SOUND 1

PHYSICS
OF
SOUND

Basic understanding of:

Basic understanding of:

- SOUND

Basic understanding of:

- SOUND
- ACOUSTICS

Basic understanding of:

- SOUND
- ACOUSTICS
- AUDIO

SOUND:

SOUND:

- What is sound?

SOUND:

- What is sound?
- How is it generated?

SOUND:

- What is sound?
- How is it generated?
- How does it propagate?

ACOUSTICS:

ACOUSTICS:

- effects of boundaries (theatre walls, floor, ceiling) on:

ACOUSTICS:

- effects of boundaries (theatre walls, floor, ceiling) on:
  - propagation

ACOUSTICS:

- effects of boundaries (theatre walls, floor, ceiling) on:
  – propagation
  – perception (psychoacoustics)

AUDIO:

AUDIO:

- sound in its electronic form

AUDIO:

- sound in its electronic form
  - Transducers

AUDIO:

- sound in its electronic form
  - Transducers
  - Processing

AUDIO:

- sound in its electronic form
  - Transducers
  - Processing
  - Transmission

AUDIO:

- sound in its electronic form
  - Transducers
  - Processing
  - Transmission
  - Recording

AUDIO:

- sound in its electronic form
  - Transducers
  - Processing
  - Transmission
  - Recording
  - Editing

AUDIO:

- sound in its electronic form
  - Transducers
  - Processing
  - Transmission
  - Recording
  - Editing
  - System design

For our purposes:

For our purposes:

Sound is the transmission of vibrations in air as perceived by the human ear.

For our purposes:

Sound is the transmission of vibrations in air as perceived by the human ear.

– Speech

For our purposes:

Sound is the transmission of vibrations in air as perceived by the human ear.

- Speech
- Music

For our purposes:

Sound is the transmission of vibrations in air as perceived by the human ear.

- Speech
- Music
- Sound Effects

Sources of sound:

Sources of sound:

Sound is generated by a vibrating source as waves of changing pressure.

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Human -- vocal chords

Sources of sound:

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Human -- vocal chords

Musical instruments -- strings

Sources of sound:

Sound is generated by a vibrating source as waves of changing pressure.

Human -- vocal chords

Musical instruments -- strings

- guitar

Sources of sound:

Sound is generated by a vibrating source as waves of changing pressure.

Human -- vocal chords

Musical instruments -- strings

- guitar
- violin

Sources of sound:

Sound is generated by a vibrating source as waves of changing pressure.

Human -- vocal chords

Musical instruments -- strings

- guitar
- violin

-- membrane

Sources of sound

Sound is generated by a vibrating source as waves of changing pressure.

Human -- vocal chords

Musical instruments -- strings

- guitar
- violin

-- membrane

- gong

Sources of sound:

Sound is generated by a vibrating source as waves of changing pressure.

Human -- vocal chords

Musical instruments -- strings

- guitar
- violin

-- membrane

- gong
- drum skin

Sources of sound:

Sound is generated by a vibrating source as waves of changing pressure.

Human -- vocal chords

Musical instruments -- strings

- guitar
- violin

-- membrane

- gong
- drum skin

Electro-mechanical -- loudspeaker diaphragm

Sound Propagation:

Sound Propagation:

Sound travels at a finite speed, dependent on the density of the medium.

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MEDIUM	M./SEC.	FT./SEC.	SPEED FACTOR

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AIR	344	1,130	1

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AIR	344	1,130	1
WATER	1,480	4,854	4.3

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MEDIUM	M./SEC.	FT./SEC.	SPEED FACTOR
AIR	344	1,130	1
WATER	1,480	4,854	4.3
CONCRETE	3,400	11,152	9.8

Sound Propagation:

Sound travels at a finite speed, dependent on the density of the medium.

MEDIUM	M./SEC.	FT./SEC.	SPEED FACTOR
AIR	344	1,130	1
WATER	1,480	4,854	4.3
CONCRETE	3,400	11,152	9.8
DRY WALL	6,600	22,304	19.6

Sound Propagation:

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Sound takes a finite time to travel from one point to another.

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Sound takes a finite time to travel from one point to another.

DISTANCE	TIME
1 mile	
1 km.	
1 foot	
1 metre	
1 inch	
1 cm.	

Sound Propagation:

Sound takes a finite time to travel from one point to another.

DISTANCE	TIME
1 mile	5 sec.
1 km.	
1 foot	
1 metre	
1 inch	
1 cm.	

Sound Propagation:

Sound takes a finite time to travel from one point to another.

DISTANCE	TIME
1 mile	5 sec.
1 km.	3 sec.
1 foot	
1 metre	
1 inch	
1 cm.	

Sound Propagation:

Sound takes a finite time to travel from one point to another.

DISTANCE	TIME
1 mile	5 sec.
1 km.	3 sec.
1 foot	0.88 msec.
1 metre	
1 inch	
1 cm.	

Sound Propagation:

Sound takes a finite time to travel from one point to another.

DISTANCE	TIME
1 mile	5 sec.
1 km.	3 sec.
1 foot	0.88 msec.
1 metre	3 msec.
1 inch	
1 cm.	

Sound Propagation:

Sound takes a finite time to travel from one point to another.

DISTANCE	TIME
1 mile	5 sec.
1 km.	3 sec.
1 foot	0.88 msec.
1 metre	3 msec.
1 inch	73 µsec.
1 cm.	

Sound Propagation:

Sound takes a finite time to travel from one point to another.

DISTANCE	TIME
1 mile	5 sec.
1 km.	3 sec.
1 foot	0.88 msec.
1 metre	3 msec.
1 inch	73 µsec.
1 cm.	30 µsec.

Sound Propagation:

Sound takes a finite time to travel from one point to another.

Rule of thumb:

Sound Propagation:

Sound takes a finite time to travel from one point to another.

Rule of thumb:

- 1 foot per millisecond

Sound Propagation:

Sound takes a finite time to travel from one point to another.

Rule of thumb:

- 1 foot per millisecond
- 1 millisecond per foot

Sound Wave Properties:

A sound wave has certain properties which define it.

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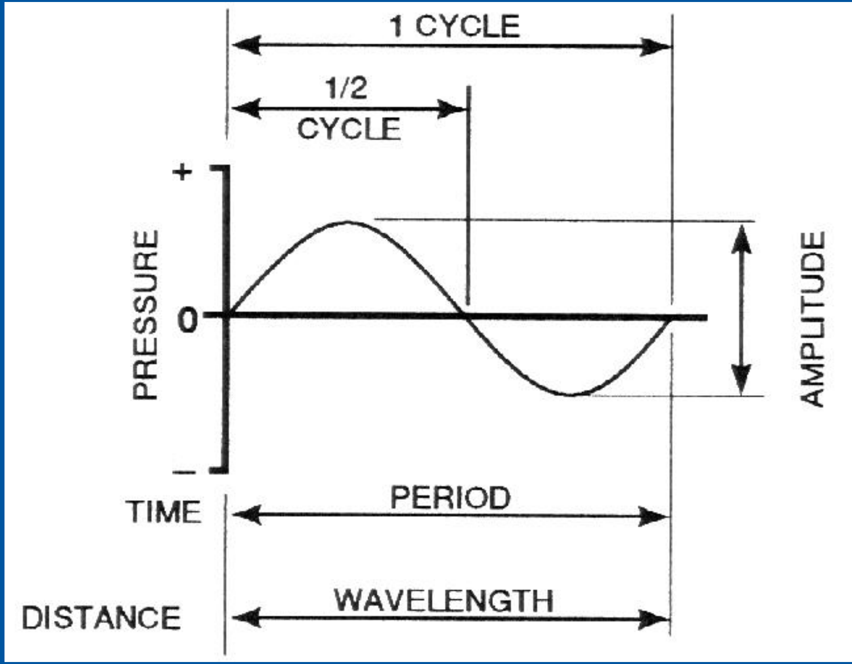
A sound wave has certain properties which define it.

