AURAVANA PROJECT

PROJECT FOR A COMMUNITY-TYPE SOCIETY

The Material System

SSS-MS-003 | May 2024

SOCIETAL SPECIFICATION STANDARD

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THE MATERIAL SYSTEM

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GREETINGS

In an effort to provide the greatest possible clarity and value the Auravana Project has formatted the system for the proposed society (of the type, 'community') **into a series of standard publications. Each standard is both a component of the total, unified system, as well as intended to be a basis for deep reflective consideration of one's own community, or lack thereof. These formal standards are "living" in that they are continually edited and updated as new information becomes available; the society is not ever established, its design and situational operation exists in an emergent state, for it evolves, as we evolve, necessarily for our survival and flourishing.**

Together, the standards represent a replicable, scalable, and comprehensively "useful" model for the design of a society where all individual human requirements are mutually and optimally fulfilled.

The information contained within these standards represent a potential solution to the issues universally plaguing humankind, and could possibly bring about one of the greatest revolutions in living and learning in our modern time. Change on the scale that is needed can only be realized when people see and experience a better way. The purpose of the Auravana Project is to design, to create, and to sustain a more fulfilling life experience for everyone, by facilitating the realization of a better way of living.

Cooperation and learning are an integral part of what it means to be a conscious individual human. A community-type societal environment has been designed to nurture and support the understanding and experience of this valuable orientation.

The design for a community-type society provides an entirely different way of looking at the nature of life, learning, work, and human interaction. These societal standards seek to maintain an essential alignment with humankind's evolving understandings of itself, combining the world of which humans are a regenerative part, with, the optimal that can be realized for all of humanity, given what is known.

The general vision for this form of society is an urgent one considering the myriad of perceptible global societal crises. Together, we can create the next generation of regenerative and fulfilling living environments. Together, we can create a global societal-level community.

THE UNIFIED SOCIETAL SYSTEM: MATERIAL SPECIFICATION STANDARD

This publication is one of six representing the proposed standard operation of a type of society given the category name, 'community' (a community-type society). This document is a specification standard for a material system.

Every society is composed of a set of core systems. Different types of societies have different internal compositions of these systems. The composition of these systems determines the type of society. The type of society described by the Auravana Project societal standard is a, community-type society. The standard is a composition of sub-system standards. The Auravana societal standard may be used to construct and duplicate community at the global level.

For any given society, there are four primary societal sub-systems. Each of these sub-systems can be specified and standardized (described and explained); each sub-system is a standard within a whole societal specification standard. The first four primary standards of the six total standards are: a Social System; a Decision System; a Material System; and a Lifestyle System. Each standard is given the name of its information system. The fifth publication is a Project Plan, and the sixth is an Overview of the whole societal system. Together, these standards are used to classify information about society, identify current and potential configurations, and operate an actual configuration. Because of the size of some of these standards, they may be split into two or more publications.

Essential figures and tables related to this standard exist beyond what is shown in this document.

Figures and tables on the website are named according to their placement in the standard.

- Those figures that could not be accommodated here are readily accessible in their full size, and if applicable, in color, on the Auravana Project's website [auravana.org/standards/figures].
- Those tables that are too large to include in this document are referenced with each standard on the Auravana Project's website [auravana.org/standards].

Articles

Article Section Headings

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List of figures

This is the list of figures within this document.
There are more figures associated with this standard than are identified in this document; those figures that could not fit are freely available through auravana.org, in full size, and if applicable, color.

List of tables

This is the list of tables within this document.
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Document Revision History

A.k.a., Version history, change log.

This document is updated as new information becomes available.
The following information is used to control and track modifications (transformations, changes) to this document.

VERSION	REVISION DATE	SUMMARY (DESCRIPTION)
003	May 2024	This document has had significant changes made to it throughout. The Overview, Land Assessment, and Measurement Accounting articles are still present, their order is different (with significant internal changes). There are now two articles related to habitat service system accounting and planning within the material system of a community-type society. Citations have been improved throughout and are now at APA 7th generation.

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The Material System Overview

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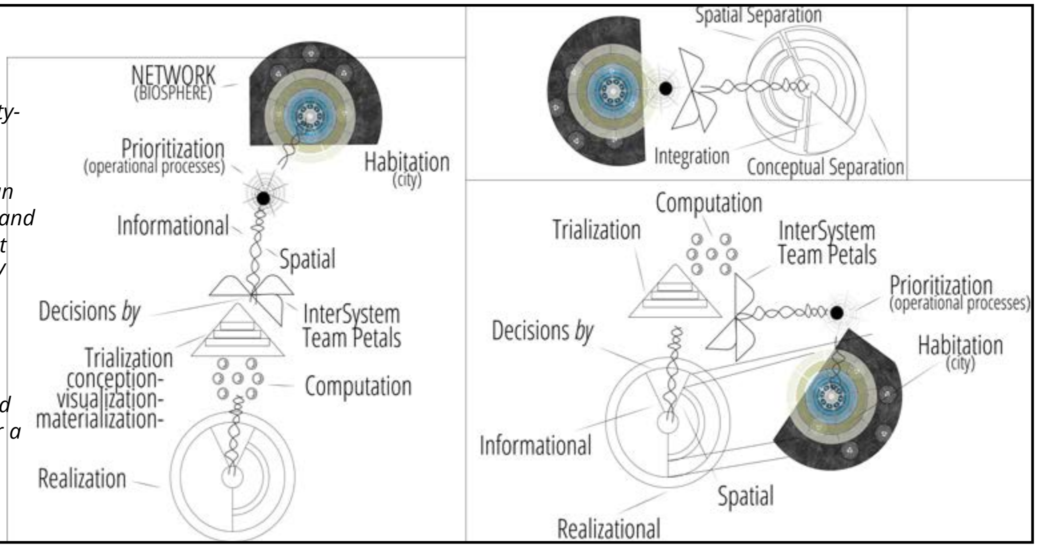
Abstract

This publication is the Material System for a community-type society. A material system describes the organized structuring of a material environment; the material structuring of community. This material system standard identifies the structures, technologies, and other processes constructed and operated in a material environment, and into a planetary ecology. A material system encodes and expresses our resolved decisions. When a decision resolves into action, that action is specified to occur in the material system. Here, behavior influences the environment, and in turn, the environment influences behavior. The coherent integration and open visualization of the material systems is important if creations are to maintain the highest level of fulfillment for all individuals. This standard represents the encoding of decisions into an environment forming lifestyles within a habitat service system. The visualization and simulation of humanity's connected material integrations is essential for maintaining a set of complex, fulfillment-oriented material constructions. As such, the material system details what has been, what is, and what could be constructed [from our information model] into our environment. This specification depicts, through language and symbols, visualization, and simulation, a material environment consisting of a planetary ecology and embedded network of integrated city systems. For anything that is to be constructed in the material system, there is a written part, a drawing part, and a simulation part, which is also how the material system is sub-divided. This standards is a proposal for current material operations and future material organization, based upon what is known about the current physical, material environment.

Graphical Abstract

Figure 1. *Depiction of several views on the realization of a community-type societal information system that cooperatively organizes a mutual human prioritized informational and spatial service system that materializes in a physical/ material environment, primarily in the form of a network of integrated city systems, that collect and serve information and material requirements for a population of humans.*



1 Introduction to the material standard

The visualization and simulation of the interconnected material reality is essential for maintaining a set of complex material constructions designed to remain in alignment with the regeneration of our highest potential state of fulfillment (i.e., our highest potentially expressed fulfillment or HPEF). In a material context, our HPEF is determined by how efficiently we re-configure the resources in our environment into services which are effective for fulfilling human needs and maintaining individuals' access to opportunities for discovery and growth.

The Material System describes what has been, what is, and what could be constructed [from the society's information model] into its material environment, and therein, a global human habitat. In other words, it is a description of what has been materialized (past material state), could be materialized (future potential material state), and what is, materializing (current operating state). It depicts the selectively materialized expression of the society's information model as well as all probable alternatives. Essentially, this is a standard for the material domain of a society. Simply, it contains all information about the material nature of society; it describes the part of the community [information] system that is, was, or could be operational at the material level. This standard addresses the materially constructed system through knowledge and tools into processes and services that combine to form technologies which function to provide resource flows and material transformations for human fulfillment.

This standard accounts for the localized placement of all material resources within the biosphere and local habitat service systems. It accounts for not only resources, but also for the material reconstruction of the common environment through integrated access to common [heritage] resources via a unified information model, one phase of which represents the product of the interaction of the other three systems, the materialization of a service system (i.e., the after decisioning comes material reconfiguration, which humans then live within for some duration of time).

This standard depicts through written word, visualization, and simulation the materialization of an integrated habitat service system, which is more commonly referred to as a total city system network. The habitat service system is the material, technical system which facilitates the fulfillment of identified human needs. The material system is a planned. The cities herein are connected and integrated into a network of cities forming a complex human community contributing to and utilizing a unified information model and a global material access system. Having access to a habitat service (city) system is a big deal in terms of access to fulfillment, access to knowledge, access to freedom, independence, and just things.

> **NOTE:** *A 'material specification' is the detailed expression of a set of intentionally designed material relationships in order to materialize (a.k.a., make, construct, create) some socio-technical object and/or service [using material resources].*

Humans experience their constructions, and so, in community, humans socially organize and plan for their constructions. This is accomplished through the social collection of information, which is feed into an shared decision space, which is transparently resolved a selected solution into a re-configuration of the common material environment. Generally, that re-configuration takes the form of a walking-garden city systems, frequently circular in nature, and composed into a distributed network of cities operating together and based upon the same information model.

The integrated city system is a controlled service space where our built world mimics and harmonizes with the regenerability principles of the natural world. If we flow with natural principles we can even amplify what we are capable of in nature; we can get even better at it, and do it in a way that keeps us harmonious with the natural world, so that we aren't fighting the flow. A city is, in part, a solution to the problem of how to sustainably meet the needs of a growing, thriving population, so as to maximally benefit from super-linear scaling. In an integrated city system, people live in walking (or mass rapid transport) distance from people and services they normally access within their spatial life radius area. Living in closer proximity allows individuals to do and communicate more [with each other] in less time.

> **NOTE:** *In community, we structure our lives and environment so that we naturally do things that are fulfilling*

In community, our evolutionary impulse gives rise to the dialectic of "progress" expressed through continuous improvement within an ecological environment, rather than continuous expansion of a made up number that a bunch of people are telling themselves a story about (i.e., "GDP"). Community accounts for that which exists, and by letting go of [artificial] narratives it can optimize therein. In the Community, technology's ability to generate abundance is fully utilized without the restrictions of an economic system that values, and thus, manufactures scarcity. In community, the capacity to automate rote tasks is fully utilized, freeing humans from tedious jobs in an economic system where they are no longer needed. Technology is embraced, not as a solution in itself, but as an extension of our abilities and power, which will be as constructive as our value systems is inclusive.

A material system is sub-composed at the highest level of:

1. Materials accounting.

2. Measurement accounting.
3. Land accounting.
4. Habitat service accounting.

A material (physical) environment can be re-configured through:

1. Work (concepts),
2. Resources (objects), and
3. People (consciousness with knowledge and skills).

The primary sub-systems of the material system are:

1. Materials accounting (objects):
   A. Land accounting (geo-spatial surface).
   B. Object accounting (products).
2. Measurement events (motions):
   A. Measuring backwards ("recording").
   B. Measuring forwards ("engineering").
3. Habitat service event accounting (for human need fulfillment):
   A. Functions.
   B. Materials (resources).
   C. Techniques.
   D. Technologies.
   E. Master-plans.
   F. Teams.

People interact and move through the material environment ("space") in the following ways:

1. Physically moving through space.
2. Interacting with other people (and other living things) in space.
3. Interacting with technologies (machines) in space.
4. Seeing space from a point in it.
5. Consuming space (eating food) in order to sustain the body.

If humans material fulfilment, it is both a requirement

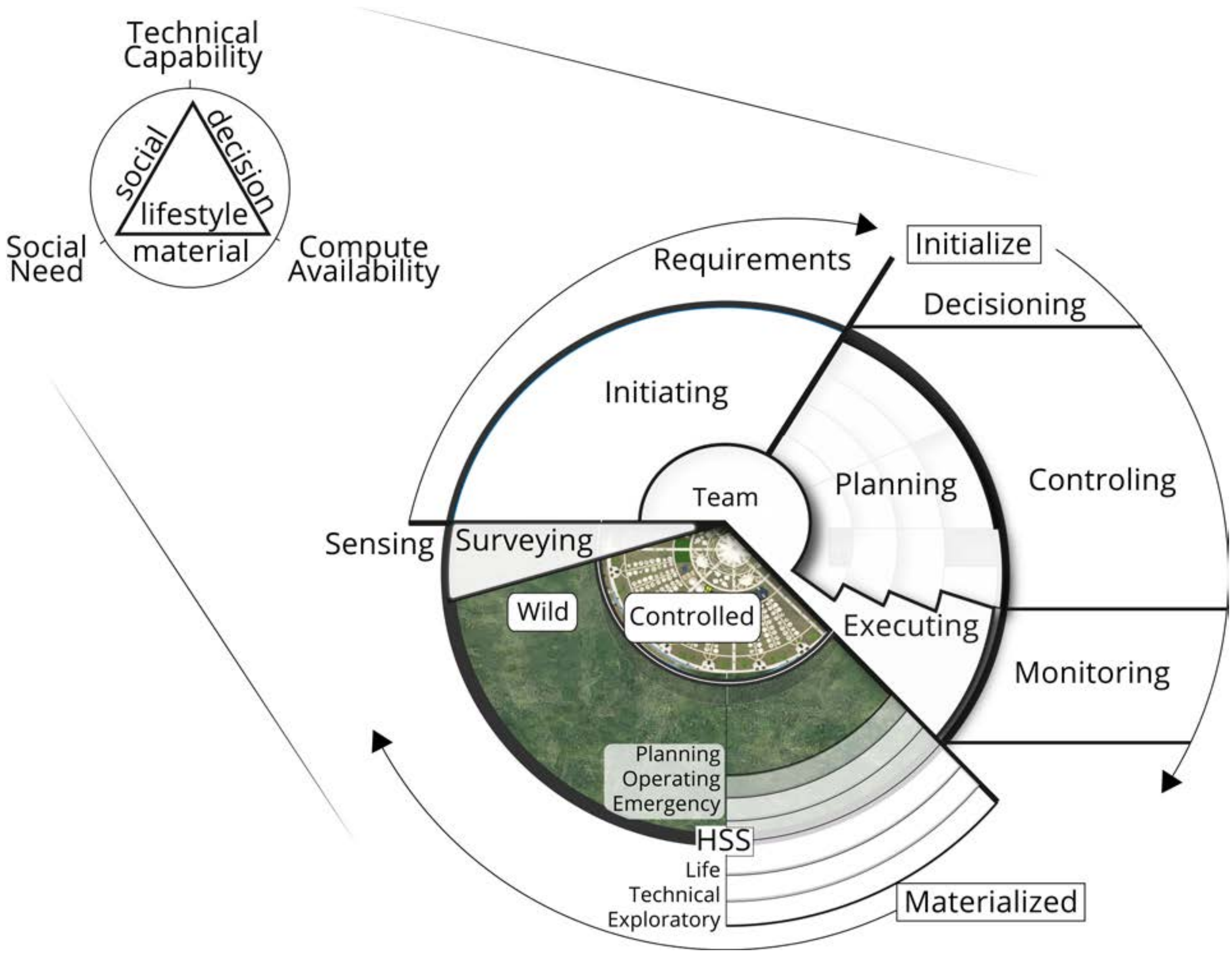


Figure 2. *The real-world community model executing [by means of teams and objects] the realization of a network of habitat services systems within a larger planetary ecology where humans have needs (real world requirements) that can be met with some level of knowledge and understanding.*

and ultimately possible to organization material reality for ultimate human flourishing.. To do so, humans require a community-type material conception of reality (the concept of operation of the material system is):

1. If 'materials' are defined as,
2. "that which is physically accounted for" (counted in quantity and quality), and
3. 'measurements' are defined as,
4. "events", then
5. services are "useful/functional events", and
6. technologies are "functional objects", composed
7. via a past service measuring some sequence of functional events, done to (i.e., operationalized to)
8. materializes technologically productive systems that meet human need fulfillment through material [habitat] services, which are created
9. through information and communications, concepts, become habitat production objects (products of service), that are
10. transported around a human's habitat life-radius [network] as a service in global human need fulfillment.

The primary material life service systems are, the life support system itself, and the exploratory support system that facilitates conscious life exploration and development.

The primary habitat service technologies are:

1. Communications is the technology of signals and messages that are created, transmitted, and received.
2. Computation is the technology of hardware operating procedures.
3. Transportation is the technology of object motion in an environment.
4. Production is the technology of object reconfiguration into a functional service-object system.

1.1 Material system accounting

The material system must account for all matter. All matter could be viewed as a resource; hence, the primary material system input into the decision system is a world where all matter is accounted for as a resource. Herein, the scale of resource accounting is:

1. **Resource accounting** - anything that is to be used for some purpose (note: that title this is also the name of this whole list).
2. **Land accounting** - where the land is accounted for.
3. **Chemicals/minerals accounting** - where all chemical elements and minerals are accounted for.
4. **Power/energy accounting** - where power production and usage is accounted for. All materials have had power/energy put into their acquisition/collection.
5. **Materials accounting** (a.k.a., resource accounting) - an account of the compositions of all chemicals into useful things.
6. **Technologies accounting** - an account of the production elements as those elements that produce useful [to human fulfillment] services and products.
7. **Services accounting** - an account of the services that production elements serve.
8. **Usages accounting** (a.k.a., material fulfillment service) - an account of the physical user and interface with services and deliverable objects/ products.
9. **Engineered habitat service production design accounting** - an account of the engineered design of the whole habitat service, including technical engineering and team co-operations. A habitat service system is composed of technologies in service to humanity, and technologies have an information level in the sense that engineering processes create them, and they have a material level in the sense that they are physically composed of material resources.
    A. **Measurement accounting** - the basis of engineering is measurement (i.e., materials quantity and quality analysis).
    B. **Projects accounting** - the basis of engineering, because all engineering is executed as a project.

1.2 Material construction

The Material Specification represents the convergence of information and matter into physical construction. In order to socially construct something into the material environment of the community [at least] three principal elements are required: a written explanation; line drawings; instrumentation and measurement. Each of these three elements is essentially a different viewport (i.e., a different window) into the same information model. We are capable of expressing our perceptions of reality via multiple mediums, such as written language, visualizations, and through ordering. When this information is combined into a single package, which can be understood by a receiving entity, then the systems design is replicable, and can be duplicated given the availability of resources.

When we encode our concepts into material structure they begin to take up space around us, which become the very constructions we live in and spend most of our lives around. From this perspective, the material specification provides descriptive reasoning for why we have constructed that which we experience as our constructions in an environment, and how to reconstruct our constructions given what is known and what is available.

In order for something to be materially constructed in community we have to know:

1. Why we are constructing.
2. What we are constructing.
3. How we are constructing.
4. The alternative ways and configurations we could be constructing.
5. And, how to replicate our current and past constructions.

In other words, the written part is our description and logical reasoning for the system as it could be, as well as the system as it presently exists in its current state of operation. Importantly, it includes instructions on how to construct different versions of the city. It also describes to the constructor/builder how to build the material design for the community.

2 The material specification standard sub-composition

The material system subcomposition:

1. The written documentation part.
2. The architectural CAD- and BIM-based drawings for the integrated city system.
3. Database of materials and their properties, and technologies
4. The 3D visually modeled and simulated representation of the integrated city system.
5. Integration of the 3D representation into a gaming engine for virtually simulating all technical operational aspects of the community.

A material system describes the material blocks/patterns that we have to work with and the optimal configuration of those patterns to sustain and evolve our fulfillment.

Material system documentation shall indicate, at a

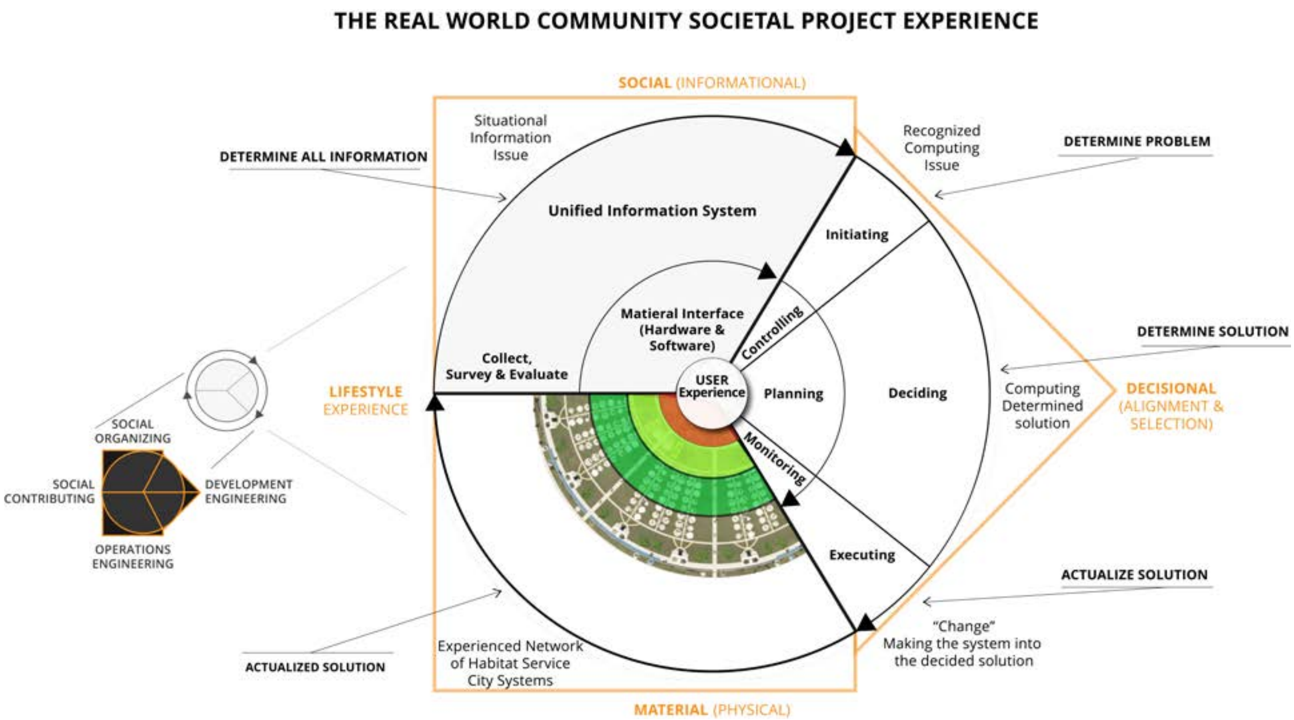


Figure 3. *This is a project to build a unified type of society where the total environment is recognized as necessary for computing a re-organization of the material environment where humans exist and persist in accordance with their behaviors, their creations, and the larger cosmic dimensional sphere. There is a material existence to human consciousness that can be physically interfaced with through human behavior (or, more precisely, an individualized consciousness behaving as a human among others similarly behaving. It is possible to orient and re-orient the materially structured environment where all humans behave together. It is possible to decide and design together a global platform composed of a network of integrated city systems where human individuals are fulfilled through the realization of a specific configuration of a socio-technical environment (i.e., a specific configuration of a material, physical environment; a specific societal object configuration environment). By planning these societal environments based upon the integration of a total information environment, it is possible to optimize material creation (Read: the material dimension of the human experience) for all of humankind and the ecological system upon which it exists.*

minimum, the following:

1. A description of the system functions, or a functional diagram.
2. Specifications of systems and their location (if available)
3. Type of materials
4. Type of technologies and requirements for their installation

In the sense that any given material environment can be interfaced with, there are seven primary relationships:

1. Identification: concepts & naming [conceptualizing and naming]
2. Location[ing]: positioning between objects.
3. Design[ing]: construction of an object.
4. Services[ing]: constructing the motion of multiple objects to serve a function.
5. Structure[ing]: the integration of multiple objects in motion.
6. Account[ing for] Materials: the composition of any given object.
7. Account[ing for] Technological modules (a.k.a., technological infrastructural modules): the construction and integration of multiple objects to serve a usage.
8. Account[ing for] Human requirements: the needs and preferences of the human users.

In the sense that any given material environment can have any of four primary gestalts:

1. Structures (objects on land or crafts in mediums)
2. Subjects (people or people-like organisms)
3. Energetics (motion, electromagnetics)
4. Terrain (planets and human re-contoured land)
5. Devices (functional objects in structures or on land for specific temporary and/or mobile use; a.k.a., tool, non-structure usable item; a consumable may, or may not, be considered a device)

2.1 *Material specification components*

There are four principal parts to the specification for the materialization of the Community.

1. Specifications - the written documentation part. A specification set may also include the drawings for the set.
2. Drawings - the graphical presentation of that which is to be constructed. Drawings are intended to depict the general configuration and layout of a design, including its size, shape, and dimensions. It informs the constructing entity of the quantities of materials needed, their placement, and their general relationship to each other. Although drawings may contain all the information about a structure that can be presented graphically, they nevertheless omit information that the contractor must have, but which is not adaptable to graphic presentation. Information in this category includes quality-related criteria for materials, specified standards of workmanship, prescribed construction methods, etc. There should be no discrepancies between drawings and written specifications.

2.2 *What is a master specification?*

A "master specification" is a template document that must be used and/or edited to execute (and/or operate) a specific project (and/or system). In other words, a master specification contains sufficient information that it can be used to complete a specific projects. Master specifications are also referred to when modifications are implemented to fit particular conditions of a given job or new specifications are incorporated.

> **NOTE:** *The Auravana Project's societal specification standard is a master specification [standard].*

In concern to a master construction specification, for example, the master may contain a list of index numbers, characteristics, specifications, units of measure, and additional information that is to be used for specific material projects.

2.3 *Specifications*

The word specification merely refers to the act of "to state explicitly or in detail" or "to be specific". There are many different types of specification. Sometimes, a "specification" is a written technical descriptions of a design, which may be contrasted with a "drawing", which is a visual depiction of a design. However, here, the total description of a design is called a "specification". Anything that is to be constructed must involve a specification. If it is needed in order to understand, construct, operate, or take down, then it is a component of a specification. A specification may also refer to a type of technical standard. In a way, these specifications represent the technical standard for community.

Note: From the commercial perspective, specifications are "that portion of the Contract Documents consisting of the written requirements for materials, equipment, systems, standards and workmanship for the Work, and performance of related services."

All specifications for the material system, including the material system itself, involve written language, symbols, drawings, and simulations. These are separated into "parts" of a specification. For anything that is to be constructed in the material system, there is a written part, a drawings part, and a simulation part, which is also how the materials system specification is itself divided.

Symbols are likely to be used throughout. Here we may refer to the part of the specification which is written as “the written part of the specification”, or “the written specification”. The written part uses verbal language: the language of reasoning (verbal reasoning) and science (scientific evidence) to describe why the system is so constructed; and, technical language describing materials, equipment, systems standards, workmanship for the work, performance measures, and performance of related services; and engineering language to describe how it is so constructed, including composition, creation, assembly, and disassembly (as well as [re]-cycling). Visual specifications include those which are represented as [technical] drawings (i.e., drawing specifications or the drawing part) and simulations (i.e., simulation specifications or the simulation part). A technical drawing precisely and visually communicates how something functions or is to be [de-]constructed. Technical drawings are understood to have one intended meaning (i.e., they are not interpretable in more than one way) -- they use visual language to ensure they are not ambiguous and relatively easy to understand. Drawings are made according to a set of conventions, which include particular views (floor plan, section etc.), sheet sizes, units of measurement and scales, annotation and cross referencing. Herein, all architectural drawings, mechanical or other sketches, and CAD drawing applications are considered [technical] drawings. A simulation, however, is the imitation of the operation of a real-world process or system over time. The act of simulating something first requires that a model be developed; this model represents the key characteristics or behaviors/functions of the selected physical or abstract system or process. The model represents the system itself, whereas the simulation represents the operation of the system over time. Any object (i.e., “material thing”) which is to be, or has been, constructed is described within a specification that includes all three parts.

Using the word “specification” without additional information to what kind of specification you refer to is confusing and considered bad practice within systems engineering. Hence, it is important to state that when we refer to the “design specifications”, what we are referring to is the comprehensive specification for the total community system, which may be called the “Community System Specification”. It is the core/kernel specification.

Specifications are mean to integrate and connect with one another. Specifications are meant to be operated and then retired or updated. The architectural construction industry organizes its specifications into divisions and levels.

> **QUESTION:** *A specification is a formalized design. Hence, the word "design" may be considered superfluous before the word specification.*

2.4 Individual technical product sheets

See addendum for individual technical product sheets, which include:

1. An individual product specification sheet.
2. A product sub-system operating parameters.

2.5 Material processes

A.k.a., Material dynamics.

There are many examples of material dynamics, including, but not limited to:

1. Biospheric/ecological dynamics
2. Water & atmospheric dynamics
3. Energy dynamics
4. Chemical dynamics
5. Structural dynamics

All systems (power systems) have resource [depletion] impacts and environmental impacts.

2.6 Material objects

Material components are the building “blocks” for creating a material system. No two or more objects can occupy the same space (spatial scarcity) at the same time (temporal scarcity). Material objects exist in countable quantities. For instance (objects may be produced/accessed in countable quantities):

1.	Milk	1 Liter.
2.	Butter	1 Pound.
3.	Apples	10 apples.
4.	Electricity	10 amps.
5.	Voltage	10 volts.
6.	Meters of street	10 meters.

2.7 Space control through space-time separation

In community, the population plans for well-being. A population create a setting that is conducive to optimized well-being and flow. Here, spaces with different lifestyle-functions that could conflict are separated by time and/or space. For example, space for noisy social interaction is separated from quiet space, either in location or time. Not only does this separation facilitate natural movement between spaces with different lifestyle- and system-oriented functions, but it reduces disturbance for those using particular spaces with set functions.

2.8 Material optimization

Human constructions become a part of the human environment. A body naturally becomes adapted (e.g., optimized) to its given environment. When individuals optimize the environment for their fulfillment they are more likely to experience optimum fulfillment. It is wise to create material structures that facilitate the alignment of behaviors at a habitat fulfillment level with human needs and human desires for purpose, potential, and play.

2.9 Economic planning and habitat elaboration

An economic plan requires an elaborate description, explanation, and specification of each habitat service sub-system. This documentation is required in order to develop a complete input-output matrix for a habitat as an economic [fulfillment] service system.

Materials Accounting System

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Keywords: material science, material science system, materials accounting, material flow, material composition

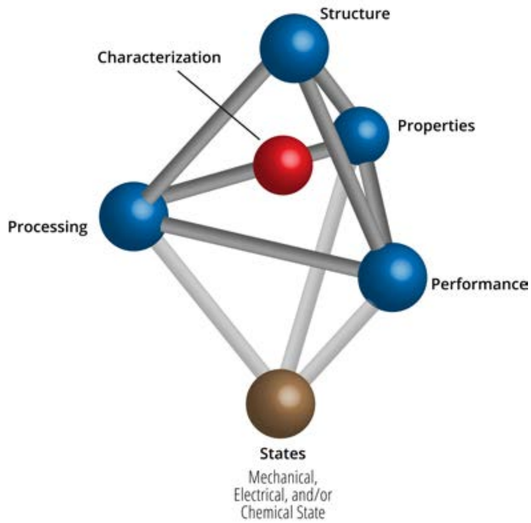
Abstract

This article addresses the significance of materials accounting, which merges the principles of material science with the detailed classification provided by material taxonomies to optimize the utilization and management of material systems within society. Material systems, encompassing everything from the basic surfaces that constitute objects to complex structures, are essential components of the physical world. These systems are characterized by a variety of material types, compositions, flows, and the processes by which materials are realized and repurposed to fulfill societal needs. The article underscores the importance of accurately understanding and documenting these elements to facilitate the intentional reconfiguration of societal infrastructure at a material level.

A key focus of the discussion is on how materials, once comprehensively accounted for, become instrumental in decision-making processes. This accounting includes not only the identification and categorization of materials but also an analysis of their interrelationships and the potential changes in their properties through combination and reconfiguration. For instance, transforming a neodymium iron core into a magnet exemplifies the dynamic nature of material properties and their impact on societal solutions. The article advocates for a complete accounting of material resources, emphasizing that the effectiveness of decisions regarding material use directly correlates with the depth of understanding of the material system involved.

Graphical Abstract

Figure 4. *Materials science characterization tetrahedron model shows how one aspect of a material affects the rest of the properties. If the structure is altered, the properties, characterization of atoms, processing, and performance will all be altered. Illustrates all the aspects of a material that an engineer should look for and understand.*



1 Introduction

The physical world is made of matter. All matter has physical presence, which may be sub-characterized as having ‘object’ and ‘location’ (i.e., distance from every object in the universe). When matter is used for human purposes, it is called a ‘material’. Therein, materials science is the design and discovery of new materials. All materials (matter) are made of chemicals. A narrow definition of material is any physical substances that things can be made from.

2 Materials versus products

A.k.a., Supplies, resources, objects.

