ANSI S1.1-1994
(ASA 111-1994)

Revision of ANSI S1.1-1960 (R1976)

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AMERICAN NATIONAL STANDARD

ACOUSTICAL TERMINOLOGY

ANSI S1.1-1994 (ASA 111-1994)

Accredited Standards Committee S1, Acoustics

Standards Secretariat
Acoustical Society of America
120 Wall Street, 32nd Floor
New York, New York 10005-3993

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Acoustical Terminology

Secretariat

Acoustical Society of America

Approved 4 January 1994

American National Standards Institute, Inc.

ABSTRACT

This standard provides definitions for a wide variety of terms, abbreviations, and letter symbols used in acoustics and electroacoustics. Terms of general use in all branches of acoustics are defined, as well as many terms of special use for architectural acoustics, acoustical instruments, mechanical vibration and shock, physiological and psychological acoustics, underwater sound, sonics and ultrasonics, and music.

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Foreword

[This foreword is for information only and is not a part of American National Standard Acoustical Terminology S1.1-1994 (ASA Catalog No. 111-1994).]

This standard was developed under the jurisdiction of Accredited Standards Committee S1, Acoustics, which has the following scope:

> *Standards, specifications, methods of measurement and test, and terminology, in the fields of physical acoustics, including architectural acoustics, electroacoustics, sonics and ultrasonics, and underwater sound, but excluding those aspects which pertain to safety, tolerance, and comfort.*

At the time this standard was submitted to Accredited Standards Committee S1, Acoustics, for final approval, the membership was as follows:

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R. L. McKinley, *Vice Chair*
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Individual experts of Accredited Standards Committee S1, Acoustics, were:

J. R. Bareham	R. M. Guernsey	L. W. Sepmeyer
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K. M. Eldred	D. L. Johnson	H. E. von Gierke
D. R. Flynn	W. W. Lang	G. S. K. Wong
W. J. Galloway	G. C. Maling Jr.	R. W. Young
E. E. Gross, Jr.	A. H. Marsh	

The *ad hoc* group on Acoustical Terminology, which assisted Accredited Standards Committee S1, Acoustics, in the preparation of this standard, had the following membership:

W. J. Galloway, Chair
A. H. Marsh,
R. W. Young

Additional assistance was provided in particular technical areas by:

P. D. Schomer	General terminology and levels
G. Winzer	Architectural acoustics

The *ad hoc* working group used as its starting point an earlier draft revision to ANSI S1.1-1960 prepared by D. L. Johnson and S. Yaniv, comments received from an informal circulation of that draft, and a review of that draft by Canadian Working Group Z107.1 under the chair of A. Behar.

Suggestions for improvement will be welcomed. They should be sent to Accredited Standards Committee S1, Acoustics, in care of the Standards Secretariat, Acoustical Society of America, 120 Wall Street, 32nd Floor, New York, New York 10005-3993. Telephone (212) 248-0373; FAX (212) 248-0146.

American National Standard

Acoustical Terminology

1 Scope

This American National Standard provides unequivocal terms used in acoustics and electroacoustics. Many terms apply to all branches of acoustics. A number of general terms from the fields of architectural acoustics, engineering acoustics, physical acoustics, physiological and psychological acoustics, sonics and ultrasonics, underwater sound, and music are also provided. Specialized terms relating to the field of vibration and shock and to the fields of psychoacoustics and bioacoustics are contained in Standards listed among the general references.

Definitions provided in this Standard are consistent with their counterparts in International Standards.

Terms defined in the previous edition of this Standard for the field of recording and reproducing sound are not provided in this edition because they are more properly the subject for other Standards.

2 General references

(1) ANSI/ASTM 634-79a, *American National Standard Definitions of Terms Relating to Environmental Acoustics.*

(2) ANSI/ASME Y10.11-1984, *Letter Symbols and Abbreviations for Quantities Used in Acoustics.*

(3) ANSI/IEEE Std 260-1978, *Standard Letter Symbols Used for Measurement.*

(4) ANSI S2.7-1982 (R1986), *American National Standard Balancing Terminology.*

(5) ANSI S2.9-1976 (R1990), *American National Standard Nomenclature for Specifying Damping Properties of Materials.*

(6) ANSI S2.31-1979 (R1986), *American National Standard Methods for the Experimental Determination of Mechanical Mobility–Part 1: Basic Definitions and Transducers.*

(7) ANSI S3.20-1973 (R1986), *American National Standard Psychoacoustical Terminology.*

(8) ANSI S3.32-1982 (R1990) *American National Standard Mechanical Vibration and Shock Affecting Man–Vocabulary.*

(9) ANSI S12.9-1988 (R 1993), *American National Standard Quantities and Procedures for Description and Measurement of Environmental Sound. Part 1.*

(10) IEV 50(801)(1984), *Acoustics and Electroacoustics.*

(11) ISO 2041-1990, *Vibration and Shock Vocabulary.*

3 General

3.01 sound. (a) Oscillation in pressure, stress, particle displacement, particle velocity, etc., in a medium with internal forces (e.g., elastic or viscous), or the superposition of such propagated oscillations. (b) Auditory sensation evoked by the oscillation described above.

NOTES

1 Not all sound waves evoke an auditory sensation; e.g., ultrasound or surface waves.

2 The medium in which the sound exists is often indicated by an appropriate adjective; e.g., air-borne, water-borne, or structure-borne.

3.02 acoustics. (a) Science of sound, including its production, transmission, and effects. (b) Those qualities of a room that together determine its character with respect to auditory effects.

3.03 acoustic, acoustical. Qualifying adjectives meaning 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.

NOTES

1 Examples that take *acoustic* are impedance, inertance, load (radiation field), output (sound power), energy, wave, medium, signal, conduit, absorptivity, and transducer.

2 Examples not having the requisite physical characteristics and therefore take *acoustical* are: society, method, engineer, school, glossary, symbol, problem,

measurement, point of view, end-use, device, and Standard.

3 Generic terms are usually modified by *acoustical*, whereas *acoustic* applies to terms with specific technical implication.

3.04 oscillation. Variation, usually with time, of the magnitude of a quantity with respect to a specified reference when the magnitude is alternately greater and smaller than the reference.

3.05 vibration. Oscillation of a parameter that defines the motion of a mechanical system.

3.06 periodic quantity. Oscillating quantity whose values recur for certain increments of the independent variable.

NOTES

1 If a periodic quantity v is a function of time t, then

$$v = f(t) = f(t+T),$$

where T, a constant, is a period of v.

2 In general, a periodic function can be expanded into a series of the form

$$y = A_0 + A_1 \sin(\omega t + a_1) + A_2 \sin(2\omega t + a_2) + \cdots,$$

where ω, a positive constant, equals 2π divided by the period T, and the A_1 and a_i are constants which may be positive, negative, or zero.

3.07 period. Smallest increment of an independent variable for which a function repeats itself.

3.08 cycle. Complete sequence of values of a periodic quantity that occur during a period.

3.09 frequency. For a function periodic in time, the reciprocal of the period. Unit, hertz (Hz).

3.10 angular frequency; circular frequency. Frequency of a periodic quantity multiplied by 2π. Unit, radian per unit time; symbol, ω.

3.11 basic frequency. For an oscillatory quantity having sinusoidal components with different frequencies, frequency of the component considered to be the most important.

NOTE–In a driven system, the basic frequency, in general, is the driving frequency; in a periodic oscillatory system, it is the fundamental frequency.

3.12 audio frequency. Frequency of a sound wave normally audible to humans. Unit, hertz (Hz).

NOTES

1 Audio frequencies range roughly from 15 Hz to 20 kHz.

2 The word "audio" may be used as a modifier to indicate a device or system intended to operate at audio frequencies, e.g., "audio amplifier."

3.13 ultrasonic frequency. Frequency higher than the nominal audio frequency range. Unit, hertz (Hz).

NOTE–The term "ultrasonic" may be used as a modifier to indicate a device or system intended to operate at an ultrasonic frequency.

3.14 infrasonic frequency. Frequency lower than the nominal audio frequency range. Unit, hertz (Hz).

NOTES

1 The term "infrasonic" may be used to indicate a device or system intended to operate at an infrasonic frequency.

2 The frequency range is often that between 1 Hz and 20 Hz when physiological effects are discussed.

3.15 peak-to-peak value. Algebraic difference between extremes of an oscillating quantity.

3.16 simple harmonic quantity. Periodic quantity that is a sinusoidal function of the independent variable. Thus

$$y = A \sin(\omega x + \phi),$$

where y is the simple harmonic quantity, A is the amplitude, ω is the angular frequency, and ϕ is the phase of the oscillation.

NOTE The maximum value of a simple harmonic quantity is amplitude A; it is sometimes called for emphasis the *single* amplitude to distinguish it from the *double* amplitude which for a simple harmonic quantity is the same as the total excursion or peak-to-peak value.

3.17 simple harmonic motion. Motion such that the displacement is a sinusoidal function of time.

3.18 phase of a periodic quantity. For a particular value of an independent variable, the fractional part of a period through which the independent variable has advanced, measured from an arbitrary reference.

NOTE–The arbitrary reference is generally so chosen as to be less than unity. In the case of a simple harmonic quantity, the reference is often taken as the last previous passage through zero amplitude from the negative to positive direction.

3.19 wave. Disturbance propagating in a given direction such that the quantity serving as a measure of the disturbance varies with position and time in a manner that at pairs of neighboring positions the disturbance is similar except for a time difference.

The velocity of propagation of the disturbance is equal to the distance between neighboring positions divided by the time difference.

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.

NOTE–See also 6.04 through 6.18.

3.20 wavelength. For a periodic wave in an isotropic medium, perpendicular distance between two wavefronts in which the displacements have a difference in phase of one complete period. Unit, meter (m).

3.21 wave number. (a) 2π divided by the wavelength of a periodic wave. (b) Angular frequency divided by speed of sound. Unit, reciprocal meter (1/m); symbol $k = \omega / c$.

3.22 harmonic. Sinusoidal quantity that has a frequency which is an integral multiple of the frequency of the periodic quantity to which it is related.

NOTE–See also 13.06.

3.23 subharmonic. Sinusoidal quantity having a frequency that is an integral submultiple of the fundamental frequency of a periodic quantity to which it is related.

NOTE–An integral submultiple is a rational fraction with a value less than unity and with integers for numerator and denominator.

3.24 signal. (a) Disturbance used to convey information. (b) Information to be conveyed over a communication system.

3.25 noise. (a) Undesired sound. By extension, noise is any unwarranted disturbance within a useful frequency band, such as undesired electric waves in a transmission channel or device. (b) Erratic, intermittent, or statistically random oscillation.

NOTES

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

2 Since definitions 3.25 (a) and (b) are not mutually exclusive, it is usually necessary to depend upon context for the distinction.

3.26 ambient noise. All-encompassing sound at a given place, usually a composite of sounds from many sources near and far.

3.27 background noise. 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.

NOTES

1 Ambient sound detected, measured, or recorded with the signal is part of the background noise.

2 Included in the definition of background noise is the interference resulting from primary electric power supplies, that separately is commonly described as *hum*.

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

NOTE–Random noise for which instantaneous magnitudes occur according to the Gaussian distribution is called "Gaussian random noise."

3.29 white noise. Noise for which the spectrum density (see 3.37) or spectrum level is independent of frequency over a specified range.

NOTE–White noise need not be random.

3.30 pink noise. Noise for which the spectrum density varies as the inverse of frequency.

3.31 reverberation. Sound that persists in an enclosed space, as a result of repeated reflection or scattering, after the sound source has stopped.

NOTE–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.

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

NOTE–See also 11.26.

3.33 modulation. Variation of some parameter characterizing a periodic oscillation. Thus amplitude modulation of a sinusoidal oscillation is a variation in the amplitude of the sinusoidal oscillation.

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

3.35 distortion. Undesired change of waveform.

Noise and certain desired changes in waveform, such as those resulting from modulation or detection, are not usually described as distortion.

3.36 spectrum. (a) Description, for a function of time, of the resolution of a signal into components, each of different frequency and (usually) different amplitude and phase. (b) "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.

3.37 spectrum density. Limit, as the bandwidth approaches zero, of the quotient of mean-square amplitude by bandwidth.

NOTES

1 In mathematical terms, the spectrum density function of an oscillation $y(t)$ is the ensemble average $G(f)$ where (when a limit exists)

$$G(f) = \lim_{T \to \infty} \left[1/T \left| \int_0^T y(t) e^{i2\pi ft} dt \right|^2 \right]$$

and f is frequency (positive only).

2 Spectrum density is the time-mean-square amplitude of the output of a filter that has unity gain in a finite frequency band; spectrum density is given by the integral of $G(f)$ with respect to frequency over the band.

3 The oscillatory function may be any time-dependent parameter, e.g., sound pressure, velocity, or acceleration of a component of a mechanical system. The unit of spectrum density is the square of the unit of the oscillatory function, divided by frequency. For example, the unit for acceleration spectral density is $(m/s^2)^2/Hz$.

3.38 power spectral density; power spectrum density. Limit, as the bandwidth approaches zero, of sound power divided by bandwidth. Unit, watt per hertz (W/Hz).

3.39 line spectrum. Spectrum whose components occur at a number of discrete frequencies.

3.40 pure tone. Line spectrum consisting of a signal at a single frequency.

NOTE–See also 13.02.

3.41 continuous spectrum. Spectrum of a wave for which the components are continuously distributed over a frequency region.

3.42 displacement. Vector quantity that specifies the change of position of a body or particle and usually measured from the mean position or position of rest. In general, displacement can be represented by a rotation vector or translation vector, or both. Units, meter (m), radian (rad).

3.43 velocity. Vector that specifies the time rate of change of displacement with respect to a reference frame. Unit, meter per second (m/s).

NOTE–If the reference frame is not inertial, the velocity is often designated "relative velocity."

3.44 acceleration. Vector that specifies the time rate of change of velocity. Unit, meter per second-squared (m/s^2).

NOTES

1 Various self-explanatory modifiers such as peak and time-mean-square are often used. The time interval should be indicated over which the mean (for example) was taken.

2 Acceleration may be (a) oscillatory, in which case it may be defined by acceleration amplitude (if simple harmonic) or the time-mean-square acceleration (if random), or (b) nonoscillatory, in which case it is designated "sustained" or "transient acceleration."

3.45 jerk. Vector that specifies the time rate of change of acceleration; jerk is the third derivative of displacement with respect to time. Unit, meter per second-cubed (m/s^3).

3.46 *g*. Acceleration produced by the force of gravity, which varies with the latitude and elevation of the point of observation. The international standard acceleration due to gravity is 9.806 650 $m/s^2 \approx 32.1739$ ft/s^2.

3.47 stiffness. Ratio of change of force (or torque) to the corresponding change in translational (or rotational) displacement of an elastic element. Unit, newton per meter (N/m).

NOTE–See also 7.30.

3.48 compliance. Reciprocal of stiffness. Unit, meter per newton (m/N).

NOTE–See also 7.31.

3.49 static pressure. Pressure that would exist at a point in the absence of a sound wave. Unit, pascal (Pa); symbol, p_s.

NOTE–One pascal is equal to one newton per square meter.

3.50 instantaneous sound pressure. Total instantaneous pressure at a point in a medium minus the static pressure at that point. Unit, pascal (Pa); symbol, *p*.

3.51 sound pressure amplitude. Absolute instantaneous pressure in any given cycle of a sound wave at some specified time. Unit, pascal (Pa).

3.52 peak sound pressure. Greatest absolute instantaneous sound pressure within a specified time interval. Unit, pascal (Pa).

NOTE–Peak sound pressure may be measured with a standard frequency weighting.

3.53 sound pressure; effective sound pressure. Root-mean-square instantaneous sound pressure at a point, during a given time interval. Unit, pascal (Pa).

NOTE–In the case of periodic sound pressures, the interval is an integral number of periods or an interval that is long compared to a period. In the case of non-periodic sound pressures, the interval should be long enough to make the measured sound pressures essentially independent of small changes in the duration of the interval.

3.54 sound exposure. Time integral of squared, instantaneous frequency-weighted sound pressure over a stated time interval or event. Unit: pascal-squared second; symbol, *E*.

NOTES

1 If frequency weighting is not specified, A-frequency weighting is understood. If other than A-frequency weighting is used, such as C-frequency weighting, an appropriate subscript should be added to the symbol; i.e., E_C.

2 Duration of integration is implicity included in the time integral and need not be reported explicitly. For the sound exposure measured over a specified time interval such as one hour, a 15-hour day, or a 9-hour night, the duration should be indicated by the abbreviation or letter symbol, for example one-hour sound exposure (1HSE or E_{1h}) for a particular hour; day sound exposure (DSE or E_d) from 0700 to 2200 hours; and night sound exposure (NSE or E_n) from 0000 to 0700 hours plus from 2200 to 2400 hours.

3 Day–night sound exposure (DNSE or E_{dn}) for a 24-hour day is the sum of the day sound exposure and ten times the night sound exposure.

4 Unless otherwise stated, the normal unit for sound exposure is the pascal-squared second.

3.55 particle velocity. In a sound field, the velocity caused by a sound wave of a given infinitesimal part of the medium, with reference to the medium as a whole. Unit, meter per second (m/s); symbol, *u*, *v*.