Amplitude

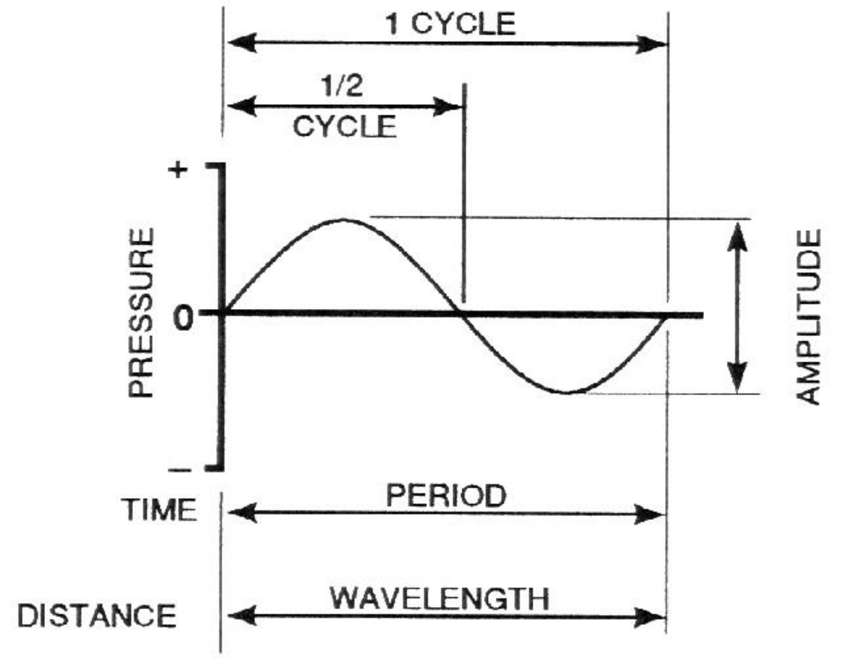


Sound Wave Properties:

A sound wave has certain properties which define it.

Amplitude

intensity of wave measured in:



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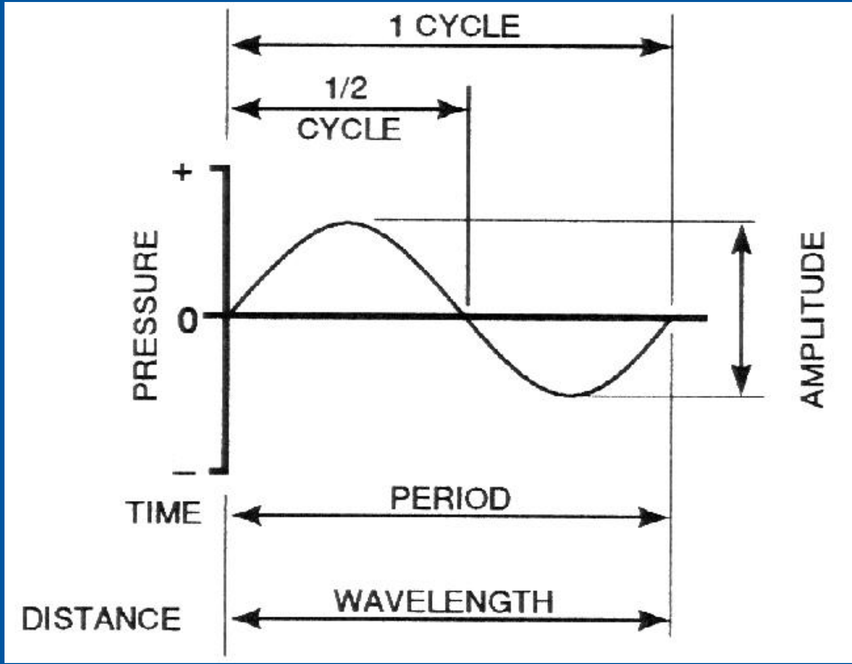


Amplitude

intensity of wave measured in:

- Pascals (pressure)

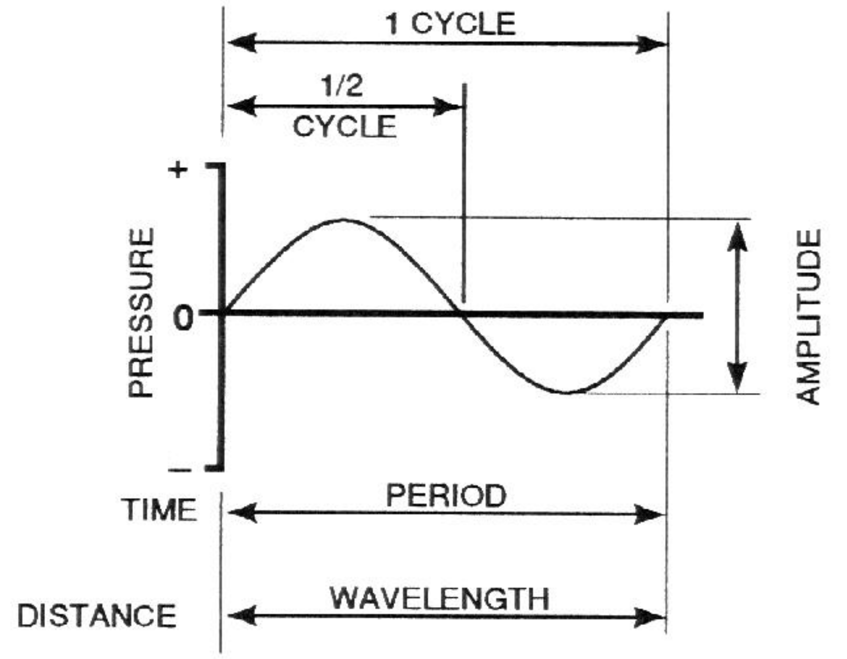
Sound Wave Properties:

A sound wave has certain properties which define it.

Amplitude

intensity of wave measured in:

- Pascals (pressure)
- dB-SPL (Sound Pressure Level)



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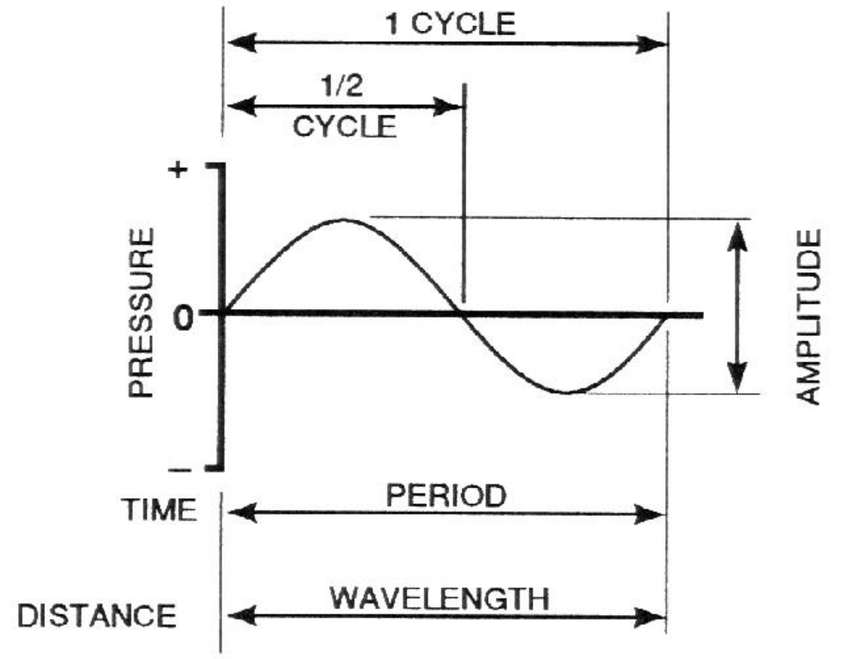