The terms ‘products’ (‘goods’) and ‘materials’ are sometimes used as if they are interchangeable, however, there are differences between them determined by what they are made of, how they are finished, and whether they are offered for use (or, sale in the market). Products are processed, finished items. That is, they are manufactured combinations of materials and perhaps other products, processed to create finished or intermediary items. 'Products' are generally distinguished from. ‘Materials’ which are raw, unprocessed substances such as sand, salt, and so on. Note here that products and materials are distinguished from ‘services’, which are activities. The names for service-type activities generally end with an -ion suffix (or, -ing and -ance), such as consultation, maintenance, installation, watering, and architecting.

Very broadly the difference between materials and products is that:

1. **Materials (resources)** - raw, unprocessed substances such as sand, salt, raw chemicals, and so on.
2. **Products ("goods")** - processed, finished items that are offered for use (or, sale in the market). That is, they are manufactured combinations of materials and perhaps other products, processed to create usable items.

NOTE: *In some parlance, a "good" may be classified as something that is in someone's possession.*

However, this apparently clear difference becomes more complex when applied to intermediary items, composite materials (such as adhesives), to finished materials (such as processed timber), to unfinished products, and so on. For example, steel, whilst it has been processed, might be considered to be a material, whilst a steel beam, which is the same material but in a different form might be considered to be a product. And yet, steel beams may be an item on an architectural materials list.

3 Materials supply chain

A.k.a., Object supply chain.

A supply chain is the breakdown and traceability of products and services, organisations, logistics, people, activities, information and resources that transform raw materials into a finished product that is fit for its purpose. In other words, supply chain is a network between organizations that supply, produce, and distribute a specific product to the final user. Notice here the similarity between the idea of an 'economic system' and the concept of a 'supply chain'. An 'economic system' is the acquisition and transformation of resources into needed products (goods) and services. Supply chain coordination (supply chain management) is the coordination of the flow of resources into goods and services, and it includes all processes that transform raw materials into final products. In the market-State, the "supply chain" is defined by the interconnected hierarchy of supply, manufacturing, distribution, and sales businesses, and their associated contracts, necessary to procure a material or built asset.

There are no businesses in a community-type society. A community-type society maintains a fully integrated supply chain. An integrated supply chain is an optimal supply chain, because it maintains the condition of efficiency through cooperation and collaboration (as opposed to scarcity; i.e., no use of money and no competition).

In the market-State, supply chains can be vertically and horizontally integrated. Horizontal integration and vertical integration are competitive strategies that companies use to consolidate their position among competitors:

1. **Vertical integration:** the process of acquiring business operations within the same production vertical. A company that opts for vertical integration takes complete control over one or more stages in the production or distribution of a product. When one organisation in a supply chain moves into a different stage of that supply chain, either by starting its own business or by acquiring an existing one.
2. **Horizontal integration** - the acquisition of a related business. A company that opts for horizontal integration will take over another company that operates at the same level of the value chain in an industry.

4 Classification of matter

A.k.a., Classification of material objects, categorization of matter, types of matter, types of material entities, physical matter resources, physical resources.

Matter may be classified at a high-level in three ways:

1. All objects are 'matter' and may be named.
2. All 'matter' can be isolated in a single frame (of the "universal movie"). A frame of a movie can be pointed to and named liquid, solid, motion, etc.
   A. State of matter: one of the distinct forms in which matter can exist.
      1. Liquids, gases, and solids are states of matter. The phases of matter (motions to matter) are the motions to matter that occur during the transition from one state to the other state. Solid, liquid, gas are states, static concepts (there is no necessary motion).
         i. Solid does not involve motion.
         ii. Liquid does not involve motion.
         iii. Vapor (gas) does not include motion.
      2. Plasma is always in motion; it is ionizing gas; it is a dynamic concept. Plasma embodies motion whereas solids, liquids, and gasses do not.
   B. All objects move, change and transform. A phase of matter is the motion occurring to an object as it changes to another definable state.

Functionally, there are three types of material that will need to be specifically and procedurally accounted for throughout their life-cycle into and out of habitat service system congratulations:

1. **Inert materials (not EM interfaceable and not fissionable):** Substances that are chemically inactive or resistant to chemical reactions under specific conditions. Inert materials form the majority of the surfaces around humans.
2. **EM interfaceable material (i.e., electromagnetic materials, conductors and semi-conductors):** Substances that possess properties suitable for interacting with the "light" along the ropes that inter-connect all atoms. EM materials allow for and enable the usage of electricity, machines, and computers.
3. **Fissionable materials (i.e., radioactive materials):** Substances capable of undergoing nuclear fission, a process where the nucleus of an atom splits into smaller parts, releasing a tremendous amount of energy. Fissionable materials may be used to generate power.
4. **Biological matter (i.e., organic matter, biotics):**

Substances that are living, or were once living.

All matter, regardless of function, has the characteristics of:

1. **Material composition (a.k.a., quantity of physical matter):**
   A. Chemicals.
   B. Elements (notably, the periodic list of elements).
   C. Atoms (as, hydrogen unit; first physical interaction volume/shape of EM ropes).
2. **State of matter (a.k.a., phase of matter):**
   A. Solid.
   B. Liquid.
   C. Gas (vapor).
   D. Plasma process (uses extremely hot and excited atoms; is a process done to objects -- gas atoms under excitation).
   E. Bose-Einstein Condensate process (uses extremely cold and unexcited atoms; is a process done to objects -- removing excitation/"thermal energy" from atoms).
3. **Purity of matter:**
   A. Pure substances.
   B. Impure substances (a.k.a., mixtures).
4. **Changes (motions of matter):**
   A. Physical (macro-object interactions).
   B. Chemical (micro-object interactions).
   C. Electromagnetic (quantum, EM-object interactions):
      1. Electrical (solid conduit).
      2. Magnetic (thread attraction).
      3. Light (rope torquing).
      4. Gravity (tense rope fanning out).
5. **Properties (of matter):**
   A. Interaction properties (discoverable phenomena and controllable phenomena).
   B. Flow properties.

Some matter has the characteristic of either, or:

1. **Carbon inclusion:**
   A. **Carbon [only] matter (a.k.a., carbon molecule, carbon compound)** - a molecule consisting only of carbon atoms. If the carbon atoms are bonded together in a specific arrangement, it may also be referred to as a "carbon structure", "carbon framework", or "carbon object".
   B. **Mixed carbon-included matter (a.k.a., hybrid material, organic matter, organic compounds)** - is matter that contains at least an atom of carbon, and contains at least one other element. Scientists generally define a molecule (of matter) as "organic" when it contains not only carbon, but also, at least one other element. Herein, organic molecules must meet two criteria:
      i. They must be made of carbon, and
      ii. They must be made by cells.
      1. **Hydrocarbons - organic compounds** composed of only carbon (C) and hydrogen (H) atoms. Hydrocarbons contain just hydrogen and carbon.
         i. Organic compounds are composed of carbon and hydrogen atoms.
      2. **Organic minerals** - are matter with a mineral attached to a carbon-containing compound. Note that some sources state that there is no such thing as an organic mineral, and that all mineral sources with carbon should be called organic compounds.
2. **No inclusion of organic material (a.k.a., inorganic materials, inorganic minerals, minerals)** - is matter that does not contain carbon. A mineral is not directly related to a single element (on the periodic table of elements), but rather, an inorganic solid that is composed of various elements or compounds in a specific chemical composition and crystalline structure. Minerals (Read: inorganic minerals) are the building blocks of rocks and are classified based on their chemical composition and crystal structure. Minerals (Read: inorganic minerals) are naturally occurring substances that do not contain carbon-hydrogen bonds and are not derived from living organisms. An inorganic mineral is a material that has never been alive; it has not been bonded with carbon.

It is possible to intentionally change the phase/stage of matter of an object through heating (or, reverse, through cooling):

1. Take a solid and heat it to a liquid.
2. Keep heating a liquid and it boils to a gas.
3. Keep heating a gas and it plasmas to elementary particles (a.k.a., the axiomatic parts of matter).

The basic known atomic structures of matter are called "elements", and they are listed on the "periodic" table of elements. Atomic structures are the secondary form of matter, after the axiomatic "elementary" form. The axiomatic/elementary parts of the material world form a set of atomic [building blocks] of this physical matter reality. These "workable" atomic [building blocks] are listed on the "periodic" table of elements. Technology is the intentional structuring/composing of these buildings blocks to form functional structures for some living [conscious] matter. Science explains and discovers about what is possible with these building blocks, and what nameable objects presently exists (or, existed in the past) as these building blocks.

The number of protons (a.k.a., protonic hydrogen, hydrogen atoms) in an atom's nucleus is known as the atomic number, which determines the element's identity (i.e., the atom's name) on the period table of identifiable elements. If the number of protons changes, the element identity changes as well. In other words, in the context of everyday chemical reactions and non-radioactive processes, where elements do not spontaneously transform into different elements under normal conditions.

It is possible for an any atom on the periodic table of atomic elements to keep the same number of protons (i.e., protoconic hydrogens), but change its "atomic mass". Atomic elements can be can be sub-classified as "isotopes". In other words, the different forms of any element of matter are called, "isotopes". For example, carbon has three naturally occurring isotopes: carbon-12 (12C), carbon-13 (13C), and carbon-14 (14C). Hydrogen also has three naturally occurring isotopes: protium (symbol: ^1H), deuterium (symbol: ^2H), and tritium (symbol: ^3H). Isotopes of an element can have distinct effective properties in their interactions with other matter.

Matter may also be classified according to its structured/ordered assembly, and source of assembly:

1. Liquids and gases are unassembled structures (flowable randomized materials).
2. Crystalline solids: Materials that have a highly ordered atomic structure exhibiting a specific and repeating crystalline pattern. Examples include metals, some ceramics, and certain minerals.
3. Amorphous solids: Meaning it lacks the long-range order found in crystalline materials
   A. Amorphous polymers: Synthetic materials with random molecular arrangements, like some plastics.
   B. Amorphous ceramics: Includes materials like glass, which lack a crystalline structure and have a disordered arrangement of atoms or molecules.
4. Composite materials: Mixtures or combinations of different materials to create a new material with desired properties. Examples include ceramic composites, metal composites, and polymer composites.
5. Natural materials: Materials derived from nature, such as wood, stone, and fibers, each with its own unique structure and properties.

4.1 *Composition of matter*

A.k.a., Composition of materials, possible material components, material elements, elements of matter.

Matter can be classified in terms of its composition, down to the axiomatic atomic (periodic) level of the material environment.

The hierarchy of components for [measured material] assembly in the real-time physical system are:

1. **Atoms (a.k.a., are all hydrogen atoms)** - basic building block of matter, representing the smallest unit of an element that retains the chemical properties of that element. The first base element is hydrogen. It could be imaged that all elements therefore are compositions of hydrogen atoms.
   A. **Elements (a.k.a., atomic types, pure element, base elements, axiomatic physical types)** - are the fundamental substances that consist of a single type of atom. Different elements have different different numbers of of protons (i.e., proton stars, hydrogen atoms) in their atomic nuclei, thus defining their chemical properties. In other words, an element is a specific spherical structure of atomic axiomatic matter (protons, electrons, and neutrons), characterized by its unique number of protons in the atomic nucleus, ignoring the electron and neutron values, and known as the atomic number. Elements cannot be broken down into simpler substances by ordinary chemical means and retain their distinctive chemical properties. Elements are organized in the periodic table based on their atomic number (the number of protons, proton stars, in an atom). Each element is represented by a unique chemical symbol, starting with the [first] atom "H" for hydrogen, the second element with two hydrogen atoms is "He" for helium. Elements can exist in various forms or isotopes, which have the same number of protons but different numbers of "neutrons", resulting in different atomic masses.
   B. All atoms are sub-composed of:
      1. **Magnetic thread (a.k.a., proton star)** - creates the proton star of the atom (a.k.a., proton). The magnetic thread is part of the universal thread object that forms the magnetic thread of the electromagnetic rope and all atoms.
      2. **Electric thread (a.k.a., electron shell)** - creates the electron shell of the atom (a.k.a., electron). Is part of the universal thread object. The electric thread is part of the universal thread object that forms the magnetic thread of the electromagnetic rope and all atoms.
      3. **"Neutron"** - is a mathematical constant (i.e., not an object). The neutron, with its mass and charge properties, is typically considered constant within the scope of most nuclear and

atomic calculations. The mass of a neutron is approximately 1.675 × 10^{-27} kilograms, and its charge is neutral (a.k.a., zero charge). These values are treated as constants in many mathematical equations involving nuclear physics, allowing scientists to make predictions, perform calculations, and model various nuclear phenomena.

2. **Tense 2 stranded DNA-like rope (a.k.a., electromagnetic rope between atoms)** - is a tense rope object as a rope connected between two entities that is not experiencing either push or pull. A tense rope can change the number of links, which can be made smaller (winded) or made longer (unwinded). In tension, no one won the "tug of war", the process by which all matter is attracted to all other. Tension is not a "force" because there is no push or pull, no "tug of war", no force. Pull means that one of the two entities pulled more and "won the tug of war". With tension, there is no stretch, even when the threads separate (producing magnetics). To pull means to move something in some direction toward a point of origin. To push means that something was moved away from a point of origin. When something is under tension, there is no push or pull.
   A. **Light** - is the torque of the electromagnetic rope connecting atomic bodies, caused by the pumping of the body (i.e., the pumping of atoms).
   B. **Electricity** - is the spinning in-place of atoms.
   C. **Magneticity** - is the outward twirlling of threads.
   D. **Gravity** - is the fanning out of tense ropes between to atomic bodies.
3. **Simple organic molecules** - an assembly of small molecules made primarily of carbon atoms bonded to hydrogen, oxygen, nitrogen, and other elements.
4. **Simple organic biomolecules** - an assembly of organic molecules present in living organisms that plays a significant role in biological processes. These molecules are essential for the structure, function, and regulation of cells and organisms (i.e., units that play a micro-functioning role).
   A. **Amino acids** - are the fundamental units that make up proteins.
   B. **Nucleotides** - are the structural units of nucleic acids, such as DNA and RNA.
5. **Complex organic biomolecules (a.k.a., macromolecules or biopolymers)** - a relatively large and complex organic molecular assembly of simple organic biomolecules (i.e., a complex biomolecular structures) that play a role in the functioning and development of living organisms (i.e., units that play a macro-functioning role in living organisms).
   A. **Proteins** - are complex macromolecules made up of long chains of amino acids.
   B. **DNA chains** - is a double-stranded helical molecule that carries the genetic instructions used in the growth, development, functioning, and reproduction of all known living organisms.
6. **Cells** - are the basic structural and functional units of living organisms. They vary in size, shape, and function but generally contain genetic material, cytoplasm, and a cell membrane. Cells carry out essential life processes and are the building blocks of tissues, organs, and organisms.
7. **Multicellular organisms** - are organisms composed of multiple cells organized into tissues, organs, and organ systems. They include plants, animals, and fungi. Each cell type performs specialized functions contributing to the overall functioning of the organism.
8. **Ecosystems** - are complex, interconnected systems formed by the interaction of living organisms (biotic factors) with their physical environment (abiotic factors) in a particular area.

Matter can be classified according to its purity:

1. **Pure matter:** All matter can be classified as either a pure substance or a mixture.
   A. **Element[al]** - the pure element. An element is matter made up of one type of atom.
   B. **Compound** - are substances that are made up of two or more elements physically bonded together.
2. **Mixture [of matter]:** A mixture is two or more substances (elements or compounds) that are mixed, but are not chemically combined. If they were chemically combined, then they would be a pure matter compound.
   A. **Homogeneous mixture** - having visibly indistinguishable parts (the same, uniform, throughout). Homogeneity in material sciences refers to the uniform composition and distribution of components within a material. A homogeneous material has consistent properties throughout, meaning that its characteristics, such as density or chemical composition, are the same at every point. This uniformity is essential for ensuring predictable and reliable performance in various applications.
   B. **Heterogeneous mixture** - having visibly distinguishable parts (not uniform throughout).

4.1.1 Base material processes

Physis has identified the following base processes that can be done to materials:

1. **Ionic base material element process (a.k.a., ions, ionic process, electron changes, electron processes, light processes)** - is a process that changes the vibration (resonant torque cycle) of an single atom. An atom (pure element) is "positively charged" when it has more calculated protons than electrons, and "negatively charged" when it has more calculated electrons than protons.
   A. The "rope" model of light process visualizes the vibration of the shell of each atom (around a proton star) and its torquing of the atomic thread interconnecting all atoms (with a rope made up of an electric thread (shell) and magnetic thread (forming the atomic star proton and atomic star shell of every atom).
      1. The shell can vibrate (pump in and out), and thus, receive torques from a distance and torque the thread interconnecting all atoms, sending vibratory signals to other atoms (i.e., atoms that vibrate send "light" back to the original atom; i.e., light travels in both directions). The shell can also shrink and gain in size, which also torques the thread (isotope changes). (Gaede, 2014)

   B. The constant value of an electronic "charge" of an electron at a constant value is defined as approximately -1.602 x 10^-19 coulombs.
   C. The "quantum jump" that generates light when an electron moves to different energy states in the atom. At the center is the proton. At the outer edge is an electron that jumps back and forth along electron shells, and when it falls to a lower energy level, a string of particles called photons comes out, and when it rises to a higher energy level it absorbs a string of photons. So the atom pushes photons out and pulls them in constantly.
   D. In the rope model, all atoms are interconnected by a rope, and as they expand and contract, they torque the rope. Light is that signal (torque traveling) along a tense rope; the torque travels at constant speed [of light] and can wind and unwind the rope into two threads, which when unwound have magnetic and electric effects/ properties (Gaede, 2014).
   E. The energy of the emitted light from a change in position of an electron can be calculated using the formula (of a rope, wherein the number of links is inversely proportional to linklength):

   $c = f\lambda$ (note: this is the rope equation)

   - Where:
     - c = speed of light (is speed at which rope is torqued),
     - f = total number of links moving within the separation between atoms; the frequency of the light torque/wave, measured in hertz (Hz), which represents the number of wave cycles passing a point per second.
     - λ = the total length between successive peaks in the rope (at the point of a thread).

   $E=hf$ (note: this is the wave equation)

   - Where:
     - E represents the energy of the photon,
     - h is Planck's constant (6.626×10−34 joule seconds),
     - f is the frequency of the emitted light.

2. **Isotopic base material element process (a.k.a., isotopes, isotope processes, proton changes, proton changes, nucleus changes, physical quantity changes to base element):** An single atom (element) that has the same number of protons (same atomic number), but changes the number of neutrons in the nucleus, leading to different atomic masses (quantity of atoms; note that this is not weight as gravity plays no role here). Isotopes (a.k.a., isotope processes) do not affect the number of protons or electrons in the atom, but alter the atomic mass (quantity of atoms) due to differing "neutron" (a.k.a., quantity of atom) counts.
   A. Fusion: Nuclear fusion is the process where two light atomic nuclei combine to form a heavier nucleus, releasing an enormous amount of energy. In the "rope" model of light, this process is the change to the size of the base atomic unit as an axiomatic structure. Is the internal mass/ size of a single atom changes.
   B. Fission: Nuclear fission is a process where the nucleus of an atom splits into smaller fragments, releasing a significant amount of energy. In the "rope" model of light, the volume of the base atomic spherical structure decreases. As the volume an atom takes up is decreasing, it torques the rope (produces light).
3. **Electric atomic motion (a.k.a., electric atom spin, electricity):** Electricity occurs when atoms spin in place, touching one another. Electricity in the form of "electric current", is when atoms twirl in place.
4. **Magnetic rope motion (a.k.a., pull force)**:

Magnetism occurs, one of the threads comes out loose and starts twirling around. The threads come loose because of the atoms spinning in place; the threads come loose because of the high speed in which the atoms are twirling (the threads get fanned out, pulled/pushed out), and the threads swing around the atoms (creating the magnetic field at 90degrees to the flow of electricity). If you have more than two atoms, you have more than two threads. It is possible to have a wall of threads that come out and start to twirl around. Instead of electron flows (little beads) moving along a wire there are atoms spinning the threads around the wire. There are not electron flows, there are the turning of atoms that spin the threads along the wire. The lines of force are physical threads that produce physical effects. There is no flow of electrons; instead, there is the turning of atoms in-situ. They either turn clockwise or counterclockwise (it doesn't matter); whichever way they turn, they turn the whole wall of threads. In this visualization, a magnet isn't divided between "north" and "south" (the north end is where the threads come out and the south end is where the threads come in), but it is divided between "top" and "bottom". Magnetic attraction occurs when the top ones the threads are moving around the magnet, going through the center and colliding against the bottom ones which are going in the opposite direction. There is no such thing as a monopole magnet. The threads come loose because of the high speed in which the atoms (electrons) are twirling (the threads get pulled/pushed out), and the threads swing around the atoms (creating the magnetic field at 90degrees to the flow of electricity).

5. **Mixture of base material element as a process (a.ka., macro-processes, macro-material processes, macro-atomic processes, bonding processes):** More than one of the base unit structures with a hydrogen-unit mass are in immediate surface proximity-contact with one another, bonded, [almost] touching one another. This is the processes of brining into close proximity individual atoms, and it occurs scale, with the elemental atomic unit being a pure atomic solid, then compounds are two or more different atomic elements (of single or pure units) chemically bond together in specific proportions. Then come substances, which are arrangements of atomic element combinations that extend through to mixtures. To these compositions of mater macro-processes can be applied:
    1. Chemical processes (Read: bonding and de-bonding processes):
        i. Plasma - combustion of gas.
        ii. Burning - combustion of solids and liquids.
    2. Physical processes:
        i. Addition - making a shaped grouping of matter larger.
        ii. Subtraction - making a shaped grouping of matter smaller.
    3. Electromagnetic process (Read: individual atom processes):
        i. Magnetics (a.k.a., magnetism, magnetic attraction).
        ii. Optics (a.k.a., light, atomic rope vibration) - rope directed torques/vibrations of the electromagnetic thread.
        iii. Electrics (a.k.a., conductics, electricity) - vibration of the electric shel electromagnetic thread.
            1. Semiconductor operations (semi-conductics, micro-electrics control, semi-electrics).

NOTE: *the tension on the rope between any two atoms may or may not be classified as a base material process.*

The following are a set of processes concerning the arrangement and number of sub-atomic particles within an atom without altering its fundamental identity, but possible altering its characteristic parameters. The elements in the periodic table of elements can go through two types of process that create changes to the element:

1. **Proton changes (a.k.a., nuclear transmutation, change to elements identity, fission, fusion, etc.)** - only the protons are involved. If the number of protons changes, then the element identity changes as well. In other words, if the number of hydrogen atoms in an element (on the period table of elements) changes, then the identity of the element on the table will change. The process of changing identities is commonly called, "nuclear transmutation" (a.k.a., nuclear transformation).
2. **Electron changes (a.k.a., chemical reactions, physio-chemical reactions)** - only electrons (a.k.a., shells or electron shells) are involved, and the element's identity remains unchanged. If only electron shells are involved (and not protons, then the elements identity will remain the same. An atom is "positively charged" when it has more protons than electrons, and "negatively charged" when it has more electrons than protons. Ions are processes where atoms gain or lose electrons, resulting in a net electrical "charge" (a net vibration/torque of the thread). This change does not affect the number of protons in the nucleus; rather, it

alters the balance between protons and electrons, resulting in a charged particle. This process occurs through light of a specific frequency "moving an electron up/down a shell" (i.e., pulsing the electron shell at a specific rate with light from another cell). This is when incoming light moves an electron down up or down a "shell", which itself, is a process that causes the emission of light from the point at which the electron moved up or down a "shell". Light can move an electron to a higher energy level or "shell" within an atom through a process called absorption or excitation. This phenomenon is described by the photoelectric effect or the absorption of photons. When an electron is moved to a higher energy shell, it is typically due to the absorption of a photon (a.k.a., rope torque), and the direction is from a source outside itself. After an electron is in an excited state at a higher energy level within an atom, it can transition to a lower energy level by releasing a photon of light. This is a process known as emission or de-excitation, and it is the process of emitting light outward at the time and point of transition of the electron to a lower state.

3. **Mass changes (a.k.a., neutron changes, count of size of atom, quantity)** - only neutrons are involved, and the element's identity remains unchanged. This process changes the isotope category of an element.

All atomic elements on the periodic table of atomic elements can transition (Read: transform/transmute) over time (and through specialized radio-active actions, radioactive decay) to another element on the periodic table of elements (i.e., all elements can change identity, change their proton number). That said, some elements (on the chart of elements) transition easily, and others do not. In this way, the periodic table of elements could be sub-categorized by those elements that transition to other elements easily (i.e., gain or lose protons easily) and those that do not:

1. **Base elements (a.k.a., non-transition elements, non-transitional elements, representative elements)** - are elements that do not transition easily, but can still transition. They are sometimes called "non-transition elements", even though they can actually transition. Under natural conditions on earth, the are elements that go easily through chemical, physical, and radioactive decay processes, but do not easily change their identity on the periodic table. These elements do not gain or lose protons easily.
2. **Transitional elements (a.k.a., transition metals)** - are elements easily go through chemical, physical, process, and when there is radioactive decay, they will quickly change their identity on the periodic table. These elements gain and lose protons easily. These elements can be concentrated and transitioned in machines called 'nuclear reactors' (a.k.a., 'chemical reactors', 'reactors').

Elements can be transitioned (Read: transmuted) in machines called reactors. There are two types of reactors:

1. **Fusion reactors (a.k.a., plasma reactors, plasma accelerators, vacuum accelerators, accelerators, laser bombarders)** - are reactors that join 2 or more lighter atoms into a larger one. This machine is typically used to transition base elements; it can cause an element to gain protons.
    A. **Plasma accelerators (heated-gas accelerators, heated-gas reactors, plasma fusion reactor)** - are where elements are turned into a gas and placed in a machines called, "plasma accelerators" (a.k.a., heated gas accelerators, etc.). The element as "plasma" is confined using magnetic fields or other techniques to prevent it from touching the walls of the reactor, which would lead to rapid cooling and disruption of the fusion process. The gas in a plasma reactor, which is used for fusion experiments, is heated through various methods to achieve the extremely high temperatures required for nuclear fusion (joining protons). Heating could be through any of the following: ohmnic (electric current), atomic acceleration, radio-frequency, magnetic compression, magnetic-thread/-field changes (i.e., changing magnetic field), and laser heating. Although the machine requires energy/power to do the heating, the merger of protons releases power (i.e., "energy", "threads"). Fusion reactors produce heat as a result of the nuclear fusion process, and this heat is transferred to a working fluid, then to steam, which then drives turbines to produce electricity.
    B. **Vacuum accelerators (a.k.a., atomic accelerators)** - where there is a "vacuum" of matter in the accelerator (i.e., it is mostly empty space in the pipe/conduit). Instead of heating, vacuum accelerators accelerate atoms around/ down a conduit/pipe. The acceleration is done through electric and/or magnetic field/thread interactions. Here, magnetic fields steer the accelerated atom(s).
    C. **Laser fusion reactors** - where an element is bombarded by laser light (EM torsion) of a specific frequency and intensity, in a specific

geo-positional arrangement; wherein, both the element and the lasers are of a specific geo-positional arrangemnet.

2. **Fission reactors (a.k.a., proton separators, concentrated isotope reactors)** - are reactors that split a larger atom into 2 or more smaller ones. Fission reactors are designed to harness the energy released from nuclear fission reactions, where the nucleus of an atom is split into smaller fragments (of neutron shells, then protons), releasing a significant amount of heat (energy) in the process. In the early 21st century, the most common type of nuclear fission involves uranium-235 (^235U) and sometimes plutonium-239 (^239Pu) as fuel. The isotope is manufactured, concentrated and formed, into rod like shaped objects, which begin nuclear decay immediately. However, when more than one rod of the nuclear material is brought into proximity with one another, the nuclear decay increases. In other words, two ore more rods brought near one another will increase the nuclear decay. In the machine "control rods" are moved to cover or uncover the radioactive (fissionable material) rods. When brought into contact with one another, the fissionable rods initiate a "chain reaction" that could run out of complete control. The changeable location of the control rods and the fissionable rods keeps the reaction at a steady and controlled rate. Fission reactors are electrical power plants. Fission reactors produce heat as a result of the nuclear fission process, and this heat is used to generate steam, which then drives turbines to produce electricity.

4.1.2 Matter phase transitioning

A.k.a., Transition of matter.

When matter changes from one state to another it is called a phase transition.

Examples of common matter phase transitions include:

1. **Deposition (direct phase transition)** - gas to solid phase transitions.
   A. For example, water vapor to ice - Water vapor transforms directly into ice without becoming a liquid, a process that often occurs on windows during the winter months.
   B. For example, physical vapor to film - Thin layers of material known as "film" are deposited onto a surface using a vaporized form of the film.
2. **Condensation (direct phase transition)** - gas to liquid phase transitions.
   A. For example, water vapor to dew - Water vapor turns from a gas into a liquid, such as dew on the morning grass.
   B. For example, water vapor to liquid water - Water vapor fogs up glasses when moving into a warm room after being in the cold
3. **Vaporization (direct phase transition; a.k.a., boiling, evaporation)** - liquid to gas phase transitions.
   A. For example, water to steam - Water is vaporized when it is boiled on the stove to cook some pasta, and much of it forms into a thick steam.
   B. For example, water evaporates - Water evaporates from a puddle or a pool during a hot summer's day.
4. **Sublimation (direct phase transition)** - sublimation is the process where a solid substance transitions directly into a gas without passing through the liquid phase. This occurs when the substance's vapor pressure exceeds the atmospheric pressure at a specific temperature, allowing particles to escape from the solid state into the gas phase. In most cases, solids turn into gases only after an intermediate liquid state.
5. **Freezing (direct phase transition; a.k.a., solidification)** - liquid to solid phase transitions.
   A. For example, water to ice - Water becomes cold enough that it turns into ice. In fact, every known liquid (except for helium) is known to freeze in low enough temperatures.
   B. For example, liquid to crystals - Most liquids freeze by a process that is known as "crystallization," whereby the liquid forms into what is known in the scientific world as a "crystalline solid."
6. **Melting (direct phase transition)** - solid to liquid phase transitions.
   A. For example, heating metal in a smelt to a high enough temperature that it turns into a liquid.
   B. For example, heating chocolate in an oven to turn it into a liquid.
7. **Plasmation (chemical process that is also a phase transition)** - a gas heated to a plasma state, where there is active separating of bonded gas atoms and the possibility for the conduct of electricity. There are natural plasmas (e.g., lighting, stars, auroras), laboratory plasmas (e.g., plasma reactors are machines that heat, pressurize, and apply EM to gas), technology application plasmas (e.g., fluorescent lights, neon signs, plasma cutting tools, and plasma screens that contain tiny pockets of gas, and when electricity is applied to them, they turn into a state of light emitting plasma). The electromagnetics are applied to turn the plasma into specific geometric arrangements and

movements.

8. **Combustion (chemical process that is also a phase transition)** - solid or liquid heated to the gas State; it may or may not become a liquid first. Combustion is not one of the direct environmental induced phase transitions. Instead, it is a chemical process involving the rapid reaction of a substance (often a fuel) with an oxidizing agent (typically oxygen), leading to the release of heat, light, and the conversion of the substance into different chemical compounds. Combustion doesn't specifically involve the direct transition of a solid into a gas, but rather a chemical reaction that may produce gaseous products as part of the reaction.

4.1.3 Matter purity

In concern to purity, matter can be classified as:

1. **Pure substances** - matter that cannot be separated by physical means.
   A. **Element** - contains only one kind of atom. Elements cannot be chemically decomposed.
   B. **Compound** - contains two or more types of atoms in whole number ratios. Compounds can be chemically decomposed.
2. **Mixture (impure substance)** - matter that can be separated by physical means.
   A. **Homogeneous mixture (a.k.a., solution)** - uniform throughout.
   B. **Heterogeneous mixture** - non-uniform distribution.
      1. **Colloids** - Particle size: 1-1000 nm, dispersed; large molecules or aggregates; and particles do not settle out of the dispersing medium due to the effects of gravity.
      2. **Suspensions** - particle size is over 1000 nm, suspended; large particles or aggregates; and particles settle out of the dispersing medium due to the effects of gravity.

4.1.4 Material properties

A.k.a., Materials factoring, properties of matter.

Materials factoring includes:

1. Physical properties.
   A. Macro-physical properties.
      1. Use in a habitat service system as a technical assembly that functions to meed human needs.
   B. Micro-physical properties.
      1. Chemical [bonding of atomic structure properties].
      2. Electrical [thread proton star].
      3. Magnetic [thread shell].
      4. Electromagnetic [rope] (a.k.a., optical, light, threaded rope).
2. Composition.
   1. Size of atoms.
   2. Quantity of individual atoms touching.
3. Decomposition – including, wearing due to use and natural decomposition.
4. Material movement of location (Read: resource flow).
5. Contamination (purity).
6. Integration and de-integration.

NOTE: *Natural objects are those not made by a human hand or machine.*

4.1.5 Forces on materials

The common mechanical forces on objects composed of materials include:

1. Tension (torsion) - a balance of forces.
2. Pressure (force) - a force greater all others.
   A. Squeeze.
   B. Stretch.
   C. Bend.
   D. Slide.
   E. Twist.

