

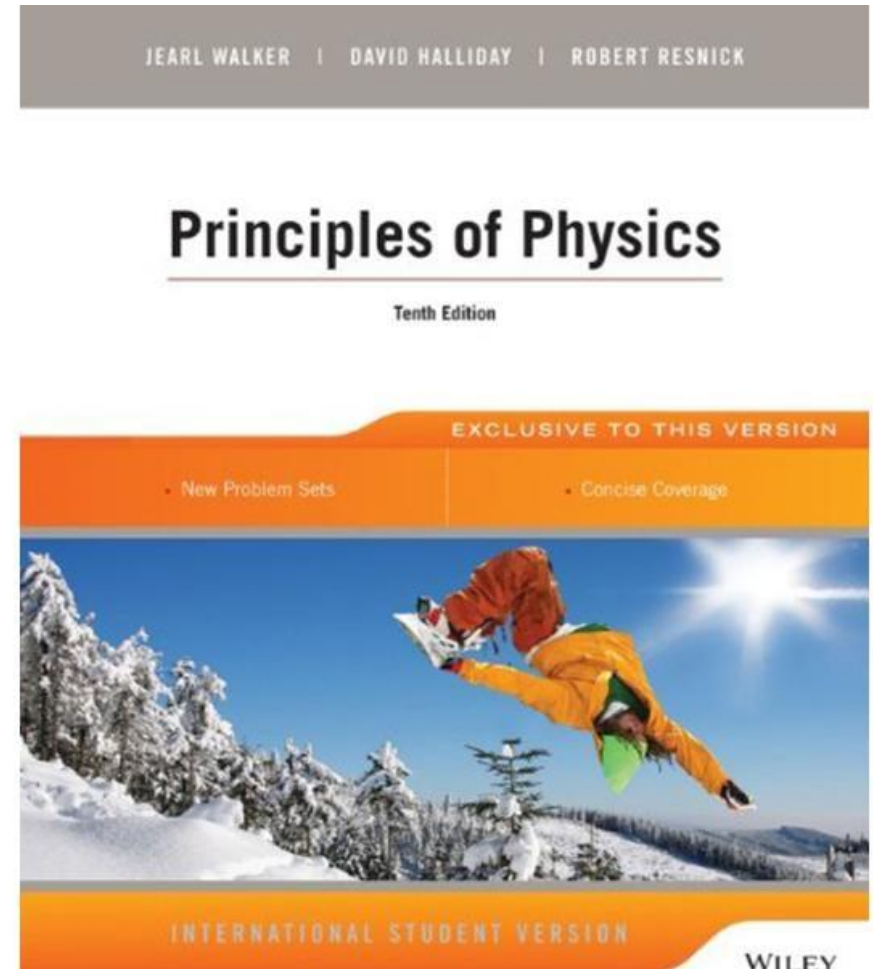


Welcome to PHYSICS 111

Semester 461

What is Physics ?

- “*Physics*” is derived from a Greek word that means “*nature*”.
- It is the study of matter and energy and interaction between them.
- It is the most fundamental of all the sciences.



