

# ISO

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION

## ISO RECOMMENDATION

### R 31

PART VII

## QUANTITIES AND UNITS OF ACOUSTICS

1st EDITION

November 1965

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Printed in Denmark

Also issued in French and Russian. Copies to be obtained through the national standards organizations.

## BRIEF HISTORY

The ISO Recommendation R 31, *Part VII – Quantities and Units of Acoustics*, was drawn up by Technical Committee ISO/TC 12, *Quantities, Units, Symbols, Conversion Factors and Conversion Tables*, the Secretariat of which is held by the Danish Standards Association, Dansk Standardiseringsråd (DS).

Work on this question by the Technical Committee began in 1956 and led, in 1960, to the adoption of a Draft ISO Recommendation.

It should be noted that the following international organizations have had these draft proposals sent to them and have taken part in the discussions at the meetings of Technical Committee ISO/TC 12:

International Committee on Weights and Measures,  
International Electrotechnical Commission,  
International Union of Pure and Applied Chemistry,  
International Union of Pure and Applied Physics  
and its Sub-Committee SUN,  
International Commission on Illumination,  
Comité International de métrologie légale,  
World Meteorological Organization,  
International Commission on Radiological Units and Measurements,  
International Telegraph and Telephone Consultative Committee.

In June 1961, this Draft ISO Recommendation (No. 440) was circulated to all the ISO Member Bodies for enquiry. It was approved, subject to some modifications of an editorial nature, by the following Member Bodies:

|                |             |                |
|----------------|-------------|----------------|
| Australia      | Hungary     | Poland         |
| Austria        | India       | Portugal       |
| Belgium        | Ireland     | Romania        |
| Canada         | Israel      | Sweden         |
| Chile          | Italy       | Switzerland    |
| Czechoslovakia | Japan       | U. A. R.       |
| Denmark        | Mexico      | United Kingdom |
| France         | Netherlands | U. S. A.       |
| Germany        | New Zealand | U. S. S. R.    |
| Greece         | Norway      | Yugoslavia     |

No Member Body opposed the approval of the Draft.

The Draft ISO Recommendation was then submitted by correspondence to the ISO Council which decided, in November 1965, to accept it as an ISO RECOMMENDATION.

## Introduction

### General remarks

This document, containing a table of *Quantities and Units of Acoustics*, is part of a more comprehensive publication dealing with quantities and units in various fields of science and technology. Other part of this more comprehensive publication are at present

ISO Recommendations R 31,

Part I (2nd edition): *The International System of Units and Quantities and Units of Space and Time*<sup>1)</sup>,

Part II: *Quantities and Units of Periodic and Related Phenomena*,

Part III: *Quantities and Units of Mechanics*,

Part IV: *Quantities and Units of Heat*,

Part V: *Quantities and Units of Electricity and Magnetism*,

Part XI: *Mathematical Signs and Symbols for Use in Physical Sciences and Technology*.

General information regarding the arrangement of the tables and the symbols and abbreviations used is to be found in the introduction to ISO/R.31/Part I, where the full definitions of fundamental units are given as an appendix.

The statements in the definition columns for quantities are given merely for identification, they are not intended to be complete definitions.

### Special remarks

The explanations in the definition columns for quantities presuppose in general linear systems.

When it is necessary to use subscripts to avoid confusion between similar symbols in different domains, the subscript "a" is recommended for the acoustical case.

The preference given to the units of the International System of Units has been indicated by placing them first.

<sup>1)</sup> The title of the first edition of this document was: "Fundamental Quantities and Units of the MKSA System and Quantities and Units of Space and Time".

