INSTRUCTOR SOLUTIONS MANUAL

VOLUME 1

DOUGLAS C. GIANCOLI'S

PHYSICS PRINCIPLES WITH APPLICATIONS

7TH EDITION

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PREFACE

This *Instructor's Solutions Manual* provides answers and worked-out solutions to all end of chapter questions and problems from chapters 1 – 15 of *Physics: Principles with Applications*, *7th Edition*, by Douglas C. Giancoli. At the end of the manual are grids that correlate the 6th edition questions and problems to the 7th edition questions and problems.

We formulated the solutions so that they are, in most cases, useful both for the student and the instructor. Accordingly, some solutions may seem to have more algebra than necessary for the instructor. Other solutions may seem to take bigger steps than a student would normally take: e.g. simply quoting the solutions from a quadratic equation instead of explicitly solving for them. There has been an emphasis on algebraic solutions, with the substitution of values given as a very last step in most cases. We feel that this helps to keep the physics of the problem foremost in the solution, rather than the numeric evaluation.

Much effort has been put into having clear problem statements, reasonable values, pedagogically sound solutions, and accurate answers/solutions for all of the questions and problems. Working with us was a team of five additional solvers – Karim Diff (Santa Fe College), Thomas Hemmick (Stony Brook University), Lauren Novatne (Reedley College), Michael Ottinger (Missouri Western State University), and Trina VanAusdal (Salt Lake Community College). Between the seven solvers we had four complete solutions for every question and problem. From those solutions we uncovered questions about the wording of the problems, style of the possible solutions, reasonableness of the values and framework of the questions and problems, and then consulted with one another and Doug Giancoli until we reached what we feel is both a good statement and a good solution for each question and problem in the text.

Many people have been involved in the production of this manual. We especially thank Doug Giancoli for his helpful conversations. Karen Karlin at Prentice Hall has been helpful, encouraging, and patient as we have turned our thoughts into a manual. Michael Ottinger provided solutions for every chapter, and helped in the preparation of the final solutions for some of the questions and problems. And the solutions from Karim Diff, Thomas Hemmick, Lauren Novatne, and Trina VanAusdal were often thought-provoking and always appreciated.

Even with all the assistance we have had, the final responsibility for the content of this manual is ours. We would appreciate being notified via e-mail of any errors that are discovered. We hope that you will find this presentation of answers and solutions useful.

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1

INTRODUCTION, MEASUREMENT, ESTIMATING

Responses to Questions

$\boxed{1.}$ (*a*) A particular person's foot. Merits: reproducible. Drawbacks: not accessible to the general public; not invariable (size changes with age, time of day, etc.); not indestructible.

(*b*) Any person's foot. Merits: accessible. Drawbacks: not reproducible (different people have different size feet); not invariable (size changes with age, time of day, etc.); not indestructible.

Neither of these options would make a good standard.

$\boxed{2.}$ The distance in miles is given to one significant figure, and the distance in kilometers is given to five significant figures! The value in kilometers indicates more precision than really exists or than is meaningful. The last digit represents a distance on the same order of magnitude as a car's length! The sign should perhaps read "7.0 mi (11 km)," where each value has the same number of significant figures, or "7 mi (11 km)," where each value has about the same % uncertainty.

3. The number of digits you present in your answer should represent the precision with which you know a measurement; it says very little about the accuracy of the measurement. For example, if you measure the length of a table to great precision, but with a measuring instrument that is not calibrated correctly, you will not measure accurately. Accuracy is a measure of how close a measurement is to the true value.

4. If you measure the length of an object, and you report that it is "4," you haven't given enough information for your answer to be useful. There is a large difference between an object that is 4 meters long and one that is 4 feet long. Units are necessary to give meaning to a numerical answer.

5. You should report a result of 8.32 cm. Your measurement had three significant figures. When you multiply by 2, you are really multiplying by the integer 2, which is an exact value. The number of significant figures is determined by the measurement.

$\boxed{6.}$ The correct number of significant figures is three: $\sin 30.0° = 0.500$.

7. Useful assumptions include the population of the city, the fraction of people who own cars, the average number of visits to a mechanic that each car makes in a year, the average number of weeks a mechanic works in a year, and the average number of cars each mechanic can see in a week.

(*a*) There are about 800,000 people in San Francisco, as estimated in 2009 by the U.S. Census Bureau. Assume that half of them have cars. If each of these 400,000 cars needs servicing twice a year, then there are 800,000 visits to mechanics in a year. If mechanics typically work 50 weeks a year, then about 16,000 cars would need to be seen each week. Assume that on average, a mechanic can work on 4 cars per day, or 20 cars a week. The final estimate, then, is 800 car mechanics in San Francisco.

(*b*) Answers will vary.

Responses to MisConceptual Questions

1. (*d*) One common misconception, as indicated by answers (*b*) and (*c*), is that digital measurements are inherently very accurate. A digital scale is only as accurate as the last digit that it displays.

2. (*a*) The total number of digits present does not determine the accuracy, as the leading zeros in (*c*) and (*d*) are only placeholders. Rewriting the measurements in scientific notation shows that (*d*) has two-digit accuracy, (*b*) and (*c*) have three-digit accuracy, and (*a*) has four-digit accuracy. Note that since the period is shown, the zeros to the right of the numbers are significant.

3. (*b*) The leading zeros are not significant. Rewriting this number in scientific notation shows that it only has two significant digits.

4. (*b*) When you add or subtract numbers, the final answer should contain no more decimal places than the number with the fewest decimal places. Since 25.2 has one decimal place, the answer must be rounded to one decimal place, or to 26.6.

5. (*b*) The word “accuracy” is commonly misused by beginning students. If a student repeats a measurement multiple times and obtains the same answer each time, it is often assumed to be accurate. In fact, students are frequently given an “ideal” number of times to repeat the experiment for “accuracy.” However, systematic errors may cause each measurement to be inaccurate. A poorly working instrument may also limit the accuracy of your measurement.

6. (*d*) This addresses misconceptions about squared units and about which factor should be in the numerator of the conversion. This error can be avoided when students treat the units as algebraic symbols that must be cancelled out.

7. (*e*) When making estimates, students frequently believe that their answers are more significant than they actually are. This question helps the student realize what an order-of-magnitude estimation is NOT supposed to accomplish.

8. (*d*) This addresses the fact that the generic unit symbol, like [*L*], does not indicate a specific system of units.

