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LIFE IS A SPRING MASS (LIASM)

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ABSTRACT

This paper is the culmination of topics having a spring mass time dependency as the root of the mathematical descriptions. The spectrum of topics ranges from simple vibrations to universe expansion, relativity, and particle physics. This also includes some non-traditional considerations and concludes with a resonance model for the Strong force and Weak force. This simple concept is amazing in that it shows up everywhere in science, but also in non-scientific endeavours. This paper is entitled "Life is a Spring Mass" or "LIASM" which is a mantra for all that aspire to this thinking.

INTRODUCTION

Many students were exposed to new exciting ideas during their educational experience. Some studied science, engineering, physics and/or mathematics to some degree and were introduced to the concept of the basic model for vibrations that being a single degree of freedom spring mass. Along with this came an understanding of natural frequency and resonance. It is not the intent of this paper to pursue mathematical details, therefore, minimal use of equations will be used here.

DISCUSSION

It is well known that simple spring mass vibrations can be classified as deterministic and random and further identified as steady state or transient with a further designation as linear or non-linear.

Sometimes resonance is misunderstood to be instantaneous failure, but the mathematics leading to this conclusion violates dividing by zero. Upon re-evaluation, structures increase displacement and thus stress with time during resonance.

Most readers of this paper will have their own expertise and, perhaps, have far more knowledge of these topics than this author. It is the intent of this paper to relate the authors fifty years of engineering, physics and mathematics as it relates to a spring mass as the underlying core of many subjects (mostly scientific, but also to non-traditional applications).

This title "LIASM", is a mantra which is chanted daily - LIASM! LIASM! LIASM! Life is a Spring Mass!!

It is well known that the spring mass equation is identical to that of an electrical circuit. Thus, early development of analog circuits to test the frequencies of structures were developed. Helmholtz resonators having similar equations were utilized in the world of acoustics.

In the venue of vibrations, assuming a separation of variables was feasible, bars, beam plates and shells utilize the same underlying spring mass time dependent equation. Similarly, strings, acoustics, electromagnetic waves, stress waves and ocean waves respond to the "LIASM" mantra, along with finite element dynamic analysis. This being said is this where the analogy ends, or can it go further?

The following are a list of subjects to consider:

THE SCIENCES

Traditional science application of the basic vibration model, the spring mass, is the integral part of the sciences.

Black Holes

One of this author's first technical papers [Cepkauskas & Lubin (1979)] considered the acceleration of a spring mass to band limited white noise. This paper illustrated that while the displacement stayed within fixed limits, the acceleration continued to increase exponentially. If one were able to sit on the spring mass, the g-forces would be overwhelming, thus equating to the forces in a black hole.

Relativity

Einstein showed that an object traveling close to the speed of light would look similar to zero velocity, except smaller. The equation reads:

$$X = \frac{X_0}{\sqrt{1-\left(\frac{V^2}{C^2}\right)}}$$

where X is the size resulting from a high velocity V and X_0 is the normal size and C is the speed of light. If one uses the relationship for rotational motion, V=ωr and recognizes C/r as having dimensions of a natural frequency ω_n, this equation becomes:

$$X = \frac{X_0}{\sqrt{1-\left(\frac{\omega^2}{\omega_n^2}\right)}}$$

A similar, but not identical equation for a spring mass with damping consist of:

$$X(t) = \frac{X_0 \sin(\omega t)}{\sqrt{\left[1-\left(\frac{\omega^2}{\omega_n^2}\right)\right]^2 + [2\xi\frac{\omega}{\omega_n}]^2}}$$

where the notation chosen as it appears with X being the spring mass displacement as a function of time and X_0 the static displacement with damping ξ.

The near equivalency of a type of resonance occurring for the spring mass and relativity would

spark the question; if one could travel beyond the speed of light could there be the type of energy dissipation analogous to damping that would prevent catastrophic resonance? An interesting topic would be to determine the equations of motion for a spring mass traveling close to the speed of light.

Stock Market Model

In the early 1980s one of the authors of [Fisher et al. (1977 & 1979] developed a successful stock market model. He and his co-authors had long discussions regarding a series of spring masses to describe changes in the market along with statistical considerations in time histories as found in statistical theory of communication text. This was also based on a similar mathematical description as formulated by Volterra to understand the stability of fish population.

