# Universal Physics: Completely Solving Zeno's Paradoxes and Discovering Space and Time Uniparticles, the Universality of Conservation Laws and Strength Laws of Nature

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**Abstract**

Physics regards the 3-dimensional space and 1-dimensional time composed of points and instants of zero dimensionality and measure but any sum of zeros is zero. The author's uniphysics by the principles of his (meta)uniphilosophy, unimathematics, and unimetrology exactly measuring the infinite discovered the co-dimensionality of the uniparticles of continuum, extent, and duration, the fundamental physical constants self-precision, and the universality of conservation and strength laws of nature.

**Keywords:** space and time, potential and actual infinity, metauniphilosophy, unimathematics, unimetrology, uniphysics, true continual infinitesimal uniparticle of extent and duration, fundamental physical constants self-precision.

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References to some subsequent works of the author on the subject are added

# Универсальная физика: полное решение апорий Зенона и открытие уничастичности пространства и времени и всеобщности законов сохранения и прочности

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## Аннотация

Классическая физика считает 3-мерное пространство и 1-мерное время вполне составленными из точек и мгновений нулевых размерности и мер. Но сумма любого множества нулей равна нулю. Унифизика по принципам (мета)унифилософии, униматематики и униметрологии автора с точным измерением бесконечно большого и малого при всеобщности законов сохранения открыла соразмерность уничастиц непрерывного, протяжённости и длительности, самоточность основных физических постоянных и первые прочностные законы природы.

**Ключевые слова:** пространство и время, потенциальная и актуальная бесконечность, метаунифилософия, униматематика, униметрология, унифизика, актуально континуально бесконечно малая уничастица протяжённости и длительности, самоточность фундаментальных физических постоянных.

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Добавляются ссылки на некоторые последующие труды автора по теме

«Книга природы написана на языке математики» (Галилео Галилей).

«Если я видел дальше других, то потому, что стоял на плечах гигантов» (Исаак Ньютон).

«В каждой естественной науке заключено столько истины, сколько в ней есть математики» (Иммануил Кант).

«Новая отрасль математики, достигнув искусства обращаться с бесконечно-малыми величинами, и в других более сложных вопросах движения даёт теперь ответы на вопросы, казавшиеся неразрешимыми» (Л. Н. Толстой).

«Все науки о Природе делятся на физику и коллекционирование марок» (Эрнест Резерфорд).

## Реферат

Понимание сущности и соотношений пространства, времени, действия, покоя и движения, постоянства (сохранения) и изменения, а также точное измерение истинных бесконечностей и бесконечно малых непосильны для классических философии и науки [1–12] около 2500 лет. См. апории Зенона

Элейского (ок. 490 – ок. 430 до н. э.) [1, с. 31–32]: «...Апория «Стрела»: если считать, что пространство, время и процесс движения состоят из некоторых «неделимых» элементов, то в течение одного такого «неделимого» тело (например, стрела) двигаться не может (ибо в противном случае «неделимое» разделилось бы), а поскольку «сумма покоев не может дать движения», то движение вообще невозможно, хотя мы его на каждом шагу наблюдаем...»

**Классическая физика** [3] вместе со всей современной наукой и философией считает пространство и время составленными из точек и мгновений нулевой меры. Но сумма любого множества нулей равна 0. Нет понимания глубинных природы и сущности не только бесконечности, вечности и процесса вообще, а значит, и мироздания в целом, но и смешанной физической величины (для 5 л воды нет известных действий между «5 л» и «вода»). К методологическому кризису и других первооснов физики [13] добавляются принципиальные изъяны традиционных математики и метрологии. Даже в механике [4–12] нет универсальных прочностных законов природы и даже напряжений, а запас прочности пригоден лишь для простого нагружения. Нет общих аналитических решений гармонических и бигармонических уравнений с ключевыми ролями и нетривиальных трёхмерных упругих задач.

Созданная по принципам (мета)унифилософии [14–16], униматематики [17–32] и униметрологии [17–20, 25–33] **универсальная физика** [19, 25, 29–57] является надстройкой над ними и избранными областями классической физики. Универсальные науки об унипространстве и бесконечности, унивремени и вечности, унидвижении и унипроцессе основанны на положительной мере точки в каждом измерении пространства и/или времени, как и об извлечении достоверных измерительных данных и для основных физических постоянных, например гравитационной по Кавендишу [30] и заряда электрона по Милликену [31]. В унимеханике деформируемого твёрдого тела аналитические науки об унипараметризации и униперестраивании решают (не)равносложные унизадачи как унисистемы функциональных уравнений и ведут к степенной и интегральной аналитическим наукам о макроэлементах. В унипрочность материалов входят основополагающие науки об универсальных напряжениях, о всеобщих прочностных законах природы и об обработке прочностной информации. В унипрочность объектов входят основополагающие науки об аналитическом макроэлементном исследовании напряжённо-деформированного состояния и прочности систем, о сосредоточении равносильного напряжения, об универсальных запасах прочности, о терпимости к ошибкам, об унинадёжности и унириске объектов. Открыты новые явления механики и прочности и многоуровневость законов природы. Впервые почти за 2500 лет найден выход из апорий Зенона и других с точным измерением бесконечностей.

## 1. Classical Physics

Along with classical philosophy [1] and mathematics [2], classical physics [3–12] cannot understand the nature and essence of space and infinity, time and eternity, action, rest and motion, constancy and change, processes and the universe without exactly measuring namely actual infinities and infinitesimals. Zeno's "Arrow" paradox proving motion impossibility at all is unsolvable for about 2500 years. Space and time are regarded as composed of zero-measure points and moments but the sum of any set of zeros is 0. There is no deep understanding the nature and essence of any mixed physical amount (for "5 liter water" there is no known operation between "5 L" and "water"). Additionally to the methodological crisis also of other fundamental principles of physics [13], there are defects of traditional mathematics [2] and metrology [3]. Even in mechanics [4–12] there are no universal stress and strength laws of nature, and the strength reserve (safety factor/margin) holds for simple (proportional) loading only. To three-dimensional elasticity problems, there are no nontrivial analytical solutions required for testing the finite element method results. There are no known general power-law solutions to the homogeneous harmonic and biharmonic equations with key roles not only in elasticity theory [4–6].

