**Chapter 1: Measurement**

1. **Introduction**

Once upon a time, there was a young girl named **“*Bujji”***who was on her way to visit her grandfather, **“*Raman”***, a brilliant inventor of toys. As Bujji was traveling to her grandfather's house, she noticed how the landscape around her was constantly changing. She observed the different speeds at which cars were passing her and how the distance between them was changing. She also noticed the changes in her own car's speed and how it affected the time it would take to reach her destination.

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When she arrived at her grandfather's house, he asked her about her Journey and she eagerly shared all the observations she had made along the way. As she was describing the speed, distance, and time it took to reach her destination, *Raman* interrupted her and asked her if she knew **what these quantities were called in physics**. *Raman* then explained that all the things she had been observing were examples of physical quantities in physics. *Bujji* was surprised to hear this, but *Raman* went on to explain that **physical quantities were used to describe the world around us in a precise and quantitative way.**

*Raman* went on to explain that some were **base quantities in physics, meaning that they were fundamental quantities that could not be defined in terms of other quantities** like distance of the travelled by car, time to travelling, mass of the car..etc.

*Bujji* was fascinated by this concept and her grandfather gave her more examples to help her understand the different base quantities. She learned that all physical quantities could be expressed in terms of **just seven base quantities, which included length, time, mass, electric current, temperature, luminous intensity, and amount of substance.**

After explaining the concept of base quantities, *Raman* went on to explain the concept of derived quantities to Bujji. He told her that **derived quantities were quantities that could be expressed in terms of one or more base quantities**. For example, velocity was a derived quantity that could be expressed as distance divided by time.

*Raman* explained that derived quantities were important because they allowed us to describe complex phenomena in the world around us. By breaking down complex quantities into their constituent parts, we could better understand how the world worked.

*Bujji* was fascinated by the concept of derived quantities and asked *Raman* for more examples. *Raman* went on to explain many more derived quantities, including acceleration, force, energy, and power. As *Bujji* listened to *Raman*, she realized that physics was not just a subject in school, but a way of understanding the world around her.

*Raman* continued his explanation to *Bujji* by telling her about the methods used to measure physical quantities. He explained that **measuring physical quantities involves comparing them to a standard or reference object**, which is used as a benchmark to determine the size or magnitude of the physical quantity.

For example, to measure the length of an object, a ruler or tape measure is used as a reference object, while a balance scale is used to measure the mass of an object. Those benchmarks are called units.



*Raman* started by explaining to *Bujji* the importance of units in measuring physical quantities. He explained that **units are used to describe the magnitude or size of a physical quantity, and without them, it would be impossible to compare or measure physical phenomena accurately**.

He then went on to explain the concept of base quantities and their respective units, such as

* Length measured in meters,
* Mass measured in kilograms,
* Time measured in seconds,
* Electric current measured in amperes,
* Thermodynamic temperature measured in kelvin,
* Luminous intensity measured in candela,
* Amount of substance measured in moles.

*Raman* also explained that derived quantities are expressed in terms of base quantities, and their units are derived from the units of the base quantities. For example, velocity is a derived quantity that is expressed in terms of length and time, so its unit is meters per second.

Next, *Raman* showed Bujji how to convert between different units of measurement. He gave examples of how to convert between meters and feet, kilograms and pounds, and Celsius and Fahrenheit. He emphasized that it was important to use the correct units for each physical quantity, and using the wrong units could lead to errors in calculations and misunderstandings.

Now that we have engaged with a fun story, let's dive into the first topic of physics: measurement. *Bujji* learned a lot about physical quantities, units, and conversions during her bujji to her grandfather's house, and we can now study these concepts in greater detail. Let's explore what *Raman* taught her about base quantities, derived quantities, and the corresponding units of each. By the end of our lesson, we will be able to apply this knowledge to solve real-world problems and understand the world around us on a deeper level.

**1.1 Definitions**

* + 1. **Physical quantities** are properties of matter or energy that can be measured using scientific instruments and expressed in terms of a numerical value and a unit of measurement.
    2. **Base quantities** are the most fundamental physical quantities, which cannot be defined in terms of other quantities. The International System of Units (SI) defines seven base quantities: length, mass, time, electric current, temperature, amount of substance, and luminous intensity. These base quantities serve as the building blocks for all other physical quantities.
    3. **Derived quantities** are physical quantities that can be expressed in terms of one or more base quantities using mathematical equations or formulae. Derived quantities are created by combining or manipulating base quantities, and they represent more complex physical properties of a system.

**1.1.4 unit** is a standardized quantity used to express physical measurements. A unit is defined by a particular amount of a fundamental physical quantity, known as a base quantity, which is assigned a standard value and used as a reference point for all other measurements of that quantity.

For example, the meter is the base unit of length in the International System of Units (SI) and is defined as the distance travelled by light in a vacuum in 1/299,792,458th of a second. Other units of length, such as the centimetre or the kilometre, are defined as multiples or fractions of the meter.

**1.2 Seven Basic quantities and its definitions and units is as follows.**

Think of the base quantities in physics as the building blocks of the language of nature. Just as the letters (A, B, C, D..) of the alphabet are the building blocks of the English language, the base quantities are the fundamental units of measure that allow us to describe the physical properties of matter and energy. Without these basic units, we would not be able to express more complex physical phenomena. Just as you can combine the letters of the alphabet to form words and sentences, we can combine the base quantities of physics to form more complex physical quantities, which help us understand the behaviour of matter and energy in the natural world.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Unit | Symbol | Physical quantity | Post-2019 formal definition[[1]](https://en.wikipedia.org/wiki/SI_base_unit#cite_note-SI_9th_edition-1) | Historical origin / justification | [Dimension symbol](https://en.wikipedia.org/wiki/Dimensional_analysis) |
| [second](https://en.wikipedia.org/wiki/Second) | s | [time](https://en.wikipedia.org/wiki/Time) | "The second, symbol s, is the SI unit of [time](https://en.wikipedia.org/wiki/Time). It is defined by taking the fixed numerical value of the caesium frequency, ∆νCs, the [unperturbed ground-state hyperfine transition frequency of the caesium 133 atom](https://en.wikipedia.org/wiki/Caesium_standard), to be 9192631770 when expressed in the unit Hz, which is equal to s−1."[[1]](https://en.wikipedia.org/wiki/SI_base_unit#cite_note-SI_9th_edition-1) | The day is divided into 24 hours, each hour divided into 60 minutes, each minute divided into 60 seconds. A second is 1 / (24 × 60 × 60) of the [day](https://en.wikipedia.org/wiki/Day). Historically, a day was defined as the [mean solar day](https://en.wikipedia.org/wiki/Mean_solar_day); i.e., the average time between two successive occurrences of local apparent solar [noon](https://en.wikipedia.org/wiki/Noon). | T |
| [metre](https://en.wikipedia.org/wiki/Metre) | m | [length](https://en.wikipedia.org/wiki/Length) | "The metre, symbol m, is the SI unit of [length](https://en.wikipedia.org/wiki/Length). It is defined by taking the fixed numerical value of the [speed of light in vacuum](https://en.wikipedia.org/wiki/Speed_of_light_in_vacuum) c to be 299792458 when expressed in the unit m s−1, where the second is defined in terms of [∆νCs](https://en.wikipedia.org/wiki/Caesium_standard)."[[1]](https://en.wikipedia.org/wiki/SI_base_unit#cite_note-SI_9th_edition-1) | 1 / 10000000 of the distance from the [Earth](https://en.wikipedia.org/wiki/Earth)'s equator to the North Pole measured on the [meridian arc through Paris](https://en.wikipedia.org/wiki/Paris_meridian). | L |
| [kilogram](https://en.wikipedia.org/wiki/Kilogram) | kg | [mass](https://en.wikipedia.org/wiki/Mass) | "The kilogram, symbol kg, is the SI unit of [mass](https://en.wikipedia.org/wiki/Mass). It is defined by taking the fixed numerical value of the [Planck constant](https://en.wikipedia.org/wiki/Planck_constant) h to be 6.62607015×10−34 when expressed in the unit J s, which is equal to kg m2 s−1, where the metre and the second are defined in terms of c and ∆νCs."[[1]](https://en.wikipedia.org/wiki/SI_base_unit#cite_note-SI_9th_edition-1) | The mass of one [litre](https://en.wikipedia.org/wiki/Litre) of [water](https://en.wikipedia.org/wiki/Water) at the temperature of melting ice. A litre is one thousandth of a cubic metre. | M |
| [ampere](https://en.wikipedia.org/wiki/Ampere) | A | [electric current](https://en.wikipedia.org/wiki/Electric_current) | "The ampere, symbol A, is the SI unit of [electric current](https://en.wikipedia.org/wiki/Electric_current). It is defined by taking the fixed numerical value of the [elementary charge](https://en.wikipedia.org/wiki/Elementary_charge) e to be 1.602176634×10−19 when expressed in the unit C, which is equal to A s, where the second is defined in terms of ∆νCs."[[1]](https://en.wikipedia.org/wiki/SI_base_unit#cite_note-SI_9th_edition-1) | The original "International Ampere" was defined electrochemically as the current required to deposit 1.118 milligrams of silver per second from a solution of [silver nitrate](https://en.wikipedia.org/wiki/Silver_nitrate). | I |
| [kelvin](https://en.wikipedia.org/wiki/Kelvin) | K | [thermodynamic temperature](https://en.wikipedia.org/wiki/Thermodynamic_temperature) | "The kelvin, symbol K, is the SI unit of [thermodynamic temperature](https://en.wikipedia.org/wiki/Thermodynamic_temperature). It is defined by taking the fixed numerical value of the [Boltzmann constant](https://en.wikipedia.org/wiki/Boltzmann_constant) k to be 1.380649×10−23 when expressed in the unit J K−1, which is equal to kg m2 s−2 K−1, where the kilogram, metre and second are defined in terms of h, c and ∆νCs."[[1]](https://en.wikipedia.org/wiki/SI_base_unit#cite_note-SI_9th_edition-1) | The [Celsius scale](https://en.wikipedia.org/wiki/Celsius_scale): the Kelvin scale uses the degree Celsius for its unit increment, but is a thermodynamic scale (0 K is [absolute zero](https://en.wikipedia.org/wiki/Absolute_zero)). | Θ |
| [mole](https://en.wikipedia.org/wiki/Mole_(unit)) | mol | [amount of substance](https://en.wikipedia.org/wiki/Amount_of_substance) | "The mole, symbol mol, is the SI unit of [amount of substance](https://en.wikipedia.org/wiki/Amount_of_substance). One mole contains exactly 6.022 140 76 × 1023 elementary entities. This number is the fixed numerical value of the [Avogadro constant](https://en.wikipedia.org/wiki/Avogadro_constant), NA, when expressed in the unit mol−1 and is called the [Avogadro number](https://en.wikipedia.org/wiki/Avogadro_number).  The amount of substance, symbol n, of a system is a measure of the number of specified elementary entities. An elementary entity may be an atom, a molecule, an ion, an electron, any other particle or specified group of particles."[[1]](https://en.wikipedia.org/wiki/SI_base_unit#cite_note-SI_9th_edition-1) | [Atomic weight](https://en.wikipedia.org/wiki/Atomic_weight) or [molecular weight](https://en.wikipedia.org/wiki/Molecular_weight) divided by the [molar mass constant](https://en.wikipedia.org/wiki/Molar_mass_constant), 1 g/mol. | N |
| [candela](https://en.wikipedia.org/wiki/Candela) | cd | [luminous intensity](https://en.wikipedia.org/wiki/Luminous_intensity) | "The candela, symbol cd, is the SI unit of [luminous intensity](https://en.wikipedia.org/wiki/Luminous_intensity) in a given direction. It is defined by taking the fixed numerical value of the [luminous efficacy](https://en.wikipedia.org/wiki/Luminous_efficacy) of monochromatic radiation of frequency 540×1012 Hz, Kcd, to be 683 when expressed in the unit [lm](https://en.wikipedia.org/wiki/Lumen_(unit)) W−1, which is equal to cd [sr](https://en.wikipedia.org/wiki/Steradian) W−1, or cd sr kg−1 m−2 s3, where the kilogram, metre and second are defined in terms of h, c and ∆νCs."[[1]](https://en.wikipedia.org/wiki/SI_base_unit#cite_note-SI_9th_edition-1) | The [candlepower](https://en.wikipedia.org/wiki/Candlepower), which is based on the light emitted from a burning candle of standard properties. | J |