Solutions to Problems

1. (*a*) 214 $\boxed{\text{3 significant figures}}$

   (*b*) 81.60 $\boxed{\text{4 significant figures}}$

   (*c*) 7.03 $\boxed{\text{3 significant figures}}$

(*d*) 0.03 $\boxed{\text{1 significant figure}}$

(*e*) 0.0086 $\boxed{\text{2 significant figures}}$

(*f*) 3236 $\boxed{\text{4 significant figures}}$

(*g*) 8700 $\boxed{\text{2 significant figures}}$

2. (*a*) $1.156 = \boxed{1.156 \times 10^0}$

(*b*) $21.8 = \boxed{2.18 \times 10^1}$

(*c*) $0.0068 = \boxed{6.8 \times 10^{-3}}$

(*d*) $328.65 = \boxed{3.2865 \times 10^2}$

(*e*) $0.219 = \boxed{2.19 \times 10^{-1}}$

(*f*) $444 = \boxed{4.44 \times 10^2}$

3. (*a*) $8.69 \times 10^4 = \boxed{86,900}$

(*b*) $9.1 \times 10^3 = \boxed{9100}$

(*c*) $8.8 \times 10^{-1} = \boxed{0.88}$

(*d*) $4.76 \times 10^2 = \boxed{476}$

(*e*) $3.62 \times 10^{-5} = \boxed{0.0000362}$

$\boxed{4.}$ (*a*) $14 \text{ billion years} = \boxed{1.4 \times 10^{10} \text{ years}}$

(*b*) $$(1.4 \times 10^{10} \text{ yr})\left(\frac{3.156 \times 10^7 \text{ s}}{1 \text{ yr}}\right) = \boxed{4.4 \times 10^{17} \text{ s}}$$

$\boxed{5.}$ $$\% \text{ uncertainty} = \frac{0.25 \text{ m}}{5.48 \text{ m}} \times 100\% = \boxed{4.6\%}$$

6. (*a*) $$\% \text{ uncertainty} = \frac{0.2 \text{ s}}{5.5 \text{ s}} \times 100\% = 3.636\% \approx \boxed{4\%}$$

(*b*) $$\% \text{ uncertainty} = \frac{0.2 \text{ s}}{55 \text{ s}} \times 100\% = 0.3636\% \approx \boxed{0.4\%}$$

(*c*) The time of 5.5 minutes is 330 seconds.

$$\% \text{ uncertainty} = \frac{0.2 \text{ s}}{330 \text{ s}} \times 100\% = 0.0606\% \approx \boxed{0.06\%}$$

7. To add values with significant figures, adjust all values to be added so that their exponents are all the same.

$$(9.2\times10^3\ \text{s})+(8.3\times10^4\ \text{s})+(0.008\times10^6\ \text{s})=(9.2\times10^3\ \text{s})+(83\times10^3\ \text{s})+(8\times10^3\ \text{s})$$
$$=(9.2+83+8)\times10^3\ \text{s}=100.2\times10^3\ \text{s}=\boxed{1.00\times10^5\ \text{s}}$$

When you add, keep the least accurate value, so keep to the "ones" place in the last set of parentheses.

8. When you multiply, the result should have as many digits as the number with the least number of significant digits used in the calculation.

$$(3.079\times10^2\ \text{m})(0.068\times10^{-1}\ \text{m})=2.094\ \text{m}^2\approx\boxed{2.1\ \text{m}^2}$$

9. The uncertainty is taken to be 0.01 m.

$$\%\ \text{uncertainty}=\frac{0.01\ \text{m}^2}{1.57\ \text{m}^2}\times100\%=0.637\%\approx\boxed{1\%}$$

10. To find the approximate uncertainty in the volume, calculate the volume for the minimum radius and the volume for the maximum radius. Subtract the extreme volumes. The uncertainty in the volume is then half of this variation in volume.

$$V_{\text{specified}}=\tfrac{4}{3}\pi r_{\text{specified}}^3=\tfrac{4}{3}\pi(0.84\ \text{m})^3=2.483\ \text{m}^3$$
$$V_{\min}=\tfrac{4}{3}\pi r_{\min}^3=\tfrac{4}{3}\pi(0.80\ \text{m})^3=2.145\ \text{m}^3$$
$$V_{\max}=\tfrac{4}{3}\pi r_{\max}^3=\tfrac{4}{3}\pi(0.88\ \text{m})^3=2.855\ \text{m}^3$$
$$\Delta V=\tfrac{1}{2}(V_{\max}-V_{\min})=\tfrac{1}{2}(2.855\ \text{m}^3-2.145\ \text{m}^3)=0.355\ \text{m}^3$$

The percent uncertainty is $\dfrac{\Delta V}{V_{\text{specified}}}=\dfrac{0.355\ \text{m}^3}{2.483\ \text{m}^3}\times100=14.3\approx\boxed{14\%}$.

11. To find the approximate uncertainty in the area, calculate the area for the specified radius, the minimum radius, and the maximum radius. Subtract the extreme areas. The uncertainty in the area is then half this variation in area. The uncertainty in the radius is assumed to be 0.1×10^4 cm.

$$A_{\text{specified}}=\pi r_{\text{specified}}^2=\pi(3.1\times10^4\ \text{cm})^2=3.019\times10^9\ \text{cm}^2$$
$$A_{\min}=\pi r_{\min}^2=\pi(3.0\times10^4\ \text{cm})^2=2.827\times10^9\ \text{cm}^2$$
$$A_{\max}=\pi r_{\max}^2=\pi(3.2\times10^4\ \text{cm})^2=3.217\times10^9\ \text{cm}^2$$
$$\Delta A=\tfrac{1}{2}(A_{\max}-A_{\min})=\tfrac{1}{2}(3.217\times10^9\ \text{cm}^2-2.827\times10^9\ \text{cm}^2)=0.195\times10^9\ \text{cm}^2$$

Thus the area should be quoted as $\boxed{A=(3.0\pm0.2)\times10^9\ \text{cm}^2}$.

12. (*a*) 286.6 mm $\quad 286.6\times10^{-3}$ m $\quad \boxed{0.2866\ \text{m}}$

(*b*) 85 μV $\quad 85\times10^{-6}$ V $\quad \boxed{0.000085\ \text{V}}$

(*c*) 760 mg $\quad 760\times10^{-6}$ kg $\quad \boxed{0.00076\ \text{kg}}$ (if last zero is not significant) (*d*) 62.1 ps 62.1×10^{-12} s $\boxed{0.0000000000621\text{ s}}$

(*e*) 22.5 nm 22.5×10^{-9} m $\boxed{0.0000000225\text{ m}}$

(*f*) 2.50 gigavolts 2.50×10^{9} volts $\boxed{2{,}500{,}000{,}000\text{ volts}}$

Note that in part (*f*) in particular, the correct number of significant digits cannot be determined when you write the number in this format.