4.2 Matter sub-types

Additional matter types include, but are not limited to:

1. **Inorganic materials (inorganic compounds) -** most inorganic compounds do not contain carbon. Inorganic materials are generally derived from non-living sources, such as rocks or minerals, and encompass such categories as glass, ceramics, metals, minerals, clays, and metals.
2. **Organic materials (a.k.a., organic compounds, organic matrices)** - contain carbon and carbon-hydrogen bonds. They are solids composed of long molecular chains. For example, polymers, hydrogels, brushes, lipids, proteins, carbohydrates, nucleic acids.
3. **Hybrid materials** - incorporate both organic and inorganic constituents.
4. **Biological materials (a.k.a., biological compounds)** - self-organization of materials from the molecular level up. The basic building blocks are start with the amino acids and proceed to polypeptides, polysaccharides, and polypeptides–saccharides.
5. **Regenerative matter (a.k.a., living matter, biology)** - life and other biologically living materials.
6. **Elemental matter (a.k.a., non-living matter)** -

the elements [of matter].

7. **Decaying matter**
   A. **Decomposing matter** - prior life; once living and now decaying/decomposing materials.
   B. **Radioactive decaying matter and transmutational matter** - the change of one element into another as a result of changes within the nucleus.
8. **Programmable matter** - matter with the ability to change its physical properties (shape, density, moduli, conductivity, optical properties, etc.).

4.3 Characterization of materials

Generally, materials are characterized (compared) according to:

1. **Composition** - Composition tells what chemicals are in a sample. The most specific description will reveal the chemical elements that are present in the sample.
2. **Structure** - The three dimensional arrangement of atoms in a sample creates its structure.
   A. **Shape** (object).
   B. **Surface geometry** (surface physics and chemistry).
3. **Properties (physical and chemical)** - Properties are the observed characteristics of a sample.
   A. **Physical properties** - include how a material responds to mechanical forces, heat, and light, displacement, or a combination (e.g., density = mass / volume).
   B. **Chemical properties** - These describe what chemical reactions are likely to occur.
4. **Performance** - The performance of a material is discussed in the context of an application.
5. **Processing and synthesis** - Various methods can be used to create materials from existing substances. For example, processing a material could be as simple as hammering a piece of copper, or flaking arrowheads from a piece of flint. Synthesis implies a major change in chemical composition; for example, polymers are synthesized by cooking mixtures of chemicals, whereupon new molecular structures result.

These categories are useful ways to understand and sort different materials.

4.4 Material data sheets (MDS)

A.k.a., Object data sheets, mechanism data sheets, process data sheets, etc.

A data sheet provides relevant and useful data on a material system. Every technological system has an accompanying data sheet(s). Data sheet types include, but may not be limited to:

1. **Technical specification sheets (a.k.a., spec sheet, data sheet, data-sheet)** - A data sheet, data-sheet, or spec sheet is a document that summarizes the performance and other characteristics of a product, machine, component (e.g., an electronic component), material, subsystem (e.g., a power supply), or software in sufficient detail that allows a buyer to understand what the product is and a design engineer to understand the role of the component in the overall system.
   A. Product specification sheet
   B. Equipment specification sheet (a.k.a., equipment data sheet)
2. **Safety data sheets (SDS)** - documents chemical hazard information.
   A. A **Chemical Abstracts Service (CAS) Registry Number** is a unique identifier for every chemical known to exist.
   B. **Material safety data sheet (MSDS)**
   C. **Hazardous materials data sheet (HMDS)**
   D. **Product safety data sheet (PSDS)**
   E. **Health product declaration (HPD) sheet**
3. **Testing data sheets (TDS)** - a document that identifies the tests and their results conducted on a part of assembly.
4. **Warranty data sheets (WDS)** - a document that identifies all warranty information provided by a manufacturer for a product.
5. **Operations sheet (OS)** - a document that lists all details of the operations needed to complete a part or assembly.
6. **Method specifications sheet** - document material selection and the construction operation process to be followed in providing construction materials and practices. Method specifications provide specifications for the final desired structure and/or mechanism (e.g., concrete thickness and strength, or the lumber dimensions, spacing, species, etc.).

4.5 Chemical abstract service (CAS) registry number

A.k.a., CAS RN, CAS number.

A CAS registry number is a unique numerical identifier assigned by the Chemical Abstracts Service (CAS) to every chemical substance described in the open scientific literature. The CAS registry is the most authoritative collection of disclosed chemical substance information:

- American Chemical Society: CAS Registry [cas.org]

Each CAS registry number (CAS RN) identifier:

1. Is a unique numeric identifier.
2. Designates only one substance.
3. Has no chemical significance.
4. Provides relevant information about a specific chemical substance.

4.6 Hazardous materials

A.k.a., Hazardous substances.

Hazardous substances are classified as substances that are toxic, very toxic, corrosive, harmful or irritants. Hazardous substances (solids, liquids or gases) exposure to which can have negative affects on the body through contact with the skin, inhalation or ingestion. Exposure to hazardous substances can result in short or long term health effects. Hazardous substances can be found both in fabrication/construction, as well as in and around (i.e., from outgassing or flaking) finished products. Hazardous material are classified as hazardous because they can cause illness or death. Exposure to a small concentration of a highly toxic chemical may cause symptoms of poisoning. The risk of handling hazardous materials is contamination (of oneself and/or an environment).

Generally, it is possible to classify hazardous waste threats according to four broad categories ("Defining hazardous", 2024)("Disposal of", 2024):

1. **Ignitability:** Ignitability means that it will catch fire easily. For example: charcoal lighter fluid, gasoline, kerosene, and nail polish. remover.
2. **Corrosivity:** Corrosive wastes can cause a chemical action that eats away materials or living tissue. Battery acid is an example.
3. **Reactivity:** Reactive waste can react with air, water, or other substances to cause rapid heating or explosions. Acids that heat up rapidly and spatter when mixed with water are examples. Fissionable materials are highly reactive.
4. **Toxicity:** Toxic wastes can cause illness or death. Some such wastes are more dangerous than others. Exposure to a small concentration of a highly toxic chemical may cause symptoms of poisoning. Pesticides, cleaning products, paints, photographic supplies, and many art supplies are examples. Toxicity includes:
   A. Plants which can cause dermatitis.
   B. Working for prolonged periods with cleaning agents, which can cause dermatitis.
   C. Prolonged contact with wet cement, which can lead to chemical burns or dermatitis.
   D. Dusty or fumy conditions, which can cause lung diseases.
   E. Off-gassing polymers, paint, glue, ink, lubricant, detergent and beauty products, which can cause dermatitis or lung disease.

4.6.1 Deleterious materials

The term 'deleterious materials' is a broad one, encompassing not only materials that are dangerous to health or which are the causes of failures in structures, but increasingly, materials which are environmentally damaging. It should be noted however that all materials can be considered deleterious under the wrong circumstances (for example, water can be very damaging and can cause extensive pollution). The list of deleterious materials has always remained fluid because as technology advances new products come onto the market and medical research establishes new risks to health.

4.6.2 Irritant material handling

When irritant materials are discovered near human occupancy, they are handled in the following way:

1. Identify material.
2. Isolate material.
3. Remove material safely.
4. Dispose of material safely.

4.6.3 Material pollution

Materials become pollutants when they are positioned in undesirable locations. Therein, metabolites can remain in the environment for decades longer than their parent compounds and are sometimes even toxic and biologically altering than their parent.

4.7 Bio-remediation (from accident or extraction)

A.k.a., Bioremediation.

Bioremediation is a specialized set of techniques in the aftermath of hazardous contamination incidents to mitigate the adverse effects of pollutants and restore affected ecosystems. This process harnesses the natural abilities of microorganisms, such as bacteria, fungi, and plants, to break down or transform contaminants into less harmful substances. Bioremediation strategies vary but often involve the introduction or enhancement of specific microorganisms that can metabolize or absorb pollutants, depending on the type of contamination. For any given situation, all potentially effective remediation techniques/strategies are assessed (e.g., oil booms, skimmers, and sorbents).These microorganisms, when provided with optimal conditions like temperature, oxygen, and nutrient levels, work to biodegrade or immobilize contaminants, rendering them less toxic or mobile. Bioremediation may involve relocation of soils and materials in order to facilitate remediation efforts.

After an assessment has recognized "harm", it produces effective remediation plans and executed operations for restoring the ecology from the "harm". Here, there is a recognition that there are two types of "harm":

1. Accidents involving hazards, where harm is caused by an accidental spill of hazardous materials into an environment, contaminating it.
2. Intentional, where there is contamination, but it is temporary, and the "harm" is not "harm" in the sense of permanent ecological destruction and "total devastation", but the necessary and temporary "harm" of extraction, replaced afterward by planned bio-remediation techniques to restore appropriately the landscape (and/or oceanscape).

5 Solid material types

Traditionally, there are three basic material types (i.e., classes of materials) are:

1. Metals (a.k.a., minerals)
2. Stones (a.k.a., rocks and minerals).
3. Ceramics (a.k.a., "advanced stone")
4. Polymers.
5. Composites.

In material science, it is more appropriate to classify materials according to their properties, but also their usages.

5.1 The material-type taxonomy

On earth, the natural materials are:

1. **Natural materials:** Materials found in the landscape that can be collected by human means.
    A. **Solids (elementary matter):**
        1. **Stone:** Various types of rocks or mineral aggregates, such as granite, marble, limestone, and sandstone, formed naturally through geological processes.
        2. **Mineral deposits** (a.k.a., *solid* ores and elemental mineral reserves).
            i. Solid hydrocarbon mineral deposits (long-term bio-mass materials of hydrogen and carbon chains, such as coal).
    B. **Liquids (elementary matter):**
        1. **Liquid mineral deposits** (a.k.a., *liquid* ores and elemental mineral reserves).
            i. Liquid hydrocarbon deposits (long-term bio-liquid-mass materials).
    C. **Gases (elementary matter):**
        1. **Gas mineral deposits** (a.k.a., *gas* ores and elemental mineral reserves).
            i. Gas hydrocarbon deposits (long-term biogas materials).
            ii. Short-term biogas materials.
    D. **Organics (biologics, life composites):**
        1. **Living organisms** and the bodies of previously living organisms.

The complete material-type taxonomy is:

1. **Crystalline solids:** Observed to have an ordered atomic structure.
    A. **Crystalline metal elements (a.k.a., crystalline metal minerals, alloy).**
    B. **Crystalline non-metal elements (a.k.a., crystalline ceramics, crystalline ceramic minerals).**

C. **Crystalline polymers.**

2. **Non-crystalline solids (a.k.a., amorphous solids):** Observed to have a lack long-range atomic order.
   A. **Non-crystalline metal elements (a.k.a., amorphous metals, metallic glasses, glassy metals).** These materials have an amorphous atomic arrangement similar to that of non-crystalline ceramics like glass. Unlike typical metals, which have a crystalline structure, amorphous metals lack a regular and ordered atomic arrangement.
   B. **Non-crystalline non-metal elements (a.k.a., non-crystalline ceramics, amorphous ceramics)**:
      1. Glass-ceramics: an amorphous solid material primarily composed of silica (silicon dioxide) and other additives. An example of glass ceramics is vitroceramics. Glass lacks a crystalline structure and exhibits properties distinct from crystalline ceramics due to its amorphous atomic arrangement.
   C. **Non-crystalline polymers (a.k.a., amorphous polymers, non-crystalline non-metal polymers, non-crystalline assemblies of non-metal monomers):**
      1. Thermoplastics (e.g., polyethylene, PVC).
      2. Thermosetting plastics (e.g., epoxy resin).
3. **Assembled solids (a.k.a., composite solids):** This category comprises materials formed by combining two or more distinct constituents to create a new material with enhanced properties. Composites can include polymers along with other materials like fibers, particles, or matrices:
   A. **Metal only assemblies (a.k.a., metal composites):** Combinations of metals with other materials, such as metal-polymer composites or metal-ceramic composites.
      1. **Metal-metal assemblies (a.k.a., metal-metal composite, metal matrix assemblies, metal matrix composites, MMC)**, for example:
         i. Aluminum matrix composites (AMCs).
         ii. Titanium matrix composites (TMCs).
         iii. Magnesium matrix composites (MMC).
   B. **Non-metal with metal assemblies (a.k.a., ceramic-metal composites, metal-ceramic composites):** These are composites combining ceramic (or some other non-metal, such as carbon) and metal constituents, to create materials with enhanced properties. Assembly in which a non-metal is bound with a metal (or, with a metal composite). May feature ceramic matrices reinforced with metal elements.
      1. **Metal-carbon fiber assemblies (a.k.a., metal-carbon fiber composites).**
   C. **Non-metal only assemblies (a.k.a., non-metal composites, ceramic composites):**
      1. **Non-metal with non-metal assembly (a.k.a., ceramic-ceramic composites):** Comprised solely of non-metal constituents, which may include oxides, nitrides, carbides, or other inorganic compounds, primarily. A ceramic-ceramic composite usually involves combining different types of non-metals, ceramics, ceramic particles, or fibers, within a non-metal or ceramic matrix, to enhance specific properties. Ceramics, including ceramic composites, usually have a crystalline structure or are composed of crystalline phases.
         i. **Stone assemblies (a.k.a., stone composites):** Natural composites of non-metal minerals found in nature.
         ii. **Concrete assemblies (a.k.a., concrete composites):** Concrete consists of a ceramic matrix (cement paste) and aggregates (sand, gravel, crushed stone) combined with water to form a solid composite material. It consists of cement (a powdered binder), aggregates (such as sand or gravel), and water.
      2. **Non-metal matrix assemblies (a.k.a., ceramic matrix composites, CMCs)**, for example:
         i. Silicon carbide fiber reinforced ceramic (sic/c).
         ii. Alumina matrix composites (AMCS).
         iii. Carbon-carbon composites (C-C).
            1. Carbon fiber - a material made from thin, strong crystalline filaments of carbon atoms. Is considered "light" weight.
            2. Carbon graphite - a crystalline layering of carbon atoms arranged in a hexagonal lattice structure, and each layer is held together by strong covalent bonds. Is a good conductor of electricity.
      3. **Non-metal with polymer [matrix] assembly (a.k.a., ceramic-polymer composites):** Composites with ceramic matrices reinforced by polymer components. These composites ceramic and another polymer materials to offer properties such as lightweight construction and improved flexibility.
   D. **Polymer matrix assemblies (a.k.a., polymer composite, polymer matrix composites, PMCs, polymer matrixes):** Composites in which a polymer matrix holds reinforcing fibers or particles. This category includes a broad range of materials characterized by large molecules composed of repeating structural units or

monomers. Polymers are classified further based on their origin, properties, and structure:

1. **Metal-polymer assemblies (a.k.a., metal-polymer composites).**
2. **Geopolymer assemblies (a.k.a., geopoloymer composites, inorganic polymer matrixes):** Geopolymer is an inorganic, amorphous, and three-dimensional aluminosilicate material formed through the polymerization of aluminosilicates in the presence of an alkaline solution, such as sodium hydroxide or potassium hydroxide. Geopolymers have properties akin to ceramics and can form durable materials used in construction, adhesives, and coatings. Inorganic materials formed by the reaction of aluminosilicate materials with an activating solution, exhibiting ceramic properties and utilized in construction, adhesives, and coatings.
    i. Combinations of ceramic constituents, often involving ceramic matrices reinforced with other ceramics, fibers, or particles to enhance properties.
3. **Natural biological polymers (natural biopolymer molecules, organic polymer matrixes):** Derived from natural sources, such as proteins (e.g., collagen, silk) and carbohydrates (e.g., cellulose, starch).
    i. Protein-based (e.g., collagen, DNA/RNA nucleic acids).
    ii. Fat-based (e.g., ketones).
    iii. Carbohydrate-based (e.g., starch, chitin).
4. **Synthetic polymers (functional synthetic polymer matrixes):** Human-made polymers created through chemical synthesis, such as polyethylene, polypropylene, polystyrene, etc.
    i. Carbon fiber-reinforced polymers (CFRPs).
        1. Epoxy matrix CFRPs.
        2. Polyester matrix CFRPs.
    ii. Thermal formability properties.
        1. Thermoplastics (e.g., polyethylene, PVC).
        2. Thermosetting polymers (thermosets; e.g., epoxy, phenolic)
    iii. Stretchy formability properties:
        1. Elastomers polymer matrix assemblies.
    iv. Reinforcement formability properties (type of reinforcement material):
        1. Fiberglass (polymer matrix with glass fibers).
        2. Aramid fiber reinforced polymer (AFRP).
        3. Carbon fiber-reinforced polymer composites (CFRP).
        4. Glass fiber-reinforced polymer composites (GFRP).

E. **Natural assemblies (a.k.a., natural composites, bio-based composites, living organism composites, life body composites, bodies):** Materials formed naturally, life/organic matter (e.g., wood is composed of lignin and cellulose, and bone comprises collagen and hydroxyapatite).
    1. **Plant assemblies (a.k.a., plant composites, natural plant composites):** Natural fiber composites consist of organic materials derived from natural sources like plant-based fibers (e.g., wood, bamboo, jute, hemp) or animal-based fibers (e.g., wool, silk). Wood is a composite material made from lignan and cellulose. These fibers are combined with a polymer matrix, often biopolymers or synthetic polymers, to form the composite. Examples of useful plant composites are:
        i. Wood composites (lignan and cellulose; lignocellulosic composite).
        ii. Bamboo composites.
    2. **Animal assemblies (a.k.a., animal composite)**, for example:
        i. Bone (collagen-hydroxyapatite composite).
        ii. Shell (calcium carbonate-protein composite).
    3. **Bio-based composites** (composites derived from natural plant and animal, and other living organismal, sources).

4. **Assembled gases and liquids (a.k.a., composite gases and composite liquids):**
    A. **Gas (simple gas mixtures):** In nature, gases are typically composed of single elements or simple molecules rather than being composite materials like those found in solid or liquid form. Gases are generally made up of individual atoms or molecules that are not combined in the same way as the components in composite materials. For instance:
        1. Elemental gases: Elements like oxygen (O_2), nitrogen (N_2), hydrogen (H_2), and helium (He) exist as individual gas molecules.
            i. Noble Gases (e.g., helium, argon).
            ii. Reactive Gases (e.g., hydrogen, oxygen)
        2. Simple molecule gases (a.k.a., compound gases): Some gases, such as carbon dioxide (CO_2), methane (CH_4), and water vapor (H_2O), consist of molecules composed of a few different atoms.
            i. Carbon compounds (e.g., methane, carbon dioxide)
            ii. Atmospheric gases (e.g., nitrogen, oxygen)
    B. **Liquids (complex liquid mixtures):** In nature, liquids are generally single substances or

homogeneous mixtures, rather than composite materials in the traditional sense found in solid composites. However, there are:

1. Inorganic liquids:
    i. Liquid metals (e.g., mercury). Note here that on earth, there are not typically liquid minerals (mercury is typically extracted).
    ii. Liquid salts (e.g., molten salts, molten thorium, etc.).
2. Organic liquids:
    i. Hydrocarbon liquids.
3. Colloidal dispersions of minerals (and organic matter) in water with the properties of an emulsion (i.e., mixture contact throughout) and a suspension (i.e., dispersion distance throughout).

5. **Functional assembled solids:**
    A. **Structural support materials (functional view)**
        1. Enclosure structure (architectural structures and surfaces).
        2. Internal mechanisms (tools).
    B. **Electromagnetic material** (functional view).
        1. Ferromagnetics (e.g., iron, cobalt, nickel alloys).
        2. Conductives (i.e., electrical conduction transport, electrical distance-transport conductors).:
            i. Metals (e.g., copper, gold, aluminum).
            ii. Conductive polymers (e.g., polyaniline).
        3. Dieletctrics (i.e., resist electricity):
            i. Ceramics (e.g., barium titanate).
            ii. Polymers (e.g., polyethylene).
        4. Semiconductors (a.k.a., electrical logic-computation conductors).
    C. **Biomaterials** (functional view; e.g., tissues, bone substitutes, bio-materials). Biomaterials have biological properties:
        1. Biodegradable polymers (e.g., PLA, PGA).
        2. Biocompatible metals (e.g., titanium alloys).
        3. Bioceramics (e.g., hydroxyapatite).

5.2 Assembled solids (a.k.a., composite materials

Composites are mixtures of two or more bonded materials. Composites are the mixture of multiple materials, which in combination offer superior properties to the materials alone. There are several different types of composite material, each with unique characteristics, making them suitable for specific applications based on their properties and constituents.

5.2.1 Stone composite materials

A.k.a., Rock.

Stone is a type of crafting material and can be used for many different purposes. Although seldom used to form entire structures, stone is greatly valued for its aesthetic appeal, durability, and ease of maintenance. The most popular types of stone include: alabaster, basalt, granite, onyx, quartzite, limestone, travertine, sandstone, marble, slate, gneiss, and serpentine. Stone that is used for structural support, curtain walls, veneer, floor tiles, roofing, or strictly ornamental purposes is called building stone. Building stone that has been cut and finished for predetermined uses in building construction and monuments is known as dimension stone.

5.2.1.1 Hazards of stone

Designers must be careful about the position of some stone material. For example,

1. Marble is terrible for countertops, because anything acid will eat into it and other chemicals will stain it.
2. Some stone is radioactive.

5.2.2 Wood composite materials

A.k.a., Engineered wood.

The types of engineered wood include the following:

1. Plywood: Plywood is made up of layers of veneer that are glued together with heat and pressure to form panels.
2. Particleboard or chipboard: A composite wood product made from wood particles or flakes bonded together with adhesive under heat and pressure.
3. Oriented strand board (OSB): An engineered wood panel made from large, flat wood strands that are oriented in specific directions and bonded together with adhesive.
4. Glued laminated timber (Glulam): A structural timber product made by laminating multiple layers of solid wood boards together with adhesive, providing enhanced strength and stability.
5. Laminated veneer lumber (LVL): A type of engineered wood product consisting of thin wood veneers that are bonded together with adhesive to create strong, load-bearing beams or panels.
6. Cross-laminated timber (CLT): A prefabricated wood panel made by stacking multiple layers of lumber boards at right angles to each other and bonding them with adhesive, creating a strong and versatile building material.
7. Parallel strand lumber (PSL): A structural lumber product composed of long, parallel wood strands that are bonded together with adhesive to form large beams or columns.
8. Laminated strand lumber (LSL): An engineered

wood product made from wood strands that are coated with adhesive and pressed into panels or beams for structural applications.

5.2.3 Bioelectronic composite materials

A.k.a., Bioelectrical materials, bio-electrical materials, biomaterial composites.

A biomaterial is any substance that has been engineered to interact with biological systems. Biomaterials are any synthetic or natural material used to improve or replace functionality in biological systems. Biomaterials are employed in components implanted into the human body for replacement of diseased or damaged body parts. These materials must not produce toxic substances and must be compatible with body tissues (i.e., must not cause adverse biological reactions). In other words, biomaterials are biocompatible and work synergistically with the biological host.

Bioelectronic use conductive polymers, organic semiconductors, carbon nanotubes, graphene, gold nanoparticles, photonic dyes, quantum dots, and microfluidic materials for applications in biosensing, bioimaging, wearable electronics, and implantable electronics.

5.2.3.1 Bioceramic polymer

Bio-ceramic polymers are a subset of ceramic polymers that incorporate bioactive or biocompatible ceramics, often used in biomedical applications. They aim to integrate the biocompatibility of ceramics with the versatility of polymers for medical implants, drug delivery systems, or tissue engineering. These materials interact favorably with biological systems, promoting compatibility and integration within the human body.

5.2.4 Natural plant composite materials

Wood and bamboo are a composite materials made from lignin and cellulose. Wood makes use of a lignin matrix and cellulose fibers to form a polymer composite. The lignin holds the cellulose compressively in place so that the cellulose fibers can carry tensile loads. Wood has excellent structural properties, in light of its low weight and high strength.

5.2.5 Ceramic composite materials

Ceramics are inorganic non-metallic materials whose formation is due to the action of heat. A ceramic is any of the various hard, brittle, heat-resistant and corrosion-resistant materials made by shaping and then firing an inorganic, non-metallic material, such as clay, at a high temperature. A ceramic is a non-metallic material composed of inorganic molecules, normally prepared by heating a powder or slurry. Many common ceramics are made up of (1) oxides, and/or (2) nitride compounds, and are highly crystalline with long-range molecular order. Some ceramics are partially or fully amorphous, with no long-range molecular order; these are typically classified as glassy materials.

> **CLARIFICATION:** *Diamond and graphite, which are two different forms of carbon, are considered to be ceramics even though they are not composed of inorganic compounds.*

The six basic ceramic materials are (Note: the first five are classified as traditional ceramics and mainly made from natural raw materials):

1. Glasses (a.k.a., whitewares).
2. Clay products (e.g., brick and tile).
3. Refractories.
4. Abrasives.
5. Cements.
6. Advanced ceramics - ceramics made from artificial or chemically modified raw materials.
    A. Electroceramics.
        1. Electronic substrate, package ceramics.
        2. Capacitor dielectric, piezoelectric ceramics.
        3. Magnetic ceramics.
        4. Optical ceramics.
        5. Conductive ceramics.
    B. Advanced structural ceramics.
        1. Nuclear ceramics.
        2. Bioceramics.
        3. Tribiological (wear-resistant) ceramics.
        4. Vehicular ceramics.

5.2.6 Glass (transparent) ceramic composite materials

Glassy materials are hard, brittle, and noncrystalline. Typical glass does not possess the regular repeating atomic structure characteristic of crystals -- the lack of crystalline grains is what results in optical transparency. Typical glass is a ceramic-type material, usually consisting of a mixture of silicates or sometimes borates or phosphates formed by fusion of silica or of oxides of boron or phosphorus with a flux and a stabilizer into a mass that cools to a rigid condition without crystallization. Glass is generally a mixture of silica sand, soda ash, and limestone. These compounds are heated together into a liquid, molded into shape, and sometimes fabricated into a structure.

In general, appropriately made and pure glass has the following material properties:

1. Non-conductive to electricity.
2. Non-reactive to water.
3. Non-reactive to acid.
4. Non-reactive to biology.
5. Evaporation from molten glass can cause release of particles in the atmosphere.

5.2.6.1 Glass sustainability

Glass is a highly recyclable material and the sources of glass making constituents are highly available on the planet. Recycling requires appropriate handling after use, collection and sorting, and then is highly circular (i.e., storage containers, in particular have a high-capacity for re-cycling). The pre-handling, before collection is very important, because co-mingling materials leads to glass breakage and a contaminated mixture of materials that makes cycling/circling the glass impossible (or sufficiently difficult not to be done). To de-recycle glass requires the process of melting it. Glass requires a lot of material to melt; hence, glass ought to be re-purposed prior to melting, where appropriate, because of the extra power (energy) required to melt and re-compose the glass.

5.2.7 Concrete (ceramic-ceramic) composite materials

Concrete is a ceramic composite made up of water, sand, gravel, crushed stone, and cement. The ingredients are mixed together thoroughly, and are poured into a form. After the concrete is completely dry, it has excellent compressive strength.

Concrete has excellent compressive strength, and unreinforced concrete blocks can be stacked miles high before the bottom-most blocks gets crushed. Concrete has little strength under tension. Modern builders work around this problem by making concrete into a composite, by embedding a rebar cage or mesh in a concrete slab, with enough thickness on either side so that when, under load, the armature stretches, the slab bends hardly at all. Because, if it did bend, cracks would instantly open up on the convex side, letting in moisture, causing the rebar to corrode, expand, and cause "spalling" (meaning the concrete structure falls apart). What's more, this is bound to happen eventually in any case, and so reinforced concrete slabs are engineered for eventual failure by being over-reinforced and under-cemented, because then they give warning of impending disaster in the form of cracks, as opposed to failing catastrophically.

Types of concrete include, but are not limited to:

1. Portland cement concrete (traditional 21st century concrete): Portland cement is the source of the cement ("glue") that holds most modern concrete together. Making portand cement requires heating a mix of limestone and clays to 1,450C.
2. Ancient Roman concrete: Portland cement with a lyme and volcanic ash mixture. Portland cement is the modern type of cement. In seawater portland cement has a lifespan of ~50 years after which it corrodes. Ancient Roman cement lasts longer. The Romans perfected a mixture that used much less lime than portland cement and cemented at 900C or lower. The Romans mixed lime and volcanic rock for regular concrete structures, while underwater structures were made with lime and volcanic ash that formed a mortar. When this mix connected with seawater, a hot chemical reaction occurred that cemented the lime and ash mixture. The secret ingredient is aluminum-rich pozzolan ash and it turns out that oil-producing Saudi Arabia has a lot of it.
3. Aircrete: Aircrete is made from a mix containing cement, lime and pulverised fuel ash (PFA) and a dash of aluminium powder. Aircrete is a material that combines the strength and durability of concrete which is physically light weight that helps make a home easy and fast to construct.
4. Cococrete/coco-peat: Cement and coconut fiber and lime and sand - a soft concrete that will start to moss up a bit when it gets wet, gives an ancient ruin look.
5. Bioconcrete: Concrete that heals itself using bacteria. The bioconcrete is mixed just like regular concrete, but with an extra ingredient -- the "healing agent." It remains intact during mixing, only dissolving and becoming active if the concrete cracks and water gets in. Tziviloglou et al., (2017) chose calcium lactate, setting the bacteria and calcium lactate into capsules made from biodegradable plastic and adding the capsules to the wet concrete mix.
6. Impermeable concrete: Concrete that does not absorb and does not retain water.
7. Porous concrete: Concrete that allows water seepage. This type of concrete is typically used on streets for rapid disposal of rainwater into the landscape.

5.2.8 Ceramic polymer composite materials

Ceramics are inorganic, non-metallic materials typically made from compounds of metallic and non-metallic elements, often formed by heating and cooling processes. A ceramic polymer has the properties of a polymer in that it forms molecular bonds with metal and wood and themselves, as well as the properties of a ceramic in that they are highly crystalline (covalent and ionic bonding), and the properties of a cement such that it can be made into a powder and doesn't require high heat. Different aggregates can be added to the ceramics to make different qualities of building materials. If there is projectile damage, then ceramic can be mixed on site to patch damage. And, the ceramic can be sprayed to resurface the whole object.

Ceramics can be chemically bonded with many different types of materials. Crucially, ceramics have the same property that makes cement so useful: the ability to mix it into a slurry and pour it into a mold without using high heat. Ceramic is fireproof, doesn't decompose readily when exposed to the elements (i.e., doesn't mold, doesn't rot, doesn't rust). Ceramic can built into multiple shapes. Phosphate ceramic polymers are some of the most usable and easy to work with ceramic polymers.

Ceramic polymers can be used as:

1. An adhesive.
2. A coating (or protective layer).
3. A complete solid surface material (i.e., engineered stone).

5.2.9 Geopolymer (3D polymeric) network composite materials

A.k.a., Geo-polymer, geopolymerization.

Geopolymer refers to an inorganic material formed by the reaction of aluminosilicates (such as fly ash or metakaolin) with an activating solution, often an alkaline solution like sodium hydroxide or potassium hydroxide to create a solid matrix without relying on conventional polymer binders like acrylic resins or epoxies. Geopolymers are typically based on industrial by-products like fly ash, slag, or metakaolin. Geopolymers utilize a different chemical process compared to the acrylic polymer-mineral blend used in the production of Corian.

Geopolymers, when activated by an alkaline solution and formed into a solid matrix, can create durable and solid structures suitable for various purposes. Geopolymers can be used as:

1. An adhesive.
2. A coating (or protective layer).
3. A complete solid surface material (i.e., engineered stone).

5.2.10 "Engineered stone" composite materials

A.k.a., Engineered solids, engineered stone, synthetic stone, artificial stone.

Engineered "stone" is a type of in-organic polymer that can be used as a construction material. For example, engineered stone for benchtops is primarily made from quartz, one of the hardest minerals on Earth. The manufacturing process involves grinding quartz into dust and then combining it with resins and pigments. Grinding it to dust requires exponentially more energy than using large cut pieces. The product of pressed and adhered mineral powder (fine grain mineral matter) is a product that replicates the beauty of natural stone.

Engineered stone (a.k.a., synthetic stone) can be made using:

1. Geopolymer mixed with in-organic material. In the production of engineered stone or synthetic stones, geopolymers serve as an alternative binder to traditional resins like polyester or epoxy used in some other types of engineered stones. They are known for their high strength and durability. The process of creating geopolymer-based engineered stone involves mixing the aluminosilicate materials with the activating solution to form a binder. This binder is then combined with aggregates like quartz, crushed stone, or glass to create the desired stone-like material (a.k.a., engineered "stone").
2. Traditional synthetic resins mixed with in-organic material. For example, "Corian", a product developed by DuPont, is not formed using a geopolymer technique but rather through the combination of acrylic polymer and natural minerals. Corian is a solid surface material, primarily made from a blend of acrylic polymer (often a type of acrylic resin) and mineral fillers such as aluminum trihydrate derived from bauxite ore. These materials are mixed together and formed into sheets or molds, which are then heated to create a solid and versatile surface material. During this process, the acrylic polymer serves as the binding agent that holds the mineral particles together, resulting in a durable and homogeneous material. Corian is a blend of acrylic polymer and natural minerals, primarily used in countertops, sinks, and various interior applications. It is known for its versatility, seamless appearance, and resistance to stains.

5.2.11 Electronic conductor composite materials

I.e., EM interfaceable, light interfaceable.

Electronic conductor composite materials, often referred to as EM (electromagnetic) and light (optical) interfaceable materials, play a critical role in various technical applications. These materials are specifically engineered to facilitate the conduction of electricity or light, depending on the intended purpose. Electronic and optical materials encompass a wide range of substances, including metals, ceramics, polymers, and glass, each tailored to excel in specific electronic or optical functions.

