Introduction

In this chapter we will consider some important concepts in Engineering. Details can be found in [1] and [2].

1. Length and angle related parameters
2. Time related parameters
3. Mass related parameters
1. Length and Angle Related Parameters

Length is a very important fundamental dimension commonly used in engineering products.

![BMW Z3](image)

**Measurement of Length**

Early humans may have used *finger length, arm span, step length, stick, rope, chains, ...* to measure the size or displacement of an object.

Today, depending on accuracy, we use: *ruler, caliper, micrometer, electronic distance measuring device ..*
**Example**

One can use a protractor to measure the height of a building as follows:

\[
H = h_1 + h_2 = h_1 + dh \tan \theta = 1.5 + 10 \tan 52^\circ = 14.3 \text{ m}
\]

**Coordinate Systems**

- Coordinate systems are used to locate things with respect to a known origin.
- In Engineering, to locate an object at point A, with respect to the origin (point 0) we generally use the following systems:

![Coordinate Systems Diagram](image)
Spherical coordinate system is used in science and engineering. This system defines a 3D space where the position of a point is specified by three numbers: \((r, \theta, \varphi)\) where

- \(r > 0\)
- \(0 \leq \theta \leq 180 \ (\pi \text{ rad})\)
- \(0 \leq \varphi < 360 \ (2\pi \text{ rad})\)

---

**Earth Geographic Coordinate System**

- This enables every location on Earth to be specified by a set of numbers and/or letters.
- Earth is divided into 360 circular arcs that are equally spaced
  - from East to West called longitudes or meridians.
  - from North to South called latitudes or parallels.

http://en.wikipedia.org/wiki/Latitude_and_longitude
- The north pole is 90° N
  The south pole is 90° S
  The 0° parallel of latitude is designated the equator.

The zero longitude was arbitrarily assigned to the arc that passes through Greenwich, England.

---

![Globe Diagram](http://www.infoplease.com/ipa/A0001769.html)

<table>
<thead>
<tr>
<th>City</th>
<th>Latitude</th>
<th>Longitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ankara, Türkiye</td>
<td>39° 55' N</td>
<td>32° 55' E</td>
</tr>
<tr>
<td>Gaziantep, Türkiye</td>
<td>37° 4' N</td>
<td>37° 23' E</td>
</tr>
<tr>
<td>Lisbon, Portugal</td>
<td>38° 44' N</td>
<td>9° 9' W</td>
</tr>
<tr>
<td>Hamburg, Germany</td>
<td>53° 33' N</td>
<td>10° 2' E</td>
</tr>
<tr>
<td>Sydney, Australia</td>
<td>34° 0' S</td>
<td>151° 0' E</td>
</tr>
</tbody>
</table>

**Gaziantep Details:**

<table>
<thead>
<tr>
<th>Latitude</th>
<th>Longitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>37° 3' 33&quot; N</td>
<td>37° 22' 57&quot; E</td>
</tr>
<tr>
<td>37.059167° N</td>
<td>37.382833° E</td>
</tr>
</tbody>
</table>

http://www.infoplease.com/ipa/A0001769.html
Example

The geographic coordinates of Gaziantep’s populated place are given by: 37° 3’ 33” N and 37° 22’ 57” E. Express the values of latitude and longitude only in degrees.

Here:

3’   =  3 min = 3/60 = 0.05° (0.05 deg)
33”  = 33 sec = 33/60/60 = 0.009167° (0.009167 deg)

22’  = 22 min = 22/60 = 0.367°
57”  = 57 sec = 57/60/60 = 0.01583°

Therefore:

37° 3’ 33” N = 37 + 0.050 + 0.009167 = 37.059167° N
37° 22’ 57” E = 37 + 0.367 + 0.015833 = 37.382833° E

Example

If you type 37.059167, 37.382833 on the webpage maps.google.com, you will get the location on the map.
Example

It takes the earth 24 hours to complete one revolution about its axis.

a) Show that every 15 degrees longitude corresponds to 1 hour.

b) Show that every 1 degree longitude corresponds to 4 minutes.