13. (*a*) 1×10^{6} volts $\boxed{\text{1 megavolt}} = 1\text{ MV}$

(*b*) 2×10^{-6} meters $\boxed{\text{2 micrometers}} = 2\ \mu\text{m}$

(*c*) 6×10^{3} days $\boxed{\text{6 kilodays}} = 6\text{ kdays}$

(*d*) 18×10^{2} bucks $\boxed{\text{18 hectobucks}} = 18\text{ hbucks}$ or 1.8 kilobucks

(*e*) 7×10^{-7} seconds $\boxed{\text{700 nanoseconds}} = 700$ ns or 0.7 μs

14. $$1\text{ hectare} = (1\text{ hectare})\left(\frac{1.000\times10^{4}\text{ m}^2}{1\text{ hectare}}\right)\left(\frac{3.281\text{ ft}}{1\text{ m}}\right)^2\left(\frac{1\text{ acre}}{4.356\times10^{4}\text{ ft}^2}\right) = \boxed{2.471\text{ acres}}$$

15. (*a*) $93\text{ million miles} = (93\times10^{6}\text{ miles})(1610\text{ m/1 mile}) = \boxed{1.5\times10^{11}\text{ m}}$

(*b*) $1.5\times10^{11}\text{ m} = (1.5\times10^{11}\text{ m})(1\text{ km}/10^{3}\text{ m}) = \boxed{1.5\times10^{8}\text{ km}}$

16. To add values with significant figures, adjust all values to be added so that their units are all the same.

$$1.80\text{ m} + 142.5\text{ cm} + 5.34\times10^{5}\ \mu\text{m} = 1.80\text{ m} + 1.425\text{ m} + 0.534\text{ m} = 3.759\text{ m} = \boxed{3.76\text{ m}}$$

When you add, the final result is to be no more accurate than the least accurate number used. In this case, that is the first measurement, which is accurate to the hundredths place when expressed in meters.

17. (*a*) $1.0\times10^{-10}\text{ m} = (1.0\times10^{-10}\text{ m})(39.37\text{ in/1 m}) = \boxed{3.9\times10^{-9}\text{ in}}$

(*b*) $$(1.0\text{ cm})\left(\frac{1\text{ m}}{100\text{ cm}}\right)\left(\frac{1\text{ atom}}{1.0\times10^{-10}\text{ m}}\right) = \boxed{1.0\times10^{8}\text{ atoms}}$$

18. (*a*) $$(1\text{ km/h})\left(\frac{0.621\text{ mi}}{1\text{ km}}\right) = 0.621\text{ mi/h, so the conversion factor is } \boxed{\frac{0.621\text{ mi/h}}{1\text{ km/h}}}.$$

(*b*) $$(1\text{ m/s})\left(\frac{3.28\text{ ft}}{1\text{ m}}\right) = 3.28\text{ ft/s, so the conversion factor is } \boxed{\frac{3.28\text{ ft/s}}{1\text{ m/s}}}.$$

(*c*) $$(1\text{ km/h})\left(\frac{1000\text{ m}}{1\text{ km}}\right)\left(\frac{1\text{ h}}{3600\text{ s}}\right) = 0.278\text{ m/s, so the conversion factor is } \boxed{\frac{0.278\text{ m/s}}{1\text{ km/h}}}.$$

Note that if more significant figures were used in the original factors, such as 0.6214 miles per kilometer, more significant figures could have been included in the answers.

$\boxed{19.}$ (*a*) Find the distance by multiplying the speed by the time.

$$1.00\ \text{ly} = (2.998\times10^{8}\ \text{m/s})(3.156\times10^{7}\ \text{s}) = 9.462\times10^{15}\ \text{m} \approx \boxed{9.46\times10^{15}\ \text{m}}$$

(*b*) Do a unit conversion from ly to AU.

$$(1.00\ \text{ly})\left(\frac{9.462\times10^{15}\ \text{m}}{1.00\ \text{ly}}\right)\left(\frac{1\ \text{AU}}{1.50\times10^{11}\ \text{m}}\right) = \boxed{6.31\times10^{4}\ \text{AU}}$$

$\boxed{20.}$ One mile is 1609 m, according to the unit conversions in the front of the textbook. Thus it is 109 m longer than a 1500-m race. The percentage difference is calculated here.

$$\frac{109\ \text{m}}{1500\ \text{m}}\times100\% = \boxed{7.3\%}$$

21. Since the meter is longer than the yard, the soccer field is longer than the football field.

$$\ell_{\text{soccer}} - \ell_{\text{football}} = 100.0\ \text{m}\times\frac{1.094\ \text{yd}}{1\ \text{m}} - 100.0\ \text{yd} = \boxed{9.4\ \text{yd}}$$

$$\ell_{\text{soccer}} - \ell_{\text{football}} = 100.0\ \text{m} - 100.0\ \text{yd}\times\frac{1\ \text{m}}{1.094\ \text{yd}} = \boxed{8.6\ \text{m}}$$

Since the soccer field is 109.4 yd compared with the 100.0-yd football field, the soccer field is $\boxed{9.4\%}$ longer than the football field.

22. (*a*) # of seconds in 1.00 yr: $1.00\ \text{yr} = (1.00\ \text{yr})\left(\frac{3.156\times10^{7}\ \text{s}}{1\ \text{yr}}\right) = \boxed{3.16\times10^{7}\ \text{s}}$

(*b*) # of nanoseconds in 1.00 yr: $1.00\ \text{yr} = (1.00\ \text{yr})\left(\frac{3.156\times10^{7}\ \text{s}}{1\ \text{yr}}\right)\left(\frac{1\times10^{9}\ \text{ns}}{1\ \text{s}}\right) = \boxed{3.16\times10^{16}\ \text{ns}}$

(*c*) # of years in 1.00 s: $1.00\ \text{s} = (1.00\ \text{s})\left(\frac{1\ \text{yr}}{3.156\times10^{7}\ \text{s}}\right) = \boxed{3.17\times10^{-8}\ \text{yr}}$

23. (*a*) $\left(\frac{10^{-15}\ \text{kg}}{1\ \text{bacterium}}\right)\left(\frac{1\ \text{proton or neutron}}{10^{-27}\ \text{kg}}\right) = \boxed{10^{12}\ \text{protons or neutrons}}$

