USEFUL INFORMATION

IMPORTANT PHYSICAL CONSTANTS

$c \equiv 299{,}792{,}458$ m/s

$\approx 3.00 \times 10^8$ m/s (speed of light)

$G = 6.673 \times 10^{-11}\ \mathrm{N \cdot m^2/kg^2}$ (gravitational constant)

$k_e = \frac{1}{4\pi\epsilon_0} = 8.988 \times 10^9\ \mathrm{N \cdot m^2/C^2}$

$\approx 9 \times 10^9\ \mathrm{N \cdot m^2/C^2}$ (electrical constant)

$h = 6.626 \times 10^{-34}\ \mathrm{J \cdot s}$ (Planck's constant)

Also: $\hbar \equiv h/2\pi = 1.0546 \times 10^{-34}\ \mathrm{J \cdot s}$

$\epsilon_0 = \frac{1}{4\pi k_e} = 8.854 \times 10^{-12}\ \mathrm{C^2/N \cdot m^2}$ (permittivity of free space)

$e = 1.602 \times 10^{-19}$ C (fundamental electric charge)

Note: The charge of the electron is $-e$ *and the charge of the proton is* $+e$

IMPORTANT PHYSICAL QUANTITIES

Electron: $m_{\mathrm{e}} = 9.11 \times 10^{-31}$ kg $\quad q_e = -e = -1.60 \times 10^{-19}$ C

Proton: $m_{\mathrm{p}} = 1.673 \times 10^{-27}$ kg $\quad q_p = +e = +1.60 \times 10^{-19}$ C

Neutron: $m_{\mathrm{n}} = 1.675 \times 10^{-27}$ kg $\quad q = 0$

$g = 9.8$ N/kg ≈ 10 N/kg (gravitational field strength near surface of earth)

ASTRONOMICAL INFORMATION

	Mass	Mean Radius	Mean distance from Earth
Moon	7.36×10^{22} kg	1.74×10^6 m	3.84×10^8 m
Earth	5.98×10^{24} kg	6.37×10^6 m	
Sun	1.99×10^{30} kg	6.96×10^8 m	1.5×10^{11} m

SI ("SYSTÈME INTERNATIONALE) UNITS

The fundamental units of the "metric system" are:

- **the kilogram (kg) for mass,**
- **the second (s) for time,**
- **the meter (m) for length, and**
- **the ampere (A) for electric current.**

In addition to the basic units of SI, multiples and submultiples can be formed used metric prefixes such as M (for mega) for 1,000,000 or μ (for micron) for 0.000001. The prefixes and their symbols are listed below. The most common ones, the ones you should know, are given in boldface.

atto (a) = 10^{-18}	femto (f) = 10^{-15}	**pico (p) = 10^{-12}**
nano (n) = 10^{-9}	**micro (μ) = 10^{-6}**	**milli (m) = 10^{-3}**
centi (c) = 10^{-2}	deci (d) = 10^{-1}	
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}	deka (da) = 10^{1}	

Some combinations of the basic units are important enough to have their own SI names and symbols. These are referred to as major derived units. For future references, here are some of the major derived units that we will encounter in Physics 112:

	MAJOR DERIVED UNITS	
Electric charge:	**the coulomb (C)**	**1 C = 1 A s**
Energy:	**the joule (J)**	**1 J = 1 kg m^2 s^{-2}**
Force:	**the newton (N)**	**1 N = 1 kg m s^{-2}**
Power:	**the watt (W)**	**1 W = 1 kg m^2 s^{-3}**

IMPORTANT CONVERSION FACTORS

1 inch = 2.54 cm (exact)

1 foot = 12 inches = 30.48 cm (exact) = 0.3048 m (exact)

1 mile = 5280 feet = 1.609 km = 1609 m

1 cal (calorie) = 4.186 J (1 Calorie or "food calorie" = 1 kcal = 4186 J)

1 Btu (British thermal unit) = 1055 J

The "weight" or gravitational force at the earth's surface on a 1-kg mass is 2.205 pounds.

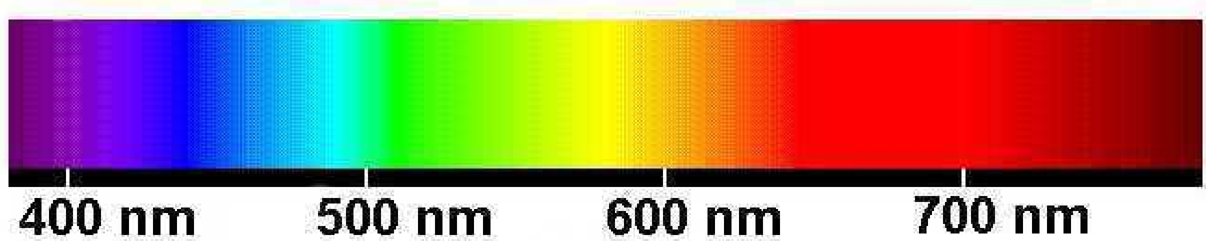
1 eV = 1.6×10^{-19} J (electron-volt, an important unit of energy)

