EP145 Introduction to Engineering

Topic 6

Length, Time and Mass Related Parameters

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http://www1.gantep.edu.tr/~bingul/ep145

Nov 2012

Introduction

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

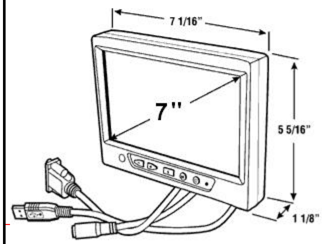
1. Length and angle related parameters
2. Time related parameters
3. Mass related parameters

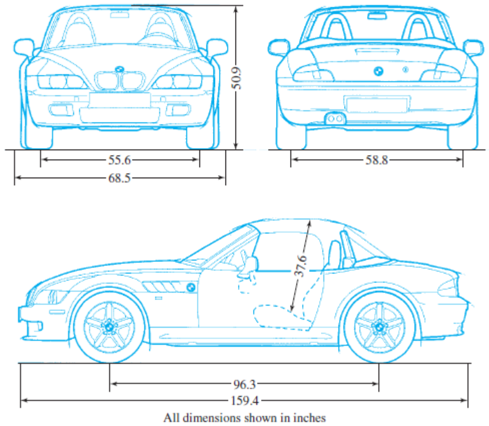
1. Length and Angle Related Parameters

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

BMW Z3

LCDP7WVGATS





Measurement of Length

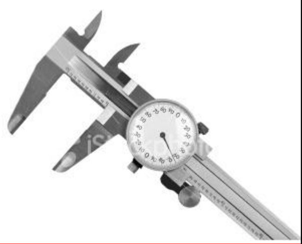
Early humans may have used

finger length, arm span, step length, stick, rope, chains, ...

to measure the size or displacement of an object.

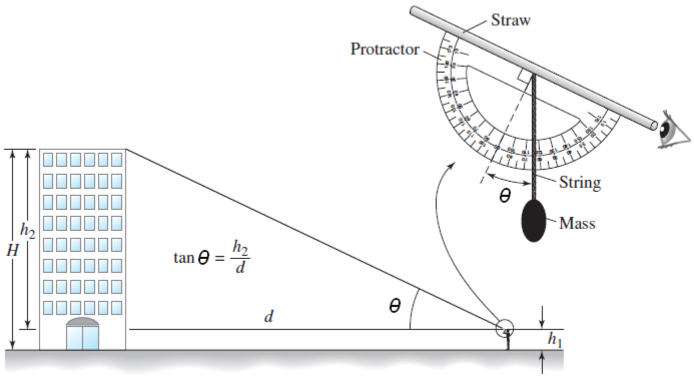
Today, depending on accuracy, we use:

ruler, caliper, micrometer, electronic distance measuring device ..



Example

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



if d = 10 m, θ = 52º and h_1 = 1.5 m then:

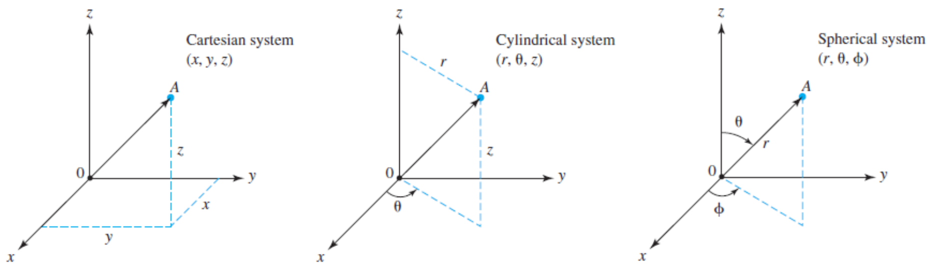
$H = h_1 + h_2$

$= h_1 + d \tan\theta$

$= 1.5 + 10 * \tan 52° =$ **14.3 m**

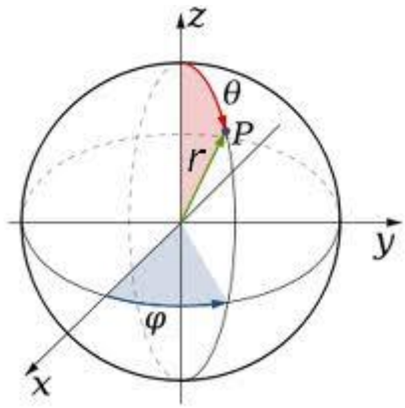
Coordinate Systems

- 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:

