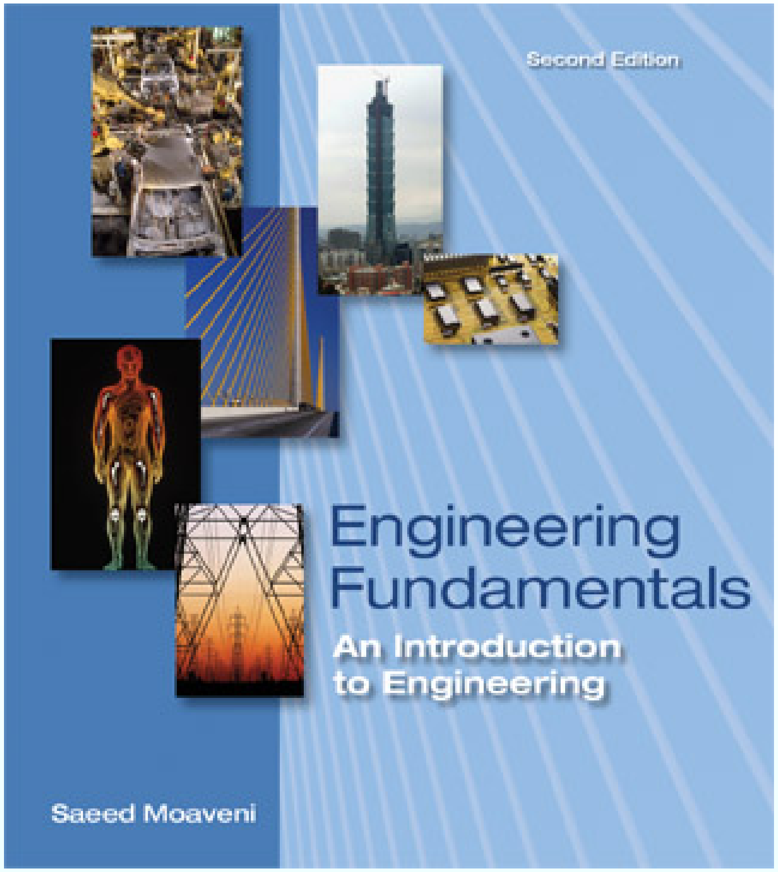
CHAPTER 9

Mass and Mass-Related Parameters



	IA	IIA	IIIB	IVB	VB	VIB	VIIB	VIIIB			IB	IIB	IIIA	IVA	VA	VIA	VIIA	VIIIA
1	1 H 1.0079																	2 He 4.003
2	3 Li 6.941	4 Be 9.012											5 B 10.811	6 C 12.011	7 N 14.007	8 O 15.999	9 F 18.998	10 Ne 20.180
3	11 Na 22.990	12 Mg 24.305											13 Al 26.982	14 Si 28.086	15 P 30.974	16 S 32.066	17 Cl 35.453	18 Ar 39.948
4	19 K 39.098	20 Ca 40.078	21 Sc 44.956	22 Ti 47.88	23 V 50.942	24 Cr 51.996	25 Mn 54.938	26 Fe 55.845	27 Co 58.933	28 Ni 58.69	29 Cu 63.546	30 Zn 65.39	31 Ga 69.723	32 Ge 72.61	33 As 74.922	34 Se 78.96	35 Br 79.904	36 Kr 83.8
5	37 Rb 85.468	38 Sr 87.62	39 Y 88.906	40 Zr 91.224	41 Nb 92.906	42 Mo 95.94	43 Tc 98	44 Ru 101.07	45 Rh 102.906	46 Pd 106.42	47 Ag 107.868	48 Cd 112.411	49 In 114.82	50 Sn 118.71	51 Sb 121.76	52 Te 127.60	53 I 126.905	54 Xe 131.29
6	55 Cs 132.905	56 Ba 137.327	57 La 138.906	72 Hf 178.49	73 Ta 180.948	74 W 183.84	75 Re 186.207	76 Os 190.23	77 Ir 192.22	78 Pt 195.08	79 Au 196.967	80 Hg 200.59	81 Tl 204.383	82 Pb 207.2	83 Bi 208.980	84 Po 209	85 At 210	86 Rn 222
7	87 Fr 223	88 Ra 226.025	89 Ac 227.028	104 Rf 261	105 Db 262	106 Sg 263	107 Bh 262	108 Hs 265	109 Mt 266	110 Uun 269	111 Uuu 272	112 Uub 277		114		116		118

