American Journal of Materials & Applied Science

Review Article

Non-Elementary Elementary Harmonic Oscillator -

Ordin SV*

Ioffe Institute of the Russian Academy of Sciences

***Address for Correspondence:** Stanislav Ordin, Ioffe Institute of the Russian Academy of Sciences, Russia, E-mail: stas_ordin@mail.ru

Submitted: 15 February 2021; **Approved:** 24 February 2021; **Published:** 08 March 2021

Cite this article: Ordin SV. Non-Elementary Elementary Harmonic Oscillator. American J Mater Appl Sci. 2021 March 08;3(1): 003-008.

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ABSTRACT

Before starting to eliminate the phenomenological error inherent in the foundations of Quantum Mechanics, its basic model of the Classical Mechanical Oscillator (CMO) was thoroughly analyzed. Within the framework of the complete solution of the CMO differential equation, the connection between its attenuation and the Heisenberg Uncertainty Principle is shown - an ideal, continuous QMO has non-physical (unobservable) characteristics that change abruptly (become physical) upon introducing even an infinitely small damping. It was shown that the quantum corrections used to take scattering into account simply compensate for the incompleteness of the Schrödinger equation. But besides this, it was revealed that the particular solution of the equation of oscillation of a mechanical oscillator, used since Newton's time, does not take into account the excitation of its natural oscillations interfering with oscillations at the frequency of the driving force. This term, missed, but very significant at high frequencies at low damping, is less than the inverse damping frequency at the recording time. Taking this term into account describes many mechanical and electrical "anomalies" as normal interference with resonant vibrations.

Keywords: Mechanical model; Complete solution of the differential equation; Damping; Heisenberg uncertainty principle; Mechanical and electrical anomalies of oscillations; Interference

INTRODUCTION

The use of the impedance (Heaviside) by the Planck method made it possible to eliminate false singularities arising in purely optical and purely electrodynamic models for describing plasma effects [1]. But, on the one hand, a careful analysis of the impedance showed that the electric oscillator gives incorrect values of the measurable parameters when its attenuation is zero. On the other hand, the impedance of the electric oscillator is in direct agreement with those used by Planck when he introduced quantization by electromagnetic waves. Whereas the Schrödinger equation was built precisely on the basis of a mechanical harmonic oscillator. As a consequence, this equation, taken as the basis of Quantum Mechanics, only qualitatively describes the hydrogen atom and gives catastrophic discrepancies between calculations and experiment with increasing atomic mass [2]. And this is quite understandable, since Quantum Mechanics, as the name suggests, was initially built within the framework of purely mechanistic concepts.

The movement of an elementary Mechanical Oscillator (MO), excluding damping, is determined by the mass m and stiffness (coefficient of elasticity) κ of the spring

$$m\cdot\ddot{x}=-\kappa\cdot x \qquad (1)$$

And it is customary to describe it as a purely harmonic dependence of the displacement coordinate x:

$$x(t)=A\cdot Cos(\Omega\cdot t) \qquad (2)$$

where $\Omega=\frac{2\pi}{T_{res}}=\sqrt{\frac{\kappa}{m}}$ - is the resonant frequency, T_{res} - is the oscillation period, and A – the oscillation amplitude. At the same time, in Quantum Mechanics, the total energy E of the harmonic oscillator was used

$$E=\frac{\kappa A^2}{2}=\frac{m\cdot\Omega^2A^2}{2}=\frac{mA^2}{2}\left(2\pi\frac{1}{T_{res}}\right)^2=\frac{mA^2c}{2}\left(\frac{2\pi}{\lambda_{res}}\right)^2 \qquad (3)$$

which in the classical case are characterized by a single resonant frequency and the possibility of continuous variation of the amplitude A. Schrödinger's rewriting of this very equation in operator form is used for quantization, which gives a discrete set of amplitudes and frequencies

$$E_n=\frac{\kappa A_n^2}{2}=\frac{m\cdot\Omega^2A_n^2}{2}=n\hbar\cdot\Omega \quad\Rightarrow\quad A_n=\sqrt{\frac{2n\hbar\cdot\Omega}{\kappa}}=\sqrt{\frac{2n\hbar}{m\cdot\Omega}} \qquad (4)$$

The realization that purely mechanistic concepts were used led to the creation of Quantum NON-MECHANICS. But, although mechanical measurements are much coarser than electrical ones, the discovered feature of electrical resonance [1] raised the question of the accuracy of calculating the oscillations of an elementary mechanical generator. The question is very important. Both in connection with the widely used calculations of wave functions, which are not entirely correct on the basis of a mechanical oscillator, and in connection with the completely correct use of the mechanical oscillator model for the primary quantization of phonons (in contrast to the secondary quantization of phonons, which gives a qualitatively different general picture of phonon branches, fundamentally which differs from the experimentally observed one [3]).

