

Solution of the recitation problems for Physics 105 (01/22/2007)

Section 006, Instructor: Ken Ahn

Chapter 1: Measurement

Problems 3, 7, 13, 17, 19(a): solved during the recitation

Problems 5, 9, 17, 19(b), 23, 24: unsolved during the recitation

3. The metric prefixes (micro, pico, nano, ...) are given for ready reference on the inside front cover of the textbook (see also Table 1–2).

(a) Since $1 \text{ km} = 1 \times 10^3 \text{ m}$ and $1 \text{ m} = 1 \times 10^6 \mu\text{m}$,

$$1 \text{ km} = 10^3 \text{ m} = (10^3 \text{ m})(10^6 \mu\text{m/m}) = 10^9 \mu\text{m}.$$

The given measurement is 1.0 km (two significant figures), which implies our result should be written as $1.0 \times 10^9 \mu\text{m}$.

(b) We calculate the number of microns in 1 centimeter. Since $1 \text{ cm} = 10^{-2} \text{ m}$,

$$1 \text{ cm} = 10^{-2} \text{ m} = (10^{-2} \text{ m})(10^6 \mu\text{m/m}) = 10^4 \mu\text{m}.$$

We conclude that the fraction of one centimeter equal to $1.0 \mu\text{m}$ is 1.0×10^{-4} .

(c) Since $1 \text{ yd} = (3 \text{ ft})(0.3048 \text{ m/ft}) = 0.9144 \text{ m}$,

$$1.0 \text{ yd} = (0.91 \text{ m})(10^6 \mu\text{m/m}) = 9.1 \times 10^5 \mu\text{m}.$$

5. Various geometric formulas are given in Appendix E.

(a) Substituting

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

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

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

7. 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

$$V = \frac{\pi}{2} r^2 z$$

where z is the ice thickness. Since there are 10^3 m in 1 km and 10^2 cm in 1 m, we have

$$r = (2000 \text{ km}) \left(\frac{10^3 \text{ m}}{1 \text{ km}} \right) \left(\frac{10^2 \text{ cm}}{1 \text{ m}} \right) = 2000 \times 10^5 \text{ cm}.$$

In these units, the thickness becomes

$$z = 3000 \text{ m} = (3000 \text{ m}) \left(\frac{10^2 \text{ cm}}{1 \text{ m}} \right) = 3000 \times 10^2 \text{ cm}$$

which yields,

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

9. We use the conversion factors found in Appendix D.

$$1 \text{ acre} \cdot \text{ft} = (43,560 \text{ ft}^2) \cdot \text{ft} = 43,560 \text{ ft}^3$$

Since 2 in. = (1/6) ft, the volume of water that fell during the storm is

$$V = (26 \text{ km}^2)(1/6 \text{ ft}) = (26 \text{ km}^2)(3281 \text{ ft/km})^2(1/6 \text{ ft}) = 4.66 \times 10^7 \text{ ft}^3.$$

Thus,

$$V = \frac{4.66 \times 10^7 \text{ ft}^3}{4.3560 \times 10^4 \text{ ft}^3/\text{acre} \cdot \text{ft}} = 1.1 \times 10^3 \text{ acre} \cdot \text{ft}.$$

13. None of the clocks advance by exactly 24 h in a 24-h period but this is not the most important criterion for judging their quality for measuring time intervals. What is important is that the clock advance by the same amount in each 24-h period. The clock

reading can then easily be adjusted to give the correct interval. If the clock reading jumps around from one 24-h period to another, it cannot be corrected since it would be impossible to tell what the correction should be. The following gives the corrections (in seconds) that must be applied to the reading on each clock for each 24-h period. The entries were determined by subtracting the clock reading at the end of the interval from the clock reading at the beginning.

CLOCK	Sun. -Mon.	Mon. -Tues.	Tues. -Wed.	Wed. -Thurs.	Thurs. -Fri.	Fri. -Sat.
A	-16	-16	-15	-17	-15	-15
B	-3	+5	-10	+5	+6	-7
C	-58	-58	-58	-58	-58	-58
D	+67	+67	+67	+67	+67	+67
E	+70	+55	+2	+20	+10	+10

Clocks C and D are both good timekeepers in the sense that each is consistent in its daily drift (relative to WWF time); thus, C and D are easily made “perfect” with simple and predictable corrections. The correction for clock C is less than the correction for clock D, so we judge clock C to be the best and clock D to be the next best. The correction that must be applied to clock A is in the range from 15 s to 17s. For clock B it is the range from -5 s to +10 s, for clock E it is in the range from -70 s to -2 s. After C and D, A has the smallest range of correction, B has the next smallest range, and E has the greatest range. From best to worst, the ranking of the clocks is C, D, A, B, E.