Thermodynamics

Professor Bowley from the University of Connecticut would often talk about the thermodynamic hidden modes of vibration, for example, matter would be presented as atoms connected by springs and adding heat would cause a dominant mode that exhibits itself as bodies expanding with temperature, i.e. coefficient of thermal expansion.

Fluid Turbulence

A power spectral density (PSD) of turbulent fluid flow is analogues to a spring mass having a base motion random white noise input. However, rather than one spring mass, there is a large number of them with stiffness increasing with every frequency. The RMS output will look just like a PSD exhibiting varying energy content for all eddy sizes.

Partners

Many occurrences in nature appear to have pairs. Thermal dynamics, for example, has the pair pressure and volume. Solid mechanics has the pair stress and strain and vibrations has force and displacement as its pair. If one knows the pairs it can make the mathematics simpler. For example, pressure is equal to a derivative of energy with respect to volume. Another derivative with respect to volume gives a material constant. This reduces thermodynamics to knowing the pairs and using basic calculus to find maximum, minimum or inflection points using the first derivative and second derivative.

Early on in the field of thermodynamics, temperature did not have a partner, thus the discovery of entropy. This is also true in the field of particle physics where discovery of one particle lead to either the search for or the discovery of a second partnering particle. These energy approaches of partners exists in kinetic and potential energy for the simple spring mass.

Expansion of the Universe

Albert Einstein assumed the universe was stationary, however, the Hubble Telescope showed the universe was expanding. In the genre of "LIASM" could it be that the universe acts like a spring mass and is presently expanding on a time scale so long that we just cannot see the change? In the future will it contract acting as a spring mass?

Planetary Motion

Time dependency of a planet shows obvious harmonic motion, but its spatial dependency is similar to that of a spring mass that overshoots equilibrium from its inertia and is restored by a spring or in the case of a planet gravitational forces.

Eigenvalue/Eigenvector Problems

In solving the problem of many spring masses expanding to multiple degrees of freedom, the results are determined using matrix/determinants techniques by what is known as eigenvalues that give natural frequencies and eigenvectors which provide corresponding modes of vibration. Approximations exist to determine the upper and lower bound frequencies of this system. The lower bound uses the Dunkerley approach which treats the system and corresponding individual frequencies like resistors in parallel.

Another form of an eigenvalue/eigenvector problem is found in stress tensors in solid mechanics, elasticity and plasticity which find the principal stress and stress invariants. The stress version uses Mohr's circle representations. This brings up the questions:

1.) Does an equivalent Mohr's circle exist for frequencies?
2.) Is Dunkerley equation applicable to stress tensors?

As a side note, these tensors and symmetry and eigenvalues are the basis for much of the various Particle Physics models.

Nuclear Reactor Design

The author has worked in the commercial nuclear power industry since the early 1970's. The philosophy for solving vibration problems was to first simplify the problem to a one or two degree of freedom system. This would provide an understanding of the phenomenon of interest, but not always provide a qualitative realistic result. The models would then be examined to a higher degree of sophistication either analytically to more complicated geometries or to numerical methods as found in stick model and finite element models.

The forces acting on structures were mostly random turbulence or acoustic loading generated by reactor coolant pumps. Also, seismic loading and a pipe break loading were considered for less probable but higher consequence events. The general subject was known as fluid structure interaction with many contributors, the most prolific being, S.S. Chen from Argonne Labs, Blevins, M.K. Au Yang from B&W and Paidoussis from McGill University [Blevins (2009) & Chen et al. (1985)].

The simplest model for random response is a simple spring mass [Cepkauskas & Lubin (1979) & Cepkauskas & Kenny et al. (1983)] subject to white noise where transfer functions using Fourier transforms leads to an average response. Typically, 3 sigma variations above the Root Mean Squared (RMS) were used for displacement, stress and fatigue. More detailed beam and eventually FEA models were used. It should be noted that the white noise input excites all modes of vibrations. Cepkauskas & Lubin (1979) was used to model a Pressurized Water Reactor (PWR) vessel having a rocking natural frequency to be able to predict normal operating reactor vessel g-levels, using measurement data for another reactor using a simple spring mass model.

