ENGINEERING MECHANICS

STATICS

Eng. Ahmed Al Shareef

General Principles

Lecture 1: Introduction to Statics

Basic Quantities – الكميات الاساسية

كميات اساسية

TABLE 1–1 Systems of Units

Name	Length طول	Time وقت	Mass كتلة	Force قوة
International System of Units	meter	second	kilogram	newton*
SI	m	s	kg	$N \left(\frac{kg \cdot m}{s^2}\right)$

$$W = mg \qquad (g = 9.81\ m/s^2)$$

weight => N

mass => kg

100 kg x 9.81 = 981 N

mass => W

Prefixes

4000 N => 4 kN ; 50 mm

10^3 → kN (Prefix: k, unit: N)

10^{-3} → mm (Prefix: m, unit: m)

TABLE 1–3 Prefixes

	Exponential Form	Prefix	SI Symbol
Multiple			
1 000 000 000	10^9	giga	G
1 000 000	10^6	mega	M
1 000	10^3	kilo	k
Submultiple			
0.001	10^{-3}	milli	m
0.000 001	10^{-6}	micro	μ
0.000 000 001	10^{-9}	nano	n

Significant Figures

sig figs

1. All nonzero digits are significant:

1.234 g has 4 significant figures,
1.2 g has 2 significant figures.

2. Zeroes between nonzero digits are significant:

1002 kg has 4 significant figures,
3.07 mL has 3 significant figures.

3. Leading zeros to the left of the first nonzero digits are not significant; such zeroes merely indicate the position of the decimal point:

0.001 °C has only 1 significant figure,
0.012 g has 2 significant figures.

Significant Figures

4. Trailing zeroes that are also to the right of a decimal point in a number are significant:

   0.0230 mL has 3 significant figures,
   0.20 g has 2 significant figures.

5. When a number ends in zeroes that are not to the right of a decimal point, the zeroes are not necessarily significant:

   190 miles may be 2 or 3 significant figures,
   50,600 calories may be 3, 4, or 5 significant figures.

Using ***engineering notation***, the potential ambiguity can be avoided. For example, if for 50, 600 significant figures are 3, 4, or 5, we would write 50,600 calories as:

$5.06 \times 10^4 \Rightarrow$ 3 sig figs

$5.060 \times 10^4 \Rightarrow$ 4 sig figs

$5.0600 \times 10^4 \Rightarrow$ 5 sig figs.

Rounding Off Numbers.

التقريب =>

Round to 3 sig figs:

$3.5587 \Rightarrow 3.56$

$0.5896 \Rightarrow 0.590$

$9.3866 \Rightarrow 9.39$

$1.341 \Rightarrow 1.34$

$0.3762 \Rightarrow 0.376$

$9.871 \Rightarrow 9.87$

$75.25 \Rightarrow 75.2$

$0.1275 \Rightarrow 0.128$

$0.2555 \Rightarrow 0.256$

Calculation

- While performing calculations, do not round off calculations until expressing the final result

  For example:

  (5.00 / 1.235) + 3.000 + (6.35 / 4.0)=4.04858... + 3.000 + 1.5875=8.630829...

  The final result should be **8.63**

- Round off final answers to three significant figures

Example 1.1

Convert 2 Km/h to m/s

$\frac{\text{Length}}{\text{Time}} \Rightarrow$ m/s

$1\,Km = 1000\,m$

$1\,h = 3600\,s$

$\frac{1\,km}{1000\,m}$ $\quad$ $\frac{1\,hr}{3600\,s}$

$$2\ \frac{\cancel{km}}{\cancel{hr}} \times \frac{1000\,m}{1\,\cancel{km}} \times \frac{\cancel{1\,hr}}{3600\,s} = 0.556\ \frac{m}{s}$$

Example 1.2

Evaluate each of the following and express with SI units having an appropriate prefix: (a) (50 mN)(6 GN), (b) (400 mm)$(0.6\ \text{MN})^2$, (c) $45\ \text{MN}^3/900\ \text{Gg}$.

a) $(50\times10^{-3}\ \text{N})(6\times10^{9}\ \text{N}) = 3\times10^{8}\ \text{N}^2$

$$3\times10^{8}\ \text{N}^2 \times \frac{1\ \text{K N}}{1000\ \text{N}} \times \frac{1\ \text{K N}}{1000\ \text{N}} = 300\ \text{K N}^2$$