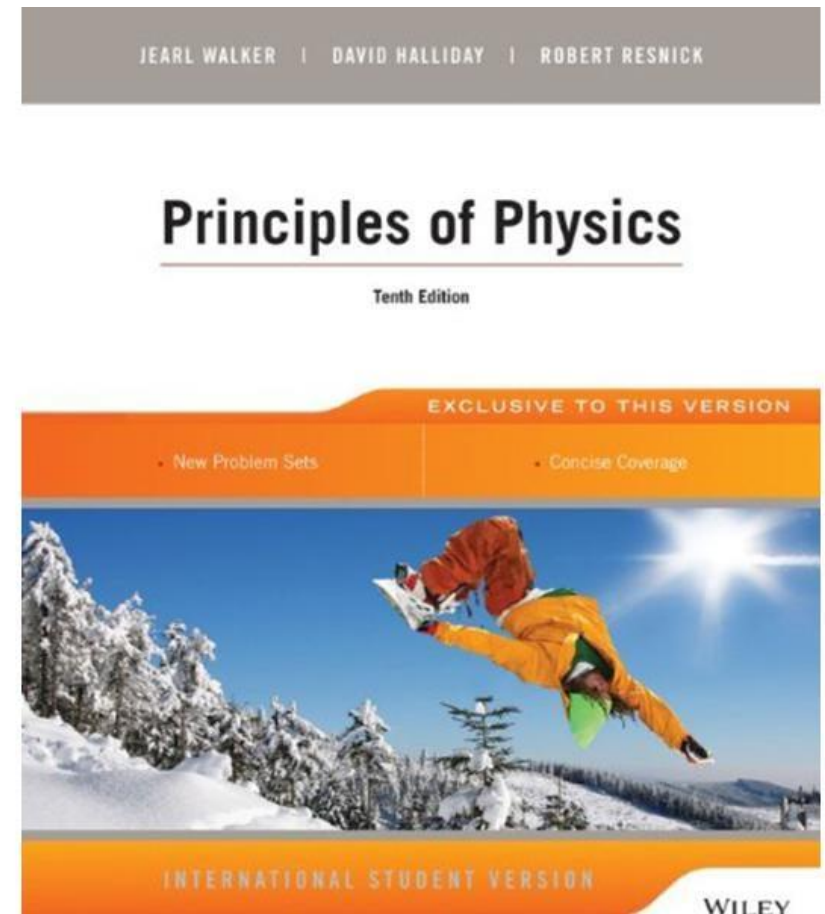
Resources

❑ **Textbook:** Principles of Physics ,
10th Ed by Jearl Walker David
Halliday, Robert Resnick

❑ **Blackboard (BB):**

- <https://eservices.iau.edu.sa/#/user/Blackboard>
- Announcements
- Online Homework (HW)
- Lecture Notes
- Syllabus
- Exam Schedules

Your own Lecture notes: Please
take notes during the lecture.



How to study Physics



Click the link for the animation

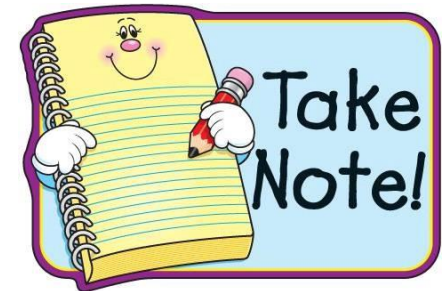
In classroom:

- I. Come to the lecture on time.
- II. Listen to the instructor.
- III. Take notes.
- IV. Interrupt the instructor to ask questions.



Outside of the classroom:

- I. Repeat what you learn.
- II. Solve the examples given in the lecture.
- III. Solve the examples from the book.
- IV. Discuss with your friends & share ideas.



Succeeding in Physics

- It is all about *commitment*, not genius.
- Maintain a *positive attitude* toward the subject matter.
- Set up a regular study *schedule*.
- Do your homework!
- Make sure you understand both “why” and “why not”.
- Interrupt the lecturer!
- Ask questions.
- Use the *office hours*.





PHYSICS 111

Measurements



Semester 461

JEARL WALKER | DAVID HALLIDAY | ROBERT RESNICK

Principles of Physics

Tenth Edition



Topics

- Units and standards
- Dimensional Analysis
- Significant Figures
- Conversions of Units

Units and standards

- Any physical quantity can be measured, such as **length** or **speed** consisting of a number and a certain unit .
- The Fundamental (Basic) physical quantities**

Length, Mass and Time

- There are three major systems of units:

Unit system	Length	Mass	Time
C.G.S	C entimeter	G ram	S econd
M.K.S (SI-Units)	M eter	K ilogram	S econd
F.P.S (British Engineering)	F oot	P ound	S econd

- SI unit system (**M.K.S**) is mainly used

Units and standards

☐ SI basic units

QUANTITY	Unit	ABB.
Length	meter	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Thermodynamic Temperature	kelvin	K
Amount of substance	mole	mol
Luminous intensity	candela	cd

☐ and lots of derived units

QUANTITY	Unit	ABB.
Area	square meter	m ²
Volume	cubic meter	m ³
Speed, Velocity	meter per second	m/s
Acceleration	meter per second squared	m/s ²
Wave number	reciprocal meter	m ⁻¹
Density	kilogram per cubic meter	kg/m ³
Specific volume	cubic meter per kilogram	m ³ /kg
Mass Fraction	kilogram per kilogram, may be represented by the number 1	kg/kg = 1

