ISSN: 2395-7639

International Journal of Multidisciplinary Research in Science, Engineering, Technology & Management (IJMRSETM)

(A Monthly, Peer Reviewed Online Journal)

Visit: www.ijmrsetm.com

Volume 2, Issue 12, December 2015

Harmonic and Non-Harmonic Oscillator

Dr. Vishramlal Bairwa

Lecturer, Dept. of Chemistry, Govt. College, Karauli, Rajasthan, India

ABSTRACT: Oscillation is the repetitive or periodic variation, typically in time, of some measure about a central value (often a point of equilibrium) or between two or more different states. Familiar examples of oscillation include a swinging pendulum and alternating current. Oscillations can be used in physics to approximate complex interactions, such as those between atoms.

Oscillations occur not only in mechanical systems but also in dynamic systems in virtually every area of science: for example the beating of the human heart (for circulation), business cycles in economics, predator–prey population cycles in ecology, geothermal geysers in geology, vibration of strings in guitar and other string instruments, periodic firing of nerve cells in the brain, and the periodic swelling of Cepheid variable stars in astronomy. The term vibration is precisely used to describe a mechanical oscillation.

Oscillation, especially rapid oscillation, may be an undesirable phenomenon in process control and control theory (e.g. in sliding mode control), where the aim is convergence to stable state. In these cases it is called chattering or flapping, as in valve chatter, and route flapping.

KEYWORDS: oscillation, harmonic, non-harmonic, dynamic, mechanical, pendulum, periodic, route, string

I.INTRODUCTION

A harmonic oscillator is a type of oscillator, which has several significant applications in classical and quantum mechanics. It functions as a model in the mathematical treatment of diverse phenomena, such as acoustics, molecular-crystal vibrations, AC circuits, elasticity, optical properties, and electromagnetic fields. When a body oscillates about its location along a linear straight line under the influence of a force that is pointed towards the mean location, and is proportional to the displacement at any moment from this location, the motion of the body is considered to be simple harmonic, and the swinging body is known as a linear harmonic oscillator or simple harmonic oscillator. This form of oscillation is the best example of periodic motion.[1]

At the molecular level, above 0K temperature, the atoms in a crystal are temporarily displaced from their normal locations due to thermal energy intake. Interatomic forces act on the displaced atoms. Under the influence of such restoring forces, individual atoms vibrate about their normal location, which is the correct location in the ideal structure. Therefore, vibrations of the individual atoms are similar to a simple harmonic oscillator.

A harmonic oscillator in classical physics is a body that is being exerted by a restoring force proportional to its displacement from its equilibrium location.

In the case of motion in one dimension,[2]

$F=-kx$

Hooke's law is generally applied to real springs for small displacements; the restoring force is usually proportional to the displacement (compression or stretching) from the equilibrium position.

ISSN: 2395-7639

International Journal of Multidisciplinary Research in Science, Engineering, Technology & Management (IJMRSETM)

(A Monthly, Peer Reviewed Online Journal)

Visit: www.ijmrsetm.com

Volume 2, Issue 12, December 2015

The constant 'K' is a measure of the spring's stiffness. The variable 'x' is selected equal to zero at the equilibrium location (negative for compression and positive for stretching). The negative sign shows the fact that 'F' is a type of restoring force, opposite to the direction of displacement 'x'. If 'F' is the lone force exerting on the system, it is known as a simple harmonic oscillator. It possesses sinusoidal oscillations about the equilibrium position with a fixed amplitude and a fixed frequency (independent of the amplitude). If a frictional force is present in the system, the harmonic oscillator is called a damped oscillator[3]. Based on the friction coefficient, a body (underdamped oscillator) can oscillate with a frequency lesser than in the undamped scenario, and amplitude descends with time. Here, a body can decay to the equilibrium location in the absence of oscillations (overdamped oscillator). In fact, the boundary solution between an overdamped oscillator and an underdamped oscillator happens at a distinct value of the friction coefficient. It is called critically damped. The harmonic oscillator is termed a driven oscillator if an outside time-dependent force exists.[4]