Example 1.2

b) $(400\,mm)(0.6\,MN)^2$

$(400\times10^{-3}\,m)(0.6\times10^{6}\,N)^2 \Rightarrow mN^2$

$\Rightarrow 1.44\times10^{11}\,mN^2$

$\Rightarrow 144\times10^{9}\,mN^2 = 144\,GmN^2$

($10^9 \rightarrow G$)

Example 1.2

c) $45\,(MN)^3 / 900\,GQ$

$$\Rightarrow \frac{45\,(10^6)^3}{900 \times 10^9} = 5 \times 10^7 \ \frac{N^3}{9}$$

$$50 \times 10^6 \ \frac{N^3}{9} = 50M \ \frac{N^3}{9}$$

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Lecture 2: Practice Problems

TABLE 1–1 Systems of Units

Name	Length	Time	Mass	Force
International System of Units	meter	second	kilogram	newton*
SI	m	s	kg	N $\left(\frac{\text{kg} \cdot \text{m}}{\text{s}^2}\right)$

SI

TABLE 1–3 Prefixes

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0.000 001	10^{-6}	micro	μ
0.000 000 001	10^{-9}	nano	n

1–1. Round off the following numbers to three significant figures: (a) 58 342 m, (b) 68.534 s, (c) 2553 N, (d) 7555 kg.

a) 58.342 kN => 58.3 kN

b) 68.534 s => 68.5 s

c) 2.553 kN => 2.55 kN

d) 7555000 g => 7.555 Mg => 7.56 Mg

1–3. Represent each of the following combinations of units in the correct SI form using an appropriate prefix: (a) kN/μs, (b) Mg/mN, (c) MN/(kg · ms). مناسب

a) $\frac{kN}{\mu s} = \frac{10^{3}}{10^{-6}} \frac{N}{s} = 10^{9} \frac{N}{s} = G \frac{N}{s}$

b) $\frac{Mg}{mN} = \frac{10^{6}}{10^{-3}} \frac{g}{N} = 10^{9} \frac{g}{N} = G \frac{g}{N}$

c) $\frac{MN}{kg.ms} = \frac{10^{6}}{10^{-3}} \frac{N}{kg.s} = 10^{9} \frac{N}{kg.s} = \frac{GN}{kg.s}$

1–5. Round off the following numbers to three significant figures: (a) 3.455 55 m, (b) 45.556 s, (c) 5555 N, (d) 4525 kg.

a) $3.45555\ m \Rightarrow 3.46\ m$

b) $45.556\ s \Rightarrow 45.6\ s$

c) $5.555\ kN \Rightarrow 5.56\ kN$

d) $4525000\ g = 4.525\ Mg = 4.52\ Mg$

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Lecture 3: Practice Problems

$4 \times 10^{-3} \Rightarrow \frac{4}{10^3} = \frac{4}{1000}$

$0.005 \times 10^{-5} \Rightarrow \frac{0.005}{100000}$

$0.45 \times 10^{-2} \Rightarrow \frac{0.45}{100}$

TABLE 1–1 Systems of Units

Name	Length	Time	Mass	Force
International System of Units	meter	second	kilogram	newton*
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أعد صياغة

1–6. Represent each of the following as a number between 0.1 and 1000 using an appropriate prefix: (a) 45 320 kN, (b) $568(10^5)$ mm, (c) 0.005 63 mg.

a) $45,320,000\ N \Rightarrow 45.32\ MN$

b) $56800\ m \Rightarrow 56.8\ km$

c) $0.00563 \times 10^{-3}\ g \Rightarrow \frac{0.00563}{1000}\ g$

$\frac{0.00563}{1000} \times \frac{1000}{1000} = 5.63 \times 10^{-6}\ g$

$\Rightarrow 5.63\ \mu g$

1–7. A rocket has a mass of $3.65(10^6)$ kg on earth. Specify its weight in SI units. If the rocket is on the moon, where the acceleration due to gravity is $g_m = 1.62$ m/s^2, determine to three significant figures its weight in SI units and its mass in SI units.

