PHOE140: Introduction to Advanced Manufacturing & Photonics

Class 3

- Units and Measurements
  - MKS or SI; CGS and FPS Systems
  - Fundamental Units and Derived Units
  - Dimensional Analysis
  - Nomenclature for numbers and scientific format
  - Data units: Bytes and Bits
  - Videos and exercise problems

Units & Measurements

System of Units = Base Units + Derived units

- A unit is any standard that is used for comparison
- Basic units of length, mass and time in the SI or International system (SI for System International d'Unites) are meter, kilogram and second
- Basic units in the CGS system are centimeter, gram and second
- Basic units in the FPS system are foot, pound and second
  - 1 foot is 12 inches; 1 inch is 2.54 cm
  - 1 pound is 16 ounces and 1 ounce is 28.35g.
    - Hence 1.0 lb is about 453.59g
- From fundamental units other derived units can be expressed. Most physically measured parameters can be boiled down to $L^x M^y T^z$.
  - e.g.: speed, area, force

Nomenclature for numbers

- For convenience in dealing with large and small numbers, we use prefixes – these are powers of ten that are used as multiplying factors to an original SI unit of measurement.
  - kilo is 10^3. Hence 1 gm x 10^3 is a Kilogram
  - milli is 10^{-3}, hence a millimeter is 1m x 10^{-3} mm

Fundamental Quantity	SI Unit	Symbol
Length	meter	m
Mass	kilogram	kg
Time	second	s
Temperature	Kelvin	K
Amount of substance	Mole	mole
Electric current	Ampere	A
Luminous Intensity	Candela	cd

In the decimal system, the value of a digit depends on its position in the number.

A digit is a single number in an integer. For example, the integer 123 has three digits.

It is important to understand place value when working with decimals because the position of the number in the decimal tells you its value.

The concept of place value is easier to understand when it is shown visually, so take a look at this Place Value Chart to see how it works.

Place Value Chart

	Fraction	Decimal	Place Value
Integers to the Left	100,000/1	100,000.0	hundred thousands
	10,000/1	10,000.0	ten thousands
	1,000/1	1,000.0	thousands
	100/1	100.0	hundreds
	10/1	10.0	tens
	1/1	1.0	ones
		.	Decimal Point
parts of 1 whole unit to the right	1/10	0.1	tenths
	1/100	0.01	hundredths
	1/1,000	0.001	thousandths
	1/10,000	0.0001	ten thousandths
	1/100,000	0.00001	hundred thousandths

Pay Attention

Be Careful!

Dimensional Analysis

- All physical quantities represented by derived units can be expressed in terms of some combination of seven fundamental or base quantities.
- Thus Length is denoted by [L], mass [M], time [T], electric current [A], temperature [K], luminous intensity [cd] and amount of substance [mol].
- Square brackets indicate that we are dealing with dimensions of the quantity.
- The dimensions of a physical quantity are the powers (or exponents) to which the base quantities are raised to represent that quantity.
- Thus dimensions of volume are $[L] \times [L] \times [L] = [L]^3$ or $[L^3]$. Volume is independent of mass and time therefore $[M^0]$ and $[T^0]$
- Therefore dimensions of volume are $[M^0][L^3][T^0]$ written in that order.
- Dimensions of a physical quantity are unchanged even if the units are represented in a system other than SI system, such as FPS.
- If Force is mass x acceleration, and acceleration is in m/s^2, what are the dimensions of force?

Dimensional Equations

- An equation obtained by equating a physical quantity with its dimensional formula is called a dimensional equation of the physical quantity. Equation for volume V is:

$$[V] = [M^0]\ [L^3][T^0]$$

- A car is travelling with a velocity of 100 km/h, write the dimensional equation for velocity v.
- $[M^0][L^1][T^{-1}]$
- Mass density is mass per unit volume and is denoted by ρ(rho)
- $[\rho] = [M^?][L^?][T^?]$

Area, Volume, Density, Acceleration, Flow Rate, etc

SI Derived Units In Terms of SI Base Units

Physical quantity	SI Unit	
	Name	Symbol
Area	square metre	m^2
Volume	cubic metre	m^3
Speed, velocity	metre per second	m/s or $m\ s^{-1}$
Angular velocity	radian per second	rad/s or $rad\ s^{-1}$
Acceleration	metre per second square	m/s^2 or $m\ s^{-2}$
Angular acceleration	radian per second square	rad/s^2 or $rad\ s^{-2}$
Wave number	per metre	m^{-1}
Density, mass density	kilogram per cubic metre	kg/m^3 or $kg\ m^{-3}$
Current density	ampere per square metre	A/m^2 or $A\ m^{-2}$
Magnetic field strength, magnetic intensity, magnetic moment density	ampere per metre	A/m or $A\ m^{-1}$
Concentration (of amount of substance)	mole per cubic metre	mol/m^3 or $mol\ m^{-3}$
Specific volume	cubic metre per kilogram	m^3/kg or $m^3\ kg^{-1}$
Luminance, intensity of illumination	candela per square metre	cd/m^2 or $cd\ m^{-2}$
Kinematic viscosity	square metre per second	m^2/s or $m^2\ s^{-1}$
Momentum	kilogram metre per second	$kg\ m\ s^{-1}$
Moment of inertia	kilogram square metre	$kg\ m^2$
Radius of gyration	metre	m
Linear/superficial/volume expansivities	per kelvin	K^{-1}
Flow rate	cubic metre per second	$m^3\ s^{-1}$

