1.1 Standards of Length, Mass, and Time

Length

The meter was redefined as the distance traveled by light in vacuum during a time interval of 1/299 792 458 second.

Mass

The SI unit of mass, the kilogram, is defined as the mass of a specific platinum–iridium alloy cylinder kept at the International Bureau of Weights and Measures at Sèvres, France.

Time

The second is now defined as 9 192 631 700 times the period of oscillation of radiation from the cesium atom.

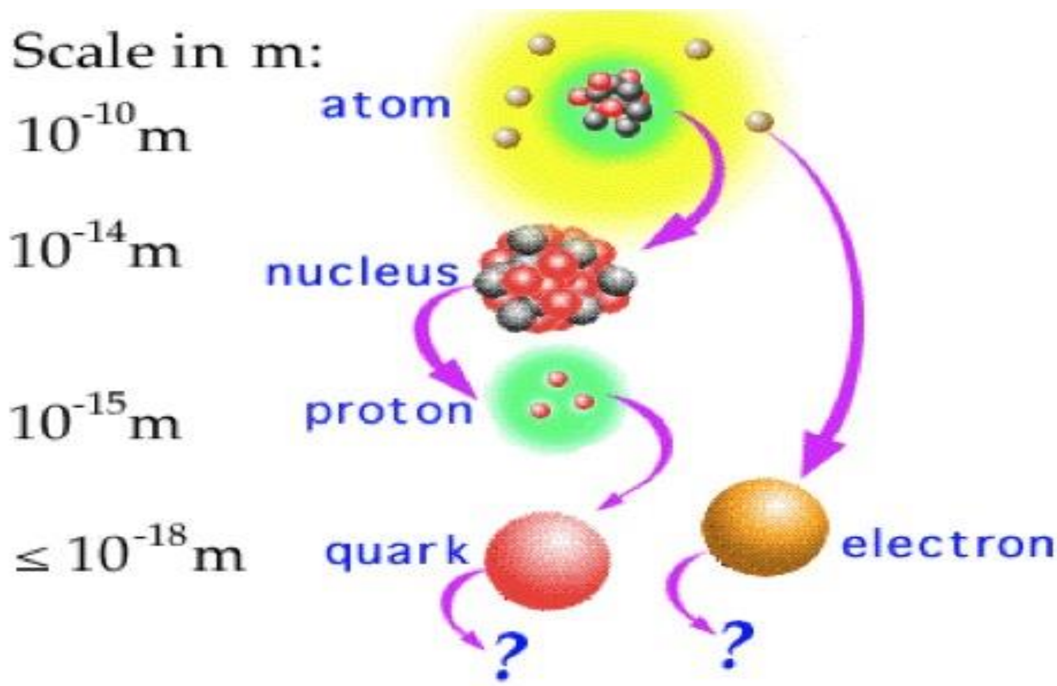
System of units

MKS, CGS, FPS

QUANTITY AND DEFINITION	METRIC cgs	METRIC MKS	ENGLISH FPS
TIME	SECOND	SECOND	SECOND
LENGTH	CENTIMETER	METER	FOOT
MASS	GRAM	KILOGRAM	slug
VELOCITY $v = d/t$	$\frac{\text{centimeter}}{\text{second}}$	$\frac{\text{meter}}{\text{second}}$	$\frac{\text{foot}}{\text{second}}$
ACCELERATION $a = v/t$	$\frac{\text{centimeter}}{\text{second}^2}$	$\frac{\text{meter}}{\text{second}^2}$	$\frac{\text{foot}}{\text{second}^2}$
FORCE $F = ma$	$\frac{\text{gm}\cdot\text{cm}}{\text{sec}^2}$ = dyne	$\frac{\text{kg}\cdot\text{meter}}{\text{sec}^2}$ = newton	POUND
ENERGY (& WORK) $W = fd$	$\frac{\text{gm}\cdot\text{cm}^2}{\text{sec}^2}$ = erg	$\frac{\text{kg}\cdot\text{meter}^2}{\text{sec}^2}$ = joule	foot·pound
POWER $P = W/t$	$\frac{\text{erg}}{\text{sec}}$	$\frac{\text{joule}}{\text{sec}}$ = watt	$\frac{\text{foot}\cdot\text{pound}}{\text{second}}$
MOMENTUM $p = mv$	$\frac{\text{gm}\cdot\text{cm}}{\text{sec}}$ = dyne·s	$\frac{\text{kg}\cdot\text{meter}}{\text{sec}}$ = N·s	$\frac{\text{slug}\cdot\text{foot}}{\text{sec}}$
TORQUE $G = F\tau$	dyne·cm	newton·meter	pound·foot
FREQUENCY	$\frac{1}{\text{sec}}$ = hertz	$\frac{1}{\text{sec}}$ = hertz	$\frac{1}{\text{sec}}$ = hertz