**1.2.1 Do we need this much accuracy in defining these base quantities units?**

Of course, the entire world can be described using only these seven base quantities, so it is crucial to be precise in their description. For example, physicists strive to develop clocks of extreme accuracy so that any time or time interval can be precisely determined and compared. You may wonder whether such accuracy is needed or worth the effort.

Here is one example of the worth: Without clocks of extreme accuracy, the Global Positioning System (GPS) that is now vital to worldwide navigation would be useless.

GPS (Global Positioning System) relies on accurate timing to determine the precise location of a receiver. GPS satellites transmit signals that are timestamped with very precise atomic clocks. The receiver on the ground compares the time the signal was transmitted with the time it was received to calculate the distance to each satellite. By combining the distances to multiple satellites, the receiver can triangulate its own position on the Earth.

Any error in the timing of the satellite signals can result in significant errors in the location calculations made by the receiver. Therefore, GPS requires extremely accurate clocks to ensure that the signals are precisely timestamped.

The GPS system uses atomic clocks, which are extremely accurate and stable over time. However, even with atomic clocks, some clock drift and errors can occur due to factors such as temperature changes and relativistic effects.

To mitigate these errors, GPS also uses a technique called differential GPS, which involves comparing the GPS signal received by the receiver with a reference signal from a known location. Any differences between the two signals can be used to correct for errors in the GPS signal.

In summary, accurate clocks are critical for GPS because the system relies on precise timing to determine location. Without accurate clocks, GPS would not be able to provide the precise location information that is required for many applications, including navigation, surveying, and scientific research.

**1.2.2 Expressing Large and Small Quantities in Physics using Scientific Notation and SI Prefixes**

To express the very large and very small quantities we often run into in

physics, we use scientific notation, which employs powers of 10. In this notation,

3 560 000 000 m =3.56 x 109 m

and 0.000 000 492 s = 4.92 X 10-7 s.

Scientific notation on computers sometimes takes on an even briefer look, as in 3.56 E9 and 4.92 E–7, where E stands for “exponent of ten.” It is briefer still on some calculators, where E is replaced with an empty space.

As a further convenience when dealing with very large or very small measurements, we use the prefixes listed in following Table As you can see, each prefix represents a certain power of 10, to be used as a multiplication factor. Attaching a prefix to an SI unit has the effect of multiplying by the associated factor.Thus, we can express a particular electric power as

1.27 X 109 watts = 1.27 gigawatts =1.27 GW

|  |  |
| --- | --- |
| Factor Prefix Symbol  1024- yotta- Y  1021 -zetta- Z  1018 -exa- E  1015 -peta- P  1012 -tera- T  109 - giga- G  106 -mega- M  103 -kilo- k  102 -hecto- h  101 -deka- da | Factor Prefix Symbol  10-1 -deci- d  10-2 -centi- c  10-3 -milli- m  10-6 -micro- m  10-9 -nano- n  10-12 -pico- p  10-15 -femto- f  10-18 -atto- a  10-21 -zepto- z  10-24 -yocto- y |

**1.2.3 Changing Units**

We often need to change the units in which a physical quantity is expressed. We do so by a method called **chain-link conversion**. In this method, we multiply the original measurement by a conversion factor (a ratio of units that is equal to unity). For example, because 1 min and 60 s are identical time intervals, we have Thus, the ratios (1 min)/(60 s) and (60 s)/(1 min) can be used as conversion factors.

1 min/60 s=1

and

60 s/1 min= 1.

This is not the same as writing 1/60 = 1 or 60 /1=1 ; each number and its unit

must be treated together. Because multiplying any quantity by unity leaves the quantity unchanged, we can introduce **conversion factors** wherever we find them useful. In chain-link conversion, we use the factors to cancel unwanted units. For example, to convert 2 min to seconds.

2 min = (2 min) (1) = (2 min)(60 s/1 min)= 120 s.

If you introduce a conversion factor in such a way that unwanted units do not cancel, invert the factor and try again. In conversions, the units obey the same algebraic rules as variables and numbers. However, **the conversion factors** are written in the style of “1 min = 60 s” rather than as a ratio. So, youneed to decide on the numerator and denominator In any needed ratio.

**1.2.4 Derived quantities:**

1. Area: The amount of space enclosed by a 2-dimensional object. It is measured in square meters (m^2).
2. Volume: The amount of space occupied by an object. It is measured in cubic meters (m^3).
3. Density: The amount of mass per unit volume. It is measured in kilograms per cubic meter (kg/m^3).
4. Speed: The rate at which an object moves. It is the magnitude of the velocity vector and is measured in meters per second (m/s).
5. Acceleration: The rate of change of velocity over time. It is measured in meters per second squared (m/s^2).
6. Force:

Definition:

Force is an influence that causes an object to undergo a change in motion or direction.

Explanation:

Force is a vector quantity, which means it has both magnitude and direction. It is typically measured in Newtons (N).

Dimensional analysis:

From Newton's second law, we know that Force (F) = mass (m) \* acceleration (a)

The base units for mass are kg, and the base units for acceleration are m/s^2

Therefore, the base units for force are kgm/s^2, which can also be written as N (Newton) using the unit conversion 1 N = 1 kgm/s^2.

1. Torque:

Torque (N\*m) = Force (N) \* Lever arm (m)

Definition:

Torque is a measure of the ability of a force to cause rotation around an axis or pivot point. It is also known as moment of force.

Explanation:

The torque acting on an object is equal to the force applied to the object multiplied by the perpendicular distance from the axis of rotation to the line of action of the force. The lever arm is the perpendicular distance between the axis of rotation and the line of action of the force.

Dimensional analysis:

Torque (N\*m) = Force (N) \* Lever arm (m)

Force (N) = Mass (kg) \* Acceleration (m/s^2)

Lever arm (m) = Length (m)

Therefore,

Torque (N\*m) = Mass (kg) \* Acceleration (m/s^2) \* Length (m)

The base units for Torque are kg \* m^2/s^2.

1. Linear Momentum (p) = Mass (m) \* Velocity (v)

Definition:

Linear Momentum is the product of an object's mass and velocity. It is a measure of the quantity of motion of an object.

Explanation:

The linear momentum of an object is directly proportional to its mass and velocity. An object with a greater mass or velocity will have a greater linear momentum. Linear momentum is a vector quantity, meaning it has both magnitude and direction. The direction of linear momentum is the same as the direction of the velocity of the object.

Dimensional analysis:

Linear Momentum (p) = Mass (m) \* Velocity (v)

Mass (m) = Kilogram (kg)

Velocity (v) = Length (m) / Time (s)

Therefore,

Linear Momentum (p) = Kilogram (kg) \* (m/s)

The base units for Linear Momentum are kg\*m/s.