SI Derived Units With Special Names

Physical quantity	SI Unit			
	Name	Symbol	Expression in terms of other units	Expression in terms of SI base Units
Frequency	hertz	Hz	-	s^{-1}
Force	newton	N	-	$kg\ m\ s^{-2}$ or $kg\ m/s^2$
Pressure, stress	pascal	Pa	N/m^2 or $N\ m^{-2}$	$kg\ m^{-1}\ s^{-2}$ or $kg\ /s^2\ m$
Energy, work, quantity of heat	joule	J	N m	$kg\ m^2\ s^{-2}$ or $kg\ m^2/s^2$
Power, radiant flux	watt	W	J/s or $J\ s^{-1}$	$kg\ m^2\ s^{-3}$or $kg\ m^2/s^3$
Quantity of electricity, electric charge	coulomb	C	-	A s
Electric potential, potential difference, electromotive force	volt	V	W/A or $W\ A^{-1}$	$kg\ m^2 s^{-3}\ A^{-1}$ or $kg\ m^2/s^3\ A$
Capacitance	farad	F	C/V	$A^2\ s^4\ kg^{-1}\ m^{-2}$
Electric resistance	ohm	Ω	V/A	$kg\ m^2\ s^{-3}\ A^{-2}$
Conductance	siemens	S	A/V	$m^{-2}\ kg^{-1}\ s^3\ A^2$
Magnetic flux	weber	Wb	V s or J/A	$kg\ m^2\ s^{-2}\ A^{-1}$
Magnetic field, magnetic flux density, magnetic induction	tesla	T	Wb/m^2	$kg\ s^{-2}\ A^{-1}$
Inductance	henry	H	Wb/A	$kg\ m^2\ s^{-2}\ A^{-2}$
Luminous flux, luminous power	lumen	lm	-	cd /sr
Illuminance	lux	lx	lm/m^2	$m^{-2}\ cd\ sr^{-1}$
Activity (of a radio nuclide/radioactive source)	becquerel	Bq	-	s^{-1}
Absorbed dose, absorbed dose index	gray	Gy	J/kg	m^2/s^2 or $m^2\ s^{-2}$

Convention for units

- Symbols for units of physical quantities are printed or written in normal (Roman) upright type.
- Standards and recommended symbols for units are written in **lower case roman upright type**, starting with **small letters**. The shorter designations for units such as **kg, m, s, cd, etc. are symbols** and not abbreviations.
- Unit names are never capitalized, for e.g: in a sentence kilogram is written starting with a small k.
- Unit symbols are **capitalized** only if they are **derived from proper names**, for example names of scientists, beginning with a capital, normal roman letter.
- Examples: m is for meter, d for the unit ‘day’,
- atm for the unit for atmospheric pressure,
- **Hz** is the unit for frequency ‘hertz’,
- **J** is the unit for ‘joule’, **A** is for ‘ampere’ and **V** is for ‘volt’.

Convention for units: Continued

- One exception is **L** for unit of ‘liter (British litre)’ to avoid confusion with Arabic numeral 1 that looks like a small l.
- **Symbols for units do not contain a full stop at the end of the letter** and **do not change in the plural**. So fifteen centimeters are written as **15 cm** and not 15 cms or 15 cm. or 15 cms.
- Prefix symbols are printed without spacing between prefix symbol and unit symbol: 5 nanoseconds is written as 5 ns
- 1 MW = 10^6W
- 1 cm = 10^{-2} m
- 1 km = 10^3m
- 1 mV = 10^{-3} V

Nomenclatures and abbreviations for Numbers

For convenience we use prefixes when dealing with small and large numbers – these are powers of ten that are used as multiplying factors to an original SI unit of measurement.

For example:

a kilo is 10^3. Hence 10 g x 10^3 is ten kilograms

10 kg for short, (note: not **K**g or kg**s**)

milli is 10^{-3}, therefore a millimeter is 1m x 10^{-3} mm

micrometer is also called a micron, is 10^{-6} m; denoted by μm

Prefixes	Value	Standard form	Symbol
Tera	1 000 000 000 000	10^{12}	T
Giga	1 000 000 000	10^{9}	G
Mega	1 000 000	10^{6}	M
Kilo	1 000	10^{3}	k
deci	0.1	10^{-1}	d
centi	0.01	10^{-2}	c
milli	0.001	10^{-3}	m
micro	0.000 001	10^{-6}	μ
nano	0.000 000 001	10^{-9}	n
pico	0.000 000 000 001	10^{-12}	p

Powers of Ten!

femtosecond is 10^{-15}
and attosecond is 10^{-18}

Prefix	Symbol	Notation
Yotta	Y	10^{24}
Zetta	Z	10^{21}
Exa	E	10^{18}
Peta	P	10^{15}
Tera	T	10^{12}
Giga	G	10^{9}
Mega	M	10^{6}
Kilo	k	10^{3}
Hecto	h	10^{2}
Deca	da	10^{1}
deci	d	10^{-1}
centi	c	10^{-2}
milli	m	10^{-3}
micro	μ	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}

Introduction to Dimensional Analysis

https://www.khanacademy.org/math/algebra/x2f8bb11595b61c86:working-units/x2f8bb11595b61c86:rate-conversion/v/dimensional-analysis-units-algebraically