SOLUTION

a) \[ \omega = \frac{360^\circ}{24 \text{ h}} = 15 \text{ degrees per hour} \]

b) \[ \omega = \left( \frac{360^\circ}{24 \text{ h}} \right) \left( \frac{1 \text{ h}}{60 \text{ min}} \right) = 0.25 \text{ degrees per minute} \]

or

\[ \omega = \left( 4 \right) \left( \frac{0.25 \text{ deg}}{4 \text{ min}} \right) = 1 \text{ degree per 4 minutes} \]

The Spherical Coordinate system is also used in AstroPhysics to measure the angular position of Sun.

The azimuth angle is the compass direction from which the sunlight is coming.

The elevation (altitude) angle is the angular height of the sun in the sky measured from the horizontal.

Both angles vary throughout the day.
Download the following animations from the course web page:
sun-elevation.swf
sun-azimuth.swf

See also:
http://www.pveducation.org/properties-of-sunlight/elevation-angle
http://www.pveducation.org/properties-of-sunlight/azimuth-angle

Example
If you type 37.059167, 37.382833 on the webpage www.sunearthtools.com,
you will get the angular position of the sun for the given time.
Example

If you type 37.059167, 37.382833 on the webpage http://www.pveducation.org/properties-of-sunlight/sun-position-high-accuracy
you will get the position of the sun accurately.
2. Time Related Parameters

- Humans use
  - Sun, Moon, Stars, Planets, …
  to keep track of long period of times.

- E.g. the lunar calendar
  - was used by many early civilizations
  - is used by many countries today

- Humans also need shorter time intervals
  - such as what today we call an hour.

- This need led to the development of clocks.

Periodic Motion

- A period \((T)\) is the time that it takes for the event to repeat itself.
  - Such as every 365.24 days the earth lines up in exactly the same position with respect to the sun

- A frequency \((f)\) is the inverse of a period.

- A spring-mass system or a simple pendulum are another examples for periodic motion.
Period and frequency of a pendulum:

\[ T = 2\pi \sqrt{\frac{g}{L}} \]
\[ f = \frac{1}{T} \]

Period and frequency of a spring-mass system:

\[ T = 2\pi \sqrt{\frac{m}{k}} \]
\[ f = \frac{1}{T} \]

**Example**

A simple pendulum of length 1 m makes 100 complete oscillations in 204 s at a certain location. What is the acceleration of gravity at this point?
Example

Determine the natural frequency of the simple spring-mass system shown in Figure.

\[ k = 5000 \text{ N/m} \]
\[ m = 2 \text{ kg} \]

- Periods and frequencies are also important in the design of electrical and electronic components.
- In general, mechanical systems have much lower frequencies than electrical/electronic systems.

<table>
<thead>
<tr>
<th>Application</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alternating current (Türkiye)</td>
<td>50 Hz</td>
</tr>
<tr>
<td>Alternating current (USA)</td>
<td>60 Hz</td>
</tr>
<tr>
<td>AM radio</td>
<td>540 kHz–1.6 MHz</td>
</tr>
<tr>
<td>FM radio</td>
<td>87–108 MHz</td>
</tr>
<tr>
<td>Emergency, fire, police</td>
<td>153–159 MHz</td>
</tr>
<tr>
<td>Personal computer clocks (2012)</td>
<td>up to 3 GHz</td>
</tr>
<tr>
<td>Wireless router (2012)</td>
<td>1–5 GHz</td>
</tr>
</tbody>
</table>
### Bit Rate

- A bit is the basic capacity of information in computing and telecommunications.

- A byte is a collection of 8 bits.
  
  \[
  1,024 \text{ Byte} = 1 \text{ kByte} = 1 \text{ kB} \quad \text{and} \quad 1,024 \text{ Byte} = 8192 \text{ bit} \\
  1,024 \text{ kB} = 1 \text{ MB} \\
  1,024 \text{ MB} = 1 \text{ GB} \\
  1,024 \text{ GB} = 1 \text{ TB}
  \]

- Bit rate is the number of bits that are transferred or processed per unit of time.

\[
\text{bit rate} = \frac{\text{bit}}{\text{second}}
\]

When quantifying large bit rates we use:

\[
1,000 \text{ bit/s} = 1 \text{ kbit/s} \quad \text{(one kilobit or one thousand bits per sec.)} \\
1,000,000 \text{ bit/s} = 1 \text{ Mbit/s} \quad \text{(one megabit or one million bits per sec.)} \\
1,000,000,000 \text{ bit/s} = 1 \text{ Gbit/s} \quad \text{(one gigabit or one billion bits per sec.)}
\]

### USB

Universal Serial Bus (USB) is an industry standard developed in the mid-1990s that defines protocols used for communication between computers and electronic devices.