## 2. Universal Physics

Following the principles of (meta)uniphilosophy [14–16], unimathematics [17–32], and unimetrology [17–20, 25–33], universal physics [19, 25, 29–57] is a superstructure over them and selected areas of classical physics. Universal physics includes universal sciences of unispace and infinity, unitime and eternity, unimotion and uniprocesses based on a positive point measure in each dimension of space and/or time, of extracting reliable measurement data including fundamental physical constants such as the gravitational constant [30] and the electron charge [31] via the classical experiments by Cavendish and Millikan, respectively, as well as deformable solid unimechanics, material unistrength, and object unistrength. In unimechanics, analytical uniparameterization science generally solves uniproblems as unisystems of functional equations. Analytical rebuilding science solves non-equicoplicated uniproblems. They both give power and integral analytical macroelement sciences. Material unistrength includes fundamental sciences of universal stresses, of universal strength laws of nature, and of strength data processing. Object unistrength includes fundamental sciences of analytic-macroelement investigating the system stress-strain state and strength, of the equivalent stress concentration, of universal safety margins, of error tolerance, and of object unireliability and unirisk. They provide discovering multi-level laws of nature, science, and life and new phenomena of mechanics and strength. Universal physics has found a way out of Zeno's and other paradoxes for the first time for about 2500 years via exactly measuring infinities and infinitesimals.

## 3. Principles of Universal Physics

### 3.1. Fundamental principles of uniphysics

1. Urgent problems priority, exclusiveness, and typificability.
2. Intuitive conceptual and methodological fundamentality priority.
3. Philosophical, mathematical, physical, engineering meaningfulness and synergy.
4. Controllability (testability, estimability, generalization, and hierarchization).
5. Creating, inventing, and discovering directionality and purposefulness.
6. The efficiency of creative inheritance, transparency, and ergonomicity.

### 3.2. Universalizability principles of uniphysics

1. Universalizability of physical amounts and laws of nature incl. conservation laws.
2. Free efficient physical quality universalizability and controllability.

### 3.3. Quasicriticality principles of uniphysics

1. Parameters reserves separability, critical and limiting relations efficiency.
2. General noncriticality (of subcritical, critical, and supercritical states).
3. General nonlimitability (of underlimiting, limiting, and overlimiting states).

### 3.4. Unimathematical principles of uniphysics

1. Tolerable simplicity (the tolerably simplest acceptable analytical solution).
2. Unimodelability, uniexpressibility, unievaluability, and unimeasurability.
3. Uniestimability, uniapproximability, and uniproblem unisolvability.
4. Unicomputability (overcoming complication, unimathematical data processing).

### 3.5. Composition and uniadditivity unimetrological principles of uniphysics

1. A space and anyone of its parts such as a line part, a figure, or a body are compositions (naturally ordered systems) of points of the same dimensionality as the space and of equal positive universal measure in each dimension for every point.
2. A time and anyone of its parts such as an interval or a segment are compositions (naturally ordered systems) of moments as time points of the same dimensionality as the time and of equal positive measure in each dimension for every moment.
3. A point can be arbitrarily properly (without any intersection) divided (distributed, partitioned, fragmented) into parts (subpoints) as quantielements whose elements coincide with the point, the (also uncountable) unisum of their quantities being 1.
4. An object content as a quantiset can be arbitrarily properly (without any intersection) divided (distributed, partitioned, fragmented) into parts contents as quantisets, the object content uniquantity coinciding with the universal (possibly uncountable) sum of the parts contents uniquantities.

5. By any properly (without any intersection) dividing (distributing, partitioning, fragmenting) a domain into parts, a universal measure of the domain and a universal integral of a function on the domain are completely (possibly uncountably) additive.

## 4. Unispace of Multidimensional Infinitesimal Points: Measure, Integration

**Classical science** [1–12] based on the real numbers without namely actual infinities and infinitesimals and on at most countable number operations cannot resolve Zeno's measure paradox on the impossibility of dividing an object of finite measure $M > 0$ into an infinite set of equal parts of measure m: if $m = 0$, then $M = 0$; if $m > 0$, then $M = +\infty$ (heap of infinities without their differentiation). Zero-measure (0M) and zero-dimensional (0D) points cannot compose 1D lines, 2D surfaces, and 3D spatial bodies. Kepler's and Cavalieri's composing an area of intervals, a volume of areas, and especially a circle of central triangles whose limits are radii has [2] no justification because of 0M and 0D points. Integration has no point-wise summation nature, is artificial, only potentially infinitesimal, and hence zero-measure fully nonsensitive without conservation law universality. For example, $\int_a^b f(x)dx$ does not depend on including or excluding zero-measure endpoints a and/or b. No common measure $M_n$ is universal also for mixed dimensions. Linear $M_1$, area $M_2$, and volume $M_3$ measures are only finitely sensitive to bounded parts of lines, surfaces, and space.

**Unimathematics** [17–32] based on uniphilosophy [14, 15] and metauniphilosophy [14, 16] is perfectly sensitive and exactly measures and integrates namely actual infinities with conservation law universality. Quantisets with element quantities q, uninumbers, also uncountable operations, and uniquantities Q as counting point unimeasures discover
Also introduce symmetric both half-interval and half-segment |a, b| as a quantiset in which the both endpoint quantities are 1/2 and the quantity of every intermediate point is 1:

$$|a, b| =^\circ {}_{1/2}a +^\circ ]a, b[ +^\circ {}_{1/2}b =^\circ {}_{-1/2}a +^\circ [a, b] +^\circ {}_{-1/2}b$$

where
$=^\circ$ is quantitative equality of quantitative elements and sets,
$+^\circ$ is quantitative addition of quantitative elements and sets,
the both satisfy the universal conservation laws.

Fundamental unimathematics discovered the essence, nature, and structure of any continuum as an extensional set, as well as the qualitative dimensionality-measure phenomenon by unifying all the separate, isolated elements into their continuum.