Introduction to the Decibel Scale

https://www.khanacademy.org/science/physics/mechanical-waves-and-sound/sound-topic/v/decibel-scale

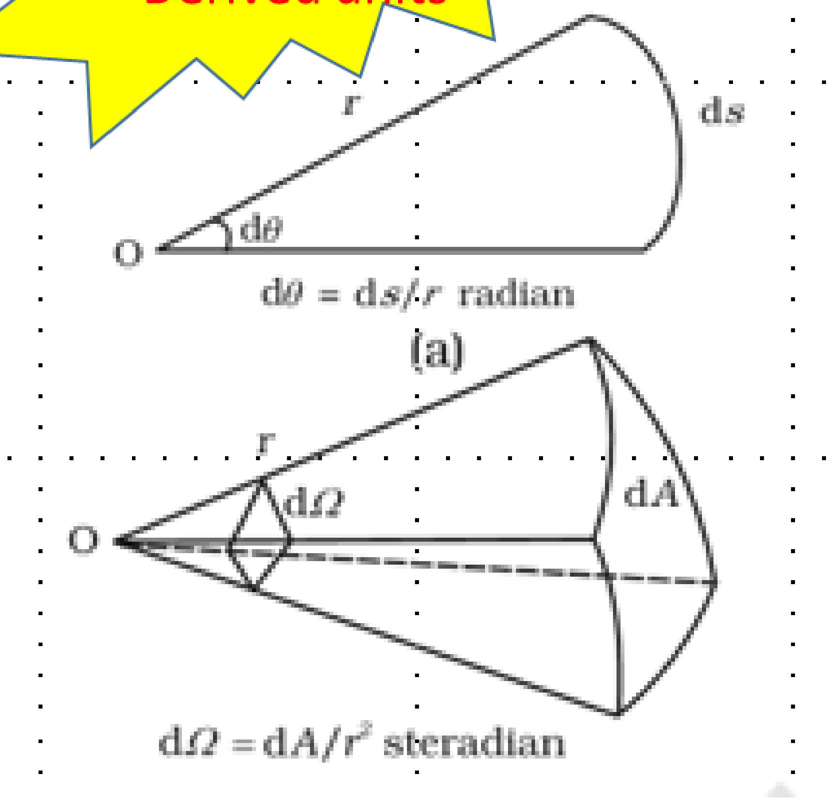
Introduction to orders of magnitude in length, mass and time

- Powers of Ten was made by Charles and Ray Eames for IBM.
- It takes us on an adventure in magnitudes.
- Starting at a picnic by the lakeside in Chicago, this famous film transports us to the outer edges of the universe.
- Every ten seconds we view the starting point from ten times farther out
- https://www.youtube.com/watch?v=0fKBhvDjuy0

Definitions of Fundamental Units

- meter: A meter is the length of the path travelled by light in vacuum during a time interval of 1/299792458 of a second.
- kilogram: A kilogram is equal to the mass of the international prototype (a platinum- Iridium alloy cylinder) kept at International Bureau of weights and Measures at Sevres near Paris, France.
- second: A second is the duration of 9192631770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the cesium 133 atom.
- ampere: An ampere is that constant current which, if maintained in two straight parallel conductors of infinite length, of negligible cross-section, and placed 1m apart in vacuum, would produce a force between these conductors equal to 2x10^7 newton per meter of conductor length.
- Kelvin: The kelvin is a fraction 1/273.16 of the thermodynamic temperature of the triple point of water.
- mole: A mole is the amount of substance of an element or compound which contains as many entities as there are atoms in 0.012kilograms of carbon-12.
- Candela: A candela is the luminous intensity in a given direction, of a source that emits monochromatic radiation of frequency 540x10^12 hertz and that has a radiant intensity in that direction of 1/683 watt per steradian
- **Plane angle θ : A plane angle $d\theta$ is the ratio of length of arc ds to the radius r**
- Solid angle $d\Omega$: solid angle $d\Omega$ is the ratio of the intercepted area dA of the spherical surface, described about the apex O as the center, to the square of its radius r.

