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**Mechanical vibration and shock — Range  
of idealized values to characterize seated-  
body biodynamic response under vertical  
vibration**

*Vibrations et chocs mécaniques — Enveloppes de valeurs probables  
caractérisant la réponse biodynamique d'individus assis soumis à des  
vibrations verticales*

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## Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this International Standard may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 5982 was prepared by Technical Committee ISO/TC 108, *Mechanical vibration and shock*, Subcommittee SC 4, *Human exposure to mechanical vibration and shock*.

This second edition cancels and replaces the first edition (ISO 5982:1981) and ISO 7962:1987, of which it constitutes an amalgamation and technical revision.

Major changes to previously given ranges of idealized values for the driving-point mechanical impedance and seat-to-head transmissibility of the seated human body were considered necessary in view of the indications that these were most probably derived by combining data sets determined over too broad a range of varying experimental conditions. The indications that several conditions associated with feet and back support, posture, excitation amplitude and subject mass could have a significant influence on measured biodynamic response led to the conclusion that the definition of a range of idealized values would only be feasible if it were based on data sets known to have been determined under a well-defined and restricted range of similar conditions. As part of this International Standard, a range of idealized values is defined only for seated individuals, exposed to sinusoidal or broad-band random vertical vibration with unweighted r.m.s. acceleration lower or equal to 5 m/s<sup>2</sup>, while the feet are resting flat on the vibrating platform (this also includes feet hanging freely for applications to seat-to-head transmissibility), the back is unsupported, and the individual body masses are within 49 kg to 93 kg. Only those data sets satisfying all of the above conditions were considered as part of the data synthesis performed to construct the envelopes defining the range of most probable values.

This International Standard incorporates the most recent data to have been published on driving-point mechanical impedance and/or apparent mass and seat-to-head transmissibility, while satisfying the conditions specified above. The frequency range for defining these values is now limited to 0,5 Hz to 20 Hz since predominant vertical vibration is known to occur within that range for several types of off-road, heavy road and industrial vehicles. As part of the annexes, an analytical model of the seated human body is provided to satisfy the range of idealized values defined for the driving-point mechanical impedance/apparent mass and seat-to-head transmissibility functions. Alternatively, mathematical expressions in the form of transfer functions are provided to approximate the mean (target) values defined for these functions. Finally, values for driving-point mechanical impedance and apparent mass are computed for specific body masses on the basis of the given model.

Annexes A to D of this International Standard are for information only.

This corrected and reprinted version of ISO 5982:2001 incorporates corrections to the Key to Figures D.1 and D.2.

## Introduction

The biodynamic response of the seated human body subjected to vibration has widely been assessed in terms of driving-point mechanical impedance or apparent mass and seat-to-head transmissibility. While the first two functions relate to the force and motion at the point of input of vibration to the body ("to the body" transfer functions), the last function refers specifically to the transmission of motion through the body ("through the body" transfer function). Knowledge of these functions under conditions representative of those encountered while driving specific types of vehicles may find applications in current laboratory procedures defined for assessing vehicle seat performance and for predicting whole-body vibration exposure levels on platforms of mobile machinery. Although such procedures currently require that specific tests be conducted with human subjects acting as test loads, these functions could form the basis for developing a mechanical system capable of simulating the human body or for deriving functions that could account for the human interface when the tests are being conducted with rigid masses. Such functions may further form the basis for developing analytical models representing the human body, which through combination with suitable suspension seat models, could provide numerical means of estimating the seat performance and of achieving optimal seat suspension and cushion design. Notwithstanding the above applications, this International Standard provides unification of available published data on the driving-point mechanical impedance, apparent mass and seat-to-head transmissibility response functions satisfying a specific set of conditions. In view of the restrictions imposed on posture and vibration excitation levels, the values defined for each of these functions might be more applicable to drivers of off-road, heavy road and industrial vehicles.

The response of the seated human body subjected to vertical vibration is dependent on several factors, including

- subject mass,
- posture and back support,
- feet support, and
- excitation amplitude.

In this International Standard, the driving-point mechanical impedance, the apparent mass and the seat-to-head transmissibility are employed to describe the biodynamic response characteristics of the seated human body to forced vertical motion of the buttocks, as a function of frequency. Alternatively, a model of the human body is provided to satisfy both simultaneously the driving-point mechanical impedance/apparent mass and seat-to-head transmissibility functions. The values for these functions have been derived from the results of driving-point mechanical impedance/apparent mass and seat-to-head transmissibility measurements performed on groups of live subjects, by different investigators while maintaining the conditions within the range mentioned in the foreword.