NOTE–The terms "instantaneous particle velocity," "effective particle velocity," "maximum particle velocity," and "peak particle velocity" have meanings that correspond with those of the related terms used for sound pressure.

3.56 wave velocity; propagation velocity. Vector quantity that specifies the speed and direction with which a sound wave passes through a medium. Unit, meter per second (m/s).

3.57 volume velocity. Rate of alternating flow of the medium through a specified surface as a result of a sound wave. Unit, cubic meter per second (m^3/s); symbols, *q*, *U*.

NOTE–Expressed mathematically, volume velocity *q* is

$$q = \int_S u \, d\sigma,$$

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

3.58 sound energy. Total energy in a given part of a medium minus the energy that would exist at that same part of the medium with no sound waves present. Unit, joule (J).

3.59 sound energy density. Sound energy contained in an infinitesimal part of a medium at a point in a sound field divided by a representative volume at that part of the medium. Unit, joule per cubic meter (J/m^3).

NOTES

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

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).

3.60 acoustic radiation pressure. Unidirectional, steady-state pressure exerted upon a surface exposed to an acoustic wave. Unit, pascal (Pa).

3.61 sound-energy flux. Time rate of flow of sound energy for one period through a specified area. Unit, watt (W); symbol, *J*.

NOTE–In a medium of density *p*, for a plane or spherical free wave having a velocity of propagation *c*, the sound energy flux through the area *S*, corresponding to a time-mean-square sound pressure p^2, is

$$J = (p^2 S \cos\theta)/\rho c,$$

where θ is the angle between the direction of propagation of the sound and the normal to area S.

3.62 sound intensity; sound-energy flux density; sound-power density. Average rate of sound energy transmitted in a specified direction at a point through a unit area normal to this direction at the point considered. Unit, watt per square meter (W/m²); symbol, I.

NOTES

1 Sound intensity in the specified direction is given by the expression

$$I = (1/T)\int_0^T pv\,dt,$$

where

T = time, which should be long compared with the reciprocal of the lowest frequency of interest;

p = instantaneous sound pressure;

v = component of instantaneous particle velocity in the specified direction; and

t = time.

2 In the case of a free plane or spherical wave having time-mean-square pressure p^2, velocity of propagation c, in a medium of density ρ, the intensity in the direction of propagation is given by

$$I = p^2/\rho c.$$

3.63 sound power. Sound energy radiated by a source per unit of time. Unit, watt (W); symbols, P or W.

3.64 efficiency. Ratio of the useful output of a physical quantity that may be stored, transferred, or transformed by a device to its total input.

NOTE–Unless specifically stated otherwise, the term "efficiency" means efficiency with respect to power.

3.65 sound absorption. Change in sound energy into some other form, usually heat, in passing through a medium or on striking a surface.

NOTE–See also 11.01.

3.66 damping. Dissipation of energy with time or distance. Respective unit, joule per second (J/s) or watt (W), or joule per meter (J/m).

3.67 relaxation time. Time taken by an exponentially decaying quantity to decrease in amplitude by a factor of $1/e \approx 0.3679$. Unit: second (s); symbol, τ.

3.68 simple sound source. Source that radiates sound uniformly in all directions under free-field conditions.

NOTE–See 6.06 for definition of free field.

3.69 strength of a sound source; strength of a simple source. Maximum instantaneous rate of volume displacement produced by a source when emitting a wave with sinusoidal time variation. Unit, cubic meter per second (m³/s).

NOTE–"Strength" is properly applicable only to sources of dimensions small with respect to the wavelength.

3.70 point source. Source that radiates sound as if from a single point.

3.71 excitation; stimulus. External force (or other input) applied to a system that causes the system to respond in some way.

3.72 response. Motion, or other output resulting from an excitation under specified conditions.

NOTES

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

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

3.73 nonlinear acoustics. Science of sound in which the amplitude of particle displacement is sufficiently large that linear approximations to the properties of the medium are no longer sufficient and thus require that higher order effects be considered.

4 Levels

4.01 level. In acoustics, logarithm of the ratio of a quantity to a reference quantity of the same kind. The base of the logarithm, the reference quantity, and the *kind* of level shall be specified.

NOTES

1 Examples of kinds of levels are electric-power level, sound-pressure-squared level, and voltage-squared level.

2 The unit of level as defined here is the logarithm of the reference ratio that is equal to the base of the logarithms.

3 A logarithm on the base the tenth root of ten is the

same as ten times the logarithm on the base ten.

4 For common logarithms on the base ten, the symbol for logarithm is "lg." For natural logarithms on the Napierian base e, the symbol is "ln."

5 In symbols,

$$L = \log_r(q/q_0),$$

where

L = level of kind determined by the kind of quantity under consideration;

r = base of logarithms and the reference ratio;

q = quantity under consideration;

q_0 = reference quantity of the same kind.

6 Differences between levels, ΔL, 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 divided out:

$$\Delta L = \log_r(q_1/q_0) - \log_r(q_2/q_0) = \log_r(q_1/q_2).$$

4.02 bel. Unit of level when the base of the logarithm is ten, and the quantities concerned are proportional to power. Unit symbol, B.

4.03 decibel. Unit of level when the base of the logarithm is the tenth root of ten, and the quantities concerned are proportional to power. Unit symbol, dB.

NOTE–Examples of quantities that qualify are power (in any form), sound pressure squared, particle velocity squared, sound intensity, sound-energy density, and 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, when no ambiguity results from so doing.

4.04 neper. Unit of level of a field quantity when the logarithm is on the Napierian base $e \approx 2.7183$. Also, unit level of a power-like quantity when the base of the logarithm is $e^2 \approx 7.389$.

NOTE–For level of a power-like quantity, one neper is approximately equal to 8.686 decibels.

4.05 frequency level. Logarithm of the ratio of a given frequency to a reference frequency. The base of the logarithm and reference frequency must be indicated.

NOTES

1 If the base of the logarithm is 2, the unit of frequency level is the octave. The reference frequency is approximately equal to 16.352 Hz for musical acoustics.

2 If the base of the logarithm is $2^{1/12}$, the unit of frequency level is the semitone. The reference frequency is approximately equal to 16.352 Hz for musical acoustics (see 13.12).

3 If the base of the logarithm is $10^{1/10}$, the reference frequency is 1 Hz. Unit symbol, N.

4.06 power level. Ten times the logarithm to the base ten of the ratio of a given power to a reference power. The reference power shall be indicated. Unit, decibel (dB).

NOTE–In sound recording a commonly used reference electric power is one milliwatt (1 mW).

4.07 sound power level. Ten times the logarithm to the base ten of the ratio of a given sound power in a stated frequency band, to the reference power of one picowatt (1 pW). Unit, decibel (dB); abbreviation, PWL; symbols, L_P or L_W.

4.08 sound pressure level. (a) Ten times the logarithm to the base ten of the ratio of the time-mean-square pressure of a sound, in a stated frequency band, to the square of the reference sound pressure in gases of 20 μPa. Unit, decibel (dB); abbreviation, SPL; symbol, L_p. (b) For sound in media other than gases, unless otherwise specified, reference sound pressure is one micropascal (1 μPa).

NOTE–A sound pressure level with reference to a pressure of 1 μPa is numerically 10 $\lg(20^2/1^2) \approx 26$ decibels greater than the sound pressure level for the same sound pressure but with reference to 20 μPa.

4.09 band pressure level. Sound pressure level for sound contained within a restricted frequency band. Unit, decibel (dB); abbreviation, BSPL; symbol, L_{pb}.

NOTE–A band may be identified by its nominal lower and upper band edge frequencies, or by its nominal midband frequency and nominal bandwidth. The nominal width of the band may be indicated by a prefactory modifier, e.g., octave-band sound pressure level, one-third-octave-band sound pressure level, or 50-Hz band level at 400 Hz.

4.10 spectrum density level; spectrum level. Level of the limit, as the width of the frequency band approaches zero, of the quotient of a specified quantity distributed within a frequency band, by the width of the band. The words "spectrum level" shall be preceded by a descriptive modifier. Unit, decibel (dB).

NOTE–For illustration, sound pressure spectrum level L_{ps} at the midband frequency is obtained practically by

$$L_{ps} = 10\ \mathrm{lg}[(p^2/\Delta f\,)/(p_0{}^2/\Delta_0 f\,)],$$

where p^2 is the time-mean-square sound pressure measured through a filter system, p_0 the reference sound pressure, Δf the nominal bandwidth of the filter system, $\Delta_0 f$ the reference bandwidth of 1 Hz. For computational purposes, with L_{pb} for the band pressure level observed through the filter, the above relation becomes

$$L_{pbs} = L_{pb} - 10\ \mathrm{lg}[\Delta f/\Delta_0 f].$$

4.11 sound level; weighted sound pressure level. Ten times the logarithm to the base ten of the ratio of A-weighted squared sound pressure to the squared reference sound pressure of 20 μPa, the squared sound pressure being obtained with fast (F) (125-ms) exponentially weighted time averaging. Alternatively, slow (S) (1000-ms) exponentially weighted time averaging may be specified; also C-frequency weighting. Unit, decibel (dB); symbol L_A, L_C.

NOTES

1 In symbols, A-weighted sound level $L_{A\tau}(t)$ at running time t is

$$L_{A\tau}(t) = 10\ \mathrm{lg}\left\{\left[(1/\tau)\int_{-\infty}^{t} p_A{}^2(\xi)^{-(t-\xi)/\tau}\mathrm{d}\xi\right] \Big/ p_0{}^2\right\},$$

where τ is the exponential time constant in seconds, ξ is a dummy variable of integration, $p_A{}^2(\xi)$ is the squared, instantaneous, time-varying, A-weighted sound pressure in pascals, and p_0 is the reference sound pressure of 20 μPa. Division by time constant τ yields the running time average of the exponential-time-weighted, squared sound-pressure signal. Initiation of the running time average from some time in the past is indicated by $-\infty$ for the beginning of the integral.

2 ANSI S1.4-1983, *American National Standard Specification for Sound Level Meters*, gives standard frequency weightings A and C and standard exponential time weightings fast (F) and slow (S).

4.12 maximum sound level; maximum frequency-weighted sound pressure level. Greatest fast (125-ms) A-weighted sound level, within a stated time interval. Alternatively, slow (1000 ms) time weighting and C frequency weighting may be specified. Unit, decibel (dB); abbreviation, MXFA; symbol, L_{AFmx} (or C and S).

4.13 peak sound pressure level; peak frequency-weighted sound pressure level. Level of peak sound pressure with stated frequency weighting, within a stated time interval. Unit, decibel (dB), example abbreviation, PKA; symbol, L_{Apk}.

4.14 time-average sound level; time-interval equivalent continuous sound level; time-interval equivalent continuous A-weighted sound pressure level; equivalent continuous sound level. Ten times the logarithm to the base ten of the ratio of time-mean-square instantaneous A-weighted sound pressure, during a stated time interval T, to the square of the standard reference sound pressure. Unit, decibel (dB); respective abbreviations. TAV and TEQ; respective symbols, L_{AT} and L_{AeqT}.

NOTES

1 A frequency weighting other than the standard A-weighting may be employed if specified explicitly. The frequency weighting that is essentially constant between limits specified by a manufacturer is called flat.

2 In symbols, time-average (time-interval equivalent continuous) A-weighted sound level in decibels is

$$L_{AT} = 10\ \mathrm{lg}\left\{(1/T)\int_{\theta}^{T} p_A^2(t)\mathrm{d}t \Big/ p_0^2\right\},$$
$$= L_{AeqT},$$

where p_A^2 is the squared instantaneous A-weighted sound pressure signal, a function of elapsed time t; in gases reference sound pressure p_0 = 20 μPa; T is a stated time interval.

3 In principle, the sound pressure signal is not exponentially time-weighted, either before or after squaring.

4.15 one-hour average sound level. Time-average sound level during a time period of one hour. Unit, decibel (dB); abbreviation, 1HL; symbol, L_{1h}.

NOTE–One-hour average sound level in decibels is related to the corresponding one-hour sound exposure level, L_{E1h}, according to

$$L_{1h} = L_{E1h} - 10\ \mathrm{lg}(3600/1),$$

where 3600 is the number of seconds in one hour, 1 s is the reference duration for sound exposure, and sound exposure E is in pascal-squared seconds.

4.16 day average sound level. Time-average sound level between 0700 and 2200 hours. Unit, decibel (dB); abbreviation, DL; symbol, L_d.

NOTE–Day average sound level in decibels is related to the corresponding day sound exposure level, L_{Ed}, according to

$$L_d = L_{Ed} - 10\ \mathrm{lg}(54\,000/1),$$

where 54 000 is the number of seconds in a 15-hour day.

4.17 night average sound level. Time-average sound level between 0000 and 0700 hours and

52200–2400 hours. Unit, decibel (dB); abbreviation, NL; symbol, L_n.

NOTE–Night average sound level in decibels is related to the corresponding night sound exposure level, L_{En}, according to

$$L_n = L_{En} - 10\ \lg(32\,400/1),$$

where 32 400 is the number of seconds in a 9-hour night.

4.18 day–night average sound level. Twenty-four hour average sound level for a given day, after addition of 10 decibels to levels from midnight to 0700 hours and from 2200 hours (10 p.m.) to midnight. Unit, decibel (dB); abbreviation, DNL; symbol, L_{dn}.

NOTES

1 Day–night average sound level in decibels is related to the corresponding day–night sound exposure level, L_{Edn}, according to

$$L_{dn} = L_{Edn} - 10\ \lg(86\,400/1),$$

where 86 400 is the number of seconds in a 24-hour day.

2 A-frequency weighting is understood, unless another frequency weighting is specified explicitly.

4.19 community noise equivalent level. Twenty-four hour average A-weighted sound level for a given day, after addition of five decibels to sound levels from 1900 hours (7 p.m.) to 2200 hours (10 p.m.), and after addition of ten decibels to sound levels from midnight to 0700 hours and from 2200 hours to midnight. Unit, decibel (dB); abbreviation, CNEL; symbol L_{den}.

4.20 normalized 8-hour average sound level. Level of time-mean-square, A-weighted sound pressure during a normalization period T_n of eight hours, such that the sound exposure therefrom is equal to the sound exposure of a time-varying sound at a place where total sound exposure occurs within a time period not necessarily eight hours. Unit, decibel (dB); abbreviation, N8hL; symbol, L_{A8hn}.

4.21 sound exposure level. Ten times the logarithm to the base ten of the ratio of a given time integral of squared instantaneous A-weighted sound pressure, over a stated time interval or event, to the product of the squared reference sound pressure of 20 micropascals and reference duration of one second. The frequency weighting and reference sound exposure may be otherwise if stated explicitly. Unit, decibel (dB); abbreviation, ASEL; symbol, L_{AE}.

NOTE–In symbols, (A-weighted) sound exposure level is

$$\begin{aligned} L_{AE} &= 10\ \lg\left\{\left[\int_0^T p_A^2(t)\mathrm{d}t\right] \Big/ p_0^2 t_0\right\} \\ &= 10\ \lg(E/E_0) \\ &= L_{AT} + 10\ \lg(T/t_0), \end{aligned}$$

where p_A^2 is the squared instantaneous A-weighted sound pressure, a function of time t; for gases $p_0 = 20\ \mu\text{Pa}$; $t_0 = 1$ s; E is sound exposure; $E_0 = p_0^2 t_0 = (20\ \mu\text{Pa})^2\text{s}$ is reference sound exposure.

4.22 particle velocity level. Ten times the logarithm to the base ten of the ratio of the time-mean-square particle velocity of a given sound or vibration to the square of a specified reference particle velocity. Unit, decibel (dB); symbol, L_v.

NOTE–Clause A.1 of ANSI S1.8-1989 notes that a reference particle velocity of 10 nanometer per second (10 nm/s) is used in ANSI S1.8-1969, in contrast with 1 nm/s preferred by ISO 1683-1983. It is particularly important to state the reference particle velocity when describing velocity levels.

4.23 (vibratory) acceleration level. Ten times the logarithm to the base ten of the ratio of a time-mean-square vibratory acceleration to the square of a specified reference acceleration. Unit, decibel (dB); symbol, L_a.

NOTES

1 Clause A.2 of ANSI S1.8-1989 notes that a reference acceleration of 10 micrometer per second squared (10 μm/s^2) is used in ANSI S1.8-1969, in contrast with 1 μm/s^2 preferred by ISO1683-1983. It is particularly important to state the reference acceleration when describing acceleration levels.

2 The numerical value of a given acceleration level is 20 dB less if based on 10 μm/s^2 than if based on 1 μm/s^2. Reference acceleration of 10 μm/s^2 is within 2% of a millionth of the international standard acceleration for free fall, g = 9.806 650 m/s^2.

4.24 sound intensity level. Ten times the logarithm to the base ten of the ratio of the intensity of a given sound in a stated direction to the reference sound intensity of 1 picowatt per square meter (1 pW/m^2). Unit, decibel (dB); abbreviation, IL; symbol, L_I.

4.25 (vibratory) force level. Ten times the logarithm to the base ten of a time-mean-square force to the square of the reference force of 1 micronewton (1 μN). Unit, decibel (dB); symbol, L_F.