1 mil	0.001 inch	0.0254 millimeter
1 inch	1,000 mils	2.54 centimeters
12 inches	1 foot	0.3048 meter
3 feet	1 yard	0.9144 meter
5.5 yards or 16.5 feet	1 rod (or pole or perch)	5.029 meters
1 mile	5,280 feet	1.6094 kilometers
40 rods	1 furlong	201.168 meters
8 furlongs	1 mile	1.6094 kilometers
3 miles	1 league	4.83 kilometers
	1 millimeter	0.03937 inch
10 millimeters	1 centimeter	0.3937 inch
10 centimeters	1 decimeter	3.937 inches
10 decimeters	1 meter	39.37 inches or 3.2808 feet
10 meters	1 decameter	393.7 inches or 32.8083 feet
10 decameters	1 hectometer	328.083 feet
10 hectometers	1 kilometer	0.621 mile or 3,280.83 feet
10 kilometers	1 myriameter	6.21 miles

1.2 The Building Blocks of Matter



1.3 Dimensional Analysis

The property of dimensional homogeneity can be useful for:

1. State the definition of a dimension and give examples of the dimensions of some basic physical quantities.
2. Use dimensions to check equations for consistency.
3. Use dimensions to derive relationships between physical quantities

Quantity	SI Unit	.	Dimension
velocity	m/s	ms^{-1}	LT^{-1}
acceleration	m/s^2	ms^{-2}	LT^{-2}
force	N $kg\ m/s^2$	$kg\ ms^{-2}$	$M\ LT^{-2}$
energy (or work)	Joule J N m, $kg\ m^2/s^2$	$kg\ m^2s^{-2}$	ML^2T^{-2}
power	Watt W N m/s $kg\ m^2/s^3$	Nms^{-1} $kg\ m^2s^{-3}$	ML^2T^{-3}
pressure (or stress)	Pascal P, N/m^2, $kg/m/s^2$	Nm^{-2} $kg\ m^{-1}s^{-2}$	$ML^{-1}T^{-2}$
density	kg/m^3	$kg\ m^{-3}$	ML^{-3}
specific weight	N/m^3 $kg/m^2/s^2$	$kg\ m^{-2}s^{-2}$	$ML^{-2}T^{-2}$
relative density	a ratio no units	.	1 no dimension
viscosity	$N\ s/m^2$ kg/m s	$N\ sm^{-2}$ $kg\ m^{-1}s^{-1}$	$M\ L^{-1}T^{-1}$
surface tension	N/m $kg\ /s^2$	Nm^{-1} $kg\ s^{-2}$	MT^{-2}

prOBLEM Show that the expression $v = v_0 + at$ is dimensionally correct, where v and v_0 represent velocities, a is acceleration, and t is a time interval.

strategY Analyze each term, finding its dimensions, and then check to see if all the terms agree with each other.

sOLUtiOn

Find dimensions for v and v_0. $[v] = [v_0] = \frac{L}{T}$

Find the dimensions of at. $[at] = [a][t] = \frac{L}{T^2}(T) = \frac{L}{T}$

reMarKs All the terms agree, so the equation is dimensionally correct.

EX2

Find a relationship between an acceleration of constant magnitude a, speed v, and distance r from the origin for a particle traveling in a circle.

sOLUtiOn

Write down the dimensions of a: $[a] = \frac{L}{T^2}$

Solve the dimensions of speed for T: $[v] = \frac{L}{T} \rightarrow T = \frac{L}{[v]}$

Substitute the expression for T into the equation for $[a]$: $[a] = \frac{L}{T^2} = \frac{L}{(L/[v])^2} = \frac{[v]^2}{L}$

Substitute $L = [r]$, and guess at the equation: $[a] = \frac{[v]^2}{[r]} \rightarrow a = \frac{v^2}{r}$

1.4 Uncertainty in Measurement and Significant Figures

No physical quantity can be determined with complete accuracy because our senses are physically limited, even when extended with microscopes, cyclotrons, and other instruments

Rules for counting significant figures are summarized below.

- Zeros *within* a number are always significant. Both 4308 and 40.05 contain four significant figures.
- Zeros that do nothing but set the decimal point are not significant. Thus, 470,000 has two significant figures.
- Trailing zeros that aren't needed to hold the decimal point are significant. For example, 4.00 has three significant figures.