Metals, known for their exceptional electrical conductivity, are commonly used in electronic conductor composites to efficiently transmit electrical signals. Ceramics, on the other hand, exhibit properties that make them ideal for specific electronic applications, such as insulating against electrical conduction or providing thermal resistance. Polymers offer versatility and can be used in electronic conductor composites to insulate, protect, or enhance mechanical properties, depending on the configuration. Glass, with its optical transparency, is often employed in optical materials to facilitate and/or control the transmission of light.

5.2.12 Electrical semiconductor composite materials

A.k.a., Semi-conductor materials.

Semiconductors are a special case of electronic material that combines two different electrically conductive materials, usually ceramics. Semiconductors are materials with electrical conductivity between conductors (like metals) and insulators (like ceramics). hey are crucial components in electronic devices and technology due to their ability to control the flow of electricity. Common semiconductors include silicon, germanium, and gallium arsenide. A semiconductor is also known as a P-N junction, where one material allows 'loose' electrons to move through an ordered structure, and the other allows holes (where an electron could be, but is not) to move in the same way. This behavior and the interactions between charge carriers and photons and phonons allows semiconductors to store binary information, form logic gates, and convert between voltage, light, heat, and force as sensors and emitters.

Semi-conductive materials makes up the following electrical systems:

1. **Light-emitting diode cells (LEDs)** - emit light when current passes through them. LEDs are used in displays, indicators, lighting, and various electronic applications.
2. **Non-light emitting diode cells** - allow current to flow in one direction and block it in the opposite direction. They're fundamental components in rectifiers, signal demodulation, and voltage regulators.
3. **Photovoltaic cells** - convert light energy into electrical power (a.k.a., "light"; electrical energy).
4. **Integrated circuits (IC; an integrated circuit cell)** - an integrated on/off switch circuit. ICs are miniaturized circuits formed by integrating multiple semiconductor devices (such as transistors, diodes, resistors, and capacitors) onto a single semiconductor substrate.
5. **Thyristors and Triacs:** These are semiconductor devices used for switching and controlling electrical power in various applications such as dimmer switches, motor controls, and power supplies.
6. **Sensors:** convert physical parameters like temperature, pressure, light, or proximity into electrical signals.

5.2.13 Graphene composite materials

A.k.a., Carbon fiber.

Graphene is a polymer, an allotrope of pure carbon comprised of a single layer of atoms.

5.2.14 Metals, alloys, and magnetic composite materials

Metals are elemental substances that readily give up electrons to form metallic bonds and conduct electricity. Almost all metals have an orderly arrangement of atoms, resulting in a crystalline structure that may have multiple crystal phases bordering each other.

Some of the important basic properties of metals are:

1. Metals are usually good electrical and thermal conductors.
2. At ordinary temperature metals are usually solid.
3. To some extent metals are malleable and ductile.
4. The freshly cut surfaces of metals are lustrous.
5. When struck metal produce typical sound.
6. Most of the metals form alloys. When two or more pure metals are melted together to form a new metal whose properties are quite different from those of original metals, it is called an alloy.

Metals may be magnetic or non-magnetic. The magnetic properties of metallic materials are due to:

1. The atoms of which these metallic materials are composed.
2. The way in which these atoms are arranged in the space lattice.

Metallic materials are typically classified according to their use in engineering as under:

1. **Pure metals** - consist of a single element. Samples of these metals contain nothing but atoms of a single metallic substance.
2. **Alloys** - contain two or more elements or alloys melted and blended together, so their chemical formulas consist of more than one element.

5.2.14.1 Metal alloys

A.k.a., Metallic alloys.

Metal alloys are classified as either ferrous or non-ferrous:

1. **Ferrous** - the group which contains mainly iron (Fe).
   A. Cast iron
   B. Steels
      1. Low alloy
      2. High alloy

2. **Non-ferrous** - other metallic materials containing no iron.

5.2.14.2 Metallurgy

A.k.a., Metallurgical science.

Metallurgy is the branch of science and technology concerned with the properties of metals and their production and purification. In other words, metallurgy, as a branch of engineering, is concerned with the production of metals and alloys, their adaptation to use, and their performance in service

Metallurgical science involves:

1. Physical metallurgy - the science of making useful products out of metals.
2. Process metallurgy (a.k.a., extraction metallurgy) - the practice of removing metals from an ore and refining the extracted raw metals into a purer form.

5.2.15 Fissionable composite materials

Fissionable materials are substances capable of undergoing nuclear fission, a process where the nucleus of an atom splits into smaller parts, releasing a tremendous amount of energy. This process is the basis for nuclear power and nuclear weapons. Common fissionable materials include uranium-235 and plutonium-239. Fissionable materials require special handling procedures.

5.2.16 Metamaterials

A metamaterial (from the Greek word μετά meta, meaning "beyond" and the Latin word material, meaning "matter" or "material") is a material engineered to have a property that is not found in naturally occurring materials. Metamaterials are composite systems whose properties are dominated not by the individual atoms, but by the properties of larger, artificially produced structures or "meta-atoms." The concept of "meta" comes from the ability to engineer artificial materials, consisting of a composite of nanoscale structures, which can respond to other materials and to light in entirely new ways. A metamaterial is an engineered material specifically designed to exhibit a behavior that can only occur at specific organizations and sizes of materials. Metamaterials often seem to break the rules of physical behavior. In other words, metamaterials are composite media that can be engineered to exhibit unique electromagnetic properties. Simply, the field of metamaterials involves designing complicated, composite structures, some of which can manipulate electromagnetic waves in ways that are impossible in naturally occurring materials. Metamaterials are usually arranged in repeating patterns, at scales that are smaller than the wavelengths of the phenomena they influence.

Metamaterials derive their properties not from the properties of the base materials, but from their newly designed structures. Their precise shape, geometry, size, orientation, and arrangement gives them their new properties.

Metamaterials have even been shown to be capable of solving integral equations by encoding parameters into the properties of an incoming electromagnetic wave through a material structure that manipulates the wave in such a way that it exits encoded with the solution to a pre-set integral equation for that arbitrary input (Estakhri, 2019).

5.2.17 Nanomaterials

A.k.a., Nano-structured materials.

Nanomaterials, synthesized from both organic and inorganic materials, are defined as the functional [solid] materials with size below 100-nm in length along at least one dimension (Zhong, 2009). In other words, nano-structured materials are defined as solids having microstructural features in the range of 1–100 nm (nano = (1-100) × 10^{-9} m) in at least in one dimension. This includes both nano-objects, which are discrete pieces of material, and nanostructured materials, which have internal or surface structure on the nanoscale; a nanomaterial may be a member of both these categories.

5.2.18 Polymer composite materials

A.k.a., Plastics material.

The term "polymer" is often used to describe plastics and other materials. Literally translated, polymer means "many units." These units are sometimes referred to as monomers, and they are the building blocks that form a plastic. Plastics/polymers are made up of millions of repeated links to make long molecules or networks that are tangled or crosslinked together. Almost all polymers use carbon atoms in very long chains. The carbon atoms may be attached to other carbon, oxygen, nitrogen, and hydrogen atoms. Polymers may or may not have an orderly arrangement of atoms. To form a plastic article, these monomers undergo a chemical change that causes them to become connected to each other. In addition to synthetic plastics, the term "polymer" also can be applied to natural biopolymers.

There are three basic types of polymers:

1. **Natural polymers** - polymers found in nature that have not undergone any chemical modification by humans.
2. **Biopolymers (a.k.a., natural biopolymers)** - natural polymers that have been chemically modified.
3. **Synthetic polymers (a.k.a., synthetic plastics)** - polymers that have been made entirely by humans.

Together, there are nine natural polymers and biopolymers:

1. Adhesion proteins.
2. Carbohydrates (and starches).
3. Cellulose.
4. Chitosan and chitin.
5. Dextrans.
6. Gelatin.
7. High-purity collagen.
8. Lignins.
9. Polyamino acids.

Natural polymers tend to be readily biodegradable, although the rate of degradation is generally inversely proportional to the extent of chemical modification.

The polymer types by usage category include:

1. Biodegradable polymers.
2. Block copolymers.
3. Π-conjugated polymers.
4. Dendrimers.
5. Engineering polymers.
6. Hydrophilic polymers.
7. Hydrophobic polymers.
8. Natural polymers and biopolymers.
9. Poly(ethylene glycol) and poly(ethylene oxide).
10. Polymers for membranes.
11. Polymer standards.
12. Silicones.

5.2.18.1 Polymer example

The material known as 'rubber' can be produced from natural rubber extracted from rubber trees (known as 'latex'; hevea brasiliensis is the scientific name of rubber tree, which belongs to the family Euphorbiaceae. Rubber can also be synthetically produced from petroleum (synthetic rubber). Synthetic rubber is superior to latex rubber in concern to chemical resistance. When synthetic rubber comes into content with gasoline or petroleum oil, it will slightly dissolve. Neoprene (another synthetic polymer) was designed to be resistant those chemical mixtures. Latex rubber, however, is superior in elasticity to synthetic rubber.

5.2.18.2 Plastic resin identification codes

Plastic resin identification codes are printed most plastic products. The identification codes always have a number, and which may sometimes be encircled by three arrows. In the case of the resin identification codes, the arrows in the shape of a recycling symbol mean nothing. The number in the middle of the arrows (if present) represents the kind of plastic the object was made from. The arrows were added for manipulation, in order to mimic the recycling symbol. The first two codes (1-PETE and 2-HDPE) are recyclable. The next four (3-6) require special equipment to recycle. The other resins are not recyclable.

5.2.19 Shape memory polymer composite materials

A.k.a., Programmable materials.

A shape memory polymer is a special material that has the ability to be deformed and held into a temporary shape and then return to and remember it's original shape. These polymers can be 4d printed; wherein, the fourth dimension allows for shape change over time.

5.2.20 Textile composite materials

A.k.a., Fiber-based materials.

A textile is a flexible material consisting of a network of natural or artificial fibers (i.e., yarn or thread). Technically, a textile is an inhomogeneous porous medium. Textiles are materials or fabrics. Yarn is produced by spinning raw fibres of materials to produce long strands. Textiles are formed by the following types of processes: weaving, knitting, crocheting, knotting, tatting, felting, braiding, etc. Textiles are materials made from fibers, thin threads or filaments that are:

1. Naturally cultivated.
2. Synthetic produced.
   A. Cellulose synthetics.
   B. Hydrocarbon synthetics.
3. A combination of both.

5.2.21 Geotextile composite materials

A.k.a., Geo-textiles; textiles used on a landscape.

Geotextile refers textiles that are used on a landscape and are generally a permeable synthetic textile-type material. Generally it is produced from polyester or polypropylene polymers. These are called geo-textiles because they are used on the landscape and in the built environment. Geotextiles are used to increase soil stability, provide erosion control or aid in drainage.

1. The functions of geotextiles (geo-applied fabrics) are:
   A. Filtration.
   B. Drainage
   C. Reinforcement.
   D. Caution.
   E. Waterproofing.
   F. Separation.
2. Geotextile fabric production methods:
   A. Woven geotextile fabrics.
   B. Non-woven geotextile fabrics.
3. Practical applications of geotextile fabric:
   A. Transportation pathworks (roadwork, railwork, etc.).

B. Cultivation (agriculture techniques).
C. Architecture (e.g., permeabilization).
D. Landscape (e.g., drainage, conduiting, retention, and breaks).

5.2.22 Smart textile composite materials

Smart textiles can be defined as textiles that are able to sense and respond to changes in their environment. They may be divided into two classes: passive and active smart textiles. Smart textiles can monitor an environment and be programmed to react in particular ways. (Koncar, 2016)

5.3 Classification of solid fibers (textiles)

Classification of textile fibers includes, but is not limited to:

1. **Natural fiber:**
   A. **Animal (protein derived).**
      1. Silk (from sericteries).
      2. Animal hair (from hair bulb).
         i. Alpaca (lama).
         ii. Cashmere.
         iii. Camel.
         iv. Feather.
         v. Goat.
         vi. Horse.
         vii. Human.
         viii. Wool (note: a highly renewable/ sustainable material given the presence of sheep).
   B. **Mineral:**
      1. Asbestos.
         i. Amosite.
         ii. Crocidolite.
         iii. Tremolite.
         iv. Actinolite.
         v. Anthophyllite.
         vi. Chrysotile.
   C. **Plant (cellulose/lignocellulose derived):**
      1. Seed fibers.
         i. Cotton.
         ii. Kapok.
         iii. Loofah.
         iv. Milk weed.
      2. Bast fibers - Bast fibre (also called phloem fibre or skin fibre) is plant fibre collected from the phloem (the “inner bark”, sometimes called “skin”) or bast surrounding the stem of certain dicotyledonous plants.
         i. Jute.
         ii. Flax (linen).
         iii. Hemp.
         iv. Kenaf.
         v. Kudzu.
         vi. Mesta.
         vii. Okra.
         viii. Rattan.
         ix. Ramie.
         x. Rosella.
         xi. Wisteria.
      3. Leaf fibers.
         i. Abaca.
         ii. Agave.
         iii. Banana.
         iv. Fique.
         v. Henequen.
         vi. Manila.
         vii. Raphia.
         viii. Sansevieria cylindrica.
         ix. Sansevieria ehrenbergii.
         x. Sansevieria trifasciata.
         xi. Sansevieria stuckyi.
         xii. Sansevieria kirkii.
         xiii. Sansevieria pinguicula.
         xiv. Sisal.
      4. Fruit.
         i. Coir.
         ii. Oil palm.
      5. Wood.
         i. Soft wood.
         ii. Hard wood.
      6. Stalk.
         i. Rice.
         ii. Wheat.
         iii. Barley.
         iv. Maize.
         v. Oat.
         vi. Rye.
      7. Grass/reeds.
         i. Bamboo.
         ii. Bagasse.
         iii. Corn.
         iv. Sabai.
         v. Rape.
         vi. Esparto.
         vii. Canary.
2. **Human made (Manufactured):**
   A. **Natural polymer (artificial, regenerated).**
      1. Alzon (protein derived).
      2. Chitosan (natural sugars derived).
      3. Cupro.
      4. Rayon (viscose/cuprammonium; cellulose derived)
      5. Modal..
      6. Polynosic.
      7. Deacetylated acetate (cellulose derived).
      8. Acetate (secondary triacetate; cellulose

derived).
9. Alginic (alginate).
10. PLA (natural sugars derived).
11. Lyocell (cellulose derived).
12. Elastodiene.
13. Tencel.
14. Rubber (natural; a.k.a., latex).

B. **Synthetic organic (synthetic polymer).**
1. Acrylic, polyvinyl.
2. Anidex.
3. Aramid/kevlar.
4. Carbon fiber.
5. Chlorofibre.
6. Elastin (elastoester).
7. Fluoro fibre (fluoropolymer, teflon).
8. Lastrile.
9. Melamine.
10. Modacrylic.
11. Novoloid.
12. Nitrile.
13. Polyamide (nylon).
14. Polyester (aromatic polyester).
15. Polyethylene.
16. Polypropylene.
17. Polyurethane.
18. Polyolefin (olefin).
19. Rubber (synthetic petroleum-based rubber).
20. Saran.
21. Spandex.
22. Sulfur.
23. Trivinyl (vinyl).
24. Vinyon.

C. **Inorganic.**
1. Metallic fiber
2. Glass fiber.
3. Boron fiber.
4. Silica carbide.

6 Gas material types

There are many types of gas, including combinations of different elemental gases. Some gases can, and others cannot, be safely compressed. A gas has molecules that are very far apart from each other, whereas a solid or liquid has molecules that are very close together.

Some of the more commonly used gases in a habitat service system are:

1. Breathable gases - Air is necessary for humans to breath. Air has various qualities and various elements, all of which must be within human parameters for humans to survive. Air is composed of oxygen, nitrogen, argon, carbon dioxide, and traces of several other gases.
2. Carbon monoxide (CO_2) - is a common waste gas from combustion and respiration of other gases.
3. Pure oxygen (O_3) - is useful for medical and construction purposes.
4. Ozone (O_3) is useful for disinfecting and eliminating unwanted bacteria and other potential pathogens. The machines used for disinfecting are not medical grade ozone generators. Firstly, they use ambient air (and not pure oxygen), and secondly, they use equipment that generally is not highly ozone resistant, so there will be some breakdown of materials.
5. Industrial usage and waste gases- are specific gases used in and drained from production technologies.
6. Technical medical gases - are specific gases used in various medical procedures and medical technologies.
7. Combustion gases - Propane, methane, and butane (etc.) are useful for combustion purposes.
8. Refrigeration gases - Are used in cooling technologies. These include but are not limited to: HFC-134a (1,1,1,2-Tetrafluoroethane), R134A Tetrafluoroethane, R438A Freon, R600A Iso Butane, and historically, R22 Chlorofluorocarbons.
9. Vapor (steam) - is useful for many purposes including electricity generation and/or heating.

NOTE: *There are many toxic gases. Gas that in low concentrations may not be harmful can be harmful in higher concentrations.*

6.1 Gas material types

There are three primary categories of gas depending upon their atomic composition:

In this way, gases can be classified as:

1. **Elemental gases:** Certain elements exist as gases at standard temperature and pressure. When the pressure is changed and is higher or lower, or when the temperature is changed and is higher or lower, the element may exist in a different form such as in liquid form or solid form. Elements will become gas at different temperatures.
2. **Pure gases:**
   A. Made up of individual atoms.
      1. Classified based on reactivity, there are noble gases, which are the least reactive of all known elements.
   B. Atomic gases:
      1. Monoatomic gases (1 atom molecules) - gases of only one atomic element. All the individual elements [in the periodic chart of elements].
      2. Diatomic gases (2 atoms molecules) - gases of only two atomic elements. Some diatomic molecules have single bonds (shared electron pairs), others have two or three. Not all atom species form diatomic molecules. Elements that exist in diatomic molecules (a molecule containing two atoms of the same element or species), include:
         i. Oxygen (O2).
         ii. Hydrogen (H2).
         iii. Nitrogen (N2).
         iv. Flourine (F2).
         v. Chlorine (Cl2).
         vi. Bromine (Br2).
         vii. Iodine (I2).
      3. Triatomic gases (3 atoms in molecules) - gases of only three atomic elements.
      4. Polyatomic gases (4 or more atoms in molecules) - gases of more than three or more atomic elements. Air is the most common polyatomic gas on the plant. For example,
         i. Phosphorus (P4).
         ii. Sulfur (S8).
         iii. Ammonium (NH4).
3. **Mixed gases:** A mixture is two or more gases. For example,
   1. Acetylene (C2H2).

Gas can have the following processes applied to it:

1. **Storage of gas** - placement of gas in a safely contained and static location.
2. **Flow of gas** - movement/transfer of gas from one location to another through a conduit, typcially referred to as a pipe.
3. **Combustion of gas** - reaction of gas with another gas (i.e., simple gas fusion; e.g., petrol).
4. **Electrification of gas** (a.k.a., plasma gases, plasming of gas, complex gas fusion) - gas electrified via electromagnetism as electric*[-laser]* light and/or electric*[-circuit]* current. Plasma is electrified gas.

6.2 Sensing gas

Instruments can be made to detect:

1. Different types of gases.
2. The concentration of a gas(s).
3. The shape of a gas(s).

7 Oil material types

A.k.a., Lipid and fat.

There are many types of oil, including combinations of different oils. Some oils can, and others cannot, be safely compressed.

Oils are used in a habitat service system for at least the following purposes:

1. **Edible oils (a.k.a., food-grade oils).**
   A. Animal oils.
   B. Some plant oils (note that many plant oils are not edible). The safer plant oils for human consumption typically come from the fruit and not from the seeds of plants, such as olive and avocado oil.
   C. Pharmaceutical oils.
2. **Inedible oils (industrial oils):**
   A. **Manufacturing oils** - oils used in the manufacturing and production process (note that some of these oils may also be used in the actual end-use operations of machines).
      1. **Solvent oils** - a chemical compound that breaks down other chemical compounds.
      2. **Lubricating oils (a.k.a., machine oils, grease oils, greasing oils, lube)** - a class of oils used to reduce the friction, heat, and wear between mechanical components.
      3. **Composition oils (a.k.a., structural producing oils)** - a class of oils used to produce the structural material of a final product (e.g., plastic, polyurethane, etc).
   B. **Combustion-power production oils** - oils used for combustion in order to produce power and heat (e.g., kerosene).
   C. **Waste oils** - are considered hazardous waste and have some dangerous properties. Waste oil is any petroleum-based or synthetic oil that, through contamination, has become unsuitable for its original purpose due to the presence of impurities or loss of original properties.

The primary sources of oil are:

1. **Animal oils** - oils from animals other than humans; (e.g., tallow, ghee, butter, cream, etc..
2. **Seed oils** (a.k.a., vegetable oils, plant seed oils) - oils from the seeds of plants, including but not limited to:
   A. Canola (rapeseed).
   B. Corn.
   C. Soy.
   D. Safflower.
   E. Sunflower.
   F. Hazelnuts.
   G. Chestnut oil.
   H. Peanut.
   I. Avocado.
   J. Etc.
3. **Combustion oils** (a.k.a.,petroleum hydrocarbon oil, oil hydrocarbons, hydrocarbon oil) - are used for combustion to produce power and/or heat.
4. **Technical and Synthetic oils** - may be sourced from a petroleum and/or seed oil bases. These oils are used in production and operation of technological systems in the habitat. Through hydrocarbon chemical refinery and chemical synthesis. Crude plant or other hydrocarbon oil is heated over a furnace that separates the hydrocarbons into different groups based on the number of atoms they contain -- their resulting molecular weight -- and then, feeds them into a nearby distillation tube. Inside this tube, the longer, typically heavier hydrocarbons sink to the bottom, while the shorter, lighter ones rise to the top. The result is that crude oil gets separated into several distinct groups of chemicals for use; such as, petroleum, gasoline and paraffin. One of these groups is naphtha, a chemical that will become the primary feedstock for making plastic. Chemical and biological processes may be applied to this oils to construct even pharmaceuticals.

NOTE: *There are many toxic/poisonous oils. Oils that in low concentrations may not be harmful can be harmful in higher concentrations.*

7.1 Sensing oils

Instruments can be made to detect:

1. Different types of oils.
2. The concentration of a oil(s).
3. The shape of an oil(s).

8 Liquid material types

There are many types of liquid, including combinations of different liquids. Some liquids can, and others cannot, be safely compressed. Some of the more commonly used liquids in a habitat service system are:

1. Water.
2. Edible liquids.
3. Gasoline (petrol).
4. Cleaning liquids.
   A. Chlorine liquid is used in cleaning, most commonly in textiles and water.
   B. Liquid soaps.
5. Solvent liquids.
6. Lubricating liquids.
7. Industrial usage and waste liquids.

> **NOTE:** *There are many toxic/poisonous liquids. Liquids that in low concentrations may not be harmful can be harmful in higher concentrations.*

8.1 Sensing liquids

Instruments can be made to detect liquids, and their concentrations.

9 Hydrocarbons

A.k.a., Petrochemicals.

Hydrocarbons derived from oil and natural gas make the manufacturing of many complex technological products possible. Petrochemicals are the feedstock chemicals for the production of many of the items in the early 21st century.

9.1 Hydrocarbon categories

There are three primary phases of matter of which hydrocarbons take [in the form of fuel and/or primary carbon chemistry resource]:

1. Liquid hydrocarbons (hydrocarbon oil).
2. Solid hydrocarbons (i.e., coal).
3. Gas hydrocarbons (i.e., natural gas).

There are many ways in which hydrocarbons can be converted:

1. Coal conversion to oil.
2. Synthetic fuels from coal.

9.2 Sensing Hydrocarbons

Instruments can be made to detect hydrocarbons, and their concentrations.

10 Material flows

A.k.a., Matter flows.

Material resource flows refers to the flow of matter/ materials within the physical (a.k.a., material) environment. Where resources are accounted for all identifying notations are tracked and calculated.

Important terminology in concern to materials flow includes:

1. **Geology** - the study of how matter deforms and flows, including its elasticity, plasticity and viscosity. In geology, rheology is particularly important in studies of moving ice, water, salt and magma, as well as in studies of deforming rocks.
2. **Geodynamics** - the deformation of earth materials.
3. **Geomorphology** - that branch of earth science concerned with the shape of terrestrial surfaces.
4. **Rheology** - the study of matter when it flows or is deformed.

10.1 Rheology

Rheology is the deformation and flow of matter; measured by a rheometer (or other). Rheology is otherwise defined as the study of flow behavior. Rheology is a well established area of study for a wide range of materials. In other words, rheology is concerned with the time-dependent deformation of bodies under the influence of applied stresses, both the magnitude and rate, whether the bodies be solid, liquid or gaseous. The term rheology originates from the Greek words 'rheo' translating as 'flow' and 'logia' meaning 'the study of', although as from the definition above, rheology is as much about the deformation of solid-like materials as it is about the flow of liquid-like materials and in particular deals with the behavior of complex viscoelastic materials that show properties of both solids and liquids in response to force, deformation and time. In practical application, rheology is most often applied to fluid materials (or materials that exhibit a time-dependent response to stress). In this sense, a secondary (or sub) definition of rheology is the study of the relationship between force (stress) and deformation (strain) of engineering materials under a set of loading and environmental conditions. (*A Basic Introduction to Rheology*, 2016)

Knowledge of rheological behavior is essential in numerous ceramic processing operations that involve slurries or pastes, including (Moreno, 2001):

1. Beneficiation (e.g., wet mixing and milling, atomization, and filtration).
2. Shape forming (e.g., slip casting-based methods, extrusion, roll forming, injection, and tape casting).
3. Coating/deposition (e.g., enameling, dipping, screening, printing, electrophoretic deposition, and spraying).

Rheometry is the method used to analyze the rheological behavior of a material. Rheological properties of a material are noted when a force is exerted on it, and as a result of which it deforms or flows. The extent to which a material deforms under a certain force depends strongly on its properties. Therein, rheometry refers to the experimental technique used to determine the rheological properties of materials.

Rheometers are measurement instruments for materials flow used to determine flow properties and viscoelastic properties of a material, the most notable of which is a:

- Rotational rheometer (a.k.a., viscometer) - measures shear flow and viscosity.

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TABLES

Table 1. Materials > Mechanics*: Major areas/branches of continuum mechanics.*

<table>
<tr><th colspan="4">Major Branches Of Continuum Mechanics</th></tr>
<tr><th>Type</th><th>Sub-Types</th><th colspan="2">Descriptions and studies</th></tr>
<tr><td rowspan="4">Continuum mechanics
The study of the physics of continuous materials</td><td rowspan="2">Solid mechanics
The study of the physics of continuous materials with a defined rest shape.</td><td colspan="2">Elasticity - Describes materials that return to their rest shape after applied stresses are removed.</td></tr>
<tr><td>Plasticity - Describes materials that permanently deform after a sufficient applied stress.</td><td rowspan="2">Rheology - The study of materials with both solid and fluid characteristics.</td></tr>
<tr><td rowspan="2">Fluid mechanics
The study of the physics of continuous materials that deform when subject to a force</td><td>Non-Newtonian fluids do not undergo strain rates proportional to the applied shear stress.</td></tr>
<tr><td colspan="2">Newtonian fluids undergo strain rates proportional to the applied shear stress.</td></tr>
</table>

Measurement Accounting System

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Abstract

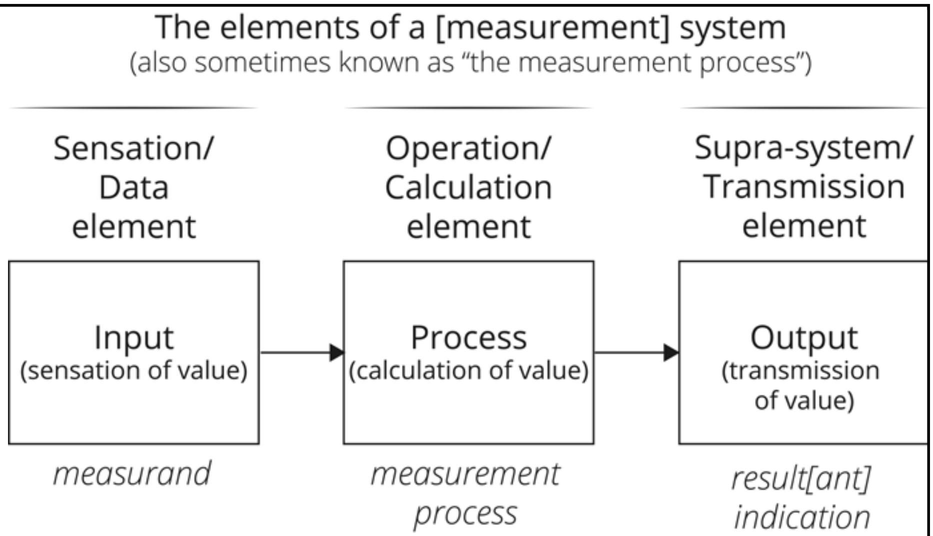
This article explores the vital role of measurement in the context of material systems, highlighting the importance of units, quantities, and taxonomies in the precise evaluation and management of materials. Material systems, consisting of the surfaces of objects, encompass a wide range of material types, compositions, flows, and materialization methods. To effectively reconfigure society at a material level, accurate measurements of the components that constitute society's physical infrastructure are essential. These measurements, particularly the distances between materials, are critical for engineering solutions that align with societal needs.

The article emphasizes how measurement serves as a foundational element in decision-making processes and operations, facilitating the development of an optimized habitat service system. This system aims to achieve global human need fulfillment and ecological regeneration by ensuring that material components are systematically coordinated. The process of measuring, therefore, is not merely a technical necessity but a strategic approach to material usage and coordination, enabling the deliberate reconfiguration of societal structures for enhanced sustainability and well-being.

By examining measurement units, quantities, and taxonomies, the article underscores the principle that effective coordination and optimization of material systems depend on what is measured. In essence, the precision and nature of measurement directly influence the potential for societal advancement, illustrating that the deliberate and informed application of measurement is key to achieving a societal configuration that maximizes human fulfillment within the constraints of available knowledge and resources.

Graphical Abstract

Figure 5. *The elements of a measurement system include sensation of input data, a means of determining alignment to prior sensed and/or prior synthesized values, and means of communicating the result of the alignment determination.*



1 Measurement in physical science and engineering

Science, engineering, and the material aspects of community are built upon measurement. Measurement is fundamental to scientific investigation and engineering. Hence, measurement is the foundation of science and knowledge. How well phenomena are measured affects what we know about them, and rigor in measurement increases the validity of analytical work. Measurement is the foundation of scientific inquiry. In order to test hypotheses, theoretical concepts must be observed at the operational level. In simple terms, only that which is defined can be measured. The physical task of designing and constructing an object (a.k.a., something) into the environment relies on measurement. In other words, engineers (i.e., individuals and systems that do these tasks) rely on measurement (and hence, metrology) to accurately design and develop physically functional systems. In order to have safe functioning of a material system it is essential for the systems design remain in some measured degree of alignment with the existent world and the principles of which it is composed.

In science, measurement is required to validate hypothesis and attain understanding. Ultimately, all measurements are used to help make decisions. Poor quality measurement data will result in inaccurate findings and faulty decisions. All measurements may eventually contribute to a[n optimal] decision. Measurement is required if actualized (e.g., materialized) systems are to operate safely and remain in alignment with our highest fulfillment. Measurements are often associated with control or regulatory mechanisms. Therein, measurement allows for traceability and adaptive feedback. For example, in air-conditioning systems, temperature measurements determine whether heat flows are increased or decreased. In each case, the measurements precede decisions to increase or decrease, or to reject or accept.

In order to communicate results unambiguously it is necessary for each of us to share the same scale for a quantity and to have access to the standards that define the scale. For metric scales the traceability problem is relatively simple: all measurements have to be related to a single standard. For the other scale types, the traceability problem can be more complicated because more standards are required.

In part, physics concerns observations, quantified through measurements, and expressed in units. The evolution of understanding around physical units is inevitably intertwined with a growing understanding of physics, the universe, and science itself. For example, after the introduction of the 'Celsius scale' (a concept based on the freezing and boiling points of water), it was only a matter of time before the notion of 'absolute zero' was conceptualized, and the 'Kelvin scale' was established. The Kelvin scale is based on the concept of "absolute zero". At "absolute zero", a hypothetical temperature, all molecular movement stops - all actual temperatures are above absolute zero. The kelvin scale has allowed for the measurement and construction of more complex[ly functional] technologies. Note here that the size of one kelvin degree is the same as the size of one degree Celsius.

> **APHORISM:** *To control the variable, it is first necessary to measure it. To measure the variable, it is first necessary to define it. To define the variable, it is first necessary to experience it. To experience the variable, it is first necessary to exist in a relationship.*

1.1 Supra-system measurement objectives

> *"When you can measure what you are speaking about, and can express it in numbers, you know something about it; but when you cannot measure it, cannot express it in numbers, your knowledge is of a meager and unsatisfactory kind; it may be the beginnings of knowledge, but you have scarcely, in your thoughts, advanced to the stage of science, whatever the matter may be. So therefore, if science is measurement, then without metrology there can be no science."*
> *– Lord Kelvin*

In practice, a supra-system applies measurement for one purpose (that is, environmental information acquisition), and four main objects:

1. **Discovery** – by a comparison of something of a presumably known quantity with something similar of an unknown quantity.
2. **Diagnosis** – by a timely comparison of the actual quantity value with its normal range.
3. **Alarm** – by continuously checking if the quantity value is inside or outside a parameter range.
4. **Titration** – finely tuning an adaptive response action to bring a quantity value toward a targeted range.

