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# Science Bridging Course
# Unit P2 – Natural sciences about the micro-, macro- and mega-world

**In this chapter you will find out:**

- Model of the world
- Length unit
- Time unit
- Mass standard

Since old times people distributed the world. The simplest distribution was like that: there are two spheres – the Earth and the Sky. The model of the world was drawn simply enough – our world is the Sun and the planets; the stars formed another Star world.

We have already mentioned that objects known to mankind are divided into three areas:

- the micro-world;
- mezzo-world;
- the macro-world;
- mega-world.

In the world of science, there are suggestions to single out two more worlds: the hippo world (the micro world in the micro world) and the hyper world (anti-mega world). This is so far a hypothetical proposition, not yet experimentally observed.

At the beginning of the $20^{th}$ century, the German physicist Planck defined fundamental constants – length ($10^{-33}$ cm) and time ($10^{-44}$ s). Later, they were called Planck's length and Planck's time. In the sphere of Planck's measurements, the general relativity theory cannot be applied, but the theory of quantum mechanics needs to be developed. It's basically a different world because the micro world is sufficiently well described.

Parallelly going deeper into the world, $20^{th}$ century science is characterised by a clear penetration deeper, i.e., galaxy cognition. The largest world known to science is Meta galaxy, which connects all galaxy clusters known to us today. Its dimensions are $10^{28}$ cm. Such distance the light travels at a speed of 300 000 km/s over 20 billion years. Our galaxy connects about 200 billion stars, one of them is the Sun with its system. The Sun is a medium sized bright star. It is thought that the age of the Sun is more than 5 billion years, and the Galaxy itself is even older. The Sun, as a star, is constantly depleting its resources, radiating energy. Later it should become a red giant (after about 3-4 billion years it will increase so that it will also include the Earth's orbit, and the Earth and other inner planets will burn. Humanity will either die or find another place suitable for life).

Some scientists think that Meta galaxy needs to be identified with the Universe. However, the bigger part state that there is abundance of such meta-galaxies in the Universe. This creates preconditions for talking about the hyper-world.

In this way micro world is an object of quantum mechanics.

Macro world is the world of classical mechanics.

The mega-world – of relative mechanics.

## The model of space and time

Everything moves – the basic principles of mechanics were defined by Newton in 1687 (The Principia – The Mathematical Principles of Natural Philosophy). Newton´ s theory proved so successful that no deviation from its laws was discovered for more than 200 years. The Newtonian theory stands as the starting point in a study of physics in these days as well.

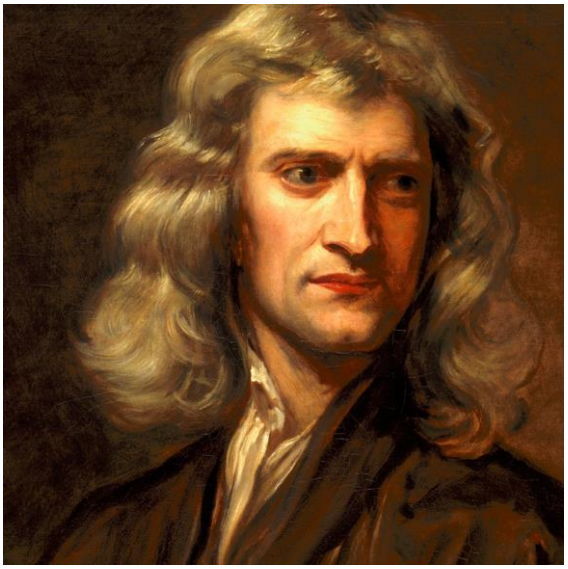
Fig. 1. Isaac Newton (https://cs.wikipedia.org/wiki/Isaac_Newton)

**Space**
A reference frame is a set of objects not moving with respect to each other that acts as a background for describing the position and motion of other objects.

The surface of the Earth is a familiar reference frame. We perceive the objects in e reference frame as occupying different places in the world, giving us reference points in something – space – which exists whether or not any objects are present. We apply rules of Euclidean geometry.
Galileo´ s relativity principle states that a second reference frame that moves at constant speed in a fixed direction with respect to the first is equally valid for describing physics.

