Section 3

ACOUSTICS

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CONTENTS

3a. Acoustical Definitions[1]

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3a-1. General

Acceleration. Acceleration is a vector that specifies the time rate of change of velocity.

Acoustic, acoustical. The qualifying adjectives "acoustic" and "acoustical" mean containing, producing, arising from, actuated by, related to, or associated with sound. *Acoustic* is used when the term being qualified designates something that has the properties, dimensions, or physical characteristics associated with sound waves; *acoustical* is used when the term being qualified does not designate explicitly something that has such properties, dimensions, or physical characteristics. Usually the generic term is modified by *acoustical*, whereas the specific technical implication calls for *acoustic*.

Acoustics. (1) Acoustics is the science of sound, including its production, transmission, and effects. (2) The acoustics of a room are those qualities that together determine its character with respect to distinct hearing.

Ambient Noise. Ambient noise is the all-encompassing noise associated with a given environment, being usually a composite of sounds from many sources near and far.

Anechoic Space or Room. An anechoic space or room is one whose boundaries absorb effectively all the sound incident thereon, thereby affording essentially free-field conditions.

Audio Frequency. An audio frequency is any frequency corresponding to a normally audible sound wave.

Note 1: Audio frequencies range roughly from 15 to 20,000 Hz.
Note 2: The word "audio" can be used as a modifier to indicate a device or system intended to operate at audio frequencies, e.g., "audio amplifier."

Background Noise. Background noise is the total of all sources of interference in a system used for the production, detection, measurement, or recording of a signal, independent of the presence of the signal.

Note 1: Ambient noise detected, measured, or recorded with the signal becomes part of the background noise.
Note 2: Included in this definition is the interferenc resulting from primary power supplies, that separately is commonly described as *hum*.

Beats. Beats are periodic variations that result from the superposition of two simple harmonic quantities of different frequencies f_1 and f_2. They involve the periodic increase and decrease of amplitude at the *beat frequency* $(f_1 - f_2)$.

[1] From "American National Standard Acoustical Terminology" (including Mechanical Shock and Vibration), S1.1—American National Standards Institute. 1430 Broadway, New York, N.Y., 1960.

Continuous Spectrum. A continuous spectrum is the spectrum of a wave the components of which are continuously distributed over a frequency region.

Damping. Damping is the dissipation of energy with time or distance.

Decay, Rate of. The rate of decay is the time rate at which the sound pressure level (or other stated characteristic) decreases at a given point and at a given time. A commonly used unit is the decibel per second.

Echo. An echo is a wave that has been reflected or otherwise returned with sufficient magnitude and delay to be detected as a wave distinct from that directly transmitted.

Efficiency. The efficiency of a device with respect to a physical quantity which may be stored, transferred, or transformed by the device is the ratio of the useful output of the quantity to its total input.

Note: Unless specifically stated otherwise, the term "efficiency" means efficiency with respect to power.

Harmonic. A harmonic is a sinusoidal quantity having a frequency that is an integral multiple of the frequency of a periodic quantity to which it is related.

Infrasonic Frequency (Subsonic Frequency). An infrasonic frequency is a frequency lying below the audio-frequency range.

Note 1: The word "infrasonic" can be used as a modifier to indicate a device or system intended to operate at an infrasonic frequency.

Note 2: The term "subsonic" was once used in acoustics synonymously with infrasonic; such usage is now deprecated.

Jerk. Jerk is a vector that specifies the time rate of change of the acceleration; jerk is the third derivative of the displacement with respect to time.

Line Spectrum. A line spectrum is a spectrum whose components occur at a number of discrete frequencies.

Microbar, Dyne per Square Centimeter. A microbar is a unit of pressure commonly used in acoustics. One microbar is equal to one dyne per square centimeter.

Note: The term "bar" properly denotes a pressure of 10^6 dynes/cm^2.

Molecular Relaxation. Molecular relaxation is the equalization of energy among the degrees of freedom of a molecule following a disturbance that produces deviations from the equilibrium distribution law.

Noise. (1) Noise is any undesired sound. By extension, noise is any unwanted disturbance within a useful frequency band, such as undesired electric waves in a transmission channel or device. (2) Noise is an erratic, intermittent, or statistically random oscillation.

Note 1: If ambiguity exists as to the nature of the noise, a phrase such as "acoustic noise" or "electric noise" should be used.

Note 2: Since the above definitions are not mutually exclusive, it is usually necessary to depend upon context for the distinction.

Particle Velocity, Effective (Root-mean-square Particle Velocity). The effective particle velocity at a point is the root-mean-square value of the instantaneous particle velocities over a time interval at the point under consideration. For periodic particle velocities, the interval must be an integral number of periods or an interval that is long compared with a period. For nonperiodic particle velocities, the interval should be long enough to make the value obtained essentially independent of small changes in the length of the interval.

Power Spectral Density. Power spectral density of a function $X(t)$ is defined by the transform

$$S(\omega) = \frac{1}{2\pi} \int_{-\infty}^{\infty} R(\tau) e^{-i\omega\tau} \, d\tau$$

where $R(\tau)$ is the autocorrelation function of $X(t)$. $S(\omega)$ is proportional to the mean-square spectrum density as follows:

$$W(f) = 4\pi S(\omega) \qquad \omega = 2\pi f$$

where $W(f)$ is the *spectrum density.*

Note 1: The factor 4π arises from the difference in frequency units (2π) and the fact that both positive and negative frequencies are allowed for $S(\omega)$, which is an even function.

Note 2: Power spectral density is used in the field of random vibrations for every class of physical quantity, including displacement, velocity, pressure, and acceleration.

Radiation Pressure, Acoustic. The acoustic radiation pressure is a unidirectional, steady-state pressure exerted upon a surface exposed to an acoustic wave.

Random Noise. Random noise is an oscillation whose instantaneous magnitude is not specified for any given instant of time. The instantaneous magnitudes of a random noise are specified only by probability distribution functions giving the fraction of the total time that the magnitude, or some sequence of magnitudes, lies within a specified range.

Note: A random noise whose instantaneous magnitudes occur according to a "normal" or "gaussian" distribution is called "gaussian random noise."

Response. The response of a device or system is the motion (or other output) resulting from an excitation (stimulus) under specified conditions.

Note 1: Modifying phrases must be prefixed to the term response to indicate what kinds of input and output are being utilized.

Note 2: The response characteristic, often presented graphically, gives the response as a function of some independent variable such as frequency or direction. For such purposes it is customary to assume that other characteristics of the input (for example, voltage) are held constant.

Reverberation. (1) Reverberation is the persistence of sound in an enclosed space as a result of multiple reflections after the sound source has stopped. (2) Reverberation is the sound that persists in an enclosed space as a result of repeated reflection or scattering after the source of the sound has stopped.

Note: The repeated reflections of residual sound in an enclosure can alternatively be described in terms of the transient behavior of the modes of vibration of the medium bounded by the enclosure.

Sound Absorption. Sound absorption is the change of sound energy into some other form, usually heat, in passing through a medium or on striking a surface.

Sound Energy. The sound energy of a given part of a medium is the total energy in this part of the medium minus the energy which would exist in the same part of the medium with no sound waves present.

Sound-energy Density. The sound-energy density at a point in a sound field is the sound energy contained in a given infinitesimal part of the medium divided by the volume of that part of the medium.

Note 1: The terms "instantaneous energy density," "maximum energy density," and "peak energy density" have meanings analogous to the related terms used for sound pressure.

Note 2: In speaking of average energy density in general it is necessary to distinguish between the space average (at a given instant) and the time average (at a given point).

Note 3: In a plane wave at a point and in a standing-wave field, averaged in space over a distance in excess of the longest wavelength, the sound-energy density is

$$D = \frac{p^2}{\rho_0 c^2} = \frac{p^2}{\gamma P_0}$$

where γ is the ratio of specific heats for the gas and is equal to 1.4 for air and other diatomic gases and P_0 is the barometric pressure.

Sound Intensity (*Sound-energy Flux Density, Sound-power Density*). The sound intensity in a specified direction at a point is the average rate of sound energy transmitted in the specified direction through a unit area normal to this direction at the point considered.

Note 1: The sound intensity in any specified direction a of a sound field is the sound-energy flux through a unit area normal to that direction. This is given by the expression

$$I_a = \frac{1}{T}\int_0^T pv_a \, dt$$

where T = integral number of periods or time long compared with period
p = instantaneous sound pressure
v_a = component of instantaneous particle velocity in direction a
t = time

Note 2: In the case of a free plane or spherical wave having the effective sound pressure p, the speed of propagation c, in a medium of density ρ, the intensity in the direction of propagation is given by

$$I = \frac{p^2}{\rho c}$$

Sound Power of a Source. The sound power of a source is the total sound energy radiated by the source per unit of time.

Sound Pressure, Effective (*Root-mean-square Sound Pressure*). The effective sound pressure at a point is the root-mean-square value of the instantaneous sound pressures over a time interval at the point under consideration. For periodic sound pressures, the interval must be an integral number of periods or an interval that is long compared with a period. For nonperiodic sound pressures, the interval should be long enough to make the value obtained essentially independent of small changes in the length of the interval.

Note: The term "effective sound pressure" is frequently shortened to "sound pressure."

Spectrum. (1) The spectrum of a function of time is a description of its resolution into components, each of different frequency and (usually) different amplitude and phase. (2) "Spectrum" is also used to signify a continuous range of components, usually wide in extent, within which waves have some specified common characteristic, e.g., "audio-frequency spectrum."

Note: The term "spectrum" is also applied to functions of variables other than time, such as distance.

Spectrum (*Spectral*) *Density.* The spectrum density of a field quantity is the mean-square output of an ideal filter per unit bandwidth, in the limit as the bandwidth approaches zero.

Note: Examples of quantities often so used are sound pressure, voltage, and acceleration.

Speed of Sound. The speed of sound is the rate at which a sound wave travels through a medium.

