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

$$R = (6.37\times10^{6}\text{ m})(10^{-3}\text{ km/m}) = 6.37\times10^{3}\text{ km}$$

into *circumference* = $2\pi R$, we obtain 4.00×10^{4} km.
(**b**) The surface area of Earth is

$$A = 4\pi R^2 = 4\pi(6.37\times10^3\text{ km})^2 = 5.10\times10^8\text{ km}^2.$$

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

$$= (4/3)\pi(6.37\times10^3\text{ km})^3 = 1.08\times10^{12}\text{ km}^3.$$

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

$$V = (½)\pi r^2 z,$$

where z is the ice thickness. Since there are 10^3 m in 1 km and 10^2 cm in 1 m, we have $r = (2000\text{ km})(10^3\text{ m}/1\text{ km})(10^2\text{ cm}/1\text{ m}) = 2000\times10^5$ cm. In these units, the thickness becomes $z = 3000\text{ m} = (3000\text{ m})(10^2\text{ cm}/1\text{ m}) = 3000\times10^2$ cm, which yields,

$$V = (½)\pi(2000\times10^5\text{ cm})^2(3000\times10^2\text{ cm}) = 1.9\times10^{22}\text{ cm}^3.$$

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

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

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

$$T = (\text{average increase in length a day})(\text{number of days}) = (0.01\text{ s/day})(365.25\text{ day/y})(2000\text{ y}) = 7305\text{ s}$$

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 $1\text{ u} = 1.661\times10^{-27}$ kg.

Thus, $N = M_E / m = 5.98\times10^{24}\text{ kg} / [(40\text{ u}) \times (1.661\times10^{-27}\text{ kg/u})] = 9.0\times10^{49}$.

28. The metric prefixes [micro (μ), 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 $r = 50\ \mu\text{m} = 50\times10^{-6}$ m is given by $A = 4\pi(50\times10^{-6}\text{ m})^2 = 3.14\times10^{-8}\text{ m}^2$. We introduce the notion of density, $\rho = m/V$, so that the mass can be found from $m = \rho V$, where $\rho = 2600\text{ kg/m}^3$. Thus, using $V = 4\pi r^3/3$, the mass of each grain is

$$m = \rho V = \rho(4\pi r^3/3) = (2600)[4\pi(50\times10^{-6})^3/3] = 1.36\times10^{-9} \approx 1.4\times10^{-9}\text{ (kg)}.$$

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

$$N = (6\text{ m}^2)/(3.14\times10^{-8}\text{ m}^2) = 1.91\times10^8.$$

Therefore, the total mass M is

$$M = Nm = (1.91\times10^8)(1.36\times10^{-9}\text{ kg}) = 0.26\text{ kg}.$$

40. (**a**) In atomic mass units, the mass of one molecule is 16+1+1 = 18 (u). Using Eq. 1–9, we find

$$18\text{ u} = (18\text{ u})(1.661\times10^{-27}\text{ kg}/1\text{ u}) = 3.0\times10^{-26}\text{ kg}.$$

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

$$N \approx (1.4\times10^{21})/(3.0\times10^{-26}) \approx 5\times10^{46}.$$

45. We convert meters to astronomical units, and seconds to minutes, using 1000 m = 1 km, 1 AU = 1.50×10^8 km, and 60 s = 1 min . Thus,

$$3.0\times10^8\text{ m/s becomes }(3.0\times10^8\text{ m})/(1\text{ s}) = (2\text{ AU}/100)/(1\text{ min}/60) = 0.12\text{ AU/min}.$$

55. In the simplest approach, we set up a ratio for the total increase in *horizontal depth* x (where Δx = 0.05 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 $N = 4.57/.19 \approx 24$ rises then under normal circumstances we would expect $N–1$ = 23 runs (horizontal pieces) in that staircase. This would yield (23)(0.05 m) = 1.15 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, 1mi = 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 μm (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 μm)。1 AU: 地球至太陽平均距離(~ 1.50×10^8 km)。

•**質量**：高度及直徑皆為 3.9 公分(cm)之鉑銥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

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

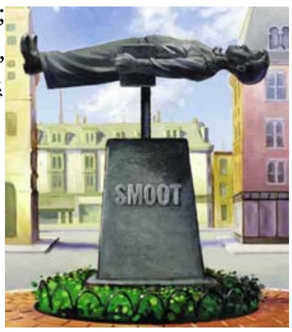
•**密度**：材料的密度為每單位體積的質量,

$$\rho = m / V .$$

•**光速**：光於真空中在 1 s 內行進 299,792,458 m,

$$c = 2.99792458 \times 10^8\ \text{m/s}.$$ (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,氪(Kr)86; cesium-133,銫(Cs)133; platinum,鉑; iridium,銥; 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, $a \times 10^n$, $1 \le |a| < 10$, n = 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… ⇒ *Ans.* **0.3**

〈例 2〉1.0/3.0 = 0.33**3**… ⇒ *Ans.* **0.33**

〈例 3〉2.0/3.0 = 0.66**6**… ⇒ *Ans.* **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_{av} (100) = 100/9.58 = 10.4**3** ⇒ *Ans.* **10.4** m/s.
v_{av} (200) = 200/19.19 = 10.4**2** ⇒ *Ans.* **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**".