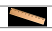
2.1 The Measures of Science

The Metric System and SI

base units- units that measure the most basic quantities found in nature

Base quantity	Base unit	Symbol
Length	meter	m
Mass	kilogram	kg
Time	second	s
Temperature	kelvin	K
Amount of substance	mole	mol
Electric current	ampere	A
Luminous intensity	candela	cd

SI Units of Measure

Unit of length	meter	The meter is the length of the path travelled by light in vacuum during a time interval of 1/299 792 458 of a second.
		
Unit of mass	kilogram	The kilogram is the unit of mass; it is equal to the mass of the international prototype of the kilogram.
		
Unit of time	second	The second is the duration of 9 192 631 770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the cesium 133 atom.
		
Unit of electric current	ampere	The ampere is that constant current which, if maintained in two straight parallel conductors of infinite length, of negligible circular cross-section, and placed 1 meter apart in vacuum, would produce between these conductors a force equal to 2 x 10^{-7} newton per meter of length.
		
Unit of thermodynamic temperature	kelvin	The kelvin, unit of thermodynamic temperature, is the fraction 1/273.16 of the thermodynamic temperature of the triple point of water.
		
Unit of amount of substance	mole	1. The mole is the amount of substance of a system which contains as many elementary entities as there are atoms in 0.012 kilogram of carbon 12; its symbol is "mol." 2. When the mole is used, the elementary entities must be specified and may be atoms, molecules, ions, electrons, other particles, or specified groups of such particles.
		
Unit of luminous intensity	candela	The candela is the luminous intensity, in a given direction, of a source that emits monochromatic radiation of frequency 540 x 10^{12} hertz and that has a radiant intensity in that direction of 1/683 watt per steradian.

https://physics.nist.gov/cuu/Units/current.html base (fundamental) units- units that measure the most basic quantities found in nature

derived units- units that utilize two or more basic quantities to form a more complex quantity

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Length	meter	m
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Luminous intensity	candela	cd

https://www.youtube.com/watch?v=nHup3fsjQJs

https://www.youtube.com/watch?v=uErMEPKp3ao

Length divided by time is velocity

m ÷ t = v

v = m/s

Length divided by time divided by time is acceleration

m ÷ t ÷ t = a

a = m/s^2

Derived Units: combination of base units used to measure additional quantities (characteristics/properties) of an event

velocity = length/time = m/s

Volume = length x length x length = m^3

density = mass/volume = kg/length x length x length = kg/m^3

force = mass x acceleration = kg x [m/(s x s) = kg m/s^2 = N

momentum = mass x velocity = kg x (m/s)

Table 3. SI derived units with special names and symbols				
	SI derived unit			
Derived quantity	**Name**	**Symbol**	**Expression in terms of other SI units**	**Expression in terms of SI base units**
plane angle	radian [a]	rad	-	$m \cdot m^{-1} = 1$ [b]
solid angle	steradian [a]	sr [c]	-	$m^2 \cdot m^{-2} = 1$ [b]
frequency	hertz	Hz	-	s^{-1}
force	newton	N	-	$m \cdot kg \cdot s^{-2}$
pressure, stress	pascal	Pa	N/m^2	$m^{-1} \cdot kg \cdot s^{-2}$
energy, work, quantity of heat	joule	J	N·m	$m^2 \cdot kg \cdot s^{-2}$
power, radiant flux	watt	W	J/s	$m^2 \cdot kg \cdot s^{-3}$
electric charge, quantity of electricity	coulomb	C	-	s·A
electric potential difference, electromotive force	volt	V	W/A	$m^2 \cdot kg \cdot s^{-3} \cdot A^{-1}$
capacitance	farad	F	C/V	$m^{-2} \cdot kg^{-1} \cdot s^4 \cdot A^2$
electric resistance	ohm		V/A	$m^2 \cdot kg \cdot s^{-3} \cdot A^{-2}$
electric conductance	siemens	S	A/V	$m^{-2} \cdot kg^{-1} \cdot s^3 \cdot A^2$
magnetic flux	weber	Wb	V·s	$m^2 \cdot kg \cdot s^{-2} \cdot A^{-1}$
magnetic flux density	tesla	T	Wb/m^2	$kg \cdot s^{-2} \cdot A^{-1}$
inductance	henry	H	Wb/A	$m^2 \cdot kg \cdot s^{-2} \cdot A^{-2}$
Celsius temperature	degree Celsius	°C	-	K
luminous flux	lumen	lm	cd·sr [c]	$m^2 \cdot m^{-2} \cdot cd = cd$
illuminance	lux	lx	lm/m^2	$m^2 \cdot m^{-4} \cdot cd = m^{-2} \cdot cd$
activity (of a radionuclide)	becquerel	Bq	-	s^{-1}
absorbed dose, specific energy (imparted), kerma	gray	Gy	J/kg	$m^2 \cdot s^{-2}$
dose equivalent [d]	sievert	Sv	J/kg	$m^2 \cdot s^{-2}$
catalytic activity	katal	kat		$s^{-1} \cdot mol$