THE ELECTROMAGNETIC SPECTRUM

This table shows the range of wavelengths, frequencies, and photon energies associated with the different parts of the electromagnetic spectrum:

Type of wave	Wavelength	Frequency (Hz)	Photon energy (J)
Radio	> 100 mm	$< 3 \times 10^{9}$	$< 2 \times 10^{-24}$
Microwave	$1 - 100$ mm	$3 \times 10^{9} - 3 \times 10^{11}$	$2 \times 10^{-24} - 2 \times 10^{-22}$
Infrared	$0.7 - 1000\ \mu$m	$3 \times 10^{9} - 3 \times 10^{11}$	$2 \times 10^{-22} - 3 \times 10^{-19}$
Optical	$400 - 700$ nm	$3 \times 10^{9} - 3 \times 10^{11}$	$3 \times 10^{-19} - 5 \times 10^{-19}$
Ultraviolet	$10 - 400$ nm	$3 \times 10^{9} - 3 \times 10^{11}$	$5 \times 10^{-19} - 2 \times 10^{-17}$
X-ray	$0.01 - 10$ nm	$3 \times 10^{9} - 3 \times 10^{11}$	$2 \times 10^{-17} - 2 \times 10^{-14}$
Gamma-ray	$< 10^{-11}$ m	$> 3 \times 10^{19}$	$> 2 \times 10^{-14}$

This diagram shows the visible or optical part of the electromagnetic spectrum from high energy to low energy:



Colors of the visible or optical spectrum, from short wavelength to long wavelength: violet, indigo, blue, green, yellow, orange, red.

MATHEMATICAL NOTATION

Physics is a quantitative subject which relies heavily on mathematics. It is important to use consistent mathematical notation.

$|\,|$ Denotes the absolute value of a scalar or the magnitude of a vector.

$\equiv$ Denotes a definition.

$=$ Denotes equality in several different ways. For example, $A = B$ would mean that the variables A and B are equal to one another in some specific situation, though probably not

in general, while $A = 14$ m would mean that A equals 14 m in some specific situtation.

$\approx$ Read as "approximately." Normally used in estimation, to indicate an approximate value that is adequate for most calculations.

Typographical rules:

• Italic fonts are used for variables, like x, y, z, m, T, $\vec{a}$, $\vec{F}$, and t. They are not used for the symbols for units.

• The symbols for units are written upright: the symbol for meter is "m" rather than "m" and the symbol for gram is "g" not "g."

• Thus "Mm" represents megameter while "Mm" might be the produce of two masses, M and m. Similarly "kg" is kilogram while "kg" is the product of two variables denoted by "k" and by "g."

• A vector quantity is denoted by an arrow above the symbol for the vector, for example, $\vec{A}$ or $\vec{F}$. The magnitude of the vector is denoted in one of two ways:

- Using the same symbol without the arrow: A is the magnitude of the vector $\vec{A}$
- Using | |: The magnitude of the vector $\vec{A}$ can be denoted $|\vec{A}|$.

MATTER PARTICLES

LEPTONS

Leptons & their electric charges

e^-	μ^-	τ^-
ν_e	ν_μ	ν_τ

$-e$
0

Antileptons & their electric charges

e^+	μ^+	τ^+
$\overline{\nu}_e$	$\overline{\nu}_\mu$	$\overline{\nu}_\tau$

$+e$
0

Names:

electron, muon, and tauon
electron's , muon's, and tauon's neutrino

Names:

antielectron (positron), antimuon, antitauon
electron's, muon's, and tauon's antineutrino

The only lepton occurring in common everyday matter is the electron.

QUARKS

Quarks and their electric charges

u	c	t
d	s	b

$+2e/3$
$-e/3$

Antiquarks & their electric charges

$\overline{u}$	$\overline{c}$	$\overline{t}$
$\overline{d}$	$\overline{s}$	$\overline{b}$

$-2e/3$
$+e/3$

Names:

up quark, charmed quark, top quark
down quark, strange quark, bottom quark

Names:

up, charmed, and top antiquarks
down, strange, and bottom antiquarks

Each of the six quarks comes in three varieties (or "colors"), called Red, Green, and Blue. Each of the six quarks comes in three varieties (or colors), called Antired, Antigreen, and Antiblue.

Composite particles consisting of quarks are called hadrons. All hadrons are "colorless" so they must have either three quarks, including one quark of each color, or a quark and an antiquark of the proper anticolor. Three quark hadrons are called baryons, and quark-antiquark hadrons are called mesons.

The only quarks occurring in common everyday matter are the up and down quarks. The neutron consists of one up and two down quarks, and thus has zero electric charge, while the proton consists of two up and one down quarks, and thus has electric charge $+e$.