System of Units = Base Units + Derived units

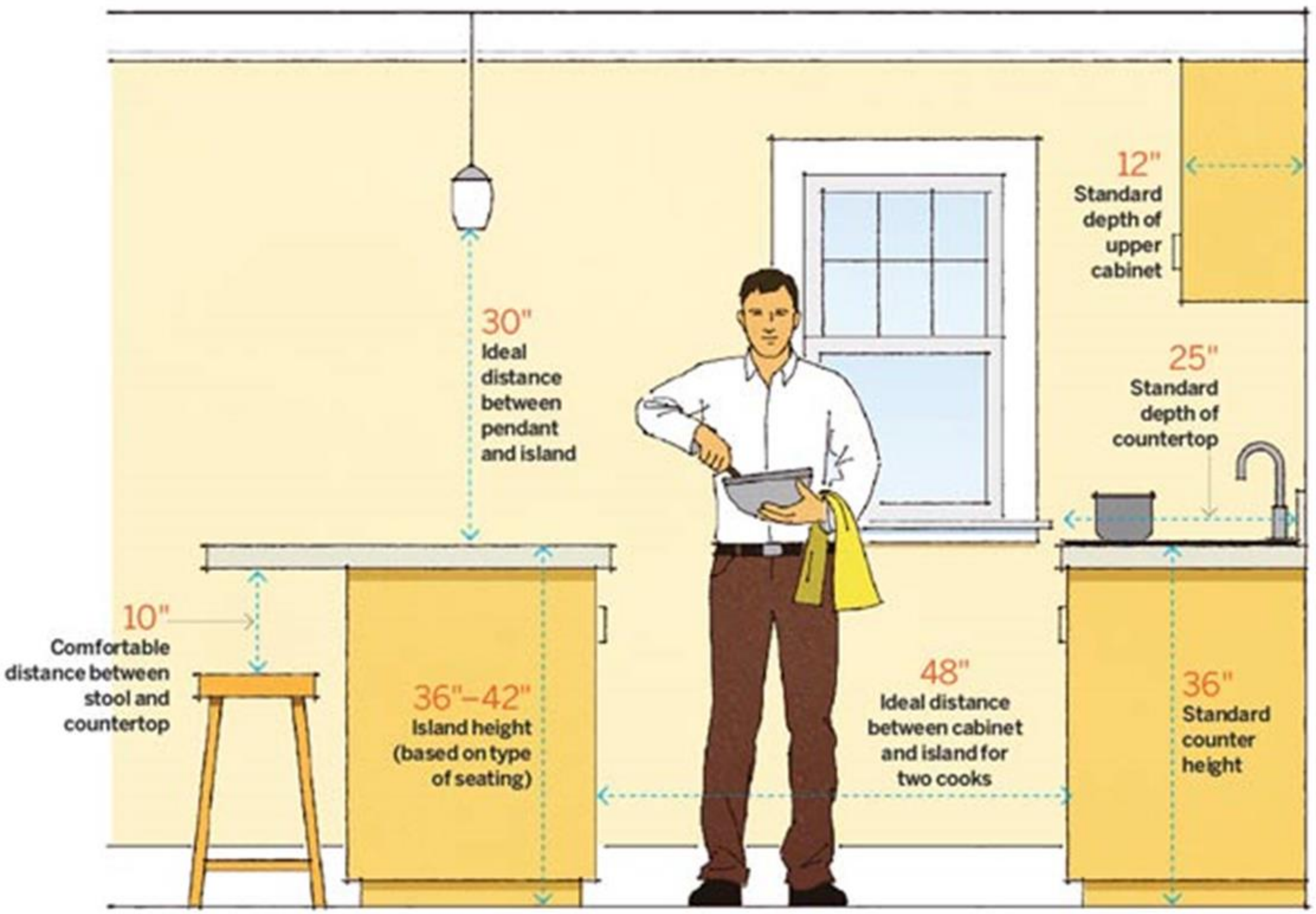


Some commonly used units that are outside SI system:

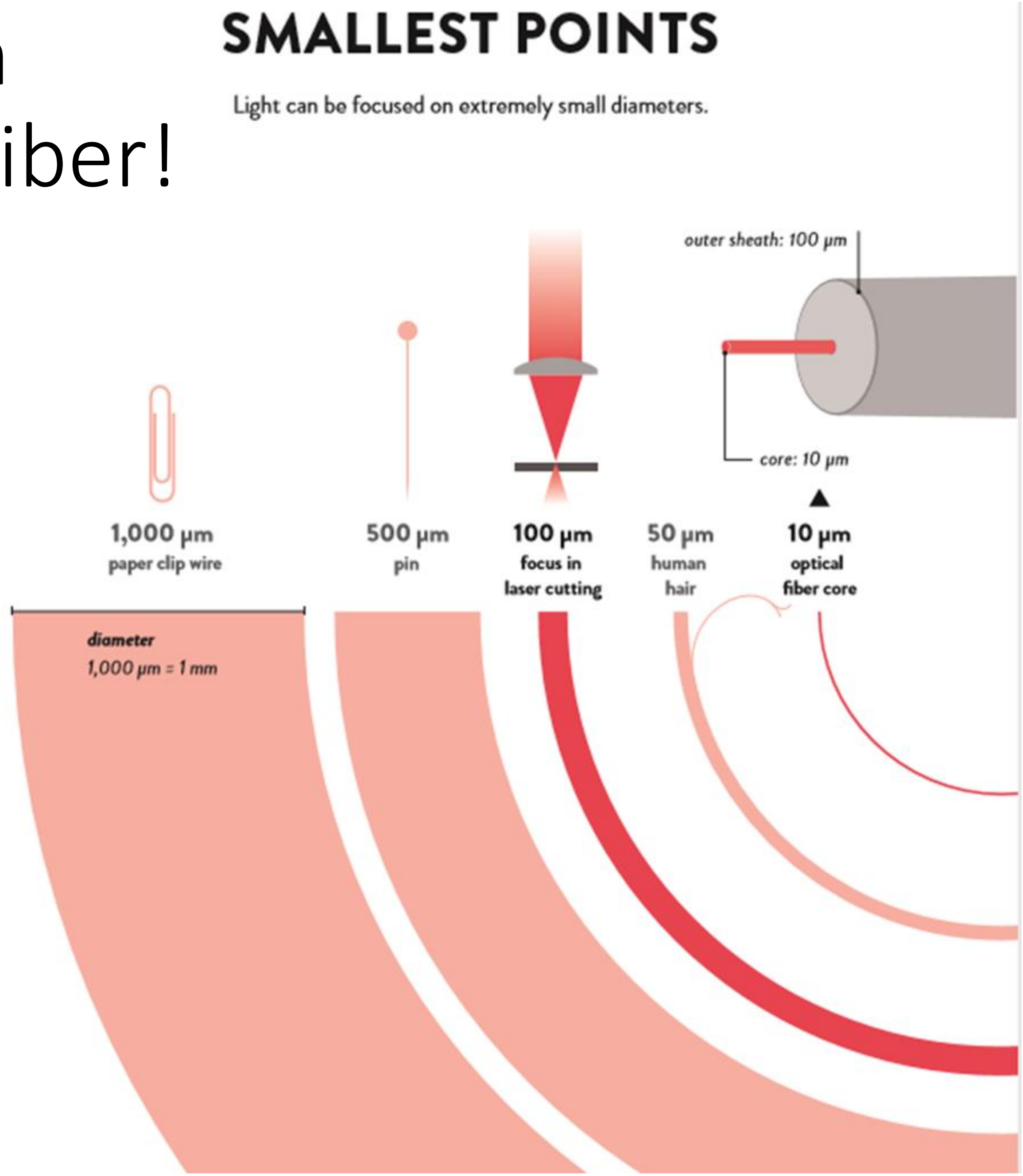
Name	Symbol	Value in SI Unit
minute	min	60 s
hour	h	60 min = 3600 s
day	d	24 h = 86400 s
year	y	365.25 d = 3.156×10^7 s
degree	°	$1° = (\pi/180)$ rad
litre	L	I $dm^3 = 10^{-3}$ m^3
tonne	t	10^3 kg
carat	c	200 mg
bar	bar	0.1 MPa = 10^5 Pa
curie	Ci	3.7×10^{10} s^{-1}
roentgen	R	2.58×10^{-4} C/kg
quintal	q	100 kg
barn	b	100 $fm^2 = 10^{-28}$ m^2
are	a	1 $dam^2 = 10^2$ m^2
hectare	ha	1 $hm^2 = 10^4$ m^2
standard atmospheric pressure	atm	101325 Pa = 1.013×10^5 Pa