In any continuum (an extensional set) [2–4], for example, on a line, in a surface, or in a space, it is possible to distinguish usual points as elements.

Define a *separated continuum* to be the set of all the separate, isolated elements, or points, of a certain continuum.

Each point as an element both of a continuum and of its *separated continuum* is zero-dimensional and zero-measure. Adding any set of zeros gives zero. Hence every *separated continuum* is zero-dimensional and zero-measure, too, even if its continuum itself is of positive dimensionality and measure. Therefore, a *separated continuum* gives namely zero contribution to its continuum dimension and measure. That is why a continuum of positive dimensionality and measure cannot coincide with its *separated continuum* and cannot consist of their usual elements, or points, only. Points as elements cannot be continuum parts. So classical mathematics based on the Cantor set theory [3, 4] cannot provide understanding continuum nature, essence, and structure. Additionally, distinguishing between belonging and inclusion leads to many well-known contradictions not only in mathematics [4], but also in philosophy [1] and life.

Universal philosophy, metaphilosophy, mathematics, physics, and metrology by the author [5-46] unify the relations of unibelonging and uni-inclusion on the base of the philosophical [1] and, in particular, mereological relationship between the whole and its parts and exclude many well-known contradictions. For example, uni-identify both a set consisting of one element and this element itself. The key Cantor concept (of a set as gathering definite, distinct objects of our perception or of our thought – which are called elements of the set – into a whole [3, 4]) remains. The same holds for the possibilities to distinguish set elements and to select and consider anyone or some of them. But it is not necessary that a set *consists* of its elements *only* and can be *reduced* to them. Any continuum (extensional set) of positive dimensionality and measure is a counterexample. Such a set and its *separated continuum* are very different but satisfy the Cantor set equality definition which is not valid at least for continua. Unlike a continuum (extensional set) of positive dimensionality and measure, a *separated continuum consists* of its usual elements, or points, which are hence its *parts* but cannot be *continuum parts*.

For introduced quantitative elements and quantitative also continual sets, define arbitrarily *correctly and properly* partitioning (splitting) them into any parts if and only if the universal conservation laws hold. This means that for any element, its quantity in a quantitative set is equal to the universal sum of the quantities of this element in all the parts of this set. Also define *regularly* partitioning (splitting) a set if and only if its parts are of equal universal measure. Such regular *continuum parts* inherit its dimensionality, have an actually continually infinitesimal unimeasure in every dimension, and are called *continual uniparticles*.

See the following example of *correctly*, *properly*, and *regularly* partitioning (splitting) symmetric both half-interval and half-segment $|0, 1|$ into $Q|0, 1| = \Omega$ also linear uniparticles of the same actually continually infinitesimal unimeasure $1/\Omega$ in the simplest first order consideration (with the first degree, or power, $\Omega$):

$$|0, 1| =^\circ |0, 1/\Omega| +^\circ |1/\Omega, 2/\Omega| +^\circ \ldots +^\circ |(\Omega - 1)/\Omega, 1| =^\circ \Sigma^\circ{}_{i=1}{}^{\Omega}|(i - 1)/\Omega, i/\Omega|.$$

The same also holds for any linearly modeled variable, e.g. for time. We may freely *correctly*, and *properly*, but not necessarily *regularly* partition (split) an n-dimensional space ($n \in N$). We may provide this purely geometrically or introduce in it any coordinate system, e.g. cylindrical or spherical. By using a Cartesian coordinate system and *correctly*, *properly*, and *regularly* partitioning (splitting), a *continuum uniparticle* is an n-dimensional parallelepiped whose dimensions are of actually continually infinitesimal unimeasures. They are equal to one another if and only if the same holds for the corresponding coordinate axes units. If and only if all of them coincide and a Cartesian coordinate system is rectangular, then a *continual uniparticle* is an n-dimensional actually continually infinitesimal cube.

Like any continuum, a *continual uniparticle* contains its separate points *belonging* to it but it cannot *consist* of them *only*.

actually infinitesimal point measure $Q_n = Q/\Omega^n$ and point-wise space nature $\Pi_{j=1}{}^n| x_j\text{-}0.5/\Omega,\ x_j+0.5/\Omega|$ of half-open/closed point $({}_{j=1}{}^n x_j)$ (in n-dimensional Euclidean space $R^n$) for which $Q({}_{j=1}{}^n x_j) = 1$, $Q_n({}_{j=1}{}^n x_j) = 1/\Omega^n$ using countable cardinality $\omega = Q\{1, 2, ...\}$ and continuum cardinality $\Omega = Q(0, 1] = Q|0, 1| = Q({}_{1/2}0 + (0, 1) + {}_{1/2}1)$. At least continually adding points or point functions gives lines, surfaces, and spaces (possibly their parts, namely open, half-open/closed, and closed intervals (segments) of length $M_1 = L$ (with $Q = L\Omega - 1$, $Q_1 = L - 1/\Omega$; $Q = L\Omega$, $Q_1 = L$; $Q = L\Omega + 1$, $Q_1 = L + 1/\Omega$, respectively), areas, and volumes) or their functions with inventing actually infinitesimal point-wise summation integration G:

$$Q|a, b| = Q\Sigma_{|a,b||}x\text{-}0.5/\Omega,$$
$$x+0.5/\Omega| = \Sigma_{|a,b|}Q|x\text{-}0.5/\Omega,$$
$$x+0.5/\Omega| = (b\text{-}a)\Omega\ 1/\Omega\ \Omega = (b\text{-}a)\Omega;$$
$$Q_1|a, b| = Q_1\Sigma_{|a,b||}x - 0.5/\Omega,$$
$$x+0.5/\Omega| = \Sigma_{|a,b|}Q_1|x\text{-}0.5/\Omega,$$
$$x+0.5/\Omega| = (b - a)\Omega\ 1/\Omega = b - a.$$
$$Q\Pi_{j=1}{}^n|a_j , b_j| = \Pi_{j=1}{}^n((b_j - a_j)\Omega) = \Omega^n\ \Pi j_{=1}{}^n\ (b_j - a_j);$$
$$Q_n\Pi_{j=1}{}^n[a_j , b_j] = \Pi_{j=1}{}^n g_n[a_j, b_j] = \Pi_{j=1}{}^n(b_j - a_j + 1/\Omega).$$