The unexplained differences between the mean modulus and phase values of mechanical impedance, apparent mass and seat-to-head transmissibility reported in studies conducted independently, under a similar range of experimental conditions, has dictated the form in which the standardized values for these functions is presented. A synthesis of measured values has been performed using data published in the literature (see annex A and the bibliography). The most probable range of values of driving-point mechanical impedance, apparent mass and seat-to-head transmissibility modulus and phase are defined as a function of frequency by upper and lower limit envelope curves, which encompass the mean values of all data sets, at each frequency. The smoothed envelopes have been constructed from successive piecewise approximations using a fixed number of points while creating an overlap. The mean of the accepted data sets, weighted according to the number of subjects involved, and standard deviation computed with respect to the weighted mean, are defined as a function of frequency, and represent the target values for all applications of this International Standard. Any data that fall within the range of idealized values defined by upper and lower limit envelope curves may be considered to be acceptable representation of the biodynamic response functions of the seated human body under the specific conditions defined.

No modulus or phase presented as a function of frequency in this International Standard corresponds precisely to the mean value measured in a single investigation involving human subjects at all frequencies. Furthermore, measured data for a single subject can appear out of range of the upper and lower limit envelope curves.

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# Mechanical vibration and shock — Range of idealized values to characterize seated-body biodynamic response under vertical vibration

## 1 Scope

This International Standard describes the range of idealized values of the driving-point mechanical impedance, apparent mass and seat-to-head transmissibility modulus and phase applicable to seated individuals subjected to  $z$ -axis sinusoidal or broad-band random vibration under specific experimental conditions. Additionally, a human body model is provided to satisfy the range of idealized values defined for driving-point mechanical impedance/apparent mass and seat-to-head transmissibility. This model is further used to compute values of driving-point mechanical impedance and apparent mass for fixed body masses which are recommended to be used as test loads in current standards defining laboratory seat testing methodologies. Alternatively, mathematical expressions in the form of transfer functions are provided to approximate the weighted mean (target) values defined for all three biodynamic response functions.

The ranges of idealized values defined in this International Standard are considered to be valid for seated subjects supported on a rigid platform, with feet supported and vibrated, and maintaining an erect seated posture without backrest support. Provisionally, the range of idealized seat-to-head transmissibility values is considered to be applicable also to the condition with the feet hanging freely. The values are defined over the frequency range 0,5 Hz to 20 Hz for subjects within the 49 kg to 93 kg mass range, subjected to sinusoidal or broad-band random vibration of unweighted r.m.s. amplitude lower than or equal to 5 m/s<sup>2</sup>. The frequency and amplitude characteristics of the vibration fall within the range for which most vibration exposure is likely to predominate while driving vehicles such as agricultural tractors, earth-moving machinery and fork-lift trucks. Application to automobiles is at present not covered by this International Standard in view of the lack of a meaningful data base for conditions involving posture and vibration excitation levels most likely associated with car driving.

The upper and lower values of modulus and phase defined at each frequency for each of the three biodynamic response functions considered represent the range of most probable or idealized values. The middle values represent overall weighted means of the human data, and define the target values for general applications. Such applications may involve the development of mechanical analogues for laboratory seat testing, or of functions to correct for the human interface when representing the body as a rigid mass, or the development of analytical human body models to be used for whole-body vibration exposure estimations or for seat and cushion design optimization.

A mathematical representation of the seated human body that falls within the upper and lower limit envelope curves defined for driving-point mechanical impedance/apparent mass and seat-to-head transmissibility is also provided in annex B, while mathematical expressions approximating the weighted mean (target) values for these functions are given in annex C. Model values of driving-point mechanical impedance and apparent mass computed for fixed body masses equal or close to those recommended in specific laboratory seat testing standards are also provided in annex D.

## 2 Normative reference

The following normative document contains provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent edition of the normative document indicated below. For

undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 5805, *Mechanical vibration and shock — Human exposure — Vocabulary*

### 3 Terms and definitions

For the purposes of this International Standard, the terms and definitions given in ISO 5805 and the following apply.

#### 3.1 driving-point mechanical impedance

complex ratio of applied periodic excitation force at frequency  $f$ ,  $F(f)$ , to the resulting vibration velocity at that frequency,  $v(f)$ , measured at the same point and in the same direction as the applied force

$$Z(f) = \frac{F(f)}{v(f)} \quad (1)$$

NOTE 1 The driving-point mechanical impedance is a complex quantity (i.e. it possesses real and imaginary parts) from which the modulus and phase can be computed.