Table 5.1 – Resonance relations

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

$$M\, d^2x/dt^2 + R\, dx/dt + Sx = A \cos \omega t,$$

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	$(1/2\pi)[S/M]^{1/2}$	$(1/2\pi)[(S/M)-(R^2/2M^2)]^{1/2}$	$(1/2\pi)[(S/M)-(R/2M)^2]^{1/2}$
Amplitude of Displacement	$A/[R(S/M)^{1/2}]$	$A/R[(S/M)-(R/2M)^2]^{1/2}$	$A/R[(S/M)-3(R/M)^2/16]^{1/2}$
Amplitude of Velocity	A/R	$A/R[1+R^2/(4MS-2R^2)]^{1/2}$	$A/R[1+R^2/(16MS-4R^2)]^{1/2}$
Phase of Displacement (Applied Force)	$\pi/2$	$\tan^{-1}[4MS/R^2-2]^{1/2}$	$\tan^{-1}[16MS/R^2-4]^{1/2}$

For values of R small compared to $(MS)^{1/2}$, there is little difference among the three cases discussed above. The frequency at velocity resonance is equal to the undamped natural frequency of the system.

5 Oscillation, vibration, and shock

5.01 forced oscillation; forced vibration. Response of a system caused by external excitation. If the response is periodic and continuing, the oscillation is steady-state.

5.02 free oscillation. Phenomenon that occurs in a system when it oscillates in the absence of forced oscillation.

5.03 self-induced vibration; self-excited vibration. Phenomenon that results within a system from conversion of nonoscillatory excitation to oscillatory excitation.

5.04 resonance. Phenomenon that exists for a system in forced oscillation when any change in the frequency of excitation results in a decrease in the response of the system.

NOTE–Velocity resonance, for example, may occur at a frequency different from that of displacement resonance; see Table 5.1.

5.05 resonance frequency. Frequency at which resonance exists. Unit, hertz (Hz).

NOTES

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

2 See Table 5.1 for resonance frequency equations for several types of resonance conditions.

5.06 Q ; quality factor. Measure of the sharpness of resonance or frequency selectivity of a resonant vibratory system having a single degree-of-freedom.

NOTE–In a mechanical system quality factor Q is equal to one-half the reciprocal of the damping ratio (see 5.31). It is commonly used only with reference to a lightly damped system, and is then approximately equal to the following:

(1) Transmissibility at resonance (see 5.28);

(2) π/δ where δ is the logarithmic decrement (see 5.30);

(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 frequency and Δf is the bandwidth between the half-power points; and

(5) $\omega M/R$ where M is mass and R is resistance.

5.07 critical speed. Speed of a rotating system that corresponds to a resonance frequency of a system.

5.08 antiresonance. Phenomenom that exists at a point for a system in forced oscillation when any change, however small, in the frequency of excitation causes an increase in the response.

NOTE–An *antiresonance frequency* is a frequency at which antiresonance occurs.

5.09 natural frequency. Frequency of free oscillation for a system. For a multiple-degree-of-freedom system, the natural frequencies are the frequencies of the normal modes of vibration. Unit, hertz (Hz).

5.10 undamped natural frequency. Frequency of free vibration resulting from only elastic and inertial forces of the system. Unit, hertz (Hz).

NOTE–For the equation of motion treated in Table 5.1, the undamped natural frequency is $(1/2\pi)(S/M)^{1/2}$. At this frequency the motion of the mass M lags the disturbing force by a phase angle of 90 degrees. For a more complicated system having several degrees of freedom, there will be as many frequencies at which the motion of the mass lags the disturbing force by a phase angle of 90 degrees as there are degrees of freedom; these are all undamped natural frequencies.

5.11 damped natural frequency. Frequency of free vibration of a damped linear system. Unit, hertz (Hz).

NOTE–Oscillation of a damped system may be considered periodic (see 3.06) in the limited sense that the time interval between zero crossings in the same direction is constant, even though successive amplitudes decrease progressively. The frequency of the oscillation is the reciprocal of this time interval. See Table 5.1 for examples.

5.12 mechanical system. Aggregate of matter comprising a defined configuration of mass, mechanical stiffness, and mechanical resistance.

5.13 equivalent system. One that may be substituted for another system for the purposes of analysis.

NOTE–Many types of equivalence are common in vibration and shock technology: (1) equivalent stiffness; (2) equivalent damping; (3) torsional system equivalent to a translational system; (4) electrical or acoustical system equivalent to a mechanical system; etc.

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

5.15 single-degree-of-freedom system. System which requires only one coordinate to define completely the configuration of the system at any instant.

5.16 multiple-degree-of-freedom system. System which requires two or more coordinates to define completely the position of the system at any instant.

5.17 continuous system; distributed system. System considered to have an infinite number of possible independent displacements. The configuration is specified by a function of a continuous spatial variable or variables, in contrast to a discrete or lumped-parameter system which requires only a finite number of coordinates to specify its configuration.

5.18 mode of vibration. Characteristic pattern assumed by a system undergoing vibration in which the motion of every particle is simple harmonic with the same frequency. Two or more modes may exist concurrently in a multiple-degree-of-freedom system.

5.19 normal mode of vibration. Mode of free vibration of an undamped system. In general, any composite motion of the system can be analyzed in terms of a summation of normal modes.

NOTES

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 inward in the negative direction, and conversely.

2 Vibration in a normal mode occurs at a natural frequency of the system.

3 The terms "natural mode," "characteristic mode," and "eigenmode" are synonymous with normal mode.

5.20 fundamental mode of vibration. Vibration of a system at the lowest natural frequency.

5.21 fundamental frequency. (a) For a periodic quantity, frequency of a sinusoidal quantity that has the same period as the periodic quantity. (b) Lowest natural frequency of an oscillating system.

5.22 modal numbers. Set of integers by which the normal modes of a system are ordered with respect to frequency.

5.23 coupled modes. Modes of vibration that are not independent but which influence one another because of energy transfer from one mode to the other.

5.24 uncoupled mode. Mode of a system that can exist concurrently with and independently of other modes.

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

5.26 vibration isolator. Resilient support that tends to isolate a system from steady-state excitation.

NOTE–See also 11.62.

5.27 dynamic vibration absorber; tuned damper. Device for reducing vibration of a primary system by the transfer of energy to an auxiliary 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.

5.28 transmissibility. 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.

5.29 subharmonic response. Periodic response of a mechanical system exhibiting the characteristic of resonance at a frequency that is a submultiple of the frequency of the periodic excitation.

5.30 logarithmic decrement. Natural logarithm (base *e*) of the ratio of any two successive amplitudes of like sign, in the decay of a single-frequency oscillation.

5.31 damping ratio. For a system with viscous damping, the ratio of viscous damping to critical damping, as defined in 5.33 and 5.35, respectively.

5.32 Coulomb damping; dry friction damping. Dissipation of energy that occurs when the motion of a particle in a vibrating system is resisted by a force whose magnitude is constant and independent of displacement and velocity, and whose direction is opposite to the direction of the velocity of the particle.

5.33 viscous damping. Dissipation of energy that occurs when the motion of a particle in a vibrating system is resisted by a force that has magnitude proportional to the magnitude of the velocity of the particle and direction opposite to the direction of the particle.

5.34 equivalent viscous damping. Value of viscous damping assumed for the purpose of analysis of a vibratory motion, such that the dissipation of energy per cycle at resonance is the same for either the assumed or actual damping force.

5.35 critical damping. Minimum viscous damping that will allow a displaced system to return to its initial position without oscillation.

5.36 nonlinear damping. Damping resulting from a damping force that is not proportional to velocity.

5.37 steady-state vibration. Vibration in a system when the velocity of each particle is a continuing periodic quantity.

5.38 transient vibration. Temporarily sustained vibration of a mechanical system, consisting of forced or free vibration, or both.

5.39 foundation. Structure that supports the gravity load of a system. It may be fixed in space or it may undergo a motion that provides excitation for the supported system.

5.40 applied shock. Excitation that, if applied to a system, would produce mechanical shock. The excitation may be either a force applied to the system or a motion of its support.

5.41 mechanical shock. Motion that occurs when the position of a system is significantly changed in a relatively short time and in a nonperiodic manner. Mechanical shock is characterized by suddenness and large displacements resulting in significant internal forces in the system.

5.42 velocity shock. Mechanical shock resulting from a nonoscillatory change in the velocity of an entire system.

5.43 snubber. Device used to increase the stiffness of an elastic system (usually by a large factor) whenever the displacement becomes larger than a specified amount.

5.44 shock absorber. Device for the dissipation of energy to modify the response of a mechanical system to an applied shock.

5.45 shock isolator; shock mount. Resilient support that tends to isolate a system from applied shock.

5.46 shock spectrum. Maximum acceleration experienced by a single-degree-of-freedom system as a function of its own natural frequency in response to an applied shock.

5.47 shock pulse. Substantial disturbance characterized by rise and decay of acceleration in a short period of time. Shock pulses are normally displayed as acceleration as a function of time.

5.48 duration of shock pulse. Time required for the acceleration of a pulse to rise from some stated fraction of the maximum amplitude and decay to the same value.

5.49 pulse rise time. 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.

5.50 impulse. Product of a force and the time during which the force is applied; more specifically, impulse is the time integral of force from an initial time to a final time, the force being time dependent and equal to zero before the initial time and after the final time.

5.51 impact. Single collision of one mass in motion with a second mass which may be in motion or at rest.

5.52 shock machine. Device for subjecting a system to controlled and reproducible mechanical shock.

6 Transmission and propagation

6.01 acoustic transmission system. Assembly of elements adapted to the transmission of sound.

6.02 mechanical transmission system. Assembly of mass, mechanical stiffness, and mechanical resistance, adapted to the transmission of mechanical power.

6.03 sound field. Region containing sound waves.

6.04 wavefront. (a) For a progressive wave in space, continuous surface that is a locus of points having the same phase at a given instant. (b) For a surface wave, continuous line that is a locus of points having the same phase at a given instant.

6.05 free progressive wave; free wave. Wave in a medium free from boundary effects.

NOTE–A free wave in a steady state can only be approximated in practice.

6.06 free sound field; free field. Field in a homogeneous, isotropic medium free from boundaries. In practice, the effects of boundaries on a free field are negligible over the region of interest.

NOTE–The actual pressure impinging on an object (e.g., an electro acoustic 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.

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

NOTES

1 Mathematically, a compressional wave is one whose velocity field has zero curl.

2 A compressional wave is a longitudinal wave.

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

6.09 shear wave; rotational wave. Wave in an elastic medium which causes an element of the medium to change its shape without a change in volume.

NOTES

1 Mathematically, a shear wave is one whose velocity field has zero divergence.

2 A shear wave in an isotropic medium is a transverse wave.

3 When shear waves combine to produce standing waves, linear displacements may result.

6.10 transverse wave. Wave in which the direction of displacement at each point of the medium is parallel to the wavefront.

6.11 bending wave. In a plate or bar, transverse wave which is a combination of compressional and rotational waves.

6.12 plane wave. Wave in which the wavefronts are everywhere parallel planes normal to the direction of propagation.

6.13 spherical wave. Wave in which the wavefronts are concentric spheres.

6.14 cylindrical wave. Wave in which the wavefronts are coaxial cylinders.

6.15 plane polarized sound wave; linearly polarized sound wave. Transverse wave, at a point in an elastic medium, in which the displacements at all times lie in a fixed plane which is parallel to the direction of propagation.

NOTE–In a plane polarized sound wave, the displacement vector at any point lies in a fixed straight line passing through the point.

6.16 elliptically polarized sound wave. Transverse wave in an elastic medium in which the displacement vector at any point rotates about the point, and has a magnitude which varies as the radius vector of an ellipse.

NOTE–An elliptically polarized wave is equivalent to two superposed plane polarized waves of simple sinusoidal form, with unequal amplitude, in which the displacements lie in perpendicular planes and are displaced in phase by $\pi/2$ radians.

6.17 circularly polarized sound wave. Transverse wave in an elastic medium in which the displacement vector at any point rotates about the point with constant angular velocity and constant magnitude.

NOTE–A circularly polarized wave is equivalent to two superposed plane polarized waves of sinusoidal form in which the displacements have the same amplitude, lie in perpendicular planes, and are displaced in phase by $\pi/2$ radians.

6.18 Rayleigh wave. 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 of the Rayleigh wave diminishes exponentially with depth into the solid.

6.19 wave interference. 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.

6.20 standing wave. 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.

6.21 stationary wave. Standing wave in which the net energy flux is zero at all points.

NOTE–Stationary waves can only be approximated in practice.

6.22 node. 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 word "node" to signify the type that is intended; e.g., displacement node, velocity node, pressure node.

6.23 antinode; loop. Point, line, or surface in a standing wave where some characteristic of the wave field has maximum amplitude.

NOTE–An appropriate modifier should be used before the word "antinode" to signify the type that is intended; e.g., displacement antinode, velocity antinode, pressure antinode.

6.24 partial node. Point, line, or surface in a standing wave system where some characteristic of the wave field has a minimum amplitude differing from zero.

NOTE–An appropriate modifier should be used before the words "partial node" to signify the type that is intended; e.g., displacement partial node, velocity partial node, pressure partial node.

6.25 speed of sound. Rate of change of particle displacement with distance for a sound wave. Unit, meter per second (m/s); symbol, c.

NOTE–In general, the speed of sound for waves of infinitesimal amplitude is equal to the square root of the quotient of an elastic quantity appropriate to a medium by its density. For sound in air the elastic constant is the product of the ratio of specific heats at constant pressure and constant volume, γ, and static pressure, P_0. At a temperature of 15 °C the speed of sound in air at sea level is approximately 341 m/s, and is proportional to the square root of absolute temperature.

6.26 Doppler effect. 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–Doppler effect is described quantitatively by

$$f_r \simeq f_s\,(1+v_r/c)/(1-v_s/c)$$

where

f_r = observed frequency;

f_s = frequency at source;

v_r = component of velocity (relative to the medium) of observation point towards source;

v_s = component of velocity (relative to the medium) of source toward observation point;

c = speed of sound in a stationary medium.

6.27 Doppler shift. Change in the observed frequency of a wave due to the Doppler effect. Unit, hertz (Hz).

6.28 acoustic propagation constant. Natural logarithm of the complex ratio of the steady-state particle velocities, volume velocities, or pressures at two points separated by unit distance in a uniform system (assumed to be of infinite length), or at two successive corresponding points in a 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.

6.29 acoustic attenuation constant. Real part of the acoustic propagation constant. Unit, neper per section or per unit distance.

6.30 acoustic phase constant. Imaginary part of the acoustic propagation constant. Unit, radian per section or per unit distance.

6.31 phase velocity. Velocity in the direction of propagation of a surface of constant phase. Unit, m/s; symbol, v_p.

NOTE–For a periodic wave, $v_p = \omega/k$ where ω is angular frequency and k is wave number.

6.32 group velocity. Velocity of propagation of the crest of a group of interfering waves where the component wave trains have slightly different individual frequencies and phase velocities. Unit, m/s; symbol, v_g.

NOTE–In symbols, group velocity is the rate of change of angular frequency with respect to wave number: $v_g = d\omega/dk$.

6.33 transmission loss. Reduction in magnitude of some characteristic of a signal between two stated points in a transmission system.

NOTES

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, since the levels are expressed in decibels, transmission loss is likewise in decibels.

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

3 See 11.42 for transmission loss in architectural acoustics.

6.34 signal transmission level. Signal level (of a kind to be specified) at a designated point in the transmission system. Unit, decibel (dB).

NOTES

1 Signal level at some specified position near the source may be taken as the zero reference level.

2 In an acoustical system the signal level is often a sound pressure level; either the reference sound pressure or in this case the reference sound pressure level must be a specified.

6.35 absorption loss. That part of the transmission loss caused by dissipation or conversion of sound energy into other forms of energy (e.g., heat) either within the medium or attendant upon reflection.

6.36 divergence loss. That part of the transmission loss resulting from divergence of sound waves in accordance with the geometry of the system (e.g., spherical waves emitted by a point source).

NOTE–For spherical waves, squared sound pressure varies inversely as the square of distance from the source; for cylindrical waves, squared sound pressure varies inversely as distance from the source.

6.37 refraction loss. That part of the transmission loss due to refraction resulting from nonuniformity of the medium.

NOTE–See also 9.21.

6.38 scattering loss. That part of the transmission loss caused by scattering within the medium or due to roughness of a reflective surface.

6.39 acoustic streaming. Name given to unidirectional flow in a fluid caused by the presence of sound waves.

6.40 acoustic dispersion. Change of speed of sound with frequency. Unit, meter per second per Hz (m/s)/Hz.

6.41 acoustic refraction. Process by which the direction of sound propagation is changed by spatial variation of the speed of sound in the medium.

6.42 specular reflection. Phenomenon by which a sound wave is returned by a surface separating two media at an angle from the normal equal to the angle of incidence.

6.43 diffraction. Process that produces a diffracted wave.

6.44 diffracted wave. Wave whose front has been changed in direction by an obstacle or other nonhomogeneity in a medium, other than by reflection or refraction.

6.45 acoustic scattering. Irregular reflection, refraction, or diffraction of sound in many directions.