To provide complete (also uncountable) both analytic and geometric additivity without intersections and absorption, for any (also corner) point (x, y), regard its angle $\alpha$ namely internal for an area, use floor function [z], and take

$$q = 1/4[1/2 + 2\alpha/\pi] + 1/8 \tan(\alpha - [1/2 + 2\alpha/\pi]\pi/2)$$

for a square or simply $q \approx \alpha/(2\pi)$ for the inscribed circle (for the 3D space, $q \approx \alpha/(4\pi)$). For internal point (x, y), $\alpha = 2\pi$, $q = 1$. For boundary differentiable point, e.g., (x, f(x)), $\alpha = \pi$, $q = 1/2$. Without above additivity,

$$G|\text{-}\omega, \omega|\times|0, f(x)| = \int_{-\infty}^{+\infty} f(x)dx;$$
$$Q_{q(x,y)}[a, b]\times[0, f(x)]=\Sigma_{[a,b]\times[0,f(x)]}q(x,y)=\Sigma_{[a,b]}\Sigma_{[0,f(x)]}q(x, y);$$
$$G_{q(x,y)}[a, b]\times[0,f(x)]=Q_{q(x,y)}[a, b]\times[0, f(x)]/\Omega^2=\Sigma_{[a,b]\times[0,f(x)]}q(x,y)/\Omega^2=\Sigma_{[a,b]}\Sigma_{[0,f(x)]}q(x, y)/\Omega^2;$$
$$G[{}_qa, {}_rb]\times[{}_s0, {}_tf(x)] = \int_a^b f(x)dx + [(q - 1/2)f(a) + (r - 1/2)f(b) + (s + t - 1)(b - a)]/\Omega + (q + r - 1)(s +t - 1)/\Omega^2;$$
$$G|a, b|\times|0, f(x)| = G[{}_{1/2}a, {}_{1/2}b]\times[{}_{1/2}0, {}_{1/2}f(x)] = \int_a^b f(x)dx;$$
$$G[a, b]\times[0, f(x)]=\int_a^b f(x)dx + [f(a)/2 + f(b)/2 + b - a]/\Omega + 1/\Omega^2$$

(for additivity, take

$$\alpha = \pi/2 + \arctan df(x)/dx \text{ at } (a, f(a)),$$
$$\alpha = \pi/2 - \arctan df(x)/dx \text{ at } (b, f(b)));$$

$$G(a, b)\times(0, f(x)) = G[{}_0a, {}_0b]\times[{}_00, {}_0f(x)] = \int_a^b f(x)dx - [f(a)/2 + f(b)/2 + b - a)]/\Omega + 1/\Omega^2.$$

$$Q\{(x, y)|x^2+y^2\leq_{1/2}r^2\}=1/2\ r\Omega\ 1\ 2\pi r\Omega=\pi r^2\Omega^2;$$

$$G\{(x,y)|x^2+y^2\leq_{1/2}r^2\}=\pi r^2\Omega^2/\Omega^2 = \pi r^2;$$

$$Q\{(x,y)|x^2+y^2\leq r^2\}=\pi(r\Omega+1/2)^2=\pi r^2\Omega^2+\pi r\Omega+\pi/4;$$

$$G\{(x,y)|x^2+y^2\leq r^2\}=\pi r^2+\pi r/\Omega+\pi/(4\Omega^2);$$

$$Q\{(x,y)|x^2+y^2<r^2\} = \pi(r\Omega-1/2)^2=\pi r^2\Omega^2-\pi r\Omega+\pi/4;$$

$$G\{(x,y)|x^2+y^2<r^2\}= \pi r^2-\pi r/\Omega+\pi/(4\Omega^2).$$

Universal space discretization, measurement, and integration via multidimensional infinitesimal points provides intelligently solving urgent complicated problems.

## 5. Multidimensional Infinitesimal Universal Space-Time, Motion, and Process

**Classical science** [1–12] based on the real numbers without namely actual infinities and infinitesimals and on at most countable number operations cannot resolve Zeno's arrow flight paradox on motion impossibility. If time is completely composed of durationless moments, then at anyone moment, the arrow cannot move because no time elapses. Generally, no process is possible. Point-wise dividing time into such moments rather than intervals and segments is a special case of Zeno's measure paradox. The 4-dimensional (4D) space-time needs efficient 2D data processing.

**Unimathematics** [17–32] based on uniphilosophy [14, 15] and metauniphilosophy [14, 16] is perfectly sensitive and exactly namely actually both infinitely and infinitesimally (with conservation law universality) operates, point-wise measures, and summation-wise integrates space, time, etc. At least continually adding points gives curves, surfaces, and space-time. After preliminarily dividing $x_j$ by their units $[x_j]$, consider $x_j$ to be pure uninumbers. Along with unicoordinate infinity $(-\infty, +\infty) = |-\omega, \omega|$, e.g., the eternity of unitime T, regard local time t, e.g., the lifetime of an object indexed via j in J, moments T and t. Consider a curve composing surface z = f(x, y, T) at this T and 2D representation curves

$$Z = R(T),$$

$$Z = R(T) + k\zeta(T),$$

$$Z = R(T) - k\xi(T)$$

using appropriate positive factor k independent of T via the spherical coordinates R, ζ, ξ transformation. Build the 3D projection only of a 4D space-time point. Every space point has at least 3D and a time instant at least 1D infinitesimal nature. Otherwise, by the common 0D point nature, Zeno's paradoxes would be valid with the impossibility of infinite division, motion, and process with change and variation at all. That is why unimathematics is necessary for real world nature understanding. Further precising infinities and infinitesimals additionally to simply ω and Ω via their operations and functions also within this (ω, Ω)-overmathematics in unimathematics, nothing to say about the next infinite cardinal numbers, makes the space-time point nature ∞D. In unimathematics, resolving Zeno's paradoxes is very simple. Take any time unit [t]. It consists of Ω time instants of [t]/Ω. Let arrow flight duration be t with simply uniform velocity v. Then t consists of $t/[t]\ \Omega$ time instants of duration $[t]/\Omega$. The arrow way is $v[t]/\Omega$ during such time instant and $v[t]/\Omega\ t/[t]\ \Omega = vt$ at all, quod erat demonstrandum. Dividing an object of measure $M > 0$ into $\omega$ equal parts gives their measure $m = M/\omega$. Multidimensional universal actually infinite and infinitesimal space-time discretization, operation, measurement, and integration discovers the nature and essence of space-time, motion, and process.

