)	316	145
alarm clock (at 1 m)	1×10^{-6}	60	sound cannon (at 1 m)	1 000	150
vacuum cleaner (at 2 m)	1×10^{-5}	70	1 tonne TNT (at 30 m) (buildings 50 % destroyed)	380 000	175.8
diesel locomotive (at 30 m)	1×10^{-4}	80	tornado	1×10^{12}	240
motorcycle (at 10 m)	1×10^{-3}	90	atomic bomb	1×10^{13}	250

Loudness and distance:

Distance (m)	Sound level (dB)
1	120
10	100
50	86
100	80
200	74
500	66
1 000	60
2 000	54
5 000	46
10 000	40

Sound safety:

Continuous dB	Permissible exposure time
85	8 h
88	4 h
91	2 h
94	1 h
97	30 min
100	15 min
103	7.5 min
106	3.75 min (<4 min)
109	1.88 min (<2 min)
112	0.94 min (~1 min)
115	0.47 min (~30 s)

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