<table>
<thead>
<tr>
<th>USB type</th>
<th>Transmission speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>USB 2.0</td>
<td>480 Mbit/s</td>
</tr>
<tr>
<td>USB 3.0</td>
<td>5 Gbit/s</td>
</tr>
</tbody>
</table>
Example
How long does it take to transfer 1.2 GB of data in your flash disk to your PC by using USB 3.0?

Volume Flow Rate
- It is defined as

\[ \text{volume flow rate} = \frac{\text{volume}}{\text{time}} \]

- Common units are:
  - m³/s or m³/min
  - L/s or L/min
  - ft³/s or ft³/min
  - gal/s (gps) or gal/min
Example
Consider the piping system shown in Figure. The average speed of water flowing through the 12-cm-diameter section of the piping system in 5 cm/s. What is the volume flow rate of water in the piping system? Express the volume flow rate in cm$^3$/s, ft$^3$/s, gpm, and L/s.

![Diagram of piping system with water flow]

Note that, we can define the flow rate as follows:

\[ Q = \text{volume flow rate} = \text{(average speed)} \times \text{(cross-sectional area)} \]

3. Mass Related Parameters
The kilogram is the unit of mass in SI; it is equal to the mass of the international prototype of the kilogram, IPK.

IPK
- was accepted in 1889
- made of a platinum alloy (90% platinum and 10% iridium)

See also:
Mass Density

- It is defined as
  \[ \text{density} = \frac{\text{mass}}{\text{volume}} \]
- or
  \[ \rho = \frac{m}{V} \]

- Common units are:
  - kg/m\(^3\)
  - g/cm\(^3\)
  - lbm/s

<table>
<thead>
<tr>
<th>Substance</th>
<th>(\rho (\text{kg/m}^3))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Helium Gas</td>
<td>0.18</td>
</tr>
<tr>
<td>Air</td>
<td>1.29</td>
</tr>
<tr>
<td>Ice</td>
<td>917</td>
</tr>
<tr>
<td>Water</td>
<td>1000</td>
</tr>
<tr>
<td>Iron</td>
<td>7860</td>
</tr>
</tbody>
</table>

Specific Gravity

- It is defined as
  \[ \text{specific gravity} = \frac{\text{density of material}}{\text{density of water at } 4 \, ^\circ\text{C}} \]

- Density of water at \(4 \, ^\circ\text{C}\) = 1 g/cm\(^3\)
Mass Flow Rate

- It is defined as
\[
\text{mass flow rate} = \frac{\text{mass}}{\text{time}}
\]
or
\[
\text{mass flow rate} = \frac{\text{mass}}{\text{time}} \cdot \frac{\text{volume}}{\text{time}} = (\text{density})(\text{volume flow rate})
\]

- Common units are:
  - kg/s, kg/min, kg/h
  - mg/min
  - lbm/s

\[
\text{flow} = \rho \text{Q}
\]

Example: Conservation of Mass

Consider the chemical reactor:

Compute the \(c_3\) assuming that the system is at steady state i.e. mass flow in = mass flow out

Mass flow 1 (in) \( : \) \(m_1 = Q_1 c_1 = (2 \text{ m}^3/\text{min})(25 \text{ mg/m}^3) = 50 \text{ mg/min}\)

Mass flow 2 (in) \( : \) \(m_2 = Q_2 c_2 = (1.5 \text{ m}^3/\text{min})(10 \text{ mg/m}^3) = 15 \text{ mg/min}\)

Mass flow 3 (out) \( : \) \(m_3 = m_1 + m_2 = 65 \text{ mg/min} = (3.5 \text{ m}^3/\text{min}) c_3 \Rightarrow c_3 = 18.6 \text{ mg/m}^3\)
Equation of Continuity

The continuity condition requires the mass flux

$$\rho A v$$

of a ideal fluid through a pipe in time $t$ is constant.

$$m_1 = \rho V_1 = \rho \Delta x_1 A_1 = \rho v_1 A_1 t$$

$$m_2 = \rho V_2 = \rho \Delta x_2 A_2 = \rho v_2 A_2 t$$

Conservation of mass:

$$m_1 = m_2$$

$$\rho v_1 A_1 t = \rho v_2 A_2 t$$

volume flow rate $= v_1 A_1 = v_2 A_2 =$ constant

Example

The container shown in Figure is being filled by Taps 1 and 2. If the water level is to remain constant,

(a) what is the volumetric flow rate of water leaving the container at 3?
(b) what is the average velocity of the water leaving the tank?
Questions

1. Table shows the observed mean radius and the mass of planets in our solar system. Determine the mass density of each planet in kg/m³, kg/L, g/cm³, lbm/ft³ units.

