PHYSICS AND MEASUREMENT

A. Systems of Measurement

1. Metric system: mks/SI units and cgs/Gaussian system

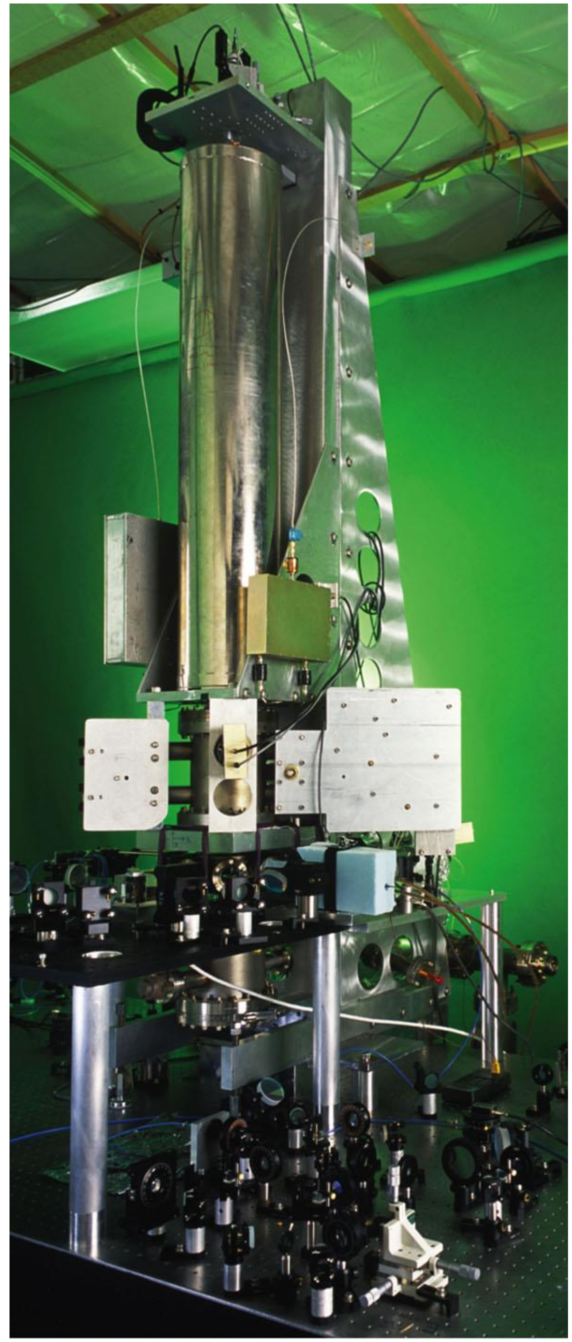
2. English system

B. Standards of Length, Mass, and Time

1. Meter is defined in terms of the distance travelled by light in vacuum during 1/299 792 458 seconds.
2. Kilogram is defined as the mass of a specific platinum-iridium alloy cylinder at the International Bureau of Weights and Measures.

3. Second is defined as 9 192 631 700 times the period of oscillation of radiation from a cesium atom.

a



b

C. Unit Prefixes

Examples:

1. 1 <u>pico</u>newton
2. 0.50 <u>centi</u>gram
3. 25 <u>kilo</u>meters

Table 1.4 Some Prefixes for Powers of Ten Used with "Metric" (SI and cgs) Units

Power	Prefix	Abbreviation
10^{-18}	atto-	a
10^{-15}	femto-	f
10^{-12}	pico-	p
10^{-9}	nano-	n
10^{-6}	micro-	μ
10^{-3}	milli-	m
10^{-2}	centi-	c
10^{-1}	deci-	d
10^{1}	deka-	da
10^{3}	kilo-	k
10^{6}	mega-	M
10^{9}	giga-	G
10^{12}	tera-	T
10^{15}	peta-	P
10^{18}	exa-	E

Checkpoint Questions

1. Enumerate the 3 basic physical quantities used in mechanics.
2. What units correspond to the SI/mks units?
3. The SI unit of time is based on the Earth's rotation. True or False?
4. Express 0.003 seconds to milliseconds.
5. Express 60 000 meters to kilometers.

D. Uncertainty and Significant Figures

1. To express uncertainty, the measurement result is written as: $x \pm \Delta x$.
   Example: (5.0 ± 0.1) mm OR 5.0(1) mm

2. Significant figures are reliably known digits.
   a. Counting significant figures
      Atlantic-Pacific rule
      i. Ignore leading zeros. Example: 0.00205
      ii. Ignore trailing zeros, unless they come after a decimal point. Example: 701.00 and 700 (doubtful)
      iii. Everything else is significant.

iv. Additional rules:

- Exact numbers have an infinite number of significant figures. Exact numbers have no effect on the measurement expressed in a numerical calculation.
- In a scientific notation, only the significand (coefficient) consists of significant figures.

b. Rules of Operation involving Significant Figures

Mathematical Operation	Significant figures in result
Multiplication or Division	Same as number with the fewest significant figures. Example: (0.745 x 2.2)/3.885 = 0.42

Mathematical Operation	Significant figures in result
Addition or Subtraction	Same as number with the fewest digits to the right of the decimal point. Example: 27.153 + 138.2 – 11.74 = 153.6

Checkpoint Questions:

1. Count the number of significant figures: 0.0608
2. Count the number of significant figures: 1 000.0
3. Count the number of significant figures: 2.46×10^{-6}
4. 5.67 J + 1.1 J + 0.9378 J = ?
5. $5.620 \times \pi = ?$

E. Dimensional Analysis

Dimensions of length, mass, and time are represented as follows:

L, M, and T.