**Time**
Newton´s definition: Absolute, true and mathematical time, of itself and from its own nature, flows equably without relation to anything external.
In Newtonian physics, time flows equally for all observers, independent of their reference frame.

The arrow of time points into the future, defined as the direction

- In which we have to memory
- In which a popped balloon explodes
- In which the universe expands.

**Principle of causality**:
An event occurs earlier in time than any other event that it causes.

In Aristotle´ s concept of space, there was a definite centre – the proper place for Earth – with different other natural places for other elements. This is incorrect. The Cartesian model is an improvement – physical theories based on it describe the world with mathematical precision. Classical physics is successful when gravity is not to strong, the speed of objects is slow, the objects are large. Twentieth-century theories, which do describe strong gravity, atomic systems, rapid motion, required revision.

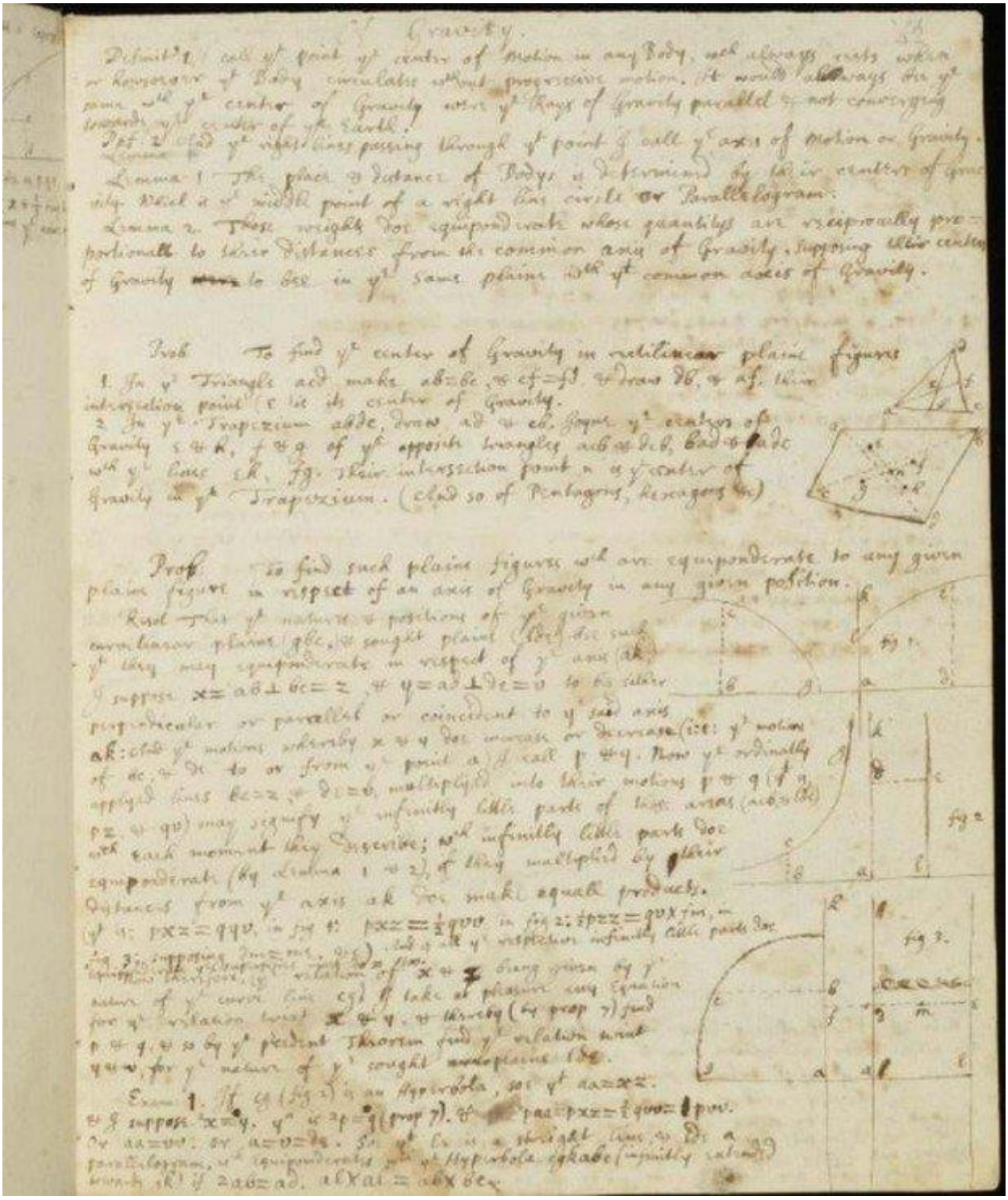

Fig. 2. I. Newton - notes (https://wordlesstech.com/sir-isaac-newtons-handwritten-notes-available-online/)

We have already mentioned that in order to normally live, we have to come to an agreement. For that agreement we use measure units, and to describe and characterise them – we use **standards.** As fewer are the standards, as simpler is the life, it seems that we should use as many of them as we are able to remember and save. However, how to pass on the information, let's say, to another civilisation?

A lot of ancient measure systems referred to human body measurements. (e.g., foot, number of fingers, and so on). It is thought that the oldest unified measurement unit is carat (carob tree beans, which are rather equal, were used as weights).

**Some standards:**

1) Length unit – 1 metre earlier was equated with 1/40 000 000 part of the circle length surrounding the Earth (that is to say, $2\ \pi\ R$). It turned out later that the Earth is a flattened sphere at the poles and therefore, 1 metre is 1/40 000 000 length part of meridian surrounding the Earth. Now, metre standard is stored in a measure and dry measure office in Paris. In order to make a one metre length standard ruler, one has to compare it with a standard. Now it is done using electromagnetic waves.