1. Angular velocity:

Angular velocity (ω) = Δθ / Δt

Definition:

Angular velocity is the rate at which an object rotates or revolves around an axis, expressed in radians per second.

Explanation:

The angular velocity is defined as the change in angular displacement (Δθ) of an object over a change in time (Δt). It is a vector quantity that points along the axis of rotation, perpendicular to the plane of rotation, and has units of radians per second.

Dimensional analysis:

Angular velocity (ω) = Δθ / Δt

Δθ = Angular displacement (radians)

Δt = Time (seconds)

Therefore, the base unit for angular velocity is radians per second (rad/s).

1. Angular momentum:

Angular momentum (kgm^2/s) = Moment of inertia (kgm^2) \* Angular velocity (rad/s)

Definition:

Angular momentum is the measure of an object's resistance to changes in rotational motion. It is a vector quantity that points in the direction of the axis of rotation.

Explanation:

The angular momentum of an object is equal to the moment of inertia of the object multiplied by its angular velocity. The moment of inertia is a measure of an object's resistance to changes in its rotational motion. It depends on the distribution of mass in the object and the axis of rotation. The angular velocity is the rate at which the object rotates around the axis of rotation.

Dimensional analysis:

Angular momentum (kgm^2/s) = Moment of inertia (kgm^2) \* Angular velocity (rad/s)

Moment of inertia (kg\*m^2) = Mass (kg) \* Radius^2 (m^2)

Angular velocity (rad/s) = Angle (rad) / Time (s)

Therefore,

Angular momentum (kg\*m^2/s) = Mass (kg) \* Radius^2 (m^2) \* Angle (rad) / Time (s)

The base units for angular momentum are kg\*m^2/s.

1. Impulse:

Definition:

Impulse is the product of force and time during which it acts on a body. It is a measure of the change in momentum of an object.

Explanation:

When a force acts on an object for a certain period of time, it causes a change in the object's momentum. The product of the force and the time for which it acts is called impulse. In other words, impulse is equal to the change in momentum of an object.

Dimensional analysis:

Impulse (N s) = Force (N) \* Time (s)

Force (N) = Mass (kg) \* Acceleration (m/s^2)

Therefore,

Impulse (N s) = Mass (kg) \* Acceleration (m/s^2) \* Time (s)

The base units for impulse are kg \* m/s.

1. Energy:

Energy (Joule) = Force (N) \* Distance (m)

Definition:

Energy is a measure of the ability of a system to do work. It is a scalar quantity that is expressed in Joules.

Explanation:

When a force is applied to an object and it moves a certain distance, energy is transferred to the object. This energy can be stored in the object and used to do work later. The amount of energy transferred is equal to the force applied multiplied by the distance the object moves.

Dimensional analysis:

Energy (Joule) = Force (N) \* Distance (m)

Force (N) = Mass (kg) \* Acceleration (m/s^2)

Distance (m) = Length (m)

Therefore,

Energy (Joule) = Mass (kg) \* Acceleration (m/s^2) \* Length (m)

The base units for Energy are kg \* m^2/s^2.

1. Kinetic energy:

Kinetic Energy (J) = 1/2 \* Mass (kg) \* Velocity^2 (m/s)^2

Definition:

Kinetic energy is the energy that an object possesses due to its motion. It is a scalar quantity that depends on the mass and speed of the object.

Explanation:

The kinetic energy of an object is directly proportional to its mass and the square of its speed. This means that an object with a greater mass or velocity will have a greater kinetic energy. Kinetic energy is a scalar quantity because it has magnitude but no direction.

Dimensional analysis:

Kinetic Energy (J) = 1/2 \* Mass (kg) \* Velocity^2 (m/s)^2

Mass (kg) = Base unit

Velocity (m/s) = Length/time

Therefore,

Kinetic Energy (J) = kg \* (m/s)^2

The base units for Kinetic Energy are kg \* m^2/s^2, which are equivalent to Joules (J).

1. Potential Energy:

Potential energy (J) = m (kg) \* g (m/s^2) \* h (m)

Definition:

Potential energy is the energy possessed by an object by virtue of its position or configuration in a gravitational field.

Explanation:

When an object is raised to a certain height above the ground, it gains potential energy due to its position in the Earth's gravitational field. The amount of potential energy gained by the object depends on its mass, the acceleration due to gravity, and the height it is raised to.

Dimensional analysis:

Potential energy (J) = m (kg) \* g (m/s^2) \* h (m)

where m = mass of the object, g = acceleration due to gravity, and h = height above the ground.

The base units for Potential energy are kg \* m^2/s^2.

1. Work:

Work (J) = Force (N) \* Distance (m) \* cos(theta)

Definition:

Work is done when a force is applied to an object and the object is displaced in the direction of the force.

Explanation:

Work is equal to the magnitude of the force multiplied by the distance moved in the direction of the force, multiplied by the cosine of the angle between the force and the displacement vectors. If the force and displacement vectors are in the same direction, the angle between them is zero, and the cosine of zero is 1, so the work done is simply equal to the force multiplied by the distance. If the force is perpendicular to the displacement, the angle between them is 90 degrees, and the cosine of 90 degrees is 0, so no work is done.

Dimensional analysis:

Work (J) = Force (N) \* Distance (m) \* cos(theta)

Force (N) = Mass (kg) \* Acceleration (m/s^2)

Distance (m) = Length (m)

Therefore,

Work (J) = Mass (kg) \* Acceleration (m/s^2) \* Length (m) \* cos(theta)

The base units for Work are kg \* m^2/s^2, which is equivalent to Joules (J)

1. Power:

Power (W) = Work (J) / Time (s)

Definition:

Power is the rate at which work is done or energy is transferred.

Explanation:

Power is a measure of how quickly work can be done. It is calculated as the amount of work done over a certain period of time. Work is the amount of energy transferred when a force is applied to an object and it moves a distance in the direction of the force. Time is the duration of the work being done.

Dimensional analysis:

Power (W) = Work (J) / Time (s)

Work (J) = Force (N) \* Distance (m)

Force (N) = Mass (kg) \* Acceleration (m/s^2)

Distance (m) = Length (m)

Therefore,

Power (W) = Force (kg \* m/s^2) \* Distance (m) / Time (s)

The base units for Power are kg \* m^2/s^3, which is also equivalent to Watts (W).

Note: The unit Watt is defined as Joule per second (J/s), where Joule is the unit for work/energy and second is the unit for time.

1. Radius of gyration:

Radius of gyration (m) = sqrt(I / m)

Definition:

The radius of gyration is a measure of the distribution of an object's mass around an axis of rotation. It represents the distance from the axis of rotation to a point where the entire mass of the object could be concentrated to create the same moment of inertia.

Explanation:

The radius of gyration is calculated using the object's moment of inertia and its mass. The moment of inertia is a measure of an object's resistance to rotational motion around an axis. The radius of gyration is the root-mean-square distance of the object's mass from the axis of rotation.

Dimensional analysis:

Radius of gyration (m) = sqrt(I / m)

Moment of inertia (I) = kg \* m^2

Mass (m) = kg

Therefore,

Radius of gyration (m) = sqrt(kg \* m^2 / kg) = sqrt(m^2) = m

The base units for the radius of gyration are meters (m).

1. Moment of inertia:

Moment of Inertia (kg m^2) = Mass (kg) \* Radius of Gyration (m)^2

Definition:

Moment of Inertia is a measure of the distribution of an object's mass around an axis. It represents the resistance of an object to rotational motion.

Explanation:

The moment of inertia of an object depends on its mass and how its mass is distributed around the axis of rotation. The radius of gyration is a measure of how far the object's mass is from the axis of rotation. It is defined as the square root of the object's moment of inertia divided by its mass.

Dimensional analysis:

Moment of Inertia (kg m^2) = Mass (kg) \* Radius of Gyration (m)^2

Radius of Gyration (m) = sqrt(Moment of Inertia / Mass)

Therefore,

Moment of Inertia (kg m^2) = Mass (kg) \* (Moment of Inertia / Mass)

The base units for Moment of Inertia are kg \* m^2.

1. Impulse:

Impulse (N\*s) = Force (N) \* Time (s)

Definition:

Impulse is a measure of the change in momentum of an object when a force is applied to it over a period of time. It is equal to the force applied to an object multiplied by the time for which the force is applied.

Explanation:

The impulse acting on an object is equal to the force applied to the object multiplied by the time for which the force is applied. This means that a larger force or a longer time of application will result in a larger impulse and a greater change in momentum of the object.

Dimensional analysis:

Impulse (N\*s) = Force (N) \* Time (s)

Force (N) = Mass (kg) \* Acceleration (m/s^2)

Therefore,

Impulse (N\*s) = Mass (kg) \* Acceleration (m/s^2) \* Time (s)

The base units for Impulse are kg \* m/s.

1. Pressure:

Pressure (Pa) = Force (N) / Area (m^2)

Definition:

Pressure is defined as the amount of force applied per unit area over which that force is distributed.

Explanation:

Pressure is a measure of the intensity of a force per unit area. It is the force applied perpendicular to a surface divided by the area of that surface. The unit for pressure is Pascal (Pa).

Dimensional analysis:

Pressure (Pa) = Force (N) / Area (m^2)

Force (N) = Mass (kg) \* Acceleration (m/s^2)

Area (m^2) = Length (m) \* Length (m)

Therefore,

Pressure (Pa) = Mass (kg) \* Acceleration (m/s^2) / Length^2 (m^2)

The base units for Pressure are kg/m\*s^2 or N/m^2

1. Escape velocity:

Definition:

Escape velocity is the minimum velocity needed for an object to overcome the gravitational attraction of a planet or other celestial body and escape its gravitational field.

