PHY215-00: Physical (SI) Units

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1 Physical (SI) Units

1. **Classical Mechanics**

   - **Length**: The SI unit is the meter (m). It is used to measure distances, displacements, lengths of objects, etc. For example, the length of a car might be measured in meters.
   - **Mass**: The SI unit is the kilogram (kg). It is used to quantify the amount of matter in an object. The mass of a person or a box can be expressed in kilograms.
   - **Time**: The SI unit is the second (s). It is used to measure the duration of events or the intervals between them. The time it takes for a pendulum to swing back and forth once can be measured in seconds.
   - **Force**: The SI unit is the newton (N). One newton is defined as the force that causes a 1-kilogram mass to accelerate at a rate of 1 meter per second squared ($1\,\mathrm{N} = 1\,\mathrm{kg} \cdot 1\,\mathrm{m/s}^2$). When you push or pull an object, the force you exert can be measured in newtons.
   - **Work and Energy**: The SI unit for both work and energy is the joule (J). One joule is equal to the work done when a force of one newton acts through a distance of one meter ($1\,\mathrm{J} = 1\,\mathrm{N} \cdot 1\,\mathrm{m}$). The energy stored in a spring

or the work done in lifting an object can be measured in joules.

- **Power**: The SI unit is the watt (W). One watt is equal to one joule per second ($1\,\mathrm{W} = 1\,\mathrm{J/s}$). It measures the rate at which work is done or energy is transferred. The power of a light bulb or an electric motor can be measured in watts.
- **Velocity and Speed**: The SI unit is meters per second (m/s). It tells how fast an object is moving and in what direction (for velocity). The speed of a car traveling on a highway might be $30\,\mathrm{m/s}$.
- **Acceleration**: The SI unit is meters per second squared ($\mathrm{m/s^2}$). It measures the rate of change of velocity. When a car speeds up or slows down, its acceleration can be measured in $\mathrm{m/s^2}$.

2. **Electromagnetism**

- **Electric Charge**: The SI unit is the coulomb (C). It quantifies the amount of electric charge. The charge on an electron is approximately $-1.6 \times 10^{-19}\,\mathrm{C}$.
- **Electric Current**: The SI unit is the ampere (A). One ampere is defined as the flow of one coulomb of charge per second ($1\,\mathrm{A} = 1\,\mathrm{C/s}$). The current in an electrical circuit can be measured in amperes.

- **Electric Potential Difference (Voltage)**: The SI unit is the volt (V). One volt is equal to one joule per coulomb ($1\,\mathrm{V} = 1\,\mathrm{J/C}$). The voltage across a battery or in an electrical circuit can be measured in volts.
- **Electric Resistance**: The SI unit is the ohm (Ω). Resistance is defined as the ratio of voltage to current ($R = V/I$). A resistor in an electrical circuit might have a resistance of $100\,\Omega$.
- **Capacitance**: The SI unit is the farad (F). One farad is defined as the capacitance of a capacitor that stores a charge of one coulomb when a potential difference of one volt is applied across it ($1\,\mathrm{F} = 1\,\mathrm{C/V}$).
- **Magnetic Field Strength**: The SI unit is the tesla (T). The magnetic field around a bar magnet or produced by an electromagnet can be measured in teslas.
- **Magnetic Flux**: The SI unit is the weber (Wb). Magnetic flux is related to the magnetic field and the area through which it passes ($\Phi = \mathbf{B} \cdot \mathbf{A}$, where $\mathbf{B}$ is the magnetic field and $\mathbf{A}$ is the area). One weber is equal to one tesla-square meter ($1\,\mathrm{Wb} = 1\,\mathrm{T} \cdot \mathrm{m}^2$).

3. **Thermodynamics**

- **Temperature**: The SI unit is the kelvin (K). The kelvin scale is an absolute temperature scale. Zero kelvin ($0\,\mathrm{K}$)

is the lowest possible temperature, also known as absolute zero. The temperature of a room might be around 293 K.

- **Heat**: The SI unit is the joule (J). Heat is a form of energy transfer. The amount of heat required to raise the temperature of a substance can be measured in joules.

  Relation between calorie and joule

  - The calorie (cal) is a non-SI unit of energy. One calorie is defined as the amount of heat energy required to raise the temperature of 1 gram of water by 1 degree Celsius. The SI unit of energy is the joule (J). The conversion factor between them is $1\ cal = 4.184\ J$.

  Relation between Calorie (with a capital C) and other units

  - When we talk about the energy content of food, the "Calorie" (with a capital C) is actually a kilocalorie ($1\ Cal = 1\ kcal$). Since $1\ kcal = 1000\ cal$, and $1\ cal = 4.184\ J$, then $1\ Cal = 1000 \times 4.184\ J = 4184\ J$.

- **Entropy**: The SI unit is joules per kelvin (J/K). Entropy is a measure of the disorder or randomness of a system.

- **Internal Energy**: The SI unit is the joule (J). The internal energy of a gas or a thermodynamic system is the sum of the kinetic and potential energies of its molecules and can be measured in joules.

- **Pressure**: The SI unit is the pascal (Pa). One pascal is equal to one newton per square meter ($1\,\mathrm{Pa} = 1\,\mathrm{N/m^2}$). The pressure exerted by a gas or a fluid can be measured in pascals.

- **Volume**: The liter (L) is a unit of volume in the metric system. One liter is defined as the volume of a cube that is 10 centimeters (0.1 meters) on each side. Mathematically, $1L = 1000\ cm^3 = 10^{-3}\ m^3$. It is commonly used to measure the volume of liquids.

4. **Quantum Physics**

- **Energy**: The SI unit is the joule (J). In quantum mechanics, the energy of a photon, for example, is related to its frequency by $E = hf$, where h is Planck's constant and f is the frequency.
- **Frequency**: The SI unit is the hertz (Hz). One hertz is equal to one cycle per second. The frequency of an electromagnetic wave or a quantum mechanical oscillator can be measured in hertz.
- **Angular Momentum**: The SI unit is joule-seconds ($\mathrm{J \cdot s}$). In quantum mechanics, angular momentum is quantized. Planck's constant ($h = 6.626 \times 10^{-34}\,\mathrm{J \cdot s}$) has the unit of angular momentum and is fundamental in quantum physics.

- **Wave Function**: The wave function in quantum mechanics is a complex-valued function and doesn't have a physical unit in the traditional sense. However, the square of the absolute value of the wave function ($|\psi|^2$), which gives the probability density, is dimensionless.