NOTE 2 This International Standard is based on measurements in which both force and velocity were measured at the same point, this being the point of introduction of vibration to the body, namely the buttocks or seat-body interface.

NOTE 3 In the case of non-harmonic vibration, driving-point mechanical impedance is determined from the force and velocity spectra.

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#### 3.2 apparent mass

complex ratio of applied periodic excitation force at frequency  $f$ ,  $F(f)$ , to the resulting vibration acceleration at that frequency,  $a(f)$ , measured at the same point and in the same direction as the applied force

$$M(f) = \frac{F(f)}{a(f)} = -j \frac{Z(f)}{2\pi f} \quad (2)$$

NOTE 1 The relationship between apparent mass and mechanical impedance is entirely determined by the fixed relationship between velocity and acceleration for which a 90° phase difference exists under periodic excitation. In the above expression,  $j = \sqrt{-1}$  represents the complex phasor between the mechanical impedance and apparent mass.

NOTE 2 In the case of non-harmonic vibration, apparent mass is determined from the force and acceleration spectra.

#### 3.3 seat-to-head transmissibility

complex non-dimensional ratio of the response motion of the head to the forced vibration motion at the buttocks or seat-body interface

NOTE 1 The ratio may be one of displacements, velocities or accelerations.

NOTE 2 The seat-to-head transmissibility is a complex quantity (i.e. it possesses real and imaginary parts) from which the non-dimensional modulus and the phase can be computed.

NOTE 3 In the case of non-harmonic vibration, seat-to-head transmissibility is determined from the motion spectra.



## 4 Driving-point mechanical impedance and apparent mass of the seated body under vertical vibration

### 4.1 Definition of values of driving-point mechanical impedance and apparent mass

The modulus and phase of the driving-point mechanical impedance and apparent mass of the seated body are given in Tables 1 and 2 respectively and (for illustration) in Figures 1 and 2 as a function of frequency, for the vertical direction of excitation. In accordance to the definitions, the modulus is given in terms of newton seconds per metre for impedance and kilograms for apparent mass. Each table and diagram contains three values of modulus and phase at each frequency. Numerical values are quoted up to four significant figures for the purpose of calculation, and do not reflect the precision of knowledge of the driving-point mechanical impedance and apparent mass. Linear interpolation is permitted to obtain values at frequencies other than those listed in Tables 1 and 2 at one-third-octave band centre frequencies.

The upper and lower limiting values at each one-third-octave band centre frequency encompass the mean values of all data sets selected, and are shown by bold continuous curves in Figures 1 and 2. The central value at each frequency, shown by fine solid curves in Figures 1 and 2, provides an estimate of the weighted mean of all data sets selected, and forms the target value for all applications. The standard deviations computed with respect to the weighted mean (target) values are also listed in Tables 1 and 2.

Applications that generate/employ values of driving-point mechanical impedance and apparent mass between the upper and lower limits given in Tables 1 and 2 at any frequency satisfy the requirements of this International Standard, and represent "to the body" transfer functions applicable to the seated human body under the conditions specified and over the frequency range of 0,5 Hz to 20 Hz.

If an application only satisfies the requirements of this International Standard at certain frequencies, then those frequencies should be stated in any description of the application.

NOTE 1 The curves in Figures 1 and 2 are derived from the data identified in annex A for driving-point mechanical impedance and apparent mass. The synthesis is performed by transforming all data to the driving-point mechanical impedance function and averaging by weighting the data according to the population of subjects involved in deriving the data. Upper and lower limiting values represent maximum and minimum values of the data sets determined at each frequency. The resulting range of idealized driving-point mechanical impedance values is further transformed to derive the corresponding range of idealized apparent mass values.

NOTE 2 The curves in Figures 1 and 2 relate to 101 test subjects within the mass range 49 kg to 93 kg. Both sinusoidal and broad-band random vibration with unweighted root-mean-square acceleration between 0,5 m/s<sup>2</sup> and 3 m/s<sup>2</sup> and frequency-weighted root-mean-square acceleration less than or equal to 2 m/s<sup>2</sup> have been used in deriving the data. Some evidence suggests that non-linearities in driving-point mechanical impedance and apparent mass responses may arise with variations in vibration amplitudes, particularly when lower vibration magnitudes are involved.