Each objective type has different requirements, with the final intention off all objectives being to facilitate optimal decisioning, which together with an optimized information model, facilitate optimal living.

A self-organizing system uses the results of measurement to adapt itself to its environment and to improved functioning. The purpose of the measurement system is to link the observer to the phenomenological process (i.e., map/model for the observer the phenomenological process).

The intention of measurement is to acquire more information to inform a more informed and reliable representation of the real world. Wherein, measurement is used for (informs) the orderly and reliable representation of observation (i.e., measurement is the reliable, usable, and practical representation of reality).

1.2 Human decisioning and measurement

Humans desire material fulfillment, which comes [in part] from a specifically ordered approach to informing decisions:

1. **Quality [of material fulfillment]** - In order to generate and sustain fulfillment, it is necessary to take decisions.
2. **Valid decisions** - The optimal decisions cannot be made unless there are good numerical data on which to base those decisions.
3. **Correct numerical data** - Those numerical data, in turn, must come from measurements, which require accuracy [if they are to be useful in deciding optimally].
4. **Calibrated measurement (accurate measurements and calibrated instruments)** - The only way to get "good" numerical data is to make accurate measurements using calibrated instruments.
5. **Traceable standards** - If it is important to compare some [set of] measurements to other measurements made at other places and other times, the instruments must be calibrated using traceable standards.

1.3 The habitat service system measurement operational subsystem

Measurement is a system's process, because its results provide feedback that allow the supra-system to optimize its conditioned functioning. The material measurement system is part of the Community's core information system.

The measurement system integrates into the habitat service system as follows:

1. System: information system core
2. Sub-system: information acquisition and data processing
3. Operations: measurement (measuring), modeling, and calculating
4. Inputs: measurable information
5. Outputs: measurement models > procedures > scales > indications

The associated science and application of measurement is known as, metrology.

Every aspect (entity) of the habitat service system is measured for the optimization of our fulfillment and the well-being of our ecology. Each supra-system and sub-system involves measurement and all operational systems have performance/operational metrics. Therein, there are multiple sub-types of metrics including, but not necessarily limited to: community metrics, project metrics, product/service/process metrics, and quality metrics.

1.4 The function of measurement

Measurement allows for the design, development, and operation of technology. Engineered objects must be designed and developed within fairly narrow limits of tolerance it they are to work at all, particularly if operational systems require interchangeable parts. In this sense, measurement is a [conceptual] device for standardization, by which there is assurance of equivalences among objects.

A second function of measurement, one which shows its scientific importance, is to make possible more subtle discriminations and correspondingly more precise descriptions.

Unambiguously detailed classifications allow for a greater understanding of the principles of reality. Knowing that one thing "depends on" another is of incomparably less scientific worth than being able to say to just what extent changes in the first correspond to changes in the second.

Measurement applies to the process of inquiry in general the ability to verify, predict, and explain. In other words, measurements makes verification, prediction, and explanation possible (i.e., it makes science possible).

> **INSIGHT:** *Measurement is the comprehended awareness of a change from baseline (a reference).*

1.5 International measurement standards

The International Vocabulary of Metrology (VIM, ISO/IEC Guide 99:2007) is the international standards document for metrology terminology, produced by the Bureau International des Poids et Measures. In general, a vocabulary is a "terminological dictionary which contains designations and definitions from one or more specific subject fields" (ISO 1087-1:2000, 3.7.2). The terminological vocabulary in the VIM pertains to metrology, the "science of measurement and its application". It also covers the basic principles governing quantities and units.

The VIM is now in its third edition (as VIM 3). VIM 1 and VIM 2 were mainly conceived by physicists and engineers for measurements in physics and engineering. Chemical measurement was considered to some degree in VIM 2.

The current ISO standards for measurement are:

1. The International Vocabulary of Metrology (VIM)
   - *VIM3: International Vocabulary of Metrology*. (2017). Bureau International de Poids et Mesures. [bipm.org]
   - *VIM4: International Vocabulary of Metrology. Fourth edition - Committee Draft (VIM4 CD).* (2021). Bureau International de Poids et Mesures. [bipm.org]
2. ISO Guide to the Expression of Uncertainty in Measurement (GUM).

- *Evaluation of measurement data - Guide to the expression of uncertainty in measurement*. (2008). Bureau International de Poids et Mesures. [bipm.org]

1.6 The international standards definition of measurement

The current definition of measurement (in VIM 4) is:

> *Measurement is a process of experimentally obtaining one or more quantity value(s) that can reasonably be attributed to a [defined] quantity. Therein, measurement is the association of one or more numerical values to existent objects or events.*

Here, there are two principles:

1. Measurement is a process of attribution (to an earlier quantity or procedure).
2. The result of which is one or more quantity values and a measurement uncertainty).

Formerly (VIM 1), measurement was defined as:

> *A quantity subject to measurement. The measurement process is one of determining the value for the quantity.*

Per this definition of measurement there are two principles:

1. A determination process whose ideal outcome pre-exists the measurement itself.
2. The measurand has a single value.

1.7 Measurement sub-defined

Generally speaking, measurement is the process of observing, determining, and recording observations, in order to facilitate understanding and decisioning. That which is recorded by an observer becomes an input into a larger information system that a population uses to adapt. And yet, it is also general parlance for measurement to mean the activity of assigning a number to an observed relationship. Measurement is the assigning of numbers (or words) to empirical objects/events according in some definite organization[al model].

> **NOTE:** *Whereas measurement facilitates understanding [in part] by mathematical-statistical operations, decisioning is facilitated by the application of algorithms optimized for adaptive control.*

Measurement is a determination whose outcome pre-exists the measurement itself. The process determines (as in, "makes known") the value of some [existent] object or event (i.e., "thing") in relation to a pre-existing model of possible [finite or infinite] values, which are logically relatable.

Here, measurement is:

1. An inquiry into a fundamental domain of unitized information in the real [existent] world;
2. The result of which a greater understanding of the real world is programmed;
3. And hence, upon which a more optimized living environment is constructed.

Measurement is the usage of logical information acquisition and determination processes that experimentally interact with a quantity as the property of an entity that expresses some amount of an existence.

Therein, there is an order relation if some expression of a property can be greater or lesser (in quantity) than another. If there is an order relation, then there is a scale. Data with scale properties can be input into statistical operations to derive greater understanding and functionality from the surrounding world.

Measurement is the quantitative comparison between a predefined standard (or procedure) and a measurand to produce a measured result. Measurement is sometimes described (particularly in the social sciences) as the quantification of qualitative observation (of that which may or may not be observed).

Measurement involves 3 principal elements:

1. **The measurand** – quantity whose value is to be measured.
2. **The measurement system** – content, processes, and instruments for comparison.
3. **The observer or control unit** – the supra-system that uses and otherwise performs calculations on the data, and updates the measurement system information and available measurand classifications.

Measurement has two principal inquiry-problem categories:

1. Determining the value of an attribute/property of an entity.
2. Determining the class of entities to which the measurement relates.

1.8 The fundamental forms (types, procedures and operations) of measurement

All measurement takes one of three different fundamental forms (types, procedures and operations) of measurement. At the fundamental, level measurement is composed of the following axiomatic information processes: counting, ordering, and/or sorting. Each of the processes is itself a separate measurement process, although in a measurement system, these processes are generally combined. These processes may otherwise be called the [fundamental] procedures and/or operations of measurement.

The three fundamental forms (process types) of measurement are:

1. **Counting (bijection)** – identifying [numerical] iterations of a similar [conceptual] pattern. This is by far the most commonly understood referent of the term 'measurement'. Bijection is how counting is defined; bijection actions are fundamental to counting for the axiom of counting is assigning copies to a number line (where, the number line is a bi-jection of the copies).
2. **Ordering** – identifying the numerical priority/positionality of a similar [conceptual] pattern. This is the process of arranging iterations into an ordered structure (i.e., arranging in order). Ordering is done through a categorial systems of tables.
3. **Sorting** – arranging [conceptual and/or numerical] iterations of a similar [conceptual] pattern into categories representing sub-divisions. Sorting is done through a findable system of databases.

These three forms are not just different versions of measurement. They are different fundamental types. The specific properties of each fundamental form of measurement determine:

1. The kinds of mathematical and statistical procedures that can be legitimately applied to a set of measures; and
2. The kinds of conclusions that can be meaningfully drawn from the application of the operations which have been run.

1.9 Characteristics of the conception of "measurement"

"Measurement" can be viewed from the following perspectives and maintains (to a lesser or greater degree) the following characteristics:

1. **Measurement theory (a.k.a., the mathematical theory of measurement)** is the view that measurement is the mapping of qualitative empirical relations to relations among numbers (or other mathematical entities). The conditions under which relations among numbers (and other mathematical entities) can be used to express relations among objects. In measurement theory, and in mathematics generally, there is a scale of possible, increasingly complex, mathematical operations.
2. **Systems theory** views measurement as the acquisition of information from an environment (including, sub-systems) for adaptive and optimized functioning.
3. **Information theory** views measurement as the gathering, interpretation, interpolation, and integration of information about a system.
4. **Signal theory** views measurement is the reception of a signal from noise and the subsequent mapping of a new iteration to a pre-existing structure for understanding signaled iteration (i.e., sensation).

And, measurement can be viewed as having the following approach-oriented characteristics:

1. **Operational** – measurement is viewed as a set of operations (operational understandings) that shape the meaning and/or evolve the use of a quantity-term in the context of a larger intention.
2. **Empirical** – measurement is viewed as the estimation of mind-independent properties and/or relations.
3. **Analytical** – measurement is viewed as the discovered exploration of empirically operational patterns.
4. **Synthetical** – measurement is viewed as the comparative integration of a standard and a measurand, which produces a result upon which mathematical-statistical operations may be run to integrate new information about an existent [environmental] system.
5. **Model-based** – measurement is the coherent assignment of values to parameters in a theoretical and/or statistical model of a process. When measured parameters are numerical they are called "quantities". Here, measurement proceeds by representing the following interactions with a set of parameters, and assigning values to a subset of those parameters based on the results of the interactions:
   A. An object or event of interest.
   B. An instrument for measurement.
   C. An environment within which the measurement procedure occurs.

1.10 The "determination" attribute of measurement

Measurement is, in part, a process of determination (or estimation. Measurement involves a determination (and/or estimation). Measurement is [in part] the estimation or determination of extent, dimension, or capacity (of a system), usually in relation to some standard and/or unit of measurement. The result of the process of measurement is the determination of a number of units of the standard (as a real number times a unit).

Among the attributes of measurement (i.e., primary characteristics or principles that compose the concept of measurement), 'evaluation' is one of those primary attributes. Here, evaluation refers to the processes of comparing, determining, and reporting a (counted) numerical value from a quantity-type source of information. The numerical value exists along a continuum of values. Here, previously unknown information is compared (viewed synchronously for pattern recognition) with a pre-existing [measurement] model [of referentially standardized, calibrated objects]. The value which is determined to map ("mirror") with the greatest alignment is then recorded into memory.

During these processes, the following events occur:

1. A numerical value (number) is determined.
2. That value is assigned to the quantity.
3. The number and quantity-type reference point are recorded into a memory.

Whereupon, a computational system (which may or may not be classified as part of the measurement system) initiates mathematical operations (as statistical calculations) on the data to acquire (determine) greater understanding (new information accurate to the accurate uncertainty of the data).

1.11 The "mapping" attribute of measurement

Measurement is, in part, a mapping process; it is an activity of assigning a number or symbol to an entity in order to characterize a property of the entity according to given rules. In specific, measurement is an empirical to formal comparative mapping process that uses numbers. Measurement presumes that it is possible to preserve an empiric relation (connection with reality), using a numerical relation [known as a magnitude, quantity, or value). Measurement involves the application of 'number' to formally map empirical processes. Here, a number system facilitates real to abstract world transposition.

A number system allows for the empirical representation of real world patterns [of objects and relationships]. Measurement may be viewed as a mapping from the empirical world to the formal, abstract[ed] world. Here, the real world is the domain of the mapping, and the mathematical (or linguistic) world is the range.

For a measurement, there must be a corresponding numerical relation system, with symbols representing the entities and numerical relations corresponding to the empirical relations.

Mapping requires that a relationship shall have been established between the objects and the numbers so that each object there corresponds exactly one number, one point in the abstract space. However, in general, several objects may be mapped on onto the same point.

When the objects are so selected that the rule of assignment permits only one object to be mapped onto any point, then there is a on-to-one correspondence.

> **NOTE:** *The space into which objects are mapped need not consist of numbers. It would be more accurate to say that what is assigned to each object is a numeral rather than a number. The rule of assignment determines certain relationships among the numerals, and it is this pattern of relationships that constitutes the abstract space.*

This type of mapping follows a principle known as the 'representation condition'. The 'representation condition' states that a measurement mapping must map the entities into numbers and empirical relations into numerical relations in such a way that the empirical relations preserve, and are preserved by, the numerical relations. In other words, the relationships which exist between the attributes of objects in the "real world" are preserved in the numbers (or words) assigned these objects in the formal/abstract world.

There are two principal types of mapping processes:

1. Qualification is the mapping of observation to characterization.
2. Quantification is the mapping of observation to number.

1.11.1 Numbering in measurement

> **Insight:** *Numbers can be applied wherever there exists logic.*

Measurement consists of rules (applied logic) for assigning numbers (numbering) to attributes of objects. More specifically, measurement is the [logical] assigning of numbers to empirical events via the application of a set of rules (predefined rules that reference a standard rule). In essence, measurement is possible because of the syntax category (concept) of a 'number'. Numbers express [the presence of] delineation or iteration. In a sense, measurement is [in part] numerical input intended to map the delineation or iteration of observed relationships. In measurement, numerical inputs (numbers) represent a quantity (value or count) of entities in relationship.

In other words, measurement is the assignment of numbers to objects or events in a systematic manner. Or, said another way, measurement consists of rules for assigning numbers to attributes of objects/events. By definition, any set of rules for assigning numbers to attributes of objects is measurement. Measurement of some attribute of a pattern ("set of things") is the process of assigning numbers or other symbols to patterns ("things") in such a way that relationships of the numbers or symbols reflect the [real] relationships of the attribute being measured.

Measurement is the application of a mutually applied semantic system of numerical pattern recognition and categorization used to quantify a property (i.e., attribute, trait, or characteristic) of an existent system. A measurement, itself, takes the form of a number and accompanying unit that connects the number to a meaning, a significant event or concept. The number represents a comparison between the property of the system (or object) being measured, and the same property of a given 'unit of measure'.

Hence, measurement is the assigned estimation or determination of a number as a given 'unit' to a characteristic (property) of an existent object or event (represented as a concept), which can be compared through numbering to other objects or events (i.e., other concepts).

Measurement is the process of systematically assigning numbers to objects and their properties to facilitate the use of mathematics in studying and describing objects and their relationships. Measurement uses numbers to quantify - to process (transform) information into a [type of information known as a] 'quantity', so that mathematical logic may be applied. Numerical input allows for the logic and precision of mathematics (and hence, calculation) to be applied to the study of nature and the design of systems reproducing through its principles. Therein, measurement uses numbers to describe (real world) processes and events.

INSIGHT: *In order to coordinate resource flows in the material (physical) environment for human and ecological fulfillment, the material environment is initially understood to be composed of 'physical quantities', which logically, are quantized in some unit (by an axiomatic conception of existence).*

1.11.2 Mathematical integration and probability in measurement

Here, there is a pattern (variable), which has been separated into a sequence of sub-patterns (sub-set), and there is the probable recognition and integration of that pattern into an adaptive model of the original pattern, which can be described mathematically.

In mathematics, a 'measure' is a function that assigns a non-negative real number (or +(numeral infinity sign)) to (specific) subsets of a set variable (commonly represented as "X", "x", "x", "x", or "y", or possibly any other letter). This variable, the measure[-and], must be countably additive – the measure of a 'large' subset that can be decomposed into a finite (or countably infinite) number of 'smaller' divided subsets, is the sum of the measures of the "smaller" subsets.

INSIGHT: *Variables (e.g., x) are measurable functions, and units (e.g., mass, length) are measurable [real world] functions. There can also exist derived functions (e.g., power).*

In mathematics, the 'additivity' and 'sigma additivity' (a.k.a., 'countable additivity') of a function defined on subsets of a given set are abstractions of the intuitive properties of size (length, area, volume) of a set. Additivity is combinability (as in, the ability to [be] combined). The combing system is called 'add', and the process therein that does the combining (additivity) is called 'adding'.

In mathematical analysis, a 'measure' of a 'set' is a systematic process of assigning a number to each suitable subset of that set, intuitively interpreted as its 'size'. In relationship to visualization, a 'measure' is a combined supra-representation (conceptualization) of the [sub-]concepts of length, area, and volume. Here, parabolic>plane>solid ["Euclidean"] geometry is used to determine suitable subsets of the n-dimensional parabolic>plane>solid ["Euclidean"] space (Rn). Points in Rn are represented in coordinates as x = (x1, ..., xn), where x1, ... , xn are real numbers, and adding subscripts to a point in R n will always represent its coordinates.

There are four operational requirements that must be met for the combining of objects in measurement are:

1. **Commutative** – when two objects are combined the outcome must be the same regardless of which object is taken first.
2. **Associative** – the outcome must be the same regardless of how the combined objects are grouped – that is, the result of combining an object with the combination of two others must be the same as combining with the third the combination of the first two.
3. **Incremental** – the operation must be incremental with respect to the ordering of relation. If two objects are equivalent with respect to that relation, then the combination of either of them with some third object is no longer equivalent to the other one, but precedes it in the order established by the relation.
4. **Equalities** – if the two equivalent objects are each combined with objects equivalent to one another, the outcomes must be equivalent.

INSIGHT: *Our mapping of the underlying nature of reality is not discrete integers, but continuous functions.*

Here, measure theory is the formal model (and its underlying logical understanding) for how mathematics defines integration and probability:

1. **Integration (∫; in operation, ∫(x); a.k.a., function)** – measurable subsets are assigned numbers by [an operational] 'function'. The procedure of calculating

an integral is called integration. An integral is a number associated with a function, and is usually called a "definite" integral. A "definite" integral is defined by a de-finiting (boundary or limiting) process. A definite integral is a formal calculation of area beneath a function. Integrals may represent the (signed) area of a region, the accumulated value of a function changing over time, or the quantity of an item given its density.

A. The modern notation follows from Leibniz's notes, and given a real-valued function and real numbers, the definite integral is written:
   - ∫ab f(x) dx

B. Definite integrals have an indefinite form as well that serves as a partial inverse to differentiation. Just as differentiation measures a function's incremental changes, a definite integral attempts to "un-do" that. Hence, integrals focus on aggregation rather than change.

2. **Probability** – the measure assigned to the whole set is given the value, 1. Therein, measurable subsets are events whose probability is given by the measure. A probability measure is a measure with a total measure of one. A 'probability space' is a measure space with a probability measure. Every probability space gives rise to a measure which takes the value 1 on the whole space (and therefore takes all its values in the unit interval [0, 1]). Such a measure is called a probability measure.
   A. A 'probability' or more precisely 'a finitely additive probability measure' is a nonnegative set function P(·) defined for sets A ∈ B that satisfies the following properties:
      - $P(A) \geq 0$ for all $A \in B$, (1.2) $P(\Omega) = 1$ and $P(\Phi) = 0$.

1.12 The common parlance definition of measurement

NOTE: *In a mathematical operation, the input is an operand, and in a measurement operation the input is a measurand. The output of measurement is an operand value.*

In common parlance, measurement is the set of operations having the object of determining the "value" of a "quantity" of some "thing". Therein, the 'measurand' is that which is being measured; it is the quantity being measured. The result of a measurement [operation] is a value attributed to a 'measurand'.

Here, there are three important aspects of measurement not apparent from common parlance "definition" of measurement above that do apply to measurement:

1. In concern to number: The results of measurement need not be numeric: grade L, red, and carbon are all legitimate measurement results in the appropriate context. One of the most valuable aspects of symbolic representation is that the symbols in the models may be used to make predictions. Mathematical models and numeric symbols particularly help to quantify predictions that might otherwise be qualitative (or subjective).
2. In concern to intention - Every measurement has a purpose. This is the distinction between a meaningful measurement and meaningless assignment of numerals. In a great many measurements, especially outside the calibration laboratory, the purpose influences the design and outcome of the measurement. Consequently, measurement results may have meaning only within the context of that purpose. Results used for other purposes or gathered without purpose are potentially dangerous.
3. In concern to decisioning - Decisions are associated with real world consequences, which may be beneficial or not beneficial [to human fulfillment and ecological stability]. This highlights the need to know the uncertainty in a measurement in order to assess its applicable usefulness.

Measurement is the symbolic representation of existence to aid in understanding, adapting, and decisioning. It is the process of symbolically representing, organizing new information according to a pre-existing model (pattern) of information.

Any of the following could be symbolically represented through measurement (Read: including, but not limited to):

1. Concept, state, object, event.
2. Quantity, magnitude, amount, weight, degree, value.
3. Quality, property, attribute, characteristic.
4. Principle, rule, statement, argument, variable.

1.13 Conditions for measurement (measurability)

APHORISM: *Only quantity is measurable.*

Measurability can be understood in a number of different ways. Axiomatically, for any measurement, the characteristic (or property) to be measured is a quantity, in that it is an amount of something. Thus, it may be thought of as the sum of a number of elementary parts, or units, of that something. Here, measurement is equivalent to the counting of such units (with reference to a standard set of those units). From this analogy, it is possible to derive the conditions that must be met in order for measurement to make sense, that is, the conditions for measurability.

The minimal conditions of measurement are:

1. **A system of counting (applied pattern recognition)**: Counting is possible due to the properties of natural numbers, which undergo an order, based on the relation "greater than or equal to," and may be added to each other. Counting is a way of assigning numbers to objects. The objects being measured are classes, and the individuals are numbered in order to be able to assign a measure to the class that they compose. Counting is a way of determining how many things there are of a certain kind.
2. **Empirical existence (ordered relation of experience as entity):** Measurement implies the empirical existence of the entity for which some magnitude (count) may be specified. Measurement is not a thought experiment, it is empirical.
3. **Properties of existence (properties)**: What is measured is not an entity (e.g., a table or bird), but an property (the other type of entity) related to it (such as, its length or mass).

In concern to counting, objects can be counted, or ordered with respect to some attribute, does not suffice to enable the measurement of magnitude in such a way that arithmetical operations can be performed on the assigned numbers. Here, it is possible to answer questions of more or less, and even to determine how many objects in the field have a greater or smaller magnitude than some given object.

That which is measurable is:

1. Everything that is experienceable, or can be translated into experience.
2. Everything that is observable, or can be translated into observation.
3. Everything that is sensible, or can be translated into sensation.

Measurement may also be understood from perspective of an adaptive system – a system that uses the result of measurement to adapt its decided functioning. Therein, there exists the:

1. **The ability to measure (operational measurability)** - Operation pre-supposes functional design. Measurement as an operation (or series of operations) pre-supposes, at least:
   A. The method of comparison.
   B. The pattern for comparison.
   C. The procedure and apparatus used for obtaining the comparison must be provable.
   D. There are two operational requirements that must be met for measurement to occur:
      1. The standard (of reference) that is used for comparison must be accurately defined.
      2. There must be a pre-existing understanding (i.e, a model) to compare with that which is being measured.
2. **That which has the ability to be measured (empirical measurability)** - Measurability is an aspect of empirical properties (or, an empirical property), which allows for comparison with other empirical properties in terms of their ratio. The measurability of that which exists may be established by demonstrating ("proving") that:
   A. The characteristic under investigation involves an empirical order relation.
   B. Then, either:
      1. A physical addition operation allows the construction of a reference measurement scale and the performing of measurement by comparison with it.
      2. Or, by finding some physical law that allows the measure to be expressed as a function of other quantities.
3. **Utilization of the measured result (adaptational)** - For measurement to be of use (i.e., for the output to be useful for the larger system),
   A. The supra-system:
      1. There must be adaptive integration of control functionality. The larger system must be able to use the new information to change every aspect of itself and its decisioning.
   B. The measurement system:
      1. Validation must be acquired.
      2. Uncertainty must be accounted for.

Measurability may also be understood from the perspective of magnitude. Having magnitude (quantity) is sufficient for measurability. All quantities (including ordinal quantities) have magnitude. Note here that nominal properties do not have magnitude (and conversely to quantities that form scales, nominal properties cannot). Nominal properties do not have magnitude, and therefore, are not measurable; however, nominal properties are usable in a measurement system.

Finally, measurability can be viewed from two perspectives:

1. That which is conceptually "measurable" is a quality.
2. That which is numerically measurable is a quantity. And, a quantity is either a scalar or a vector.

1.14 Clarification of the term "measure"

In common parlance, the word ""measurement" is used to refer to the result of a measurement process as indicated by a measuring instrument. In the science of measurement, this result is known as an "indication", and not a “measurement” or a “measure”. It is logical that the term "measurement" relates to the whole [systems-oriented] process of obtaining a quantity value (indication) through comparison.

Measurement is sometimes defined as the act of determining a measure (quantity, or quality) of some thing. Herein, a measure is a single quantitative attribute of an entity – the basic building block for a measurement. To measure is to express as a number (or measure, or quantity) an extent aspect or aspects of a physical and/or conceptual system, a "value" (in some unit). To measure is to compare in a significant way any component (part) of a situation (system). In engineering, complexity is expressed mathematically using numeric sequencing (numbers) and numeric operators (functional symbols).

Measurement (verb) is a form of observation-memory (verb), where the result of the observation-memory (verb) is the assignment of a quantity to a thing (the subject being observed). In common parlance, the term measurement may refer to the act of measuring, counting/sequencing numbers to mirror a pattern in the phenomenological environment, and then, take the data and run statistical operations on it.

> **NOTE:** *The output of that which measure does is called an ‘indication’ (also sometimes called a measure, a measurement, or a signal response).*

A measure is a quantitative indication of the extent, amount, dimension, or size of some attribute of a system, product or process. A "measure" is a quantity or amount given as a real number. It is the result of a method that involves an inquiry resolution process to determine how much [of something which is quantifiable] there is, or how many there are. A measure is a quantity logically assigned (given) to something (physical or conceptual) that can be quantified. Measurement (measuring and mensuration) is the act or process of assigning numbers to phenomena according to a rule “the measurements were carefully done”; “his mental measuring proved remarkably accurate”.

There has long been confusion over the definition and appropriate usage of the term ‘measure’. Although measurement is what something does, the term "measure" has several meanings in common parlance. For this reason, it is generally not used without further qualification. For example, the term measure is often used in the following qualified ways:

1. An instrument of measure – an instrument, a device, a tool for determining measurements.
2. A measuring device - an instrument, a device, or a tool for determining measurements.
3. A unit of measure – a constant quantity that serves as a standard of measurement for some dimension.
4. A method of measure – the steps, stages, or processes taken to determine a measurement.
5. A scale of measure (level of measurement) - a classification that describes the nature of information within the numbers assigned to variables.
6. A particular measure[ment] – the ‘indication’, result, quantity value, or determined value of a measurement.

> **NOTE:** *In mathematics, a compound measure is a measure composed of two (or more) other measures (of a different type). A compound measure is based on two component measures (i.e., it is a measure with two integrated compounds; it is a “compound” measure). For example, speed is a compound measure composed of a measure of length (kilometers) and a measure of time (hours). Density is also a compound measure, composed of a measure of mass (grams) and a measure of volume (cubic centimeters). Density refers to how compact a substance is.*

1.15 Clarification of the term "metric"

In common parlance, the term metric has the following different, but related, meanings:

1. In general, metric means the whole conception and process of measurement. Etymologically, according to the Oxford dictionary, the word ‘measure’ is derived from the Latin word, mētīrī (or Ancient Greek, métron). Hence, the words measure and metric are often used synonymously/ interchangeably. Here, the difference between metric and measure is:
   A. A ‘measure’ (dimension) is a fundamental or unit-specific term.
   B. A ‘metric’ can be derived from one or more measures (dimensions).
2. Tracking – In measurement, there is the tracking of that which is being measured over time. A ‘metric’ is a quantitative measure of the degree to which a system, component or process possesses a given attribute. A metric is a quantifiable measure that is used to track and assess the status of a specific process. Metrics are measures that are being tracked. There are two primary categories of tracked metrics:
   A. Performance metrics.
   B. Calibration (Diagnostic) metrics.
3. Standards – In measurement, there is the standardization of that which has been measured previously in time, for purposes of understanding, experimentation, and optimization. A ‘metric’ is a standard for comparison and/or reference. There are two primary categories of standard metrics:
   A. Performance standards.

A. Calibration (Diagnostic) standards.

Wherever measurement occurs there may be a metric. In practice, metrics are the result of tracking measurements over time.

> **INSIGHT:** *'Normalization' occurs when metrics (moral and numerical) that [are known to] cause suffering, become normal, accepted and opted for by a population.*

In concern to tracking, a metric is a measure or combination of measures for quantitatively assessing, controlling, or improving a process, product, or team. Here, a metric is a standard reportable measure used to assess an operation.

In terms of performance, a metric is the desired and/or intended operating numerical value. A metric is a performance value ("performance measure") to be met by a system's process. New measurements (Read: measurement results) are compared to metrics (selected earlier measurement results, benchmarks). The metrics represent the decided and/or optimal value that the measure[d result] should be. A metric represents an earlier measurement(s) against which later (or newer) measurements will be taken to ensure that the system producing measured signals is operating as objective[ly] and functionally as intended. A metric is a previously defined value that a system, when measured, should express. It represents an earlier measurement used as a reference for later measurements. Here, 'metric' means the "standard" numerical or qualitative value, which should be output as a result of the measurement operation.

For any given project or system, where inputs, processes, and outputs are measured, each may have its own associated metric. For example, the inputs must be of a certain metric type (specification metrics); the processes have performance metrics (functional metrics); and, to the supra-system, the outputs have their own metrics usability metrics.

As a standard, a metric is a point of comparing or evaluating some property or attribute of existence and/or performance. A metric is a referential comparison standard against which some property, attribute, characteristic, or performance is being compared.

> **NOTE:** *In concern to measurement as a mapping process, the measurement mapping and rules are usually, together, called a metric.*

In terms of measurement, the standard to which the measurand is being compared is [called] a metric. For example, imagine the length of a solid object (measurand) being measured along ("against") a ruler. The ruler represents the measurement standard (i.e., the metric). And, that ruler was likely made from an earlier standard [metric]. If the ruler were a one meter standard ruler, then the metric [for measuring the object] would be a one meter standard ruler.

The process of defining new performance metrics involves, in order:

1. Determine entity category.
2. Identify measurement entity.
3. Identify attributes of the entity that are to be measured.
4. Define metrics.
5. This will define "success" or "failure" to meet a performance or other operations objective.

2 Numbers

A.k.a., Counts, sequences, enumerations.

Within the context of measurement, numbers serve as the foundational of the measurement system. Numbers record representations of quantifiable attributes and motions, making them indispensable for assessing, monitoring, and controlling resources with precision. Be it the quantification of raw material volumes, labor hours, energy consumption rates, or any other measurable aspect of the world, numbers function as the universal language of measurement. They establish the crucial framework for decisioning and efficient material coordination, providing society with the tools to navigate the intricate terrain of resource accounting and habitat production with confidence, accuracy and clarity. Throughout society, numerical information is systematically identified, recorded, categorized, manipulated, and applied in various fields of science, technology, engineering, and mathematics, facilitating a structured approach to societal [human need] fulfillment accounting, analysis, and problem-solving in diverse domains.

It is important to note here that numbers (or, more specifically, the act of counting), are inextricably interconnected with the discipline of mathematics. Mathematics itself is a structured system for using numbers to describe, discover, and control physical phenomena. Mathematics is an area of knowledge that includes the topic of numbers, formula, and quantities and their changes. Arithmetic is the beginning branch of mathematics that deals with numbers using various operations on them. Basic math[ematics] operations are addition, subtraction, multiplication and division.

In mathematics, the concept of "number" encompasses various relationships and attributes, including:

1. **The mathematical conception of numbers**: Numbers can be understood in different ways, such as natural numbers for counting and sequencing, whole numbers for direct values, integers for inverse values, and further classifications like rational, irrational, real, imaginary, and complex numbers.
2. **The mathematical notation of numbers**: The methodological expression of a number.
   A. **Symbol representation** – a sign of operation and/or a representation of a constant [number].
   B. **Numeral representation** – the digits of the numeral system.
   C. **Radix/base** – the cardinal of the [non-repeated] sequence of digits in the number system. The finite number of digits used in the numbering process is called the radix/base [of the selected number system].
3. **The mathematical operation of numbers**: Work can be done on numbers using operators to produce lower entropy.
   A. Linear count operations:
      1. Addition.
      2. Subtraction.
      3. Multiplication.
      4. Division.
      5. Exponentiation.
      6. Root extraction.
   B. Equality count operations:
      1. Comparison (equal to, not equal to).
      2. Equality expressions (e.g., a = b).
   C. Order count operations.
      1. Comparison (greater than, less than, greater than or equal to, less than or equal to).
      2. Sorting.
      3. Finding maximum and minimum values.
   D. Binary count operations.
      1. Bitwise operations (AND, OR, XOR).
      2. Bit shifting.
      3. Binary addition and subtraction.
   E. Specialized operations:
      1. Trigonometric functions (e.g., sine, cosine, tangent).
      2. Logarithmic and exponential functions.
      3. Matrix operations (e.g., matrix multiplication, determinant calculation).
      4. Calculus operations (e.g., differentiation, integration).
      5. Set operations (e.g., union, intersection, complement).
      6. Statistical operations (e.g., mean, median, standard deviation).
      7. Complex number operations (e.g., complex multiplication, conjugation).