## 6. Deformable Solid Unimechanics

**Deformable solid mechanics** [4–12] uses nonuniversal dimensional mechanical stresses without expressing their risk (danger). There are no known namely analytical solutions to nontrivial three-dimensional problems without the relative smallness of some characteristic solids sizes such as thickness even in thick plate theory.

**Deformable solid unimechanics** [19, 25, 34, 39, 40, 47–49, 57] defines unistresses. General uniparametrization theory in analytical uniparametrization science searches for a general solution to a uniproblem in its general pseudosolutions. General (possibly infinite) linear combination theory explicitly solves a uniproblem as a unisystem of equations naturally introducing infinite linear independence. In particular, to the homogeneous harmonic equation $\nabla^2\varphi(x, y, z) = 0$ over desired function $\varphi(x, y, z)$ in the Cartesian coordinates, x, y, z, in the class of power series

$$\varphi(x, y, z) = \Sigma_{i=0}^{\infty}\Sigma_{j=0}^{\infty}\Sigma_{k=0}^{\infty}a_{ijk}x^iy^jz^k,$$

linear combination theory determines the most general solution

$$\varphi(x, y, z) = \Sigma_{i=0}^{\infty}\Sigma_{j=0}^{\infty}\Sigma_{k=0}^{\infty}(-1)^{[i/2]}[i/2]!(i!j!k!)^{-1}\Sigma_{m=0}^{[i/2]}(j + 2m)!(k + 2[i/2] - 2m)!\{m!([i/2] - m)!\}^{-1}a_{i-2[i/2],\ j+2m\ ,\ k+2[i/2]-2m}x^iy^jz^k$$

where $[r]$ = entier r = floor r is the integral part of a real number r, $a_{0jk}$ and $a_{1jk}$ are two arbitrary number sequences, $0 \le j < \infty$, $0 \le k < \infty$. To the homogeneous biharmonic equation $\nabla^2\nabla^2L(r, z) = 0$ over desired function $L(r, z)$ in the cylindrical coordinates, r, z, in the class of power series

$$L(r, z) = \Sigma_{i=0}^{\infty}\Sigma_{j=0}^{\infty}a_{ij}r^{2i}z^j,$$

the most general solution is

$$L(r, z) = \Sigma_{i=0}^{\infty}\Sigma_{j=0}^{\infty}(-1)^{i+1}i!^{-2}j!^{-1}[(2i + j - 2)!\ i\ 2^{2-2i}a_{1,\ 2i+j-2} + (2i + j)!(i - 1)2^{-2i}a_{0,\ 2i + j}]r^{2i}z^j$$

where $k! = 1$ and $a_{1k} = 0$ by $k < 0$; $a_{0j}$ and $a_{1j}$ are two arbitrary number sequences.

## 7. Material Unistrength (Universal Material Strength Science)

**Material strength science** [4–12] uses nonuniversal dimensional mechanical stresses without expressing their risk (danger) degrees. For an arbitrarily anisotropic material with different resistances to tensions and compressions and for any variable loads with possibly rotating the principal directions of the stress state at a material point during loading, there are no common limiting state criteria [9, 10] for triaxial mechanical stresses and no universal strength laws of nature. The Tresca and Huber-von-Mises-Hencky criteria are quite nonsensitive to pressure with significant effect on strength in the Nobel prize winner Bridgman experiments [7] and prescribe values 2 and $3^{1/2}$ to the ratio of the tensile and shear strengths whereas it varies from 1 to 4.

**Material unistrength** [19, 25, 34–39, 41–46, 50–56] discovers universal stresses, or unistresses, $\sigma_j°$. For stationarily loading any anisotropic material, $\sigma_j° = \sigma_j/|\sigma_{Lj}|$ where $\sigma_{Lj}$ is, for usual principal stress $\sigma_j$ , its limiting value which has the direction and sign of $\sigma_j$ and acts at the same material's point, the both other principal stresses vanishing, and the other loading conditions being the same. Universalize the Galilei, Tresca, Huber-von Mises-Hencky, and Pisarenko-Lebedev strength criteria:

$$\sigma_j° = \sigma_j/\sigma_t\ (\sigma_j \geq 0),\ \sigma_j°= \sigma_j/\sigma_c\ (\sigma_j < 0),\ j = 1, 2, 3,$$

$$\sigma_{eG}° = \max\{|\sigma_1°|, |\sigma_2°|, |\sigma_3°|\} \leq 1,$$

$$\sigma_{eT}° = \sigma_1° - \sigma_3° \leq 1,$$

$$\sigma_{eHvMH}° = \sigma_i° = \{[(\sigma_1° - \sigma_2°)^2 + (\sigma_2° - \sigma_3°)^2 + (\sigma_3° - \sigma_1°)^2]/2\}^{1/2} \leq 1,$$

$$\sigma_{ePL}° =(1- \chi)\max\{|\sigma_1°|, |\sigma_2°|, |\sigma_3°|\}+\chi\{[(\sigma_1° - \sigma_2°)^2 + (\sigma_2° - \sigma_3°)^2 + (\sigma_3° - \sigma_1°)^2]/2\}^{1/2} \leq 1.$$