(*b*) $\left(\frac{10^{-17}\ \text{kg}}{1\ \text{DNA molecule}}\right)\left(\frac{1\ \text{proton or neutron}}{10^{-27}\ \text{kg}}\right) = \boxed{10^{10}\ \text{protons or neutrons}}$

(*c*) $\left(\frac{10^{2}\ \text{kg}}{1\ \text{human}}\right)\left(\frac{1\ \text{proton or neutron}}{10^{-27}\ \text{kg}}\right) = \boxed{10^{29}\ \text{protons or neutrons}}$

(*d*) $\left(\frac{10^{41}\ \text{kg}}{1\ \text{Galaxy}}\right)\left(\frac{1\ \text{proton or neutron}}{10^{-27}\ \text{kg}}\right) = \boxed{10^{68}\ \text{protons or neutrons}}$

24. The radius of the ball can be found from the circumference (represented by "c" in the equations below), and then the volume can be found from the radius. Finally, the mass is found from the volume of the baseball multiplied by the density $(\rho = \text{mass/volume})$ of a nucleon.

$$c_{\text{ball}} = 2\pi r_{\text{ball}} \rightarrow r_{\text{ball}} = \frac{c_{\text{ball}}}{2\pi}; \; V_{\text{ball}} = \tfrac{4}{3}\pi r_{\text{ball}}^3 = \tfrac{4}{3}\pi\left(\frac{c_{\text{ball}}}{2\pi}\right)^3$$

$$m_{\text{ball}} = V_{\text{ball}}\rho_{\text{nucleon}} = V_{\text{ball}}\left(\frac{m_{\text{nucleon}}}{V_{\text{nucleon}}}\right) = V_{\text{ball}}\left(\frac{m_{\text{nucleon}}}{\tfrac{4}{3}\pi r_{\text{nucleon}}^3}\right) = V_{\text{ball}}\left(\frac{m_{\text{nucleon}}}{\tfrac{4}{3}\pi\left(\tfrac{1}{2}d_{\text{nucleon}}\right)^3}\right)$$

$$= \tfrac{4}{3}\pi\left(\frac{c_{\text{ball}}}{2\pi}\right)^2\left(\frac{m_{\text{nucleon}}}{\tfrac{4}{3}\pi\left(\tfrac{1}{2}d_{\text{nucleon}}\right)^3}\right) = m_{\text{nucleon}}\left(\frac{c_{\text{ball}}}{\pi d_{\text{nucleon}}}\right)^3 = (10^{-27}\text{ kg})\left(\frac{0.23\text{ m}}{\pi(10^{-15}\text{ m})}\right)^3$$

$$= 3.9\times10^{14}\text{ kg} \approx \boxed{4\times10^{14}\text{ kg}}$$

25. (*a*) $2800 = 2.8\times10^3 \approx 1\times10^3 = \boxed{10^3}$

(*b*) $86.30\times10^3 = 8.630\times10^4 \approx 10\times10^4 = \boxed{10^5}$

(*c*) $0.0076 = 7.6\times10^{-3} \approx 10\times10^{-3} = \boxed{10^{-2}}$

(*d*) $15.0\times10^8 = 1.5\times10^9 \approx 1\times10^9 = \boxed{10^9}$

26. The textbook is approximately 25 cm deep and 5 cm wide. With books on both sides of a shelf, the shelf would need to be about 50 cm deep. If the aisle is 1.5 m wide, then about 1/4 of the floor space is covered by shelving. The number of books on a single shelf level is then $\tfrac{1}{4}(3500\text{ m}^2)\left(\frac{1\text{ book}}{(0.25\text{ m})(0.05\text{ m})}\right) = 7.0\times10^4$ books. With 8 shelves of books, the total number of books stored is as follows:

$$\left(7.0\times10^4\,\frac{\text{books}}{\text{shelf level}}\right)(8\text{ shelves}) \approx \boxed{6\times10^5\text{ books}}$$

27. The distance across the U.S. is about 3000 miles.

$$(3000\text{ mi})(1\text{ km}/0.621\text{ mi})(1\text{ h}/10\text{ km}) \approx \boxed{500\text{ h}}$$

Of course, it would take more time on the clock for a runner to run across the U.S. The runner obviously could not run for 500 hours non-stop. If he or she could run for 5 hours a day, then it would take about 100 days to cross the country.

28. A commonly accepted measure is that a person should drink eight 8-oz. glasses of water each day. That is about 2 quarts, or 2 liters of water per day. Approximate the lifetime as 70 years.

$$(70\text{ yr})(365\text{ d}/1\text{ yr})(2\text{ L}/1\text{ d}) \approx \boxed{5\times10^4\text{ L}}$$

$\boxed{29.}$ An NCAA-regulation football field is 360 feet long (including the end zones) and 160 feet wide, which is about 110 meters by 50 meters, or 5500 m^2. We assume the mower has a cutting width of

0.5 meters and that a person mowing can walk at about 4.5 km/h, which is about 3 mi/h. Thus the distance to be walked is as follows:

$$d = \frac{\text{area}}{\text{width}} = \frac{5500\ \text{m}^2}{0.5\ \text{m}} = 11000\ \text{m} = 11\ \text{km}$$

At a speed of 4.5 km/h, it will take about $11\ \text{km} \times \frac{1\ \text{h}}{4.5\ \text{km}} \approx \boxed{2.5\ \text{h}}$ to mow the field.

$\boxed{30.}$ There are about 3×10^8 people in the U.S. Assume that half of them have cars, that they drive an average of 12,000 miles per year, and that their cars get an average of 20 miles per gallon of gasoline.

$$(3\times10^8\ \text{people})\left(\frac{1\ \text{automobile}}{2\ \text{people}}\right)\left(\frac{12{,}000\ \text{mi/auto}}{1\ \text{yr}}\right)\left(\frac{1\ \text{gallon}}{20\ \text{mi}}\right) \approx \boxed{1\times10^{11}\ \text{gal/yr}}$$

31. In estimating the number of dentists, the assumptions and estimates needed are:
    - the population of the city
    - the number of patients that a dentist sees in a day
    - the number of days that a dentist works in a year
    - the number of times that each person visits the dentist each year

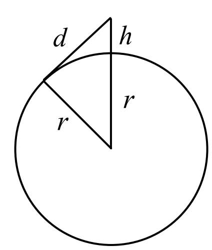
We estimate that a dentist can see 10 patients a day, that a dentist works 225 days a year, and that each person visits the dentist twice per year.