Every number has the following two attributes:

1. **Value**: The number a numeral represents is called its value.
2. **Sign**: The dimensional direction of the value. In general, there are two signs, positive (+) and negative (-). The number zero (0) has no sign and may be considered to have a neutral sign.

A number is a count or measurement, that is really an idea in "our" minds, which may represent a state or condition of the real-world. "We" write or talk about numbers using numerals such as “4” or “four”. "We" could also hold up 4 fingers, or tap the ground 4 times. These are all different ways of referring to the same number (i.e., value, count).

INSIGHT: *Number represents movement, counting is a movement.*

There are also special numbers (e.g., π, Pi) that can't be written exactly, because they are continuous/unending numbers, but are still numbers because they have meaning as a count, and practical usage. A number is [the value or count] of a set of something similar. It is the conceptual expression of an iterating pattern. A given pattern may or may not exist, and if it exists, then how many iterations of that pattern exist. Geometrically speaking, it may also be said that a number is the "sum" of identical (indistinguishable) fractal points. The concept "sum" introduces a mathematical concept/unit, sum (or algebraic total of that which is indistinguishable).

As a concept, "number" represents the presence of the iteration of information (i.e., the presence of patter). Once a pattern is present, logic (as math[ematics]) can be applied to process (calculate). A number is what satisfies the axioms of its number system. In mathematics, a number is a mathematical object used to count, measure, and label.

Numbering and mathematical logic are used to model and understand the universe:

1. To number is to understand iteration.
2. To map is to understand relationship.
3. To calculate is to understand creation.
4. To articulate is to create.

> **INSIGHT:** *The primary function of numbering object and spaces in community is for identification and wayfinding. Numbering allows for coherent creation and dis-creation.*

When a sensation is being measured by counting with numbers, the understanding is language independent, and numeration is language dependent visualized as a specific linguistic expression. More simply, the process of counting and understanding numeric values is universal and not tied to any specific language, but when you represent these numbers in a particular language, it becomes language-dependent and is expressed using linguistic expressions. In essence, counting is a universal concept, but how we represent those counts through language can vary.

Each characterized conceptualization of a number involves the linguistic/logical creation of a 'mathematical construct[ive]' operation (or process). Some of the following characterizations represent groups of constructs. Within that which is termed the "real" number system, there is an increasing order of mathematical constructive complexity, moving from natural numbers at the lowest order, to rational/irrational at the highest order. The misnamed, "imaginary" numbers, represent the extension of the number system into a second (conceptual and not object referential), angular (perpendicular) dimension. The imaginary notations are merely notations that represent concepts, and do not have a physical or tangible existence beyond their role as tools for conveying ideas, concepts, or values. They are abstract in nature, used primarily in contexts such as mathematics or theoretical discussions, where they serve a specific purpose without embodying any physical form.

2.1 *Number[ing] conception*

Number is the verb "to count". Number is a dynamic concept, and involves two or more frames of the universal movie. Number requires at least two frames of the universal move because the counter is making a comparison between two frames to increment the count higher a number of the same unit. Number is a comparison against other numbers. Change has to occur to count. Numbers, numerals, and operators are the language of mathematics.

1. Number (verb): to count (one, two, ...).
2. Numbering - naming each count (e.g., two shakes of the hand, three taps, ten objects). To give a new label to the amount (to the quantity of shakes of the hand, of taps, of objects).
3. Meaning depicted with a numeral.

The basic characteristics of numbers are:

1. Number = dynamic concept.
2. Number = the verb, to count.
   A. Only integers can be counted.
3. Cannot count to 0. The 0 cannot be counted. 0 is not a number because you can't count 0 anything. There is no unit of anything to count. 0 is the absence of numbers, absence of a unit of things to count.
4. Cannot count to infinity. Infinity just means you count forever.
   A. There is always a highest number, for example, running out of space in your notebook while writing increasingly higher numbers, because the material world is finite.
5. Fraction = operation.
6. Negative numbers = operation.
7. Numeral = symbol and not number. Numeral is the symbol used to represent counting.
8. Only integers can be counted; fractions, negative signs, decimals, imaginary numbers, etc., cannot be counted.
   - 2/3, for example, is a fraction of a whole unit (e.g., cut bread and eat 2/3 pieces).
     - 2 and 3 are numerals (in 2/3).
     - / = what you do with them (the operation).
   - 1.53, for example, is a fraction of a whole unit (e.g., measure 1.53 cm).
     - 35 = different format of a fraction (in 1.35).
9. In math, a field is a region of numbers with decreasing values (decreasing strengths) away from

ground zero.

> **CLARIFICATION:** *A fraction can be turned into a decimal, which is a different way of writing the fraction. Of course, the issue is that "we" can't count to a fraction. Only individual units can be counted. Measurement, unlike counting, almost always has to do with fractions and decimals, whereas counting is always units (the integers).*

A number is a specific value (quantity or [ac]count). Other words for the term "number" includes, but may not be limited to:

1. Quantity – how much?
2. Value – what size?
3. Count – what placement?

There are two types of counts:

1. The edges/points that determine the boundaries.
2. The spans between the boundaries/objects.

Numeral is the symbol and number is the specific count. A "number" is an abstraction/concept, and a numeral is the way that people denote (sign/signify) that concept. A number is an abstraction represented by a symbol called a numeral. A numeral is a symbol or name that stands for a number. What that symbol looks like is technically irrelevant. However, if a meaningful relationship were present between the symbol and the meaning (number) it conveyed, then that would be optimal for efficient processing. Note that frequently the words “number” and “numeral” are used synonymously/interchangeably, although technically, there is a difference.

Numbers express meaning, and numerals are the symbols (signifiers) used to communicate the meaning. Therein, numbering is the assigning of meaning in the form of a number to something. As an ad-jective, "numerical" means expressed in numbers, or relating to numbers.

> **NOTE:** *Something for which mathematical logic has no application is not a number. For example, a so-called “telephone number” is not a number. The symbols/digits in a telephone “number” cannot be added together to get another number, or any relevant mathematical pattern. If mathematics cannot be applied, then symbolized identifier (e.g., “telephone number”) is not a number. A telephone “number” is a sequence of digits assigned to a communicating user. It is essentially, the name or address of the user. It is a string of decimal digits (i.e., sequence of digits) that uniquely indicates a network termination point (or user), and is required in the routing of network traffic; it is an identifier assigned to a user. A “telephone number” is a data structure, it is not a single value. Similarly, an IP address is not a number as such, but a string representation of X number of bits/bytes. The IPv4 (protocol) address is made up of 32 bits (4 bytes, 4 octets). The IPv6 (protocol) address is 128 bits (16 bytes, 16 octects). A number is not the same as a location identifier, there is a difference of type.*

2.1.1 Thinking through counting

In order to fully understand counting in the context of thinking, it is important to place it into the context of a theorem:

1. Ideas are [becoming] concepts.
2. Concepts are divided patterns (objects and relationships).
3. Patterns are structured through principles.
4. Principles are rules.
5. Rules are states (or, statements) of action.
6. Action is motion.
7. Motion is the result of the instantiation of a resolved information set (space), a decision.
8. An information set (space) resolves into a decision through the logical processing of present information. There may be internal (sub-system, subjective) and external (system, objective) logic here.
9. Logic is pattern recognition.
10. Pattern recognition is awareness.
11. Awareness is the totality of “your” present experience.
12. Counting and sequencing are the basis of mathematical understanding.
13. Pattern recognition is the basis of intelligence.
14. Logic is the basis of conceptual understanding.
15. Decisioning is the basis of optimization.
16. Motion is the basis of sensation.
17. Action is the basis of creation.
18. Rules are the basis coordination.
19. Principles are the basis of cooperation.

Simplistically, ‘abstraction’ is the act of giving a short and easy to remember name to something that is long and complicated. By doing this, you absolve yourself of needing to remember the long and complicated stuff. “Abstraction” is the one of the bases of computer science and information processing. In computation, bit patterns represent instructions (operations, processes) for [at least]:

1. Load [an iteration].
2. Store [an iteration].
3. Add [an iteration].
4. Multiply [an iteration].

Bit patterns are hard for humans to remember; hence, they are further encode as assembly language mnemonics (note: assembly language is a base-16, sexadecimal/hexadecimal, number system). Operating systems further abstract the physical hardware that might be connected to a computer, in order to extend functionality (i.e., make it more easily shareable by multiple applications).

For example, in computation, virtual memory is commonly thought of as “paging”, which it is, but there is more to the conceptualization. All physical hardware defines a fixed set of categories (names) where program data can be stored. These names/categories are the “physical addresses”. If application-programs were forced to always use physical addresses they would constantly have to interrupt/disrupt each other, from which errors are the result.

Virtual memory allows every program to virtually work with some fixed set of addresses, that start at zero, and increase in a finite or infinite . Further, they can pretend that they have this whole address space to themselves. The operating system then takes care of making sure that programs don’t end up using the same physical memory or otherwise destroying each other. Again, we simplify high level code by introducing an abstraction layer that essentially does name translation.

The higher-level software applications also have their own collections of abstractions. Some are important enough to have unique names. Most of these applications are constructed out of three axiomatic abstractions:

1. **Model** – how the application stores the basic data (units).
2. **View** – how the application displays the data for the user (entity higher up the supra-systems decision resolution hierarchy). This is the visible part of the user interface (or, the information that is accessible).
3. **Controller** – how the application responds to commands. This is the less visible part of the user interface. It determines which sequences of actions are possible, and thus, what workflows it can support.

In an non-unified model, abstraction boundaries tend to leak out, which is what makes fixing systems in a non-unified model complicated.

An **array** is a systematic arrangement of similar objects – a data structure that contains groups of elements (information sets). When an array is composed of numbers, then those numbers are usually presented in a row and column, matrix, [notational] format. An array is commonly signed with, { } (although there are a variety of other signs).

With the above understandings in mind, the five principles (or principle conceptualizations) of counting are:

1. **The one-to-one principle (a.k.a., one-one principle)** – Assign a single tag (reference association, label, name, category, value, number, word, sign, symbol) to each counted or sequenced object (item, thing, event) in the array [of categorically similar patterns]. In other words, assign only one name/label to each individually counted/sequenced pattern. The two processes required here, to be performed on the collection of objects, are partitioning and tagging. Every item being counted needs to be transferred from the to-be-counted category to the counted category (partitioning), while a distinct tag must be logically associated, not to be used again in the counting sequence (tagging). If an item is not assigned a number name or is assigned more than one number name, the resulting count will be incorrect (illogical). The two processes requiring coordination:
   A. The partitioning process (a.k.a., intervaling, pattern recognition) – recognizing [dis]similarity, and the memory/record/awareness its presence. In other words, moving from the to-be-counted category to the counted category.
   B. The tagging process (a.k.a., naming, label, neologizing) – identifying, selecting, and assigning a tag, name, or otherwise, label/category. Naming the separation of [dis] similarity. There are at least three tags for every [dis]similar pattern:
   C. A tag representing the category of pattern presenting itself as a sequence/count of intervals and patterns. This is generally notated/expressed as a word (number, e.g., two, three) or letter.
   D. A tag representing the sequence of the pattern. This is generally notated/expressed as a numeral.
   E. A tag representing the interval of the pattern. This is generally notated/expressed as a numeral.
2. **The stable-order principle** – The counted tags must be arranged in a stable (i.e., repeated) order. To be able to count also means knowing that the list of words used must be in a repeatable order. This principle calls for the use of a stable list that is at least as long as the number of items to be counted; if you only know the number names up to ‘six’, then you obviously are not able to count seven items. For example, someone who counts 1, 2, 3 for one particular collection of three objects, and 2, 1, 3 for a different collection, cannot be said to have an understanding of the stable-order principle – although that person would appear to have an understanding of the one-one principle. However,

a person who repeatedly counts a three-item collection as 2, 1, 3 does appear to have grasped the stable-order principle – although, in this case, has not yet learned the conventional sequence of number names.

   A. From this principle comes the **radix/base** of all number systems.

3. **The Cardinal principle** - On condition that the one-one and stable-order principles have been followed, the number name allocated to the final object in a collection represents the number of items in that collection, its 'value'. The last number-word of an array of counted items has a special meaning: it represents the set as a whole [value] and the numerosity of this set of items. Note that the cardinal principle pre-assumes the one-one and stable-order principles [are encoded]. The final number name is different from the earlier ones in that it not only 'names' the final object, signaling the end of the count, but also tells you how many objects have been counted: it indicates what is called, the numerosity of the collection. If someone recounts a collection ({1,2,3,..}) when asked, how many objects there are, then they have not yet grasped this principle.

These three principles are considered by Gelman and Gallistel to be the 'how-to-count' principles as they specify the way in which the counting operation must be executed (i.e., proceed). The remaining two are 'what-to-count' principles, as they define what can actually be counted.

4. **The abstraction principle** – The real-ization of what is counted. The logical mapping of relationships in consciousness through a nominal "scale" (name only) measure stored in memory.

When the how-to-count principles are combined with the abstraction principle, there is an order of magnitude rise in functional expressibility (i.e., enhanced creativity).

2.1.2 Numeric abstraction

A.k.a., Enumeration.

Numbers are an abstraction (conceptual) and do not exist in the real (physical) world. However, just because something conceptualized does not exist as an object in the real physical world, does not mean that it is subjective (i.e., disconnected from the physical world). The number "4", as in, 4 of something (e.g., a count of 4 coconuts), is not something in the real physical world, but it also is not subjective (i.e., disconnected from the physical world). There is an experiential relationship between the numerical signifier "4", the [as]signed numerical meaning "four", and the physical sensation [of 4/four] of something [which can be characterized as unique or different than other things]. The number "4" does not exist, but that does not mean any numerical signifier [of meaning] can be assigned to [the experience and conscious count/awareness of] 4 coconuts. In other words, if 4 coconuts are present in front of someone sensing the real [physical] world, then it cannot be logically said that 3 or 5, or any number/count other than 4 (four), are present.

The scientific method also does not exist in the real world, but that does not mean that the scientific method is subjective. The idea that if something does not exist in the real [physical] world, that it is then subjective[ly disconnected from that world], is not valid. Some conceptual abstractions objectively express an existent relationship in the real physical world, and other conceptual abstracts do not express any relationship to, or in, the real [physical] world.

When there is no experiential reference point for a conceptual abstraction, that conception is commonly said to be "subjective" – related to a separate[d] subject, which is dis-connected from the other (or, all other) subjects in a unified object[ive world].

2.1.3 Numbers as presence and absence

There are *two principle types of numbers* categorized by [the] presence [of existence].

1. The non-zero numbers (presence) - A non-zero number can be used for two purposes: to describe the size of a set, or to describe the position of an element in a sequence. In any number system there is must be more than one symbol used to represent the concept of presence – presence cannot exist without a relationship indicating the presence of two things.
   A. For example, the symbols (digits): 1,2,3,4,5, etc.
2. The zero number (absence) - A zero number is used for the absence of a set. In any number system there is only one symbol used to represent the concept of whole absence.
   A. For example, the symbol (digit): 0.

2.1.4 Number notation

There are various ways that numbers can be written or diagrammed:

1. **The number line** – a number line is a graphical way to visualize numbers by placing them on a straight line, usually with zero in the middle, positive numbers to the right and negative numbers to the left.
2. **Decimal notation (a.k.a., decimal notation)** - a common way to represent real numbers. A string of digits and a decimal point (dot). Digits to the left of the point are increasing powers of ten, those

to right are increasing negative powers of ten. For example, 456.65 and -385.109. The numbers on the left side of the dot represent whole numbers, and the numbers on the right side represent decimal values. The point/dot is a decimal signifier – signifying that the numbers coming after it (to the right) are decimal (and not whole) numbers.

A. Note: Different countries officially designate different symbols for the decimal point. In most English-speaking countries, the decimal point is usually denoted by a period/dot to separate the whole number from its fractional parts. However, in continental Europe, the decimal point is usually denoted with the comma. The choice of symbol for the decimal point affects the choice of symbol for the thousands separator, which is largely used in digit grouping.

B. Note: In computing, dot-decimal notation is a string of digits of decimal numbers, each pair separated by a full stop (dot). For example, 192.168.0.1 or 255.255.255.0. The dot in computing is always represented as a dot and never as a comma.

3. **Ratios/fractions (percentages; decimals)** – a fraction is two quantities written one after the other with a symbol indicating that one is a ratio (or fraction) of the other. For example, 3/4 [of an apple]. Every fraction can also be written as a decimal, and vice versa. A fraction differentiates (or "measures") parts versus the whole.
   A. XX/YY
   B. XX is the part
   C. YY is the whole
4. **Normal form (scientific notation)** - a number in normal form consists of two parts: a coefficient and an exponent (power of ten). For example, the distance to the sun is 93000000 miles. This can be more conveniently written as 93×106 miles. 93 is the coefficient and 6 is the exponent.

2.1.5 The real number line: visual positioning

A.k.a., The number line.

The number line is a series of dots (Read: points, degrees, or packets of information) representing iteration, along a single dimension. Between each dotted sub-division there is an interval. The interval has a beginning, commonly known as it's "position". Therein, the interval's value is the duration of its position. Each interval has a position [of beginning]. That value has a numerical sequence [value] and a unit [value].

NOTE: *Counting necessitates units and sequence.*

A real number line (or simply, number line) allows for the visual display of real numbers by associating them with unique points (positions) on a line. The real number associated with a point is called a coordinate.

Numbers can be conceptualized to exist along a one-dimensional continuum known as a number line (where 0, positive, and negative numbers, fractions, and [ir] rational numbers are all possibly present).

"Imaginary" numbers are not just left or right on this 1st dimensional number line; they exist in a whole different dimension. Algebraically, this new dimension has the expression, the square root of negative 1, √-1. The result of combining a number along the 1st dimensional number line and a number along the 2nd dimensional number line is a functional two-dimensional form, a "complex" number.

The conceptualization of 'number' includes this extra dimension, which has a referential association with the 1st dimensional number line.

Using the word "imaginary" as a label for this category of number conceptualization is a horrible decision. This extra dimension allows for the full visualization of the functional expression: f(x) = x2 + 1. The function crosses the x axis in a two-dimensional graph in this other dimension. This is an extra dimension that the conceptualization of numbers posses. It has been misnamed. The name suggests these numbers are not as "real" as counting numbers, which is not accurate. It has been suggested that these numbers should instead be given the name, lateral. From here on, lateral means imaginary.

The poor selection of a name for the categorically named positioning operation is the most significant reason why people don't understand that a negative times negative is positive, or a pure positive "imaginary" times pure positive "imaginary" is negative real number.

Carl Friedrich Gauss, who gave the first clear exposition of complex numbers and due to his contributions to the theory of electromagnetism, the international unit of magnetic induction is called by his name, the gauss, wrote, "If we call +1, -1, and √-1 had been called direct, inverse and lateral units, instead of positive, negative, and imaginary (or impossible) units, such an obscurity would have been out of the question." (English translation from German)

Gauss suggested that the concept presently/previously known as "negative" (-) should be renamed as 'inverse' (-). Logically, inverse times inverse is direct. Or, positive is forward, and negative is backward. If the operation is inverse, and then inverse again, of the result is the original direction, like backward and then backward is forward.

The new names [for the positioning operation] are as follows:

- +1 = positive one OR direct one [unit]
- -1 = negative one OR inverse one [unit]
- √-1 = imaginary one or lateral one [unit]

Gauss's "imaginary" number name is lateral number (side number). When direct lateral times direct lateral, which is $\sqrt{-1} * \sqrt{-1} = -1$, then $-1 * \sqrt{-1}$ is inverse lateral, $-\sqrt{-1}$, then inverse lateral * direct lateral is direct, $-\sqrt{-1} * \sqrt{-1} = +1$. The square root of a negative number can be solved for with the square root of -1 times the negative number, logically creating the expression of lateral movement (i.e., a movement different to the original axis).

There are two ways to perceive/categorize an angle:

1. Degrees, the swivel an observer went through to follow an object. Degrees are the observers viewpoint.
2. Radians, the distance the object moved on its path. Radians are the mover's viewpoint.
3. Radians are used in operational physics formulas, including but not limited to sine, cosine, etc., wherein 'radians' refers to the distance the object moved.

2.2 A number system with a base-count

A.k.a., A number base-count system, commonly just called "number system".

Different number systems, such as the decimal (base-10), binary (base-2), octal (base-8), and hexadecimal (base-16), are utilized based on their applicability to various contexts, ranging from everyday counting and measurement to computer programming and digital electronics. Each system's base indicates the number of unique digits, including zero, that it uses to represent numbers. A real-world number system represents a fully functional tool for mapping the real-world.

A number system is a set of objects (often numbers), operations, and the rules governing those operations.

1. A unary [number] system has one numeral in the set {1}.
2. A binary [number] system has two numerals in the set {1,2}.
3. A trinary [number] system has three numerals in the set {1,2,3}.
4. The decimal [number] system has ten numerals in the set {0,1,2,3,4,5,6,7,8,9}.

2.3 A number system with class-division

A.k.a., Number classes, categories of numbers, classes of numbers, number sets.

A number system is the logical composition of sets of symbolic [numeral] digits, that are used to represent the possible enumerations of the concept of 'number'. The system is the concept 'number', which is decomposed into mathematically operative, numerical subsets [of the unified 'number' system set].

2.3.1 Sets

I.e., Set theory, group theory, division theory.

A set (or group, system) is a collection of objects, typically grouped within braces { }, where each object is called an element (part or sub-system). For example, {red, green, blue} is a set of colors. A subset is a set consisting of elements that belong to a given set. For example, {green, blue} is a subset of the color set above. A set with no elements is called the empty set and has its own special notation, { } or Ø.

Group theory in the context of numbers generates an organization of different number[ing] systems, starting with the natural [counting] numbers N:

1. Integers Z.
2. Rationals Q.
3. Reals R.
4. Complex plane C.
5. And, higher dimensions.

It should be possible to agree on the following hierarchy and relationship between different sets of numbers:

- $N \subset Z \subset Q \subset R$
  - where, $\subset$ means subset

1. Define the subset relationship:
   A. The symbol "$\subset$" represents a subset relationship between two sets. If set A is a subset of set B (written as $A \subset B$), every element in A is also an element in B.
2. Explain the implication of the subset relationship:
   A. When an element x is a member of set A, and A is a subset of B, then x is also a member of B. However, being a member of B does not necessarily mean x is a member of A.
3. Introduce the number[ing] sets:
   A. There exists a well-defined hierarchical relationship among different sets of numbers: natural numbers (N), integers (Z), rational numbers (Q), and real numbers (R), denoted as:
   - $N \subset Z \subset Q \subset R$.
4. Highlight potential misunderstandings:
   A. The elements in R are called numbers.
   B. The elements in the subsets are called numbers too.
   C. Focusing solely on a specific set A and ignoring its relationship to a broader set B might lead to disagreements, especially when broader categories or characteristics represented by Bare being discussed.
5. Rational numbers as "numbers":

A. Rational numbers (Q) are classified as "numbers" because they extend the set of integers (Z) by including division. This classification is based on their mathematical properties and their inclusion in the set of real numbers (R).

6. Clarify the use of the term "number":
   A. The term "number" applies to elements within R and its subsets (N, Z, Q). This terminology reflects the mathematical and hierarchical nature of these sets, acknowledging that elements of subsets are also considered numbers, without diminishing their value or status within the broader numerical system.

2.3.2 Number classes

A.k.a., The numbering sets, the number sets.

Number classes refer to categories of numbers defined by their properties. The "natural" [counting] numbers form the first set of numbers upon which [mathematical] operations can be performed. This number system begins with the conception of natural counting numbers. In its axiomatic essence, number means satisfying a standard form (mirroring, meeting criteria for). Here, a natural number represents a fundamental and identifiable repeating and/or repeated pattern (i.e., a counted pattern):

1. A past, finite number of sequenced digits (i.e., counted).
2. A current, ongoing sequencing of digits (i.e., counting).
3. A future, simulated sequencing of digits (a.k.a., engineering).

AXIOM: *Counting numbers are the origin of all numbers. Ordered pairs exist – a sequence of patterns exists. ∴ Complex numbers exist. ∴ Complex thoughts exist.*

The concept of "number" is composed of [at least] the following characterizations, which are otherwise, conceptualizations of the concept, "number". Together, the possible numerals at each level of conceptualization are known as a 'set' (mathematical). The sets of numbers in the real-world number system include, but may not be limited to (i.e., number[ing] has the following sub-classes, sub-divisions):

1. **[N] A natural [counting] number (positive integers)** – the concept of, [the numerical mapping of] pattern recognition as a finite sequence of digits, through which an infinite sequence of numbers (numerical meaning) may exist. A finite sequence of digits representing an order of iteration. For example, 1,2,3,4,5,6,7,8,9. There are infinitely many natural numbers; the set of natural numbers is infinite -- as is the set of all squared numbers, the even numbers, the odd numbers, the rational numbers, and the irrational numbers. There is a hierarchy of these infinities, the so-called transfinite numbers. In counting, someone can simply keep adding 1 to the previous number to get more and more. Natural numbers are investigated in an area of mathematics called Number theory.
   A. Counting numbers are actual symbols that can be visually expressed and used to represent numbers. Counting numbers are now called positive whole numbers.
   B. Number has 'value'.
   C. The set of natural numbers.

2. **[W] A whole [counting] number (zero integer)** – the concept of the absence of that which is being counted, together with the principle of a natural number. The absence is commonly expressed with (represented by) the symbol (digit), 0. There is one addition to the finite number of digits in the natural counting conceptualization of 'number', the absence of the pattern being sequenced. Depending on perspective, zero may be considered unsigned, or may be considered its own sign. Note that the first such "unreal" in the "real" versus "unreal" paradigm was the zero.
   A. Number has 'magnitude'.
   B. The set of whole numbers.

3. **[Z] An integers number (negative integer)** – the concept of a opposite (i.e., different state, direction, or reverse) applied to the sequencing pattern, together with the principles of a natural counting number and a whole number. Sign of a direction - it is common to label certain directions as positive (+, or nothing) or negative (-). Negative numbers are the next most obvious addition, as [in part] the representation of a reverse in direction. If something is not a whole number, then it is not an integer. In other words, an integer can be negative, positive, or zero; and it is at the integer level of the characterized conceptualization of number that the concept of a 'negative integer' is added. The conceptualization level is 'integer', but the new conceptualization at this level is the 'negative integer'. A negative integer has a sign in front of the digit, -4,-3,-2,-1. Besides zero (when it is considered a sign), the concept of sign originates from the property of there being a possible "polar" difference in any given number representing the presence of the pattern. The idea of a "change of sign/state" is used throughout mathematics and physics to denote the additive inverse (negation, or

multiplication by −1). Note that a decimal number (e.g., 132.493) is not an integer. Integers can be added, subtracted, and multiplied. In application, the negative symbol is just a relative symbol, not an absolute value. In other words, "-5" is not conceived as "negative 5", but as something opposite of something else.

A. What does it mean to subtract (take away) a larger positive integer from a smaller.
B. Negative integers double the number of elements/digits present.
C. Number has 'sign'.
D. The set of integer numbers. There are infinitely many integers sequencing in two opposite directions.
E. With the conception of "negative" (inverse) and "positive"(direct), the concept of "opposite" arises (e.g., the opposite of -3 is 3; or, the opposite of unsigned numeral A, is signed numeral A). The "double-negative" property says that the opposite of a negative number is not a negative number (i.e., the opposite of -7 is –(-7).

4. **[R] A real number (a field, plane)** – is a value that represents the quantity [of a sequence] along a single dimension (a line). In between any two given real numbers there exists an infinity of real numbers. Real numbers can be visualized as points on an infinitely long number line. The word "real" was historically introduced to distinguish between the real and imaginary roots of polynomials. The term, 'polynomial' comes from poly- 'many,' on the pattern of multinomial (a pattern named "term"). A polynomial is an expression of more than two algebraic terms. In other words, a polynomial is an expression consisting of variables (or indeterminates) and coefficients, that involves only the operations of addition, subtraction, multiplication, and non-negative integer exponents. Polynomials are used to form polynomial equations, which encode a wide range of problems.
    A. In mathematics, a plane is a flat, two-dimensional surface that extends infinitely far. A plane is the two-dimensional analogue of a point (zero dimensions), a line (one dimension) and three-dimensional space.
    B. A field is a two-dimensional plane with the natural addition of vectors.
    C. The real number line/set. The mathematical terms line and set, as applied to the real numbers, come from two different philosophical approaches to knowing and naming things. The term line as a representation of the real numbers, such as in the real number line, descended from geometry (Euclid), whereas the use of the term set as a representation of the real numbers, descended from algebra, and specifically set theory, introduced by Cantor.
    D. A line has no thickness, because a line is a mathematical construct conceived as a tightly strung string of points (data packets) formed by the junction of two planes, where an infinite subdivision could occur.

5. **[Q] A rational [ratio-nal] number (fractions of prior numbers)** – a ratio (fraction) of any of the individual prior conceptualization, with the exception that 0 is not ever a denominator. Rational numbers are quotients (Q), which are the result of division (i.e., sub-division). In a fraction, the denominator represents the number of equal parts in a whole, and the numerator represents how many parts are signified (i.e., "being considered"). In other words, a ratio of a positive (e.g., using the 1 integer: 1/1, -1/1, 0/1 (is 1), but never 1/0 (which has no meaning and an undefined result). The number above and below are members of the same integer set. A decimal number (1.5) is a rational number because the digit(s) to the right of the symbol are just another way of writing a ratio (fraction). Rational numbers are integers, and fractions of integers, put together, but there are not any other numbers. All rational numbers may be represented in radix point or fractional form. Fractions/ratios have three forms of notation: radix point notation; fractional/ratio notation; and graph (visual) notation.

    CLARIFICATION: *The language becomes confusing here because, to say, rational seems to indicate that the fractions were somehow more qualitatively "rational" than the irrational numbers. Here, that meaning should not be present; instead what is meant is ratio (i.e., A/B, A : B).*

    A. **Radix point (e.g., decimal) notation** – for example, 0.5. The decimal expansion of rational numbers is either finite (like 0.73), or it eventually consists of repeating blocks of digits (like 0.73454545...).
    B. **Fractional/ratio notation** – for example, 1/2 or 1:2.
        1. The expression 1 / 2 represents both the operation of division and the resulting number. This is an example of a "procept", the combination of process and concept (More completely, a procept is an amalgam of three components: a process which produces a mathematical object and a symbol which is

used to represent either process or object.).

2. The procept property of y/x . In common parlance, there are separate definitional entries for division, quotient, fraction, ration, and proportionality. This is an inconsistent nomenclature. Instead, ratio is the input of division, and number is the result of division. This is not a definition of number but a distinction between input and output of division. It is suggested to use the terms, (static) quotient, for the form with numerator y "divided by" denominator x.
3. Multiplication is not a precept; there is a clear distinction between the operation 2 • 3, and the resulting number 6. It is also logical to say that 2 • 3 = 3 • 2. The word "multiplication" could be completely replaced by the term 'group', and 'grouping'. With 6 identical elements, there can be organized 3 groups of 2.
4. (static) quotient[y, x] = y / x

C. **Graphing** – this content is well visualized as a graph. Here, it could be said that there is the notion of proportional space: {denominator x, numerator y}
   1. In a two number line graph, the denominator (cause) on the horizontal axis and the numerator (effect) on the vertical axis (instead of reversed), as it should be because of the difference quotient in calculus.

D. If a rational number is equal to an integer, it is written as the integer, otherwise:
   1. The rational number is written as an integer plus or minus a quotient of natural numbers.
      i. The integer part is not written when it is 0, unless the quotient part is 0 too (and then the whole is the integer 0).
         1. When the integer part is 0 then plus is not written and minus is transformed into the negative sign written before the quotient part.
      ii. The integer part is written when the quotient part has a denominator that isn't 0 or 1. When the integer part is nonzero or one, then there is plus or minus for the quotient part in the same direction as the sign of the integer part (reasoning in the same direction).
      iii. The quotient part is not written when the numerator is 0 (and then the whole is an integer).
      iv. The quotient part is written when the quotient part consists of a quotient (form) with an (absolute) value smaller than 1.
      v. The quotient part is simplified by elimination of common primes.

6. **An irrational [ir-ratio-nal] number (an irrational root)** – a [real] number that cannot be expressed as a fraction. Irrational, but can be expressed on a number line. Some numbers cannot be written as a ratio of two integers; they cannot be expressed as a fraction of integers (non-fractions). It was discovered that the square root of 2 cannot be written as a fraction. Neither π (pi) nor e can be written as fractions. Note that Cantor, the inventor of set theory, published a paper defining irrational numbers as convergent sequences of rational numbers. What is being observed in the category called the "irrational" (i.e., the irrational numbers) are the numbers that "fill in" all the "gaps" between the rationals [on a number line]. Irrational numbers are those which can't be written as a fraction (which don't have a repeating decimal expansion). Those rational numbers which aren't the result of polynomial equations with rational coefficients.
   A. The diagonal of a unit square cannot be represented by a ratio of two integers. And yet, this number does have a direct geometric representation [in the number system].
   B. Rationals are the separation of the whole into parts, and irrationals are a unique category of this type of separation.
   C. Irrationals are uncountably infinite.
   D. The set of irrational numbers.