Traditionally, almost since Newton's time, the oscillations of a harmonic oscillator are described by a particular solution obtained by the method of separation of variables in a differential equation with the subsequent solution of the already obtained algebraic equation. The solution is, in principle, particular, but it qualitatively reflects the main properties of the CMO. This simplified solution was also used by me earlier in the analysis of forced oscillations of a harmonic oscillator [4]. For the transparency of the analysis, in the calculations, the frequency of the driving force and the damping frequency reduced to the resonance frequency were used, and the amplitude of the driving force reduced to the mass was taken equal to unity. By themselves, these assumptions do not violate the general nature of the reasoning and the conclusions obtained. But a rigorous solution to the harmonic oscillator equation with zero initial conditions: displacement and, either the velocity or acceleration at the initial moment of time are equal to zero, gives a general solution consisting of the interference of many harmonics. Including for the Ideal case, and at zero attenuation of the QMO, the total oscillation consists of the interference of two harmonics, each of which has its own frequency dependence of the oscillation amplitude

$$x''[t]+x[t]=\mathrm{Sin}[\Omega t] \qquad \text{Þ}$$

$$x[t]=\frac{\Omega\,\mathrm{Sin}[t]-\mathrm{Sin}[\Omega t]}{-1+\Omega^2}=$$

$$\frac{\Omega}{-1+\Omega^2}\mathrm{Sin}[t]-\frac{1}{-1+\Omega^2}\mathrm{Sin}[\Omega t] \qquad (5)$$

The frequency of the harmonic described by the first term of the complete solution without damping is strictly equal to the resonance frequency, and the frequency of the second harmonic is strictly equal to the oscillation frequency of the harmonic driving force. The total interference of these harmonics for a number of frequencies is shown in figure 1.

In this case, each harmonic has its own frequency dependence, moreover, the frequency dependence of the second harmonic completely coincides with the frequency dependence of the oscillation amplitude of a harmonic oscillator, obtained by the method of separation of variables (Figure 2) The red curve in figure 2 corresponds to the missed "anomalous" oscillations at the resonant frequency for an arbitrary frequency of the driving force, which, as can be seen from figure 2, have little effect on the total amplitude at low frequencies, but exceed the "normal" oscillations (at the frequency of the driving force - blue curve of dots) the greater, the higher the frequency of oscillations of the driving force.

The amplitude of the total oscillation strictly at the resonant frequency has the following time dependence and, naturally, tends to infinity:

$$\text{Limit}\left[\frac{\text{Ù S i n[t] - S i n[Ùt]}}{\text{Ù1 + }^{2}}\right]_{\text{Ù}\to 1} = 1/2\ (-t\,\text{Cos}[t] + \text{Sin}[t]) \qquad (6)$$

The modulus of the amplitude of the total oscillation without damping (gray curve in figure 2) coincides with good accuracy with the sum of the moduli of the amplitudes of the harmonics (blue and red curves in figure 2) and with the time asymptotics of the magnitudes of the maxima of interference oscillations under the action of a harmonic driving force at different frequencies (points in figure 2). And at frequencies of the driving force, different from the resonant frequency, at infinite times, the amplitude of oscillations is set to a finite value, both of the harmonics at the frequency of the driving force, and of a finite value of the amplitude of oscillations strictly at the resonance frequency. Moreover, purely resonant oscillations at frequencies below the resonant one make a small contribution to the total amplitude of oscillations, and at frequencies of the driving force above the resonant one, it is in the purely ideal case that they are decisive - oscillations at the resonant frequency are orders of magnitude larger than the oscillations at the frequency of the driving force. Thus, in the very property of an ideal oscillator there is a number of observed effects: the specificity of the sounds of the violin, and the sound coloration of the voices of people, animals, birds, and a number of problems of sound and color rendering, and flutter with an increase in the speed of the air flow past the aircraft, and the vibration of the propeller, and cavitation in a water flow, and, in principle, the photoelectric effect at photon energies greater than the bandgap of semiconductors used in the detector, and the problem of Fourier transform of signals (and all of the above - in the first order, and not in the form of corrections for Mathieu anharmonicities [5].