Measurement	Time Interval in Seconds	Measurement	Time Interval in Seconds
Lifetime of the proton (predicted)	3×10^{40}	Time between human heartbeats	8×10^{-1}
Age of the universe	5×10^{17}	Lifetime of the muon	2×10^{-6}
Age of the pyramid of Cheops	1×10^{11}	Shortest lab light pulse	1×10^{-16}
Human life expectancy	2×10^9	Lifetime of the most unstable particle	1×10^{-23}
Length of a day	9×10^4	The Planck time ^a	1×10^{-43}

Measurement	Length in Meters	Object	Mass in Kilograms
Distance to the first galaxies formed	2×10^{26}	Known universe	1×10^{53}
Distance to the Andromeda galaxy	2×10^{22}	Our galaxy	2×10^{41}
Distance to the nearby star Proxima Centauri	4×10^{16}	Sun	2×10^{30}
Distance to Pluto	6×10^{12}	Moon	7×10^{22}
Radius of Earth	6×10^6	Asteroid Eros	5×10^{15}
Height of Mt. Everest	9×10^3	Small mountain	1×10^{12}
Thickness of this page	1×10^{-4}	Ocean liner	7×10^7
Length of a typical virus	1×10^{-8}	Elephant	5×10^3
Radius of a hydrogen atom	5×10^{-11}	Grape	3×10^{-3}
Radius of a proton	1×10^{-15}	Speck of dust	7×10^{-10}
		Penicillin molecule	5×10^{-17}
		Uranium atom	4×10^{-25}
		Proton	2×10^{-27}
		Electron	9×10^{-31}

The **dimension** of any physical quantity expresses its dependence on the base quantities as a product of symbols. It is used;

- i. **To check the correctness** of a derived relationship or equation.
 - ii. **To convert units** of quantity from one System to another.
 - iii. **To derive** the dependency between physical quantities.
- ☐ If the right-hand side **(R.H.S)** has the same dimensions in the left-hand side **(L.H.S)** the equation is said to be dimensionally correct.
 - ☐ Only same type of quantities can be added, subtracted or multiplied etc.
 - ☐ Numbers, angles, all trigonometric functions, exponential functions, logarithms have no dimension.

Dimensional Analysis

- Every base quantity is expressed by a symbol for the dimension

Base Quantity	Symbol for Dimension
Length	L
Mass	M
Time	T
Current	I
Thermodynamic temperature	Θ
Amount of substance	N
Luminous intensity	J

Ex: The dimension of area of a circle: **Area** = πr^2

$$A = (\text{radius} \times \text{radius}) = [L^2]$$

Table 1.3 Base Quantities and Their Dimensions

Ex: Find the dimension of force ($F=ma$).

The unit for force is: $kg \frac{m}{s^2} = \left[M \frac{L}{T^2} \right] = [MLT^{-2}]$

Ex: Find the dimension of power ($P=W/t$).

The unit for power is: $kg \frac{m^2}{s^3} = \left[M \frac{L^2}{T^3} \right] = [ML^2T^{-3}]$

Example: Determine which formulas are dimensionally consistent.

$$a) V = \pi r^2 h$$

$$b) V = 2\pi r^2 + 2\pi r h$$

Solution.

The equation contains five terms. L.H.S. and the R.H.S. must have the same dimensions. Since $[r]$ and $[h]$ = length, they have the same dimension.

$$a) V = [1][L^2][L] = [L^3] \text{ volume is } m^3 \text{ so it is correct}$$

$$b) V = [1][1][L^2] + [1][1][L][L] = [L^2] + [L^2] = 2[L^2] = [1][L^2] = [L^2] \text{ incorrect}$$



$V \neq [L^2]$ incorrect. Because the volume has a unit of m^3

Remember numbers have a dimension of $[1]$

■ EXAMPLE 1.2 Find an Equation

GOAL Derive an equation by using dimensional analysis.

PROBLEM Find a relationship between a constant acceleration a , speed v , and distance r from the origin for a particle traveling in a circle.

STRATEGY Start with the term having the most dimensionality, a . Find its dimensions, and then rewrite those dimensions in terms of the dimensions of v and r . The dimensions of time will have to be eliminated with v , because that's the only quantity (other than a , itself) in which the dimension of time appears.