Lanthanide series	58 Ce 140.115	59 Pr 140.908	60 Nd 144.24	61 Pm 145	62 Sm 150.36	63 Eu 151.964	64 Gd 157.25	65 Tb 158.925	66 Dy 162.5	67 Ho 164.93	68 Er 167.26	69 Tm 168.934	70 Yb 173.04	71 Lu 174.967
Actinide series	90 Th 232.038	91 Pa 231.036	92 U 238.029	93 Np 237.048	94 Pu 244	95 Am 243	96 Cm 247	97 Bk 247	98 Cf 251	99 Es 252	100 Fm 257	101 Md 258	102 No 259	103 Lr 262

Figure 9.1 The chemical elements to date (2001).

Mass - derived parameters

- Density = mass/volume
- Specific gravity = density/density of water at 4^{o}C
- Specific volume = volume/mass = 1/ density
- Specific weight = weight/volume = density * g

(g = acceleration due to gravity)

TABLE 9.1 Density, Specific Gravity, and Specific Weight of Some Materials (at room temperature or at the specified temperature)

Material	Density (kg/m^3)	Specific Gravity	Specific Weight (N/m^3)
Aluminum	2740	2.74	26,880
Asphalt	2110	2.11	20,700
Cement	1920	1.92	18,840
Clay	1000	1.00	9810
Fireclay brick	1790@100°C	1.79	17,560
Glass (soda lime)	2470	2.47	24,230
Glass (lead)	4280	4.28	41,990
Glass (Pyrex)	2230	2.23	21,880
Iron (cast)	7210	7.21	70,730
Iron (wrought)	7700@100°C	7.70	75,540
Paper	930	0.93	9120
Steel (mild)	7830	7.83	76,810
Steel (stainless 304)	7860	7.86	77,110
Wood (ash)	690	0.69	6770
Wood (mahogany)	550	0.55	5400
Wood (oak)	750	0.75	7360
Wood (pine)	430	0.43	4220

Fluids

Standard air	1.225	0.0012	12
Gasoline	720	0.72	7060
Glycerin	1260	1.26	12,360
Mercury	13,550	13.55	132,930
SAE 10 W oil	920	0.92	9030
Water	1000@4°C	1.0	9810

Volume flow rate

- Engineers design flow-measuring devices to determine the amount of material or a substance flowing through a pipeline in a processing plant.

- They calculate it by:

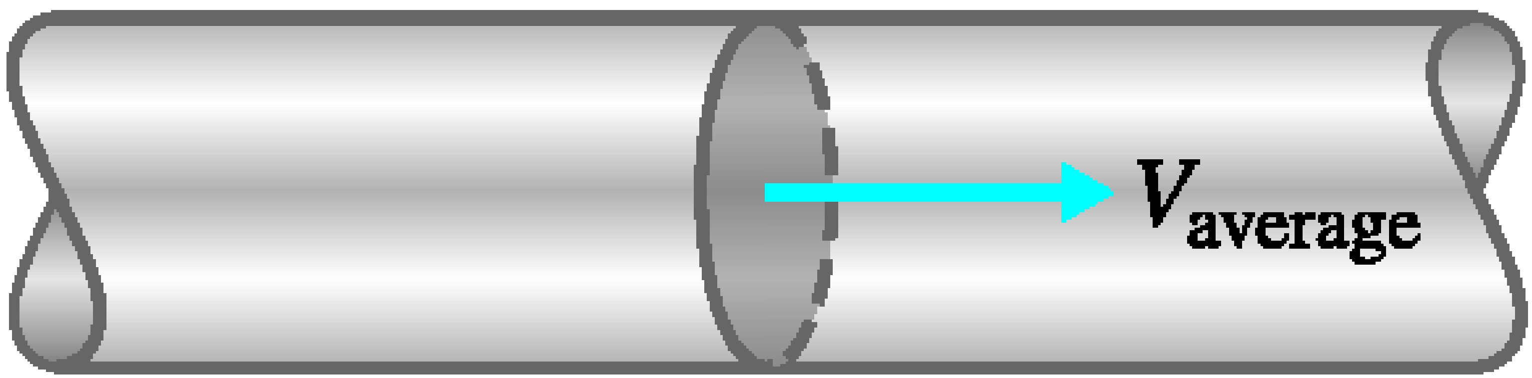
Volume flow rate = volume/time

= area x length/time

= area x (average velocity)

The latter formula is practically simpler to determine

- Common units are: m^3/s, m^3/h, L/s, ml/s, ft^3/s (cfs), gal/min (gpm), gal/day (gpd)


$V_{average}$

Example

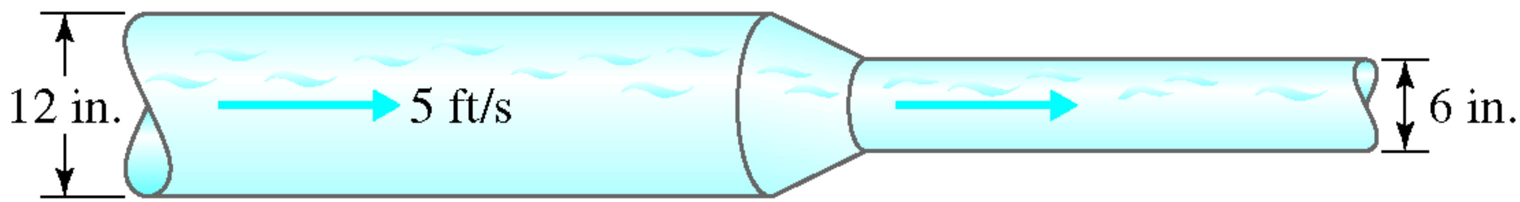


Figure 8.10 The piping system of Example 8.4.

- What is the volume flow rate of the water in the piping system? Express the answer in ft^3/s, gpm and L/s. what is the average speed of water in the 6-in diameter pipe?

Example

$$volume\ flow\ rate = (average\ velocity)(cross - sectional\ area)$$

$$Q = 5\left(\frac{ft}{s}\right)\frac{\pi}{4}\left(12\ in \cdot \frac{1\ ft}{12\ in}\right)^2 = 3.926\ ft^3/s$$

$$Q = 3.926\left(\frac{ft^3}{s}\right)\left(\frac{7.48\ gal}{1\ ft^3}\right)\left(\frac{60\ s}{1\ \min}\right) = 1762\ gpm$$

$$Q = 3.926\left(\frac{ft^3}{s}\right)\left(\frac{28.3168\ L}{1\ ft^3}\right) = 111.2\ L/s$$

$$average\ speed = Q/cross - sectional\ area$$

$$= \frac{3.926}{\frac{\pi}{4}(0.5ft)^2} = 20\ ft/s$$

Mass flow rate

- Mass flow rate

  = (displaced mass)/time

  = (volume/time)(mass/volume)

  = volume flow rate * density

Mass moment of inertia

- It is a measure of how hard it is to rotate something (with respec its center of rotation)