(*a*) For San Francisco, the population as of 2010 was about 800,000 (according to the U.S. Census Bureau). The number of dentists is found by the following calculation:

$$(8\times10^5\ \text{people})\left(\frac{2\ \text{visits/yr}}{1\ \text{person}}\right)\left(\frac{1\ \text{yr}}{225\ \text{workdays}}\right)\left(\frac{1\ \text{dentist}}{10\ \text{visits/workday}}\right) \approx \boxed{700\ \text{dentists}}$$

(*b*) For Marion, Indiana, the population is about 30,000. The number of dentists is found by a calculation similar to that in part (*a*), and would be about $\boxed{30\ \text{dentists}}$. There are about 40 dentists (of all types, including oral surgeons and orthodontists) listed in the 2012 Yellow Pages.

32. Consider the diagram shown (not to scale). The balloon is a distance $h = 200$ m above the surface of the Earth, and the tangent line from the balloon height to the surface of the Earth indicates the location of the horizon, a distance *d* away from the balloon. Use the Pythagorean theorem.



$$(r+h)^2 = r^2 + d^2 \quad\rightarrow\quad r^2 + 2rh + h^2 = r^2 + d^2$$

$$2rh + h^2 = d^2 \quad\rightarrow\quad d = \sqrt{2rh + h^2}$$

$$d = \sqrt{2(6.4\times10^6\ \text{m})(200\ \text{m}) + (200\ \text{m})^2} = 5.1\times10^4\ \text{m} \approx \boxed{5\times10^4\ \text{m}}(\approx 80\ \text{mi})$$

33. At \$1,000 per day, you would earn \$30,000 in the 30 days. With the other pay method, you would get $\$0.01(2^{t-1})$ on the *t*th day. On the first day, you get $\$0.01(2^{1-1}) = \$0.01$. On the second day, you get $\$0.01(2^{2-1}) = \$0.02$. On the third day, you get $\$0.01(2^{3-1}) = \$0.04$. On the 30th day, you get $\$0.01(2^{30-1}) = \$5.4\times10^6$, which is over 5 million dollars. Get paid by the $\boxed{\text{second method}}$.

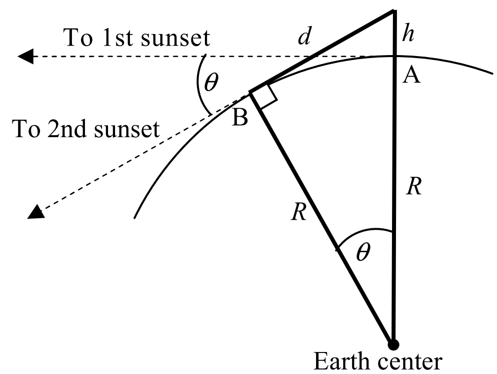
34. In the figure in the textbook, the distance d is perpendicular to the radius that is drawn approximately vertically. Thus there is a right triangle, with legs of d and R, and a hypotenuse of $R+h$. Since $h \ll R,\ h^2 \ll 2Rh.$

$$d^2 + R^2 = (R+h)^2 = R^2 + 2Rh + h^2 \quad \rightarrow \quad d^2 = 2Rh + h^2 \quad \rightarrow \quad d^2 \approx 2Rh \quad \rightarrow \quad R = \frac{d^2}{2h}$$

$$= \frac{(4400\ \text{m})^2}{2(1.5\ \text{m})} = \boxed{6.5\times10^6\ \text{m}}$$

A better measurement gives $R = 6.38\times10^6$ m.

35. For you to see the Sun "disappear," your line of sight to the top of the Sun must be tangent to the Earth's surface. Initially, you are lying down at point A, and you see the first sunset. Then you stand up, elevating your eyes by the height $h = 130$ cm. While you stand, your line of sight is tangent to the Earth's surface at point B, so that is the direction to the second sunset. The angle θ is the angle through which the Sun appears to move relative to the Earth during the time to be measured. The distance d is the distance from your eyes when standing to point B.



Use the Pythagorean theorem for the following relationship:

$$d^2 + R^2 = (R+h)^2 = R^2 + 2Rh + h^2 \quad \rightarrow \quad d^2 = 2Rh + h^2$$

The distance h is much smaller than the distance R, so $h^2 \ll 2Rh$ which leads to $d^2 \approx 2Rh$. We also have from the same triangle that $d/R = \tan\theta$, so $d = R\tan\theta$. Combining these two relationships gives $d^2 \approx 2Rh = R^2\tan^2\theta$, so $R = \dfrac{2h}{\tan^2\theta}$.

The angle θ can be found from the height change and the radius of the Earth. The elapsed time between the two sightings can then be found from the angle, because we know that a full revolution takes 24 hours.

$$R = \frac{2h}{\tan^2\theta} \quad \rightarrow \quad \theta = \tan^{-1}\sqrt{\frac{2h}{R}} = \tan^{-1}\sqrt{\frac{2(1.3\ \text{m})}{6.38\times10^6\ \text{m}}} = (3.66\times10^{-2})^\circ$$

$$\frac{\theta}{360^\circ} = \frac{t\ \text{sec}}{24\ \text{h}\times\dfrac{3600\ \text{s}}{1\ \text{h}}} \quad \rightarrow$$

$$t = \left(\frac{\theta}{360^\circ}\right)\left(24\ \text{h}\times\frac{3600\ \text{s}}{1\ \text{h}}\right) = \left(\frac{(3.66\times10^{-2})^\circ}{360^\circ}\right)\left(24\ \text{h}\times\frac{3600\ \text{s}}{1\ \text{h}}\right) = \boxed{8.8\ \text{s}}$$

36. Density units $= \dfrac{\text{mass units}}{\text{volume units}} = \boxed{\left[\dfrac{M}{L^3}\right]}$

37. (*a*) For the equation $\upsilon = At^3 - Bt$, the units of At^3 must be the same as the units of υ. So the units of *A* must be the same as the units of υ/t^3, which would be $\boxed{L/T^4}$. Also, the units of *Bt* must be the same as the units of υ. So the units of *B* must be the same as the units of υ/t, which would be $\boxed{L/T^2}$.

    (*b*) For *A*, the SI units would be $\boxed{\text{m/s}^4}$, and for B, the SI units would be $\boxed{\text{m/s}^2}$.

38. (*a*) The quantity υt^2 has units of $(\text{m/s})(\text{s}^2) = \text{m}\bullet\text{s}$, which do not match with the units of meters for *x*. The quantity 2*at* has units $(\text{m/s}^2)(\text{s}) = \text{m/s}$, which also do not match with the units of meters for *x*. Thus this equation $\boxed{\text{cannot be correct}}$.

