Ministry of Higher Education and Scientific Research

Al-Ma’moun University College

كليــة المــأمون الجامعـة

للعام الدراسي (2023–2024)

Physics

Lecture (1)

Prof. Dr. Zina A. Al Shadidi

Introduction

Physics is based on the measurement of physical quantities. Certain physical quantities have been chosen as base quantities (such as length, time, and mass); each has been defined as a standard and given a unit of measure (such as meter, second, and kilogram). Other physical quantities are defined in terms of the base quantities and their standards and units.
Science and engineering are based on measurements and comparisons. Thus, we need rules about how things are measured and compared, and we need experiments to establish the units for those measurements and comparisons. One purpose of physics (and engineering) is to design and conduct those experiments. 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.

Measuring Things

We discover physics by learning how to measure the quantities involved in physics. Among these quantities are length, time, mass, temperature, pressure, and electric current. We measure each physical quantity in its own units, by comparison with a standard. The unit is a unique name we assign to measures of that quantity. The standard corresponds to exactly 1.0 unit of the quantity. As you will see, the standard for length, which corresponds to exactly 1.0 m, is the distance traveled by light in a vacuum during a certain fraction of a second. We can define a unit and its standard in any way we care to. However, the important thing is to do so in such a way that scientists around the world will agree that our definitions are both sensible and practical.

Factor	Prefix[a]	Symbol
10^{24}	yotta-	Y
10^{21}	zetta-	Z
10^{18}	exa-	E
10^{15}	peta-	P
10^{12}	tera-	T
10^{9}	**giga-**	**G**
10^{6}	**mega-**	**M**
10^{3}	**kilo-**	**k**
10^{2}	hecto-	h
10^{1}	deka-	da
10^{-1}	deci-	d
10^{-2}	**centi-**	**c**
10^{-3}	**milli-**	**m**
10^{-6}	**micro-**	**μ**
10^{-9}	**nano-**	**n**
10^{-12}	**pico-**	**p**
10^{-15}	femto-	f
10^{-18}	atto-	a
10^{-21}	zepto-	z
10^{-24}	yocto-	y

Base Quantities

Quantity	Unit Name	Unit Symbol
Length	meter	m
Time	second	s
Mass	kilogram	kg

The International System of Units

In 1971, the 14th General Conference on Weights and Measures picked seven quantities as base quantities, thereby forming the basis of the International System of Units, abbreviated SI from its French name and popularly known as the metric system. Many SI derived units are defined in terms of these base units. For example, the SI unit for power, called the watt (W), is defined in terms of the base units for mass, length, and time.

$$1\,watt\ = 1\,W\ = 1\,kg\ \cdot\ m^2/s^3$$

Where the last collection of unit symbols is read as kilogram-meter squared per second cubed.
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

$$3\,560\,000\,000\,m\ = 3.56\ \ 10^9\,m$$
$$0.000\,000\,492\,s =\ 4.92\ \ 10^{-7}\,s.$$
$$1.27 \times\ \ 10^9\,watts =\ 1.27\,gigawatts\ = 1.27\,GW$$
$$2.35\ \times\ 10^{-9}\,s = 2.35\,nanoseconds = 2.35\,ns$$

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:

$$\frac{1\,min}{60\,s} = 1\quad and\ \frac{60\,s}{1\,min}\ = 1$$

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, we have

$$2\,min =\ (2\,min)(1) =\ (2\,min)\left(\frac{60\,s}{1\,min}\right) =\ \ 120\,s$$

Length

Meter defined as the distance between two fine lines engraved near the ends of a platinum–iridium bar, the standard meter bar, 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. These secondary standards were used to produce other, still more accessible standards, so that ultimately every

measuring device derived its authority from the standard meter bar through a complicated chain of comparisons.
Eventually, a standard more precise than the distance between two fine scratches on a metal bar was required. 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 (a particular isotope, or type, of krypton) in a gas discharge tube that can be set up anywhere in the world.

In the words of the 17th General Conference on Weights and Measures:
The meter is the length of the path traveled by light in a vacuum during a time interval of 1/299 792 458 of a second. This time interval was chosen so that the speed of light c is exactly

$$c = 299\ 792\ 458\ m/s.$$

Time

Time has two aspects. For civil and some scientific purposes, we want to know the time of day so that we can order events in sequence. In much scientific work, we want to know how long an event lasts. Thus, any time standard must be able to answer two questions: "When did it happen?" and "What is its duration?"
Any phenomenon that repeats itself is a possible time standard. Earth's rotation, which determines the length of the day.

Measurement	Time Interval in Seconds	Measurement	Time Interval in Seconds
Lifetime of the proton (predicted)	3×10^{40}	Time between human heartbeats	8×10^{-1}
Age of the universe	5×10^{17}	Lifetime of the muon	2×10^{-6}
Age of the pyramid of Cheops	1×10^{11}	Shortest lab light pulse	1×10^{-16}
Human life expectancy	2×10^{9}	Lifetime of the most unstable particle	1×10^{-23}
Length of a day	9×10^{4}	The Planck time[a]	1×10^{-43}

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.

Mass

The Standard Kilogram

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

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, has been assigned a mass of 12 atomic mass units (u). The relation between the two units is

$$1\,u\ = 1.660\,538\,86\ \ \times 10^{27}\ kg,$$

Density

Density, ρ (lowercase Greek letter rho) is the mass per unit volume:

$$\rho = \frac{m}{V}$$

Densities are typically listed in kilograms per cubic meter or grams per cubic centimeter. The density of water (1.00 gram per cubic centimeter) is often used as a comparison. Fresh snow has about 10% of that density; platinum has a density that is about 21 times that of water.