Taking into account the nonzero attenuation, the above equation (5) has the following form:

$$x''[t] + \gamma \cdot x'[t] + x[t] = \text{Sin}(\omega \cdot t) \qquad (7)$$

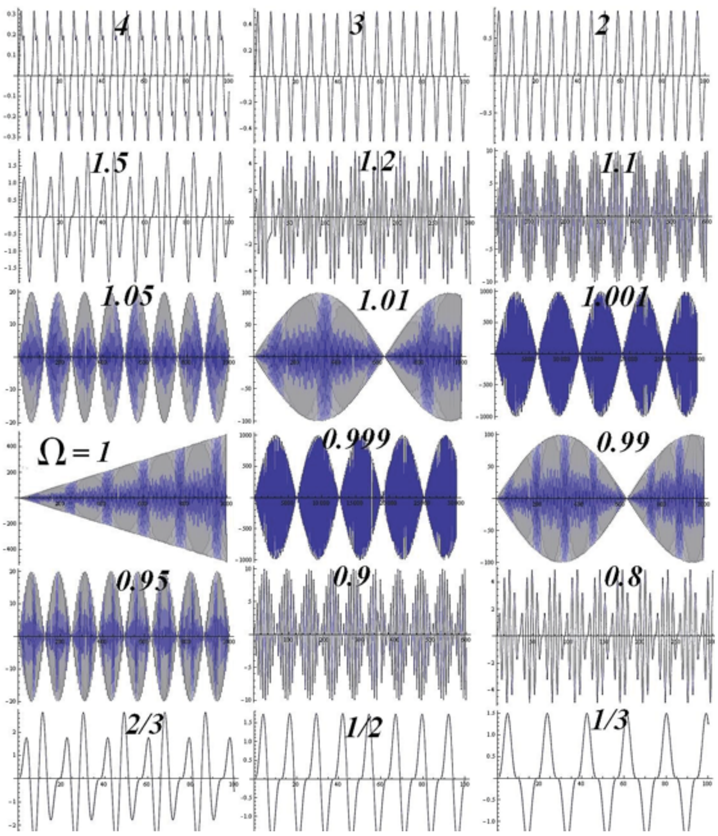

Figure 1: A set of interferences of natural resonant oscillations of an ideal mechanical oscillator with oscillations of a set of frequencies of a harmonic driving force in the absence of damping.

Its complete (without separation of variables) solution contains two terms, which are also determined by the natural resonance frequency and the frequency of harmonic oscillations

$$\frac{\Omega\left(2+\gamma\left(\sqrt{\gamma^2-4}-\gamma\right)-2\Omega^2+e^{t\sqrt{-4+\gamma^2}}\left(\gamma^2+\gamma\sqrt{\gamma^2-4}+2\Omega^2-2\right)\right)}{e^{\frac{1}{2}t\left(\gamma+\sqrt{-4+\gamma^2}\right)}2\sqrt{\gamma^2-4}\left(1+\left(\gamma^2-2\right)\Omega^2+\Omega^4\right)}-$$
$$-\frac{\gamma\Omega\,\mathrm{Cos}(\Omega t)+\left(\Omega^2-1\right)\mathrm{Sin}(\Omega t)}{\left(1+\left(\gamma^2-2\right)\Omega^2+\Omega^4\right)} \quad (8)$$

The second term, in principle, corresponds to a particular algebraic solution, but only for the frequencies of the driving harmonic force, so that it does not contain any interference features:

$$x=\frac{1}{1+\gamma\cdot\Omega+\Omega^2}\mathrm{Sin}(\Omega\cdot t)\Rightarrow A_x=\frac{1}{1+\gamma\cdot\Omega-\Omega^2} \quad (9)$$

The resulting complete solution in the limit gives (in contrast to the particular) a rigorous mathematical transition to the solution of the equation without damping 5 when the damping tends to zero in it. But, as will be shown below, physically infinitesimal attenuation leads to a transformation of the frequency dependence.

This complete solution is also an interference oscillation, the maximum amplitude of which has a characteristic time-dependent (Figure 3 and Figure 4).

As can be seen from the figures, in contrast to the ideal case, the interference of oscillations after reaching the asymptotics drops off sharply in amplitude at times greater than the reciprocal damping frequency.