- $I_{z\text{-}z} = m\, r^2$

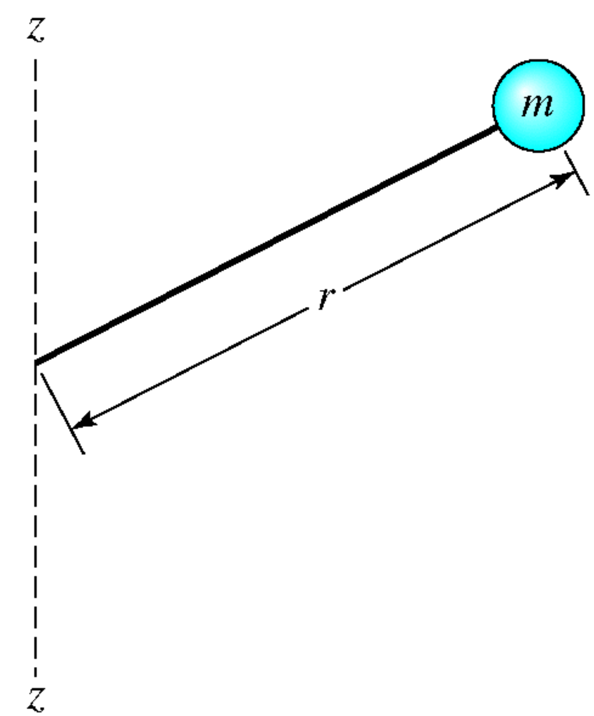


Figure 9.2
The mass moment of inertia of a point mass.

Mass moment of inertia

- $I_{z\text{-}z} = m_1 r_1^2 + m_2 r_2^2 + m_3 r_3^2$

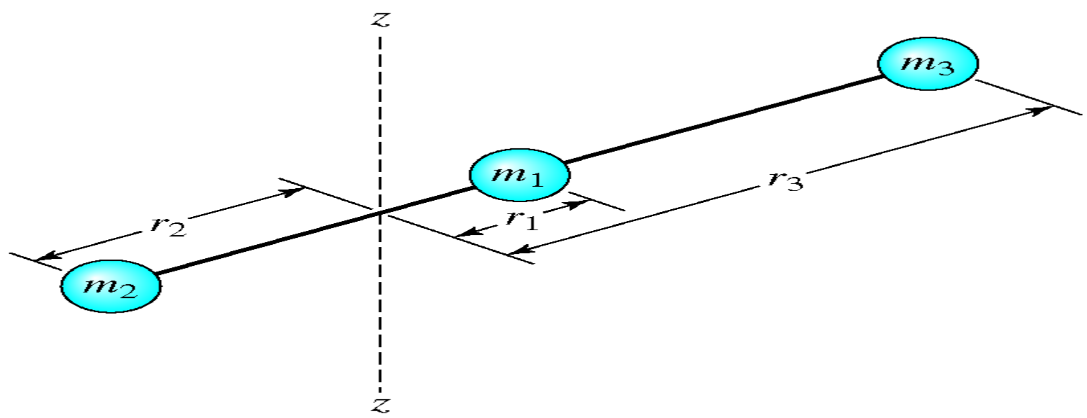


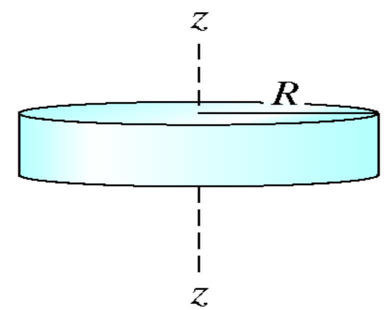
Figure 9.3
Mass moment of inertia of a system consisting of three point masses.