$W = mg$

$W_e = m g_e = 3.65 \times 10^6 \text{ kg} \left(9.81 \frac{m}{s^2}\right) = 35,806,500 \text{ N}$

$W_e = 35.8 \text{ MN}$

$W_m = 3.65 \times 10^6 (1.62) = 5,913,000 \text{ N}$

$W_m = 5.91 \text{ MN}$

$m_e = m_m = 3.65 \times 10^9 \text{ g} = 3.65 \text{ Gg}$

1–17. Evaluate (204 mm)(0.004 57 kg)/(34.6 N) to three significant figures and express the answer in SI units using an appropriate prefix.

m → sigs figs
→ SI
kg - g

$$\frac{204 \times 10^{-3} \times 0.00457}{34.6} \quad \frac{m \cdot kg}{N}$$

$$= 2.69 \times 10^{-5}$$

$$\frac{2.69}{100000} \times \frac{10}{10}$$

$$\frac{26.9}{1000,000} \Rightarrow 26.9\,\mu \quad \frac{m \cdot kg}{N}$$

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Lecture 4: Gravitational Attraction

Newton's Law of Gravitational Attraction. Shortly after formulating his three laws of motion, Newton postulated a law governing the gravitational attraction between any two particles. Stated mathematically,

$$F = G\frac{m_1 m_2}{r^2} \tag{1–2}$$

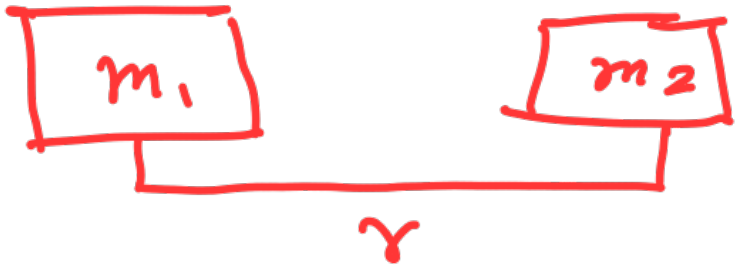
where

F = force of gravitation between the two particles

G = universal constant of gravitation; according to experimental evidence, $G = 66.73(10^{-12})\ \text{m}^3/(\text{kg}\cdot\text{s}^2)$

m_1, m_2 = mass of each of the two particles

r = distance between the two particles



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International System of Units	meter	second	kilogram	newton*
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0.000 001	10^{-6}	micro	μ
0.000 000 001	10^{-9}	nano	n

$5 4.335 \times 10^{5}$

5.4335×10^{6}

نزود على الأس ← يسار

532.43×10^{4}

$\Rightarrow 5324.3 \underline{10^{3}}$

x

نقلل من الأس ← يمين

1–13. Using the SI system of units, show that Eq. 1–2 is a dimensionally homogeneous equation which gives F in newtons. Determine to three significant figures the gravitational force acting between two spheres that are touching each other. The mass of each sphere is 200 kg and the radius is 300 mm.

$$F = G\frac{m_1 m_2}{r^2}$$

$r = 600\ mm$

$$F = G\frac{200 \times 200}{0.6^2} = 7.41 \times 10^{-6}\ N$$

$m_1 = m_2 = 200\ kg$ $\Rightarrow F = 7.41\ \mu N$

1–14. Evaluate each of the following and express with an appropriate prefix: (a) $(430\ \text{kg})^2$, (b) $(0.002\ \text{mg})^2$, and (c) $(230\ \text{m})^3$.

a) $[430\ \text{kg}]^2 \Rightarrow 430^2\ \text{k}^2\text{g}^2$ $(\text{kg})^2$

$[430 \times 10^3]^2\ \text{g}^2 \Rightarrow 1.85 \times 10^{11}\ \text{g}^2$

$\Rightarrow 0.185 \times 10^{12}\ \text{g}^2 \Rightarrow 0.185\,(10^6)^2\ \text{g}^2$

$0.185\ \text{M g}^2$

b) $(0.002\,mg)^2$

$$\left[0.002 \times 10^{-3}\right]^2 g^2$$

$$\Rightarrow 4 \times 10^{-12}\, g^2$$

$$\Rightarrow 4 \times (10^{-6})^2\, g^2 \Rightarrow 4\mu g^2$$

μ

c) $(230\ m)^3$

$[230]^3\ m^3$

$\frac{12167000}{10^9}\ m^3 \Rightarrow 0.012167\ km^3$

$\Rightarrow 10.0122\ km^3$

Convert: (a) 200 lb · ft to N · m, (b) 350 lb/ft^3 to kN/m^3, (c) 8 ft/h to mm/s. Express the result to three significant figures. Use an appropriate prefix.