So, measurement times less than the reciprocal damping

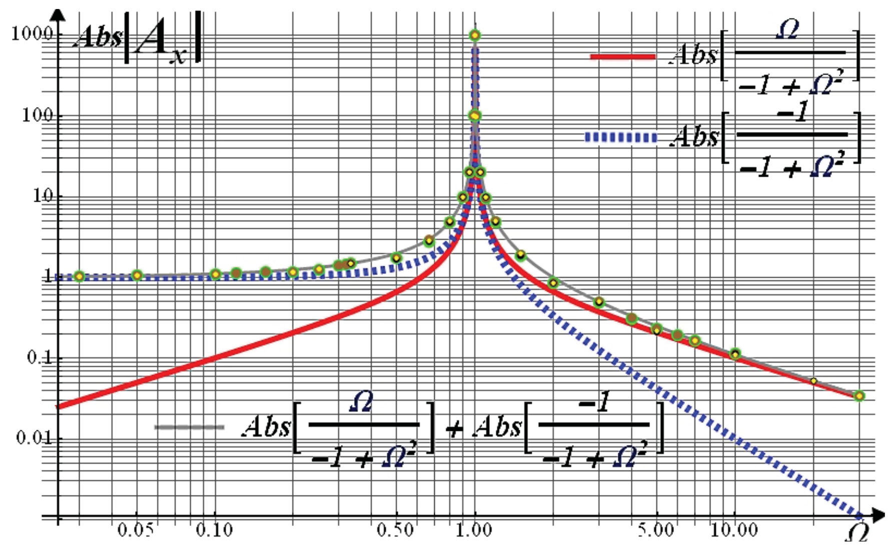

Figure 2: Frequency dependences of the amplitudes of the oscillation harmonics of the Ideal mechanical oscillator (blue and red curves) and the interference amplitudes of these harmonics (gray curve).

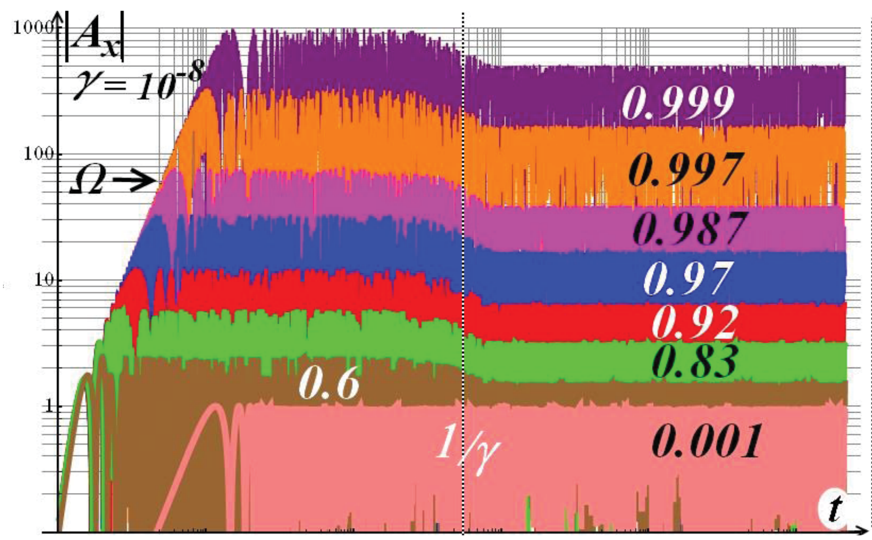

Figure 3: Transient processes and reaching the asymptotic of the modulus of the amplitude of the total oscillations of the harmonic oscillator at times above the inverse damping frequency 2π/γ for different frequencies of harmonic oscillations of the driving force Ω below the resonance frequency.