## 7. Acoustics

| Item No. | Quantity                                    | Symbol      | Definition <sup>1)</sup>                                                                                                             | Remarks                                                                                                                                                                                                            |
|----------|---------------------------------------------|-------------|--------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 7-1.1    | period, periodic time                       | $T$         | Time of one cycle.                                                                                                                   |                                                                                                                                                                                                                    |
| 7-2.1    | frequency                                   | $f, \nu$    | $f=1/T$                                                                                                                              | Concerning the standard tuning frequency (standard musical pitch), see ISO/R 16-1955.                                                                                                                              |
| 7-3.1    | frequency interval                          |             | The frequency interval between two frequencies is the logarithm to a specified base of the ratio between them.                       |                                                                                                                                                                                                                    |
| 7-4.1    | angular frequency, circular frequency       | $\omega$    | $\omega=2\pi f$                                                                                                                      |                                                                                                                                                                                                                    |
| 7-5.1    | wavelength                                  | $\lambda$   |                                                                                                                                      |                                                                                                                                                                                                                    |
| 7-6.1    | circular wave number                        | $k$         | $k = \frac{2\pi}{\lambda}$                                                                                                           |                                                                                                                                                                                                                    |
| 7-7.1    | density (mass density)                      | $\rho$      | Mass divided by volume.                                                                                                              |                                                                                                                                                                                                                    |
| 7-8.1    | static pressure                             | $p_s$       | Pressure that would exist with no sound waves present.                                                                               | The root mean square value of the quantities 7-8.2, 7-9.1, 7-10.1, 7-11.1 and 7-12.1 are often called "effective" values, and the same symbols are often used without modification to denote the effective values. |
| 7-8.2    | (instantaneous) sound pressure              | $p$         | The difference between the instantaneous pressure and the static pressure.                                                           |                                                                                                                                                                                                                    |
| 7-9.1    | (instantaneous) sound particle displacement | $\xi, (x)$  | Instantaneous displacement of particle of the medium from its mean position.                                                         |                                                                                                                                                                                                                    |
| 7-10.1   | (instantaneous) sound particle velocity     | $u, v$      | $u = \frac{\partial \xi}{\partial t}$                                                                                                |                                                                                                                                                                                                                    |
| 7-11.1   | (instantaneous) sound particle acceleration | $a$         | $a = \frac{\partial u}{\partial t}$                                                                                                  |                                                                                                                                                                                                                    |
| 7-12.1   | (instantaneous) volume velocity             | $q, U$      | Instantaneous rate of volume flow due to sound wave across an area.                                                                  |                                                                                                                                                                                                                    |
| 7-13.1   | velocity of sound                           | $c$         | Velocity of propagation of sound wave.                                                                                               |                                                                                                                                                                                                                    |
| 7-14.1   | sound energy density                        | $E$         | Mean sound energy in a given volume divided by that volume.                                                                          | If the energy density is varying with time, the mean must be taken over an interval during which the sound may be considered statistically stationary.                                                             |
| 7-15.1   | sound energy flux, sound power              | $P, (N, W)$ | Sound energy transferred in a certain time interval, divided by the duration of that interval.                                       |                                                                                                                                                                                                                    |
| 7-16.1   | sound intensity                             | $I, J$      | For unidirectional sound energy flux, sound energy flux through an area normal to the direction of propagation divided by that area. |                                                                                                                                                                                                                    |

<sup>1)</sup> The statements in this column are given merely for identification and they are not intended to be complete definitions.