2) Time unit – 1 second is one 3600 part of an hour, and an hour is 1/24 part of a day. However, the Earth goes round its axis not very equally, therefore, one has to define a second more accurately. Atom's structure was used, and it was ascertained that under certain conditions an atom spins like a top, and such spinning is very stable. Such spinning determines the finest structure of the atom's radiated light spectrum. Today, 1 second – is equal to the duration of 9 192 631 770 periods of vibration of the ground state of caesium atom.

Today, science has also the other standards or derived units. Mass standard is – 1 kg. However, mass can be expressed by energy E units $\boldsymbol{E=mc^2}$. Practically, today it is enough of one standard and three fundamental constants for establishing most of the quantities.

There are quantities which are established by an agreement. E.g., a classical thing – **left-right**. It turned out that referring to natural laws one can objectively ascertain, where is left and where is right. Finally, why our world contains matter and not antimatter. Biologists know that the activity of molecules depending on their twisting direction, differs. **This is symmetry**. It determines nature describing quantity conservation laws. E.g., energy endurance law defines kinetic energy (movement energy) turning into potential (conservative energy). Explaining micro-world phenomena, it was ascertained that energy conception is related to the body mass, e.g., thermonuclear reaction. Moving body mass has to depend on the movement speed. If increasing body speed its mass will increase, then it will be more and more difficult to accelerate it, we will come to the limit, in order to reach it we will have to provide infinite energy. If infinite efforts are necessary, thus it is an unreachable limit. However, it turns out that this unreachable speed is equal to the light speed in vacuum. However, if the light spreads at "a light speed", it means that it is not material, because it does not have a rest mass. So, what is mass? Still, nobody knows. Nobel prize would be given for that.

Impulse endurance law defines that processes take place in the same energy space. E.g., a recoil phenomenon. There are still more complex phenomena e.g., thermodynamics.

Even more complex system is such, to the elements of which the features depending on interaction are granted, independent activity freedom or even mind. So was developed chaos and instability theory.

Human perceives himself in space and time. Three space coordinates, the fourth measure is time. Movement in time is very peculiar because it is one direction traffic without any stops. And if there are worlds, moving differently.