Commonly Used units

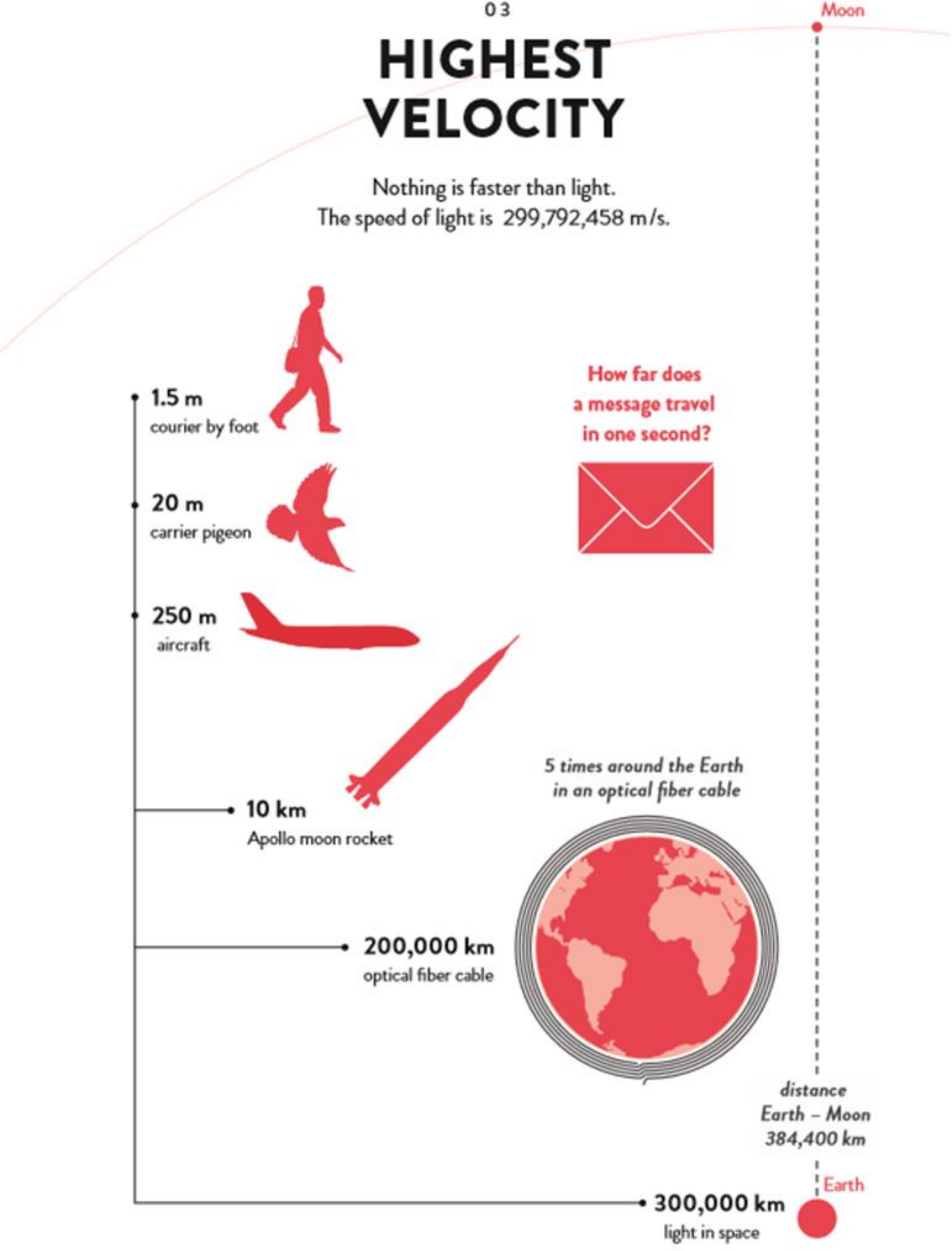
Customary Units	Metric Units
1 inch	2.54 cm
1 mil	0.0254 mm
1 foot	30.48 cm
1 yard	0.914 m
1 mile	1.609 km
1 ounce	28.35 g
1 pound	454 g
1 fluid ounce	29.574 ml
1 quart	0.946 l
1 gallon	3.785 l