- ***In multiplying (dividing) two or more quantities, the number of significant figures in the final product (quotient) is the same as the number of significant figures in the least accurate of the factors being combined, where least accurate means having the lowest number of significant figures.***
- ***When numbers are added (subtracted), the number of decimal places in the result should equal the smallest number of decimal places of any term in the sum (difference).***

Ex

Several carpet installers make measurements for carpet installation in the different rooms of a restaurant, reporting their measurements with inconsistent accuracy, as compiled in next table Compute the areas for **(a)** the banquet hall, **(b)** the meeting room, and **(c)** the dining room, taking into account significant figures. **(d)** What total area of carpet is required for these rooms?

	Length (m)	Width (m)
Banquet hall	14.71	7.46
Meeting room	4.822	5.1
Dining room	13.8	9

Solution

Compute the area of the banquet hall.
Count significant figures:

$14.71\text{ m} \rightarrow 4\text{ significant figures}$

$7.46\text{ m} \rightarrow 3\text{ significant figures}$

To find the area, multiply the numbers keeping only three d

$14.71\text{ m} \times 7.46\text{ m} = 109.74\text{ m}^2 \rightarrow 1.10 \times 10^2\text{ m}^2$

(b) Compute the area of the meeting room.
Count significant figures:

$$4.822 \text{ m} \rightarrow 4 \text{ significant figures}$$
$$5.1 \text{ m} \rightarrow 2 \text{ significant figures}$$

To find the area, multiply the numbers keeping only two digits:

$$4.822 \text{ m} \times 5.1 \text{ m} = 24.59 \text{ m}^2 \rightarrow 25 \text{ m}^2$$

(c) Compute the area of the dining room.
Count significant figures:

$$13.8 \text{ m} \rightarrow 3 \text{ significant figures}$$
$$9 \text{ m} \rightarrow 1 \text{ significant figure}$$

To find the area, multiply the numbers keeping only one digit:

$$13.8 \text{ m} \times 9 \text{ m} = 124.2 \text{ m}^2 \rightarrow 100 \text{ m}^2$$

(d) Calculate the total area of carpet required, with the proper number of significant figures.
Sum all three answers without regard to significant figures:

$$1.10 \times 10^2 \text{ m}^2 + 25 \text{ m}^2 + 100 \text{ m}^2 = 235 \text{ m}^2$$

The least accurate number is 100 m^2, with one significant

$$235 \text{ m}^2 \rightarrow 2 \times 10^2 \text{ m}^2$$

Round numbers

- Round to the nearest hundred (838.274) is 800
- Round to the nearest ten (838.274) is 840
- Round to the nearest one (838.274) is 838
- Round to the nearest tenth (838.274) is 838.3
- Round to the nearest hundredth (838.274) is 838.27

Banker's rounding: This method uses the Gauss rule that if you are in an perfect half case, you must round to the nearest digit that can be divided by 2 (0, 2,4,6,8). This rule is important to obtain more accurate results with rounded numbers after operation.

```
                    1 digit                   1 digit
Unrounded    "Standard" Rounding    "Gaussian rounding"
  27.25          27.3                   27.2
  27.45          27.5                   27.4
+ 27.55        + 27.6                 + 27.6
=======        ======                 ======
  82.25          82.4                   82.2
```

1.5 Conversion of Units

$$1 \text{ mi} = 1\,609 \text{ m} = 1.609 \text{ km} \qquad 1 \text{ ft} = 0.304\,8 \text{ m} = 30.48 \text{ cm}$$

$$1 \text{ m} = 39.37 \text{ in.} = 3.281 \text{ ft} \qquad 1 \text{ in.} = 0.025\,4 \text{ m} = 2.54 \text{ cm}$$

Ex

How many centimeters in 15 in?

$$15.0 \text{ in.} = 15.0 \cancel{\text{in.}} \times \left(\frac{2.54 \text{ cm}}{1.00 \cancel{\text{in.}}}\right) = 38.1 \text{ cm}$$

Ex

If a car is traveling at a speed of 28.0 m/s, is the driver exceeding the speed limit of 55.0 mi/h?