Mass moment of inertia

- For a body of any shape:
- $I_{z\text{-}z} = \int r^2 dm$

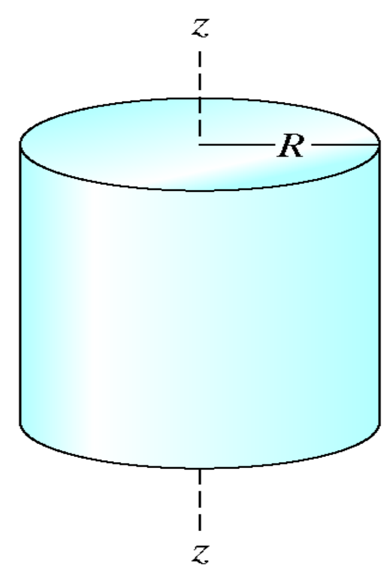
Disk

$$I_{z-z} = \frac{1}{2} mR^2$$



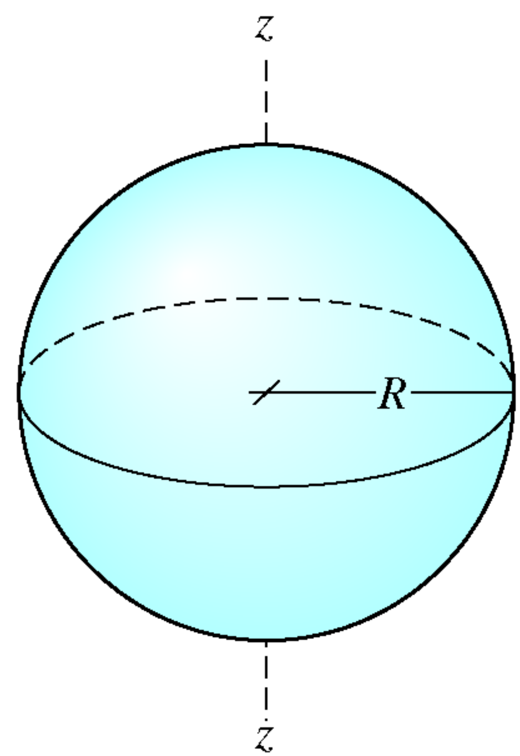
Circular Cylinder

$$I_{z-z} = \frac{1}{2} mR^2$$



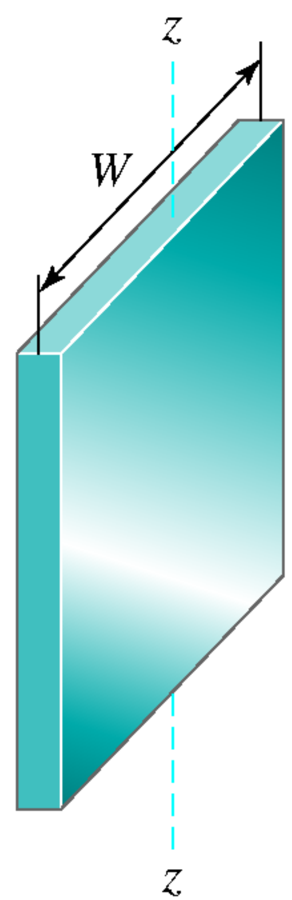
Sphere

$$I_{z-z} = \frac{2}{5} mR^2$$



Thin Rectangular Plate

$$I_{z-z} = \frac{1}{12} m W^2$$



Example 9.1

- Determine the mass moment of inertia of a steel shaft (around its axis) that is 2m long and has a diameter of 10 cm. the density of steel is 7860kg/m^3.

- Answer: 0.154Kg m^2

Momentum

- $\vec{L} = m\,\vec{V}$
- A man of mass 70 Kg running at 10m/s has a momentum of 700 Kg m/s

Momentum

- A bullet moving at 1000m/s, having a mass of 4g. Its momentum is 4Kg m/s

- It has a high momentum due to its speed. That is why it can penetrate objects and do harm. (This is also due to its small contact area)

Example 9.2

- Compare linear momentum of :
  - Person 80 kg ; 3m/s
  - Car 2000 kg ; 30 m/s

- Answer:
  - Person: 240 kg m/s
  - Car : 60 000 kg m/s

Conservation of mass

- Rate of accumulation = rate of fluid – rate of fluid
  of fluid entering leaving