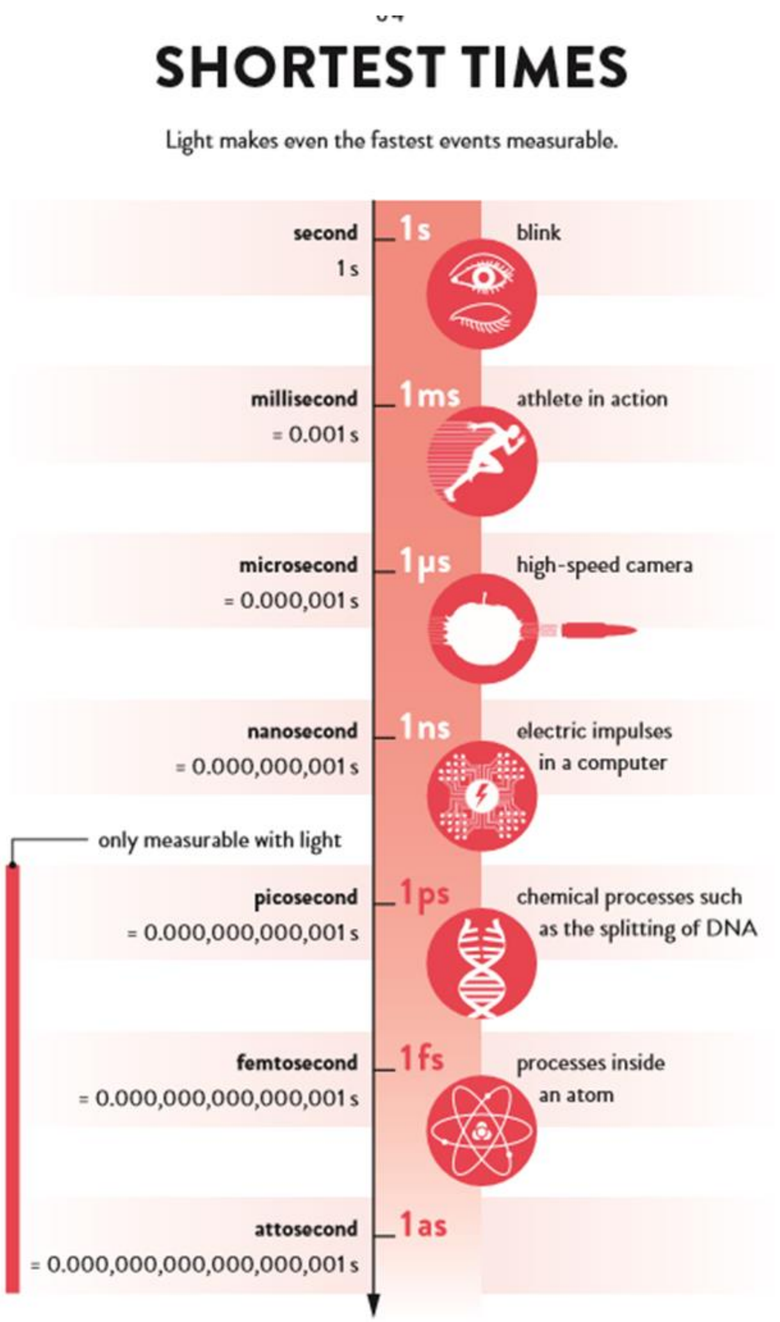
Compare a paper clip in diameter to an optical fiber!



Distance traveled in 1 s!!



Time Scale: From a second to attosecond!