We have mentioned that a minimal distance which can be experimentally perceived is $10^{-18}$ metre. The biggest distance from which signals are received is about $10^{29}$ metre. The defining numbers are not perceived because the first distance is one hundred millionth part of the atom's diameter, and the second – a distance, which the light spread several milliards of years.

There is no clear limit dividing micro, macro, and mega-worlds. We understand the Earth as a macro-world, however, as the Sun system element, it is also part of the mega-world. The Sun system consists of 8 planets. **The Earth** – a cosmic body in the Universe. Universe concepts/expanding, shrinking, pulsating; from the first Big Bang to the next, lepton and photon ocean, and so on/- basically are different however, the cognition expanding, this concept is specified and deepened. It is very difficult to understand the size of the Universe and its boundaries /*Galaxy → Galaxy clusters → meta-galaxy → Universe*/. E.g., from the centre of Galaxy light has been spreading to us for 32000 years, from its one edge to the other – 100000 years, and where are the other galaxies and their clusters?!

The solar system is rather well known today, however, by no means can we state that it is explored completely, despite the fact that space crafts have visited almost all planets, showed from a closer distance their images, and their satellites. Historical experience shows that to perceive the planet Earth's position in the solar system was not so easy. Mankind has covered a long and difficult path of cognition. The best known are ***Geocentric*** (Ptolemy) and ***Heliocentric*** (Nicolaus Copernicus) solar system models. We know that the solar system consists of a star and eight planets orbiting it (*Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune, Pluto is a dwarf planet*) and other bodies: asteroids, planetary satellites and artificial satellites, comets, and so on. **Johan Kepler** (1571-1630) identified that planets move around the Sun in ellipses, and that the square of the period of the planet is proportional to the cube of the semi major axis of its orbit. In the solar system, the Earth is the third planet counting from it. The distances between planets and the Sun are great, difficult for us to understand, e.g., if a spacecraft flew at a speed of 30 km/s, then it would fly to the farthest planet Pluto and back in 14 years.

Thus, from the Sun to Pluto is 6 billion km. The Earth group planets – Mercury, Venus, Earth, Mars. The giants of the planet – Jupiter, Saturn, Uranus, Neptune.

How did the Universe emerge? The works of Einstein, Friedman, Hubble and others showed that meta-galaxy is constantly expanding, galaxies are moving away from each other. Thus, it was a primary centre of something. This is called The Big Bang. Nobody knows what existed before the Big Bang. The energy generated during the explosion turned into atomic particles. After about 1 billion years after the Explosion, gravity pulled hydrogen and helium into the clouds, spinning gas balls formed, and the first galaxies and stars appeared.