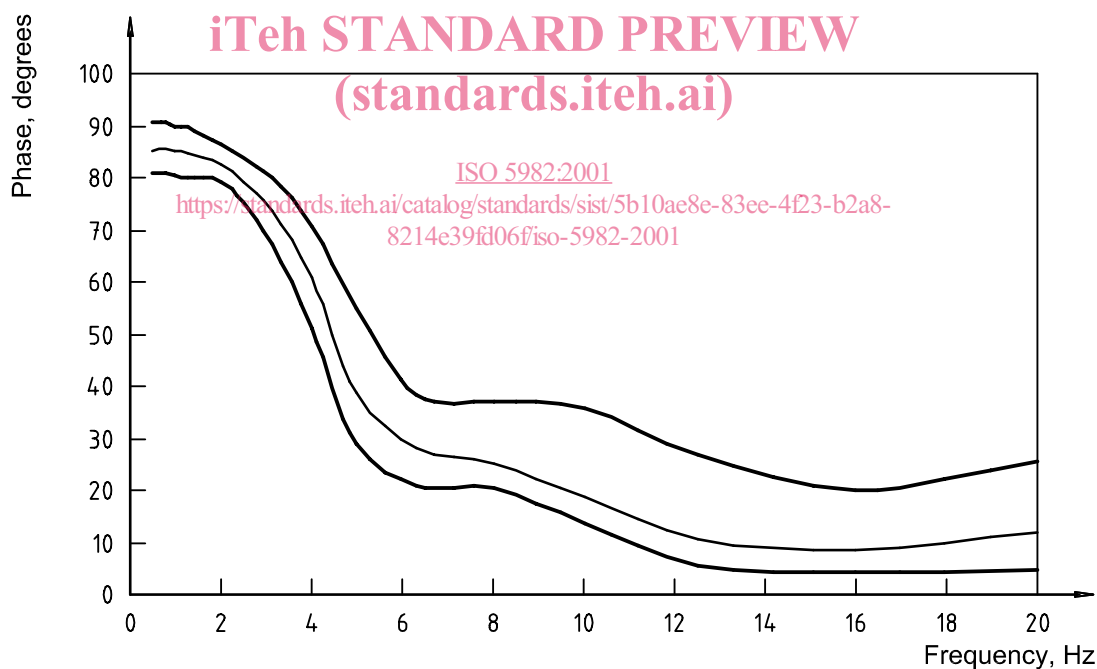
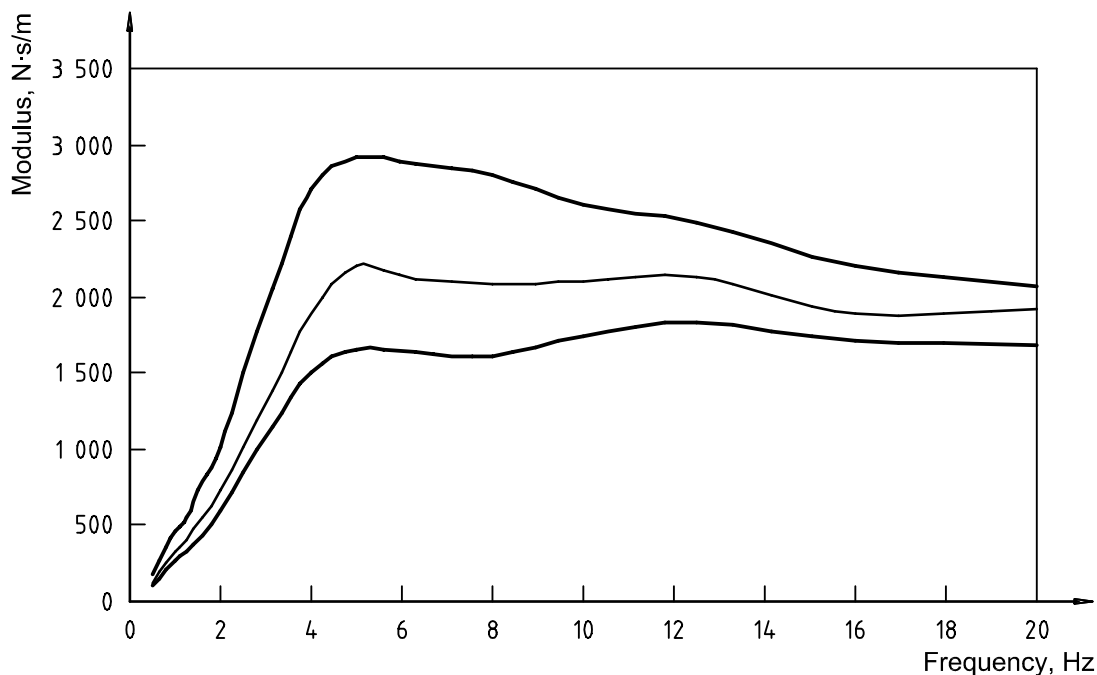
### 4.2 Applicability of values of driving-point mechanical impedance and apparent mass