https://physics.nist.gov/cuu/Units/units.html

Special names of derived units

Derived quantity	Name	Symbol
dynamic viscosity	pascal second	Pa·s
moment of force	newton meter	N·m
surface tension	newton per meter	N/m
angular velocity	radian per second	rad/s
angular acceleration	radian per second squared	rad/s^2
heat flux density, irradiance	watt per square meter	W/m^2
heat capacity, entropy	joule per kelvin	J/K
specific heat capacity, specific entropy	joule per kilogram kelvin	J/(kg·K)
specific energy	joule per kilogram	J/kg
thermal conductivity	watt per meter kelvin	W/(m·K)
energy density	joule per cubic meter	J/m^3
electric field strength	volt per meter	V/m
electric charge density	coulomb per cubic meter	C/m^3
electric flux density	coulomb per square meter	C/m^2
permittivity	farad per meter	F/m
permeability	henry per meter	H/m
molar energy	joule per mole	J/mol
molar entropy, molar heat capacity	joule per mole kelvin	J/(mol·K)
exposure (x and rays)	coulomb per kilogram	C/kg
absorbed dose rate	gray per second	Gy/s
radiant intensity	watt per steradian	W/sr
radiance	watt per square meter steradian	$W/(m^2 \cdot sr)$
catalytic (activity) concentration	katal per cubic meter	kat/m^3

