PHYSICS FOR ENGINEERING I

(PHYS 1210)

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Course Contents

References

1. ***Serway Jewett, "Physics for Scientists and Engineers", THOMSON BROOKS/COLE, 6th Edition.*** *Or 9th Edition.*
2. ***Halliday, Resnick, Walker, "Fundamentals of Physics", WILEY, 6th Edition.***
3. ***Young and Freedmann, "University Physics", PEARSON ADDISON WESLEY, 11th Edition.***

Assessment

	Assessment task (e.g. essay, test, group project, examination etc.)	Week due	%
1	Attendance, Participation and Homework	Every weeks	15
2	Mid Term Exam	8	20
3	Quizzes	…	10
4	Laboratory reports & Tests	Every weeks	15
5	Final Exam	17	40

Chapter 1:

Physics and Measurement

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Physics and Measurement

- ✓ Units & Dimensions.
- ✓ Dimensional Analysis.
- ✓ Conversion of Units.
- ✓ Density and Atomic Mass.
- ✓ Estimates and Order-of-Magnitude Calculations.
- ✓ Significant Figures.

Units & Dimensions

Units

- *SI (metric)*
  - kilogram (kg)
  - meter (m)
  - second (s)
- *English system*
  - pound (lb)
  - foot (ft)
  - second (s)

lb = 0.45359 kg

ft = 0.3048 m

Units & Dimensions

A dimension is a property that can be counted, measured, or calculated.

Basic quantities

- Length, mass, time

Derived quantities

- Velocity, acceleration, force, pressure etc…

Standards of Length, Mass, and Time

Length: (m)
The meter (m) was redefined as the distance traveled by light in vacuum during a time of 1/299 792 458 second.

Mass: (kg)
The kilogram (kg), is defined as the mass of a specific platinum–iridium alloy cylinder kept at the International Bureau of Weights and Measures at Sèvres, France.

Time: (s)
The second (s) is now defined as 9 192 631 770 times the period of vibration of radiation from the cesium atom.

The seven fundamental (or primary) dimensions and their units in SI	
Dimension	**Unit**
Length	meter (m)
Mass	kilogram (kg)
Time	second (s)
Temperature	Kelvin (K)
Electric current	Ampere (A)
Amount of light	candela (cd)
Amount of matter	mole (mol)

Length	m		Work	
Mass	kg		Heat	
Time	s		Energy	
Area	m^2		Power	
Volume	m^3			
Velocity				
Acceleration				
Density				
Specific Volume				
Mass flow rate				
Discharge				
Pressure				
Force				

SI Unit Prefixes

Factor	Prefix	Symbol
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{2}	hecto	h
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p

Useful Conversion Factors:

Length:	1 ft = 0.3048 m	Power:	1 hp = 745.7 W
	1 in. = 25.4 mm		1 ft · lbf/s = 1.356 W
Mass:	1 lbm = 0.4536 kg		1 Btu/hr = 0.2931 W
	1 slug = 14.59 kg	Area	1 ft^2 = 0.0929 m^2
Force:	1 lbf = 4.448 N		1 acre = 4047 m^2
	1 kgf = 9.807 N	Volume:	1 ft^3 = 0.02832 m^3
Velocity:	1 ft/s = 0.3048 m/s		1 gal (US) = 0.003785 m^3
	1 ft/s = 15/22 mph		1 gal (US) = 3.785 L
	1 mph = 0.447 m/s	Volume flow rate:	1 ft^3/s = 0.02832 m^3/s
Pressure:	1 psi = 6.895 kPa		1 gpm = 6.309×10^{-5} m^3/s
	1 lbf/ft^2 = 47.88 Pa	Viscosity (dynamic)	1 lbf · s/ft^2 = 47.88 N · s/m^2
	1 atm = 101.3 kPa		1 g/(cm · s) = 0.1 N · s/m^2
	1 atm = 14.7 psi		1 Poise = 0.1 N · s/m^2
	1 in. Hg = 3.386 kPa	Viscosity (kinematic)	1 ft^2/s = 0.0929 m^2/s
	1 mm Hg = 133.3 Pa		1 Stoke = 0.0001 m^2/s
Energy:	1 Btu = 1.055 kJ		
	1 ft · lbf = 1.356 J		
	1 cal = 4.187 J		

Dimensional Analysis

In physics, the word *dimension* denotes the physical nature of a quantity.

the dimensions of Length: L,
Mass: M,
and Time: T.

Quantity	Area (A)	Volume (V)	Speed (v)	Acceleration (a)
Dimensions	L^2	L^3	L/T	L/T^2
SI units	m^2	m^3	m/s	m/s^2
U.S. customary units	ft^2	ft^3	ft/s	ft/s^2

Example 1.1

Show that the expression $v = at$, where v represents speed, a acceleration, and t an instant of time, is dimensionally correct.