Linearly correct criterion $\sigma_e = F(\sigma_1 , \sigma_2 , \sigma_3) = \sigma_L$ via constant x and generalizing:

$$\sigma_e = F(\sigma_1, \sigma_2, \sigma_3) + x\sigma_2 = \sigma_L,\ \sigma_e° = F(\sigma_1°, \sigma_2°, \sigma_3°) = 1,$$

$$\sigma_e° = F(\sigma_1°, \sigma_2°, \sigma_3°) + x\sigma_2° = 1.$$

For variably loading with initial mean cycle stress $\sigma_{m0j}(t)$ at time t in $T = [t_0, t_1]$,

$$\sigma_j°(t) = [\sigma_j(t)-\sigma_{m0j}(t)]/|\sigma_{Lj}(t)-\sigma_{m0j}(t)|.$$

For each uniaxial stress process $\sigma_j(t)$, its own reserve $n_j$ is defined by the similar limiting process $n_j\sigma_j(t)$ with possibly taking damage accumulation into account. Determine the equidangerous cycle of unistresses with mean stress $\sigma_{mj}°$ and amplitude stress $\sigma_{aj}°$, then the constantly vectorial reduced unistress $\boldsymbol{\sigma}_j° = (\sigma_{mj}°, \sigma_{aj}°)$ via the limiting amplitude diagram. Now choose the most dangerous, possibly depending on t, permutations of the stationary indexes ju of the unordered unistresses without $\sigma_{1u}° \geq \sigma_{2u}° \geq \sigma_{3u}°$. The final universal criterion is

$$\sigma_e° = \max\{\sup_{t\in T} \max_{ju(t)} F(\sigma_{1u}°(t), \sigma_{2u}°(t), \sigma_{3u}°(t)), \max_{ju} |F(\boldsymbol{\sigma}_{1u}°, \boldsymbol{\sigma}_{2u}°, \boldsymbol{\sigma}_{3u}°)|\} = 1.$$

**General power strength theory.** The $\tau_L/\sigma_L$ ratio of shear $\tau_L$ and normal $\sigma_L$ limiting stresses of materials [54] takes values at least between 0.25 and 1, not only 1/2 (Tresca), $3^{-1/2}$ (Mises). Limiting surfaces are convex by $1/2 \leq \tau_L/\sigma_L \leq 2/3$ [11].

In material unistrength [19, 25, 34–39, 41–46, 50–56], general power strength theory [55] including general linear strength theory [53] generalizing Yu's twin shear unified strength theory [11] also fits all these and other data. Use principal stresses $\sigma_1 \geq \sigma_2 \geq \sigma_3$ , limiting stress $\sigma_L$ such as yield stress $\sigma_y$ or ultimate strength $\sigma_u$ , namely $\sigma_{Lt}$ in tension and $\sigma_{Lc}$ in compression with $\sigma_{Lc} \geq 0$ and $\alpha = \sigma_{Lt}/\sigma_{Lc}$ if $\sigma_{Lt} \neq \sigma_{Lc}$ . Define relative (reduced) principal stresses $\sigma_j°$ via dividing $\sigma_j$ by the modulus $|\sigma_{jL}|$ of $\sigma_{jL}$ of the same sign in the same direction by vanishing the remaining two principal stresses under the same remaining load conditions:

$$\sigma_j° = \sigma_j / |\sigma_{jL}|\ (j = 1, 2, 3),\ \sigma_1° \geq \sigma_2° \geq \sigma_3°.$$

Consider one-sided limitations for $\sigma_e$ and $\sigma_e°$ whose values can be negative or imaginary and use nonnegative $|\sigma_e|$ and $|\sigma_e°|$. Generalize Hosford's criterion [9] via

$$\sigma_e = [a_{13}(\sigma_1 - \sigma_3)^k + a_{12}(\sigma_1 - \sigma_2)^k + a_{23}(\sigma_2 - \sigma_3)^k]^{1/k} \leq \sigma_L\ (k > 0).$$

Uniaxial limiting stresses in tension and compression give strength criteria form

$$\sigma_e^\circ = \{a(\sigma_1^\circ - \sigma_3^\circ)^k + (1 - a)[(\sigma_1^\circ - \sigma_2^\circ)^k + (\sigma_2^\circ - \sigma_3^\circ)^k]\}^{1/k} \leq 1.$$

Pure shear reduced limiting stresses $\sigma_1^\circ = \tau_L/\sigma_{Lt}$ , $\sigma_2^\circ = 0$ , $\sigma_3^\circ = - \tau_L/\sigma_{Lc}$ give ($k \neq 1$)

$$\sigma_e^\circ = \{(\sigma_{Lt}^k\sigma_{Lc}^k/\tau_L^k - \sigma_{Lt}^k - \sigma_{Lc}^k)/[(\sigma_{Lt} + \sigma_{Lc})^k - \sigma_{Lt}^k - \sigma_{Lc}^k](\sigma_1^\circ - \sigma_3^\circ)^k +$$
$$[(\sigma_{Lt} + \sigma_{Lc})^k - \sigma_{Lt}^k\sigma_{Lc}^k/\tau_L^k]/[(\sigma_{Lt} + \sigma_{Lc})^k - \sigma_{Lt}^k - \sigma_{Lc}^k][(\sigma_1^\circ- \sigma_2^\circ)^k + (\sigma_2^\circ - \sigma_3^\circ)^k]\}^{1/k} \leq 1.$$

In the simplest case $k = 2$ and then additionally by $\sigma_{Lt} = \sigma_{Lc} = \sigma_L$ , we have criteria