Convert meters to miles: $$28.0 \text{ m/s} = \left(28.0 \frac{\cancel{\text{m}}}{\text{s}}\right)\left(\frac{1.00 \text{ mi}}{1\,609 \cancel{\text{m}}}\right) = 1.74 \times 10^{-2} \text{ mi/s}$$

Convert seconds to hours: $$1.74 \times 10^{-2} \text{ mi/s} = \left(1.74 \times 10^{-2} \frac{\text{mi}}{\cancel{\text{s}}}\right)\left(60.0 \frac{\cancel{\text{s}}}{\cancel{\text{min}}}\right)\left(60.0 \frac{\cancel{\text{min}}}{\text{h}}\right) = 62.6 \text{ mi/h}$$

1.6 Estimates and Order-of-Magnitude Calculations

For many problems, knowing the approximate value of a quantity—within a factor of 10 or so—is sufficient. This approximate value is **called an order-of magnitude** estimate, and requires finding the power of 10 that is closest to the actual value of the quantity. For example, 75 kg, 10^2 kg, where the symbol, means "is on the order of" or "is approximately". Increasing a quantity by three orders of magnitude means that its value increases by a factor of 103 =1000.

1.7 Coordinate Systems

To locate a point in space we need to use what is called coordinate systems

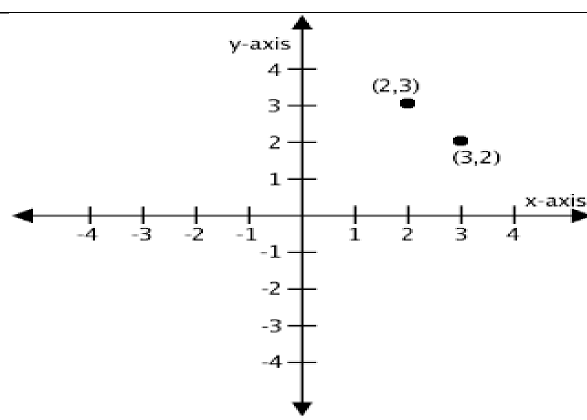
A coordinate system used to specify locations in space consists of the following:

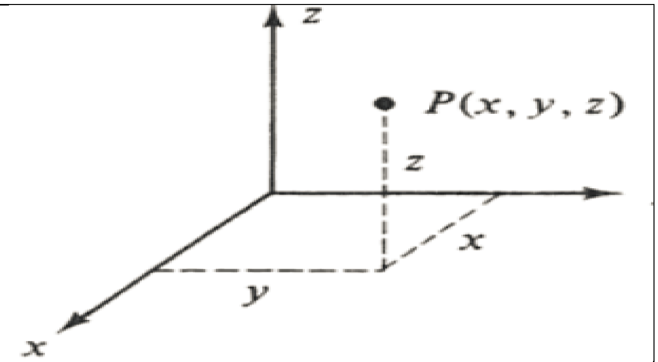
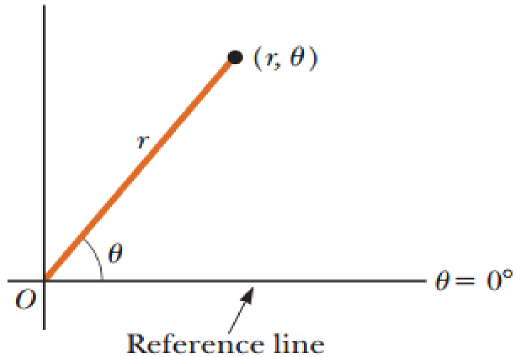
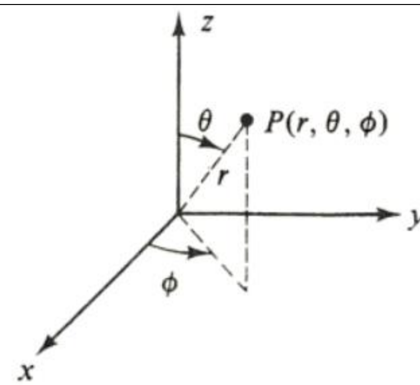
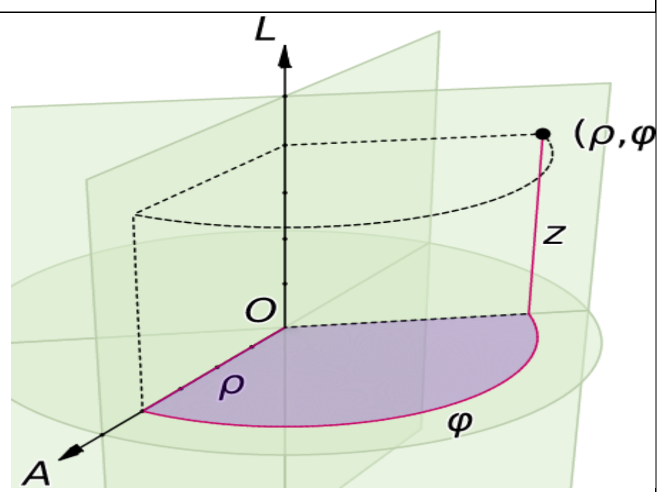
■ A fixed reference point O, called the origin