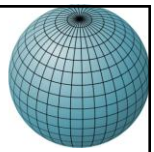


- Spherical coordinate system is used in science and engineering.
- This system is defines a 3D space where the position of a point is specified by three numbers: (r, θ, φ) where

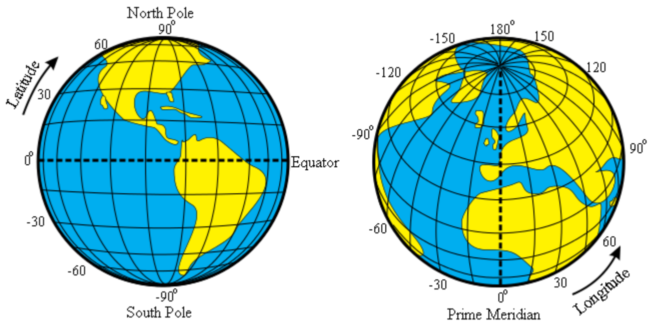
$r > 0$
$0 \leq \theta \leq 180$ (π rad)
$0 \leq \varphi < 360$ (2π rad)



Earth Geographic Coordinate System

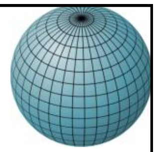


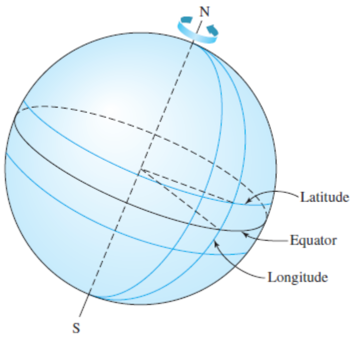
- This enables every location on Earth to be specified by a set of numbers and/or letters.
- Earth is divided into 360 circular arcs that are equally spaced
  - from East to West called longitudes or meridians.
  - from North to South called latitudes or paralles.



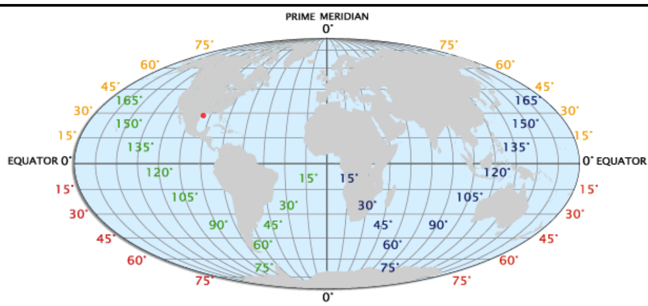
http://en.wikipedia.org/wiki/Latitude_and_longitude

- 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.



City	Latitude	Longitude
Ankara, Türkiye	39° 55' N	32° 55' E
Gaziantep, Türkiye	37° 4' N	37° 23' E
Lisbon, Portugal	38° 44' N	9° 9' W
Hamburg, Germany	53° 33' N	10° 2' E
Sydney, Australia	34° 0' S	151° 0' E

N: North

S: South

E: East

W: West

Gaziantep Details:

Latitude	Longitude
37° 3′ 33″ N	37° 22′ 57″ E
37.059167° N	37.382833° E

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

Example

The geographic coordinates of Gaziantep's populated place are given by: 37º 3' 33" N and 37º 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)