$$\sigma_e^\circ = \{[\sigma_{Lt}\sigma_{Lc}/(2\tau_L^2) - (\sigma_{Lt}^2 + \sigma_{Lc}^2)/(2\sigma_{Lt}\sigma_{Lc})](\sigma_1^\circ - \sigma_3^\circ)^2 +$$
$$[(\sigma_{Lt}^2 + \sigma_{Lc}^2)/(2\sigma_{Lt}\sigma_{Lc}) - \sigma_{Lt}\sigma_{Lc}/(2\tau_L^2)][(\sigma_1^\circ- \sigma_2^\circ)^2 + (\sigma_2^\circ - \sigma_3^\circ)^2]\}^{1/2} \leq 1,$$
$$\sigma_e^\circ = \{[\sigma_L^2/(2\tau_L^2) - 1](\sigma_1^\circ - \sigma_3^\circ)^2 + [2 - \sigma_L^2/(2\tau_L^2)][(\sigma_1^\circ- \sigma_2^\circ)^2 + (\sigma_2^\circ - \sigma_3^\circ)^2]\}^{1/2} \leq 1,$$
$$\sigma_e^\circ = \sigma_1^\circ - \sigma_3^\circ \leq 1 \text{ (universalized Tresca's criterion) by } \tau_L/\sigma_L = 1/2,$$
$$\sigma_e^\circ = \{[(\sigma_1^\circ - \sigma_3^\circ)^2 + (\sigma_1^\circ - \sigma_2^\circ)^2 + (\sigma_2^\circ - \sigma_3^\circ)^2]/2\}^{1/2} \leq 1 \text{ (Mises et al.) by } \tau_L/\sigma_L = 1/3^{1/2},$$
$$\sigma_e^\circ = [(\sigma_1^\circ - \sigma_2^\circ)^2 + (\sigma_2^\circ - \sigma_3^\circ)^2]^{1/2} \leq 1 \text{ by } \tau_L/\sigma_L = 1/2^{1/2}.$$

Use general homogeneous symmetric polynomials $P_i(\sigma_{1n}^\circ, \sigma_{2n}^\circ, \sigma_{3n}^\circ)$ of power i:

$$\sigma_e^\circ = [\sum_{i=0}^N a_iP_i(\sigma_{1n}^\circ, \sigma_{2n}^\circ, \sigma_{3n}^\circ)]^{1/N} \leq 1.$$

In the unstressed state, $\sigma_e^\circ = 0$ is natural and leads to $a_0 = 0$. Case $N = 2$ gives form

$$\sigma_e^\circ = [a_1(\sigma_{1n}^\circ+\sigma_{2n}^\circ+\sigma_{3n}^\circ) + a_2(\sigma_{1n}^{\circ 2}+\sigma_{2n}^{\circ 2}+\sigma_{3n}^{\circ 2}) + b_2(\sigma_{1n}^\circ\sigma_{2n}^\circ+\sigma_{1n}^\circ\sigma_{3n}^\circ+\sigma_{2n}^\circ\sigma_{3n}^\circ)]^{1/2} \leq 1.$$

Replace usual $\sigma_1 + \sigma_2 + \sigma_3$ and reduced $\sigma_{1n}^\circ + \sigma_{2n}^\circ + \sigma_{3n}^\circ$ "hydrostatic sums" with their continuous functions f and $f^\circ$ vanishing at $- \sigma_{Lc}$ , 0, $\sigma_{Lt}$ and -1, 0, 1, respectively:

$$\sigma_e^\circ=[\sigma_{1n}^{\circ 2} + \sigma_{2n}^{\circ 2} + \sigma_{3n}^{\circ 2} - a(\sigma_{1n}^\circ\sigma_{2n}^\circ + \sigma_{1n}^\circ\sigma_{3n}^\circ + \sigma_{2n}^\circ\sigma_{3n}^\circ) + bf^\circ(\sigma_{1n}^\circ+\sigma_{2n}^\circ+\sigma_{3n}^\circ)]^{1/2} \leq 1.$$

Constant a provides considering true values of $\tau_L/\sigma_L$ and not only predefined $3^{-1/2}$ by $a = 1$. This leads by $b = 0$ to ellipsoidal (by $-2 < a < 1$) and hyperboloidal (by $a > 1$) limiting surfaces and to "hydrostatic" strength limited in compression and unlimited in tension with concavity everywhere, respectively. This clearly contradicts strength test data and Drucker's postulate [9, 10]. The Huber-von-Mises-Hencky cylinder [8–10] lies between those limiting surfaces as their limiting case. Using $b \neq 0$ with

$$f^\circ(\sigma_{1n}^\circ + \sigma_{2n}^\circ + \sigma_{3n}^\circ) = \sigma_{1n}^\circ + \sigma_{2n}^\circ + \sigma_{3n}^\circ + 1 \text{ if } \sigma_{1n}^\circ + \sigma_{2n}^\circ + \sigma_{3n}^\circ \leq -1,$$
$$f(\sigma_{1n}^\circ + \sigma_{2n}^\circ + \sigma_{3n}^\circ) = 0 \text{ if } -1 \leq \sigma_{1n}^\circ + \sigma_{2n}^\circ + \sigma_{3n}^\circ \leq 1,$$
$$f(\sigma_{1n}^\circ + \sigma_{2n}^\circ + \sigma_{3n}^\circ) = \sigma_{1n}^\circ + \sigma_{2n}^\circ + \sigma_{3n}^\circ - 1 \text{ if } \sigma_{1n}^\circ + \sigma_{2n}^\circ + \sigma_{3n}^\circ \geq 1$$

makes limiting surfaces paraboloidal. Hence general power strength theory provides considering any ratio of shear and normal limiting stresses of materials.

Material unistrength gives hierarchies of universal strength laws of nature.

## 8. Object Unistrength (Universal Object Strength Science)

**Object strength science** [4–12] uses nonuniversal dimensional mechanical stresses without expressing their risk (danger) degrees. There are no universal strength laws of nature. The common reserve is valid for simple loading only. The finite element method gives often unverifiable and inadequate "black box" results.

**Object unistrength** [19, 25, 34–56] based on material unistrength includes the fundamental sciences of analytical macroelements, equivalent stress concentration factors, universal reserves, reliabilities, risks, error tolerance, and analytical fatigue.