Solution:

SOLUTION

Identify the dimensions of v from Table 1.5: $[v] = \frac{L}{T}$

Identify the dimensions of a from Table 1.5 and multiply by the dimensions of t: $[at] = \frac{L}{T^2} T = \frac{L}{T}$

Therefore, $v = at$ is dimensionally correct because we have the same dimensions on both sides. (If the expression were given as $v = at^2$, it would be dimensionally *incorrect*. Try it and see!)

Conversion of Units

Length

	m	cm	km	in.	ft	mi
1 meter	1	10^2	10^{-3}	39.37	3.281	6.214×10^{-4}
1 centimeter	10^{-2}	1	10^{-5}	0.393 7	3.281×10^{-2}	6.214×10^{-6}
1 kilometer	10^3	10^5	1	3.937×10^4	3.281×10^3	0.621 4
1 inch	2.540×10^{-2}	2.540	2.540×10^{-5}	1	8.333×10^{-2}	1.578×10^{-5}
1 foot	0.304 8	30.48	3.048×10^{-4}	12	1	1.894×10^{-4}
1 mile	1 609	1.609×10^5	1.609	6.336×10^4	5 280	1

Conversion of Units

Mass	kg	g	slug	u
1 kilogram	1	10^3	6.852×10^{-2}	6.024×10^{26}
1 gram	10^{-3}	1	6.852×10^{-5}	6.024×10^{23}
1 slug	14.59	1.459×10^4	1	8.789×10^{27}
1 atomic mass unit	1.660×10^{-27}	1.660×10^{-24}	1.137×10^{-28}	1

Note: 1 metric ton = 1 000 kg.

Conversion of Units

Time	s	min	h	day	yr
1 second	1	1.667×10^{-2}	2.778×10^{-4}	1.157×10^{-5}	3.169×10^{-8}
1 minute	60	1	1.667×10^{-2}	6.994×10^{-4}	1.901×10^{-6}
1 hour	3 600	60	1	4.167×10^{-2}	1.141×10^{-4}
1 day	8.640×10^4	1 440	24	1	2.738×10^{-5}
1 year	3.156×10^7	5.259×10^5	8.766×10^3	365.2	1

Conversion of Units

Speed	m/s	cm/s	ft/s	mi/h
1 meter per second	1	10^2	3.281	2.237
1 centimeter per second	10^{-2}	1	3.281×10^{-2}	2.237×10^{-2}
1 foot per second	0.304 8	30.48	1	0.681 8
1 mile per hour	0.447 0	44.70	1.467	1

Note: 1 mi/min = 60 mi/h = 88 ft/s.

Example 1.2

On an interstate highway in a certain region of KSA, a car is traveling at a speed of 38.0 m/s. Is the driver exceeding the speed limit of 75.0 mi/h?

Solution:

SOLUTION

Convert meters in the speed to miles: $(38.0 \text{ m/s})\left(\frac{1 \text{ mi}}{1\,609 \text{ m}}\right) = 2.36 \times 10^{-2} \text{ mi/s}$

Convert seconds to hours: $(2.36 \times 10^{-2} \text{ mi/s})\left(\frac{60 \text{ s}}{1 \text{ min}}\right)\left(\frac{60 \text{ min}}{1 \text{ h}}\right) = 85.0 \text{ mi/h}$

The driver is indeed exceeding the speed limit and should slow down.

WHAT IF? What if the driver were from outside the United States and is familiar with speeds measured in kilometers per hour? What is the speed of the car in km/h?

Answer We can convert our final answer to the appropriate units:

$$(85.0 \text{ mi/h})\left(\frac{1.609 \text{ km}}{1 \text{ mi}}\right) = 137 \text{ km/h}$$

Figure 1.3 shows an automobile speedometer displaying speeds in both mi/h and km/h. Can you check the conversion we just performed using this photograph?

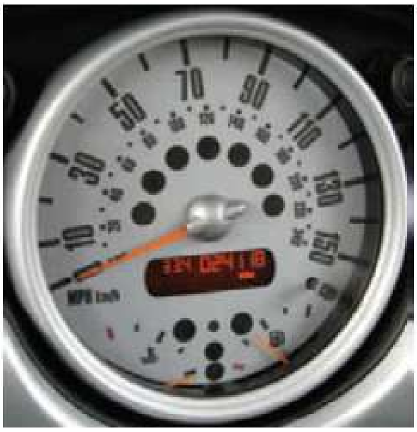

Figure 1.3 The speedometer of a vehicle that shows speeds in both miles per hour and kilometers per hour.