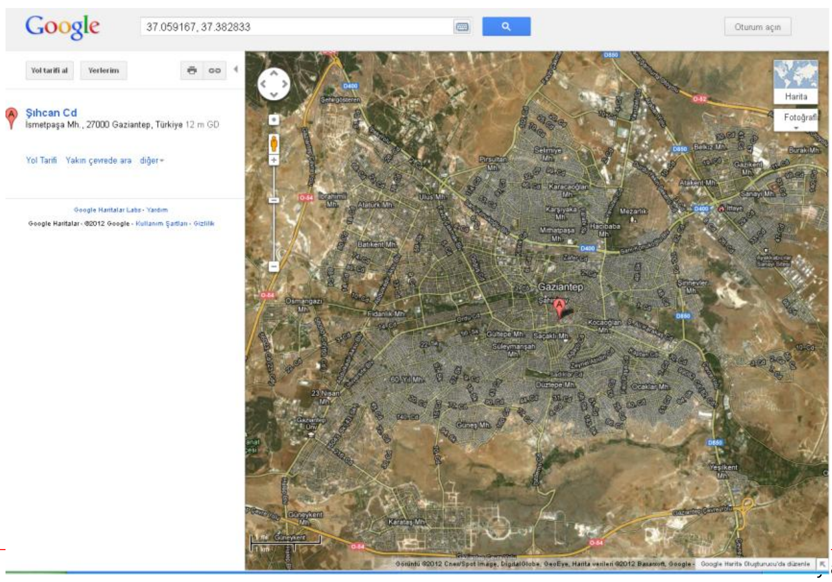
22′ = 22 min = 22/60 = 0.367°
57″ = 57 sec = 57/60/60 = 0.01583°

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 minute.

SOLUTION

a) $$\omega = \frac{360^o}{24\,\text{h}} = 15\,\text{degrees per hour}$$

b) $$\omega = \left(\frac{360^o}{24\,\text{h}}\right)\left(\frac{1\,\text{h}}{60\,\text{min}}\right) = 0.25\,\text{degrees per minute}$$

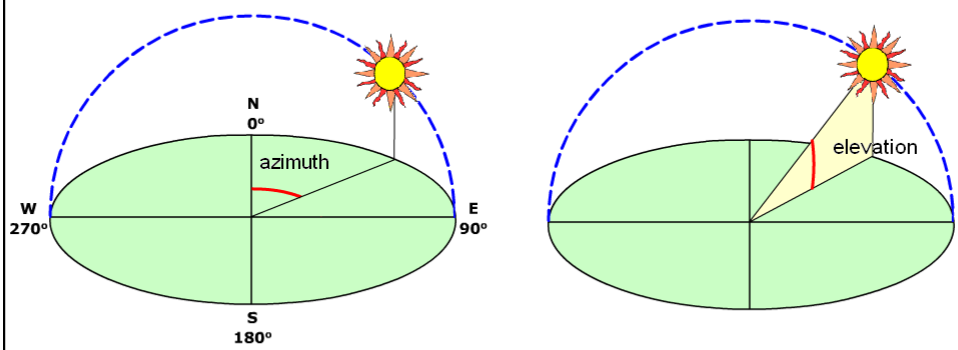
or

$$\omega = \frac{4}{4}\left(0.25\frac{\text{deg}}{\text{min}}\right) = 1\,\text{degree per 4 minute}$$

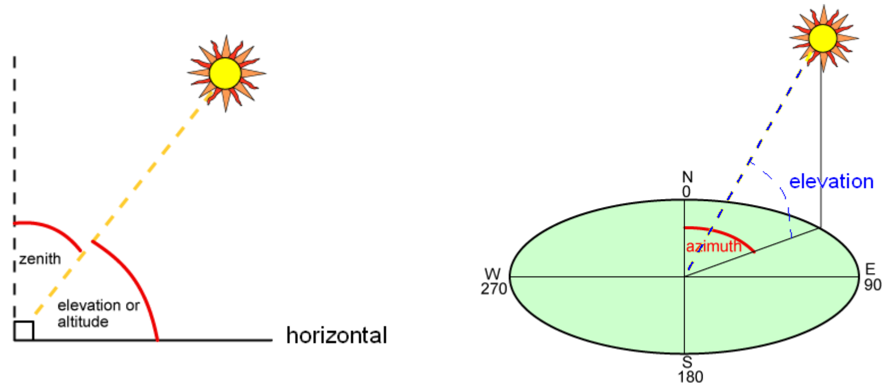
The Spherical Coordinate system is also used in AstroPhysics to measure the angular position of Sun.

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.