https://physics.nist.gov/cuu/Units/units.html

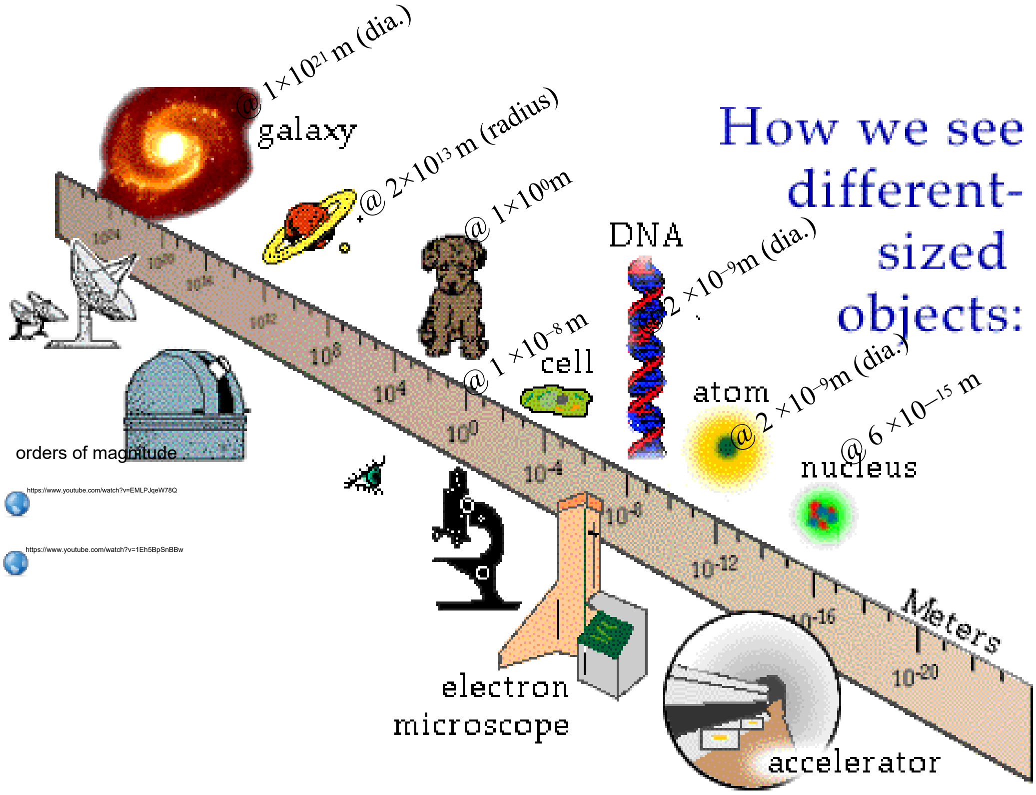
Metric prefixes

	prefix	*symbol*	*value*	*exponent*
	giga	G	1,000,000,000	10^9
	mega	M	1,000,000	10^6
	kilo	k	1,000	10^3
	hecto	h	100	10^2
	deka	da	10	10^1
meters, liters, etc..	base unit		1	10^0
	deci	d	0.1	10^{-1}
	centi	c	0.01	10^{-2}
	milli	m	0.001	10^{-3}
	micro	μ	0.000001	10^{-6}
	nano	n	0.000000001	10^{-9}

Metric prefixes

	prefix	*symbol*	*value*	*exponent*	
	giga	G	1,000,000,000	10^9	$\times 10^3$
	mega	M	1,000,000	10^6	
	kilo	k	1,000	10^3	
	hecto	h	100	10^2	
	deka	da	10	10^1	$\times 10^1$
meters, liters, etc..	base unit		1	10^0	
	deci	d	0.1	10^{-1}	
	centi	c	0.01	10^{-2}	
	milli	m	0.001	10^{-3}	
	micro	μ	0.000001	10^{-6}	
	nano	n	0.000000001	10^{-9}	$\times 10^{-3}$

Scientific Notation



orders of magnitude

https://www.youtube.com/watch?v=EMLPJqeW78Q

https://www.youtube.com/watch?v=1Eh5BpSnBBw

Converting units:

Whenever units are given in nonstandard units we have to convert them into standard units. We use a conversion factor to do this!

key: a conversion factor is a fraction whose value is equal to "1", therefore, multiplying a measurement by it doesn't change the value of the quantity- just the units it's expressed in!

example: Little Jimmy observed an insect traveled 30 m in 1.5 hours. What is its speed in "m/s?

Note that the time is given in standard units, so you have to convert it before you calculate speed.

The conversion factor units have to be arranged so that the unwanted (nonstandard) unit cancel out and the desired unit remains, so, there is only one possible arrangement of units in the conversion factor.

For changing "hours" to "seconds" you could have $\frac{1\ hr}{\ }$ or, $\frac{3600\ s}{\ }$

da .... there's 3600 s in one hour!!!!

Only $\frac{3600\ s}{1\ hr}$ works because it's the only arrangement of units where "hours" cancel and "seconds" remain

$$1.5\ \cancel{hr}\left(\frac{3600\ s}{1\ \cancel{hr}}\right) = 5400\ s$$

Therefore v = d/t = 30 m / 5400 s = .0056 m/s

or, $$\frac{30\ m}{1.5hr}\left[\frac{1hr}{3600\ s}\right] = .0056\ m/s$$

hint: if you always list the larger unit in the conversion factor at a value of "1", you will avoid fractions in your numerator or denominator

0.12 km = _______ m $\quad 0.12\ \cancel{km}\left\{\frac{1000\ m}{1\ \cancel{km}}\right\} = 120\ m$

.12 x 1000 = 120
"km's" cancel and you're left with "m"

$\frac{1000\ m}{1\ km}$ not, $\frac{1\ m}{.001\ km}$ not, $\frac{1\ m}{(1/1000)km}$

all three are correct and will work, but you will probably make fewer mistakes with the first one!