7. **[C] A complex number (a complex field)** – a field that extends the "real" field, 2D visualization) - A set of real numbers and non-real numbers put together would be a "complex" set of numbers, and hence, the concept given to this category is 'complex'. Complex numbers answer the problem of determining the square root of negative real numbers. Complex numbers are the final step in a sequence of increasingly "unreal" extensions to the [natural] number system that humans have found it necessary to add over the centuries in order to express increasingly sub-divided, significant, numerical concepts. Complex numbers are typically represented graphically as points in the 2D plane, and the rules of addition and multiplication are equivalent to certain operations on lengths and angles. A complex number is a number that has both a Real and an Imaginary part. That is it has 'length' residing along the Real number line (the usual numbers we're all familiar with), what we call the Real axis, and a 'height' residing along an axis perpendicular to that Real number line, which we call the Imaginary axis. In

mathematics, the complex plane or z-plane is a geometric representation of the complex numbers established by the “real” axis and the perpendicular “imaginary” axis. This is visualized as a modified Cartesian plane, with the real part of a complex number represented by a displacement along the x-axis, and the imaginary part by a displacement along the y-axis. The concept of the complex plane allows a geometric interpretation of complex numbers. Here, it is the “function” that [visually] distributes the number along the z-axis. Complex numbers form a two-dimensional “vector space” over the “real” numbers. Therein, for each complex number c, there exists real numbers a and b such that c=a + i*b. Here, complex numbers are visualized as a two dimensional plane (the “regular” axis, and the “I” axis). Complex numbers have the added property that rotation in this “plane” is simply a multiplication by a complex number (this, too, has a rigid mathematical definition, that “every R-automorphism is represented by multiplication”. Let’s call these 3 properties 1,2 and 3.

A. Just like coordinates can be plotted on the x,y plane, complex numbers are represented in the complex plane. In a normal x,y plane there is no connection between the two dimensions; there are there are no rules about how they can relate to one another. In a complex plane, there are the rules of algebra. i has to do with rotation on a complex plane. Angles can be determined through the additional use of trigonometry.
B. The i as a notation of a complex number, and using notation makes the math more simple.
C. It is a field.
D. It is two-dimensional vector-space over the reals.
E. At every rotation in the vector space is represented by multiplication.
F. Every non-contradictory equation, algebraic or transcendental, has a solution within the application of complex numbers. The present understanding is that their addition finalizes (or wholes) the number system into a self-sufficient, consistent system.
G. Complex numbers exist in the same way “real” number exists, they’re involved in our daily technically computational societal operations. Complex numbers are used for the representation of various physical phenomena, including states of particles and the behavior of electrical currents. They are also necessary (or, at least, efficient) at computing 3D visual space (i.e., computer graphics). All electric and magnetic systems behave like complex numbers express in numerical and graphical notation.
H. The Cartesian coordinate system but two such real number lines drawn orthogonally across one another at what is called the origin, used to visualize the mapping of a real function from one real number line called x to another “real number line” called y. The rest of mathematics is supported upon this foundation [of operation].
I. Complex numbers are best represented in a coordinate system were the x-axis shows the real part and the y-axis shows the imaginary part of the complex number. Therein, complex numbers use the Cartesian (x, y; x +iy) coordinates, or use an angle and the distance from a fixed point (the origin) as polar coordinates (rei0).
J. The polar equation becomes 1 x e π × i = -1, or e π × i + 1 = 0. This equation is significant because it involves all the fundamental constants in mathematics: 0,1,e,π, and i. These numbers are a numerical-conceptual mapping to relationships in the existent world.
K. A complex number is a point on the two dimensional “field” plane of a real number. The absolute value of a complex number is its distance to the origin, and let’s call its “angle” the angle it forms with the positive x-axis. The Real numbers are just the x-axis, and “i” is just (0,1). So the real number 1 is (1,0) and -1 is (-1,0). Then multiplying complex numbers multiplies their absolute values and adds the angles. That’s why (0,1) times itself is -1 = (-1,0). 90 degrees plus 90 degrees = 180 degrees.

INSIGHT: *In mathematics, the complex numbers are the final step/level/order in the sequenced system of counting numbers [as patterned iterations). From this perspective, every other number is just a sub-set of the complex numbers; the complex numbers are that which is presently understood to be real, and an existent part of the functionally real world.*

8. **A transcendental number** – a transcendental number is a [possibly] complex number that is not an algebraic number—that is, not a root (i.e., solution) of a nonzero polynomial equation with integer coefficients. Hence, a transcendental number is not a finite or repeating set of digits, and also not representable as a root. It is real or complex number that is not algebraic – that is, it is not a root of a non-zero polynomial equation with integer (or, equivalent, ration) coefficients. Transcendental numbers can’t be defined as the solution to a specific algebraic equation. Every real transcendental number must also be irrational,

since a rational number is, by definition, an algebraic number of degree one.

A. For example, π (pi) - 3.1415926535897...
B. For example, e (Euler's number) is the base of the natural logarithm - the unique number whose natural logarithm is equal to one - 2.71828.
C. Everything that exists follows eternal rules describable as ratios of numbers. Thus, any number could be written as a ratio. For example, 5 as 5/1 or 0.5 as 1/2. Even a number with an infinite decimal sequence can exist as a ratio. All of these are rational numbers. Historically, one number was found to violate this rule. A square with each side measuring 1 unit according to Pythagoras theorem: a2 + b2 = c2. The diagonal of the square length would be square root (sqrt) of 2. Square root of 2 cannot be expressed as a ratio of two integers (e.g., 45/34 or 33/283), and is thus an irrational number because it can't be written as a ratio of two integers.

9. **[i] An imaginary number** - Imaginary numbers are conceived of as numbers, but are not real numbers. Literally, imagined numbers. “Imaginary” numbers visualize a 3d graph. The poorly named “imaginary” numbers (number system) represent the second dimensional (or angular) data point (coordinate) of a number – here, formal relationships can now be constructed (and functions generated) between the two axes (dimensions). All of the [other] “real” numbers are presentable on a one dimensional number line. “Imaginary” numbers exist to extend the functional [mathematical] operation of the numbering system. The poorly named “imaginary” numbers represent an angular separation from the one dimensional number line into a two dimensional numbering system, with the second dimension existing, and capable of being visualized, as perpendicular to the first. Because it couldn’t initially be conceived of possibly existing in the real number world it was given the name imaginary or impossible. In response to this understanding, the other set of numbers gets called real. And, when a number contains these two parts, it is called a complex number. Imaginary numbers are not on the “real” number line, but in mathematics, they are just as real as any other formally conceptualized number. Where negatives rotate in 180 degrees , i rotates 90 degrees. i^2 is -1.
   A. Imaginary do not exist apart from the real numbers, but exist in what is conceived of as a 90°perpendicular dimension. They are the natural extension of the number system from one to two dimensions. Numbers can be conceived of as two dimensional.
   B. The imaginary number [set] – there is only one number here.

Unique conceptual classes of numbers include, but are not limited to:

1. Natural number level - Even and odd – every other sequence, with even and odd, existing one sequence off of the other.
2. Ratio level - Prime numbers – are numbers whose factors are 1 and that number. A number that has more than three numbers that go into that number is the opposite. 7 and 3 are prime.
3. Natural number level - Infinite numbers – the smallest of which is the number of integers, represented by ℵ0.
4. Division-algebra (quaternions octonions)
5. Going to 4D (i.e. Quaternion), multiplication is no longer commutative. Going to 8D (i.e., octonions).
6. Sign of angle, the “degree” of change between two subdivisions.
7. Sign of change - the delta symbol, Δ.

2.4 A number system with dimensions

A.k.a., A number system with dimensionality.

In mathematics and physics, the concept of dimensions plays a crucial role in identifying objects, defining relationships, and explaining phenomena. Each dimension adds a layer of complexity and requires additional information for accurate representation:

1. One dimension: To define a location in one dimension, a single piece of information is necessary.
   A. 1 edge (a.k.a., 1 dimension): 1 piece of information is required to define location in that dimension. A real number is required to define location in one dimension, , representing position along a linear scale.
2. Two dimensions: For two-dimensional spaces, two pieces of information are required to specify a location.
   A. Either,
      1. Two real numbers (e.g., 2 edges), or
      2. A single complex number, which inherently contains two pieces of information (note: a complex number holds two pieces of information in a single number).
   B. When only real numbers are used, a vector matrix becomes essential for managing multiple data points. Conversely, complex numbers

streamline this process by encapsulating two-dimensional information within a single entity. Regardless of the approach (real vectors or complex numbers), operations for translation, rotation, integration, and duplication (or subtraction) need to be clearly defined. If 2 dimensions contain only real numbers, then a vector matrix must be generated to hold multiple pieces of information. A vector matrix is not necessary for complex numbers.

   C. For both the real vectors and the complex numbers, operations must be defined for translation, rotation, and integration, and duplication (or subtraction).

3. Three dimensions and beyond: Moving into three dimensions, either,
   A. A 1•3 matrix with three real numbers can represent spatial locations, or
   B. the concept of complex numbers can be extended to accommodate three pieces of information, which introduces an even more complex system.
      1. This "extension" necessitates the creation of a new operation with an additional "imaginary" axis, allowing for the expansion into higher dimensions (axes).

NOTE: *The math becomes a lot more complicated as dimensions are added, and computers are required to do the computation.*

To move from 2 dimensions to 3 dimensions, a new operation is created with another “imaginary” axis:

1. 2 dimensional complex number would be 2+3i.
2. 3 dimensional complex number will be 2+3i+4j.
3. 4 dimensional complex number would be 2+3i+4j+5k.

There is no one one-dimensional complex imaginary number; because, complex numbers inherently possess two dimensions by their very nature. A complex number is typically represented in the form:

$a + bi$

- where,
  - a and b are real numbers.
  - i is the imaginary unit with the property that $i^2 = -1$.
  - a represents the real part of the complex number, which can be thought of as the position along the real axis (or the x-axis) in a two-dimensional plane known as the complex plane.
  - bi represents the imaginary part, which corresponds to the position along the imaginary axis (or the y-axis) in the complex plane.

2.4.1 The zero as unity perspective

NOTE: *The cycling process is called iteration. The output of on operation becomes the input of another, and so on.*

The path the earth follows as it spirals around the sun can be described as 0, a circle, and however, the year is divided, each division is part of the whole 0 cycle. The earth itself rotates around an axis, a circular motion that defines a day as the passage of the risen sun to sunset and back to sunrise.

The number of days can be described as 1 each, or as sets of days, as weeks or months, and in a tangible and quite natural way, the circle, cycle of 0, can be said to be the natural phenomenon that allows each 1 day to exist, just as the earth’s cycle around the sun allows a year to exist.

Without the 0 cyclical movement 1 doesn’t exist and 1 cycle isn’t complete until the circle 0 has been drawn. In both these natural instances, 0 can be said to be a unified 1 or the completion of a cyclical movement that is now designated as 1 symbolic and naturally significant 0. One (1) earth completes each of the circles that describe a visual 0 path, and each 0 has a tangible form that is described by 1 earth and 1 sun. So, does 1 + 1 = 0 or does 0 = 1 + 1.

Does the cycle 0 exist before that which is describing it, or does the cycle 0 only exist because 1 + 1 brings it to the attention of human minds? Zero (0) is a symbol, a tangible cyclical passage that describes unity, but it also describes the completion of 1 day or 1 year.

The end of a year does not result in nothing any more than the end of a day does, they both bring a new cycle, a new 0, that will be unified until the current natural course of events principally determines that the cycle is no longer sustainable, and for the purposes of community, fulfilling. Through subsequent divisions, new 0s, cycles will be formed (as 10,100,1000,10000). In math, these cycles are known as “orders of” [the concept] ‘magnitude’. Each cycle is another “level” (a.k.a., “order”) of the iteration (as in, a whole new sub-division).

The minds that first described a 0, what we now call zero, didn’t imagine it, 0 was real as a unifying circle or cycle, and the concept of someone taking all the candies to leave nothing described something else.

The process of subdividing a fixed line (concept) infinitely leads to something that is infinitely long - the Mandelbrot set. More (“finer”) divisions are always possible, and the “finer” the view, the greater the number of divisions. However, mathematically, something which is infinite cannot be measured. Hence, everything which is to be measured must be conceptually and/or mathematically bound.

Non-Euclidean geometry is a consistent system of definitions, assumptions, and proofs that describe objects as points, lines, and planes.

A fractal is something that is self-similar. It is an operation (mathematical process) involving the iteration of an equation with an input coming from an output. Take a number, process it through the 'formula', the result is a number, which is then fed back into the formula. And, that whole process is consecutively iterated, over and over again. What happens when this occurs many times? The structure of numbers that appears is called a 'set' (the Julius set in particular). The Julius set can be visualized (as a whole) on a graph with two axes representing two scales with at least 1 fixed reference point (i.e., with at least one self-similar subdivision). This point represents their unification.

It is possible to understand this, because in mathematics there is a system of definitions, assumptions, and proofs that describe objects as points, lines, and planes (a.k.a., non-Euclidean geometry).

The perspective can be on a one-to-one basis or a one-less-one basis. In concern to a one-less-one basis, the first condition has no condition before it, and hence, zero is conceived. The second one (condition) has one (condition) before it. The third one (condition) has two (conditions) before it. And so on.

The decimal numeral system is a column system until 9 units transcend into zero, a new column. A unifying zero is used because what has gone before is agreed on, and the next column starts with the transcended one, as one ten.

2.4.2 A continuum

A continuum is a whole of differentiated parts, where the differentiated parts have continuity. The parts are intrinsically differentiated by their relation to the whole, which forms a unified whole. (and hence, the whole is whole/unified). The various analogical uses of the term continuity express the extensiveness of the concept. Relative to the primary analogate, which is the extensive continuum, the parts may be understood under two formalities (eventually becoming formulas, expressions, and arguments):

1. The analytic [part]: a whole that is divisible without end into (analytic) parts, of which there is no smallest. This is interval (the pattern sensation) part.
2. The compositive [part]: a whole, the extremities of whose (compositive) parts are one. This is the sequence part, the iteration. This is a composite of [the following information inquiry processes], which can return data or no data:
    A. How many sequential iterations are possible?
    B. How many sequential iterations are associated ("take up by") the pattern?
    C. Where in the possible sequence of iterating patterns do the intervals start (initiate) and stop (terminate)?

Continuity (without separation, continuous in existence) is logically related to contiguity (bounded in existence, direct contact, complete separation, axiom) and consecutiveness (sequence of separation/occurrence, order); all three (continuity, contiguity, and consecutiveness) refer to extension, but constitute a different ordering of parts. There is the sensation of a whole, and then, its parts and the sequential ordering of those parts.

A whole sub-divides (i.e., "has separation") if some element of a different [extensive] nature integrates ("intervenes") between any part of the ordered whole, to form an interval of parts. Note that it is presently thought that continua (multiple continuous extents, series, or wholes) are encoded into humans cognition means of a scanning motion [of the extensional sensation sub-system].

In other words, a continuum is essentially one, though it has distinguishable parts, whereas both contiguous and consecutive entities are pluralities only, the former with parts distinguished and bounded (separation), the latter with parts separated in sequence (order).

The origin of the notion of continuum is most readily traced to the sensible experience of physical extension, which is the first formal effect of dimensional quantification, manifesting factual material unity but remaining subject to division. "I am that I am" is a definitional phrase for "pattern and sequence", which may be numerically notated as "1,2,3,1,2".

All continua are divisible into parts, that are themselves divisible continua; and since such division does not add anything, the positions of the divisions must be marked by pre-contained indivisibles. Division is generally not considered as a form of separation. The actual division of an abstract continuum is accomplished by the mental removal of a portion of the continuum or the establishment of an indivisible boundary, which becomes a categorically designated separation. Division produces two continua that are either contiguous or consecutive. Boundaries on a continuum of composite parts are resolved by situ or position (the differentia of dimensive quantity). When there are positions (more than one position), then there is geometry in a pattern (or at least, the possible expression of a geometric pattern).

Here, each pattern represents an extensive magnitude, a 'value'. That 'value' position may be fixed as local [motion; i.e., position], or provide relative motion and/or time as a continuum (i.e., relative position).

Though attained in sensation, the abstracted concept of continuum is primarily mathematical; when used in a physical sense, the term is a secondary analogate. It is possible to unity notational priority in the mathematical continuum with experiential priority in the physical continuum. Visually, abstractions are first represented by lines, then angled lines, then surfaces, then three dimensional surfaces, then the iteration of dimensional surfaces (as time).

> **INSIGHT:** *Disagreements about physical existence are often traced to the problem of*

experiencing reality without an interruption of adaptive continuity.

There are two types of continuum from the perspective of consciousness:

1. In a static continuum, all parts coexist and are known immediately
2. In a flowing continuum, the parts, successive in existence, are known only through the representations of memory.

Both types are understood as wholes divisible into parts, distinguished but not interrupted, which have the same nature as the whole; but a flowing continuum is a becoming, hence its parts are never a being, even when considered abstractly.

The mathematical representation of flowing continua requires greater abstraction than that of static continua, since mathematics abstracts from motion. The mathematical notion is subject to further analogical extensions within that order.

Mathematics has one antiquated original separation forming arithmetic (the science of the discrete) and geometry (the science of the continuous). Today, analytical geometry is their unification.

A reference forms a one-to-one corresponding convention to a pattern on an existing continuum. A sensed referential similarity forms a numerical 1 to 1 relationship mapping. From the instantiation of this initial relationship map comes [models and operations for] counting, fractioning, and then, [sub-]dimensioning.

2.5 A number system with numerals

A.k.a., A system for visualization and communication of counts, system of enumeration.

A numeral is a symbol or group of symbols, or a word in a natural language that represents a number (a count). A numeral system (or system of numeration) is a way to write numbers. Numerals are the visualization (a.k.a., notation or combination of digits) used to represent numbers. Numerals can consist of a single digit (base-unit) or a combination of digits (i.e., combination of base units). Numerals are the physical representation of numbers through symbols or sets of symbols. Different cultures and mathematical systems have developed unique numerals, such as Arabic numerals (1, 2, 3, etc.), Roman numerals (I, II, III, etc.), and tally marks, and others. A numeral is a symbol or name that stands for a number, the counting (sequencing concept). A numeral is an idea/concept signified by a numeral, which is visualized (i.e., the signifier). That which is being counted, measured, or otherwise given a numerical value is the sign, or otherwise, concept. The different ways of visually representing numbers are referred to as numerical notational forms.

The terms 'number system' and 'numeral system' are often used synonymously. It may be clearer to present a slight differentiation between the two terms, where the term 'number system' represents the internal logic of the system, and the term 'numeral notation' represents the written expression of the system.

2.5.3 "Digits" in a number system

Digits are the basic symbols used in a number system to represent numbers. In the decimal system, there are ten digits: 0, 1, 2, 3, 4, 5, 6, 7, 8, and 9. Other number systems use a different number of digits, such as two in the binary system (0 and 1). Digits are used to compose numbers. Digits are the finite number of symbols used in a number system to represent values, typically ranging from 0 to (n-1), where "n" is the base of the numeral system.

A single digit is a single symbol used to make numerals. In a numeral system with base (radix) "n", each digit represents one of "n" symbols. These symbols are used to express whole numbers starting from zero up to "n-1." A digit in mathematics is like a letter in linguistics. A number can be represented by one digit (0-9 are one-digit numbers) or more than one digit (10 and greater are two or more digit numbers). A digit (letter) is one of the individual symbols used in writing a number (word), and the term “numeral” could refer to either one of the symbols or the set of symbols used to represent a number.

For clarification,

1. Digits make up numerals, and
2. numerals stand for the "idea" of a specific count[ed "number"].

A number can be a numeral only, or any combination of numerals and signs. A number can be written with one or more words, letters, numerical digits, or symbols. A number is a concept that has various representations/notations/expression:

- Twenty one or two ten one
- XLII
- 42
- -42
- 1010102
- 2A16
- 7x6

Something made up of digits is not necessarily a number. A number has a numeral value, while digit is just a representation.

NOTE: *The allowance for reusing numerals (symbols) simplifies arithmetic.*

2.5.3.1 Base digits

A.k.a., Radix digits.

Every number system has a specific [finite] number of unique digits known as its base/radix (i.e., the number of unique digits in the system).

In mathematical numeral systems, the radix or base is the number of unique digits, including zero. Etymologically, 'radix' is a Latin word for "root". Root can be considered a synonym for base in the arithmetical sense. For example, for the deci-mal system (the most common system in use today, coming from the ten fingers/digits of humans) the radix (base) is ten, because it uses the ten digits from 0 through 9. If numerical representations greater than 9 are required, then a new position is required (10,11,12,13,14,...,99,100,...,999,100 0...).

> **DEFINITION:** *The word "base" in mathematics is used to refer to a particular mathematical object that is used as a building block.*

Different numeral systems have a different number of base digits:

1. In the base 10 (a.k.a., decimal, radix 10) number/ numeral system:
   A. The digits are: 0,1,2,3,4,5,6,7,8,9.
   B. The numbers are: Zero, one, two, three, four, five, six, seven, eight, nine.
   C. A random numeral is: "153" is made up of 3 digits ("1", "5", and "3").
2. In the base two (binary) number system, the digits are:
   A. 0,1.
   B. The digits 0 and 1 are then used to represent numbers as follows: 0, 1, 10, 11, 100, 101, 110, 111, 1000, 1001,
3. In the base sixteen (a.k.a., hexadecimal, sexadecimal), another six digits are required to represent the numbers ten through fifteen. Hexadecimal uses the digits 0-9, followed by the letters A-F to represent values from 10 to 15.
   A. 0,1,2,3,4,5,6,7,8,9,A,B,C,D,E,F.

2.5.4 "Positionality" in a numeral system

Number/numeral systems may be categorized by either positional or non-positional notational encoding logic. There are two primary ways in which numbers can be represented/encoded. They can either be encoded positionally, or encoded without position having meaning (i.e., non-positionally). Positional [numeral system] notation is distinguished from non-positional notation by its use of the same symbol for different "orders of" magnitude (different meanings). For example, the "ones place" (1), "tens place" (10), "hundreds place" (100) – the 1 repeats three time, and means something different each time (one, ten, then hundred). In a positional numeral system, the position of any given digit in a number has [logarithmic] mathematical significance.

2.5.4.1 Non-positional numerals

Non-positional number/numeral system (non-positional notation): Characters/digits are position invariant, meaning each character represents the same value regardless of its position. In Roman numerals, for example, the symbol V always means "five", whether it occurs last in a numeral string (e.g., XXV), next to last (XXVI), third from last (XXVII) or fourth from last (XXVIII). In the Roman numeric system, each numeral has a fixed value, rather than representing multiples of the base number (e.g., 10, 100, and so on), according to position. Hence, there is no need for "place keeping" zeros. Notice that in the Roman system, position still has relevancy (e.g., I before V or X indicates one less), but that relevancy has no fixed zero relationship, no positional relevance [relative to the number as a whole].The unary (base-1, tally marks) numeral system, frequently used for counting, is non-position: /=1; //=2; ///=3; ////=4; /////=5; //////=6; etc.

- **Unary (non-positional)** – every natural number is represented by a corresponding number of symbols. If the symbol "/" is chosen, for example, the number seven would be represented by /////// (seven of the symbol "/"). Any number (i.e., any value) can be represented by combining these digits. The unary [numeral] system can be modified by introducing different symbols for certain values.

> **NOTE:** *Arithmetic operations are possible, but more difficult.*

Non-positional number systems have a base number of repeating digits, which may be 1 or more. However, they are not (generally) categorically named after their base, they are given cultural names.

Note: It could be said that there are cultural number/ numeral systems. Cultural numeral systems involve unique character/symbol visualizations, and they include but are not limited to: Babylonian, Egyptian, Vedic, Greek, Roman, Chinese, Arabic, Hebrew, Indian, etc. In this category, the numerals and their rules are viewed as having arrived due to unique cultural values and symbols. Simply, a cultural numeral system is the name of any given numeral system a specific "culture" uses, and it may be positional or non-positional.

2.5.4.2 Positional numerals

Positional number/numeral system (positional notation, place-value notation): Place (position) has value (meaning). Where a digit occurs in a number (as a string of digits) determines its meaning. A positional number system gives different meaning to the same symbol depending on its position. The position dictates rules to manipulate the symbols, not their value (magnitude). In a positional number system, the value of each digit is determined by which place it appears in the full number. A positional (numeral) system is a system for representation of numbers by an ordered set of numerals symbols (called digits) in which the value of a numeral symbol depends on its position. For each position a unique symbol or a limited set of symbols is used.

The base of a positional number system is, how many digits (symbols) there are for each position in a number.

In a positional system, the value of a symbol is given by the order of its position expressed in the bases (or radices) of the system. The total value of the represented number in a positional number is the sum of the values assigned to the symbols of all positions. For each position that the number is in, in that system has a relative symbol or meaning, and in a way relates to the number directly next to it. The total value of a positional number is the total of the resultant values of all positions. For each position that the number is in, in that system has a relative symbol or meaning, and in a way relates to the number directly next to it.

In a positional [notation] numeral system each position is related to the next by a constant multiplier (i.e., base) of that numeral system. The different numeral systems sub-categorized by different bases are given the suffixes -ary, -imal, and -al. Each position represents a different base.

Positional number systems are categorized by their radix/base. Each iteration of the base forms a magnitude of sequentially iterating order (known as "orders of magnitude").

There are generally considered two sets of rules for encoding positional information: [a] "standard" [set of] rules; and [a] "non-standard" [set of] rules:

1. Standard positional numeral systems/notation – whole number orders of magnitude from base/radix 2 onward.
   A. Binary, ternary, quaternary, quinary,...,decimal, sexagesimal,...
   B. The non-standard positional numeral systems are.
2. Bijective numeration.
   A. Signed-digit representation.
   B. Negative bases.
   C. Complex bases.
   D. Non-integer bases.

In any standard positional numeral system, the number x and its base y are conventionally written as (x) y, although for base ten the subscript is usually assumed and not written, as it is the most common way to express value (by our organism, because of our 10 fingers). For example, (100)10 (in the decimal system) represents the number one hundred, while (100)2 (in the binary system with base 2) represents the number four.

With the use of a radix point ("."; e.g., decimal point in base-10), the positional notation can be extended to include fractions and the numeric expansions of numbers into rational and real categories (i.e., into a "real" [one dimensional, root = base/radix] set). Note that the point/dot takes on the name of the numeral system. For example, the point/dot in the:

1. Binary numeral system may be called, a binary point.
2. Quinary system it may be called, a quinary point.
3. Decimal system, it may be called, a decimal point.

Examples of positional numerals include, but are not limited to:

1. **Binary (positional)** – two digits (or numerals), 0 or 1. Any number (i.e., any value) can be represented by combining these two digits. This is a base 2 (binary numeral) system. Hence, there are two values. The binary numeral system can be physically implemented with a two-state device.
   A. Positional systems obtained by grouping binary digits by three (octal numeral system) or four (hexadecimal numeral system) are commonly used.
2. **Decimal (positional) Arithmetic [numeral system]** – representation refers exclusively, in common use, to the written numeral system employing numerals as the digits for a radix 10 ("decimal") positional notation. The ten base digits (or numerals): 0,1,2,3,4,5,6,7,8,9 or (0,...,9). Any number (i.e., any value) can be represented by combining these digits. This numeral system is sometimes confusingly called the "arithmetic numeral system". The value assigned to a digit is applied/processed positionally: one's place (1), ten's place (10), hundred's place (100). The system is composed of ten digits, and hence, the position of a digit is used to signify the power of ten that the digit is to be multiplied with: 304 is equivalent to (=) 3×100 + 0×10 + 4×1; or more precisely 3×102 + 0×101 + 4×100.
3. **Phi numeral system (positional)** – is also known as: golden ratio base, golden section base, golden mean base, phi-base, base-ϕ, and phinary. It uses the "golden" ratio (symbolized by the Greek letter ϕ, the irrational number (1 + √5)/2 ≈ 1.61803399 symbolized by the Greek letter φ) as its base.
   A. Additive systems - In additive systems numbers are formed by putting together (in a row) several single characters in order of descending value with each character being repeated as many times as required. In expression, this type of system is known as unary/additive notation.

Note that additive systems may have additive and subtractive notation. For example, the best known form of additive notation is the Roman system which was similar to the ancient Greek system using letter symbols for powers of 10 and for the intermediate numbers 5, 50 and 500. The symbols used were I for 1, V for 5, X for 10, L for 50, C for 100, D for 500 and M for 1000. Thus 1969 would be written as MDCCCCLXVIIII. A subtractive notation was also used so that, for example, 4 could be written as IV as well as IIII, and 1949 as MDCCCCXLVIIII.

B. Multiplicative systems - In multiplicative systems there are two kinds of symbols with the symbols of one kind modifying multiplicatively the values of the second kind of symbols.
C. Arithmetic table

The **decimal point** is the dot (.) placed after the figure representing units in a decimal fraction. A decimal mark is any symbol used to separate the fractional part of a decimal from the whole part. A decimal number usually means there is a decimal point (.) in the number. The decimal point is exactly to the right of the units position and sets the reference standard for all other positions. The number to the left of the decimal is called the “whole number”.

For example,

- 17.591
  - 17 is the whole number.
  - Every movement of a digit further left gets 10 times bigger.
  - Every movement of a digit further right gets 10 times smaller.
- 0.1 = 1/10 = 1 tenth
- 17.591 = 17 + 5/10 + 9/100 + 1/1000

2.5.4.3 Number system bases

This is just a way of writing a value down.

1. Roman numerals: I (1), V (5), x (10), L (50), C (100), D (500), M (1000)
2. Base 10 is a number system that uses 10 digits: 0-9.
3. Base 2: 0,1.
4. For bases bigger than 10, capital letters are used as symbols. For example, the sexadecimal (a.k.a., hexadecimal) numeral system (base 16) uses the numerical digits 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F.

The most common bases are binary and hexadecimal (used by computers) and decimal (used by people, because of their ten fingers).

2.5.4.4 Converting [between] bases

In order to convert a decimal number into its representation in a different number base, it is necessary to be able to express the number in terms of powers of the other base. For example, to convert the decimal (based 10) number "100" to base 4, it is necessary to express "100" as the sum of powers of 4:

$$100 = (1 \cdot 4^3) + (2 \cdot 4^2) + (1 \cdot 4^1) + (0 \cdot 4^0)$$

And, to simplify further:

$$100 = (1 \cdot 64) + (2 \cdot 16) + (1 \cdot 4) + (0 \cdot 1)$$

Here, each digit is represented in base 4 using its equivalent value in base 10. In this case, "100" in base 4 is equal to "64" plus "32" plus "4" plus "0" in base 10. So, "(1 • 64) + (2 • 16) + (1 • 4) + (0 • 1)" is just a way of expressing the value "100" in base 10 using the powers of 4.

Now, take the coefficients (the numbers multiplied by the powers of 4) from this expression:

1. Coefficient for 4^3 (highest power): 1
2. Coefficient for 4^2: 2
3. Coefficient for 4^1: 1
4. Coefficient for 4^0 (lowest power): 0

Then, arrange these coefficients together, reading from left to right, to form the number in base 4:

- 100 = 1210 base 4

In this representation, "1210" in base 4 means that it is equal to:

- $(1 \cdot 4^3) + (2 \cdot 4^2) + (1 \cdot 4^1) + (0 \cdot 4^0)$ in base 10, which simplifies to "100" in base 10. So, "1210" in base 4 is equivalent to "100" in base 10.

2.5.4.5 Numeral system sub-inputs

A numeral system has the following sub-inputs:

1. The symbols: Roman numerals, binary, decimal, fractions, scientific notation, etc.
   - For example, the decimal system has the following symbols: 0,1,2,3,4,5,6,7,8,9, -
2. Rules for combining
   - For example, the decimal system has the following rules:
   - Ordering: -9,-8,-7,-6,-5,-4,-3,-2,-1,0,1,2,3,4,5,6,7,8,9
   - Every symbol to the right represents a one value (or count) increase [in the expressed quantity].
   - Combining: 11,12,13,23,33,45,...
   - When a symbol appears to the right of another symbol it is added.
   - Scaling: 10,20,30,100,200,300,1000, 1100,...

- Every additional digit represents an increasing (left) or decreasing (right) factor (a.k.a., multiple) of ten.

3. Thus, the creation of a logical numeral system: 0,1,2 ,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,30,40, 50,60,70,80,90,100,200,300,...

Numeral systems may be classified by the symbol (and therein, the number of symbols used):

Table 2. Measurement > Numbers*: Table shows base 10 counting symbols in different languages.*

Name	Base number of symbols	Symbols
Greek numerals	10	ō α β γ δ ε ζ η θ ι ...
Western Arabic numerals	10	0 1 2 3 4 5 6 7 8 9
Roman numerals	10	N I II III IV V VI VII VIII IX XL C D M

2.5.1 "Operations" in a number system

A.k.a., Mathematics.

The concept, "number" has the following properties, which represent the fundamental operations that can occur to counts.

The fist operation of an applied number system is the operation of counting:

1. **Sequencing**: Creating another one (sensing another pattern, an equal interval) – the sensation or creation of iteration.
   A. Counting (sequence[d/ing]), for example:
      1. 0,1,2,3,4,5,6,...