Explanation:

The escape velocity from a planet depends on its mass and radius. To calculate escape velocity, we use the formula:

v = sqrt((2GM)/r)

where v is the escape velocity, G is the gravitational constant (6.674 × 10^-11 N·m^2/kg^2), M is the mass of the planet, and r is the distance from the center of the planet to the object.

In order to escape the gravitational field of a planet, an object must achieve a velocity greater than or equal to the escape velocity. If the object has less than the escape velocity, it will be pulled back by the planet's gravity and will eventually fall back to the surface. If the object has exactly the escape velocity, it will move away from the planet and its path will be a parabolic trajectory. If the object has a velocity greater than the escape velocity, it will move away from the planet and its path will be a hyperbolic trajectory.

Dimensional analysis:

sqrt((2GM)/r) = sqrt((2 \* Nm^2/kg^2 \* kg)/m) = sqrt(2Nm^2/m) = sqrt(2Nm) = m/s

Therefore, the units of escape velocity are meters per second (m/s).

1. Orbital velocity:

Orbital Velocity (m/s) = √(Gravitational Constant \* Mass of Central Body / Distance from Center of Central Body)

Definition:

Orbital velocity is the minimum velocity required by an object to maintain a stable orbit around another object, such as a planet or a star.

Explanation:

The velocity required for an object to maintain a stable orbit around a central body depends on the gravitational attraction between the two objects, as well as the distance between them. The closer the object is to the central body, the stronger the gravitational attraction and the higher the required velocity. The formula for orbital velocity takes into account the gravitational constant (G), the mass of the central body (M), and the distance from the center of the central body (r).

Dimensional Analysis:

Orbital Velocity (m/s) = √(Gravitational Constant \* Mass of Central Body / Distance from Center of Central Body)

Gravitational Constant (m^3/(kg\*s^2)) = Force (N) \* Distance^2 (m^2) / (Mass (kg) \* Distance (m))

Therefore,

Gravitational Constant (m^3/(kg\*s^2))) = Mass (kg) \* Acceleration (m/s^2) \* Distance (m) / Distance^3 (m^3)

Mass of Central Body (kg)

Distance from Center of Central Body (m)

Substituting the dimensional analysis into the formula for orbital velocity:

Orbital Velocity (m/s) = √[(Mass (kg) \* Acceleration (m/s^2) \* Distance (m)) / (Distance^3 (m^3))] \* √(Mass of Central Body (kg) / Distance from Center of Central Body (m))

Simplifying:

Orbital Velocity (m/s) = √(Acceleration (m/s^2) \* Distance (m) \* Mass of Central Body (kg) / Distance from Centre of Central Body (m))

The base units for orbital velocity are m/s.

1. Gravitational potential energy:

Gravitational potential energy (J) = Mass (kg) \* Gravity (m/s^2) \* Height (m)

Definition:

Gravitational potential energy is the energy an object possesses due to its position in a gravitational field. It is the energy an object has because of its height above the ground.

Explanation:

The gravitational potential energy of an object is directly proportional to its mass, the acceleration due to gravity, and its height above a reference point. The reference point is usually taken to be the ground.

Dimensional analysis:

Gravitational potential energy (J) = Mass (kg) \* Gravity (m/s^2) \* Height (m)

Mass (kg) = kg

Gravity (m/s^2) = m/s^2

Height (m) = m

Therefore,

Gravitational potential energy (J) = kg \* m^2/s^2

The base units for Gravitational potential energy are kg \* m^2/s^2.

1. Elastic potential energy:

Elastic potential energy (J) = 1/2 \* Spring constant (N/m) \* (Displacement (m))^2

Definition:

Elastic potential energy is the energy stored in an object due to its deformation, such as a stretched or compressed spring.

Explanation:

When an object is stretched or compressed, work is done on the object which stores energy within it. This energy is called elastic potential energy and is directly proportional to the amount the object is stretched or compressed and the spring constant, which is a measure of the stiffness of the spring.

Dimensional analysis:

Elastic potential energy (J) = 1/2 \* Spring constant (N/m) \* (Displacement (m))^2

Spring constant (N/m) = Force (N) / Displacement (m)

Displacement (m) = Length (m)

Therefore,

Elastic potential energy (J) = 1/2 \* (Force (N) / Length (m)) \* (Length (m))^2

The base units for Elastic potential energy are kg \* m^2/s^2, which is equivalent to joules (J).

1. shear rate: It refers to the rate at which a fluid is subjected to shear deformation. Shear deformation is the result of applying a force to a material such that the material is distorted or deformed. When a fluid is subjected to shear deformation, its layers move relative to each other, resulting in a change in shape and a deformation of the fluid. The rate at which this deformation occurs is called the shear rate. In other words, shear rate is the rate at which the velocity gradient in a fluid changes with respect to distance. It is usually expressed in units of inverse seconds (s^-1). The shear rate is an important factor in determining the viscosity of a fluid.
2. Viscosity:

Viscosity (Pa\*s) = Shear stress (Pa) / Shear rate (s^-1)

Definition:

Viscosity is a measure of a fluid's resistance to flow. It describes the internal friction within a fluid and is related to the rate of deformation of the fluid.

Explanation:

When a force is applied to a fluid, it causes the fluid to flow. However, different fluids respond differently to the same force, depending on their internal structure. Viscosity is a measure of how much a fluid resists this deformation and is caused by the friction between the fluid's particles. It is often described as the fluid's "thickness" or "stickiness."

The viscosity of a fluid can be measured using a viscometer, which measures the fluid's resistance to flow. The two most common types of viscometers are the rotational viscometer and the capillary viscometer.

Dimensional analysis:

Viscosity (Pa\*s) = Shear stress (Pa) / Shear rate (s^-1)

Shear stress (Pa) = Force (N) / Area (m^2)

Shear rate (s^-1) = Velocity gradient (s^-1) = (Velocity difference (m/s) / Distance (m))

Therefore,

Viscosity (Pa\*s) = Force (N) \* Time (s) / Area (m^2) \* Velocity difference (m/s) / Distance (m)

The base units for viscosity are kg / m\*s.

1. Dynamic viscosity:

Dynamic viscosity (Pa\*s) = Shear stress (Pa) / Shear rate (s^-1)

Definition:

Dynamic viscosity, also known as absolute viscosity, is a measure of a fluid's resistance to flow under an applied force or stress.

Explanation:

The dynamic viscosity of a fluid is determined by the way its molecules interact with each other. When a force or stress is applied to a fluid, such as when it flows through a pipe, the fluid experiences a shear stress. The shear rate is the rate at which layers of the fluid move relative to each other, which is caused by the shear stress. The dynamic viscosity is the ratio of the shear stress to the shear rate.

Dimensional analysis:

Dynamic viscosity (Pa\*s) = Shear stress (Pa) / Shear rate (s^-1)

Shear stress (Pa) = Force (N) / Area (m^2)

Shear rate (s^-1) = Velocity gradient (s^-1)

Therefore,

Dynamic viscosity (Pa\*s) = Force (N) \* Time (s) / Area (m^2) \* Velocity gradient (s^-1)

The base units for dynamic viscosity are kg/(m\*s)

1. Kinematic viscosity:

Kinematic viscosity (m²/s) = Dynamic viscosity (Pa\*s) / Density (kg/m³)

Definition:

Kinematic viscosity is a measure of a fluid's resistance to flow under the influence of gravity. It is the ratio of the dynamic viscosity of the fluid to its density.

Explanation:

Dynamic viscosity is a measure of a fluid's resistance to flow due to internal friction, while density is a measure of the fluid's mass per unit volume. Therefore, the kinematic viscosity gives an idea of how quickly the fluid will flow under the influence of gravity, taking into account both its resistance to flow and its density.

Dimensional analysis:

Kinematic viscosity (m²/s) = Dynamic viscosity (Pa\*s) / Density (kg/m³)

Dynamic viscosity (Pa\*s) = Force per unit area (Pa) \* Time (s)

Density (kg/m³) = Mass (kg) / Volume (m³)

Therefore,

Kinematic viscosity (m²/s) = (Force per unit area (Pa) \* Time (s)) / (Mass (kg) / Volume (m³))

Simplifying,

Kinematic viscosity (m²/s) = Length²/time

The base units for kinematic viscosity are m²/s.

1. Young’s Modulus:

Young's Modulus (E) = Stress (σ) / Strain (ε)

Definition:

Young's Modulus is a measure of the stiffness or elasticity of a material. It is the ratio of the stress applied to a material to the resulting strain.

Explanation:

When a force is applied to a material, it deforms or changes shape. The amount of deformation is called strain. Stress is the force applied per unit area of the material. Young's Modulus describes how much a material deforms when a given stress is applied to it. It is a measure of how rigid the material is.

Dimensional analysis:

Young's Modulus (E) = Stress (σ) / Strain (ε)

Stress (σ) = Force (N) / Area (m^2)

Strain (ε) = Change in length (m) / Original length (m)

Therefore,

Young's Modulus (E) = Force (N) / Area (m^2) / (Change in length (m) / Original length (m))

The base unit for Young's Modulus is N/m^2 or Pa (Pascals).

1. Bulk Modulus:

Bulk modulus (Pa) = -(Pressure change (Pa) \* Volumetric strain)/Volume change

Definition:

Bulk modulus is a measure of the ability of a material to withstand changes in volume under external pressure.

Explanation:

When a material is subjected to an external pressure, its volume decreases. The volumetric strain is the ratio of the change in volume to the original volume of the material. The bulk modulus is the ratio of the external pressure applied to the volumetric strain produced. It is a measure of how much the material resists changes in volume due to external pressure.

