

Chapter 1 *Measuring*

02. (a) Using the conversion factors 1 inch = 2.54 cm exactly and 6 picas = 1 inch, we obtain

$$0.80 \text{ cm} = (0.80 \text{ cm})(1 \text{ inch}/2.54 \text{ cm}) \\ \times (6 \text{ picas}/1 \text{ inch}) \approx 1.9 \text{ picas.}$$

(b) With 12 points = 1 pica, we have

$$0.80 \text{ cm} = (0.80 \text{ cm})(1 \text{ inch}/2.54 \text{ cm}) \\ \times (6 \text{ picas}/1 \text{ inch})(12 \text{ points}/1 \text{ pica}) = 23 \text{ points.}$$

05. Various geometric formulas are given in Appendix E. (a) Substituting

$$R = (6.37 \times 10^6 \text{ m})(10^{-3} \text{ km}/\text{m}) = 6.37 \times 10^3 \text{ km}$$

into *circumference* =  $2\pi R$ , we obtain  $4.00 \times 10^4 \text{ km}$ .

(b) The surface area of Earth is

$$A = 4\pi R^2 = 4\pi(6.37 \times 10^3 \text{ km})^2 = 5.10 \times 10^8 \text{ km}^2.$$

(c) The volume of Earth is  $V = (4/3)\pi R^3$

$$= (4/3)\pi(6.37 \times 10^3 \text{ km})^3 = 1.08 \times 10^{12} \text{ km}^3.$$

07. The volume of ice is given by the product of the semicircular surface area and the thickness. The area of the semicircle is  $A = \pi r^2/2$ , where  $r$  is the radius. Therefore, the volume is

$$V = (1/2)\pi r^2 z,$$

where  $z$  is the ice thickness. Since there are  $10^3 \text{ m}$  in  $1 \text{ km}$  and  $10^2 \text{ cm}$  in  $1 \text{ m}$ , we have  $r = (2000 \text{ km})(10^3 \text{ m}/1 \text{ km})(10^2 \text{ cm}/1 \text{ m}) = 2000 \times 10^5 \text{ cm}$ . In these units, the thickness becomes  $z = 3000 \text{ m} = (3000 \text{ m})(10^2 \text{ cm}/1 \text{ m}) = 3000 \times 10^2 \text{ cm}$ , which yields,

$$V = (1/2)\pi(2000 \times 10^5 \text{ cm})^2(3000 \times 10^2 \text{ cm}) \\ = 1.9 \times 10^{22} \text{ cm}^3.$$

18. The last day of the 20 centuries is longer than the first day by

$$(20 \text{ century})(0.001 \text{ s}/\text{century}) = 0.02 \text{ s.}$$

The average day during the 20 centuries is  $(0+0.02)/2 = 0.01 \text{ (s)}$  longer than the first day. Since the increase occurs uniformly, the cumulative effect  $T$  is

$$T = (\text{average increase in length a day})(\text{number of days})$$

$$= (0.01 \text{ s}/\text{day})(365.25 \text{ day}/\text{y})(2000 \text{ y}) = 7305 \text{ s}$$

or roughly two hours.

23. If  $M_E$  is the mass of Earth,  $m$  is the average mass of an atom in Earth, and  $N$  is the number of atoms, then  $M_E = Nm$  or  $N = M_E/m$ . We convert mass  $m$  to kilograms using  $1 \text{ u} = 1.661 \times 10^{-27} \text{ kg}$ .

$$\text{Thus, } N = M_E/m = 5.98 \times 10^{24} \text{ kg} / [(40 \text{ u}) \\ \times (1.661 \times 10^{-27} \text{ kg}/\text{u})] = 9.0 \times 10^{49}.$$

28. The metric prefixes [micro ( $\mu$ ), pico, nano, ...] are given for ready reference on the inside front cover of the textbook (see also Table 1-2). The surface area  $A$  of each grain of sand of radius  $r = 50 \mu\text{m} = 50 \times 10^{-6} \text{ m}$  is given by  $A = 4\pi(50 \times 10^{-6} \text{ m})^2 = 3.14 \times 10^{-8} \text{ m}^2$ . We introduce the notion of density,  $\rho = m/V$ , so that the mass can be found from  $m = \rho V$ ,

where  $\rho = 2600 \text{ kg}/\text{m}^3$ . Thus, using  $V = 4\pi r^3/3$ , the mass of each grain is

$$m = \rho V = \rho(4\pi r^3/3) = (2600)[4\pi(50 \times 10^{-6})^3/3] \\ = 1.36 \times 10^{-9} \approx 1.4 \times 10^{-9} \text{ (kg).}$$