The values of driving-point mechanical impedance and apparent mass are applicable to the seated human body, subjected to sinusoidal or broad-band random vertical vibration, while seated on a rigid surface with the feet resting flat on the base platform and the back being unsupported. The limits of applicability approximately correspond to the range of measurement conditions over which data were obtained, as follows:

- a) the posture is described as erect seated without backrest support, while the feet are supported and vibrated;
- b) the mass of the subjects ranges from 49 kg to 93 kg;
- c) the r.m.s. amplitude of unweighted sine and random excitation is between 0,5 m/s<sup>2</sup> and 3,0 m/s<sup>2</sup> with predominance of frequencies within the range from 0,5 Hz to 20 Hz. Frequency-weighted r.m.s. amplitudes less than or equal to 2 m/s<sup>2</sup> were also part of the vibration excitations considered.

**Table 1 — Modulus and phase of the mean (target) and range of idealized driving-point mechanical impedance of the seated body under vertical vibration**

Frequency Hz	Modulus N·s/m				Phase degrees			
	Mean	Upper limit	Lower limit	Standard deviation	Mean	Upper limit	Lower limit	Standard deviation
0,5	157	222	128	44	85,4	90,8	81,0	3,2
0,63	199	282	163	57	85,6	90,8	81,0	3,4
0,8	256	362	211	71	85,5	90,6	81,0	3,0
1	327	459	270	56	84,9	89,9	80,3	3,7
1,25	418	587	343	66	84,6	89,6	80,2	3,3
1,6	553	789	452	74	83,7	88,2	79,9	2,9
2	728	1 019	596	131	82,4	86,3	79,0	2,4
2,5	953	1 408	811	171	79,8	84,4	76,2	1,8
3,15	1 349	2 005	1 117	246	74,2	80,2	68,2	3,2
4	1 894	2 705	1 506	373	60,7	70,6	51,1	6,5
5	2 201	2 919	1 657	428	38,6	54,8	29,0	12,1
6,3	2 120	2 883	1 641	362	28,0	39,0	20,9	5,4
8	2 088	2 797	1 611	373	25,2	36,9	20,3	6,6
10	2 095	2 609	1 748	282	18,8	35,9	13,7	9,9
12,5	2 139	2 492	1 836	258	10,8	27,3	5,8	8,6
16	1 898	2 204	1 714	172	8,6	20,2	4,4	7,6
20	1 922	2 075	1 679	335	12,1	25,5	4,8	10,2



NOTE For an explanation of the lines, see 4.1.

**Figure 1 — Mean (target) and range of idealized values for the driving-point mechanical impedance of the seated body under vertical vibration**

Table 2 — Modulus and phase of the mean (target) and range of idealized apparent mass of the seated body under vertical vibration

Frequency Hz	Modulus kg				Phase degrees			
	Mean	Upper limit	Lower limit	Standard deviation	Mean	Upper limit	Lower limit	Standard deviation
0,5	50,0	70,7	40,7	14,0	-4,6	0,8	-9,0	3,2
0,63	50,3	71,2	41,2	14,4	-4,4	0,8	-9,0	3,4
0,8	51,0	72,0	42,0	14,1	-4,5	0,6	-9,0	3,0
1	52,0	73,0	43,0	8,9	-5,1	-0,1	-9,7	3,7
1,25	53,2	74,7	43,7	8,4	-5,4	-0,4	-9,8	3,3
1,6	55,0	78,5	45,0	7,4	-6,3	-1,8	-10,1	2,9
2	57,9	81,1	47,4	10,4	-7,6	-3,7	-11,0	2,4
2,5	60,7	89,6	51,6	10,9	-10,2	-5,6	-13,8	1,8
3,15	68,2	101,3	56,4	12,4	-15,8	-9,8	-21,8	3,2
4	75,4	107,6	59,9	14,8	-29,3	-19,4	-38,9	6,5
5	70,1	92,9	52,7	13,6	-51,4	-35,2	-61,0	12,1
6,3	53,6	72,8	41,4	9,1	-62,0	-51,0	-69,1	5,4
8	41,5	55,7	32,0	7,4	-64,8	-53,1	-69,7	6,6
10	33,3	41,5	27,8	4,5	-71,2	-54,1	-76,3	9,9
12,5	27,2	31,7	23,4	3,3	-79,2	-62,7	-84,2	8,6
16	18,9	21,9	17,1	1,7	-81,4	-69,8	-85,6	7,6
20	15,3	16,5	13,4	2,7	-77,9	-64,5	-85,2	10,2