Dimensional analysis:

Bulk modulus (Pa) = -(Pressure change (Pa) \* Volumetric strain)/Volume change

Pressure change (Pa) = Force (N)/Area (m^2)

Volumetric strain = Change in volume (m^3)/Original volume (m^3)

Volume change (m^3) = Final volume (m^3) - Initial volume (m^3)

Therefore,

Bulk modulus (Pa) = -(Force (N)/Area (m^2) \* (Change in volume (m^3)/Original volume (m^3)))/(Final volume (m^3) - Initial volume (m^3))

The base units for Bulk modulus are kg/m\*s^2.

1. Shear modulus:

Shear modulus, also known as the modulus of rigidity, is a material property that describes the ability of a material to resist deformation in response to an applied shear stress.

Symbol: G

Unit: Pa (Pascal)

Definition:

Shear modulus is defined as the ratio of the shear stress to the corresponding shear strain within the proportional limit of a material.

Explanation:

When a shear stress is applied to a solid material, the material will deform and experience a change in shape. Shear modulus is a measure of the ratio between the shear stress and the resulting deformation caused by the stress. The higher the shear modulus, the less the material will deform under a given shear stress.

Mathematically, the equation for shear modulus can be expressed as:

Shear modulus (G) = Shear stress (τ) / Shear strain (γ)

where τ is the applied shear stress, and γ is the resulting shear strain.

Dimensional analysis:

Shear modulus (G) = Shear stress (τ) / Shear strain (γ)

Shear stress (τ) = Force (F) / Area (A)

Shear strain (γ) = Length (L) / Length (L)

Therefore,

Shear modulus (G) = Force (F) / Area (A) / Length (L)

The base units for Shear modulus are kg/m\*s^2, which can be simplified to Pa (Pascal).

1. Poisson’s ratio:

Definition: Poisson's ratio is the negative ratio of the lateral and axial strain of a material when it is under stress.

Explanation:

When a material is subjected to stress, it deforms in three dimensions. The deformation can be measured as the change in length, width, and thickness of the material. Poisson's ratio relates the change in width or thickness to the change in length when the material is under stress. It is a measure of the tendency of a material to deform laterally when subjected to axial loading.

Imagine a rubber band being stretched lengthwise. As the rubber band is stretched, it becomes thinner in width. This decrease in width is due to the rubber band experiencing a transverse strain. Poisson's ratio expresses the relationship between the longitudinal strain and the transverse strain.

Poisson's ratio is defined as the ratio of the relative change in the width of an object to the relative change in its length when a force is applied perpendicular to its length. For example, if a material has a Poisson's ratio of 0.3, then a 1% increase in length would result in a 0.3% decrease in width.

Poisson's ratio is a property of a material that can affect its behavior under stress. For example, if a material has a high Poisson's ratio, it will experience a greater decrease in width when subjected to tension or compression, which can affect its overall stability and strength.

Poisson's ratio is always negative, as the lateral strain is always in the opposite direction to the axial strain. For example, if a material is stretched in one direction, it will tend to contract in the other two directions perpendicular to the direction of stretching.

Dimensional Analysis: Poisson's ratio is dimensionless.

The formula for Poisson's ratio is:

ν = - (lateral strain) / (axial strain)

Since strain is dimensionless, Poisson's ratio is also dimensionless.

The typical range of Poisson's ratio for most materials is between 0.1 and 0.5.

1. Terminal velocity:

Definition:

Terminal velocity is the highest velocity that a falling object can attain when the resistance of the medium through which it is falling prevents further acceleration.

Explanation:

When an object is falling through a fluid (such as air or water), it experiences two forces: the force of gravity pulling it downwards, and the resistance force of the medium pushing against it in the opposite direction. As the object falls faster, the resistance force also increases until a point is reached where the two forces balance each other out. At this point, the object no longer accelerates and reaches its maximum velocity, known as the terminal velocity.

The terminal velocity of an object depends on a number of factors, including its mass, surface area, and the density and viscosity of the fluid it is falling through. For example, a feather falling through air will reach its terminal velocity much more slowly than a rock of the same size due to the differences in their mass and surface area.

Terminal velocity can also be affected by external factors such as air pressure and temperature. At higher altitudes, where air pressure is lower, objects will reach their terminal velocity at a lower speed.

Dimensional analysis:

Terminal velocity (m/s) = (2 \* mass \* gravity) / (density of medium \* cross-sectional area \* drag coefficient)

where:

mass is in kilograms (kg)

gravity is in meters per second squared (m/s^2)

density of medium is in kilograms per cubic meter (kg/m^3)

cross-sectional area is in square meters (m^2)

drag coefficient is unitless

The base units for Terminal Velocity are meters per second (m/s).

1. Reynold’s number:

Reynolds number = (density \* velocity \* length scale) / dynamic viscosity

Definition:

The Reynolds number is a dimensionless quantity used in fluid mechanics to predict the flow pattern of a fluid. It is named after Osborne Reynolds, who first described the concept in 1883. The Reynolds number is used to determine whether a flow is laminar or turbulent.

Explanation:

The Reynolds number is calculated by taking the product of the density, velocity, and a characteristic length scale of the fluid, and dividing it by the dynamic viscosity. The characteristic length scale is typically the diameter of a pipe or the length of a flat plate.

If the Reynolds number is less than 2000, the flow is considered laminar and smooth, while a Reynolds number greater than 4000 indicates turbulent flow. A Reynolds number between 2000 and 4000 is a transitional region where the flow can exhibit both laminar and turbulent characteristics.

Dimensional analysis:

Reynolds number = (density \* velocity \* length scale) / dynamic viscosity

Density = Mass / Volume

Velocity = Length / Time

Length scale = Length

Dynamic viscosity = Force \* Time / Area

Therefore,

Reynolds number = (Mass / Volume) \* (Length / Time) \* Length / (Force \* Time / Area)

Simplifying,

Reynolds number = (Density \* Velocity \* Length scale) / Dynamic viscosity

The Reynolds number is a dimensionless quantity, meaning it does not have any units.

1. Surface tension:

Surface Tension (N/m) = Force (N) / Length (m)

Definition:

Surface tension is the property of a liquid surface that describes the force acting on the surface per unit length.

Explanation:

When a liquid is placed on a surface, the molecules of the liquid are attracted to each other more strongly than they are attracted to the molecules of the surface. This results in the formation of a surface layer with a higher density of molecules. The surface tension is the force that acts on this layer and is caused by the attraction of the molecules to each other. For example, in water, the oxygen atoms in the water molecules are slightly negatively charged, while the hydrogen atoms are slightly positively charged. This creates a dipole moment, or a separation of charges, in each water molecule.

When the water molecules come into contact with each other at the surface of the liquid, the negative end of one molecule can be attracted to the positive end of another molecule, creating an electrostatic interaction. These interactions contribute to the cohesive forces between the molecules and the surface tension of the liquid. The surface tension is directly proportional to the force acting on the surface and inversely proportional to the length of the surface.

Dimensional analysis:

Surface Tension (N/m) = Force (N) / Length (m)

Force (N) = Mass (kg) \* Acceleration (m/s^2)

Length (m) = Distance (m)

Therefore,

Surface Tension (N/m) = Mass (kg) \* Acceleration (m/s^2) / Distance (m)

The base units for surface tension are kg/s^2.

1. Surface energy:

Surface Energy (J/m^2) = Work (J) / Area (m^2)

Definition:

Surface energy is the energy required to increase the surface area of a liquid or solid. It is a measure of the cohesive forces that hold the molecules together at the surface.

Explanation:

When a liquid or solid is exposed to air or another phase, the molecules at the surface experience a net inward force due to the cohesive forces between them. This results in a tendency for the surface area to decrease and for the system to minimize its surface energy. The work required to increase the surface area of a material by a certain amount is equal to the surface energy of the material, divided by the area.

Dimensional analysis:

Surface Energy (J/m^2) = Work (J) / Area (m^2)

Work (J) = Force (N) \* Distance (m)

Area (m^2) = Length (m) \* Length (m)

Therefore,

Surface Energy (J/m^2) = Force (N) \* Distance (m) / (Length (m) \* Length (m))

The base units for surface energy are kg/s^2

1. Angle of contact:

Definition:

The angle of contact is the angle between the tangent to the liquid surface at the point of contact and the solid surface, measured inside the liquid.

Explanation:

The angle of contact is determined by the intermolecular forces between the liquid and solid surfaces, as well as the forces between the liquid molecules. If the adhesive forces between the liquid and solid surfaces are stronger than the cohesive forces within the liquid, then the liquid will wet the solid surface and the angle of contact will be small (less than 90 degrees). If the cohesive forces within the liquid are stronger than the adhesive forces between the liquid and solid surfaces, then the liquid will form a droplet on the solid surface and the angle of contact will be large (greater than 90 degrees).

Dimensional analysis:

The angle of contact is a dimensionless quantity and does not have units.

However, the intermolecular forces that determine the angle of contact can be analyzed in terms of force (N) and distance (m). The forces can be expressed using the units of Newtons (N), and the distances can be expressed using the units of meters (m).

Therefore, the intermolecular forces that affect the angle of contact can be analyzed using dimensional analysis with the base units of N and m.

1. Heat:

Definition:

Heat is a form of energy that is transferred from one object or system to another due to a difference in temperature. Heat can be transferred through conduction, convection, and radiation.

Q = mcΔT represents the amount of heat energy transferred between two objects or systems as a result of a temperature difference. Q is the amount of heat energy transferred, m is the mass of the object being heated or cooled, c is the specific heat capacity of the material, and ΔT is the temperature difference between the initial and final states.