## 7. Acoustics

Units  
7-1.a ... 7-16.b

| Item No. | Name of unit and in certain cases abbreviation for this name | International symbol for unit | Definition                                                                                    | Conversion factors                                                         | Remarks                                                                                                             |
|----------|--------------------------------------------------------------|-------------------------------|-----------------------------------------------------------------------------------------------|----------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------|
| 7-1.a    | <b>second</b>                                                | s                             | See 0-3. *)                                                                                   |                                                                            |                                                                                                                     |
| 7-2.a    | hertz                                                        | Hz                            | 1 Hz is the frequency of a periodic phenomenon of which the periodic time is 1 s              |                                                                            | 1 Hz = 1 s <sup>-1</sup><br>Cycle per second, c/s, is used primarily in English speaking countries.<br>1 c/s = 1 Hz |
| 7-3.a    | octave                                                       |                               | When the specified base of the logarithm is 2, the frequency interval is measured in octaves. |                                                                            |                                                                                                                     |
| 7-4.a    | reciprocal second                                            | s <sup>-1</sup>               |                                                                                               |                                                                            |                                                                                                                     |
| 7-5.a    | <b>metre</b>                                                 | m                             | See 0-1. *)                                                                                   |                                                                            |                                                                                                                     |
| 7-6.a    | reciprocal metre                                             | m <sup>-1</sup>               |                                                                                               |                                                                            |                                                                                                                     |
| 7-7.a    | kilogramme per cubic metre                                   | kg/m <sup>3</sup>             |                                                                                               |                                                                            | 1 kg/m <sup>3</sup> = 10 <sup>-3</sup> g/cm <sup>3</sup>                                                            |
| 7-8.a    | newton per square metre                                      | N/m <sup>2</sup>              |                                                                                               |                                                                            | This unit is also called pascal.                                                                                    |
| 7-8.b    | bar                                                          | bar                           |                                                                                               | 1 bar = 10 <sup>5</sup> N/m <sup>2</sup> (exactly)                         | The microbar (1 μbar = 1 dyn/cm <sup>2</sup> ) is also called barye.                                                |
| 7-8.c    | dyne per square centimetre                                   | dyn/cm <sup>2</sup>           |                                                                                               | 1 dyn cm <sup>2</sup> = 10 <sup>-1</sup> N/m <sup>2</sup> (exactly)        |                                                                                                                     |
| 7-9.a    | metre                                                        | m                             |                                                                                               |                                                                            |                                                                                                                     |
| 7-10.a   | metre per second                                             | m/s                           |                                                                                               |                                                                            |                                                                                                                     |
| 7-11.a   | metre per second squared                                     | m/s <sup>2</sup>              |                                                                                               |                                                                            |                                                                                                                     |
| 7-12.a   | cubic metre per second                                       | m <sup>3</sup> /s             |                                                                                               |                                                                            |                                                                                                                     |
| 7-13.a   | metre per second                                             | m/s                           |                                                                                               |                                                                            |                                                                                                                     |
| 7-14.a   | joule per cubic metre                                        | J/m <sup>3</sup>              |                                                                                               |                                                                            |                                                                                                                     |
| 7-14.b   | erg per cubic centimetre                                     | erg/cm <sup>3</sup>           |                                                                                               | 1 erg/cm <sup>3</sup> = 10 <sup>-1</sup> J/m <sup>3</sup> (exactly)        |                                                                                                                     |
| 7-15.a   | watt                                                         | W                             |                                                                                               |                                                                            |                                                                                                                     |
| 7-15.b   | erg per second                                               | erg/s                         |                                                                                               | 1 erg/s = 10 <sup>-7</sup> W (exactly)                                     |                                                                                                                     |
| 7-16.a   | watt per square metre                                        | W/m <sup>2</sup>              |                                                                                               |                                                                            |                                                                                                                     |
| 7-16.b   | erg per second square centimetre                             | erg/(s · cm <sup>2</sup> )    |                                                                                               | 1 erg/(s · cm <sup>2</sup> ) = 10 <sup>-3</sup> W/m <sup>2</sup> (exactly) |                                                                                                                     |

\*) ISO Recommendation R 31/Part I.