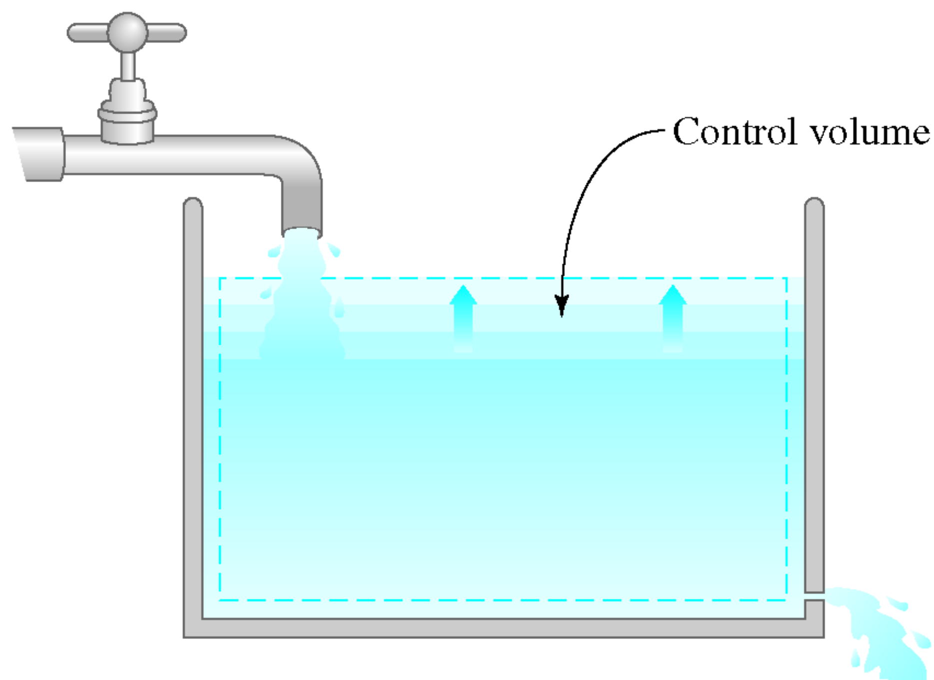


Figure 9.4
The rate at which water enters the container minus the rate at which water leaves the container should be equal to the rate of accumulation or depletion of the mass of water within the container.

Example 9.3

- How much water is stored after 5 min in each of the tanks? How long will it take to fill the tanks?

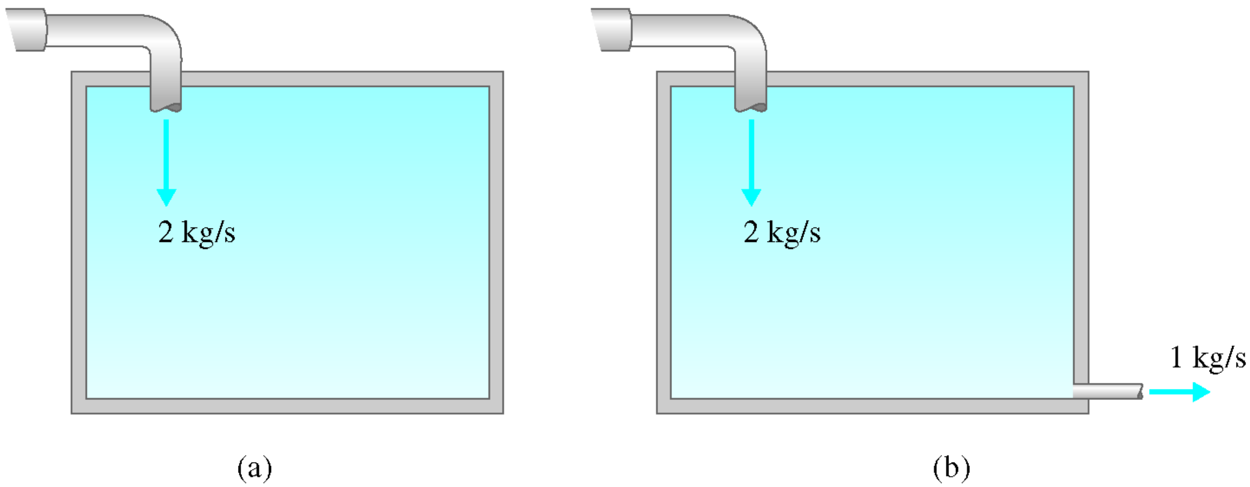


Figure 9.5
The tanks of Example 9.3.

Example 9.3

- Density of water 1000kg/m^3
- Tank 1:
  - rate of water entering 2 kg/s
  - Volume of tank: 12 m^3
- Tank 2:
  - rate of water entering 2 kg/s
  - Volume of tank: 12 m^3
  - Rate of water leaving :1 kg/s