Explanation:

The equation Q = mcΔT relates the amount of heat energy transferred to the mass of the object being heated or cooled, the specific heat capacity of the material, and the temperature difference between the initial and final states. The specific heat capacity of a material is the amount of heat energy required to raise the temperature of 1 kg of the material by 1 degree Celsius.

Dimensional analysis:

Q = mcΔT

Q (unit of energy) = m (unit of mass) \* c (unit of specific heat capacity) \* ΔT (unit of temperature)

The SI units of mass, specific heat capacity, and temperature are kilograms (kg), joules per kilogram per degree Celsius (J/kg·°C), and degrees Celsius (°C), respectively. Therefore, the dimensional analysis of the equation becomes:

Q (unit of energy) = kg \* J/kg·°C \* °C

Simplifying the equation, we get:

Q (unit of energy) = J (unit of energy)

Therefore, the base unit for heat energy (Q) is the joule (J)

1. Latent heat:

Definition:

Latent heat is the amount of heat energy required or released to change the state of a substance without changing its temperature. This heat energy is either absorbed or released by a substance during a phase transition, such as melting or vaporization.

Explanation:

When a substance undergoes a phase change, it absorbs or releases energy without a change in temperature. For example, when ice melts into water at 0°C, it absorbs energy from its surroundings, but its temperature remains constant until all the ice has melted. Similarly, when water vapor condenses into liquid water at 100°C, energy is released, but the temperature of the water remains constant until all the water has condensed.

Latent heat is expressed in units of energy per unit of mass, such as J/kg or cal/g. The amount of latent heat required or released during a phase change depends on the specific substance and the conditions under which the phase change occurs.

Dimensional analysis:

Latent heat (J/kg) = Energy (J) / Mass (kg)

The base units for latent heat are kg \* m^2/s^2, which are equivalent to joules (J)

1. Specific heat:

Definition:

Specific heat refers to the amount of heat energy required to raise the temperature of a substance by one unit of temperature per unit of mass. It is the measure of the amount of thermal energy that is required to change the temperature of a given amount of substance.

Explanation:

The specific heat of a substance is defined as the amount of heat energy required to raise the temperature of one unit of mass of the substance by one degree Celsius (or one Kelvin). It is an extensive property, meaning that it depends on the amount of the substance present.

The specific heat of a substance is related to its internal energy, which is the total energy of the microscopic motion of the particles that make up the substance. The internal energy of a substance is affected by changes in temperature, pressure, and the number of particles present.

Dimensional analysis:

The dimensional formula for specific heat can be derived as follows:

Specific heat (J/kg\*K) = Heat energy (J) / (Mass (kg) \* Temperature change (K))

Heat energy (J) = Force (N) \* Distance (m)

Force (N) = Mass (kg) \* Acceleration (m/s^2)

Distance (m) = Length (m)

Simplifying this expression, we get:

Specific heat (J/kg\*K) = (m^2/s^2)/K

The base units for specific heat are J/kg\*K.

1. Specific heat capacity:

Definition: Specific heat refers to the amount of heat energy required to raise the temperature of a substance by one unit of temperature per unit of mass. It is the measure of the amount of thermal energy that is required to change the temperature of a given amount of substance.

Explanation: The specific heat of a substance is defined as the amount of heat energy required to raise the temperature of one unit of mass of the substance by one degree Celsius (or one Kelvin). It is an extensive property, meaning that it depends on the amount of the substance present.

The specific heat of a substance is related to its internal energy, which is the total energy of the microscopic motion of the particles that make up the substance. The internal energy of a substance is affected by changes in temperature, pressure, and the number of particles present.

Dimensional analysis:

The dimensional formula for specific heat can be derived as follows:

Specific heat (J/kg\*K) = Heat energy (J) / (Mass (kg) \* Temperature change (K))

Heat energy (J) = Force (N) \* Distance (m)

Force (N) = Mass (kg) \* Acceleration (m/s^2)

Distance (m) = Length (m)

Therefore,

Heat energy (J) = Mass (kg) \* Acceleration (m/s^2) \* Length (m)

Substituting these values into the equation for specific heat, we get:

Specific heat (J/kg\*K) = (Mass (kg) \* Acceleration (m/s^2) \* Length (m)) / (Mass (kg) \* Temperature change (K))

Simplifying this expression, we get:

Specific heat (J/kg\*K) = (m^2/s^2)/K

The base units for specific heat are J/kg\*K.

Specific heat capacity

Specific heat capacity is defined as the amount of heat required to raise the temperature of a unit mass of a substance by one degree Celsius (or Kelvin).

Mathematically, it can be expressed as:

Specific heat capacity (c) = Q / (m \* ΔT)

where:

Q = heat energy supplied or removed (in J)

m = mass of the substance (in kg)

ΔT = change in temperature (in °C or K)

Explanation:

Specific heat capacity is a measure of the amount of heat required to raise the temperature of a unit mass of a substance by one degree Celsius (or Kelvin). In other words, it represents how much heat energy is needed to increase the temperature of a given mass of a substance by a certain amount.

For example, the specific heat capacity of water is 4.18 J/g°C, which means that it takes 4.18 Joules of heat energy to raise the temperature of 1 gram of water by 1 degree Celsius.

Dimensional analysis:

The dimensions of specific heat capacity can be derived from the equation as follows:

Specific heat capacity (c) = Q / (m \* ΔT)

Q has the dimensions of energy (J)

m has the dimensions of mass (kg)

ΔT has the dimensions of temperature (K or °C)

Therefore, the dimensions of specific heat capacity are:

[c] = [Q] / ([m] \* [ΔT]) = [kgm^2/s^2]/([kg][K]) = [m^2/s^2\*K]

The base units for specific heat capacity are J/(kgK) or J/(kg°C).

1. Top of Form
2. Internal energy:

Internal energy is the total energy of a system that includes the kinetic energy of its particles and the potential energy due to the interactions between the particles. It is a state function, meaning it depends only on the current state of the system, not on the path taken to reach that state.

Explanation:

The internal energy of a system is the sum of the kinetic energy and potential energy of its particles. The kinetic energy is due to the motion of the particles, while the potential energy arises from the interactions between the particles. The internal energy can change due to the transfer of energy as heat or work.

When energy is transferred as heat, it can increase the kinetic energy of the particles, resulting in an increase in the internal energy of the system. When work is done on the system, it can also increase the internal energy by increasing the potential energy of the particles.

Dimensional analysis:

The SI unit of internal energy is joules (J). The dimension of internal energy can be determined using the dimensions of its components:

Kinetic energy: kgm^2/s^2

Potential energy: kgm^2/s^2

Therefore, the dimension of internal energy is also kg\*m^2/s^2.

1. Enthalpy:

Definition:

Enthalpy (H) is a thermodynamic property that represents the total heat content of a system at a constant pressure. It is defined as the sum of the internal energy of the system plus the product of the pressure and volume of the system.

Explanation:

Enthalpy is a thermodynamic property that measures the total energy of a system. It takes into account both the internal energy of the system, which is the sum of the kinetic and potential energies of the particles within the system, and the work done by the system on its surroundings. Enthalpy is typically used to describe energy changes during chemical reactions or phase changes.

Mathematically, enthalpy is expressed as H = U + PV, where U is the internal energy of the system, P is the pressure, and V is the volume. Enthalpy is a state function, meaning that it depends only on the initial and final states of the system, and not on the path taken between those states.

Dimensional analysis:

The units of enthalpy are energy per unit mass, typically joules per kilogram (J/kg). The units of internal energy are also joules per kilogram (J/kg), and the units of pressure are newtons per square meter (N/m^2) or pascals (Pa). The units of volume are cubic meters (m^3).

Using the equation H = U + PV, we can see that the units of enthalpy are:

H = U + PV = (J/kg) + (N/m^2) x (m^3/kg)

Simplifying the units, we get:

H = J/kg + Nm/kg = J/kg + J/kg = J/kg

Therefore, the units of enthalpy are joules per kilogram (J/kg).

In summary, enthalpy is a thermodynamic property that describes the total heat content of a system at a constant pressure. It is a state function that depends only on the initial and final states of the system, and is expressed as the sum of the internal energy of the system and the product of the pressure and volume. The units of enthalpy are joules per kilogram (J/kg).

1. Entropy:

Definition:

Entropy is a thermodynamic property that describes the amount of thermal energy in a system that is unavailable to do useful work. It is a measure of the disorder or randomness of a system. Entropy is denoted by the symbol "S" and its unit is joules per Kelvin (J/K).

Explanation:

Entropy is a measure of the degree of disorder or randomness of a system. It is a thermodynamic quantity that describes the number of possible ways that the energy in a system can be arranged. In other words, it describes the number of ways that the molecules in a system can be arranged that would result in the same macroscopic properties, such as temperature and pressure.

The second law of thermodynamics states that the entropy of an isolated system will tend to increase over time. This means that in any process, the total entropy of the system and its surroundings will always increase. For example, when a hot object is placed in contact with a cold object, the heat energy will flow from the hot object to the cold object until both objects reach the same temperature, and the total entropy of the system will increase.

Dimensional analysis:

Entropy (S) = Energy (J) / Temperature (K)

The base units for entropy are kgm^2/s^2K.

1. RMS Speed of gas molecules:

Definition:

The root-mean-square (rms) speed of gas molecules is a measure of the average speed of gas particles in a sample of gas. It is defined as the square root of the average of the squares of the individual speeds of the gas particles.

Explanation:

The rms speed of gas molecules is derived from the kinetic theory of gases, which assumes that gases are made up of a large number of tiny particles that are in constant random motion. The speed of each gas particle is proportional to its temperature and inversely proportional to its mass. Thus, lighter gas particles, such as hydrogen and helium, have higher rms speeds than heavier particles, such as nitrogen and oxygen, at the same temperature.