Dimensions can be treated as algebraic quantities, hence:

1. Quantities can be added or subtracted only if they have the same dimensions. Example: M + M is ok, but not L - T

2. The terms on both sides of an equation must have the same dimensions.

F. Unit Conversion

Unit Conversion is the process of finding and expressing quantities to its equivalent.

Checkpoint Questions:

1. Is it possible for two quantities to have the same dimensions but different units?

   Is it possible for two quantities to have the same units but different dimensions?

2. You can always add two numbers that have the same units (e.g. 6 meters + 3 meters). Can you always add two numbers that have the same dimensions?

3. In the equation $y = c^n a t^2$ you wish to determine the integer value (1, 2, etc.) of the exponent *n*. The dimensions of *y*, *a*, and *t* are known. It is also known that *c* has no dimensions. Can dimensional analysis be used to determine *n*?

** The following are dimensions of various physical parameters. Here [L], [T], and [M] denote, respectively, dimensions of length, time, and mass.

	Dimension		Dimension
Distance (x)	[L]	Acceleration (a)	$[L]/[T]^2$
Time (t)	[T]	Force (F)	$[M][L]/[T]^2$
Mass (m)	[M]	Energy (E)	$[M][L]^2/[T]^2$
Speed (v)	[L]/[T]		

Which of the following equations are dimensionally correct?

(a) $F = ma$

(b) $x = \frac{1}{2}at^3$

(c) $E = \frac{1}{2}mv$

(d) $E = max$

(e) $v = \sqrt{Fx/m}$

*Show that the following equations can't be dimensionally correct: $v = v + at^2$ and $a = Fm - x$

* The speed of light is about 3.00×10^8 m/s. Convert this figure to miles per hour. 1 mi. = 1 609 m, 1 hr = 3 600 s

** A small turtle moves at a speed of 186 furlongs per fortnight. Find the speed of the turtle in centimetres per second. Note that 1 furlong = 220 yards and 1 fortnight = 14 days. 1 furlong = 220 yards, 1 fortnight = 14 days, 1 hr = 3 600 s, 1 m = 100 cm, 1 m = 1.094 yard, 1 day = 24 hr

* The amount of water in reservoirs is often measured in acre-ft. One acre-ft is a volume that covers an area of one acre to a depth of one foot. An acre is 43 560 ft^2. Find the volume in SI units of a reservoir containing 25.0 acre-ft of water. 1 acre = 43 560 ft^2, 1 m = 3.281 ft

** A house is 50.0 ft long and 26 ft wide and has 8.0-ft high ceilings. What is the volume of the interior of the house in cubic meters and in cubic centimetres?
1 m = 3.281 ft, 1 m = 100 cm

** An estate on the California coast was offered for sale for $4,950,000. The total area of the estate was 102 acres.

a) Considering the price of the estate to be proportional to its area, what was the cost of one square meter of the estate?

1 acre = 43 560 ft^2, 1 ft = 0.3048 m

b) What would be the price of a portion of the estate the size of a postage stamp (7/8 in. by 1 in)? 1 m = 100 cm, 1 in = 2.54 cm

** Express the answer in significant figures:

a) $(4.5\ \text{ft})(7.2\ \text{ft})(12.4\ \text{ft}) + (5.42\ \text{ft})^3 = ?$

b) $\dfrac{(45.2\ \text{kg})\ (13.7\ \text{m})}{(2.65\ \text{s})^2} = ?$

** Which unit is larger?

a) 1 centimetre or 1 millimeter?

b) 1 cm^3 or 1 m^3

** The density of lead is 11.3 g/cm^3. What is this value in kilograms per cubic meter? 1kg = 1000g, 1 m = 100 cm

** A bottle of wine known as a magnum contains a volume of 1.5 liters. A bottle known as a jeroboam contains 0.792 U.S. gallons. How many magnums are there in one jeroboam? 1 magnum = 1.5 liters, 1 jeroboam = 0.792 US gallons, 1 US gallon = 3.7854 liters