65 mph = ________ km/hr

$$65 \frac{\text{miles}}{\text{hour}} \left(\frac{1.61 \text{ km}}{1 \text{ mile}}\right)\left(\frac{1 \text{ hour}}{3600 \text{ s}}\right) =$$

Another way to do the same conversion is to identify the exponent values of the measurement and the metric prefixes.

0.12 km = ______ m

1) express the measured value in scientific notation

$0.12 \text{ km} = 1.2 \times 10^{-1} \text{ km}$

2) insert your conversion factor with the proper metric units (what you have and what you need)

$$1.2 \times 10^{-1} \text{ km} \left(\frac{\_\_\_\_ \text{m}}{\_\_\_\_ \text{km}}\right) = \_\_\_\_\_\_\_\_\_\_ \text{ m}$$

3) put a "1" (or 10^0) by the largest prefix in the conversion factor

$$1.2 \times 10^{-1} \text{ km} \left(\frac{\_\_\_\_ \text{m}}{10^0 \text{ km}}\right) = \_\_\_\_\_\_\_\_\_\_ \text{ m}$$

4) outside the conversion bracket list the exponent value of the metic prefix(s) inside the bracket. In this case "m" is a base unit with a value of 1, or 10^0 , hence the 0, and kilo means 1000, or 10^3, hence, the "3"

$$1.2 \times 10^{-1} \text{ km} \left(\frac{\_\_\_\_ \text{m}}{10^0 \text{ km}}\right)^{0}_{3} = \_\_\_\_\_\_\_\_\_\_ \text{ m}$$

5) list the exponential separation of the metric units in the conversion factor (in this case there an exponential separation of 3 (meaning 10^3 or 1000)

$$1.2 \times 10^{-1} \text{ km} \left(\frac{\_\_\_\_ \text{m}}{10^0 \text{ km}}\right)^{0}_{3} > 3 = \_\_\_\_\_\_\_\_\_\_ \text{ m}$$

6) This is now the value to insert in the conversion factor

$$1.2 \times 10^{-1} \text{ km} \left(\frac{10^3 \text{ m}}{10^0 \text{ km}}\right)^{0}_{3} > 3 = \_\_\_\_\_\_\_\_\_\_ \text{ m}$$

7) Because you listed your measurement in scientific notation you can list your primary units in your answer and then and then determine the exponent

$$1.2 \times 10^{-1} \text{ km} \left(\frac{10^3 \text{ m}}{10^0 \text{ km}}\right) = 1.2 \times 10^{-?} \text{ m}$$

8) determine you exponent by add (because you're multiplying) and subtracting (because you're dividing)

$$1.2 \times 10^{-1} \text{ km} \left(\frac{10^3 \text{ m}}{10^0 \text{ km}}\right) = 1.2 \times 10^{-?} \text{ m} = 1.2 \times 10^{2} \text{ m}$$

$10^{-1} \times 10^3$ is -1 + 3 which is 2 (10^2)

$10^2 \div 10^0$ is 2 - 0, which is 2

2 stands for 10^2 , that's the exponent in you answer

recap: -1 + 3 - 0 = 2

1. universal/ everyone understands/ reproducible standards
2. da
3. derived are combinations of base
4. really- sprinters run about 10 m/s
5. centimeter, millimeter, kilometer
6. unit analysis

30. a) 5×10^{12} m
    b) 1.66×10^{-10} m
    c) 2.003×10^{9} m
    d) 1.030×10^{-7} m

31. a) 0.423 m
    b) 6.2×10^{-12} m
    c) 2.1×10^{4} m
    d) 2.3×10^{-5} m
    e) 2.14×10^{-4} m
    f) 5.7×10^{-7} m

32. a) 6.12×10^{9} s
    b) 2.94×10^{-6} m
    c) 1.25×10^{-4} kg
    d) 7.50×10^{7} g

33. 0.31 mg, 1021 μg, 0.000006 kg, 11.6 mg