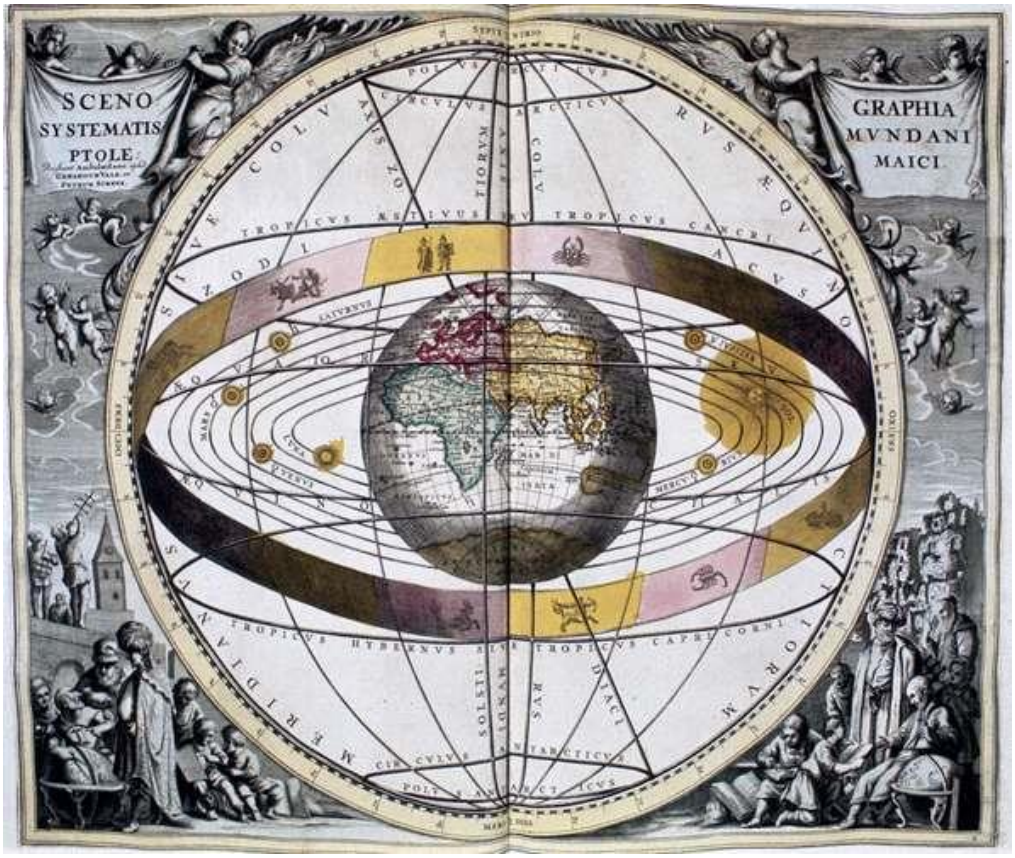


Fig. 3. Geocentric system (https://www.britannica.com/science/geocentric-model)