A harmonic is a wave with a frequency that is a positive integer multiple of the fundamental frequency, the frequency of the original periodic signal, such as a sinusoidal wave. The original signal is also called the 1st harmonic, the other harmonics are known as higher harmonics. As all harmonics are periodic at the fundamental frequency, the sum of harmonics is also periodic at that frequency. The set of harmonics forms a harmonic series.[5]

The term is employed in various disciplines, including music, physics, acoustics, electronic power transmission, radio technology, and other fields. For example, if the fundamental frequency is 50 Hz, a common AC power supply frequency, the frequencies of the first three higher harmonics are 100 Hz (2nd harmonic), 150 Hz (3rd harmonic), 200 Hz (4th harmonic) and any addition of waves with these frequencies is periodic at 50 Hz.[6]

In music, harmonics are used on string instruments and wind instruments as a way of producing sound on the instrument, particularly to play higher notes and, with strings, obtain notes that have a unique sound quality or "tone colour". On strings, bowed harmonics have a "glassy", pure tone. On stringed instruments, harmonics are played by touching (but not fully pressing down the string) at an exact point on the string while sounding the string (plucking, bowing, etc.); this allows the harmonic to sound, a pitch which is always higher than the fundamental frequency of the string.[7]

Harmonics may also be called "overtones", "partials" or "upper partials". The difference between "harmonic" and "overtone" is that the term "harmonic" includes all of the notes in a series, including the fundamental frequency (e.g., the open string of a guitar). The term "overtone" only includes the pitches above the fundamental. In some music contexts, the terms "harmonic", "overtone" and "partial" are used fairly interchangeably. Most acoustic instruments emit complex tones containing many individual partials (component simple tones or sinusoidal waves), but the untrained human ear typically does not perceive those partials as separate phenomena. Rather, a musical note is perceived as one sound, the quality or timbre of that sound being a result of the relative strengths of the individual partials. Many acoustic oscillators, such as the human voice or a bowed violin string, produce complex tones that are more or less periodic, and thus are composed of partials that are near matches to integer multiples of the fundamental frequency and therefore resemble the ideal harmonics and are called "harmonic partials" or simply "harmonics" for convenience (although it's not strictly accurate to call a partial a harmonic, the first being real and the second being ideal).[8]

Oscillators that produce harmonic partials behave somewhat like one-dimensional resonators, and are often long and thin, such as a guitar string or a column of air open at both ends (as with the modern orchestral transverse flute). Wind instruments whose air column is open at only one end, such as trumpets and clarinets, also produce partials resembling harmonics. However they only produce partials matching the odd harmonics, at least in theory. The reality of acoustic instruments is such that none of them behaves as perfectly as the somewhat simplified theoretical models would predict.[9]

Partials whose frequencies are not integer multiples of the fundamental are referred to as inharmonic partials. Some acoustic instruments emit a mix of harmonic and inharmonic partials but still produce an effect on the ear of having a definite fundamental pitch, such as pianos, strings plucked pizzicato, vibraphones, marimbas, and certain pure-sounding bells or chimes. Antique singing bowls are known for producing multiple harmonic partials or multiphonics. [3] [4] Other oscillators, such as cymbals, drum heads, and other percussion instruments, naturally produce an abundance of inharmonic

ISSN: 2395-7639

International Journal of Multidisciplinary Research in Science, Engineering, Technology & Management (IJMRSETM)

(A Monthly, Peer Reviewed Online Journal)

Visit: www.ijmrsetm.com

Volume 2, Issue 12, December 2015

partials and do not imply any particular pitch, and therefore cannot be used melodically or harmonically in the same way other instruments can.[10]

Dynamic tonality, building on the work[5] of William Sethares, introduces the notion of pseudo-harmonic partials, in which the frequency of each partial is aligned to match the pitch of a corresponding note in a pseudo-Just tuning, thereby maximizing the consonance of that pseudo-harmonic timbre with notes of that pseudo-just tuning.[6][7][8][9]

Harmonic Oscillator Examples

Important mechanical examples include acoustic systems, pendulums with low displacement angles, and springs with weights. There are analogous systems, such as electrical harmonic oscillators (RLC circuits). The model of the harmonic oscillator is very important in physical science. Any body that is subject to a force in steady equilibrium functions as a harmonic oscillator (small vibrations). Harmonic oscillators exist extensively in nature. They have been reverse-engineered into many man-made devices. They are the fundamental sources of almost all sinusoidal waves and vibrations.[11]