SOLUTION

Write down the dimensions of a :

$$[a] = \frac{L}{T^2}$$

Solve the dimensions of speed for T :

$$[v] = \frac{L}{T} \rightarrow T = \frac{L}{[v]}$$

Substitute the expression for T into the equation for $[a]$:

$$[a] = \frac{L}{T^2} = \frac{L}{(L/[v])^2} = \frac{[v]^2}{L}$$

Substitute $L = [r]$, and guess at the equation:

$$[a] = \frac{[v]^2}{[r]} \rightarrow a = \frac{v^2}{r}$$

- ❑ **Significant figures (digits)**, refer to the number of important single **digits in a measurement**.
- ❑ They indicate the reliability or precision when stating a quantity.

❖ **Three basic rules for the significant figures**

1) Non-zero digits are always significant.

- ✓ A number like 26.38 has **four** and 7.94 has **three**.
- ✓ If there is **no decimal** point, the whole number is significant: 1974 has **four** significant figures .

2) Any zeros between two significant figures are significant.

- ✓ A number like 406 has **three** significant figures .

3) A final zero in the decimal portion ONLY are significant.

- ✓ Here are two examples of this rule with the zeros this rule affects in boldface:

(a) 0.005**00** (b) 0.0304**0** (c) 2.3**0** x 10⁻⁵ (d) 4.5**00** x 10¹²

- ✓ Final zeros to the right of the decimal **are significant**. There are **FOUR** significant figures in **92.00**

Problem 78 / P.41: Determine the number of significant figures in the following measurements:

i. 0.0009 m ii. 15,450.0 SAR. iii. 87.990 L iv. 30.42.

Solution: i. 1 sig. fig ii. 6 sig. fig iii. 5 sig. fig iv. 4 sig. fig

Addition and subtraction:

- Count the number of significant figures in the decimal portion ONLY of each number in the problem
- Add or subtract in the normal fashion
- Round the answer to the **LEAST** number of places in the **decimal portion** of any number in the problem.



Check Your Understanding

$$\text{Ex: } 3.6 \text{ cm} - 0.57 \text{ cm} = 3.0 \text{ cm (NOT 3.03)}$$

1

2

1

Decimal portions

(the least decimal portion in the answer will be 2)

$$\text{Ex: } 3.461728 + 14.91 + 0.980001 + 5.2631 = 24.614829 = 24.61$$

6

2

6

4

2

Multiplication and division rules:

- The **LEAST** number of significant figures in any number of the problem determines the number of significant figures in the answer.

(Look at the entire number, not just the decimal portion)



Check Your Understanding

Ex1: $3.10 \times 4.520 = ?$ (the least significant figure has three sig. fig. , so the answer should be round to 3 sig. fig.) = **14.0**
3 sig. 4 sig.

Ex2: $2.0 / 3.0 = 0.67$ (same rule is applied for division)
2 sig. 2 sig. 2 sig.

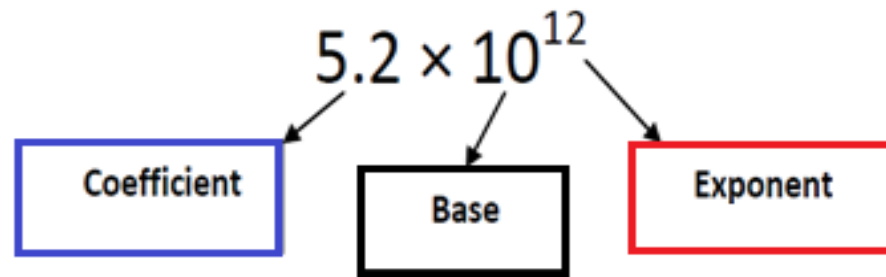
Scientific notation

- Physical quantities are often expressed in **scientific notation**, which takes two equivalent forms. For example:

Mean age of the Earth: $1.3 \times 10^{17} \text{ s}$

Radius of Earth r_{Earth} : $6.37 \times 10^6 \text{ m}$

Scientific Notation:



□ How numbers are written in scientific notation

- **Coefficient** is chosen from greater than or equal 1 less than 10
- **Base** is shown as 10.
- **Exponent** is given as a power of 10.

The most common writing is: $1.3\text{E}17 \text{ s}$, $6.37\text{E}6 \text{ m}$ it is quicker to type. What does your calculator show?



Check Your Understanding

Ex: Lets get back to class activity. Write the numbers in scientific notation.