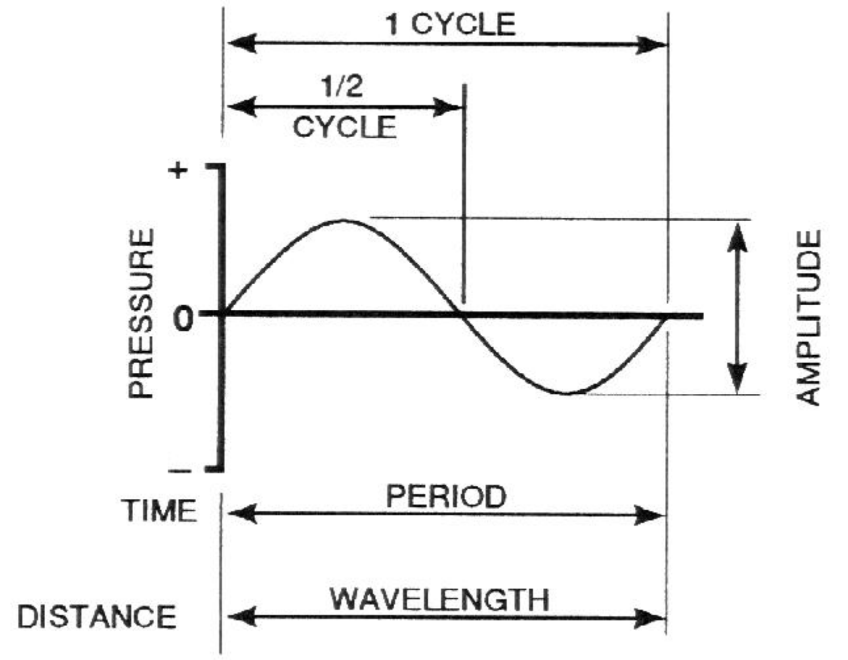
Amplitude

intensity of wave measured in:

- Pascals (pressure)
- dB-SPL (Sound Pressure Level)
- volts (electrical)

Sound Wave Properties:

A sound wave has certain properties which define it.



Sound Wave Properties:

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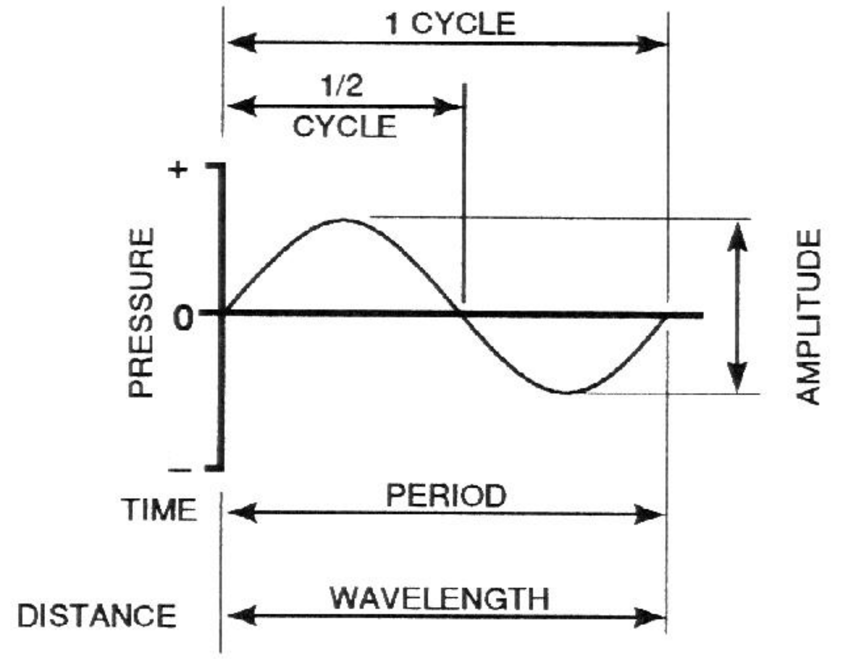
Frequency

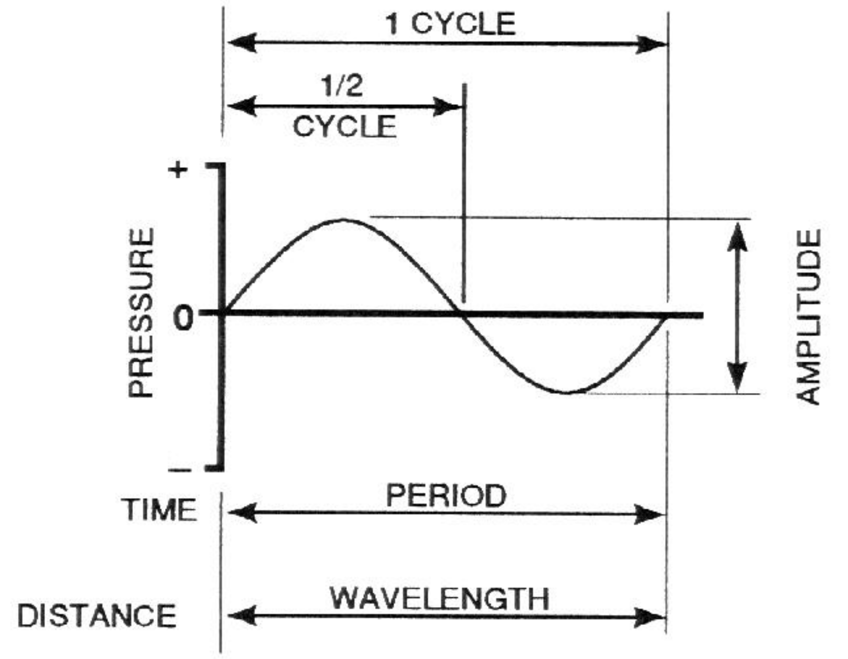


Sound Wave Properties:

A sound wave has certain properties which define it.

Frequency

number of repetitions per second measured in:



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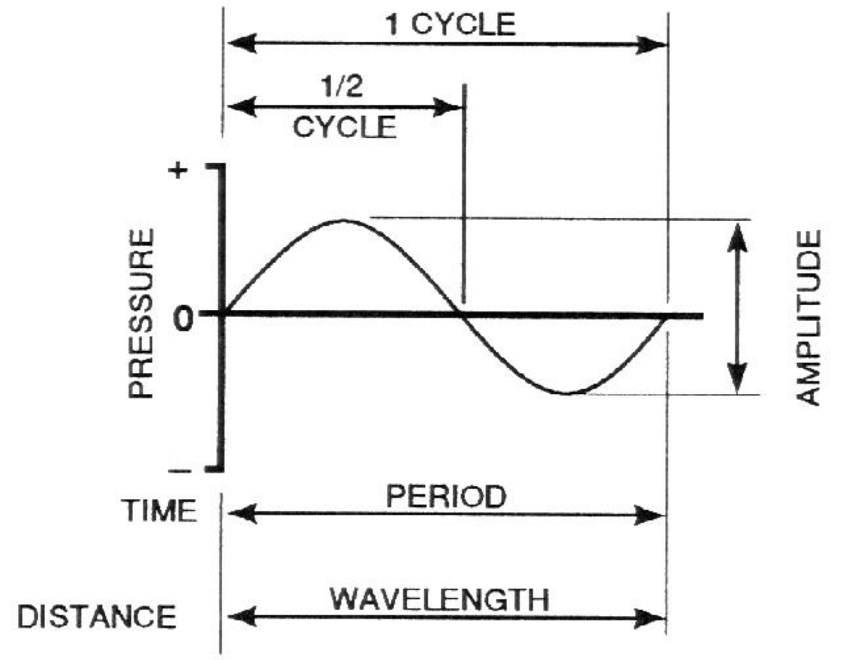