Various Examples of length, mass and time

Some Lengths	(m)
Diameter of the Universe	$1 \cdot 10^{26}$
Distance to the nearest star (Proxima Centauri)	$4 \cdot 10^{16}$
Mean distance from Earth to Moon	$4 \cdot 10^{8}$
Mean radius of the Earth	$6 \cdot 10^{6}$
Length of a soccer field	$1 \cdot 10^{2}$
Size of the smallest dust particles	$1 \cdot 10^{-4}$
Size of cells of most living organisms	$1 \cdot 10^{-5}$
Diameter of a hydrogen atom	$1 \cdot 10^{-10}$
Diameter of an atomic nucleus	$1 \cdot 10^{-14}$
Diameter of a proton	$1 \cdot 10^{-15}$

Some Time Intervals	(s)
Age of the Universe	$5 \cdot 10^{17}$
Age of the Earth	$1 \cdot 10^{17}$
Average age of student	$3 \cdot 10^{7}$
One day	$8.64 \cdot 10^{4}$
Time between normal heartbeat	$8 \cdot 10^{-1}$
Period of typical radio waves	$1 \cdot 10^{-6}$
Period of visible light waves	$2 \cdot 10^{-15}$

Size of object or distance	Length (m)
Size of a proton	10^{-15}
Size of atomic nucleus	10^{-14}
Size of hydrogen atom	10^{-10}
Length of typical virus	10^{-8}
Wavelength of light	10^{-7}
Size of red blood corpuscle	10^{-5}
Thickness of a paper	10^{-4}
Height of the Mount Everest above sea level	10^{4}
Radius of the Earth	10^{7}
Distance of moon from the Earth	10^{8}
Distance of the Sun from the Earth	10^{11}
Distance of Pluto from the Sun	10^{13}
Size of our galaxy	10^{21}
Distance to Andromeda galaxy	10^{22}
Distance to the boundary of observable universe	10^{26}

Some Masses	(kg)
Universe	$1 \cdot 10^{52}$
Milky Way Galaxy	$7 \cdot 10^{41}$
Sun	$2 \cdot 10^{30}$
Earth	$6 \cdot 10^{24}$
Human	$7 \cdot 10^{1}$
Mosquito	$1 \cdot 10^{-5}$
Bacterium	$1 \cdot 10^{-15}$
Hydrogen atom	$1.7 \cdot 10^{-27}$
Electron	$9 \cdot 10^{-31}$

- Powers of 10 video
- Distances
  - light years
- Masses
  - megaton
- Time
  - Nanosecond
- Small letters for less than one unit and capital letters for greater than one unit (except kilo uses small k)
- Order of magnitude calculations
- Dust particles in a room- concept of clean room

Event	Time interval(s)
Life-span of most unstable particle	10^{-24}
Time required for light to cross a nuclear distance	10^{-22}
Period of x-rays	10^{-19}
Period of atomic vibrations	10^{-15}
Period of light wave	10^{-15}
Life time of an excited state of an atom	10^{-8}
Period of radio wave	10^{-6}
Period of a sound wave	10^{-3}
Wink of eye	10^{-1}
Time between successive human heart beats	10^{0}
Travel time for light from moon to the Earth	10^{0}
Travel time for light from the Sun to the Earth	10^{2}
Time period of a satellite	10^{4}
Rotation period of the Earth	10^{5}
Rotation and revolution periods of the moon	10^{6}
Revolution period of the Earth	10^{7}
Travel time for light from nearest star	10^{8}
Average human life-span	10^{9}
Age of Egyptian pyramids	10^{11}
Time since dinosaurs became extinct	10^{15}
Age of the universe	10^{17}

Range of time intervals in seconds:
Order of magnitude for a period of a light wave: 10^{-15}s

Speed of light is : 299 792 458 m/s
Distance between sun and earth varies from: 147 million km and
152 million km.

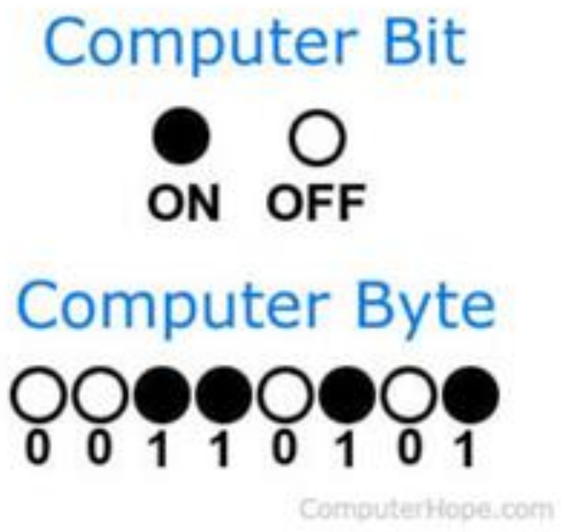
How long does sunlight take to reach the earth?

Prefix	Symbol	Notation
yotta	Y	10^24
zetta	Z	10^21
exa	E	10^18
peta	P	10^15
Tera	T	10^12
Giga	G	10^9
Mega	M	10^6
Kilo	k	10^3
Hecto	h	10^2
Deca	da	10^1
deci	d	10^-1
		-2
		-3
		-6
		-9
		12

Data Units

UNIT	ABBREVIATION	STORAGE
Bit	B	Binary Digit, Single 1 or 0
Nibble	-	4 bits
Byte/Octet	B	8 bits
Kilobyte	KB	1024 bytes
Megabyte	MB	1024 KB
Gigabyte	GB	1024 MB
Terabyte	TB	1024 GB
Petabyte	PB	1024 TB
Exabyte	EB	1024 PB
Zettabyte	ZB	1024 EB
Yottabyte	YB	1024 ZB

A bit is denoted by small b, not B



Bit

The smallest unit of data in a computer is called Bit (Binary Digit). A bit has a single binary value, either 0 or 1. In most computer systems, there are eight bits in a byte. The value of a bit is usually stored as either above or below a designated level of electrical charge in a single capacitor within a memory device.