Simple Harmonic Oscillator

A simple harmonic oscillator is a type of oscillator that is either damped or driven. It generally consists of a mass' m', where a lone force 'F' pulls the mass in the trajectory of the point x = 0, and relies only on the position 'x' of the body and a constant k. The Balance of forces is,[12]

F=ma

Quantum Model of the Harmonic Oscillator

The quantum harmonic oscillator is the subatomic analogue version of the conventional harmonic oscillator. It is one of the most relevant model systems in quantum physics. A random smooth potential can generally be estimated as a harmonic potential at the locale of a stable equilibrium point. It is one of the rare quantum-mechanical systems, which has an exact known analytical solution. This class of harmonic oscillators is characterised by its Schrödinger Equation. The harmonic oscillator only possesses discrete energy states as is valid of the one-dimensional body in a box problem. It is one of the basic applications of quantum physics that opens up the vast quantum world. Systems with unsolved equations are usually broken into small systems. An oscillator is a mechanical or electronic device that works on the principles of oscillation: a periodic fluctuation between two things based on changes in energy. Computers, clocks, watches, radios, and metal detectors are among the many devices that use oscillators.[11]

A clock pendulum is a simple type of mechanical oscillator. The most accurate timepiece in the world, the atomic clock, keeps time according to the oscillation within atoms. Electronic oscillators are used to generate signals in computers, wireless receivers and transmitters, and audio-frequency equipment, particularly music synthesizers. There are many types of electronic oscillators, but they all operate according to the same basic principle: an oscillator always employs a sensitive amplifier whose output is fed back to the input in phase. Thus, the signal regenerates and sustains itself. This is known as positive feedback. It is the same process that sometimes causes unwanted "howling" in public-address systems.[10]

How oscillators work

The frequency at which an oscillator works is usually determined by a quartz crystal. When a direct current is applied to such a crystal, it vibrates at a frequency that depends on its thickness, and on the manner in which it is cut from the original mineral rock. Some oscillators employ combinations of inductors, resistors, and/or capacitors to determine the frequency. However, the best stability (constancy of frequency) is obtained in oscillators that use quartz crystals.

ISSN: 2395-7639

International Journal of Multidisciplinary Research in Science, Engineering, Technology & Management (IJMRSETM)

(A Monthly, Peer Reviewed Online Journal)

Visit: www.ijmrsetm.com

Volume 2, Issue 12, December 2015

In a computer, a specialized oscillator, called the clock, serves as a sort of pacemaker for the microprocessor. The clock frequency (or clock speed) is usually specified in megahertz (MHz), and is an important factor in determining the rate at which a computer can perform instructions.[9]

II.DISCUSSION

Non-harmonic oscillation is that oscillation which can not be expressed in terms of single harmonic function. Example : $y = a \sin \omega t + b \sin 2\omega t$.

Before learning what is meant by forced oscillation and resonance, let us know what oscillation is and its types. The regular variation in position or magnitude about a central point or about a mean position is known as oscillation. Damped oscillation, forced oscillation, and free oscillation are some of the types of simple harmonic motion.

The free oscillation possesses constant amplitude and period without any external force to set the oscillation. The oscillation that fades with time is called damped oscillation. When a body oscillates by being influenced by an external periodic force, it is called forced oscillation.[8]

Simple harmonic oscillation

A simple harmonic oscillator is an oscillator that is neither driven nor damped. It consists of a mass m, which experiences a single force F, which pulls the mass in the direction of the point $x = 0$ and depends only on the position x of the mass and a constant k. Balance of forces (Newton's second law) for the system is

$F=ma$

The motion is periodic, repeating itself in a sinusoidal fashion with constant amplitude A. In addition to its amplitude, the motion of a simple harmonic oscillator is characterized by its period , the time for a single oscillation or its frequency , the number of cycles per unit time. The position at a given time t also depends on the phase φ, which determines the starting point on the sine wave. The period and frequency are determined by the size of the mass m and the force constant k, while the amplitude and phase are determined by the starting position and velocity.