Further reading:
https://www.britannica.com/science/Ptolemaic-system

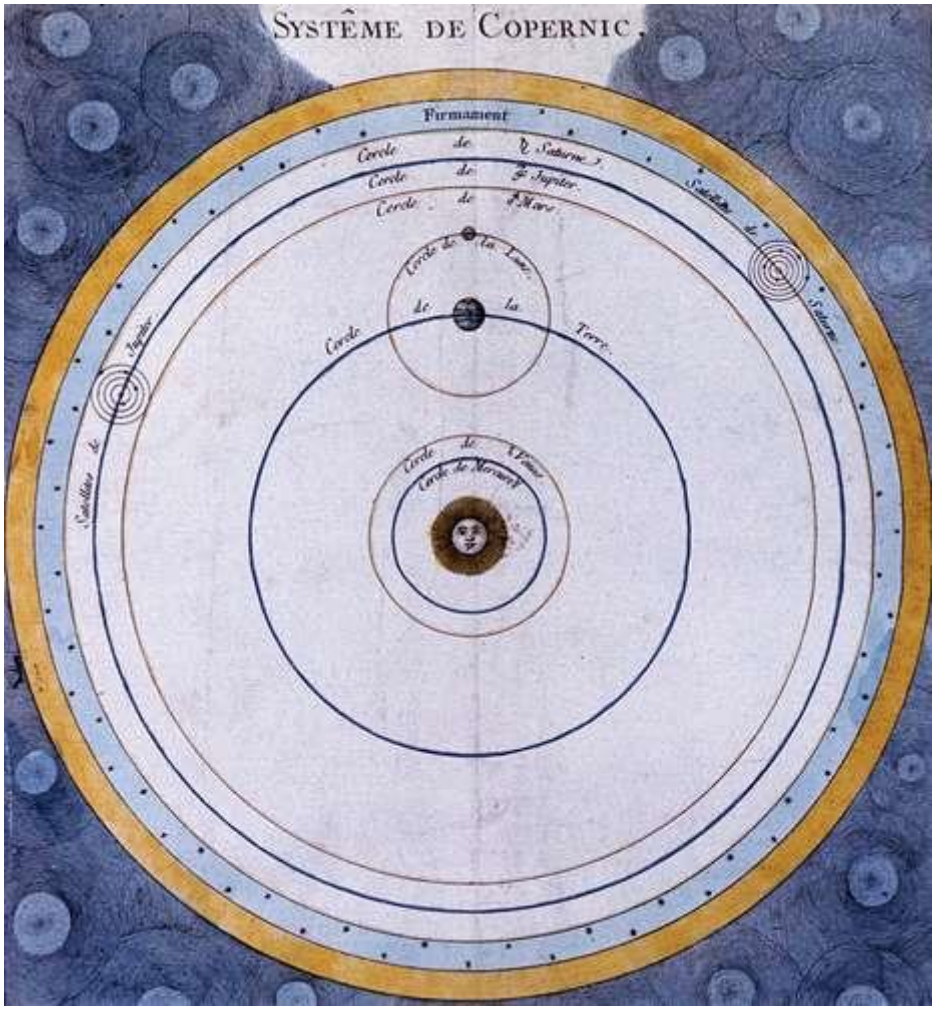


Fig. 4. Copernican system (https://www.britannica.com/science/Copernican-system)

Further reading:
https://www.britannica.com/science/Copernican-system

Questions:

1. What is a reference frame?
2. What was Newton´ s definition of time?
3. What is the arrow of time?

Further reading
https://plato.stanford.edu/entries/newton-principia/

https://www.youtube.com/watch?v=W-LYzPueH_k

Table 1. New definitions of basic SI units

The Seven Base Units of the new SI are defined as in the table below*

| Quantity | SI unit |
|---|---|
| time | The **second**, symbol s, is the SI unit of time. It is defined by taking the fixed numerical value of the caesium frequency $\Delta\nu_{Cs}$, the unperturbed ground-state hyperfine transition frequency of the caesium 133 atom, to be 9192 631 770 when expressed in the unit Hz, which is equal to $s^{-1}$. |
| length | The **metre**, symbol m, is the SI unit of length. It is defined by taking the fixed numerical value of the speed of light in vacuum $c$ to be 299 792 458 when expressed in the unit m $s^{-1}$, where the second is defined in terms of the caesium frequency $\Delta\nu_{Cs}$. |
| mass | The **kilogram**, symbol kg, is the SI unit of mass. It is defined by taking the fixed numerical value of the Planck constant $h$ to be $6.626\ 070\ 15 \times 10^{-34}$ when expressed in the unit J s, which is equal to kg $m^2$ $s^{-1}$, where the metre and the second are defined in terms of $c$ and $\Delta\nu_{Cs}$. |
| electric current | The **ampere**, symbol A, is the SI unit of electric current. It is defined by taking the fixed numerical value of the elementary charge $e$ to be $1.602\ 176\ 634 \times 10^{-19}$ when expressed in the unit C, which is equal to A s, where the second is defined in terms of $\Delta\nu_{Cs}$. |
| thermodynamic temperature | The **kelvin**, symbol K, is the SI unit of thermodynamic temperature. It is defined by taking the fixed numerical value of the Boltzmann constant $k$ to be $1.380\ 649 \times 10^{-23}$ when expressed in the unit J $K^{-1}$, which is equal to kg $m^2$ $s^{-2}$ $K^{-1}$, where the kilogram, metre and second are defined in terms of $h$, $c$ and $\Delta\nu_{Cs}$. |
| amount of substance | The **mole**, symbol mol, is the SI unit of amount of substance. One mole contains exactly $6.022\ 140\ 76 \times 10^{23}$ elementary entities. This number is the fixed numerical value of the Avogadro constant, $N_A$, when expressed in the unit $mol^{-1}$ and is called the 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. |
| luminous intensity | The **candela**, symbol cd, is the SI unit of luminous intensity in a given direction. It is defined by taking the fixed numerical value of the luminous efficacy of monochromatic radiation of frequency $540 \times 10^{12}$ Hz, $K_{cd}$, to be 683 when expressed in the unit lm $W^{-1}$, which is equal to cd sr $W^{-1}$, or cd sr $kg^{-1}$ $m^{-2}$ $s^3$, where the kilogram, metre and second are defined in terms of $h$, $c$ and $\Delta\nu_{Cs}$. |

*Table reproduced from https://www.bipm.org/utils/en/pdf/si-revised-brochure/Draft-SI-Brochure-2018.pdf (accessed 31 Oct 2018). The concept of base units and derived units was used to define the SI until 2018. These categories, although not essential in the new SI, are maintained in view of their convenience and widespread use.