A byte is abbreviated with a “B”. (A bit is abbreviated with a small “b”). Computer storage is usually measured in byte multiples. For example, an 820 MB hard drive holds a nominal 820 million bytes – or megabytes – of data. Byte multiples are based on powers of 2 and commonly expressed as a “rounded off” decimal number. For example, one megabyte (“one million bytes”) is actually 1,048,576 (decimal) bytes.

https://www.computerhope.com/issues/chspace.htm article on bytes and bits

https://youtu.be/y45v5SLjxaM

Bits and Bytes video clip

Morse Code Alphabet

The International morse code characters

A	.-	N	-.	0	-----
B	-...	O	---	1	.----
C	-.-.	P	.--.	2	..---
D	-..	Q	--.-	3	...--
E	.	R	.-.	4	....-
F	..-.	S	...	5	.....
G	--.	T	-	6	-....
H	....	U	..-	7	--...
I	..	V	...-	8	---..
J	.---	W	.--	9	----.
K	-.-	X	-..-	Fullstop	.-.-.-
L	.-..	Y	-.--	Comma	--..--
M	--	Z	--..	Query	..--..

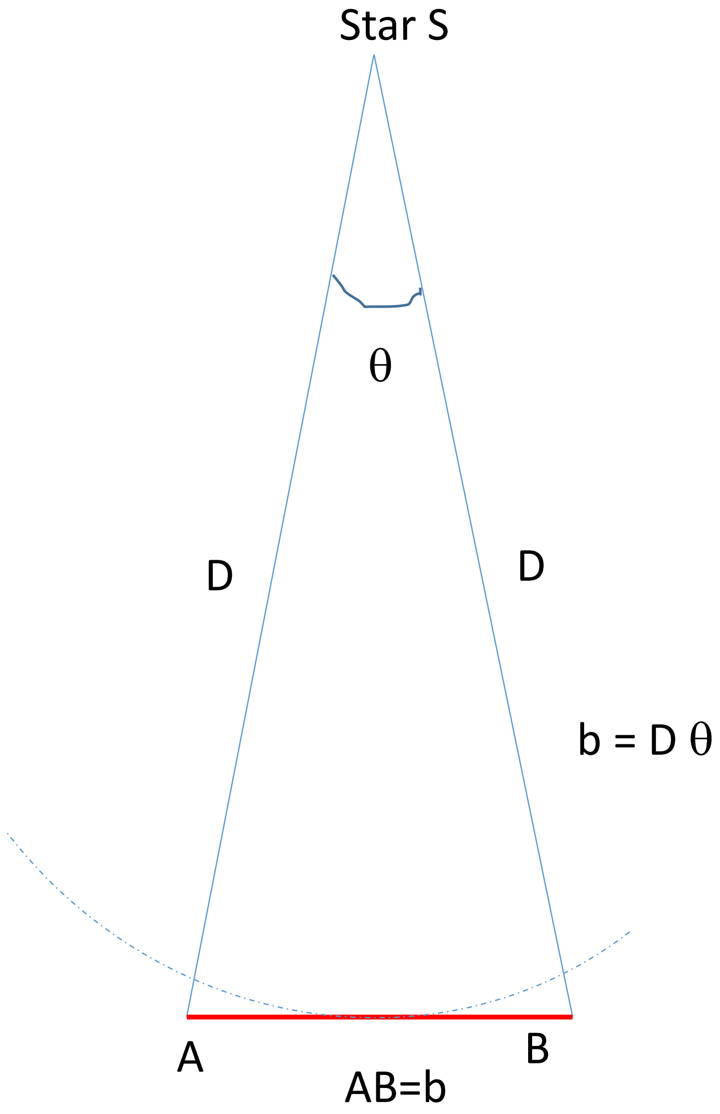
Morse Code

Share

Morse code is a method used in telecommunication to encode text characters as standardized sequences of two different signal durations, called dots and dashes or dits and dahs. Morse code is named for Samuel F. B. Morse, an inventor of the telegraph.

The dot duration is the basic unit of time measurement in Morse code transmission. The duration of a dash is three times the duration of a dot. Each dot or dash within a character is followed by period of signal absence, called a space, equal to the dot duration. The letters of a word are separated by a space of duration equal to three dots, and the words are separated by a space equal to seven dots.[1] To increase the efficiency of encoding, Morse code was designed so that the length of each symbol is approximately inverse to the frequency of occurrence in text of the English language character that it represents. Thus the most common letter in English, the letter "E", has the shortest code: a single dot. Because the Morse code elements are specified by proportion rather than specific time durations, the code is usually transmitted at the highest rate that the receiver is capable of decoding. The Morse code transmission rate (speed) is specified in groups per minute, commonly referred to as words per minute

Examples of Measurement:



The distance of a planet or star from the earth can be measured using a parallax method.
What is parallax?
Hold a pencil in front of you with a specific object in the background far away. Now look at this object with one eye. Now close the first eye and see the same object with the second eye. You notice that the pencil is shifted away from the object. This is called parallax and the shift in position is called the basis, which in this case is the distance between your eyes.

To measure the distance D of a distant star S by the parallax method, we need to observe it from two different positions on earth. Position A and position B. We measure the angle θ between the two directions along which the start is viewed at these two points A and B. Let distance AB = b.
$b = D\theta$, therefore $D = b/\theta$