SOLUTION

a) $(200\ \text{lb} \cdot \text{ft})\left(\frac{4.4482\ \text{N}}{1\ \text{lb}}\right)\left(\frac{0.3048\ \text{m}}{1\ \text{ft}}\right) = 271\ \text{N} \cdot \text{m}$ **Ans.**

b) $\left(\frac{350\ \text{lb}}{1\ \text{ft}^3}\right)\left(\frac{1\ \text{ft}}{0.3048\ \text{m}}\right)^3\left(\frac{4.4482\ \text{N}}{1\ \text{lb}}\right) = 55.0\ \text{kN/m}^3$ **Ans.**

c) $\left(\frac{8\ \text{ft}}{1\ \text{h}}\right)\left(\frac{1\ \text{h}}{3600\ \text{s}}\right)\left(\frac{0.3048\ \text{m}}{1\ \text{ft}}\right) = 0.677\ \text{mm/s}$ **Ans.**

Additional Problems on **Chapter 1**

TABLE 1–1 Systems of Units

Name	Length	Time	Mass	Force
International System of Units	meter	second	kilogram	newton*
SI	m	s	kg	$\mathrm{N}\left(\frac{\mathrm{kg}\cdot\mathrm{m}}{\mathrm{s}^2}\right)$

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0.000 000 001	10^{-9}	nano	n

What is the weight in newtons of an object that has a mass of (a) 8 kg, (b) 0.04 kg, and (c) 760 Mg?

SOLUTION

(a) $W = 9.81(8) = 78.5\ \text{N}$ **Ans.**

(b) $W = 9.81(0.04)(10^{-3}) = 3.92(10^{-4})\ \text{N} = 0.392\ \text{mN}$ **Ans.**

(c) $W = 9.81(760)(10^{3}) = 7.46(10^{6})\ \text{N} = 7.46\ \text{MN}$ **Ans.**

Represent each of the following combinations of unit in the correct SI form: (a) Mg/ms, (b) N/mm, (c) mN/(kg · μs).

SOLUTION

(a) $$\frac{\text{Mg}}{\text{ms}} = \frac{10^3\,\text{kg}}{10^{-3}\,\text{s}} = 10^6\,\text{kg/s} = \text{Gg/s}$$ **Ans.**

(b) $$\frac{\text{N}}{\text{mm}} = \frac{1\,\text{N}}{10^{-3}\,\text{m}} = 10^3\,\text{N/m} = \text{kN/m}$$ **Ans.**

(c) $$\frac{\text{mN}}{(\text{kg}\cdot\mu\text{s})} = \frac{10^{-3}\,\text{N}}{10^{-6}\,\text{kg}\cdot\text{s}} = \text{kN/(kg}\cdot\text{s)}$$ **Ans.**

Convert: (a) 200 lb · ft to N · m, (b) 350 lb/ft^3 to kN/m^3, (c) 8 ft/h to mm/s. Express the result to three significant figures. Use an appropriate prefix.

SOLUTION

a) $(200\ \text{lb} \cdot\ \text{ft})\left(\frac{4.4482\ \text{N}}{1\ \text{lb}}\right)\left(\frac{0.3048\ \text{m}}{1\ \text{ft}}\right) = 271\ \text{N} \cdot \text{m}$ **Ans.**

b) $\left(\frac{350\ \text{lb}}{1\ \text{ft}^3}\right)\left(\frac{1\ \text{ft}}{0.3048\ \text{m}}\right)^3\left(\frac{4.4482\ \text{N}}{1\ \text{lb}}\right) = 55.0\ \text{kN/m}^3$ **Ans.**

c) $\left(\frac{8\ \text{ft}}{1\ \text{h}}\right)\left(\frac{1\ \text{h}}{3600\ \text{s}}\right)\left(\frac{0.3048\ \text{m}}{1\ \text{ft}}\right) = 0.677\ \text{mm/s}$ **Ans.**

Represent each of the following quantities in the correct SI form using an appropriate prefix: (a) 0.000 431 kg, (b) $35.3(10^3)$ N, and (c) 0.005 32 km.