| Item No. | Quantity                        | Symbol               | Definition 1)                                                                                                                                                                                                                                           | Remarks                                                                                                                                                                                                                               |
|----------|---------------------------------|----------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 7-17.1   | specific acoustic impedance     | $Z_s, (W)$           | The complex representation of sound pressure at a point in a sound wave divided by the complex representation of particle velocity at that point.                                                                                                       | <p>In these definitions, the quantities entering the numerators and denominators are here assumed to be sinusoidal.</p> $Z_a = \frac{Z_s}{S}; \quad Z_m = SZ_s,$ <p>where <math>S</math> is the area of the surface considered.</p>   |
| 7-18.1   | acoustic impedance              | $Z_a, (Z)$           | The complex representation of average sound pressure at a vibrating surface divided by the complex representation of volume velocity at that surface.                                                                                                   |                                                                                                                                                                                                                                       |
| 7-19.1   | mechanical impedance            | $Z_m, (w)$           | The complex representation of total force at a surface (or at a point) of a mechanical system divided by the complex representation of average particle velocity at that surface (or of particle velocity at that point) in the direction of the force. |                                                                                                                                                                                                                                       |
| 7-20.1   | sound power level               | $L_P, (L_N, L_W)$    | Ten times the common (Briggsian) logarithm of the ratio of a given sound power to a reference power.                                                                                                                                                    | The reference power must be explicitly stated.                                                                                                                                                                                        |
| 7-21.1   | sound pressure level            | $L_p, (L)$           | Twenty times the common (Briggsian) logarithm of the ratio of a given sound pressure to a reference pressure.                                                                                                                                           | The reference pressure must be explicitly stated. It is recommended that for sound in air the value $2 \times 10^{-5} \text{ N/m}^2$ ( $2 \times 10^{-4} \text{ dyn/cm}^2$ ) should be universally adopted as the reference pressure. |
| 7-22.1   | damping coefficient             | $\delta$             | <p>If a quantity is a function of time <math>t</math> given by</p> $F(t) = Ae^{-\delta t} \sin \frac{2\pi(t-t_0)}{T},$ <p>then <math>\delta</math> is the damping coefficient.</p>                                                                      |                                                                                                                                                                                                                                       |
| 7-23.1   | logarithmic decrement           | $\Delta$             | Product of damping coefficient and period.                                                                                                                                                                                                              | See also ISO/R 31/Part II.                                                                                                                                                                                                            |
| 7-24.1   | attenuation coefficient         | $\alpha$             | <p>If a quantity is a function of distance <math>x</math> given by</p> $F(x) = Ae^{-\alpha x} \cos \beta(x-x_0),$ <p>then <math>\alpha</math> is the attenuation coefficient and <math>\beta</math> is the phase coefficient.</p>                       | See also ISO/R 31/Part II.                                                                                                                                                                                                            |
| 7-24.2   | phase coefficient               | $\beta$              |                                                                                                                                                                                                                                                         | When $\alpha$ is negligible, $\beta$ is often replaced by $k$ , the circular wave number. See 7-6.1.                                                                                                                                  |
| 7-24.3   | propagation coefficient         | $\gamma$             | $\gamma = \alpha + j\beta$                                                                                                                                                                                                                              |                                                                                                                                                                                                                                       |
| 7-25.1   | dissipation coefficient         | $\delta$             | Ratio of the sound energy flux dissipated to the incident sound energy flux.                                                                                                                                                                            | <p>These quantities are dimensionless.</p> $\delta + \varrho + \tau = 1$                                                                                                                                                              |
| 7-25.2   | reflection coefficient          | $r, \varrho$         | Ratio of the sound energy flux reflected to the incident sound energy flux.                                                                                                                                                                             |                                                                                                                                                                                                                                       |
| 7-25.3   | transmission coefficient        | $\tau$               | Ratio of the sound energy flux transmitted to the incident sound energy flux.                                                                                                                                                                           |                                                                                                                                                                                                                                       |
| 7-25.4   | acoustic absorption coefficient | $\alpha, (\alpha_a)$ | $\alpha = \delta + \tau$                                                                                                                                                                                                                                |                                                                                                                                                                                                                                       |

1) See footnote on page 4.

## 7. Acoustics (continued)

Units  
7-17.a ... 7-24.a

| Item No. | Name of unit and in certain cases abbreviation for this name | International symbol for unit           | Definition | Conversion factors                                                                                 | Remarks                                     |
|----------|--------------------------------------------------------------|-----------------------------------------|------------|----------------------------------------------------------------------------------------------------|---------------------------------------------|
| 7-17.a   | newton second per metre cubed                                | $\text{N} \cdot \text{s}/\text{m}^3$    |            |                                                                                                    |                                             |
| 7-17.b   | dyne second per centimetre cubed                             | $\text{dyn} \cdot \text{s}/\text{cm}^3$ |            | $1 \text{ dyn} \cdot \text{s}/\text{cm}^3 = 10 \text{ N} \cdot \text{s}/\text{m}^3$<br>(exactly)   | This unit is also called rayl.              |
| 7-18.a   | newton second per metre to the fifth                         | $\text{N} \cdot \text{s}/\text{m}^5$    |            |                                                                                                    |                                             |
| 7-18.b   | dyne second per centimetre to the fifth                      | $\text{dyn} \cdot \text{s}/\text{cm}^5$ |            | $1 \text{ dyn} \cdot \text{s}/\text{cm}^5 = 10^5 \text{ N} \cdot \text{s}/\text{m}^5$<br>(exactly) |                                             |
| 7-19.a   | newton second per metre                                      | $\text{N} \cdot \text{s}/\text{m}$      |            |                                                                                                    |                                             |
| 7-19.b   | dyne second per centimetre                                   | $\text{dyn} \cdot \text{s}/\text{cm}$   |            | $1 \text{ dyn} \cdot \text{s}/\text{cm} = 10^{-3} \text{ N} \cdot \text{s}/\text{m}$<br>(exactly)  |                                             |
| 7-20.a   | decibel                                                      | dB                                      |            |                                                                                                    | See also remark to 2-8.a, ISO/R 31/Part II. |
| 7-21.a   | decibel                                                      | dB                                      |            |                                                                                                    |                                             |
| 7-22.a   | neper per second                                             | $\text{Np}/\text{s}$                    |            |                                                                                                    | See also ISO/R 31/Part II.                  |
| 7-23.a   | neper                                                        | Np                                      |            |                                                                                                    | See also remark to 2-7.a, ISO/R 31/Part II. |
| 7-24.a   | reciprocal metre                                             | $\text{m}^{-1}$                         |            |                                                                                                    |                                             |
|          |                                                              |                                         |            |                                                                                                    |                                             |