Static Pressure. The static pressure P_0 at a point in the medium is the pressure that would exist at that point with no sound waves present. At normal barometric pressure, P_0 equals approximately 10^5 newtons/m^2 (10^6 dynes/cm^2). This corresponds to a barometer reading of 0.751 m (29.6 in.) Hg (mercury) when the temperature of the mercury is 0°C. Standard atmospheric pressure is usually taken to be 0.760 m Hg at 0°C.

Strength of a Simple Sound Source. (1) The strength of a simple sound source is the maximum instantaneous rate of volume displacement produced by the source when emitting a wave with sinusoidal time variation. The unit is volume per second. (2) The strength of a simple sound source is the rms magnitude of the rate of volume displacement produced by the source when emitting a wave with sinusoidal time variation. The unit is volume per second.

Note 1: The user should specify (1) or (2) above.
Note 2: A simple sound source is one whose dimensions are small with respect to the wavelength.

Subharmonic. A subharmonic is a sinusoidal quantity having a frequency that is an integral submultiple of the fundamental frequency of a periodic quantity to which it is related.

Ultrasonic Frequency. An ultrasonic frequency is a frequency lying above the audio-frequency range. The term is commonly applied to elastic waves propagated in gases, liquids, or solids.

Note 1: The term "ultrasonic" can be used as a modifier to indicate a device or system intended to operate at an ultrasonic frequency.
Note 2: "Supersonic" was a term once used in acoustics synonymously with ultrasonic; such usage is now deprecated.

Velocity. Velocity is a vector that specifies the time rate of change of displacement with respect to a reference frame.

Note: If the reference frame is not inertial, the velocity is often designated "relative velocity."

Vibration. Vibration is an oscillation wherein the quantity is a parameter that defines the motion of a mechanical system.

Volume Velocity. Volume velocity is the rate of alternating flow of the medium through a specified surface due to a sound wave.

Note: Expressed mathematically the volume velocity V is

$$V = \int_S v \, d\sigma$$

where v is the component of particle velocity normal to the element of surface $d\sigma$. The integration is performed over surface S through which the medium is oscillating.

Wave. A wave is a disturbance which is propagated in a medium in such a manner that at any point in the medium the quantity serving as measure of disturbance is a function of the time while at any instant the displacement at a point is a function of the position of the point.

Any physical quantity that has the same relationship to some independent variable (usually time) that a propagated disturbance has, at a particular instant, with respect to space may be called a wave.

Wavelength. The wavelength of a periodic wave in an isotropic medium is the perpendicular distance between two wavefronts in which the displacements have a difference in phase of one complete period.

Wave Velocity (Velocity of Propagation). The velocity of propagation is a vector quantity that specifies the speed and direction with which a sound wave travels through a medium.

White Noise. White noise is a noise whose spectrum density (or spectrum level) is substantially independent of frequency over a specified range.

Note: White noise need not be random.

3a-2. Levels

Band Power Level. The band power level of a sound for a specified frequency band is the sound power level for the sound contained within the restricted band.

Band Pressure Level. The band pressure level of a sound for a specified frequency band is the sound pressure level for the sound contained within the restricted band. The reference pressure must be specified.

Note: The band may be specified by its lower and upper cutoff frequencies, or by its geometric center frequency and bandwidth. The width of the band may be indicated by a prefatory modifier; e.g., octave band (sound pressure) level, half-octave band level, third-octave band level, 50-Hz band level.

Decibel. The decibel is one tenth of a bel. Thus, the decibel is a unit of level when the base of the logarithm is the tenth root of 10, and the quantities concerned are proportional to power.

Note 1: Examples of quantities that qualify are power (any form), sound pressure squared, particle velocity squared, sound intensity, sound-energy density, voltage squared. Thus the decibel is a unit of sound-pressure-squared level; it is common practice, however, to shorten this to sound pressure level because ordinarily no ambiguity results from so doing.

Note 2: The logarithm to the base the tenth root of 10 is the same as ten times the logarithm to the base 10: e.g., for a number X^2, $\log_{10^{1/10}} X^2 = 10 \log_{10} X^2 = 20 \log_{10} X$. This last relationship is the one ordinarily used to simplify the language in definition of sound pressure level, etc.

Intensity Level (Sound-energy Flux Density Level). The intensity level, in decibels, of a sound is ten times the logarithm to the base 10 of the ratio of the intensity of this sound to the reference intensity. The reference intensity shall be stated explicitly.

Note 1: A common reference sound intensity is 10^{-16} watt/cm² in a specified direction.

Note 2: In a free progressive plane or spherical wave there is a known relation between sound intensity and sound pressure, so that sound intensity level can be deduced from a measurement of sound pressure level. In general, however, there is no simple relation between the two, and a measurement of sound pressure level should not be reported as one of intensity level.

Level. In acoustics, the level of a quantity is the logarithm of the ratio of that quantity to a reference quantity of the same kind. The base of the logarithm, the reference quantity, and the *kind* of level must be specified.

Note 1: Examples of kinds of levels in common use are electric power level, sound-pressure-squared level, voltage-squared level.

Note 2: The level as here defined is measured in units of the logarithm of a reference ratio. Also, a factor like 10 or 20 often precedes the logarithm to appropriately expand the scale; e.g., see Sound Pressure Level and Sound Power Level.

Note 3: In symbols,

$$L = \log_r \frac{q}{q_0}$$

where L = level of kind determined by the kind of quantity under consideration, measured in units of $\log_r r$

r = base of logarithms and the reference ratio

q = the quantity under consideration

q_0 = reference quantity of the same kind

Note 4: Differences in the levels of two like quantities q_1 and q_2 are described by the same formula because, by the rules of logarithms, the reference quantity is automatically divided out:

$$\log_r \frac{q_1}{q_0} - \log_r \frac{q_2}{q_0} = \log_r \frac{q_1}{q_2}$$

Neper. The neper is a unit of level when the logarithm is on the napierian base e. Use of the neper is restricted to levels of quantities analogous to electric current.

Note 1: Examples of quantities that qualify are voltage, current, particle velocity, sound pressure.
Note 2: One neper is equal to 8.686 dB.

Noise Level. (1) Noise level is the level of noise, the type of which must be indicated by further modifier or context.

Note: The physical quantity measured (e.g., voltage), the reference quantity, the instrument used, and the bandwidth or other weighting characteristic must be indicated.

(2) For airborne sound, unless specified to the contrary, noise level is the weighted sound pressure level called sound level; the weighting must be indicated.

Peak Level. The peak level is the maximum instantaneous level that occurs during a specified time interval. In acoustics, peak sound pressure level is to be understood, unless some other kind of level is specified.

Sound Level. Sound level is a weighted sound pressure level obtained by the use of metering characteristics and the weightings *A*, *B*, and *C* specified in Standard Specifications for Sound Level Meters, ANSI S1.4—1971 (revision of S1.4—1961). The weighting employed must always be stated. The reference pressure is 0.0002 microbar.

Note: A suitable method of statin the weight ng is, for example, "The *A*-sound level was 43 dB."

Sound Power Level. The sound power level in decibels is ten times the logarithm to the base 10 of the ratio of a given power to a reference power.

Note 1: The internationally standardized reference power is 10^{-12} watt.
Note 2: In engineering acoustics in the United States, the reference power formerly was 10^{-13} watt, because sound pressure level approximately equals the sound power level (reference 10^{-13} watt) minus ten times the logarithm to the base 10 of the area through which the total sound power passes, when the area is expressed in square feet.

Sound Pressure Level. The sound pressure level, in decibels, of a sound is 20 times the logarithm to the base 10 of the ratio of the pressure of this sound to the reference pressure. The reference pressure shall be explicitly stated.

Note 1: The following reference pres ures ar in common use:
a. 2×10^{-4} microbar
b. 1 microbar
Reference pressure *a* is in general use for mea urements concerned with hearing and with sound in air and liquids, while *b* has gained widespread acceptance for calibration of transducers and various kinds of sound measurements in liquids.
Note 2: Unless otherwise explicitly stated, it is to be understood that the sound pressure is the effective (rms) sound pressure.
Note 3: It is to be noted that in many sound fields the sound pressure ratios are not the square roots of the corresponding power ratios.

Spectrum Density Level (*Spectrum Level*). The spectrum density level of a specified signal at a particular frequency is equal to ten times the logarithm to the base 10 of the *spectrum density*. Ordinarily, this has significance only for a signal having a continuous distribution of components within the frequency range under consideration. The words "spectrum density level" cannot be used alone but must appear in combination with a prefatory modifier; e.g., pressure, velocity, voltage.

Note: For illustr t on, if L_{ps} be a desired pressure spectrum density level, p the effective pressure measured through the filter system, p_0 reference sound pressure, Δf the effective bandwidth of the filter system and $\Delta_0 f$ the reference bandwidth (1 Hz), then

$$L_{ps} = 10 \log_{10} \frac{p^2/\Delta f}{p_0^2/\Delta_0 f}$$

For computational purposes, if L_p is the band pressure level observed through the lter, the above relation re uces to

$$L_{ps} = L_p - 10 \log_{10} \frac{\Delta f}{\Delta_0 f}$$

Velocity Level. The velocity level, in decibels, of a sound is 20 times the logarithm to the base 10 of the ratio of the particle velocity of the sound to the reference particle velocity. The reference particle velocity shall be stated explicitly.

3a-3. Oscillation, Vibration, and Shock

Antiresonance. For a system in forced oscillation, antiresonance exists at a point when any change, however small, in the frequency of excitation causes an increase in the response at this point.

Coulomb Damping (Dry Friction Damping). Coulomb damping is the dissipation of energy that occurs when a particle in a vibrating system is resisted by a force whose magnitude is a constant independent of displacement and velocity, and whose direction is opposite to the direction of the velocity of the particle.

Critical Damping. Critical damping is the minimum viscous damping that will allow a displaced system to return to its initial position without oscillation.

Degrees of Freedom. The number of degrees of freedom of a mechanical system is equal to the minimum number of independent generalized coordinates required to define completely the positions of all parts of the system at any instant of time. In general, it is equal to the number of independent generalized displacements that are possible.