The formula for rms speed of gas molecules is given by:

vrms = √(3kT/m)

where vrms is the rms speed, k is the Boltzmann constant, T is the temperature in kelvin, and m is the mass of one molecule of the gas.

Dimensional analysis:

The Boltzmann constant k has units of J/K, temperature T has

units of K, and mass m has units of kg. Therefore, the units of the rms speed are:

vrms = √(3 J/K \* K / kg) = √(3 m^2/s^2) = m/s

The units of the rms speed are in meters per second, which is the same as the units of velocity.

In summary, the rms speed of gas molecules is a measure of the average speed of gas particles in a sample of gas and is derived from the kinetic theory of gases. The formula for the rms speed involves the Boltzmann constant, temperature, and mass of the gas particles, and the units of the rms speed are in meters per second.

1. Degrees of freedom:

Degrees of freedom refer to the number of ways in which a system is free to move or store energy. In other words, it is the number of independent parameters that are needed to describe the state of a system. The number of degrees of freedom of a dynamical system is defined as the total number of co-ordinates or independent variables required to describe the position and configuration of the system.

In physics, degrees of freedom are classified into two main types: translational and rotational.

1. Translational Degrees of Freedom: These refer to the motion of a system as a whole in a straight line. For example, a particle moving in one dimension has one translational degree of freedom, while a particle moving in three dimensions has three translational degrees of freedom.
2. Rotational Degrees of Freedom: These refer to the rotation of a system around a particular axis. For example, a rigid body rotating in three dimensions has three rotational degrees of freedom.
3. (a) A particle moving in a straight line along any one of the axes has one degree of freedom (e.g). Bob of an oscillating simple pendulum.

(b) A particle moving in a plane (X and Y axes) has two degrees of freedom. (e.g) An ant that moves on a floor.

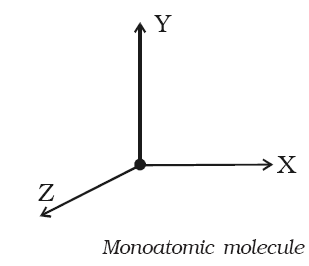
(c) A particle moving in space (X, Y and Z axes) has three degrees of freedom. (e.g) a bird that flies.

4. A point mass cannot undergo rotation, but only translatory motion. A rigid body with finite mass has both rotatory and translatory motion. The rotatory motion also can have three co-ordinates in space, like translatory motion; Therefore a rigid body will have six degrees of freedom ; three due to translatory motion and three due to rotatory motion.

In addition to these two main types, there are also other types of degrees of freedom that may be relevant in certain contexts. These include vibrational degrees of freedom (related to the oscillation of atoms or molecules within a system), electronic degrees of freedom (related to the movement of electrons within a system), and more.

The total number of degrees of freedom in a system is related to the number of particles in the system and the number of ways in which they can move or store energy. The number of degrees of freedom is also related to the total internal energy of the system.

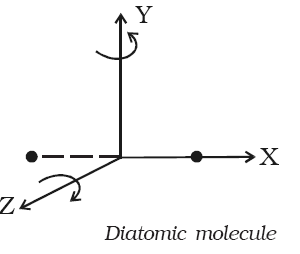
**Monoatomic molecule**



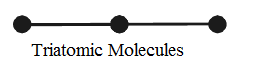
Since a monoatomic molecule consists of only a single atom of point mass it has three degrees of freedom of translatory motion along the three co-ordinate axes as shown in figure.

Examples : molecules of rare gases like helium, argon, etc.

**Diatomic molecule**

The diatomic molecule can rotate about any axis at right angles to its own axis. Hence it has two degrees of freedom of rotational motion in addition to three degrees of freedom of translational motion along the three axes. So, a diatomic molecule has five degrees of freedom as shown in figure. Examples: molecules of O2, N2, CO, Cl2, etc.

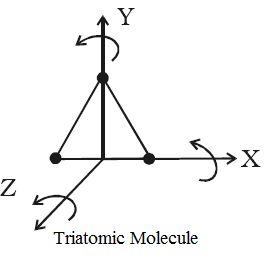
**Triatomic molecule (Linear type)**



In the case of triatomic molecule of linear type, the centre of mass lies at the central atom. It, therefore, behaves like a diamotic moelcule with three degrees of freedom of translation and two degrees of freedom of rotation, totally it has five degrees of freedom as shown in figure. Examples: molecules of CO2, CS2, etc.

**Triatomic molecule (Non-linear type)**

A triatomic non-linear molecule may rotate, about the three mutually perpendicular axes,  as  shown  in  figure.  Therefore,  it possesses three degrees of freedom of rotation in addition to three degrees of freedom of translation along the three co-ordinate axes Hence  it  has  six  degrees  of  freedom Examples : molecules of H2O, SO2, etc.



In all  the  above  cases,  only  the translatory  and  rotatory  motion  of  the molecules have been considered. The vibratory motion of the molecules has not been taken into consideration.

Dimensional Analysis:

The dimension of degrees of freedom is typically expressed as a unitless quantity. The number of degrees of freedom in a system can be calculated using the formula:

f = 3N - m

where f is the number of degrees of freedom, N is the number of particles in the system, and m is the number of constraints or restrictions on the system's motion or energy storage.

The dimension of f is unitless.

1. Mean free path:

Definition:

Mean free path is a measure of the average distance a particle travels between collisions with other particles in a gas or liquid.

Explanation:

When a particle moves through a gas or liquid, it collides with other particles, causing it to change direction and lose energy. The mean free path is the average distance a particle can travel without colliding with another particle. The mean free path depends on the size and shape of the particles, the temperature and pressure of the gas or liquid, and the concentration of the particles.

Dimensional analysis:

The mean free path is defined as the ratio of the mean free time to the particle velocity. The mean free time is defined as the average time between collisions.

Mean free path (m) = Mean free time (s) x Particle velocity (m/s)

Particle velocity (m/s) = Distance (m) / Time (s)

Therefore,

Mean free path (m) = Mean free time (s) x (Distance (m) / Time (s))

The base units for mean free path are meters (m).

The mean free time can be calculated using the following formula:

λ = 1/(√2 \* π \* d^2 \* n \* σ)

where:

d: molecular diameter (L)

n: number density of molecules (1/L^3)

σ: cross-sectional area of the molecules (L^2)

The mean free path is an important concept in the study of gas and liquid behavior, and is used in various fields such as thermodynamics, fluid mechanics, and atmospheric science.

1. Avagadro’s number:

Definition:

Avogadro's number is a physical constant that represents the number of constituent particles (such as atoms, molecules, or ions) in one mole of a substance. It is defined as exactly 6.022 x 10^23 particles per mole.

The concept of Avogadro's number arises from the idea of the mole, which is a unit of measurement used in chemistry to express the amount of a substance. One mole of a substance is defined as the amount of that substance that contains the same number of particles as there are atoms in exactly 12 grams of carbon-12.

Avogadro's number is named after Amedeo Avogadro, an Italian scientist who first proposed in 1811 that equal volumes of gases at the same temperature and pressure contain the same number of particles. His hypothesis eventually became known as Avogadro's law, which played a significant role in the development of the kinetic theory of gases.

Dimensional analysis:

Avogadro's number is dimensionless, as it is simply a ratio of the number of particles in a sample of a substance to the amount of that substance (measured in moles).

1. Spring restoring force:

Spring restoring force refers to the force that tries to bring a spring back to its original length or position when it is stretched or compressed. It is also known as Hooke's law, named after the 17th-century physicist Robert Hooke, who first described the relationship between the force applied to a spring and its resulting deformation.

The formula for the restoring force of a spring is:

F = -kx

where F is the restoring force, x is the displacement from the spring's equilibrium position, and k is the spring constant, which represents the stiffness of the spring. The negative sign in the formula indicates that the restoring force is always in the opposite direction to the displacement from the equilibrium position.

Explanation:

When a spring is stretched or compressed from its equilibrium position, it experiences a force that tries to bring it back to that position. This force is known as the restoring force. The restoring force of a spring is directly proportional to the amount of displacement from its equilibrium position. The stiffer the spring, the greater the restoring force for a given displacement.

For example, consider a spring with a spring constant of 10 N/m that is stretched 0.1 m from its equilibrium position. The restoring force on the spring would be:

F = -kx = -(10 N/m)(0.1 m) = -1 N

This means that the force acting on the spring is 1 N in the opposite direction to the displacement.

Dimensional Analysis:

The unit of spring constant k is N/m, and the unit of displacement x is m. Therefore, the unit of the restoring force F is N. The dimensional formula for the restoring force can be expressed as [M L T^-2].

1. Force Constant:

Force constant, denoted by k, is a measure of the stiffness of a spring. It is defined as the force required to extend or compress a spring per unit length change. Mathematically, it can be expressed as:

k = F/x

where k is the force constant, F is the force applied to the spring, and x is the displacement of the spring from its original position.

Explanation:

When a spring is stretched or compressed, it exerts a force that is proportional to the distance it has been stretched or compressed. The constant of proportionality is the force constant of the spring. In other words, the force constant is a measure of how much force is required to produce a certain amount of displacement in the spring. The force exerted by a spring is given by Hooke's law, which states that the force is proportional to the displacement:

F = -kx

where F is the force exerted by the spring, k is the force constant, and x is the displacement from the equilibrium position. The negative sign indicates that the force is always in the opposite direction to the displacement.

Dimensional analysis:

The SI unit of force constant is newtons per meter (N/m). From the equation k = F/x, we can see that the units of force constant are the same as the units of force divided by the units of displacement, which is N/m.