## General reserve theory

To realistically determine the reserves of the stress states vs. the critical ones, usual safety factor $n_L$ is not sufficient because of the ambiguity of approaches:

$$F(\sigma_1 , \sigma_2 , \sigma_3) = \sigma_L , \sigma_e = F(\sigma_1 , \sigma_2 , \sigma_3), n_L = \sigma_L/\sigma_e;$$

$$F^\gamma(\sigma_1 , \sigma_2 , \sigma_3)/\sigma_l^{\gamma-1} = \sigma_L , \sigma_{e\gamma} = F^\gamma(\sigma_1 , \sigma_2 , \sigma_3)/\sigma_L^{\gamma-1},$$

$$n_{L\gamma} = \sigma_L/\sigma_{e\gamma} = \sigma_L^\gamma/F^\gamma(\sigma_1 , \sigma_2 , \sigma_3) = n_L^\gamma$$

takes on any positive values when choosing suitable values of $\gamma$ and even by its common unit value can take on too optimistic very dangerous values. In **example 1**

$$(\sigma_1 = 250 \text{ MPa}, \sigma_2 = 240 \text{ MPa}, \sigma_3 = 210 \text{ MPa}, \sigma_L = 235 \text{ MPa}),$$

$$n_L = 5.9, n_L\sigma_1 - \sigma_3/n_L = 1439 \text{ MPa} >> \sigma_L .$$

In **example 2**, a bar with strengths 100 MPa in tension ($\sigma_t$) and 800 MPa in compression ($\sigma_c$) is independently contracted and stretched by two force pairs. Stress

$$\sigma = \sigma^- + \sigma^+ = -500 \text{ MPa} + 400 \text{ MPa} = -100 \text{ MPa}, n_l = \sigma_c/|\sigma| = 8,$$

$$n_L\sigma^- + \sigma^+/n_L = -3950 \text{ MPa} << - \sigma_c , \sigma^-/n_L + n_L\sigma^+ = 3137.5 \text{ MPa} >> \sigma_L .$$

The main idea to realistically determine the reserve of a system under consideration is separately taking the reserves of its original parameters into account, each of these reserves being expressed via a common additional number. It is obtained from the condition that, by the worst realizable combination of the values of these parameters arbitrarily modified within the bounds determined by the corresponding reserves, the state of at least one element of the system becomes limiting, no element of it being in an overlimiting state. In a general problem, for any function of an arbitrary set of variables, where $(\alpha)$ means that index $\alpha \in A$ is optional,

$$z = f[_{\alpha\in A}\ z_\alpha], Z = f[_{\alpha\in A}\ Z_\alpha], z_{(\alpha)} \in Z_{(\alpha)}.$$

The genuine values of the independent variables $z_\alpha$ and of the dependent one z usually deviate from their values calculated. Those should belong to their admissible sets (domains) $[Z_{(\alpha)}]$ if the problem has certain limitations like strength criteria in strength problems. Otherwise, it is necessary to determine such a combination of the restrictions $Z_\alpha$ of the admissible sets $[Z_\alpha]$ that $[Z]$ contains $f[_{\alpha\in A}\ Z_\alpha]$. For the numeric measures of those restrictions, or the reserves of the independent variables, it is sufficient that, for any $\alpha \in A$, $[Z_{(\alpha)}]$ is included into a certain Hilbert space $L_{(\alpha)}$. It has the norm $||z_{(\alpha)}||_{(\alpha)}$ of each element $z_{(\alpha)}$ and the scalar product $(z_{(\alpha)}, z'_{(\alpha)})_{(\alpha)}$ of each pair of elements $z_{(\alpha)}$ and $z'_{(\alpha)}$. An additive approach extends the relative error and naturally determines the neighborhood $Z_{(\alpha)}(\delta_{(\alpha)}, z_{0(\alpha)})$ of set $Z_{(\alpha)}$ with respect to element $z_{0(\alpha)} \in L_{(\alpha)}$ with error $\delta_{(\alpha)} \geq 0$ as the set of all $z'_{(\alpha)} \in L_{(\alpha)}$ with

$$||z'_{(\alpha)} - z_{(\alpha)}||_{(\alpha)} \leq \delta_{(\alpha)}||z_{(\alpha)} - z_{0(\alpha)}||_{(\alpha)}.$$

The additive reserve of set $Z_{(\alpha)}$ by set $[Z_{(\alpha)}]$ with respect to element $z_{0(\alpha)}$ is defined as

$$n_{a(\alpha)} = 1 + \sup\{\delta_{(\alpha)} \geq 0: Z_{(\alpha)}(\delta_{(\alpha)}, z_{0(\alpha)}) \subseteq [Z_{(\alpha)}]\}.$$

The multiplicative approach develops, generalizes, and extends the safety factor:

$$n_{m(\alpha)} = \sup\{n_{(\alpha)} \geq 1: Z_{(\alpha)}(n_{(\alpha)}\exp(i\varphi_{(\alpha)}), z_{0(\alpha)}) \subseteq [Z_{(\alpha)}]\}(0 \leq \varphi_{(\alpha)} \leq \pi).$$

By the both approaches, reserves $n_\alpha$ can be expressed via different nondecreasing functions of an additive reserve $n_{fa}$ or of a multiplicative one $n_{fm}$ , respectively, the both being common for reserves $n_\alpha$ and determined by the condition that there is an element $z \in Z$ in a limiting state by the worst realizable combination of all $z_\alpha$:

$$n_{fa} = \sup\{n \geq 1: f[_{\alpha\in A}\, Z_\alpha(n_\alpha(n), z_{0\alpha})] \subseteq [Z]\},$$

$$n_{fm} = \sup\{n \geq 1: f[_{\alpha\in A}\, Z_\alpha(n_\alpha(n)\exp(i\varphi_\alpha(n_\alpha(n))), z_{0\alpha}) \subseteq [Z]\}.$$

For simply (proportionally) loading, the multiplicative reserve is obtained from

$$F(n_{fm}\sigma_1\,, n_{fm}\sigma_2\,, n_{fm}\sigma_3) = \sigma_L\,.$$

By equal reserves of all $z_\alpha$, in **example 1** we have for $n_{fa}$ and $n_{fm}$ 1.423 and 1.5, in **example 2** for $n_{fmt}$ in tension and $n_{fmc}$ in compression 1.25 and 2 much less than $n_L$.

## Conclusion

Universal physics based on a positive point measure by the principles of (meta)uniphilosophy, unimathematics, and unimetrology is a superstructure over them and selected areas of classical physics. It improves fundamental physical constants, opens new horizons for discovering the essence, phenomena, and laws of space and infinity, time and eternity, rest and movement, natural, technical, and social sciences, and gives a way out of Zeno's and other paradoxes 2500 years unsolvable.

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