Dynamic Vibration Absorber (Tuned Damper). A tuned damper is a device for reducing vibration of a primary system by the transfer of energy to an auxiliary resonant system which is tuned to the frequency of the vibration. The force exerted by the auxiliary system is opposite in phase to the force acting on the primary system.

Forced Oscillation (Forced Vibration). The oscillation of a system is forced if the response is imposed by the excitation. If the excitation is periodic and continuing, the oscillation is steady state.

Free Vibration. Free oscillation of a system is oscillation that occurs in the absence of forced oscillation.

Fundamental Frequency. (1) The fundamental frequency of a periodic quantity is the frequency of a sinusoidal quantity which has the same period as the periodic quantity. (2) The fundamental frequency of an oscillating system is the lowest natural frequency. The normal mode of vibration associated with this frequency is known as the fundamental mode.

Impact. An impact is a single collision of one mass in motion with a second mass which may be either in motion or at rest.

Impulse. Impulse is the product of a force and the time during which the force is applied; more specifically, the impulse is $\int_{t_1}^{t_2} F\,dt$ where the force F is time-dependent and equal to zero before time t_1 and after time t_2.

Isolation. Isolation is a reduction in the capacity of a system to respond to an excitation attained by the use of a resilient support. In steady-state forced vibration, isolation is expressed quantitatively as the complement of transmissibility.

Mechanical Shock. Mechanical shock occurs when the position of a system is significantly changed in a relatively short time in a nonperiodic manner. It is characterized by suddenness and large displacements, and develops significant internal forces in the system.

Natural Frequency. Natural frequency is the frequency of free oscillation of a system. For a multiple-degree-of-freedom system, the natural frequencies are the frequencies of the normal modes of vibration.

Normal Mode of Vibration. A normal mode of vibration is a mode of free vibration of an undamped system. In general, any composite motion of the system is analyzable into a summation of its normal modes.

Note 1: The characteristic pattern of motion typically consists of a space distribution one part of which is negative in relation to the other part. Thus, at the same time that the particles in one part are moving outward in the positive direction from their positions of equilibrium, the particles in the other part are moving outward in the negative direction, and conversely.

Note 2: Vibration in a no mal mode occurs at a natural frequency of the undamped system.

Note 3: The terms "natural mode," "characteristic mode," and "eigen mode" are synonymous with normal mode.

Pulse Rise Time. The pulse rise time is the interval of time required for the leading edge of a pulse to rise from some specified small fraction to some specified larger fraction of the maximum value.

Q (Quality Factor). The quantity Q is a measure of the sharpness of resonance or frequency selectivity of a resonant vibratory system having a single degree of freedom, either mechanical or electrical.

Note 1: In a mechanical system, this quantity is equal to one-ha f the reciprocal of the damping ratio. It is commonly used only with reference to a lightly damped system, and is then approximately equal to the foll wing:

(1) Transmissibility at resonance
(2) π/δ, where δ is the logarithmic decrement
(3) $2\pi W/\Delta W$, where W is the stored energy, and ΔW the energy dissipation per cycle
(4) $f_r/\Delta f$, where f_r is the resonance freq ency, and Δf is the bandwidth between the half-power points

Note 2: Historically the letter Q was an arbitrarily chosen symbol to designate the ratio of reactance to resistance of a circuit element. The name "quality fa tor" was introduced later.

Resonance. Resonance of a system in forced oscillation exists when any change, however small, in the frequency of excitation causes a decrease in the response of the system.

Note: Velocity resonance, for example, may occur at a frequenc different from that of displacement resonance; see Tab e 3a-1.

Resonance Frequency (Resonant Frequency). A resonance frequency is a frequency at which resonance exists.

Note 1: In case of possible confusion the type of resonance must be indicated, e.g., velocity resonance frequency.

Note 2: See Table 3a-1.

Self-induced (Self-excited) Vibration. The vibration of a mechanical system is self-induced if it results from conversion, within the system, of nonoscillatory excitation to oscillatory excitation.

Shock Spectrum. A shock spectrum is a plot of the maximum acceleration experienced by a single-degree-of-freedom system, as a function of the natural frequency of that system, in response to an applied shock.

Transmissibility. Transmissibility is the nondimensional ratio of the response amplitude of a system in steady-state forced vibration to the excitation amplitude. The ratio may be one of forces, displacements, velocities, or accelerations.

Velocity Shock. Velocity shock is a mechanical shock resulting from a nonoscillatory change in velocity of an entire system.

Vibration Isolator. A vibration isolator is a resilient support that tends to isolate a system from steady-state excitation.

TABLE 3a-1. RESONANCE RELATIONS

In the case of a system whose motion can be described by the equation

$$M\frac{d^2x}{dt^2} + R\frac{dx}{dt} + Kx = A\cos\omega t$$

the characteristics of the different kinds of resonance in terms of the constants of the above equation are as follows:

	At velocity resonance	At displacement resonance	Damped natural frequency
Frequency	$\frac{1}{2\pi}\sqrt{\frac{K}{M}}$	$\frac{1}{2\pi}\sqrt{\frac{K}{M}-\frac{R^2}{2M^2}}$	$\frac{1}{2\pi}\sqrt{\frac{K}{M}-\frac{R^2}{4M^2}}$
Amplitude of displacement	$\frac{A}{R\sqrt{\frac{K}{M}}}$	$\frac{A}{R\sqrt{\frac{K}{M}-\frac{R^2}{4M^2}}}$	$\frac{A}{R\sqrt{\frac{K}{M}-\frac{3R^2}{16M^2}}}$
Amplitude of velocity	$\frac{A}{R}$	$\frac{A}{R\sqrt{1+\frac{R^2}{4MK-2R^2}}}$	$\frac{A}{R\sqrt{1+\frac{R^2}{16MK-4R^2}}}$
Phase of displacement with reference to applied force	$\frac{\pi}{2}$	$\tan^{-1}\sqrt{\frac{4MK}{R^2}-2}$	$\tan^{-1}\sqrt{\frac{16MK}{R^2}-4}$

For values of R, small compared with $\sqrt{KM}$, there is little difference between the three cases discussed above. The frequency at velocity resonance is equal to the undamped natural frequency of the system. Other symbols are also employed depending upon the quantity represented by x; for example, c is frequently used instead of R.

Viscous Damping. Viscous damping is the dissipation of energy that occurs when a particle in a vibrating system is resisted by a force that has a magnitude proportional to the magnitude of the velocity of the particle and direction opposite to the direction of the particle velocity.

3a-4. Sound Transmission and Propagation

Absorption Loss. Absorption loss is that part of the transmission loss due to the dissipation or conversion of sound energy into other forms of energy (e.g., heat), either within the medium or attendant upon a reflection.

Acoustic Attenuation Constant. The acoustic attenuation constant is the real part of the acoustic propagation constant. The commonly used unit is the neper per section or per unit distance.

Acoustic Dispersion. Acoustic dispersion is the change of speed of sound with frequency.

Acoustic Phase Constant. The acoustic phase constant is the imaginary part of the acoustic propagation constant. The commonly used unit is the radian per section or per unit distance.

Acoustic Propagation Constant. The acoustic propagation constant of a uniform system or of a section of a system of recurrent structures is the natural logarithm of the complex ratio of the steady-state particle velocity, volume velocities, or pressures at two points separated by unit distance in the uniform system (assumed to be of infinite length), or at two successive corresponding points in the system of recurrent structures (assumed to be of infinite length). The ratio is determined by dividing the value at the point nearer the transmitting end by the corresponding value at the more remote point.

Acoustic Refraction. Acoustic refraction is the process by which the direction of sound propagation is changed due to spatial variation in the speed of sound in the medium.

Acoustic Scattering. Acoustic scattering is the irregular reflection, refraction, or diffraction of a sound in many directions.

Antinode (Loop). An antinode is a point, line, or surface in a standing wave where some characteristic of the wave field has maximum amplitude.

Note: The appropriate modifier should be used before the word "antinode" to signify the type that is intended, e.g., displacement antinode, velocity antinode, pressure antinode.

Backscattering Cross Section. The acoustic backscattering cross section of an object is an area equal to 4π times the product of the square of a unit distance and the square of the sound pressure scattered by the object, back in the direction from which the sound has come as observed at unit distance from the acoustic center of the object, divided by the square of the sound pressure of the plane wave incident on the object. The unit of the cross section is the square of the unit distance.

Note 1: In symbols, if σ_b is the backscattering cross section, p_{sb}^2 is the square of the backscattered sound pressure, r_0 the unit distance and p_i^2 the square of the incident sound pressure,

$$\sigma_b = \frac{4\pi p_{sb}^2 r_0^2}{p_i^2}$$

Note 2: The scattering cross section for any other direction is similarly defined; the direction must be specified.

Compressional Wave. A compressional wave is a wave in an elastic medium which causes an element of the medium to change its volume without undergoing rotation.

Note 1: Mathematically, the velocity field of a compressional wave has zero curl.
Note 2: A compressional plane wave is a longitudinal wave.

Diffraction. Diffraction is that process that produces a diffracted wave.

Diffracted Wave. A diffracted wave is one whose front has been changed in direction by an obstacle or other inhomogeneity in a medium, otherwise than by reflection or refraction.

Divergence Loss. Divergence loss is that part of the transmission loss due to the divergence on spreading of the sound rays in accordance with the geometry of the system (e.g., spherical waves emitted by a point source).

Doppler Effect. The Doppler effect is the phenomenon evidenced by the change in the observed frequency of a wave in a transmission system caused by a time rate of change in the effective length of the path of travel between the source and the point of observation.

Note: The effect is described quantitatively by

$$f_r = \frac{1 + v_r/c}{1 - v_s/c} f_s$$

where f_r = observed frequency
f_s = frequency at source
v_r = component of velocity (relative to the medium) of observation point toward source
v_s = component of velocity (relative to the medium) of source toward observation point
c = speed of sound in a stationary medium

Insertion Loss. The insertion loss, in decibels, resulting from insertion of a transducer in a transmission system is ten times the logarithm to the base 10 of the ratio of the power delivered to that part of the system that will follow the transducer, before the insertion of the transducer, to the power delivered to that same part of the system after insertion of the transducer.