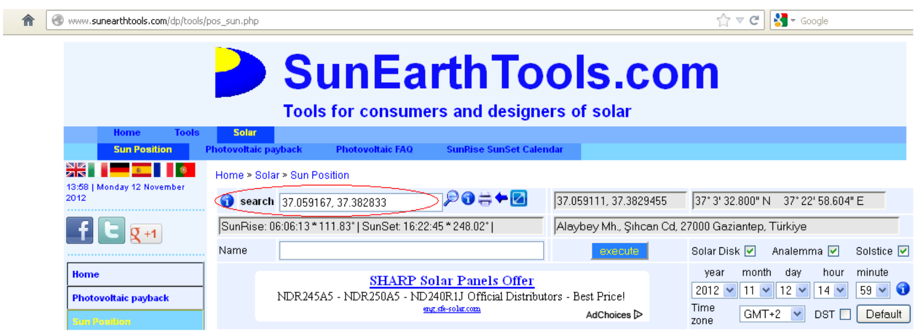


Download the following animations from the course web page:
sun-elevation.swf
sun-azimuth.swf

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.



www.sunearthtools.com

Step (minute): 60 execute download Excel table

Date:	12/11/2012	
coordinates:	37.059111 , 37.3829455	
location:	Alaybey Mh., AžÄ±hcan Cd, 27000 Gaziantep, TÃ¼rkiye	
hour	Elevation	Azimuth
06:06:13	-0.833°	111.83°
7:00:00	8.79°	120.29°
8:00:00	18.51°	131.07°
9:00:00	26.61°	143.82°
10:00:00	32.35°	158.86°
11:00:00	34.99°	175.73°
12:00:00	34.06°	193.04°
13:00:00	29.73°	209.08°
14:00:00	22.67°	222.93°
15:00:00	13.65°	234.58°
16:00:00	3.32°	244.56°
16:22:45	-0.833°	248.02°

sun position	Elevation	Azimuth	latitudes	longitudes
10/11/2012 15:08	12.69°	236.43°	37.059111° N	37.3829455° E
twilight	Sunrise	Sunset	Azimuth Sunrise	Azimuth Sunset
twilight -0.833°	06:04:08	16:24:20	111.13°	248.72°
Civil twilight -6°	05:36:41	16:51:44	107.09°	252.74°
Nautical twilight -12°	05:05:32	17:22:52	102.64°	257.17°
Astronomical twilight -18°	04:34:56	17:53:27	98.32°	261.47°
daylight	hh:mm:ss	diff. dd+1	diff. dd-1	Noon
10/11/2012	10:20:12	-00:01:50	00:01:54	11:14:14

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.

PSA Algorithm Sun's Position Calculator

Year 2012 Month 11 Day 14

The date displayed is UTC, i.e. at Greenwich.

Hour 14 Minute 0 Second 0

Longitude = 37.059167 Latitude = 37.382833

Azimuth **243.9017** degrees

Zenith **86.8806** degrees

Elevation **3.1194** degrees

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 countaries today

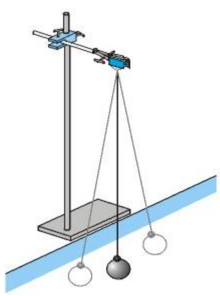
- Humans also needs shorter time intervals *such as what today we call an **hour***.

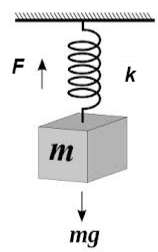
- This need led to the development of clocks.

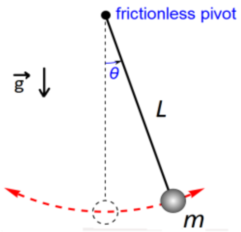
Periodic Motion

- 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.



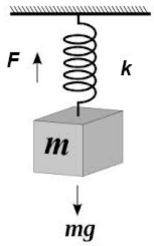




Period and frequency of a pendulum:

$$T = 2\pi\sqrt{\frac{g}{L}}$$

$$f = \frac{1}{T}$$



Period and frequency of a spring-mass system:

$$T = 2\pi\sqrt{\frac{m}{k}}$$

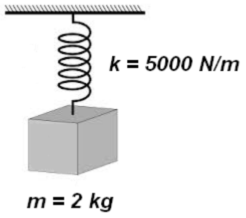
$$f = \frac{1}{T}$$

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.



- 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.