6.46 scattering cross section. Of an object, an area equal to 4π times the product of the square of a unit radius and the time-mean-square sound pressure scattered by the object, averaged over a sphere of 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, meter squared (m^2).

NOTES

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

$$\sigma = 4\pi p_s^2 r_0^2 / p_i^2.$$

2 Measurements of scattering cross section should be made at a distance sufficiently great that the sound appears to be scattered from a single point called the acoustical center.

6.47 backscattering cross section. Of an object, an area equal to 4π times the product of the square of a unit radius and the mean-square time average of the sound pressure scattered by the object, back in the direction from which the sound has come as observed at unit radius from the acoustic center of the object, divided by the mean-square time average 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, meter squared (m^2).

NOTES

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 radius, and p_i^2 the square of the incident sound pressure,

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

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

6.48 scattering differential. 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 scattering object exceeds the plane-wave free-field pressure level of the sound incident upon the object. The scattering differential of an object is 10 times the logarithm to the base 10 of the ratio of the scattering cross section to the surface area of the sphere of unit radius surrounding the object.

NOTES

1 In symbols, if Δ is the scattering differential, and the other symbols are those of 6.46:

$$\Delta = 10 \lg(\sigma/4\pi r_0^2) = 10 \lg(p_s^2/p_i^2).$$

2 The scattering differential is an average for all directions. The backscattering differential (see 9.05) or the scattering differential for any other specified direction is similarly defined. For a perfectly scattering sphere the scattering differential is equal to the backscattering differential.

3 If the scattering differential is a function of frequency or pulse duration of the incident sound or of the orientation of the object, these factors should be specified.

7 Transducers and linear systems

7.00 linear system. System in which, for every element in the system, the response is proportional to the excitation.

NOTE–The time-dependent properties of each element of a linear system can be represented by a set of linear differential equations with constant coefficients.

7.01 acoustical system. System capable of receiving, transmitting, or generating acoustic signals.

7.02 mechanical system. System capable of generating, transmitting, or receiving mechanical signals.

7.03 complex parameter. Complex quantity representing a real quantity that varies sinusoidally with time (such as sound pressure, vibratory velocity, voltage), or the ratio of two such quantities of the same frequency, which can be expressed in the form $(a+jb)$ with real part a and imaginary part b, or as a phasor $Ae^{j\theta}$ with modulus A and argument θ.

NOTES

1 Throughout this section, all parameters (mechanical, acoustical, or electrical) are considered to be complex, unless specified otherwise.

2 The convention of $+j = (-1)^{1/2}$ is observed here, whereby a positive-going sinusoidal wave is represented by $\mathrm{Re}[e^{j(\omega t-kx)}]$, mass reactance by $+j\omega M$, stiffness reactance by $-jS/\omega$; with wave number $k = \omega/c$, angular frequency ω, speed of sound c; mass M; stiffness S.

7.04 transducer. Device designed to receive an input signal of a given kind and to provide an output signal of a different kind, in such a manner that desired characteristics of the input signal appear in the output signal.

7.05 passive transducer. Transducer such that the energy of the output signal is derived exclusively from the input signal.

NOTE–A microphone or hydrophone with an accompanying preamplifier is a form of passive transducer.

7.06 active transducer. Transducer such that the energy of the output signal is derived at least in part from sources other than the input signal.

7.07 reversible transducer. Transducer capable of transforming an electric signal into an acoustic or mechanical signal, and the converse.

7.08 reciprocal transducer. Linear, passive, reversible electromechanical or electroacoustic transducer such that coupling is equal for transduction in either direction.

7.09 transfer function. For a linear system, quotient of the Fourier or Laplace transform of an ouptut signal by the same transform of the input signal, with all initial conditions zero.

7.10 sensitivity. Quotient of a specified quantity describing the output signal of a transducer by another specified quantity describing the corresponding input signal.

7.11 relative sensitivity. Ratio of the sensitivity of a transducer under a particular condition to a stated reference sensitivity of the same kind.

7.12 sensitivity level. Of a transducer, output level of stated kind minus the input level of stated kind that caused the output level. Unit, decibel (dB).

7.13 impedance. At a specified frequency, quotient of a dynamic field quantity (e.g., force, sound pressure) by a kinematic field quantity (e.g., vibration velocity, particle velocity), or quotient of a voltage by a current.

NOTES

1 The term impedance is normally applied to a linear system and to steady sinusoidal signals.

2 In the case of a transient, impedance as a function of frequency is the ratio of the respective Fourier or Laplace transforms.

7.14 conjugate impedances. Impedances whose real components (resistances) are equal and whose imaginary components (reactances) are equal but of opposite sign.

NOTE–Conjugate impedances are expressed by conjugate complex quantities.

7.15 admittance. Reciprocal of impedance.

7.16 immittance. A general term denoting either impedance or admittance.

NOTE–Use of immittance in electroacoustics is strongly deprecated.

7.17 driving point impedance. Quotient of a dynamic field quantity (e.g., force, sound pressure) at one point in a system by the resulting kinematic field quantity (e.g., vibration velocity or particle velocity) at the same point.

7.18 transfer impedance. Quotient of a dynamic field quantity at one point in a system by the resulting kinematic field quantity at a different point.

7.19 short-circuit impedance. For a transducer which converts a mechanical or acoustic signal into an electric signal, input impedance of stated kind—mechanical or acoustic—when the output is connected to a load of zero impedance (i.e., short-circuit). Unit, newton second per meter (N·s/m).

7.20 free impedance. For a transducer which converts an electric signal into a mechanical or acoustic signal, input impedance when the output is connected to a load of zero impedance.

7.21 loaded impedance. For a transducer, input impedance of stated kind, electric, mechanical or acoustic, when the output is connected to a stated load.

7.22 open-circuit impedance. For a transducer which converts a mechanical or an acoustic signal into an electric signal, input impedance—mechanical or acoustic—when the output is connected to a load of infinite impedance (i.e., open circuit). Unit, newton per meter second [N/(m/s)] or pascal per cubic meter second [Pa/(m^3/s)], respectively.

7.23 blocked impedance. For a transducer that converts an electric signal into a mechanical or an acoustic signal, input impedance when the output is connected to a load of infinite impedance.

7.24 motional impedance. Of a transducer, loaded electric impedance minus the electric impedance when mechanically blocked (open circuit).

NOTE–This definition is best applied to transducers with gyroscopic (antireciprocal) coupling.

7.25 motional admittance. Of a transducer, the loaded electric admittance minus the electric admittance when mechanically blocked.

NOTE–This definition is best applied to transducers with transformer coupling.

7.26 mechanical impedance (at a point). In a linear mechanical system, quotient of a force applied at a point by the resulting component of velocity in the direction of the force. Unit, newton per (meter per second) [N/(m/s)].

NOTE–In the case of torsional mechanical impedance the terms "force" and "velocity" are replaced by "torque" and "angular velocity."

7.27 mechanical resistance. Real part of a mechanical impedance. Unit, newton per (meter per second) [N/(m/s)].

7.28 mechanical reactance. Imaginary part of a mechanical impedance. Unit, newton per (meter per second) [N/(m/s)].

7.29 apparent mass. Quotient of force by the resulting in-phase acceleration during sinusoidal motion. Unit, kilogram (kg).

7.30 stiffness. In a system in which friction and inertia are negligible during sinusoidal motion, quotient of force at a point by the in-phase displacement at the point, caused by the force. Unit, newton per meter (N/m).

NOTE–In the case of torsional stiffness, "force" and "displacement," respectively, are replaced by "torque" and "angular displacement."

7.31 compliance. Reciprocal of stiffness. Unit, meter per newton (m/N).

NOTE–See also 3.48.

7.32 electromechanical transducer. Transducer designed to receive an electric input signal and to furnish a mechanical output signal, or vice versa.

7.33 specific acoustic impedance. At a point in a sound field, quotient of sound pressure by particle velocity. Unit, pascal per (meter per second) [Pa/(m/s)].

7.34 specific acoustic resistance. Real part of the specific acoustic impedance.

7.35 specific acoustic reactance. Imaginary component of the specific acoustic impedance.

7.36 specific acoustic admittance. Reciprocal of the specific acoustic impedance. Unit, (meter per second) pascal [(m/s)/Pa].

NOTE–The real part of specific acoustic admittance is specific acoustic conductance, the imaginary part is specific acoustic susceptance.

7.37 characteristic impedance. Product of the equilibrium density and speed of sound in a medium. Unit, pascal per (meter per second) [Pa/(m/s)].

7.38 acoustic impedance. At a specified surface, complex quotient of acoustic pressure by volume velocity through the surface. Unit, pascal per (cubic per meter second) [Pa/(m^3/s)].

NOTE–Pascal per cubic meter second (pascal second per cubic meter) is also called an acoustic ohm.

7.39 acoustic resistance. Real part of acoustic impedance.

7.40 acoustic reactance. Imaginary part of acoustic impedance.

7.41 acoustic mass; inertance. At a frequency for which inertia is dominant, quotient of sound pressure by the resulting in-phase volume acceleration during sinusoidal motion. Unit, kilogram per meter to the fourth power, (kg/m^4).

7.42 acoustic stiffness. For a system in which friction and inertia are negligible, quotient of sound pressure by the resulting in-phase displacement during sinusoidal motion. Unit, pascal per meter (Pa/m).

7.43 acoustic compliance. Reciprocal of acoustic stiffness. Unit, meter per pascal (m/Pa).

7.44 acoustic admittance. Reciprocal of acoustic impedance. Unit, (cubic meter per second) per pascal [(m^3/s)/Pa].

7.45 electroacoustic transducer. Transducer designed to receive an electric input signal and to supply acoustic output signals, or vice versa.

7.46 reference point. Point, whose position is specified with respect to the transducer geometry, to which electroacoustic characteristics of a transducer are referred, preferably at the origin of angular coordinates on the principal axis.

7.47 principal axis; reference axis. Axis passing through the reference point that serves to define angular coordinates for description of directional characteristics of an electroacoustic transducer.

7.48 effective acoustical center; virtual acoustical center. For an electroacoustic transducer used for sound emission, in a specified direction, for a specified frequency and range of distances, position of the virtual point source from which sound pressure varies inversely as distance.

NOTE–The effective acoustical center of a reciprocal transducer when used for sound reception is coincident with the acoustical center when used for sound emission.

7.49 pressure sensitivity; voltage sensitivity. Of an electroacoustic transducer for sound reception, for a specified frequency, quotient of the output open-circuit voltage by the sound pressure acting on the part of the transducer designed to receive sound. Unit, volt per pascal (V/Pa).

NOTE–Root-mean-square voltage and sound pressure are usually specified. If the load impedance is other than that of an open-circuit, it shall be specified.

7.50 free-field sensitivity. Of an electro-acoustic transducer for sound reception, for a specified frequency and a specified direction of sound incidence, quotient of the output open-circuit voltage by the sound pressure in the undisturbed plane progressive free field. Unit, volt per pascal (V/Pa).

NOTE–Root-mean-square voltage and sound pressure are usually specified. If the load impedance is other than that of an open-circuit, it shall be specified.

7.51 diffraction factor. For a specified frequency and a specified direction of sound incidence, ratio of sound pressure acting on the part of the transducer designed to receive sound, to the free-field sound pressure that would exist at the same place in the absence of the transducer.

7.52 free-field current sensitivity. Of an electroacoustic transducer for sound reception, for a specified frequency and a specified direction of incidence, quotient of the short-circuit current at the output terminals of the transducer by the sound pressure in the undisturbed plane progressive free-field wave. Unit, ampere per pascal (A/Pa).

7.53 sensitivity to voltage; transmitting voltage response. Of an electroacoustic transducer for sound emission, for a specified frequency, quotient of the sound pressure in a free field at a specified distance from the effective acoustical center, and in a specified direction, by the signal voltage applied at the input terminals. Unit, pascal per volt (Pa/V).

NOTE–When the effective acoustical center of the transducer cannot be easily determined, the distance should be measured from the reference point of the transducer.

7.54 sensitivity to current; transmitting current response. Of an electroacoustic transducer for sound emission, for a specified frequency, quotient of the sound pressure at a specified distance from the acoustical center, and in a specified direction, by the current flowing at the electrical input terminals. Unit, pascal per ampere (Pa/A).

NOTE–When the effective acoustical center of the transducer cannot be easily determined, the distance should be measured from the reference point of the transducer.

7.55 sensitivity to electric power; transmitting power response. Of an electroacoustic transducer for sound emission, at a specified frequency, quotient of the time-mean-square sound pressure in a free field at a specified distance from the effective acoustical center of the transducer, and in a specified direction, by the electric power input. Unit, pascal squared per watt (Pa^2/W).

NOTE–When the effective acoustical center of the transducer cannot be easily determined, the distance should be measured from the reference point of the transducer.

7.56 reciprocity principle. For an electroacoustic transducer that is linear, passive, and reversible, principle according to which: (a) the relation between the voltage sensitivity (transmitting voltage response) of the transducer functioning as a receiver of sound (e.g., a microphone), and the sensitivity to current (transmitting current response) of the transducer functioning as an emitter of sound, and, (b) the relation between the current sensitivity of the transducer functioning as a receiver of sound (e.g., a microphone) and the sensitivity to voltage (transmitting voltage response) of the transducer functioning as an emitter of sound, depend only on the geometry of the transducer, the frequency, and the physical properties of the medium.

7.57 reciprocity parameter. For a reciprocal electroacoustic transducer at a specified frequency: (a) quotient of the voltage sensitivity of the transducer functioning as a receiver of sound (e.g., a microphone) by the sensitivity to current (transmitting current response) of the transducer functioning as an emitter of sound; or (b) quotient of the current sensitivity of the transducer functioning as a receiver of sound (e.g., a microphone) by the sensitivity to voltage (transmitting voltage response) of the transducer acting as an emitter of sound.

7.58 close-talking sensitivity. Of a microphone, for a specified frequency, quotient of the output open-circuit voltage by the sound pressure, at the position previously occupied by the microphone reference point, in the undisturbed sound field produced by a specified source that simulates the acoustical characteristics of a human head and mouth. Unit, volt per pascal (V/Pa).

NOTES

1 If the load impedance is other than that of an open-circuit, it should be specified.

2 This definition is relevant only to microphones used close to the mouth.

7.59 axial sensitivity. Of a microphone, for a specified frequency, free-field sensitivity to a plane progressive sound wave whose direction of propagation is toward the reference point and along the principal axis. Unit, volt per pascal (V/Pa).

7.60 random-incidence sensitivity. Of an electroacoustic transducer for sound reception, at a specified location, for a specified frequency, quotient of the root-mean-square open-circuit output voltage due to a succession of sound waves incident with equal probability from all directions, by the root-mean-square sound pressure at that location due to a single such free sound wave in the absence of the electroacoustic transducer. Unit, volt per pascal (V/Pa).

7.61 diffuse-field sensitivity. Of an electro-acoustic transducer for sound reception, for a specified frequency, quotient of the root-mean-square open-circuit output voltage due to sound waves arriving more-or-less simultaneously with equal probability from all directions, by the root-mean-square sound pressure at that location due to the same sound waves but in the absence of the electroacoustic transducer. Unit, volt per pascal, (V/Pa).

7.62 directional pattern. Description, presented graphically in polar coordinates or in a table, of the sensitivity level of an electroacoustic transducer as a function of the direction of propagation of the radiated or incident sound, in a specified plane and at a specified frequency.

7.63 directivity factor. (a) Of an electroacoustic transducer for sound emission, at a specified frequency, ratio of the time-mean-square free-field pressure at a fixed point on the principal axis, to the time-mean-square sound pressure over the surface of a sphere concentric with the effective center of the transducer and passing through the fixed point. (b) Of an electroacoustic transducer for sound reception, at a specified frequency, ratio of the time-mean-square free-field sensitivity to sound waves that arrive along the principal axis, to the time-mean-square sensitivity to a succession of sound waves that arrive at the transducer with equal probability from all directions.

7.64 directional gain; directivity index. Of a transducer, ten times the logarithm to the base ten of the directivity factor. Unit, decibel (dB).

NOTE–Directional gain may be given for directions other than that of the principal axis, if the direction is specified.

7.65 angular deviation loss. Sensitivity level along the principal axis minus the sensitivity level of the transducer for a specified direction. Unit, decibel (dB).

7.66 beam width. At a specified frequency, in a specified plane including the beam axis, 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. Unit, degree.

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

7.67 shading. Method of controlling the directional response pattern of a transducer through control of the distribution of phase and amplitude of the transducer action over the active face.

7.68 insertion loss. Ten times the logarithm to the base ten of the ratio of the power delivered to that part of the system that will follow the transducer, before insertion of the transducer, to the power delivered to the same part of the system after insertion of the transducer. Unit, decibel (dB).

NOTE–If the input power, or the output power, or both consist of more than one component, the particular component should be specified.

7.69 equivalent noise pressure; inherent noise pressure. Of an electroacoustic transducer or system used for sound reception, 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. Unit, pascal (Pa).

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.

7.70 equivalent noise pressure level. Of a transducer, ten times the logarithm to the base ten of the ratio of the square of the equivalent noise pressure to the square of the stated reference pressure. Unit, decibel (dB).