Note: If the input power or the output power or both consist of more than one component, the particular component must be specified

Longitudinal Wave. A longitudinal wave is a wave in which the direction of displacement at each point of the medium is normal to the wavefront.

Node. A node is a point, line, or surface in a standing wave where some characteristic of the wave field has essentially zero amplitude.

Note: The appropriate modifier should be used before the wo d "node" to signify the type that is intended, e.g., displacement node, velocity node, pressure node.

Partial Node. A partial node is the point, line, or surface in a standing wave system where some characteristic of the wave field has a minimum amplitude differing from zero.

Note: The appropriate modifier should be used wi h the words "partial node" to signify the type that is intended; e.g., displacement partial node, velocity partial node, pressure partial node.

Plane Wave. A plane wave is a wave in which the wavefronts are everywhere parallel planes normal to the direction of propagation.

Rayleigh Wave. A Rayleigh wave is a surface wave associated with the free boundary of a solid, such that a surface particle describes an ellipse whose major axis is normal to the surface, and whose center is at the undisturbed surface. At maximum particle displacement away from the solid surface the motion of the particle is opposite to that of the wave.

Note: The propagation velocity of a Rayleigh wave is slightly less than that of a shear wave in the solid; the wave amplitude o: the Rayleigh wave diminishes exponentially with depth.

Refraction. Acoustic refraction is the process by which the direction of sound propagation is changed because of spatial variation in the speed of sound in the medium.

Refraction Loss. Refraction loss is that part of the transmission loss due to refraction resulting from nonuniformity of the medium.

Refracted Wave. A refracted wave is one whose front has been changed in direction owing to refraction.

Scattering Cross Section. The acoustic scattering cross section of an object is an area equal to 4π times the product of the mean-square sound pressure scattered by the object, averaged over a sphere of unit radius surrounding the object, and the square of the unit radius, divided by the square of the sound pressure of the plane wave incident upon the object. The unit of the cross section is the square of the unit radius.

Note 1: In symbols, if σ is the scattering cross section, p_s^2 the average mean-square scattered sound pressure, r_0 the unit radius, and p_i^2 the square of the incident sound pressure,

$$\sigma = \frac{4\pi p_s^2 r_0^2}{p_i^2}$$

Note 2: Actual measurements must be made at a distance sufficiently great that the sound appears to be scattering from a single point called the acoustic center.

Scattering Differential. The scattering differential is the amount by which the level of the scattered mean-square sound pressure averaged over all directions at a specified unit distance from the effective acoustic center of the object exceeds the plane-wave free-field pressure level of the sound incident upon the object. The scattering differential of an object is ten times the logarithm to the base 10 of the ratio of the scattering cross section to the area of the sphere of unit radius surrounding the object.

Note 1: In symbols, if Δ is the scattering differential, and the other symbols are those of *scattering cross section*:

$$\Delta = 10 \log \frac{\sigma}{4\pi r_0^2} = 10 \log \frac{p_s^2}{p_i^2}$$

Scattering Loss. Scattering loss is that part of the transmission loss due to scattering within the medium or due to roughness of the reflecting surface.

Shear Wave (Rotational Wave). A shear wave is a wave in an elastic medium which causes an element of the medium to change its shape without a change of volume.

Note 1: Mathematically, the velocity field of a shear wave has zero divergence.
Note : A plane shear wave in an isotropic medium is a transverse wave.

Sound Field, Free (Free Field). A free sound field is a field in a homogeneous, isotropic medium free from boundaries. In practice it is a field in which the effects of the boundaries are negligible over the region of interest.

Note: The actual pressure impinging on an object (e.g., electroacoustic transducer) placed in an otherwise free sound field will differ from the pressure which would exist at that point with the object removed unless the acoustic impedance of the object matches the acoustic impedance of the medium.

Standing Wave. A standing wave is a periodic wave having a fixed distribution in space which is the result of interference of progressive waves of the same frequency and kind. Such waves are characterized by the existence of nodes or partial nodes and antinodes that are fixed in space.

Stationary Wave. A stationary wave is a standing wave in which the net energy flux is zero at all points.

Note: Stationary waves can be only approximated in practice.

Streaming (Acoustic). Acoustic streaming is the name given to unidirectional flow currents in a fluid that are due to the presence of acoustic waves.

Transmission Loss. Transmission loss is the reduction in the magnitude of some characteristic of a signal between two stated points in a transmission system.

Note 1: The characteristic is often some kind of level, such as power level or voltage level. In acoustics the characteristic that is commonly measured is sound pressure level. Thus, if the levels are expressed in decibels, the transmission-level loss is likewise in decibels.

Note 2: It is imperative that the characteristic concerned (such as the sound pressure level) be clearly identified because in all transmission systems more than one characteristic is propagated.

Wavefront. (1) The wavefront of a progressive wave in space is a continuous surface which is a locus of points having the same phase at a given instant. (2) The wavefront of a progressive surface wave is a continuous line which is a locus of points having the same phase at a given instant.

Wave Interference. Wave interference is the phenomenon which results when waves of the same or nearly the same frequency are superposed and is characterized by a spatial or temporal distribution of amplitude of some specified characteristic differing from that of the individual superposed waves.

3a-5. Complex Parameters of Linear Systems

Acoustic Compliance. (1) The acoustic compliance of an enclosed volume of gas is equal to the magnitude of the ratio of the volume displacement of a piston forming one side of the volume to the pressure caused by the displacement (units cm^5/dyne or m^5/newton). (2) Acoustic compliance is the reciprocal of acoustic stiffness.

Acoustic Impedance. The acoustic impedance of a fluid medium on a given surface lying in a wavefront is the complex ratio of the sound pressure (force per unit area) on that surface to the flux (volume velocity or particle velocity multiplied by the area) through the surface. When concentrated rather than distributed impedances are considered, the impedance of a portion of the medium is based on the pressure difference effective in driving that portion and the flux (volume velocity). The acoustic impedance may be expressed in terms of mechanical impedance divided by the square of the area of the surface considered (units dyne-sec/cm^5 or newton-sec/m^5).

Note 1: Velocities in the direction along which the impedance is to be specified are considered positive.
Note 2: The real part of an acoustic impedance is *acoustic resistance*, and the imaginary part is *acoustic reactance.*

Acoustic Mass (Acoustic Inertance). Acoustic mass is the quantity which, when multiplied by 2π times the frequency, gives the acoustic reactance.

Acoustic Mobility. The acoustic mobility of a fluid medium on a given surface lying in a wavefront is the complex ratio of the flux (volume velocity, or particle velocity multiplied by the area) to the acoustic stress acting normal to the surface. When concentrated rather than distributed mobilities are considered, the mobility of a portion of the medium is based on the flux and the acoustic stress acting through that portion (units cm^5/dyne-sec or m^5/newton-sec).

Note: The acoustic mobility may be expressed in terms of the mechanical mobility multiplied by the square of the area of the surface considered.

Acoustic Ohm (cgs). An acoustic resistance, reactance, or impedance has a magnitude of one acoustic (cgs) ohm when a sound pressure of one microbar produces a volume velocity of one cubic centimeter per second.

Note: In the mks system the expression mks acoustic ohm is used.

Acoustic Resistance. Acoustic resistance is the real component of the acoustic impedance.

Acoustic Reactance. Acoustic reactance is the imaginary component of the acoustic impedance.

Acoustic Stiffness. Acoustic stiffness is the quantity which, when divided by 2π times the frequency, gives the acoustic reactance.

Analogous Impedance. Analogous impedances have classically been defined as the quotients of the following complex amplitudes:

Mechanical impedance Z_M = force across/velocity through
Rotation impedance Z_R = torque across/angular velocity through
Acoustic impedance Z_A = sound pressure across/volume velocity through
Electric impedance Z_E = voltage across/current through

The real part of each impedance above is called the *resistance*, and the imaginary part the *reactance.* The reciprocal of any impedance is an *admittance* whose real part is a *conductance* and imaginary part a *susceptance.*

Analogy. An analogy is a recognized relationship of consistent mutual similarity between the equations and structures appearing within two or more fields of knowledge, and an identification and association of the quantities and structural elements that play mutually similar roles in these equations and structures, for the purpose of facilitating transfer of knowledge of mathematical procedures of analysis and behavior of the structures between these fields.

Characteristic Impedance (*Intrinsic Impedance*). The characteristic impedance of a medium is the ratio of the effective sound pressure at a given point to the effective particle velocity at that point in a free plane progressive sound wave.

Note 1: The characteristic impedance is equal to the product of the density and the speed of sound in the medium.

Note 2: The characteristic impedance of an acoustic medium is analogous to the characteristic impedance of an infinitely long electrical transmission line.

Impedance. An impedance is the ratio of two complex quantities whose arguments increase linearly with time and whose real (or imaginary) parts represent a forcelike and velocitylike quantity respectively.

Note 1: Examples of forcelike quantities are force, sound pressure, voltage, temperature, electric field strength. Examples of velocitylike quantities are velocity, volume velocity, current, heat flow, magnetic flux.

Note 2: The terms and definitions related to impedance pertain to single-frequency quantities in the steady state and to systems whose properties are independent of the magnitudes of these quantities. These quantities can be represented mathematically by complex exponential functions of time. Under these conditions the factors involving time cancel out in the ratios called for, leaving complex numbers independent of time. Solutions based on complex exponential functions under these conditions give the solution for real sinusoidal oscillations.

Because of the similarity of electrical, mechanical, and acoustical transmission theory, the same terminology is used in the three cases. Where confusion is likely to occur, the proper term should be prefixed to the general term, e.g., "acoustic transfer impedance," but unless otherwise specified, the definitions apply not only in acoustics but in mechanics as well. While acoustics is a branch of mechanics, it is found convenient to distinguish an acoustic system from a mechanical one whenever elastic wave motion is an essential feature.