Density

The density ρ of any substance is defined as its mass per unit volume:

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

Where:
ρ : the density
m: the mass
V: the volume

Densities of Various Substances

Substance	Density ρ (10^3 kg/m^3)
Platinum	21.45
Gold	19.3
Uranium	18.7
Lead	11.3
Copper	8.92
Iron	7.86
Aluminum	2.70
Magnesium	1.75
Water	1.00
Air at atmospheric pressure	0.0012

Atomic Mass

The numbers of protons and neutrons in the nucleus of an atom of an element are related to **the atomic mass** of the element, which is defined as the mass of a single atom of the element measured in atomic mass units (**u**) where

1 u = 1.660 538 7 x 10^{-27} kg.

Example 1.3

A solid cube of aluminium (density 2.70 g/cm^3) has a volume of 0.200 cm^3. It is known that 27.0 g of aluminium contains 6.02 x 10^{23} atoms. How many aluminium atoms are contained in the cube?

Solution:

A solid cube of aluminum (density 2.70 g/cm^3) has a volume of 0.200 cm^3. It is known that 27.0 g of aluminum contains 6.02×10^{23} atoms. How many aluminum atoms are contained in the cube?

Solution Because density equals mass per unit volume, the mass of the cube is

$$m = \rho V = (2.70\ \text{g/cm}^3)(0.200\ \text{cm}^3) = 0.540\ \text{g}$$

To solve this problem, we will set up a ratio based on the fact that the mass of a sample of material is proportional to the number of atoms contained in the sample. This technique of solving by ratios is very powerful and should be studied and understood so that it can be applied in future problem solving. Let us express our proportionality as $m = kN$, where m is the mass of the sample, N is the number of atoms in the sample, and k is an unknown proportionality constant. We write this relationship twice, once for the actual sample of aluminum in the problem and once for a 27.0-g sample, and then we divide the first equation by the second:

$$m_{\text{sample}} = kN_{\text{sample}} \qquad m_{27.0\ \text{g}} = kN_{27.0\ \text{g}} \quad \rightarrow \quad \frac{m_{\text{sample}}}{m_{27.0\ \text{g}}} = \frac{N_{\text{sample}}}{N_{27.0\ \text{g}}}$$

Notice that the unknown proportionality constant k cancels, so we do not need to know its value. We now substitute the values:

$$\frac{0.540\ \text{g}}{27.0\ \text{g}} = \frac{N_{\text{sample}}}{6.02 \times 10^{23}\ \text{atoms}}$$

$$N_{\text{sample}} = \frac{(0.540\ \text{g})(6.02 \times 10^{23}\ \text{atoms})}{27.0\ \text{g}}$$

$$= 1.20 \times 10^{22}\ \text{atoms}$$

Estimates and Order-of-Magnitude Calculations

The estimate may be made even more approximate by expressing it as an order of magnitude, which is a power of ten.

We use the symbol ~ , for "*is on the order of.*"

The orders of magnitude for the following lengths:

$$0.008\,6\ \text{m} \sim 10^{-2}\ \text{m} \qquad 0.002\,1\ \text{m} \sim 10^{-3}\ \text{m} \qquad 720\ \text{m} \sim 10^{3}\ \text{m}$$

Significant Figures

The number of *significant figures* in a measurement can be used to express something about the uncertainty.

Suppose we are asked to measure the radius of a compact disc using a meter-stick as a measuring instrument. Let us assume the accuracy to which we can measure the radius of the disc is 6 ± 0.1 cm.

radius lies somewhere between 5.9 cm and 6.1 cm.

Note that *the significant figures* include the first estimated digit. Therefore, we could write the radius as (6.0 ± 0.1) cm.

Zeros may or may not be significant figures.

Those used to position the decimal point in such numbers as **0.03** and **0.0075** are not significant. Therefore, there are **one** and **two** significant figures, respectively, in these two values.

1500
1.5 x 10³ if there are two significant figures in the measured value,
1.50 x 10³ if there are three significant figures, and
1.500 x 10³ if there are four.

The same rule holds for numbers less than 1,

so **2.3 x 10⁻⁴** has two significant figures
(and therefore could be written **0.000 23**)

and **2.30 x 10⁻⁴** has three significant figures
(also written as **0.000 230**)

- When multiplying several quantities, the number of significant figures in the final answer is the same as the number of significant figures in the quantity having the smallest number of significant figures. The same rule applies to division.

$$A = \pi r^2 = \pi(6.0\ \text{cm})^2 = 1.1 \times 10^2\ \text{cm}^2$$

- When numbers are added or subtracted, the number of decimal places in the result should equal the smallest number of decimal places of any term in the sum or difference.

$$23.2 + 5.174 = 28.4$$