<table>
<thead>
<tr>
<th>Planet</th>
<th>Mean Radius (km)</th>
<th>Mass (x 10^{24} kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mercury</td>
<td>2439.7</td>
<td>0.330104 ± 0.000836</td>
</tr>
<tr>
<td>Venus</td>
<td>6051.8</td>
<td>4.86732 ± 0.0049</td>
</tr>
<tr>
<td>Earth</td>
<td>6371.0 ± 0.1</td>
<td>5.97216 ± 0.00060</td>
</tr>
<tr>
<td>Mars</td>
<td>3389.50 ± 2</td>
<td>0.641693 ± 0.00064</td>
</tr>
<tr>
<td>Jupiter</td>
<td>69911 ± 5</td>
<td>1898.13 ± 19</td>
</tr>
<tr>
<td>Saturn</td>
<td>58232 ± 5</td>
<td>668.319 ± 0.057</td>
</tr>
<tr>
<td>Uranus</td>
<td>25362 ± 7</td>
<td>86.8103 ± 0.0087</td>
</tr>
<tr>
<td>Neptune</td>
<td>24622 ± 19</td>
<td>102.410 ± 0.910</td>
</tr>
<tr>
<td>Pluto</td>
<td>1151 ± 6</td>
<td>0.01309 ± 0.00018</td>
</tr>
</tbody>
</table>

2. For each planet, determine the value of length of a simple pendulum whose period is 1 s. Note that, if the mass of the planet is M and mean radius is R, then the gravitational acceleration can be evaluated by:

\[ g = \frac{GM}{R^2} \]

where \( G \) is the universal gravitational constant and has the value:

\[ G = 6.67300 \times 10^{-11} \text{ m}^3 \text{ kg}^{-1} \text{ s}^{-2} \]

3. Indoor Air Pollution

Suppose that you are designing a ventilation system for a restaurant.

By using Octave, solve for the steady-state concentration of carbon monoxide (CO) concentration \( c_1 \), \( c_2 \), \( c_3 \) and \( c_4 \) in each room.
4. How long does it take to transfer 400 MB of data in your flash disk to your PC by using (a) USB 2.0 and (b) USB 3.0?

5. We are interested in determining the mass-flow rate of fuel from the gasoline tank of a small car to its fuel injection system. The gasoline consumption of the car is 15 kilometers per liter when the car is moving at the speed of 90 km/h. The specific gravity of gasoline is 0.72. If there were one million of these cars on the road, how many kilograms of gasoline are burned every hour? [2].

6. The coordinates of a city is given by: 41.050683 N, 29.031186 E. Express the coordinate in terms of deg, min and sec format. Where is the city?

7. The geographic coordinates of a town is given by: +32° 54' 31", -7° 15' 15", this equivalent to +32° 54' 31" N, 7° 15' 15" E. Express the values of latitude and longitude only in degrees. Where is the town?

8. A plugged dishwasher sink with the dimensions of 14 in. x 16 in. x 6 in. is being filled with water from a faucet with an inner diameter of 1 in. If it takes 220 seconds to fill the sink to its rim, estimate the mass flow of water coming out of the faucet.

9. In the concentration of orange juice, fresh juice containing $s_1 = 7.08\%$ solids is fed to a vacuum evaporator at a rate of $L = 1000$ kg/h. In the evaporator, water is removed at a rate of $W$(kg/h) and the solid content is increased to $s_2=58\%$. Calculate
   a) the outlet concentration $C$(kg/h)
   b) removed water rate $W$(kg/h).
   
   \[\text{Answer: a) } C = 122.1 \text{ kg/h concentrated juice b) } W = 877.9 \text{ kg/h water}\]
References