Intrinsic Impedance. See Characteristic Impedance.

Mechanical Compliance. The mechanical compliance of a springlike device is equal to the magnitude of the ratio of the displacement of the device to the force that produced the displacement (units cm/dyne or m/newton).

Mechanical Impedance. The mechanical impedance at a point or an interface of a mechanical system is the complex ratio of a sine-wave force acting on the system at that point or interface to the sine-wave velocity resulting from that force (units dyne-sec/cm or newton-sec/m).

Note 1: The ratio of force to displacement is sometimes also called mechanical impedance; this usage is deprecated.

Note 2: If the force and velocity are measured at the same point, the ratio is designated driving-point impedance; if they are measured at different points, the ratio is designated *transfer impedance.*

Mechanical Ohm (*cgs*). A mechanical resistance, reactance, or impedance has a magnitude of a mechanical (cgs) ohm when a force of 1 dyne/cm² produces a velocity of 1 cm/sec.

Note: In the mks system, the expression mks mechanical ohm is used.

Mechanical Reactance. Mechanical reactance is the imaginary part of the mechanical impedance.

Mechanical Resistance. Mechanical resistance is the real part of the mechanical impedance.

Mobility. Analogous mobilities are defined as the quotients of the following complex amplitudes:

Mechanical mobility Z_M = velocity across/force through
Rotational mobility Z_R = angular velocity across/torque through
Acoustic mobility Z_A = volume velocity across/sound pressure
Through electric impedance Z_E = voltage across/current through

The real part of each mobility is called the *responsiveness* and the imaginary part the *excitability.* The reciprocal of any mobility is an *immobility* whose real part is an *unresponsiveness* and imaginary part an *unexcitability.*

Rayl. The rayl is the magnitude of a specific acoustic resistance, reactance, or impedance for which a sound pressure of one microbar produces a linear velocity of one centimeter per second (dyne-sec/cm³). When expressed in newton-sec/m³ it is called the mks rayl.

Rotational Impedance. A rotational impedance is the complex ratio of a torque to angular velocity (or a relative angular velocity).

Specific Acoustic Compliance. The specific acoustic compliance of a springlike device or an enclosed volume of gas is equal to the magnitude of the ratio of the displacement of the device or of a piston forming one side of the volume to the pressure that produced the displacement (units cm³/dyne or m³/newton).

Specific Acoustic Impedance (Unit Area Acoustic Impedance). The specific acoustic impedance at a point in the medium is the complex ratio of sound pressure to particle velocity.

Specific Acoustic Mass. The specific acoustic mass is the quantity which when multiplied by 2π times the frequency gives the specific acoustic reactance associated with the kinetic energy of the medium (units g/cm² or kg/m²).

Specific Acoustic Reactance. Specific acoustic reactance is the imaginary component of the specific acoustic impedance (units dyne-sec/cm³ or newton-sec/m³).

Specific Acoustic Stiffness. The specific acoustic stiffness is the reciprocal of the specific acoustic compliance.

Specific Acoustic Resistance. Specific acoustic resistance is the real component of the specific acoustic impedance.

3a-6. Transducer Parameters

Acoustical Reciprocity Theorem. In an acoustic system comprising a fluid medium having bounding surfaces S_1, S_2, S_3, . . . and subject to no impressed body forces, if two distributions of normal velocities v'_n and v''_n of the bounding surfaces produce pressure fields p' and p'', respectively, throughout the region, then the surface integral of $(p''v'_n - p'v''_n)$ over all the bounding surfaces S_1, S_2, S_3, . . . vanishes.

Note: If the region contains only one simple source, the theorem reduces to the form ascribed to Helmholtz; viz., in a region as described, a simple source at A produces the same sound pressure at another point B as would have been produced at A had the source been located at B.

Available Power. (1) The available power of a linear source of electric energy is the quotient of the mean square of the open-circuit terminal voltage of the source divided by four times the resistive component of the internal impedance of the source.

Note: The available power would be delivered to a load impedance that is the conjugate of the internal impedance of the source and is the maximum power that can be delivered by that source.

(2) The available power of a sound-field, with respect to a given object placed in it, is the power which would be abstracted from the acoustic medium by an ideal trans-

ducer having the same dimensions and the same orientation as the given object. The dimensions and their orientation with respect to the sound field must be specified.

Note: The acoustic power available to an electroacoustic transducer, in a plane-wave sound field of a given frequency, is the product of the free-field sound intensity by the effective area of the transducer.

For this purpose the effective area of an electroacoustic transducer, for which the surface velocity distribution is independent of the manner of excitation of the transducer, is $1/4\pi$ times the product of the receiving directivity factor by the square of the wavelength of a free progressive wave in the medium.

If the physical dimensions of the transducer are small in comparison with the wavelength, the directivity factor is near unity and the effective area varies inversely as the square of the frequency. If the physical dimensions are large in comparison with the wavelength, the directivity factor is nearly proportional to the square of the frequency and the effective area approaches the actual area of the active face of the transducer.

Available Power Efficiency. The available power efficiency of an electroacoustic transducer used for sound reception is the ratio of the electric power available at the electric terminals of the transducer to the acoustic power available to the transducer.

Note 1: For an electroacoustic transducer which obeys the reciprocity principle, the available power efficiency in sound reception is equal to the transmitting efficiency.

Note 2: In a given narrow-frequency band, the available power efficiency is numerically equal to the fraction of the open-circuit mean-square thermal noise voltage present at the electric terminals which is contributed by thermal noise in the acoustic medium.

Available Power Response. The available power response of an electroacoustic transducer used for sound emission is the ratio of the mean-square sound pressure apparent at a distance of 1 meter in a specified direction from the effective acoustic center of the transducer to the available electric power from the source.

Note 1: The sound pressure apparent at a distance of 1 meter can be found by multiplying the sound pressure observed at a remote point where the sound field is spherically divergent by the number of meters from the effective acoustic center of the transducer to that point.

Note 2: The available power response is a function not only of the transducer but also of some source impedance, either actual or hypothetical, the value of which must be specified.

Beam Width. The beam width of a directional transducer, at a given frequency in a given plane including the beam axis, is the angle included between the two directions, one to the left and the other to the right of the axis, at which the angular deviation loss has a specified value.

Note: Beam widths are commonly specified for an angular deviation loss of 3, 6, or 10 dB, the choice depending upon the directivity of the transducer or upon its intended application. The particular angular deviation loss can be indicated conveniently by use of a term such as "3-dB beam width."

Directional Gain (Directivity Index). The directional gain of a transducer, in decibels, is ten times the logarithm to the base 10 of the directivity factor.

Directional Response Pattern (Beam Pattern). The directional response pattern of a transducer used for sound emission or reception is a description, often presented graphically, of the response of the transducer as a function of the direction of the transmitted or incident sound waves in a specified plane and at a specified frequency.

Note 1: A complete description of the directional response pattern of a transducer would require three-dimensional presentation.

Note 2: The directional response pattern is often shown as the response relative to the maximum response.

Directivity Factor. (1) The directivity factor of a transducer used for sound emission is the ratio of the sound pressure squared, at some fixed distance and specified direction, to the mean-square sound pressure at the same distance averaged over all directions from the transducer. The distance must be great enough so that the sound appears to diverge spherically from the effective acoustic center of the source. Unless otherwise specified, the reference direction is understood to be that of maximum response. (2) The directivity factor of a transducer used for sound reception is the ratio of the square of the open-circuit voltage produced in response to sound waves arriving in a specified direction to the mean-square voltage that would be produced in a perfectly diffused sound field of the same frequency and mean-square sound pressure.

Note 1: This definition can be extended to cover the case of finite frequency bands whose spectrum can be specified.

Note 2: The average free-field response can be obtained in various ways, such as

a. By the use of a spherical integrator

b. By numerical integration of a sufficient number of directivity patterns corresponding to different planes

c. By integration of one or two directional patterns whenever the pattern of the transducer is known to possess adequate symmetry

Dynamic Range. The dynamic range of an electroacoustic transducer used for sound reception is the difference between the overload pressure level and the equivalent pressure level of the noise.

Note 1: The useful dynamic range is limited at the low-level end by noise in the medium (acoustic noise) or by electrical circuit noise. The nature of the noise limit must be stated explicitly (e.g., ambient noise, equipment noise, thermal noise, etc).

Note 2: The method of overload determination and the type of overload must be specified (i.e., signal distortion, overheating, damage, etc).

Effective Acoustic Center. The effective acoustic center of an acoustic generator is the point from which the spherically divergent sound waves, observable at remote points, appear to diverge.

Effective Bandwidth. The effective bandwidth of a specified transmission system is the bandwidth of an ideal system which (1) has uniform transmission in its pass-band equal to the maximum transmission of the specified system and (2) transmits the same power as the specified system when the two systems are receiving equal input signals having a uniform distribution of energy at all frequencies.

Note: This can be expressed mathematically as follows:

$$\text{Effective bandwidth} = \int_0^\infty G\,df$$

where f is the frequency in hertz, and G is the ratio of the power transmission at the frequency f to the transmission at the frequency of maximum transmission.

Electroacoustical Reciprocity Theorem. For an electroacoustic transducer satisfying the reciprocity principle, the quotient of the magnitude of the ratio of the open-circuit voltage at the output terminals (or the short-circuit output current) of the transducer, when used as a sound receiver, to the free-field sound pressure referred to an arbitrarily selected reference point on or near the transducer, divided by the magnitude of the ratio of the sound pressure apparent at a distance d from the reference point to the current flowing at the transducer input terminals (or the voltage applied at the input terminals), when used as a sound emitter, is a constant, called the "reciprocity constant," independent of the type or constructional details of the transducer.