For the acoustic-structure interaction [Cepkauskas & Stevens (1983), Cepkauskas (1985)] the

simplest model would be a two degree of freedom with the first spring mass representing the dominant acoustic mode of the liquid media with frequency ω_L and the second spring mass the structure of interest with frequency ω_S. This model would be base driven by a deterministic driving force with frequency ω_P representing the acoustic output of the pump. When all three frequencies were aligned high structural response would occur. This behavior is similar to a vibration absorber, but high structural response of the second mass (structure) is not the desired output.

For the seismic load a simple base driven spring mass is used. This idea is expanded to a spectrum analysis with many spring mass models or a time history response. A higher degree of sophistication is obtained with "stick models" and FEA.

One of the author's first assignments [Cepkauskas (1979)] in the nuclear industry was to resolve a discrepancy in the literature in predicting acoustic loading on a Pressurized Water Reactor (PWR) core support barrel (CSB), which is a large cantilevered cylinder structure that supports the nuclear fuel. The CSB is surrounded by a liquid annulus within the reactor vessel, which is a second cylindrical pressure vessel with spherical heads. This problem modelled in cylindrical coordinates, was defined as a time dependent boundary condition problem with liquid acoustic time dependency of a spring mass. The philosophy above was applied and a one-dimensional pipe was used to provide an understanding of the problem. This led to a new technique for solving time dependent problems found in [Fisher et al. (1977) & Cepkauskas (1979)]. It resolved the discrepancy in [Cepkauskas (1979)] and lead to several papers in various disciplines for time dependent boundary value solutions [Cepkauskas (1985, 2010, 2012-b & 2017), Cepkauskas & Morake (2010), Cepkauskas & Thanjekwayo (2008), Mudaly & Cepkauskas (2009) and Morake & Cepkauskas (2010)].

Another aspect of fluid structure-interaction is to find the frequency of the structure in air and then find the solution with water acting on the vibrations of the mass. The simplest model is a single degree of freedom spring mass with the structural mass plus an added mass due to interaction with the surrounding fluid. Many approaches expanded on this subject to include beams, plates and shells with fluid structure interface having the fluid velocity or acceleration equal to the velocity or acceleration of the structure, or in a continuum sense, having components of the structure stress tensor to equal the pressure tensor.

Many of these analytical predictions were tested using simple experiments but were finally verified using the US NRC Regulatory Guide 1.20 [Ko & Kim (2018)]. For the Palo Verde Reactor in Arizona, U.S.A. [Van Brunt & Ferguson (1987)] some flaws were found prior to loading fuel by the Comprehensive Vibration Monitoring Program (CVAP). The CVAP consisted of operating the reactor without fuel for several weeks while monitoring pressure, temperature, stress, strain and frequencies. After design improvements were made the test was repeated successfully. In many cases these simpler vibration models proved to be successful, thus a victory for "LIASM".

Physics

Not too long ago the small parts of an atom were the electron, proton and neutron. In the last hundred years many new particles have been discovered. In addition, it has been found that the proton, for example, is made up of smaller particles called quarks with added characteristics described as up, down, charm, strange etc. In particle physics a recurring model called a Feynman diagram which describes all four forces, of Gravity, Electromagnetic, Weak and Strong. This is included in details of the Standard Model having roots in symmetry and anti-symmetry as found in Noether's theorem with champions such as Planck, Einstein, Gell-Man, Schwinger, Feynman, Glashow and Higgs [Frampton & Glashow (1980)].

One approach to particle physics is string theory. It uses the string equation with spring mass time dependency.

The existence of neutrino oscillations shows the existence of three forms of neutrinos, this is similar to having a three degree of freedom spring mass that exhibits three different frequencies and mode shapes. Schrodinger's equation and the Dirac equation has some spring mass time dependency for spin ½ particles. The Klein Gordon equation for spin 1 has all the ingredients of a spring mass equation. These equations are similar to acoustic wave equations except that rather than finding frequencies the solution provides energy levels for particles [Griffiths (2008)].

An introduction to some of the ingredients of particle physics exists in [Cepkauskas (1974)], where wave propagation was considered in the ocean signal transmission. The use of Fourier analysis, Born approximation and Green's function techniques is applicable in particle physics.