Frequency

number of repetitions per second measured in:

- hertz (Hz)

Sound Wave Properties:

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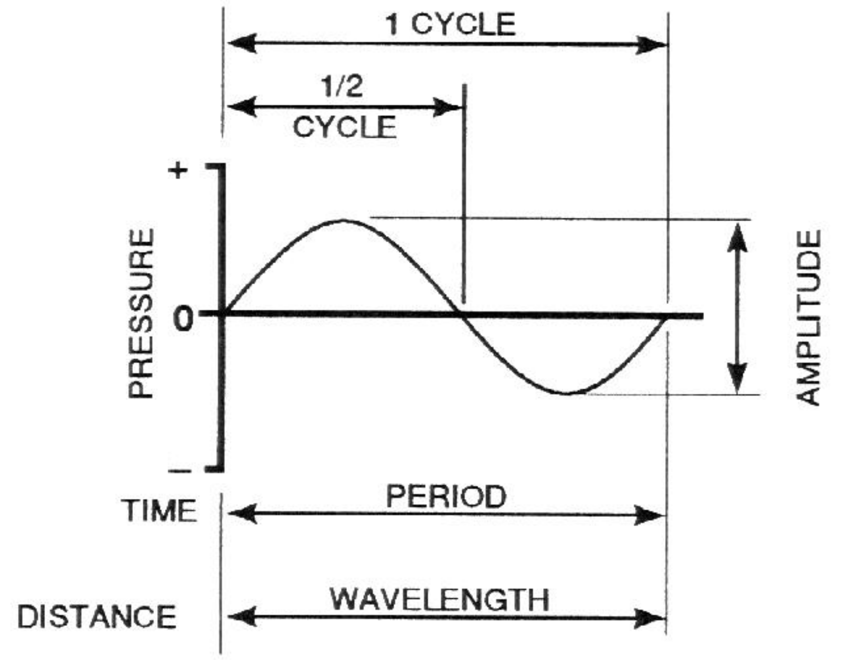

Frequency

number of repetitions per second measured in:

- hertz (Hz)
- cycles per second (cps)

Sound Wave Properties:

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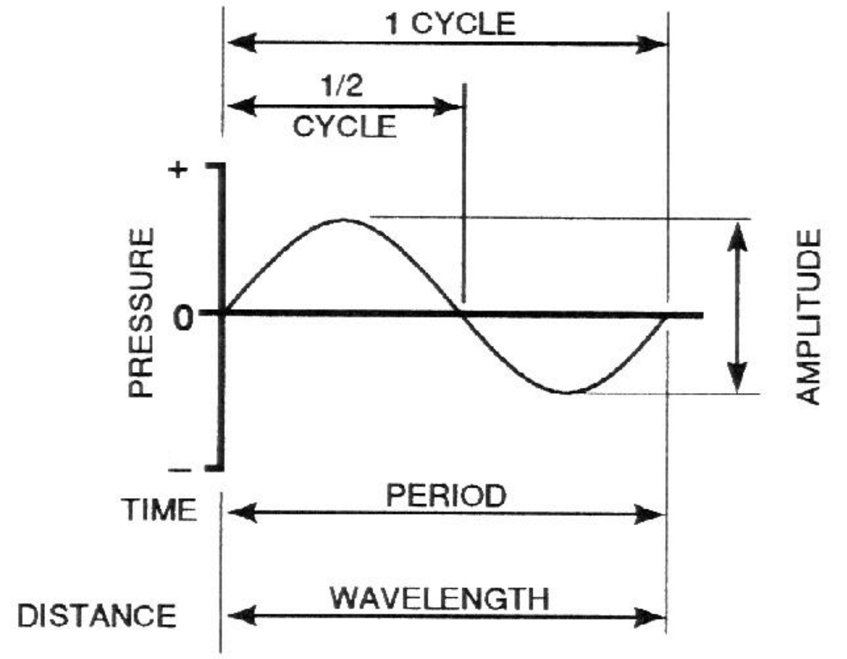

Sound Wave Properties:

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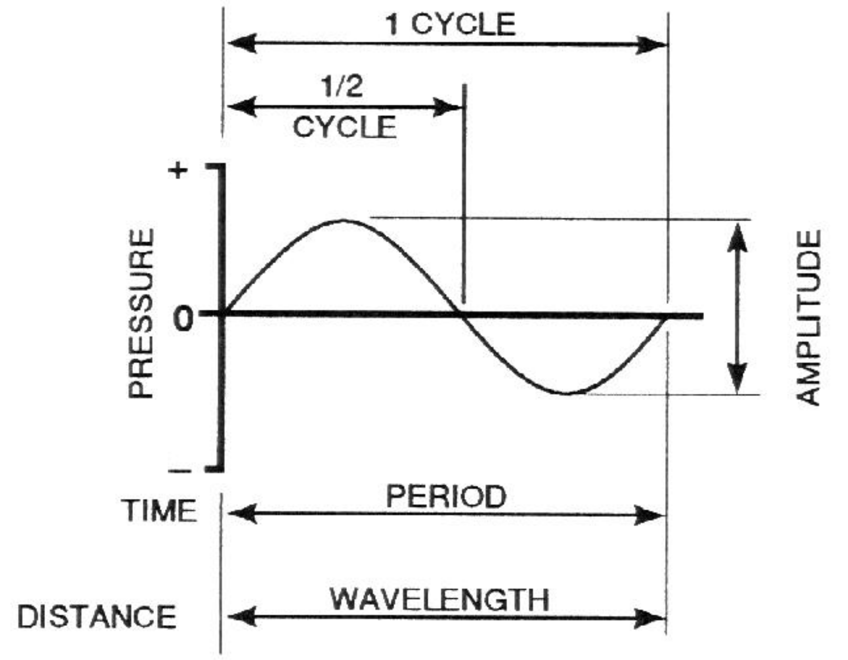
Period



Sound Wave Properties:

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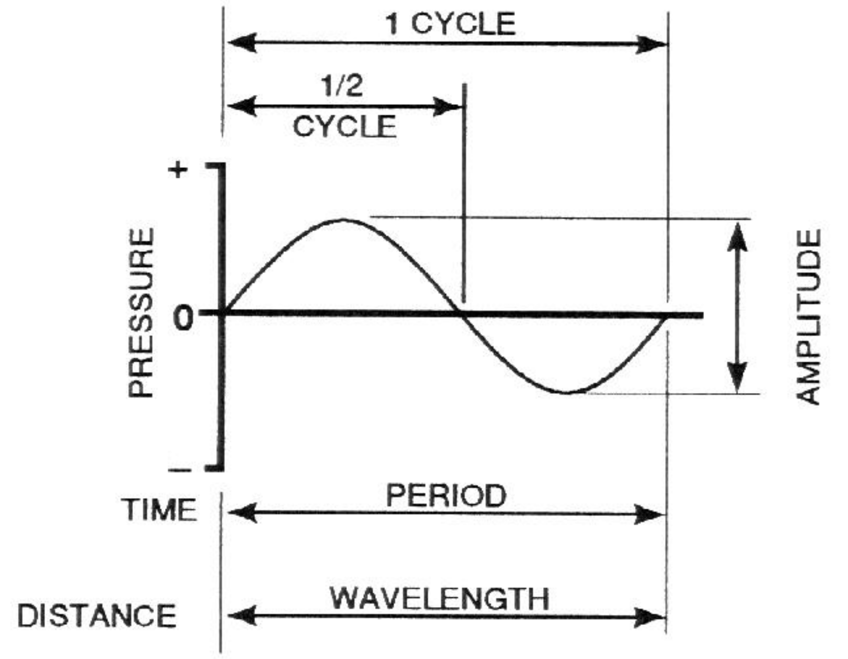
Period

time to complete one cycle:



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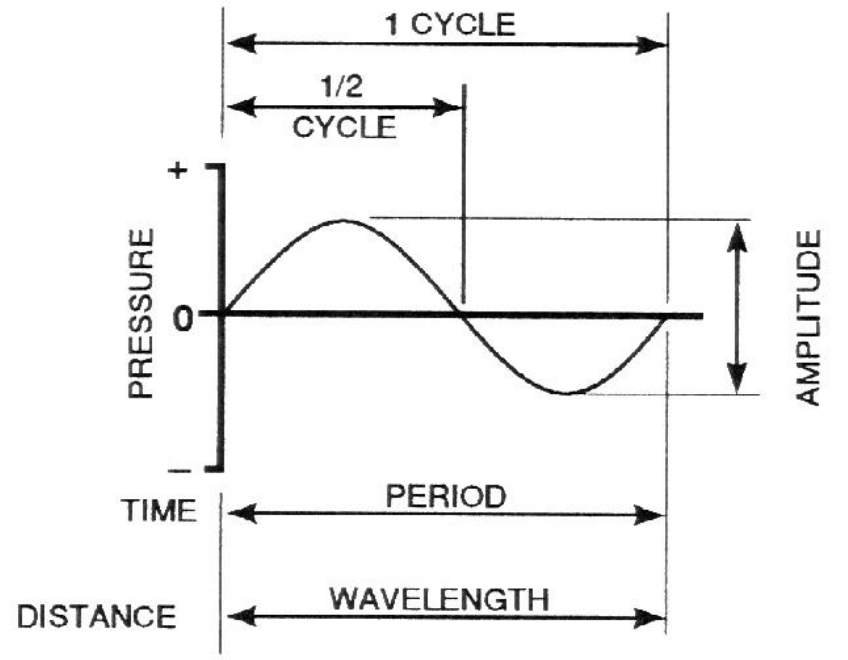


Period

time to complete one cycle:

1/frequency, measured in:

Sound Wave Properties:

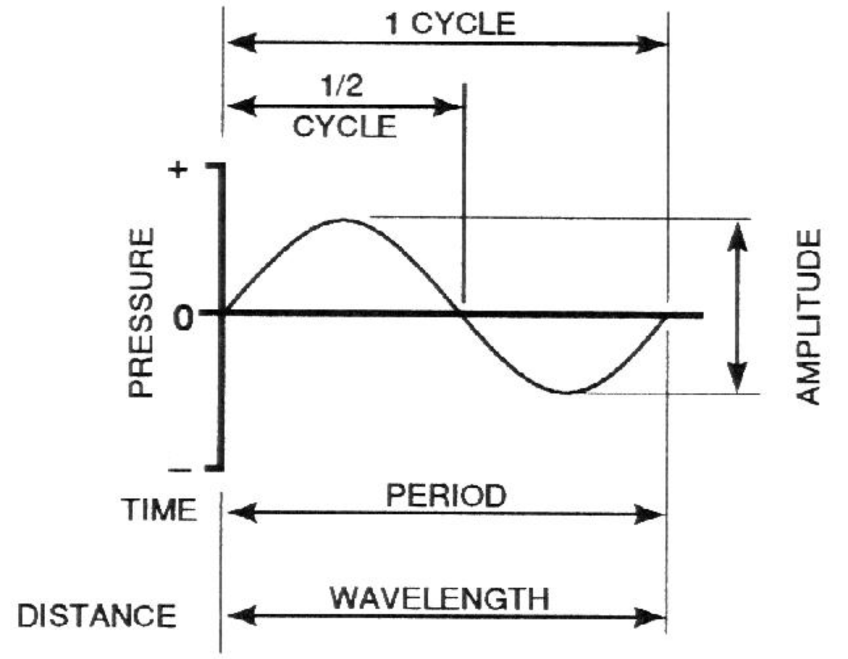
A sound wave has certain properties which define it.

Period

time to complete one cycle:

1/frequency, measured in:

- seconds per cycle (sec.)



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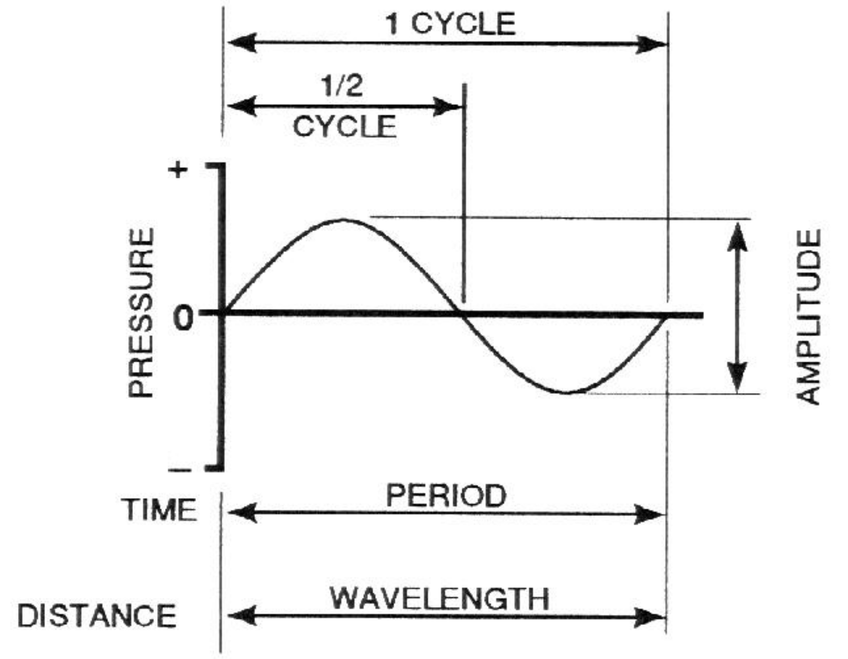

Period

time to complete one cycle:

1/frequency, measured in:

- seconds per cycle (sec.)
- milliseconds per cycle (msec.)

Sound Wave Properties:

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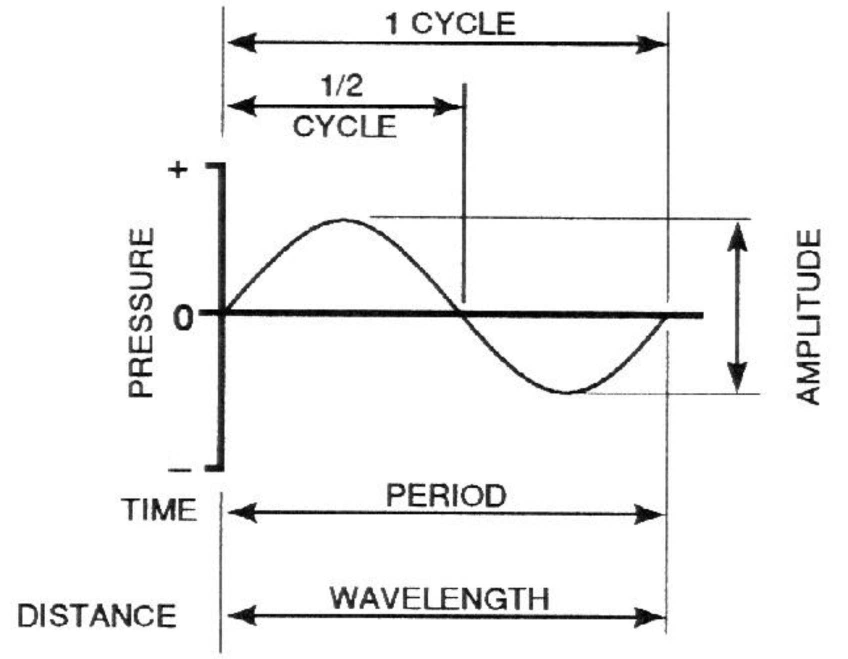

Sound Wave Properties:

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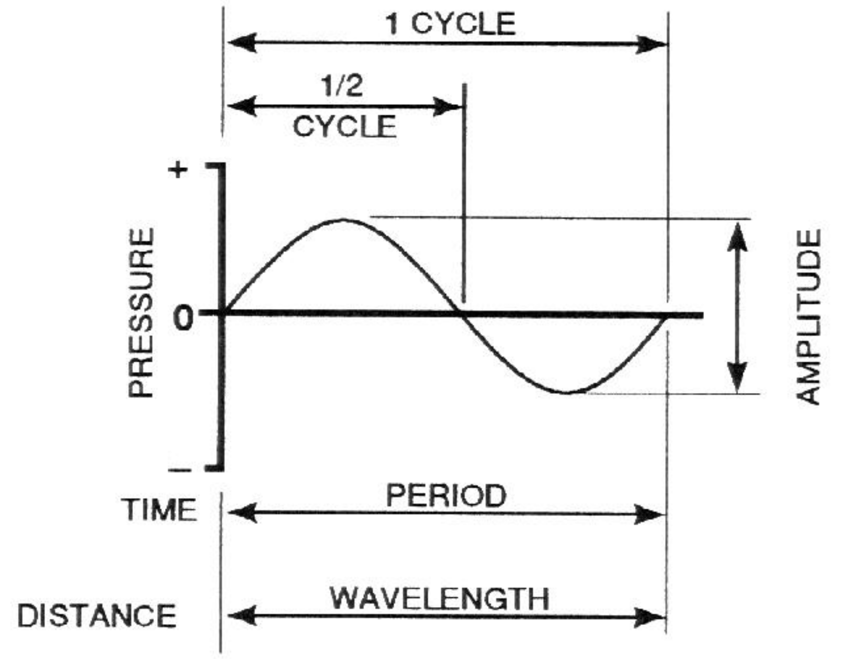
Wavelength:



Sound Wave Properties:

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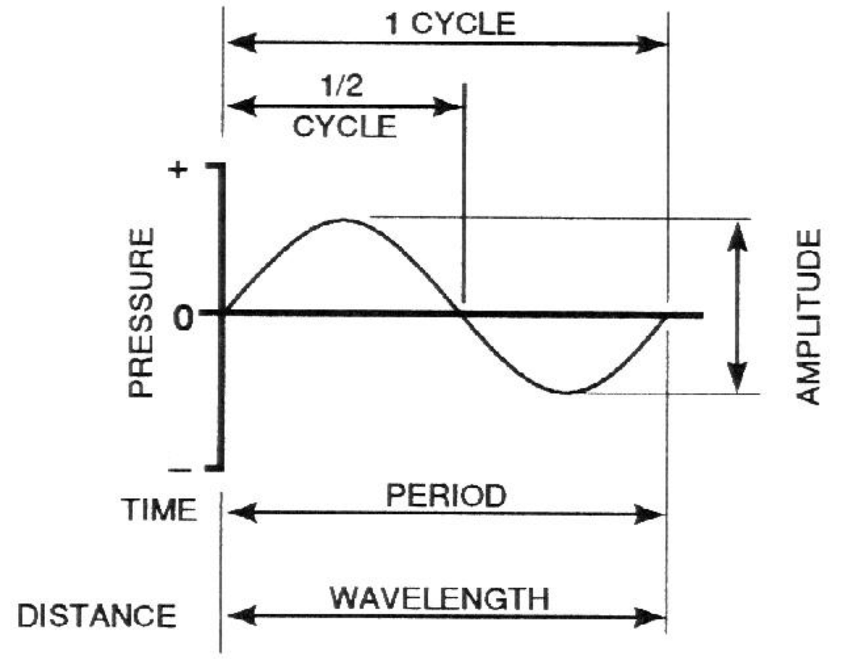
Wavelength:

distance to complete one cycle:



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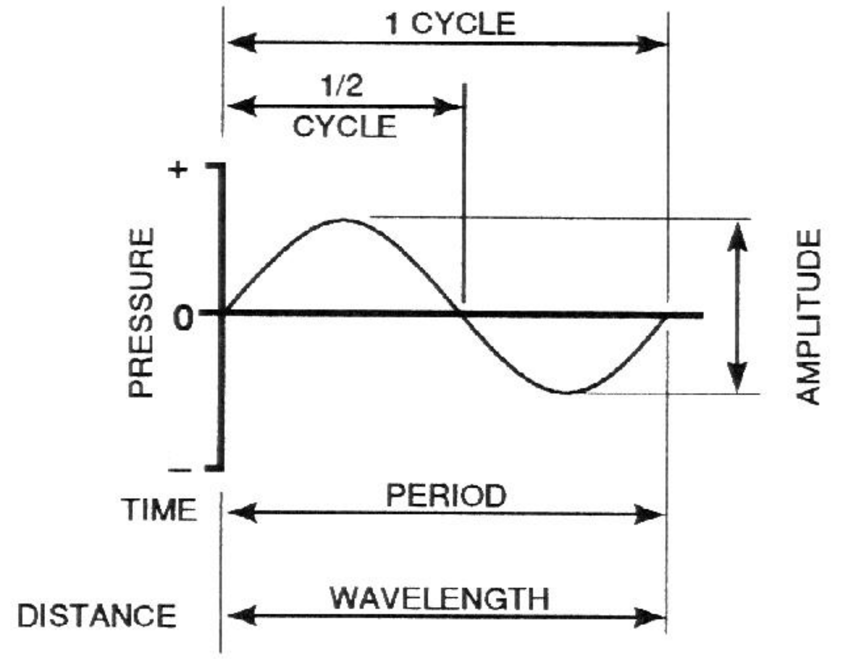


Wavelength:

distance to complete one cycle:

speed/frequency, measured in:

Sound Wave Properties:

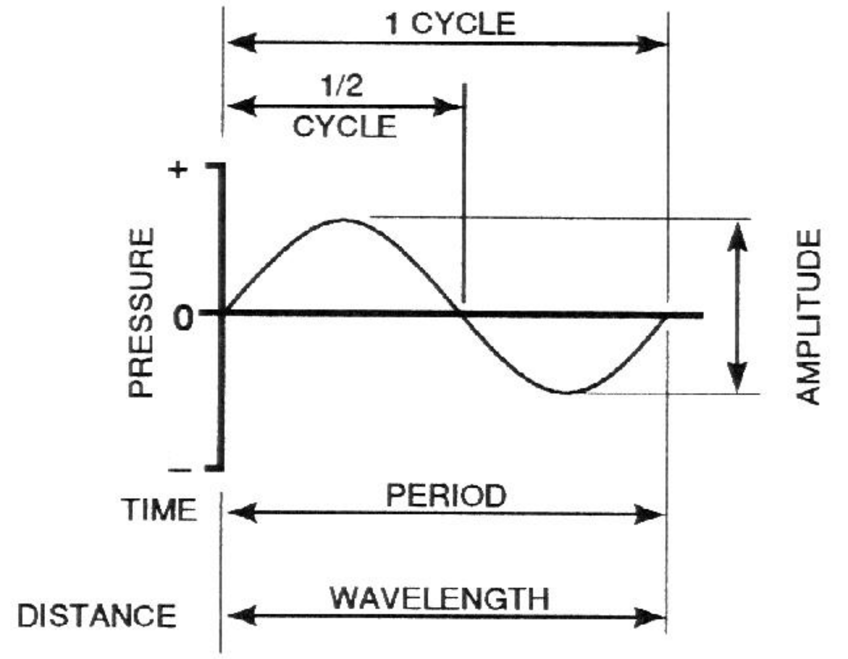
A sound wave has certain properties which define it.

Wavelength:

distance to complete one cycle:

speed/frequency, measured in:

- metres (m.)