    (*b*) The quantity $\upsilon_0 t$ has units of $(\text{m/s})(\text{s}) = \text{m}$, and $\frac{1}{2}at^2$ has units of $(\text{m/s}^2)(\text{s}^2) = \text{m}$. Thus, since each term has units of meters, this equation $\boxed{\text{can be correct}}$.

    (*c*) The quantity $\upsilon_0 t$ has units of $(\text{m/s})(\text{s}) = \text{m}$, and $2at^2$ has units of $(\text{m/s}^2)(\text{s}^2) = \text{m}$. Thus, since each term has units of meters, this equation $\boxed{\text{can be correct}}$.

39. Using the units on each of the fundamental constants (*c*, *G*, and *h*), we find the dimensions of the Planck length. We use the values given for the fundamental constants to find the value of the Planck length.

$$\ell_P = \sqrt{\frac{Gh}{c^3}} \rightarrow \sqrt{\frac{[L^3/MT^2][ML^2/T]}{[L/T]^3}} = \sqrt{\left[\frac{L^3L^2T^3M}{MT^3L^3}\right]} = \sqrt{\left[\frac{L^5}{L^3}\right]} = \sqrt{\left[L^2\right]} = [L]$$

$$\ell_P = \sqrt{\frac{Gh}{c^3}} = \sqrt{\frac{(6.67\times10^{-11}\ \text{m}^3/\text{kg}\bullet\text{s}^2)(6.63\times10^{-34}\ \text{kg}\bullet\text{m}^2/\text{s})}{(3.00\times10^8\ \text{m/s})^3}} = 4.05\times10^{-35}\ \text{m}$$

Thus the order of magnitude is $\boxed{10^{-35}\ \text{m}}$.

40. The percentage accuracy is $\dfrac{2\ \text{m}}{2\times10^7\ \text{m}}\times100\% = \boxed{1\times10^{-5}\%}$. The distance of 20,000,000 m needs to be distinguishable from 20,000,002 m, which means that $\boxed{\text{8 significant figures}}$ are needed in the distance measurements.

41. Multiply the number of chips per wafer by the number of wafers that can be made from a cylinder. We assume the number of chips per wafer is more accurate than 1 significant figure.

$$\left(400\,\frac{\text{chips}}{\text{wafer}}\right)\left(\frac{1\ \text{wafer}}{0.300\ \text{mm}}\right)\left(\frac{250\ \text{mm}}{1\ \text{cylinder}}\right) = \boxed{3.3\times10^5\ \frac{\text{chips}}{\text{cylinder}}}$$

42. Assume that the alveoli are spherical and that the volume of a typical human lung is about 2 liters, which is $0.002\ \text{m}^3$. The diameter can be found from the volume of a sphere, $\frac{4}{3}\pi r^3$.

$$\tfrac{4}{3}\pi r^3 = \tfrac{4}{3}\pi (d/2)^3 = \frac{\pi d^3}{6}$$

$$(3\times 10^8)\pi \frac{d^3}{6} = 2\times 10^{-3}\ \text{m}^3 \quad \rightarrow \quad d = \left[\frac{6(2\times 10^{-3})}{3\times 10^8\ \pi}\text{m}^3\right]^{1/3} = \boxed{2\times 10^{-4}\ \text{m}}$$

43. We assume that there are 40 hours of work per week and that the typist works 50 weeks out of the year.

$$(1.0\times 10^{12}\ \text{bytes})\times\frac{1\ \text{char}}{1\ \text{byte}}\times\frac{1\ \text{min}}{180\ \text{char}}\times\frac{1\ \text{hour}}{60\ \text{min}}\times\frac{1\ \text{week}}{40\ \text{hour}}\times\frac{1\ \text{year}}{50\ \text{weeks}} = 4.629\times 10^4\ \text{years}$$

$$\approx \boxed{46{,}000\ \text{years}}$$

44. The volume of water used by the people can be calculated as follows:

$$(4\times 10^4\ \text{people})\left(\frac{1200\ \text{L/day}}{4\ \text{people}}\right)\left(\frac{365\ \text{days}}{1\ \text{yr}}\right)\left(\frac{1000\ \text{cm}^3}{1\ \text{L}}\right)\left(\frac{1\ \text{km}}{10^5\ \text{cm}}\right)^3 = 4.38\times 10^{-3}\ \text{km}^3/\text{yr}$$

The depth of water is found by dividing the volume by the area.

$$d = \frac{V}{A} = \frac{4.38\times 10^{-3}\ \text{km}^3/\text{yr}}{50\ \text{km}^2} = \left(8.76\times 10^{-5}\ \frac{\text{km}}{\text{yr}}\right)\left(\frac{10^5\ \text{cm}}{1\ \text{km}}\right) = 8.76\ \text{cm/yr} \approx \boxed{9\ \text{cm/yr}}$$

45. We approximate the jar as a cylinder with a uniform cross-sectional area. In counting the jelly beans in the top layer, we find about 25 jelly beans. Thus we estimate that one layer contains about 25 jelly beans. In counting vertically, we see that there are about 15 rows. Thus we estimate that there are $25\times 15 = 375 \approx \boxed{400\ \text{jelly beans}}$ in the jar.

46. The volume of a sphere is given by $V = \tfrac{4}{3}\pi r^3$, so the radius is $r = \left(\frac{3V}{4\pi}\right)^{1/3}$. For a 1-ton rock, the volume is calculated from the density, and then the diameter from the volume.

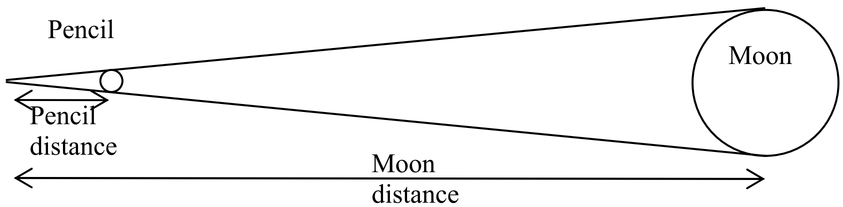
$$V = (1\ \text{T})\left(\frac{2000\ \text{lb}}{1\ \text{T}}\right)\left(\frac{1\ \text{ft}^3}{186\ \text{lb}}\right) = 10.8\ \text{ft}^3$$

$$d = 2r = 2\left(\frac{3V}{4\pi}\right)^{1/3} = 2\left[\frac{3(10.8\ \text{ft}^3)}{4\pi}\right]^{1/3} = 2.74\ \text{ft} \approx \boxed{3\ \text{ft}}$$