Note: The reciprocity constant is given by

$$\left|\frac{M_0}{S_0}\right| = \left|\frac{M_s}{S_s}\right| = \frac{2d}{\rho f} \cdot 10^{-7}$$

where M_0 = free-field voltage sensitivity as a sound receiver referred to arbitrary reference point on or near transducer, open-circuit volts/microbar

M_s = free-field current sensitivity referred to arbitrary reference point on or near transducer, short-circuit amp/microbar

S_0 = sound pressure produced at distance d cm from arbitrary reference point, microbars/amp of input current

S_s = sound pressure produced at distance d cm from arbitrary reference point, microbars/volt applied at the input terminals

f = frequency, Hz

ρ = density of medium, in g/cm^3

d = distance from arbitrary reference point on or near transducer to point at which sound pressure established by transducer when emitting is evaluated, cm

Equivalent Noise Pressure (*Inherent Noise Pressure*). The equivalent noise pressure of an electroacoustic transducer or system used for sound reception is the root-mean-square sound pressure of a sinusoidal plane progressive wave, which, if propagated parallel to the principal axis of the transducer, would produce an open-circuit signal voltage equal to the root mean square of the inherent open-circuit noise voltage of the transducer in a transmission band having a bandwidth of 1 Hz and centered on the frequency of the plane sound wave.

Note: If the equivalent noise pressure of the transducer is a function of secondary variables, such as ambient temperature or pressure, the applicable value of these quantities should be stated explicitly.

Insertion Loss. The insertion loss, in decibels, resulting from insertion of a transducer in a transmission system is ten times the logarithm to the base 10 of the ratio of the power delivered to that part of the system that will follow the transducer before the insertion of the transducer to the power delivered to that same part of the system after insertion of the transducer.

Note: If the input power or the output power or both consist of more than one component, the particular component must be specified.

Principal Axis. The principal axis of a transducer used for sound emission or reception is a reference direction for angular coordinates used in describing the directional characteristics of the transducer. It is usually an axis of structural symmetry or the direction of maximum response, but if these do not coincide, the reference direction must be described explicitly.

Relative Response. The relative response of a transducer, in decibels, is the amount by which the response under some particular condition exceeds the response under a reference condition that should be stated explicitly.

Sensitivity Level; Response Level (*Sensitivity*)(*Response*). The sensitivity (or response) level of a transducer, in decibels, is 20 times the logarithm to the base 10 of the ratio of the amplitude sensitivity to the reference sensitivity, where the amplitude is a quantity proportional to the square root of power. The kind of sensitivity and the reference sensitivity must be indicated.

Note: For a microphone, the free-field voltage-pressure sensitivity is the kind often used, and a common reference sensitivity is $s_0 = 1$ volt per microbar. The square of the sensitivity is proportional to a power ratio. The free-field voltage sensitivity-squared level, in decibels, is therefore $S = 10 \log (s^2/s_0^2) = 20 \log (s/s_0)$. Often, sensitivity-squared level in decibels can be shortened, without ambiguity, to sensitivity level in decibels, or simply sensitivity in decibels.

3a-7. Underwater Sound

Active Sonar (*Echo-ranging Sonar*). In an active sonar system, a pulse of acoustic energy is generated by an underwater source and radiated outward; such pulse being reflected in part by an object and transmitted back to an underwater receiver; said reflected pulse yielding information as to distance, bearing angle, and character of object.

Passive Sonar (Listening Sonar). Passive sonar is the method or equipment by which information concerning a distant object is obtained by evaluation of sound generated by the object.

Sea Noise. Sea noise is that portion of the ambient noise in the sea that remains if the noise components contributed by marine life, terrestrial noise, and precipitation, and by ships, traffic, and other identifiable man-made sources are excluded.

Sonar. Sonar is the method or equipment for determining, by underwater sound, the presence, location, or nature of objects in the sea.

Note: The word "sonar" is an acronym derived from the expression "SOund NAvigation and Ranging."

Sonar Background Noise. Sonar background noise is the total noise that interferes with the reception of the desired signal. The noise is that presented to the final receiving element, such as a recorder or the ear of a listener.

Target Strength. In underwater sound, the target strength of an object is the backscattering differential of an object for sound scattered back along the path of the incident sound. Unless otherwise specified, the reference distance is 1 yard. (See *Scattering Differential* under Sec. 3a-4.)

3a-8. Sonics

Cavitation. Sonically induced cavitation in a liquid is the formation, growth, and collapse of gaseous and vapor bubbles due to the action of intense sound waves.

Cavitation Noise. Cavitation noise is the noise produced in a liquid by gaseous or vaporous cavitation.

Electrostriction. Electrostriction is the phenomenon wherein some dielectric materials experience an elastic strain when subjected to an electric field, this strain being independent of the polarity of the field.

Hydrodynamic Oscillator. A hydrodynamic oscillator is a transducer for generating sound waves in fluids, in which a continuous flow through an orifice is modulated by a reciprocating valve system controlled by acoustic feedback.

Jet-edge Generator. A jet-edge sonic generator is a fluid dynamic transducer, involving vortex formation, in which stabilization is achieved by hydrodynamic feedback between a jet and an edge.

Macrosonics. Macrosonics is the technology of sound at signal amplitudes so large that linear approximations are not valid.

Note: Processing techniques usually involve macrosonics.

Magnetostriction. Magnetostriction is the phenomenon wherein ferromagnetic materials experience an elastic strain when subjected to an external magnetic field. Also, magnetostriction is the converse phenomenon in which mechanical stresses cause a change in the magnetic induction of a ferromagnetic material.

Oseen Force. An Oseen force is a steady force exerted on a suspended particle by second-order velocity effects resulting from second harmonic content in a distorted wave.

Piezoelectricity. Piezoelectricity is the property exhibited by some asymmetrical crystalline materials which when subjected to strain in suitable directions develop electric polarization proportional to the strain. Inverse piezoelectricity is the effect in which mechanical strain is produced in certain asymmetrical crystalline materials when subjected to an external electric field; the strain is proportional to the electric field.

Sonics. Sonics is the technology of sound in processing and analysis. Sonics includes the use of sound in any noncommunication process.

Ultrasonics. Ultrasonics is the technology of sound at frequencies above the audio range.

Note: Supersonics is the general subject covering phenomena associated with speed higher than the speed of sound (as in the case of aircraft and projectiles traveling faster than sound). This term was once used in acoustics synonymously with "ultrasonics"; such usage is now deprecated.

3a-9. Architectural Acoustics

Anechoic Room (Free-field Room). An anechoic room is one whose boundaries absorb effectively all the sound incident thereon, thereby affording essentially free-field conditions.

Dead Room. A dead room is a room that is characterized by an unusually large amount of sound absorption.

Decay Constant. The decay constant is the exponential power by which sound decays after the source is stopped (units sec^{-1}).

Note: If p_0 is the effective sound pressure at $t = 0$, $p(t)$ is the effective sound pressure at time t, and the two are related by

$$p(t) = p_0 e^{-kt}$$

then k is the decay constant.

Diffuse Sound Field. A diffuse sound field is one in which the time average of the mean-square sound pressure is everywhere the same and the flow of energy in all directions is equally probable.

Direct Sound Wave. A direct sound wave in an enclosure is a wave emitted from a source prior to the time it has undergone its first reflection from a boundary of the enclosure.

Note: Frequently, a sound wave is said to be direct if it contains reflections that have occurred from surfaces within about 0.05 sec after the sound was first emitted.

Echo. An echo is a wave that has been reflected or otherwise returned with sufficient magnitude and delay to be detected as a wave distinct from that directly transmitted. In architectural acoustics the word "echo" is generally restricted to mean "unwanted echo." The word "reflection" is generally used to mean "desired echo."

Equivalent Absorption Area of an Object or of a Surface. Area of a surface having a sound power absorption coefficient of unity that would absorb sound energy at the same rate as the object or the surface. In the case of a surface, the equivalent absorption area is the product of the area of the surface and its sound power absorption coefficient. In the case of an object in a given situation in a room, the equivalent absorption area is the increase of the equivalent absorption area produced in the room by the introduction of the object.

Eyring Coefficient. Equivalent sound absorption area attributed to a surface by the Eyring reverberation time formula, divided by the area of the surface.

Flutter Echo. A flutter echo is a rapid succession of reflected pulses resulting from a single initial pulse.

Live Room. A live room is a room that is characterized by an unusually small amount of sound absorption.

Mean Free Path. The mean free path for sound waves in an enclosure is the average distance sound travels between successive reflections in the enclosure.

Noise Reduction. In architectural acoustics, noise reduction generally is the difference between the effective sound pressure levels (in decibels) between the noise fields on opposite sides of a noise-reducing panel, with all sources of sound being on one side of the panel.

Random Incidence. If an object is in a diffuse sound field, the sound is said to strike the object at random incidence.

Rate of Decay. The rate of decay is the time rate at which the sound pressure level (or other stated characteristic) decreases at a given point and at a given time. A commonly used unit is the decibel per second.

Reflection. A reflection is an echo that occurs in combination with the direct sound or with other reflections or both to produce desired acoustical effects in a room, such as enhancement of the direct sound, reverberation, etc.

Reverberant Sound. Reverberant sound is that part of the sound in an enclosure that has undergone one or more reflections from the boundaries of the enclosure.

Reverberation Room. A reverberation room is a room having a long reverberation time, especially designed to make the sound field therein as diffuse as possible.

Reverberation Time. The reverberation time of an enclosure, for a sound of given frequency or frequency band, is the time after the source has been stopped that would be required for the sound pressure level in the enclosure to decrease by 60 dB.

Room Absorption. Room absorption is the sum of Sabine absorptions due to objects and surfaces in a room, and of dissipation in the medium within the room.

Room Constant. The room constant is equal to the product of the average absorption coefficient of the room and the total internal area of the room divided by the quantity one minus the average absorption coefficient.

Sabin. The sabin is a unit of absorption having the dimensions of square feet.

Note: The *metric sabin* has the dimension of square meters.

Sabine Absorption. Sabine absorption is that absorption defined by the Sabine reverberation time equation. Sabine absorption is equal to 24 times the volume of a room divided by the product of the reverberation time therein, the speed of sound, and the common logarithm of the Naperian base.