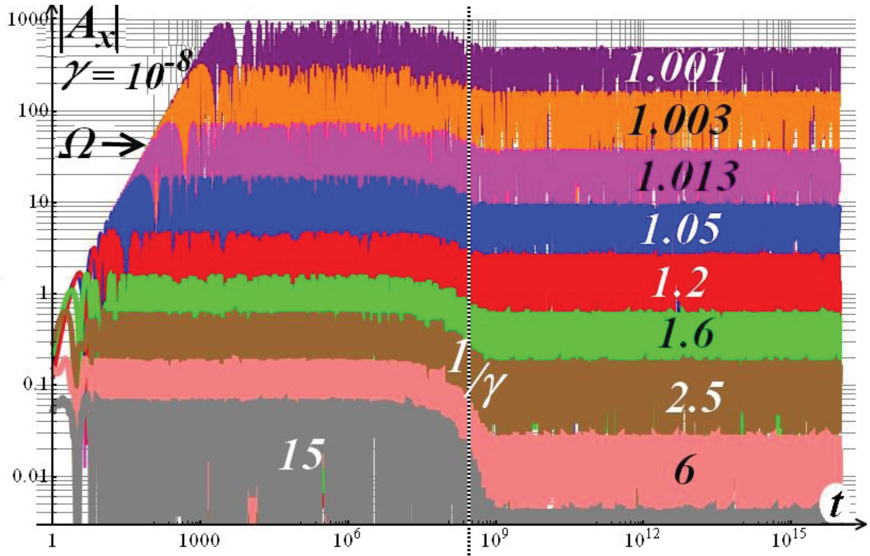

Figure 4: Transient processes and reaching the asymptotic of the modulus of the amplitude of the total oscillations of the harmonic oscillator at times above the inverse damping frequency 2π/γ for different frequencies of harmonic oscillations of the driving force Ω above the resonance frequency.

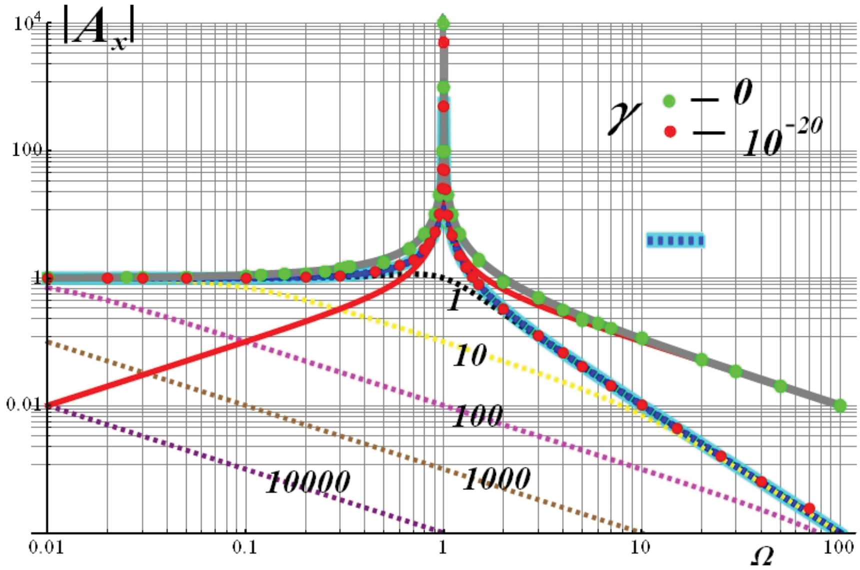

Figure 5: Sharpening of the maximum at the resonance frequency due to natural resonance oscillations (the first term of the complete solution of the equation for the elementary harmonic oscillator (dots show the measurements / calculations of the amplitude of the total oscillations when the measurement time tends to infinity -10300 periods).

frequency give a large addition near the resonant frequency, and for frequencies above the resonant frequency, a giant addition to the interference amplitude. And for the ideal case, when, one might say, the measurement time of a stationary process is infinite, this additive is decisive. Whereas the introduction of damping leads, at computation/measurement times greater than the reciprocal damping frequency, to a sharp decrease in the contribution of the intrinsic resonance at the frequency of the driving force.

Thus, the Heisenberg Uncertainty Principle simply takes into account the smallest allowable attenuation that was initially missed in the Schrödinger equation. And additional "quantum corrections" to attenuation in turbid media, which give a smaller green laser bandwidth [6-8], are apparently also determined by the fact that the attenuation is introduced "over" Schrödinger's idealization - their nature is not taken into account in the classical model of the complete solutions for oscillator vibrations. And within the framework of the complete solution, taking into account the influence of damping manifests itself in the first term, in the compression of the band of the natural resonance oscillations in the medium, while the second term, determined by the tuning of the resonator and, thereby, the tuning of the coherence frequency - the driving force, depends on damping much weaker (Figure 5).

And so, the initially discovered non-physical (jump-like) divergence of the reflection of the Ideal Electric Oscillator from the Real required a fundamental consideration of its attenuation - the vacuum impedance. A similar jump-like change with the introduction of an arbitrarily small non-zero damping is observed for the MO phase, which is eliminated taking into account the Heisenberg Uncertainty Principle, but gives reason to assume the presence of the Certainty Principle.

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