17. The time on any of these clocks is a straight-line function of that on another, with slopes $\neq 1$ and y-intercepts $\neq 0$. From the data in the figure we deduce

$$t_C = \frac{2}{7}t_B + \frac{594}{7}$$

$$t_B = \frac{33}{40}t_A - \frac{662}{5}.$$

These are used in obtaining the following results.

(a) We find

$$t'_B - t_B = \frac{33}{40}(t'_A - t_A) = 495 \text{ s}$$

when $t'_A - t_A = 600 \text{ s}$.

(b) We obtain

$$t'_C - t_C = \frac{2}{7}(t'_B - t_B) = \frac{2}{7}(495) = 141 \text{ s}.$$

(c) Clock B reads $t_B = (33/40)(400) - (662/5) \approx 198$ s when clock A reads $t_A = 400$ s.

(d) From $t_C = 15 = (2/7)t_B + (594/7)$, we get $t_B \approx -245$ s.

19. We introduce the notion of density:

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

and convert to SI units: $1 \text{ g} = 1 \times 10^{-3} \text{ kg}$.

(a) For volume conversion, we find $1 \text{ cm}^3 = (1 \times 10^{-2} \text{ m})^3 = 1 \times 10^{-6} \text{ m}^3$. Thus, the density in kg/m^3 is

$$1 \text{ g}/\text{cm}^3 = \left(\frac{1 \text{ g}}{\text{cm}^3} \right) \left(\frac{10^{-3} \text{ kg}}{\text{g}} \right) \left(\frac{\text{cm}^3}{10^{-6} \text{ m}^3} \right) = 1 \times 10^3 \text{ kg}/\text{m}^3.$$

Thus, the mass of a cubic meter of water is 1000 kg.

(b) We divide the mass of the water by the time taken to drain it. The mass is found from $M = \rho V$ (the product of the volume of water and its density):

$$M = (5700 \text{ m}^3) (1 \times 10^3 \text{ kg}/\text{m}^3) = 5.70 \times 10^6 \text{ kg}.$$

The time is $t = (10\text{h})(3600 \text{ s/h}) = 3.6 \times 10^4 \text{ s}$, so the *mass flow rate* R is

$$R = \frac{M}{t} = \frac{5.70 \times 10^6 \text{ kg}}{3.6 \times 10^4 \text{ s}} = 158 \text{ kg/s}.$$

23. We introduce the notion of density, $\rho = m/V$, and convert to SI units: $1000 \text{ g} = 1 \text{ kg}$, and $100 \text{ cm} = 1 \text{ m}$.

(a) The density ρ of a sample of iron is therefore

$$\rho = (7.87 \text{ g}/\text{cm}^3) \left(\frac{1 \text{ kg}}{1000 \text{ g}} \right) \left(\frac{100 \text{ cm}}{1 \text{ m}} \right)^3$$

which yields $\rho = 7870 \text{ kg/m}^3$. If we ignore the empty spaces between the close-packed spheres, then the density of an individual iron atom will be the same as the density of any iron sample. That is, if M is the mass and V is the volume of an atom, then

$$V = \frac{M}{\rho} = \frac{9.27 \times 10^{-26} \text{ kg}}{7.87 \times 10^3 \text{ kg/m}^3} = 1.18 \times 10^{-29} \text{ m}^3.$$

(b) We set $V = 4\pi R^3/3$, where R is the radius of an atom (Appendix E contains several geometry formulas). Solving for R , we find

$$R = \left(\frac{3V}{4\pi} \right)^{1/3} = \left(\frac{3(1.18 \times 10^{-29} \text{ m}^3)}{4\pi} \right)^{1/3} = 1.41 \times 10^{-10} \text{ m}.$$

The center-to-center distance between atoms is twice the radius, or $2.82 \times 10^{-10} \text{ m}$.

24. (a) The volume of the cloud is $(3000 \text{ m})\pi(1000 \text{ m})^2 = 9.4 \times 10^9 \text{ m}^3$. Since each cubic meter of the cloud contains from 50×10^6 to 500×10^6 water drops, then we conclude that the entire cloud contains from 4.7×10^{18} to 4.7×10^{19} drops. Since the volume of each drop is $\frac{4}{3}\pi(10 \times 10^{-6} \text{ m})^3 = 4.2 \times 10^{-15} \text{ m}^3$, then the total volume of water in a cloud is from 2×10^3 to $2 \times 10^4 \text{ m}^3$.

(b) Using the fact that $1 \text{ L} = 1 \times 10^3 \text{ cm}^3 = 1 \times 10^{-3} \text{ m}^3$, the amount of water estimated in part (a) would fill from 2×10^6 to 2×10^7 bottles.

(c) At 1000 kg for every cubic meter, the mass of water is from two million to twenty million kilograms. The coincidence in numbers between the results of parts (b) and (c) of this problem is due to the fact that each liter has a mass of one kilogram when water is at its normal density (under standard conditions).
