Fundamental of Physics

Textbook:
Fundamental of Physics
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chapters covered for first semester: Chapter 1-20,
Exams: Mid and Final

Contents

1 Measurement

1.1 The International System of Units (SI)

Factor	Prefix	Symbol
Length	meter	m
Time	second	s
Mass	kilogram	kg

Prefix for SI Units

Quantity	Unit Name	Unit Symbol
10^9	giga-	G
10^6	mega-	M
10^3	kilo-	k
10^{-2}	centi-	c
10^{-3}	milli-	m
10^{-6}	micro-	μ
10^{-9}	nano-	n
10^{-12}	pico-	p

1.1.1 Scientific notation

Scientific notation, also known as standard form or as exponential notation, is a way of writing numbers that accommodates values too large or small to be conveniently written in standard decimal notation. Scientific notation has a number of useful properties and is often favored by scientists, mathematicians and engineers, who work with such numbers.

In scientific notation all numbers are written like this:

$$a \times 10^b$$

("a times ten to the power of b"), where the exponent b is an integer, and the coefficient a is any real number whose absolute value is at least one but less than ten ($1 \leq |a| < 10$).

1.1.2 Significant figures

In decimal notation any zero or series of zeros next to the decimal point are ambiguous, and may or may not indicate significant figures (when they are they should be underlined to explicitly show that they are significant zeros). In scientific notation, however, this ambiguity is resolved, because any zeros shown are considered significant by convention. For example, using scientific notation, the speed of light in SI units is 2.99792458×10^8 m/s and the inch is 2.54×10^{-2} m; both numbers are exact by definition of the units "inches" per cm and "meters" in terms of the speed of light. In these cases, all the digits are significant. A single zero or any number of zeros could be added on the right side to show more significant digits. e.g. the speed of light may be written as

$$c = 2.99792458000 \times 10^8 m/s$$

since the above condition is exact.

1.1.3 Ambiguity of the last digit in scientific notation

It is customary in scientific measurements to record all the significant digits from the measurements, and to guess one additional digit if there is any information at all available to the observer to make a guess. The resulting number is considered more valuable than it would be without that extra digit, and it is considered a significant digit because it contains some information leading to greater precision in measurements and in aggregations of measurements (adding them or multiplying them together).

1.2 Length

In 1972, the newborn Republic of France established a new system of weights and measures. Its corner stone was the meter, defined to be one ten-millionth of the distance from the north pole to the equator. Later, for practical reasons, this Earth standard was abandoned and the meter came to be defined as the distance between two fine lines engraved near the ends of a platinum-iridium bar, the standard meter, which was kept at the International Bureau of Weights and Measures near Paris. Accurate copies of the bar were sent to standardizing laboratories throughout the world.

Eventually, modern science and technology required a standard more precise than the distance between two fine scratches on a metal bar. In 1960, a new standard for the meter, based on the wavelength of light, was adopted. Specifically, the standard for the meter was redefined to be 1,650,763.73 wavelengths of a particular orange-red light emitted by atoms of krypton-86 in a gas discharge tube. This awkward number of wavelengths was chosen so that the new standard would be close to the old meter-bar standard.

By 1983, however, the demand for higher precision had reached such a point that even the krypton-86 standard could not meet it. The meter was redefined as the distance traveled by light in a specified time interval.

The meter is length of the path traveled by light in a vacuum during a time interval of $(299, 792, 458)^{-1}$ *of a second.*

The time interval was chosen so that the speed of light c is exactly

$$c = 299,792,458 m/s$$

1.2.1 Some Approximate Lengths

Measurement	Length in Meters
Distance to the first galaxies formed	2×10^{26}
Distance to the Andromeda galaxy	2×10^{22}
Distance to the nearby star Proxima Centauri	4×10^{16}
Distance to Pluto	6×10^{12}
Radius of Earth	6×10^{6}
Height of Mt. Everest	9×10^{3}
Thickness of a print page	1×10^{-4}
Length of a typical virus	1×10^{-8}
Radius of a hydrogen atom	5×10^{-11}
Radius of a proton	1×10^{-15}

1.3 Time

Any phenomenon that repeats itself is a possible time standard. Earth's rotation, which determines the length of the day, has been used in this way for centuries. To meet the need for a better time standard, atomic clocks have been developed. An atomic clock at the National Institute of Standards and Technology in Boulder, Colorado, is the standard for Coordinated Universal Time in the United States.

The 13th General Conference on Weights and Measures in 1967 adopted a standard second based on the cesium clock:

One second is the time taken by 9,192,631,770 oscillations of the light (of a specified wavelength) emitted by a cesium-133 atom.

Atomic clocks are so consistent that, in principle, two cesium clocks would have to run for 6000 years before their readings would differ by more than one second. Even such accuracy pales in comparison with that of clocks currently being developed; their precision may be 1 part in 10^{18}— that is, 1s in about 3×10^{10} years.

1.3.1 Some Approximate Time Intervals

Measurement	Time Interval in Seconds
Lifetime of a proton (predicted)	1×10^{39}
Age of the universe	5×10^{17}
Age of the pyramid of Cheops	1×10^{11}
Human life expectancy	2×10^{9}
Length of a day	9×10^{4}
Time between human heartbeat	8×10^{-1}
Lifetime of the muon	2×10^{-6}
Shortest lab light pulse	1×10^{-16}
Lifetime of the most unstable particle	1×10^{-23}
The planck time	1×10^{-43}

In physics, the Planck time is the time required for light to travel, in a vacuum, a distance of 1 Planck length. The Planck length is equal to 1.616252×10^{-35} meters. The Planck length can be defined from three fundamental physical constants: the speed of light in a vacuum, Planck's constant, and the gravitational constant. Current theory suggests that one Planck length is the smallest distance or size about which anything can be known.

1.4 Mass

1.4.1 The standard kilogram

The SI standard of mass is a platinum-iridium cylinder kept at the International Bureau of Weights and Measures near Paris and assigned, by international agreement, a mass of 1 kilogram. Accurate copies have been sent standardizing laboratories in other countries, and the masses of other bodies can be determined by balancing them against a copy.

1.4.2 A second mass standard

The masses of atoms can be compared with one another more precisely than they can be compared with the standard kilogram. For this reason, we have a second mass standard. It is the carbon-12 atom, which, by international agreement, have been assigned a mass of 12 atomic mass units (u). The relation between the two units is

$$1\ u = 1.6605402 \times 10^{-27} kg$$

with an uncertainty of ± 10 in the last two decimal places.

1.4.3 Some Approximate Masses

Object	Mass in Kilograms
Known Universe	1×10^{53}
Our galaxy	2×10^{41}
Sun	2×10^{30}
Moon	7×10^{22}
Asteroid Eros	5×10^{15}
Small mountain	1×10^{12}
Ocean Liner	7×10^{7}
Elephant	5×10^{3}
Grape	3×10^{-3}
Speck of dust	7×10^{-10}
Penicillin molecule	5×10^{-17}
Uranium atom	4×10^{-25}
Proton	2×10^{-27}
Electron	9×10^{-31}