** a) $F = ma$

$$\frac{ML}{T^2} \stackrel{\checkmark}{=} M \cdot \frac{L}{T^2}$$ dimensionally correct

b) $x = \frac{1}{2} a t^3$

$$L \neq \frac{L}{\cancel{T^2}} \cancel{T^3}$$

c) $E = \frac{1}{2} m v$

$$\frac{ML^2}{T^2} \neq M \cdot \frac{L}{T}$$

d) $E = max$

$$\frac{ML^2}{T^2} = M \cdot \frac{L}{T^2} \cdot L$$

$$\frac{ML^2}{T^2} \stackrel{\checkmark}{=} \frac{ML^2}{T^2}$$ dimensionally correct

e) $v = \sqrt{Fx/m}$

$$\frac{L}{T} = \sqrt{\frac{\cancel{M}L}{T^2} \cdot L \cdot \frac{1}{\cancel{M}}}$$

$$\frac{L}{T} = \sqrt{\frac{L^2}{T^2}}$$

$$\frac{L}{T} \stackrel{\checkmark}{=} \frac{L}{T}$$ dimensionally correct

* $v = v + at^2$ $\qquad$ $a = Fm - x$

$$\frac{L}{T} = \frac{L}{T} + \frac{L}{\cancel{T^2}} \cancel{T^2} \qquad \frac{L}{T^2} = \frac{ML}{T^2} \cdot M - L$$

$$\boxed{\frac{L}{T} \neq \frac{L}{T} + L} \qquad \boxed{\frac{L}{T^2} \neq \frac{M^2L}{T^2} - L}$$

* $$3.00 \times 10^8 \frac{\cancel{m}}{\cancel{s}} \left(\frac{1\,mi}{1609\,\cancel{m}}\right)\left(\frac{3600\,\cancel{s}}{1\,hr}\right) \simeq \boxed{6.71 \times 10^8\ mi/hr}$$

** $$186 \frac{\text{furlongs}}{\text{fortnight}} \left(\frac{220\ \text{yards}}{1\ \text{furlong}}\right)\left(\frac{1\,m}{1.094\ \text{yard}}\right)\left(\frac{100\,cm}{1\,m}\right) \simeq 3.740 \times 10^6 \frac{cm}{\text{fortnight}}$$

$$3.740 \times 10^6 \frac{cm}{\text{fortnight}} \left(\frac{1\ \text{fortnight}}{14\ \text{days}}\right)\left(\frac{1\ \text{day}}{24\ \text{hrs}}\right)\left(\frac{1\ \text{hr}}{3600\,s}\right) \simeq \boxed{3.09\ \frac{cm}{s}}$$

* $$25.0\ \text{acre} \cdot \cancel{ft}\left(\frac{43\,560\ ft^2}{1\ \text{acre}}\right)\left(\frac{1\,m}{3.281\,ft}\right)^3 \simeq \boxed{3.08 \times 10^4\ m^3}$$

** $$50.0\,ft \times 26\,ft \times 8.0\,ft \left(\frac{1\,m}{3.281\,ft}\right)^3 \simeq \boxed{294\ m^3}$$

$$294\,m^3 \left(\frac{100\,cm}{1\,m}\right)^3 \simeq \boxed{2.9 \times 10^8\ cm^3}$$

** a) $$\frac{\$\,4\,950\,000}{102\ \text{acres}}\left(\frac{1\ \text{acre}}{43\,560\,ft^2}\right)\left(\frac{1\,ft}{0.3048\,m}\right)^2 \simeq \$\,11.99/m^2$$

$$\simeq \boxed{\$\,12/m^2}$$

b) $$\frac{\$\,11.99}{m^2}\left(\frac{1\,m}{100\,cm}\right)^2\left(\frac{2.54\,cm}{1\ \text{inch}}\right)^2 \simeq \$\,7.74 \times 10^{-3}/in^2$$

$$\frac{\$7.74\times10^{-3}}{\cancel{in}^2}\left(\frac{7}{8}\,\cancel{in}\times 1\,\cancel{in}\right) \simeq \boxed{\$\,0.007}$$

** a) $\boxed{5.6\times10^{2}\ ft^{3}}$

b) $\boxed{88.2\ \frac{Kg\cdot m}{s^{2}}}$

** a) $1\,cm = 10^{-2}\,m$

$1\,mm = 10^{-3}\,m$

$\boxed{1\,cm > 1\,mm}$

b) $$1\,\cancel{cm^3}\left(\frac{1\,m}{100\,\cancel{cm}}\right)^3 \simeq 10^{-6}\,m^3$$ $\boxed{1\,m^3 > 1\,cm^3}$

** $$11.3\,\frac{\cancel{g}}{\cancel{cm^3}}\left(\frac{1\,Kg}{1000\,\cancel{g}}\right)\left(\frac{100\,\cancel{cm}}{1\,m}\right)^3 \simeq \boxed{11\,300\ Kg/m^3}$$

** $$1\,\cancel{jeroboam}\left(\frac{0.792\ US\ \cancel{gallons}}{1\ \cancel{jeroboam}}\right)\left(\frac{3.7854\,\cancel{L}}{1\ US\ \cancel{gallon}}\right)\left(\frac{1\ magnum}{1.5\,\cancel{L}}\right)$$

$\simeq \boxed{2\ magnums}$