Note 1: The unit of absorption is the sabin when the unit of area is the square foot, or the metric sabin when the unit of area the square meter.

Sabine Coefficient. The Sabine coefficient of a surface, is the increase in Sabine absorption, due to introduction of the surface into a room, divided by the area of the surface.

Sound Absorption. Sound absorption is the property possessed by materials and objects of absorbing sound energy, due to either the propagation in a medium or the dissipation when sound strikes a surface.

Sound Power Absorption Coefficient. The SPAC at a given frequency and for specified conditions, of a surface, is the fraction of incident sound power not reflected from the surface. Unless otherwise specified, a diffuse sound field at the surface is to be understood.

Sound Power Reflection Coefficient. This coefficient of a surface, at a given frequency and for specified conditions, is the fraction of incident sound power reflected by the surface.

Sound Pressure Reflection Coefficient. This coefficient of a surface, at a given frequency and for specified conditions, is the fraction of incident sound pressure reflected by the surface.

Sound Reduction between Rooms. The sound reduction, in decibels, between two rooms is the amount by which the mean-square sound pressure level averaged throughout the source room exceeds the same level averaged throughout the receiving room.

Sound-transmission Coefficient. The sound-transmission coefficient of a partition is the fraction of incident sound transmitted through it. Unless otherwise specified, transmission of sound energy between two diffuse sound fields is assumed.

Sound-transmission Loss of a Partition. The sound-transmission loss of a partition is a measure of sound insulation. Expressed in decibels, it is ten times the logarithm to the base 10 of the reciprocal of the sound-transmission coefficient of the partition. Unless otherwise specified, the sound fields on both sides of the partition are assumed to be diffuse.

Statistical Absorption Coefficient. The SAC is the absorption coefficient measured or calculated with plane waves at randomly distributed angles of incidence.

3a-10. Hearing and Speech

Air Conduction. Air conduction is the process by which sound is conducted to the inner ear through the air in the outer ear canal as part of the pathway.

Articulation (Percent Articulation) and Intelligibility (Percent Intelligibility). Percent articulation or percent intelligibility of a communication system is the percentage of the speech units spoken by a talker or talkers that is correctly repeated, written down, or checked by a listener or listeners.

The word "articulation" is used when the units of speech material are meaningless syllables or fragments; the word "intelligibility" is used when the units of speech material are complete, meaningful words, phrases, or sentences.

Note 1: It is important to specify the type of speech material and the units into which it is analyzed for the purpose of computing the percentage. The units may be fundamental speech sounds, syllables, words, sentences, etc.

Note 2: The percent articulation or percent intelligibility is a property of the entire communication system: talker, transmission equipment or medium, and listener. Even when attention is focused upon one component of the system (e.g., a talker, a radio receiver), the other components of the system should be specified.

Note 3: The kind of speech material used is identified by an appropriate adjective in phrases such as "syllable articulation," "individual sound articulation," "vowel (or consonant) articulation," "monosyllabic word intelligibility," "discrete word intelligibility," "discrete sentence intelligibility."

Audiogram (Threshold Audiogram). An audiogram is a graph showing hearing loss as a function of frequency.

Auditory Sensation Area. The auditory sensation area is the region enclosed by the curves defining the threshold of pain and the threshold of audibility as functions of frequency.

Aural Critical Band. The aural critical band is that frequency band of sound, being a portion of a continuous-spectrum noise covering a wide band, that contains sound power equal to that of a simple (pure) tone centered in the critical band and just audible in the presence of the wide-band noise.

Note 1: By "just audible" is meant audible in a specified fraction of the trials.

Note 2: The use of the aural critical band to estimate masking should be limited to masking by noises having continuous spectra without excessive slopes or irregularities and to cases where masking exceeds 15 dB.

Note 3: In order to be just audible in a wide-band continuous noise, the level of a simple tone in decibels must exceed the spectrum level of the continuous noise (at the same frequency) by ten times the logarithm to the base 10 of the ratio of the critical bandwidth to unit bandwidth.

Aural Harmonic. An aural harmonic is a harmonic generated in the auditory mechanism.

Average Speech Power. The average speech power for a stated time interval is the average value of the instantaneous speech power over that interval.

Bone Conduction. Bone conduction is the process by which sound is conducted to the inner ear through the cranial bones.

Composite Noise-exposure Index. The sum of partial noise-exposure indices for all relevant sound levels over a working week (40 hours).

Difference Limen (*Differential Threshold, Just Noticeable Difference*). A difference limen is the increment in a stimulus that is just noticed in a specified fraction of the trials. The relative difference limen is the ratio of the difference limen to the absolute magnitude of the stimulus to which it is related.

Electrophonic Effect. Electrophonic effect is the sensation of hearing produced when an alternating current of suitable frequency and magnitude from an external source is passed through an animal.

Equivalent Continuous Sound Level. That sound level in dB(A) which, if present for 40 hours in one week, produces the same composite noise-exposure index as the various measured sound levels over one week.

Formant. A formant of a complex sound is a frequency range of the spectrum of the sound within which the partials have relatively large amplitudes.

Note: The central frequency within the formant range is called the formant frequency.

Hearing Level (*Hearing Loss, Hearing Threshold Level*). The hearing level of an ear at a specified frequency is the amount, in decibels, by which the threshold of audibility for that ear exceeds the standard audiometric threshold.

Note: See International Standards Organization (ISO) Recommendation R-389 (E) for standard reference zero for pure-tone audiometers.

Impairment of Hearing for Conversational Speech. The hearing of a subject for conversational speech is considered to be impaired if his hearing level is shifted by 25 dB or more, averaged over the test frequencies 500, 1,000 and 2,000 Hz compared with the threshold given in ISO Recommendation R-389, Standard Reference Zero for the Calibration of Pure-tone Audiometers. Percent of total impairment is generally taken to equal 1.5 times the number of decibels of hearing impairment for speech. Thus total impairment occurs at 92 dB average hearing level at the three test frequencies.

Instantaneous Speech Power. The instantaneous speech power is the rate at which sound energy is being radiated by a speech source at any given instant.

Level above Threshold (*Sensation Level*). The level above threshold of a sound is the pressure level of the sound in decibels above its threshold of audibility for the individual observer or for a specified group of individuals.

Loudness. Loudness is the intensive attribute of an auditory sensation in terms of which sounds may be ordered on a scale extending from soft to loud.

Note: Loudness depends primarily upon the sound pressure of the stimulus, but it also depends upon the frequency and waveform of the stimulus.

Loudness Contour. A loudness contour is a curve that shows the related values of sound pressure level and frequency required to produce a given loudness sensation for the typical listener.

Loudness Level. The loudness level of a sound, in phons, is numerically equal to the median sound pressure level, in decibels, relative to 0.0002 microbar, of a free progressive wave of frequency 1,000 Hz presented to listeners facing the source, which in a number of trials is judged by the listeners to be equally loud.

Note: The manner of listening to the unknown sound, which must be stated, may be considered one of the characteristics of that sound.

Loudness-level Contour. A loudness-level contour is a curve that shows the related values of sound pressure level and frequency required to produce a given loudness level for the typical listener.

Masking. (1) Masking is the process by which the threshold of audibility for one sound is raised by the presence of another (masking) sound. (2) Masking is the amount by which the threshold of audibility of a sound is raised by the presence of another (masking) sound. The unit customarily used is the decibel.

Masking Audiogram. A masking audiogram is a graphical presentation of the masking due to a stated noise. This is plotted, in decibels, as a function of the frequency of the masked tone.

Mel. The mel is a unit of pitch. By definition, a simple tone of frequency 1,000 Hz, 40 dB above a listener's threshold, produces a pitch of 1,000 mels. The pitch of any sound that is judged by the listener to be n times that of 1-mel tone is n mels.

Partial Noise-exposure Index. An index determined by a sound level and its duration within a working week (40 hours).

Peak Speech Power. The peak speech power is the maximum value of the instantaneous speech power within the time interval considered.

Phon. The phon is the unit of loudness level, as specified in definition of loudness level.

Pitch. Pitch is that attribute of auditory sensation in terms of which sounds may be ordered on a scale extending from low to high. Pitch depends primarily upon the frequency of the sound stimulus, but it also depends upon the sound pressure and waveform of the stimulus.

Note: The pitch of a sound can be described by the frequency or frequency level of that simple tone having a specified sound pressure level which is judged by listeners to produce the same pitch.

Recognition Differential. The recognition differential for a specified aural detection system is that amount by which the signal level exceeds the noise level presented to the ear when there is a 50 percent probability of detection of the signal. The bandwidth of the system, within which signal and noise are presented and measured, must be specified.

Note 1: The signal and noise need not be measured actually at the ear but may be measured at any convenient point in the system, provided it is established that the difference between the signal level and noise level at that point is the same as the difference at the ear.

Note 2: The psychophysical method chosen for testing probability of detection must adequately control errors of commission as well as errors of omission.

Risk. Risk of hearing impairment is the difference between the percentage of people with impaired hearing in a noise-exposed group and the percentage of people with impaired hearing in a non-noise-exposed (but otherwise equivalent) group.

Risk of Hearing Impairment for Conversational Speech. The particular value of risk when the impairment of hearing in question is as described in Impairment of Hearing for Conversational Speech.

Sone. The sone is a unit of loudness. By definition, a simple tone of frequency 1,000 Hz, 40 dB above a listener's threshold, produces a loudness of 1 sone. The loudness of any sound that is judged by the listener to be n times that of the 1-sone tone is n sones.

Note 1: A millisone is equal to 0.001 sone.

Note 2: The loudness scale is a relation between loudness and level above threshold (sensation level) for a particular listener. In presenting data relating loudness in sones to sound pressure level or in averaging the loudness scales of several listeners, the thresholds (measured or assumed) should be specified.