## Quantities

## 7. Acoustics (continued)

7-26.1 ... 7-30.1

| Item No. | Quantity                                          | Symbol     | Definition <sup>1)</sup>                                                                                                                                                                                                                                                                                                                                                                                           | Remarks                                                                                                                                                                                                 |
|----------|---------------------------------------------------|------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 7-26.1   | sound reduction index, sound transmission loss    | $R$        | $10 \log_{10} \frac{1}{\tau}$                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                                                                                                                                         |
| 7-27.1   | equivalent absorption area of a surface or object | $A$        | The equivalent absorption area of a surface or object in a diffuse sound field is that area of a surface having the absorption factor of unity which, if diffraction effects are neglected, would in the same diffuse sound field absorb the same power.                                                                                                                                                           |                                                                                                                                                                                                         |
| 7-28.1   | reverberation time                                | $T$        | Time required for the average sound energy density in an enclosure to decrease to $10^{-6}$ of the initial value (by 60 dB) after the source has stopped.                                                                                                                                                                                                                                                          |                                                                                                                                                                                                         |
| 7-29.1   | loudness level                                    | $L_N, (A)$ | <p>The loudness level of a sound is defined by</p> $L_N = 20 \log_{10} \left( \frac{p_{\text{eff}}}{p_{0\text{eff}}} \right)_{1 \text{ kHz}}$ <p>where <math>p_{\text{eff}}</math> is the effective sound pressure of a standard pure tone of 1 kHz which is judged by a normal observer under standardized listening conditions as being equally loud, and</p> $p_{0\text{eff}} = 2 \times 10^{-5} \text{ N/m}^2$ | <p>The standardized listening conditions are given in ISO/R 226-1961.</p> <p>These quantities are dimensionless.</p> <p>These are not purely physical quantities, but entail subjective evaluation.</p> |
| 7-30.1   | loudness                                          | $N$        | The loudness is the normal observer's auditory estimate of the ratio between the strength of the sound considered and that of a reference sound having a loudness level of 40 phons.                                                                                                                                                                                                                               |                                                                                                                                                                                                         |
|          |                                                   |            |                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                                                                                                                                         |

<sup>1)</sup> See footnote on page 4.

## 7. Acoustics (continued)

Units  
7-26.a ... 7-30.a

| Item No. | Name of unit and in certain cases abbreviation for this name | International symbol for unit | Definition | Conversion factors                            | Remarks                                                                                                                                    |
|----------|--------------------------------------------------------------|-------------------------------|------------|-----------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------|
| 7-26.a   | decibel                                                      | dB                            |            |                                               |                                                                                                                                            |
| 7-27.a   | square metre                                                 | m <sup>2</sup>                |            |                                               |                                                                                                                                            |
| 7-27.b   | square foot                                                  | ft <sup>2</sup>               |            | 1 ft <sup>2</sup> = 0.092 9030 m <sup>2</sup> | This unit is also called sabin                                                                                                             |
| 7-28.a   | second                                                       | s                             |            |                                               |                                                                                                                                            |
| 7-29.a   | phon                                                         |                               |            |                                               |                                                                                                                                            |
| 7-30.a   | sone                                                         |                               |            |                                               | A standard relation between loudness in sone and loudness level in phon has been adopted for practical use and is given in ISO/R 131-1959. |
|          |                                                              |                               |            |                                               |                                                                                                                                            |