1. Simple Harmonic Motion kinetic energy:

In simple harmonic motion, an object oscillates back and forth around a central equilibrium position with a restoring force that is directly proportional to the displacement from the equilibrium position. The motion can be described in terms of the object's kinetic and potential energy.

The kinetic energy of an object in simple harmonic motion is given by the equation:

KE = (1/2)mv^2

where KE is the kinetic energy, m is the mass of the object, and v is the velocity of the object.

In simple harmonic motion, the velocity of the object is constantly changing as it moves back and forth, reaching a maximum value at the equilibrium position and decreasing to zero at the maximum displacement. At any point in time, the velocity can be expressed in terms of the amplitude, A, and the position, x, using the equation:

v = ± √(k/m) \* √(A^2 - x^2)

where k is the spring constant.

Substituting this expression for velocity into the equation for kinetic energy, we get:

KE = (1/2)m(± √(k/m) \* √(A^2 - x^2))^2

Simplifying, we get:

KE = (1/2)k(A^2 - x^2)

This equation tells us that the kinetic energy of an object in simple harmonic motion is directly proportional to the square of the amplitude of the motion minus the square of the displacement from the equilibrium position. This means that the kinetic energy of the object is highest at the equilibrium position, where the displacement is zero, and decreases as the object moves away from the equilibrium position.

1. Velocity in simple harmonic motion:

In simple harmonic motion, the velocity of an object can be expressed as a function of its displacement from equilibrium. The velocity of the object changes as it moves back and forth, oscillating around the equilibrium point.

At any point in time, the velocity of the object can be calculated using the following equation:

v(t) = ±ω \* sqrt(A^2 - x(t)^2)

where:

v(t) is the velocity of the object at time t

ω is the angular frequency of the motion

A is the amplitude of the motion (maximum displacement from equilibrium)

x(t) is

the displacement of the object from equilibrium at time t

Note that the velocity is positive when the object is moving away from equilibrium and negative when it is moving toward equilibrium. The maximum velocity occurs at the equilibrium point, where x(t) = 0 and v(t) = ±ωA.

Dimensional analysis of velocity in simple harmonic motion:

Velocity (m/s) = Angular frequency (s^-1) \* displacement (m)

1. Potential energy in S.H.M:

Definition:

Potential energy is the energy possessed by an object due to its position or configuration. In the case of simple harmonic motion (SHM), potential energy is the energy stored in a spring or any other object that has a restoring force proportional to the displacement from the equilibrium position.

Explanation:

The potential energy in SHM can be expressed as U = (1/2)kx^2, where U is the potential energy, k is the force constant of the spring, and x is the displacement from the equilibrium position. The potential energy is maximum when the displacement from the equilibrium position is maximum and is zero when the displacement is at the equilibrium position.

Dimensional analysis: The unit of potential energy can be derived from its equation U = (1/2)kx^2. The unit of force constant k is N/m (newtons per meter) and the unit of displacement x is m (meters). Therefore, the unit of potential energy U is:

U = (1/2)(N/m)(m)^2 = N\*m = Joule (J)

Hence, the base unit of potential energy is Joule, which is equivalent to kg\*m^2/s^2 in SI units.

1. Speed of wave:

Definition:

The speed of a wave is the rate at which the disturbance caused by the wave travels through a medium. It is a measure of how fast a wave travels through a given medium.

Explanation:

The speed of a wave is determined by the properties of the medium through which the wave is traveling. The wave speed can be affected by factors such as the temperature, pressure, and density of the medium. In general, the speed of a wave increases with increasing temperature and pressure, and decreases with increasing density.

Dimensional Analysis:

The units for the speed of a wave can be derived using dimensional analysis.

Speed (m/s) = Distance (m) / Time (s)

Therefore, the base units for the speed of a wave are m/s. The speed of a wave can also be expressed in other units, such as km/h or miles/hour, but these units can be converted to the base units of m/s using conversion factors.

1. Electrostatic force (as defined in coulomb’s law law):

Coulomb's law is a fundamental law of electrostatics that describes the interaction between two-point charges. The law states that the electrostatic force between two-point

charges is directly proportional to the product of their charges and inversely proportional to the square of the distance between them. The mathematical expression for Coulomb's law is given by:

F = k \* (q1 \* q2) / r^2

where F is the electrostatic force, k is Coulomb's constant, q1 and q2 are the charges of the two point charges, and r is the distance between the charges.

Explanation:

Coulomb's law states that the force between two point charges is proportional to the product of their charges and inversely proportional to the square of the distance between them. The force is attractive if the charges are opposite in sign and repulsive if the charges are the same.

The proportionality constant k is Coulomb's constant, which has a value of 8.9876 x 10^9 N \* m^2 / C^2. This value determines the strength of the electrostatic force between the charges.

Dimensional analysis:

The dimensional formula for electrostatic force is:

F = [M L T^-2]

The dimensional formula for Coulomb's constant is:

k = [M^-1 L^3 T^4 A^-2]

The dimensional formula for charge is:

q = [T A]

The dimensional formula for distance is:

r = [L]

Therefore, using dimensional analysis, we can rewrite Coulomb's law as:

[M L T^-2] = [M^-1 L^3 T^4 A^-2] \* [T A]^2 \* [L]^-2

Simplifying this expression, we get:

[M L T^-2] = [M L T^-2]

This shows that the units on both sides of the equation are consistent, and the equation is dimensionally correct.

1. Electric field:

Electric field is a vector field that describes the electric force experienced by a charged particle at any given point in space. It is defined as the force per unit charge exerted by a stationary point charge on a test charge placed at a point in space.

Explanation:

Electric field strength at a point is given by the force per unit charge experienced by a test charge placed at that point. The direction of the electric field is the direction of the force experienced by a positive test charge. The electric field is a vector quantity, with both magnitude and direction, and is represented by the symbol E.

Units:

The SI unit of electric field is newtons per coulomb (N/C) or volts per meter (V/m). Other commonly used units are electronvolts per meter (eV/m) and statvolts per centimeter (statV/cm).

Dimensional analysis:

The dimensional formula for electric field is [M^1L^1T^-3A^-1], where M is mass, L is length, T is time, and A is electric current.

Electric field (E) = Force (F) / Charge (q)

Force (F) = Mass (m) \* Acceleration (a)

Charge (q) = Current (I) \* Time (t)

Acceleration (a) = Length (L) / Time (T)^2

Current (I) = Electric charge (Q) / Time (t)

Substituting the above expressions, we get:

Electric field (E) = [M^1L^1T^-3A^-1] = [(M^1)(L^1)(T^-2)] / [(T^-1)(L^1)(T)] = [M^1L^1T^-3A^-1]

1. Electric Dipole moment:

Electric dipole moment (p) = charge (q) \* distance of separation (d)

where charge is in coulombs (C) and distance of separation is in meters (m).

Definition:

An electric dipole is a pair of equal and opposite point charges separated by a distance. The electric dipole moment is a measure of the strength of the dipole, and is defined as the product of the magnitude of one of the charges and the distance between the charges. It is a vector quantity that points from the negative charge to the positive charge.

Explanation:

Faraday observed that when a charged object was brought near another object, it could cause a force to be exerted on the second object, even if the two objects were not in contact.

Faraday realized that this phenomenon could be explained by the presence of an invisible "field" surrounding the charged object, which could exert a force on other charged objects in the vicinity. He called this field an "electrotonic state," and he developed a series of mathematical equations to describe its behavior.

Later, the concept of an electric field was further developed by James Clerk Maxwell, a Scottish physicist who is considered one of the most important scientists in the history of physics.

When an electric field is applied to an electric dipole, the charges experience a force that tends to align the dipole with the field. This causes the dipole to experience a torque, which causes it to rotate until it is aligned with the field. The magnitude of the torque is proportional to the product of the electric field strength and the dipole moment.

Units:

The SI unit for electric dipole moment is the coulomb-meter (Cm). However, it is also commonly expressed in the debye (D), where 1 debye = 3.33564 × 10^-30 Cm.

Dimensional analysis:

Using the formula for electric dipole moment, we can see that the dimensions are:

p = q \* d

[C\*m] = [C] \* [m]

Therefore, the dimensions of electric dipole moment are [charge] \* [length], which is equivalent to [current] \* [time] \* [length].

1. Electric potential:

Definition:

Electric potential, also known as voltage, is a measure of the electric potential energy per unit charge in an electric circuit.

Explanation:

Electric potential is a measure of the potential energy that a unit electric charge would have at a point in space. It is defined as the amount of work needed to move a unit charge from a reference point to a point in an electric field without acceleration. The electric potential difference between two points in an electric field is the change in electric potential energy per unit charge between the two points.

Dimensional analysis:

The SI unit of electric potential is the volt (V), which is defined as one joule per coulomb (J/C).

Electric potential (V) = Electric potential energy (J) / Charge (C)

Electric potential energy (J) = Charge (C) \* Electric potential difference (V)

Electric potential difference (V) = Work (J) / Charge (C)

Charge (C) = Current (A) \* Time (s)

Work (J) = Force (N) \* Distance (m)

Therefore:

Electric potential (V) = Electric potential energy (J) / Charge (C) = (Force (N) \* Distance (m)) / (Current (A) \* Time (s))

The base units for electric potential are kg·m^2·s^-3·A^-1.

In summary, electric potential is a measure of the electric potential energy per unit charge in an electric circuit. It is defined as the amount of work needed to move a unit charge from a reference point to a point in an electric field without acceleration. The dimensional analysis of electric potential involves the relationships between electric potential, electric potential energy, charge, work, force, distance, current, and time, and the base units for electric potential are kg·m^2·s^-3·A^-1.