Threshold of Audibility (Threshold of Detectability). The threshold of audibility for a specified signal is the minimum effective sound pressure level of the signal that is capable of evoking an auditory sensation in a specified fraction of the trials. The characteristics of the signal, the manner in which it is presented to the listener, and the point at which the sound pressure level is measured must be specified.

Note 1: Unless otherwise indicated, the ambient noise reaching the ears is assumed to be negligible.

Note 2: The threshold is usually given as a sound pressure level in decibels relative to 0.0002 microbar.

Note 3: Instead of the method of constant stimuli, which is implied by the phrase "a specified fraction of the trials," another psychophysical method (which should be specified) may be employed.

Threshold of Discomfort. The threshold of discomfort for a specified signal is the minimum effective sound pressure level of that signal which, in a specified fraction of the trials, will stimulate the ear to a point at which the sensation of feeling becomes uncomfortable.

Threshold of Feeling (or Tickle). The threshold of feeling (or tickle) for a specified signal is the minimum sound pressure level at the entrance to the external auditory canal which, in a specified fraction of the trials, will stimulate the ear to a point at which there is a sensation of feeling that is different from the sensation of hearing.

Threshold of Pain. The threshold of pain for a specified signal is the minimum effective sound pressure level of that signal which, in a specified fraction of the trials, will stimulate the ear to a point at which the discomfort gives way to definite pain that is distinct from mere nonnoxious feeling of discomfort.

Timbre. Timbre is that attribute of auditory sensation in terms of which a listener can judge that two sounds similarly presented and having the same loudness and pitch are dissimilar.

Note: Timbre depends primarily upon the spectrum of the stimulus, but it also depends upon the waveform, the sound pressure, the frequency location of the spectrum, and the temporal characteristics of the stimulus.

3a-11. Music

Cent. The cent is the interval between two sounds having as a basic frequency ratio the twelve-hundredth root of 2.

Note: The interval in cents between any two frequencies is 1,200 times the logarithm to the base 2 of the frequency ratio. Thus, 1,200 cents equal 12 equally tempered semitones equal 1 octave.

Complex Tone. (1) A complex tone is a sound wave containing simple sinusoidal components of different frequencies. (2) A complex tone is a sound sensation characterized by more than one pitch.

Equally Tempered Scale. An equally tempered scale is a musical scale formed by a division of the octave into a number (usually 12) of equal intervals (see Table 3a-2).

TABLE 3a-2. EQUALLY TEMPERED INTERVALS

Name of interval	Frequency ratio	Cents
Unison	1:1	0
Minor second or semitone	1.059463:1	100
Major second or whole tone	1.122462:1	200
Minor third	1.189207:1	300
Major third	1.259921:1	400
Perfect fourth	1.334840:1	500
Augmented fourth: diminished fifth	1.414214:1	600
Perfect fifth	1.498307:1	700
Minor sixth	1.587401:1	800
Major sixth	1.681793:1	900
Minor seventh	1.781797:1	1,000
Major seventh	1.887749:1	1,100
Octave	2:1	1,200

Fundamental. The fundamental is the component in a periodic wave corresponding to the fundamental frequency.

Harmonic. A harmonic is a partial whose frequency is an integral multiple of the fundamental frequency.

Note: The term "overtone" has frequently been used in place of "harmonic," the nth harmonic being called the $(n - 1)$ overtone. The term overtone is now deprecated in order to reduce ambiguity in the numbering of the components of a complex tone.

Harmonic Series of Sounds. A harmonic series of sounds is one in which each basic frequency in the series is an integral multiple of a fundamental frequency.

Interval. The interval between two sounds is their spacing in pitch or frequency, whichever is indicated by the context. The frequency interval is expressed by the ratio of the frequencies or by a logarithm of this ratio.

Octave. (1) An octave is the interval between two sounds having a basic frequency ratio of 2. (2) An octave is the pitch interval between two tones such that one tone may be regarded as duplicating the basic musical import of the other tone at the nearest possible higher pitch.

Note 1: The interval in octaves between any two frequencies is the logarithm to the base 2 (for 3.322 times the logarithm to the base 10) of the frequency ratio.

Note 2: The frequency ratio corresponding to an octave pitch interval is approximately, but not always exactly, 2:1.

Overtone. (1) An overtone is a physical component of a complex sound having a frequency higher than that of the basic frequency (see Partial below). (2) An overtone is a component of a complex tone having a pitch higher than that of the fundamental pitch.

Note: The term overtone is now deprecated. See Harmonic.

Partial. (1) A partial is a physical component of a complex tone. (2) A partial is a component of a sound sensation which can be distinguished as a simple tone that cannot be further analyzed by the ear and which contributes to the timbre of the complex sound.

Note 1: The frequency of a partial may be either higher or lower than the basic frequency and may or may not be an integral multiple or submultiple of the basic frequency. If the frequency is not a multiple or submultiple, the partial is inharmonic.

Note 2: When a system is maintained in steady forced vibration at a basic frequency equal to one of the frequencies of the normal modes of vibration of the system, the partials in the resulting complex tone are not necessarily identical in frequency with those of the other normal modes of vibration.

Scale. A musical scale is a series of notes (symbols, sensations, or stimuli) arranged from low to high by a specified scheme of intervals, suitable for musical purposes.

Semitone (Semit, Half Step). The semitone is the interval between two sounds having a basic frequency ratio approximately the twelfth root of 2.

Note: The interval in equally tempered semits between any two frequencies is 12 times the logarithm to the base 2 (or 39.86 times the logarithm to the base 10) of the frequency ratio.

Simple Tone (Pure Tone). (1) A simple tone is a sound wave the instantaneous sound pressure of which is a simple sinusoidal function of the time. (2) A simple tone is a sound sensation characterized by its singleness of pitch.

Note: Whether a listener hears a tone as simple or complex (see Complex Tone) is dependent upon ability, experience, and listening attitude.

Standard Tuning Frequency (Standard Musical Pitch). The standard tuning frequency is the frequency for the note A_4, namely, 440 Hz.

TABLE 3a-3. RELATIONS AMONG VARIOUS ACOUSTICAL UNITS

Quantity	Dimension	cgs unit	mks unit	Conversion factor*	British unit	Conversion factor†
Mass	M	gram	kilogram	10^{-3}	slug	6.854×10^{-5}
Velocity (linear)	LT^{-1}	cm per sec	meter per sec	10^{-2}	ft per sec	3.281×10^{-2}
Force	MLT^{-2}	dyne	newton	10^{-5}	lb weight	2.248×10^{-6}
Sound pressure	$ML^{-1}T^{-2}$	dyne per sq cm [microbar]	newton per sq meter	10^{-1}	lb per sq ft	2.089×10^{-3}
Volume velocity	L^3T^{-1}	cu cm per sec	cu meter per sec	10^{-6}	cubic foot per sec	3.531×10^{-5}
Sound energy	ML^2T^{-2}	erg	joule	10^{-7}	ft-lb	7.376×10^{-8}
Sound-energy density	$ML^{-1}T^{-2}$	erg per cu cm	joule per cu meter	10^{-1}	ft-lb per cu ft	2.089×10^{-3}
Sound-energy flux [sound power of source]	ML^2T^{-3}	erg per sec	watt	10^{-7}	ft-lb per sec	7.376×10^{-8}
Sound-energy-flux density [sound intensity]	MT^{-3}	erg per sec per sq cm	watt per sq meter	10^{-3}	(ft-lb per sec) per sq ft	6.847×10^{-5}
Mechanical impedance	MT^{-1}	mechanical ohm [dyne-sec per cm]	mks mechanical ohm [newton-sec per meter]	10^{-3}	lb-sec per ft	6.854×10^{-2}
Acoustic impedance [resistance, reactance]	$ML^{-4}T^{-1}$	acoustical ohm [dyne-sec per cm^5]	mks acoustical ohm [newton-sec per m^5]	10^5	(lb per sq ft) per (cu ft per sec)	59.61
Specific acoustic impedance	$ML^{-2}T^{-1}$	rayl [acoustical ohm × sq cm]	mks rayl [mks acoustical ohm × sq meter]	10	(lb per sq ft) per (ft per sec)	6.366×10^{-5}
Acoustic inertance	ML^{-4}	gram per cm to the fourth power	kilogram per meter to the fourth power	10^5	slug per (ft to the fourth power)	59.16
Acoustic stiffness	$ML^{-4}T^{-2}$	(gram per cm to the fourth power) per sq sec	(kilogram per meter to the fourth power) per sq sec	10^5	(slug per ft to the fourth power) per sq sec	59.16
Acoustic compliance	$M^{-1}L^4T^2$	(cm to the fifth power) per dyne	(meter to the fifth power) per newton	10^5	(ft to the fifth power) per lb	1.690×10^{-2}

* Multiply a magnitude expressed in cgs units by the tabulated conversion factor to obtain magnitude in mks units.

† Multiply a magnitude expressed in cgs units by the tabulated conversion factor to obtain magnitude in British units. These conversion factors were calculated on the basis of standard acceleration due to gravity.

Note: M, L, T represent mass, length, and time, respectively, in the sense of the theory of dimensions. Mks mechanical ohm, and mks acoustical ohm, rayl, and mks rayl are proposed terms. Alternate terms and units are in square brackets.

Note: It is recommended that tuning and retuning of musical instruments be within an accuracy of plus or minus 0.5 Hz at the standard tuning frequency when the instruments are played where the ambient temperature is 22°C (71.6°F).

Tone. (1) A tone is a sound wave capable of exciting an auditory sensation having pitch. (2) A tone is a sound sensation having pitch.

Vibrato. The vibrato is a family of tonal effects in music that depend upon periodic variations of one or more characteristics of the sound wave.

Note: When the particular characteristics are known, the term "vibrato" should be modified accordingly: e.g., frequency vibrato, amplitude vibrato, phase vibrato, and so forth.

3a-12. Acoustical Units

Acoustical Units. In different sections of acoustics at least three systems of units are in common use: the centimeter-gram-second (cgs), the meter-kilogram-second (mks), and the British. Table 3a-3 is provided to facilitate conversion from one system of units to another.