We observe that (because a cube has six equal faces) the indicated surface area is  $6 \text{ m}^2$ . The number of spheres (the grains of sand)  $N$  that have a total surface area of  $6 \text{ m}^2$  is given by

$$N = (6 \text{ m}^2)/(3.14 \times 10^{-8} \text{ m}^2) = 1.91 \times 10^8.$$

Therefore, the total mass  $M$  is

$$M = Nm = (1.91 \times 10^8)(1.36 \times 10^{-9} \text{ kg}) = 0.26 \text{ kg.}$$

40. (a) In atomic mass units, the mass of one molecule is  $16+1+1 = 18 \text{ (u)}$ . Using Eq. 1-9, we find

$$18 \text{ u} = (18 \text{ u})(1.661 \times 10^{-27} \text{ kg}/1 \text{ u}) = 3.0 \times 10^{-26} \text{ kg.}$$

(b) We divide the total mass by the mass of each molecule and obtain the (approximate) number of water molecules:

$$N \approx (1.4 \times 10^{21})/(3.0 \times 10^{-26}) \approx 5 \times 10^{46}.$$

45. We convert meters to astronomical units, and seconds to minutes, using  $1000 \text{ m} = 1 \text{ km}$ ,  $1 \text{ AU} = 1.50 \times 10^8 \text{ km}$ , and  $60 \text{ s} = 1 \text{ min}$ . Thus,

$$3.0 \times 10^8 \text{ m}/\text{s} \text{ becomes } (3.0 \times 10^8 \text{ m})/(1 \text{ s}) \\ = (2 \text{ AU}/100)/(1 \text{ min}/60) = 0.12 \text{ AU}/\text{min.}$$

55. In the simplest approach, we set up a ratio for the total increase in *horizontal depth*  $x$  (where  $\Delta x = 0.05 \text{ m}$  is the increase in horizontal depth per step)

$$x = N_{\text{step}}\Delta x = (4.57/0.19)(0.05 \text{ m}) = 1.2 \text{ m.}$$

However, we can approach this more carefully by noting that if there are  $N = 4.57/0.19 \approx 24$  rises then under normal circumstances we would expect  $N-1 = 23$  runs (horizontal pieces) in that staircase. This would yield  $(23)(0.05 \text{ m}) = 1.15 \text{ m}$ , which - to two significant figures - agrees with our first result.

(如發現錯誤煩請告知 jyang@mail.ntou.edu.tw, Thanks.)

Q. 下列那個單位不是國際單位系統(SI)中之基本單位? (a)公斤 (b)公分 (c)秒 (d)以上皆是。

失之毫釐，差以千里！差以毫釐，謬以千里！

*How can a building sink into the ground?*

建物如何才會下陷地裏？

web1.科學發展月刊

<http://nr.stic.gov.tw/ejournal/nscm/nscm.htm>

web2.國家度量衡標準實驗室

<http://www.nml.org.tw/>

●備忘錄●

## 7 個 SI 基本量、因次及單位

因次 dimension	長度 length	質量 mass	時間 time	溫度 temperature	電流 current	輝(光)度 luminous intensity	物質量 quantity
單位 unit	m meter	kg kilogram	s second	K Kelvin	A Ampere	cd candela 坎德拉*	mol mole 莫耳

\*部譯名稱為新燭光。(小)時 h, 分 min; 基本量(單位) → 導出量(單位); 1M = 1 百萬.

\*1 ft = 30.48 cm, 1 in = 2.54 cm, 1 mi = 1.6093 km, 1 nautical mile = 1.852 km, 1G = 10 億

## 第 1 章 量測

• **時間**：銫(Cs)133 原子發出某特定波長的光振動 9,192,631,770 次所需的時間定為 **1 秒(s)**。

• **長度**：光於真空中在 299,792,458 分之 1 秒內行進的距離定為 **1 公尺(m)**。1  $\mu\text{m}$  (micron 微米) =  $10^{-6}$  m; 1 nm (nanometer 奈米) =  $10^{-9}$  m; 若物體某一維度小於 100 nm 稱為**奈米材料** (cf. 人頭髮厚度/直徑約 100  $\mu\text{m}$ )。1 AU: 地球至太陽平均距離( $\sim 1.50 \times 10^8$  km)。