Application	Frequency
Alternating current (Türkiye)	50 Hz
Alternating current (USA)	60 Hz
AM radio	540 kHz–1.6 MHz
FM radio	87–108 MHz
Emergency, fire, police	153–159 MHz
Personal computer clocks (2012)	up to 3 GHz
Wireless router (2012)	1-5 GHz

Bit Rate

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

- A byte is a collection of 8 bits.

```
1,024 Byte = 1 kByte = 1 kB   and  1,024 Byte = 8192 bit
1,024 kB   = 1 MB
1,024 MB   = 1 GB
1,024 GB   = 1 TB
```

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

$$\text{bit rate} = \frac{\text{bit}}{\text{second}}$$

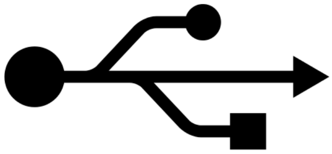
When quantifying large bit rates we use:

```
        1,000 bit/s = 1 kbit/s (one kilobit or one thousand bits per sec.)
    1,000,000 bit/s = 1 Mbit/s (one megabit or one million bits per sec.)
1,000,000,000 bit/s = 1 Gbit/s (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.

USB type	Transmission speed
USB 2.0	480 Mbit/s
USB 3.0	5 Gbit/s



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

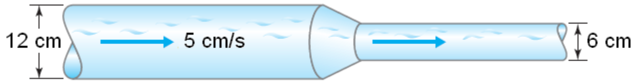
- It is defined as

$$\text{volume flow rate} = \frac{\text{volume}}{\text{time}}$$

- Common units are:
  - m^3/s or m^3/min
  - L/s or L/min
  - ft^3/s or ft^3/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.



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

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

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:
http://www.bipm.org/en/scientific/mass/prototype.html

Mass Density

- It is defined as

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

- or

$$\rho = \frac{m}{V}$$

Density of some substances
(at standard temperature and pressure)

Substance	$\rho(\text{kg/m}^3)$
Helium Gas	0.18
Air	1.29
Ice	917
Water	1000
Iron	7860

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

Specific Gravity

- It is defined as

$$\text{specific gravity} = \frac{\text{density of material}}{\text{density of water at 4 } ^{\text{o}}\text{C}}$$

- Density of water at 4 ^{o}C = 1 g/cm^3

Mass Flow Rate

$$\dot{m}$$

- It is defined as $$\text{mass flow rate} = \frac{\text{mass}}{\text{time}}$$

  or

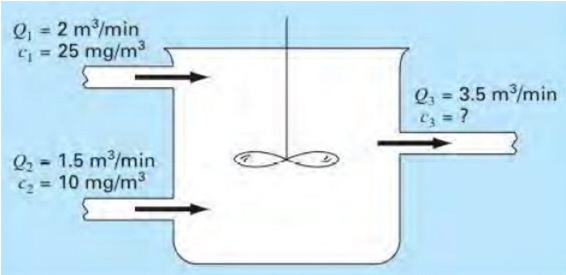
$$\text{mass flow rate} = \frac{\text{mass}}{\text{time}}$$
$$= \frac{(\text{density})(\text{volume})}{\text{time}}$$
$$= (\text{density})\left(\frac{\text{volume}}{\text{time}}\right)$$
$$= (\text{density})(\text{volume flow rate})$$

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

$$\dot{m} = \rho Q$$

Example: *Conservation of Mass*

Consider the chemical reactor:



Q: flow rate
c: concentration of chemical substance

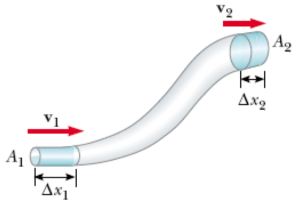
Compute the c_3 assuming that the system is at steady state i.e. mass flow in = mass flow out

Mass flow 1 (in) : $\dot{m}_1 = Q_1 c_1$ = (2 m^3/min)(25 mg /m^3) = 50 mg/min

Mass flow 2 (in) : $\dot{m}_2 = Q_2 c_2$ = (1.5 m^3/min)(10 mg/m^3) = 15 mg/min

Mass flow 3 (out) : $\dot{m}_3 = \dot{m}_1 + \dot{m}_2$ = 65 mg/min = (3.5 m^3/min) c_3 => c_3 = 18.6 mg/m^3

Equation of Continuity



The continuity condition requires the mass flux

$$\rho A v$$

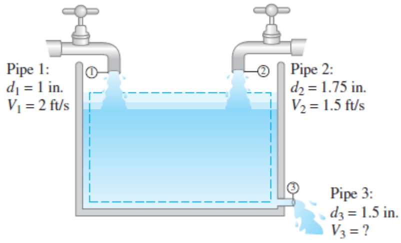
of a ideal fluid through a pipe in time *t* is constant.

$$m_1 = \rho V_1 = \rho \Delta x_1 A_1 = \rho v_1 A_1 t$$
$$m_2 = \rho V_2 = \rho \Delta x_2 A_2 = \rho v_2 A_2 t$$

Conservation of mass:

$$m_1 = m_2$$
$$\rho v_1 A_1 t = \rho v_2 A_2 t$$
$$\text{volume flow rate} = v_1 A_1 = v_2 A_2 = \text{constant}$$

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 sytem. Determine the mass density of each planet in kg/m³, kg/L, g/cm³, lbm/ft³ units.

Planet	Mean Radius	Mass
	(km)	(x 10^{24} kg)
Mercury	2439.7 [D] ±1.0	0.330104 [F] ±.000036
Venus	6051.8 [D] ±1.0	4.86732 [G] ±.00049
Earth	6371.00 [D] ±.01	5.97219 [H] ±.00060
Mars	3389.50 [D] ±.2	0.641693 [I] ±.000064
Jupiter	69911 [D] ±6	1898.13 [J] ±.19
Saturn	58232 [D] ±6	568.319 [K] ±.057
Uranus	25362 [D] ±7	86.8103 [L] ±.0087
Neptune	24622 [D] ±19	102.410 [M] ±.010
Pluto	1151 [C] ±6	.01309 [N] ±.00018

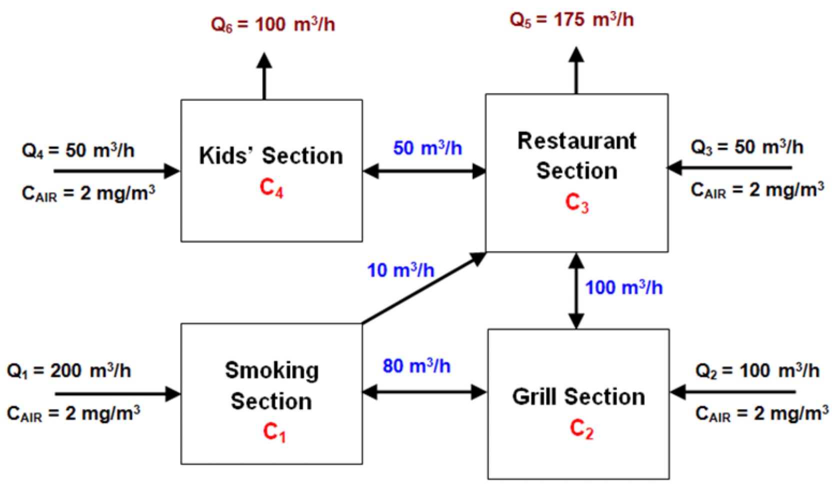
2. For each planet, determine the value of length of a simple pendulum whose period is 1 s. Note that, if the mass of the palanet is M and mean radius is *R*, then the gravitational acceleration can be evaluated by:

$$g = \frac{GM}{R^2}$$

where *G* is the universal gravitational constant and has the value:
G = 6.67300 x 10^{-11} m³ kg⁻¹ 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?

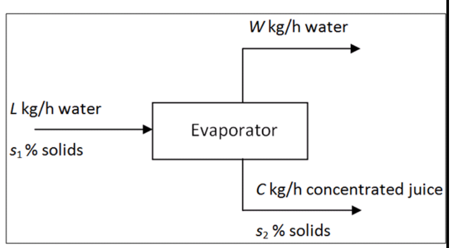
5. We are interested in determining the mass-flow rate of fuel from the gasoline tank of a small car to its fuel injection system. The gasoline consumption of the car is 15 kilometers per liter when the car is moving at the speed of 90 km/h. The specific gravity of gasoline is 0.72. If there were one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

6. The coordintes 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).
[*Answer: a) C = 122.1 kg/h concentrated juice b) W = 877.9 kg/h water*]



References

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   Cengage Learning (2011)