SOLUTION

a) $0.000\,431\text{ kg} = 0.000\,431\left(10^3\right)\text{ g} = 0.431\text{ g}$ **Ans.**

b) $35.3\left(10^3\right)\text{ N} = 35.3\text{ kN}$ **Ans.**

c) $0.005\,32\text{ km} = 0.005\,32\left(10^3\right)\text{ m} = 5.32\text{ m}$ **Ans.**

Represent each of the following combinations of units in the correct SI form using an appropriate prefix: (a) Mg/mm, (b) mN/μs, (c) μm $\cdot$ Mg.

SOLUTION

a) $\text{Mg/mm} = \dfrac{10^3\,\text{kg}}{10^{-3}\text{m}} = \dfrac{10^6\,\text{kg}}{\text{m}} = \text{Gg/m}$ **Ans.**

b) $\text{mN}/\mu\text{s} = \dfrac{10^{-3}\,\text{N}}{10^{-6}\,\text{s}} = \dfrac{10^3\,\text{N}}{\text{s}} = \text{kN/s}$ **Ans.**

c) $\mu\text{m} \cdot \text{Mg} = \left[10^{-6}\,\text{m}\right] \cdot \left[10^3\,\text{kg}\right] = (10)^{-3}\,\text{m} \cdot \text{kg}$

$= \text{mm} \cdot \text{kg}$ **Ans.**

Represent each of the following combinations of units in the correct SI form using an appropriate prefix: (a) m/ms, (b) μkm, (c) ks/mg, and (d) km $\cdot$ μN.

SOLUTION

a) $\text{m/ms} = \left(\dfrac{\text{m}}{(10)^{-3}\,\text{s}}\right) = \left(\dfrac{(10)^{3}\,\text{m}}{\text{s}}\right) = \text{km/s}$ **Ans.**

b) $\mu\text{km} = (10)^{-6}(10)^{3}\,\text{m} = (10)^{-3}\,\text{m} = \text{mm}$ **Ans.**

c) $\text{ks/mg} = \left(\dfrac{(10)^{3}\,\text{s}}{(10)^{-6}\,\text{kg}}\right) = \left(\dfrac{(10)^{9}\,\text{s}}{\text{kg}}\right) = \text{Gs/kg}$ **Ans.**

d) $\text{km}\cdot\mu\text{N} = [(10)^{3}\,\text{m}][(10)^{-6}\,\text{N}] = (10)^{-3}\,\text{m}\cdot\text{N} = \text{mm}\cdot\text{N}$ **Ans.**

Represent each of the following combinations of units in the correct SI form: (a) $\mathrm{GN}\cdot\mu\mathrm{m}$, (b) $\mathrm{kg}/\mu\mathrm{m}$, (c) N/ks^2, and (d) $\mathrm{KN}/\mu\mathrm{s}$.

SOLUTION

(a) $\mathrm{GN}\cdot\mu\mathrm{m} = 10^9(10^{-6})\,\mathrm{N}\cdot\mathrm{m} = \mathrm{kN}\cdot\mathrm{m}$ **Ans.**

(b) $\mathrm{kg}/\mu\mathrm{m} = 10^3\,\mathrm{g}/10^{-6}\,\mathrm{m} = \mathrm{Gg}/\mathrm{m}$ **Ans.**

(c) $\mathrm{N}/\mathrm{ks}^2 = \mathrm{N}/10^6\,\mathrm{s}^2 = 10^{-6}\,\mathrm{N}/\mathrm{s}^2 = \mu\mathrm{N}/\mathrm{s}^2$ **Ans.**

(d) $\mathrm{kN}/\mu\mathrm{s} = 10^3\,\mathrm{N}/10^{-6}\,\mathrm{s} = 10^9\,\mathrm{N}/\mathrm{s} = \mathrm{GN}/\mathrm{s}$ **Ans.**

Represent each of the following with SI units having an appropriate prefix: (a) 8653 ms, (b) 8368 N, (c) 0.893 kg.