7.71 dynamic range. Of an electroacoustic transducer used for sound reception, the difference between the highest input sound pressure level achievable without exceeding a specified nonlinearity or distortion of the output signal, for a specified frequency range, and the lowest input sound pressure level for which the level nonlinearity is within specified tolerances, or the equivalent noise pressure level, as appropriate. Unit, decibel (dB).

NOTES

1 Useful dynamic range is limited at low sound pressure levels by noise in the medium (acoustic sounds) or by electric circuit noise. The nature of the noise limit should be stated explicitly (e.g., ambient sounds, equipment noise, thermal noise, etc.).

2 The method of nonlinearity or distortion determination and the type of nonlinearity or distortion should be specified (e.g., tolerance for signal level deviation from a nonlinear response, overheating, damage, etc.).

7.72 transducer voltage coupling loss; coupling loss. Of an electroacoustic transducer consisting of a sound-receiving element (e.g., microphone or hydrophone) and associated electrical system, for a specified frequency, ten times the logarithm to the base ten of the ratio of the time-mean-square of the open-circuit output voltage of the electroacoustic element to the time-mean-square of the open-circuit voltage of the associated electrical system. Unit, decibel (dB)

NOTE–To facilitate the use of an electroacoustic element having a high electrical impedance, the element is usually combined with a device such as a preamplifier or transformer. A piezoelectric hydrophone, for example, may consist of a crystal and preamplifier. The free-field voltage sensitivity is then specified in terms of the open-circuit crystal voltage.

7.73 mobility analogy. Analogy in which some of the quantities in the following groups are considered analogous:

(1) mechanical, rotational, and acoustic mobilities, and electric impedance;

(2) velocity across, angular velocity across, volume velocity across;

(3) force through, torque through, sound pressure through, and current through, etc.

7.74 mobility. Analogous mobilities are defined as the ratios 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 =	voltage across/current through.

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

8 Acoustical apparatus and instruments

8.01 filter; wave filter. Transducer for separating waves on the basis of their frequency.

8.02 all-pass filter. Filter designed to introduce a phase shift or delay over a band of frequencies without introducing appreciable attenuation or distortion at those frequencies.

8.03 bandpass filter. Filter with a single transmission band or passband with relatively low attenuation extending from a lower band-edge frequency greater than zero to a finite upper band-edge frequency.

8.04 band-elimination filter; band-rejection filter; notch filter. Filter having a single attenuation band, neither of the band-edge frequencies being zero or infinite.

8.05 filter "octave" frequency ratio. Symbol G, used to define an "octave" frequency ratio for the specification of the bandwidth of filters. For exact octaves, $G_2 = 2$. "Octave" frequency ratio $G_{10} = 10^{3/10} \approx 1.995262$.

NOTE–G_{10} is preferred for the design of bandpass filters.

8.06 filter bandwidth designator. 1/b, the reciprocal of a positive integer (including 1) that specifies a fraction of an octave band for a set of contiguous bandpass filters.

8.07 filter exact midband frequency. Geometric mean of the lower and upper band-edge frequencies, symbols f_1 and f_2, respectively, of a bandpass filter. Midband frequency, symbol f_m, has a specified relationship to a reference frequency, f_r, such that the ratio of the exact midband frequencies of any two contiguous bandpass filters of a specified fractional octave bandwidth is the same. When the denominator of the *bandwidth designator*, 1/b, is an odd number (e.g., 1/3 octave), exact midband frequencies of any filter in a set of filters are determined from

$$f_m = [G^{(x/b)}](f_r)$$

and when the denominator of the bandwidth designator is an even number (e.g., 1/12 octave), exact midband frequencies of any filter in a set of filters are determined from

$$f_m = [G^{(2x+1)/(2b)}](f_r),$$

where x is any integer, positive, negative, or zero and G represents one or the other of the "octave" frequency ratios defined in 8.05. Unit, hertz (Hz).

NOTES

1 For one-third octaves, $G^{1/3}$ is the ratio of the exact midband frequencies for contiguous frequency bands. For base ten systems $(G_{10})^{1/3} \approx 1.258\,925$ and for base two systems $(G_2)^{1/3} \approx 1.259\,921$.

2 ANSI S1.11-1986, *American National Standard Specification for Octave-Band and Fractional-Octave-Band Analog and Digital Filters* specifies reference frequency $f_r = 1000$ Hz.

8.08 filter nominal midband frequency. For a set of contiguous one-third octave bandpass filters, frequency of a specified series such as the *preferred-frequency* series that includes 100, 125, 160, 200, 250, 315, 400, 500, 630, 800, and 1000 hertz, extended by successive multiplication or division by 10. For a set of contiguous octave bandpass filters, the nominal midband frequency is one of a series such as the *preferred frequency* series that includes 16, 31.5, 63, 125, 250, 500, 1000, 2000, 4000, and 8000 hertz, extended by successive multiplication or division by 10^3. Unit, hertz (Hz).

NOTES

1 Preferred frequencies are defined in ANSI S1.6-1984 (R 1990), *American National Standard Preferred Frequencies, Frequency Levels, and Band Numbers for Acoustical Measurements.* The reference frequency for Band Numbers is 1 Hz.

2 Over any 1:10 range of frequency the average difference between exact and nominal midband frequencies for the G_{10} frequency ratio is −0.047%; the maximum difference is −0.944%. Over the usual audio range of frequency from 20 Hz to 20 000 Hz the average difference between exact and nominal midband frequencies for the G_2 frequency ratio is −0.202%; the maximum difference is 0.825%.

8.09 filter exact band-edge frequencies. Frequencies of the lower and upper edges of an ideal bandpass filter, symbols f_1 and f_2, respectively. Band-edge frequencies are determined from

$$f_1 = [G^{(-1/2b)}](f_m); \quad f_2 = [G^{(+1/2b)}](f_m),$$

where f_m is an exact midband frequency, 1/b is the bandwidth designator, and G is one or the other of the octave frequency ratios defined in 8.05. Unit, hertz (Hz).

8.10 filter bandwidth. Difference between the upper and lower exact band-edge frequencies and, hence, the nominal width of the passband. Unit, hertz (Hz).

8.11 filter bandwidth quotient. Figure-of-merit measure of the relative bandwidth, or sharpness, of a bandpass filter, described by the ratio of the nominal midband frequency to the nominal bandwidth.

8.12 filter attenuation band. Continuous range of frequencies over which the filter introduces an attenuation equal to or less than a specified maximum. Unit, hertz (Hz).

8.13 high-pass filter. Filter having a single transmission band from some band-edge frequency greater than zero up to infinite frequency.

8.14 low-pass filter. Filter having a single transmission band extending from a frequency near zero to some finite band-edge frequency.

8.15 microphone. Electroacoustic tranducer that produces electric signals when excited by acoustic signals.

8.16 omnidirectional microphone. Microphone whose response is essentially independent of the direction of the incident sound over a specified frequency range.

8.17 directional microphone. Microphone whose response is dependent on the direction of the incident sound.

8.18 frontal-incidence microphone. Microphone having essentially a constant sensitivity, as a function of frequency, over a specified frequency range, when in a free field and pointed at the source of the sound; i.e., at frontal incidence.

NOTE–Sensitivity that is essentially independent of frequency is in contrast to that for a true pressure microphone which has increased sensitivity at higher frequencies, varying with the angle of incidence of a sound wave, due to reflection at the microphone diaphragm. A frontal incidence microphone is designed to correct for this disturbance.

8.19 random-incidence microphone. Omnidirectional microphone having essentially a constant sensitivity, as a function of frequency over a specified frequency range, for free-field sound waves that are successively incident on the microphone from essentially all directions with equal probability.

NOTES

1 The frequency response of a random-incidence microphone is similar to that of a true pressure microphone; see 8.20.

2 Random-incidence response is essentially equal to diffuse-field response where sound waves impinge on a microphone more-or-less simultaneously with equal probability from all directions.

8.20 pressure microphone. Microphone that responds to sound pressure.

NOTE–A pressure microphone has a sensitivity which increases with frequency due to reflection at the microphone diaphragm, which causes a pressure increase. The effect is due solely to the geometry of the microphone and occurs when sound wavelengths are short compared with the diameter of the microphone.

8.21 pressure-gradient microphone. Microphone that responds to a gradient in sound pressure with distance.

8.22 bone conduction microphone. Microphone actuated by contact with the cranial bone.

8.23 carbon microphone. Microphone whose operation depends upon the variations in contact resistance between carbon granules.

8.24 close-talking microphone; boom microphone. Microphone designed particularly for use close to the mouth of a talker.

8.25 electrostatic microphone; capacitor microphone; condenser microphone. Microphone that consists of a capacitor and whose operation depends upon interaction between its electric field and the change of its electrostatic capacitance when exposed to the pressure of a sound wave.

8.26 electret microphone; prepolarized microphone. Electrostatic microphone in which the polarizing charge results from an internal permanent charge on one of the capacitor electrodes.

8.27 electrodynamic microphone; moving-conductor microphone. Microphone whose operation depends upon the generation of an induced current in a conductor moving in a magnetic field.

8.28 electromagnetic microphone. Microphone whose operation depends upon the variation in the reluctance of a magnetic field.

8.29 electronic microphone. Microphone whose operation depends upon the variations of electronic flux by the motion of one of the electrodes of a transistor.

8.30 lapel microphone. Microphone designed for positioning on the clothing of a user.

8.31 line microphone. Directional microphone consisting of an array of transducers arranged in a straight line or the acoustical equivalent.

8.32 lip microphone. Microphone designed for use in contact with the lips of a user.

8.33 magnetostriction microphone. Microphone whose operation depends upon the magnetostrictive properties of a material.

8.34 mask microphone. Microphone designed for use inside an oxygen mask or other respiratory mask.

8.35 moving-coil microphone. Electrodynamic microphone in which the transducing element has the form of a coil.

8.36 multiple microphone. Device containing two or more associated microphones in order to obtain directional effects.

8.37 noise canceling microphone. Microphone capable of discriminating against ambient sound arriving from specified directions or distances.

8.38 piezoelectric microphone. Microphone in which the transducing element is a piezoelectric device.

8.39 probe microphone. Microphone adapted to explore a sound field without significantly disturbing it.

8.40 ribbon microphone. Electrodynamic microphone in which the sensing element is a thin conducting ribbon that is moved directly by a sound wave.

8.41 standard microphone. Microphone whose frequency and directional responses are accurately known through a primary calibration.

8.42 telephone transmitter. Microphone used in a telephone system.

8.43 thermal microphone; hot wire microphone. Microphone designed to operate by the changes in the resistance of a hot wire resulting from the cooling or heating effects associated with the presence of a sound wave.

8.44 throat microphone. Microphone actuated by contact with the throat close to the larynx.

8.45 earphone. Electroacoustic transducer intended to be closely coupled acoustically to the ear.

8.46 insert earphone. Small earphone designed to be fitted into the outer ear or to be attached directly to a connecting element such as an ear mold.

8.47 acoustic coupler. Cavity of specified shape and volume used for the calibration of earphones or microphones in conjunction with a calibrated microphone adapted to measure the sound pressure developed within the cavity.

NOTE–An acoustic coupler is specified in S3.7-1994, *American National Standard Method for Coupler Calibration of Earphones.*

8.48 mechanical coupler. Device to present a specified mechanical impedance to a vibrator applied with a specified static force and equipped with an electromechanical transducer to measure the mechanical force level at the surface of contact between vibrator and mechanical coupler.

NOTE–See also 8.55.

8.49 electrostatic actuator. Device comprising an auxiliary electrode that allows the application of an electrostatic force to the diaphragm of a microphone in order to obtain a calibration over a limited range of frequencies.

8.50 pistonphone. Device having one or more rigid pistons which can be given a reciprocating motion at a nominal frequency and amplitude used to establish a nominal sound pressure in a closed cavity of small dimensions. The sound pressure level in the closed cavity may be established by a comparison calibration under specified environmental conditions.

8.51 artificial ear. Device used to calibrate earphones incorporating a calibrated microphone for measuring sound pressure and an acoustic coupler such that the acoustic impedance is similar to that presented by an average human ear at any given frequency.

NOTE–See ANSI S3.7-1994, *American National Standard Method for Coupler Calibration of Earphones.*

8.52 artificial mastoid; mastoid simulator. Device simulating the mechanical impedance of an average human mastoid which is used to calibrate bone vibrators.

8.53 artificial mouth; mouth simulator. Device consisting of a loudspeaker unit mounted in a baffle or an enclosure shaped to produce a radiation pattern similar to that of an average human mouth.

8.54 artificial voice; voice simulator. Complex sound, usually emitted by an artificial mouth, whose spectrum corresponds to that of an average human voice.

8.55 bone vibrator; bone-conduction vibrator. Electromechanical transducer intended to produce the sensation of hearing by vibrating the cranial bones.

8.56 audiometer. Device used to measure hearing sensitivity, specifically hearing level, as a function of frequency.

NOTES

1 A manual audiometer is a pure-tone audiometer in which the signal presentations, frequency, hearing

level selection, and recording of results are performed manually.

2 A Bekesy audiometer is a pure-tone audiometer where hearing level variations are under the subject's control. Signal presentations, frequency selection or frequency variation, and recording of subject responses are implemented and recorded automatically.

3 A computer-controlled audiometer is a pure-tone audiometer in which the test procedure is controlled by a computer.

8.57 speech audiometer. Audiometer to measure hearing with either live or recorded speech signals.

8.58 hearing aid; hearing instrument. Portable instrument, fitted individually to the listener, intended to aid the hearing of a person with impaired hearing, usually consisting of a microphone, an amplifier, and an earphone (receiver) or bone vibrator.

8.59 hearing protector. Personal device worn to reduce harmful auditory or annoying subjective effects of sound.

8.60 earplug. Hearing protector that is inserted into the ear canal.

8.61 earmuff. Hearing protector worn over the pinna of an ear.

8.62 acoustic amplifier. Device in which energy is added to an acoustical wave by interaction with mechanical or electric energy.

8.63 acoustic bridge. Device for measuring the acoustic impedance by comparison with an adjustable known impedance.

8.64 acoustic radiometer. Instrument for measuring acoustic radiation pressure.

8.65 interferometer. Device used to produce and measure the interference between two or more wave trains.

8.66 Rayleigh disk. Disk on a torsion suspension designed to measure the sound particle velocity in a fluid.

8.67 spectrum analyzer; sound analyzer. Device to be used to determine the frequency spectrum of a sound.

8.68 sound level meter. Device to be used to measure sound pressure level with a standardized frequency weighting and indicated exponential time weighting for measurements of sound level, or without time weighting for measurement of time-average sound pressure level or sound exposure level.

NOTE–See also 4.11.

8.69 integrating-averaging sound level meter. Device for measuring the level of time-mean-square frequency-weighted sound pressure during a stated time interval.

NOTE–See also 4.14.

8.70 sound locator. Electroacoustic device to be used to locate a sound source.

8.71 sterophonic sound system. Sound system in which microphones, transmission channels, and loudspeakers or earphones are used to provide the listener with a sensation of spatial distribution of sound sources.

8.72 thermophone. Electroacoustic transducer in which sound waves of calculable magnitude result from the expansion and contraction of the air adjacent to a conductor whose temperature varies in response to an electric current input.

8.73 vibration meter. Device used to measure the displacement velocity, or acceleration of an oscillating body.

8.74 visible speech apparatus; sound spectrograph. Device that displays a spectrum of speech as a function of time, to aid in the recognition of voice sounds.

8.75 vocoder. Apparatus to be used to conduct a specialized analysis of speech signals followed by a corresponding speech synthesis.

8.76 Helmholtz resonator. Hollow, rigid-walled, gas or liquid-filled cavity sound used as a resonator.

NOTES

1 If the cavity is spherical in shape, the fundamental frequency, f_0, of a Helmholtz resonator is approximately.

$$f_0 = (c/2\pi)\cdot(A/LV)^{1/2},$$

where c is the speed of sound, V is the volume of the sphere, A is the neck cross-sectional area, and L is the effective length of the neck, all in consistent units.

2 The cavity may be partially or completely filled with a porous material.

8.77 silencer; muffler. Duct designed to reduce the level of sound. The sound reducing mechanisms may be either absorptive or reactive, or a combination.

8.78 loudspeaker; speaker. Electroacoustic transducer intended to radiate acoustic power into the air, the acoustic waveform being essentially equivalent to the electric input.

8.79 loudspeaker unit. Electroacoustic transducer used as a loudspeaker without its associated acoustical enclosure or baffle.

8.80 acoustical baffle. Shielding device used with a loudspeaker unit to increase the effective acoustic pathlength between the front and back of the loudspeaker unit.

8.81 acoustical enclosure Assembly of an enclosure, one or more loudspeaker units, and other associated parts such as filters, transformers, or other passive elements.

8.82 acoustic radiating element. Vibrating surface of a transducer that produces sound waves.

8.83 cone loudspeaker. Loudspeaker unit in which the radiating unit has the shape of a cone.

8.84 dome loudspeaker. Loudspeaker unit in which the radiating unit is in the form of a spherical segment.

8.85 electrodynamic loudspeaker; moving-conductor loudspeaker; moving-coil loudspeaker. Loudspeaker designed to operate by the motion of a conductor or a coil carrying a varying current in a steady magnetic field.