• **質量**：高度及直徑皆為 3.9 公分(cm)之鉑銻合金圓柱體的質量為 **1 公斤(kg)**。**第二質量標準**是以碳 12 原子的質量定為 **12 原子質量單位(u)**, 即

$$1 \text{ u} = 1.66053886 \times 10^{-27} \text{ kg}.$$

• **密度**：材料的密度為每單位體積的質量,

$$\rho = m/V.$$

• **光速**：光於真空中在 1 s 內行進 299,792,458 m,  $c = 2.99792458 \times 10^8$  m/s. (每秒近 30 萬公里)

measuring, 量測; standard, 標準; unit, 單位; International System of Units (SI units) 國際單位標準; metric system, 公制系統; base unit, 基本單位; derived unit, 導出單位; scientific notation 科學記號; significant figure/digit, 有效數字/位數; prefix, 字首; conversion factor, 轉換因子; second standard, 副標準; pale, 顯得遜色; astronomical unit (AU) 天文單位; Global Positioning System (GPS) 全球定位系統; Daylight Saving Time, 日光節約時間; Universal Time, 世界標準時; Universal Time Coordinated (UTC), 協調世界標準時; NIST: National Institute of Standards and Technology, 國家標準與科技研究所; Sevres, 塞弗爾(巴黎西南郊); Boulder, 圓石市; liquefaction, 液化/土壤液化(指土壤狀態由固體轉變為液體); krypton-86, 氬(Kr)86; cesium-133, 銫(Cs)133; platinum, 鉑; iridium, 銻; carbon-12, 碳(C)12;



\*Armstrong (Apollo 11):

“**That’s one small step for a man, one giant leap for mankind.**” (對個人來說, 這是一小步, 但對人類來說, 卻是跨了一大步)

• **有效數字(figure)及計算之有效位數(digit)**

**科學記法**,  $a \times 10^n$ ,  $1 \leq |a| < 10$ ,  $n = \text{integer}$ .

**加減運算** 答案之精確度由加減數中“**最小精確度的數**”決定, 注意: 運算項須具相同單位(因次).

**乘除運算** 答案之有效位數通常最大為乘除數中有效位數最少者.

〈例 1〉 $1/3 = 0.333333... \Rightarrow \text{Ans. } \mathbf{0.3}$

〈例 2〉 $1.0/3.0 = 0.333... \Rightarrow \text{Ans. } \mathbf{0.33}$

〈例 3〉 $2.0/3.0 = 0.666... \Rightarrow \text{Ans. } \mathbf{0.67}$

〈例 4〉2009/08 柏林世界田徑賽 U. Bolt 以 9.58 s (19.19 s) 破 100 m (200 m) 世界記錄, 試計算其平均速率. *Sol.*  $v_{\text{av}}(100) = 100/9.58 = 10.43 \Rightarrow \text{Ans. } \mathbf{10.4}$  m/s.

$$v_{\text{av}}(200) = 200/19.19 = 10.42 \Rightarrow \text{Ans. } \mathbf{10.4}$$
 m/s.

J1. “**自然科學之母—物理科學**”, 唐富欽, 科學發展 366 期(92 年 6 月) 5。

J2. “**公尺滄桑史—度量衡今昔之一**”, 葉李華, 科學發展 350 期 (91 年 2 月) 81。

J3. “**一公尺有多長**”, 盧聖華, 科學發展 389 期 (94 年 05 月) 74。 J4. “**經緯度的故事**”, 蔡雅芝, 科學發展 392 期 (94 年 8 月), 68-77 頁。

J5. “**現代社會的韻律與時間**”, 郭文華, 科學發展 378 期 (93 年 06 月) 81。

J6. “**遲到不遲到? 時刻的文化感知**”, 郭文華, 科學發展 381 期 (93 年 09 月) 79。

J7. “**問, 時間為何物?**”(專輯), 科學人 No.9 (2002 年 11 月)。 J8. “**時間是雙向的嗎?**” S.M. Carroll, 科學人 No.77, 2008 年 7 月。

J9. “**奈米科技與生活**”, 陳貴賢, 科學發展 398 期 (95 年 02 月) 46; 〈要了解無限前景的奈米科技, 也要避免被廣告噱頭所誤導。〉

J10. 有關 “Smoot” (*Prob.* 1-6), 見科學人 No.22 (2003/12) 103←。

\* On Dec. 29, 1959, at the California Institute of Technology, Nobel Laureate Richard P. Feynman gave a talk at the annual meeting of the American Physical Society that has become one of the twentieth century’s classic science lectures, titled “**There’s plenty of room at the bottom**”.