SOLUTION

a) $8653\ \text{ms} = 8.653(10)^3(10^{-3})\ \text{s} = 8.653\ \text{s}$ **Ans.**

b) $8368\ \text{N} = 8.368\ \text{kN}$ **Ans.**

c) $0.893\ \text{kg} = 893(10^{-3})(10^3)\ \text{g} = 893\ \text{g}$ **Ans.**

Evaluate each of the following to three significant figures and express each answer in SI units using an appropriate prefix: (a) $(684\ \mu\text{m})/(43\ \text{ms})$, (b) $(28\ \text{ms})(0.0458\ \text{Mm})/(348\ \text{mg})$, (c) $(2.68\ \text{mm})(426\ \text{Mg})$.

SOLUTION

a) $$(684\ \mu\text{m})/43\ \text{ms} = \frac{684(10^{-6})\ \text{m}}{43(10^{-3})\ \text{s}} = \frac{15.9(10^{-3})\ \text{m}}{\text{s}}$$
$$= 15.9\ \text{mm/s}$$ **Ans.**

b) $$(28\ \text{ms})(0.0458\ \text{Mm})/(348\ \text{mg}) = \frac{\left[28(10^{-3})\ \text{s}\right]\left[45.8(10^{-3})(10)^{6}\ \text{m}\right]}{348(10^{-3})(10^{-3})\ \text{kg}}$$
$$= \frac{3.69(10^{6})\ \text{m}\cdot\text{s}}{\text{kg}} = 3.69\ \text{Mm}\cdot\ \text{s/kg}$$ **Ans.**

c) $$(2.68\ \text{mm})(426\ \text{Mg}) = \left[2.68\left(10^{-3}\right)\ \text{m}\right]\left[426\left(10^{3}\right)\ \text{kg}\right]$$
$$= 1.14\left(10^{3}\right)\ \text{m}\cdot\ \text{kg} = 1.14\ \text{km}\cdot\text{kg}$$ **Ans.**

The density (mass/volume) of aluminum is $5.26\ \text{slug/ft}^3$. Determine its density in SI units. Use an appropriate prefix.

SOLUTION

$$5.26\ \text{slug/ft}^3 = \left(\frac{5.26\ \text{slug}}{\text{ft}^3}\right)\left(\frac{\text{ft}}{0.3048\ \text{m}}\right)^3\left(\frac{14.59\ \text{kg}}{1\ \text{slug}}\right)$$

$$= 2.71\ \text{Mg/m}^3 \qquad \textbf{Ans.}$$

Evaluate each of the following to three significant figures and express each answer in SI units using an appropriate prefix: (a) $(212\ \text{mN})^2$, (b) $(52800\ \text{ms})^2$, and (c) $[548(10^6)]^{1/2}\ \text{ms}$.

SOLUTION

(a) $(212\ \text{mN})^2 = \left[212(10)^{-3}\ \text{N}\right]^2 = 0.0449\ \text{N}^2 = 44.9(10)^{-3}\ \text{N}^2$ **Ans.**

(b) $(52\,800\ \text{ms})^2 = \left[52\,800(10)^{-3}\right]^2\ \text{s}^2 = 2788\ \text{s}^2 = 2.79\left(10^3\right)\ \text{s}^2$ **Ans.**

(c) $\left[548(10)^6\right]^{\frac{1}{2}}\ \text{ms} = (23\,409)(10)^{-3}\ \text{s} = 23.4(10)^3(10)^{-3}\ \text{s} = 23.4\ \text{s}$ **Ans.**

Water has a density of $1.94\ \text{slug/ft}^3$. What is the density expressed in SI units? Express the answer to three significant figures.

SOLUTION

Using Table 1–2, we have

$$\rho_w = \left(\frac{1.94\ \text{slug}}{\text{ft}^3}\right)\left(\frac{14.5938\ \text{kg}}{1\ \text{slug}}\right)\left(\frac{1\ \text{ft}^3}{0.3048^3\ \text{m}^3}\right)$$

$$= 999.8\ \text{kg/m}^3 = 1.00\ \text{Mg/m}^3 \qquad \textbf{Ans.}$$

Evaluate each of the following to three significant figures and express each answer in SI units using an appropriate prefix: (a) 354 mg(45 km)/(0.0356 kN), (b) (0.004 53 Mg) (201 ms), and (c) 435 MN/23.2 mm.

