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**Physics and Measurement**

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| **CHAPTER OUTLINE** |

1.1 Standards of Length, Mass, and Time

1.2 Matter and Model Building

1.3 Dimensional Analysis

1.4 Conversion of Units

1.5 Estimates and Order-of-Magnitude Calculations

1.6 Significant Figures

\* An asterisk indicates a question or problem new to this edition.

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| **ANSWERS TO OBJECTIVE QUESTIONS** |

OQ1.1 The meterstick measurement, (a), and (b) can all be 4.31 cm. The meterstick measurement and (c) can both be 4.24 cm. Only (d) does not overlap. Thus (a), (b), and (c) all agree with the meterstick measurement.

OQ1.2 Answer (d). Using the relation



we find that



OQ1.3 The answer is yes for (a), (c), and (e). You cannot add or subtract a number of apples and a number of jokes. The answer is no for (b) and (d). Consider the gauge of a sausage, 4 kg/2 m, or the volume of a cube, (2 m)3. Thus we have (a) yes; (b) no; (c) yes; (d) no; and (e) yes.

OQ1.4 41 € ≈ 41 € (1 L/1.3 €)(1 qt/1 L)(1 gal/4 qt) ≈ (10/1.3) gal ≈ 8 gallons, answer (c).

OQ1.6 The number of decimal places in a sum of numbers should be the same as the smallest number of decimal places in the numbers summed.



OQ1.7 The population is about 6 billion = 6 × 109. Assuming about 100 lb per person = about 50 kg per person (1 kg has the weight of about 2.2 lb), the total mass is about (6 × 109)(50 kg) = 3 × 1011 kg, answer (d).

OQ1.8 No: A dimensionally correct equation need not be true. Example: 1 chimpanzee = 2 chimpanzee is dimensionally correct.

Yes: If an equation is not dimensionally correct, it cannot be correct.

OQ1.9 Mass is measured in kg; acceleration is measured in m/s2. Force = mass × acceleration, so the units of force are answer (a) kg⋅m/s2.

OQ1.10 0.02(1.365) = 0.03. The result is (1.37 ± 0.03) × 107 kg. So (d) 3 digits are significant.

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| **ANSWERS TO CONCEPTUAL QUESTIONS** |

CQ1.1 Density varies with temperature and pressure. It would be necessary to measure both mass and volume very accurately in order to use the density of water as a standard.

CQ1.2 The metric system is considered superior because units larger and smaller than the basic units are simply related by multiples of 10. Examples: 1 km = 103 m, 1 mg = 10–3 g = 10–6 kg, 1 ns = 10–9 s.

CQ1.3 A unit of time should be based on a reproducible standard so it can be used everywhere. The more accuracy required of the standard, the less the standard should change with time. The current, very accurate standard is the period of vibration of light emitted by a cesium atom. Depending on the accuracy required, other standards could be: the period of light emitted by a different atom, the period of the swing of a pendulum at a certain place on Earth, the period of vibration of a sound wave produced by a string of a specific length, density, and tension, and the time interval from full Moon to full Moon.

CQ1.4 (a) 0.3 millimeters; (b) 50 microseconds; (c) 7.2 kilograms

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| **SOLUTIONS TO END-OF-CHAPTER PROBLEMS** |

Section 1.1 Standards of Length, Mass, and Time

P1.1 (a) Modeling the Earth as a sphere, we find its volume as



Its density is then



(b) This value is intermediate between the tabulated densities of aluminum and iron. Typical rocks have densities around 2000 to 3000 kg/m3. The average density of the Earth is significantly higher, so higher-density material must be down below the surface.

P1.2 With *V* = (base area)(height),  and  we have



P1.3 Let *V* represent the volume of the model, the same in  for both. Then  and 

Next, 

and 

P1.4 (a)  where d is the diameter.

Then 

(b) 

P1.5 For either sphere the volume is  and the mass is  We divide this equation for the larger sphere by the same equation for the smaller:



Then 

**\*P1.6** The volume of a spherical shell can be calculated from



From the definition of density, , so



Section 1.2 Matter and Model Building

P1.7 From the figure, we may see that the spacing between diagonal planes is half the distance between diagonally adjacent atoms on a flat plane. This diagonal distance may be obtained from the Pythagorean theorem,  Thus, since the atoms are separated by a distance *L =* 0.200 nm, the diagonal planes are separated by 

P1.8 (a) Treat this as a conversion of units using   
1 Cu-atom = 1.06 × 10–25 kg, and 1 cm = 10–2 m:



(b) Thinking in terms of units, invert answer (a):



(c) For a cube of side *L*,



Section 1.3 Dimensional Analysis

P1.9 (a) Write out dimensions for each quantity in the equation

*vf* = *vi + ax*

The variables *vf* and *vi* are expressed in units of m/s, so

[*vf*] = [*vi*] = LT –1

The variable *a* is expressed in units of m/s2; [*a*] = LT –2

The variable *x* is expressed in meters. Therefore, [*ax*] = L2 T –2

Consider the right-hand member (RHM) of equation (a):

[RHM] = LT –1+L2 T –2

Quantities to be added must have the same dimensions. Therefore, 

(b) Write out dimensions for each quantity in the equation

*y* = (2 m) cos (*kx*)

For *y*, [*y*] = L

for 2 m, [2 m] = L

and for (*kx*), 

Therefore we can think of the quantity *kx* as an angle in radians, and we can take its cosine. The cosine itself will be a pure number with no dimensions. For the left-hand member (LHM) and the right-hand member (RHM) of the equation we have