47. We do a "units conversion" from bytes to minutes, using the given CD reading rate.

$$(783.216\times 10^6\ \text{bytes})\times\frac{8\ \text{bits}}{1\ \text{byte}}\times\frac{1\ \text{s}}{1.4\times 10^6\ \text{bits}}\times\frac{1\ \text{min}}{60\ \text{s}} = 74.592\ \text{min} \approx \boxed{75\ \text{min}}$$

48. A pencil has a diameter of about 0.7 cm. If held about 0.75 m from the eye, it can just block out the Moon. The ratio of pencil diameter to arm length is the same as the ratio of Moon diameter to Moon distance. From the diagram, we have the following ratios.



$$\frac{\text{Pencil diameter}}{\text{Pencil distance}} = \frac{\text{Moon diameter}}{\text{Moon distance}} \rightarrow$$

$$\text{Moon diameter} = \frac{\text{Pencil diameter}}{\text{Pencil distance}}(\text{Moon distance}) = \frac{7\times10^{-3}\text{ m}}{0.75\text{ m}}(3.8\times10^{5}\text{ km}) \approx \boxed{3500\text{ km}}$$

The actual value is 3480 km.

49. To calculate the mass of water, we need to find the volume of water and then convert the volume to mass. The volume of water is the area of the city (48 km^2) times the depth of the water (1.0 cm).

$$\left[(48\text{ km}^2)\left(\frac{10^5\text{ cm}}{1\text{ km}}\right)^2\right](1.0\text{ cm})\left(\frac{10^{-3}\text{ kg}}{1\text{ cm}^3}\right)\left(\frac{1\text{ metric ton}}{10^3\text{ kg}}\right) = 4.8\times10^5\text{ metric tons} \approx \boxed{5\times10^5\text{ metric tons}}$$

To find the number of gallons, convert the volume to gallons.

$$\left[(48\text{ km}^2)\left(\frac{10^5\text{ cm}}{1\text{ km}}\right)^2\right](1.0\text{ cm})\left(\frac{1\text{ L}}{1\times10^3\text{ cm}^3}\right)\left(\frac{1\text{ gal}}{3.78\text{ L}}\right) = 1.27\times10^8\text{ gal} \approx \boxed{1\times10^8\text{ gal}}$$

50. The person walks 4 km/h, 12 hours each day. The radius of the Earth is about 6380 km, and the distance around the Earth at the equator is the circumference, $2\pi R_{\text{Earth}}$. We assume that the person can "walk on water," so ignore the existence of the oceans.

$$2\pi(6380\text{ km})\left(\frac{1\text{ h}}{4\text{ km}}\right)\left(\frac{1\text{ day}}{12\text{ h}}\right) = 835\text{ days} \approx \boxed{800\text{ days}}$$

51. The volume of the oil will be the area times the thickness. The area is $\pi r^2 = \pi(d/2)^2$.

$$V = \pi(d/2)^2 t \rightarrow d = 2\sqrt{\frac{V}{\pi t}} = 2\sqrt{\frac{1000\text{ cm}^3\left(\frac{1\text{ m}}{100\text{ cm}}\right)^3}{\pi(2\times10^{-10}\text{ m})}} = \boxed{3\times10^3\text{ m}}$$

This is approximately 2 miles.

52. $\left(\frac{8\text{ s}}{1\text{ yr}}\right)\left(\frac{1\text{ yr}}{3.156\times10^7\text{ s}}\right)\times100\% = \boxed{3\times10^{-5}\%}$

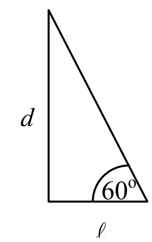
53. (*a*) $1.0\,\text{Å} = \left(1.0\,\text{Å}\right)\left(\frac{10^{-10}\text{ m}}{1\,\text{Å}}\right)\left(\frac{1\text{ nm}}{10^{-9}\text{ m}}\right) = \boxed{0.10\text{ nm}}$

(*b*) $1.0\,\overset{\circ}{\mathrm{A}} = \left(1.0\,\overset{\circ}{\mathrm{A}}\right)\left(\dfrac{10^{-10}\ \mathrm{m}}{1\,\overset{\circ}{\mathrm{A}}}\right)\left(\dfrac{1\ \mathrm{fm}}{10^{-15}\ \mathrm{m}}\right) = \boxed{1.0\times10^{5}\ \mathrm{fm}}$

(*c*) $1.0\ \mathrm{m} = (1.0\ \mathrm{m})\left(\dfrac{1\,\overset{\circ}{\mathrm{A}}}{10^{-10}\ \mathrm{m}}\right) = \boxed{1.0\times10^{10}\ \overset{\circ}{\mathrm{A}}}$

(*d*) $1.0\ \mathrm{ly} = (1.0\ \mathrm{ly})\left(\dfrac{9.46\times10^{15}\ \mathrm{m}}{1\ \mathrm{ly}}\right)\left(\dfrac{1\,\overset{\circ}{\mathrm{A}}}{10^{-10}\ \mathrm{m}}\right) = \boxed{9.5\times10^{25}\ \overset{\circ}{\mathrm{A}}}$

54. Consider the diagram shown. Let ℓ represent the distance he walks upstream. Then from the diagram find the distance across the river.



$$\tan 60^{\circ} = \frac{d}{\ell} \quad\rightarrow\quad d = \ell\tan 60^{\circ} = (65\ \text{strides})\left(\frac{0.8\ \mathrm{m}}{\text{stride}}\right)\tan 60^{\circ} = \boxed{90\ \mathrm{m}}$$

55. (*a*) Note that $\sin 15.0^{\circ} = 0.259$ and $\sin 15.5^{\circ} = 0.267$, so $\Delta\sin\theta = 0.267 - 0.259 = 0.008$.

$$\left(\frac{\Delta\theta}{\theta}\right)100 = \left(\frac{0.5^{\circ}}{15.0^{\circ}}\right)100 = \boxed{3\%} \qquad \left(\frac{\Delta\sin\theta}{\sin\theta}\right)100 = \left(\frac{8\times10^{-3}}{0.259}\right)100 = \boxed{3\%}$$

(*b*) Note that $\sin 75.0^{\circ} = 0.966$ and $\sin 75.5^{\circ} = 0.968$, so $\Delta\sin\theta = 0.968 - 0.966 = 0.002$.

$$\left(\frac{\Delta\theta}{\theta}\right)100 = \left(\frac{0.5^{\circ}}{75.0^{\circ}}\right)100 = \boxed{0.7\%} \qquad \left(\frac{\Delta\sin\theta}{\sin\theta}\right)100 = \left(\frac{2\times10^{-3}}{0.966}\right)100 = \boxed{0.2\%}$$

A consequence of this result is that when you use a protractor, and you have a fixed uncertainty in the angle ($\pm 0.5^{\circ}$ in this case), you should measure the angles from a reference line that gives a large angle measurement rather than a small one. Note above that the angles around 75° had only a 0.2% error in sin θ, while the angles around 15° had a 3% error in sin θ.