In [Cepkauskas (2012-a, 2013, 2019 & 2020)] a simple frequency equation for the four forces were investigated leading to actual single degree of freedom spring mass frequency equations for each force. This approach was limited to the five constants; speed of light, Planck's, gravitational, Coulomb and Boltzmann's along with five dimensional parameters of time, length, charge, temperature and mass. The goal of this effort was to use the "LAISM" approach to find simple spring mass equations. Maybe one day the entirety of particle physics will include the "LIASM" approach.

LIFE

How vibrations can be understood in terms of nature.

Medicine

Cancer is described as a mutation of normal cells morphing into abnormal cells which grow uncontrollably. These cell mutations are the result of a phenomenon similar to resonance. High doses of x-rays have been determined to cause such cell mutations. In many situations, x-rays have been replaced by the use of sound waves. Because x-rays have small wavelengths comparable to the wavelength of the human cell, over exposure creates a condition similar to resonance within the cells. However, the use of ultrasound, with its much larger wavelengths, avoids this resonance-like response.

In Eastern medicine acupuncture needles are reported to vibrate or "dance" [Rues (2014)] as the flow of energy, Qi, is stimulated. This appears to be much like flow-induced or aero-induced vibrations discussed in other sections of this paper. Some acupuncture treatments now stimulate this process by accentuating needle vibration by inducing low voltage electrical oscillations. Eastern medicine also uses sound from bells or "singing bowls" [Trivedi and Saboo (2019)] producing a feeling of tranquility and healing. The scientific understanding of this healing is not well understood, but the ingredients appear to consist of a driving frequency of the sound waves aligning in some manner with the human body's natural frequencies.

Psychology

Most vibrations texts introduce the concept of input/output relationships. Typically, if the system (i.e. transfer function) is deterministic and the input is deterministic, then the output is also deterministic. For

the same system, if the input is random then the output is also random. What if the system [H(ω)] is random? An example of this type of problem is sending a sound signal in the ocean where the speed of sound has random fluctuations [Cepkauskas ((1974)], the received signal is distorted, such that it can be unrecognizable from the sent signal due to reverberation effects.

Psychology can be compared to a spring mass where the mass or stiffness is random, that is, the person subjective conscience varies from his objective conscience. A person's behavior is a result of the degree to which this variation exists. If the behavior is extreme, a kind of resonance exists and this extreme behavior at resonance only depends on the system's damping from internal and external sources. Thus, one can say, "Hello, how are you?" to a rational person and receive a "normal" response, but, the more a person's subjective conscience is exposed to greater variations, statistically the occurrence of an "abnormal" response exists.

World Events

Another type of spring mass is the pendulum, with its repeating back and forth motion. This brings to mind words of the philosopher George Santayana [Wikipedia], "those who cannot remember the past are condemned to repeat it", referring to the cyclic drive of human behavior of wars, power and politics. Another example is found in the Bible book of Judges, when the Israelites would turn against the Creator only to return to Him time and again. The pendulum effect is also seen in other Bible accounts of the many occurrences of feast and famine.

Resonance

The biblical account of the Walls of Jericho could have been the result of resonance, similar to the case of soldiers marching over a bridge causing its collapse. Soldiers are trained to march out of step when crossing a bridge to avoid resonance. Tacoma Narrows Bridge collapse, a modern-day example, was due to aero-induced vibrations reaching resonance. An interesting video of this occurrence can be found on the internet at:

https://www.youtube.com/watch?v=j-zczJXSxnw

Music

All musical instruments are connected to the time dependency of a spring mass, such as the vibrations of a string, acoustics of a horn [Morake] or vibrations of a membrane. But what makes music pleasant to the ear? Why does the combination of the notes C,E,G produce a harmonious sound while a discord such as C, D, E cause dissatisfaction to the ear? The answer is related to the same principal of vibration. For an in-debt look into the physics of music see [White & White (2014)].

Light

Visible electromagnetic light with specific frequencies and wavelength has the ingredients of "LIASM". For an in-debt investigate the physics of light see [Waldman (1983)].

CONCLUSION

The present paper provides insight into the existence of the simple spring mass equation in many areas in science and life in general.

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