Sound Wave Properties:

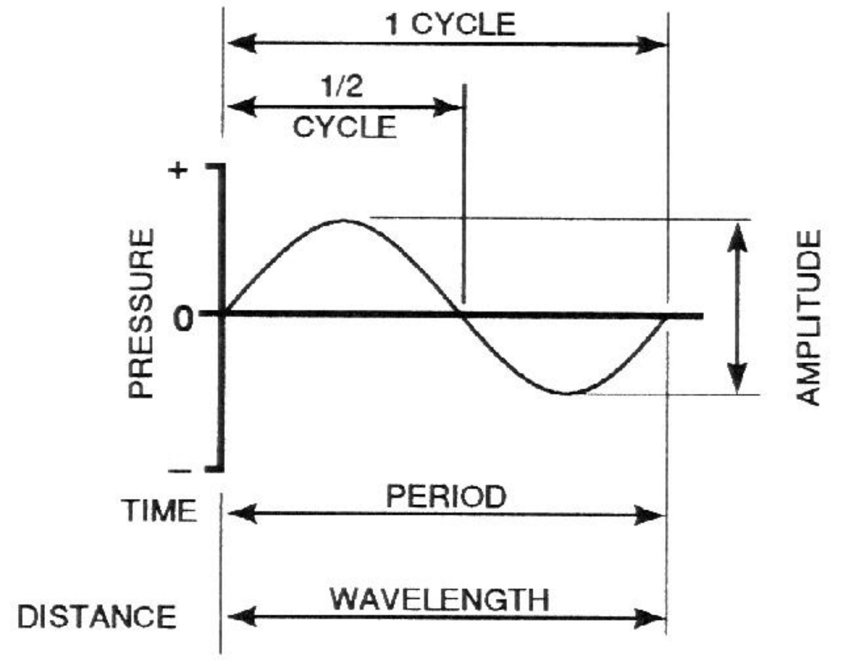
A sound wave has certain properties which define it.

Wavelength:

distance to complete one cycle:

speed/frequency, measured in:

- metres (m.)
- feet (ft.)



Range of Human Hearing:

Range of Human Hearing:

Amplitude			

Range of Human Hearing:

Amplitude			
Low			
20 μPascals			

Range of Human Hearing:

Amplitude			
Low	High		
20 µPascals	20 Pascals		

Range of Human Hearing:

Amplitude		Frequency	
Low	High		
20 μPascals	20 Pascals		

Range of Human Hearing:

Amplitude		Frequency	
Low	High	Low	
20 µPascals	20 Pascals	20 Hz	

Range of Human Hearing:

Amplitude		Frequency	
Low	High	Low	High
20 µPascals	20 Pascals	20 Hz	20 kHz

Range of Human Hearing:

Amplitude		Frequency	
Low	High	Low	High
20 µPascals	20 Pascals	20 Hz	20 kHz
1,000,000:1			

Range of Human Hearing:

Amplitude		Frequency	
Low	High	Low	High
20 µPascals	20 Pascals	20 Hz	20 kHz
1,000,000:1		1000:1	

Amplitude vs Frequency:

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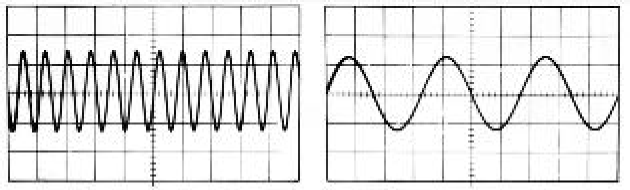
These two waveforms have the same amplitude, but the one on the right has 4 times the period (hence 1/4 the frequency).



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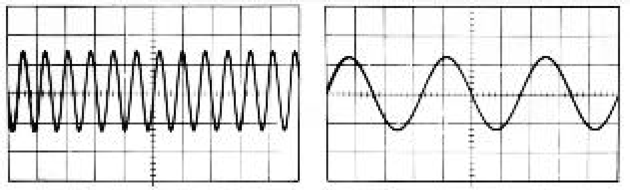
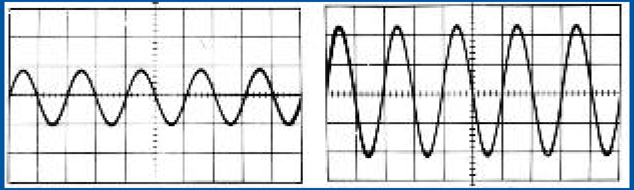


These two waveforms have the same period (hence the same frequency), but the one on the right is 2 times the amplitude.



Frequency and Musical Pitch:

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The musical equivalent of frequency is pitch.

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- A higher frequency has a higher pitch.

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- ‘A’ above middle ‘C’ has a frequency of 440 Hz.

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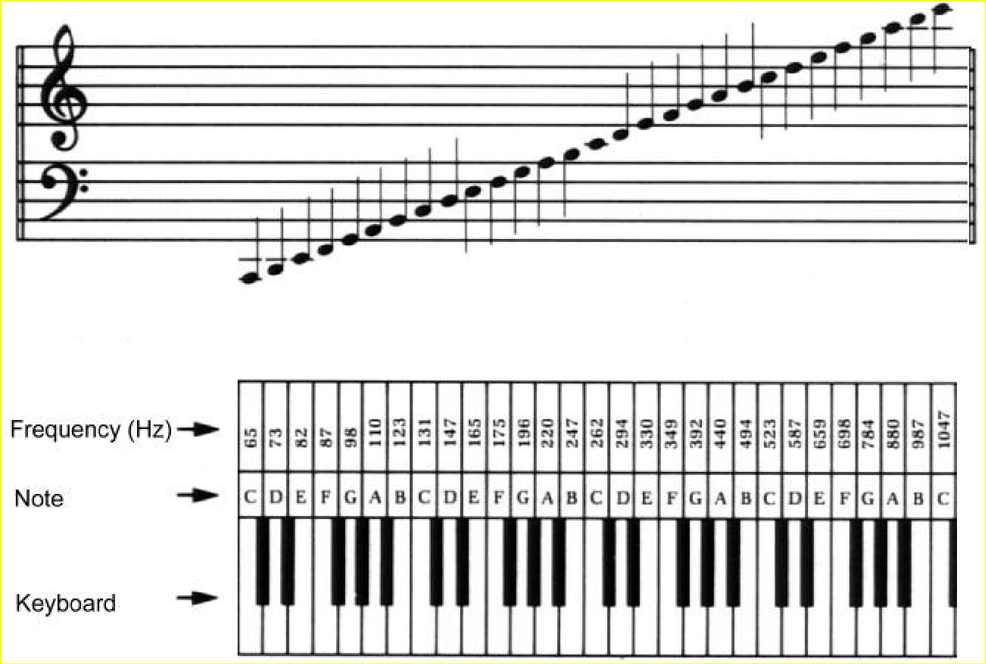
The musical equivalent of frequency is pitch.

- A higher frequency has a higher pitch.
- ‘A’ above middle ‘C’ has a frequency of 440 Hz.
- A doubling of frequency is called an octave.