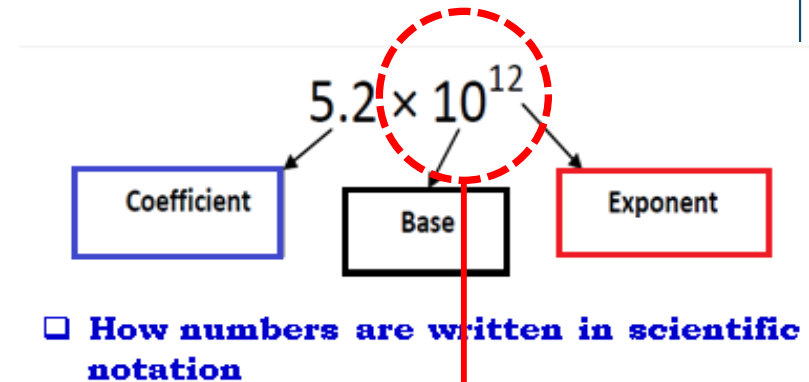
Number	Scientific Notation	Number	Scientific Notation
2675	2.675×10^3	1.501	1.501×10^0
0.005	5×10^{-3}	0.200	2.00×10^{-1}
9680	9.680×10^3	560×10^6	5.6×10^8
770.	7.70×10^2	0.3682	3.682×10^{-1}

Metric Prefixes

- The larger and the smaller units are defined in multiplies of 10 from the standard unit.

Prefix	Symbol	Meaning	Prefix	Symbol	Meaning
yotta-	Y	10^{24}	yocto-	y	10^{-24}
zetta-	Z	10^{21}	zepto-	z	10^{-21}
exa-	E	10^{18}	atto-	a	10^{-18}
peta-	P	10^{15}	femto-	f	10^{-15}
tera-	T	10^{12}	pico-	p	10^{-12}
giga-	G	10^9	nano-	n	10^{-9}
mega-	M	10^6	micro-	μ	10^{-6}
kilo-	k	10^3	milli-	m	10^{-3}
hecto-	h	10^2	centi-	c	10^{-2}
deka-	da	10^1	deci-	d	10^{-1}

Table 1.2 Metric Prefixes for Powers of 10 and Their Symbols



Ex: The capacity (size) of the **Hard Disk Drive** of my laptop is:
5.2 Tera Byte=**5.2 TB**

Ex: Determine the prefixes for the following expressions.

- i) 2.3 **G**Hz Processor ii) 1 **k**m distance iii) 4**m**s response time

Solution:

- i) 2.3×10^9 Hz Processor ii) 1×10^3 m distance iii) 4×10^{-3} s response time

Metric Prefixes: Length, Mass and Time

- The Prefixes can be applied to many basic or derived units.
- Power of ten can be expressed by a prefix.

1-Length:

Unit	Power	Prefix
1 kilometer	10^3 m	1 km
1 centimeter	10^{-2} m	1 cm
1 millimeter	10^{-3} m	1 mm
1 micrometer	10^{-6} m	1 μ m
1 nanometer	10^{-9} m	1 nm

2-Mass:

Unit	Power	Prefix
1 kilogram	10^3 g	1 kg
1 milligram	10^{-3} g = 10^{-6} kg	1 mg
1 microgram	10^{-6} g = 10^{-9} kg	1 μ g

3-Time:

Unit	Power	Prefix
1 millisecond	10^{-3} s	1 ms
1 microsecond	10^{-6} s	1 μ s
1 nanosecond	10^{-9} s	1 ns

■ EXAMPLE 1.3 Carpet Calculations

GOAL Apply the rules for significant figures.

PROBLEM Several carpet installers make measurements for carpet installation in the different rooms of a restaurant, reporting their measurements with inconsistent accuracy, as compiled in Table 1.6. Compute the areas for (a) the banquet hall, (b) the meeting room, and (c) the dining room, taking into account significant figures. (d) What total area of carpet is required for these rooms?

Table 1.6 Dimensions of Rooms in Example 1.3

	Length (m)	Width (m)
Banquet hall	14.71	7.46
Meeting room	4.822	5.1
Dining room	13.8	9

SOLUTION

(a) Compute the area of the banquet hall.