56. Utilize the fact that walking totally around the Earth along the meridian would trace out a circle whose full 360° would equal the circumference of the Earth.

$$(1\ \text{minute})\left(\frac{1^{\circ}}{60\ \text{minute}}\right)\left(\frac{2\pi(6.38\times10^{3}\ \mathrm{km})}{360^{\circ}}\right)\left(\frac{0.621\ \mathrm{mi}}{1\ \mathrm{km}}\right) = \boxed{1.15\ \mathrm{mi}}$$

57. Consider the body to be a cylinder, about 170 cm tall $(\approx 5'7'')$, and about 12 cm in cross-sectional radius (which corresponds to a 30-inch waist). The volume of a cylinder is given by the area of the cross section times the height.

$$V = \pi r^{2}h = \pi(0.12\ \mathrm{m})^{2}(1.7\ \mathrm{m}) = 7.69\times10^{-2}\ \mathrm{m}^{3} \approx \boxed{8\times10^{-2}\ \mathrm{m}^{3}}$$

58. The units for each term must be in liters, since the volume is in liters.

$$[\text{units of } 4.1][\text{m}] = [\text{L}] \quad \rightarrow \boxed{[\text{units of } 4.1] = \frac{\text{L}}{\text{m}}}$$

$$[\text{units of } 0.018][\text{year}] = [\text{L}] \quad \rightarrow \quad \boxed{[\text{units of } 0.018] = \frac{\text{L}}{\text{year}}}$$

$$\boxed{[\text{units of } 2.7] = \text{L}}$$

59. Divide the number of atoms by the Earth's surface area.

$$\frac{\text{number of atoms}}{\text{m}^2} = \frac{6.02\times10^{23}\ \text{atoms}}{4\pi R_{\text{Earth}}^2} = \frac{6.02\times10^{23}\ \text{atoms}}{4\pi(6.38\times10^6\ \text{m})^2} = \boxed{1.18\times10^9\ \frac{\text{atoms}}{\text{m}^2}}$$

This is more than a billion atoms per square meter.

60. The density is the mass divided by volume. There will be only 1 significant figure in the answer.

$$\text{density} = \frac{\text{mass}}{\text{volume}} = \frac{6\ \text{g}}{2.8325\ \text{cm}^3} = 2.118\ \text{g/cm}^3 \approx \boxed{2\ \text{g/cm}^3}$$

61. Multiply the volume of a spherical universe times the density of matter, adjusted to ordinary matter. The volume of a sphere is $\frac{4}{3}\pi r^3$.

$$m = \rho V = (1\times10^{-26}\ \text{kg/m}^3)\tfrac{4}{3}\pi\left((13.7\times10^9\ \text{ly})\times\frac{9.46\times10^{15}\ \text{m}}{1\ \text{ly}}\right)^3(0.04)$$

$$= 3.65\times10^{51}\ \text{kg} \approx \boxed{4\times10^{51}\ \text{kg}}$$

Solutions to Search and Learn Problems

1. Both Galileo and Copernicus built on earlier theories (by Aristotle and Ptolemy), but those new theories explained a greater variety of phenomena. Aristotle and Ptolemy explained motion in basic terms. Aristotle explained the basic motion of objects, and Ptolemy explained the basic motions of astronomical bodies. Both Galileo and Copernicus took those explanations of motion to a new level. Galileo developed explanations that would apply in the absence of friction. Copernicus's Sun-centered theory explained other phenomena that Ptolemy's model did not (such as the phases of Venus).

2. From Example 1–7, the thickness of a page of this book is about 6×10^{-5} m. The wavelength of orange krypton-86 light is found from the fact that 1,650,763.73 wavelengths of that light is the definition of the meter.

$$1\ \text{page}\left(\frac{6\times10^{-5}\ \text{m}}{1\ \text{page}}\right)\left(\frac{1{,}650{,}763.73\ \text{wavelengths}}{1\ \text{m}}\right) = 99\ \text{wavelengths} \approx \boxed{100\ \text{wavelengths}}$$

3. The original definition of the meter was that 1 meter was one ten-millionth of the distance from the Earth's equator to either pole. The distance from the equator to the pole would be one-fourth of the circumference of a perfectly spherical Earth. Thus the circumference would be 40 million meters: $\boxed{C = 4\times10^7\ \text{m}}$. We use the circumference to find the radius.

$$C = 2\pi r \rightarrow r = \frac{C}{2\pi} = \frac{4\times10^7\ \text{m}}{2\pi} = \boxed{6.37\times10^6\ \text{m}}$$

The value in the front of the textbook is 6.38×10^6 m.

4. We use values from Table 1–3.

$$\frac{m_{\text{human}}}{m_{\substack{\text{DNA}\\ \text{molecule}}}} = \frac{10^2\ \text{kg}}{10^{-17}\ \text{kg}} = \boxed{10^{19}}$$

5. The surface area of a sphere is given by $4\pi r^2$, and the volume of a sphere is given by $\frac{4}{3}\pi r^3$.

(*a*) $$\frac{A_{\text{Earth}}}{A_{\text{Moon}}} = \frac{4\pi R_{\text{Earth}}^2}{4\pi R_{\text{Moon}}^2} = \frac{R_{\text{Earth}}^2}{R_{\text{Moon}}^2} = \frac{(6.38\times10^3\ \text{km})^2}{(1.74\times10^3\ \text{km})^2} = \boxed{13.4}$$

(*b*) $$\frac{V_{\text{Earth}}}{V_{\text{Moon}}} = \frac{\frac{4}{3}\pi R_{\text{Earth}}^3}{\frac{4}{3}\pi R_{\text{Moon}}^3} = \frac{R_{\text{Earth}}^3}{R_{\text{Moon}}^3} = \frac{(6.38\times10^3\ \text{km})^3}{(1.74\times10^3\ \text{km})^3} = \boxed{49.3}$$