A number can have [at least] the following operations repeated on it:

1. Scaling (order of magnitude), for example:
   A. 1,10,100,1000; 10,20,30,40
2. Flipping (inverse), for example:
   A. 1,-1;2,-2;3,-3;4,-4
3. Rotating (angle,radian), for example:
   A. 3i;9i;3+4i
4. Linearity operations (i.e., linear patterns, linear algebra, operations performed along a number line):
   A. (+) Addition.
   B. (-) Subtraction.
   C. (•) Multiplication.
   D. (/) Division.

The conceptual evolution of the addition operation viewed from the perspective of sub-division (or pattern recognition):

1. Addition.
   A. An additional sub-division/pattern in the sequence.
2. Inverse addition (subtraction).
   A. Reverse sub-division/inverse of pattern in the sequence.
3. Repeated addition (multiplication).

> **NOTE:** *In linear algebra, when there are two numbers in awareness/memory, the larger will always lie to the right or left (up or down) of the smaller one. Symbols are used to communicate relationships between numbers [on the number line].The operation minus from the sign of a negative number (as -2 = negative 2).*

There are equality relationships (i.e., equality patterns, statistics and probabilities math, statistical operations):

- (=) is equal to, of equal value.
- (≠) does not equal, is not of equal value.
- (≈) is approximately equal to.
- (=) set.
- (==) Equals.
- (===) identical.

There are order relationships (i.e., order patterns, optimization):

- (<) less than.
- (>) greater than.
- (≤) less than or equal to.
- (≥) greater than or equal to.

There is also a set of axiomatic operations that can be performed on hardware using "binary" machine language. It is relevant to note here that "binary" data can have logical operations performed on it, specifically the discrete logical operators:

- AND.
- OR.
- NOT.

These three axiomatic operators, also known as "Boolean" operators, allow computers to perform logical operations on binary data.

> **NOTE:** *In logic, and hence, mathematics, there is an order to operations (i.e., an order to relationships). In mathematics, this order is known as 'the order of operations'.*

Mathematical operations are also called, functions, expressions, number sets, and operations. Physical operations are also called, formulas, functions, and operations. The mathematical operation is a notation for mapping patterns of [information] movement.

In the sense that a solution involves numbers, there is synthesis and analysis:

1. **Synthesis**: Combining more than one into one (e.g., 1+1) – integrating two of the same categorical values into one [whole] value of the same category, addition. A "sum" is produced. The operation: addition of two similar data points (values). The result: the sum "product" of those values.
   A. Integration: Repeatedly combining more than one into one (1+1+1) has its own notation, 1x3, multiplication. Multiplication is the repeated integration of a sequence value and a [whole] category value, which produces a new information "product". This number has two data points, sequence [value] and category [value]. Multiplication is repeated addition.
      1. The operation.
      2. The result.
2. **Analysis**: Separating one into more than one (e.g., 1/2) - subdividing one interval [value] into more than one interval [value]. This is divisioning (as "subtraction").
   A. Delineation: Repeatedly subdividing one or more, into one or more is called "division". Division produces a new information product known as a 'quotient'. Division is repeated subtraction [to form a new interval].
      1. The operation.
      2. The result.

Analysis could be viewed as measurement, and synthesis as the integration of a measurement toward greater understanding and more refined models.

2.5.1 The integral function

A.k.a., Multiplication.

Integrals are usually described as the inverse of differentiation, finding the area under the curve, and so on. Integrals allow for the 'multiplication' of changing numbers. Take for example, "3 x 4 = 12"; what if one quantity is changing? It is not possible to multiply changing numbers, so the next operation is to integrate (integration), a more complex multiplication operation.

With regular multiplication, it can be assumed that the value of one unit holds for the entire whole. Integration (piece-by-piece) is required when there is change/time. Time/change becomes a series of instants, each with its own value. Add up the instances (i.e., distance moved) on an instant-by-instant basis.

Multiplication is the understood beginning of [numerical] integration. A number can be broken into units (whole and partial). Then, each unit (piece) can be multiplied (duplicated) by a sequence of iterations, and the results can be added:

1. **The addition operation:** Integers can be added together (integrated) into another number, a piece of data, a result [of calculation].
2. **Multiplication operation at integer level of conceptualization:** Integers can be repeatedly added together (repeated integration). With integers, multiplication is repeated addition.
3. **Multiplication operation at negative number level of conceptualization:** with negative numbers, multiplication is flipping.
4. **Multiplication operation at "real" number level of conceptualization:** with real numbers, multiplication is scaling.
5. **Multiplication operation at complex number level of conceptualization:** with complex numbers, multiplication is rotating and scaling.

2.5.1.6 Multiplicative model

Multiplication is:

- To multiply one number *n* (a multiplicand) by another *m* (a multiplier) means to repeat a multiplicand *n* as an addend *m* times. The result of multiplying is called a product.

The multiplicative model is:

- Product (dividend) is factor (divisor) • factor (quotient).
- Dividend – the number being divided.
- Divisor or factor – the number that will divide the dividend exactly.
- When a multiplication fact is known, then a division fact must also be known.
- Divisible – can be divided without a remainder.
- Quotient – the result of division.

> **CLARIFICATION:** *To duplicate is to make an "exact" (or as close to) copy; a second copy of the pattern. One might offer the idea that instead of subtract, 'sublicate' (reverse of duplicate) means "to take away".*

There are multiplication and division tables. There is one model for multiplication:

1. Repeated addition is the model for multiplication.
2. Multiplier – the number of sets (of a patter).
3. Multiplicand – the value/amount in each set.
4. Product/result – multiplier multiplied by the multiplicand (i.e., multiplier x multiplicand = product). Here, order in the operation is irrelevant.
5. For example, 4x6 = 6+6+6+6 = 24.

2.5.2 The quadratic function

A quadratic function is one of the form f(x) = ax2 + bx + c, where a, b, and c are numbers with a not equal to zero. The graph of a quadratic function is a curve called a parabola. Parabolas may open upward or downward and vary in "width" or "steepness", but they all have the same basic "U" shape.

A quadratic function is graphically represented by a parabola with vertex located at the origin, below the x-axis, or above the x-axis. Therefore, a quadratic function may have one, two, or zero roots. Here, 'roots' are also called x-intercepts or zeros.

2.5.3 The division function

Relationships between division and multiplication operations include:

1. Division is the opposite of multiplication.
2. Division as a process is a multidimensional notion.
3. Division expresses the concept that from a whole [number] there is an equal divisioning [number]. Division is the separation of a number into equal parts. Division may be viewed as a form of repeated subtraction from a whole.
4. Division is the operation of repeated sub-divisioning. The result of the division operation is new data about a pre-existing number.
5. To divide is to separate one into more than one, equally or unequally. Division is the repetition of separating one into more than one.
6. Multiplication is a form of repeated addition.
7. Multiplication is repeated addition. The result of the multiplication operation is.
8. The multiplication [function as an] operation asks, How many in all; how many [units] in whole [unit]; how many all together?
9. Multiplication is: factor (group sequence) x factor (group value) = product
10. Addition is the combining of two or more. To multiply is to take one out and duplicate it one, and then, combine the sequence and interval values into a "product".

The repeated summation of one "factor" and another "factor". The word factor could be replaced by any word meaning

The division [function as an] operation asks, How many each; how many groups; what is each share/partition?

There are two models for division:

1. Partition division (also known as partitive, sharing and grouping division) is a way of understanding division in which you divide an amount into a given number of groups. If you are thinking about division this way, then 12 ÷ 3 means 12 things divided evenly among 3 groups, and we wish to know how many is in 1 (each) group.
2. Measurement division (also called repeated subtraction division), is a way of understanding division in which you divide an amount into groups of a given size. If you are thinking about division this way, then 12 ÷ 3 means 12 things divided evenly into groups of 3, and we wish to know how many groups we can make.

2.5.4 The scaling function

NOTE: *In order to communicate results unambiguously it is necessary for each of us to share the same scale for a quantity and to have access to the standards that define the scale.*

A scale is a totally ordered numerical structure onto which physical quantities are mapped, with the mapping preserving the structure of the original physical quantity. Every scale can be realized using mathematical concepts.

Length and angle scales are realized with mathematical concepts. Hardness, temperature, and other environmental scales are realized using concepts from physics rather than mathematics. Both length and angle scales are linear scales. Length requires a unit length to be defined. Early unit length standards were realized as end bars,in which the fundamental unit was the distance between the two ends of the bar. The meter, the fundamental unit of length, is now defined from concepts in physics, rather than being based on the results of a mathematical survey of a geographical artefact.

The fundamental unit is then divided upon a continuum, into a 'scale'. It may be divided equally, or unequally (and its visual representation as equal or unequal depends upon the particular notation). Mathematically, division is interpolation, which is the computation of new data points from known discrete points. For the length scale, this consists of dividing the unit length, defined by a line scale, into equal lengths, and for angular scales, dividing the circle into equal angles.

Euclid's Elements provides various geometrical constructions to divide lengths into equal parts and constructions for particular angles and angular bisection.

NOTE: *A 'chart' is a two-axis scale (or continuum). A three-dimensional 'Cartesian coordinate system/scale' is a three-axis scale (e.g., x,y,z).*

A scale is a system[s approach] that we use to perceive [existence], by the method of arranging data [of a similar pattern] in [logical] order.

Every scale requires the following elements:

1. Visually expressed with iterative markings representing the division of a pattern.
2. An ordered numerical/linguistic notation.
3. At least one categorical dimension.

The word scale has several applications, all of which relate to the idea that there exists a divisional iteration of a pattern.

> **CLARIFICATION:** *The term 'continuum' has a relationship to the concept of 'scale'. A continuum is a set of iterations on a scale, which have a particular characteristic to different degrees. Any continuous whole comprising of individual units with a logical progression can be considered a continuum. The term is also given to a body that can be continually sub-divided into infinitesimal elements with properties being those of the bulk material. And, a continuum is a region of filled space.*

2.5.4.1 A scale as a tool for understanding a discontinuous category - scale as a discontinuous category (understanding)

There exists a pattern, and the pattern repeats along an ascending or descending scale. Here, a scale is a conceptual-mathematical visualizing tool for divisional categorization. Numbers can be placed/positioned in order (as intervals) along one or more lines to create a visual scale, which represents a discontinuous category of information. The numerical space between divisions may be equal or unequal.

A number/numerical scale is a line on which the marks of separation have been given numerical names or labels. A number scale is constructed by starting with a line, and a line segment of fixed amount (or magnitude), which represents the first level (or order) of magnitude. Levels (or orders) therefrom may exist at equal or unequal separated magnitudes.

A 'scale' is a way of visualizing spatial size/quantity categorizations with division marks indicating (divisioning, sectioning, or proportioning). Here, a scale is a type of discontinuous, ordered rank of categories or sizes. More generally, a 'scale' refers to a differentiated category of size. Here, the term 'scale' implies the discontinuous (divisioning) idea of, orders of magnitude. A scale forms a sequence of ascending or descending units/intervals of equal or unequal proportion.

> **NOTE:** *A scale can be used as an organizing structure for understanding something.*

A scale mathematically and/or visually represents portions of a whole. A proportion is a way of expressing how the size or magnitude of one thing relates to that of another.

The degree of separation between iterations (e.g., adaptive repetition of 0-9 (1st order of magnitude), to 10-99 (2nd order of magnitude), and so on) may be conceived of as a number, named a 'radix' or 'base'. There are ten [conceptual] degrees of separation between each iteration in the deci-mal number/numeral system (0-9). When these iterations are expressly notated along a [number] line, that is called a number scale.

Each iteration [of the pattern] on the scale (1,10,100,...) represents a positionally relevant ["order of"] magnitude based on the base/radix of the applied number/numeral system. The presence of an ordered difference (rank) among a set of something similar is embodied by the word "order", as in, "order of magnitude".

The order of magnitude [of a scale] is dependent on its base (radix), and on whether the scale is linear or non-linear.

A scale may have equal or unequal divisioning. A non-linear scale consists of unequally spaced divisions (sections or proportions). A scale that has equal divisions is called 'linear', and an unequally divided scale is called 'non-linear':

1. **Linear scale (equally divisioned scale, proportional scale)** – where the divisions (marks) are evenly spaced. On a linear scale, a change between two values is perceived on the basis of the difference between the values. For example, a change from 1 to 2 would be perceived as the same amount of increase as from 4 to 5. Visually, each line, grid or marking [visible on the scale] is equal in value or size. The divisions, sections or proportions on a linear scale are directly proportional (i.e., equal). The relationship between the variables is directly proportional. Thus, a linear scale is sometimes called a, **proportional scale**. A proportional/linear scale always has an "order of magnitude" [off difference between intervals] of one.
    A. As a "gauging/comparing" tool, the linear scale is used to obtain the accurate measurement of: distance, mass, volume, etc.
    B. Machines utilize a linear scale in order to produce precisely desired outputs. Examples of linear scale tools include: ruler, measuring tape, measuring cylinder, graph sheet, etc.
2. **Non-linear scale (unequally divisioned scale, non-proportional scale)** – where the divisions (marks) are unevenly (or not equally) spaced. The relationship between the variables is not directly proportional. In a non-linear scale, the divisions, sections, or proportions are uneven/unequal. This means that the visible lines, grids, or other divisional markings (which may appear equally spaced in the visualization) are not equal or constant in value or size. The divisions, sections, or proportions are not directly proportional. Thus, a non-linear scale is sometimes called a, **non-proportional scale**. Note that because the divisions (marks) are not evenly/equally spaced, it is more challenging for a human to accurately read the scale.
    A. The **logarithmic scale (order of magnitude scale)** is a well-known type of non-linear scale. Visually, each mark on the log scale is

the previous mark multiplied by a value. In a logarithmic scale, values are proportional to the logarithms of the scale numbers. On a logarithmic scale, a change between two values is perceived on the basis of the ratio of the two values. That is, a change from 1 to 2 (ratio of 1:2) would be perceived as the same amount of increase as a change from 4 to 8 (also a ratio of 1:2). A logarithmic scale implies and is based on "orders of" magnitude, rather than individual incrementation, as in a linear scale. Each mark on the logarithmic scale is calculated to be the previous mark multiplied by a value set for the log. A logarithmic scale is marked off in orders of magnitude, that is, each mark on the scale as you move left to right is larger by a multiple of the scales set value, than the one preceding it. If the scales value is 10, then one mark to the right is 10 times larger and one mark to the left is 10 times smaller. On a linear scale the distance from 1.00 to 10.0 is ten times longer than the distance from 0.1 to 1.0. On the logarithmic scale these two distances are equal. Take note that logarithmic does not always mean base 10.

B. The decade log scale is one of the most well-known log scales. One decade is a factor of 10 difference between two numbers (an order of magnitude difference) measured on a logarithmic scale. A decade is a set of ten, or an interval of ten. In the decade log scale, there is a base 10 interval between increasingly higher order whole-number exponentials. For example, 100(1), 101(10), 102(100), 103(1000, 1k), 104(10000, 10k), 105(100000, 100k).

C. One of the most well-known ratios is the "golden" ratio (phi). In geometry, a golden spiral is a logarithmic spiral whose growth factor is φ, the golden ratio. The Golden ratio is a special number found by dividing a line into two parts so that the longer part divided by the smaller part is also equal to the whole length divided by the longer part. It is often symbolized using phi, after the 21st letter of the Greek alphabet. The term 'Phi' was given to the ratio number "in honor of Phidias, the lead sculptor of the Parthenon in Greece". In an equation form, it looks like this: a/b = (a+b)/a = 1.6180339887498948420 ...

CLARIFICATION: *In a non-linear system a change in the output is not proportional to a change in the input. In a linear system, a change in the output is proportional to a change in the input.*

2.5.4.2 A scale as a tool for comparing (gauging)

A scale is a tool used to compare new information to a pre-existing [dimensional] iterative pattern of information, producing new data. A "scale" often signifies a receptor or method that can reliably map a number to a given phenomenon. In this usage, the term may also be part of the proper name of the method signified. This usage implies a comparison of entities, but not the discontinuous idea of "orders of magnitude".

As conceptual instruments, for example: the Mohs scale (hardness), Scoville scale (heat of capsaicin), Kelvin scale (temperature), ph scale, Borg scale (physical exertion), Richter scale (earthquake), and stellar magnitude.

As a physical tool (instrument), confusingly, a scale is also the name of a measuring instrument for weight, as well as another name for a ruler (an instrument for measuring length). Common [physical] length scale measurement gauges include: the Vernier scale, linear scale, engineer's scale, architects scale, scale of duration, scale of calibrated dial.

CLARIFICATION: *Measurement display "gauges" are instruments most often used in situations where the thing being measured changes regularly in time, such as in the measuring of volume of something we being used (e.g., fuel gauge).*

2.5.4.3 Scale in mathematics (fractioning)

"Scale" is a common term in mathematics, usually signifying a proportion. This usage implies a comparison of entities, but not the discontinuous idea of "orders of magnitude".

2.5.4.4 Scale as continuous representation system (modeling)

"Scale" can refer to a continuous representation system (model) that signifies an inter-related set of phenomena. This usage implies a comparison of entities, but not the discontinuous idea of "orders of magnitude". One thing represents another thing, but at a different size. The 'scale ratio' of a model represents the proportional ratio of a linear dimension of the model to the same feature of the original.

For example, a smaller 3-dimensional "scale" model of a building, or the scale[d down] drawings of the elevations or plans of a building.

The scale can be expressed in four ways:

1. In words (i.e., lexically using a lexical scale; e.g., one centimeter to one meter).
2. As a ratio (e.g., 1:100).
3. As a fraction (e.g., 1/100).
4. As a graphical (bar) scale.

To scale something is to produce a smaller or larger representation of something. The scaled [down] version of the thing is somewhat confusingly called a 'model' [representation]. A "scale model" is a [physical] model, a representation or copy of an object that is larger or smaller than the actual size of the object, which seeks to maintain the relative proportions (the scale factor) of the physical size of the original object. Very often the scale model is smaller than the original and used as a guide to making the object in full size.

Other examples of a scaled representation system include: the scale on a topological map, a musical scale, and a gauge of measurement.

An object (or representation) can be scaled proportionally and non-proportionally.

1. If an object is being scaled, and its representation maintains proportions after scaling, then it is a proportional scale (i.e., the scaling process/operation used a fixed ratio).
2. If an object is being scaled, and its representation does not maintain proportions, then it is a non-proportional scale (e.g., it may have been scaled along the x-axis, and not equally along the y-axis). This type of scaling is sometimes known as sub-dimensional scaling (i.e., scaling of the unique dimensions of some thing).

2.5.4.5 Scale as providing numerical measurement

Scaling is a term used to describe the way that an operational definition can be conceptualized to provide numerical measurement. Usually the term is applied only to ordinal or interval level measures, as nominal scaling is really just a matter of classification within a set of categories, as we saw above. There are a vast number of different scaling techniques and procedures.

1. **Counting frequencies** - the simplest scaling involves natural measures like the counting of instances of occurrence of events. Such occurrence is absolute in nature and can be measured in terms of its "frequency". Scales reflecting measures of frequency are at the ratio level of measurement.
2. **Measuring magnitude** - of which the Likert scale is a typical example. In this measurement procedure, verbal "anchors", which define the extremes of the dimension being measured, are provided to allow a range of responses to some specific question. It is a mistake to assume that the measurement obtained from magnitude scales such as the ones above is at the interval or ratio level because we have no way of determining that the distances between adjacent scale points are really equal.

2.5.5 The order of magnitude functions

The term/phrase 'order of magnitude' is used to mean more than one thing. The term 'order of magnitude' has two meanings. In its first meaning, it refers to a type of scale. In its second meaning, it refers to a degree (or iterative mark) in a scale of the 'order of magnitude' class. Here, orders of magnitude also known as degrees of separation, and an 'order of magnitude' is one degree of separation, one interval (one sequence).

2.5.5.1 In concern to the term as a class of scale

An order of magnitude is the class of scale (or magnitude) of any amount, where each class contains values of a fixed ratio to the class preceding it. In other words, an order of magnitude is a scale of repeating numerals with a fixed multiple factor (ratio). Here, the term 'ratio' is the relative magnitudes of two quantities (usually expressed as a quotient (the result of division).

In a scale of the 'order of magnitude' type, there is an exponential change of plus-or-minus 1 in the value of a quantity or unit along the continuum.

Any whole number can be an order of magnitude, because any whole number can be radix/base.

In a linear scale, the fixed ratio is one. In a non-linear scale the fixed ratio is not one. An order of magnitude is a number assigned to the ratio of quantities. If the ratio of quantities at each interval is one, then a linear scale exists. If it is not one, then a non-linear scale exists.

Mathematically, the logarithmic scale is used to calculate orders of magnitude.

If the amount being scaled is 10, and the scale is the base 10 exponent being applied to this amount, then to be an order of magnitude greater is to be 10x (times) as large. Such differences in order of magnitude can be measured on the logarithmic scale in "decades" (i.e. factors of ten). Therein, if there are two quantities are of the same order of magnitude, and if one is less than 10 times as large as the other, then the number of magnitudes that the quantities differ is specified to within a power of 10.

The 'order of magnitude' of a scale is the constant factor (ratio) used in division or multiplication to increment a value on the scale.

1. "One order of magnitude more than a given value" - means the multiplication of a given value by the factor (a.k.a., power) of the scale. 100 is an order of magnitude larger than 10. (102 > 101)
2. "One order of magnitude less than a given value" - means the division of a given value by the factor (a.k.a., power) of the scale.

When the ratio/factor is 10, then:

1. One order of magnitude more than 1, is 10 (101); and, one order of magnitude less than 1, is 0.1.
2. Six orders of magnitude more than 1 is 1,000,000 (a million or 106).
3. A value growing by four orders of magnitude implies it has grown by a factor of 10,000 or 104.
4. The order of magnitude of a final number is the number of powers of 10 contained in the number.

The number of powers of 10 contained in 10000 is 104.

2.5.5.2 In concern to estimation

Order of magnitude means a number's nearest power [of some base]. If the magnitude of order is 10, then this means a number's nearest power of ten.

2.5.5.3 In concern to the term as a degree in an 'order of magnitude' scale

An order of magnitude is a degree, or a degree change, in a continuum of size or quantity (of measurement). Here, the term 'magnitude' is the property of relative size or extent (whether large or small).

1. "Its length was on the order of a meter".
2. "The explosion is of a low order of magnitude."

2.5.6 The exponent functions

When a number is multiplied by itself (e.g., 2x2, 4x4, 10x10), the process is called squaring. When a number is multiplied by itself three times (e.g., 2x2x2, 4x4x4, 10x10x10), the process is called cubing. A number multiplied by itself four times has no unique name/label, and is, and thereafter, "raising it to the fourth (fifth, sixth, ...) power". Squaring is raising to the second power, and cubing is raising to the third power.

The power to which a number is raised is the exponent of that number:

- $\text{base}^{\text{exponent}}$
- $\text{base}^{\text{power}}$

There are two commonly accepted notations for the mathematical operation of "raising to a power". For example, raising ten to the power of two:

1. 10^2
2. 10^2

A number can be raised to any power, including decimals. The logarithm of a number is the power that some base number must be raised to get that number.

Logarithms compress scales. A linear scale is like a ruler on which each step on the scale adds a unit: to get two meters, one meter is added to one meter; to get three meters, one meter is added onto another, to which another is added. Conversely, on a logarithmic scale, each step on the scale is a multiple of the preceding step.

For example,

- Log10 1 = 0
- Log10 10 = 1
- Log10 100 = 2
- Log10 1000 = 3
- ...

If the logarithms of two numbers are added together, the result is the logarithm of the product (not the sum) of the two numbers. This reflects the fact that steps on a logarithmic scale are multiples.

When a number is multiplied by itself more than once, it can be expressed (in notation) in terms of an "exponent" - the exponent is a little number to the upper right of the number that says, "this is how many times the number has been multiplied by itself". So,2 x 2 x 2 = 23. The "logarithm" is the reverse of this operation. When we ask, "what is log_2(8)" we are asking, "what is the base 2 logarithm of the number 8", or, "how many times did we multiply 2 (the base) to get the number 8". The answer to this question is the exponent from above.

Logarithms are useful in comparing values that vary over a large range.

In mathematics, the logarithm is the inverse operation to exponentiation. That means the logarithm of a number is the exponent to which another fixed number, the base, must be raised to produce that number. In simple cases the logarithm counts factors in multiplication. For example, the base 10 logarithm of 1000 is 3, as 10 to the power 3 is 1000 (1000 = 10 × 10 × 10 = 103); 10 is used as a factor three times. More generally, exponentiation allows any positive real number to be raised to any real power, always producing a positive result, so the logarithm can be calculated for any two positive real numbers b and x where b is not equal to 1. The logarithm of x to base b, denoted logb(x), is the unique real number y such that by = x. For example, log2 64 = 6, as 64 = 26.

- 26 = 64
- 2 is the base
- 6 is the exponent
- 64 is the result of the operation
- Log2 64 = 6 or Logbase x = exponent

On a logarithmic scale, each delineation/division ("tick mark") on the scale is the previous tick mark multiplied by some number (or value). A logarithmic scale is a nonlinear scale used when there is a large range of quantities. It is based on orders of magnitude, rather than a standard linear scale with equal divisions.

A **physical logarithmic scale** is a scale [of measurement], a tool for comparison, that uses the logarithm of a physical quantity instead of the quantity itself.

Table 3. Measurement > Numbers*: Table showing base 10 counting in exponential and logarithmic form.*

Exponential form	Logarithmic form
10^3=1000	Log10(1000)=Log1000=3
10 is base	

2.5.7 Number classes in statistics

There are multiple types of numbers, which fall into two principal categories: counting numbers and scalar numbers.

1. **Counting numbers (a.k.a., natural numbers, whole numbers, finite cardinal numbers)** – count the presence of something. Positive whole numbers, which have no fractional parts. There are no negative counting numbers. Counting numbers stop at zero.
   A. **Cardinal (expresses iteration)** – pattern/similarity; whole numbers (e.g., 1, 2, 3, etc.). Cardinal numbers are also known as "counting numbers" and are used to count things. Cardinal numbers are the symbol-unit response to the [numerical] inquiry, "How many?"
      1. Cardinal measures refers to the size of something, "How large?". The interval 'level/scale of measurement' is also known as the cardinal level of measure.
   B. **Ordinal numbers (a.k.a., positional numbers; expresses position)** – order/place (e.g., first, second, third, etc.). Ordinal numbers are numbers that denote an item's position or order in a sequence. They are used to indicate hierarchy, sequence, or rank, such as first, second, third, and so on. Ordinal numbers are also known as "position numbers" and are used to place things. Ordinal numbers are the symbol-unit response to the [numerical] inquiry, "Which one?" (or, "What position?").
      1. Ordinal measures refer to the order or the measure, like the order of the cardinality.
2. **Scalar numbers** - real numbers used to measure some quantity to any desired degree of accuracy. Numbers are strings of digits used to indicate magnitude. In measurement applications, numbers measure the presence of a quantity, known as "magnitude".
   A. **Signed numbers:** Signed numbers are numbers that include a sign (either positive or negative) to indicate their magnitude relative to zero. They can represent quantities that may increase or decrease, such as temperatures above or below a certain point, elevations below sea level, or balances that can be in debt (negative) or surplus (positive). Signed numbers include both positive and negative integers and real numbers. Signed numbers expand the concept of scalar numbers by including the dimension of directionality in terms of being above or below a reference point (zero). They encompass both positive and negative values of counting numbers, whole numbers, and real numbers.
      1. **Positive numbers:** A positive number is a number different than zero, preceded by a "+" (plus) sign. Sometimes positive numbers are not preceded by any sign. If a number is not preceded by a sign it is considered to be a positive number.
         i. Example of positive numbers: 5; +3; +7; ...
      2. Negative numbers: A negative number is a number different than zero, preceded by a "–" (minus) sign. Negative numbers are always preceded by a "–" sign.
      3. The absolute value of a number is the value of the number without a sign. The absolute value of a number is written as shown:
         i. |a| is the absolute value of the number a and has a positive value.
         ii. Example of absolute value of a number: |+9| is equal with 9; |-7| is equal with 7; |0| is equal with 0;.....

INSIGHT: *In the Dutch language, for instance, it has different words for number ("getal", as in the list of natural numbers, or the pure decimal system, old-English "tale") and cardinal number ("aantal", the number of elements, English "tally"). Historically, the concept 'number' was synonymous, but it has since been given a broader meaning (i.e., negative, and complex numbers). Hence, in Dutch, the broader meaning of number is called getal, and aantal refers to the cardinal number or count [of something]. Aantal is an arithmetic value, expressed by a word, symbol, or figure, representing a particular quantity used in counting and making calculations, and for showing order.*

If there is only the number sequence of set S = {1, 2, 3, ...}. Then, cardinal number of set A" is the number of elements in the set. It is not a specific kind of number (like rational or complex). Similarly, ordinal is not a special number, but merely S applied to ordering. The following question is meaningless, "Is zero an ordinal or cardinal number?" Zero can be the value of the cardinal number of a set. Whether counting starts with 0 is an issue of convenience, though not entirely logical. When you have a list of elements, it is not so practical to start the labeling with 0, since the rank numbers might become adjectives that differ from the proper ranks. However, the tendency would be to associated "level 3" with "the third level", with "third" the adjective of "three". It appears difficult to suppress that tendency.

Math can be applied to both counting and scalar numbers. For counting, 2 apples + 3 apples = [a count of] 5 apples. And, cardinal and ordinal numbers can be used together in the same argument (i.e., in the same sentence/operation).

Nominal numbers are also known as "categorical numbers" and are used to categorize things. Nominal/categorical numbers are numeric codes - numerals used for labelling or identification only. For example, a licensing identification (ID) "number" is not a number; it cannot be used to measure anything, and mathematics does not apply. It is simply a string of symbols/

characters that identifies one particular ID from many IDs. Arithmetic cannot be done on the IDs because they are not numbers, they are identifiers (i.e., labels). For efficiency, the selection of identifiers should make logical [conceptual]. "Identifying" numbers are neither counting nor scalar numbers; instead, they are the symbols used to identify something or act as an identifying label. For example, a phone “number”, or id “number” are not scalars.

- **Nominal numbers (a.k.a., label category, id numbers)** – structure through name (naming) and identity (identifying). Nominal numbers can be single (e.g., 2, 4, 5, 3, 1) or grouped. (e.g., 234, 4432, 53, 3344, 153).

Table 4. Measurement > Numbers*: Table shows counting and scalar number ordering.*

Set A is counted using ordered {1,2,3...}	Order in A is not relevant	Order in A is relevant
Counting (process; “order some or all”)	{1,2,3...}	{1st, 2nd, 3rd, ...}
Cardinal (result) (“how many elements are there?”)	{1,2,3,...}	{1,2,3,...}

2.5.7.1 Cardinal numbers (a.k.a., whole numbers, natural numbers, or counting numbers)

In mathematics, cardinal numbers, or cardinals for short, are a generalization of the natural numbers used to measure the cardinality (size or magnitude) of sets. The cardinality of a finite set is a natural number: the number (count) of elements in the set. Cardinal numbers are the natural numbers beginning with 0. The counting numbers are exactly what can be defined formally as the [finite] cardinal numbers.

> **NOTE:** *The transfinite cardinal numbers describe the sizes of infinite sets.*

When we have a set of objects, the cardinality of the set is the number of objects it contains. Formally, counting numbers are the set of all non-negative integers.

The scale of cardinal numbers are (i.e., the cardinal number scale is):

- 0,1,2,3,4,5,6,7,8,9,10,...

Cardinal numbers are integers that can be zero or positive. The usage of a cardinal number assume that the thing(s) being counted are not divisible. There can be 4 of a system, but never 3½ of a system.

3 Metrology

A.k.a., Measurement science.

In VIM3, metrology is defined as the science of measurement and its application. Metrology includes all theoretical and practical aspects of measurement, including the measurement of uncertainty and any field of application. It is the experimental and theoretical study of [weights and] measurement to ensure an optimized determination of the level of uncertainty in any field of science and technology. In practical terms, metrology ensures calibrated instruments deliver accurate results, and engineered systems operate effectively. Metrology is an integral part of the theory of epistemology, gnoseology (Read: the study or philosophy of knowledge). Metrology is the study of obtaining accurate quantitative knowledge. Metrology is the basis for empirical science and engineering. It allows for the generation of knowledge (as ordered information with logical uncertainty) of existence by transferring observational data into formal theory, and expressing them with logic (i.e., mathematical-statistical).

> **CLARIFICATION:** *Metrology should not be confused with meteorology, which is the science of weather phenomenon.*

Performing a measurement means comparing an unknown physical, existent quantity (or quality) with a quantity (or quality) of the same type. The quantity of the same type to which the unknown quantity is being compared may be considered by a population as a reference, a standard, quantity. That standard may be expressed as itself, as in the case of a meter length ruler (a tool) for measuring a meter of length, or more complexly expressed as in the case of a magnetic resonance machine (an instrument) for measuring tissue position. A measurement necessarily involves a reference frame and therefore units. In the not so distant past, there were numerous units used to measure the same physical dimension, which caused engineering problems. The first coherent system of units only appeared with the French revolution: the metric system.

Metrology is a Greek language derived term for the science of measurement:

1. Metro = measurement.
2. Logy = science (or, study of).

> **NOTE:** *In its practical application, metrology requires standardization between cooperating individuals, groups, and systems.*

Processes in metrology include:

1. Establishing units of measurement.
2. Developing methods of measurement.
3. Analyzing accuracy.