Count significant figures:

14.71 m → 4 significant figures

7.46 m → 3 significant figures

To find the area, multiply the numbers keeping only three digits:

$$14.71 \text{ m} \times 7.46 \text{ m} = 109.74 \text{ m}^2 \rightarrow 1.10 \times 10^2 \text{ m}^2$$

(b) Compute the area of the meeting room.

Count significant figures:

4.822 m → 4 significant figures

5.1 m → 2 significant figures

To find the area, multiply the numbers keeping only two digits:

$$4.822 \text{ m} \times 5.1 \text{ m} = 24.59 \text{ m}^2 \rightarrow 25 \text{ m}^2$$

(c) Compute the area of the dining room.

Count significant figures:

13.8 m → 3 significant figures

9 m → 1 significant figure

To find the area, multiply the numbers keeping only one digit:

$$13.8 \text{ m} \times 9 \text{ m} = 124.2 \text{ m}^2 \rightarrow 100 \text{ m}^2$$

Unit Conversion

- A physical quantity needs **conversion** from one to another. We generally use **SI (MKS) unit system**.

Ex: Apply the strategy for solving conversion of 80 km/h to m/s.

i) Identify the units : kilometer (km) and hour (h).

ii) Determine the relationship between the units.

$$1 \text{ km} = 1000 \text{ m}$$

$$1 \text{ h} = 3600 \text{ s}$$

iii) Determine the **conversion factor** (in fraction form):

$$\frac{1000 \text{ m}}{1 \text{ km}} = 1$$

$$\frac{1 \text{ h}}{3600 \text{ s}} = 1$$

You can use as many **conversion factor** as you wish.

Quantity $\times$ *conversion factor* $\longrightarrow$ *Target unit*

$$80 \frac{\cancel{\text{km}}}{\cancel{\text{h}}} \times \frac{1000 \text{ m}}{1 \cancel{\text{km}}} \times \frac{1 \cancel{\text{h}}}{3600 \text{ s}} = 22 \text{ m/s}$$

25

Metric Prefixes: Unit Conversion

- When you express a physical quantity in another set of units, you must use **a conversion factor** to convert it to the appropriate one.

Length

1 inch = 2.54 centimeters

1 millimeter = 0.039 inches

1 foot = 30.5 centimeters

1 centimeters = 0.39 inches

1 yard = 0.91 meters

1 meter = 3.28 feet

1 mile = 1.61 kilometer

1 kilometer = 0.62 miles

Volume

1L = $10^{-3} m^3$

1L = 1.0567 qt

1 gal = 3.786 L

Mass

1 ounce (oz) = 28.35 grams

1 gram = 0.0353 oz

1 pound (lb) = 0.454 kg

1 kilogram = 2.2046 lb

Temperature

$K = ^\circ C + 273.15$

$^\circ C = \left(\frac{5}{9}\right) (^\circ F - 32)$

$^\circ F = \left(\frac{9}{5}\right) ^\circ C + 32$

Energy

1 cal = 4.184 J

1 eV = $1.602 \times 10^{-19} J$

1 J = $1 kg \frac{m^2}{s^2}$

Metric Prefixes: Unit Conversion

Ex: What is the elevation in Feet of an elevation of 8000 m?

i) Identify the units : feet (ft) and meter (m).

$$1 \text{ ft} = 12 \text{ in}$$

$$1 \text{ in} = 2.54 \text{ cm}$$

$$100 \text{ cm} = 1 \text{ m}$$

Quantity $\times$ *conversion factor* $\longrightarrow$ *Target unit*

$$8000 \text{ m} \times \frac{100 \cancel{\text{cm}}}{1 \cancel{\text{m}}} \times \frac{1 \cancel{\text{in}}}{2.54 \cancel{\text{cm}}} \times \frac{1 \text{ ft}}{12 \cancel{\text{in}}} = \frac{8000 \times 100}{2.54 \times 12} = \dots \text{ ft}$$

$$8000 \text{ m} = 26247 \text{ ft}$$

Ex 1.2/P.20: The distance from the university to home is 10 mil. and it usually takes 20 min to drive this distance. Calculate the average speed in meters per second (m/s).