8.86 electromagnetic loudspeaker. Loudspeaker designed to operate by the variations in the reluctance of a magnetic field.

8.87 electrostatic loudspeaker. Loudspeaker designed to operate by electrostatic forces.

8.88 magnetostriction loudspeaker. Loudspeaker that operates by deformation of a magnetostrictive material.

8.89 piezoelectric loudspeaker. Loudspeaker that operates by deformation of a piezoelectric material.

8.90 pneumatic loudspeaker. Loudspeaker that generates high-intensity sound by controlled variations of the instantaneous volume flow of an air stream.

8.91 multicellular loudspeaker. Horn loudspeaker in which the radiating element is coupled to the medium by means of two or more juxtaposed horns.

8.92 dividing network. Electrical device to control the ranges of frequency applied to various loudspeakers.

8.93 crossover frequency. Of an electrical dividing network, frequency at which equal electric powers are delivered to each of the adjacent electrical circuits when all circuits are terminated in specified impedances. Unit: hertz (Hz).

8.94 multichannel loudspeaker. Assembly consisting of two or more loudspeakers, usually with one or more dividing networks, designed to radiate simultaneously in particular frequency bands.

8.95 horn; acoustic horn. Tube of varying cross section intended to achieve an acoustic impedance match and to produce a directional effect.

8.96 horn loudspeaker. Loudspeaker in which the radiating element is coupled to the medium by means of a horn.

8.97 conical horn. Horn whose cross-sectional area increases as the square of the axial length.

8.98 exponential horn. Horn whose cross sectional area increases exponentially with axial length.

8.99 horn mouth. End of a horn where the cross-sectional area is largest.

8.100 horn throat. End of a horn where the cross-sectional area is smallest.

8.101 circumaural earphone. Earphone having a cavity large enough to cover the region of the head including and surrounding the pinna.

8.102 supra-aural earphone. Earphone applied externally to the outer ear.

8.103 telephone earphone. Earphone designed for use in a telephone set.

9 Underwater acoustics

9.01 sonar. Method or equipment used to obtain information regarding objects in the sea by underwater sound.

NOTE–The term sonar is an acronymn for SOund Navigation And Ranging.

9.02 active sonar. Method or equipment by which information concerning a distant object is obtained by evaluating its effects on the sound generated by the equipment.

9.03 passive sonar. Method or equipment by which information concerning a distant object is generated by analyzing the sound generated by the object.

9.04 sonar equations. Working relationships relating the basic parameters of the sound source, the target, the medium, and the signal detection system, used either to predict the performance of a sonar equipment having a known design or to design a sonar equipment to preestablished criteria.

9.05 object backscattering differential; target strength. Difference between the sound pressure level corresponding to the backscattered field obtained at a distance of one meter from the acoustical center of the scattering object and the sound pressure level of the incident plane sound wave. Unit, decibel (dB).

NOTES

1 Unless otherwise stated the reference distance is understood to be 1 meter.

2 Target strength is given by

$$N_{ts} = L_{so} - L_1 - 10\ \lg(A_{ob}/4\pi r_0^2),$$

where N_{ts} is the target strength, L_{s0} is backscattered sound pressure level at the reference distance, L_i is the incident sound pressure level, A_{ob} is the backscattering cross section of the target, r_0 is the distance and $4\pi r_0^2$ is the spherical surface area for the object backscattering differential.

9.06 sonar background noise. Total noise that interferes with the reception of the desired signal and is presented to the final receiving element such as a recorder or the human ear.

9.07 reverberation limited condition. Condition in which detection by an active sonar is limited by the reverberation part of the sonar background noise.

9.08 relative reverberation level. Difference, on a reference axis of the source, between the sound pressure level due to reverberation and the sound pressure level due to the direct wave. Unit: decibel (dB).

9.09 noise-limited condition. Condition in which detection is limited by sonar background noise other than reverberation.

9.10 sea noise. Sound in the sea emitted by natural sources such as currents, rain, water waves, wind, and others.

9.11 sonar dome. Nominally acoustically transparent enclosure used to minimize noise by reduction of turbulence and cavitation arising from motion in the water.

9.12 sonar dome insertion loss. Difference in transmission loss between the electrical terminals of a transducer and an external field point at which the signal is received, with and without the sonar dome. Unit, decibel (dB).

9.13 sonar dome loss directivity pattern. Insertion loss of a sonar dome as a function of direction of sound transmission.

9.14 sonar source level; axial source level. Sound pressure level on the axis of the sound projector at a reference distance of 1 meter from the effective acoustical center of the projector. Unit, decibel (dB).

9.15 sonar self-noise. That part of the sonar background noise caused by the sonar, machines, ship movement, or sonar platform movement.

NOTE–Sonar self-noise is usually described in terms of the equivalent plane wave arriving at the transducer from the direction of maximum response.

9.16 hydrophone. Transducer that produces electric signals in response to waterborne acoustic signals.

9.17 underwater sound projector. Electroacoustic transducer that converts electric signals into acoustic waves in water.

9.18 shaded transducer. Transducer whose directional response has been modified through control of the distribution of phase and amplitude over the active face.

9.19 array gain. Signal level received on an array of hydrophones minus the signal level received on a single element.

9.20 underwater radiated noise. Sound radiated into water by surface vessels, submarines, or fixed installations.

9.21 refraction. Phenomenon by which the direction of propagation of a sound wave is changed as a result of a spatial variation in the speed of sound.

NOTE–Factors influencing the speed of sound in sea water include temperature, salinity, and depth.

9.22 limiting ray. Ray tangential to a horizontal plane at which the propagation velocity goes through a maximum.

9.23 surface layer. Zone just below the ocean surface in which the velocity of sound is susceptible to daily and local changes due to heating, cooling, and wind action.

9.24 sound channel. Zone in the sea within which the sound velocity as a function of depth passes through a minimum.

9.25 convergence zone. Region of the sea close to the surface where sound rays are concentrated at great range from the source by refraction at great depth.

9.26 shadow zone. Zone of the ocean into which sound rays are unable to penetrate by reason of refraction.

9.27 crossover range. Range within which the propagation loss caused by divergence is equal to that caused by absorption.

9.28 thermocline. Ocean layer near the surface within which the water temperature changes rapidly with depth.

9.29 deep isothermal layer. Ocean layer below the thermocline extending to the bottom of the sea which has a nearly constant temperature and in which the velocity of sound increases with depth.

9.30 deep scattering layer. Layer of scatterers located at a certain depth and which returns echoes.

9.31 propagation anomaly. Difference between the actual propagation loss at a given distance and the computed propagation loss for the same path in the case of spherical divergence or other specified propagation.

9.32 quenching water. Condition of sea water encountered in shallow water or near the hull of a ship particularly in rough sea, characterized by the presence of many air bubbles.

9.33 scattering cross section of an object or volume. Equivalent area intercepting an amount of sound power of a plane progressive wave equal to that scattered in all directions by the object or by the scattering volume. Unit, square meter (m^2).

9.34 scattering cross section of a surface (bottom). Area of a plane progressive wave intercepting an amount of sound power equal to that scattered from the stated surface over a hemisphere. Unit, square meter (m^2).

9.35 surface (bottom) backscattering strength. Difference between the sound pressure level corresponding to the backscattered field obtained at a distance of one meter from the acoustical center of the scattering surface (bottom) element and the sound pressure level of the incident sound wave. Unit, decibel (dB).

9.36 surface (bottom) scattering coefficient. Ratio of the scattering cross section of a scattering surface (bottom) to the area of that surface.

9.37 backscattering cross section of a surface (bottom). Scattering cross section of a surface that scatters isotropically over a hemisphere and returns an echo equal to that from the actual scatterer.

9.38 volume backscattering differential; volume scattering strength. Difference between the sound pressure level corresponding to the backscattered field obtained at a reference distance of one meter from the acoustic center of the scattering volume and the sound pressure level of the incident plane wave. Unit, decibel (dB).

9.39 volume scattering coefficient. Quotient of the scattering cross section of the volume under consideration by that volume.

9.40 bathythermogram. Plot of water temperature in the ocean as a function of depth. Alternatively, a device used to measure water temperature in the ocean as a function of depth.

9.41 velocimeter. Device used to measure the time traveled by short pulses between a projector and a receiver of known separation, and thus to calculate the local speed of sound.

10 Sonics and ultrasonic testing

10.01 sonics. Technology of sound in processing and analysis. Includes the use of sound in any non-communication process.

10.02 ultrasonics. Technology of sound at frequencies above the audible range.

10.03 ensonify. To expose an object to a sound field in a process or analysis.

10.04 macrosonics. Technology of sound at signal amplitudes so large that linear approximations are not valid.

NOTE–Processing of materials by sonic techniques usually involves macrosonics.

10.05 flaw detection. Process of locating imperfections in solid materials by observing internal reflections or a variation in transmission through the materials as a function of sound-path location.

10.06 agglomeration. Union of small particles suspended in a fluid medium into larger aggregates by the action of sound waves.

10.07 sonic cleaning; degreasing. Cleaning of contaminated materials by the action of intense sound in the liquid in which the material is immersed, usually involving cavitation, see 10.11.

10.08 sonic soldering. Method of joining metals by metallic bonding alloys through the use of mechanical vibrations to break up the surface oxides.

10.09 sonic surgery. Use of focused ultrasound to produce precisely circumscribed alterations at predetermined sites within the tissue.

10.10 sonic viscometry. Determination of the coefficients of viscosity of liquids or slurries by measurement of the acoustic properties of a transmitted wave, or by the reaction of such a medium on a transducer.

10.11 cavitation. Formation, growth, and collapse of gaseous and vapor bubbles in a liquid due to the action of intense sound waves.

10.12 cavitation noise. Noise produced in a liquid by gaseous or vaporous cavitation.

10.13 drilling. Process of cutting or shaping materials with an abrasive slurry driven by a reciprocating tool usually attached to an electromechanical transducer.

10.14 Oseen force. Steady force exerted on a suspended particle by second-order velocity effects resulting from second harmonic content in a distorted wave.

10.15 sonoluminescence. Luminescence produced in liquids by sonically induced cavitation.

10.16 molecular relaxation. Equalization of energy among the degrees of freedom of a molecule following a disturbance that produces deviations from the equilibrium distribution law.

10.17 piezoelectricity. Property exhibited by some asymmetrical crystalline materials which when subjected to strain in suitable directions develop electric poalrization 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.

10.18 electrostriction. 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.

10.19 magnetostriction. Phenomenon wherein ferromagnetic materials experience an elastic strain when subjected to an external magnetic field.

10.20 piezomagnetism. Phenomenon exhibited by some polarized ferromagnetic materials which when subjected to elastic strain in suitable directions develop magnetic polarization proportional to the strain. Inverse piezomagnetism is the effect in which mechanical strain is produced in certain polarized ferromagnetic materials when subjected to an external magnetic field; the strain is proportional to the magnetic field.

10.21 Schlieren method. Technique by which light refracted by the density variations resulting from sound waves is used to produce a visible image of the sound field.

10.22 sonic applicator, medical. Self-contained electromechanical transducer designed for local application of sound for therapeutic purposes.

10.23 pressure gain factor. Of a focusing transducer, ratio of peak pressure amplitude at the focus to the peak pressure amplitude at the radiating surface.

10.24 hydrodynamic oscillator. 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.

10.25 jet-edge generator. Fluid dynamic transducer, involving vortex formation, in which stabilization is achieved by hydrodynamic feedback between a jet and an edge.

10.26 image convertor. Device for making acoustic field configurations optically visible.

10.27 acoustic holography. Inspection method using the phase interference between sound waves from an object and a reference signal to obtain an image of reflectors in the object under test.

10.28 ultrasonic spectroscopy. Analysis of the frequency spectrum of an ultrasonic signal.

10.29 search unit. Electroacoustic device used to transmit and or receive ultrasonic energy.

NOTE–The device may incorporate more than one transducer.

10.30 dual search unit. Search unit containing two side-by-side elements with one serving as a transmitter and the other as a receiver.

10.31 collimator. Device used to control the size and direction of an ultrasonic beam.

10.32 couplant. Substance used between the search unit and the test surface to permit or improve the transmission of acoustical energy.

10.33 bubbler. Device used to couple an ultrasonic beam to the test piece.

10.34 angle beam. Wave train traveling at an angle measured from the normal to the test surface to the centerline of the beam.

10.35 beam axis. Acoustic centerline of an ultrasonic search unit's beam pattern as described by the locus of points of maximum sound pressure in the far field and its extentions into the near field.

10.36 beam spread. Divergence of the ultrasonic beam as a result of propagation through a medium.

10.37 focused beam. Converging energy of a sound beam at a specified distance.

10.38 delay line. Liquid or solid material placed in front of a projecting transducer to introduce a time delay to an ultrasonic wave train.

10.39 delayed sweep. Horizontal sweep whose start is delayed in order to prevent the appearance of unwanted early response information on the screen.

10.40 control echo. Reference signal from a constant reflecting surface such as a back-reflection.

10.41 dead zone. Distance from the surface of the test object to the nearest depth that can be inspected.

10.42 penetration. In ultrasonics, the maximum depth in a material from which useful ultrasonic back reflections can be obtained.

10.43 base line. In ultrasonic testing, the distance trace (i.e., horizontal) across the A-scan.

10.44 A-scan. In ultrasonic testing, method of data presentation utilizing a horizontal base line that indicates distance or time and a vertical deflection from the base line which indicates amplitude.

10.45 B-scan. In ultrasonic testing, a method of data presentation which provides a cross-sectional view of the test piece.

10.46 C-scan. In ultrasonic testing, a method of data presentation which yields a plan view of a test object or any discontinuities.

10.47 continuous wave. Continuous flow of ultrasonic waves as opposed to pulsed waves.

10.48 pulse. A transient ultrasonic or electric signal.

10.49 pulse echo method. In ultrasonic testing, an inspection method in which the presence and position of a reflector are indicated by the reflected pulse amplitude and time.

10.50 amplitude. In ultrasonic testing, the vertical pulse height of a signal, usually base to peak, when indicated by an A-scan presentation.

10.51 reflector. Interface at which an ultrasonic beam encounters a change in acoustic impedance and at which at least part of the acoustic energy is reflected.

10.52 loss of backreflection. In ultrasonic testing, absence of or significant reduction of an ultrasonic signal from the back surface of the object under test.

10.53 immersion testing. In ultrasonic testing, an inspection method where the search unit and the material are submerged in a liquid.

10.54 wave train. Succession of ultrasonic waves arising from the same source, having the same characteristics and propagating along the same path.

11 Architectural acoustics

11.01 sound absorption. At a specified frequency or specified frequency band, property of a material or an object whereby sound energy is converted into heat by propagation in a medium or when sound strikes the boundary between two media.

NOTE–See also 3.65.

11.02 sound power absorption coefficient. At a given frequency and for specified conditions, of a surface, fraction of incident sound power absorbed or otherwise not reflected from the surface. Unless otherwise specified, a diffuse sound field is understood.

11.03 statistical sound power absorption coefficient. Sound power absorption coefficient measured or calculated with plane waves at randomly distributed angles of incidence.

11.04 sound power reflection coefficient; sound reflection coefficient. At a stated frequency and for specified conditions, of a surface, fraction of sound power reflected by the surface, incident randomly or from a specified direction.

11.05 sound pressure reflection coefficient. For plane waves of specified frequency and for a given angle of incidence, ratio of the sound pressure amplitude of the reflected wave to that of the incident wave.

11.06 equivalent absorption area. Of a surface or of an object, area of a surface having a sound power absorption coefficient of unity that would absorb the same amount of sound power in a reverberation room with a diffuse sound field 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.

11.07 reverberation time. Of an enclosure, for a stated frequency or frequency band, time that would be required for the level of the time-mean-square sound pressure in the enclosure to decrease by 60 dB, after the source has been stopped. Unit, second (s).

11.08 decay rate. At a stated frequency, time rate at which sound pressure level decreases in a room. Unit, decibel per second (dB/s).

NOTE–Decay rate d in a reverberant room is related to reverberation time T by

$$T = 60\ \mathrm{dB}/d.$$

11.09 Eyring absorption coefficient. Sound power absorption coefficient attributed to a surface as by the Eyring reverberation-time equation.

NOTE–The Eyring reverberation-time equation is

$$T = (24 \ln 10)V/[-cS \cdot \ln(1-\bar{\alpha})]$$
$$= 55.26\ V/[-cS \cdot \ln(1-\bar{\alpha})],$$

where T is the reverberation time, V is the volume of the room, c is the speed of sound in air, and S is the total interior surface area. The area-weighted mean Eyring coefficient is

$$\bar{\alpha} = \Sigma S_i \alpha_i / S,$$

where S_i is the area of the ith surface and α_i is its Eyring sound power absorption coefficient.

11.10 Sabine absorption. Sound absorption defined by the Sabine reverberation-time equation. Unit, metric sabin.

NOTES

1 The dimensionally complete Sabine reverberation-time equation is

$$T = (24 \ln 10)(\mathrm{dB})V/cA$$
$$= 55.26\ (\mathrm{dB})V/cA,$$

where T is the reverberation time, V is the volume of the room, c is the speed of sound in air, and A is the Sabine absorption. The decibel is usually omitted.