The velocity and acceleration of a simple harmonic oscillator oscillate with the same frequency as the position, but with shifted phases. The velocity is maximal for zero displacement, while the acceleration is in the direction opposite to the displacement.[7]

A parametric oscillator is a driven harmonic oscillator in which the drive energy is provided by varying the parameters of the oscillator, such as the damping or restoring force. A familiar example of parametric oscillation is "pumping" on a playground swing.[4][5][6] A person on a moving swing can increase the amplitude of the swing's oscillations without any external drive force (pushes) being applied, by changing the moment of inertia of the swing by rocking back and forth ("pumping") or alternately standing and squatting, in rhythm with the swing's oscillations. The varying of the parameters drives the system. Examples of parameters that may be varied are its resonance frequency and damping .[6]

Parametric oscillators are used in many applications. The classical varactor parametric oscillator oscillates when the diode's capacitance is varied periodically. The circuit that varies the diode's capacitance is called the "pump" or "driver". In microwave electronics, waveguide/YAG based parametric oscillators operate in the same fashion. The designer varies a parameter periodically to induce oscillations.

Parametric oscillators have been developed as low-noise amplifiers, especially in the radio and microwave frequency range. Thermal noise is minimal, since a reactance (not a resistance) is varied. Another common use is frequency conversion, e.g., conversion from audio to radio frequencies. For example, the Optical parametric oscillator converts an input laser wave into two output waves of lower frequency.

Parametric resonance occurs in a mechanical system when a system is parametrically excited and oscillates at one of its resonant frequencies. Parametric excitation differs from forcing, since the action appears as a time varying modification on a system parameter. This effect is different from regular resonance because it exhibits the instability phenomenon.[5]

III.RESULTS

The quantum harmonic oscillator is the quantum-mechanical analog of the classical harmonic oscillator. Because an arbitrary smooth potential can usually be approximated as a harmonic potential at the vicinity of a stable equilibrium point, it is one of the most important model systems in quantum mechanics. Furthermore, it is one of the few quantum-mechanical systems for which an exact, analytical solution is known.[1][2][3] First, the energies are quantized, meaning that only discrete energy values (integer-plus-half multiples of $\hbar\omega$) are possible; this is a general feature of quantum-mechanical systems when a particle is confined. Second, these discrete energy levels are equally spaced, unlike in the Bohr model of the atom, or the particle in a box. Third, the lowest achievable energy (the energy of the $n = 0$ state, called the ground state) is not equal to the minimum of the potential well, but $\hbar\omega/2$ above it; this is called zero-point energy. Because of the zero-point energy, the position and momentum of the oscillator in the ground state are not fixed (as they would be in a classical oscillator), but have a small range of variance, in accordance with the Heisenberg uncertainty principle.[4]

The ground state probability density is concentrated at the origin, which means the particle spends most of its time at the bottom of the potential well, as one would expect for a state with little energy. As the energy increases, the probability density peaks at the classical "turning points", where the state's energy coincides with the potential energy. (See the discussion below of the highly excited states.) This is consistent with the classical harmonic oscillator, in which the particle spends more of its time (and is therefore more likely to be found) near the turning points, where it is moving the slowest. The correspondence principle is thus satisfied. Moreover, special nondispersive wave packets, with minimum uncertainty, called coherent states oscillate very much like classical objects, as illustrated in the figure; they are not eigenstates of the Hamiltonian.

As in the one-dimensional case, the energy is quantized. The ground state energy is N times the one-dimensional ground energy, as we would expect using the analogy to N independent one-dimensional oscillators. There is one further difference: in the one-dimensional case, each energy level corresponds to a unique quantum state. In N-dimensions, except for the ground state, the energy levels are degenerate, meaning there are several states with the same energy.