■ A set of specified axes, or directions, with an appropriate scale and labels on the axes

■ Instructions on labeling a point in space relative to the origin and axes

In general we have Cartesian coordinates "2-dim. X-Y or 3-dim. X-Y-Z"

Coordinate		
Cartesian	Two dimensions XY	

	Three dimensions XYZ	
polar	$r \text{ and } \theta$	
Spherical	$r, \theta \text{ and } \varphi$	
Cylindrical coordinate	$\rho, \varphi \text{ and } z$	

Summary

Standards of Length, Mass, and Time: The physical quantities in the study of mechanics can be expressed in terms of three fundamental quantities: length, mass, and time, which have the SI units meters (m), kilograms (kg), and seconds (s), respectively.

The Building Blocks of Matter: Matter is made of atoms, which in turn are made up of a relatively small nucleus of protons and neutrons within a cloud of electrons. Protons and neutrons are composed of still smaller particles, called quarks.

Dimensional Analysis: Dimensional analysis can be used to check equations and to assist in deriving them. When the dimensions on both sides of the equation agree, the equation is often correct up to a numerical factor. When the dimensions don't agree, the equation must be wrong.

Uncertainty in Measurement and Significant Figures: No physical quantity can be determined with complete accuracy. The concept of significant figures affords a basic method of handling these uncertainties. A significant figure is a reliably known digit, other than a zero used to locate the decimal point. The two rules of significant figures are as follows:

(a) When multiplying or dividing using two or more quantities, the result should have the same number of significant figures as the quantity having the fewest significant figures.

(b) When quantities are added or subtracted, the number of decimal places in the result should be the same as in the quantity with the fewest decimal places.

Use of scientific notation can avoid ambiguity in significant figures. In rounding, if the last digit dropped is less than 5, simply drop the digit; otherwise, raise the last retained digit by one.

Conversion of Units

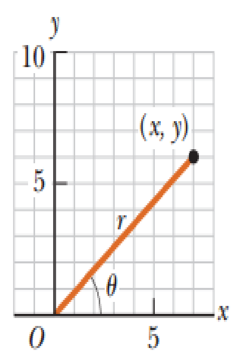
Units in physics equations must always be consistent. In solving a physics problem, it's best to start with consistent units. Converting units is a matter of multiplying the given quantity by a fraction, with one unit in the numerator and its equivalent in the other units in the denominator, arranged so the unwanted units in the given quantity are canceled out in favor of the desired units.

Estimates and Order-of-Magnitude Calculations:

Sometimes it's useful to find an approximate answer to a question, either because the math is difficult or because information is incomplete. A quick estimate can also be used to check a more detailed calculation. In an order-of magnitude calculation, each value is replaced by the closest power of ten, which sometimes must be guessed or estimated when the value is unknown. The computation is then carried out. For quick estimates involving known values, each value can first be rounded to one significant figure.

Coordinate Systems

The Cartesian coordinate system consists of two perpendicular axes, usually called the x-axis and y-axis, with each axis labeled with all numbers from negative infinity to positive infinity. Points are located by specifying the x- and y-values. Polar coordinates consist of a radial coordinate r, which is the distance from the origin, and an angular coordinate u, which is the angular displacement from the positive x-axis.



A point in the plane can be described with Cartesian coordinates (x, y) or with the polar coordinates (r, θ).

1.8 Trigonometry:

The three most basic trigonometric functions of a right triangle are the sine, cosine, and tangent, defined as follows:

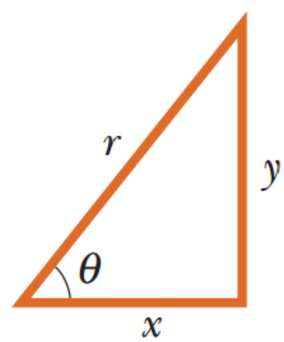
$$\sin\theta = \frac{\text{side opposite }\theta}{\text{hypotenuse}} = \frac{y}{r}$$

$$\cos\theta = \frac{\text{side adjacent to }\theta}{\text{hypotenuse}} = \frac{x}{r} \quad \textbf{[1.1]}$$

$$\tan\theta = \frac{\text{side opposite }\theta}{\text{side adjacent to }\theta} = \frac{y}{x}$$

The **Pythagorean theorem** is an important relationship between the lengths of the sides of a right triangle:

$$r^2 = x^2 + y^2 \quad \textbf{[1.2]}$$



where r is the hypotenuse of the triangle and x and y are the other two sides.