2 In a reverberant room of volume V, speed of sound c, and decay rate d, Sabine absorption is

$$A = 0.921\ Vd/c.$$

The pure number 0.9210 is equal to 0.4 ln 10 = 0.4/lge.

11.11 metric sabin. Unit of Sabine absorption, equal to one decibel square meter $(\mathrm{dB}) \cdot \mathrm{m}^2$.

11.12 room absorption. Sum of Sabine absorptions due to objects and surfaces in a room, and due to dissipation of energy in the medium within the room. Unit, metric sabin.

NOTES

1 With A_i as the Sabine absorption of the ith surface or object or medium in a room, total room absorption is $A = \Sigma A_i$.

2 Sabine absorption A_m due to dissipation in the medium, in a room of volume V, is

$$A_m = (0.4 \ln 10)\beta V = 0.921\ \beta V,$$

where β is the attenuation coefficient of the medium in decibels per unit length.

11.13 Sabine absorption coefficient; sound absorption coefficient. Ratio of Sabine absorption of a surface to the area of the surface. Unit, metric sabin per square meter, often omitted.

NOTE–With a_i as the Sabine absorption coefficient of the ith surface whose area is S_i, the Sabine absorption attributed to the surface is $A_i = S_i a_i$.

11.14 noise reduction coefficient. Arithmetic mean of sound absorption coefficients at 250, 500, 1000, and 2000 Hz, rounded to the nearest 0.05 metric sabin per square meter.

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

NOTE–Reverberation rooms are useful for measurement of Sabine absorption coefficients and sound power absorption coefficients; with the latter, the sound power of a steady source.

11.16 live room. Room characterized by a relatively small amount of sound absorption.

11.17 mean-free path. Average distance traveled by sound waves in an enclosure between successive reflections, where the average is over a large number of reflections and all initial directions of propagation. Unit, meter (m).

11.18 random incidence. Incidence of sound waves successively from all directions with equal probability.

NOTE–If an object is in a diffuse sound field the sound is said to strike the object at random incidence.

11.19 direct sound field. That portion of a sound field, in an enclosure, which arrives from the sound source without having undergone any reflection.

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

11.21 diffuse-field distance. Distance from the acoustic center of a sound source at which the mean-square sound pressure of the direct field in a specified direction is equal to the mean-square sound pressure of the reverberant sound in the room containing the source. Unit, meter (m).

11.22 anechoic room. Test room whose surfaces absorb essentially all of the incident sound energy over the frequency range of interest, thereby affording nearly free-field conditions over the measurement surface.

NOTE–The word *anechoic* is derived from the Greek words meaning *without echo*.

11.23 hemi-anechoic room. Test room with a hard, reflecting floor whose other surfaces absorb essentially all the incident sound energy over the frequency range of interest, thereby affording nominally free-field conditions above a reflecting plane.

11.24 dead room. Room characterized by a relatively large amount of sound absorption and a relatively short reverberation time.

11.25 audiometric test room. Enclosed space used for testing hearing.

NOTE–See ANSI S3.1-1991, *American National Standard Maximum Permissible Ambient Noise Levels for Audiometric Test Rooms.*

11.26 echo. Reflected sound wave that arrives with sufficient magnitude and time delay as to be distinguishable as a repetition of the direct sound.

NOTE–See also 3.32.

11.27 multiple echo. Succession of separate echoes originating from a single sound.

11.28 flutter echo. Rapid but nearly even succession of echoes originating from the same sound source.

11.29 specific impedance of a wall. Quotient of the sound pressure acting on a wall or wall covering by the particle velocity normal to the wall. Unit, pascal per meter per second [Pa/(m/s)].

11.30 specific admittance of a wall. Quotient of the particle velocity normal to a wall by the sound pressure acting on the wall. Reciprocal of the wall impedance. Unit, meter per second per pascal [(m/s)/Pa].

11.31 radiation factor. Ratio of sound power radiated by a plate of a specified area, vibrating with a given time-mean-square velocity over the area, to that power which would be emitted as a plane wave by a plate of the same area vibrating in phase with the same vibration velocity.

11.32 radiation index. Ten times the logarithm to the base ten of the radiation factor. Unit: decibel (dB).

11.33 dissipation. Conversion of sound energy into heat.

11.34 dissipation coefficient. Ratio of sound energy dissipated as heat to the energy of the incident sound wave.

11.35 porous sound absorber. Material with interconnected voids that presents resistance to the flow of gas or liquid through the material.

11.36 porosity. Ratio of the volume of voids in a porous sound absorbing material to the total volume.

11.37 flow resistance. Quotient of the difference of air pressure across a sheet of porous material by the volume velocity of airflow through the sheet. Unit, pascal per (cubic meter per second) [Pa/(m^3/s)].

11.38 specific flow resistance. Quotient of the difference in air pressure across a sheet of porous acoustical material by the velocity of airflow through the sheet; i.e., flow resistance divided by the area of the porous sheet. Unit, pascal per (meter per second) [Pa/(m/s)].

11.39 flow resistivity. Specific flow resistance divided by the thickness of the porous sheet. Unit, pascal per (square meter per second) [Pa/(m^2/s)].

11.40 average sound pressure level in a room. Ten times the logarithm to the base ten of the ratio of the space and time average of squared sound pressure to the squared reference sound pressure, the space average being taken over the total volume of the room, except for the regions of the room where the direct field of the source and the near field of the boundaries are of significance. Unit, decibel (dB).

11.41 level difference; noise reduction; sound isolation between rooms. Between two rooms in a specified frequency band, difference between the space-time average sound pressure levels in the two enclosed spaces when one or more sound sources operates in one of the rooms. Unit, decibel (dB); respective abbreviations, D and NR.

11.42 normalized level difference; normalized noise reduction. Level difference between rooms plus ten times the logarithm to the base ten of the ratio of the reverberation time in the receiving room to reference reverberation time of 0.5 s. Unit, decibel (dB); abbreviation, NNR.

11.43 transmission loss; sound insulation. Of a partition, for a specified frequency or frequency band, difference in decibels between the average sound pressure levels in the reverberant source and receiving rooms, plus ten times the logarithm to the base ten of the ratio of the area of the common partition to the total Sabine absorption in the receiving room. Unit, decibel (dB); abbreviation, TL.

NOTE–See also 6.33.

11.44 sound transmission coefficient. At a stated frequency, fraction of incident sound power transmitted through a partition. Symbol, τ.

NOTE–Unless otherwise stated, transmission of sound energy between two diffuse sound fields is assumed.

11.45 sound transmission class. Single-number rating of airborne sound insulation of a building partition, derived by fitting a reference rating curve to the sound transmission loss values measured for the 16 contiguous 1/3 octave frequency bands with nominal midband frequencies of 125 Hz to 4000 Hz inclusive, by a standard method. The reference rating curve is fitted to the 16 measured transmission loss values such that the sum of deficiencies (transmission losses less than the reference rating curve), does not exceed 32 dB, and no single deficiency is greater than 8 dB. Sound transmission class is the numerical value of the oridinate (y axis) of the reference contour at 500 Hz. Unit, decibel (dB); abbreviation, STC. For sound transmission class 50 dB, for example, the reference rating curve consists of a straight line from 34 dB at 125 Hz to 49 dB at 400 Hz; a straight line from 49 dB at 400 Hz to 54 dB at 1250 Hz; and a straight line constant at 54 dB from 1250 Hz to 4000 Hz.

NOTE–The standardized method of determining sound transmission class is provided in ASTM E413-87, *Classifications for Rating Sound Insulation*.

11.46 sound reduction index. Single-number rating of airborne sound insulation of a partition, in decibels, for the 16 frequencies at 1/3 octave intervals from nominal midband frequencies of 100 Hz to 3150 Hz inclusive. For sound reduction index 50 dB, for example, the reference sound insulations lie on a reference rating curve consisting of a straight line from 31 dB at 100 Hz to 49 dB at 400 Hz; a straight line from 49 dB at 400 Hz to 54 dB at 1250 Hz; a straight line from 54 dB at 1250 Hz to 54 dB at 3150 Hz. The reference rating curve is to be matched to the 16 determinations of sound insulation of a partition in such a way that the sum of the deficiencies is not greater than 32 dB, and each deficiency is not greater than 8 dB. The sound reduction index is equal to the sound insulation rating curve at 500 Hz. Unit, decibel (dB); symbol, R.

NOTE–The above definition is the sound reduction index given in ISO 140/6:1978, *Acoustics—Measurement of Sound Insulation in Buildings and of Building Elements* and ISO 717/1:1982, *Acoustics—Rating of Sound Insulation in Buildings and of Building Elements*.

11.47 noise isolation class. Single-number rating of the 16 level differences between two rooms obtained by use of the reference rating curve defined for sound transmission class. Unit, decibel (dB); abbreviation, NIC.

11.48 normalized noise isolation class. Single-number rating of the 16 normalized level differences, obtained by use of the reference rating curve defined for sound transmission class. Unit, decibel (dB); abbreviation, NNIC.

11.49 structure-borne sound. Sound for which a significant portion of the transmission path from source to receiver takes place in a solid structure rather than through a liquid or gas.

11.50 flanking sound transmission. In sound transmission measurement, the transmission of sound from the sound source room to the receiving room by paths other than through the partition under test.

NOTE–Flanking transmission may include structure-borne sound transmission.

11.51 impact sound pressure level. Average sound pressure level in a specified frequency band in the receiving room under a test floor being excited by the standardized impact sound source. Unit, decibel (dB).

NOTE–The impact sound source specified in ASTM E492-90, *Standard Method for Laboratory Measurement of Impact Sound Transmission Through Floor–Ceiling Assemblies Using the Tapping Machine* and ISO 140/6:1978 *(op. cit.)* consists of a row of five equally spaced hammers, the distance between end hammers being 400 mm. The mass of each hammer is 0.5 kg. Cams rotate to lift hammers successively, to allow a free drop of 40 mm, causing 10 impacts per second.

11.52 normalized impact sound pressure level. For a specified frequency band, average sound pressure level in decibels due to the standardized impact sound source, plus ten times the logarithm to the base ten of the ratio of the Sabine absorption in the receiving room to the reference Sabine absorption of ten metric sabins. Unit, decibel (dB).

11.53 normalized impact sound index. Single-number rating of normalized impact sound pressure level for 16 successive 1/3 octave bands from nominal midband frequencies of 100 Hz to 3150 Hz inclusive. Reference values for an impact sound index of 60 dB, for example, lie on a reference rating curve consisting of a straight line from 62 dB at 100 Hz to 62 dB at 315 Hz; a straight line from 62 dB to 57 dB at 1000 Hz; a straight line from 57 dB to 42 dB at 3150 Hz. The reference curve is matched to the 16 normalized impact sound pressure levels in such a way that the mean excess above the rating curve is not greater than 2 dB and an excess is not greater than 8 dB. Normalized impact sound index is the impact sound pressure level where the rating curve crosses the ordinate at 500 Hz. Unit, decibel (dB); abbreviation, NISI.

11.54 impact insulation class. One hundred and ten decibels minus the normalized impact sound index. Abbreviation, IIC.

11.55 mass-law sound transmission loss. Phenomenon whereby doubling the mass per unit area of a panel, or doubling the frequency for a given mass per unit area, increases the sound transmission loss by six decibels.

11.56 limp wall. Panel or wall whose sound transmission properties are determined by the mass per unit area of the panel without stiffness.

11.57 coincidence effect. Phenomenon that occurs when the wavelength of the flexural wave in a panel equals that of the trace wavelength of an acoustic wave of the same frequency.

NOTE–At coincidence there exists a high degree of coupling between the flexural wave in the panel and the acoustic wave; accordingly, the transmission loss of a panel is greatly reduced at coincidence.

11.58 critical frequency. Of a panel or partition, the lowest frequency at which the coincidence effect occurs. Unit, hertz (Hz).

NOTES

1 At the critical frequency, the sound wave in the panel travels parallel to the surface of the partition.

2 The critical frequency, f_0, of a single-leaf partition is

$$f_0 = 3^{1/2}\rho c / \pi t Y,$$

where ρ is the mass density of the panel, c is the speed of sound in air, t is the panel thickness, and Y is the Young's modulus, all in consistent units.

11.59 duct lining. Layer of porous material placed on the inner surface of a duct to attenuate sound that propagates through the duct.

11.60 insertion loss. Of a silencer or other sound reducing element in a specified frequency band, the decrease in sound pressure level measured at the location of the receiver when a sound insulator is inserted in the transmission path between the sound source and the receiver. Unit, decibel (dB).

11.61 shielding. Phenomenon whereby sound reduction is provided by interposing a wall or partition between a sound source and a receiver.

11.62 vibration isolation. Reduction achieved in the ability of a system to vibrate in response to a mechanical oscillation through the use of a resilient coupling.

NOTE–See also 5.26.

12 Physiological and psychological acoustics

12.01 pitch. 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 content of the sound stimulus, but it also depends upon the sound pressure and the waveform of the stimulus. Unit, mel.

NOTE–The pitch of a sound may be described by the frequency or frequency level of that simple tone having a specified sound pressure level that is judged by listeners to produce the same pitch.

12.02 mel. Unit of pitch. By definition, a simple tone of frequency 1000 hertz, 40 decibels above a listener's threshold, produces a pitch of 1000 mels. The pitch of any sound that is judged by the listener to be n times that of a 1-mel tone is n mels.

12.03 loudness. That attribute of auditory sensation in terms of which sounds may be ordered on a scale extending from soft to loud. Unit, sone.

NOTE–Loudness depends primarily upon the sound pressure although it also depends upon the frequency, waveform, and duration of the sound.

12.04 sone. Unit of loudness. One sone is the loudness of a pure tone presented frontally as a plane wave of 1000 Hz and a sound pressure level of 40 dB, re 20 μPa.

NOTE–The loudness of a sound that is judged by a listener to be n times that of the 1-sone tone is n sones.

12.05 loudness level. Of a sound, the median sound pressure level in a specified number of trials of a free progressive wave having a frequency of 1000 Hz that is judged equally loud as the unknown sound when presented to listeners with normal hearing who are facing the source. Unit, phon.

NOTE–The manner of listening to the unknown sound must be specified.

12.06 calculated loudness level. Loudness level calculated by a specified procedure. Unit, phon.

NOTES

1 Such procedures are given in ANSI S3.4-1980 (R1986), *American National Standard Procedure for the Computation of Loudness of Noise*, and in ISO 5.32:1975, *Method for Calculating Loudness Level* .

2 Calculated loudness level in phons is related to loudness in sones by the equation

$$L = 10 \log_2 n_s,$$

where L is loudness level in phons and n_s is loudness in sones.

3 A twofold change in loudness corresponds to an interval of 10 phons.

12.07 phon. Unit of loudness level, judged or calculated as specified in definitions 12.05 and 12.06.

12.08 equal-loudness contour. Curve that shows, as a function of frequency, the sound pressure level required to cause a given loudness for a listener having normal hearing, listening to a specified kind of sound in a specified manner.

12.09 timbre. That attribute of auditory sensation which enables a listener to judge that two nonidentical sounds, similarly presented and having the same loudness and pitch, are disimilar.

NOTE–Timbre depends primarily upon the frequency spectrum, although it also depends upon the sound pressure and the temporal characteristics of the sound.

12.10 judged perceived noise level. Sound pressure level of a frontally presented octave band of pink noise centered on 1000 Hz having a duration of 2 s that is subjectively judged equally noisy to a given sound. Unit, decibel (dB).

12.11 perceived noise level. Frequency-weighted sound pressure level obtained by a stated procedure that combines the sound pressure levels in the 24 one-third octave bands with midband frequencies from 50 Hz to 10 kHz. Unit, decibel (dB); abbreviation, PNL; symbol, L_{PN}.

NOTE–Procedures for computing perceived noise level are stated in Federal Aviation Regulation Part 36, *Noise Standards: Aircraft Type and Airworthiness Certification*, Appendix B, and in International Civil Aviation Organization Annex 16, Volume 1, *Aircraft Noise*, Third Edition, July 1993.

12.12 perceived noiseiness; noisiness. Prescribed function of sound pressure levels in the 24 one-third octave bands with nominal mid-band frequencies from 50 Hz to 10 kHz that is used in the calculation of perceived noise level. Unit, noy; abbreviation, n.

NOTE–The prescribed function is given in Federal Aviation Regulation Part 36, *Noise Standards: Aircraft Type and Airworthiness Certification*, Appendix B, and in International Civil Aviation Organization Annex 16, Volume 1, *Aircraft Noise*, Third Edition, July 1993.

12.13 noy. Unit of perceived noisiness, equal to the perceived noisiness of a one-third octave band of noise centered on 1 kHz and having a sound pressure level of 40 dB.

12.14 tone-corrected perceived noise level. Perceived noise level obtained by adding an adjustment that is related to the degree of irregularity that may occur among contiguous one-third octave band sound pressure levels of an aircraft noise. Unit, decibel (dB); abbreviations, PNLT, TPNL; symbol, L_{PNT}.

NOTES

1 The adjustment procedure is described in Federal Aviation Regulation Part 36, *Noise Standards: Aircraft Type and Airworthiness Certification*, Appendix B, and in International Civil Aviation Organization Annex 16, Volume 1, *Aircraft Noise*, Third Edition, July 1993.