The degeneracy can be calculated relatively easily. As an example, consider the 3-dimensional case: Define $n = n_1 + n_2 + n_3$. All states with the same n will have the same energy. For a given n, we choose a particular n_1. Then $n_2 + n_3 = n - n_1$. There are $n - n_1 + 1$ possible pairs $\{n_2, n_3\}$. n_2 can take on the values 0 to $n - n_1$, and for each n_2 the value of n_3 is fixed. [3]

The oscillators are electronic circuits that make a respective electronic signal generally the sine wave and the square wave. It is very important in other types of electronic equipment such as quartz which is used as a quartz oscillator. The amplitude modulation radio transmitters use the oscillation to generate the carrier waveform. The AM radio receiver uses a special oscillator it is called a resonator to tune a station. The oscillators are present in computers, metal detectors, and also in guns. This article discusses an overview of different types of oscillator circuits & their working. The oscillator is a mechanical or electronic device and the working principle of the oscillator is, the periodic change between the two things depends on the changes in the energy. The oscillations are used in radios, watches, metal detectors, and in many other devices.The oscillator converts the DC (direct current) from the power supply to an AC (alternating current), used in many electronic devices. The signal used in the oscillator is a sine wave & the square wave. The best examples of an oscillator are, the signals are broadcasted by the television transmitter and radio, CLKs which are used in the computers and also in the video games.[2]

ISSN: 2395-7639

International Journal of Multidisciplinary Research in Science, Engineering, Technology & Management (IJMRSETM)

(A Monthly, Peer Reviewed Online Journal)

Visit: www.ijmrsetm.com

Volume 2, Issue 12, December 2015

IV.CONCLUSIONS

The quantum pendulum is fundamental in understanding hindered internal rotations in chemistry, quantum features of scattering atoms, as well as numerous other quantum phenomena. Though a pendulum not subject to the small-angle approximation has an inherent nonlinearity, the Schrödinger equation for the quantized system can be solved relatively easily. A quantum machine is a human-made device whose collective motion follows the laws of quantum mechanics. The idea that macroscopic objects may follow the laws of quantum mechanics dates back to the advent of quantum mechanics in the early 20th century.[1][2] However, as highlighted by the Schrödinger's cat thought experiment, quantum effects are not readily observable in large-scale objects. Consequently, quantum states of motion have only been observed in special circumstances at extremely low temperatures. The fragility of quantum effects in macroscopic objects may arise from rapid quantum decoherence.[3] Researchers created the first quantum machine in 2009, and the achievement was named the "Breakthrough of the Year" by Science in 2010.[12]

REFERENCES

1. Fowles & Cassiday (1986, p. 86)
2. ^ Kreyszig (1972, p. 65)
3. ^ Tipler (1998, pp. 369, 389)
4. ^ Case, William. "Two ways of driving a child's swing". Archived from the original on 9 December 2011. Retrieved 27 November 2011.
5. ^ Case, W. B. (1996). "The pumping of a swing from the standing position". American Journal of Physics. 64 (3): 215–220. Bibcode:1996AmJPh..64..215C. doi:10.1119/1.18209.
6. ^ Roura, P.; Gonzalez, J.A. (2010). "Towards a more realistic description of swing pumping due to the exchange of angular momentum". European Journal of Physics. 31 (5): 1195–1207. Bibcode:2010EJPh...31.1195R. doi:10.1088/0143-0807/31/5/020. S2CID 122086250.
7. Fowles, Grant R.; Cassiday, George L. (1986), Analytic Mechanics (5th ed.), Fort Worth: Saunders College Publishing, ISBN 0-03-089725-4, LCCN 93085193
8. Hayek, Sabih I. (15 Apr 2003). "Mechanical Vibration and Damping". Encyclopedia of Applied Physics. WILEY-VCH Verlag GmbH & Co KGaA. doi:10.1002/3527600434.eap231. ISBN 9783527600434.
9. Kreyszig, Erwin (1972), Advanced Engineering Mathematics (3rd ed.), New York: Wiley, ISBN 0-471-50728-8
10. Serway, Raymond A.; Jewett, John W. (2003). Physics for Scientists and Engineers. Brooks/Cole. ISBN 0-534-40842-7.
11. Tipler, Paul (1998). Physics for Scientists and Engineers: Vol. 1 (4th ed.). W. H. Freeman. ISBN 1-57259-492-6.
12. Wylie, C. R. (1975). Advanced Engineering Mathematics (4th ed.). McGraw-Hill. ISBN 0-07-072180-7.