Solution: *Simply convert*

$$\begin{array}{ccc} \frac{10 \text{ mile}}{20 \text{ min}} & \text{to} & \frac{\text{m}}{\text{s}} \end{array} \quad \frac{10 \text{ mile}}{20 \text{ min}} = 0.5 \frac{\text{mile}}{\text{min}}$$
$$0.5 \frac{\text{mile}}{\text{min}} \times \frac{1609 \text{ m}}{1 \text{ mile}} \times \frac{1 \cancel{\text{min}}}{60 \text{ s}} = \frac{0.5 \times 1609}{60} = 13 \frac{\text{m}}{\text{s}}$$



Check Your Understanding

Ex. 1.1/ P.19: Restate the mass $1.93 \times 10^{-6} \text{ g}$ using a metric prefix.

Solution: $1.93 \times 10^{-6} \text{ g} = 1.93 \mu\text{g}$ $\mu = 10^{-6}$ μ : *Micro*

Ex: Your hairs grow at the rate of 1mm per day. Find their growth rate in nm s^{-1} (nm/s)

$$\frac{1 \text{ mm}}{1 \text{ day}} = \frac{1 \text{ mm}}{1 \text{ day}} \times \frac{1 \times 10^{-3} \text{ m}}{1 \text{ mm}} \times \frac{10^9 \text{ nm}}{1 \text{ m}} \times \frac{1 \text{ day}}{24 \times 60 \times 60 \text{ s}} = 11.57 \text{ nm/s}$$

Ex: The prefix meaning 0.001 is _____.

- A) Milli- B) Centi- C) Deci- D) Kilo-



Ex: The 6 MB cash memory is equivalent to _____.

- A) 10^{-12} bytes B) 10^9 bytes C) 10^6 bytes D) 10^6 kbytes



$$1 \text{ mi} = 1\,609 \text{ m} = 1.609 \text{ km}$$

$$1 \text{ ft} = 0.3048 \text{ m} = 30.48 \text{ cm}$$

$$1 \text{ m} = 39.37 \text{ in.} = 3.281 \text{ ft}$$

$$1 \text{ in.} = 0.0254 \text{ m} = 2.54 \text{ cm}$$

■ EXAMPLE 1.4 Pull Over, Buddy!

GOAL Convert units using several conversion factors.

PROBLEM If a car is traveling at a speed of 28.0 m/s , is the driver exceeding the speed limit of 55.0 mi/h ?

STRATEGY Meters must be converted to miles and seconds to hours, using the conversion factors listed on the front end-sheets of the book. Here, three factors will be used.

SOLUTION

Convert meters to miles:

$$28.0 \text{ m/s} = \left(28.0 \frac{\cancel{\text{m}}}{\text{s}}\right) \left(\frac{1.00 \text{ mi}}{1\,609 \cancel{\text{m}}}\right) = 1.74 \times 10^{-2} \text{ mi/s}$$

Convert seconds to hours:

$$\begin{aligned} 1.74 \times 10^{-2} \text{ mi/s} &= \left(1.74 \times 10^{-2} \frac{\text{mi}}{\cancel{\text{s}}}\right) \left(60.0 \frac{\cancel{\text{s}}}{\text{min}}\right) \left(60.0 \frac{\cancel{\text{min}}}{\text{h}}\right) \\ &= 62.6 \text{ mi/h} \end{aligned}$$

■ EXAMPLE 1.5

Press the Pedal to the Metal

GOAL Convert a quantity featuring powers of a unit.

PROBLEM The traffic light turns green, and the driver of a high-performance car slams the accelerator to the floor. The accelerometer registers 22.0 m/s^2 . Convert this reading to km/min^2 .

STRATEGY Here we need one factor to convert meters to kilometers and another two factors to convert seconds squared to minutes squared.

.....

SOLUTION

Multiply by the three factors:

$$\frac{22.0 \cancel{\text{m}}}{1.00 \cancel{\text{s}}^2} \left(\frac{1.00 \text{ km}}{1.00 \times 10^3 \cancel{\text{m}}} \right) \left(\frac{60.0 \cancel{\text{s}}}{1.00 \text{ min}} \right)^2 = 79.2 \frac{\text{km}}{\text{min}^2}$$

.....

PROBLEMS

3. How many m/s are there in 1.0 mi/h?

PROBLEMS

23. A $2.00\text{ m} \times 3.00\text{ m}$ plate of aluminium has a mass of 324 kg . What is the thickness of the plate? (The density of aluminium is $2.7 \times 10^3\text{ kg/m}^3$.)