SOLUTION

a) $$(354\text{ mg})(45\text{ km})/(0.0356\text{ kN}) = \frac{\left[354\left(10^{-3}\right)\text{ g}\right]\left[45\left(10^{3}\right)\text{ m}\right]}{0.0356\left(10^{3}\right)\text{ N}}$$

$$= \frac{0.447\left(10^{3}\right)\text{ g}\cdot\text{m}}{\text{N}}$$

$$= 0.447\text{ kg}\cdot\text{m/N}$$ **Ans.**

b) $$(0.00453\text{ Mg})(201\text{ ms}) = \left[4.53\left(10^{-3}\right)\left(10^{3}\right)\text{ kg}\right]\left[201\left(10^{-3}\right)\text{ s}\right]$$

$$= 0.911\text{ kg}\cdot\text{s}$$ **Ans.**

c) $$435\text{ MN/23.2 mm} = \frac{435\left(10^{6}\right)\text{ N}}{23.2\left(10^{-3}\right)\text{ m}} = \frac{18.75\left(10^{9}\right)\text{ N}}{\text{m}} = 18.8\text{ GN/m}$$ **Ans.**

A concrete column has a diameter of 350 mm and a length of 2 m. If the density (mass/volume) of concrete is 2.45 Mg/m^3, determine the weight of the column in pounds.

SOLUTION

$$V = \pi r^2 h = \pi\left(\tfrac{0.35}{2}\,\text{m}\right)^2 (2\,\text{m}) = 0.1924\,\text{m}^3$$

$$m = \rho V = \left(\frac{2.45(10^3)\text{kg}}{\text{m}^3}\right)\left(0.1924\,\text{m}^3\right) = 471.44\,\text{kg}$$

$$W = mg = (471.44\,\text{kg})\left(9.81\,\text{m/s}^2\right) = 4.6248\left(10^3\right)\text{N}$$

$$W = \left[4.6248\left(10^3\right)\text{N}\right]\left(\frac{1\,\text{lb}}{4.4482\,\text{N}}\right) = 1.04\,\text{kip}$$ **Ans.**

If a man weighs 155 lb on earth, specify (a) his mass in slugs, (b) his mass in kilograms, and (c) his weight in newtons. If the man is on the moon, where the acceleration due to gravity is $g_m = 5.30\ \text{ft/s}^2$, determine (d) his weight in pounds, and (e) his mass in kilograms.

SOLUTION

a) $m = \dfrac{155}{32.2} = 4.81\ \text{slug}$ **Ans.**

b) $m = 155\left[\dfrac{14.59\ \text{kg}}{32.2}\right] = 70.2\ \text{kg}$ **Ans.**

c) $W = 155(4.4482) = 689\ \text{N}$ **Ans.**

d) $W = 155\left[\dfrac{5.30}{32.2}\right] = 25.5\ \text{lb}$ **Ans.**

e) $m = 155\left[\dfrac{14.59\ \text{kg}}{32.2}\right] = 70.2\ \text{kg}$ **Ans.**

Two particles have a mass of 8 kg and 12 kg, respectively. If they are 800 mm apart, determine the force of gravity acting between them. Compare this result with the weight of each particle.

SOLUTION

$$F = G\frac{m_1 m_2}{r^2}$$

Where $G = 66.73\left(10^{-12}\right)\ \mathrm{m}^3/(\mathrm{kg}\cdot\mathrm{s}^2)$

$$F = 66.73\left(10^{-12}\right)\left[\frac{8(12)}{(0.8)^2}\right] = 10.0\left(10^{-9}\right)\ \mathrm{N} = 10.0\ \mathrm{nN}$$ **Ans.**

$$W_1 = 8(9.81) = 78.5\ \mathrm{N}$$ **Ans.**

$$W_2 = 12(9.81) = 118\ \mathrm{N}$$ **Ans.**