Frequency and Musical Pitch:



Frequency Ranges of Musical Instruments:

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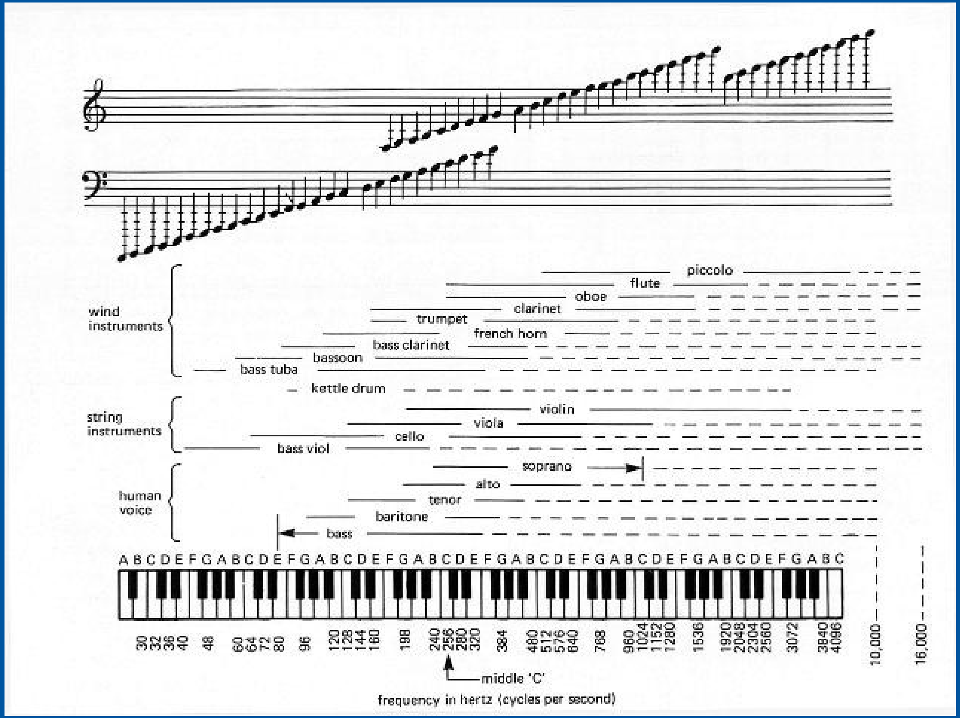

Frequency vs. Period and Wavelength:

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Lower frequencies have longer wavelengths and periods.

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Frequency	Period	Wavelength	
20 Hz	50 msec.	56.4 ft.	17.2 m.

Frequency vs. Period and Wavelength:

Lower frequencies have longer wavelengths and periods.
Higher frequencies have shorter wavelengths and periods.

Frequency	Period	Wavelength	
20 Hz	50 msec.	56.4 ft.	17.2 m.
200 Hz	5 msec.	5.5 ft.	1.72 m.

Frequency vs. Period and Wavelength:

Lower frequencies have longer wavelengths and periods.
Higher frequencies have shorter wavelengths and periods.

Frequency	Period	Wavelength	
20 Hz	50 msec.	56.4 ft.	17.2 m.
200 Hz	5 msec.	5.5 ft.	1.72 m.
2 kHz	0.5 msec.	6.67 in.	17.2 cm.

Frequency vs. Period and Wavelength:

Lower frequencies have longer wavelengths and periods.
Higher frequencies have shorter wavelengths and periods.

Frequency	Period	Wavelength	
20 Hz	50 msec.	56.4 ft.	17.2 m.
200 Hz	5 msec.	5.5 ft.	1.72 m.
2 kHz	0.5 msec.	6.67 in.	17.2 cm.
20 kHz	0.05 msec.	0.67 in.	17.2 mm.

Sound Pressure:

Sound Pressure:

Source	Sound Pressure (μPascals)	Distance

Sound Pressure:

Source	Sound Pressure (μPascals)	Distance
Threshold of Hearing	20	0.0 mm.

Sound Pressure:

Source	Sound Pressure (µPascals)	Distance
Threshold of Hearing	20	0.0 mm.
Sound Stage	200	1.0 mm.

Sound Pressure:

Source	Sound Pressure (μPascals)	Distance
Threshold of Hearing	20	0.0 mm.
Sound Stage	200	1.0 mm.
Cinema Audience	2,000	10.0 mm.

Sound Pressure:

Source	Sound Pressure (µPascals)	Distance
Threshold of Hearing	20	0.0 mm.
Sound Stage	200	1.0 mm.
Cinema Audience	2,000	10.0 mm.
Conversation	20,000	10.0 cm.

Sound Pressure:

Source	Sound Pressure (μPascals)	Distance
Threshold of Hearing	20	0.0 mm.
Sound Stage	200	1.0 mm.
Cinema Audience	2,000	10.0 mm.
Conversation	20,000	10.0 cm.
Noisy Factory	200,000	1.0 m.

Sound Pressure:

Source	Sound Pressure (μPascals)	Distance
Threshold of Hearing	20	0.0 mm.
Sound Stage	200	1.0 mm.
Cinema Audience	2,000	10.0 mm.
Conversation	20,000	10.0 cm.
Noisy Factory	200,000	1.0 m.
Niagara Falls	2,000,000	10.0 m.

Sound Pressure:

Source	Sound Pressure (μPascals)	Distance
Threshold of Hearing	20	0.0 mm.
Sound Stage	200	1.0 mm.
Cinema Audience	2,000	10.0 mm.
Conversation	20,000	10.0 cm.
Noisy Factory	200,000	1.0 m.
Niagara Falls	2,000,000	10.0 m.
Threshold of Pain	20,000,000	100.0 m.

Sound Pressure:

Let’s use a logarithmic scale to represent relative intensities.

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Let’s use a logarithmic scale to represent relative intensities.

Each increase of 10 times in intensity is represented by an increase of 20 decibels (dB) in Sound Pressure Level (SPL).

Sound Pressure:

Source	Sound Pressure (µPascals)	dB-SPL
Threshold of Hearing	20	
Sound Stage	200	
Cinema Audience	2,000	
Conversation	20,000	
Noisy Factory	200,000	
Niagara Falls	2,000,000	
Threshold of Pain	20,000,000	

Sound Pressure:

Source	Sound Pressure (µPascals)	dB-SPL
Threshold of Hearing	20	0
Sound Stage	200	
Cinema Audience	2,000	
Conversation	20,000	
Noisy Factory	200,000	
Niagara Falls	2,000,000	
Threshold of Pain	20,000,000	

Sound Pressure:

Source	Sound Pressure (μPascals)	dB-SPL
Threshold of Hearing	20	0
Sound Stage	200	20
Cinema Audience	2,000	
Conversation	20,000	
Noisy Factory	200,000	
Niagara Falls	2,000,000	
Threshold of Pain	20,000,000	

Sound Pressure:

Source	Sound Pressure (μPascals)	dB-SPL
Threshold of Hearing	20	0
Sound Stage	200	20
Cinema Audience	2,000	40
Conversation	20,000	
Noisy Factory	200,000	
Niagara Falls	2,000,000	
Threshold of Pain	20,000,000	

Sound Pressure:

Source	Sound Pressure (μPascals)	dB-SPL
Threshold of Hearing	20	0
Sound Stage	200	20
Cinema Audience	2,000	40
Conversation	20,000	60
Noisy Factory	200,000	
Niagara Falls	2,000,000	
Threshold of Pain	20,000,000	

Sound Pressure:

Source	Sound Pressure (μPascals)	dB-SPL
Threshold of Hearing	20	0
Sound Stage	200	20
Cinema Audience	2,000	40
Conversation	20,000	60
Noisy Factory	200,000	80
Niagara Falls	2,000,000	
Threshold of Pain	20,000,000	

Sound Pressure:

Source	Sound Pressure (µPascals)	dB-SPL
Threshold of Hearing	20	0
Sound Stage	200	20
Cinema Audience	2,000	40
Conversation	20,000	60
Noisy Factory	200,000	80
Niagara Falls	2,000,000	100
Threshold of Pain	20,000,000	

Sound Pressure:

Source	Sound Pressure (μPascals)	dB-SPL
Threshold of Hearing	20	0
Sound Stage	200	20
Cinema Audience	2,000	40
Conversation	20,000	60
Noisy Factory	200,000	80
Niagara Falls	2,000,000	100
Threshold of Pain	20,000,000	120

Range of Human Hearing:

Amplitude		Frequency	
Low	High	Low	High
20 µPascals	20 Pascals	20 Hz	20 kHz
1,000,000:1		1000:1	

Range of Human Hearing:

Amplitude		Frequency	
Low	High	Low	High
20 µPascals	20 Pascals	20 Hz	20 kHz
1,000,000:1		1000:1	
120 dB-SPL		>10 octaves	

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- 10 dB is perceived as doubling or halving.