2 The adjustment is intended to account for the extra subjective noisiness caused by pronounced audible tones such as may be generated by airplace propellers, compressors, turbines, or fans and may vary from 0 to 6 2/3 dB.

12.15 effective perceived noise level. Level of the time integral of the antilogarithm of one-tenth of tone-corrected perceived noise level over the duration of an aircraft flyover, the reference duration being 10 s. Unit, decibel (dB); abbreviation, EPNL; symbol, L_{EPN}.

NOTE–The integral is usually approximated by summation, over the top ten decibels of an aircraft noise signal of the antilogarithms of one-tenth of tone-corrected perceived noise level at successive 0.5 s intervals.

12.16 air conduction. Transmission of sound through the outer and middle ear to the inner ear.

12.17 bone conduction. Transmission of sound to the inner ear primarily by means of mechanical vibration of the cranial bones.

12.18 air-bone gap. For the ear of an individual at a specified frequency, the difference between the hearing threshold levels for air conduction and bone conduction. Unit, decibel (dB).

12.19 hearing threshold; threshold of audibility. For a given listener and specified signal, the minimum (a) sound pressure level or (b) force level that is capable of evoking an auditory sensation in a specified function of trials. Sound reaching the ears from other sources is assumed to be negligible. Unit, decibel (dB).

NOTES

1 The characteristics of the test signal, the manner in which it is presented to the listener, and the place at which the sound pressure level or force level is measured should be specified.

2 ANSI S3.21-1978 (R 1992), *American National Standard Method for Manual Pure-Tone Threshold Audiometry* recommends that a hearing threshold be defined as the lowest sound pressure level or force level at which responses occur in at least 50% of ascending trials.

12.20 masked threshold. Hearing threshold for a specified sound in the presence of another sound. Unit, decibel (dB).

12.21 equivalent threshold level. For monaural listening, at a specified frequency, for a specified type of transducer, and for a stated force of application of the transducer to the human head, the vibration level, or sound pressure level set up by that transducer in a specified coupler or artificial ear when the transducer is activated by that voltage which, with the transducer applied to the ear concerned, would correspond with the hearing threshold. Unit, decibel (dB).

12.22 reference equivalent threshold level. At a specified frequency, for a specified type of transducer, for a specified type of coupler or artificial ear, the mean value of the equivalent threshold levels of an adequately large number of ears of otologically normal listeners between the ages of 18 and 30 years, inclusive. Unit, decibel (dB).

NOTES

1 Reference equivalent threshold sound pressure levels for several types of earphones when used with one standard coupler are given in ANSI S3.6-1989, *American National Standard Specification for Audiometers*.

2 Reference equivalent threshold force levels are given in ANSI S3.43-1992, *American National Standard Reference Zero for the Calibration of Pure-Tone Bone-Conduction Audiometers*.

12.23 threshold of pain. For a given listener the minimum sound pressure level of a specified sound which will stimulate the ear to a sensation of definite pain. Unit, decibel (dB).

12.24 hearing level; hearing threshold level. For a specified signal, amount in decibels by which the hearing threshold for a listener, for either one or two ears, exceeds a specified reference equivalent threshold level. Unit: decibel (dB).

NOTE–Use of the term "hearing loss" instead of hearing level is deprecated. The term "hearing loss' refers to the physiological cause of the change in hearing level, e.g., conductive hearing loss of sensorineural hearing loss.

12.25 pure-tone audiogram. Graph showing hearing level as a function of frequency.

12.26 auditory sensation area. Region enclosed by the curves defining the hearing threshold and the threshold of pain as a function of frequency.

12.27 sensation level; level above threshold. For an individual listener and a specified sound signal, amount by which a sound pressure level or force level exceeds the hearing threshold for that sound. Unit: decibel (dB).

NOTE–The conditions of the measurements are to be specified.

12.28 recruitment. In certain cases of hearing impairment (e.g., cochlear) an apparent increase in loudness with increasing stimulus magnitude at a rate greater than for a normal ear.

12.29 masking. (a) The process by which the threshold of hearing for one sound is raised by the presence of another (masking) sound. (b) The amount by which the threshold of hearing for one sound is raised by the presence of another (masking) sound, expressed in decibels.

12.30 masking audiogram. Graph showing the amount by which the hearing threshold for a pure tone or narrow band of noise is raised by a stated masking sound, plotted in decibels as a function of the frequency of the pure tone or narrow band of noise.

12.31 auditory critical band. (a) Frequency band within which the loudness of a band of continuously distributed sound of constant sound pressure level is independent of its bandwidth. (b) Frequency band of sound, being a portion of a continuous-spectrum noise covering a wide band, that contains a sound pressure level equal to that of a continuous pure tone centered in the critical band and just audible in the presence of the wide band noise. Unit, hertz (Hz).

NOTE–By "just audible" is meant audible in a specified fraction of the trials, for a specified manner of listening.

12.32 detection. In acoustics, determination of the presence of an acoustic signal.

12.33 detection differential; recognition differential. For a specified aural detection system, that amount by which the signal level exceeds the noise level presented to the ear for a stated probability of detection. Unit, decibel (dB).

NOTE–The bandwidth of the system within which signal and noise are presented and measured must be specified.

12.34 difference limen for loudness. For an individual listener and a sound of specified frequency in specified conditions of trials, the minimum change of sound pressure level that is just noticed as a change in loudness. Unit, decibel (dB).

12.35 difference limen for pitch. For an individual listener and a sound of specified frequency, in specified conditions of trails, the minimum fractional change of the frequency that is just noticed as a change of pitch.

12.36 relative differential limen of frequency. For a given listener, ratio of the minimum perceptible frequency difference of two successively presented sinusoidal tones, to the frequency at which the difference threshold is being measured.

12.37 aural harmonic. Harmonic of a given stimulus generated and heard in the auditory mechanism.

12.38 electrophonic effect. Sensation of hearing produced when an alternating current of suitable frequency and magnitude from an external source is passed through a person.

12.39 instantaneous speech power. Rate at which sound energy is radiated by a speech source at any given instant. Unit, watt (W).

12.40 peak speech power. Maximum value of the instantaneous speech power within the time interval considered. Unit, watt (W).

12.41 average speech power. For a stated time interval, the arithmetic mean instantaneous speech power over that interval. Unit, watt (W).

12.42 formant. Of a complex sound, a range of frequencies in which there is an absolute or relative maximum in the sound spectrum. Unit, hertz (HZ).

NOTE–The frequency at the maximum is the formant frequency.

12.43 articulation; intelligibility. Percentage of speech units correctly received out of those transmitted.

NOTES

1 The word "articulation" is used when the units of speech material are meaningless syllables of fragments; the word "intelligibility" is used when the units of speech material are complete, meaningful words, sentences, or phrases. The term "intelligibility" is commonly associated with speech production as well as to speech reception.

2 The type of speech material used should be specified (i.e., phonemes, syllables, words phrases, or sentences). Speech identification is provided by an appropriate adjective, for example, syllable articulation,

vowel (or consonant) articulation, word intelligibility, sentence intelligibility, etc.

12.44 speech interference level. One-fourth of the sum of the band sound pressure levels for octave bands with nominal midband frequencies of 500, 1000, 2000, and 4000 Hz. Unit, decibel; abbreviation, SIL; symbol, L_{SI}.

12.45 central masking. Masking that occurs when the signal is presented to one ear and the masking sound to the other.

NOTE–The site of central masking is in the higher auditory pathways of the brain.

12.46 backward masking. Condition in which the signal appears after the masking sound.

12.47 forward masking. Condition in which the signal appears before the masking sound.

12.48 remote masking; downward masking. Phenomenon in which an intense band of noise raises the threshold of hearing for sounds lower in frequency than that of the noise.

12.49 acoustic trauma. Ear injury caused by a sudden and intense acoustic stimulus that causes a degree of permanent or temporary hearing loss.

12.50 noise induced temporary threshold shift. Temporary hearing loss occurring as a result of noise exposure. Abbreviation. NITTS.

12.51 noise induced permanent threshold shift. Permanent hearing loss resulting from noise exposure. Abbreviation, NIPTS.

13 Musical Acoustics

13.01 tone. (a) Sound wave capable of exciting an auditory sensation having pitch. (b) Sound sensation having pitch.

13.02 simple tone; pure tone. (a) Sound wave, the instantaneous sound pressure of which is a simple sinusoidal function of time. (b) Sound sensation characterized by its singleness of pitch.

NOTES

(1) Whether or not a listener hears a tone as simple or complex depends upon ability, experience, and listening attitude.

(2) See also 3.40.

13.03 complex tone. (a) Sound wave containing simple harmonic components of different frequencies. (b) Sound sensation characterized by more than one pitch.

13.04 fundamental. Component of a periodic wave having the lowest frequency (see 3.21).

13.05 partial. (a) Simple sinusoidal component of a complex tone. (b) Component of a sound sensation which may be distinguished as a simple tone that cannot be further analyzed by the ear and which contributed to the timbre of the complex sound (see 12.09).

NOTES

1 The frequency of a partial may be either higher or lower than the basic frequency and may not be an integral multiple or submultiple of the basic frequency (for definition of basic frequency, see 3.11). If the frequency is not a multiple or submultiple, the partial is inharmonic.

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 of the resulting complex tone are not necessarily identical in frequency with those of the other normal modes of vibration.

13.06 harmonic. Partial whose frequency is an integral multiple of the fundamental frequency.

NOTES

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

2 See also 3.22.

13.07 harmonic series of sounds. One in which each basic frequency in the series is an integral multiple of a fundamental frequency.

13.08 note. Conventional designation indicating pitch and duration; also the tone sensation itself or the sound pressure causing the sensation. The word serves when no distinction is desired among the symbol, the sensation, and the physical stimulus.

NOTE–Letter symbols from A to G are conventionally used to designate basic notes. Subscripts consisting of integers designate successive octave increases in frequency, starting at C_0. See Table 13.2.

13.09 vibrato. Family of tonal effects in music that depend upon periodic variations of one or more characteristics of the sound wave.

ERRATA

AMERICAN NATIONAL STANDARD
ACOUSTICAL TERMINOLOGY

ANSI S1.1-1994 (ASA 111-1994)

The definitions of clauses **12.46 backward masking** and **12.47 forward masking** in S1.1-1994 *American National Standard Acoustical Terminology* were reversed. Unfortunately this was not discovered in the review process. It is suggested that users of the document may make a simple correction by crossing out the present word **backward** in **12.46**, writing **forward** in place of it, and conversely, crossing out the present word **forward** in **12.47**, writing **backward** in its place. The clause numbers should also be reversed to match the index.

The correct definitions should read:

12.46 backward masking. Condition in which the signal occurs before the masking sound.

12.47 forward masking. Condition in which the signal occurs after the masking sound.

The definitions for these terms in the more recently issued S3.20-1995 *American National Standard Bioacoustical Terminology* are correct as published.

Accredited Standards Committee S1, Acoustics

Standards Secretariat
Acoustical Society of America
120 Wall Street, 32nd Floor
New York, New York 10005-3993

Table 13.1 – Interval comparisons in different mathematical tuning systems

	Pythagorean			Equally Tempered		Just		
	Origin	Ratio	Cents	Ratio	Cents	Origin	Ratio	Cents
Unison	1:1	1.000	0.00	1.000	0	1:1	1.000	0.00
Minor Second	2^8:3^5	1.054	90.22	1.059	100	16:15	1.067	111.73
Lesser Major Second	3^2:2^3	1.125	203.91	1.122	200	10:9	1.111	182.40
Greater Major Second						9:8	1.125	203.91
Minor Third	2^5:3^3	1.185	294.13	1.189	300	6:5	1.200	315.64
Major Third	3^4:2^6	1.266	407.82	1.260	400	5:4	1.250	386.31
Perfect Fourth	2^2:3	1.333	498.04	1.335	500	4:3	1.333	498.04
Augmented Fourth	3^6:2^9	1.424	611.73	1.414	600	45:32	1.406	590.22
Diminished Fifth	2^{10}:3^6	1.405	588.27	1.414	600	64:45	1.422	609.78
Perfect Fifth	3:2	1.500	701.96	1.498	700	3:2	1.500	701.96
Minor Sixth	2^7:3^4	1.580	792.18	1.587	800	8:5	1.600	813.69
Major Sixth	3^3:2^4	1.688	905.87	1.682	900	5:3	1.667	884.36
Minor Seventh	2^4:3^2	1.778	996.09	1.782	1000	7:4	1.750	968.83
Harmonic Minor Seventh						16:9	1.778	996.09
Grave Minor Seventh						9:5	1.800	1017.60
Major Seventh	3^5:2^7	1.898	1109.78	1.888	1100	15:8	1.875	1088.27
Octave	2:1	2.000	1200.00	2.000	1200	2:1	2.000	1200.00

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.

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

13.11 octave. Unit of logarithmic frequency interval between two frequencies when the base of the logarithm is two.

13.12 semitone; half-step. Unit of logarithmic frequency interval between two frequencies when the base of the logarithm is the twelfth root of two.

NOTE–In equally tempered semitones, the interval between any two frequencies is 12 times the logarithm to the base 2 (or ≈39.86314 times the logarithm to the base 10) of the frequency ratio.

13.13 cent. Unit of logarithmic frequency interval when the base of the logarithm is the 1200th root of two.

NOTE–One octave is 1200 cents.

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

13.15 Pythagorean scale. Musical scale in which the frequency intervals are represented by ratios of integral powers of the numbers 2 and 3. (See Table 13.1.)

13.16 just scale. Musical scale formed by octave rearrangement of the notes of three consecutive triads, each having the frequency ratio 4:5:6 or 10:12:15. (See Table 13.1.)

NOTE–For consecutive triads, the highest note of one triad is the lowest note of the next.

13.17 equally tempered scale. Musical scale formed by division of the octave into a number (usually twelve) of equal intervals. (See Table 13.1.)

13.18 standard tuning frequency; standard musical pitch. Frequency for the note A_4, 440 Hz. (See Table 13.2.)

Table 13.2 – Frequencies in hertz (Hz) and frequency levels in semitones counted (sc) up from C_0 for the usual equally tempered scale. Subscripts by octaves above C_0. C_0 approximately equals 16.352 Hz so that A_4 = 440 Hz exactly

Frequency			Frequency			Frequency		
Note	Level, sc	Frequency, Hz	Note	Level, sc	Frequency, Hz	Note	Level, sc	Frequency, Hz
B_2	35	123.47	B_5	71	987.77	B_8	107	7902.1
	34	116.54		70	932.33		106	7458.6
A_2	33	110.00	A_5	69	880.00	A_8	105	7040.0
	32	103.83		68	830.61		104	6644.9
G_2	31	97.999	G_5	67	783.99	G_8	103	6271.9
	30	92.499		66	739.99		102	5919.9
F_2	29	87.307	F_5	65	698.46	F_8	101	5587.7
E_2	28	82.407	E_5	64	659.26	E_8	100	5274.0
	27	77.782		63	622.25		99	4978.0
D_2	26	73.416	D_5	62	587.33	D_8	98	4698.6
	25	69.296		61	554.37		97	4434.9
C_2	24	65.406	C_5	60	523.25	C_8	96	4186.0
B_1	23	61.735	B_4	59	493.88	B_7	95	3951.1
	22	58.270		58	466.16		94	3729.3
A_1	21	55.000	A_4	57	440.00	A_7	93	3520.0
	20	51.913		56	415.30		92	3322.4
G_1	19	48.999	G_4	55	392.00	G_7	91	3136.0
	18	46.249		54	369.99		90	2960.0
F_1	17	43.654	F_4	53	349.23	F_7	89	2793.8
E_1	16	41.203	E_4	52	329.63	E_7	88	2637.0
	15	38.891		51	311.13		87	2489.0
D_1	14	36.708	D_4	50	293.66	D_7	86	2349.3
	13	34.648		49	277.18		85	2217.5
C_1	12	32.703	C_4	48	261.63	C_7	84	2093.0
B_0	11	30.868	B_3	47	246.94	B_6	83	1975.5
	10	29.135		46	233.08		82	1864.7
A_0	9	27.500	A_3	45	220.00	A_6	81	1760.0
	8	25.957		44	207.65		80	1661.2
G_0	7	24.500	G_3	43	196.00	G_6	79	1568.0
	6	23.125		42	185.00		78	1480.0
F_0	5	21.827	F_3	41	174.61	F_6	77	1396.9
E_0	4	20.602	E_3	40	164.81	E_6	76	1318.5
	[illegible]	19.445		39	155.56		75	1244.5
D_0	2	18.354	D_3	38	146.83	D_6	74	1174.7
	1	17.324	D_3		138.59		73	1108.7
C_0	0	16.352	C_3	36	130.81	C_6	72	1046.5

NOTE–Tuning or retuning of musical instruments is recommended within plus or minus 0.5 Hz at the standard tuning frequency, when the instruments are played where the ambient temperature is 22 °C (72 °F).

13.19 musical frequency level. In semitones, 12 times the logarithm to the base 2 of the ratio of the frequency of a sound to the reference frequency of 16.352 Hz, so chosen that A_4 = 440 Hz exactly.

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